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缅甸岩溶地质概况

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摘 要: 缅甸岩溶地质研究正处于快速发展阶段, 系统综合的岩溶地质资料有助于从宏观上了解缅甸岩溶情况。文章在系统收集资料的基础上, 综合多种尺度地质图、水文地质图、构造图及其遥感资料, 编制 1∶100 万缅甸岩溶地质分布图, 从地质演化过程、岩性组合、气候环境等方面综合剖析岩溶作用的背景条件, 以此总结缅甸岩溶分布规律和岩溶景观特征, 为“全球岩溶地质”数据库提供基础支持。缅甸的岩溶分布面积达 7×10^4 km^2, 是东南亚岩溶分布面积第二大的国家, 厚层的古生代碳酸盐岩地层、复杂的构造运动、温润多雨的气候、活跃的生物活动等均有利于岩溶作用的发生, 其发育峰林、峰丛、洞穴岩溶景观, 岩溶景观资源潜力巨大, 具有全球最高的生物多样性, 但同时也面临着生态被破坏、干旱、洪涝等地质环境问题。

关键词: 缅甸; 岩溶地质; 岩溶景观; 洞穴
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0 引 言

缅甸岩溶分布面积约 7×10^4 km^2, 约占其国土面积的 12%, 是东南亚第二大岩溶区, 其分布在缅甸东部的掸邦高原、印缅造山带和掸邦斜坡, 形成于奥陶系–白垩系沉积的碳酸盐岩地层中, 其中掸邦高原二叠系–三叠系石灰岩地层中岩溶作用最强。

缅甸地质研究基础较薄弱, 起步于 19 世纪 20 年代, 初期主要有英国、印度、日本等外国地质学家对缅甸区域地质、矿产地质、石油地质等开展过调查研究[1–11], 直到 20 世纪 60、70 年代, 缅甸地质学家对缅甸地质的研究有了显著贡献[12–31]。但由于政治和基础设施落后等原因, 缅甸岩溶学的研究开展较少, 是亚洲岩溶研究较少的国家之一, 1986 年到 2004 年, 只有少数洞穴学家从洞穴角度探索了缅甸的岩溶地貌。2009 年开始, 由来自瑞士、英国、德国、缅甸等 13 个国家的 59 名洞穴探险家组成的探险队, 成立缅甸洞穴勘探项目(Myanmar Cave Documentation Project), 探索缅甸掸邦 (Shan) 和克耶邦 (Kayah)–克伦邦 (Kayin) 一带的岩溶地貌、岩溶洞穴、洞穴生物, 并科普岩溶地质、岩溶洞穴学科知识。该项目出版了 3 本详细描述洞穴的书籍, 建立了包含 800 个数据对象和 110 km 洞穴通道的数据库[32], 是目前缅甸岩溶洞穴研究的唯一综合性成果资料。本文在此基础上, 综合缅甸地质资料、遥感数据, 从地质演化过程、气候环境等角度分析其岩溶作用的过程, 总结缅

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甸岩溶分布规律，以期为“全球岩溶地质”数据库提供基础支持。

1 地质背景

缅甸位于中南半岛西北部，国土面积为 676 578 km^2，东南与老挝、泰国为邻，东北与中国接壤，西北与印度、孟加拉国为界，西南濒临孟加拉湾和安达曼海，海岸线长 2 832 km；地势总体呈北高南低，西部、东部、北部以高山为主，中部为伊洛瓦底江 (Ayeyarwady) 冲积平原，南部沿海盆地，境内最高峰位于克钦邦 (Kachin) 北部，开卡博峰（Hkakabo Razi）海拔 5 881 m。

缅甸大地构造位置属于印度板块与欧亚板块碰撞造山带构造结东侧，构造形态特征总体上呈南北走向。实皆（Sagaing）断层由北向南将缅甸分为西缅 (West Burma) 地块和掸–泰 (Shan-Thai) 地块两部分（图 1 a）[33−35]，西缅 (West Burma) 地块包括缅甸中央盆地、印缅造山带和若开海岸带 3 个次级构造单元，掸–泰 (Shan-Thai) 地块（滇缅马苏地块）在缅甸境内又分为太公–密支那 (Tagaung-Myitkyina) 变质带和掸邦高原两个次级构造单元。实皆断层是印度板块与欧亚板块之间的右旋横推断层，连接着安达曼海的扩张中心和喜马拉雅前缘的大陆汇聚带，长度 1 500 km，每年以 18 mm 的速度做右旋运动，是缅甸的主要活动断层之一，控制着缅甸的构造地质[36−37]。西缅地块是冈瓦纳超大陆北缘的一部分，东以实皆断裂为界，西以安达曼逆冲断层为界[38]，其主要由澳大利亚起源的古生代变质沉积岩和厚层复理石、蛇绿岩套组成，蛇绿岩套主要为基性–超基性构造杂岩。掸–泰地块在中国境内称为保山地块，与欧亚板块相连，从中国云南保山向南延伸，经过缅甸、泰国、马来半岛，一直延伸到苏门答腊岛，其主要由含高原石灰岩和变质杂岩的老严群组成。

