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鄂西鹤峰埃迪卡拉系灯影组叠层石及其生态环境讨论

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提要:【研究目的】扬子区鄂中台地埃迪卡拉系灯影组赋存丰富的叠层石, 但尚未有报道对其进行系统描述。通过识别台地西南端鹤峰白果坪剖面灯影组中的叠层石种类、分析沉积环境, 阐述古环境对叠层石形态分布的控制, 为后续开展鄂中台地埃迪卡拉纪的叠层石研究提供参考。**【研究方法】**通过剖面测量和镜下观察, 于白果坪灯影组白云岩中识别出平直纹层、*Stratifera* 层状、微波状纹层三种层状叠层石和一种 *Baicalia* 柱状叠层石。**【研究结果】**研究认为上述的叠层石类型分别对应周期性暴露(前两种类型)、潟湖(微波状)和潮间带—潮下带上部(柱状)的生态位。对比与白果坪剖面灯影组同期叠层石的形态及分布规律, 可知形成叠层石的微生物群落强烈受控于古水深等环境条件。层状叠层石生态区间宽, 柱状及其他形态叠层石仅见于局限地区, 多样性较低。**【结论】**扬子区碳酸盐岩台地长期稳定的大范围潮坪环境造成的广泛分布浅水生态位和局限分布较深水生态位, 是导致灯影组沉积期叠层石多样性低的主要原因。

关 键 词: 埃迪卡拉系; 灯影组; 叠层石; 古环境; 浅水生态位; 地质调查工程; 鄂西

创 新 点: 识别出鄂中台地西南缘的四种叠层石种类, 分析了它们的发育环境。

中图分类号: P534.3; P588.248 **文献标志码:** A **文章编号:** 1000−3657(2024)02−0623−09

Stromatolites of the Ediacaran Dengying Formation in Hefeng, western Hubei Province and its ecological environment discussion

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Abstract: This paper is the result of geological survey engineering.

[Objective] The Ediacaran Dengying Formation in the Central−Hubei Platform of the Yangtze region hosts abundant stromatolites, yet there is a lack of systematic reports on them. This study aims to address this gap by identifying stromatolite types in the Dengying Formation at the Baiguoping section in the southwestern part of the platform. Through this, we analyze the sedimentary environment, aiming to elucidate the influence of the ancient environment on stromatolite distribution. The insights gained serve as a

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valuable reference for future research on Ediacaran stromatolites in the Central−Hubei Platform. **[Methods]** Utilizing section surveys and microscopic observations, this study identifies stratiform and columnar stromatolites in the dolostones of the Ediacaran Dengying Formation at the Baiguoping section. Stratiform stromatolites include flat−laminated, *Stratifera*, and wavy−laminated forms, columnar stromatolite see the *Baicalia* form genus. **[Results]** In the southwestern Central−Hubei Platform, these stromatolites are associated with various environments: Periodic exposure settings for the flat−laminated and *Stratifera* forms, lagoon environments for the wavy−laminated form and intertidal to upper subtidal zones for the columnar stromatolites. Published data reveals that during the deposition period of the Ediacaran Dengying Formation, stratiform stromatolites were abundant on the Yangtze Platform, meanwhile columnar and other stromatolite forms were rare, indicating limited morphological diversity. **[Conclusions]** The scarcity of stromatolite variations can be attributed to widespread shallow water niches and locally deeper water niches resulting from long−term stable tidal flat environments in the Yangtze Platform.

Key words: Ediacaran; Dengying Formation; stromatolite; paleoenvironment; shallow water niche; geological survey engineering; western Hubei Province

Highlights: Four types of stromatolites have been identified in the southwestern part of the Central−Hubei Platform, with an analysis of their developmental environments.

