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贵州松桃寒武系第二统清虚洞组腕足动物 *Eohadrotreta zhenbaensis* 的发现*

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提要　微型腕足动物化石镇巴始壮贝 *Eohadrotreta zhenbaensis* 常见于陕南、峡东水井沱组与黔东麻江九门冲组等地寒武纪地层中, 在贵州松桃盘信寒武系第二统清虚洞组薄层灰岩中为首次发现。通过与华南其他地区 *E. zhenbaensis* 的背壳长宽比及中隔板等结构特征比较, 发现松桃盘信清虚洞组 *E. zhenbaensis* 与浅水扬子地台的陕南、峡东地区的 *E. zhenbaensis* 壳体内部特征较为相似, 包括肉茎孔形成阶段、肉茎孔封闭阶段及交互沟伸长阶段 3 个生长发育阶段标本, 与较深水过渡区麻江的 *E. zhenbaensis* 略有差异。贵州松桃盘信寒武系第二统清虚洞组 *E. zhenbaensis* 的发现, 扩展了该属化石在华南寒武纪第二世的古地理分布, 丰富了该组腕足动物组成面貌, 为研究 *E. zhenbaensis* 形态结构特征提供了新材料。

关键词　*Eohadrotreta*　微型腕足动物　清虚洞组　寒武系　贵州松桃

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THE DISCOVERY OF *EOHADROTRETA ZHENBAENSIS* (BRACHIOPODA) FROM THE CAMBRIAN SERIES 2 TSINGHSUTUNG FORMATION OF SONGTAO, GUIZHOU

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Abstract　Micro-brachiopod *Eohadrotreta zhenbaensis* has been constantly reported in Cambrian Series 2 of South

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China, such as the Shuijingtuo Formation of southern Shaanxi Province, western Hubei Province and Jiumenchong Formation of east Guizhou Province. Herein, for the first time, we report a large number of *E. zhenbaensis* collected from the thin limestone of the Cambrian Stage 4 Tsinghsutung Formation at the Panxin section in Songtao County of Guizhou Province. The specimens of *E. zhenbaensis* from the Tsinghsutung Formation include the whole 3 development stages, pedicle foramen forming stage, pedicle foramen enclosing stage and intertrough increasing stage. The morphological characteristics of *E. zhenbaensis* reported herein are more similar to the specimens from the Shuijingtuo Formation of southern Shaanxi and western Hubei in the shallow Yangtze platform, but they are slightly different from these from the Jiumenchong Formation of east Guizhou in slightly deep water slope. In short, the discovery of the *E. zhenbaensis* from the Cambrian Series 2 Tsinghsutung Formation at Panxin section further expands its paleogeographic distribution of this genus during Cambrian Epoch 2 in South China, which can also enrich the brachiopod assemblages from the Tsinghsutung Formation, and provide new material for the study of the morphologic variations of *E. zhenbaensis*.

SYSTEMATIC PALEONTOLOGY

Subphylum Linguliformea Williams *et al*., 1996
Class Lingulata Gorjansky and Popov, 1985
Order Acrotretida Kuhn, 1949
Superfamily Acrotretoidea Schuchert, 1893
Family Acrotretidae Schuchert, 1893
Subfamily Acrotretinae Schuchert, 1893
Genus *Eohadrotreta* Li and Holmer, 2004

Type species *Eohadrotreta zhenbaensis* Li and Holmer, 2004

Description *Eohadrotreta zhenbaensis* has a ventribiconvex and subcircular to transversely oval shell. The average valve length is 1095 μm, with variations from 514 μm to 1745 μm in the dorsal valve. The length-width ratio is on average 0.845. The dorsal cardinal muscle scars are pronounced, on average 456 μm long and 1010 μm wide. The median septum is well developed, which extends anteriorly to two-thirds of dorsal valve length (about 0.73 of valve length). Furthermore, the submedian septum is well developed on both sides of the median septum. The median buttress is well developed. The average dorsal pseudointerarea width is 745 μm, to about 1/3 of the valve width. The average valve length is 1085 μm, with variations from 315 μm to 1873 μm in the ventral valve. The ventral pseudointerarea is procline, divided by a narrow elongate intertrough (on average is 94 μm). On the internal surface of ventral valve, the apical process and the paired cardinal muscle scars are developed.

