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► To cite this version:

Sylvie Crasquin, Marie-Béatrice Forel, Aihua Yuan, Galina Nestell, Merlynd Nestell. Species of *Hollinella* (Palaeocopida: Ostracoda: Crustacea) as stratigraphical indices of the Late Permian–Early Triassic post-extinction interval. *Journal of Systematic Palaeontology*, 2017, 16 (3), pp.213-224. 10.1080/14772019.2017.1283648 . hal-02052760

HAL Id: hal-02052760

<https://hal.sorbonne-universite.fr/hal-02052760>

Submitted on 28 Feb 2019

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

3
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11 **Abstract**

12
13 Members of the Ostracoda Order Palaeocopida, except for two very rare genera
14 (*Puncia* and *Manawa*), disappeared in the stratigraphic record close to the Permian – Triassic
15 boundary (PTB) event. Species of the genus *Hollinella* are often present just after the end
16 Palaeozoic mass extinction event, in the latest Permian and earliest Triassic beds. They are
17 one of the latest representatives of the Palaeocopida, the typical Palaeozoic straight dorsal
18 border ostracods. The Early Triassic species are assigned by most authors to *Hollinella tingi*
19 (Patte, 1935), but this assignment is incorrect. This species is present in the latest Permian and
20 the earliest Triassic, and therefore is considered as a biostratigraphic index fossil of the post-
21 mass extinction interval. A revision of the *Hollinella* species from this interval is presented
22 herein. Three *Hollinella* species occur in the earliest Triassic and are assigned to *Hollinella*
23 *panxiensis* Wang 1978, *Hollinella magninoda* Wang 1978 and *Hollinella (Hollinella)*
24 *lungcamensis* sp. nov. This new species of the post-PTB event and present in strata exposed
25 in the northern part of Vietnam is described. These three species cross the PTB and *H. (H.)*
26 *lungcamensis* is characteristic for the post extinction period (latest Changhsingian – earliest
27 Induan).

28
29 **Keywords:** Permian – Triassic extinction event; ostracods; Palaeocopida;
30 biostratigraphic index.

32 **Introduction**

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

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

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

54

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

56

57 It is important to note that the genus *Hollinella* frequently shows significant intraspecific
58 variability. Sexual dimorphism is apparent from different adventral structures (for example,
59 a large and striated velum in females, which is absent or replaced by a small nodule row in
60 males) and the stronger anteroventral convexity of the female carapace – corresponding to
61 the brood pouch. The carapace shape of *Hollinella* shows also strong ontogenetic variations.
62 Such variability is also recorded from many other palaeocopid taxa (for example, Sohn 1950
63 for Kirkbyidae and Miltonellidae; Bless & Jordan 1972 for Hollinellidae; Watabe & Kaesler
64 2004 for Paraparchitidae).

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

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

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

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

79 In 1964, Ishizaki assigned specimens discovered in the Early Pennsylvanian (Late
80 Carboniferous) of Japan to *Hollinella tingi*. The preservation of the figured specimen (Ishizaki
81 1964: pl. 1, fig. 1) is so poor that it is impossible to confirm its assignment. The stratigraphic
82 range in the Early Pennsylvanian is therefore questionable.

83

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

85

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

91 In 1978, Wang figured and described four *Hollinella* species from the Late
92 Changhsingian and Early Induan of Western Guizhou and North-Eastern Yunnan: *H. tingi*
93 (Wang 1978: pl. 1, figs 5-7), and three new species including *H. magninoda* (Wang 1978: pl. 1,
94 fig. 11), *H. panxiensis* (Wang 1978: pl. 1, figs 1-4), and *H. capacilacuna* (Wang 1978: pl. 1, figs
95 8-10). English translations are absent from Wang's paper. We made these translations and
96 give them in the annexe (some passages are unclear in the original descriptions. Our
97 translation is literal and without interpretation). With regard to these "descriptions" and the
98 illustrations (Wang 1978), we suggest that: *Hollinella capacilacuna* and *H. magninodosa* are

99 valid species and are Late Permian in age.

