



## Research paper

# *Neohornibrookella sorrentae* (Chapman and Crespin, 1928) and allied ostracod taxa from the Neogene of southeastern Australia: Systematic and palaeoceanographical relationships, palaeoecology and palaeobiogeography

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## ABSTRACT

Three closely allied shallow marine taxa, *Neohornibrookella sorrentae* (Chapman and Crespin), *Neohornibrookella glyphica* (Neil), and *Neohornibrookella nepeani* sp. nov. are recorded from latest early Miocene to late Pliocene strata in southeastern Australia. These taxa, together with *Neohornibrookella quadranodosa* (Holden) from the Miocene of Midway Island (Northwestern Hawaiian Islands), form a morphologically distinct group of relatively large species (the *sorrentae*-group) within the genus *Neohornibrookella* Jellinek. Latitudinal expansion of the subtropical and warm-temperate climatic belts together with the influence of warm western boundary surface currents associated with the North and South Pacific gyres, are likely to have played key roles in the Miocene dispersal of this species group. Species of the *sorrentae*-group first migrated south from equatorial west Pacific regions into southeastern Australia during the early Miocene, under the influence of the East Australian Current. During three time intervals (i) latest early Miocene, (ii) latest late Miocene and (iii) earliest late Pliocene, forceful pulses of the East Australian Current played a significant role in propelling the widespread distribution of thermophilic *Neohornibrookella* species across southeast Australian shallow marine realms. During intervening middle and late Miocene times, *Neohornibrookella* species are only sporadically present across the Bass Strait region of southeast Australia, indicating a weaker East Australian Current influence and the cooling influence of coastal upwelling. During the mid early Pliocene *Neohornibrookella* species disappeared from the western Bass Strait region, suggesting the complete exclusion of East Australian Current waters from this region. This was probably due to the counteracting influence of the eastward flowing Zeehan Current (extension of the Leeuwin Current) impinging on the western Bass Strait region. This mid early Pliocene palaeobiogeographical partition in Bass Strait, defined by the distribution of *sorrentae*-group species, is here termed the Bassian Gateway. The two species, *N. sorrentae* and *N. glyphica*, occur concurrently during the mid Miocene in southeast Australia, but are associated with different lithofacies. It is hypothesised that there is a heterochronic evolutionary relationship expressed in the ornament of these two species. The thaerocytherid genera *Neohornibrookella* Jellinek, *Tenedocythere* Sissingh and *Bosasella* Bonaduce are here included in the new ostracod subfamily Tenedocytherinae.

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## 1. Introduction

The three southeast Australian Miocene ostracod species *Neohornibrookella sorrentae* (Chapman and Crespin, 1928), *Neohornibrookella glyphica* (Neil, 1994) and *Neohornibrookella nepeani* sp. nov., together with *Neohornibrookella quadranodosa* (Holden, 1976) from the Miocene of Midway Island (Northwestern Hawaiian Islands), form a morphologically distinctive species group within the genus *Neohornibrookella* Jellinek, 1993 of the cytheroid family

Thaerocytheridae Hazel, 1967. This is here designated the *sorrentae* species group. Species within this group have previously been variously assigned to the genera *Hermanites* Puri, 1955, *Tenedocythere* Sissingh, 1972 and *Thaerocythere* Hazel, 1967 (Holden, 1976; McKenzie, 1981; Neil, 1994; Mostafawi, 2002). However, in this study, the morphological characteristics that define the genus *Neohornibrookella* are broadened to include this species group, which it is argued, better reflects phylogenetic and palaeobiogeographical relationships (Sections 2 and 5.1). Two other species groups, the *transoceanica*-group, and the *titanikos*-group, are also here included in the genus *Neohornibrookella*. Thaerocytherid species of the genera *Neohornibrookella*, *Tenedocythere* and *Bosasella* Bonaduce, 1985 are assigned to the new, largely tropical

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to warm temperate shallow marine subfamily, Tenedocytherinae. Systematic descriptions pertinent to this study are presented in Appendix A.

