

贵州剑河寒武纪杷榔动物群中的海绵化石组合^{*}

王秋军 彭进^{**} 文荣琴 刘帅 王德智

(贵州大学资源与环境工程学院和贵州省古生物研究中心, 贵阳 550025, gzpengjin@126.com)

提要 贵州寒武纪杷榔动物群的海绵动物是近年在剑河辣子寨村发现的新类群。辣子寨剖面的海绵动物组合多样性高,化石保存好。经鉴定有普通海绵纲细丝海绵科的 *Leptomitrus tereticusculus* Chen *et al.*, 1989, *Leptomitrus* cf. *L. conicus* García-Bellido *et al.*, 2007 和 *Paraleptomitella* sp., 斗篷海绵科的 *Choiaella* cf. *C. ovata* Zhao and Yang in Yang *et al.*, 2003 和 *Choia* sp.; 六射海绵纲的 *Saetaspongia* sp., 计有 5 属 6 种和一些属种待定的海绵化石。剑河辣子寨村杷榔组海绵类群的发现丰富了杷榔动物群的组成面貌,扩展了寒武纪第四期海绵动物的古地理分布区,增加了寒武纪第四期海绵动物分异演化的信息,为海绵动物分类学、古生态学和埋藏学研究提供了新材料。

关键词 海绵 杷榔动物群 杷榔组 寒武系 贵州

1 前言

贵州东部寒武系发育,保存有丰富的古生物化石。2004 年凯里市第四中学巫宜山老师和学生们在凯里市西北郊的翁岭塘进行科普活动时,发现了棘皮动物的始海百合和三叶虫共同保存的化石标本,经贵州大学赵元龙教授考查后确认层位是杷榔组。随后,贵州大学赵元龙、彭进等在凯里市西北郊的杷榔组采集了化石、进行鉴定研究,确认杷榔组中上部存在一个新的布尔吉斯页岩型化石组合,命名为杷榔动物群(Peng *et al.*, 2005)。杷榔组在贵州东部分布广泛,2005 年起贵州大学研究团队对这一区域的杷榔组开展了大量的野外工作,十多年来先后发现了该动物群的 9 个产地(Peng *et al.*, 2005, 2010, 2012a, b, c; 彭进等, 2006, 2010; 达扬等, 2011; 马海涛等, 2011; 赵元龙等, 2015; 申震等, 2016), 采集到大量的化石标本。杷榔动物群是继凯里生物群之后在贵州东部乃至湖南西部地区发现的又一个较深水相区布尔吉斯页岩型生物群(Peng *et al.*, 2010, 2012a, 2016; Liu and Lei, 2013)。

杷榔动物群不同产地的生物类群组成有较明显的差异,其中以凯里的翁岭塘和菩萨寨、台江的革一、剑河的交榜和辣子寨以及镇远的江古的化石类群较丰富(Peng *et al.*, 2005; 彭进等, 2007; 彭进, 2009; 秦琴等, 2010)。2014 年在剑河辣子寨剖面杷榔组发现了杷榔动物群。化石采集整理后,发现该产地为杷榔动物群类群组成最丰富的产地(申震等, 2016; 刘帅等, 2017; 文荣琴等, 2017), 不仅产有棘皮动物、节肢动物、腕足动物、蠕虫动物、软舌螺类、刺胞动物、开腔骨类, 2015 年起还发现了一新类群——海绵动物。连续几年的发掘及化石标本整理,经鉴定海绵类有普通海绵纲细丝海绵科的 *Leptomitrus tereticusculus* Chen *et al.*, 1989, *Leptomitrus* cf. *L. conicus* García-Bellido *et al.*, 2007 和 *Paraleptomitella* sp., 斗篷海绵科的 *Choia* sp. 和 *Choiaella* cf. *C. ovata* Zhao and Yang in Yang *et al.*, 2003, 六射海绵纲的 *Saetaspongia* sp., 约 5 属 6 种以及其他分类位置待定的海绵化石。该产地的海绵化石保存好,以海绵体为主,分散保存的骨针少;一些海绵保存有矿物薄膜、碳质薄膜及黄铁矿化等特征,表明这些海绵化石有较好的埋藏条件(刘帅

收稿日期:2018-05-08

^{*} 国家自然科学基金(41672005, 41172005, 4133101)、国家重点基础研究发展规划项目(973 项目)(2013CB835002, 2015FY310100-5)、贵州省古生物研究中心建设基金(黔科合计 Z 字[2014]4003 号)、贵州省科技计划项目(黔科合平台人才[2017]5788 号)和贵州大学引进人才科研项目(贵大人基合字[2015]35 号)联合资助。

^{**} 通讯作者:彭进,教授,主要从事寒武纪古生物学与地层学研究。

等, 2017)。剑河辣子寨杷榔组海绵化石的发现, 不仅丰富了杷榔动物群的组成面貌, 而且扩展了海绵动物的古地理分布区, 增加了寒武纪第四期海绵动物分异演化的信息, 为海绵动物分类学、古生态学和埋藏学研究提供了新材料。

2 地质背景

贵州寒武系沉积区可分为扬子区、江南过渡区、江南盆地区。杷榔组主要分布在地处江南过渡区的贵州东部和湖南西部(插图 1-a; Peng *et al.*, 2005; Liu and Lei, 2013)。其中, 贵州剑河一带的杷榔组出露较完整, 呈北—东向分布, 由一套斜坡相的灰绿色和灰黄色泥、页岩组成, 与上覆清虚洞组灰白色—灰色薄层灰岩、下伏变马冲组的深灰色泥、页岩均为整合接触, 厚 192 m(插图 1-b)。

杷榔组生物地层的划分最早是依据掘头虫类三叶虫组合带建立,其底部为 *Arthricocephalus* 带,顶部为 *Arthricocephalus-Changaspis-Balangia* 组合带(周志毅等,1980),其间经历了较多的变化(彭进,2009;秦琴等,2010; Peng *et al.*, 2010)。新的研究工作表明,掘头虫类三叶虫 *Arthricocephalus chauveaui* Bergeron, 1899 在贵州东部杷榔组中分布最