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1 引 言

埃迪卡拉纪华南板块扬子陆表海发育多个浅海碳酸盐台地(马永生等, 2009),向东南方向过渡为深水页岩和硅质岩相,经绍兴—宜春、衡阳—南宁断裂带与华夏古陆西侧盆地复理石相为邻(唐烽等, 2009)。鄂中台地西南缘的鄂西地区埃迪卡拉系地层序列由下部陡山沱组白云岩、黑色页岩、泥质灰岩、磷块岩(Jiang et al., 2011)和上部灯影组白云岩、灰岩(Wang et al., 1998; Zhu et al., 2003, 2007; Zhou and Xiao, 2007; Duda et al., 2016)组成。鄂中台地陡山沱组白云岩中常见层状叠层石,磷块岩中发现有 *Nucleella*、*Baicalia*、*Boxonia*、*Paraconophyton*、*Conophyton* 等形态属(陈辉能等, 1996);灯影组中纹层状白云岩非常发育并可确认存在微型叠层石(曹瑞骥和俞从流, 1991)。在相邻地区(诸如云南、四川、贵州和湖南等地)的灯影组中,叠层石等微生物岩亦被广为报道(陈孟莪, 1991; 刘树根等, 2016; 宋金民等, 2017)。除了对叠层石形态学、显微结构及古地理等研究以外,与之相关的成矿机制研究近年来也越发受到重视(张伟等, 2015)。

鄂西鹤峰白果坪剖面位于扬子区中部鄂中台地的西南端(图 1a、b),埃迪卡拉系陡山沱组和之上的灯影组出露完好。灯影组与下伏陡山沱组黑色泥岩呈整合接触,整体呈向上变浅序列,三分性明显。下段为灰白色中—厚层、块状白云岩夹砂屑白云岩,中段为黑色泥质白云岩与白云质泥岩不等厚互层,上段为灰白色中—厚层纹层状白云岩,顶部为暴露面溶蚀角砾白云岩。灯影组与上覆寒武系牛蹄塘组呈不整合接触。本文首次报道在该剖面灯影组下段和上段白云岩中发现的叠层石(图 1c),详细剖析其形态学和微相特征,并开展古环境讨论。

2 鹤峰白果坪灯影组叠层石特征

灯影组下段叠层石发现于剖面下部总厚度约 20 m 的层段内,由泥质白云岩、泥微晶白云岩与鲕粒、砂屑白云岩组成韵律层(图 2),斜层理、鱼骨状交错层理发育,表现为潮间带—潮下带上部沉积特征。可识别出 4 期宏观形态相似的叠层石,其底面略平整,顶面波状起伏,纵断面为隆起与凹陷的单调交替,隆起呈丘状、穹顶状,高 30 cm 至 50 cm 不等,形态特征显示为 *Stratifera* 属叠层石。自下而上,第 1、2、4 期叠层石纹层生长为丘状或穹顶状

