

Reassessment of Australia's oldest freshwater snail, *Viviparus* (?) *albascopularis* Etheridge, 1902 (Mollusca: Gastropoda: Viviparidae), from the Lower Cretaceous (Aptian, Wallumbilla Formation) of White Cliffs, New South Wales

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Abstract

Viviparus (?) *albascopularis* Etheridge, 1902 is Australia's oldest documented fossil freshwater gastropod. The taxon was established on the basis of a single opalised shell from the Lower Cretaceous (Aptian) marine deposits of the Wallumbilla Formation (Doncaster Member) at White Cliffs, New South Wales. Reassessment indicates that original placement in the caenogastropod family Viviparidae is justified; however, the specimen is reassigned to the endemic Australian genus *Notopala* Cotton, 1935 on the basis of shell morphology and close morphometric similarity to extant species. Implications for the origins and current distribution of Australian viviparid taxa are discussed.

Introduction

The fossil record of Australian Cretaceous non-marine gastropods is depauperate and very poorly known. Nearly all the currently identified material has been recovered from the middle–upper Albian (Lower Cretaceous) fluvial–lacustrine deposits of the Grimian Ck Formation at Lightning Ridge in north-western New South Wales (NSW). This assemblage comprises primarily viviparids, although numerous other groups, including thiarids (Hamilton-Bruce *et al.* in press), succinids, camaenids (currently under study) and amphibolids (B. J. Smith, R. J. Hamilton-Bruce and B. P. Kear, unpublished data) are also present (Dettman *et al.* 1992; Smith 1999; Hamilton-Bruce *et al.* 2002). The only other documented Australian Cretaceous non-marine gastropod fossil is a single opalised shell (AM F17456) from the Aptian (Lower Cretaceous) marine sediments of the Wallumbilla Formation (Doncaster Member) at White Cliffs, NSW (Burton and Mason 1998: see figs 1,2 for detailed geological and locality maps of the area). This specimen was described (from a private collection belonging to a Mr H. Y. L. Brown of Adelaide, later acquired by the Australian Museum) by Etheridge (1902) and tentatively assigned to *Viviparus* (?) *albascopularis*, recognising similarity to members of the currently extant caenogastropod family Viviparidae. The present paper provides a revised description of the holotype (AM F17456) and only known specimen of *V.* (?) *albascopularis* Etheridge and reinterprets its taxonomic placement. Implications for the origins and distribution of Australian viviparid taxa are discussed.

The Lower Cretaceous (Aptian) opal-bearing deposits of White Cliffs have long been known as a productive locality for fossils. Anderson (1892) briefly remarked on the presence of mollusc remains, crinoids and wood. Jaquet (1893) recorded belemnite

cephalopods and Devonian invertebrate fossils preserved as impressions in large erratic clasts. These were interpreted as a product of reworking from underlying Palaeozoic conglomerates. Etheridge (1897, 1902, 1904) reported the occurrence of bivalves, ammonites, naticid gastropods, plesiosaurs and ichthyosaurs. More recent studies by White (1926), Molnar (1980, 1991) and Kemp (1991) have also identified lungfish and dinosaur remains.

Viviparus (?) *albascopularis* Etheridge is currently the oldest known Australian fossil freshwater gastropod and one of the earliest members of the Viviparidae. Today, this cosmopolitan family comprises various taxa, characterised by medium–large-sized turbiniform shells, possessing a rounded body whorl, moderately high and pointed spire, wide, round aperture and a concentric, horny operculum (Smith 1992). Within Australia, the distribution of the group is limited to a few species occurring in the large drainage basins that span much of the arid centre, northern tropical and coastal regions.

