

A NEW SILURIAN EURYPTERID (ARTHROPODA: CHELICERATA) FROM CHINA

by O. ERIK TETLIE*, PAUL A. SELDEN† and DONG REN‡

*Department of Geology and Geophysics, Yale University, PO Box 208109, New Haven, CT 06520-8109, USA; e-mail: erik.tetlie@yale.edu

†The Paleontological Institute, University of Kansas, Lindley Hall, 1475 Jayhawk Blvd, Lawrence, Kansas 66045, USA, and Department of Palaeontology, The Natural History Museum, Cromwell Road, London SW7 5BD, UK; e-mail: paulselden@mac.com

‡Department of Biology, Capital Normal University, 105 Xisanhuanbeilu, Haidian District, Beijing 100037, PR China; e-mail: rendongprof@yahoo.com.cn

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Abstract: The oldest eurypterid from China is described as *Hughmilleria wangi* sp. nov., from the Xiaoxiyu Formation (Silurian: latest Llandovery) of Hunan Province. *H. wangi* is relatively similar to two species from North America, but differs in the development of epimera on the postabdomen, a slightly wider carapace, a styliiform telson and the dimensions of the penultimate podomere of the paddle. The Llandovery age of the specimen substantially reduces the ghost range of the genus *Hughmilleria*. The exact phylogenetic relationship between the different

species in *Hughmilleria*, the most basal genus in the pterygotid clade, cannot be resolved because the plesiomorphic states within this clade are poorly known. The shapes of the telson and swimming paddle of the Chinese species suggest that it is more primitive than its North American relatives, which is in accord with its greater age.

Key words: Eurypterida, South China Plate, *Hughmilleria*, Llandovery, Telychian.

EURYPTERIDS are aquatic Palaeozoic chelicerates that have been found mostly in Silurian and Lower Devonian deposits of North America and Europe. Outside of the palaeocontinents of Avalonia, Armorica, Baltica, Iberia and Laurentia, occurrences are very scarce. Of the around 200 species considered to be valid (OET, unpublished data), only 16 are from outside these palaeocontinents (Table 1). It should be noted that some additional occurrences of unnamed eurypterids are known from these palaeocontinents; these have been adequately listed by Braddy *et al.* (1995, 2002), Braddy and Almond (1999) and Tetlie *et al.* (2004), and are not repeated here. All occurrences from these parts of the world are therefore significant, and can help to demonstrate that at least some eurypterids were more widespread than previously thought. It is possible that our lack of knowledge of eurypterids from outside Europe and North America is a collecting and research bias rather than a genuine absence of eurypterid fossils from these areas. Here, we report on the first unequivocal Silurian eurypterid from China, *Hughmilleria wangi* sp. nov., a single specimen from the Xiaoxiyu Formation (late Llandovery), Tielupo Township, Longshan County, Hunan Province, and four (or five) specimens figured by Wang *et al.* (1988) from the same horizon in western Hunan. During the Silurian Period, the South China Plate was on the western margin of Gondwana, close to what became the Arabian, North China, Greater India and Australian plates (Cocks and

Torsvik 2002). The only Silurian eurypterids known from these areas are the three species of *Eurypterus* described by Chang (1957), pterygotid fragments from Saudi Arabia (Al-Hajri and Paris 1998) and *Pterygotus* (?) *australis* McCoy, 1899 from Australia. Eurypterids described earlier from China include *Adelophthalmus chinensis* (Grabau, 1920) from the Early Permian (Asselian?) Chaokockwang Formation, Kaiping District, Hopeh Province. Later, Chang (1957) named three species of *Eurypterus* (Table 1) from the lower Sintan shale (Wenlockian), Hsin Tan, Hubei Province. However, these specimens are in need of a redescription in order to affirm their status (see Tetlie 2006a).

