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Species of *Hollinella* (Palaeocopida, Ostracoda, Crustacea) as stratigraphic indices of the Late Permian - Early Triassic post extinction interval

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Abstract

Members of the Ostracoda Order Palaeocopida, except for two very rare genera (*Puncia* and *Manawa*), disappeared in the stratigraphic record close to the Permian – Triassic boundary (PTB) event. Species of the genus *Hollinella* are often present just after the end Palaeozoic mass extinction event, in the latest Permian and earliest Triassic beds. They are one of the latest representatives of the Palaeocopida, the typical Palaeozoic straight dorsal border ostracods. The Early Triassic species are assigned by most authors to *Hollinella tingi* (Patte, 1935), but this assignment is incorrect. This species is present in the latest Permian and the earliest Triassic, and therefore is considered as a biostratigraphic index fossil of the post-mass extinction interval. A revision of the *Hollinella* species from this interval is presented herein. Three *Hollinella* species occur in the earliest Triassic and are assigned to *Hollinella panxiensis* Wang 1978, *Hollinella magninoda* Wang 1978 and *Hollinella* (*Hollinella*) *lungcamensis* sp. nov. This new species of the post-PTB event and present in strata exposed in the northern part of Vietnam is described. These three species cross the PTB and *H. (H.) lungcamensis* is characteristic for the post extinction period (latest Changhsingian – earliest Induan).

Keywords: Permian – Triassic extinction event; ostracods; Palaeocopida; biostratigraphic index.

Introduction

Specimens of the genus *Hollinella* Coryell, 1928 (Palaeocopida, Ostracoda, Crustacea) are present in many sections of the Permian – Triassic boundary interval. Although the preservation is quite always very poor, these occurrences are remarkable because this genus is one of the latest representatives of the Palaeocopida, an emblematic Palaeozoic straight dorsal border ostracod group which disappears after the Permian – Triassic boundary event (PTBE). Three extremely rare genera, *Promanawa*, *Puncia* and *Manawa*, assigned to the Palaeocopida (Superfamily Puncioidea; Horne *et al.* 2002) are still extant in the Southern Pacific area (e.g., Hornibrook 1949, 1963). Some authors, however, consider that there are no living members of the Palaeocopida (see Martin & Davis 2001, p. 29-30). Except these three genera, the last well-dated Palaeocopida are known from the Early Anisian (genus *Triassicindivisia*; Forel & Crasquin 2011, Crasquin & Forel 2013).

Among the residual Early Triassic Palaeocopida (Crasquin-Soleau *et al.* 2004), only one species is supposed to cross the PTBE and it is assigned to *Hollinella tingi* (Patte, 1935). *H. tingi* was described in 1935 by Patte from the Early Permian of South China, but it is not the species which occurs in the earliest Triassic. All specimens discovered in the earliest Triassic, which are quite often preserved as moulds, were assigned to *H. tingi* by non-specialists, and this error was repeated many times. The aim of this paper is to clarify a very confused situation.

A new species, *Hollinella (H.) lungcamensis* sp. nov., is described from the post-PTBE of Northern Vietnam.

Original description of *Hollinella tingi* (Patte, 1935)

It is important to note that the genus *Hollinella* frequently shows significant intraspecific variability. Sexual dimorphism is apparent from different adventral structures (for example, a large and striated velum in females, which is absent or replaced by a small nodule row in males) and the stronger anteroventral convexity of the female carapace – corresponding to the brood pouch. The carapace shape of *Hollinella* shows also strong ontogenetic variations. Such variability is also recorded from many other palaeocopid taxa (for example, Sohn 1950 for Kirkbyidae and Miltonellidae; Bless & Jordan 1972 for Hollinellidae; Watabe & Kaesler 2004 for Paraparchitidae).

According to the revision of the Hollinellidae by Bless & Jordan (1972), *Hollinella tingi*

is very poorly known. The species was originally described as *Beyrichia tingi* in 1935 by Patte from the Early Permian T'ungstzu and Takuhsinch'ang Districts of South China. No holotype was designated by Patte (1935). The preservation of this material is poor and its description was based on external moulds only. The original description in French is reproduced in the annexe.

The species was published once more by Hou (1954). Its description was written in Chinese and in English. The English version is not the exact translation of the Chinese one. Note that in Hou's description and in the translation below, the orientation of the carapace is reversed, and males and females are confused. The English translation made by the third author of the present paper is given in the annex.

Hou (1954) figured the "holotype" (Hou 1954: pl. 1, fig. 2a). It is not clear if her "holotype" is the original and the true one, or if it is a lectotype. Hou found this species in Early Permian black shale of the Chihhsia Formation (Western Hubei, South China).

In 1964, Ishizaki assigned specimens discovered in the Early Pennsylvanian (Late Carboniferous) of Japan to *Hollinella tingi*. The preservation of the figured specimen (Ishizaki 1964: pl. 1, fig. 1) is so poor that it is impossible to confirm its assignment. The stratigraphic range in the Early Pennsylvanian is therefore questionable.

***"Hollinella tingi"* and the PTBE**

In studies of Permian-Triassic ostracods, specimens of *Hollinella* are frequently reported from the latest Permian and the earliest Triassic. In most of these papers, the specimens of *Hollinella* are assigned to *H. tingi*. As explained in Crasquin-Soleau *et al.* (2004), all these specific assignments are incorrect. The first erroneous determination was made by Wang (1978), and thereafter repeated again and again by other authors.

In 1978, Wang figured and described four *Hollinella* species from the Late Changhsingian and Early Induan of Western Guizhou and North-Eastern Yunnan: *H. tingi* (Wang 1978: pl. 1, figs 5-7), and three new species including *H. magninoda* (Wang 1978: pl. 1, fig. 11), *H. panxiensis* (Wang 1978: pl. 1, figs 1-4, and *H. capacilacuna* (Wang 1978: pl. 1, figs 8-10). English translations are absent from Wang's paper. We made these translations and give them in the annexe (some passages are unclear in the original descriptions. Our translation is literal and without interpretation). With regard to these "descriptions" and the illustrations (Wang 1978), we suggest that: *Hollinella capacilacuna* and *H. magninodosa* are

valid species and are Late Permian in age.