100 For the present authors, the specimens assigned to *H. tingi* and specimens assigned to
101 *H. panxiensis* belong to the same species, *H. panxiensis*, which has no long posterodorsal
102 spine, but just a small lateral flattening (pinch) of the posterior cardinal angle (Wang 1978: pl.
103 1, figs 1-4). L_3 is elongated antero-posteriorly. When the velum is completely developed, it
104 extends from the anterior cardinal angle to the posterior cardinal angle. Some small nodules
105 could be present on the upper part of L_3 . The specimen illustrated by Wang (1978) on pl. 1,
106 fig. 6 differs slightly by its higher height/length ratio possibly due to ontogeny and could be
107 determined as *H. panxiensis*?

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

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

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

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

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

131 long spines at cardinal angles; p.39, pl. 1, fig. 2-3) is a synonym with *Hollinella magninoda*
132 Wang, 1978). The specimens assigned to *H. tingi* (p. 39, pl. 1, figs 5-6) do not belong to that
133 species. The first one has a very different lateral outline and is very badly preserved (pl. 1, fig.
134 5) and the second one (pl. 1, fig. 6) shows a strong reticulation in front of L₁ and seems to have
135 a ventral ridge. We assign it to *H. panxiensis* based on the presence of the pinch at the cardinal
136 angles. The specimen of “*H. tingi*” illustrated in Hao (1992b; pl. 1, fig.1) from the
137 Changhsingian of Guizhou could be conspecific with *H. panxiensis* due to its complete velum
138 extending along the entire free margins. In a paper on the Changhsingian from Guizhou, Hao
139 (1993) assigned two specimens to *H. tingi* (Hao 1993: pl. 1, figs 1-2). The illustration is of poor
140 quality and there is no description. As can be seen on plate 1 of Hao (1993), the cardinal
141 pinches are indistinct, but the specimens show an elongated antero-posteriorly L₃ like the
142 specimens of Wang (1978). Furthermore, the velum begins at the anterior cardinal angle and
143 ends at the posterior cardinal angle. We consider that these specimens could belong to *H.*
144 *panxiensis*. In the same paper, Hao described a new species: *H. echinata*. The three illustrated
145 specimens are quite small (L: 0.81-0.83mm). The description is a summary and very general.
146 The author just mentioned that the “border” of *H. echinata* possesses many short spines. In
147 his publications from 1994 and 1996, Hao illustrated ostracods from the Permian - Triassic
148 interval in Guizhou Province, but pictures of *Hollinella* are identical to those in the publications
149 from 1992a and 1992b.

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

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

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

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

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

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

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

166

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

168

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

177 This rich material is quite well preserved and permits a detailed study of a new species
178 of *Hollinella* which is characteristic of the post-extinction event. The assemblage shows a high
179 morphological diversity including all the transitional forms between the extremes (Figs 2 and
180 5). Herein, 201 specimens were measured (H and L include here the adventral structure; fig.
181 3). The length (L) ranges between 426 and 1130µm and the height (H) between 282 and
182 807µm. Specimens of all this size range evenly occur in all the 12 samples.

183 *Hollinella (H.) lungcamensis* sp. nov. (see description below) shows different
184 morphotypes. A first group has free margins ornamented by several rows of spines (see figs.
185 2, 4, 5) from anterior cardinal angle (ACA) to the posterior cardinal angle (PCA). The second
186 group has a well-developed velum which is completely calcified forming a continuous blade
187 from the ACA to the posteroventral part of the carapace. The posterior part of the carapace is
188 ornamented by spines. All transitional forms between these two extremes are represented. If
189 we plot the size of specimens with spines and specimens with a complete velum on an H/L
190 diagram (fig. 4), it becomes clear that this morphological variability is due to ontogenesis.