GEOLOGICAL SETTING

The Xiaoxiyu Formation is some 480 m thick and conformable with the underlying Xiushan Formation, but its top is unconformable with a basal pebbly sandstone of the Middle Devonian Yuntaikuan Formation (Chen *et al.* 2002). It consists of shales and muddy siltstones with fine sandstone partings, typically purple to grey or grey-green in colour, near the base. Higher beds are mainly yellow-green to grey-green calcareous shales, sandy shales, muddy siltstones and siltstones, coarsening upwards. Near the top of the formation are purplish shales, siltstones and fine sandstones. Cross-bedding and ripple marks

TABLE 1. Chronological list of named eurypterids from palaeocontinents other than Baltica, Laurentia, Avalonia, Iberia and Armorica. Asterisks suggest taxa that might be based on undiagnostic material.

Ordovician		
<i>Onychopterella augusti</i>	Braddy <i>et al.</i> , 1995	South Africa
Silurian		
<i>Eurypterus loi</i> *	Chang, 1957	China
<i>Eurypterus styliformis</i> *	Chang, 1957	China
<i>Eurypterus yangi</i> *	Chang, 1957	China
<i>Melbournopterus crossotus</i>	Caster and Kjellesvig-Waering, 1953	Australia
<i>Pterygotus? australis</i> *	McCoy, 1899	Australia
<i>Rhinocarcinosoma dosonensis</i>	Braddy <i>et al.</i> , 2002	Vietnam
<i>Slimonia boliviana</i>	Kjellesvig-Waering, 1973	Bolivia
Devonian		
<i>Acutiramus cf. bohemicus</i>	Burrow <i>et al.</i> , 2002	Australia
<i>Adelophthalmus waterstoni</i>	Tetlie <i>et al.</i> , 2004	Australia
<i>Borchgrevinkium taimyrensis</i>	Novojilov, 1959	Siberia
<i>Hibbertopterus sewardi</i> *	Strand, 1926	South Africa
<i>Nanahughmilleria schiraensis</i> *	Pirozhnikov, 1957	Siberia
<i>Parahughmilleria matarakensis</i> *	Pirozhnikov, 1957	Siberia
<i>Pterygotus bolivianus</i>	Kjellesvig-Waering, 1964	Bolivia
<i>Stylonurus (?) menneri</i>	Novojilov, 1959	Siberia
Carboniferous		
<i>Cyrtoctenus wittebergensis</i>	Waterston <i>et al.</i> , 1985	South Africa
<i>Megarachne servinei</i>	Hünicken, 1980	Argentina
<i>Unionopterus anastasiae</i>	Chernyshev, 1948	Kazakhstan
Permian		
<i>Adelophthalmus chinensis</i>	Grabau, 1920	China
<i>Hastimima whitei</i>	White, 1908	Brazil

occur in the upper part. Fossils occur mainly in the lower part, and are similar to those in the underlying Xiushan Formation, which include trilobites (*Coronocephalus rex*, *Encrinuroides changningensis*), brachiopods (*Salopinella minuta*, *Aegiria grayi*, *Nalivkinia magna*), nautiloids (*Sichuanoceras* sp., *Neosichuanoceras eoluminus*), conodonts (*Ambalodus galerus*, *Apsidognathus tuberculatus*), chitinozoans (*Angochitina longicollis*, *Eisenackitina* sp., *Geron gracilis*) and gastropods (*Hormotoma kutsingensis*). Additionally, the trace fossils *Thalassinoides*, *Chondrites* and *Skolithos* occur in the middle of the Xiaoxiyu Formation. The bivalve *Modiomorpha*, and the acritarchs *Mogeria cabotti*, *Stophomorpha ovata* and *Domacia limaciformis* have been recovered from the top of the formation. The Xiaoxiyu Formation has been correlated with the *crenulata* (graptolite) Biozone (topmost Telychian, upper Llandovery) (Chen *et al.* 2002).