Key words *Eohadrotreta*, micro-brachiopod, Tsinghsutung Formation, Cambrian, Songtao of Guizhou

1 前 言

腕足动物是一类具左右对称性背、腹壳，以纤毛腕滤食的海洋底栖固着无脊椎动物，在地质历史中占有重要地位(王钰，1966; Zhang *et al*., 2008)。寒武纪腕足动物化石丰富，最早的腕足动物化石可能是来自于澳大利亚寒武系第二阶中的神父贝类(Topper *et al*., 2013)。而可靠的舌形贝型亚门腕足动物化石在寒武系第三阶中才被发现(Harper *et al*., 2017)。乳孔贝类始壮贝属 *Eohadrotreta* 自 2004 年建属以来(Li and Holmer, 2004)，已相继报道于扬子板块上的陕南、峡东、黔东南地区(Li and Holmer, 2004; 何树兴等, 2016; Zhang *et al*., 2016a; Zhang *et al*., 2016b, 2018a, 2018b)，华北板块南缘(Pan *et al*., 2019)，以及喜马拉雅、澳大利亚南部地区和南极洲等地(Popov *et al*., 2015; Betts *et al*., 2017; Claybourn *et al*., 2020)，是寒武系第二统洲际地层对比的重要潜在化石(张志亮等，2017)。该属目前已报道的种包括有 *Eohadrotreta zhenbaensis*、*E. zhujiahensis* 和 *E. haydeni* (Li and Holmer, 2004; Popov *et al*., 2015)。其中 *E. zhenbaensis* 是华南碳酸盐台地上寒武纪早期腕足动物群中最为广泛分布的物种之一(Zhang *et al*., 2016a)。前人已对华南地区寒武系水井沱组中的 *E. zhenbaensis* 壳体超微结构进行了研究，发现其壳体内表面保存了大量精美的表皮细胞印模，并对这些表皮细胞印模的分布规律进行了研究(Zhang *et al*., 2016b; 张志亮等, 2017)。此外, Zhang 等(2018b)对 *E. zhenbaensis* 的个体发育模式进行研究，将其划分成肉茎孔形成、肉茎孔封闭和交互沟伸长 3 个阶段；且发现 *E. zhenbaensis* 具有较显著的异速生长发育模式，主要以腹交互沟加速伸长，以及背中隔板对应复杂化等为发育特征(Zhang *et al*., 2018b)。但乳孔贝类的早期起源以及与其他舌形贝类的系统学关系还很难确定(Holmer and Po-

pov, 2000), 仍需大量的化石证据去证实。

近期, 笔者通过酸蚀法在贵州松桃盘信剖面寒武系清虚洞组薄层灰岩中获得了大量保存精美的 *Eohadrotreta* 化石标本, 鉴定为 *E. zhenbaensis*。*E. zhenbaensis* 为首次在松桃清虚洞组中发现, 可为研究该区清虚洞组的化石组成面貌及加深对 *Eohadrotreta* 形态特征的认识提供新的化石证据, 同时也扩展了该属化石在华南寒武纪第二世的古地理分布。

2 地质背景

本文研究材料采自盘信剖面清虚洞组, 剖面位于贵州省铜仁市松桃县盘信镇一带(图 1-A)。在寒武纪早期, 松桃盘信剖面位于扬子台地边缘(图 1-B)(周志毅等, 1979)。贵州松桃地区寒武系广泛分布, 由下而上包括留茶坡组、九门冲组、杷榔组、清虚洞组、高台组、石冷水组及娄山关群(尹恭正, 1987)。清虚洞组岩性主要为灰岩、白云质灰岩及豹皮状灰岩。最早, 尹赞勋(1945)等在距湄潭县城东 1 公里清虚洞附近命名了一套“清虚洞石灰岩”, 后由卢衍豪(1962)将其改称清虚洞组, 以湄潭茅坪梅子湾剖面为标准剖面(周志毅等, 1979)。

