● 西南及邻区地质矿产科研专著丛书

上扬子台地早、中三叠世岩相古地理及沉积矿产的环境控制

● 地质矿产部成都地质矿产研究所

● 重庆出版社

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重 庆 出 版 社
1989年·重庆

特约编辑：李文汉
责任编辑：王镇寰
封面设计：高仲成
技术设计：刘忠凤

地质矿产部成都地质矿产研究所
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重庆出版社出版、发行（重庆长江二路205号）
新 华 书 店 经 销 重庆印制一厂印刷

开本787×1092 1/16 印张15.25 插页 17 字数 341 千
1989年 7 月第一版 1989年 7 月第一版第一次印刷
印数：1—1,440

ISBN 7-5366-0984-7/P·24
科技新书目193—319 定价：7.15元

内 容 简 介

本书系统阐述了上扬子台地及其邻区早、中三叠世沉积相、古地理和沉积矿产的环境控制。从台地到盆地共划分出9大环境48种沉积相，并使用地层图法、等时面法、水平断面投影法、相参数法、稳定同位素法等，编制了各种岩相古地理图。同时系统阐述了台地在发展演化上的古构造、古地理特点和蒸发盐的相模式、油气及其它矿产的岩相控制条件。

本书在台地沉积模式、成盐成钾作用及一些基础地质问题方面，都提出了很多新观点，且在岩相古地理研究方法上有许多创新。

本书是该区迄今有关早、中三叠世沉积相及古地理研究最系统的成果，对教学、科研以及从事盐业、石油地质人员均有参考价值。

全书约30万字，插图130余幅，图版12个。

序

吴应林等同志所著《上扬子台地早、中三叠世岩相、古地理及沉积矿产的环境控制》一书，系接受中国地质科学院于1981年下达《上扬子台地早、中三叠世岩相、古地理及蒸发岩沉积模式》课题研究任务，经五年辛勤工作所获成果。本书主要根据该研究报告撰写所成。上扬子区下、中三叠统是我国重要的含油气及含盐层位，到70年代，地质工作者已在油气地质的研究及油气的开发方面取得了显著成绩。然而，作为我国盐类资源最有远景的上扬子区下、中三叠统，从找钾的角度来看，尚存在不少问题。没有取得重大突破的原因之一，是在沉积相模式的研究上还要探索新的路子，使我们的认识能更深化一步。

吴应林等同志从野外地层相标志的研究开始，在大量的野外第一性资料和室内大量测试数据的基础上，分析了沉积环境，再建其古地理，无论是理论探讨，还是工作方法上，均有不少创见。作者对上扬子区的沉积相、沉积模式、古地理作了详细的阐述，划分出9类环境48种岩相，阐明了其展布规律。通过系统的编图，总结出台地沉积作用的历史演化，可以认为作者在沉积相、古地理方面的研究是迄今该区有关三叠系研究的最系统最完整的一份成果。

作者关于下、中三叠统间的绿豆岩顶、底板沉积相和碳酸盐的碳、氧稳定同位素，以及绿豆岩的岩石学，常量、微量元素地球化学的综合研究，均取得了有价值的成果。所提出的绿豆岩的成因及其环境意义具有巨大说服力。如此全面地深入地研究和阐述绿豆岩是无前例的。在我国首次采用等时面和$\delta^{18}O$、$\delta^{13}C$研究绿豆岩的沉积相古地理，微地貌及顶、底板沉积相获得成功，提供了一种古地理研究方法的范例。

作者在蒸发岩相模式的研究方面，也取得了十分重要的进展。根据残留的原生构造、沉积序列，划分出15种蒸发岩类型，具有普遍的参考意义。所提出的成盐模式表明绝大部分属萨布哈型，指出了主要聚盐区。根据成盐阶段的分析，提出在该区仅能形成硫酸钾矿床，杂卤石是硫酸钾矿床的基本形式。作者这些新的观点对该区找钾工作有重要参考意义。