宽, 占地层厚度最长, 支持将杷榔组的生物地层厘定为 *A. chauveau* 一个带 (闫巧洁等, 2014; 申震等, 2016; Peng *et al.*, 2016)。 *A. chauveau* 首现层位之下为寒武系过渡相区的黔东统南皋阶 (Peng and Babcock, 2001; 闫巧洁等, 2014)。此外, 杷榔组也出现了大量的 *Redlichia* (*Pteroredlichia*) *chinesis* (Walcott, 1905) (梁博炎等, 2017), 根据华南地区三叶虫生物地层框架的对比, 杷榔组和云南乌龙箐组为同一时代, 属于沧浪铺期中晚期。因此, 杷榔动物群同云南关山生物群的时代基本相当 (Luo *et al.*, 2007; 罗惠麟等, 2008; Peng *et al.*, 2010), 可以与澳大利亚寒武系 Ordian 阶底部进行对比 (Öpik, 1970; Nedin, 1995)。而杷榔组常见的 *Arthricocephalites chauveau*, *A. intermedius* Zhou in Lu *et al.*, 1974 (或者 *A. jishouensis* Zhou *et al.*, 1977), *Changaspis elongata* Lee in Chein, 1961 等见于北美格陵兰的 Henson Gletsche 组中、下部层位 (Blaker and Peel, 1997; 彭进, 2009)。依据上述三叶虫属种的对比, 杷榔组的时代相当于寒武纪第二世第四期, 对应于斜坡相区黔东世的都匀期 (Peng and Babcock, 2001)。海绵化石产出层位位于剑河辣子寨剖面杷榔组中上部灰绿色、灰黄色泥岩中 (插图 1-b)。

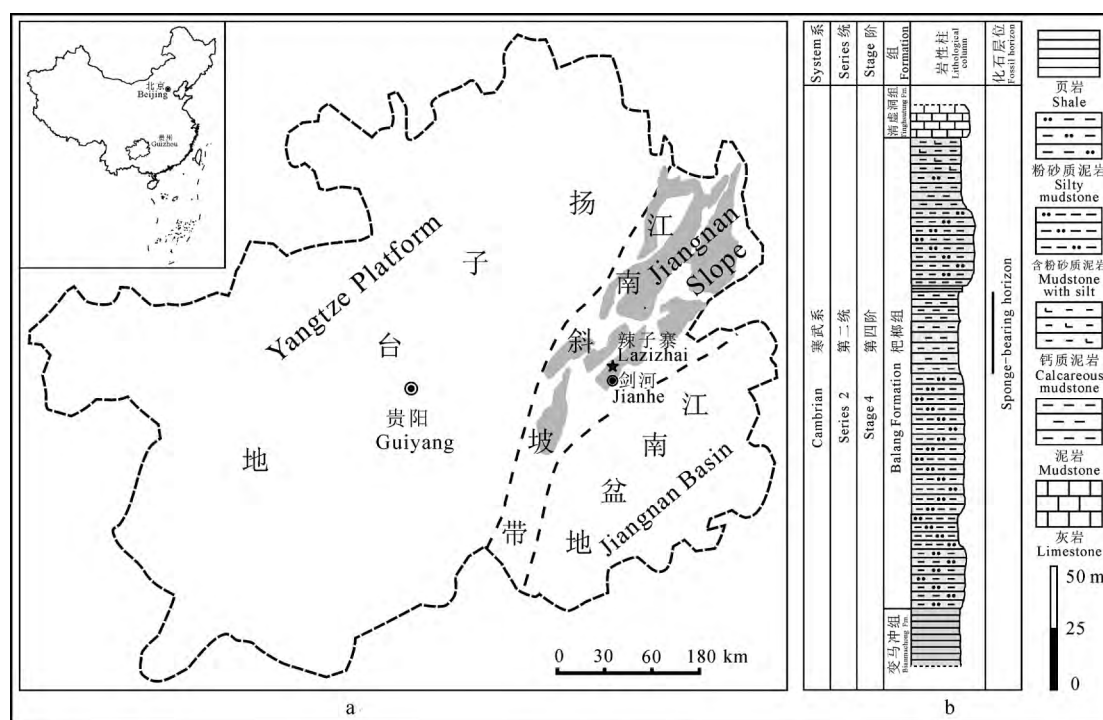


插图 1 贵州寒武系杷榔组分布(阴影部分)、化石点(星号)(a)和辣子寨剖面岩性柱状示意图(b)。

Map showing the distribution of the Cambrian Balang Formation (grey areas), fossil locality (star) (a) and lithological column of Lazizhai section of the Balang Formation (b) from Guizhou.

3 海绵化石的组成

剑河把榔组辣子寨剖面的海绵动物类群组成多样、化石数量多,对采集的 127 块标本进行初步鉴定,识别出普通海绵纲(插图 2-a—j)、六射海绵纲(插图 3-f,l)2 个纲的代表及一些分类位置待定的类群(插图 3-a—j,m)。这里描述的海绵化石主要保存为海绵体,也有少量离散的骨针化石(插图 3-k)。所有标本均使用 VHX-100K 超景深三维显微系统照相。化石标本保存在贵州大学贵州省古生物研究中心,标本编号中 JLS 代表剑河辣子寨剖面、HM 为海绵缩写。

3.1 普通海绵纲

普通海绵纲包括细丝海绵科的 *Leptomitrus teretiusculus* Chen *et al.*, 1989, *Leptomitrus* cf. *L. conicus* García-Bellido *et al.*, 2007, *Paraleptomitella* sp. 和斗篷海绵科的 *Choia* sp., *Choiaella* cf. *C. ovata* Zhao and Yang in Yang *et al.*, 2003, 化石标本数量相对较多,占到海绵标本总数的 19%。

细丝海绵科的 *Leptomitrus teretiusculus* 14 块标本,个体长柱形,长 13.51—45.49 mm、宽 2.92—14.36 mm,最大的个体长 45.49 mm、宽 14.36 mm(插图 2-a),外骨层由大骨针互相叠接组成的骨棒和分布于其间的小骨针组成,骨棒互相平行,纵向延伸可达海绵体的整个长度。其特征与澄江生物群、剑河生物群和凯里生物群中的 *L. tereticusculus* 一致(陈均远等, 1989; 赵元龙等, 2011; Hou *et al.*, 2017; 王圆等, 2017)。

Leptomitrus cf. *L. conicus* 有 2 块标本(插图 2-h,j),个体外形轮廓以倒圆锥形为特征,个体较大,长分别为 57.86 mm 和 119.00 mm、宽分别为 36.54 mm 和 46.15 mm,其外骨层由互相平行、均匀分布、纵向延伸的大骨针组成,内骨层由水平单轴小骨针组成。相似种的个体形态与西班牙寒武纪的 *L. conicus* García-Bellido *et al.*, 2007(García-Bellido *et al.*, 2007)较相似,但标本未保存弯钩形的基部,与 *L. conicus* 有些区别。目前该种标本数量较少,是化石保存上的差异,还是种间差异,有待新材料增加分析,这里暂时归为 *Leptomitrus* cf. *L. conicus*。

细丝海绵科的 *Paraleptomitella* sp. 2 块标本,个体外型长柱形,标本保存不全,长分别为

19.43 mm 和 22.02 mm,宽分别为 5.89 mm 和 6.74 mm;其外骨层主体格架呈菱网状,由微弯弓形、单轴双尖状、互不叠接的骨针交错排列而成。把榔组的 *Paraleptomitella* sp. 与澄江生物群中的 *P. dictyodroma* Chen *et al.*, 1989(陈均远等, 1989; Hou *et al.*, 2017)较相似,但外骨层的弯弓形骨针明显比后者的细。本文未进行详细的系统鉴定,暂时定为 *Paraleptomitella* sp.。

