古生物学报, 61(3): 418–426 (2022年9月)
Acta Palaeontologica Sinica, 61(3): 418–426 (September 2022)

·研究论文·

DOI: 10.19800/j.cnki.aps.2021077

古盘虫类有孔虫起源及其壳壁发育证据*

盛青怡**

中国科学院南京地质古生物研究所, 南京 210008

提要 古盘虫类有孔虫是维宪早期到谢尔普霍夫早期最有用的生物地层标志微体化石之一, 广泛分布于正常浅海底栖环境。古盘虫超科里的平古盘虫亚科从早维宪中期开始出现, 具有最原始的壳壁结构。它将古盘虫类与其祖先假砂盘虫类联系起来。平古盘虫亚科壳壁主要是黑色微粒状。透明放射层局限在脐部或延伸覆盖到内部壳圈的壳缘。平古盘虫从何而来? 即古盘虫类的祖先问题, 一直存在争议。本文通过研究湖南邵阳马栏边剖面石磴子组连续演化的*Lapparentidiscus*和*Viseidiscus*, 证实了*Lapparentidiscus*是古盘虫类的祖先, 早期演化序列为*Lapparentidiscus talasicus–Viseidiscus eospirillinoides–Viseidiscus monstratus*, 古盘虫类的透明放射层是以替代而非填充的形式出现的, 透明放射层逐渐替代黑色微粒层, 并从脐部逐步扩展到壳缘。

关键词 有孔虫 古盘虫类 维宪阶 华南 演化序列

中文引用 盛青怡, 2022. 古盘虫类有孔虫起源及其壳壁发育证据. 古生物学报, 61(3): 418–426. DOI: 10.19800/j.cnki.aps.2021077

英文引用 Sheng Qing-yi, 2022. The origin of primitive archaediscacean foraminifers and the development of their wall structure. Acta Palaeontologica Sinica, 61(3): 418–426. DOI: 10.19800/j.cnki.aps.2021077

The origin of primitive archaediscacean foraminifers and the development of their wall structure

SHENG Qing-yi

Nanjing Institute of Geology and Palaeontology, *Chinese Academy of Sciences*, *Nanjing* 210008

Abstract Archaediscacean foraminifers are perhaps one of the most useful biostratigraphic marker microfossils from the early Visean to early Serpukhovian. They are widespread in normal marine, benthic, shallow-shelf carbonate environments. The subfamily Planoarchaediscinae of the superfamily Archaediscacea appeared in the middle early Visean. The wall structure of the planoarchaediscins is the most primitive in this superfamily, which provides an evolutionary link between the Archaediscidae and the ancestral pseudoammodiscids. The wall of the archaediscaceans is predominantly dark and microgranular. The hyaline-radial layer is either limited to the umbilical area, or it forms a thin covering over the sides, or sometimes it covers the periphery of the interior volutions. Regarding the ancestor of the archaediscids, this topic is still open to debate. This study focuses on the specimens of *Lapparentidiscus* and *Viseidiscus* with continuous stratigraphic appearances from the Shidengzi Formation at the Malanbian section in South China. The result suggests that *Lapparentidiscus* is a unique pseudoamrnodiscid that gives rise to the archaediscids. The evolution trend of primitive archaedis ca-

收稿日期: 2021-12-29; 改回日期: 2022-06-17; 录用日期: 2022-06-30

*国家自然科学基金(41702016, 41630101)、江苏省自然科学基金(BK20171102)及现代古生物学和地层学国家重点实验室(20172109)联合资助。

**通讯作者: 盛青怡, 助理研究员, e-mail: qysheng@nigpas.ac.cn

cean foraminifers is: *Lapparentidiscus talasicus–Viseidiscus eospirillinoides–Viseidiscus monstratus*. The hyaline-radial layer of the archaediscids appears as a replacement instead of a filling. It replaces the dark, microgranular layer gradually, and extends from the umbilical area to the sides.

SYSTEMATIC PALEONTOLOGY

Order　FORAMINIFERA Eichwald, 1830
Suborder　FUSULINIDA Wedekind, 1937
Family　Pseudoammodiscidae Conil and Lys in Conil and Pirlet, 1970
Genus　*Lapparentidiscus* Vachard, 1980
***Lapparentidiscus talasicus* (Mikhno in Mikhno and Balakin, 1975)**
(Fig. 2-1–2-7)

Diagnosis　The test is small, narrowly discoidal, and shallowly umbilicate. The undivided, planispirally coiled tubular chamber comprises 4 to 5.5 whorls. Coiling is initially involute and evolute in the last one or two whorls. The chamber, circular in axial section, expands very quickly in the last few whorls. The wall is dark and microgranular. The aperture is simple and terminal. The diameter of the test is 250–400 μm; the width of the test is 60–100 μm; and the width to diameter ratio is 0.20–0.25. The diameter of the proloculus is 15–30 μm. The height of the tubular chamber is 40–80 μm in the last whorl. The thickness of the wall of the last whorl is 12–16 μm.

