Seventh Symposium on Salt, Vol. I 205–210 (1993)
Elsevier Science Publishers B.V., Amsterdam

Characteristics of the Potash Deposits in Western Yunnan, China

Kaiye Shuai

China University of Geosciences, Beijing 100083, China

ABSTRACT

Mesozoic–Cenozoic red-bed basins of western Yunnan contain many saline deposits. The most favorable period for the formation of salt beds was during the Late Cretaceous to the Early Paleogene, some 60–70 million years ago. The salt series, called the Mengyejing Formation, consists of brownish-red mudstone, siltstone, and evaporite composed of layered salt and potash-bearing salt associated with 10–60% clay gravels, with cobbles normally 2–20 cm in diameter. The mineral assemblage is mainly halite, sylvite, and carnallite, so the potash deposit of this area may be classified as a chloride type, similar to that in Thailand and Laos.

The provenance of evaporites is similar to sea water, as confirmed by the mineral components, content of bromine, rubidium, and other trace elements, stable isotope composition of carbon and sulfur. Evidently, the salt basin also received deep metamorphic brines, judging from the abnormal base metal content (Cu, Pb, Zn), the high temperature determined from gas–liquid inclusions, the tectonic environment of a rift valley, and the volcanic beds intercalated in the salt sequence.

INTRODUCTION

Although one of the largest potash deposits in the world was discovered on the Khorat Plateau of Thailand and Laos (Hite, 1974; Hite and Japakasetr, 1979), the series of potash-bearing salt deposits in the western part of Yunnan province, China, are less well known.

Yunnan is the most important rock-salt-producing district in China and has a long history of exploitation. Early in the Ming Dynasty (1368–1664 A.D.), the cavern method of mining was popularized. The salt layers are buried at shallow depths (commonly less than 200 m), making for easy exploration and exploitation. In fact, many deposits in this area are due to the widely distributed salt springs which attracted all kinds of wild or domestic animals. Following rumors about "hot taste salt", Mengyejing potash deposit — the first potash deposit of China — was discovered in the 1960s. Since then, potash-bearing salt deposits have been explored one after another. Compared with the deposits of Khorat Plateau, the deposit of the "Mengyejing type" is small, both in scale and grade, but its particular geologic and structural environment cause it to form the unique characteristics that are the subject of this paper.

BACKGROUND OF GEOLOGY AND TECTONICS

Comprising an area of about 70,000 km^2, the basin of western Yunnan is a typical rift basin (Shuai, 1987) located clearly between two deep boundary faults which are accompanied by volcanism and metamorphism. Ailaoshan Fault is in the east, adjacent to the Central Yunnan Block. Lancangjiang Fault is in the west and adjacent to the Lincang and Baoshan Blocks (Fig. 1).

Salt deposits occur in the red beds of the Upper Triassic to Paleocene, the total thickness of which is more than 10,000 m. Paleontologic and stratigraphic study of the region showed that its lithologic characteristics are strikingly similar to those of the Khorat Group (Table 1).

The evaporite deposits are found mainly in three stratigraphic units: (a) Upper Triassic Series, Waigucun Formation (gypsum, rock salt); (b) Middle Jurassic Series, Hepingxiang Formation (gypsum–anhydrite); (c) Upper Cretaceous to Paleocene Series, Mengyejing Formation (gypsum, rock salt and potash). The latter, corresponding to the Maha Sarakham Formation of the Khorat Plateau, is the target that will be discussed in detail.

From the contact relation of the stratigraphic

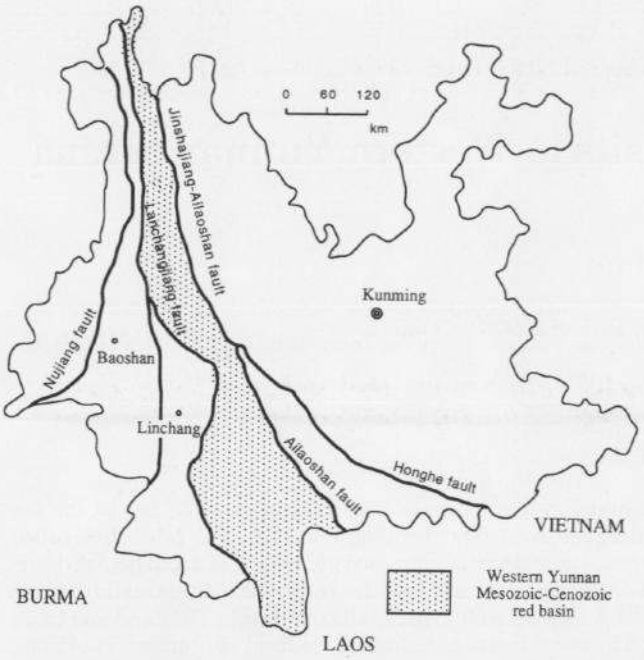

Fig. 1. Sketch map of Yunnan province, China, indicating location of the Mesozoic–Cenozoic red basin of western Yunnan.