191

192 **Sexual dimorphism and ontogenetic variability in the Palaeocopida**

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

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

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

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

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

225

226 **Repository**

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

229

230 **Systematics**

231

232 Abbreviations (fig. 7)

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

234 ACA: anterior cardinal angle; PCA: posterior cardinal angle

235 S₁, S₂, S₃: sulcus from anterior to posterior

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

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

239

240 Class **Ostracoda** Latreille, 1806

241 Subclass **Podocopa** Sars, 1866

242 Order **Palaeocopida** Henningsmoen, 1953

243 Suborder **Beyrichicopina** Scott, 1961

244 Superfamily **Hollinoidea** Swartz, 1936

245 Family **Hollinellidae** Bless & Jordan, 1971

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

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

248 **Hollinella (Hollinella) lungcamensis** Crasquin, sp. nov.

249 (Figs 3-5)

250

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

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

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

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

259 **Material.** Holotype: P6M3775, right valve (fig. 5C), sample VN20. Paratypes: P6M3776, left
260 valve (fig. 5A), sample VN20; P6M3777, left valve (fig. 5E), sample VN25. Additional material:
261 201 complete valves and carapaces, many fragments.

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

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

267 ACA very obtuse (130-140°); lobation well developed: L₁ quite always visible, anterior part is
268 smoothed out, top of L₁ located at anterior fourth of L, not passing over hinge line, occasionally
269 with spines; S₁ quite deep, oriented backwards, base at 27-30% of H and 36-38% of L; L₂ always
270 distinct, vertical and narrow, axis at 42-45% of L; S₂ narrow, vertical, base located high (26-
271 30% of H); L₃ bulbous, rounded, large (diameter 37– 39% of L), highest part just at hinge line
272 (quite not overpassing), covered with spines which can be long; spines are also distributed on
273 the surface of the valves and on free margins of PB; ventral lobe poorly developed. Dorsal
274 view: diamond-like carapace outline, hinge line straight.

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

280 Late ontogenetic stages and adults (L>750µm and H>550µm): AB with large radius of
281 curvature with maximum of curvature at 51-58% of H; S₃ and L₄ visible in most specimens. The
282 velate structure is a large smooth velum which begins a little below ACA. Some spines could
283 be present just at the anterior end of the velum. VB is largely rounded and bordered by the
284 velum which decreases and disappears at the junction with PB where it is replaced by spines;
285 maximum of curvature of VB is located at 33-38% of L; velum relatively broad comprising 17-
286 23% of H; PB with large radius of curvature with maximal convexity located at 25-29% of H, PB
287 covered by numerous spines; PCA 105-110°; carapace outline in ventral view diamond-like
288 with large antrum space anteriorly, right and left velums distinct at AB, posterior part of AB
289 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 - 1130 μ m; H = 282 - 807 μ m; W = 419-488 μ m (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

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

335

336

337 **Conclusion**

338

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

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

356

357

358 Acknowledgments:

359 The authors thank Mark Williams (University of Leicester, UK), anonymous reviewer and the editors
360 for their constructive comments and corrections on the first version of the manuscript. We thank
361 Justine Jacquot and Charlène Letenneur (CR2P - MNHN) for drawing of figures 6 and 7 and Alexandre
362 Lethiers (CR2P - UPMC) for the production of figure 5. Y.A. is supported by the Chinese projects number
363 B08030 (111 Project), 41572001 and 41430101 (NFSC Project).

364

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- 486

487 Legend of figures

488

489

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

492

493 Figure 2: Interpretative drawing of some specimens of *Hollinella (H.) lungcamensis* sp. nov.

494 A, B, C: adults with well-developed velum as adventral structure; A: female in left lateral view;
495 B: male in left lateral view; C: male in right lateral view; D, E, F: juveniles with spines as
496 adventral structures; D and F in left lateral view and E in right lateral view. Scale bar is 100µm.