The fossil record for Viviparidae is known from the Jurassic–Recent (*Viviparus* Montfort, 1810), with a tentative report based on an internal shell mold (?*Bernicia* Cox, 1927), possibly of marine origin, from the Early Carboniferous of England (Brookes-Knight *et al.* 1960). The group's Australian record is very sparsely documented. Cotton (1935) described a species of *Notopala* Cotton, 1935 (*N. wanjacalda*) from upper Pleistocene sediments along the Murray River, near Sunnyside, South Australia (SA), and noted a second taxon (*Notopala* sp.) from the same deposit, which showed strong similarity to the extant *N. hanleyi* (von Frauenfeld, 1862). Dettman *et al.* (1992) reported viviparid snail shells from the Lower Cretaceous (middle-upper Albian) deposits of Lightning Ridge, NSW, as did Smith (1999), who also recorded representatives of the Naticidae, Thiaridae and Ellobiidae. Recently, Hamilton-Bruce *et al.* (2002) described a new genus (*Albianopalin*) and two new species of viviparid from Lightning Ridge, as well as indeterminate material attributable to the currently extant endemic Australian taxon *Notopala*. Other Australian non-marine gastropod fossils (all of Tertiary age) have been documented by Chapman (1937), McMichael (1968), Archer *et al.* (1994), Arena (1997) and Pledge *et al.* (2002). Occurrences from elsewhere in Australasia are rare, particularly in Cretaceous sediments. Some of the few examples include viviparids (genera uncertain) and thiarids (?*Melanooides* Olivier, 1804) from the Cenomanian–?Santonian (Upper Cretaceous) of New Zealand (Henderson *et al.* 2000) and possible thiarids (*Pyrgulifera* Meek, 1871) from both the Campanian–lower Maastrichtian (Upper Cretaceous) of the Chatham Islands (Stilwell 1998) and ?Campanian of New Caledonia (Henderson *et al.* 2000).

Material and methods

Material registered as the holotype of *V. (?) albascopularis* Etheridge includes a single shell with broken aperture margin and protoconch (AM F17456), preserved entirely in potch (non-precious or common opal). The specimen is derived from an unknown mine locality in the opal-bearing deposits of White Cliffs near Wilcannia in north-western NSW. The lithostratigraphic nomenclature for Lower Cretaceous rocks of the White Cliffs area was recently discussed by Burton and Mason (1998), who placed them within the Doncaster Member of the Wallumbilla Formation (Eromanga Basin), a unit of Aptian–middle Albian (115–approximately 100 million years ago; *sensu* Lowrie *et al.* 1980) age. However, the White Cliffs opal-bearing sediments are regarded as representing only the lower Aptian section of the Doncaster Member and comprise predominantly sandy/silty claystone and fine-grained sandstones deposited in a near-shore coastal marine setting (Burger 1988; Burton and Mason 1998). Determinations of palaeolatitude place the White Cliffs area as high as 70°S during the Early Cretaceous (Embleton 1984). Palaeoclimatic indicators for the region also suggest predominantly cool, strongly seasonal conditions with winter freezing (Frakes and Francis 1988, 1990; Sheard 1990; Frakes *et al.* 1995; De Lurio and Frakes 1999; Henderson *et al.* 2000). Estimates of sea level isotopic palaeotemperatures in the south-western section of the

Eromanga Basin have yielded averages as low as 12.2°C (Stevens and Clayton 1971; Dettman *et al.* 1992). However, Selwood *et al.* (1994) reported revised isotopic data supporting much cooler ocean temperatures during the Early Cretaceous. Indeed, Pirrie *et al.* (1995) indicated palaeotemperatures of around 10°C based on Early Albian belemnites from the Carnarvon Basin, Western Australia (situated at approximately 45° palaeolatitude during the Cretaceous). In contrast, Huber *et al.* (1995) and Huber and Hoddell (1996) argued that minimal pole-to-equator thermal gradients existed during much of the Middle–Late Cretaceous. This was also discussed by Henderson *et al.* (2000), who noted that although palaeotemperatures at 70°–80° latitude would certainly have been more equitable than they are today, evidence such as the distinct growth-banding in Australian Cretaceous wood (Dettman *et al.* 1992), and the presence of potentially ice-rafted quartzite/porphyritic boulders (Frakes and Francis 1988, 1990; Frakes *et al.* 1995) and glendonites (crystal aggregates pseudomorphing the calcium carbonate hexahydrate mineral ikaite; Sheard 1990; DeLurio and Frakes 1999) attests to the strong seasonality and winter freezing along the inboard extremity of the Australian epicontinental seaway during the Aptian.