缅甸地处阿尔卑斯–喜马拉雅造山带与印度尼西亚岛弧连接处，经历了复杂的构造过程。晚石炭世–早二叠世，掸–泰地块从冈瓦纳大陆西北边缘分离向北平移，于三叠世就位于印支那 (Indosinia) 地块的西侧；西缅地块在侏罗纪，从澳大利亚北部的冈瓦纳北缘分离向北漂移，白垩纪处于俯冲带之上，白垩纪–始新世处于稳定的近赤道古纬度，到达苏门答腊以北的南北向位置[39]，其受新生代安达曼海底的弧后扩张影响，与安达曼海蛇绿岩一起沿着实皆断裂以 15~20 $mm \cdot a^{-1}$ 的速度向东北移动，在中新统早期（20Ma）左右，就位于掸–泰地块边缘[40−45]。其受东喜马拉雅构造结和印度板块向东挤压影响，在缅甸中部盆地形成 NNW-SSE 向雁行式褶皱和南北向的右旋剪切带，地质构造主要受印度板块向北俯冲控制，出露地层较全，既发育有古生代沉积建造，又发育有完整的中、新生代地层序列，地层和构造具明显分区性（图 1 b）。

前寒武系：结晶基底（Chaung Magyil 群）主要分布在缅甸东北部克钦邦和掸邦的西北部、中部，掸邦与曼德勒省 (Mandalay) 的交界处，克钦变质岩和抹谷（Mogok）片麻岩最为典型。

寒武系：主要分布在掸邦斜坡的北部和南部，岩性以砂岩、页岩为主。

奥陶系：分布在掸邦，岩性以石灰岩和砂岩为主，在克耶邦（Kayah）也有奥陶系石灰岩地层出露，主要为掸邦北部 Naungkangyi 群和掸邦南部 Pindaya 群，掸邦南部碳酸盐岩较北部发育，在东枝–曼德勒（Taunggyi-Mandalay）发育中厚层石灰岩，在耶岸镇（Ye-ngan）Wunbye 组石灰岩厚 1 633 m。曼德勒以东的 Lokepyin 组石灰岩厚度超过 900 m[4]。

志留系：主要分布在掸邦北部和掸邦南部，北部主要以硅质碎屑沉积岩为主，在眉谬（Maymyo）一带发育 Nyaungbaw 组中厚层纯石灰岩。

泥盆系：零星出露在掸邦北部和掸邦南部，在曼德勒–眉谬一带，发育 Maymyo组碳酸盐岩，岩性为薄层黑色石灰岩、白云岩化石灰岩、黑色页岩和礁石灰岩。

石炭系：主要分布在掸邦南部和孟邦–克伦邦 (Mon-Kayin) 一带，岩性以沉积碎屑岩和石灰岩为主。

石炭系–二叠系：主要分布在掸邦东部和南部、克耶邦、克钦邦东部和德林达依省 (Tanintharyi) 大部分地区，岩性以凝灰岩、沉积碎屑岩为主，德林达依省的 Mergui 群主要为凝灰岩和集块岩。

二叠系：岩性以石灰岩和红层为主，主要有克钦邦东北部 Legwi 石灰岩组，孟邦–德林达依省一带 Tharabwin 石灰岩组和 Moulmein 石灰岩组，红层分布在克耶邦。

