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安徽巢湖密西西比亚系和州组四射珊瑚层组成及其古生态和古地理特征*

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提要 石炭纪密西西比亚纪是四射珊瑚演化的重要时期, 其中谢尔普霍夫期受海西造山运动和晚古生代大冰期的影响, 很多地区缺乏碳酸盐岩沉积, 四射珊瑚记录较少。安徽省巢湖市万山埠剖面和州组底部发育了近原地保存的单体四射珊瑚层, 其厚度约5 cm, 横向展布数十米。根据有孔虫化石确定该珊瑚层的时代为谢尔普霍夫早期。和州组珊瑚层仅由单体珊瑚*Yuanophyllum kansuense*组成, 珊瑚个体保存较好, 相互接触, 多呈倒伏状。与基底泥粒灰岩相比, 单体珊瑚*Y. kansuense*之间为泥粒—颗粒灰岩, 亮晶方解石含量明显增加, 这指示*Y. kansuense*珊瑚层的形成与该时期相对海平面降低所导致的水动力增强有关。在古地理上, 维宪晚期至谢尔普霍夫期的单体珊瑚*Y. kansuense*分布于古特提斯洋东部的低纬度地区, 尤其是在中国华南和西北地区广泛分布。

关键词 单体四射珊瑚 石炭纪 谢尔普霍夫期 古特提斯洋东部 华南

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The composition of a Mississippian rugose coral biostrome from the Hezhou Formation near Chaohu City, Anhui Province, and its paleoecological and paleogeographical characteristics

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Abstract The Mississippian subperiod (Early Carboniferous) represents a crucial period for the evolution of rugose corals. During the Serpukhovian (Late Mississippian), carbonate deposition was limited in many regions due to the Hercynian orogeny and the Late Paleozoic Ice Age, resulting in sparse rugose coral records. A solitary rugose coral parabiostrome is discovered at the base of the Hezhou Formation at the Wanshanbu section near Chaohu City, Anhui Province. This coral biostrome is approximately 5 cm thick and extends laterally for tens of meters. Based on foraminiferal biostratigraphy, the age of the coral biostrome is proposed as early Serpukhovian. The Hezhou coral biostrome is exclusively composed of the solitary rugose coral species *Yuanophyllum kansuense*. The corallites are well-preserved, closely packed, and mostly toppled. Compared with the underlying packstone, the microfacies of the matrix among *Y. kansuense* skeletons vary from packstone to grainstone, accompanied by a distinct increase in sparry calcite. This suggests that the development of the *Y. kansuense* biostrome is linked to enhanced hydrodynamic energy resulting from a relative sea-level fall during this time. Paleogeographically, *Y. kansuense* was distributed across low-latitude regions of the eastern Paleo-Tethys Ocean during the late Visean to Serpukhovian, and was particularly widespread in South and Northwest China.

Key words Solitary rugose coral, Carboniferous, Serpukhovian, eastern Paleo-Tethys Ocean, South China

1 引 言

石炭纪是地质历史时期的关键气候转折期之一, 强烈的海西造山运动和陆地植物的繁盛导致了显著的气候变冷, 南半球冈瓦纳大陆广泛发育冰川沉积, 使得石炭纪成为显生宙最大的冰室气候时期(要乐等, 2023; DiMichele, 2014; Goddéris *et al*., 2017; Wang *et al*., 2019)。冰川的扩张和消减伴随全球海平面频繁周期性变化, 导致低纬度地区广泛发育碎屑岩沉积或暴露面(Saunders and Ramsbottom, 1986; Wang *et al*., 2013; Fielding, 2021)。维宪晚期至谢尔普霍夫期是冰期发育的重要时期, 气候变冷及其伴随的全球海平面降低和碳酸盐岩沉积的减少对海洋生态系统造成了严重影响, 在谢尔普霍夫期发生了次一级的生物灭绝事件, 造成了约30%的属一级的海洋物种消失(Stanley and Powell, 2003; Balseiro and Powell, 2020; Yao *et al*., 2022)。

作为浅水碳酸盐岩相区广泛发育的四射珊瑚, 其多样性和丰度在密西西比亚纪维宪晚期达到最高值(Fedorowski, 1981; Aretz, 2010; Yao *et al*., 2020)。国内外学者对该时期的四射珊瑚做了详细的研究, 如西欧、北非、土耳其、顿涅茨盆地、莫斯科盆地、中国、日本、澳大利亚、北美等地区(Fedorowski, 1981, 2022; Wang *et al*., 2022)。随后的谢尔普霍夫期, 四射珊瑚属种多样性降低, 分布范围也更加局限, 珊瑚报道较少(Fedorowski, 1981, 2022; Wang *et al*., 2022; Yao *et al*., 2023a)。华南地区谢尔普霍夫期碳酸盐岩地层发育, 四射珊瑚较为丰富, 前人在湘黔桂地区做了详细的珊瑚系统古生物学研究(吴望始, 1964; 吴望始、赵嘉明, 1989; Yü, 1933; Lin *et al*., 2012)。安徽地区谢尔普霍夫期四射珊瑚报道较少(严幼因, 1987; 林巍等, 2022; Yü, 1933)。

