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陕南张家沟剖面寒武纪早期微体化石 *Hexaconularia sichuanensis* 的新材料*

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提要 陕南西乡张家沟剖面的寒武系下部岩层中发现了大量原始锥石类,根据整体形态特征和原始锥石类化石分类方案将其归属到六方锥石属 *Hexaconularia*。前人对于六方锥石分类方案众多,本文对其进行重新厘定。本文报道的六方锥石新材料在中央锥面上具有两条不连续的角沟,这不仅丰富了种内特征,而且为六方锥石的壳体演化趋势提供了依据。前人发现的该类化石与本文描记的化石类型相同,产地不同,因而具有地层对比意义。

关键词 六方锥石 原始锥石类 口部 宽川铺组 梅树村期

1 引 言

早寒武世梅树村期动物群代表着“寒武纪生命大爆发”生命辐射的序幕阶段,处于承前(埃迪卡拉生物群)启后(澄江动物群)的关键位置。扬子台地北缘纽芬兰统幸运阶(传统早寒武世梅树村期)磷质地层序列清晰、化石丰富,是世界公认全球研究条件最好的地区之一,该地区产出大量三维磷酸盐化骨骼化石(Qian and Bengtson, 1989; Steiner *et al.*, 2004; Liu *et al.*, 2014a, b),是寒武纪早期前三叶虫时代生物地层对比的依据(Peng *et al.*, 2000)。原始锥石类化石是一种特殊的早期小壳化石,1980 年以前的研究认为,锥石类化石仅产出于中寒武世至三叠纪的地层中,其生存年代较短,被归为刺细胞动物门(钱逸,1999)。在中国扬子台地边缘寒武纪早期梅树村期的含磷酸盐地层中埋藏着丰富的的原始锥石类化石,这些化石与锥石动物的骨骼形态相近,但又具有明显的原始性状,表现为化石个体微小而且没有隔壁刺和面中线,故称为原始锥石类(protoconulariids)(钱逸,1999)。原始锥石类化石在陕西宁强、西乡(刘云焕等,2005),云南晋宁、安宁、永善(蒋志文,1980;罗惠麟等,1982),川西峨眉、马边、雷坡(殷继成等,1980;陈孟莪,1982;何廷贵,1984;邢裕盛等,1984)和川北南江(杨暹和、何原相,1983)的寒武纪早期的第Ⅰ、Ⅱ组合带中都有分布,另外,在印度喜马拉雅地区相当层位也有发现(钱逸,1999)。从地理分布上来看,中国扬子台地西缘的陕西宁强和四川峨嵋两地区的原始锥石类化石分布最多,属种最全,最具有代表性(刘云焕等,2011)。

原始锥石类按其形态组合特征可以分为两种不同的类型,即骨状壳类 carinachitids 和六方锥石类 hexangulaconulariids。六方锥石科(Hexangulaconulariidae He, 1987)根据中央锥面与侧锥面之间的角沟是否明显,分为两个属 *Arthrochites* Chen, 1982 和 *Hexaconularia* He and Yang, 1986。其中,分节壳属 *Arthrochites* Chen, 1982 壳体的中央锥面和侧锥面之间的角沟不明显甚至缺失,横切面呈椭圆形。六方锥石属 *Hexaconularia* He and Yang, 1986 壳体为扁平阔六方锥体,横断面六边形,六个

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锥面均有横肋，共有四个角沟（何原相、杨暹和，1986）。

钱逸（1999）根据原始锥石类化石内部的形态差异特征将其分为骨状锥石科（Carinachitidae）和六角锥石科（Hexangulaconulariidae）（He，1987）。后经刘云焕（刘云焕等，2005，2011）对新种做了两次补充，且结合 Iten 等（2010）对于六方锥石属 *Hexaconularia* 的重新厘定，最终形成 2 科 5 属的分类方案（表Ⅰ）：Carinachitidae He，1987 包括 *Carinachites* Qian，1977，*Emeiconularia* Qian *et al.*，1997 和 *Pentaconularia* Liu *et al.*，2011；Hexangulaconulariidae He，1987 包括 *Arthrochites* Chen，1982 和 *Hexaconularia* He and Yang，1986。

原始锥石类生存时间很短，*Carinachites*，*Arthrochites* 都产于梅树村阶第一组合带的中部层位（郑曦，2010）。其分布范围不广，局限于中国扬子台地的西缘，均发现于寒武纪早期梅树村期含磷碳酸盐地层中，这些化石无一例外地保存为磷质（钱逸等，1997）。