二叠系–三叠系：高原石灰岩群，是缅甸岩溶地貌发育的主要层位，主要分为白云质灰岩、硅质石灰岩和礁灰岩三个岩石层序，分布在掸邦、克耶邦、克

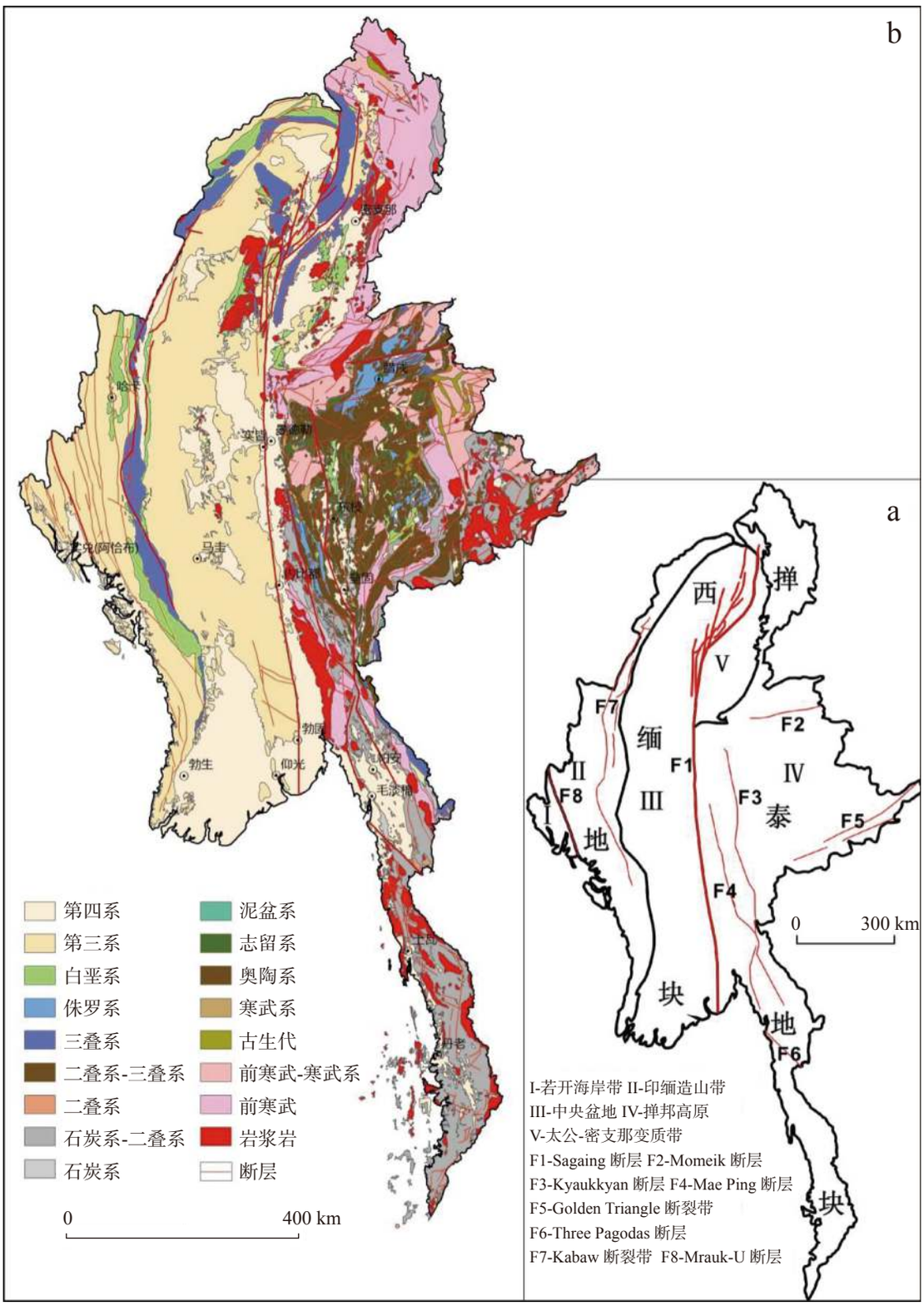

图 1　缅甸构造简图(a)[33-35]和缅甸地质简图(b)[46-47]

Fig. 1　Structural map (a) and geological sketch map (b) of Myanmar

伦邦，向北西延伸至中国的云南保山地块的沙子坡组、大凹子组和腾冲地块的大东场组，向东与泰国北部二叠系高原岩溶连接，与泰国的 Ratburi 石灰岩组和马来西亚 Chuping 石灰岩组和 Kodiang 石灰岩组相对应。