*Neohornibrookella* (*sorrentae*-group) species first appear in the southeast Australian fossil record in the early Miocene, and disappear in the latest Pliocene. Prior to extinction, there was an apparent strong association with Pacific gyre currents. This association is here used to: (i) evaluate the late Cenozoic confluence history of opposing ocean currents within the Bass Strait region of southeastern Australia, and (ii) delineate spatial and temporal palaeobiogeographical patterns in Neogene marine ostracod distribution across the Bass Strait seaway (Section 5).

## 2. Systematic relationships

The palaeobiogeographical and palaeoceanographical interpretations presented later in this paper (Sections 4.1 and 4.3) directly relate to, and are predicated on the taxonomic definitions of the ostracod genus *Neohornibrookella* and its composite species groups as defined below.

### 2.1. *Neohornibrookella* generic concept

*Neohornibrookella* Jellinek, 1993 was originally erected as a monospecific taxon to accommodate a species from modern coastal waters of Kenya, identified by Jellinek (1993) as *Cythere lactea* Brady 1866. Jellinek (1993) also regarded *C. lactea*, which was originally described from Australian marine waters, as a senior synonym of *Hermanites transoceanica* Teeter, 1975 from the Caribbean. Keyser and Schöning (2000), Mostafawi (2002) and Mostafawi et al. (2005) concurred with Jellinek's (1993) synonymy of these two taxa. Jellinek's (1993) concept of the carapace morphology for *C. lactea* Brady follows that of Holden (1976). It was Jellinek's (1993) clear intention that *H. transoceanica* Teeter, 1975 be the type species, his nomination of *C. lactea* Brady, 1866 as such, being only because he believed the former species name to be a junior synonym of the later species name. However, Whatley et al. (2004) and Titterton and Whatley (2008) considered the original hand drawn illustrations of *C. lactea* in Brady (1866) to not closely resemble *H. transoceanica* Teeter, 1975. We have examined light microscope images of the syntype specimen of *C. lactea* Brady, 1866 (courtesy of David Horne), which is currently housed within the G. S. Brady Collection in the Discovery Museum, Newcastle upon Tyne, United Kingdom. This left valve specimen, is the only type material for *C. lactea* s.s. (see also discussion in Titterton and Whatley, 2008). This specimen is of a different species to that represented by the type material of *H. transoceanica* Teeter (1975; fig. 11p, r) (D. Horne pers. comm. to MW). The hand drawn illustration of the external left valve of *C. lactea* in Brady (1866, pl. 60, fig. 3a) faithfully reproduces the posterodorsal ridge ornament of this species, which is different to that in *H. transoceanica* as illustrated in Teeter, 1975 (fig. 11p, r). Despite uncertainty relating to the identity of the type species for *Neohornibrookella*, in this study we have assumed that the valve and carapace features of *H. transoceanica* specimens from Kenyan coastal marine waters, misidentified as *C. lactea* Brady, 1866 by Jellinek (1993; pl. 28, figs. 436–443), are the primary defining characters for this genus. This view accords with the current consensus concerning the defining carapace characters of *Neohornibrookella* (e.g. Keyser and Schöning, 2000; Mostafawi, 2002 and Mostafawi et al., 2005). A forthcoming publication will provide formal resolution of the type species identity for *Neohornibrookella* – and this taxonomic issue is not further discussed in detail here.

Jellinek (1993) considered the presence of three frontal muscle scars to be a key morphological characteristic of his new genus *Neohornibrookella*. Jellinek's (1993) emphasis on this character as a generic diagnostic feature is reflected by his establishment of a different genus *Paraquadracythere* Jellinek, 1993 to accommodate the species

*Cythere deltoides* Brady, 1890, which Jellinek (1993) indicated had two frontal muscle scars. However, Labutis (1977) illustrated three frontal muscle scars in specimens of *C. deltoides* from Gladstone Harbour on the Great Barrier Reef, northeast Australia. Thus, there seems to be a degree of intraspecific variability in the frontal muscle scars for this species, and the genus *Paraquadracythere* is, therefore, here regarded as a junior synonym of *Neohornibrookella* (as also suggested by Mostafawi, 2002).

