Journal of Natural History
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tnah20

A primitive representative of the Parabathynellidae (Bathynellacea, Syncarida) from the Yilgarn Craton of Western Australia

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Published online: 21 Feb 2007.

Journal of Natural History, 2005; 39(39): 3423–3433

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(Accepted 7 September 2005)

Abstract
Billibathynella humphreysi gen. et sp. nov. is described from calcrete aquifers located in the Yilgarn Craton of north-western Australia. This is the first parabathynellid known from the Australian Precambrian shields, which have never been inundated by the sea. A comparison of the primitive species so far known from Australia and other continents points to the new species as being the most primitive among the parabathynellids. It further suggests that the new genus has an affinity to *Notobathynella* Schminke, but differs in having a six-segmented antenna and a large epipod of the male thoracopod VIII. An attempt to relate the primitiveness of the new species to the historiogeological characteristics of the region has led to the conclusion that the recent parabathynellids could have emerged from freshwater epigean ancestors. It is further assumed that the transition of their ancestors to groundwaters happened in Notogaea.

Keywords: *New genus, new species, Parabathynellidae, Western Australia*

Introduction

Bathynellaceans are typical inhabitants of continental groundwaters, which occur world-wide. Since no mechanism is known by which the species could have been dispersed beyond the interstitial, they are particularly interesting subjects for historical zoogeography (Schminke 1974; Camacho and Coineau 1989; Camacho 2003). There are two families in this order, the Bathynellidae and the Parabathynellidae. Because of the greater richness in taxonomic characters, the species of the latter family are taxonomically better studied than those of the Bathynellidae. Currently, we know almost 120 parabathynellid species comprising 35 genera (cf. Schminke 1986; Coineau 1996; Camacho et al. 2000). Of these, five genera are known from Notogaea: *Notobathynella* Schminke, 1973, *Chilibathynella* Schminke, 1973, *Atopobathynella* Schminke, 1973, *Hexabathynella*, Schminke, 1972, and *Kimberleybathynella* Cho et al., 2005. Here we describe a new species, for which the sixth genus of the Australian continent is erected. This species is particularly interesting because of two following points of view. First, it displays primitiveness in all characters and is

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Published 23 December 2005.

ISSN 0022-2933 print/ISSN 1464-5262 online © 2005 Taylor & Francis
DOI: 10.1080/00222930500345806

comparable to the stem species of the Parabathynellidae, as hypothesized by Schminke (1973). Second, the locality where the new species was discovered is the Yilgarn Craton of Western Australia, which has not been inundated by sea water since at least the Palaeozoic (Humphreys 1999). Hence the new species is expected to bring a novel aspect to the taxonomy as well as the historical zoogeography of the family Parabathynellidae.

Material and methods

The material was collected using a large hand net (350 μm mesh) after abseiling into the well. The well is concrete lined at the top but with bare calcrete near the floor, and about 6 m deep. The water was 0.2 m deep with the following characteristics: temperature 26.0°C; pH 7.49; specific conductance 2.61 mS cm^{-1}; dissolved oxygen 6.37 mg l^{-1}. The well is reported by the land manager to have consistently yielded 30,000 gallons h^{-1} (136 kl h^{-1}) of irrigation water, for which it is no longer used. Description of the typical calcrete habitat is provided by Humphreys (1999, 2001).

The samples were prepared and mounted in a mixture of glycerin–formalin. For drawing and investigation, a Nikon Eclipse E600 microscope with differential interference contrast equipment was used with oil immersion. The type materials of the new species herein described are permanent preparations deposited in the collection of the Western Australian Museum, Perth (WAM).

Billibathynella gen. nov.

Diagnosis

Parabathynellidae. Body elongated and cylindrical. Antennule seven-segmented. Antenna seven-segmented. Labrum flat with numerous teeth on its free margin. Incisor process of mandible with more than five spines. Mandibular palp twice as long as wide. Maxilla four-segmented. Thoracopods I–VII with exopod of more than five segments (up to 10). Male thoracopod VIII almost rectangular, 1.5 times longer than width; protopod protruded at inner distal corner; epipod large, triangular, its distal part covering penial region of protopod; basipod without setae, inner margin of basipod drawn out into projection. Uropod with numerous spines on sympod; endopod with two distal spines, two plumose setae near base, three distal setae and a protrusion on disto-outer margin, inner spines variable in number; exopod with numerous setae and a basi-ventral seta. Anal operculum flat to slightly concave. Furcal rami elongated, with two large distal spines and numerous spines on inner margin.