安徽巢湖万山埠剖面密西西比亚系和州组底部发育了单体四射珊瑚层, 本文通过珊瑚的系统古生物学研究, 揭示了珊瑚的属种组成; 根据有孔虫化石确定了珊瑚层的时代; 结合珊瑚的埋藏学特征和沉积微相类型探讨了珊瑚层的形成过程与相对海平面变化的关系; 基于同时期其它地区同种珊瑚的分布, 重建了珊瑚的生物古地理特征。

2 地质背景及剖面介绍

本文研究的巢湖万山埠剖面(GPS: 117°50′49″E; 31°39′27″N)位于安徽省巢湖市北约6 km, 靠近万山埠村(图1-A–1-B)。维宪期—谢尔普霍夫期, 万山埠剖面在古地理上位于古特提斯洋东部的华南板块。依据大地构造划分, 该剖面属于下扬子地台, 沉积相属于陆源浅水沉积(图1-C), 以碎屑岩和碳酸盐岩发育为主。

万山埠剖面出露较为连续的密西西比亚纪地层(图1-D), 自下而上可以划分为高骊山组(C_{1g})及和州组(C_{1h}) (图2-A)。高骊山组的岩性以杂色碎屑岩为主(图2-B); 和州组是一套以灰黑色生屑灰岩和灰岩夹黄绿色泥页岩为主的地层, 其中下部为灰色生物碎屑泥粒—颗粒灰岩夹黄绿色泥页岩(图2-B)。本文研究的珊瑚层位于和州组底部, 厚度约5 cm, 横向分布广, 野外可追索数十米。珊瑚层由单体四射珊瑚组成, 珊瑚丰度很高, 沿层面密集分布, 个体保存较为完好(图2-C–2-D)。

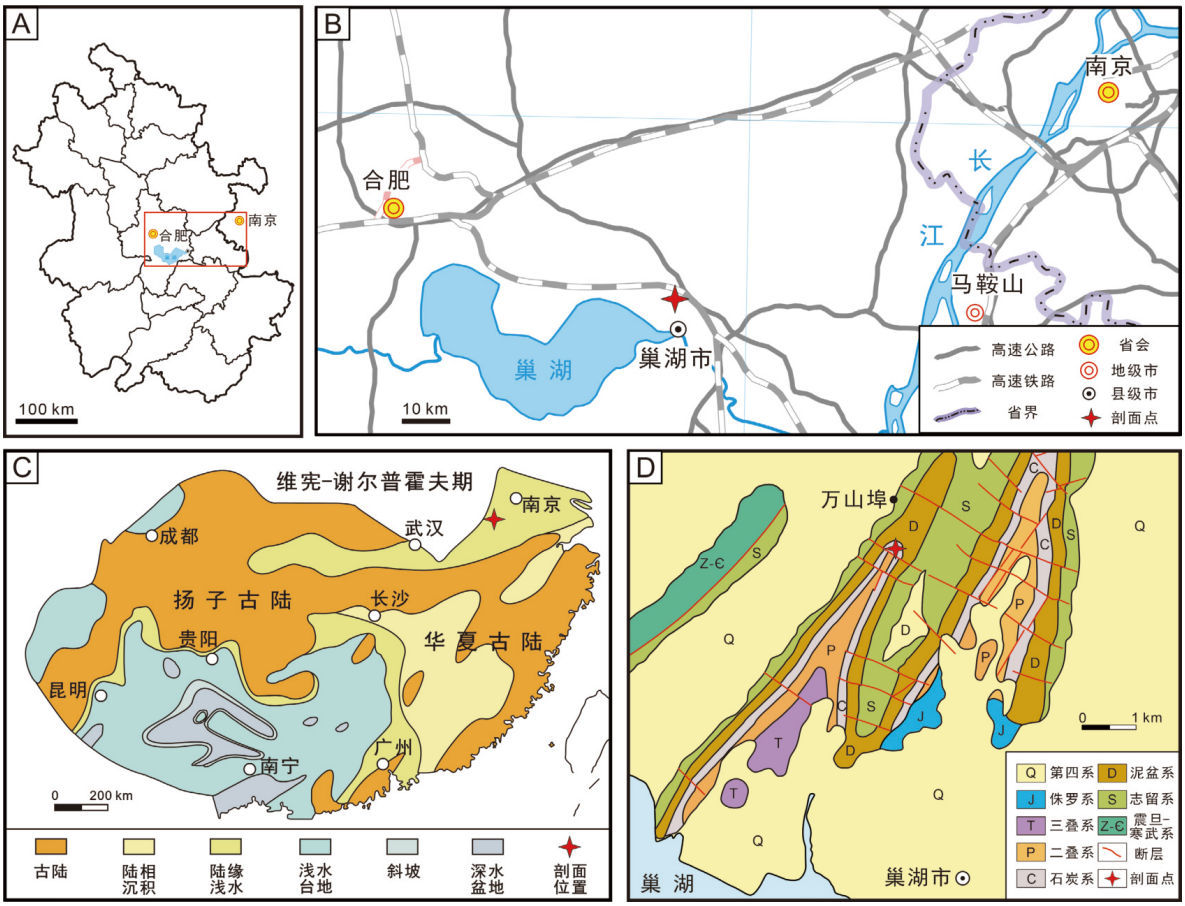


图1 研究剖面的地理位置图、华南板块古地理图和研究区地质图

Fig. 1 Geographic location of the section, paleogeographic map of the South China Block, and geological map of the study area