MATERIAL AND METHODS

This study is based on a single specimen, part and counterpart, which was collected in 1992 by Professor Wang Jun-qing of the Institute of Vertebrate Palaeontology and Palaeoanthropology, Chinese Academy of Sciences (CAS),

who donated it to the Key Laboratory of Insect Evolution and Environmental Changes, College of Life Science, Capital Normal University, Beijing, China (CNUB; Dong Ren, Curator). The specimen is a mould with darker brown cuticle remnants in a brown siltstone. Some tergites and other pieces belonging to another eurypterid, of similar size to the one described here, are scattered on the rock adjacent to the part. This suggests that either the specimen described here died in the act of moulting, and the scattered remains are its moulted exoskeleton, or (perhaps more likely) the fossil forms part of a concentration of eurypterid remains. Such concentrations are quite common in eurypterid-bearing strata; for example, *Hughmilleria socialis* Sarle, 1903, from the Pittsford Member of the Vernon Formation, Salina Group, of the New York Silurian commonly occurs in strings of dismembered parts known as 'windrows' (Samuel J. Cieurca, pers. comm. 2006).

The specimen was studied and drawn using a Leica MZ16 stereomicroscope with a drawing tube. Photographs were taken on a Nikon D1X digital camera; processing was carried out using Adobe Photoshop CS2, and pencil drawings were prepared for publication using Adobe Illustrator CS2, on a Macintosh PowerBook G4 running OS X.

SYSTEMATIC PALAEOLOGY

Suborder EURYPTERINA Burmeister, 1843

Superfamily PTERYGOTOIDEA Clarke and Ruedemann, 1912

Remarks. The superfamily Pterygotoidea as defined by Tetlie (2004) includes the pterygotid genera *Pterygotus*, *Acutiramus*, *Erettopterus* and *Jaekelopterus* in addition to the more basal genera *Slimonia*, *Salteropterus*, *Herefordopterus* Tetlie, 2006b and *Hughmilleria*.

Family unassigned

Remarks. Tollerton (1989) assigned *Hughmilleria* Sarle, 1903 to the family Hughmilleriidae, which also included *Nanahughmilleria* Kjellesvig-Waering, 1961, *Grossopterus* Størmer, 1934a and *Waeringopterus* Leutze, 1961 under his scheme. This family was based on plesiomorphic character states including the presence of *Hughmilleria*-type spiniferous walking legs. Tetlie (2004) used the same family name for *Hughmilleria* and *Herefordopterus*, the two most basal genera in the Pterygotoidea. However, as it is clear that the two form a paraphyletic assemblage, we choose not to assign *Hughmilleria* to a family.

Genus HUGHMILLERIA Sarle, 1903

Diagnosis. Small pterygotoid; carapace parabolic or subquadrate with oval marginal eyes; epistoma present between ventral plates; chelicerae able to extend beyond carapace margin; appendages II–V spiniferous, of *Hughmilleria*-type; swimming leg narrow; petaloid A metastoma; opisthosoma with midsection second-order differentiation; telson variable; cuticular sculpture consisting of striations and angular lunules. (Emended from Størmer 1973.)

Included species. *H. socialis* Sarle, 1903, *H. shawangunk* Clarke, 1907, *H. wangi* sp. nov. and possibly *H. (?) lanceolata* (Salter, 1856).

Hughmilleria wangi sp. nov.

Text-figures 1–2

1988 *Eurypterus* cf. *styliformis* Zhang 1957; Wang *et al.* pl. 1, figs 5, 12, 20, 23

Derivation of name. After Professor Wang Jun-qing, who collected this fossil in 1992 (see 'Material and methods' for details).

Holotype. Well-preserved, almost complete body; registration numbers CNUB-E-HLT2006001-1 (part) and -2 (counterpart);

collected from the Xiaoxiyu Formation, upper Llandovery (Telychian); Tielupo Township, Longshan County, Hunan Province, South China. Specimen housed in the Key Laboratory of Insect Evolution and Environmental Changes, the College of Life Science, CNUB, as noted above.