Type species

Billibathynella humphreysi gen. et sp. nov., here designated.

Etymology

The generic name refers to one taxon and is named after Dr W. F. Humphreys, alias Bill (Perth, Australia) for his great contributions to the research on the Australian groundwater fauna. Gender feminine.

Billibathynella humphreysi sp. nov.
(Figures 1–5)

Material examined

Holotype: adult ♂, dissected on five slides, coll. Western Australian Museum, Perth (WAM C 34441). Allotype: adult ♀, dissected on five slides, coll. Western Australian Museum, Perth (WAM C 34442). Paratypes: two ♂♂ (WAM C 34443, C 34487) and three ♀♀ (WAM C 34488–34490) each as whole specimen in a slide. Locus typicus. Gascoyne, Mt Padbury Station, Western Australia, Australia, irrigation well at homestead site 411 (26°41′44″S, 118°42′53″E), BES 9305. 6 June 2002, leg. W. F. Humphreys and L. Leijs. Other locality: Mt Padbury Station, irrigation well at homestead site 410 (26°41′42″S, 118°42′51″E).

Description of male

Body length 6.30 mm (other males: 6.16, 5.45 mm), approximately 13 times as long as wide. Head as long as anterior three thoracic segments combined (Figure 1).

Antennule (Figure 2A) seven-segmented. First segment with one seta on inner distal margin, with five simple dorsal setae, and with one dorsal, two lateral and one ventromedial plumose seta. Second segment with one group of four plumose setae and with six simple setae on inner distal margin. Third segment with two lateral setae and six setae on inner distal margin. Inner flagellum of third segment with three simple setae. Fourth segment with one stub seta and one plumose seta on dorsal margin, and with two stub setae and two plumose setae on outer distal apophysis. Fifth segment with four setae on inner margin, with two aesthetascs and one simple seta dorsally. Sixth segment with four setae on inner margin, with two aesthetascs and one seta dorsally, and with one aesthetasc. Seventh segment with three subterminal aesthetascs and four simple setae.

Antenna (Figure 2B) seven-segmented, as long as the length of antennular segments 1–4. Setal formula: 0 + 0/0 + 0/1 + 1/1 + 1/0 + 0/2 + 1/4(1).

Labrum (Figure 2C) flat with 28 teeth. Fourteen frontal teeth of more or less equal size flanked by small teeth on both sides. Inner surface with numerous combs of ctenidia and teats.

Mandible (Figure 2D) with incisor process of six teeth. Tooth of ventral edge triangular. Spine row consisting of 14 spines. Palp of two segments, distal segment with two apical setae and one subterminal seta.

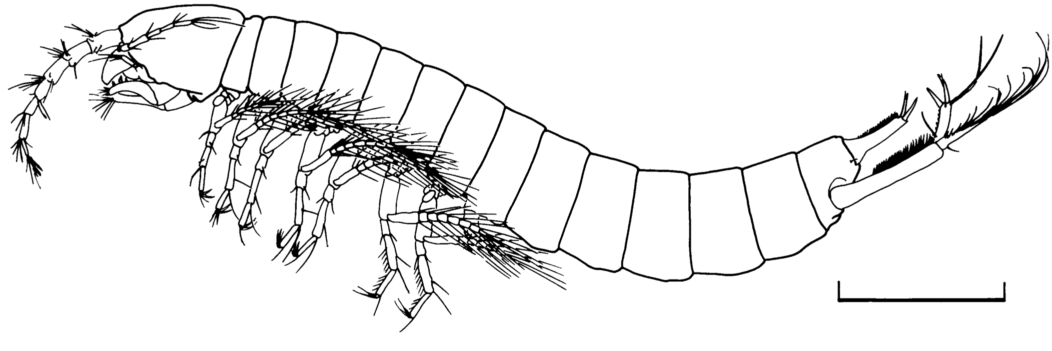

Figure 1. *Billibathynella humphreysi* sp. nov., holotype (♂). Scale bar: 1 mm.