For the present authors, the specimens assigned to *H. tingi* and specimens assigned to *H. panxiensis* belong to the same species, *H. panxiensis*, which has no long posterodorsal spine, but just a small lateral flattening (pinch) of the posterior cardinal angle (Wang 1978: pl. 1, figs 1-4). L_3 is elongated antero-posteriorly. When the velum is completely developed, it extends from the anterior cardinal angle to the posterior cardinal angle. Some small nodules could be present on the upper part of L_3 . The specimen illustrated by Wang (1978) on pl. 1, fig. 6 differs slightly by its higher height/length ratio possibly due to ontogeny and could be determined as *H. panxiensis*?

In 1981, Wei illustrated three specimens from the Induan - Olenekian interval of Sichuan (Wei 1981: pl. 1, figs 1-3), and assigned them to *Hollinella tingi*. The first two specimens (Wei 1981: pl. 1, figs 1 and 2) are very poorly preserved and the assignment appears dubious. The specimen figured on pl. 1, fig. 3 (ibid.) is not a *Hollinella*, but a Kloedenellid species.

In 1985, Kozur illustrated a specimen of *Hollinella tingi* (pl. 13, fig. 3) from the Werfenian (Induan) of the Bükk Mountains (Hungary). It is impossible to determine this corroded and abraded specimen at the specific level. In any case, it is not *H. tingi*. Furthermore, it is not reasonable to use this specific determination as a stratigraphic index for the Permian - Triassic boundary as suggested by Kozur (1985).

In 1987, Shi & Chen illustrated specimens assigned to *H. tingi* (pl. 16, figs 2-5) from the early and middle Changhsingian of the Meishan section but gave no description. The specimen figured on pl. 16, fig. 2, is close to *H. panxiensis*; it apparently shows cardinal pinches, but the carapace is quite longer. The three other specimens (Shi & Chen 1987: pl. 16, figs 3-5) are poorly preserved and/or broken, but the three lobes are distinct and ornamentation could be observed on L_3 (fig. 3). Shi & Chen (1987) studied all Changhsingian ostracods of the Meishan section and did not report the species from the upper part of the section. We consider that these specimens belong to *H. panxiensis*.

Hao (1992a, b, 1993, 1994 and 1996) illustrated specimens of *Hollinella*, including *H. tingi*, from the Late Permian and/or the Induan of Guizhou.

In 1992a, Hao presented eleven ostracod species from the Early Triassic, including three species of *Hollinella*: *Hollinella* cf. *H. plana* Jiang 1983 (p. 39, pl. 1, fig. 1) is not a species of *Hollinella*, but a Kloedenellid ostracod; *Hollinella unispinata* (a new species characterized by

long spines at cardinal angles; p.39, pl. 1, fig. 2-3) is a synonym with *Hollinella magninoda* Wang, 1978). The specimens assigned to *H. tingi* (p. 39, pl. 1, figs 5-6) do not belong to that species. The first one has a very different lateral outline and is very badly preserved (pl. 1, fig. 5) and the second one (pl. 1, fig. 6) shows a strong reticulation in front of L₁ and seems to have a ventral ridge. We assign it to *H. panxiensis* based on the presence of the pinch at the cardinal angles. The specimen of “*H. tingi*” illustrated in Hao (1992b; pl. 1, fig.1) from the Changhsingian of Guizhou could be conspecific with *H. panxiensis* due to its complete velum extending along the entire free margins. In a paper on the Changhsingian from Guizhou, Hao (1993) assigned two specimens to *H. tingi* (Hao 1993: pl. 1, figs 1-2). The illustration is of poor quality and there is no description. As can be seen on plate 1 of Hao (1993), the cardinal pinches are indistinct, but the specimens show an elongated antero-posteriorly L₃ like the specimens of Wang (1978). Furthermore, the velum begins at the anterior cardinal angle and ends at the posterior cardinal angle. We consider that these specimens could belong to *H. panxiensis*. In the same paper, Hao described a new species: *H. echinata*. The three illustrated specimens are quite small (L: 0.81-0.83mm). The description is a summary and very general. The author just mentioned that the “border” of *H. echinata* possesses many short spines. In his publications from 1994 and 1996, Hao illustrated ostracods from the Permian - Triassic interval in Guizhou Province, but pictures of *Hollinella* are identical to those in the publications from 1992a and 1992b.

Forel & Crasquin (2011) illustrated four species of *Hollinella* from the Griesbachian (Early Triassic) of the Meishan PTB GSSP's section: *H. cf. H. martensiformis*, *H. cf. H. panxiensis*, *H. sp. 1*, and *H. sp. 2*.

- *H. cf. H. martensiformis* is a species similar to the Late Permian *H. martensiformis* of the same section (Crasquin *et al.* 2010), characterized by its long and straight dorsal border with accurate cardinal angles, tubercles on the upper part of L₃ and a row of tubercles along the ventral margin. It is also very close to the species from Vietnam (see below).

- *H. cf. panxiensis*: The specimens are quite poorly preserved and could belong to *H. panxiensis*.

- *H. sp.1* and *H. sp.2* are so badly preserved that a specific assignment is impossible.

In a study on the Late Permian – Early Triassic boundary interval of North Iran (Elikah Valley section, Central Albourz; Forel *et al.* 2015), some Late Permian *Hollinella* have been illustrated as *H. sp. 1*, *H. sp. 2* and *H. sp. 4*, and two Early Triassic species as *H. sp.3* and *Hollinellidae*?

indet. All the material is poorly preserved and does not allow a more precise determination.

Two tables are proposed in the annexe to summarize the distributions of all the listed species and the systematic attributions considered valid in this paper.

