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JURASSIC–CRETACEOUS BOUNDARY AMMONITE *BLANFORDICERAS* (MOLLUSCA: CEPHALOPODA) FROM FORTISSIMO-1 WILDCAT WELL, BROWSE BASIN, NORTHWEST SHELF, AUSTRALIA

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ABSTRACT—Jurassic–Cretaceous ammonites are particularly robust fossil tools in global stratigraphy and correlation. The successive evolution and extinction of these cephalopod mollusks was so rapid that many ammonite zones are no more than one million years in duration. A well-preserved ammonite specimen from the Fortissimo-1 core, Browse Basin, NW Australia is assignable to the widespread latest Jurassic dimorphic berriaselline genus, *Blanfordiceras* Cossmann, recorded previously from the Spiti area, Nepal, Tibet, Madagascar, Papua-New Guinea, Antarctica, and southern South America. This is the first report of ammonites of this age in the Australian region. The evolute shell of an estimated 90–100 mm diameter (when extrapolated) and pronounced ornamentation of variably bifurcating, curvilinear and flexuous ribs, intercalated with simple, non-bifurcating ribs, is consistent with *Blanfordiceras wallichi* (Gray, 1832), which has traditionally been restricted to the uppermost Tithonian Stage, ca. 146.5–145.5 Ma, but may well have survived into the earliest part of the Berriasian. The first recorded occurrence of this ammonite in Australia fills an anomalous absence in the paleobiogeographic distribution of Jurassic–Cretaceous boundary ammonites in the Indo-SW Pacific Subrealm with important implications for the calibration of offshore rocks and wells in Australia.

INTRODUCTION

THE ESCALATION of the break-up of the supercontinent Pangaea throughout the Jurassic Period caused an overall rise in global sea-level and increased shelf area, which is preserved as widespread marine sediments (and thus, fossils) across the globe. The Middle and Late Jurassic were intervals of climate amelioration with a reduction in the latitudinal thermal gradient and marked faunal differentiation temporally. Marine faunal connections were such that the coasts of Gondwana, including those of the Australian region, were largely populated by wide-ranging macroinvertebrate assemblages of Tethyan origin, including those of the Australian region. As such, there was inferred free interchange of marine waters from the high to low latitudes that resulted in the equable conditions of the Late Jurassic Southern Hemisphere (see Stevens, 1997).

The Browse Basin, a major petroleum region, is located offshore of the northwest margin of the Australian mainland in the eastern Indian Ocean in water depths ranging from only 20 m to >2,000 m, and comprises sediments of Permian to Quaternary age with a maximum thickness of 12 km. During the Late Jurassic, the basin was positioned in mid-Austral latitudes and its sediments and fossil biotas were deposited in a major depocenter along this paleobiogeographic Indo-Southwest Pacific Subrealm (Stevens, 1997) (see Fig. 1). Syn-rift Lower and Middle Jurassic sediments are overlain by sandstones and shales that reflect the initial break-up of Gondwana and the initial presence of sea-floor spreading. The presence of a latest Jurassic ammonite in the Fortissimo-1 wildcat well core provides evidence of this continental disassembly and subsequent marine incursions into the Browse Basin in the latest Jurassic. It also provides further refinement of the basin's biostratigraphic framework. Significantly, the successive evolution and extinction of ammonoid taxa was so rapid during the Mesozoic that most ammonite zones are no more than one million years in duration (Ogg in Gradstein et al., 2004), such that the discovery in a petroleum well of an ammonite can offer excellent biostratigraphic control, when microfossil data are wanting. In fact, the Late Jurassic time scale is "based on the magnetostratigraphic correlation of Tethyan and Boreal ammonite zones…" (Ogg in Gradstein et al., 2004, p. 341; Ogg et al., 2008). In the Fortissimo-1 well, palynomorph yields are relatively low and poorly preserved, so the ammonite assists greatly in constraining the age of offshore Australian deposits.