sequences, three angular non-conformities reflect the regional fold movement. The first, between Permian and Middle Triassic strata, represents the collision of the Burma–western Yunnan Plate and the Indo-China Plate (Fig. 2). The second, found only in the eastern margin of the western Yunnan basin along the Ailaoshan Fault, occurred before the Late Triassic period, and was due to the collision of the South China Plate and the united western Yunnan Plate. The last non-conformable contact distributed throughout the basin is considered to be the effect of the collision of the India Plate with the Eurasian Plate. The strong crustal shortening deformed all the stratigraphic units, including the salt-bearing series, folding and fracturing approximately at the end of Eocene epoch. The red basin was uplifted and changed gradually into one of the drainage divides of Yunnan Plateau.

CHARACTERISTICS OF THE POTASH DEPOSITS

Acquiring its name from the Mengyejing potash deposit, Mengyejing Formation consists mainly of brownish-red mudstone, siltstone, and evaporite.

The standard and ubiquitous fossils, from the Late Cretaceous to the Paleocene are abundant ostracoda: *Sinocypris, Parailyocypris, Eucypris, Limnocythere, Ilyocypris,* etc. In comparison with general evaporite formation, such as Maha Sarakham Formation of Khorat Plateau, the profile of the salt-bearing member in this region is unique. The cyclothem is composed entirely of layered rock salt (or potash) associated with 10–60% clay gravel, with pebbles normally 2–20 cm in diameter. This mixed type of profile can only be found in those active structure zones and probably formed synchronously with the reformation of salt bodies. Many salt bodies are irregular in shape (Fig. 3), some even occur as ptygmatic structures and diapirs. The varied rock masses in the interior of salt bodies, the scratches, and many pressure traces show that the salt bodies underwent plastic flow since their sedimentation.

TABLE 1

Stratigraphic correlation of two salt basins

Age	Western Yunnan	Khorat Plateau	Character
E_3	Mengla	Absence	Sandstone, basal conglomerate
E_2	Denghei	Absence	Siltstone, sandstone
K_2–E_1	Mengyejing	Maha Sarakham	Evaporite, mudstone
	Mangang	Khok Kruat	Sandstone, siltstone
K_1	Jingxing	Phu Phan	Massive sandstone, shale
J_3	Bazhulu	Sao Khua	Sandstone, siltstone
J_2	Hepingxiang	Phra Wihan	Marlite, shale, evaporite
J_1	Yangjiang	Phu Khadung	Sandstone, conglomerate
T_3	Maichuqing Sanhedong Waigucun	Nam Phong	Coal-bearing sandstone, shale, limestone, evaporite and basal conglomerate
T_2	Manghui	Unnamed	Andesite, rhyolite, basalt, tuff
P_2	Maokou	Ratburi limestone	Massive limestone with shale and sandstone

With regard to their mineralogical composition, the potash deposits in western Yunnan consist mainly of halite (NaCl), sylvite (KCl), and a small amount of carnallite ($KMgCl_3{\cdot}6H_2O$), which may be classified into the chloride type of potash deposit, much the same as those found in Khorat Plateau (Table 2).

Bromine geochemistry is very useful in analyzing the prospective value of potash (Borchert and Ri-