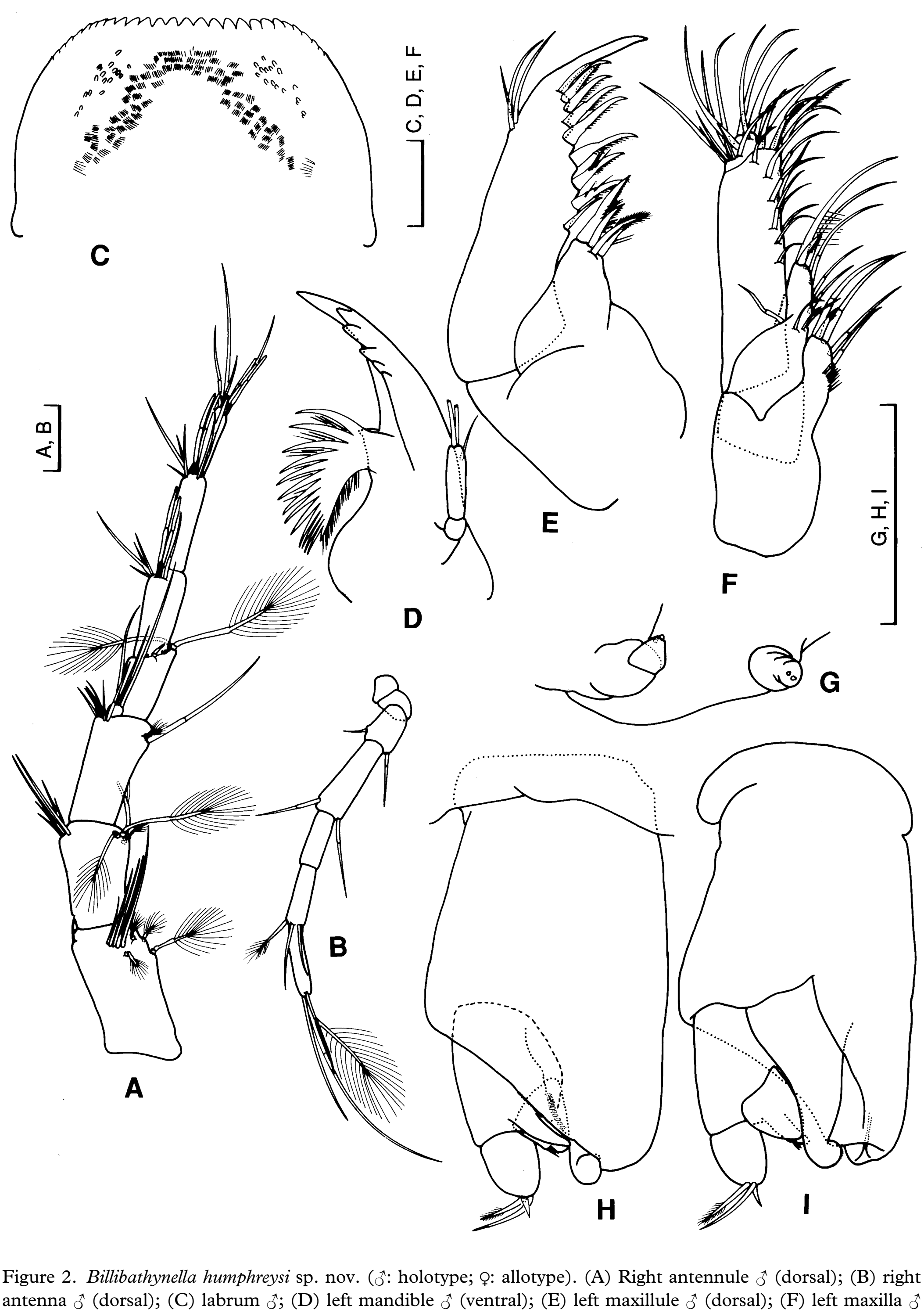

Figure 2. *Billibathynella humphreysi* sp. nov. (♂: holotype; ♀: allotype). (A) Right antennule ♂ (dorsal); (B) right antenna ♂ (dorsal); (C) labrum ♂; (D) left mandible ♂ (ventral); (E) left maxillule ♂ (dorsal); (F) left maxilla ♂ (dorsal); (G) right and left thoracopods VIII ♀ (ventral); (H) left thoracopod VIII ♂ (inner lateral); (I) right thoracopod VIII ♂ (outer lateral). Scale bars: 0.1 mm.