从地理分布上来看，中国扬子台地西缘的陕西宁强和四川峨嵋两地区的原始锥石类化石分布最多，属种最全，最具有代表性（刘云焕等，2011）。扬子台地北缘的陕西宁强石钟沟剖面和西乡张家沟剖面的宽川铺组原始锥石类化石产出十分丰富，本文拟对这一层位产出的化石类群进行描述探究，以丰富我们对寒武纪大爆发之初生物多样性的认知。

2 产地与层位

样品采集于陕西省宁强县石钟沟剖面和西乡县张家沟剖面的寒武系下部宽川铺组，该段是一套含磷含硅的浅海碳酸盐岩沉积地层，且与上覆郭家坝组地层为平行不整合接触，与下伏地层为整合接触。岩性为灰色—灰白色块状细晶灰岩、巨厚层状细晶灰岩、致密块状含磷生物灰岩、薄层状微晶—细晶白云质灰岩。该产地层位曾产出丰富的 *Olivooides*，*Quadrapyrgites* 化石（Steiner *et al.*，2014；Liu *et al.*，2014a；Shao *et al.*，2015），已知最古老的鳃曳状环神经动物（Liu *et al.*，2014b；Shao *et al.*，2016a，b），各类管状化石（王琪等，2017）和已知最古老的后口动物（Han *et al.*，2017）。

该地层富含微骨骼化石，其化石组合面貌可与早寒武世梅树村阶微骨骼化石对比，时代归属早寒武世梅树村期。

3 材料与方法

对富含小壳化石的磷酸盐矿层中所取样品，用浓度为 8%—9% 的冰醋酸浸解处理，每隔 5 天进行洗样并更换同浓度的的醋酸一次。不溶残渣用 120 目分样筛将样品分离，所得样品用恒温箱烘烤或自然晾干，然后在实体双目显微镜下手工挑样获得标本，最后用长安大学教育部重点实验室的 Quanta650 电子显微镜扫描成像。文中所示标本保存于长安大学地球科学与资源学院微体古生物实验室。

4 六方锥石描述

刺细胞动物门 Cnidaria Hatschek，1888

钵水母纲 Cyphozoa Götte，1887

锥石目 Conulariida Miller and Gurley，1896

六角锥石科 Hexangulaconulariidae He，1987

六方锥石属 ***Hexaconularia*** He and Yang，1986

模式种 *Hexaconularia sichuanensis* He and Yang，1986

特征 壳体小，呈扁平状，两瓣对称，壳面呈锥形，梯形，三角形。具有两个宽面，每个宽面上有一个较宽的中央锥面，中央锥面的两侧各有一个对称分布的侧锥面。无论是中央锥面还是侧锥面，均有明显的横肋。横肋平行排列，条纹清晰，从底端到口端长度逐渐变大，横肋间距从 0.038—0.091 mm 不等（表Ⅰ）。一般在锥面的中部横肋间距较小，口端和低端间距较大。中央锥面和侧锥面之间有明显的角沟，角沟深切宽阔，较为明显，横肋在此有明显转折，且被角沟截断。此外，在中央锥面上还有两条对称分布的角沟，角沟较浅且不连续，被横肋间断，在壳体口端角沟较为明显，从口端到底端逐渐消失。锥体顶端钝圆，保存完整，有清晰的纹理，纹理非定向排列（插图 1，2）。

表Ⅰ 六方锥石壳体度量表

The shell measurements of *Hexaconularia sichuanensis*

化石标本	壳体可见长度（mm）	壳体宽度（mm）	横肋间距（mm）
No. XX637	0.659	0.849	0.059—0.066
No. XX638	0.742	0.963	0.039—0.055
No. XX644	0.770	0.847	0.038—0.060
No. XX256	0.971	0.742	0.038—0.070
No. XX646	1.007	1.487	0.038—0.051
No. XX649	1.064	1.231	0.038—0.077
No. XX168	0.315	0.407	0.015—0.030
No. XX648	1.000	1.606	0.076—0.091