Locality and horizon　Malanbian section, Shaoyang County, Hunan Province; 334.3–347 m of the Shidengzi Formation.

Superfamily　Archaediscacea Cushman, 1928 *nom. trans.* Piller, 1978
Family　Archaediscidae Cushman, 1928 *nom. trans.* Chernysheva, 1948
Subfamily Planoarchaediscinae Mamet, 1975
Genus　*Viseidiscus* Mamet, 1975
***Viseidiscus eospirillinoides* (Brazhnikova, 1967)**
(Fig. 2-8–2-14)

Diagnosis　The test is small, narrowly discoidal, and shallowly umbilicate. The undivided, planispirally coiled tubular chamber comprises 4 to 5 whorls. Coilingis initially involute and subsequently evolute. The chamber expands relatively quickly in the last few whorls. The wall is predominantly dark and microgranular. The weak, unstable, discontinuous hyaline-radial layer is limited to the umbilical area. The aperture is simple and terminal. The diameter of the test is 240–350 μm; the width of the test is 60–95 μm; and the width to diameter ratio is 0.22–0.30. The diameter of the proloculus is 14–20 μm. The height of the tubular chamber is 45–70 μm in the last whorl. The thickness of the wall of the last whorl is 10–15 μm.

Locality and horizon　Malanbian section, Shaoyang County, Hunan Province; 339–344 m of the Shidengzi Formation.

***Viseidiscus monstratus* (Grozdilova and Lebedeva, 1954)**
(Fig. 2-15–2-20)

Diagnosis　The test is small, narrowly discoidal, and shallowly umbilicate. The undivided, planispirally coiled tubular chamber comprises 4 to 5 whorls. Coiling is initially involute and evolute in the last one or two whorls. The lumina is open. The chamber floor is convex. The chamber expands rapidly in the last few whorls. The wall is composed of a continuous dark microgranular layer and a thin hyaline-radial layer deposited on umbilical sides and, in some cases, also over the periphery of initial volutions. The hyaline-radial layer is absent in evolute whorls. The aperture is simple and terminal. The diameter of the test is 200–350 μm; the width of the test is 60–90 μm and the width to diameter ratio is 0.20–0.27. The diameter of the proloculus is 15–25 μm. The height of the tubular chamber is 45–70 μm in the last whorl. The thickness of the wall of the last whorl is 10–15 μm.

Locality and horizon　Malanbian section, Shaoyang County, Hunan Province; 340.2–347 m of the Shidengzi Formation.

Key words　foraminifera, archaediscids, Visean, South China, evolution pattern

1　前　言

古盘虫类有孔虫最早出现在石炭纪维宪早期, 在正常浅海底栖环境下广泛分布, 直到宾夕法尼亚亚纪中期消失。它们是维宪早期到谢尔普霍夫早期最典型的生物地层标志微体化石之一。古盘虫最基本的形态特征是发育初房和没有隔壁的、绕卷的管状第二房室。壳壁结构、壳体形状、绕卷方式、缝合线形态和次生沉积的发育状况形成了丰富的形态特征, 也是分类的重要依据。关于古盘虫类的分类体系存在很多的争论(Cushman, 1928; Chernysheva, 1948; Dain and Grozdilova, 1953; Miklukho-Maklay, 1957; Mamet, 1975; Pirlet and Conil, 1977; Loeblich and Tappan, 1984; Brenckle *et al*., 1987; Vachard, 1988)。Brenckle等(1987)的分类方案(表1)反映了两个主要的演化趋势: 壳壁结构中微粒层的消减和管状房室的充填(图1)。

表 1 古盘虫类有孔虫的分类方案(修改自 Brenckle *et al*., 1987)
Table 1 Classification of the archaediscacean foraminifers (modified from Brenckle *et al*., 1987)

古盘虫超科 Archaediscacea (部分)			
古盘虫科 Archaediscidae			星古盘虫科 Asteroarchaediscidae
平古盘虫亚科 Planoarchaediscinae	哈萨克斯坦盘虫亚科 Kasachstanodiscinae	古盘虫亚科 Archaediscinae	
Viseidiscus	*Glomodiscus*	*Archaediscus*	*Asteroarchaediscus*
Planoarchaediscus	*Uralodiscus*	*Planospirodiscus*	*Neoarchaediscus*
	Paraarchaediscus	*Betpakodiscus*	*Permodiscus*
	Kasachstanodiscus	*Brownediscus*	*Brenckleina*
		Eosigmoilina	