斗篷海绵科的 *Choia* sp. (插图 2-i)仅有 1 块标本,可见盘体局部,盘体半径不少于 19.45 mm,尚见辐射状的盘体骨针和冠状骨针(插图 2-e,i)。其特征与遵义牛蹄塘海绵动物群和澄江生物群的 *Choia* 化石(杨兴莲等, 2003; Hou *et al.*, 2017)都相似,但保存不完整,缺少种一级的详细分类信息,暂定作 *Choia* sp.,有待新的化石标本发现作更深入分类研究。

斗篷海绵科的 *Choiaella* cf. *C. ovata*(插图 2-g)共 2 块标本,外形近似圆形,单轴针状双尖骨针构成的骨针束从中心区域向四周辐射,无冠状骨针,长 14.84—16.21 mm、宽 11.78—13.91 mm,最大的个体(插图 2-g)长 16.21 mm、宽 13.91 mm。研究后发现,把榔组的相似种虽然与澄江生物群的 *C. radiata* Rigby and Hou, 1995(Rigby and Hou, 1995; Hou *et al.*, 2017)和凯里生物群的 *C. ovata*(杨兴莲等, 2003; 赵元龙等, 2011)较相似;但其表面有相互交错的骨针(插图 2-g),区别于澄江动物群中的 *C. radiata*,而是否和凯里生物群的 *C. ovata* 属于同一种,还需仔细对比研究。

斗篷海绵科另外 3 块化石(插图 2-c,d)具有密集分布、辐射状的小骨针和极少数的大骨针;长 7.82—13.86 mm、宽 8.02—10.98 mm。这些化石与斗篷海绵科的一些属种有较相似的外形和骨针特征,但标本只保存一部分,暂时归为 choiid 相似类型。

3.2 六射海绵纲

六射海绵纲有 *Saetaspongia* sp. 和一属种未定的类型,但标本数量少,仅占到海绵标本总数的 5%。

Saetaspongia Mehl and Reitner in Steiner *et al.*, 1993 的目、科分类位置一直存在争议,一种观点基于羽状骨针束特征将其归为原始单轴海绵目(Botting and Peel, 2016);另一观点认为其具有明显的六射骨针而支持将该属归属于网针目原始海绵

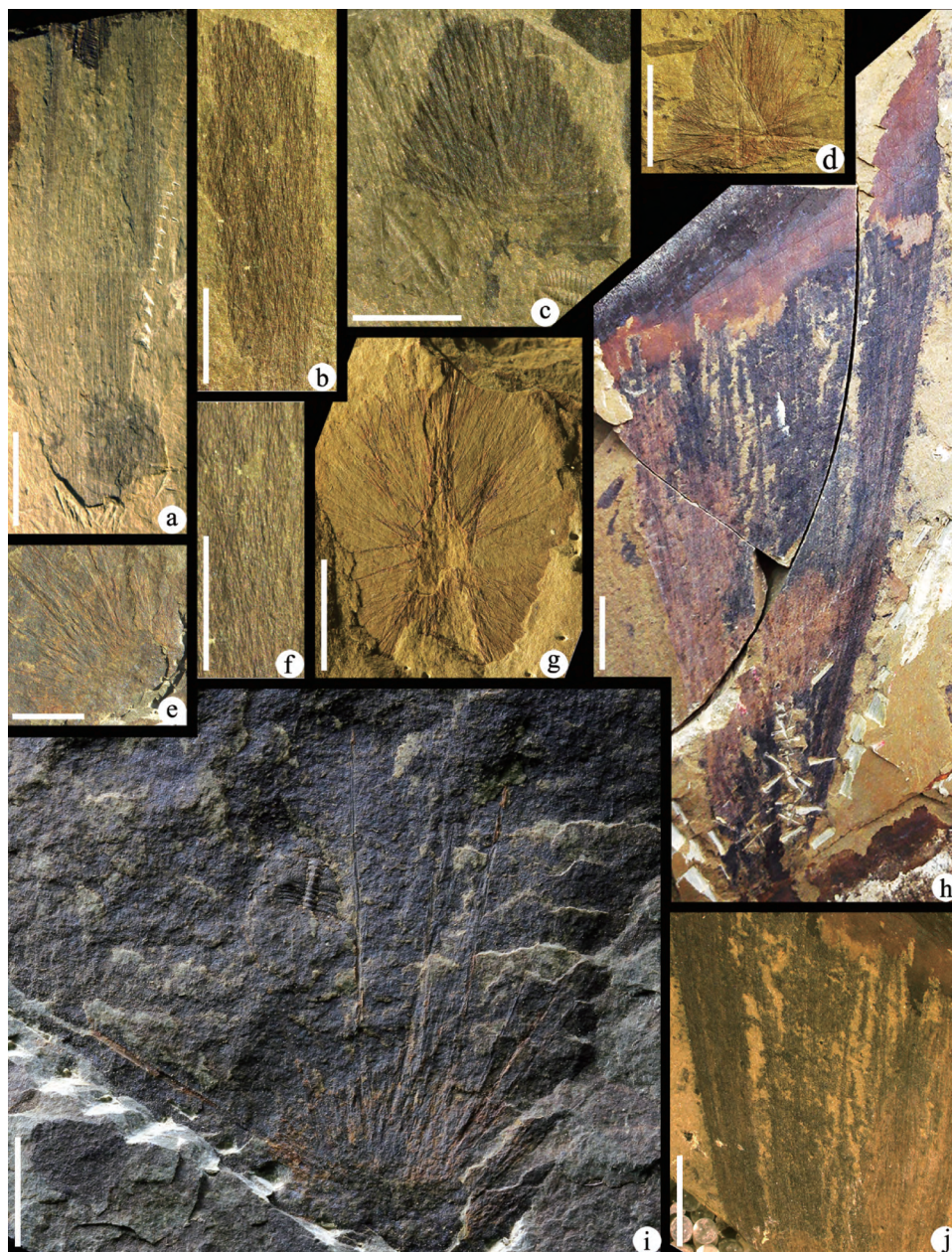


插图2 贵州剑河辣子寨剖面寒武系杷榔组的普通海绵纲的化石代表

Representatives of demospongiae from the Lazizhai section of the Cambrian Balang Formation in Jianhe, Guizhou.