Shell diameters were measured using the method of Boycott (1928), defined as ‘... the greatest dimension that can be found starting with the edge of the lip to a point on the opposite side of the shell on the last whorl’. Shell measurements were made to the nearest 0.05 mm using dial calipers.

The Australian Museum, Sydney is abbreviated as AM throughout.

Systematics

Class GASTROPODA

Superorder CAENOGASTROPODA

Superfamily VIVIPARIOIDEA

Family VIVIPARIDAE Gray, 1847

Diagnosis

Medium to large dextral, turbiniform shells with rounded body whorl, spire moderately high and pointed, aperture wide and round to distinctly lunate–ovate, lirae present or absent and horny, concentric operculum.

Remarks

The above diagnosis follows Smith (1992), modified to accommodate the presence of a distinctly lunate–ovate aperture and spiral lirae on the last body whorl of the holotype specimen, AM F17456. Viviparid snails are, as their name suggests, live bearing and are found in both lotic and lentic systems throughout the world (Browne 1978). Within Australia, the family is currently represented by the extant native genera *Notopala*, *Larina* Adams, 1851 and *Centrapala* Cotton, 1935 (see Smith 1992) and the introduced *Bellamyia heudei guangdongensis* (Kobelt, 1906), an Asian species now recorded in the wild in NSW (Shea 1994).

Australian endemic viviparids have undergone extensive taxonomic revision in recent years (the most inclusive analysis currently being undertaken by W. Ponder of the Australian Museum, personal communication, 2002), with better understanding of intraspecific shell variation and morphometric data resulting in a substantial reduction in the number of accepted species (see Sheldon and Walker 1993). However, many of the key characteristics used to determine interrelationships, such as shell colour and form of the operculum, are usually lost in fossil material; therefore, only structural features of the shell (see below) can be used to assign them to taxa.

Genus *Notopala* Cotton, 1935

Notopala Cotton, 1935: 339. Type species (by original designation): *Paludina hanleyi* von Frauenfeld, 1864.

Diagnosis

Shell dextral, globose–conic, subumbilicate, up to 5 whorls, ventricose to angulate below the periphery; spiral lirae present on periostracum of last body whorl in some taxa; aperture large and subovate to lunate–ovate, aperture size equal to or greater than height of spire, operculum corneous (unknown in fossil taxa).

Remarks

Despite the recovery of AM F17456 from a deposit of marine origin, its shell morphology fits within the currently accepted diagnosis of *Notopala* and Viviparidae with only slight modification (the presence of a distinctly lunate–ovate aperture and calcified spiral lirae on the last body whorl). To justify placement within the family and to establish a basis for both generic reassignment and comparison with extant species, we have applied parts of the morphometric data gathered by Sheldon and Walker (1993). The histogram in Fig. 1 is based on measurements of shell characteristics for each of the living Australian species of *Notopala* (derived from Sheldon and Walker 1993) and illustrates the morphometric similarity of AM F17456, redescribed herein, to currently existing members of the genus.

***Notopala albascopularis* (Etheridge, 1902)**

(Fig. 2A–D)

Viviparus (?) *albascopularis* Etheridge, 1902: 43; pl. VII, figs 8,9.