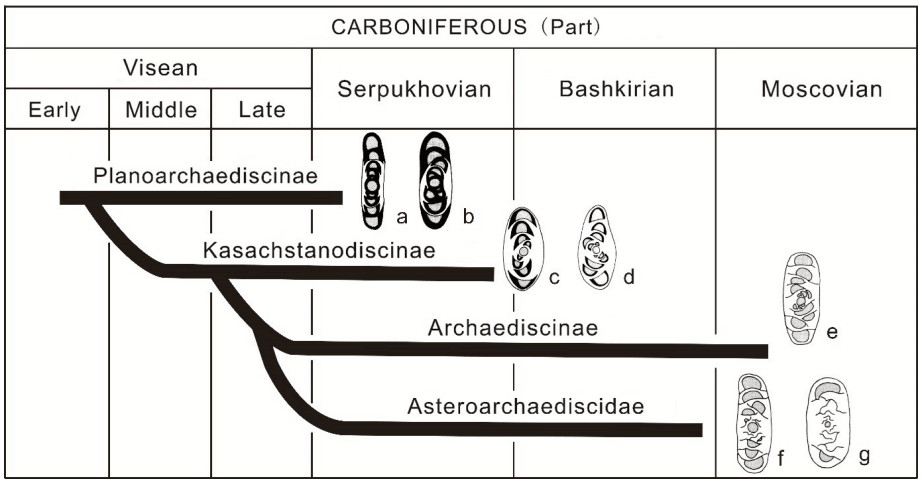

图 1 古盘虫超科的演化(各亚科起止时代来自 Brenckle *et al*., 1987)

Fig. 1 Phylogeny of the Archaediscacea (ranges of subfamilies are from Brenckle *et al*., 1987)

素描图为样品中出现的属: a. *Viseidiscus*; b. *Planoarchaediscus*; c. *Glomodiscus*; d. *Paraarchaediscus*; e. *Archaediscus*; f. *Neoarchaediscus*; g. *Asteroarchaediscus*。

Illustrated genera: a. *Viseidiscus*; b. *Planoarchaediscus*; c. *Glomodiscus*; d. *Paraarchaediscus*; e. *Archaediscus*; f. *Neoarchaediscus*; g. *Asteroarchaediscus*.

壳壁结构中微粒层的消减体现在古盘虫超科的起源与早期演化中。古盘虫超科里平古盘虫亚科从早维宪中期开始出现, 它的壳壁结构是最原始的。它将古盘虫类与其祖先假砂盘虫类联系起来。平古盘虫亚科壳壁主要是黑色微粒状。透明放射层局限在脐部或延伸覆盖到内部壳圈的壳缘。该亚科有两个属: *Viseidiscus*和*Planoarchaediscus*, 其中*Viseidiscus*包括所有壳壁以黑色微粒层为主的平旋的古盘虫类, *Planoarchaediscus*则包括其他壳壁以黑色微粒层为主、早期倾斜绕卷、后期平旋的古盘虫类。哈萨克斯坦盘虫亚科在接近维宪中期时开始出现, 黑色微粒层和透明放射层都比较发育。这种壳壁结构反映了平古盘虫亚科到古盘虫亚科转变的过渡阶段, 即黑色微粒层为主过渡到透明放射层为主。在哈萨克斯坦盘虫亚科内, 也体现了这种壳壁结构的转变, *Glomodiscus*和*Uralodiscus*黑色微粒层非常发育, 而到了*Kasachstanodiscus*和*Paraarchaediscus*黑色微粒层明显变弱了。

古盘虫亚科从维宪晚期开始出现, 它的透明放射层是古盘虫科里最发育的。至星古盘虫科, 壳壁的黑色微粒层仅在少数标本中发育。这些标本主要发现在维宪晚期到谢尔普霍夫早期。这一时期正是哈萨克斯坦盘虫亚科逐渐演化成古盘虫亚科的阶段。星古盘虫科从维宪最晚期开始出现, 管状房室部分或几乎全部被有机成因的次生沉积充填。壳壁只有一层透明放射层。

关于古盘虫类的祖先，Conil等(1980)认为*Brunsia*和*Pseudoammodiscus*是古盘虫类的两个祖先。但是, Hance等(2011)认为*Lapparentidiscus*是古盘虫类的唯一祖先。Vachard (1988)指出古盘虫类的透明放射层是以替代而非填充的形式出现的。这些争议一直没有解决。华南古盘虫类有孔虫极为发育。本文试图通过研究华南的早期古盘虫类, 来探讨古盘虫类的祖先和早期的演化序列。