a. *Leptomitius teretiusculus*, 显示管状海绵体及骨架外层由竖直的、单轴大骨针组成, JLSHM2625A。 b. *Paraleptomitella* sp., 显示管状海绵体及骨架外层由微弯弓形、单轴骨针组成, JLSHM111。 c, d. choiid 相似海绵, 显示 *Choiaella*-like 外形和密集分布、辐射状的骨针, JLSHM126, JLSHM128。 e. 图 i 的局部放大, 显示盘体上辐射状的、单轴骨针。 f. 图 b 的局部放大, 显示密集排列的、微弯弓形的骨针。 g. *Choiaella* cf. *C. ovata*, 显示卵圆形海绵体及辐射状的、单轴骨针, JLSHM127A。 h, j. *Leptomitius* cf. *L. conicus*, 显示倒圆锥形海绵体及骨架外层由单轴大骨针组成, JLSHM9A, B。 i. *Choia* sp., 显示盘体、辐射状单轴大骨针和冠状骨针, JLSHM1701A。除图 h、j 上比例尺线条等于 1 cm 外, 其余图上比例尺线条等于 5 mm。

a. *Leptomitius teretiusculus*, showing the tubular shape and the outer skeletal layer consisting of vertical, coarse monaxons, JLSHM2625A. b. *Paraleptomitella* sp., showing the tubular shape and the outer skeletal layer consisting of slightly curved monaxons, JLSHM111. c, d. choiid-like sponges, showing the *Choiaella*-like shape and radiating, dense monaxons, JLSHM126, JLSHM128. e. enlargement of fig. i, showing the central disk composed of radiating monaxons. f. enlargement of fig. b, showing closely spaced, slightly curved, fine spicules. g. *Choiaella* cf. *C. ovata*, showing the ovate shape and the skeleton composed of radiating thatch of small monaxons, JLSHM127A. h, j. *Leptomitius* cf. *L. conicus*, showing the obconical shape and the outer skeletal layer composed of radiating thatch of coarse monaxons, JLSHM9A, B. i. *Choia* sp., showing the central disk, coarse monaxons radiating from the disk, and coronal spicules, JLSHM1701A. Except for scale bar on picture j equals 1 cm, scale bars on other pictures equal 5 mm.

科(Chen *et al.*, 2015)。因此,关于该属的确切目、科分类位置还有待新的化石证据来佐证。本研究中科、目不定的 *Saetaspongia* sp. 标本只有 1 块(插图 3-l),保存较完整,长 13.52 mm、宽 9.82 mm,单轴骨针组成羽状骨针束,以及骨针都被包裹在体壁内、不突出体壁表层。未定种与三岔海绵动物群、牛蹄塘海绵动物群中的 *S. densa*(Steiner *et al.*, 1993; 杨兴莲等, 2010)较相似,但由单轴骨针组成的羽状骨针束是按顺时针有规律排列,区别于已报道的 *Saetaspongia* 其他种(Steiner *et al.*, 1993; Rigby and Hou, 1995; 杨兴莲、赵元龙, 2000; 杨兴莲等, 2010; Botting and Peel, 2016; 王圆等, 2017),本文未进行详细的分类学研究,暂时定为 *Saetaspongia* sp.。

六射海绵纲的化石还发现仅骨针方式保存的 5 块标本,长 34.64—51.24 mm、宽 16.40—39.88 mm,骨针呈十字骨针保存,骨针中部直径较大,向两端逐渐变细。本文只对杷榔组的六射海绵纲骨针化石形态进行简要的描述,未进行属、种分类位置研究。

3.3 其它暂未分类的海绵

杷榔组还发现了其他暂未分类的海绵化石(插图 3-a—e, g—j, m),数量丰富,占到海绵标本总数的 76%。目前这些化石保存不完整,缺少分类信息,其纲及以下分类单元的归属还有待进一步化石采集,仅初步鉴定出三种类型。

第一类(插图 3-b, j)共 3 块标本,只保存中间部分,个体较大,长 21.99—108.46 mm、宽 19.54—61.46 mm,最大的个体(插图 3-j)长 108.46 cm、宽 61.46 cm,具有较长的单轴骨针(能达到 6 cm),与产自贵州南皋丹寨牛蹄塘组的 *S. densa*(杨兴莲等, 2010, 352—353 页,图版 II, 图 3, 4)较相似,但未见单轴骨针组成羽状骨针束,且骨针是否都被包裹在体壁内、不突出体壁表层还有待再确定。

第二类(插图 3-c, m)有 3 块标本,个体较大,长 20.80—21.30 mm、宽 6.03—11.20 mm。该类化石具有松散的、较长弯曲的大骨针,与三岔海绵动物群中的 *Hyalosinica archaica* Mehl and Reitner in Steiner *et al.*, 1993(Steiner *et al.*, 1993, p. 305, 306, pl. 4, figs. 1a, b, text-fig. 8)较相似,但骨针排列比后者的稀疏。

第三类(插图 3-h)有 2 块标本,仅保存海绵体中间部分,长 18.06—19.94 mm、宽 14.41—19.94 mm。该类化石可见骨针密集分布,在外侧一

些区域的骨针组成羽状骨针束向外辐射,与发现于三岔海绵动物群的 *S. densa*(Steiner *et al.*, 1993, p. 310, pl. 3, fig. 1, text-fig. 13)较相似,但标本边缘未保存,对于骨针是否都被包裹在体壁内、不突出体壁表层还有待进一步确定。

以上三种类型虽然都与六射海绵纲的一些属种较相似,但都未发现有六射骨针或十字骨针保存,因此是否将其归属于六射海绵纲的类群还需进一步的研究。

另有未分类的化石标本(插图 3-a, d, e, g, i)仅保存化石的中间一部分,见有单轴和双轴骨针,暂时未发现六射或者十字大骨针。除此之外,还有四射骨针的化石标本(插图 3-k),射针长 9.31 mm。

4 讨 论

众所周知,华南寒武纪扬子沉积区的海绵动物常见,可以出现在台地浅水和斜坡较深水相区的环境中(杨兴莲等, 2005b; 朱茂炎, 2010; Wu *et al.*, 2014; 王圆等, 2017)。第二世至第三世的海绵化石见于扬子区的牛蹄塘生物群(杨兴莲、赵元龙, 2000; 杨兴莲等, 2003, 2005a, 2010; 王平丽等, 2005; Yang *et al.*, 2005; 赵元龙等, 2006)、荷塘海绵动物群(Xiao *et al.*, 2005; Botting *et al.*, 2014)、澄江生物群(陈均远等, 1989, 1990; Rigby and Hou, 1995; Chen *et al.*, 2015; Hou *et al.*, 2017)、三岔海绵动物群(Steiner *et al.*, 1993; Mehl and Erdtmann, 1994)、黄柏岭海绵动物群(Wu *et al.*, 2005)、剑河生物群(王圆等, 2017)和凯里生物群(杨兴莲等, 2003; 赵元龙等, 2011; Yang *et al.*, 2017)等生物群中。杷榔组海绵化石的发现细化了寒武纪第二世至第三世海绵动物的演化序列,其中海绵动物的 *Leptomit*, *Paraleptomitella*, *Choiaella*, *Choia* 或 *Saetaspongia* 出现在时代较早的浅水相中的牛蹄塘生物群(杨兴莲、赵元龙, 2000; 杨兴莲等, 2003, 2005a, b, 2010; 赵元龙等, 2006)和澄江生物群中(陈均远等, 1989; Rigby and Hou, 1995),并上延至时代较晚的较深水相的剑河生物群(王圆等, 2017)和凯里生物群中(杨兴莲等, 2003, 2005b; 赵元龙等, 2011)。杷榔动物群中海绵动物的出现,再次证实了起源于寒武纪早期的海绵动物在寒武纪早中期已经迁移扩展至台缘外斜坡陆架过渡相区的较深水区、扩展了海绵动物的古地理分布区,且一直延续进入时代较晚的、较深水的剑河生物群(王圆等, 2017)和凯里生物群(杨兴莲