Material examined

Holotype. AM F17456. Type locality and horizon: White Cliffs Opal Field (exact mining claim locality unknown), near Wilcannia, north-western NSW. The deposits form part of the Doncaster Member of the Wallumbilla Formation (Rolling Downs Group), Eromanga Basin, and are of Aptian age (see Burton and Mason 1998). This corresponds to the *Cyclosporites hughesii*–lower-most *Crybelosporites striatus* spore–pollen Zones and *Odontochitina operculata*–*Diconodinium davidii* dinoflagellate zones of Helby *et al.* (1987).

Diagnosis

With the features of the genus; irregular, pustular lirae present on the last body whorl; aperture somewhat poorly preserved but distinctly lunate–ovate and markedly adapically situated.

Description

Shell (Fig. 2A–C) dextral, turbiniform, very slightly carinate, subglobose, 21.65 mm high, 20.05 mm maximum diameter, 13.55 mm aperture length, 11.5 mm aperture width, 8.1 mm spire length. Teleconch four complete whorls and broken parts indicating further whorls, probably up to five. Whorls impressed. Relatively evenly spaced fine spiral prosocline growth lines on lower three whorls. Aperture large (13.55 mm high), slightly subangular, distinctly ovate–lunate, markedly adapically situated. Opal replacement of original shell material indicates 12 or more irregular, pustular lirae on the last body whorl (Fig. 2D).

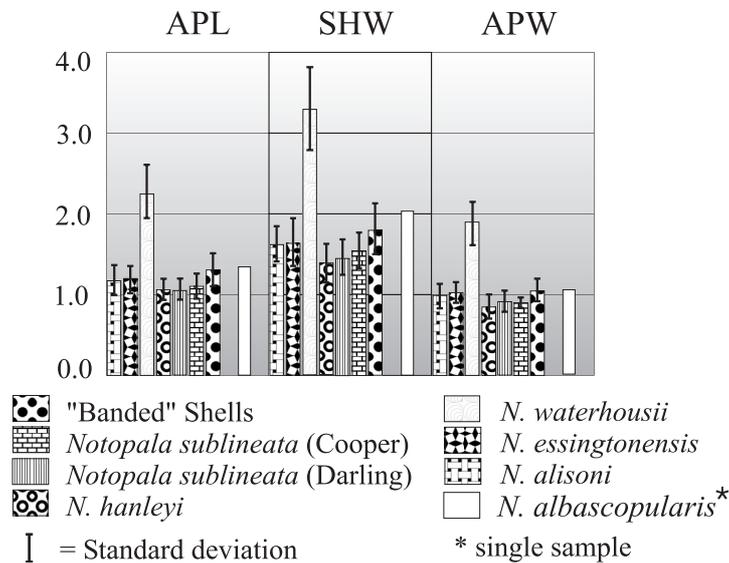


Fig. 1. Histogram showing results of morphometric analysis. Taxa include living species of *Notopala* (measurements modified from Sheldon and Walker 1993) and *N. albascopularis* (Etheridge, 1902), AM 17456. APL, aperture length; APW, aperture width; SHW, shell width.

Remarks

Holotype unique. The presence of irregular, pustular lirae on the last body whorl and a distinctly lunate-ovate, markedly adapically situated aperture separates *N. albascopularis* (Etheridge, 1902) from other species of *Notopala*. The generic reassignment of the holotype specimen is highly significant because previously none of the currently living native Australian viviparid genera was known from deposits older than middle-upper Albian (upper-most Lower Cretaceous). This temporal range is now extended back to the Aptian.