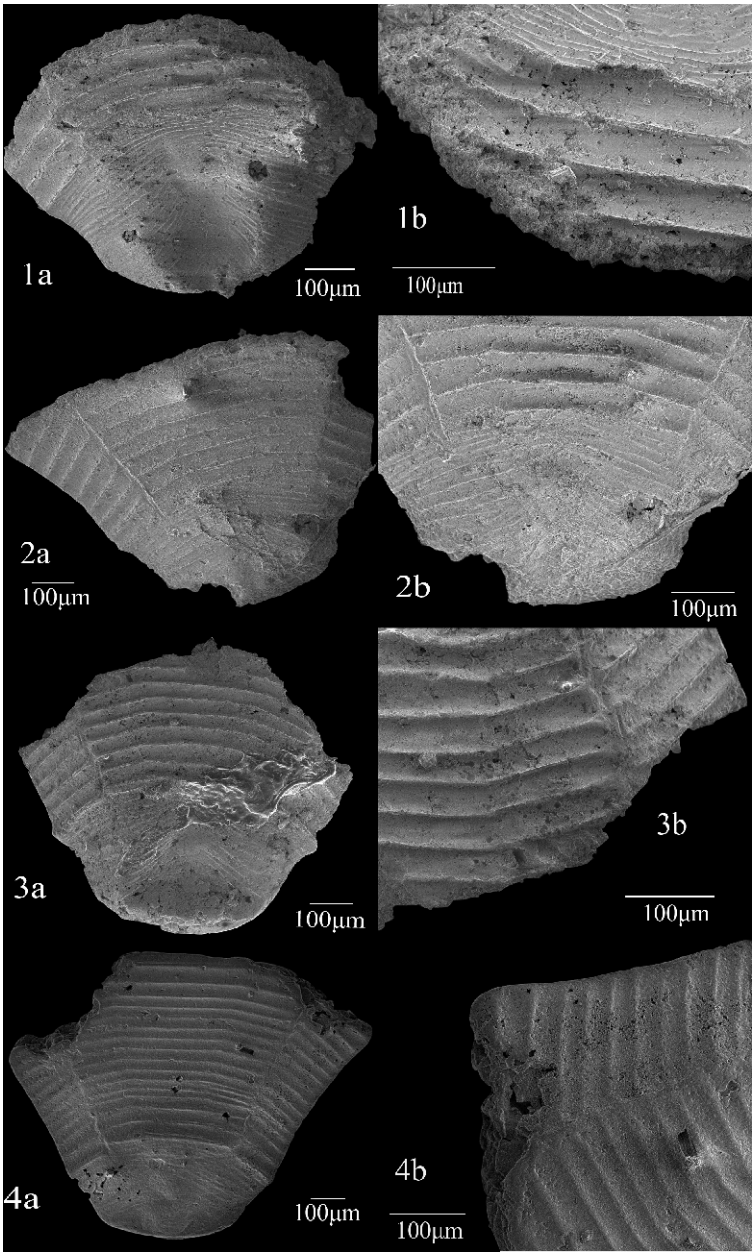

插图 1　西乡生物群中六方锥石属 *Hexaconularia* He and Yang，1986 的特征

The features of *Hexaconularia* He and Yang，1986 from Xixiang biota

1a. **外视，六方锥石化石的整体形态，呈梯形，锥面上可见明显的横肋，中央锥面与侧锥面之间的角沟清晰可见。标本号**：XX637；1b. **为** 1a **放大后局部，横肋清晰，中央锥面上角沟较浅，横肋在此处有轻微转折**；2a. **外视，整体形态，可见清晰的横肋和角沟，角沟连续并截断横肋。标本号**：XX638；2b. **为** 2a **的局部放大，中央锥面上的角沟不明显**；3a. **外视，六方锥石的整体形态，横肋清晰，中央锥面和侧锥面之间的角沟明显。标本号**：XX644；3b. **为** 3a **放大后局部，中央锥面上的角沟不明显，横肋在此处有转折**；4a. **外视，横肋间距在口端和底端较宽，中间较窄。标本号**：XX256；4b. **为** 4a **局部放大，角沟连续并切断横肋**。

1a. External view. The characteristics of *Hexaconularia* as a whole is trapezoidal. There are obvious transverse ribbings on the face. The corner grooves between the central face and the lateral face are clearly visible. Sample No. XX637；1b. Detail of 1a. These transverse ribbings are clearly. The corner groove on the central face is shallow. These transverse ribbings have a slight turning point here；2a. External view. The overall characteristics，these transverse ribbings and corner grooves are clearly. These corner grooves are continuous and cut off the transverse ribbings. Sample No. XX638；2b. Detail of 2a. The corner groove on the central face is not obvious；3a. External view. The characteristics of *Hexaconularia* as a whole，these transverse ribbings is clearly. The corner groove between the central face and the lateral face is obvious. Sample No. XX644；3b. Detail of 3a. The corner groove on the central face is not obvious. These transverse ribbings have a turning point here；4a. External view. The spacing of transverse ribbings is wider at the apex and apertural terminature，narrower in the middle. Sample No. XX256；4b. Detail of 4a. The corner groove is continuous and cut off the transverse ribbings.