结合前人研究, 贵州松桃地区寒武系清虚洞组岩性主要以灰岩为主, 分为上下两部分:下部为黑色泥质条带状灰岩, 产 *Redlichia chinensis*; 上部为灰色厚层灰岩, 含 *Redlichia* sp.等三叶虫(林焕令等, 1966)。本文研究剖面位于松桃县盘信镇街东 1 km 附近, 该剖面清虚洞组出露不全, 底部未出露, 上部被植被覆盖, 主要出露的为清虚洞组下部黑-灰黑色夹泥质条带灰岩与碳质薄层灰岩, 厚约 37 m。马志鑫等(2013)邻区麻江清虚洞组灰色薄层夹泥质条带灰岩段的沉积环境分析显示其可能也为较浅水的缓坡相沉积。

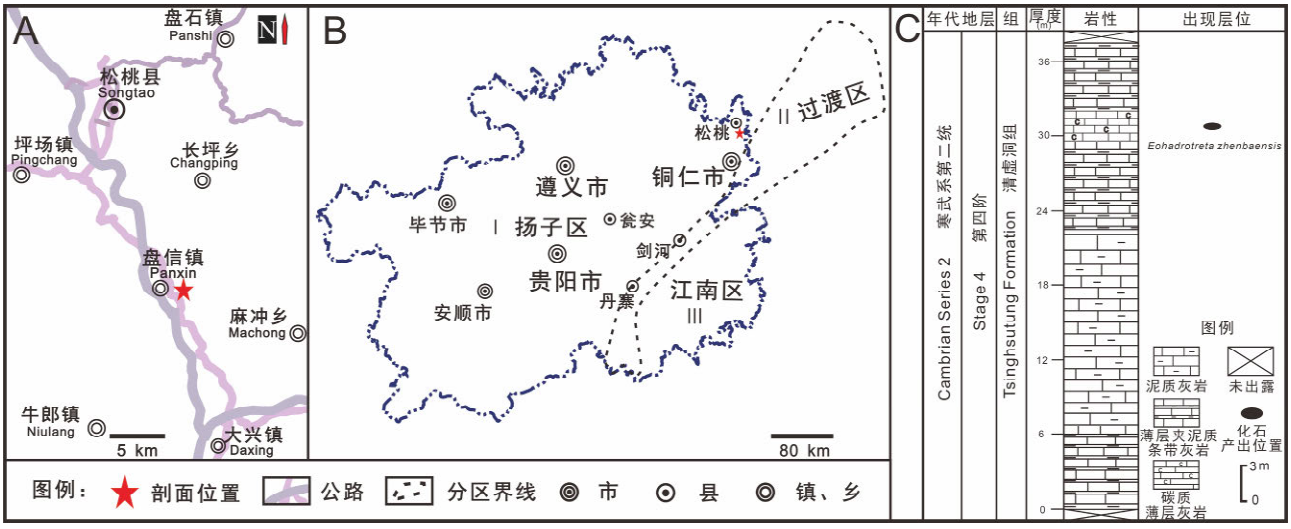

图 1 A. 贵州松桃盘信剖面地理位置图; B. 贵州寒武纪早期沉积分区图(据周志毅等, 1979 修改); C. 镇巴始壮贝化石产出层位

Fig. 1 A: Map showing the geographic location at Panxin section of Songtao County, Guizhou Province; B: The stratigraphic districts of early Cambrian of Guizhou (modified from Zhou *et al*., 1979); C: Stratigraphic occurrence of *Eohadrotreta zhenbaensis*

我们对采自贵州松桃盘信剖面清虚洞组灰岩样品使用酸蚀法处理后, 在黑-灰黑色薄层碳质灰岩中获得了大量的微体化石, 主要包括腕足动物化石、海绵骨针及管状化石等。通过观察鉴定, 我们发现这些腕足动物化石中有大量的镇巴始壮贝 *Eohadrotreta zhenbaensis*。本文描述的 *E. zhenbaensis* 均产于松桃盘信剖面的清虚洞组薄层碳质灰岩中(图 1-C)。