Discussion

The fossil record of Australian non-marine gastropods is very sparsely documented, with the majority of existing reports describing material of Tertiary to Holocene age. Mesozoic specimens have, to date, only been identified from middle to upper Albian (Lower Cretaceous) sediments of the Griman Ck Formation at Lightning Ridge in northern NSW (Dettman *et al.* 1992; Smith 1999; Hamilton-Bruce *et al.* 2002). Therefore, recovery of *N. albascopularis* (Etheridge, 1902) from the Aptian deposits of the Wallumbilla Formation (Doncaster Member) at White Cliffs gives this taxon the distinction of being both Australia's oldest definitively assigned non-marine gastropod and the earliest recorded representative of the Viviparidae in Australia. Recognition of *N. albascopularis* as a viviparid also serves to extend the family's temporal range in this region back to at least the later stages of the Early Cretaceous and, given its Jurassic-Recent fossil record in Europe, suggests a possible pre-Jurassic Pangean origin for the group. By the Early Cretaceous, the family had clearly diversified within the Gondwanan region, establishing key endemic taxa that still exist as descendant lineages today. This may be seen, to some extent, in the strong morphological similarity between *N. albascopularis* and other currently extant Australian

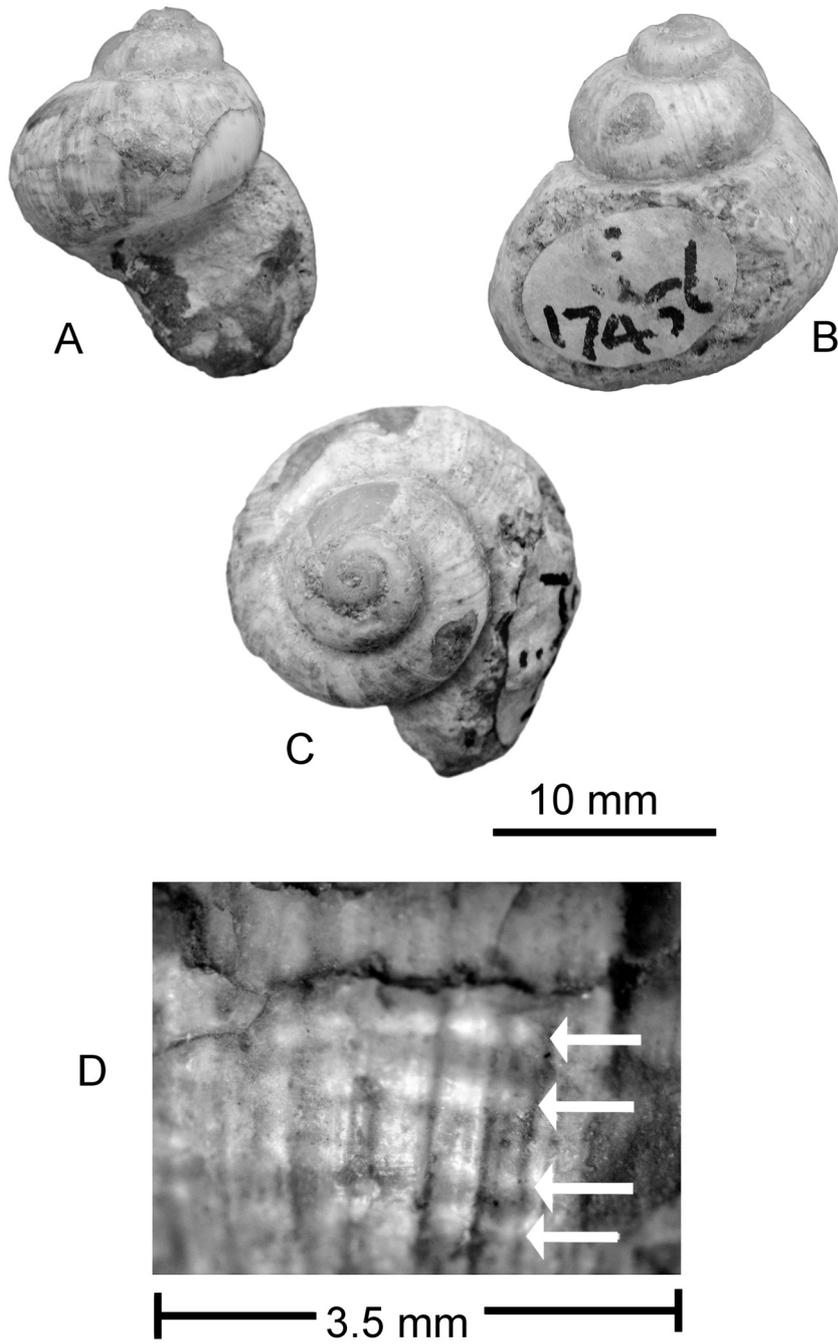


Fig. 2. AM 17456 *Notopala albiscopularis* (Etheridge, 1902) in (A) apertural, (B) dorsal and (C) apical views. (D) Magnified section of last body whorl showing lirae (arrowed).

species of *Notopala*, particularly *N. hanleyi* and *N. sublineata* (Conrad, 1850) (see Fig. 1), both of which could potentially represent morphological derivatives. However, further study and the discovery of additional fossil material are required before any definitive phylogenetic relationship can be demonstrated.

Although there are numerous records of Cretaceous freshwater bivalves from Australia (McMichael 1957; Ludbrook 1985; Jell and Duncan 1986; Dettman *et al.* 1992; Hocknull 1997), there are very few for non-marine gastropods of the same period. Indeed, most of the better documented terrestrial units, including the Wonthaggi Formation, Eumeralla Formation and Koonwarra Beds (Korumburra Group) of Victoria (see Jell and Duncan 1986; Rich *et al.* 1988; Rich and Rich 1989) and Winton Formation of Queensland and SA (see Ludbrook 1985; Dettman *et al.