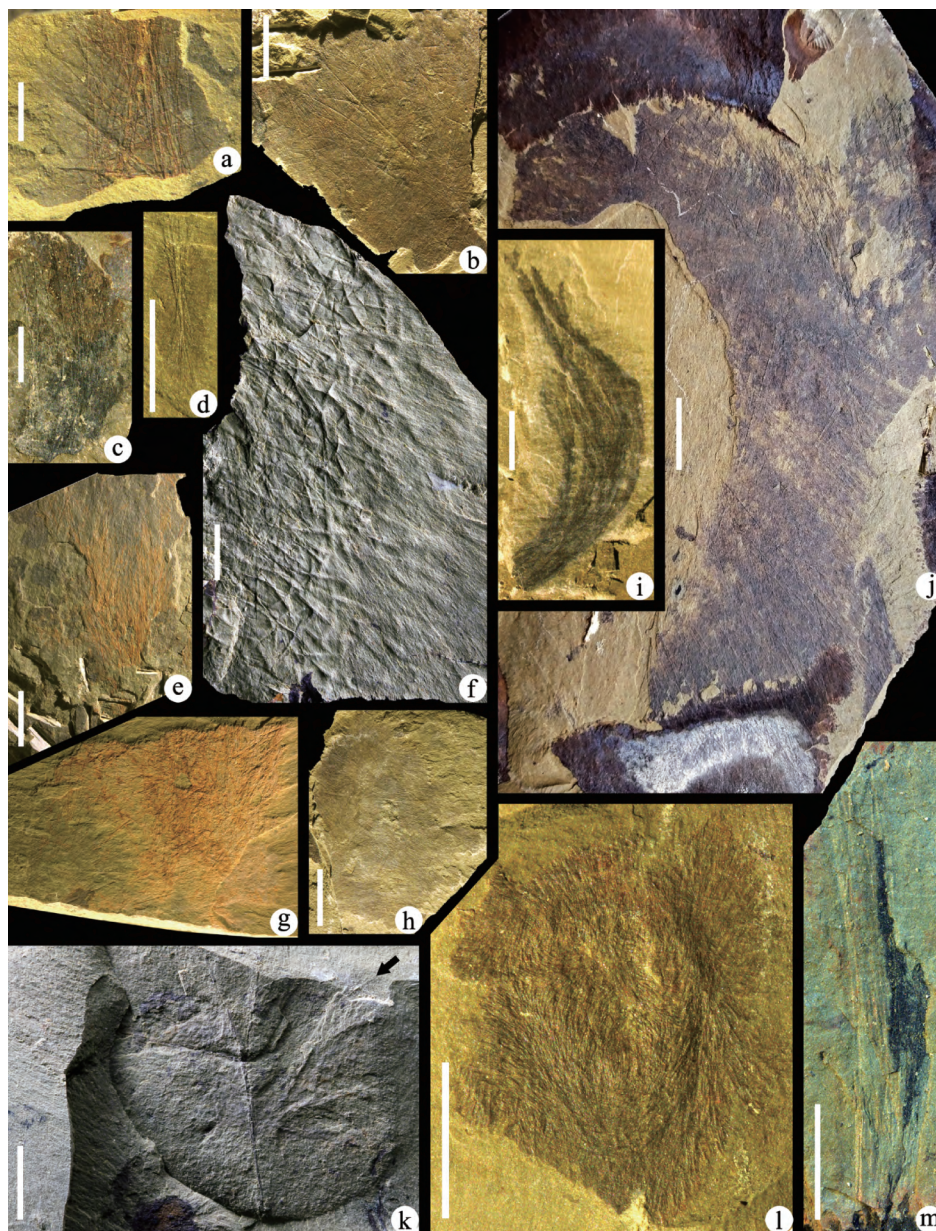


插图3 贵州剑河辣子寨剖面寒武系杷榔组的六射海绵纲及其它海绵化石代表

Representatives of hexactinellid and other sponge fossils from the Lazizhai section of the Cambrian Balang Formation in Jianhe, Guizhou.

a. 部分保存的标本显示黄铁矿化的、无规则排列的大骨针, JLSHM120. b, j. 部分保存的标本显示交错排列的、长的单轴骨针, JLSHM101, JLSHM406A. c, m. 部分保存的标本显示松散的、弯曲的大骨针, JLSHM108, JLSHM80. d. 部分保存的标本显示束状的单轴双射骨针, JLSHM30406. e. 部分保存的标本显示黄铁矿化的骨针, JLSHM119. f. 部分保存的标本显示十字骨针, JLSHM163. g. 部分保存的标本显示黄铁矿化的、交错排列的骨针, JLSHM112. h. 部分保存的标本显示骨针密集分布, 在外侧一些区域的骨针组成羽状骨针束向外辐射, JLSHM2625A. i. 部分保存的标本显示弯曲的骨针束, JLSHM5056. k. 多射骨针, 显示不在同一平面内的5条单射针(右上角指示其中的1条单射针), JLSHM93. l. *Saetasporgia* sp., 显示卵圆形海绵体及包裹在海绵体内的骨针和由单轴骨针组成的羽状骨针束, JLSHM130. 除图j上比例尺线条等于1 cm外, 其余图上比例尺线条等于5 mm.

a. Partial specimen showing pyritized, irregularly-oriented coarse spicules, JLSHM120. b, j. Partial specimens showing overlapping arrays of fine elongated monaxons, JLSHM101, JLSHM406A. c, m. Partial specimens showing loosely twisted, coarse spicules, JLSHM108, JLSHM80. d. Partial specimen showing bundled diactins, JLSHM30406. e. Partial specimen showing pyritized spicules, JLSHM119. f. Partial specimen showing stauractines, JLSHM163. g. Partial specimen showing overlapping arrays of pyritized spicules, JLSHM112. h. Partial specimen showing the plumose arrays of monaxons, JLSHM2625A. i. Partial specimen showing twisted, bundled spicules, JLSHM5056. k. Polyactinal, showing five rays (the upper-right arrow marks a ray), JLSHM93. l. *Saetasporgia* sp., showing the ovate shape, fine diactins not protruding beyond the outer surface of the sponge body, and the plumose arrays of monaxons, JLSHM130. Except for scale bar on picture j equals 1 cm, scale bars on other pictures equal 5 mm.