2　研究材料与剖面概况

本文的研究材料采自湖南邵阳的马栏边剖面(起点处GPS: 27°22′35″ N、111°33′40″ E)。该剖面位于湖南省邵阳市新邵县田心乡马栏边水库旁, 在长沙西南方向约170 km, 隶属于湘桂地层小区。湘桂地层小区位于扬子陆块与华夏陆块之间的陆间裂谷盆地; 由东、西两侧NE、NEE向断裂控制, 南与钦州盆地相接, 包括湘南、湘中、桂中和粤西等地(Wang *et al*., 2013)。密西西比亚纪早期沉积以碳酸盐岩为主, 夹少量砂泥质碎屑岩; 密西西比亚纪晚期沉积三分, 上、下部为灰岩, 中部是含煤碎屑岩系, 部分地区上部是灰岩夹石膏层, 为局限沉积环境。宾夕法尼亚亚纪本区普遍发育碳酸盐岩沉积, 为较深水缓坡、台地沉积环境, 局部地区为局限、浅滩沉积环境(Wang *et al*., 2013)。

马栏边剖面发育了一套泥盆系到石炭系的地层, 是湘中泥盆–石炭系的经典剖面, 其沉积、生物和同位素地层都有过研究(裘松余、林甲兴, 1982; 湖南省地质矿产局区域地质调查队, 1987; 谭正修, 1990; Hance *et al*., 2011; Yao *et al*., 2015)。本文讨论的有孔虫化石来自马栏边剖面石磴子组最上部的一个有孔虫带*Viseidiscus*带(盛青怡, 2016), 这是维宪阶的第二个有孔虫带(Wang *et al*., 2019)。石磴子组下伏陡岭坳组, 上覆测水组, 厚152 m, 在剖面中自195–347 m, 岩性以厚层灰岩为主, 地层出露连续, 无明显的沉积间断, 以有孔虫为代表的浅水相化石丰富, 时代从杜内晚期到维宪早期, 是开展古盘虫类早期演化序列研究的理想层段。

3　系统古生物学

拉伯盘虫属　Genus *Lapparentidiscus* Vachard, 1980

塔拉斯拉伯盘虫　*Lapparentidiscus talasicus* (Mikhno in Mikhno and Balakin, 1975)

(图2-1–2-7)

1975　*Ammodiscus*? *talasicus* Mikhno in Mikhno and Balakin, p. 28, 29, pl. 2, figs. 11–13.

1980　*Lapparentidiscus bokanensis* Vachard, p. 285–290, pl. 15, figs. 1, 2.

1984　*Eodiscus hubeiensis*林甲兴, 141页, 图版6, 图31–33。

1990　*Quasidiscus hubeiensis*林甲兴等, 205页, 图版22, 图28, 29。

2011　*Lapparentidiscus hubeiensis* Hance *et al*., p. 47, pl. 44, figs. 6–8, 10–12.

特征　壳小, 窄形圆盘状, 脐部微凹。管状房室无隔壁, 平旋。4–5.5个壳圈, 大部分内旋, 只有最后一、两个壳圈外旋。最后一两圈扩展速度明显加快, 在轴切面呈近圆形。壳壁黑色、微粒状。口孔简单, 位于房室末端。壳体直径为250–400 μm, 宽度为60–100 μm, 轴率为0.20–0.25。初房直径为15–30 μm。最后一圈房室高度40–80 μm。最后一圈壳壁厚度为12–16 μm。

讨论　Vachard (1980)在建立*Lapparentidiscus*属时命名了新种*L. bokanensis*作为这个属的模式种。但是, *L. bokanensis* 其实是*Ammodiscus*? *talasicus* Mikhno in Mikhno and Balakin, 1975的同物异名。*L. bokanensis*的模式标本来自阿富汗中部的V_{2a}带(维宪中下部), *L. talasicus*的模式标本来自于西天山的C_1V_1层(维宪下部)。*Lapparentidiscus* 在文献里比较少见, 主要因为有些标本被放在*Pseudoammodiscus*或*Mediocris*这两个属里了。在中国曾被放在*Eodiscus* Vdovenko, 1970和*Quasidiscus* Lin *et al*., 1990这两个属里, 前者建属时没考虑到这个属名已经被三叶虫类占用, 林甲兴等(1990)建立新属名*Quasidiscus*来代替*Eodiscus*, 但是*Lapparen–tidiscus* Vachard, 1980建立时间在前。根据优先律, 应用属名*Lapparentidiscus* Vachard, 1980代替*Quasidiscus* Lin *et al*., 1990。