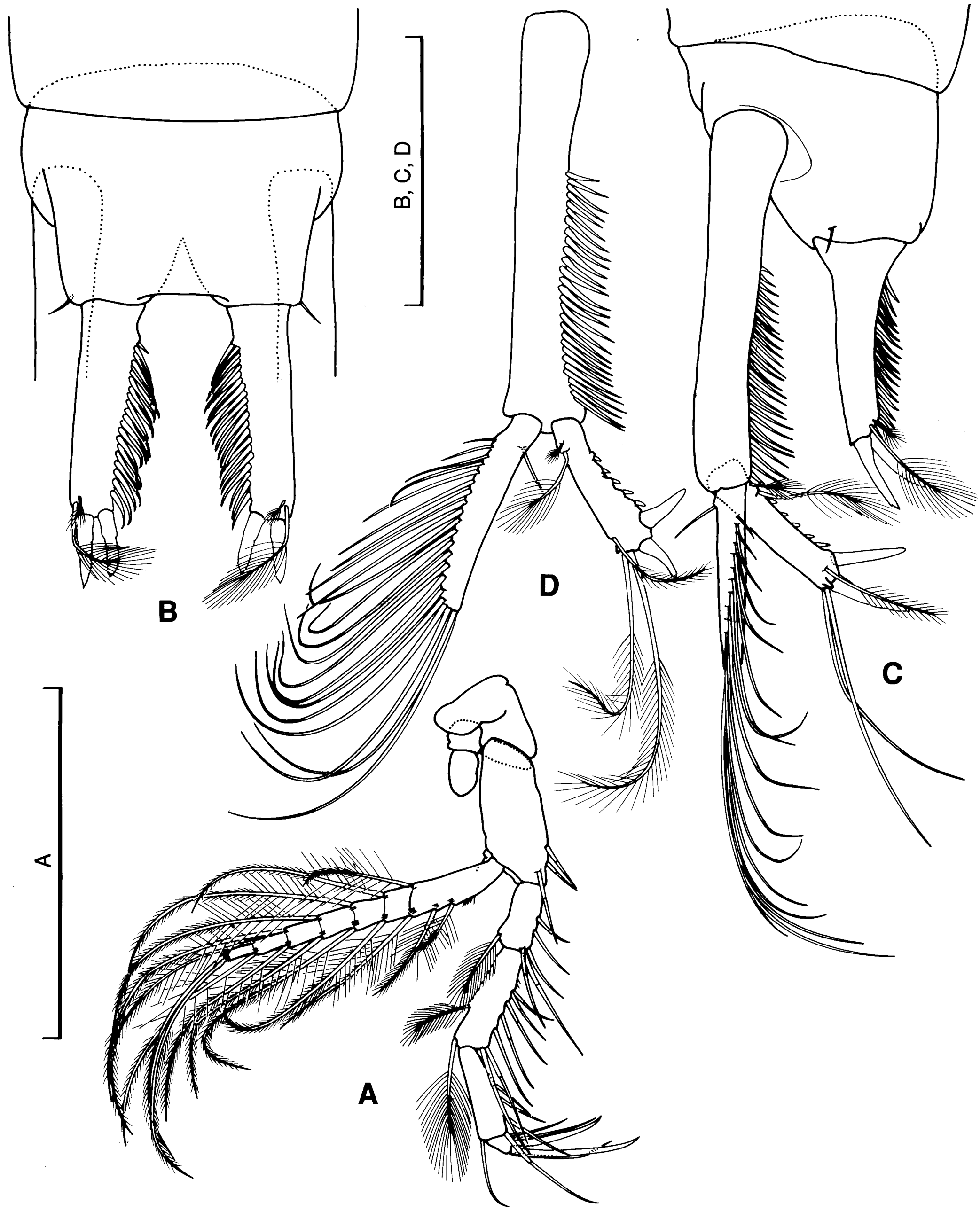

Figure 3. *Billibathynella humphreysi* sp. nov. (holotype). (A) Right thoracopod I ♂ (frontal); (B) pleotelson and furcal rami ♂ (dorsal); (C) pleotelson, furcal rami, and uropod ♂ (lateral); (D) left uropod ♂ (dorsal). Scale bars: 0.5 mm.

Maxillule (Figure 2E) two-segmented. Proximal segment with four claw-like setae on inner distal margin. Distal segment with two terminal claws, eight claws on inner edge, and three simple setae on outer distal margin.