等,2003;赵元龙等,2011)。新的发现为研究寒武纪海绵动物生态演化过程提供了化石依据,在演化序列中起承上启下的作用。

把榔动物群的海绵动物化石标本数量中普通海绵纲的类群占到海绵标本总数的 19%,包含细丝海绵科和斗篷海绵科的 4 属 5 种;六射海绵纲类群的标本数仅占总数的 5%,仅有 *Saetaspongia* 和一属种未定的类型;其他暂未分类的化石标本数量丰富,占到海绵标本总数的 76%。目前的数据显示其与荷塘、三岔、黄柏岭海绵动物的区别在于后三者均以六射海绵占绝对优势为特征(朱茂炎,2010;Wu *et al.*, 2014);也不同于澄江和凯里生物群的海绵类,后二者以普通海绵类分别占海绵标本总数的 68%(Wu *et al.*, 2014)和 83%(杨兴莲等,2005b)为特征;应该代表了一个不同的群落组合。

因此,无论丰度、分异度还是保存情况,把榔动物群海绵动物类群的组合都与以上华南生物群的海绵动物组合有些差异,该海绵动物类群组合能为寒武纪海绵动物古生态学研究提供新的证据。

致谢 贵州大学兰天、杨宇宁老师,硕士生王圆在化石鉴定和论文写作过程中提供帮助,贵州大学古生物学与地层学专业研究生及剑河八郎村村民刘峰、刘泽福等参与了化石采集,评审专家提出宝贵修改意见,在此一并致以衷心的感谢。

参 考 文 献 (References)

- Blaker M R, Peel J S, 1997. Lower Cambrian trilobites from North Greenland. *Meddelelser om Grønland Geoscience*, **35**: 1—145.
- Botting J P, Peel J S, 2016. Early Cambrian sponges of the Sirius Passet Biota, North Greenland. *Papers in Palaeontology*, **2**(4): 463—487.
- Botting J P, Yuan Xun-lai, Lin Jih-pai, 2014. Tetradial symmetry in early poriferans. *Chinese Science Bulletin*, **59**(7): 639—644.
- Chen Ai-lin, Müller W E G, Hou Xian-guang, Xiao Shu-hai, 2015. New articulated protospongiid sponges from the Early Cambrian Chengjiang Biota. *Palaeoworld*, **24**(1): 46—54.
- Chen Jun-yuan (陈均远), Hou Xian-guang (侯先光), Li Guo-xiang (李国祥), 1990. New Lower Cambrian demosponges—*Quadrolaminiella* gen. nov. from Chengjiang, Yunnan. *Acta Palaeontologica Sinica (古生物学报)*, **29**(4): 402—413 (in Chinese with English abstract).
- Chen Jun-yuan (陈均远), Hou Xian-guang (侯先光), Lu Hao-zhi (路浩之), 1989. Lower Cambrian leptomitids (Demospongiae), Chengjiang, Yunnan. *Acta Palaeontologica Sinica (古生物学报)*, **28**(1): 17—37 (in Chinese with English abstract).
- Da Yang (达扬), Peng Jin (彭进), Zhao Yuan-long (赵元龙), Ma Hai-tao (马海涛), Gu Yu (谷雨), 2011. Preliminary investigation on sedimentary environment of the Balang Formation in Geyi, Taijiang, eastern Guizhou, China. *Geological Review (地质论评)*, **57**(4): 574—582 (in Chinese with English abstract).
- García-Bellido D C, Gozalo R, Chirivella Martorell J B, Linán E, 2007. The demosponge genus *Leptomit* and a new species from the Middle Cambrian of Spain. *Palaeontology*, **50**(2): 467—478.
- Hou Xian-guang, Siveter D J, Siveter, D J, Aldridge R J, Cong Pei-yun, Gabbott S E, Ma Xiao-ya, Purnell M A, Williams M, 2017. The Cambrian Fossils of Chengjiang, China: The Flowering of Early Animal Life. Chichester: John Wiley & Sons. 1—327.
- Liang Bo-yan (梁博炎), Peng Jin (彭进), Wen Rong-qin (文荣琴), Liu Shuai (刘帅), 2017. Ontogeny of the trilobite *Redlichia (Pteroredlichia) chinensis* (Walcott, 1905) from the Cambrian Balang Formation. *Acta Palaeontologica Sinica (古生物学报)*, **56**(1): 25—36 (in Chinese with English abstract).
- Liu Qing, Lei Qian-ping, 2013. Discovery of an exceptionally preserved fossil assemblage in the Balang Formation (Cambrian Series 2, Stage 4) in Hunan, China. *Alcheringa: An Australasian Journal of Palaeontology*, **37**(2): 269—271.
- Liu Shuai (刘帅), Wen Rong-qin (文荣琴), Peng Jin (彭进), Liang Bo-yan (梁博炎), Wang Qiu-jun (王秋军), 2017. A preliminary study on taphonomy of the Balang Lagerstätte from the Cambrian (Stage 4), Balang Formation at Jianhe, Guizhou, China—Example for Lazizhai section of the Balang Formation. *Acta Palaeontologica Sinica (古生物学报)*, **56**(3): 282—300 (in Chinese with English abstract).
- Luo Hui-lin, Fu Xiao-ping, Hu Shi-xue, Li Yong, Hou Shu-guang, You Ting, Pang Ji-yuan, Liu Qi, 2007. A new arthropod, *Guangweicaris* Luo, Fu et Hu gen. nov. from the Early Cambrian Guanshan Fauna, Kunming, China. *Acta Geologica Sinica (English Edition)*, **81**(1): 1—7.
- Luo Hui-lin (罗惠麟), Li Yong (李勇), Hu Shi-xue (胡世学), Fu Xiao-ping (傅晓平), Hou Shu-guang (侯蜀光), Liu Xing-yao (刘兴尧), Chen Liang-zhong (陈良忠), Li Feng-jun (李锋军), Pang Ji-yuan (庞纪院), Liu Qi (刘琦), 2008. Early Cambrian Malong Fauna and Guanshan Fauna of Eastern Yunnan, China. Kunming: Yunnan Science and Technology Press. 1—134 (in Chinese).
- Ma Hai-tao (马海涛), Peng Jin (彭进), Zhao Yuan-long (赵元龙), Da Yang (达扬), Sun Hai-jing (孙海静), 2011. Discovery of the Balang Fauna at Luojiatang, Yangqiao, Cengong, Guizhou, and its significance in the early evolution of metazoa. *Geological Review (地质论评)*, **57**(5): 743—748 (in Chinese with English abstract).
- Mehl D, Erdtmann B D, 1994. *Sanshapentella dapingi* n. gen., n. sp.—A new hexactinellid sponge from the Early Cambrian (Tommotian) of China. *Berliner Geowissenschaftliche Abhandlungen*, **E13**: 315—318.
- Nedin C, 1995. The Emu Bay Shale, a Lower Cambrian fossil Lagerstätte, Kangaroo Island, South Australia. *Australasian Association of Palaeontologists Memoir*, **18**: 31—40.
- Öpik A A, 1970. *Redlichia* of the Ordian (Cambrian of northern