三叠系：主要分布在若开邦–钦邦 (Rakhaing-

Chin) 东北边缘、实皆省北部、克钦邦西部、太公–密支那一带和克伦邦东部，中下三叠统以碳酸盐岩沉积为主，厚度可达千米，上三叠统以薄层泥岩、粉砂岩为主。若开邦–钦邦东北边缘岩性主要由厚层含藻类化石的深海复理石沉积岩和部分蛇绿岩组成；实皆省北部封闭盆地发育薄层蒸发岩和页岩；克伦邦东部为石灰岩。

侏罗系：在掸邦高原东北部发育石灰岩和红层，在德林达依省发育 Mergui 的红层，克伦邦–克耶邦发育的红色砂岩。

白垩系：在克钦邦南部及与实皆省的交界处，发育 Kabaw 组和薄层含 *Orbitolina*的石灰岩；在格劳（Kalaw）盆地发育红层和粉砂岩；在印缅造山带发育复理石沉积单元，包括含 *Globotruncana* 的石灰岩。

第三系：主要发育复理石和磨拉石沉积建造，在沿海地区发育部分礁灰岩。

第四系：沿着大河谷发育抹谷宝石砾石、Uyu 粗砾石、伊洛瓦底江的阶地和冲积层，在掸邦发育红土。

2 岩溶作用条件

2.1 地层发育厚层纯碳酸盐岩

缅甸岩溶主要发育在奥陶系–三叠系地层中（表 1，图 2），其中在西部山脉和太公–密支那构造带白垩系地层发育薄层石灰岩，岩溶作用较弱；二叠系–三叠系、泥盆系、志留系奥陶系发育厚层纯石灰岩、白云岩，碳酸盐岩厚度达几百到上千米，石灰岩的 $CaCO_3$ 含量在 80%~96%，白云岩中 CaO+MgO 含量超过 50%。在胶梅 (Kyaukme)西北部出露的二叠系–三叠系石灰岩厚度达 5 000 m，岩溶作用较强，而在格劳发育红层岩溶。

2.2 构造运动

缅甸位于印度板块倾斜碰撞的东部边缘，北部连接沿喜马拉雅山脉的印度–亚洲板块碰撞带，南部连接安达曼海，经历了复杂的板块碰撞拼贴及碰撞后的伸展、走滑运动。区域构造格架主要受印度板块向东北挤压和实皆断裂右旋走滑运动控制。新生代印度板块与亚洲板块碰撞及随后的喜马拉雅造山运动使得板块内发生大变形。中新世以来，印度板块持续向北俯冲、实皆断裂每年以 18 mm 的速度做右旋走滑运动，安达曼海不断扩张，掸邦高原形成一系列弧形走滑断层和褶皱，地层碳酸岩盐经历多次的挤压、伸展、右旋变形事件。第四纪强烈的抬升和侵蚀，造成地层、河流的强烈切割，碳酸盐岩层序发生断裂、解体，岩石节理、裂隙发育，为岩溶地貌的形成提供了有利条件。受主断裂–实皆断裂控制，区内的断层、褶皱构造呈近南北走向，控制着掸邦高原石灰岩山脉的延伸方向。

2.3 温润多雨的气候

缅甸北部属于亚热带气候，南部属于热带气候，

表 1 缅甸岩溶主要发育层位、特征及分布

Table 1 Main karst development layers, characteristics and distribution in Myanmar

序号	地层名称	地层年代	厚度/m	分布区域	特征	来源
1	Natteik	二叠系–三叠系	1 000	掸邦南部	透镜状石灰岩，发育峰林岩溶、落水洞	[48]
2	Nwebangyi	二叠系–三叠系	2 500~5 000	掸邦北部	高度角砾状白云岩、白云质灰岩、碎屑灰岩，局部发育鲕状灰岩，发育洼地、大型洞穴和天坑	[49]
3	Thitsipin	二叠系–三叠系	700~1 100	掸邦南部	石灰岩、白云岩，发育南北向山脊、落水洞、天坑、岩溶峡谷、洞穴，峰丛洼地	[48]
4	Moulmein	二叠系	<1 000	孟邦–德林达依省、克伦邦、克耶邦	石灰岩，发育崎岖岩溶山	[50]
5	Maymyo	泥盆系	几千米	眉谬	含化石白云质石灰岩	[51]
6	Nyaungbaw	志留系	几千米	眉谬	红色、棕褐色、灰色、蓝色石灰岩，含大量泥质物质	[51]
7	Wunbye	奥陶系	1 200~1 800	掸邦南部	粗晶状石灰岩；发育岩溶高地，发育大量的洞穴和天坑，洞穴大多平行于层理发育	[51]
8	Lokepyin	奥陶系	400~900	掸邦南部	蓝色石灰岩夹薄层粉砂岩	[51]

