层状白云岩储层特征与成因

——以黔桂地区泥盆系、石炭系及湘鄂交界地区三叠系为例

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地质出版社

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内 容 简 介

本书是对黔桂地区泥盆系、石炭系和湘鄂交界地区三叠系层状白云岩研究成果的总结，研究区面积近36万 km^2。内容包括层状白云岩的岩石学、地球化学及其对成因、演化、储渗性和在区域上的空间展布规律的探讨。所建立的研究区层状白云岩的10种地质模式，可作为我国碳酸盐岩地层中层状白云岩油气勘探和预测的对比资料，也可用于层状白云岩中其它矿产资源勘探的基础资料。

本书可供从事沉积学、石油地质学教学与科研工作的人员参考。

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前　言

本书是原中国石油天然气总公司“八五”重点攻关项目“中国油气储层研究”中的一个子课题的研究成果。研究范围和层系包括处于华南南部被动大陆边缘的黔、桂两省的泥盆系、石炭系和处于克拉通内湘鄂交界地区的三叠系，研究区面积约 36 万 km^2。

层状白云岩是世界上碳酸盐岩地层中最主要的油气储渗体，同时也是许多有色金属硫化物矿产及某些非金属矿产的有效储层之一。我国四川盆地是多层系的油气区，在已知 13 个产油气层系中，有 8 个为碳酸盐岩储层。其中，除下侏罗统自流井组的大安寨段为湖相含泥质介壳石灰岩、下二叠统以生物灰岩段多于白云岩段外，其它层系均为层状白云岩或以层状白云岩为主的储层，包括震旦系灯影组、上石炭统黄龙组、上二叠统长兴组、下三叠统飞仙关组和嘉陵江组、中三叠统雷口坡组。震旦系灯影组的最大有效储层段，厚达 50～120m，下三叠统嘉陵江组可达 50～100m。陕甘宁盆地奥陶系马家沟组为含膏盐的层状白云岩，是目前我国已探明的面积最广、储量最大的天然气储层。华北震旦系雾迷山组层状白云岩是华北油田主要油气储层之一。此外，南疆塔里木盆地下奥陶统亦发育有层状白云岩储层。在国外，层状白云岩同样是碳酸盐岩地层中最主要的储集岩，如北美二叠纪盆地中的二叠系及阿尔伯达盆地泥盆系的生物礁白云岩、威利斯顿盆地 Cabin Creek 油田的上泥盆统、美国得克萨斯州 Comenche 区的下白垩统、加拿大萨斯喀彻温省米得尔油田的密西西比系查理士组、俄罗斯乌克蒂尔气田的石炭系和二叠系、伏尔加-乌拉尔盆地的上泥盆统、中东侏罗系阿拉伯组 D 段等。

世界油气勘探生产资料表明，石油天然气储量和产量的近 50% 来自碳酸盐岩地层，而碳酸盐岩地层中油气量的 80% 又是由层状白云岩中产出的。在我国，尽管已成功地从碳酸盐岩地层中，尤其是从层状白云岩地层中勘探出了不少油气藏，但与国外相比，无论储量和产量均有较大的差距。目前，国外天然气与石油的储量比大致为 1:1，我国则大致为 1:9，而碳酸盐岩地层中的天然气剩余储量比则更小。在我国南方陆区，除四川盆地外，油气勘探尚无大的突破。为了改变这种不正常的情况，极需加强碳酸盐岩，特别是层状白云岩的超前研究，研究其岩石学、地球化学、成因、演化、储渗性，找出其空间展布规律，建立适合于研究区层状白云岩的储层地质模式。这不仅可为我国南方提供对比资料，亦可作为我国其它地区层状白云岩油气勘探和预测的借鉴模式。这就是“八五”期间原石油天然气总公司科技局和课题组立题的指导思想。

1996 年 7 月 21～26 日在海南省三亚市召开了“南方油气勘探会议”。原石油天然气总公司周永康副总经理在会议结束的讲话中着重指出：“南方原型盆地在古生代到中三叠世期间处于特提斯有利位置，具良好的含油气远景，具有与世界其它特提斯域类似的含油气特征和资源丰度。从目前南方各地发现的大量古油藏及 1500 多处油苗，以及钻遇古生代地层的井有一半以上都见油气显示的情况看，南方油气分布是极其广泛的。”研究南方古生界和三叠系层状白云岩的重要性不言自明了。