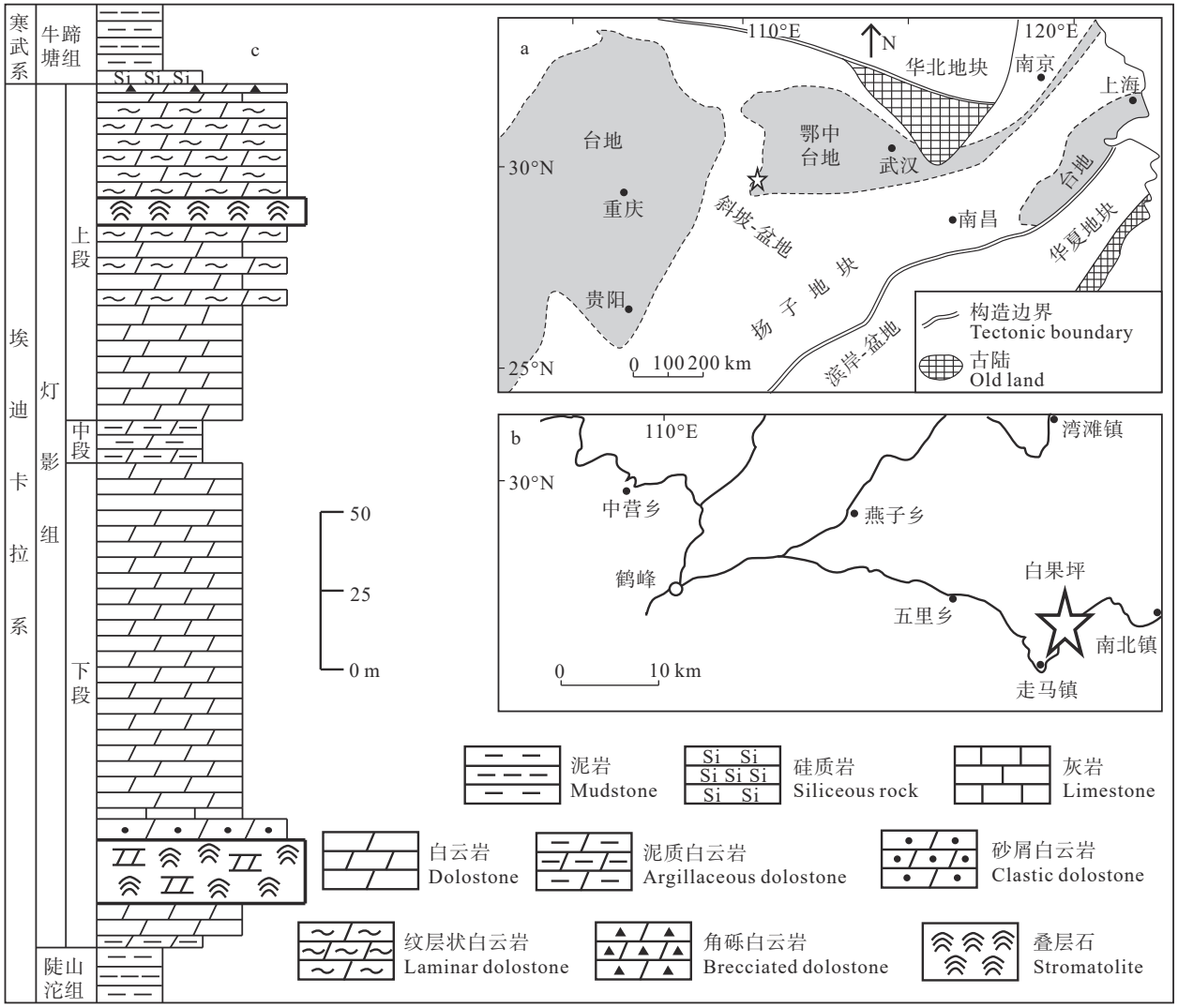

图 1　鄂西鹤峰白果坪剖面位置和埃迪卡拉系灯影组岩性序列

a—埃迪卡拉系灯影组沉积期古地理图(据马永生等, 2009 修改); b—剖面交通位置图; c—灯影组岩性柱状图

Fig.1　Location and lithological sequences of the Ediacaran Dengying Formation in the Baiguoping section of Hefeng, western Hubei

a–Paleogeographic reconstruction of the Ediacaran Dengying Formation depositional interval (modified from Ma Yongsheng et al., 2009); b–Location of the Baiguoping section; c–Lithological logging of the Dengying Formation

(图 2a), 叠层石高宽比(aspect ratio)为 1.2~1.9。而第 3 期叠层石纹层开始生长时略呈席状, 向上生长呈小型丘状(图 2b), 高宽比低(仅为 0.8~1.3)。

灯影组下段叠层石见 3 类纹层: (1)微晶白云石暗色层和粉晶白云石亮色层, 亮色层中含大量砂屑和藻团粒(图 3a), 见于第 1、2、4 期和第 3 期下部; (2)硅质暗色层和粉晶白云石亮色层(图 3b), 暗色层显似藻黏结结构(图 3c), 这种现象在 4 期叠层体中均有显示; (3)由藻席叠置生长形成的藻黏结纹层, 分层不明显, 单层顶部的相对较暗层为藻席生长表面, 内部黏结藻团粒、砂屑等颗粒, 可见藻黏结结构(图 3d, e), 仅见于第 3 期上部。叠层体隆起间均充填白云岩砂屑, 砂屑内部重结晶程度不一, 部分内部完全重结晶呈细晶—中晶状, 边缘具泥晶套, 部分见藻黏结结构(图 3f), 推测为藻席来源。

灯影组上段叠层石赋存层厚约 8 m。下部 7 m 为零星露头出露, 宏观特征与灯影组下段的穹窿状、丘状叠层石相似, 亦可识别为 *Stratifera*。从距该层顶部约 1 m 处开始, 叠层体发育为柱状, 分叉, 基部收缩, 向上变大, 高宽比为 1.3~2.2。柱体表面层理叠复, 可与另一柱体相连, 纹层间见有泥质白云岩充填物, 呈不规则透镜状, 柱体直径几厘米至