3 系统古生物学

舌形贝型亚门 Subphylum Linguliformea Williams *et al*., 1996

舌形贝纲 Class Lingulata Gorjansky and Popov, 1985

乳孔贝目 Order Acrotretida Kuhn, 1949

乳孔贝超科 Superfamily Acrotretoidea

Schuchert, 1893

乳孔贝科 Family Acrotretidae Schuchert, 1893

乳孔贝亚科 Subfamily Acrotretinae Schuchert, 1893

始壮贝属 Genus *Eohadrotreta* Li and Holmer, 2004

模式种 *Eohadrotreta zhenbaensis* Li and Holmer, 2004

种征 壳体腹双凸形, 轮廓呈亚圆形至横卵形, 变态壳表面具有圆形坑状结构。腹壳从微凸至宽锥形变化; 腹假铰合面下倾型至前倾型, 交互沟发育; 肉茎孔(pedicle foramen)发育初期呈开放状态, 中期开始封闭; 腹主肌痕(cardinal muscle scars)明显; 侧脉管(vascula lateralia)发育; 顶突(apical process)微弱发育; 无顶坑构造。背壳微凸; 背假铰合面短, 呈直倾型; 中突(median buttress)发育; 中隔板(median septum)发育明显, 且向前延伸超过 1/2 壳长(Li and Holmer, 2004; Holmer and Popov, 2007; Zhang *et al*., 2016a; Li *et al*., 2017)。

产地与层位 华南陕南、峡东及黔东麻江, 华北板块南缘, 喜马拉雅, 澳大利亚, 南极洲; 寒武系第二统。

镇巴始壮贝 *Eohadrotreta zhenbaensis* Li and Holmer, 2004

(图 2–4)

2004 *Eohadrotreta zhenbaensis*, Li and Holmer, p. 204-208, figs. 11–13.

2007 *Eohadrotreta zhenbaensis*, Holmer and Popov, 2560–2562, figs. 1693–1694.

2010 *Eohadrotreta zhenbaensis*, 汪洋等, p. 516, 图版III, 图 1, 2。

2015 *Eohadrotreta zhenbaensis*, Yang *et al*., figs. 9E, 9F.

2016 *Eohadrotreta zhenbaensis*, Zhang *et al*., figs. 4, 5.

2016 *Eohadrotreta zhenbaensis*, 何树兴等, 插图 4, 5。

2017 *Eohadrotreta zhenbaensis*, 张志亮等, 插图 2–7。

2017 *Eohadrotreta zhenbaensis*, Li *et al*., pl. 3, figs 6–10.

2018a *Eohadrotreta zhenbaensis*, Zhang *et al*., figs. 1, 2b–2h, 3.

2018b *Eohadrotreta zhenbaensis*, Zhang *et al*., figs. 3–6.

2019 *Eohadrotreta* cf. *zhenbaensis*, Pan *et al*., fig. 3

2020 *Eohadrotreta zhenbaensis*, Claybourn *et al*., figs. 5, 6.

材料 共 100 枚标本, 腹壳 43 枚, 背壳 52 枚, 背腹壳共同保存的 5 枚, 其中保存较好且内部结构较清晰的标本, 腹壳 9 枚, 背壳 10 枚, 背腹壳共同保存的有 2 枚。

描述 壳体轮廓呈亚圆形至横圆形, 壳体形态结构复原图如下(图 2, 3)。背壳微凸, 轮廓圆形至横圆形(图 2-A, 4-A, 4-E, 4-G), 壳长为 514 μm 到 1745 μm, 平均壳长为 1095 μm; 壳宽为 599 μm 到 2404 μm, 平均壳宽为 1367 μm。壳体平均长宽比为 0.845, 壳宽稍长于壳长(表 1)。背壳外表面发育同心环纹(图 4-F); 变态壳外表面布满圆形坑状壳饰(图 4-H)。背壳内部主肌痕(Cardinal muscle scar)发育明显 (图 4-B, 4-C), 平均主肌痕长为 456 μm, 平均主肌痕宽为 1010 μm (表 1); 中突(median buttress)发育(图 4-B); 背中隔板(median septum)明显发育(图 4-C, 4-D), 平均中隔板长 1324 μm, 呈舌状向前延伸至壳长的中前位置(图 4-B), 平均中隔板长与壳长比(L_s/L_m)为 0.73 (表 1); 成熟中隔板两侧明显发育副中隔板(submedian septum)。背壳假铰合面宽(W_p)为 745 μm, 占整个壳宽 1/3 (W_p/W_m 为 0.31, 见表 1)。