* 1992; Hocknull 1997), have yet to produce any identifiable gastropod remains. The reasons for this apparent absence are unknown, but could be related to preservational biases, such as shells rapidly breaking up or dissolving after death. However, isolated specimens, such as the holotype of *N. albascopularis*, seem to have, on occasion, survived transport over considerable distances (perhaps on floating vegetation) prior to eventual burial. This scenario also appears to have been common for many of the other fossils at White Cliffs, which include a high proportion of terrestrial plant remains (Anderson 1892; Jaquet 1893; Etheridge 1902; Newton 1914), freshwater invertebrates (Etheridge 1902; Newton 1914; McMichael 1957; Dettman *et al.* 1992) and occasional freshwater/terrestrial vertebrates (White 1926; Molnar 1980, 1991; Kemp 1991), all probably derived from fluvial input into the near-shore marine depositional environment.

Another factor possibly influencing the distribution of Early Cretaceous freshwater gastropods in Australia may have been the strongly seasonal cool to cold climates, which characterised many of the high-latitude continental (Douglas and Williams 1982; Gregory *et al.* 1989; Dettman *et al.* 1992; Cantrill 1998) and marine (Frakes and Francis 1988, 1990; Sheard 1990; Frakes *et al.* 1995; De Lurio and Frakes 1999) environments of the time. Although this may have limited the number of available habitats for non-marine gastropod species, it does not appear to have restricted overall taxonomic diversity or specimen numbers in the few deposits where they occur. Indeed, it is interesting to note that in the Lower Cretaceous freshwater river and lake deposits of Lightning Ridge, viviparids are one of the most common invertebrate faunal elements, far outnumbering other sympatric groups, such as thiarids, ellobiids and naticids (Smith 1999). The reasons for this apparent success are unknown, but could be related to the ability of the viviparids to give birth to live young and, thus, secure a competitive advantage over their contemporaries (however, larval brooding is also present in thiarids). Similarly, strict adaptation to freshwater may have enabled Cretaceous viviparids to rapidly colonise available upstream habitats. This contrasts with naticids and thiarids, whose Cretaceous record is largely derived from near-shore marine strata (see Etheridge 1902, Ludbrook 1966; Dettman *et al.* 1992; Stilwell 1998; Henderson *et al.* 2000), and may reflect a preference for more brackish water conditions around estuaries and coastal lagoons.

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