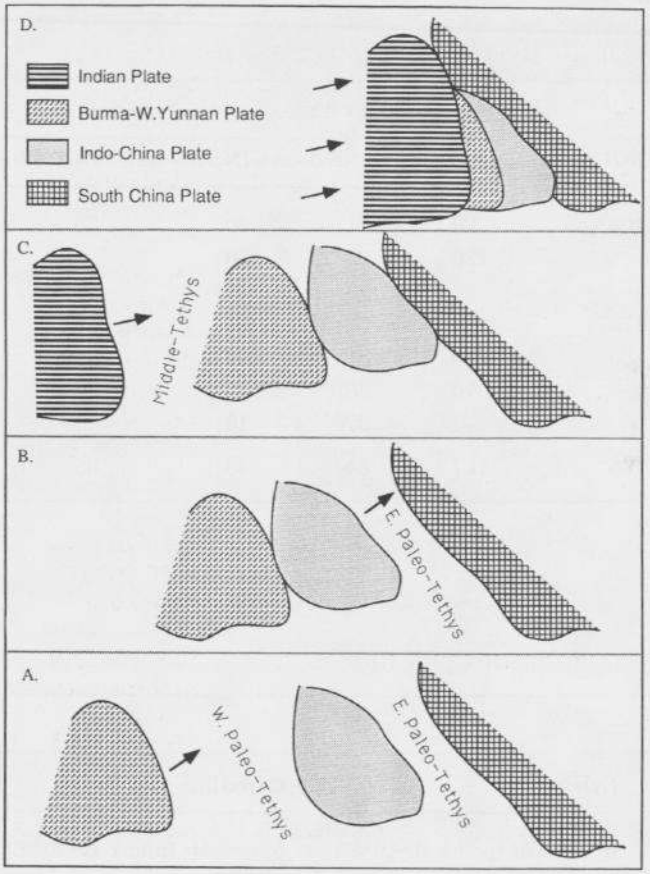

Fig. 2. Simplified model of plate movement showing how the continents match in the south-west part of China. A, before the Permian; B, between the Permian and the Middle Triassic; C, before the Late Triassic; D, after the Eocene.

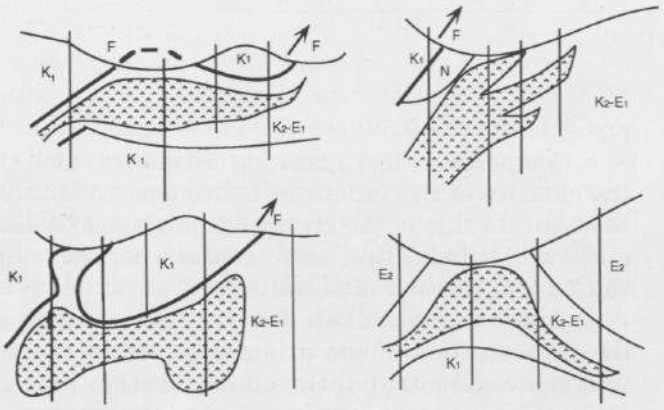

Fig. 3. Exploration sections for various shapes of salt bodies, shown by light pattern.

TABLE 2

Correlation of essential mineral composition

Type	Western Yunnan	Khorat Plateau	Molecular formula
Chloride	Halite	Halite	NaCl
	Sylvite	Sylvite	KCl
	Rinneite		$K_3NaFeCl_6$
	Carnallite	Carnallite	$KMgCl_3 \cdot H_2O$
		Tachyhydrite	$CaMg_2Cl_6 \cdot 12H_2O$
Sulfate	Gypsum	Gypsum	$CaSO_4 \cdot 2H_2O$
	Anhydrite	Anhydrite	$CaSO_4$
	Celestite		$SrSO_4$
Carbonate	Calcite	Calcite	$CaCO_3$
	Dolomite	Dolomite	$CaMg(CO_3)_2$
	Magnesite	Magnesite	$MgCO_3$

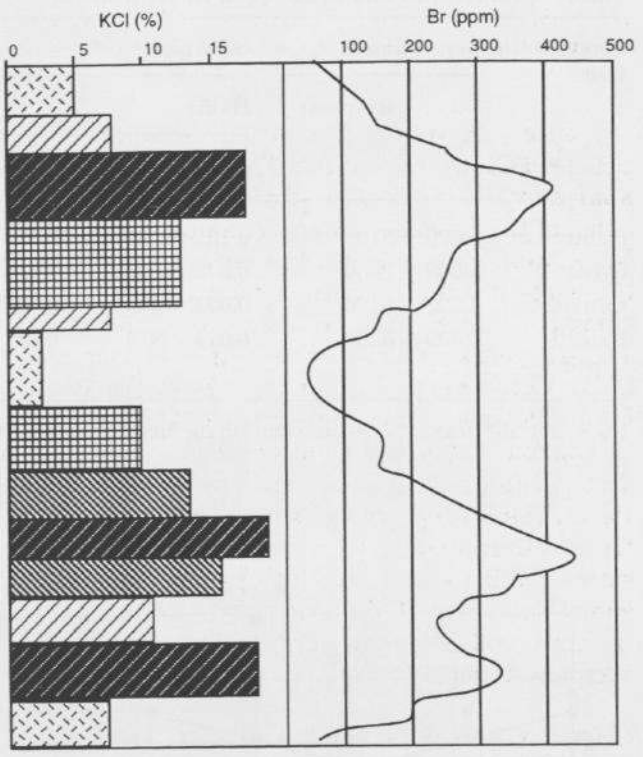

Fig. 4. Diagrammatic column of Mengyejing potash deposit, showing the close correlation of bromine and potash. The patterns represent different drilling cores.