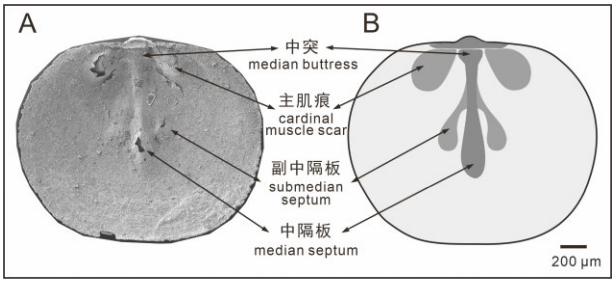

图 2 镇巴始壮贝背壳内部形态结构复原图

Fig. 2 Reconstruction of internal morphology and structure on the dorsal valve of *Eohadrotreta zhenbaensis*

A. 背壳内视, 标本编号: D4px2-2-02; B. 背壳内部形态结构复原图; (形态结构术语引自张志亮等., 2017)。

A. Interior of dorsal valve, Specimen No.: D4px2-2-02; B. Reconstruction of internal morphology and structure of dorsal valve; the anatomic terms of *Eohadrotreta zhenbaensis* after Zhang *et al*., 2017.

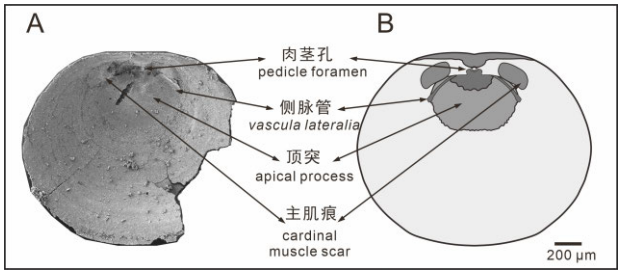

图 3 镇巴始壮贝腹壳内部形态结构复原图

Fig. 3 Reconstruction of internal morphology and structure on the ventral valve of *Eohadrotreta zhenbaensis*

A. 腹壳内视, 标本编号: D4px2-2-03; B. 腹壳内部形态结构复原图; (形态结构术语引自张志亮等., 2017)。

A. Interior of ventral valve, Specimen No.: D4px2-2-03; B. Reconstruction of internal morphology and structure of ventral valve; the anatomic terms of *Eohadrotreta zhenbaensis* after Zhang *et al*., 2017.