The available specimen from the Foritissimo-1 core is preserved in lateral view, but the displayed morphologic characters are sufficient to determine its affinity with the *Blanfordiceras wallichi* (Gray, 1832) of the latest Jurassic (late Tithonian, probably coeval to upper part of Chron M20 and lower M19, ca. 146.5–145.5 Ma; Yin and Enay, 2004). Here, we present a description and image of the specimen, along with available data on the biostratigraphic and paleogeographic range of the group. Importantly, this is the first record of the group in the latest Jurassic to earliest Cretaceous(?) of Australia.

SYSTEMATIC PALEONTOLOGY

The single specimen described and figured in this paper (Fig. 2) was discovered by Shell Development (Australia) Proprietary Limited of Perth, WA, and is housed in the paleontology collections in the Department of Earth and Planetary Sciences of the Western Australian Museum in Welshpool (Perth). This specimen was coated with ammonium chloride prior to macrophotography to enhance preserved morphologies and has been subsequently cleaned to remove any residue.

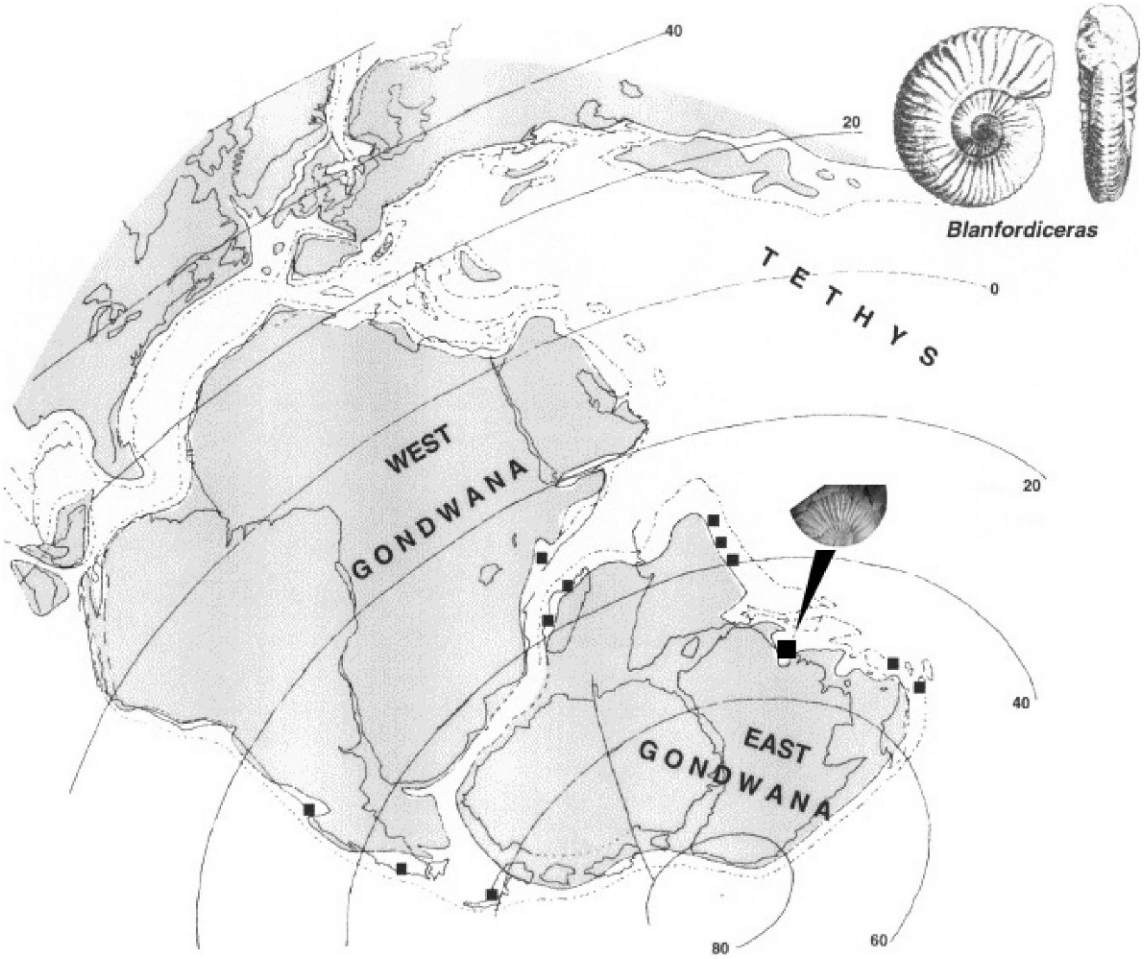

FIGURE 1—Paleobiogeographic distribution of *Blanfordiceras* from the latest Jurassic, with expansion of range to include NW Australia, as implied by the Fortissimo-1 specimen (slightly modified from Enay and Cariou, 1999).