chard, 1964; Braitsch, 1971) because the content of bromine is in direct proportion to that of potash (Table 3). The statistical data acquired from different mines show the following characteristics:

1. Br content of halite increases with the stage of salification (Fig. 4);

2. In general, the Br values of halite in rock salt are 80–120 ppm ($Br \cdot 10^3/Cl$ about 0.10–0.20), in potash-bearing salt rock are 120–200 ppm ($Br \cdot 10^3/Cl$ 0.20–0.30), and in potash rock are more than 200

TABLE 3

Average content of bromine in different ore types (ppm)

Mine	A Type (KCl > 3%)		B Type (KCl 1~3%)			C Type (KCl < 1%)			
	INS <5%	INS >25%	INS <5%	INS 5–25%	INS >25%	INS <5%	INS 5–25%	INS 25–50%	INS >50
Mengla	346	160	132	106	103	90	51	40	38
Zhengdong						120	61	60	
Mohei							75	40	19
Mengyejing	376	315	187	145	178	100	66	80	20
Jinggu	510	310	243	225	265	210	91	80	36
Anbanjing						70	38	40	30
Huiduan							37	13	
Main value	375	308	172	139	168	127	64	48	35

INS — content of insoluble substances.

TABLE 4

Theoretic values of Br and $Br \cdot 10^3/Cl$ on different stages

Concentrated stage	Liquid phase		Solid phase								
	SG	Br (ppm)	Halite			Sylvite			Carnallite		
			b	Br (ppm)	$Br \cdot 10^3/Cl$	b	Br (ppm)	$Br \cdot 10^3/Cl$	b	Br (ppm)	$Br \cdot 10^3/Cl$
Halite	1.220	510	0.13	66	0.11						
Sylvite	1.308	2360	0.073	172	0.28	0.73	1720	3.62			
Carnallite	1.325	3420	0.073	249	0.41	0.73	2490	5.24	0.52	1778	4.6
Eutectic point	1.359	5200	0.073	379	0.63						

SG — specific gravity; b — distribution coefficient (Braitsch, 1971).

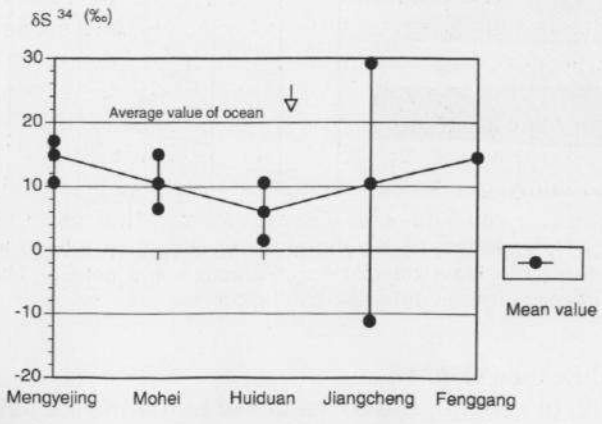

Fig. 5. Distributing range of isotopic composition of sulfur in some saline deposits, western Yunnan.

ppm ($Br \cdot 10^3/Cl > 0.30$);

3. Compared with evaporating seawater (Table 4), the changes of Br content in halite agree with the theoretical value in the precipitating stage of halite and sylvite, indicating some contact between the salt-forming basin and seawater;

4. Based on regional studies, it is now clear that the concentration of the primary brines increased from north to south, i.e., the salinity level in Khorat Plateau is higher than that in western Yunnan.

There are traces of rubidium in halite, normally <10 ppm from analysis of hundreds of samples of the mineral. The content is in direct ratio with K and Br, about 44~52 ppm in sylvite and 63 ppm in carnallite, which is similar to the theoretical value of primary potash separated from seawater.

Although the sulfur isotopic composition of evaporite deviate a little from the standard value of

TABLE 5

Heavy metal contents of some brines and evaporites

Element	Ocean water	Atlantis II deep Red Sea[a]	Cheleken thermal brine[a]	Paradox evaporite USA[b]	Prairie evaporite Canada[b]	Evaporite of western Yunnan[c]
Cu	0.001–0.09	0.26	0.9–15	6.5	0.45	5–870
Pb	0.004–0.005	0.63	3.6–77	1.2	1.13	5–74
Zn	0.005–0.014	5.40	0.9–5.35	0.56	1.15	1–150

Data from [a]K. Dunham, 1970; [b]D. Thiede et al., 1978; Author.

marine sulfate in that time (Fig. 5), and the δC^{13} value, between –6.5 to 3.0‰ (basically in 0‰), may be evidence of the inflow of seawater.