***Hollinella* species from the Permian – Triassic boundary in Vietnam**

New material has been discovered in the latest Permian - Early Triassic boundary interval of the Hong Ngai Formation at the Lung Cam section, Northern Vietnam. In the Late Permian-Early Triassic this area belonged to the southern margin of the South China Craton and was a shallow marine carbonate platform (Son *et al.* 2007). The Lung Cam section was recently resampled and analysed in detail (Nestell *et al.* 2015; Wardlaw *et al.* 2015). More than 200 specimens of *Hollinella*, associated with numerous other ostracod species (work in progress) were found in residues of 12 conodont samples (from VN 15 up to VN28) located above the extinction event and around the PTB (fig. 1).

This rich material is quite well preserved and permits a detailed study of a new species of *Hollinella* which is characteristic of the post-extinction event. The assemblage shows a high morphological diversity including all the transitional forms between the extremes (Figs 2 and 5). Herein, 201 specimens were measured (H and L include here the adventral structure; fig. 3). The length (L) ranges between 426 and 1130µm and the height (H) between 282 and 807µm. Specimens of all this size range evenly occur in all the 12 samples.

Hollinella (H.) lungcamensis sp. nov. (see description below) shows different morphotypes. A first group has free margins ornamented by several rows of spines (see figs. 2, 4, 5) from anterior cardinal angle (ACA) to the posterior cardinal angle (PCA). The second group has a well-developed velum which is completely calcified forming a continuous blade from the ACA to the posteroventral part of the carapace. The posterior part of the carapace is ornamented by spines. All transitional forms between these two extremes are represented. If we plot the size of specimens with spines and specimens with a complete velum on an H/L diagram (fig. 4), it becomes clear that this morphological variability is due to ontogenesis.

Sexual dimorphism and ontogenetic variability in the Palaeocopida

Sexual dimorphism and ontogenetic variability in palaeocopids (Van Veen 1922;

Jaanusson 1957; Henningsmoen 1965; Kesling 1969) and particularly in the Hollinellidae (see example on fig. 6) (Jaanusson 1957; Henningsmoen 1965; Bless & Jordan 1970, 1972) has been known for a long time.

The shape of the carapace changes during each moult. Some features develop gradually during the ontogeny whereas others appear suddenly at the transition to the adult stage. Five to six stages of growth, including the adult, are recorded for *Hollinella*. In the genus *Hollinella* the ventral lobe is further developed than L₂ and L₃ during early ontogeny, whereas L₂ and L₃ become more prominent in the latest juvenile stages. Early instars are often completely smooth, whereas latest ones become granulose. In the Carboniferous species, which show a tubulous layer during maturity, the last immature stage may possess a completely developed velum. Antero- and/or posterodorsal spines occur frequently in juvenile stages of *Hollinella*. They may or may not persist until maturity (Bless & Jordan 1972).

Sexual dimorphism usually appears in the adult stage, but some pre-adult dimorphism has been described from the last or two last juvenile stages (Bless 1970; Bless *et al.* 1969; Forel *et al.* 2015 and references included). Such pre-adult dimorphism applies to the lobation, and the size and shape of the adventral structures. In the “true dimorphic” genera, for example of the Hollinidae family (Bless & Jordan 1971, 1972), the tecnomorph specimens keep the same morphology during ontogeny and the heteromorphs develop different adventral structures. In the “trimorphic” genera (Bless & Jordan 1972), juveniles are clearly morphologically different due to the partial absence of secretion of calcite prisms in juveniles, so that the velum is not formed. According to Bless & Jordan (1972), presumed heteromorphs differ from presumed adult tecnomorphs by the following characters: in heteromorphs L₃ is larger than the domicilium (part of the carapace exclusive of projecting velate structure) and the velum width is smaller than the domicilium. The space between the right and left velums, the antrum, can be ornamented in heteromorphs and smooth in tecnomorphs.

Herein, the ontogenetic variability is expressed by the progressive calcification of the spines forming a continuous velum with all the transitional forms in between during the ontogeny. Sexual dimorphism is sometimes observable at some of the largest specimens. Some males show a greater height and some females are more elongated with the maximum of height in the posterior part. But it is difficult to assign gender for a great majority of the adult specimens.

Repository

All the specimens are deposited in the collections of Pierre et Marie Curie University, Paris, France, under the prefix P6M.

Systematics

Abbreviations (fig. 7)

AB: anterior border, PB: posterior border; DB: dorsal border; VB: ventral border

ACA: anterior cardinal angle; PCA: posterior cardinal angle

S₁, S₂, S₃: sulcus from anterior to posterior

L₁, L₂, L₃, L₄: lobes from anterior to posterior

L: maximum length of carapace; H: maximum height of carapace; W: maximum width of carapace

Class **Ostracoda** Latreille, 1806

Subclass **Podocopa** Sars, 1866

Order **Palaeocopida** Henningsmoen, 1953

Suborder **Beyrichicopina** Scott, 1961

Superfamily **Hollinoidea** Swartz, 1936

Family **Hollinellidae** Bless & Jordan, 1971

Genus **Hollinella** Coryell, 1928 emend. Kellett, 1929

Subgenus **Hollinella (Hollinella)** Coryell, 1928

Hollinella (Hollinella) lungcamensis Crasquin, sp. nov.

(Figs 3-5)

Diagnosis. A species of *Hollinella (Hollinella)* with clearly expressed lobation (L₁ to L₄) but without ventral lobe; spines along free margin and on lobes; ontogenetic variability of velar structures: spines at free margins are replaced by continuous velum which joins ACA and posteroventral part of the carapace; sexual dimorphism expressed by thickening of posterior part of the carapace.

Derivation of name. After Lung Cam section, Northern Vietnam (type locality).

Type locality. Lung Cam section, Northern Vietnam (23°14'30"N; 105°13'20"E)

Type level. Sample VN20, Hong Ngai Formation, latest Changhsingian, latest Permian.

Material. Holotype: P6M3775, right valve (fig. 5C), sample VN20. Paratypes: P6M3776, left valve (fig. 5A), sample VN20; P6M3777, left valve (fig. 5E), sample VN25. Additional material: 201 complete valves and carapaces, many fragments.