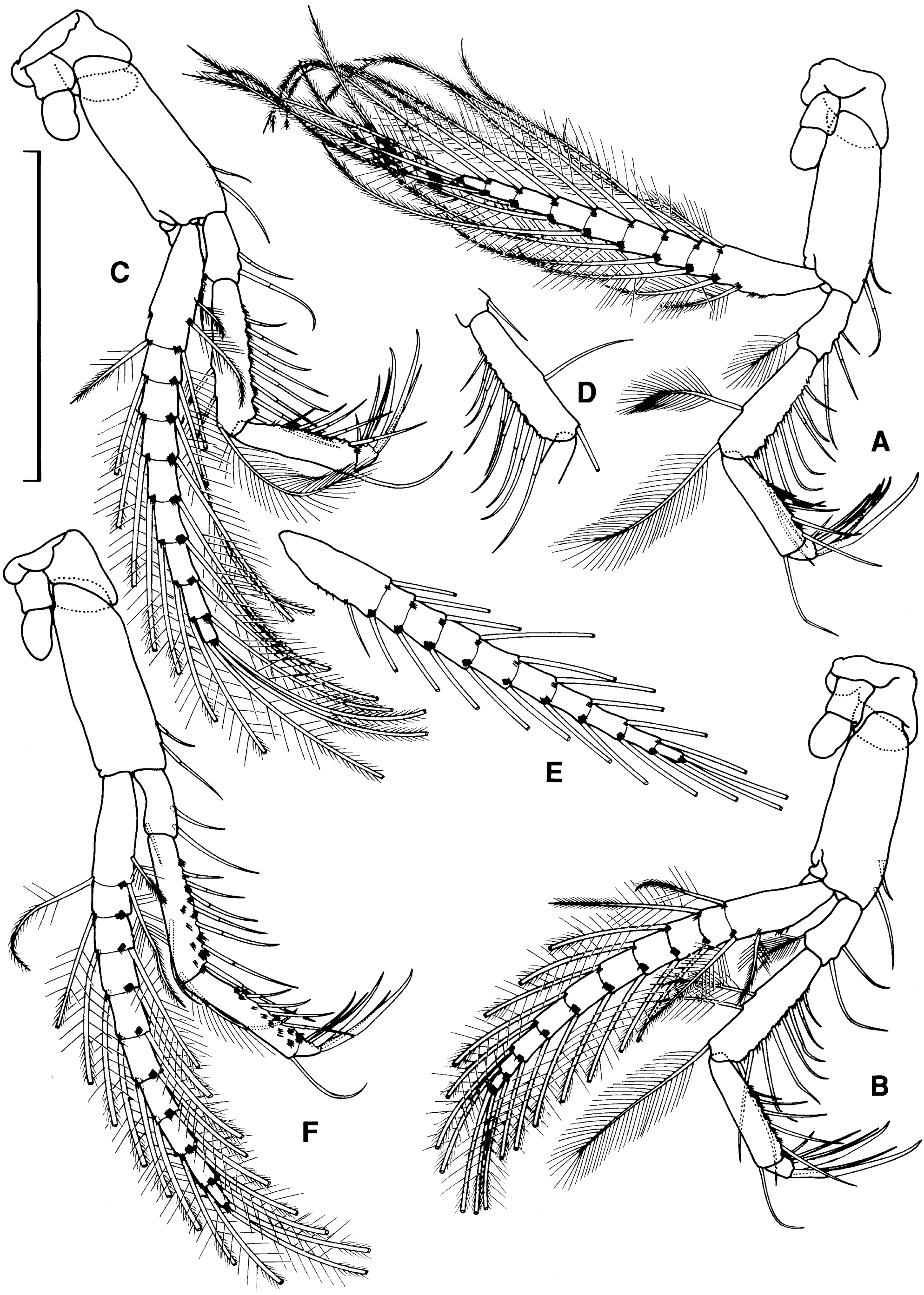

Figure 4. *Billibathynella humphreysi* sp. nov. (holotype). (A) Right thoracopod II ♂ (frontal); (B) right thoracopod III ♂ (frontal); (C) right thoracopod IV ♂ (frontal); (D) second segment of the endopod of the left thoracopod IV ♂ (frontal); (E) exopod of the left thoracopod IV ♂ (frontal); (F) right thoracopod V ♂ (frontal). Scale bar: 0.5 mm.