产地层位　湖南邵阳马栏边剖面石磴子组334.3–347 m (图3)。

时代分布　维宪期。主要分布在古特提斯地区, 现俄罗斯、乌克兰、法国、伊朗、乌兹别克

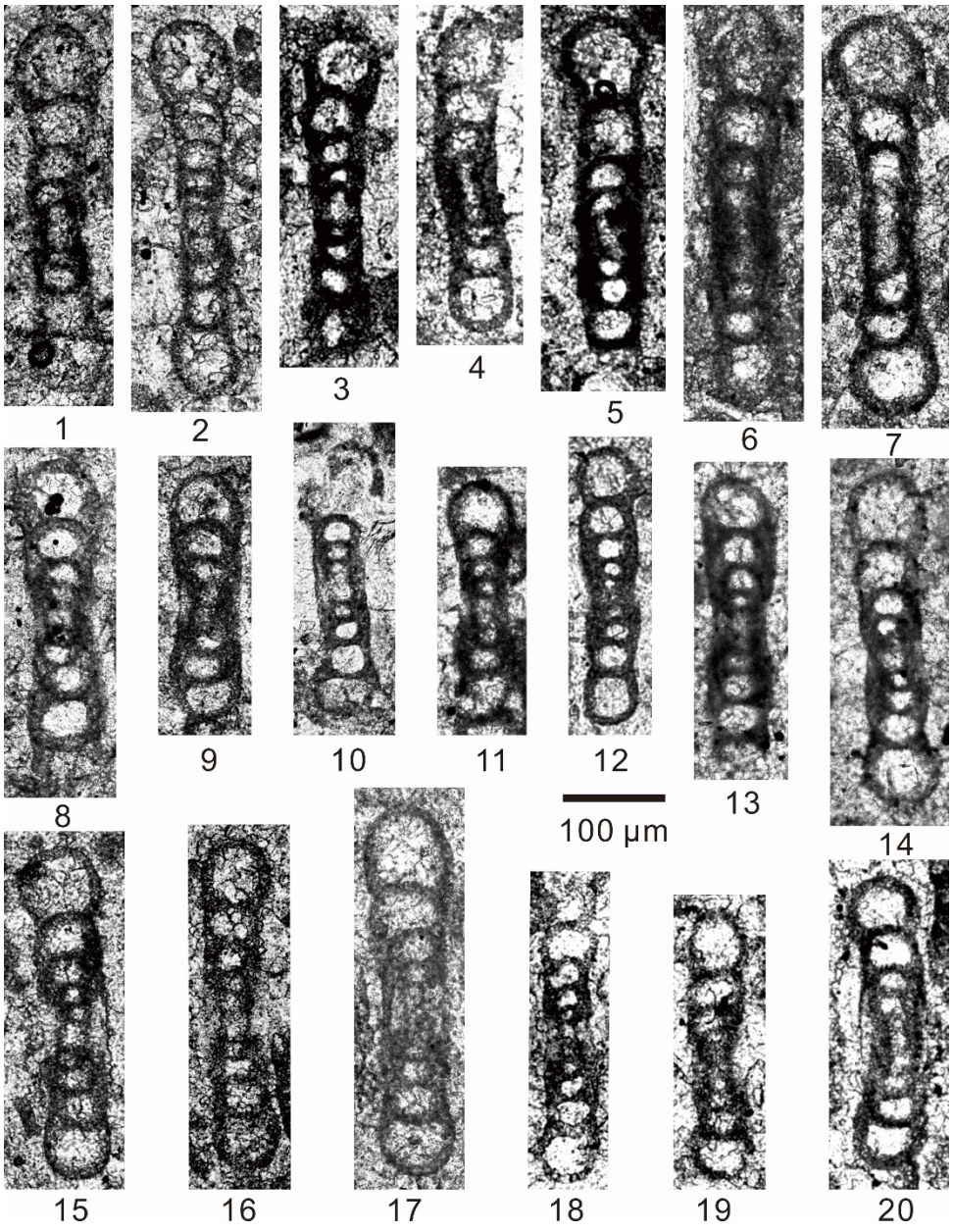

图 2 马栏边剖面的拉伯盘虫和威赛盘虫

Fig. 2 *Lapparentidiscus* and *Viseidiscus* from the Malanbian section

1–7. *Lapparentidiscus talasicus* (Mikhno in Mikhno and Balakin,1975): 1. 轴切面, 石磴子组 334.3 m (标本号 3340301); 2. 轴切面, 340.3 m (3400301); 3. 轴切面, 341 m (3410001); 4. 近轴切面, 342 m (3420001); 5. 轴切面, 341 m (3410002); 6. 近轴切面, 344 m (3440001); 7. 近轴切面, 340.3 m (3400302); 8–14. *Viseidiscus eospirillinoides* (Brazhnikova, 1967): 8. 轴切面, 339.3 m (3390301); 9. 近轴切面, 339 m (3390001); 10. 轴切面, 340.3 m (3400303); 11. 轴切面, 340.6 m (3400601); 12. 轴切面, 340.2 m (3400201); 13, 轴切面, 344 m (3440002); 14. 轴切面, 340.6 m (3400602); 15–20, *Viseidiscus monstratus* (Grozdilova and Lebedeva, 1954): 15. 轴切面, 340.6 m (3400603); 16. 轴切面, 340.3 m (3400304); 17. 近轴切面, 347 m (3470001); 18. 轴切面, 340.2 m (3400202); 19. 近轴切面, 343 m (3430001); 20. 轴切面, 343 m (3430002).