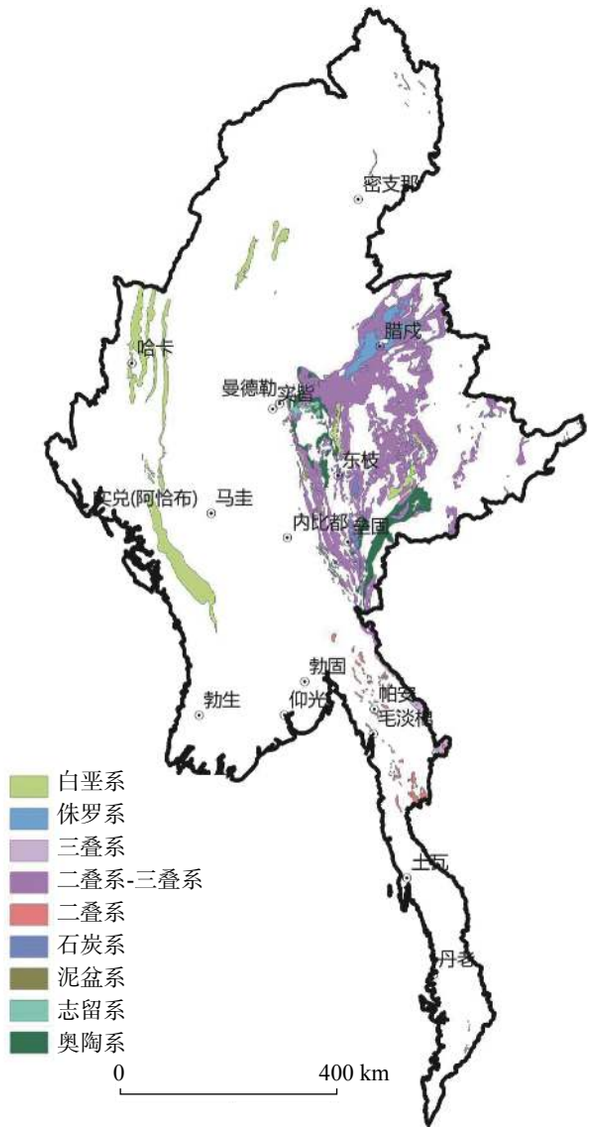

图 2　缅甸岩溶地质分布图[46-47]

Fig. 2　Karst distribution in Myanmar

11 月至次年 1 月为冬季，2-4 月为旱季，5-10 月为雨季，主要受西南季风影响，年降雨量充沛（表 2），南部和西部沿海地区年降雨量达 5 000 mm，北部和东部山区达 1 250~3 000 mm，1958—2021 年，缅甸全国降雨指数为 2 329.0 mm·a^{-1}。其强降雨量促进了岩溶作用过程。

2.4　活跃的生物活动

缅甸是东南亚生物多样性较高的地区之一，保留着大片的原始森林，同时也广泛发育海洋生态系统，其生态系统目前是受干扰最小的[52]。在缅甸掸邦岩溶区，由于石灰岩山脉陡峭，地方自治限制进入，掸邦高原的大部分石灰岩山脉、山丘被茂密的

表 2　缅甸主要岩溶区年平均降雨量（2011–2020）

Table 2　Annual average rainfall in the karst areas of Myanmar (2011-2020)

序号	地区	降雨量/mm·a^{-1}
1	克钦邦	2 339.4
2	克耶邦	894.2
3	克伦邦	3 217.6
4	钦邦	1 832.5
5	实皆省	1 445.1
6	德林达依省	5 088.7
7	勃固省	2 088.4
8	孟邦	4 726.2
9	若开邦	4 455.4
10	掸邦	1 359.8

森林、草地覆盖，拥有世界上最丰富的生物多样性[52]。设立保护区是保护生物多样、保持生态系统平衡的重要途径，在《缅甸 30 年森林总体规划（2002—2031 年）》中指出，到 2031年，缅甸生物多样性保护区总面积达到国土面积的 10%。截至 2018 年，缅甸共建立 42 个生物多样性保护区，生物多样性保护效果显著。2010 年，在缅甸掸邦岩溶区发现了金丝猴、金猫，羚牛等珍贵物种。2014—2020 年，国际动植物协会对缅甸岩溶区的蝙蝠、爬行动物、无脊椎动物、植物进行调查时，发现超过 100 种新的物种，其中有 19 种新壁虎物种[53]。