497

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

500

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

504

505 Figure 5: Specimens of *Hollinella (H.) lungcamensis* sp. nov. from the latest Permian -

506 earliest Triassic of the Lung Cam section, Northern Vietnam. All the specimens are at the

507 same scale and scale bar is 200µm. When possible, the gender of specimen is indicated. The

508 numbers with the prefix P6M correspond to the collection numbers of Pierre et Marie Curie

509 University (Paris) Micropalaeontology collection.

510 **A**, paratype, left lateral external view of a left valve, ♀, P6M3776; **B**, left lateral external view

511 of a left valve, ♂, P6M3778; **C**, holotype, right lateral external view of a right valve, ♂,

512 P6M3775; **D**, right lateral external view of a right valve, ♂, P6M3779; **E**, paratype, left lateral

513 external view of a left valve, ♀, P6M3777; **F**, left lateral external view of a left valve, ♀,

514 P6M3780; **G**, left lateral external view of a left valve, ♀, P6M3781; **H**, right lateral external view

515 of a complete carapace, ♀, P6M3782; **I**, right lateral external view of a complete carapace,

516 P6M3783; **J**, left lateral external view of a left valve, P6M3784; **K**, right lateral external view of

517 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.

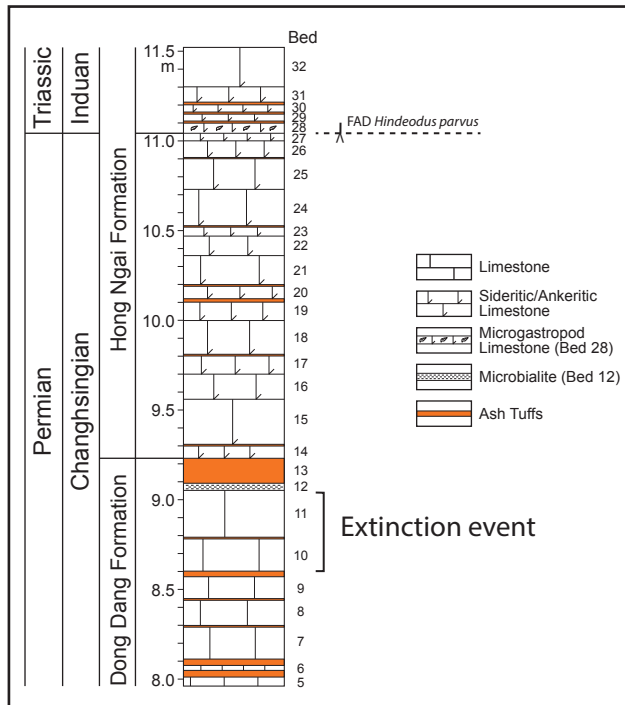
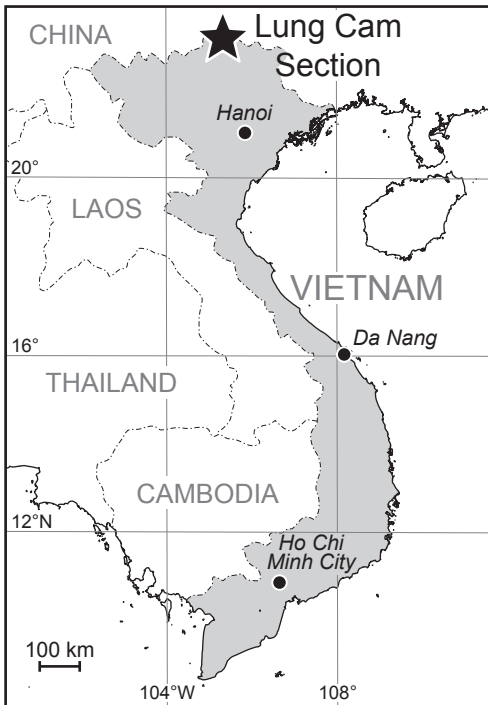
539 **A.** external view of right valve: S₁, S₂, S₃: sulcus from anterior to posterior; L₁, L₂, L₃, L₄: lobes
540 from anterior to posterior; L: maximum length of carapace; H: maximum height of carapace;
541 small dots indicate the location of maximum of convexity of AB, PB and VB.