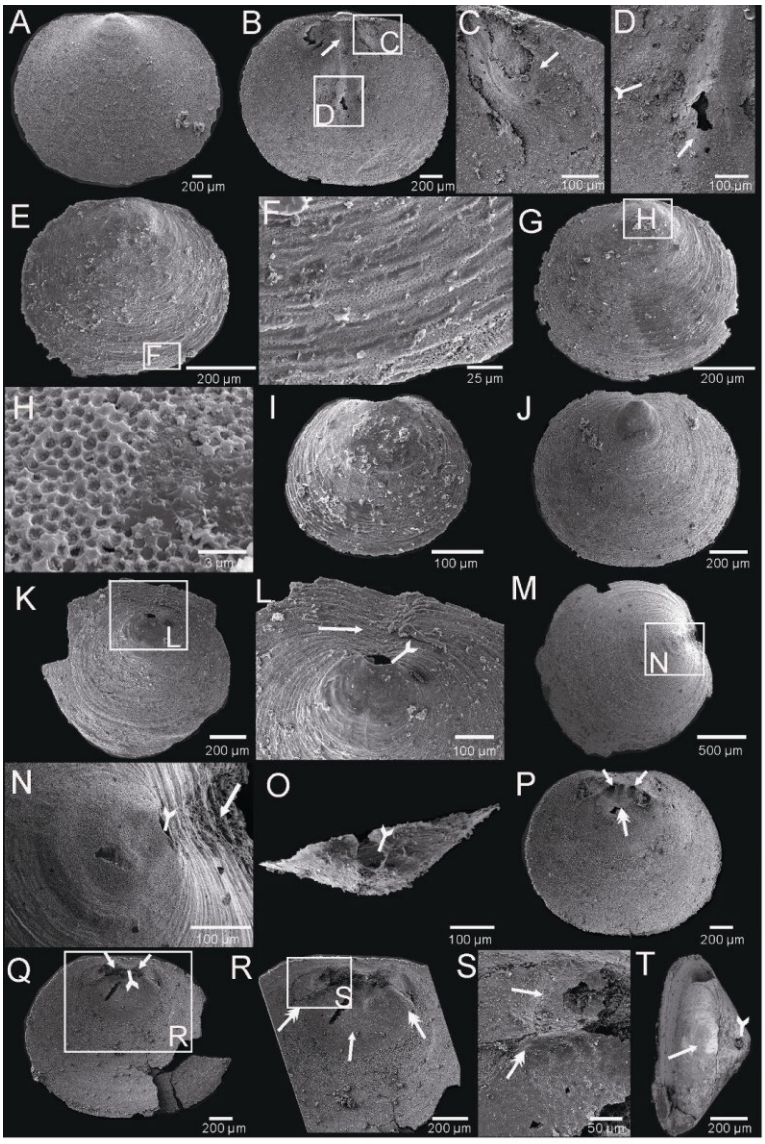

图 4　贵州松桃盘信剖面清虚洞组镇巴始壮贝

Fig. 4　*Eohadrotreta zhenbaensis* from the Tsinghsutung Formation at Panxin section in Songtao, Guizhou

A. 背壳外视, A7px2-6-19; B. 背壳内视, D4px2-2-02, 中突(单箭头); C. B 的放大视图, 背主肌痕(单箭头); D. B 的放大视图, 背中隔板(单箭头), 副中隔板(尾箭头); E. 背壳外视, A8px2-5-16; F. E 的放大视图, 同心纹饰; G. 背壳外视, A8px2-5-12; H. G 的放大视图, 胎壳表面圆坑状壳饰; I. 较小腹壳外视, B7px2-6-38; J. 较大腹壳外视, A8px2-5-25; K. 腹壳外视, C5px2-3-01; L. K 的放大视图, 交互沟(单箭头), 肉茎孔(尾箭头); M. 较大腹壳外视, D5px2-2-03; N. M 的放大视图, 肉茎孔(尾箭头), 交互沟(单箭头); O. 腹壳后视, 未封闭肉茎孔(尾箭头), C5px2-3-33; P. 腹壳内视, D4px2-2-04; Q. 腹壳内视, 肉茎孔(尾箭头), 顶坑(单箭头), D4px2-2-03; R. Q 的放大视图, 侧脉管(双箭头), 顶突(单箭头); S. Q 的放大视图, 腹主肌痕(箭头), 侧脉管(双箭头); T. 背腹壳铰合标本, 肉茎孔(尾箭头), 背幼壳(单箭头), L1px2-2-05。所有标本保存在贵州大学古生物研究中心。

A. Exterior view of dorsal valve, px2-6-19; B. interior view of dorsal valve, D4px2-2-02, median buttress (arrow); C. magnification of square in B, cardinal muscle scars of dorsal valve (arrow); D. magnification of square in B, median septum of dorsal valve (arrow), submedian septum (tailed arrow); E. exterior view of dorsal valve, A8px2-5-16; F. magnification of square in E, concentric ornament of dorsal valve; G. xterior view of dorsal valve, A8px2-5-12; H. magnification of square in G, the circular pits on protegulum of dorsal valve; I. exterior view of ventral valve, B7px2-6-38; J. exterior view of ventral valve, A8px2-5-25; K. exterior view of ventral valve, C5px2-3-01; L. magnification of square in K, pedicle foramen (tailed arrow), intertrough (arrow); M. exterior view of ventral valve, D5px2-2-03; N. magnification of square in M, pedicle foramen (tailed arrow), intertrough (arrow); O. posterior view of ventral valveopening pedicle foramen (tailed arrow), C5px2-3-33; P. interior view of ventral valve, D4px2-2-04; Q. interior view of ventral valve, pedicle foramen (tailed arrow), apical pits (arrows), D4px2-2-03; R. magnification of square in Q, *vascula lateralia* (double arrow), apical process (arrow); S. magnification of square in Q, cardinal muscle scars of ventral valve (arrows), *vascula lateralia* (double arrow); T. articulated dorsal and ventral valves, L1px2-2-05, pedicle foramen (tailed arrow), larval shell of dorsal valve (arrow). All specimens are reposited in the Guizhou Research Centre for Palaeontology, Guizhou University, Guiyang, China (GRCP, GU).