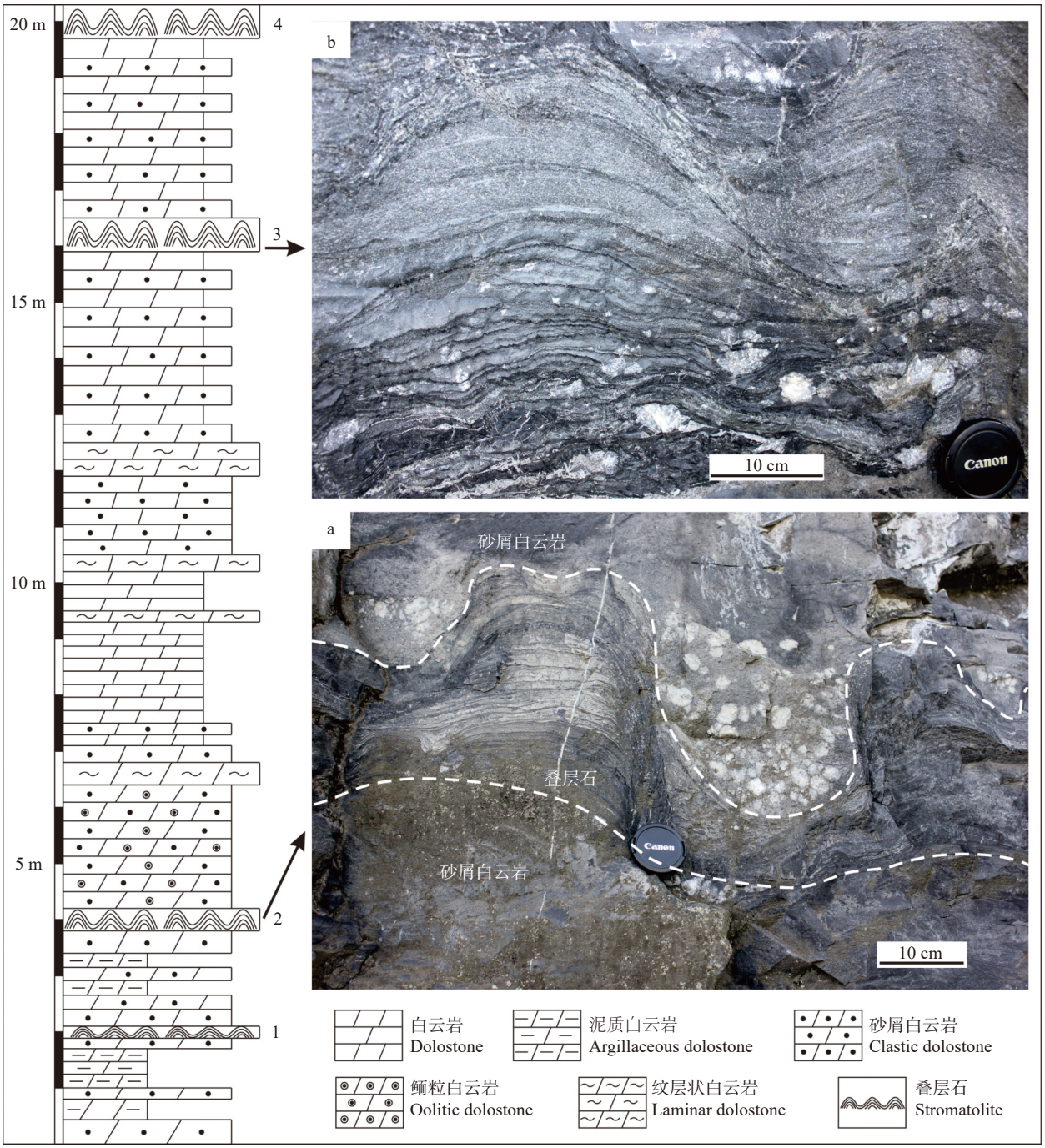

图 2 白果坪剖面灯影组下部白云岩中的叠层石层位和形态学

a—第 2 期穹顶状叠层体; b—第 3 期叠层体从席状—丘状的形态学变化

Fig.2 Occurrence horizons and morphology of the stromatolites from the dolomites, Lower Member of the Dengying Formation in the Baiguoping section

a–Dome–shape stromatolites of the Stage 2; b–Morphological change of the stromatolites from original mat–shape to dome–shape upward in the Stage 3

十几厘米不等(图 4a、b), 横断面呈圆形、近椭圆形, 柱体间紧密排列(图 4c、d), 可归为 *Baicalia* 形态属。其纹层由微晶白云石暗层和粉晶白云石亮层组成(图 4e), 局部暗层可见藻黏结结构(图 4f)。