安徽省行政区划图[审图号: 皖S(2025)59号](**A**); 万山埠剖面交通位置图[审图号: 皖S(2025)48号], 图1-A中红框放大图(**B**); 华南板块维宪期—谢尔普霍夫期古地理图(修改自冯增昭等, 1999)及剖面位置(**C**); 研究区的地质简图及剖面位置(修改自王道轩等, 2005) (**D**)。

Administrative divisions of Anhui Province [Approval Number for Map Review: Wan S (2025) No. 59](**A**); Enlargement of the rectangular area in A, showing the location of the Wanshanbu section, Chaohu City, Anhui Province [Approval Number for Map Review: Wan S (2025) No. 48](**B**); Visean-Serpukhovian paleogeography of the South China Block, showing sedimentary facies modified from (Feng *et al*., 1999) and the location of the section (**C**); Geological map of study area, showing the location of the Wanshanbu section (**D**)(modified from Wang *et al*., 2005).

3 材料与方法

从万山埠剖面和州组珊瑚层及其上下岩层中采集了9块珊瑚化石标本和9块岩石样品。对保存完好的珊瑚个体, 从珊瑚根部到萼部进行了较为连续的切片, 以获取青年期和成年期的横切面, 并在横切面之间制作了纵切面, 共定向磨制了19张珊瑚化石和12张岩石薄片(宽×高: 约50 mm × 75 mm; 100 mm × 150 mm), 用于珊瑚和有孔虫化石属种鉴定以及沉积微相类型的划分。珊瑚的系统古生物学鉴定主要是参考Hill (1981)和Yü (1933); 微相类型划分参考Dunham (1962)。本文所研究的标本均保存于中国科学院南京地质古生物研究所。

4 系统古生物学

珊瑚纲 Class Anthozoa Ehrenberg, 1834

四射珊瑚亚纲 Subclass Rugosa Milne-Edwards and Haime, 1850

十字珊瑚目 Order Stauriida Verrill, 1865

柱管珊瑚亚目 Suborder Aulophyllina Hill, 1981

柱管珊瑚科 Family Aulophyllidae Dybowski, 1873

棚珊瑚亚科 Subfamily Dibunophyllinae Wang, 1950

袁氏珊瑚属 Genus *Yuanophyllum* Yü, 1931

模式种 *Yuanophyllum kansuense* Yü, 1931

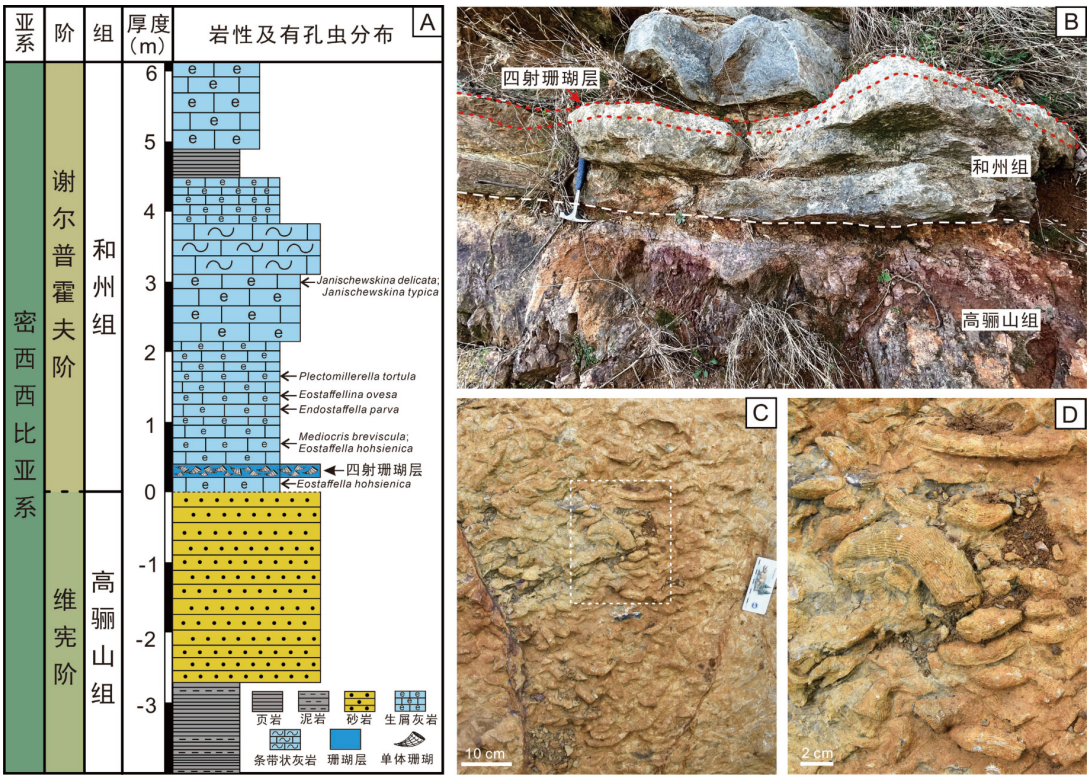


图2 巢湖万山埠剖面岩性柱状图、产出珊瑚化石层的野外露头及珊瑚层表面的珊瑚密集保存照片

Fig. 2 Lithologic column of the Wanshanbu section near Chaohu City, outcrop of the coral biostrome, and photos of the densely preserved rugose corals