最后，值得提出的是作者在研究方法上也具开拓性，除使用了等时面及氧、碳同位素研究古地理微地貌而外，例如在编图等方面也提出了新的值得借鉴的方法。

本人与吴应林等同志共事多年，对他们的研究有一定了解，感到这部专著无论在理论上、方法上均有其特色，其论点对当前我国蒸发盐类地质的研究及找矿也有实际意义，是我国迄今所见的一部有较高研究水平的著作。借此以序言数语向读者推荐。

刘宝珺

1987年12月

ABSTRACT

REGIONAL GEOLOGY

The Upper Yangtze area covering an area of 5,000,000km^2 is a carbonate isolated platform in the western part of the Yangtze Plate.

Basement folding of the Yangtze Plate occurred during the Jinning orogeny (820—970×10Ma). Of the pre-Triassic sediment cover, the Ordovician, Silurian, Devonian and Carboniferous are mostly missing. In a few regions the Middle and Upper Cambrian are also missing. The Yangtze Plate consists of the Upper Yangtze Platform in the west, the Jiangnan and Jingxi Platform (shoal) in the east, and the Yangtze Shelf which lies between them(Fig.2-1) It was a minor plate between Tethys and the Pacific during the Triassic. Its northern part was a stable margin, the Qinling Sea Basin, which collided with the Northern Continent of China to form the Indosinian fold belts of Qinling and Dabashan during the Late Triassic. In the south and west there was an active margin, which included the South China Sea Basin in the south east, the Qian (Guizhou) Gui (Guangxi) Sea Basin in the south west, and West Sichuan Sea Basin in the west. The movement of the plate occurred between the Early and Middle Triassic and during the Late Triassic, and resulted in the closure of the sea and uplift of the basin in succession, forming the Indosinian fold belt of the South China, West Sichuan Plateau and Qinling region. In particular, the movement occurring between the Early and Middle Triassic had the greatest influence upon deposition of sediments of that age on the platform, resulting in the uplifting of the South China orogenic belt in the east and the deposition of the molassoid formation (the Badong Red Bed) occurring in many places of the eastern part of the plate.

The basement of the Upper Yangtze Platform consists of four crystalline rock blocks which extend from NE to SW and are different in lithology and hardness (Fig. 2-3). Among them, the crystalline block in Kangdian and Central Sichuan is composed of separate magmatic complex and formed a topographical high during the Early and Middle Triassic. In west Sichuan it consists of sedimentary-metamorphic and acid magmatic rocks with medium degree of tectonic stability; in the east (East Sichuan, West Hubei, and Guizhou-Yunnan) the crystalline block consists of sedimentary-metamorphic rocks with lower degree of tectonic stability and it was of lowland in topography, in which there were a few local highlands consisting of magmatic rocks. The general topography of the platform was high in the west and low in the east, and at the margin there were some discontinuous islands (Kangdian) and highlands (Longmenshan mountains, Zhenba, Wushan, Guiyang and Xingyi), between which channels leading to the inner shelf basin were located.

Subdivision and correlation of the Triassic of the Upper Yangtze Platform are presented in the following table.

Series	Stage	WEST AND CENTER		EAST	
		Member	*Formation*	*Formation*	*Member*
MIDDLE	*Ladinian*	T_2t	*Tianjingshan*		
	T_2^2	T_2l^4	*Leikoupo*	*Badong*	T_2b^4
	Anisian	T_2l^3			T_2b^3
		T_2l^2			T_2b^2
T_2	T_2^1	T_2l^1			T_2b^1
LOWWER	*Olenkian*	T_1j^5	*Jialingjiang*		T_1j^5
		T_1j^4			
		T_1j^3			
		T_1j^2			
	T_1^2	T_1j^1			T_1j^1
	Indian	T_1f^4		*Daye*	
T_1	T_1^1	T_1f^1	*Feixianguan*		T_1d

SEDIMENTARY FACIES AND PALEOGEOGRAPHY

1. Sedimentary Facies

The authors consider the sedimentary facies as ancient products in a depositional environment or as distinctive sediment associations formed in a sedimentary environment We recognize and describe the following facies types:

(1) Open-sea basin (lower slope to basin) deposits

Facies 1—terrigenous-clastic turbidite (Plate Ⅲ-3).