Diagnosis. *Hughmilleria* with subquadrate carapace, epimera on postabdominal tergites, styliform telson, swimming leg podomere 8 with L/W ratio of 1.76.

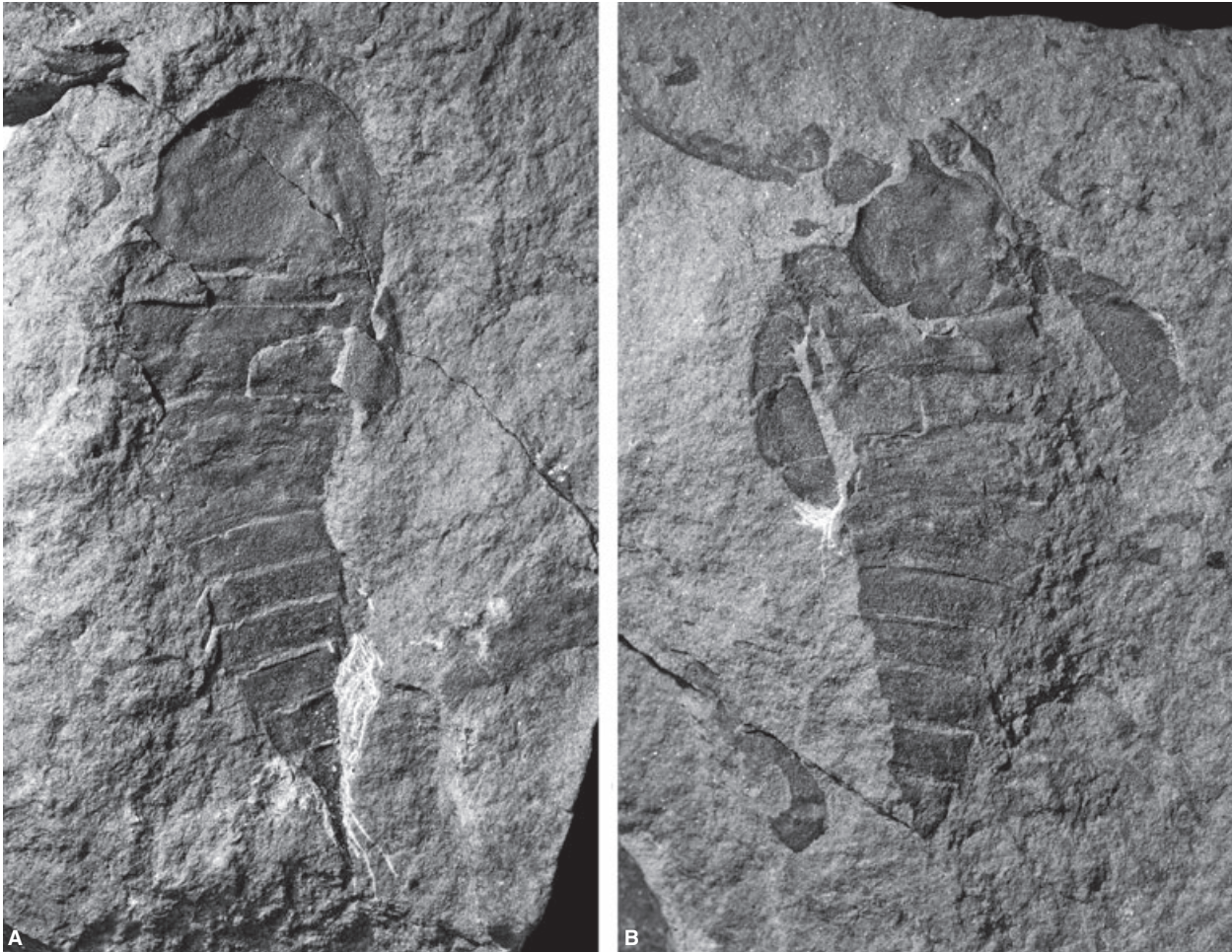
Description. Carapace 10.3 mm long, 13.2 mm wide (estimated), L/W ratio 0.78 (estimated), lateral angle 93 degrees. Carapace shape subquadrate (*sensu* Tollerton 1989). Narrow anterior marginal carapace rim. No eyes or ocelli visible. Walking legs not preserved. Swimming leg coxa of typical *Hughmilleria*-type with large anterodistal rounded 'ear'; podomere 2 short, rectangular; podomere 3 triangular, tapering posteriorly so that 2 and 4 touch at posterior margin; podomere 4 short, rectangular; podomere 5 triangular, similar in shape to 2 but about twice as large; 4–5 and 5–6 joints apparently rather flexible; podomere 6 almost semicircular; podomere 7 rather wide, much elongated, forming most of paddle area, anterodistal corner produced into short projection, L/W ratio between 1.20 and 1.37; podomere 7a relatively large, extending to about one-half length of podomere 8; podomere 8 oval, L/W ratio 1.76; tiny podomere 9 visible on right swimming leg. Metastoma incomplete, but posterior two-thirds, including truncated posterior margin, suggest that shape was petaloid A (*sensu* Tollerton 1989).

