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宜昌界岭地区 Tremadocian 早期微生物成因构造的发现

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提要:【研究目的】微生物成因构造(MISS)是国际研究热点之一。中国地质学家较多关注前寒武纪的MISS, 而较少研究其他时期的该类构造。奥陶纪早期微生物的繁盛是全球性的, 但MISS此前仅见于法国和加拿大纽芬兰等地的浅水碎屑岩, 中国目前尚无报道。**【研究方法】**通过野外调查和剖面测量, 本文首次在宜昌界岭地区早奥陶世Tremadocian早期地层(南津关组上部)中发现微生物成因构造。**【研究结果】**宜昌界岭地区的微生物成因构造主要为微生物席生长构造和微生物席破坏构造。其中值得注意的是, 微生物席破坏构造与广泛发育于前寒武纪的臼齿构造形态上具有相似性。**【结论】**该MISS的发现, 不仅丰富了全球含MISS的地层单元, 也对显生宙微生物岩研究具有重要理论意义。这一发现也是对宜昌市地质遗迹的重要补充。

关　键　词: 微生物成因构造; Tremadocian早期; 地质遗迹; 南津关组; 地质调查工程; 宜昌; 湖北

创　新　点: 首次识别出宜昌地区早奥陶世微生物成因构造, 其中微生物席破坏构造与臼齿构造形态上具有相似性。

中图分类号: Q911.6　　**文献标志码:** A　　**文章编号:** 1000−3657(2024)05−1727−08

Discovery of microbially induced sedimentary structures of Early Tremadocian in Jieling area, Yichang, Hubei Province

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

[Objective] Microbially induced sedimentary structures (MISS), one of the international research hotspots, have been paid more attentions in Precambrian rather than other period in China. Microbials flourished globally in the Early Ordovician. However, the MISS was found in the shallow water clastic rocks in France and Newfoundland of Canada, but not yet reported in China. **[Methods]**

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Here, we first discovered the MISS at the upper Nantsinkuan Formation of Early Tremadocian of Early Ordovician in Jieling area, Yichang, Hubei Province. **[Results]** The MISS at Jieling contained microbial mat growth features and microbial mat destruction features. It is noteworthy that the microbial mat destruction features are morphologically similar to the molar tooth that widely developed in Precambrian. **[Conclusions]** The discovery of the MISS in Jieling not only enriches the global MISS−bearing stratigraphic units, but also has important theoretical significance for the study of Phanerozoic microbialites. Moreover, it is an important supplement to the geological relics of Yichang City.

Key words: Microbially induced sedimentary structures (MISS); Early Tremadocian; geological relics; Nantsinkuan Formation; geological survey engineering; Yichang City; Hubei Province

Highlights: The microbially induced sedimentary structures from Early Ordovician in Yichang area was first identified. The microbial mat destruction features are morphologically similar to the molar tooth.

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1　引　言

微生物岩及微生物成因构造一直是国际上研究的热点(Schieber, 2007; 史晓颖等, 2008a, b; 刘治成等, 2015; 梅冥相等, 2014, 2019; 余聪等, 2015; 王文之等, 2016; Sarkar et al., 2016; Chu et al., 2017; Xu et al., 2017; 邢智峰等, 2020; Bayet−Goll and Daraei, 2020; Bayet−Goll et al., 2021; 李姐等, 2022; 谢树成等, 2023; El Kabouri et al., 2023)。奥陶纪生物大辐射初期的特马豆克期(Tremadocian)又是微生物造礁向后生动物造礁转变的关键时期(詹仁斌等, 2013),因此 Tremadocian 期的微生物礁一直备受学者的瞩目(朱忠德等, 1990; 曹隽等, 2009; 肖传桃等, 2016; Zhang et al., 2016)。然而,与大量的早奥陶世微生物岩研究形成鲜明对照的是,微生物成因构造仅在零星几个地点有所发现(Noffke, 2000; Harazim et al., 2013; Hints et al., 2014),中国目前尚未见报道。