Facies 2—grey clay shale interbedded with thinly-bedded deep grey argillaceous limestone, containing open-sea organism fossils

Facies 3—thinly-bedded siliceous rock or interbedded with shale and thinly-bedded micritic limestone (Plate Ⅲ-1)

Facies 4—nodular limestone (Plate Ⅰ-3,4,6).

(2) Fore-platform slope deposits

Facies 5—shaly to thinly-bedded micritic limestone and slab-like limestone (Plate Ⅰ-5).

Facies 6—calcareous breccia and medium-bedded fine-crystalline dolostone (Plate Ⅰ-9,10,11,12.).

(3) Open-platform deposits

Facies 7—homgeneous, slab-like. argillaceous micritic limestone (Plate Ⅱ-1).

Facies 8—homgeneous, medium-bedded micritic limestone

Facies 9—shale interbeded with thinly-bedded marl, containing shallow-sea fossils.

Facies 10—wackestone (Plate Ⅱ-10).

(4) Shoal deposits

Facies 11—Loferite cyclic layer (Fig. 3-4, Plate Ⅱ-7, Ⅰ-8, Ⅱ-2,11).

Facies 12—recrystalline-grained dolostone.

Facies 13—cross-bedded, oolitic limestone and sparry calcirudite (Plate Ⅱ-2,4,5,8 and Ⅱ-3).

Facies 14—micritic limestone with oolitic lump and calcirudite with giant shell fragment (Plate Ⅲ-4,6,8,9 and Fig 3–12,16,17,18).

Facies 15—laminated, oolitic limestone with lag layer.

Facies 16—cross-bedded, fining-upward calcarenite with lag gravel

(5) Restricted platform deposits

Facies 17—grainstone interbedded with stromatholic limestone (Plate Ⅵ-2, 3,4,10,11).

Facies 18—banded limestone (Plate Ⅵ-1,8 and Ⅴ-9).

Facies 19—cyclic layer consisting of sparry shell limestone or/and planar-cross-bedding sandstone and flaser sandy mudrock (Fig. 3-5 and Plate Ⅴ-1,3, 4,5,6,7,8,9).

Facies 20—grey micritic limestone and vermiform limestone.

Facies 21—black marl and argillaceous limestone with calcareous mudrock.

Facies 22—purple-red terrigenous claystone containing euryhaline organism fossils or interbedded with marl (Plate Ⅱ-2 and Ⅳ-7).

Facies 23—cyclic layer consisting of lenticular or layer fine-grain-size sandstone with cross dedding, and flaser silty mudrock

Facies 24—cyclic layer consisting of trough and tabular-cross-bedding sandstone, flaser-bedding sandstone and mudrock

(6) Platform evaporite plain deposits.

Facies 25—fine-crystalline dolodtone with monocrystalline or drusy anhydrite, and grain dolostone with anhydrite.

Facies 26—dolomitic mudrock and argillaceous micritic dolostone.

Facies 27—nodular anhydrite and chickenwire anhydrite.

Facies 28—algal-mat anhydrite

Facies 29—swallow-tail anhydrite.

Facies 30—sucrosic anhydrite.

Facies 31—enterolithic anhydrite, saline clay and mudy anhydrite rock.

Facies 32—laminated dolomitic anhydrite rock.

Facies 33—laminated magnesite anhydrite rock

Facies 34—laminated. calcareous-argillaceous anhydrite rock.

Facies 35—polyhalite rock.

Facies 36—halite rock.

Facies 37—halite rock with K, Mg sulfate.

Facies 38—grauberite rock.

Facies 39—purple-red mudrock and siltstone with anhydrite nodule.