Occurrences. samples VN15, VN18, VN19, VN20, VN21, VN22, VN23, VN24, VN25, VN26, VN27, VN28, Lung Cam section (fig. 1), Northern Vietnam, Hong Ngai Formation, latest Changhsingian (latest Permian) – Griesbachian (*parvus* zone), earliest Triassic.

Description. Species of *Hollinella* (*Hollinella*) with long straight DB (68 – 80% of total L) and clear morphological variations between dimorphs occurring early in ontogenesis.

ACA very obtuse (130-140°); lobation well developed: L₁ quite always visible, anterior part is smoothed out, top of L₁ located at anterior fourth of L, not passing over hinge line, occasionally with spines; S₁ quite deep, oriented backwards, base at 27-30% of H and 36-38% of L; L₂ always distinct, vertical and narrow, axis at 42-45% of L; S₂ narrow, vertical, base located high (26-30% of H); L₃ bulbous, rounded, large (diameter 37– 39% of L), highest part just at hinge line (quite not overpassing), covered with spines which can be long; spines are also distributed on the surface of the valves and on free margins of PB; ventral lobe poorly developed. Dorsal view: diamond-like carapace outline, hinge line straight.

Early ontogenetic stages: ACA very obtuse; maximum of convexity of AB located above mid H; S₃ and L₄ invisible; the free margins are covered with several rows of isolated spines. When the specimens reach 790-800µm, the space between velar spines is progressively calcified, calcification forming a continuous velum. Carapace outline in dorsal view biconvex with maximum width at mid L.

Late ontogenetic stages and adults (L>750µm and H>550µm): AB with large radius of curvature with maximum of curvature at 51-58% of H; S₃ and L₄ visible in most specimens. The velate structure is a large smooth velum which begins a little below ACA. Some spines could be present just at the anterior end of the velum. VB is largely rounded and bordered by the velum which decreases and disappears at the junction with PB where it is replaced by spines; maximum of curvature of VB is located at 33-38% of L; velum relatively broad comprising 17-23% of H; PB with large radius of curvature with maximal convexity located at 25-29% of H, PB covered by numerous spines; PCA 105-110°; carapace outline in ventral view diamond-like with large antrum space anteriorly, right and left velums distinct at AB, posterior part of AB covered by spines; maximum width located at the posterior third of L.

290 Sexual dimorphism appears during ontogeny before the adult stage (and sexual maturity), as
291 observed in material from North Iran (Forel *et al.* 2015). This dimorphism is characterized by
292 the larger PB radius of curvature and the greater posterior carapace thickness at the females.

293 **Dimensions.** L = 426 - 1130µm; H = 282 - 807µm; W = 419-488µm (fig. 3).

294 **Remarks.** *Hollinella (Hollinella) lungcamensis* sp. nov. is very similar to *H. ulrichi* (Knight, 1928)
295 from the Late Carboniferous – Early Permian of the South-Central United States, Wales, the
296 Netherlands, Belgium and Germany (see complete synthesis on *H. ulrichi* (Knight, 1928) in
297 Bless & Jordan 1972). The two species have the same ornamentation at the free margin and
298 the same ontogenetic variability and sexual dimorphism. The main difference is the fusion of
299 L₁ and L₂ and the spines which are more irregularly distributed at the ventral margin of *H.*
300 *ulrichi*.

301 *H. spinulosa* Demanet, 1949 from the Late Carboniferous of Southern Limburg, the
302 Netherlands and Campine Basin of Belgium (see synthesis in Bless & Jordan 1972) shows less
303 and wider arranged spines on the free margins and a reticulate carapace surface.

304 *H. echinata* Hao, 1993 from the Changhsingian (Late Permian) of Guizhou, South China has the
305 same lobes, the same spines as *H. lungcamensis* sp. nov., but its velum runs from ACA to PCA
306 and the H/L ratio is lower.

307 *H. panxiensis* Wang, 1978 from the Wuchiapingian (Late Permian)– Induan (Early Triassic) of
308 South China has a complete velum extending from ACA to PCA, a distinct ventral lobe and
309 flattened cardinal angles.

310 *H. magninoda* Wang, 1978 from the Wuchiapingian – Induan of South China has long spines
311 at ACA and PCA and a broad velum (1/3 of H).

312 The new species is attributed to the subgenus *Hollinella (Hollinella)* in regard of the clearly
313 identified L₂, the velum which ended at the lower part of BP and the presence of a row of
314 ventral spines in larval stages (see fig. 6).

315 ***Hollinella* from the South China Block**

316 *Hollinella tingi* has also been reported, but not illustrated, from marginal marine environments
317 of the so-called Permian-Triassic Transition Beds and the overlying Lower Triassic Kayitou
318 Formation of Yunnan (Mide section) and Guizhou (Tucheng section), South China (e.g., Yu *et*
319 *al.* 2010). Recent fieldwork enabled the second author to collect abundant *Hollinella*
320 specimens from the lowermost Kayitou Formation of the Mide section (preliminary analysis in

Bercovici *et al.* 2015). These specimens are mostly preserved as moulds on the surface of cracked siltstone/fine sandstone. Abundant specimens occur with the two valves still attached dorsally in a butterfly shape indicating very quiet hydrodynamic conditions at the time of deposition and rapid burial. Although extremely abundant, these *Hollinella* specimens are poorly preserved and corroded so that the original surface structure is usually not observable. Despite poor preservation, all observed specimens could correspond to *Hollinella panxiensis* described above. The size range of all specimens of this assemblage suggests that several ontogenetic stages are present. The individual stages can, however, hardly be differentiated because specimens cannot be extracted from the matrix and are often only partially exposed. Sexual dimorphism is clearly visible in the *Hollinella* specimens from Mide. No ostracods have been found so far in the underlying Late Permian Xuanwei Formation in the Mide section. The monospecific assemblage of *Hollinella panxiensis* from this very marginal marine succession seems to result from a short proliferation event during unstable conditions.