除上述 *Stratifera* 和 *Baicalia* 叠层石之外, 白果坪剖面灯影组纹层状白云岩非常发育, 白云岩厚度

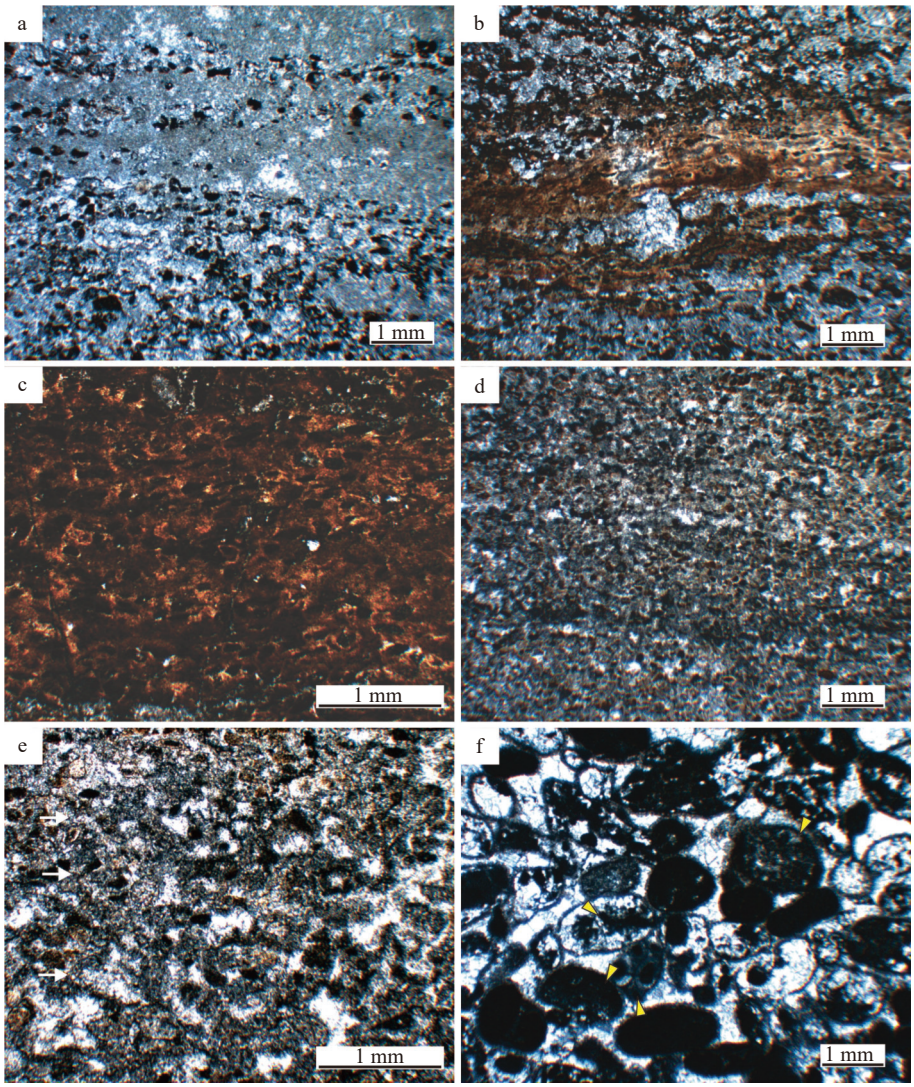

图 3　白果坪剖面灯影组下段 *Stratifera* 叠层石微相

a—微晶白云石暗色层和粉晶白云石亮色层; b—硅质暗色层和粉晶亮色层; c—硅质暗色层略显藻黏结结构; d—藻黏结层; e—藻黏结结构; f—叠层体穹窿间的砂屑白云岩, 砂屑可见藻黏结结构(黄色箭头)

Fig.3　Microfacies of the *Stratifera* from the Lower Member of the Dengying Formation in the Baiguoping section

a–Micritic crystal dark layers and recrystallized bright layers; b–Siliceous dark layers and recrystallized bright layers; c–Blurry microbial bound structure of the siliceous dark layer; d–Microbial bound layers; e–Microbial bound structures; f–Microbial bound structures of the intraclastic dolostones enclave in the stromatolite domes