微生物成因构造(Microbially Induced Sedimentary Structures,简称 MISS)是微生物群与沉积环境相互作用,并通过微生物生命代谢、生长、破坏、腐烂等过程在沉积物中留下的各种生物−沉积构造(Schieber, 2004)。这些沉积构造由于不是突出于地层的正向生长构造而有别于叠层石。Schieber (2007)根据微生物席生命发展过程的不同阶段形成的构造,把 MISS 分为五大类:微生物席生长构造、微生物席代谢构造、微生物席破坏构造、微生物席腐烂构造和微生物席成岩构造。

笔者在中扬子地区进行中国地质调查局项目的野外地质调查过程中,首次在湖北宜昌界岭地区早奥陶世 Tremadocian 早期地层(南津关组)发现丰富的 MISS,对于显生宙的微生物岩研究具有重要理论意义,同时也是对宜昌市地质遗迹的重要补充。

2　区域地质概况

界岭地区位于湖北省西部,在大地构造位置上属于中扬子地台。研究区奥陶系三统齐全,地层序列与大坪阶“金钉子”剖面——黄花场剖面一致。奥陶系下统自下而上大致包括西陵峡组、南津关组、分乡组和红花园组,中统大致包括大湾组和牯牛潭组,上统包括庙坡组、宝塔组、临湘组和五峰组(汪啸风等, 1987)。本区奥陶系以碳酸盐岩为主,间夹页岩或钙质页岩。在区域构造上,研究区奥陶系围绕黄陵背斜周缘分布(图 1)。

本次发现的 MISS 见于南津关组上部(图 1)。南津关组在黄陵背斜东翼南厚北薄,宜昌南津关一带厚 100 m,至界岭一带递减为 80 m,大致可分为 3 段。第一段(O_1n^1)为浅—深灰色中—厚层弱白云石化生物碎屑灰岩、含生屑砂屑灰岩,夹少量黄绿色页岩;第二段(O_1n^2)为灰白色中—厚层细—粉晶白云岩、含砾砂屑白云岩,鸟眼构造发育;第三段(O_1n^3)为浅灰—灰色中—厚层亮晶砾屑砂屑灰岩、含生屑泥晶灰岩、泥晶灰岩,含黑色燧石条带或结核。南津关组的大化石较为丰富,但几乎都产在第