1–7. *Lapparentidiscus talasicus* (Mikhno in Mikhno and Balakin,1975): 1. axial section, Shidengzi Formation, 334.3 m (No. 3340301); 2. axial section, 340.3 m (3400301); 3. axial section, 341 m (3410001); 4. near-axial section, 342 m (3420001); 5. axial section, 341 m (3410002); 6. near-axial section, 344 m (3440001); 7. near-axial section, 340.3 m (3400302); 8–14. *Viseidiscus eospirillinoides* (Brazhnikova, 1967): 8. axial section, 339.3 m (3390301); 9. near-axial section, 339 m (3390001); 10. axial section, 340.3 m (3400303); 11. axial section, 340.6 m (3400601); 12. axial section, 340.2 m (3400201); 13. axial section, 344 m (3440002); 14. axial section, 340.6 m (3400602); 15–20, *Viseidiscus monstratus* (Grozdilova and Lebedeva, 1954): 15. axial section, 340.6 m (3400603); 16. axial section, 340.3 m (3400304); 17. near-axial section, 347 m (3470001); 18. axial section, 340.2 m (3400202); 19. near-axial section, 343 m (3430001); 20. axial section, 343 m (3430002).

斯坦、阿富汗、摩洛哥、土耳其等国家境内, 以及中国南部和塔里木等地区。

威赛盘虫属　Genus *Viseidiscus* Mamet, 1975

始绕旋威赛盘虫　*Viseidiscus eospirillinoides* (Brazhnikova, 1967)

(图2-8–2-14)

1967　*Planoarchaediscus eospirillinoides* forma *typica* Brazhnikova in Brazhnikova *et al*., p. 164, 165, pl. 10, fig. 10, pl. 51, figs. 7–9, 12, 13.
1967　*Planoarchaediscus eospirillinoides* forma *involuta* Brazhnikova in Brazhnikova *et al*., p. 165, 166, pl. 51, figs. 10, 11, 14.
1983　*Planoarchaediscus eospirillinoides* 王克良, 图版3, 图10, 11。
2016　*Lapparentidiscus bokanensis* Zandkarimi *et al*., fig. 6, no. 25.

特征　壳体小。圆盘状, 脐部微凹。管状房室无隔壁, 平旋。4–5个壳圈。大部分壳圈内旋, 只有最后一、两个壳圈外旋。壳圈的扩张速度比较稳定, 除了最后一两个壳圈扩张速度较快。壳壁黑色、微粒状, 只在脐部出现微弱的、不稳定、不连续的透明放射层。口孔简单, 房室末端。壳体直径为 240–350 μm, 宽度为 60–95 μm, 轴率为 0.22–0.30。初房直径为14–20 μm。最后一圈房室高度为45–70 μm。最后一圈壳壁厚度为10–15 μm。

讨论　模式标本来自于第聂伯罗–顿涅茨凹地(Dnieper–Donets Depression)维宪阶Yasnaya Polyana亚阶的Tula层。Brazhnikova (1967)在命名新种的时候, 将 *P. eospirillinoides*分成两个变型: *typicus*和*involutus*。Brenckle和Marchant (1987)认为后一个变型是前一个的幼年体, 没必要分出来。本文认同这种观点, 在观察化石薄片的过程中, 也发现了幼年体(3–4个壳圈)与成年体同时存在的现象。Brazhnikova (1967)在描述*P. eospirillinoides*时提到, 产自Tula层的*P. eospirillinoides*与产自之上较新的Oka亚阶的*P. monstratus*形态相近, 两者最大的区别就是壳壁结构, *P. eospirillinoides*黑色微粒壳壁中有不连续的透明放射颗粒。

产地层位　湖南邵阳马栏边剖面石磴子组 339–344 m (图3)。

时代分布　维宪期。乌克兰、伊朗、捷克和中国南部地区。

蒙斯特拉威赛盘虫　*Viseidiscus monstratus* (Grozdilova and Lebedeva, 1954)

(图2-15–2-20)