(7) Shoreside plain deposits

Facies 40—motley mudrock and siltstone.

Facies 41—purple-red mudrock and siltstone with calcareous nodule.

(8) Alluvial plain deposits

Facies 42—continental alluvial cyclic layer.

Facies 43—shoreside alluvial cyclic layer.

(9) Volcanic ash deposits

Facies 44—claystone with largely siliceous beds.

Facies 45—siliceous claystone or clayey silica rock with an abundance of siliceous pisolith.

Facies 46—tuffaceous claystone with siliceous beds

Facies 47—siliceous-clayey tuff or tuffaceous claystone without siliceous bed.

Facies 48—clayey tuff.

2. Facies-Paleogeographical Mapping

In this book there are seven facies-paleogeographical maps by stages, that is, A) Feixiangquan (Indian) stage of the Early Triassic, B)—D) Jialingjiang (Olenian) stage of the Early Triassic (T_1j): B) T_1j^1—T_1j^2, C) T_1j^3—T_1j^4, D) T_1j^5, E)—F) Leikoupo (Anisian) stage (T_2l) of the Middle Triassic: E) T_2l^1—T_2l^2, F) T_2l^3 and G) late stage (T_2l^4—T_2t) of the Middle Triassic (Latest Anisian to Ladinian), and two ones of adjoining rock of the interfaces between the Permian and Triassic, Lower and Middle Series of Triassic. These maps are plotted by different mapping methods based on features of each stratigraphic unit and the studying point which is desirous to be emphasized:

(1) The seven mapping units are sedimentary cycles which can be commonly correlatable in the platform.

(2) The two interfaces chosen have quite well correlation marks which help to do the study of the sedimentary facies of the isotime surface.

(3) The facies map of the Feixianguan stage (Indian) is drawn by horizontal projection of cross sections.

(4) The facies maps of other stages are plotted by ratio of dolostone to limestone and isopach methods.

3. Paleogeographical Features of Feixianguan (Indian) Stage of Early Triassic (Fig. 3-8 to 3-29).

The paleogeography of the Early Triassic was largely affected by Kangdian Island land on the western margin of the platform, which was the only source area for terrigenous clasts at that time. There are the following paleogeographical subdivisions towards east from the island lands: alluvial plain—tidal flat—lagoon—barrier beach—open platform—open-sea basin. The barrier beach was of an ooid sheet aggraded laterally towards the margin of the platform from the old land. In the landward side of the beach there was an washover fan that developed into a sabkha later.

4. Paleogeographical Features of Jialingjiang (Olenikian) Stage 1(T_1j^1—T_1j^2) of Early Triassic

Sediments in this stage consist of a shoaling-upward sequence from transgression to regrssion, ended by sabkha. During this stage, there were the following paleogeographical subdivisions toward east from west: shoreside sabkha(I, alluvial plain, tidal flat—sabkha)—sabkha platform (II, lagoon-sabkha, a sabkha platform progradating towards lagoon from coast)—shoal (Ⅲ, shoal-sabkha) —bay (Ⅳ, open platform-sabkha)—fore platform slope (Ⅴ)—open-sea basin (Ⅵ). First, a coastal sabkha plain occurred in the margin of the old land. Then its progradation towards the lagoon took place, forming the sabkha platform (subdivision Ⅱ), which was developed to the open platform by late regression (Fig. 3-30 to 3-36).