黔桂地区是华南陆块中上古生界地层发育最齐全的海盆，其中泥盆系、石炭系碳酸盐岩厚度达1000～5000m或更厚。湘鄂交界区的三叠系仅下统碳酸盐岩厚度就达1139～1887m。在这样巨厚的碳酸盐岩地层中，广泛发育了各种类型的白云岩体。野外产状具多样性，可以呈星散小斑块状，规则或不规则的细小脉状，大小不等、形态各异的斑(团)块状、小透镜状，不规则的串珠状，或纵向上呈漏滴状，孤立或成排的大透镜状，延伸远、规模大、顺层理方向展布的似层状或与层理交切的“脉状”，以及成层性好、区域上具固定层位的巨厚层(厚的可达百米以上)白云岩。除最后这类产状的厚层状白云岩主要为准同生交代成因外，其它各类产状的白云岩无疑是在沉积期后成岩作用的不同阶段及不同的成岩环境中，由一种或多种地质因素联合作用下交代原石灰质沉积物形成的。白云岩体中白云石的含量变化极大，高的可达90%以上，甚至巨厚的岩体均由白云石组成，含量低的仅占30%～50%或更少。白云岩体与石灰岩围岩的边界可以截然分开，也可以是逐渐过渡的。我们不能对上述产状多样、白云石含量各异的白云岩体不分主次地研究。从工业油气储渗体出发，仅对那些白云岩含量>50%，延伸远、规模大的似层状大透镜体或“脉状”白云岩体和区域上具固定层位、厚度大的层状白云岩体进行研究。

本成果是对近40个层状白云岩地面剖面和钻井岩心点进行详细研究取得的。工作中，我们十分重视层状白云岩所在地层组、段，或岩心井段地层的沉积环境，对白云岩体的产状进行了详细的观察、追踪和丈量，注意了与石灰岩围岩的接触关系及孔隙发育规律等，并有目的地进行系列采样。大量野外、岩心和室内研究工作表明，沉积环境不仅控制了原始沉积物岩性和组构特征，也制约了同成岩期和埋藏成岩期不同白云石化的形成机制。尤其是黔桂地区，晚古生代位于被动大陆边缘，北东和北西向两组基底断裂形成了连陆台地、孤立台地和台间海槽相间的古地理格局；不同亚环境中由不同白云石化机理形成的层状白云岩，其产状、规模、展布、储渗性等都有明显的差别。

对所采样品在薄片观察基础上系统地进行了各项地球化学测试分析，并结合野外和井下资料，采用岩石学与地球化学相结合，沉积环境与成岩环境相结合，成岩阶段与白云石化作用及演化相结合，无机与有机成岩作用相结合的思路，对单项和多项资料作相关性分析，最终建立了研究区所研究层位中的层状白云岩储层概念模式，包括同生成岩环境中的潮坪潮汐泵汲白云石化模式，潮下海水泵汲白云石化模式，近地表混合水白云石化模式，埋藏成岩环境中的调整-压实排挤流白云石化模式，有机质参与的压实排挤流白云石化模式，以埋藏热水为主的混合白云石化模式，以埋藏热盐水为主的混合白云石化模式，以及与区域构造断裂有关的构造热液白云石化模式。

本书虽然是“八五”期间的研究成果，但大量基础资料是作者所在的西南石油学院碳酸盐岩研究室“七五”期间所承担的部级项目“中国南方泥盆、石炭纪岩相古地理及含油气性研究”、“西南地区海相碳酸盐岩相模式在油气勘探中的应用”，和国家自然科学基金资助项目(基金编号4880109)“滇黔桂地区晚古生代深水碳酸盐岩及控油气控矿性研究”等所积累的。因此，这份成果凝聚了更多同志的劳动和智慧，他们是黄继祥、沈昭国、林维澄、张廷山教授，赵劲松、何远苾副教授等。此外，有多名研究生先后参加了研究工作。广西地质研究所吴诒教授级高工，无论是在野外工作和室内综合分析都给予了无私的协助，广西石油勘探指挥部的张可怀、张合鉴等同志也给予了多方面的支持，在此，表示衷心的谢意！

作者感谢以裘怿楠同志为主任的课题专家验收评议组。专家们鉴于该成果的学术水平

和对我国层状白云岩中油气勘探的实用意义，在验收评议书中“建议修改后正式出版”。还要感谢原石油天然气总公司科技局和西南石油学院“油气藏地质与开发工程国家重点实验室”给予出版经费资助。

作　　者

1998 年 3 月

于西南石油学院

Preface

This book is written based on part of the research products of the "Eighth-Five Year Plan" key research project sponsored by China National Petroleum Corporation titled as "Study of Oil/Gas Reservoirs in China". The interest formations of the study are Devonian and Carboniferous Systems developed in Guizhou and Guangxi Provinces at the passive continental margin of Southern China and the Trassic Systems developed in the juncture areas between Hunan and Hubei Provinces at craton. The working area is about $0.36 \times 10^6 km^2$.