巢湖万山埠剖面岩性柱状图和有孔虫化石分布(**A**); 高骊山组与和州组的岩性接触面和珊瑚层的分布位置(**B**); 单体四射珊瑚层的野外照片(**C**); 图2-C中白框的放大照片(**D**)。

Lithologic column of the Wanshanbu section near Chaohu City and distribution of the foraminifers (**A**); lithologic boundary between the Gaolishan and Hezhou formations, and the distribution of the coral biostrome (**B**); field photo of the coral biostrome (**C**); enlargement of the rectangular area in C (**D**).

产地层位 甘肃武威臭牛沟组; 密西西比亚纪维宪期。

讨论 *Yuanophyllum*一属最早由Yü (1931)基于甘肃和华南地区的材料建立, 在建立之初并未归入任何一科, 随后在Yü (1933)的文章中将其归入顶饰珊瑚科Lophophyllidae。之后, Hill (1981)认为*Yuanophyllum*属于柱管珊瑚科Aulophyllidae中的棚珊瑚亚科Dibunophyllinae, 在其描述中顶饰珊瑚科Lophophyllidae为无鳞板且轴部结构更简单、更稳定的单体珊瑚, 而*Yuanophyllum*具有较宽的鳞板带且多变的轴部结构与棚珊瑚亚科Dibunophyllinae更相近, 所以本文采用Hill (1981)的分类方案。该属与似棚珊瑚*Arachnolasma* Grabu, 1922一属在个体大小、一级隔壁长, 以及发育中板等特征十分相似, 但是*Yuanophyllum*的二级隔壁不太发育或呈短脊状, 一级隔壁在主部加厚显著, 且主隔壁后退, 主内沟发育, 轴部结构简单不形成蛛网状, 以及鳞板多呈人字形等特征可与*Arachnolasma*所区分(Yü, 1933; Minato and Rowett, 1967)。

甘肃袁氏珊瑚 *Yuanophyllum kansuense* Yü, 1931

(图3-A–3-K)

1931 *Yuanophyllum kansuense* Yü, Yü C C, p. 27, fig. 4.

1933 *Yuanophyllum kansuense* Yü, Yü C C, p. 46, pl. III, figs. 1–6.

1937 *Yuanophyllum kansuense* Yü, Yü C C, p. 30–31, pl. VII, figs. 2a–d.

1962 *Yuanophyllum kansuense* Yü, 骆金锭、赵嘉明, p. 149, pl. 12, figs. 10–13。

1963 *Yuanophyllum kansuense* Yü, 范影年, p. 284, pl. 6, figs. 1a–c。

1964 *Yuanophyllum kansuense* Yü, 吴望始, p. 61, pl. XIII, figs. 1–3。

1966 *Yuanophyllum kansuense* Yü, 林英锪, p. 191–192, pl. I, figs. 9a–b, 10a–c, pl. II, figs. 1a–b。

1978 *Yuanophyllum kansuense* Yü, 俞建章等, p. 33, pl. 8, figs. 7a–c, 8a–c, pl. 9, figs. 1a–b。

1980 *Yuanophyllum kansuense* Yü, 范影年, p. 25, pl. 16, figs. 1a–b, 2a–b, 5a–b。

2003 *Yuanophyllum kansuense* Yü, Fan *et al.*, p. 302, pl. 27, figs. 5a–b。

2012 *Yuanophyllum kansuense* Yü, Lin *et al.*, p. 332–333, pl. 1, figs. J–K.

2022 *Yuanophyllum kansuense* var. β Yü, 林巍, p. 446, figs. 3A–E。

材料 来自安徽巢湖和州组的9块珊瑚化石标本。标本号WSB0, WSB0.3, WSB0.3-1, WSB0.3-2, WSB0.3-3, WSB0.3-4, WSB0.3-5, WSB0.3-6, WSB0.3-7, 共制作薄片19片, 包括横切面13片, 纵切面6片。

描述 中大型牛角状单体四射珊瑚, 外壁常被侵蚀。

横切面: 单骸直径6.4—27.5 mm, 隔壁数30—55(图4)。青年期, 一级隔壁长且加厚明显, 延伸至中板, 彼此相连, 呈羽状排列, 中板强烈加厚(图3-A–3-B, 3-F)。成年期对部隔壁减薄, 主部仍加厚明显(图3-C, 3-G), 主隔壁缩短, 主内沟显著, 中板减薄, 始终与对隔壁相连(图3-I–3-J)。鳞板带窄, 约为半径的1/3, 鳞板多为人字形。二级隔壁不甚发育, 仅成年期个体部分发育, 呈短脊状。