3　岩溶分布特征

缅甸岩溶主要分布在伊洛瓦底江以东的掸邦高原山地和安达曼海的南部（图 2）。在北部的克钦邦、西部钦邦、实皆省也发育部分岩溶地貌。掸邦高原是缅甸最大的岩溶区，岩溶面积达 6.3×10^4 km^2，呈南北向带状从掸邦向南延伸 1 500 km 到达丹老群岛（Mergui Archip elago），向北延伸至中国云南岩溶区，向东延伸至泰国高原岩溶和洼地岩溶区[54]，主要分布在腊戍、胶梅、眉谬、耶岸、格劳、宾朗、克耶邦、帕安、毛淡棉和丹老群岛等地区，岩溶主要发育在二叠系–三叠系、三叠系、奥陶系、志留系地层石灰岩、白云岩中，发育峰林、峰丛、洞穴、落水洞、天坑等岩溶景观，石灰岩山峰海拔高 900~1 800 m。二叠系–三叠系地层石灰岩是岩溶强发育的主要层位，部分地层厚 5 000 m。缅甸地貌主要由地层岩石控制，碎屑岩出露的地区，覆

盖厚层土壤，发育混圆形山丘地貌；在碳酸盐岩地区，发育突兀的山脊、锥形山峰和封闭洼地，纯石灰岩地区一般为山地，生长茂密树林，在白云岩地区为宽广草地。帕安是高山岩溶向洼地岩溶的过渡区域，掸邦北部–帕安主要发育南北向的锯齿状石灰岩山脊、岩溶峡谷、洞穴和天坑，石灰岩山峰陡峭，平均海拔 1 100 m，在宾朗到帕安主要发育峰丛洼地。在帕安发育的峰林，几乎每座石灰岩山丘都发育有洞穴，洞穴长 400~800 m，大部分洞穴已被开发，建设成为寺庙[55]。帕安以南的安达曼海南部主要发育孤峰平原和石灰岩岛屿，其石灰岩山丘高 400 m，沿北西–南东向发育，岩溶丘陵环绕着形成小的封闭岩溶盆地，石灰岩山丘几乎裸露，只生长少量植物。

4 洞 穴

缅甸发育有数量庞大的洞穴系统，许多洞穴被用于建造寺庙，可追索到几个世纪以前。Pindaya、Shweoo Min、Sadan、Pho Win Taung、DatDawTaung、Kawgun 等洞穴，因洞内灿烂的佛教文化，成为缅甸著名的佛教朝拜地。掸邦的 Pindaya 洞，以洞内有超过 8 000 座佛像成为缅甸最著名的佛教朝拜地和旅游洞穴。缅甸洞穴主要分布在掸邦高原二叠系–三叠系石灰岩地层中，而奥陶系石灰岩地层洞穴发育不太好，该地区地质演化历史、构造作用相差不大，洞穴走向主要受断裂控制，大部分洞穴沿断层发育。掸邦高原地形和气候上南北差异较大，在北部发育岩溶带状山脊区，发育天坑和长的洞穴，而在南部沿海孤峰平原区，降雨量大，几乎每座石灰岩山峰都发育有短的脚洞。

缅甸系统调查洞穴起步较晚，有关资料大部分在殖民时期由英国学者所记录，基本上都是关于洞穴动物群的记录[56−61]。1948 年缅甸独立后，大部分岩溶区属于民族自治区，未对外国人开放，掸邦岩溶和洞穴的调查很少，部分地区是完全未知的。2009 年以前，只有少数来自澳大利亚、法国等外国的洞穴学者和蝙蝠研究者有机会进入缅甸，形成了一些比较有价值的资料[62−70]。2009 年，瑞士、英国、德国、缅甸等 13 个国家联合开展缅甸洞穴勘探项目，对全国范围内岩溶地貌、洞穴开展系统调查。截止 2020 年，缅甸已探明的洞穴系统有 800 多条，超过 1 km 长的洞穴有 13 条 (表 3)，出版了 3 本缅甸洞穴探测报告[71−73]，而这些洞穴尚未完成全部的勘探。探明最长的洞穴是位于掸邦东部 Monghpyak 地区的 Som Hein 洞，该洞穴于 2020 年 1 月完成了 11 600 m