Layered dolomite is the major oil/gas reservoirs of carbonate rocks in the world, and is one of the effective reservoirs for diversified nonferrous metal sulfide minerals and some non-metal minerals as well. Sichuan basin has various oil/gas producing formations, of its 13 known producing formations, 8 are the carbonate reservoirs, of which except that the Daanzhai Section. Ziliujing Formation of Lower Jurrasic is muddy-Shelly limestone of Lacustrine Facies, and the Lower Permian has better developed biogenic limestone than dolomite, in all the other producing formations, the layered dolomite is the predominant reservoir type, such as Dengying Formation of Sinian, Huanglong Formation and Jialinjiang Formation of Lower Trassic and Leikoupo Formation of Lower Trassic. The maximum effective thickness of reservoirs in Dengying Formation of Sinian reaches 50～120m, and that of Jialinjiang Formation of Middle Trassic reaches 50～100m. Dolomite is also the major reservoir type in some other basins of China. For instance, the gypsum-salt bearing layered dolomite reservoirs in Majiagou Formation of Ordervician in Ordos Basin, its being currently the gas reservoir with largest area and richest reserves proved in China; The layered dolomite of Wumishan Formation of Sinian, being one of the major oil/gas reservoirs in Hubei oil field; and in Tarim Basin also developed layered dolomite reservoirs in Lower Ordervician. Layered dolomite is also the worldwide predominant carbonate reservoir, such as the Permian in Permian Basin of North America, the Devonian in Alberta Basin the Upper Devonian in Cabin Creak oil field of Weiliston Basin, the lower Cretaceous in comenche area in Texas of America, the Charles formation of Mississppian in Midel oil field of Canadal, the Carboniferous and Permian in wuketir gas field and the upper Devonian in Furjia-Wular Basin of Russia, the D interval in Arab Formation Jurasic of Middle East, etc.

Oil/gas and production data in the world indicates that about 50% of oil/gas reserves and production are from carbonate rocks, of which 80% is from layered dolomite. In China, although large numbers of oil/gas reservoirs have been discovered in carbonate, especially in layered dolomite, the reserves and production of oil/gas obtained are much lower in comparison with that in some other countries Presently, the world ratio of oil remaiming reserves vs. gas remaining reserves is around 1∶1, whereas that in China is much greater, reaching 9∶1, and for carbonate reservoirs, this ratio is even much lower. By now except in Sichuan Basin, no significant

breakghrough on oil/gas exploration has been ever made yet in Southern China continental areas. To study carbonate rocks particularly the layered dolomite covering its petrology, geochemistry, distribution, formation, evolution, pores and permeability etc. to understand its spatial distribution and establish the gealogical model of layered dolomite reservoirs of interest areas is of great significance to the improvement of the current situation. It will not only provide references for the exploration activities of Southern China, but also can work as a reference model for the oil/gas exploration and prediction in layered dolomite in other areas of China. This is the point of departure of the Science and Technology Bureau of CNPC to have this project in progress.

On July 21～July 26 of 1996, "CNPC Meeting on Oil and Gas Exploration in Southern China" was held in Sanya City, Hainan Province. Mr. Zhou Yongkang, the former president of CNPC emphasized in his closing remarks that "The original southern China basin was in a favorable position in Tertis domin during Paleozoic to middle Trassic with their oil/gas bearing features and quantity similar to those in other Tertis areas in the world. The large numbers of paleo-reservoirs, over 1500 oil seepages and the oil/gas shows in over half wells drilled in Paleozoic formations in Souther China areas all suggest that oil/gas are widely distributed in these areas and is of very fine exploration prospects." The importance of the Paleozoic and Trassic layered dolomite of Southern China is well reflected in this speech.