一般十几厘米至几十米不等, 层理平直(图 5a)或微起伏(图 5b), 难以进一步厘定其形态属, 本文简称为平直纹层叠层石和微起伏纹层叠层石。平直纹层叠层石主要出现于灯影组下部和上部, 以上部最常见。其特征表现为近水平的平直纹层状构造, 单层 0.3~0.8 cm 厚, 微相显示为无纹层的粉—细晶白云岩。微起伏纹层叠层石主要见于中部, 层段内透镜体或条带均由其组成, 以不规则纹层为特征, 单层厚 0.4~1.1 cm。微相显示为不连续层, 由具藻黏结结构的暗色层和粉—细晶白云石亮色层组成(图 5c), 可见大藻团块生长于层理间(图 5d)。

3　讨　论

介于新元古代晚期冰期(Marinoan glaciation)与寒武纪生命大爆发之间的埃迪卡拉纪广泛发育宏体藻类(唐烽等, 2008; 袁训来等, 2016)、刺饰疑源类和埃迪卡拉型动物(Xiao and Laflamme, 2009), 标志着前寒武纪“微生物世界”向“多细胞真核生物

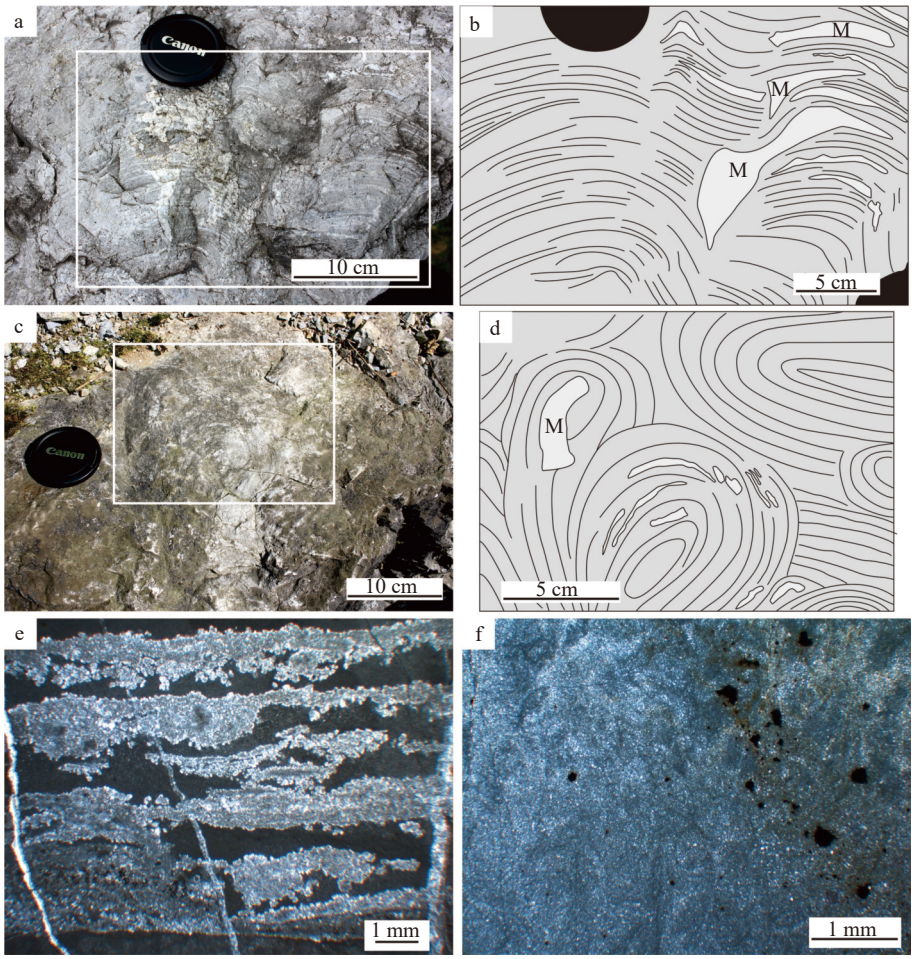

图 4 白果坪剖面灯影组上段 *Baicalia* 叠层石

a, b—*Baicalia* 叠层石纵面露头和素描 (M: Argillaceous micrite); c, d—*Baicalia* 叠层石露头顶视和素描; e—泥晶白云石暗色层和微粉晶亮色层; f—藻黏结结构