In this study a broad range of species and associated carapace morphologies, are included within *Neohornibrookella*. This is a much broader concept of this genus than originally proposed by Jellinek (1993). Three informal species groups are proposed for *Neohornibrookella*, which are differentiated on characteristics of carapace size and ornament as follows:

(i) *Neohornibrookella transoceanica* (Teeter, 1975), *Neohornibrookella deltoides* (Brady, 1890), *Neohornibrookella setigera* (Holden, 1976) and *Neohornibrookella trinidadensis* (Coimbra and Carreño, 2012) form the first group, here referred to as the *transoceanica*-group. Within the genus *Neohornibrookella*, these are relatively small to medium-sized species that generally possess two short oblique ribs running across an indistinct subcentral tubercle.

(ii) *Neohornibrookella sorrentae* (Chapman and Crespin, 1928), *Neohornibrookella glyphica* (Neil, 1994), *Neohornibrookella nepeani* sp. nov., and *N. quadrinodosa* (Holden, 1976) form the second group here referred to as the *sorrentae*-group. Within the genus *Neohornibrookella* these are relatively large species that have a distinct subcentral tubercle with usually indistinct superimposed ribs.

(iii) *Neohornibrookella titanikos* (Whatley et al., 2000), *Neohornibrookella stasiotes* (Whatley et al., 2004) and *Neohornibrookella alloios* (Whatley et al., 2000) form the third group, here referred to as the *titanikos*-group. Within the genus *Neohornibrookella* these are medium-sized to large species, where the main ridges posterior of the subcentral tubercle join to form a three-sided, broadly sub-triangular, ornamental feature.

Geographical and chronological parameters of these informal species groups are outlined in Section 5.1. A further fossil species, *Cythere bavarica* Lienenklaus, 1896 (sensu Bonaduce et al., 1986), from the Miocene of the Mediterranean may be ancestral to *Neohornibrookella* species.

### 2.2. *Tenedocythere* generic concept

The concept of *Tenedocythere* was established by Sissingh (1972) on fossil species from the eastern Mediterranean such as *Tenedocythere prava* (Baird, 1850) (type species) and *Tenedocythere mediterranea* (Ruggieri, 1962). Bonaduce et al. (1986) and Mostafawi (2002) extended the number of fossil species assigned to this genus, but all these were also from the Mediterranean region. Holden (1976), McKenzie (1981, 1986), Whatley and Jones (1999), Whatley et al. (2000, 2004) and Titterton and Whatley (2008) took a broader view of the range in carapace morphology, including, for instance, *C. deltoides* Brady, 1890 and *H. transoceanica* Teeter, 1975, within this genus. In this study the concept of the genus *Tenedocythere* is confined to Mediterranean fossil and Recent species (i.e., sensu Bonaduce et al., 1986 and Mostafawi, 2002), which in addition to *T. prava* and *T. mediterranea*, includes *Tenedocythere exornata* (Terquem, 1878), *Tenedocythere scalprata* Bonaduce et al., 1986, *Tenedocythere parallela* Bonaduce et al., 1986, *Tenedocythere cruciata* Bonaduce et al., 1986, *Tenedocythere subulata* Bonaduce et al., 1986, *Tenedocythere perplexa* Bonaduce et al., 1986, *Tenedocythere birestis* Bonaduce et al., 1986, *Tenedocythere obsoleta* Bonaduce et al., 1986, *Tenedocythere scabriuscula* Bonaduce et al., 1986 and *Tenedocythere numerata* (Terquem, 1878). Of further note, Mostafawi (2002) has divided these Mediterranean *Tenedocythere* species into two groups – the *prava* and *exornata* species groups.

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