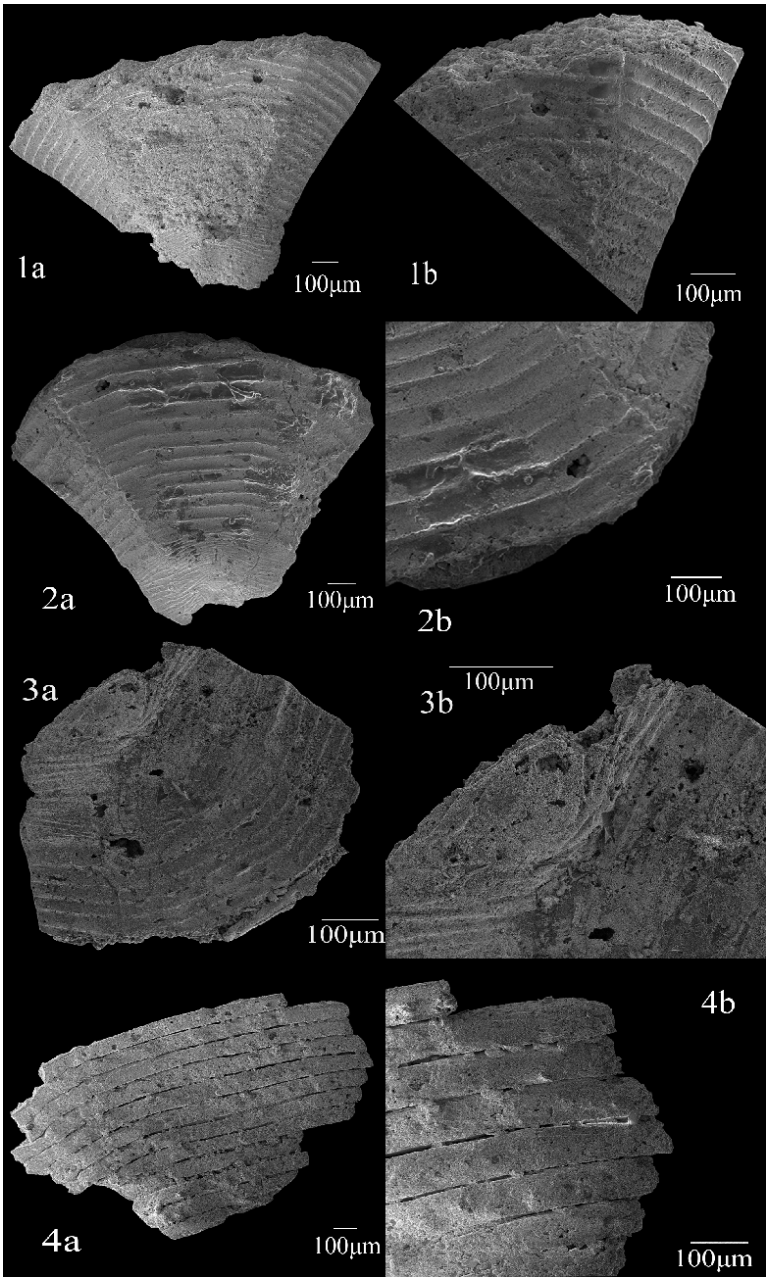

插图 2　西乡生物群中六方锥石属 *Hexaconularia* He and Yang，1986 的特征

The features of *Hexaconularia* He and Yang，1986 from Xixiang biota

1a. **外视，六方锥石的整体形态，呈扇形，中央锥面与侧锥面之间的角沟明显且连续，切断横肋。标本号**：XX646；1b. **为** 1a **放大后局部，中央锥面上角沟不明显，横肋在此有轻微转折**；2a. **外视，在口端横肋间距明显增大，中央锥面和侧锥面之间的角沟清晰且较宽。标本号**：XX649；2b. **为** 2a **放大后的局部，可以清楚地看到中央锥面和侧锥面之间的角沟较宽，截断横肋。中央锥面上的角沟不明显，横肋在角沟处有转折**；3a. **外视，锥面上横肋清晰，中央锥面和侧锥面之间的角沟较宽，中央锥面上的角沟不明显。标本号**：XX168；3b. **为** 3a **放大后部分**；4a. **外视，化石保存不完整，横肋之间开裂。标本号**：XX648；4b. **为** 4a **局部放大，横肋之间开裂、裂缝清晰。**