表 3 缅甸已知最长洞穴列表（截止 2020 年 4 月）[32]

Table 3 Longest cave of Myanmar (by the end of April, 2020)

序号	洞穴名称	位置	长度/m
1	Som Hein	Monghpyak	11 600
2	Kyauk Khaung (Stone Cave)	Ywangan	4 790
3	Phruno River Cave	Hpruso	4 580*
4	Red River Cave	Bawlakhe	4 095
5	Namun Spring Cave	Pinlaung	2 628
6	Kyet Cave	Loikaw	2 194
7	Stone Spring Cave	Ywangan	1 917
8	Ho Hwe Cave	Hopon	1 875
9	Mondowa Guh	Taunggyi	1 770
10	Hopon Spring Cave	Hopon	1 655
11	Na Gar Gu (Dragon Cave)	Ywangan	1 654
12	White water Buffalo and Tiger Cave	Hopon	1 343
13	Ya Thay Pyan	Hpa-An	1 252
14	Phoe Inn Cave	Ywangan	1 210

注：*表示未完成探测，不是最终的长度。

Note: * indicates that the probe is uncompleted, so, it is not the final length.

的勘测[36]；Namun Spring(图 3)和 Kyauk Khaung(图 4)是探明洞穴中河洞的代表，洞内水流随着季节降雨量变化而变化，洞穴通道大部分被地下河淹没，雨季洞内溪流流量较大，会淹没部分洞穴通道，洞内随处可见深的潜水坑，其发育有大量石笋、石钟乳、石柱、石幔和大型的泉华滩。

5　结　语

缅甸岩溶发育强烈，全国范围内岩溶发育面积达 7×10^4 km^2，是东南亚岩溶发育面积第二大国家，具有较大的岩溶资源潜力。缅甸岩溶分布主要受区内构造和地层岩性控制，岩溶地貌由北至南呈带状石灰岩山脊—峰丛洼地—峰林平原变化。古生代和中生代厚层纯碳酸盐岩地层是岩溶发育的主要层位，温润多雨的气候和活跃的生物活动加速了岩溶作用过程，其与中国云南岩溶具有相似起源。缅甸岩溶研究、洞穴调查工作比较薄弱，岩溶区干旱、洪涝灾害不断加剧，亟待开展详细的岩溶水文地质调查工作。

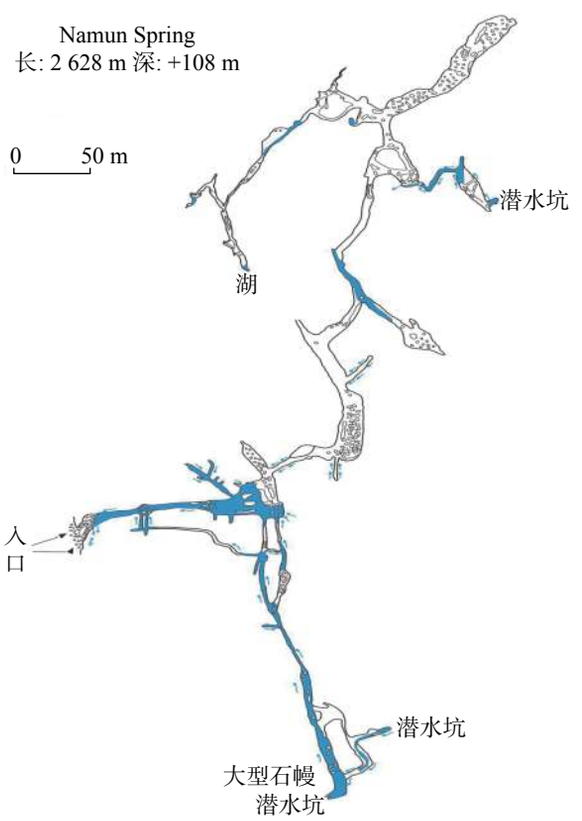

图 3　Namun Spring 洞穴[71]