纵切面: 中板直且连续, 早期中板加厚明显(图3-D, 3-H), 后期逐渐减薄(图3-E, 3-K)。横板不完整呈拉长泡沫状, 向中板缓慢上升, 在与中板相接处变陡, 5 mm内8—12条。鳞板带不完整, 常被侵蚀, 鳞板呈小泡沫状, 靠近内圈处较陡。

讨论 本文的标本与Yü (1933)报道的*Yuanophyllum kansuense*相比, 单骸直径和隔壁数稍大(图4-A); 与林巍等(2022)所报道安徽巢湖地区的*Y. kansuense* var. β, 在单骸直径和隔壁数上均较为相似(图4-A)。*Y. kansuense* var. β是Yü (1933)建立的变种, 其特征为单骸直径和隔壁数稍大, 轴部横板更为密集(5 mm内约有16—18条) (图4-B), 林英锪(1966)基于甘肃景泰黑山的标本认为其轴部横板更为平坦和密集是一个稳定的特征, 将该变种提升为新种*Y. multitabulatum*。虽然本文的标本单骸直径及其隔壁数较大, 但是纵切面上轴部横板平缓且密集的特征不明显(5 mm内约8—12条), 所以本文将其归到*Y. kansuense*, 同时观察林巍等(2022)报道的安徽巢湖标本发现, 其轴部横板并不密集(5 mm内约9—10条), 其特征更像*Y. kansuense*, 因此也将其归入该种; 另外, 在湖南、贵州和甘肃地区报道的*Y. kansuense*具有相似的横板分布特征(5 mm内约8—11条) (吴望始, 1964; 林巍, 2013; Yü, 1933), 这表明横板分布分散是*Y. kansuense*的稳定特征, 可以被用来与*Y. multitabulatum*区分(骆金锭、赵嘉明, 1962; 林英锪, 1966; Yü, 1933; Fan *et al*., 2003) (图4-B)。新疆哈密雅满苏组(珊瑚直径30 mm, 隔壁数54) (俞建章等, 1978)、四川松潘总长沟组(珊瑚直径25—32 mm, 隔壁数53—60) (范影年, 1980)、西藏改则日湾茶卡组(珊瑚直径30 mm, 隔壁数55) (Fan *et al*., 2003)、湖南中部梓门桥组(珊瑚直径17—35 mm, 隔壁数41—62) (范影年, 1963)等地层中均报道了单骸直径和隔壁数稍大的*Y. kansuense*标本。另外, 范影年(1963)和林巍(2013)报道的*Y. kansuense*标本中有一级隔壁末端扭结成网状, 形成略似蛛网状结构的现象, 在本文标本中也有部分发育(图3-C), 这些现象可能是种内形态的变化。

产地层位 安徽省巢湖市和州组, 密西西比亚纪谢尔普霍夫早期。

5 讨 论

5.1 四射珊瑚和有孔虫生物地层

甘肃袁氏珊瑚*Yuanophyllum kansuense*是*Yuanophyllum*带的标志分子, 其中*Yuanophyllum*带是我国华南密西西比亚系中上部的四射珊瑚带(Yü, 1931, 1933, 1937), 其时代为密西西比亚纪维宪晚期至谢尔普霍夫期(Wang *et al*., 2022)。巢湖万山埠剖面有孔虫化石较为丰富, 主要分布于剖面下部0—3 m的生物碎屑灰岩中(图2-A), 以蝶类有孔虫*Eostaffella*属为主, 其中*E. hohsienica*最为常见, 为谢尔普霍夫期的特征分子(张遴信, 1962)。在万山埠剖面的1.7 m和3 m处分别发现了有孔虫*Plectomillerella tortula*和*Janischewskina delicata* (图2-A), 这两个种的首现被认为是确定谢尔普霍夫阶底部的标志分子(Kulagina *et al*., 2003; Kulagina *et al*., 2008; Groves *et al*., 2012)。此外, 在该剖面还发现了*J. typica*、*Eostaffellina ovesa*、*Endostaffella parva*、*Mediocris breviscula*等谢尔普霍夫早期*P. tortula*带中常见的有孔虫分子(Sheng *et al*., 2018)。因此根据有孔虫动物群面貌, 和州组底部珊瑚层对应的时代为谢尔普霍夫早期。

5.2 珊瑚层的古生态特征

巢湖万山埠剖面单体四射珊瑚层中的珊瑚个体相互接触, 大部分保存较为完好, 仅外壁和鳞板带被不同程度地损坏(图2-C–2-D, 图3), 较完整保存的珊瑚个体所占珊瑚总体的比例约为90%, 在基底和珊瑚层接触面上可见少量珊瑚破碎(图5-A)。与单体