In Southern China continental segment, the Middle—Upper Paleozoic formations are best developed in Guizhou and Guangxi areas. There Devonian and Carboniferous carbonates reach 1000～5000m or more in thickness, and in the juncture areas of Hunan and Hubei Provinces, only the lower Trassic carbonate alone can be thick to 1139～1887m. In these carbonate formations of great thickness are widely developed various dolomite rocks which occurred in the field with diversified occurrence, such as scattered small patches, regular or irregular fine veins, patches and lumps with different size and shapes, small lenticles, irregular paternosters, large lenticles isolated or occurred in lines in profiles, layered－like ones distributed along bedding, or vein-like ones crossing bedding as well as the thick dolomite (may reach over 100m) with stable regional distribution. Except that the thick dolomite is formed through penecontemporaneous metasomasis mechanism, all the dolomite of other occurrence above are obviously the products of limestones replaced by dolomite under the control of one or more geological elements during different post-deposition diagenesis phases and different diagenesis environment. The content of dolomite varies greatly in dolomite rocks, it can be high to over 90%, sometimes a thick dolomite body can be even totally composed of dolomite, and it may also be bow to 30%～50% or even lower. The boundary between dolomite and its host limestone can be very clear, or show a transitional relationship between the two rocks. It will not make any sense if we study all those dolomite of different occurrence above, our interest dolomite are those which can serve as commercial oil/gas reservoirs. Usually these dolomite are widely distributed and extended, and contain over 50% or dolomite, such as those layered-like large lenticle of vein dolomite and thick layered dolomite with stable regional distribution.

This research project is based on detailed study on about 40 surface profiles and coring

horizons of dolomite. In the progress of our study, we attached great importance to the sedimentary environment of layered dolomite in defferent geological formations or intervals, carefully observed, traced and measured the occurrence of dolomite, paid attention to the contact relationship between dolomite and limestone as well as the development and distribution of pores, and also systematically cored dolomite samples. The great amount of field study and Lab analysis reveals that sedimentary environment ont only controlled the composition and textures of original sediments, but also controlled the mechanism of dolomitization during syndiagenetic and burial diagenesis phases. The areas of Guizhou and Guangxi Provinces were in the passive continental marginal area during Paleozoic, where the two NW and NE oriented basement fractures created a paleogeographical pattern composed of continental-linked platform isolated platform and trough in between. The layered dolomite formed by different dolomitization mechanism in different sub－sedimentary environment are quite different in their occurrence, scales, distribution and porosity and permeability development.

Based on thin section identification and analysis of dolomite samples and combining with field and well data also integrating petrology with geochemistry, sedimentary environment with diagenetic environment diagenesis phase with dolomitization and its evolution and inorganic diagenesis with organic diagenesis, we carried out the correlation analysis of various related data and established the conceptual models of layered dolomite reservoirs of interest horizons of the working area. These models includes: active tial pumping dolomitization model, active seawater pumping dolomitization model, dorag mixed dolomitization model, carmibalazation squeeze compaction flow dolomitization model, squeeze compaction flow participating with participation of organic matter dolomiization model, buried hot-water dorag dolomitization model, buried hot brine dorag dolomitization model, and texture hydrothermal dolomitization model associated with regional faults.

Although this book is the product of our "Eighth-Five Year Plan" research project, the great numbers of original data are accumulated during the past many years by the Carbonate Research Division of Southwest Petroleum Instiute , which the author belongs to, through research projects of CNPC during the "Seventh-Five Year Plan" titled as "Study on the Paleogeography Oil/gas Bearing Features of Devonian and Carboniferous of China" and "Marine Carbonate Petrofacies Models in Southwestern China Areas and its Application in Oil and Gas Exploration", as well as the project sponsored by the State Natural Science Funding Commission titled as "Study on Late Paleozoic Deep Water Carbonate and its Controlling on Oil/Gas and on Mineral Deposits" (Funding number 4880109). This book, therefore, is the crystallization of wisdom and contribution of many our colleagues. I sincerely thank Prof. Huang Jixiang, Prof. Shen Shaoguo, Prof. Lin Weicheng, Prof. Zhang Tingshan. Associate Prof. Zhao Jinsong and Associate Prof He Yuanxin et al for their great effort provided to the project. I also appreciate the help of many our graduate students and the disinterested assistance of Prof Wu Zhi from Guangxi Geology Research Institute on both our field work and Lab analysis as well as the help on various aspects of Mr. Zhang Kebei and Mr. Zhang Hejian from Guangxi Petroleum Explo-

ration Bureau.