Opisthosomal ventral structures, e.g. genital opercula, sternites, not visible. Width of opisthosomal tergites increases to tergite 3/4, posterior to which is a gradual decrease without an abrupt constriction (first order opisthosomal differentiation; Tollerton 1989). Short (0.5 mm), angular epimera on postabdominal tergites. Short (= 6.2 mm) styliform telson.

Remarks. Wang *et al.* (1988), in a paper dealing with the stratigraphy of the Xiushan and Xiaoxiyu formations, figured four specimens of postabdomens and telsons (pl. 1, figs 5, 12, 20, 23) that appear to be conspecific to *H. wangi*, based on the same telson shape and the presence of small epimera on the postabdominal segments. However, they assigned these specimens to the problematic taxon *Eurypterus* cf. *styliformis* Chang, 1957. In addition, Wang *et al.* (1988) figured a fifth specimen that resembles a eurypterid carapace (pl. 1, fig. 2), but they assigned it to the agnathan *Eugaleaspis xiushanensis* Liu, 1983. We are not certain whether this specimen represents a eurypterid. The specimens figured by Wang *et al.* do not otherwise add anything to what can be interpreted from the holotype.

DISCUSSION

The similarities between *H. wangi* sp. nov. and *H. socialis*/*H. shawangunk* are striking [*H. shawangunk* is relat-