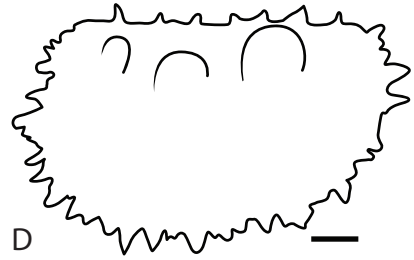
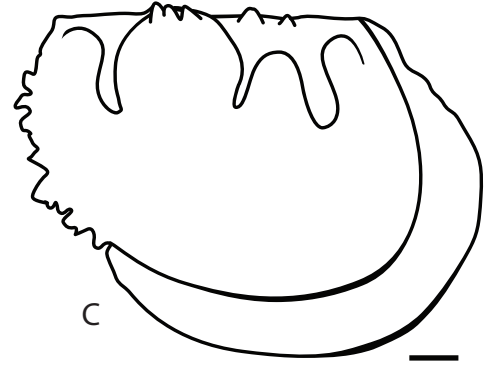
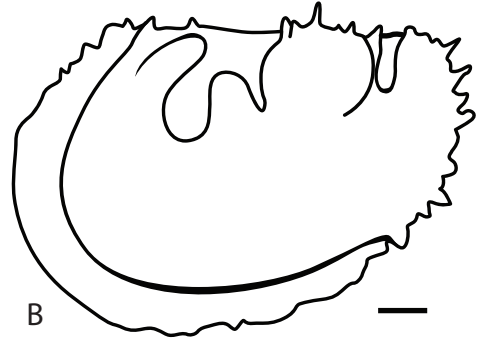
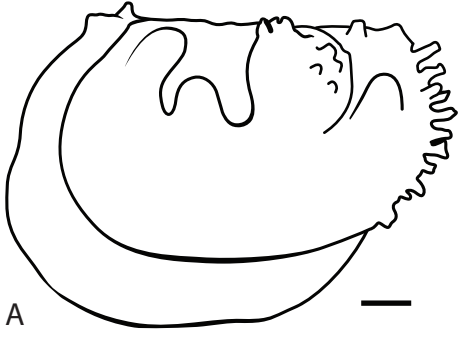
542 **B.** external view of right valve: AB: anterior border, PB: posterior border; DB: dorsal border;
543 VB: ventral border; ACA: anterior cardinal angle; PCA: posterior cardinal angle.