Conclusion

Hollinella tingi (Patte, 1935) does not occur in the latest Permian – Early Triassic. Three *Hollinella* species are recognized in the latest Permian - earliest Triassic and assigned to *Hollinella panxiensis* Wang, 1978, *Hollinella magninoda* Wang, 1978 and *Hollinella* (*H.*) *lungcamensis* sp. nov. The first two species have quite a long stratigraphic range extending from the Wuchiapingian to the Griesbachian. *H. (H.) lungcamensis*, for the time being, is only present in the Hong Ngai Formation in Vietnam, which is of topmost Changhsingian and earliest Induan (*H. parvus* zone) age. *H. (H.) lungcamensis* is characteristic for the post-extinction period. In the Lung Cam section, *H. (H.) lungcamensis* is associated with many other palaeocopid and podocopid ostracod taxa (work in progress) and with foraminifers of the genera *Geinitzina*, *Nodosaria*, *Globivalvulina*, the species *Hyperammina deformis*, *Ammodiscus kalhori*, and microconchids (Nestell *et al.* 2015). The detailed geochemical analysis of foraminiferal tests and pyrite clusters led Nestell *et al.* (2015) to evoke euxinic conditions at the seabed and a carbon-enriched sea-water column. The source of the carbon could have been global coal fly ash or forest fire-dispersed charcoal, or a combination of both,

which accumulated in the Palaeo-Tethys Ocean. The presence of benthic ostracods in the same samples, however, indicates that the bottom water could not be anoxic nor dysoxic. The analysis of the total ostracod assemblages will improve these ecological data.

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Legend of figures

Figure 1: Location map and stratigraphic column of the Lung Cam section in Northern Vietnam with sample numbers (log modified after Nestell *et al.* 2015).

Figure 2: Interpretative drawing of some specimens of *Hollinella (H.) lungcamensis* sp. nov. A, B, C: adults with well-developed velum as adventral structure; A: female in left lateral view; B: male in left lateral view; C: male in right lateral view; D, E, F: juveniles with spines as adventral structures; D and F in left lateral view and E in right lateral view. Scale bar is 100µm.

Figure 3: Height/length diagram of *Hollinella (H.) lungcamensis* sp. nov. from Vietnam with indication of individual samples.

Figure 4: Height/length diagram of *Hollinella (H.) lungcamensis* sp. nov. with indication of specimens with velum or spines on free margins and indication of identified males and females.

Figure 5: Specimens of *Hollinella (H.) lungcamensis* sp. nov. from the latest Permian - earliest Triassic of the Lung Cam section, Northern Vietnam. All the specimens are at the same scale and scale bar is 200µm. When possible, the gender of specimen is indicated. The numbers with the prefix P6M correspond to the collection numbers of Pierre et Marie Curie University (Paris) Micropalaeontology collection.

A, paratype, left lateral external view of a left valve, ♀, P6M3776; **B**, left lateral external view of a left valve, ♂, P6M3778; **C**, holotype, right lateral external view of a right valve, ♂, P6M3775; **D**, right lateral external view of a right valve, ♂, P6M3779; **E**, paratype, left lateral external view of a left valve, ♀, P6M3777; **F**, left lateral external view of a left valve, ♀, P6M3780; **G**, left lateral external view of a left valve, ♀, P6M3781; **H**, right lateral external view of a complete carapace, ♀, P6M3782; **I**, right lateral external view of a complete carapace, P6M3783; **J**, left lateral external view of a left valve, P6M3784; **K**, right lateral external view of a right valve, P6M3785; **L**, right lateral external view of a complete carapace, ♀, P6M3786; **M**,

518 left lateral external view of a complete carapace, ♂, P6M3787; **N**, right lateral external view
 519 of a right valve, ♀, P6M3788; **O**, left lateral external view of a complete carapace, P6M3789;
 520 **P**, right lateral external view of a complete carapace, P6M3790; **Q**, left lateral external view of
 521 a left valve, P6M3791; **R**, left lateral external view of a left valve, P6M3792; **S**, left lateral
 522 external view of a complete carapace, P6M3793; **T**, right lateral external view of a complete
 523 carapace, P6M3794; **U**, left lateral external view of a left valve, P6M3795; **V**, left lateral
 524 external view of a left valve, P6M3796; **W**, right lateral external view of a complete carapace,
 525 P6M3797; **X**, left lateral external view of a complete carapace, P6M3798; **Y**, right lateral
 526 external view of a complete carapace, P6M3799; **Z**, left lateral external view of a complete
 527 carapace, P6M3800; **A'**, left lateral external view of a complete carapace, P6M3801; **B'**, right
 528 lateral external view of a complete carapace, P6M3802; **C'**, dorsal external view of a complete
 529 carapace, P6M3803; **D'**, ventral external view of a juvenile complete carapace, P6M3804; **E'**;
 530 ventral external view of a complete carapace, ♂, P6M3805; **F'**, ventral external view of a
 531 complete carapace, ♀, P6M3806 (for figs. 5C' to F' the anterior border is up).

532

533 Figure 6: Schematic representation of ontogenetic variations in some genera and subgenera
 534 of Hollinellidae (modified after Bless & Jordan 1970).

535

536 Figure 7: Schematic representation of *Hollinella* (*Hollinella*) *lungcamensis* sp. nov. with
 537 descriptive terms and abbreviations used in text. The small arrows indicate the anterior part
 538 of the carapace.