5. Paleogeographical Features of Jialingjiang (Olenikian) stages 2(T_1j^3—T_1j^4) and 3 (T_1j^5) of Early Triassic

Both the stages are essentially similar in sequence and paleogeographical framework. We recognize the following paleogeographical subdivisions from the island land (west) to south-east: shoreside sabkha (Ⅰ)—sabkha platform (Ⅱ)—shoal (Ⅲ)—bay (Ⅳ)—fore-platform slope (Ⅴ)—open-sea basin (Ⅵ). At first, the Upper Yangtze Platform was a bay (Fig. 5-7). As a result of progradation of the sabkha, it evolved into a sabkha platform (Ⅱ) progradating towards lagoon from the shoreside (Ⅰ), meanwhile coastal salt lakes formed in its margin, which became playa lakes when the sea level fell. This extended the sabkha to the open platform (Fig. 3-37 to 3-55)

6. Paleogeographical Features of Leikoupo (Anisian) Stage 1 (T_2l^1—T_2l^2) of Middle Triassic

During the Middle Triassic epoch, a great change in paleogeography is marked by the rise of all the margins of the platform, which turned into exposed old lands or an occasionally exposed area of deposition and leaching. It is speccially obvious that the east part of South China including the Jiangnan Platform began with rise, to form a land, which was a major source area of detrital materials of terrigenous origin. The other events which occurred between the Early and Middle Triassic were the marine regression and volcanic activity. A layer of volcanic ash ("mung bean") one to five metres thick was deposited across the platform and its marginal area. The platform began with the topography of a basin, it was high in both east and west (old lands) and low in north and south, with a decline tendency towards north (Fig. 3-56 to 3-68).

According to the sedimentary facies in the top of sequences, the paleogeographical subdivisions in preper order from the basin to both side old lands are as follow: platform salt lake (Ⅲ)—temporary desiccation lagoon (Ⅱ)—shoreside plain (Ⅰ); the subdivisions from the basin to the sea are placed as follows: platform salt lake (Ⅲ)—temporary desiccation lagoon (Ⅱ)—bay (l_3)—platform marginal slope (Ⅳ)—open sea basin (Ⅵ).

In the area of subdivision Ⅰ there is alternation of marine with nonmarine red-clastic rocks; in subdivision Ⅱ—laminated, argillaceous dolostone hundreds of metres thick; in the subdivision Ⅲ—argillaceous dolostone and anhydrite.

7. Paleogeographical Features of Leikoupo (Anisian) Stage 2 (T_2l^3) of Middle Triassic

The platform inner-shelf basin was an open sea at first, where a series of limestone containing ammonoids was deposited. It then was evolved to a restricted bay which would breake down into lagoons and salt lakes. There are the following paleogeographical subdivisions from the basin to the land: salt lake (Ⅳ)—temporary desiccation lagoon (Ⅲ)—shoreside plain (I_1); the subdivisions are placed from the basin to the sea: salt lake (Ⅳ)—lagoon (Ⅴ)—platform marginal slope (Ⅵ)—open-sea basin (Ⅶ). (Fig. 3-69 to 3-74).

In the area of subdivision Ⅳ there are marl and halite; in the subdivision Ⅲ—shaly marl and dolostone; in the subdivision Ⅴ—nodular limestone containing ammonoids and brachiopods; in subdivisions I_1 and Ⅰ—red beds; Ⅱ—tidal-flat and sabkha deposits with dissolution calcarenite or oolitic limestone.

8. Paleogeographical Features of Late Stage (T_2l^4—T_2t) of Middle Triassic (Fig. 3-75 to 3-78).

The stage is essentially similar to the Leikoupo stage 1 (T_2l^1—T_2l^2) in paleogeographical features, but the margin had undergone the late reformation of diagenetic solution because of exposure. This is specially clear in the south margin, Where there is a calcareous sand shoal dissolved in diagenesis, similar to the loferite sequence, which has been confirmed by us. Previously, it was considered to be a large barrier reef over 1000km long.

There are the following paleogeographical subdivisions from the basin to the both side old lands: salt lake (I_2)—temporary desiccation lagoon (I_3, III_1)—shoreside plain (II); the subdivisions are placed from the basin to the sea: salt lake (I_2)—temporary desiccation lagoon (III_1)—lagoon (III_2)—platform marginal shoal (III_3, I_1)—platform marginal slope (III_4).