I appreciate the project Evaluation Group leading by Prof. Qiu Yinan for their comments on our final report "suggest to make some necessary revise and be formally published" based on the academic level and the practical application of our project in the oil/gas exploration of layered dolomite of China and also appreciate the Science and Technology Bureau, CNPC and the "State Key Laboratory on Oil/Gas Reservoir Geology and Development Engineering" of Southwest Petroleum Institute for their sponsoring the publication of the book.

Author

March, 1998.

Finished in south west petroleum Institute

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第一章　黔桂地区区域地质背景

第一节　概　　况

研究区包括广西及贵州省的毕节—贵阳一线以南的黔西南、黔南地区(该线以北无泥盆系、石炭系碳酸盐岩沉积),面积约 30 万 km^2。

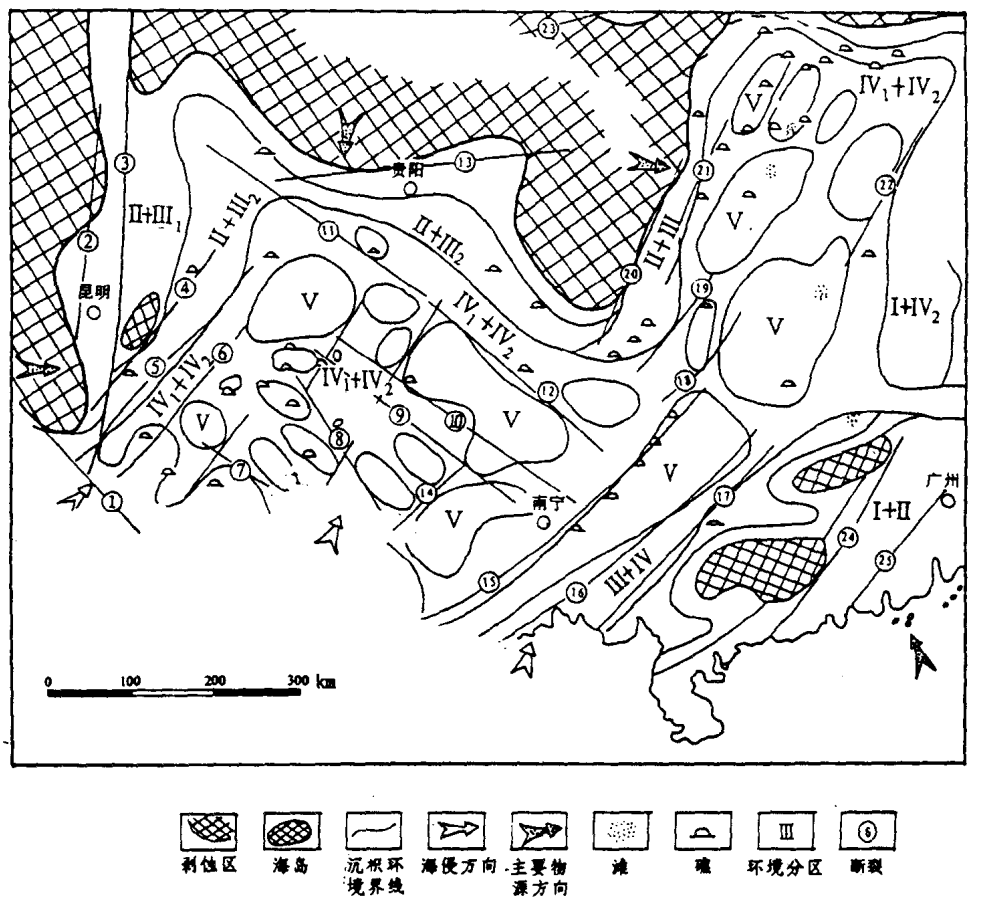

图 1-1　黔桂地区中泥盆世沉积环境及断裂分布图

(据西南石油学院碳酸盐岩研究室,1988,略有修改)