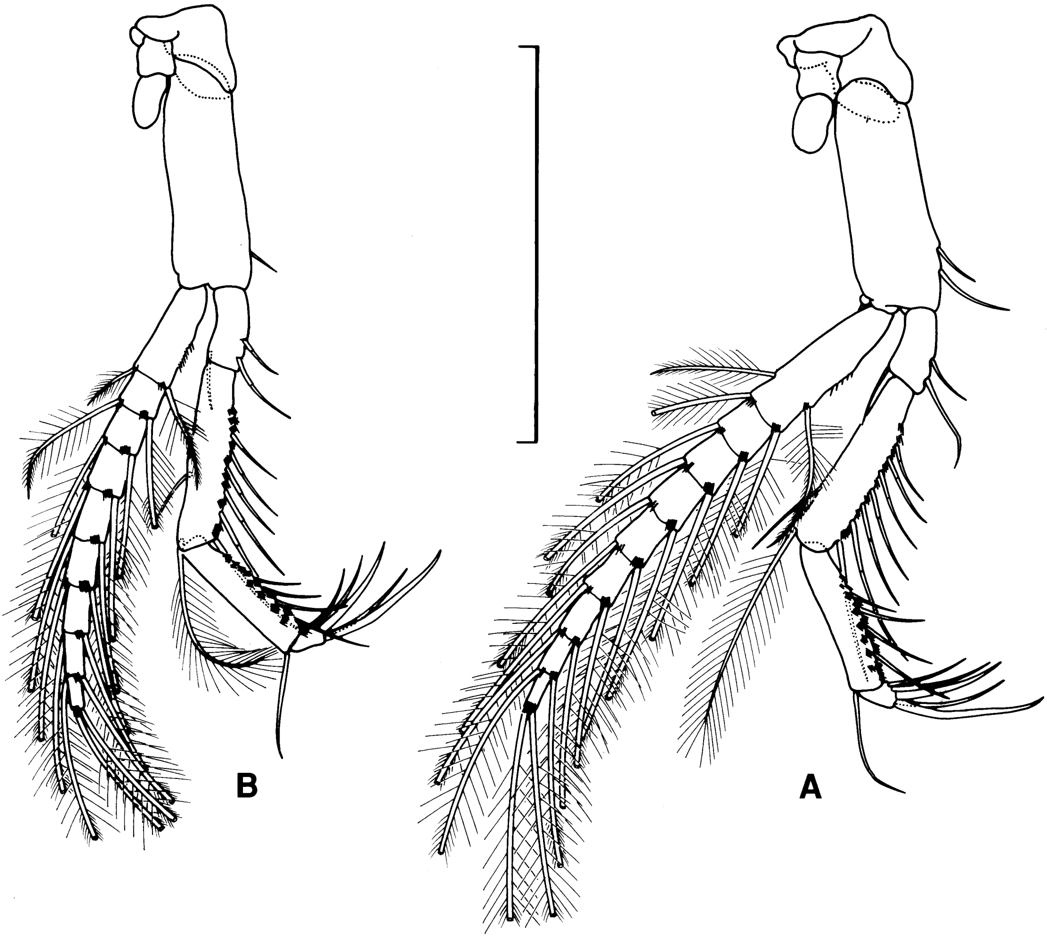

Figure 5. *Billibathynella humphreysi* sp. nov. (holotype). (A) Right thoracopod VI ♂ (frontal); (B) right thoracopod VII ♂ (frontal). Scale bar: 0.5 mm.

Maxilla (Figure 2F) four-segmented, setal formula 5-10-17-11.

Thoracopods I–VII (Figures 3A, 4A, B, F, 5A, B). Thoracopods I–IV increasing in size posteriorly. Thoracopods IV–VII similar in size. Thoracopods I–VII each bearing one epipod on protopod. Three setae on the basipod of thoracopod I, two setae on thoracopods II–VI, and one seta on thoracopod VII. The number of segments of the exopod of thoracopods I–VII: 7-9-10-9/10-10-9-9. The endopod of thoracopods I–VII four-segmented, setal formulae:

Thoracopod I	5 + 1/7 + 2/4 + 1/5(3)
Thoracopod II	3 + 1/8 + 2/5 + 1/6(4)
Thoracopod III	2 + 1/8 + 3/5 + 1/6(4)
Thoracopod IV	2 + 1/8 + 3, 9 + 2/5 + 1/6(4)
Thoracopod V, VI	2 + 1/7 + 2/4 + 1/5(3)
Thoracopod VII	2 + 1/6 + 2/4 + 1/5(3)

Thoracopod VIII (Figure 2H, I) rectangular in lateral view, 1.5 times longer than wide. Protopod massive, with prominent penial region with a distal opening. Inner margin of the distal opening with tiny denticles. Epipod large, triangular, distal part covering penial region of protopod. Basipod without setae, inner margin of basipod drawn out into projection. Exopod one-third of basipod in size, triangular, bearing two subterminal setae. Endopod as large as exopod, with three distal setae.