Fig. 3　Namun Spring Cave

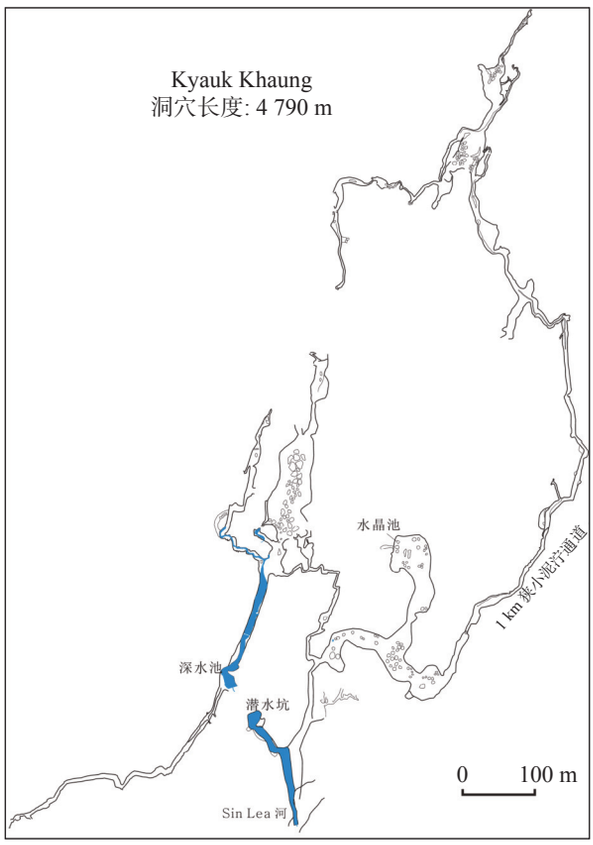

图 4　Kyauk Khaung 洞穴[71]

Fig. 4　Kyauk Khaung Cave

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An overview of karst geology in Myanmar

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Abstract With a widespread area of karst accounting for about 12% of the national territory, Myanmar, the second largest country in Southeast Asia in terms of karst area, has great potential of karst resources. However, due to outdated infrastructure and other reasons, the research on karst geology in Myanmar started late with a weak foundation. Having been in the developing stage of karst geology research in Myanmar, comprehensive karst geological data is conducive to understanding karst in this country. On the basis of systematic data collection, this study synthesizes remote sensing data with geologic map, hydrogeologic map, and structural map on various scales. It comprehensively analyzes the background conditions of karstification from the geological evolution process, lithologic combination, and climate and environment, and summarizes the karst distribution law and the characteristics of karst landscape in Myanmar.

Extending to the borders of Thailand, Laos and China, karst in Myanmar covers an area of 70,000 km^2, distributed in the high land and mountainous area of Shan State to the east of the Irrawaddy River and the south of Andaman Sea. Some karst landforms are also developed in Kachin State in the north, Chin State in the west and Sagaing State in the northwest. Mainly developed in the Permian-Lower Triassic limestone and Early Ordovician limestone, karst on the Shan Plateau in the east is the largest karst area in Myanmar, with an area of about 63,000 km^2. The belt-shaped karst extends 1,500 kilometers from Shan State to Myeik Archipelago in a south-north direction. Intensity of karstification in Myanmar is controlled by many geological factors such as stratigraphic lithology, geological structure and environment. Thick Paleozoic carbonate strata, warm and rainy climate, complex tectonic movements and active biological activities are all conducive to the occurrence of karstification. The thick layers of Permian-Triassic, Triassic, Ordovician, and Silurian periods, pure limestone, and dolomite are the main layers of karst development, especially 5,000-meter-thick Permian-Triassic limestone in Shan State. With the highest biodiversity in the world, active biological activities in Myanmar facilitate karstification. The karst landform in Myanmar is controlled by stratigraphic lithology, with the development of peak forests, peak clusters, and karst cave landscapes. From north to south, karst landforms change from limestone ridges, canyons, cluster-peak depressions to peak forest plains. Hpa-an is a transitional area from high mountain karst to depression karst.

Key words Myanmar, karst geology, karst landscape, cave

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（上接第 732 页）

project—"storing" and "diverting" in the upper reaches, "blocking" in the middle reaches, and "intercepting" in the lower reaches—has been adopted to increase the level of the underground river by 70 cm from the outlet to Baxian lake. This project can shorten the period of keeping a low water level by more than one month. In view of the dispersed drainage characteristics of the Mudong lake system, the technology of regulating water resources by "diverting" at the entrance and "intercepting" at the outlet was adopted. The water level at the exit was raised by 30 cm and the water level in the core area by 10-20 cm, delaying the time of keeping the low water level for more than two months.

Key words Huixian karst wetland, storage height, underground river system, dispersed drainage system, Guilin

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