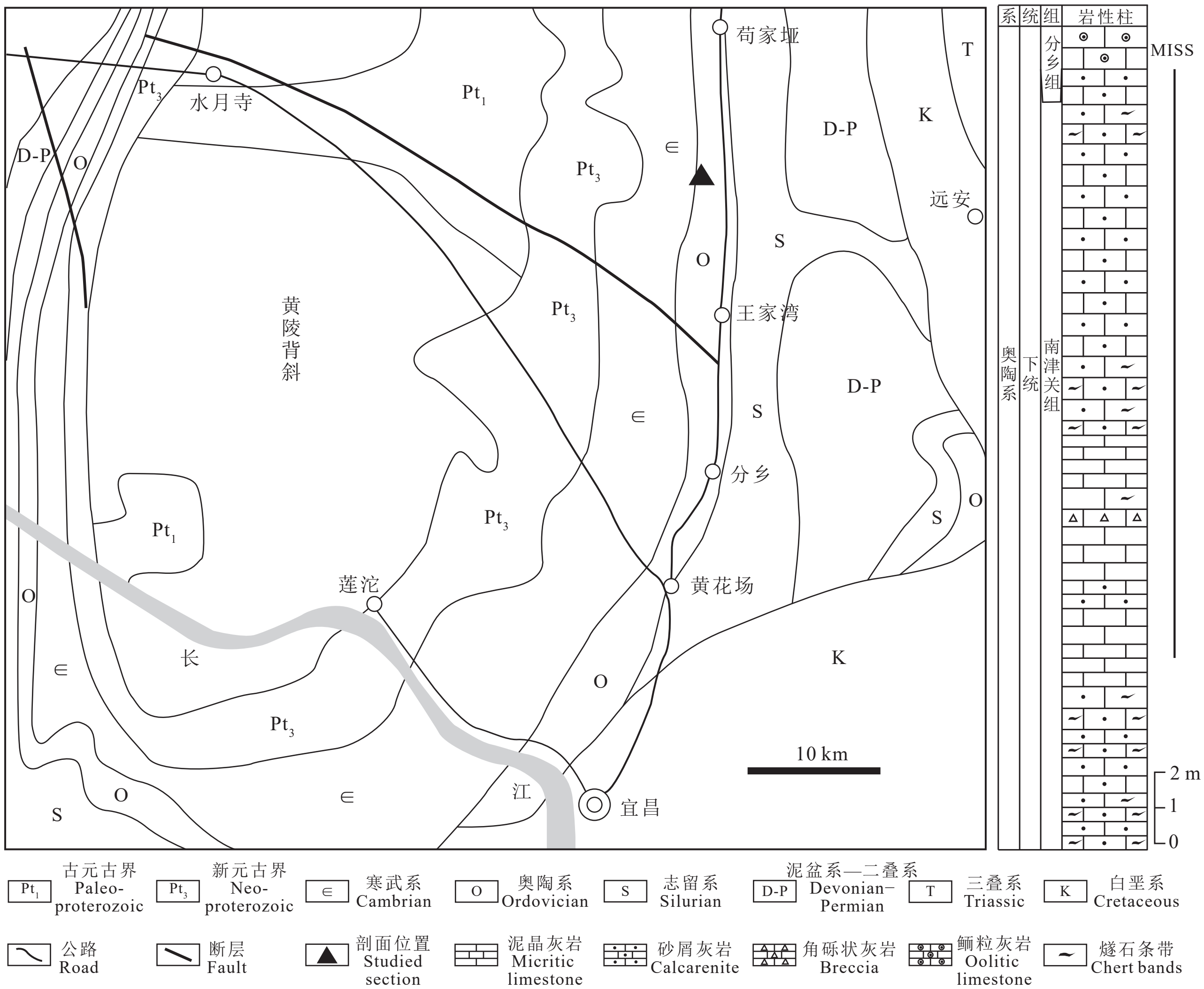

图 1 宜昌界岭地区地质简图及南津关组上部地层剖面图
Fig.1 Geological map and lithostratigraphic logging of the Upper Nantsinkuan Formation at Jieling, Yichang

一段，见三叶虫 *Asaphellus inflatus*, *Dactylocephalus dactyloides*, *Asaphopsisimmanis*，笔石 *Dictyonema*? *yichangense*, *D.*? *ramosum*, *D.*? *huanghuaense* 及腕足类 *Tritoechiaabnormis* 等(汪啸风等, 1987)。其时代属于 Tremadocian 早期。

3 南津关组微生物成因构造

宜昌界岭的早奥陶世碳酸盐岩发育丰富的微生物岩及微生物成因构造。南津关组灰岩中发育的微生物岩包括凝块石和叠层石，其中以凝块石为主，可形成高 0.4 m、宽 1 m 的丘状建隆(图 2a)；叠层石少见，呈孤立出现，在横断面上显示出良好的同心环结构(图 2b)。

界岭地区发现的 MISS 主要为微生物席生长构造和微生物席破坏构造(图 3)，尚未发现与微生物席新陈代谢、腐烂分解相关的构造。

3.1 微生物席生长构造

微生物席生长构造是微生物席发育过程中由于微生物群落活动和生长方式、速率发生变化而在席表形成的各种构造。在层面上它们常常表现为微瘤状、簇状和刺状突起以及网状生长脊(史晓颖等, 2008a)。南津关组发现的微生物席生长构造主要为不规则网状生长脊，由细小灰泥脊交互形成不规则多边形结构(图 3a、b、c)：脊宽 1~5 mm，突出层面 1~3 mm，网孔小于 9 cm。网状生长脊在现代砂质潮坪发育的微生物席表面常见(Gerdes et al.,