- Australia and New South Wales). Bulletin of Bureau of Mineral Resources, Geology and Geophysics, **114**: 1—66.
- Peng Jin (彭进), 2009. The Qiongzhusi (Cambrian) Balang Fauna from Eastern Guizhou, South China. Ph. D. Thesis. Nanjing: Nanjing University. 1—137 (in Chinese with English summary).
- Peng Jin, Feng Hong-zhen, Fu Xiao-ping, Zhao Yuan-long, Yao Lu, 2010. New bradoriid arthropods from the Early Cambrian Balang Formation of eastern Guizhou, South China. Acta Geologica Sinica (English edition), **84**(1): 56—68.
- Peng Jin (彭进), Feng Hong-zhen (冯洪真), Zhao Yuan-long (赵元龙), Fu Xiao-ping (傅晓平), Wang Yu-xuan (王宇轩), 2007. *Tuzoia* from the Lower Cambrian Balang Formation, eastern Guizhou, China. Geological Review (地质论评), **53**(3): 397—403 (in Chinese with English abstract).
- Peng Jin, Huang Di-ying, Zhao Yuan-long, Sun Hai-jing, 2016. Palaeoscolecid from the Balang Fauna of the Qiongzhusi (Cambrian Series 2), Guizhou, China. Geological Magazine, **153**(3): 438—448.
- Peng Jin, Sun Hai-jing, Zhao Yuan-long, Tai Tong-shu, 2012a. The Jiaobang Section: The Balang Formation and the Balang Fauna (Cambrian Series 2, Stage 4) near Jiaobang Village, Jianhe County, Guizhou Province, China. Journal of Guizhou University (Natural Science) (贵州大学学报, 自然科学版), **29**(Suppl. 1): 125—132.
- Peng Jin, Sun Hai-jing, Zhao Yuan-long, Yan Qiao-jie, 2012b. The fossiliferous Geyi section of the Balang Formation (Cambrian Series 2, Stage 4) near Taijiang County, Guizhou Province, South China. Journal of Guizhou University (Natural Sciences) (贵州大学学报, 自然科学版), **29**(Suppl. 1): 87—97.
- Peng Jin (彭进), Zhao Yuan-long (赵元龙), Qin Qin (秦琴), Yan Xu (闫旭), Ma Hai-tao (马海涛), 2010. New material of brachiopods from the Qiongzhusi (Lower Cambrian) Balang Formation, eastern Guizhou, South China. Acta Palaeontologica Sinica (古生物学报), **49**(3): 365—379 (in Chinese with English abstract).
- Peng Jin, Zhao Yuan-long, Sun Hai-jing, 2012c. Discovery and significance of *Naraoia* from the Qiongzhusi (Lower Cambrian) Balang Formation, eastern Guizhou, South China. Bulletin of Geosciences, **87**(1): 143—150.
- Peng Jin, Zhao Yuan-long, Wu Yi-shan, Yuan Jin-liang, Tai Tong-shu, 2005. The Balang Fauna—A new Early Cambrian fauna from Kaili City, Guizhou Province. Chinese Science Bulletin, **50**(11): 1159—1162.
- Peng Jin (彭进), Zhao Yuan-long (赵元龙), Yang Xing-lian (杨兴莲), 2006. Trilobites of the upper part of Lower Cambrian Balang Formation, southeastern Guizhou Province, China. Acta Palaeontologica Sinica (古生物学报), **45**(2): 235—242 (in Chinese with English abstract).
- Peng Shan-chi, Babcock L E, 2001. Cambrian of the Hunan-Guizhou region, South China. Palaeoworld, **13**: 3—51.
- Qin Qin (秦琴), Peng Jin (彭进), Fu Xiao-ping (傅晓平), Da Yang (达扬), 2010. Restudy of *Changaspis* (Lee), 1961 from Qiongzhusi (Early Cambrian) Balang Formation near eastern Guizhou, South China. Acta Palaeontologica Sinica (古生物学报), **49**(2): 220—230 (in Chinese with English abstract).
- Rigby J K, Hou Xian-guang, 1995. Lower Cambrian demosponges and hexactinellid sponges from Yunnan, China. Journal of Paleontology, **69**(6): 1009—1019.
- Shen Zhen (申震), Peng Jin (彭进), Wen Rong-qin (文荣琴), Liu Shuai (刘帅), 2016. *Arthrocephalites* (Trilobite) from the Cambrian and its stratigraphic significance. Acta Palaeontologica Sinica (古生物学报), **55**(1): 9—18 (in Chinese with English abstract).
- Steiner M, Mehl D, Reitner J, Erdtmann B D, 1993. Oldest entirely preserved sponges and other fossils from the lowermost Cambrian and a new facies reconstruction of the Yangtze Platform (China). Berliner Geowissenschaftliche Abhandlungen, **9**: 293—329.
- Wang Ping-li (王平丽), Zhao Yuan-long (赵元龙), Yang Xing-lian (杨兴莲), Yang Rong-jun (杨荣军), 2005. *Crumillospongia biporosa* (sponge) from the Early Cambrian Niutitang Biota in Guizhou Province. Acta Micropalaeontologica Sinica (微体古生物学报), **22**(2): 196—201 (in Chinese with English summary).
- Wang Yuan (王圆), Yang Xing-lian (杨兴莲), Zhao Yuan-long (赵元龙), Duan Xiao-lin (段晓林), 2017. A preliminary study of sponge fossils from the Cambrian “Tsinghsutung Formation” of Guizhou, China. Acta Palaeontologica Sinica (古生物学报), **56**(2): 176—188 (in Chinese with English abstract).
- Wen Rong-qin (文荣琴), Peng Jin (彭进), Liu Shuai (刘帅), Liang Bo-yan (梁博炎), 2017. *Occacaris* from the Cambrian Balang Formation, Jianhe County, Guizhou Province. Acta Palaeontologica Sinica (古生物学报), **56**(3): 271—281 (in Chinese with English summary).
- Wu Wen, Yang Ai-hua, Janussen D, Steiner M, Zhu Mao-yan, 2005. Hexactinellid sponges from the Early Cambrian black shale of South Anhui, China. Journal of Paleontology, **79**(6): 1043—1051.
- Wu Wen, Zhu Mao-yan, Steiner M, 2014. Composition and tiering of the Cambrian sponge communities. Palaeogeography, Palaeoclimatology, Palaeoecology, **398**: 86—96.
- Xiao Shu-hai, Hu Jie, Yuan Xun-lai, Parsley R L, Cao Rui-ji, 2005. Articulated sponges from the Lower Cambrian Hetang Formation in southern Anhui, South China: Their age and implications for the early evolution of sponges. Palaeogeography, Palaeoclimatology, Palaeoecology, **220**(1): 89—117.
- Yan Qiao-jie (闫巧洁), Peng Jin (彭进), Zhao Yuan-long (赵元龙), Wen Rong-qin (文荣琴), Sun Hai-jing (孙海静), 2014. Restudy of sedimentary and biostratigraphy of the Qiongzhusi (Cambrian) Balang Formation at Jianhe, Guizhou, China—Example for Jiaobang Section of the Balang Formation. Geological Review (地质论评), **60**(4): 893—902 (in Chinese with English abstract).
- Yang Xing-lian (杨兴莲), Zhao Yuan-long (赵元龙), 2000. Sponges of the Lower Cambrian Niutitang Formation Biota in Zunyi, Guizhou, China. Journal of Guizhou University of Technology (Natural Science Edition) (贵州工业大学学报, 自然科学版), **29**(6): 30—38 (in Chinese with English abstract).
- Yang Xing-lian, Zhao Yuan-long, Babcock L E, Peng Jin, 2017. A