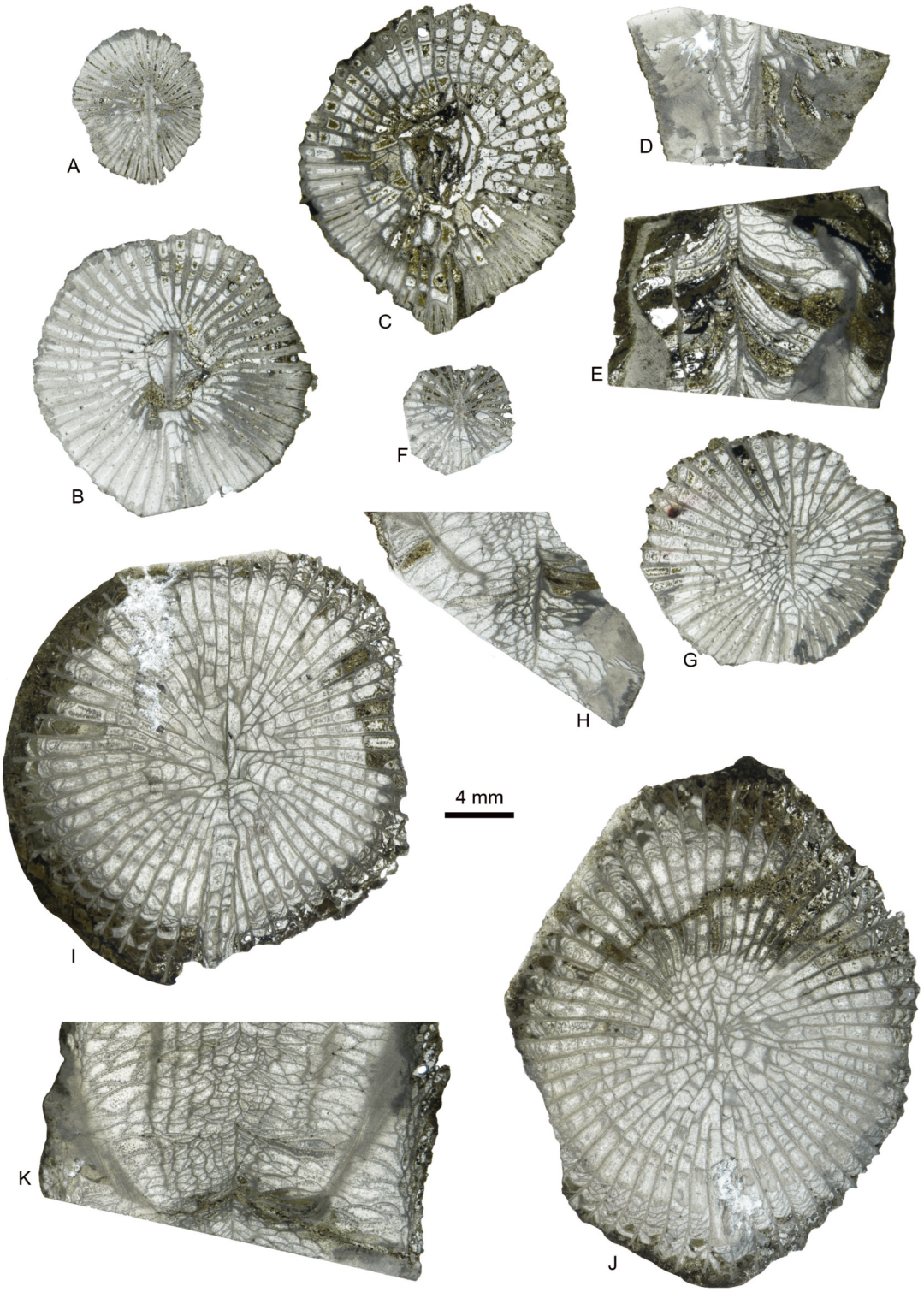


图3 安徽巢湖万山埠剖面和州组珊瑚层中的单体四射珊瑚 *Yuanophyllum kansuense* Yü, 1931

Fig. 3 *Yuanophyllum kansuense* Yü, 1931 from the Hezhou Formation at the Wanshanbu section, Anhui Province

A–**E**. 标本WSB0.3-1, **A**–**C**. 横切面; **D**, **E**. 纵切面。 **F**–**H**. 标本WSB0.3-3; **F**, **G**. 横切面, **H**. 纵切面; **I**–**K**. 标本WSB0.3-2, **I**, **J**. 横切面, **K**. 纵切面。

A–**E**. Sample WSB0.3-1: **A**–**C**, transverse sections; **D**, **E**. longitudinal sections. **F**–**H**. Sample WSB0.3-3: **F**, **G**, transverse sections; **H**, longitudinal section. **I**–**K**. Sample WSB0.3-2: **I**, **J**, transverse sections; **K**, longitudinal section.

珊瑚的原始生活状态不同, 和州组珊瑚层中的珊瑚个体以倒伏状和无定向分布为特征, 大部分(~95%)珊瑚个体平行层面近水平保存, 少数个体垂直层面直立保存(图2-C–2-D)。这些埋藏学特征指示该珊瑚层受到了水流作用的改造再沉积形成, 但没有经历长距离的搬运磨蚀, 属于近原地珊瑚层(Parabiostromes) (Kershaw, 1994)。该剖面的珊瑚层仅由发育鳞板带和简单轴部构造的中大型单体甘肃袁氏珊瑚*Yuanophyllum kansuense*组成(图5-A), 分异度很低, 丰度很高, 这反映*Y. kansuense*具有群居生长特征。*Y. kansuense*珊瑚层属于Hill (1938)划分的具鳞板或中柱的Caniniid—Clisiophyllid动物群类型, 指示珊瑚生长在相对较浅、富氧、陆源碎屑和有机质较少的水体环境。贵州雅水地区维宪中期上司组底部也发育了原地—近原地保存的单体四射珊瑚层, 它与和州组珊瑚层具有相似的埋藏形式, 但具有不同的珊瑚属种组成, 上司组珊瑚层以具鳞板的大型单体中国贵州珊瑚*Kueichouphyllum sinense*为主(Yao *et al*., 2016)。另外, 古特提斯洋西部的爱尔兰地区也发育了维宪晚期近原地保存的