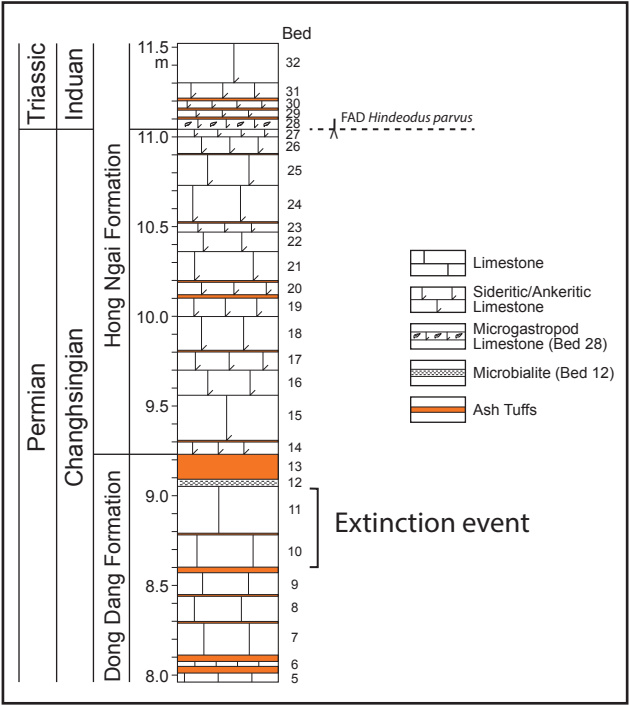
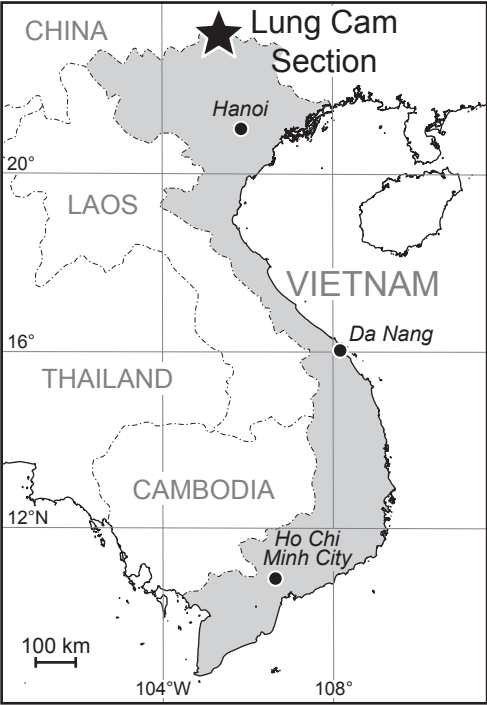
539 **A.** external view of right valve: S₁, S₂, S₃: sulcus from anterior to posterior; L₁, L₂, L₃, L₄: lobes
 540 from anterior to posterior; L: maximum length of carapace; H: maximum height of carapace;
 541 small dots indicate the location of maximum of convexity of AB, PB and VB.

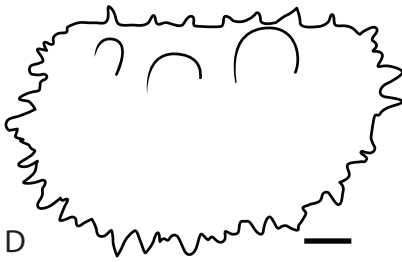
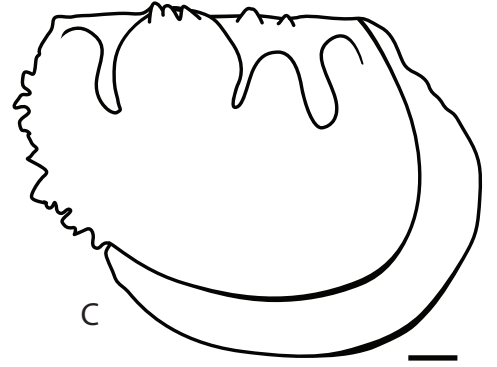
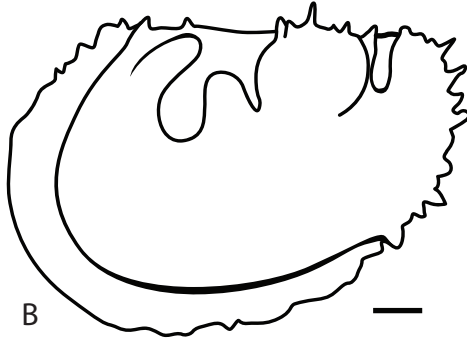
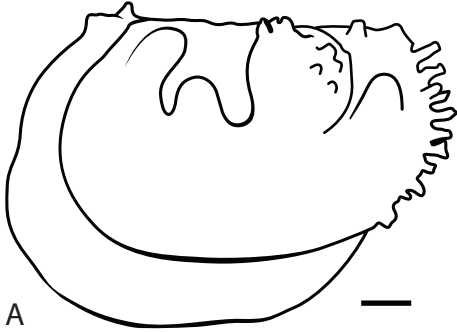
542 **B.** external view of right valve: AB: anterior border, PB: posterior border; DB: dorsal border;
 543 VB: ventral border; ACA: anterior cardinal angle; PCA: posterior cardinal angle.

544 **C.** Ventral view; W: maximum width of carapace.