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

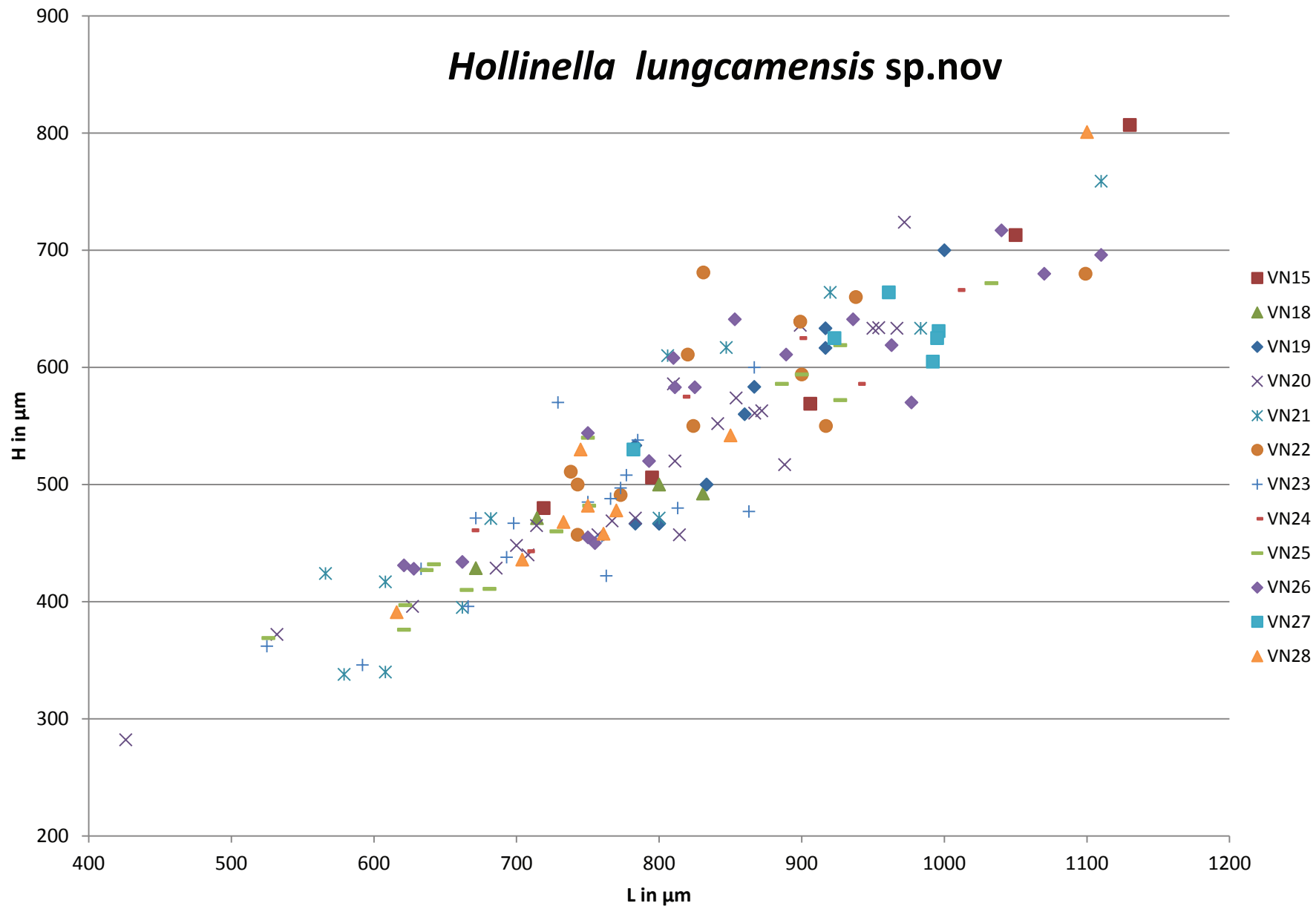
545 **D.** Dorsal view: L₁ to L₃ and S₁ to S₃, lobes and sulcus same as A.