On the area of subdivision I_2, coastal and continental evaporites deposited; I_3 and III_1—laminated, argillaceous dolostone; II—red clastic rocks; III_2—limestone interbedded with dolostone; III_3—calcareous sand deposits of loferite sequence formed in the shoal; I_1—tidal-flat deposits.

9. Depositional Models

The depositional models of the Upper Yantze Platform have the characteristics of a continental-marginal carbonate platform, which can be grouped under the following types in comparision with the facies models from J. Fred Reed (1974, 1985).

(1) Barrier ramp type. It largely occurred in the eastern and northern margin of the platform during the stages of Feixianguan (T_1f), Jialingjiang (T_1j) and Earliest Leikoupo (T_2l^1).

(2) Ramp-distally steepened type. It mainly occurred in the southern and northern-western margins of the platform, at the stage of T_1f.

(3) Rimmed shelf type. It largely developed in the southern and northern-western margins of the platform, at the stage of T_1j and T_2l^1.

(4) Inner-shelf basin type. It occurred at the stages of T_2l^2 to T_2l^4, among them, at the stage of T_2l^3 the basin was of deepwater, but at the stages of T_2l^2 and T_2l^4 — of shallow water.

The evolution direction of the above types is from type 1 and 2 (T_1f) to the type 3 (T_1j — T_2l^1), then to the type 4 (T_2l^2 to T_2l^4).

10. Distribution Regularities of Terrigenous Clasts in the Platform

There are two types: barrier and basin one.

(1) Barrier type. Terrigenous clasts mainly are distributed in the inside of the barrier beach (T_1f, T_1j), that is the Z zone from the model of Irwin (Irwin, 1965). It can be divided into three subzones considering the distribution of clastic materials in it.

Subzone A: a fine-grained belt occurring in the lagoon.

Subzone B: a coarse-grained belt occurring in the lagoon margin close to the land coast, and the lower part of the tidal flat.

Subzone C: a fine-grained belt occurring in the upper part of the tidal flat.

(2) Basin type. It largely occurs in the Middle Triassic, and the distribution of clastic materials follows the regularity of the mechanical differentiation: fining towards the centre from the margin of a basin.

11. Distribution Regularities of the Oolite in the Platform

There are three types:

(1) Barrier oolitic shoal. a) Oolites formed a barrier shoal, they are distributed in the shape of a sheet with the lateral aggradation of the shoal, but the thickness increases towards the margin of the platform (T_1f). b) Oolites formed platform marginal shoals in northern-western and southern margins

(T_1j, T_2l,

(2) Tidal delta. It mainly occurs in mouths of channels between some highlands and old lands in margins of the platform, such as in West Sichuan, North-West Sichuan, North-East Sichuan, East Sichuan and so on.

(3) Tidal flat. It is largely distributed within the platform and in the regions of East and South Sichuan where lagoons and tidal channels developed well.

The types 1 and 2 mentioned above are thick-bedded and the type 3 is thin-bedded in occurrence.

"MUNG BEAN" ROCK

The "mung bean" rock whose initial rock is volcanic tuff is a good key bed for the study of shortest-stage facies. In addition its petrological studies are of great significance for paleogeographical reconstruction.

1. Petrology of "Mung Bean" rock

Alteration products of the volcanic tuff, the "mung bean" rock can be divided into four types: (1)Claystone with siliceous bed at the bottom, (2) Siliceous claystone or clayey silica rock with an abundance of siliceous pisolith, (3) Tuffaceous claystone with few of siliceous bed at the bottom, (4)Siliceous, clayey tuff or tuffaceous claystone without siliceous bed at the bottom. All of them are distributed in the platform in the shape of circles. The outer circle is taken by the type 1 of rock, in which leached and precipitated layers are clear because of soil-forming weathering. The inner circle consists of the type 4 of rock, in which leached and precipitated layers are not clear due to weakly soil-forming weathering (Fig. 4-1).