First pleopod absent.

Uropod (Figure 3B–D) bearing 28 spines of equal size on inner margin of sympod. Endopod 40% as long as sympod, with two distal spines and five small spines on inner margin, with two dorsal plumose setae near the base, and with two terminal plumose setae and one subterminal plumose seta on outer margin. A protrusion exists between terminal and subterminal plumose setae. Exopod slightly longer than endopod, with one basi-ventral seta, and with 22 setae on outer and terminal margin.

Pleotelson (Figure 3B, C) with one seta near the base of furcal rami on both sides. Anal operculum flat.

Furcal rami four times as long as wide, with two large distal spines, and 21 spines on inner margin, and with two dorsal setae.

Description of female

The female differs from the male in thoracopod VIII. Body length 6.02 mm (other females: 5.94, 5.82, 5.80 mm).

The right and left thoracopods VIII (Figure 2G) not fused, cone-shaped, as large as the endopod of the male thoracopod VIII, with two distal denticles.

Remarks

The new species is probably the most primitive member of the Parabathynellidae. The richness of the extremities in teeth, claws and setae, the high number of segments of thoracopodal exopod and finally the large body size are the indices (Table I). From the Australian continent two genera are known as being primitive: *Chilibathynella* and *Notobathynella*. According to Schminke (1973), *Chilibathynella* has a balloon-shaped male thoracopod VIII, five-segmented antenna, one-segmented exopod of thoracopods I–VII and thus differs from the new species significantly. *Notobathynella*, in contrast, is similar to the new species in many aspects. For example, the male thoracopod VIII of *Notobathynella* is very similar to that of the new genus in its rectangular form, in having the massive protopod with prominent penial region, in the basipod drawn out into projection, and in the triangular exopod. Although fewer in number, the exopods of thoracopods I–VII of *Notobathynella* display a relatively large number of segments (2-3-4-4-4-3-3). However, *Notobathynella* has a five- to six-segmented antenna and lacks the basi-ventral seta on the uropodal exopod. In addition, the epipod of the male thoracopod VIII never covers the penial region of the protopod and the basipod bears a seta. Hence, we propose for the new species a new genus *Billibathynella* gen. nov.

In terms of the primitiveness of the extremities, *Allobathynella* Morimoto and Miura, 1957, occurring in East Asia, is also comparable with the new species, *B. humphreysi*. According to Schminke (1973), this genus includes the most primitive members of the Parabathynellidae. However, even the basal representative of *Allobathynella*, *A. gigantea pluto* Morimoto, 1963, is at most only 3.30 mm long and has a six-segmented antenna, a

Table I. Morphological differences between seven species known as being primitive within the family Parabathynellidae.

	1	2	3	4	5	6	7
Body length (mm)	6.3	3.3	2.0	2.3	1.5	2.7	1.7
Number of antennular segments	7	8	7	7	7	7	7
Number of antennal segments	7	6	6	5	4	3	6
Number of teeth on labrum	28	14	20	16	14	14	16
Number of teeth on incisor process	6	7	6	8	7	5	6
Number of spines in spine row	15	12	8	7	8	9	7 – 8
Number of spines on distal endite of maxillule	10	7	7	6	7	7	7
Setation on maxilla	5-10-17-11	3-4-10-7	4-5-10-8	3-6-11-7	3-4-11-5	3-6-21	2-3-10-2
Number of exopodal segments of thoracopods I–VII	7-9-10-10-10-9-9	4-6-6-7-7-7-6	2-3-4-4-4-3-3	1-1-1-1-1-1-1	2-3-3-3-3-3-3	3-4-5-5-5-5-5	3-4-5-5-5-4-4
Pleopod I	Absent	Present	Absent	Present	Absent	Present	Present
Number of spines on uropodal sympod	28	18	10	11	11	12	6–7
Number of spines on uropodal endopod	7	3	5	2	2	2	2
Number of setae on uropodal exopod	23	6	4	4	4	3	4–6
Number of spines on furcal rami	21	6	10	9	7	9	4
Continent	Australia	East Asia	Australia	Australia	South America	Africa	Malaysia