E. zhenbaensis、*E. zhujiahensis* 和 *E. haydeni*, 常见于华南陕南(Li and Holmer, 2004)、峡东(张志亮等, 2017; Zhang *et al*., 2018b)、黔东麻江地区(何树兴等, 2016)、华北板块南缘(Pan *et al*., 2019)、喜马拉雅(Popov *et al*., 2015)、澳大利亚和南极洲等地区(Claybourn *et al*., 2020)。*E. zhenbaensis* 与 *E. zhujiahensis* 的区别主要为后者肉茎孔封闭较晚, 且在发育后期肉茎孔逐渐远离变态壳(Li and Holmer, 2004); 与 *E. haydeni* 的明显不同主要在于 *E. haydeni* 背中隔板(median septum)和假铰合面(pseudointerarea)不发育, 中突(median buttress)和主肌痕 (cardinal muscle scar) 不明显 (Popov *et al*., 2015)。

松桃盘信的 *Eohadrotreta zhenbaensis* 标本背壳平均长宽比值 0.845 (表 1)与峡东地区水井沱组 *E. zhenbaensis* 标本比值 0.851 (张志亮等, 2017, 表Ⅰ)相近, 背中隔板和两侧副中隔板明显发育(图 2, 4-B, 4-D)与陕南(Li and Holmer, 2004, Fig. 11-L)和峡东水井沱组 *E. zhenbaensis* (Zhang *et al*., 2016a, Figs. 4-L, 4-M; 张志亮等, 2017, 图 3-C; Zhang *et al*., 2018b, Figs. 5-J, 5-M)标本相似; 与黔东麻江九门冲组 *E. zhenbaensis* 标本背壳长宽比值(0.781, 何树兴等, 2016, 表Ⅰ)和背中隔板呈纺锤状, 两侧副中隔板不发育(何树兴等, 2016, 插图 5-A, 5-E)略有差异。

讨论 根据 Zhang 等(2018b)对华南水井沱组 *Eohadrotreta zhenbaensis* 个体发育及形态结构研究显示, *E. zhenbaensis* 的生长发育模式可划分为肉茎孔形成阶段(T1)、肉茎孔封闭阶段(T2)和交互沟伸长阶段(T3)。肉茎孔形成阶段(T1)的特征表现为背壳壳长在 346 μm 到 448 μm 之间, 腹壳壳长最大值为 450 μm, 肉茎孔呈开放状, 肉茎孔长小于肉茎孔宽(L_f<W_f)。肉茎孔封闭阶段(T2)的背壳壳长在 448 μm 到 785 μm 之间, 中隔板较低, 向前延伸至壳长 53%, 腹壳壳长在 450 μm 到 750 μm 之间, 肉茎孔逐渐封闭。交互沟伸长阶段(T3)的特征为背壳壳长最小值为 785 μm, 中隔板较发育, 向前延伸至壳长 69%, 前部出现双枝分叉, 两侧副中隔板发育, 腹壳壳长最小值为 750 μm, 肉茎孔近圆形至椭圆形, 肉茎孔长大于肉茎孔宽(L_f>W_f) (表 3)。

表 1 镇巴始壮贝背壳主要结构尺寸及比率

Table 1 Main dimensions and ratios of dorsal valve structure of *Eohadrotreta zhenbaensis*