- new vauxiid sponge from the Kaili Biota (Cambrian Stage 5), Guizhou, South China. *Geological Magazine*, **154** (6): 1334—1343.
- Yang Xing-lian, Zhao Yuan-long, Wang Yue, Wang Ping-li, 2005. Discovery of sponge body fossils from the late Meishucunian (Cambrian) at Jinsha, Guizhou, South China. *Progress in Natural Science*, **15**(8): 708—712.
- Yang Xing-lian (杨兴莲), Zhao Yuan-long (赵元龙), Wu Wei-yi (吴维义), 2003. Discovery of the Early and Middle Cambrian Choiidae from Guizhou, SW China. *Acta Micropalaeontologica Sinica* (微体古生物学报), **20**(3): 286—295 (in Chinese with English abstract).
- Yang Xing-lian (杨兴莲), Zhao Yuan-long (赵元龙), Zhu Mao-yan (朱茂炎), 2005a. New sponges from the Lower Cambrian of Guizhou. *Acta Palaeontologica Sinica* (古生物学报), **44**(3): 454—463 (in Chinese with English abstract).
- Yang Xing-lian (杨兴莲), Zhao Yuan-long (赵元龙), Zhu Mao-yan (朱茂炎), Cui Tao (崔滔), Yang Kai-di (杨凯迪), 2010. Sponges from the Early Cambrian Niutitang Formation at Danzhai, Guizhou and their environmental background. *Acta Palaeontologica Sinica* (古生物学报), **49**(3): 348—359 (in Chinese with English abstract).
- Yang Xing-lian (杨兴莲), Zhu Mao-yan (朱茂炎), Zhao Yuan-long (赵元龙), Wang Yue (王约), 2005b. Cambrian sponge assemblages from Guizhou. *Acta Micropalaeontologica Sinica* (微体古生物学报), **22**(3): 295—303 (in Chinese with English abstract).
- Zhao Yuan-long (赵元龙), Peng Jin (彭进), Wu Meng-yin (伍孟银), Luo Xiu-chun (罗秀春), Wen Rong-qin (文荣琴), Liu Yu-juan (刘玉娟), 2015. A new type eocrinoids of echinoderms from the Balang Formation in Cambrian at Xiasi Town, Majiang County, Guizhou Province, China. *Earth Science-Journal of China University of Geosciences* (地球科学-中国地质大学学报), **40**(2): 249—260 (in Chinese with English summary).
- Zhao Yuan-long (赵元龙), Yang Rong-jun (杨荣军), Yang Xing-lian (杨兴莲), Mao Yong-qin (毛永琴), 2006. Globular sponge fossils from the Lower Cambrian in Songlin, Guizhou Province, China. *Geological Journal of China Universities* (高校地质学报), **12**(1): 106—110 (in Chinese with English abstract).
- Zhao Yuan-long (赵元龙), Zhu Mao-yan (朱茂炎), Babcock L E, Peng Jin (彭进), 2011. The Kaili Biota: Marine Organisms from 508 Million Years Ago. Guiyang: Guizhou Science and Technology Press. 1—251 (in Chinese with English summary).
- Zhou Zhi-yi (周志毅), Yuan Jin-liang (袁金良), Zhang Zheng-hua (张正华), Wu Xiao-ru (吴孝儒), Yin Gong-zheng (尹恭正), 1980. Calcification and correlation of Cambrian strata from Guizhou Province, China. *Journal of Stratigraphy* (地层学杂志), **4**(4): 273—281 (in Chinese).
- Zhu Mao-yan (朱茂炎), 2010. The origin and Cambrian explosion of animals: Fossil evidences from China. *Acta Palaeontologica Sinica* (古生物学报), **49**(3): 269—287 (in Chinese with English abstract).

THE SPONGE ASSEMBLAGE FROM THE CAMBRIAN BALANG FAUNA OF JIANHE, GUIZHOU

WANG Qiu-jun, PENG Jin, WEN Rong-qin, LIU Shuai and WANG De-zhi
(Guizhou Research Centre for Palaeontology and College of Resource and Environmental Engineering,
Guizhou University, Guiyang 550025, gzpengjin@126.com)

Key words Sponge, Balang Fauna, Balang Formation, Cambrian, Guizhou of China

Abstract

Sponge fossils described herein are from the Cambrian Balang Fauna of Guizhou and represent a newly discovered group of this biota. The sponge assemblage was collected from the Lazizhai section of the Balang Formation at Jianhe and is dominated by well-preserved fossils, which reveals high species diversity. These sponge fossils include representatives of *Leptomitrus tereticusculus* Chen

et al., 1989, *Leptomitrus* cf. *L. conicus* García-Bellido *et al.*, 2007, *Paraleptomitella* sp., *Choiella* cf. *C. ovata* Zhao and Yang in Yang *et al.*, 2003, *Choi* sp., *Saetaspongia* sp. and some undetermined taxa. The newly discovered sponge fossils not only enrich our knowledge of the diversity and composition of the Balang Fauna but also extend the geographic distribution of Cambrian (Stage 4) sponges, as well as provide new material for taxonomy, paleoecology and taphonomy of Cambrian sponges.