The content of clay minerals are as follows: in the west part of the platform, the area of type 1, montmorillonite$\leqslant$10%, illite$\geqslant$90%; in the east part of the platform (East Sichuan), montmorillonite 30% (part of area, 60-100%), illite 70% (Fig. 4-6). All the changes in content of some other chemical composition such as SiO_2 (Fig. 4-7), K_2O (Fig. 4-8), MgO (Fig. 4-12), Fe_2O_3 (Fig. 4-9), CaO (Fig. 4-11), Sr (Fig. 4-13) reflect the same changing regularities. For the above information, we suggest that the west part of the platform was subaerial but the east was drowned.

2. The Sedimentary Facies of Adjoining Rocks 3m Thick above and below the "Mung Bean" Rock (Fig. 4-17, 4-18, 4-19)

The facies are placed in proper order from the old land and platform margin to North-East Sichuan as follows: I_1 (Facies 39) — I_2 (Facies 25) — II_1 (Facies 32) — II_2 (Facies 33 and 35) — III (Facies 34) — IV (Facies 3 and 4)

3. The $\delta^{13}C$ and $\delta^{18}O$ Values in Carbonates of Adjoining Rocks of the "Mung Bean" Rock (Fig. 4-21 to 4-24)

The results of carbon-and-oxygen stable isotope are well correspondent to those of sedimentary facies and petrology of "mung bean" rocks. All the results draw the outline of the microtopography of the platform showing three lines of highlands and depressions extending from NE to SW. Among the depressions the deepest parts are located in East Sichuan and North-East Sichuan, where the extremely minus values of the $\delta^{18}O$ and $\delta^{13}C$ in carbonates are interpreted as reflecting of continental playa lakes supplied with continental water only as compared with the normal values of $\delta^{18}O$ and $\delta^{13}C$ in carbonates of Luodian area which was of the open sea to the south of the platform.

THE ORIGIN AND FACIES MODELS OF EVAPORITES

1. The Distribution of Evaporites (Fig. 5-14)

The evaporites predominantly consist of anhydrite, halite and polyhalite. The anhydrite which occurs at a large number of horizons is distributed over an area of 400,000 km^2. The halite occurs in the following thirteen regions: Nanchong (1), Zigong (2), Weiyuan (3), Chengdu (4), Jiangyou (5), Daxian (6), Dianjiang (7), Xuanhan (8), Wangcang (9), Qijiang (10), Wanxian (11), Jiannan (12), Zhongxian (13) Polyhalite has been found only in regions 1, 2, 4, 7, 8 and 11. Among them region 1, Nanchong, is the largest one in size, where the halite covers an area of 30,000km^2, and polyhalite — 10,000km^2. There are six halite-bearing stratigraphic horizons: T_1j^2, T_1j^4, T_1j^5, T_2l^1, T_2l^3, and T_2l^4. Region 1 has the most halite-bearing horizons and a maximum thickness of 200m of halite.

2. Fabrics and Rock Types Indicating the Origin of Evaporites (Fig.5-1 and Plate VIII to X)

(1) Ankydrock From the pseudomorphs of gypsum remaining in anhydrite and comparision of them with gypsum crystal shapes forming on modern coastline, and by recongnition of other features, we describe swallow-tail gypsum (1), short -prismatic and pseudorhombic gypsum (2), clasti crystalline gypsum

(3), slab gypsum (4), flat gypsum (5), columnar gypsum (6), petal gypsum (7), crystal druse gypsum (8), and microcrystalline gypsum etc. all of which can be used for the interpretation of depositional environments

(2) Polyhalite rocks. Microcrystalline polyhalite is domonant. It was formed by replacing gypsum and occurs in the shape of felt and sphaerolite. In addition, crystalline polyhalite of various shapes is present; this is second generation, growing along the margin or bottom wall of the microcrystallline polyhalite.

(3) Halite rocks. They show mosaic texture. Residual primary structures are mainly as follows: a) algal-laminated, banded, thin anhydrite interbeds, which are common and broken to brecciated lumps due to diagenesis. b)banded structure consisting of bands of different colours, c) grainy floor halite, which is uncommon.