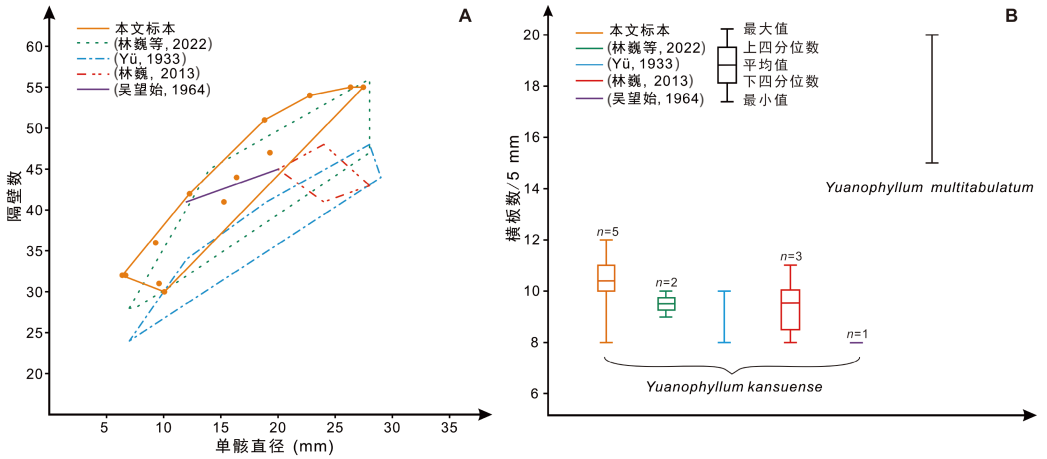


图4 *Yuanophyllum kansuense*单骸直径与隔壁数关系图(**A**)及*Y. kansuense*与 *Y. multitabulatum* 在5 mm之内横板数对比图(**B**)

Fig. 4 Corallite diameter plotted against the number of major septa for *Yuanophyllum kansuense* (**A**) and comparison of the number of tabulae per 5 mm between *Y. kansuense* and *Y. multitabulatum* (**B**)

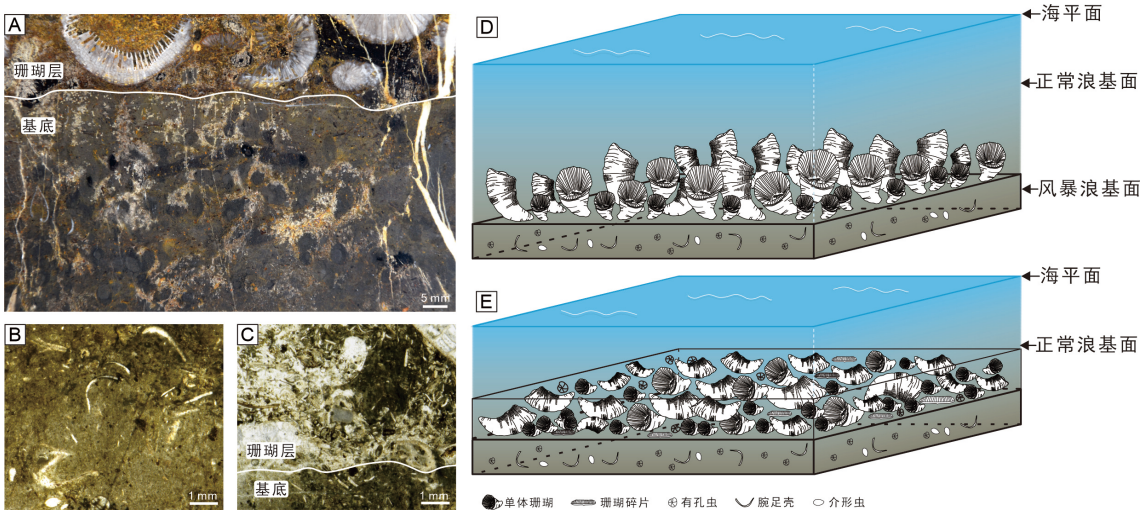


图5 和州组单体四射珊瑚层古生态特征

Fig. 5 Paleoecological characteristics of the solitary rugose coral biostrome of the Hezhou Formation

珊瑚层及基底光面照片(**A**); 基底泥粒灰岩(**B**); 基底与珊瑚层分界及珊瑚之间的泥粒—颗粒灰岩(**C**); 珊瑚生长示意图(**D**); 珊瑚保存示意图(**E**)。

Polished-slab of the coral biostrome and its substrate (**A**); Photo of thin-section showing packstone of the substrate (**B**); Photo of thin-section showing the boundary between the coral biostrome and its substrate, and the packstone and grainstone in the interspaces among the coral skeletons (**C**); Schematic diagram of coral growth (**D**); Schematic diagram of coral preservation (**E**).