With the exception of seawater, the salt basin evidently received brine from another source which can be summed up as follows.

The contents of heavy metal in this region exceed the normal marine evaporites (Table 5). Some base metals, Cu, Pb, Zn for example, are 10,000~100,000 times the content in seawater.

By determining the gas–liquid inclusions of halite or sylvite, the results obtained (Table 6) indicate that all the minerals recrystallized in a temperature range of 60–200°C (with homogenization method). As for the isotopic age, the values determined from a few potash rocks are 10~25 Ma (K-Ar method). These are definitely younger than the age of sedimentation. This can be explained by a metamorphic age of post-diagenesis.

TABLE 6

List of the determining temperature of inclusions

Mine	Number of samples	Mineral	Temperature (°C)
Mengyejing	16	Halite	28–215
	50	Halite	100–275
	3	Halite, sylvite	35–260
	50	Halite	10–220
Fenggang	5	Halite	90–148
	3	Halite	50–160
Mohei	3	Halite	60–70
	1	Halite	40
Qiaohou	2	Halite	25–60
Anbanjing	1	Halite	50
Shangyong	1	Halite	23
Yixiang	3	Halite	50–90
Mengban	6	Halite	30–75

DISCUSSIONS ON THE ORIGIN OF POTASH DEPOSIT

The continental segment of Yunnan united mainly during the Late Permian. After that time a rift basin began to develop in western Yunnan. At first, volcanic activity occurred along two boundary faults, Ailaoshan and Lancangjiang, and formed the Middle Triassic Series of acidic to basic volcanic rocks which had a thickness of 3000 m. Then, the rift basin subsided from the Late Triassic to early Tertiary time and deposited carbonate formation, coal-bearing formation, red formation, and evaporite formation, successively. During the period of the Late Cretaceous to the Paleocene, the weather was extremely hot and dry. Seawater flowed through the narrow channel near Tibet. Many fractures allowed flow into the basin both on the surface and underground, and the basin water evolved into the kind of brine which was of a chloride type and became rich in potassium and magnesium gradually southward. The Mengyejing potash deposit and other potash-bearing salt deposits with economic value were thus precipitated in some favorable centers of subsidence. Finally, accompanied by the collision of the Indian Plate and the Eurasia Plate at the end of the Eocene, the rift basin closed and was lifted up. The crustal compression was very intense and all the salt layers were deformed and metamorphosed. Various faults crossed the primary large salt basin, dissecting it into many parts. Some of these have been eroded, some are covered with thrust sheets; the residual parts which can be seen today are small, incomplete in shape, rich in salt with clay gravel, but common in potash-bearing.

CONCLUSIONS

In general, the evaporites of western Yunnan are the inevitable outcome of the geologic–tectonic evolution of the Mesozoic–Cenozoic era in the local area.

The strong pressure caused by the collision between the India and Eurasia Plates is the most important factor for developing the deformation and metamorphism of saline deposits. Although situated in basically the same tectonic position, the salt basin of Khorat Plateau, preserving all the primary sedimentary structure, has suffered only a little shortening since the diagenetic stage because of the stable crystalline base.

ACKNOWLEDGEMENTS

Many Chinese geologists contributed to this paper. I am especially indebted to Yuan Jianqi, Huo Chengyu and Cai Keqin (China University of Geosciences), Luo Kehua and Yuan Pinquan (Yunnan Bureau of Geology and Mineral Resources). I would like to thank Arthur G. Sylvester (University of California, Santa Barbara), who reviewed the manuscript and gave constructive suggestions.

REFERENCES

Borchert, H. and Richard, O.M., 1964. Salt deposits; the origin, metamorphism and deformation of evaporites: London, Princeton, N.J., Van Nostrand, 338 pp.

Braitsch, O., 1971. Salt Deposits; Their Origin and Composition: New York, Springer-Verlag, 297 pp.

Hite, R.J., 1974. Evaporite deposits of the Khorat Plateau, northern Thailand. In: A.H. Coogan (Editor), Fourth Symposium on Salt, The Northern Ohio Geological Society, Inc., Cleveland, 1: 135–146.

Hite, R.J. and Japakasetr, T., 1979. Potash deposits of the Khorat plateau, Thailand and Laos. Economic Geology, 74: 448–458.

Shuai, K., 1987. Geologic-tectonic evolution and evaporite formation of Mesozoic–Cenozoic era in Yunnan. Geoscience, 1 (2): 207–229.