1954　*Archaediscus monstratus* Grozdilova and Lebedeva, p. 61, pl. 7, figs. 17, 18.
1966　*Planoarchaediscus monstratus* Bogush and Yuferev, p. 159, pl. 11, figs. 4, 5.
1970　*Planoarchaediscus monstratus* Bogush and Yuferev, pl. 8, figs. 14, 15.
1976　*Ammarchaediscus* (*Ammarchaediscus*) sp. Conil, pl. 3, fig. 26.
1977　*Ammarchaediscus* (*Ammarchaediscus*) *monstratus* Conil and Pirlet in Pirlet and Conil, pl. 3, figs. 53–56.
1978　*Viseidiscus kumyrlensis* Marfenkova, p. 98, pl. 8, fig. 21.
1980　*Ammarchaediscus* (*Ammarchaediscus*) *monstratus* Conil *et al*., pl. 7, figs. 17, 18 (= Pirlet and Conil, 1977, pl. 3, figs. 55, 56).
1987　*Viseidiscus monstratus* Brenckle and Marchant, p. 81, pl. 2, figs. 1–7.
2003　*Viseidiscus monstratus* Brenckle and Milkina, pl. 2, fig. 9.
2009　*Viseidiscus monstratus* Brenckle *et al*., pl. 8, figs. 11, 18–20.
2011　*Ammarchaediscus involutus* Hance *et al*., p. 49, 50, pl. 51, fig. 4.
2015　*Viseidiscus monstratus* Shen and Wang, fig. 4, A, C.
2016　*Ammarchaediscus* cf. *eospirillinoides* Zandkarimi *et al*., fig. 6, no. 29.

描述　壳体小, 窄形圆盘状, 脐部宽。管状房室无隔壁, 平旋。4–5个壳圈。大部分壳圈内旋, 只有最后一、两个壳圈外旋。房室无充填。房室底面凸。口孔简单, 位于管状房室末端。壳壁主要由连续的黑色微粒层组成, 透明放射层局限在脐部, 或有时延伸覆盖到内部壳圈的壳缘。壳体后期外旋的壳圈没有透明放射层。壳圈数: 4–5; 直径: 200–350 μm; 宽度: 60–90 μm; 轴率: 0.20–0.27; 初房直径: 15–25 μm; 最后一圈壳壁厚度: 10–15 μm; 最后一圈房室高度: 45–70 μm。

讨论　模式标本来自于俄罗斯维宪阶的Oka亚阶。Grozdilova和Lebedeva (1954)在描述模式种的时候, 说早期的壳圈是倾斜绕卷的。但是, Brenckle在1984年7月检查模式标本后, 认为虽然切面不是非常好, 仍然可以推断出早期壳圈是平旋的(Brenckle and Marchant, 1987; Brenckle, 1993, pl. 5, figs. 20–21)。正因为模式种与描述之间的不一致, 在后来的研究中就有了不同的意见。Miklukho-Maklay (1956)将该种归入*Planoarchaediscus*。其他学者有的认同模式种与描述之间的差异, 将该种放在*Planoarchaediscus*属(如Bogush and Yuferev, 1966; Brazhnikova in Brazhnikova *et al*., 1967); 有的学者将其归入一个新的平旋的属(如Pirlet and Conil, 1977; Brenckle and Marchant, 1987)。本文采用后一种做法, 将该种归入*Viseidiscus*属。