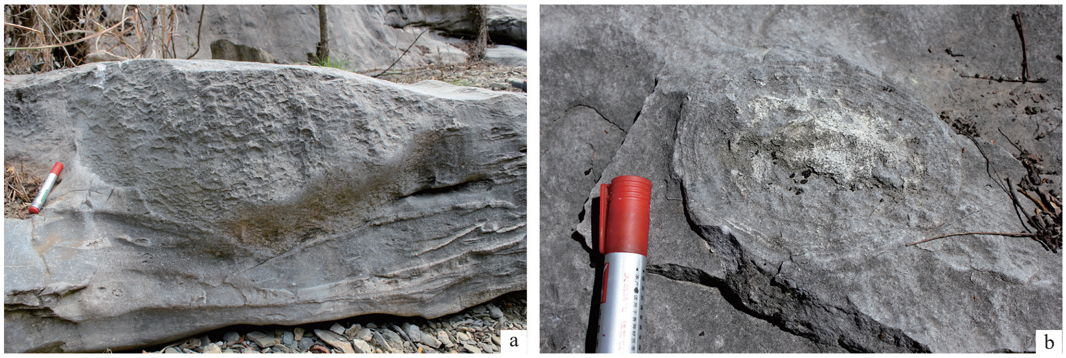

图 2 宜昌界岭南津关组灰岩中的微生物岩(a—凝块石;b—叠层石)
Fig.2 Microbialites in the Nantsinkuan Formation in Jieling, Yichang (a–Thrombolite; b–Stromatolite)

2000; Banerjee and Jeevankumar, 2005),网孔大小与微生物席发育的成熟状态有关,发育的时间越长,形成的网孔越小。

3.2 微生物席破坏构造

微生物席破坏构造是由于微生物席遭受物理性破坏而发生破裂、卷曲、变形、褶皱或被搬运再沉积而形成的一系列相关构造。在前寒武纪硅质碎屑岩沉积地层中,这类构造最为丰富,最常见的构造包括各种形态的脱水裂痕、卷边裂痕、席片、席卷和部分微皱痕构造(史晓颖等, 2008a)。在南津关组灰岩层面上识别的微生物席破坏构造主要为脱水裂痕(图 3d、e、f),呈丝带状和斑点状两种形态。大多数丝带状脱水裂痕相互独立分布,少数穿插表现出多次叠加:裂痕一般长 1~10 cm,宽 2~6 mm,层内可见高 3~7 mm,不穿刺层面。斑点状脱水裂痕为小椭球状,分布稀疏。

4 讨 论

微生物席是微生物群落响应环境变化而形成于水体/沉积界面附近的层状构造。现代微生物席几乎发育于各种环境,从深海到内陆沙漠、蒸发盐坪到湖沼湿地、高热温泉到南极冰海均有出现(Schieber, 2007)。目前在地层记录中报道的大部分 MISS,特别是微生物席生长和破坏构造,主要发育于潮间带上部至潮上带下部(史晓颖等, 2008a)。

一般认为 MISS 主要集中在前寒武纪;显生宙除生物危机期和特殊环境背景下发育少量 MISS 外(如 P–T 界线, Chu et al., 2017),在底栖动物发育的正常环境中非常少见(史晓颖等, 2008a)。Davies et al.(2016)通过统计全球含 MISS 地层单元的数据分析表明,显生宙时期发育的 MISS 要多于前寒武纪,占比可高达地层记录的 60%(图 4)。