546

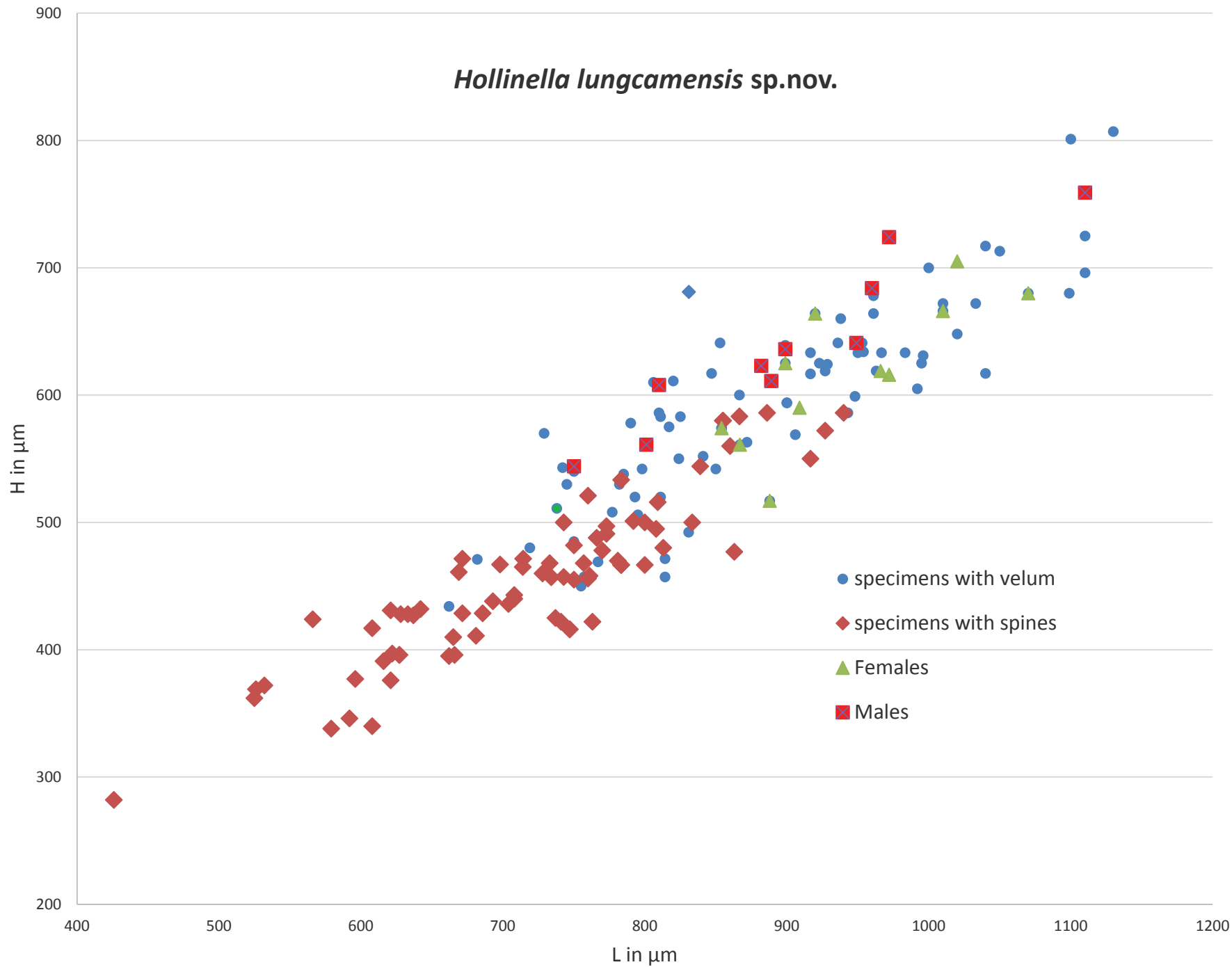


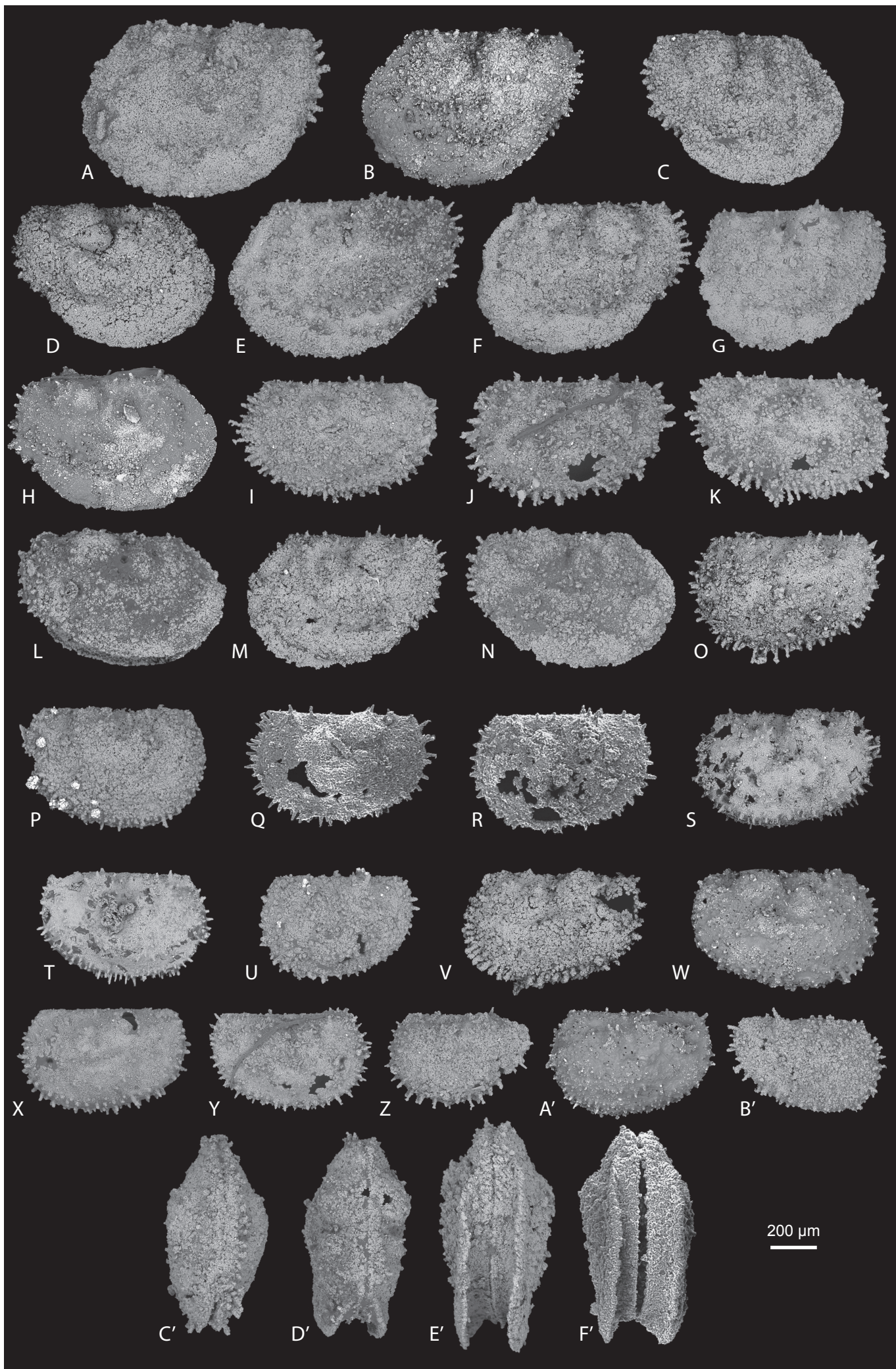


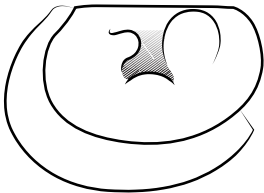
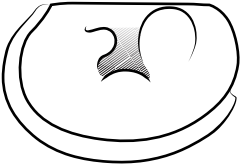
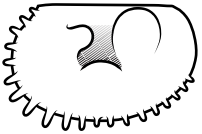
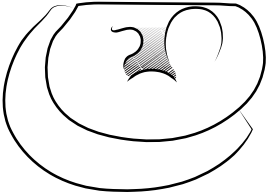
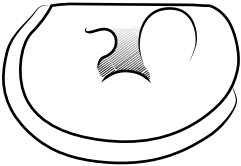
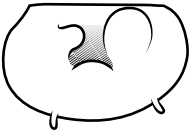
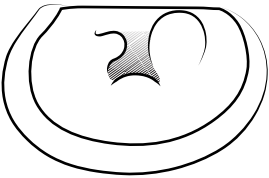
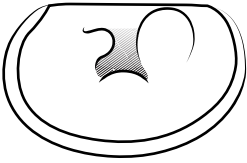
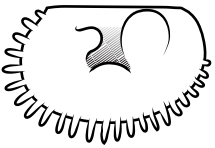
Hollinella lungcamensis sp.nov



Hollinella lungcamensis sp.nov.





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