四射珊瑚层, 但这些珊瑚层主要以丛状复体的丛管珊瑚*Siphonodendron*占主导, 含有少量单体四射珊瑚(Aretz *et al*., 2010; Yao *et al*., 2016)。

万山埠剖面和州组珊瑚层下部基底的微相类型为泥粒灰岩(图5-B), 生物颗粒主要包括腕足类、有孔虫、介形虫等, 生物颗粒较破碎, 分选一般, 颗粒之间以泥晶组分为主, 含有少量亮晶方解石。这些特征指示基底沉积时的水深位于正常浪基面与风暴浪基面之间, 水动力较低, 适宜珊瑚生存繁殖(图5-D)。与基底相比, 珊瑚层中的生物碎屑和亮晶方解石含量明显增加(图5-C), 这反映该时期相对海平面降低, 珊瑚层水深靠近正常浪基面, 水动力显著增强(Yao *et al*., 2016)。与复体造礁珊瑚不同, 单体四射珊瑚个体常常分离生长, 不能形成坚硬的格架来抵抗水动力扰动(Yao *et al*., 2023b)。因此, 在相对海平面降低和水动力增强的影响下, 单体四射珊瑚呈聚集倒伏状的形式保存(图5-E)。

5.3　珊瑚古地理分布

甘肃袁氏珊瑚 *Yuanophyllum kansuense*最早在我国西北地区的甘肃武威臭牛沟组中发现, 且十分丰富(Yü, 1931, 1933)。除此之外, 在青海德令哈怀头他拉组(骆金锭、赵嘉明, 1962)、新疆哈密市雅满苏组(俞建章等, 1978; Huang *et al*., 2019)、莎车县和什拉甫组(Liao and Rodríguez, 1999), 以及西藏改则县日湾茶卡组(Fan *et al*., 2003)等密西西比亚纪维宪晚期和谢尔普霍夫期的地层中均有报道。*Y. kansuense*在华南地区维宪晚期至谢尔普霍夫期的地层也被广泛发现, 如贵州雅水上司组(Lin *et al*., 2012)、湖南中部梓门桥组(范影年, 1963; 吴望始, 1964)、广西桂林罗城组(李镇梁等, 2002), 以及安徽巢湖和州组(林巍等, 2022; Yü, 1933)。

除中国之外, 该种在日本东北部北上山地维宪晚期的Onimaru组 (Minato and Rowett, 1967; Nikawa, 1983)、泰国东北部(Fontaine *et al*., 1991)、俄罗斯库兹涅茨克盆地等地区维宪期地层中也有报道(Dobrolyubova *et al*., 1966; Minato and Rowett, 1967)。然而, *Y. kansuense*在古特提斯洋西部的西欧、北非等地区没有发现, 表明该珊瑚种为古特提斯洋东部的特征分子(图6)。由于报道的*Y. kansuense*的时代缺乏精细的年代地层框架约束, 该珊瑚分子的起源与扩散路径还需进一步研究。



图6 密西西比亚纪维宪期至谢尔普霍夫期 *Yuanophyllum kansuense*的古地理分布(古地理图修改自Huang *et al*., 2018)

Fig. 6 Paleogeographical distribution of *Yuanophyllum kansuense* during the Visean to Serpukhovian of the Mississippian (map modified from Huang *et al*., 2018)

1. 研究剖面; **2**. 湖南、贵州和广西等地; **3**. 四川松潘县; **4**. 日本北上山地; **5**. 青海德令哈市和甘肃武威市; **6**. 新疆塔里木盆地; **7**. 新疆东天山; **8**. 俄罗斯库兹涅茨克盆地; **9**. 西藏改则县; **10**. 泰国东北部。图中蓝色代表仅在维宪期有记录, 红色代表可延至谢尔普霍夫期。

1. Study section; **2**. Guangxi, Guizhou and Hunan provinces; **3**. Songpan County of Sichuan Province; **4**. Kitakami mountain of Japan; **5**. Delingha City of Qinghai Province and Wuwei City of Gansu Province; **6**. Tarim Basin of Xinjiang Uygur Autonomous Region; **7**. Eastern Tianshan of Xinjiang Uygur Autonomous Region; **8**. Kuznetsk Basin of Russia; **9**. Gerze County of Xizang Autonomous Region; **10**. Northeast Thailand. In the figure, blue solid triangles represent coral records only from the Visean Stage, while red solid triangles represent coral records from the Visean to Serpukhovian stages.

6 结 论

安徽巢湖万山埠剖面和州组底部的四射珊瑚层厚度约5 cm, 横向分布数十米。通过有孔虫化石确定该珊瑚层的时代为谢尔普霍夫早期。和州组珊瑚层仅由发育鳞板带和简单轴部构造的中大型单体珊瑚*Yuanophyllum kansuense*组成。珊瑚丰度高, 个体相互支撑, 以倒伏状成层保存。*Y. kansuense*珊瑚层形成于相对海平面降低和水动力增强时期。在古地理上, 维宪晚期至谢尔普霍夫期*Y. kansuense*分布于古特提斯洋东部的低纬度地区, 尤其是在中国的华南和西北地区广泛分布。

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