扬子区早奥陶世特马豆克期是微生物造礁向后生动物造礁转变的时期,由此形成的新生态域对奥陶纪生物大辐射起到了重要的促进作用(詹仁斌等, 2013)。湖北松滋刘家场地区南津关组下部发现的 Pelmatozoan 生物礁,表明继中寒武世古杯点礁衰亡之后,后生动物第一次恢复造礁的时间是 Tremadocian 早期(肖传桃等, 2016)。可能正是由于后生动物的滤食消耗和生物礁的阻断,导致了奥陶纪微生物席的发育极为局限。迄今为止,仅在法国(Noffke, 2000)和加拿大纽芬兰(Harazim et al., 2013)的奥陶纪浅水碎屑岩中发现 MISS,在爱沙尼亚的奥陶纪深水黑色页岩(Hints et al., 2014)中发现微生物席。因此,在宜昌界岭地区发现奥陶纪 MISS,无疑是对全球含 MISS 地层单元的重要补充,对于显生宙的微生物岩研究具有重要理论意义。

值得注意的是,本次发现的脱水裂痕构造,与广泛发育于前寒武纪细粒碳酸盐中的“臼齿状构造”形态上较为一致(梅冥相, 2007)。但臼齿构造的发育时限往往严格局限在新太古代至新元古代,在显生宙没有发育迹象(王水炯和黄慧, 2009)。目前臼齿构造成因尚有很多争议,主要观点有:蒸发岩构造、脱水收缩作用、生物成因、地震作用、气体膨胀和运移以及风暴成因等(黄秀等, 2010; 旷红伟等, 2011; 杨宝忠等, 2019)。其中,地震成因和生物成因是当前比较流行的两种解释(王水炯和黄慧, 2009; 王振涛和李现根, 2020)。考虑到界岭地区奥陶系缺乏同沉积断裂等常见的地震标志,同时发育