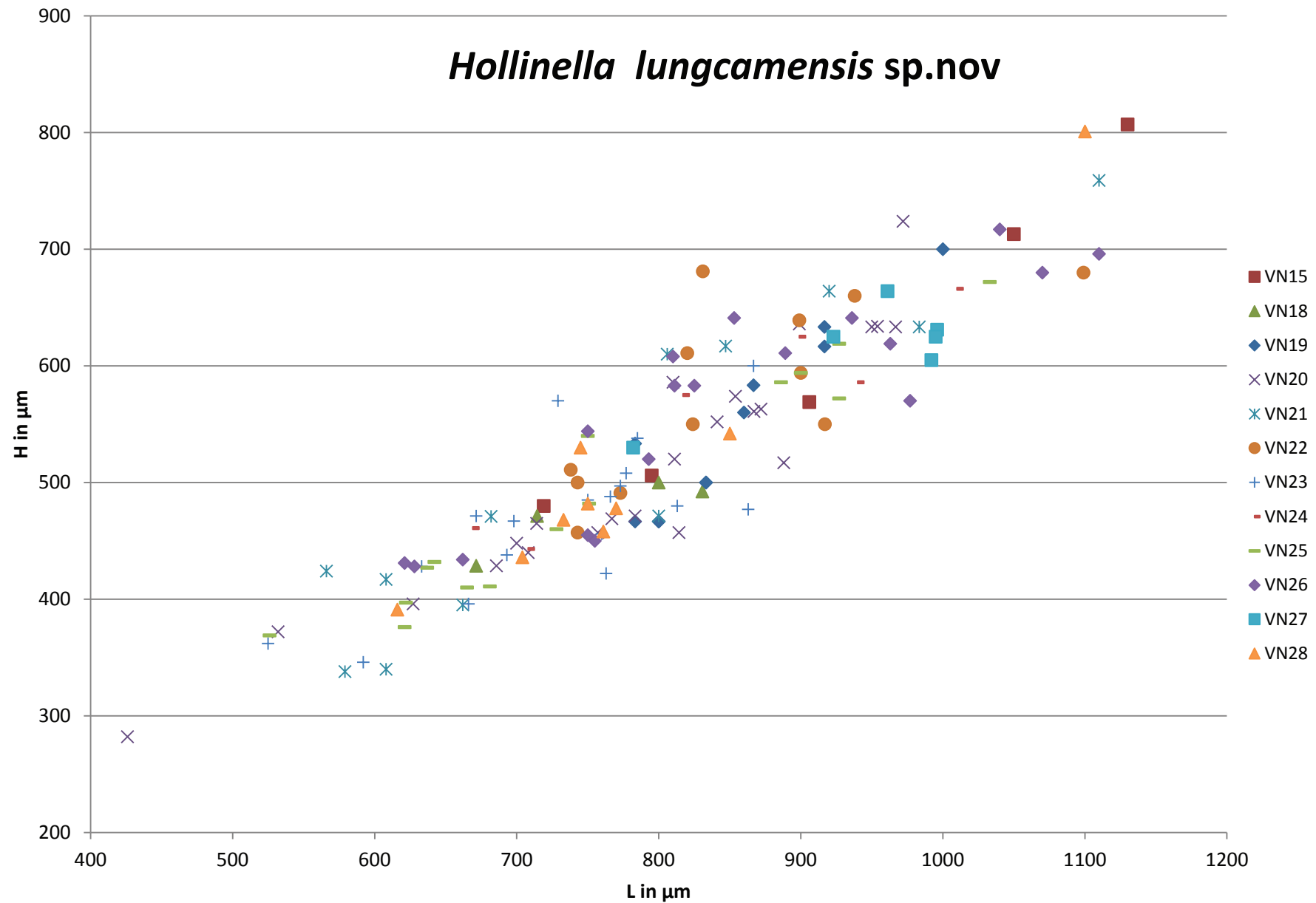
545 **D.** Dorsal view: L₁ to L₃ and S₁ to S₃, lobes and sulcus same as A.