Species: 1, *Billibathynella humphreysi* n. sp.; 2, *Allobathynella gigantea pluto* Mortimoto, 1963; 3, *Notobathynella remota* Schminke, 1973; 4, *Chilibathynella australiensis* Schminke, 1973; 5, *Psalidobathynella stocki* Schminke, 1979; 6, *Afrobathynella trimera* Schminke, 1976; 7, *Batubathynella malaya* (Sars, 1929).

labrum with 14 teeth, a mandible with seven teeth on the incisor process and 12 spines in the spine row, an exopod formula of thoracopods I–VII of 4-5-6-6-6-6-6, 18 spines on the uropodal sympod, and six spines on the furcal rami. Except for the eight-segmented antennule (cf. Morimoto 1963), the primitiveness of *A. gigantea* thus does not go beyond that of *B. humphreysi.* The new species rather seems to resemble the hypothetical stem species of the Parabathynellidae, which Schminke (1973) has reconstructed based on the summation of primitive characters of the family known at that time. The differences of the stem species from *B. humphreysi* may exist only in the three-segmented mandibular palp, in the male and female thoracopods VIII with the form slightly different from the other thoracopods, the possession of two epipods on each of thoracopods I–VII, the presence of two-segmented pleopods on the first and second pleomeres, and the number and the position of the setae on the pleotelson.

Billibathynella humphreysi has been collected from irrigation wells located in the calcrete aquifer in the arid zone of Australia, where typical karst features have been developed, with sinkholes with a large water body (Sanders 1974; Barnett and Commander 1985; Humphreys 2001). Since the sinkholes usually provide unconfined spaces, one could argue that the unusual body size of *B. humphreysi* has been developed secondarily in adaptation to the free water, as supposed by Noodt (1964) for *Bathynella baicalensis* Bazikalova, 1954 and *Baicalobathynella magna* Bazikalova, 1954, the largest and the most primitive representatives of the family Bathynellidae from the bottom of Lake Baikal. Accordingly, the marine interstitial ancestor of the Parabathynellidae could have invaded the continental groundwater via the coastal interstitial (thalassoid origin: Boutin and Coineau 1987; Coineau 1996; Camacho 2003). As in both species from Lake Baikal, however, *B. humphreysi* does not differ from other species of the Parabathynellidae in basic body plan, even lacking pleopods, and thus shows no sign of adaptation to the free water habitat. The habitat of the nominative form of *Allobathynella gigantea* Morimoto, 1959 also supports the primitiveness of *B. humphreysi*. *A. gigantea* is much smaller (2.35 mm) and equipped with fewer teeth, setae, or spines on the proper extremities and thus seems to be more suitably adapted to interstitial spaces than *B. humphreysi*. However, the former species is likely to favour free water, since it was found abundantly under stones on the bottom of a shallow dug well exposed to the faint sunlight (Morimoto 1959). In terms of the origin of the Parabathynellidae, on the other hand, it is worthy to mention that both *B. humphreysi* and *A. gigantea* occur in regions which have mostly not been submerged by the sea since the Palaeozoic (Morimoto 1959; Watts and Humphreys 2000). As Schminke (1972) remarked for the two bathynellids from Lake Baikal, it does not seem to be a simple coincidence that *B. humphreysi*, the most primitive form within the Parabathynellidae, occurs just in one of the oldest far inland areas of the world. This fact strongly suggests that the extant parabathynellids have been derived from a surface water limnic ancestor (limnocoid origin: Schminke 1973). It is also probable that the transition to groundwater happened in Notogaea. A way to test this hypothesis on the centres of origin of the family, however, would be an extensive investigation of the groundwater fauna of old cratons in far inland areas of the gondwanan fragments.

Acknowledgements

This work was supported by a grant (Project 3-4-2) of the Sustainable Water Resources Research Center of 21st Century Frontier and "Prediction of contaminant transport and ecological application of microbial species in subsurface environments for remediation of groundwater systems" (code 03-8103) of the Korea Institute of Geoscience and Mineral Resources. The material was collected under funding to W. F. Humphreys and C. H. S. Watts from the Australian Biological Resources Study.

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