Fig.4 The *Baicalia* stromatolite from Upper Member of the Dengying Formation in the Baiguoping section

a, b–Longitudinal view of the *Baicalia* from the outcrop and its sketch (M: Argillaceous micrite); c, d–Top view of the *Baicalia* from the outcrop and its sketch; e–Micritic dark layers and powder crystal bright layers; f–Microbial bound structures

世界”的转变(Kennedy, 2013)。微生物群落聚合胶结作用形成的微生物席仍在海洋环境中占据主要的生态位,多数埃迪卡拉型生物也与其相伴生(Meyer et al., 2014)。叠层石为微生物在生长和新陈代谢活动过程中黏附和沉淀矿物质或捕获矿物颗粒形成的生物沉积构造(Walter, 1976),是微生物席生长和生理活动的结果。最近的定量化研究表明,叠层石丰度似乎在埃迪卡拉纪降到了整个新元古代的最低水平(Peters et al., 2017),然而,扬子碳酸盐岩台地上埃迪卡拉纪的叠层石仍然丰富。陈孟莪(1991)综述贵州息烽—开阳、湖南石门、湖北荆襄、云南东川等地的埃迪卡拉纪叠层石,包括 *Baicalia*、*Boxonia*、*Collenia*、*Cryptozoon* 等多个形态属;赵东旭(1992)描绘重庆城口陡山沱组中的锰质叠层石;曹瑞骥和袁训来(2006)记录浙江江山等地西峰寺组磷矿中的 *Conophyton*、*Jacutophyton* 和 *Linella*;川西叠层石存在于露头和钻井剖面(王文之等, 2016; 刘树根等, 2016; 宋金民等, 2017; Li et al., 2021; 罗垚等, 2022; 李安鹏等, 2023; Zhou and Li, 2023)。上述反差可能是扬子台地当时广泛发育的浅水环境的反映,其有利于叠层石的生长。

湖北鹤峰埃迪卡拉系灯影组以层状叠层石为主体,又以平直纹层叠层石和微起伏纹层叠层石占大多数,具明显隆起形态的层状叠层石(*Stratifera* 形态属)和柱状叠层石仅赋存于局限层位。*Stratifera* 形态属层状叠层石可见明显藻黏结结构,显示其微

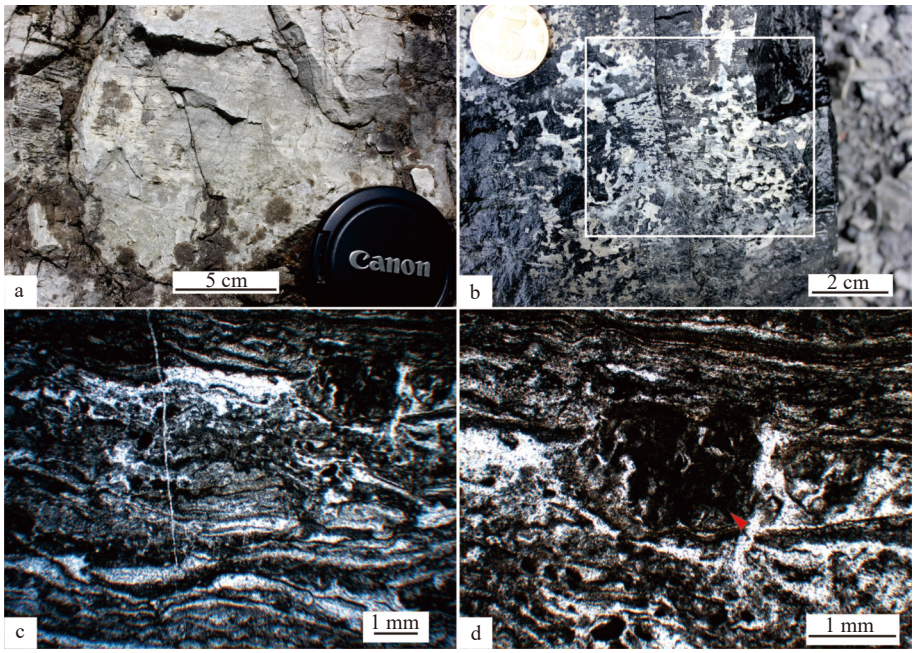

图 5　白果坪剖面灯影组白云岩纹层和微生物结构

a—席状纹层叠层石露头; b—小波状纹层叠层石(方框); c, d—小波状纹层叠层石微相, c 显示藻黏结暗色层和粉—细晶白云石亮色层, d 为纹层中的藻团块(红色箭头)