产地层位　湖南邵阳马栏边剖面石磴子组 340.2–347 m (图3)。

时代分布　维宪期。俄罗斯、哈萨克斯坦、乌克兰、西欧、中国南部地区、土耳其、伊朗、埃及等地区。

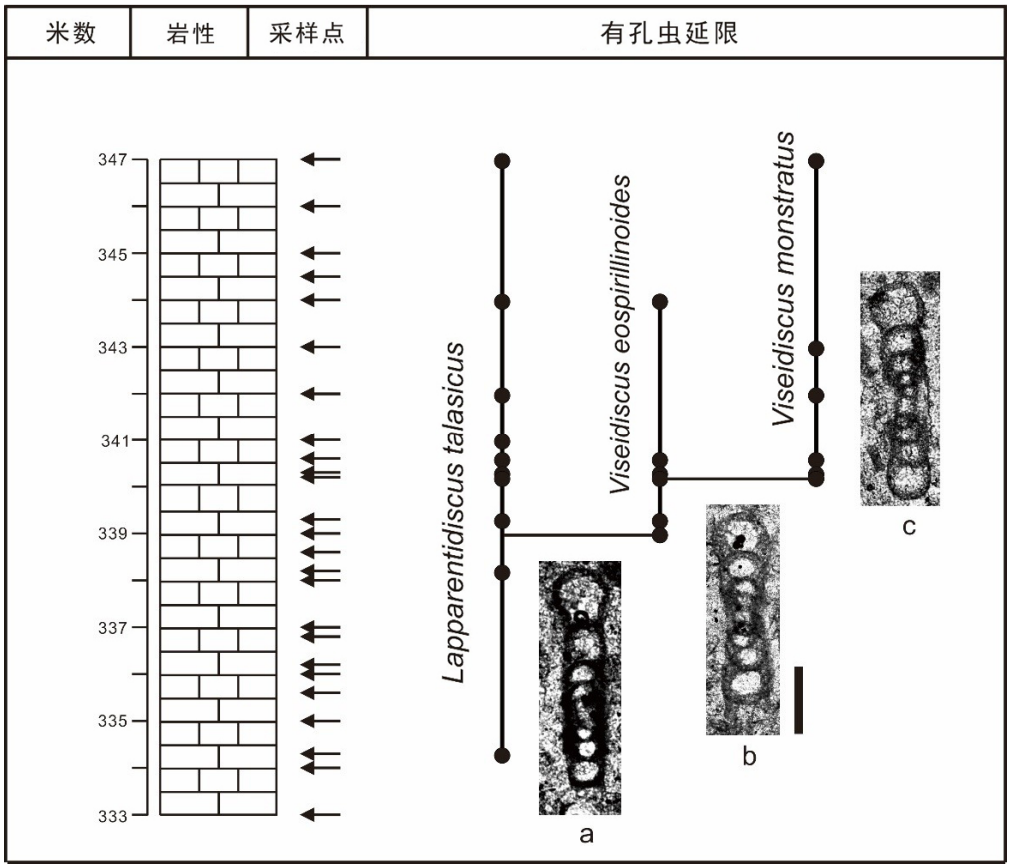

图 3 马栏边剖面石磴子组中 *Lapparentidiscus* 与 *Viseidiscus* 的延限及演化图

Fig. 3 Range and evolution of *Lapparentidiscus* and *Viseidiscus* from the Shidengzi Formation at the Malanbian section

a. *Lapparentidiscus talasicus* (即图 2-5); b. *Viseidiscus eospirillinoides* (即图 2-8); c. *Viseidiscus monstratus* (即图 2-15)。比例尺为 100 μm。

a. *Lapparentidiscus talasicus* (see fig. 2-5); b. *Viseidiscus eospirillinoides* (see fig. 2-8); c. *Viseidiscus monstratus* (see fig. 2-15). Scale bar is 100 μm.

4 古盘虫类的早期演化序列

Conil等(1980)曾认为*Brunsia*和*Pseudoammodiscus*是古盘虫类的两个祖先, 而Hance等(2011)认为*Lapparentidiscus*是古盘虫类的唯一祖先。*Lapparentidiscus*与*Pseudoammodiscus*的主要区别在于后者始终平旋、外旋, 壳圈匀速扩展; *Lapparentidiscus*与*Brunsia*的主要区别在于后者早期壳圈绕旋。*Lapparentidiscus*、*Pseudoammodiscus*和*Brunsia*在马栏边剖面石磴子组中都出现了, 但标本特征表明早期古盘虫类*Viseidiscus*的祖先应为*Lapparentidiscus*。在石磴子组先后连续出现的一系列标本中, *Lapparentidiscus talasicus*、*Viseidiscus eospirillinoides*、*Viseidiscus monstratus*这三个种在大小、形态、绕卷方式等方面非常相似, 都是早期平旋、内旋, 最后一两个壳圈外旋; 早期壳圈匀速扩展, 最后一两个壳圈的扩展速度明显加快。这三个种最大的区别就在于它们的壳壁结构。*L. talasicus*的壳壁是黑色微粒状; *V. eospirillinoides*脐部的黑色微粒层中开始出现不连续的、斑驳的透明放射颗粒, 逐渐替代黑色微粒; *V. monstratus*脐部的透明放射层已经比较发育、稳定和明显了, 有时还会延伸到最初的一两个壳圈的壳缘, 但是还未延伸到最后一两个壳圈的壳缘。这些标本展示了古盘虫类的早期演化序列(图3): *Lapparentidiscus talasicus* (Mikhno in Mikhno and Balakin, 1975)–*Viseidiscus eospirillinoides* (Brazhnikova, 1967)–*Viseidiscus monstratus* (Grozdilova and Lebedeva, 1954)。从而证实了两个观点: 1) *Lapparentidiscus*是古盘虫类的祖先; 2) 古盘虫类的透明放射层是以替代而非填充的形式出现的, 透明放射层逐渐替代黑色微粒层, 并从脐部逐步扩展到壳缘。

5 结　论

华南马栏边剖面石磴子组先后连续出现的有孔虫标本证实了 *Lapparentidiscus* 是古盘虫类的祖先，早期演化序列为 *Lapparentidiscus tatasicus–Viseidiscus eospirillinoides–Viseidiscus monstratus*, 古盘虫类壳壁的黑色微粒层逐渐被透明放射层替代, 并从脐部扩展到壳缘。

致谢　评审专家提出宝贵修改建议，Paul Brenckle博士进行交流讨论, 特别是廖卓庭研究员多年给予学术帮助, 在此一并致谢。

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