环境:I.陆区;Ⅱ.过渡区;Ⅲ.连陆碳酸盐台地;$Ⅲ_1$.连陆内缘碳酸盐台地;$Ⅲ_2$.连陆外缘碳酸盐台地;$Ⅳ_1$.台地边缘斜坡;$Ⅳ_2$.台间海槽;Ⅴ.孤立碳酸盐台地。断裂名称:①哀牢山断裂;②普渡河断裂;③小江断裂;④曲靖断裂;⑤弥勒-盘县断裂;⑥南盘江断裂;⑦文山断裂;⑧那坡-富宁断裂;⑨西林-田东断裂;⑩隆林-巴马断裂;⑪垭都-紫云断裂;⑫南丹-忻城断裂;⑬贵阳-新晃断裂;⑭下雷-东平断裂;⑮凭祥-大黎断裂;⑯灵山-藤县断裂;⑰博白-梧州断裂;⑱荔蒲断裂;⑲柳州-灵川断裂;⑳三江-融安断裂;㉑步城-洞口断裂;㉒柳州-衡山断裂;㉓慈利-大庸断裂;㉔吴川-四合断裂;㉕恩平-连平断裂

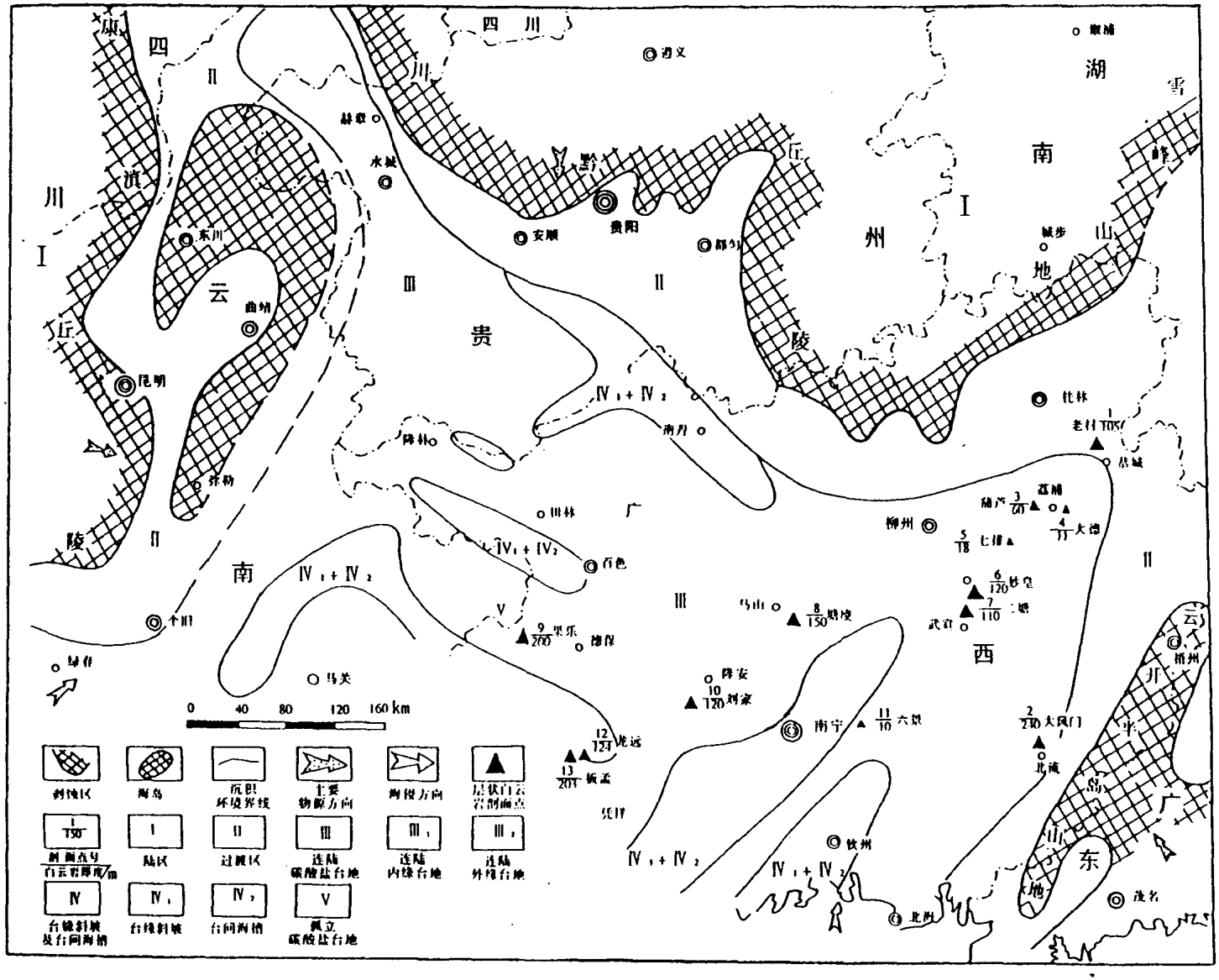

图 1-2　黔桂地区早泥盆世沉积环境及层状白云岩分布图

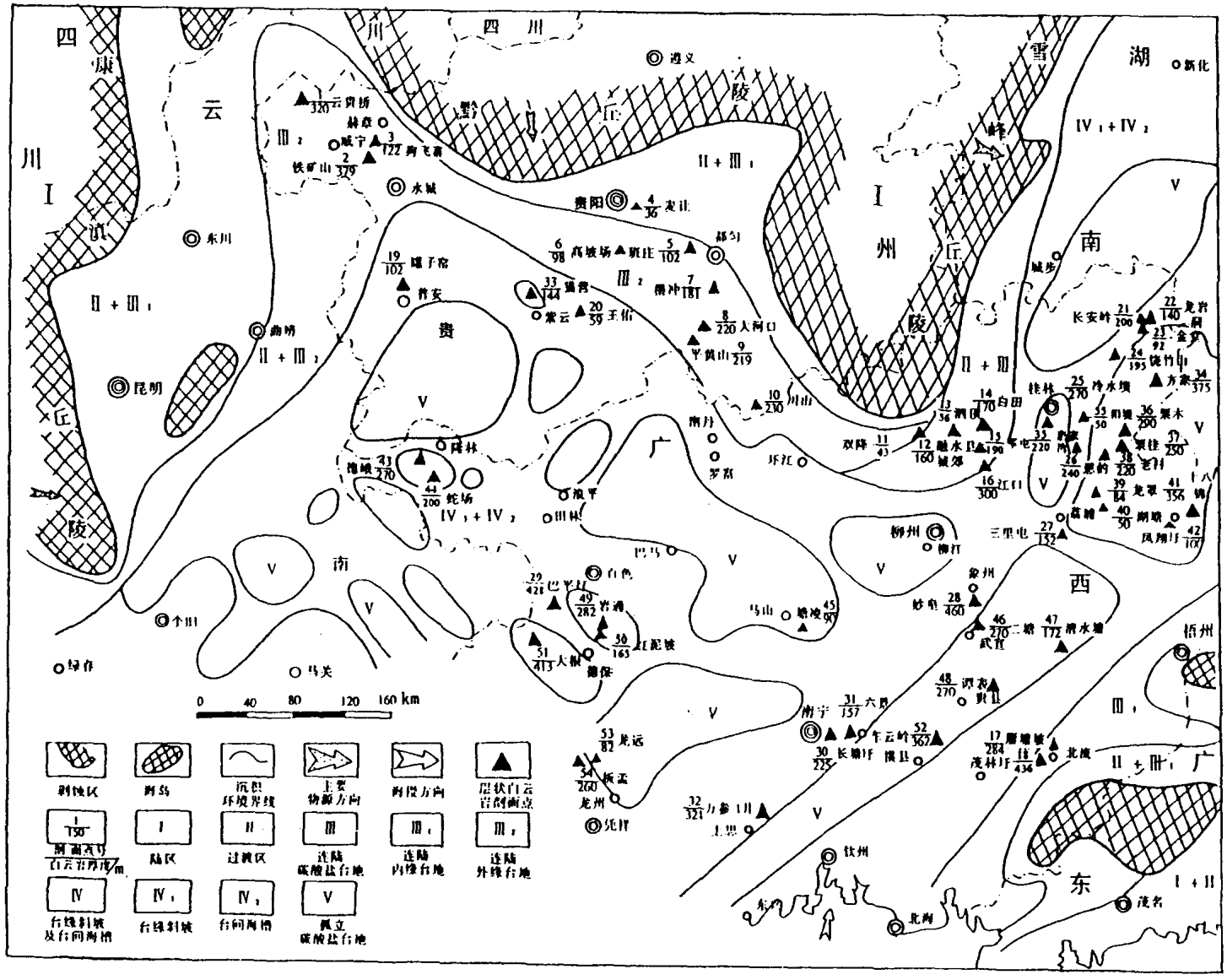

图 1-3　黔桂地区中泥盆世沉积环境及层状白云岩分布图