Fig.5　Dolomitic laminae and microbial structures of the Dengying Formation in the Baiguoping section

a–Outcrop of the mat−shape laminar stromalite; b–Minor wave−shape laminar stromatolite (square); c, d–Microfacies of the minor wave−shape laminar stromatolite; photograph c showing microbial bound dark layers and powder−fine crystal light layers, photograph d showing microbial peloids (red arrow) within laminar

生物席发育特征。平直纹层和微起伏纹层叠层石因白云岩化可改变原始藻席结构, 但仍可归于微生物席成因。柱状叠层石微观形态与层状叠层石接近, 但建席群落可能不同。张昀和 Copper(1993)、曹瑞骥和袁训来(2006)分别研究北美古元古代冈费林特组和华南新元古代九顶山组叠层石的内部微生物群落组成, 显示层状叠层石主要由球状菌藻类为主的群落组成, 而柱状叠层石主要为丝状菌藻类群落。

层状叠层石在扬子台地灯影组沉积期地层中非常常见, 主要以纹层状白云岩记录于各个已报道的灯影组剖面和区域地质调查报告中(王文之等, 2016; 刘树根等, 2016; 宋金民等, 2017), 显示为该沉积期的特征沉积现象之一, 其中以平直纹层叠层石为最, *Stratifera* 属和微波状纹层叠层石相对较少。Awramik(1984)认为 *Stratifera* 属生长于周期性暴露的环境下, 此推论也适合于平直纹层叠层石。鹤峰白果坪灯影组下部白云岩中的 *Stratifera* 叠层石、泥质、泥微晶白云岩与砂屑白云岩组成韵律层, 反映了该地区潮坪带水体在不同能量条件下的周期性变化, 平直纹层叠层石则代表长期稳定的潮坪环境。与之相反, 微波状纹层叠层石形成水深可能相对较深且能量较为动荡(Kuang et al., 2019)。Duda et al.(2016)在阐述宜昌地区灯影组中部石板滩段黑色灰岩时, 以局限的分布范围, 分析其为台内盆地沉积产物。鹤峰地区灯影组中部黑色白云岩与之相似, 分布也局限于鹤峰—石门一带(Zhu et al., 2003), 但因其为泥质白云岩与白云质泥岩的不等厚互层, 很可能处于潟湖环境, 相似的岩性和沉积特征表明白果坪剖面的微波状纹层叠层石生长环境与之类似。

鹤峰白果坪剖面的柱状叠层石较为少见。曹瑞骥和赵文杰(1978)记录遵义松林灯影组中同样有 *Baicalia* 发育, 浙江江山则见有 *Jacutophyton* 和 *Linella* 生长, 江山—上饶一带有锥状叠层石 *Conophyton* 与 *Jacutophyton* 相伴生(曹瑞骥和袁训来, 2006; 乔丹等, 2019)。Walter (1976)论述元古宙叠层石形态与古环境之关系, 锥状叠层石限制在潮下带, 是盆地或斜坡环境(代表透光带下限, 水深 200 m 以内)的优势分子; 柱状叠层石则出现在比该生态

位更浅的环境。总体而言，扬子台地长期稳定，以大范围潮坪环境贯穿整个灯影组沉积期，台地浅水适合层状叠层石生长，利于柱状等其他形态叠层石生长的相对深水生态位较少，这可能是该时期扬子台地具有较低叠层石分异度的原因。

4 结 论

湖北鹤峰埃迪卡拉系灯影组纹层状白云岩中频繁发育微生物岩，可识别出 *Stratifera* 层状、平直纹层、微波状纹层三种层状叠层石和一种 *Baicalia* 柱状叠层石，平直纹层叠层石最多，*Stratifera* 主要见于灯影组下部，微波状纹层叠层石赋存于中部，柱状叠层石发现于近顶部，不同类型叠层石的纵向更替主要受控于古水深及相对海平面变化。*Stratifera* 和平直纹层叠层石指示周期性暴露的古环境特征，微波状纹层叠层石生长于潟湖，柱状叠层石集中于潮间带—潮下带上部。层状叠层石是扬子台地灯影组沉积期最为常见的叠层石类型，它得益于台地长期维持稳定大潮坪环境。较深水生态位相对较少不利于柱状等其他形态叠层石生长，造成了该时期台地上较低的叠层石分异度。

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