Phylum MOLLUSCA Linnaeus, 1758
Class CEPHALOPODA Cuvier, 1797
Subclass AMMONOIDEA Zittel, 1884
Suborder AMMONITINA Hyatt, 1889
Superfamily ENDEMOCERATOIDEA Schindewolf, 1966
Family NEOCOMITIDAE Salfeld, 1921
Subfamily BERRIASELLINAE Cossmann, 1907
Genus BLANFORDICERAS Cossmann, 1907

Blanfordiceras COSSMANN, 1907, p. 64.

Type species.—(By original designation) *Ammonites wallichi* Gray, 1832.

Discussion.—The genus *Blanfordiceras* is widespread in upper Tithonian to lowermost Berriasian(?) marine deposits of the Spiti area, Nepal, southeastern Tibet, Madagascar, Papua-New Guinea, Antarctica, southern South America (Enay and Cariou, 1999; Hikuroa, 2004; Hu et al., 2008, and references within), and NW Australia (this work). Taxonomic confusion persists in the literature between *Blanfordiceras* and *Berriasella,* the latter of which has a definite lappet and a relatively narrow and non-persistent ventral groove (Yin and Enay, 2004). *Blanfordiceras* microconch individuals are characterized by a smooth, wide, ventral band which is bound by variably developed tuberculate ribs, and weakly developed ribs with fewer tubercles in macroconch specimens; whereas, the ventral groove of *Berriasella* is relatively narrow and not persistent, even absent in some species of *Berriasella* (Yin and Enay, 2004, p. 40). *Blanfordiceras'* stratigraphic range is not yet conclusively known, but current data indicate a dominance of the group in the upper Tithonian Stage and possibly survival into the lowermost Berriasian beds. However, there are no substantiated occurrences in the Berriasian (Yin Jiarun, personal commun. 2009).

BLANFORDICERAS WALLICHI (GRAY, 1832)
Figure 2

Ammonites wallichi GRAY, 1832, Vol. 1, pl. C, fig. 3; *wallichii* (*sic.*), CRICK, 1904, p. 123.

Blanfordiceras wallichi (GRAY), COSSMANN, 1907, p. 64.; SPATH, 1934, p.15, 16, pl. 6, figs. 6a, b (and extensive list of synonymies from 1863 to 1933); THOMPSON, 1983, p. 317, fig. 3i; STEVENS, 1997, p. 60, 83, 86, 102; HIKAROA, 2004, p. 171, pl. 25, figs. 6–12 ; YIN AND ENAY, 2004, p. 25–27, 29, Fig. 7-3a, 7-3b, 7-4a, 7-4b, 7-7; HU ET AL., 2008, p. 305.

Description.—Shell small- to medium-sized for genus (preserved diameter 78.0 mm, estimated complete diameter of ~90 mm), loosely serpenticone, evolute, seemingly moderately compressed but venter embedded in matrix and prepared as much as possible without its destruction (thus, whether or not persistent groove present in most species not assessable), shell ornamented with sub-evenly spaced, strong, but variably bifurcating curvilinear and flexuous ribs, intercalated with simple, non-bifurcating ribs; some ribs with very poorly

FIGURE 2—*Blanfordiceras wallichi* (Gray, 1832), upper Tithonian Stage to possibly earliest Berriasian Stage, Fortissimo-1 well, Browse Basin, nearly complete phragmocone in lateral view coated with ammonium chloride to enhance marked ornamentation configuration of shell. Ventral region embedded in matrix.

developed, closely spaced tubercles towards venter, which become more widely(?) spaced, ~5 mm apart, towards peristome; the position of the bifurcation on the ribs is positioned relative to the venter; some do not bifurcate at all. Conch of incomplete phragmocone somewhat crushed and slightly distorted due to compaction, enhancing flush nature of whorls.