(4) Genetic types of evaporites. According to the genetic marks of textures and structures, we have divided the evaporites into the following genetic types: algal-mat anhydrock(1), swallow-tail anhydrock(2), sucrosic anhydrock (3), laminated dolomitic anhydrock (4), laminated magnesite anhydrock (5), enterolithic and nodular anhydrock (6), limestone and dolostone with anhydrite crystalline druse (7), bedded polyhalite rock (8), banded polyhalite rock (9), halite-bearing polyhalite rock (10), banded halite rock (11), halite rock with anhydrite breccia and lumps (12), lump halite rock (13), grauberite rock (14), For their depositional environments of above types of evaporites, the types 3, 4, 5, 6, 7, 12 and 13 was formed under sabkha; the type 5 which contains magnesite, and the type 14 and the greater part of polyhalite—mainly under a playa lake.

3. Section Types and Their Depositional Environments of Halite-Bearing Sequences (Fig. 5-2,3)

The halite-bearing sequences can be divided into six types of sections based on the composition and lithological characters of the adjoining rocks of halite beds: (1) all the adjoining rocks are composed of algal-mat or laminated anhydrock, (2) the floor consists of algal-mat anhydrock but the top layer is banded anhydrock, (3)the adjoining rocks are sucrosic and massive anhydrock, (4) the adjoining rocks—banded anhydrock, (5) laminated, magnesite-bearing anhydrock, (6) laminated, magnesite-bearing anhydrock overlaid and underlaid with laminated, argillaceous dolostone.

In respect of the depositional environments of above types of sections, types 1 and 2 are of a coastal salt lake, types 3 and 4—sabkha, and types 5 and 6

—a playa lake Types 2, 4, and 5 occur in T_1j^5 and T_2l^1, types 3 and 5 occur in T_1j^4, the type 1 — T_2l^3, and type 6 — T_2l^4 The sections in T_1J^4, T_1j^5 and T_2l^1 have the similar evolutional sequence: lagoon—tidal barrier—sabkha—coastal salt lake—playa lake; but sections in T_2l^3 and T_2l^4 show the other evolutional sequence: bay—lagoon—salt lake—playa lake.

4. Facies Models of Evaporites

The deposition of evaporites in the studied area can be ascribed to two models: platform sabkha model which occurs in the Members of T_1j^4, T_1j^5 and T_2l^1, and intraplatform desiccation salt lake model which occurs in the Members of T_2l^3 and T_2l^4.

(1) Platform sabkha model (Fig. 5-7 to 5-11). First a sabkha plain formed in the barrier bay due to the progradation, where coastal salt lakes then developed, last, they were evolved to playa lakes because of the later marine regression.

(2) Inner-shelf desiccation lake model (Fig. 5- 12, 13). The swelling of the platform margin resulted in some divided basins separated from the bay to become lagoons or salt lakes, which also would be developed to playa lakes under the condition of regression.

5. The Models of Saline Mineral Zonation (Fig. 5-15)

The saline mineral zonation in sabkha salt lakes of the platform is of tear-drop pattern. Most of evaporites occur near the channel, so their zonation appears as multicentre because there are many channels in the srea and islands in the lagoon.

The saline mineral zonation in the platform inner-shelf desiccation lake appear as the bulls-eye pattern.

ENVIRONMENTAL CONTROL OF OIL, GAS, AND OTHER MINERAL DEPOSITS

1. Oil and Natural Gas

The change in abundance of organic carbon in the stages of Feixianguan, Jialingjiang and Leikoupo essentially shows the same tendency towards increase from west to east (Fig. 6-1 to 6-2). East Sichuan and South Sichuan where organic carbon makes up 0.2–0.5 percent have better oil-generating potentiality, specially in the north part of the East Sichuan, this is the most ideal place for oil accumulation. Therefoe we consider the normally shallow sea in