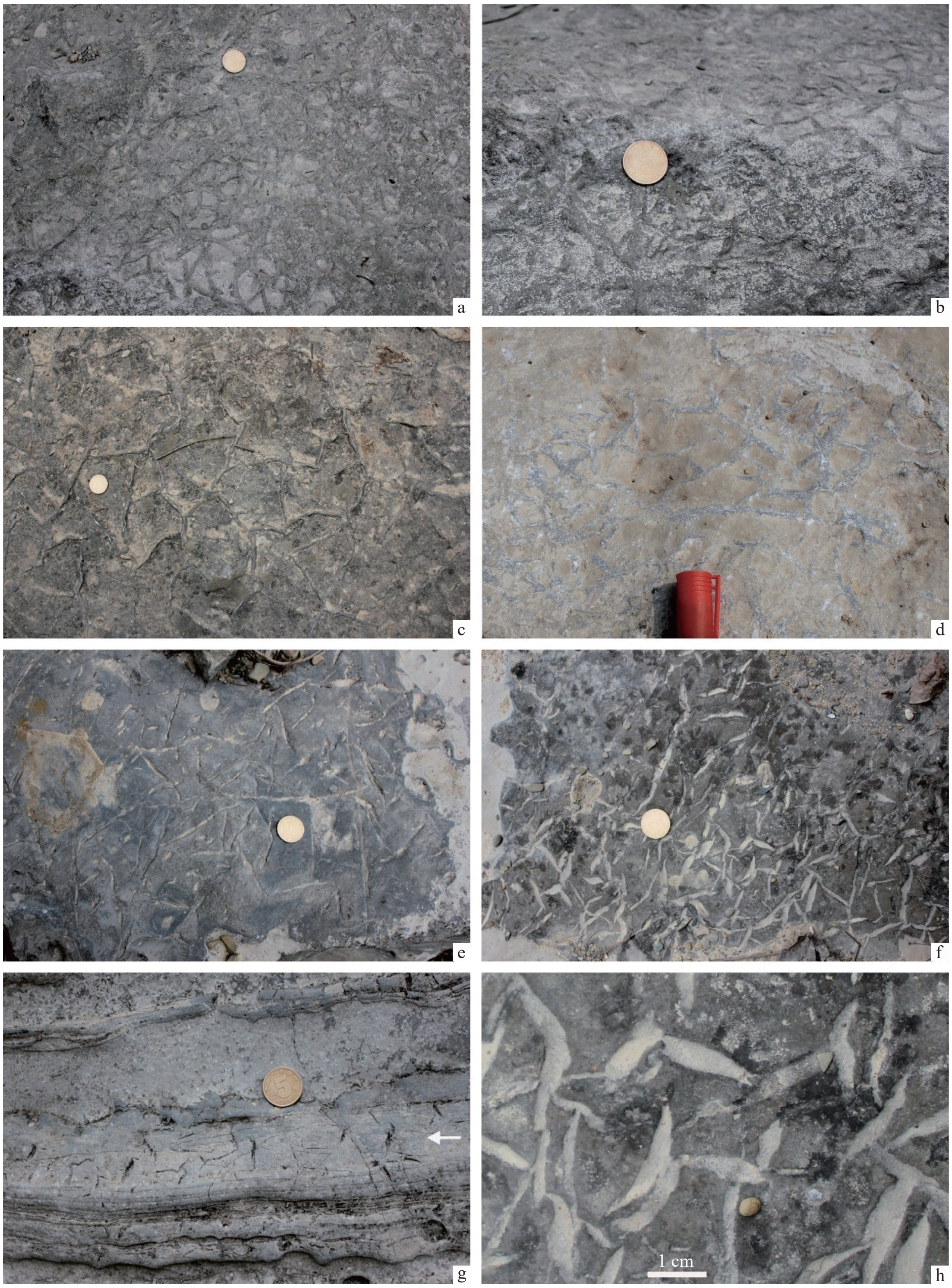

图 3 宜昌界岭南津关组灰岩中的微生物席生长和破坏构造

a、c、d—微生物席表面的不规则网状生长脊; b—微生物席网状生长脊的断面形态; e、f—灰岩层面的微生物席脱水裂痕; g—微生物席脱水裂痕的断面形态; h—f 的局部放大

Fig.3 Mat growth and destruction structures in the Nantsinkuan Formation in Jieling, Yichang

a, c, d–Irregular net−like growth ridges on the surface of the microbial mat; b–Sectional morphology of the net−like growth ridges of the microbial mat; e, f–Dehydration cracks of the microbial mat on the limestone bed; g–Sectional morphology of the dehydration cracks of the microbial mat; h–Partial enlargement of f

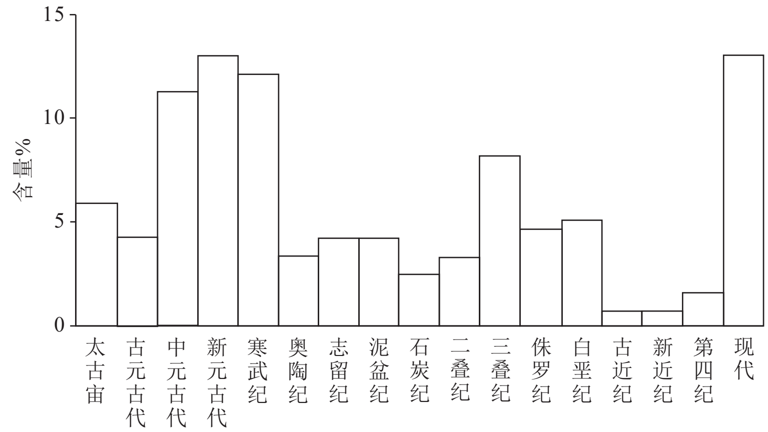

图 4 全球地层记录中的 MISS 时代分布(据 Davies et al., 2016)
Fig.4 Distribution of reported MISS in the global stratigraphic records (after Davies et al., 2016)

典型的微生物岩,因此笔者认为研究区该类构造应归于生物成因。

5 结 论

(1)宜昌界岭地区早奥陶世 Tremadocian 早期南津关组上部发育的微生物成因构造,主要为微生物席生长构造和微生物席破坏构造。

(2)研究区发育的微生物席破坏构造与前寒武纪广泛发育的臼齿构造形态上相似。

(3)研究区 MISS 的发现,不仅丰富了全球含 MISS 的地层单元,也对显生宙微生物岩研究具有重要理论意义,同时也是对宜昌市地质遗迹的重要补充。

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