Figured specimen.—WAM 10.30.

Dimensions.—Diameter of partial phragmocone (microconch or possibly fragmentary macroconch) 78.0 mm, estimated complete diameter of ~90–100 mm.

Locality.—Fortissimo-1 wildcat well, Northwestern Australia: S 13°47′02″, E 123°24′37″.

Occurrence.—Upper Swan Formation, informally the 'Swan shale event' between the Upper Swan A sands and Upper Swan B/C sands. The ammonite is derived from the top of a distinctly muddy interval. This is likely in the uppermost Tithonian, probably equivalent to the global *Durangites* ammonite Zone, Chron M19 (certainly no older than M20) (Ogg in Gradstein et al., 2004; Yin and Enay, 2004), ca. 146.5–145.5 Ma per Ogg et al. (2008), in eastern Himalayas belonging to *Blanfordiceras wallichi* assemblage, to possibly lowermost Berriasian.

Discussion.—The evolute shell, ornament configuration of bifurcating curvilinear and flexuous primary ribs with intercalated simpler ribs, and estimated complete diameter of test approaching 10 cm, are all characters consistent with the widespread late Tithonian species *Blanfordiceras wallichi* (Gray, 1832) (see nearly identical specimen to the Fortissimo-1 individual in Yin and Enay (2004, fig. 3a)). Species of *Blanfordiceras* exhibit marked dimorphism expressed by the presence of macro- and microconchs, and both can be recognized in extensive collections of *B. wallichi* from the late Tithonian of eastern Himalayan Tibet (Yin and Enay, 2004). The extrapolated diameter of the Fortissimo-1 specimen is ~90–100 mm, which is consistent with most specimens of *B. wallichi* microconchs, as is the bifurcated nature of primary ribs with evidence of variably developed tubercles, albeit relatively poorly developed on this individual. Despite the confusion in the literature regarding the similarities of some microconchs with species of *Berriasella* as discussed above, all available evidence indicates a secure assignment of the Fortissimo-1 specimen to *Blanfordiceras wallichi*.

In terms of dating the ammonite, associated palynomorph yields in the marine facies are unsurprisingly low in the Fortissimo-1 well, but the forms identified by Robin Helby (Shell Australia) within centimeters of the ammonite belong to either the lowermost microplankton zone of the Cretaceous Period, *Pseudoceratium iehiense* Zone, or the overlying *Kalyptea wisemaniae* Zone—both from the lower Berriasian (see Helby et al., 2004). Fortunately, there are a number of wells in the area, several with better palynologic data, which allow well-to-well correlation of the interval containing the ammonite. This interval represents the *K. wisemaniae* regional marker and corresponds to a third-order flooding surface. A sample taken ~8 m above the ammonite in the same core has been assigned to the middle *K. wisemaniae* Zone (on a *Meiourogonyaulax diaphantis* Acme; early Berriasian in age); a sample very near to the ammonite is consistent with the lower subzone, represented by a down-hole increase and decrease in *Systematophora palmula* and in *M. diaphantis*, respectively, and early Berriasian in age (Shell Australia, unpubl. data). The slight disparity in the inferred, global, latest Tithonian age of the ammonite and associated microplankton zonations may represent the true survival of *Blanfordiceras wallichi* into the earliest Cretaceous in the Indo-South-West Pacific Subrealm,

or the slight offset of calibration of local and international stages.

Given the rarity of well-preserved Jurassic–Cretaceous boundary ammonites in Australian sequences, coupled with their fundamental role for Mesozoic stratigraphy and correlation, this new datum assists in refining the local biostratigraphy, especially correlations in the petroleum-bearing systems of the North West Shelf. Moreover, further discoveries will hopefully resolve the tantalizing prospect of survivorship of *Blanfordiceras wallichi* into the earliest Cretaceous.

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