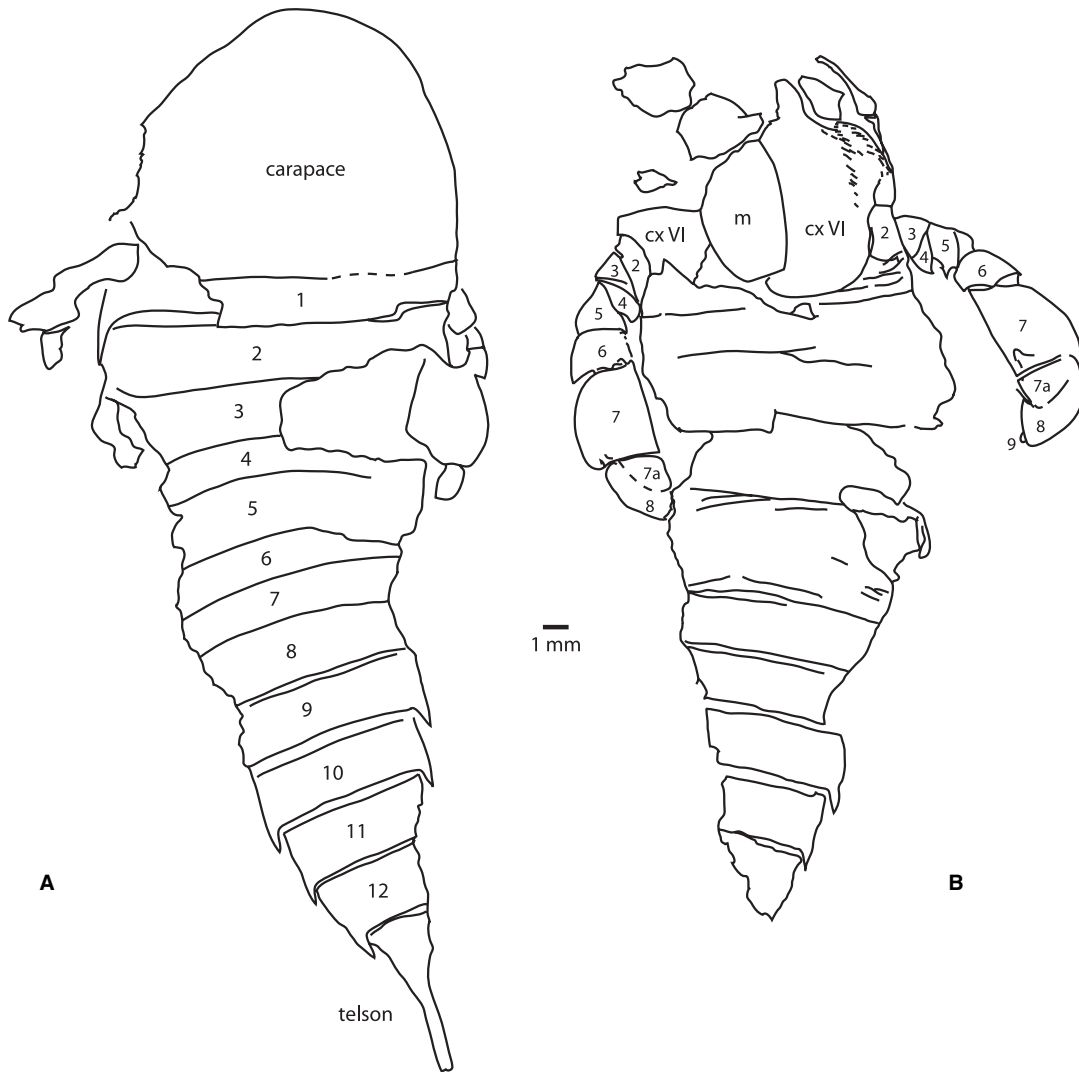


TEXT-FIG. 1. *Hughmilleria wangi* sp. nov., Tielupo Township, Longshan County, Hunan Province, China; Xiaoxiyu Formation, upper Llandovery (Telychian). A, dorsal part, CNUB-E-HLT2006001-1. B, ventral counterpart, CNUB-E-HLT2006001-2; both $\times 4.5$.

ively poorly known (see Clarke 1907 or Clarke and Ruedemann 1912 and so similar to *H. socialis* that only the best known species, *H. socialis*, is discussed here]; in fact, only four differences between them can be found. The first is the presence of epimera on the entire postabdomen in *H. wangi*; epimera are found only on the seventh segment of *H. socialis*. The second is in the shape of the telson. In *H. socialis* this is lanceolate (Tollerton 1989) but with a slightly bulbous anterior end. In *H. wangi* it is styliform, i.e. broad anteriorly, but tapering rapidly into a thin spike. The third difference is the proportionally shorter and broader podomere 8 in the swimming leg of *H. wangi* compared with *H. socialis*. The L/W ratio of podomere 8 in *H. socialis* is 2.05–2.10 whereas in *H. wangi* it is 1.76 (Table 2). The last difference is the slightly wider carapace of *H. wangi*, which has an L/W ratio of 0.78; similarly flattened specimens of *H. socialis* have L/W ratios ranging from 0.85 to 1.01. We do not have access to a complete carapace of *H. socialis* as small as that of the Chinese specimen, but it is apparent (OET,

unpublished data) that it is the larger specimens of this species that have low carapace L/W ratios. Extrapolating the L/W ratio band of *H. socialis* predicts that specimens of the same size as the Chinese specimen would be expected to have L/W ratios between 1.00 and 1.10.