D	W_m	W_c	W_p	L_m	L_c	L_s	L_p	L_m/W_m	W_p/W_m	L_p/L_m	L_s/L_m
N	18	9	9	17	9	9	9	17	6	5	5
Mean	1367	1010	745	1095	456	1324	79	0.845	0.31	0.04	0.73
Min	599	671	494	514	268	900	52	0.776	0.28	0.03	0.65
Max	2404	1591	1142	1745	702	1753	90	0.901	0.36	0.05	0.81
S	530	283	212	381	140	321	23	0.036	0.024	0.006	0.062

注: 所有测量数据单位为 μm; 缩写: D. 背壳; N. 数量; S. 标准差; Min. 最小值; Max. 最大值; L_m, W_m. 壳长与宽; L_c, W_c. 主肌痕长与宽, L_p, W_p. 假铰合面长与宽; L_s. 中隔板长。

Note: All measurements are in micrometers; Abbreviations: D. dorsal valve; N. number of specimens; S. standard deviation; Min. minimum; Max. maximum; L_m, W_m. length and width of valves; L_c, W_c. length and width of cardinal muscle scar; L_p, W_p. length and width of pseudointerarea; L_s. length of median septum.

表 2 镇巴始壮贝腹壳主要结构尺寸及比率

Table 2 Main dimensions and ratios of ventral valve structure of *Eohadrotreta zhenbaensis*

V	L_f	W_f	L_m	W_m	L_i	L_f/W_f	L_m/W_m
N	4	7	7	7	8	4	6
Mean	71	79	1085	1254	94	0.985	0.854
Min	62	66	315	381	24	0.79	0.809
Max	79	104	1873	1683	158	1.19	0.898
S	6	11	421	469	48	0.147	0.031

注: 所有测量数据单位为 μm; 缩写: V. 腹壳; L_f, W_f. 肉茎孔长与宽; L_i. 交互沟长; 其他缩写见表 1。

Note: All measurements are in μm; Abbreviations: V. ventral valve; L_f, W_f. length and width of pedicle foramen; L_i. length of intertrough; other abbreviations see table 1.

表 3　华南水井沱组镇巴始壮贝不同生长阶段特征比较

Table 3　Comparison of the characteristics of the different ontogenetic development stages of *Eohadrotreta zhenbaensis* from the Shuijingtuo Formation of South China

	背壳体长度	中隔板(median septum) 特征	腹壳体 长度	肉茎孔 特征	肉茎 孔长
肉茎孔形成阶段(T1)	346–448	中隔板很浅, 占壳长 40%	<450	肉茎孔呈开放状(L_f<W_f)	25–65
肉茎孔封闭阶段(T2)	448–785	中隔板较低, 占壳长 53%	450–750	肉茎孔逐渐封闭(L_f</>W_f)	28–89
交互沟生长阶段(T3)	785–1965	中隔板稍微发育; 中隔板发育, 占壳长 69%, 前部出现双枝分叉; 中隔板末端发育膨大的三角形凸起	750–1700	近圆形-椭圆形(L_f>W_f)	67–146

注: 所有测量数据单位为 μm; 缩写见表 2 (引自 Zhang *et al*., 2018b)。

Note: All measurements are in μm; abbreviations see table 2 (from Zhang *et al*., 2018b).

通过与华南水井沱组中的 *Eohadrotreta zhenbaensis* 不同生长阶段特征的对比(表 3),发现松桃盘信清虚洞组的 *E. zhenbaensis* 标本也可分为上述 3 个生长发育阶段。如处于肉茎孔形成阶段(T1) (图 4-I), 腹壳长为 315 μm, 肉茎孔呈开放状; 肉茎孔封闭阶段(T2) (图 4-E, 4-G, 4-O), 背壳长小于 785 μm (图 4-E, 4-G), 肉茎孔逐渐封闭(图 4-O); 交互沟伸长阶段(T3), 背壳长大于 785 μm (图 4-A, 4-B), 背中隔板发育(图 4-C, 4-D), 腹壳长大于 750 μm (图 4-J, 4-K, 4-M, 4-P, 4-Q), 交互沟发育且相对延长(图 4-L, 4-N)。

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