546

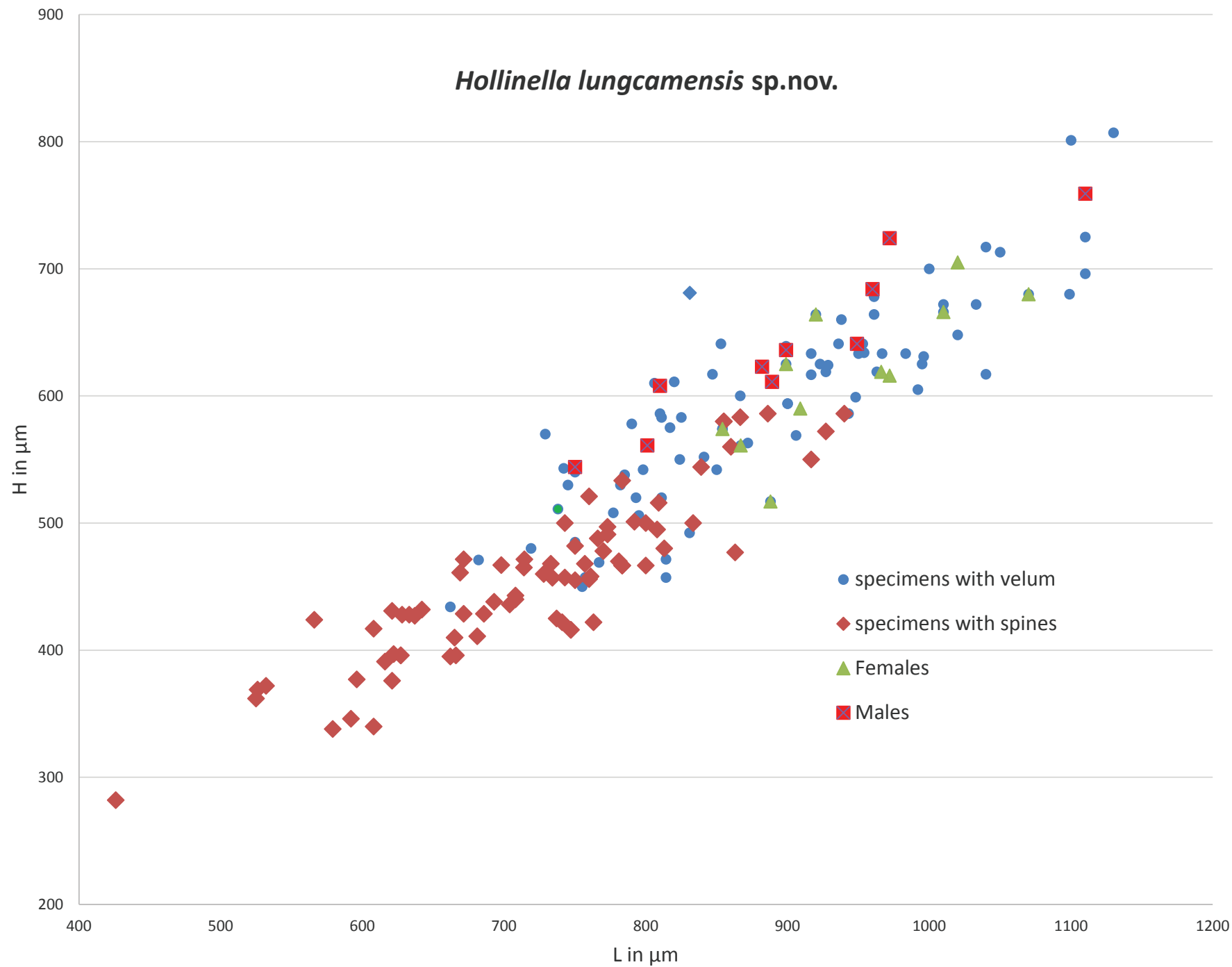


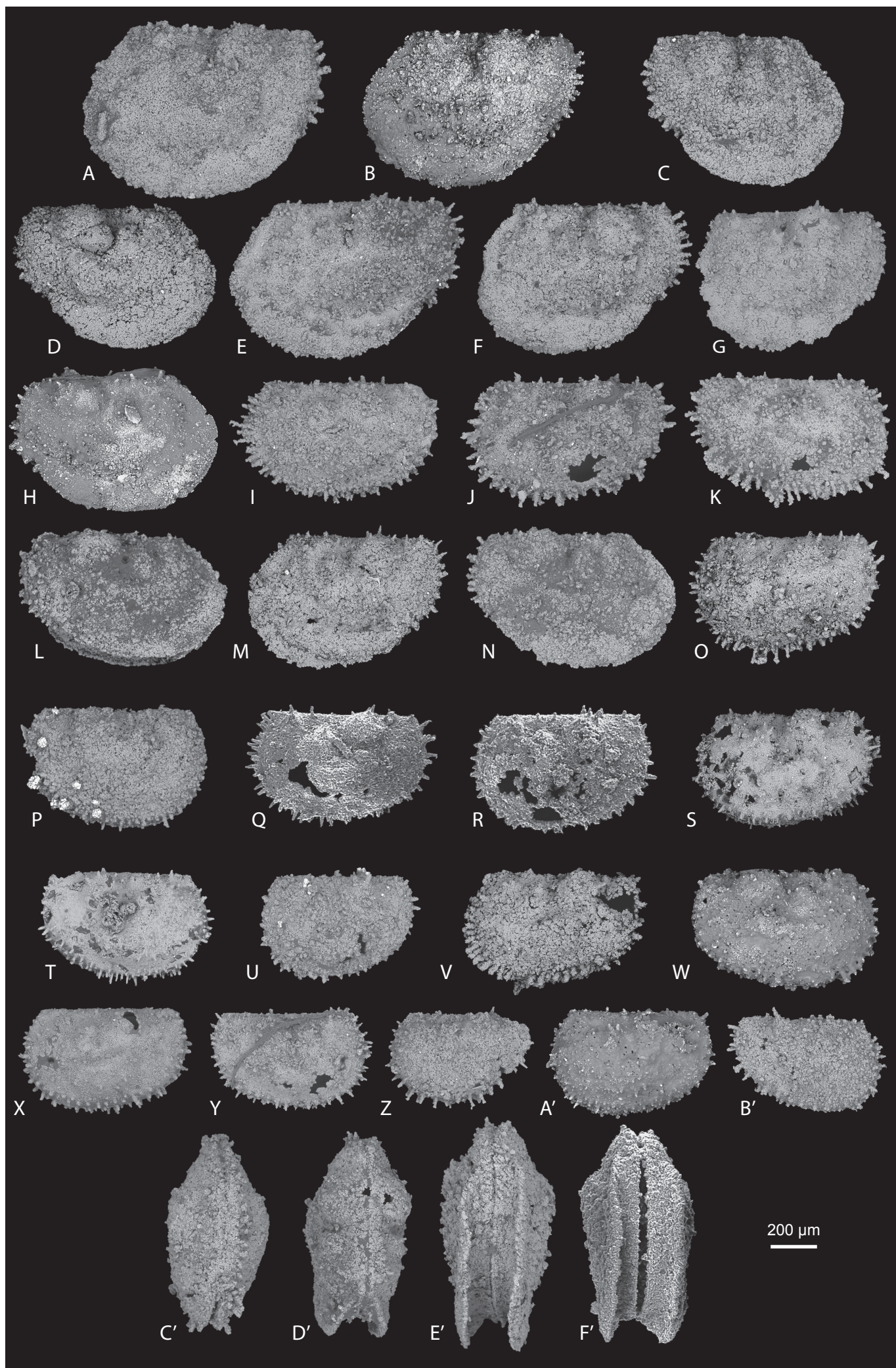


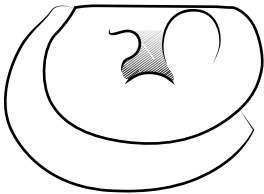
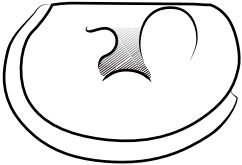
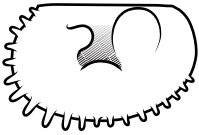
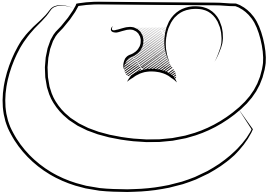
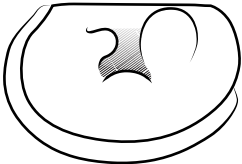
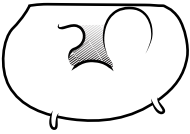
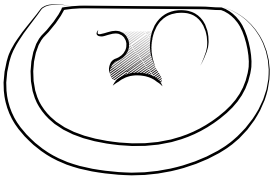
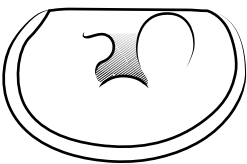
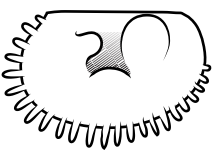
Hollinella lungcamensis sp.nov



Hollinella lungcamensis sp.nov.





	♂	♀	juvenil
<i>Hollinella (Hollinella)</i>			
<i>Hollinella (Kessingella)</i>			
<i>Hollinella (Praehollinella)</i>			
<i>Jordanites</i>	