The presence of epimera on the entire postabdomen is unique in the Pterygotoidea clade, and only occurs elsewhere in the more derived genera *Adelophthalmus* von Meyer, 1853 and *Parahughmilleria* Kjellesvig-Waering, 1961 in the sister-clade Adelophthalmoidea (consisting of *Nanahughmilleria*, *Parahughmilleria*, *Adelophthalmus* and probably the lesser known genera *Unionopterus* Chernyshev, 1948, *Pittsfordipterus* Kjellesvig-Waering and Lettze, 1966 and *Bassipterus* Kjellesvig-Waering and Lettze, 1966), so it cannot be used to determine the relationship between *H. wangi* and the other members of the Pterygotoidea. The same is true for the telson, although the general successive increases in width of the telson from *H. wangi* to *H. socialis*/*H. shawangunk* to *Herefordopterus banksii* (Salter, 1856) to *Slimonia* Page, 1856 and



TEXT-FIG. 2. *Hugmillera wangi* sp. nov., as for Text-figure 1; explanatory camera lucida drawings: cx, coxa; m, metasoma.

TABLE 2. Length/width ratios (ranges and averages) of podomeres 7 and 8 in the swimming legs of the taxa discussed in the text. Numbers in parentheses refer to the numbers of specimens on which the average is based. For more information, see Størmer (1973), although he included 7a in the length measurement of podomere 7.

Taxon	VI-7 L/W range	VI-7 L/W mean	VI-8 L/W range	VI-8 L/W mean
<i>H. wangi</i>	1.20–1.37	1.29 (2)	1.76	1.76 (1)
<i>H. socialis</i>	1.25–1.37	1.31 (2)	2.05–2.10	2.08 (2)
<i>N. norvegica</i>	1.15–1.66	1.46 (12)	1.69–2.11	1.97 (4)
<i>P. hefteri</i>	1.00–1.08	1.03 (3)	1.34–1.53	1.46 (5)
<i>A. sievertsi</i>	1.16–1.54	1.33 (5)	1.84–2.06	1.92 (5)

Salteropterus Kjellesvig-Waering, 1951, and through to the pterygotids, might suggest that *H. wangi* is more basal than *H. socialis*. However, the telson shape in *H. wangi* may be an apomorphy, especially since the basal members of the sister-clade, the Adelophthamoidea, exemplified by *Nanahughmilleria norvegica* (Kiær, 1911), also have a lan-

ceolate telson (see Størmer 1934b), albeit not so expanded anteriorly as in *H. socialis*. There is a similar situation for the podomeres of the swimming leg as for the telson. The podomere ratios of *H. wangi*, *H. socialis*, *Parahughmilleria hefteri* Størmer, 1973, *Nanahughmilleria norvegica* and *Adelophthalmus sievertsi* Størmer, 1969 (see Poschmann

2006) are given in Table 2. The dimensions of podomere 8 are more similar between *H. wangi* and the members of the Adelophthalmoidea than between *H. wangi* and *H. socialis*. This again conforms with the interpretation that *H. wangi* is more basal than its North American counterparts, which is also supported by the greater antiquity of the Chinese specimen; however, as this evidence is only based on ratios and not on any proper synapomorphies, we do not address the question of the phylogenetic position of *H. wangi* any further. The age of the oldest *Hughmilleria* from North America, *H. shawangunk*, has been very difficult to establish (Plotnick 1999), with all ages between Llandoveryan and Ludlovian possible. We therefore note that the late Llandovery age of the Chinese species moves the potential ghost range of *Hughmilleria* from Ludlow to late Llandovery, but it is possible that the age of at least some of the localities producing *H. shawangunk* could be earlier Llandovery (Plotnick 1999).

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