1a. External view. The characteristics of *Hexaconularia* as a whole is fan-shaped. The corner groove between the central face and the lateral face is obvious and continuous，cut off these transverse ribbings. Sample No. XX646；1b. Detail of 1a. The corner groove on the central face is not obvious. These transverse ribbings have a slight turning point here；2a. External view. The spacing of these transverse ribbings is significantly increased at the apertural. The corner groove between the central face and the lateral face is clearly wider. Sample No. XX649；2b. Detail of 2a. The corner groove between the central face and the lateral is wider and cut off these transverse ribbings. The corner groove on the central face is not obvious. These transverse ribbings have a turning point here；3a. External view. These transverse ribbings are clearly. The corner groove between the central face and the lateral face is wider. The corner groove on the central is not obvious. Sample No. XX168；3b. Detail of 3a；4a. External view，fossil incomplete preservation，split between ribs. Sample No. XX648；4b. Detail of 4a. There are clear cracks between the ribs.

比较与讨论　化石标本形态特征与何原相(1986)报道的六方锥石相似，将其归属于六方锥石属 *Hexaconularia* He and Yang，1986。所不同的是本文标本中央锥面上还有两条不连续的角沟，角沟呈“八”字形，在口端角沟较为明显，横肋在此有轻微转折。角沟不连续且被横肋间断，从口端到底端角沟逐渐变得不明显甚至消失。角沟的增加增大了壳内软体活动的空间，是六方锥石动物适应生存环境的结果。

将本文中的新材料与在陕南宁强石钟沟剖面发现的 *H. ningqiangensis* Zheng，2012（郑亚娟，2012）相比，后者具有十个锥面，中央锥面上的角沟明显且连续切断横肋，而本文中的中央锥面上的两条角沟不明显且不连续。故推测六方锥石的中央锥面上角沟的变化，可能为六方锥石演化上的过渡。

产地层位　陕西省西乡县张家沟，寒武系下部宽川铺组。

5　结　论

1）西乡张家沟地区发现的原始锥石类，与扬子台地北缘其他地区寒武纪梅树村期磷质地层中发现的原始锥石类类型大致相同，丰富了早古生代原始锥石类的资料和对寒武纪大爆发之初生物多样性的认知。

2）本文报道的六方锥石新材料在中央锥面上还有两条不连续的角沟，可能反映了六方锥石的壳体演化趋势，而角沟的增加增大了壳内软体活动的空间，是六方锥石动物适应生存环境的结果，为进一步揭示寒武纪大爆发之初生命的个体发育规律和系统分类提供了新材料。

3）原始锥石类化石主要产出于陕西宁强、川北南江、川西峨眉、云南晋宁等地的寒武系下部宽川铺组。本文报道的西乡张家沟产出相同化石的层位也应为宽川铺组，西乡张家沟和上述宁强宽川铺等地的寒武系下部宽川铺组的沉积地层属于“同时异相”沉积。

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NEW MATERIALS OF EARLY CAMBRIAN MICROFOSSILS *HEXACONULARIA SICHUANENSIS* FROM ZHANGJIAGOU SECTION IN SOUTHERN SHAANXI

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Key words　*Hexaconularia*, protoconularriids, mouthparts, Kuanchuanpu Formation, Meishucun Stage

Abstract

A large number of protoconulariid fossils were found in the lower Cambrian strata of Zhangjiagou Section in Xixiang, South Shaanxi. According to its overall morphological and the classification of protoconulariid fossils which belong to *Hexaconularia*. Predecessors made many classifications about *Hexaconularia*, but we reclassified it. There are two shallow and discontinuous corner grooves at the central face. This not only enriches the intraspecific characteristics, but also provides the basis for the evolution trend of shell. The same type as fossils described in this article have been reported by predecessors but from different places, thus it has important research meaning to the stratigraphic comparison.