

An Investigation on Evaporating Experiments for Qinghai Lake Water, China

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Abstract: Qinghai Lake is located in the northeastern part of Qinghai-Xizang (Tibet) Plateau, and it is a typical continental brackish-water lake. The lake water belongs to sodium sulphate subtype with a salinity of 14.07 g/l, and obviously differs from seawater in chemical composition. It is saturated by CaCO_3 and aragonite is separating out. In order to reveal the evolving tendency of the lake water, salt-separating sequences and forming conditions of various salt deposits, we took a large amount of lake-water near the southern bank of the lake and carried out the evaporating and freezing-evaporating experiments. The evaporating experimental results show that, hydromagnesite is first separated with the lake-water being concentrated, and then halite, thenardite, bloedite, picromente, epsomite, sylvite and carnallite precipitated successively. The results of freezing evaporation show that, first hydromagnesite, and then mirabilite, nesquehonite, halite, epsomite, carnallite and bischofite separated, respectively. The final mother liquid of those experiments were preserved for 1-2 months (in laboratory) and borates were precipitated. The above salt-separating sequence and crystallization pathway obviously differ from those of seawater, and are similar to some saline lakes on Qinghai-Xizang (Tibet) Plateau and some ancient lake basins of Tertiary in the eastern China, such as Dalongtan Playa (Qaidam Basin) and Dawenkou Basin (Shandong province) etc. Therefore, these experimental results are very important for illustrating the evolving tendency of the Qinghai-Lake water and the formation and evolution of the salt lakes of Qinghai-Xizang (Tibet) Plateau, as well as the formation of potash deposits and other salt resources in continental lake basins.

Key words: Qinghai Lake; Evaporating experiment; Salt-separating; Plateau; Playa

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1 INTRODUCTION

Qinghai Lake is located in an intermontane rift-depression basin of the southern side of Qilian mountains. It covers an area of 4340 km² with an altitude of 3193.92 m a. s. l. and with the maximum depth of 27m. In the northeast there are many small

lakes (Gahai and Haiyan Bay etc.) separated or semi-separated from the lake. And in the east, the Erhai lake is isolated from it. The external drainage is fiercely developing. The biggest river-Buha River is situated at the west of the lake and its total inflow into the lake for a year makes up 67% of the total runoff. The annual average temperature is 0.9-2.7°C, the annual evaporation is 3.8 times of the

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annual precipitation, and thus this area belongs to high-cold semi-arid prairie climate. Qinghai Lake began to be formed in the Mid-pleistocene epoch (0.5 Ma B. P. at least)^[1]. The lacustrine sedimentation has rather developed since the Late Pleistocene period, and consists of a suite of dark-colour calcareous muds enriched in organic material with the obvious fine lamination^[2,3].

Qinghai-Lake water is 14.07 g/l in salinity and belongs to sodium sulphate subtype, and is a typical continental water body (Table 1). In the water the main chemical components are, cations $\text{Na}^+ > \text{Mg}^{2+} > \text{K}^+ > \text{Ca}^{2+}$ and anions $\text{Cl}^- > \text{SO}_4^{2-} > \text{HCO}_3^- + \text{CO}_3^{2-}$. Compared with seawater, there is obviously difference in chemical composition, characteristic coefficients and hydrochemical types, such as high-B-Li and low-Br contents, high-Mg-SO₄ and low-Ca contents, etc. It shows the characteristics of the salt lakes and lakes on Qinghai-Xizang Plateau. At present, the Qinghai-Lake water is saturated by CaCO₃ and aragonite is separating (Fig. 1, Photo. 1). At the eastern bank of Haiyan bay hydromagnesite is distributed (Photo. 2).

The water bodies of the continental lake basins

mainly have two chemical types: the sulphate and carbonate types. Qinghai Lake is typical of the former. In order to reveal the evolution process and salt-separating sequence of the water body, we carried out the research on evaporating experiment for Qinghai-Lake water. It is more important to explain the formation and evolution of the salt lakes on Qinghai-Xizang Plateau and the formation of some salt deposits. However, little effort has been made, at home or abroad, to the study of such an evaporating experiment for the low-concentration water-body.

2 EXPERIMENTS

2.1 Experimental Method

A water sample of approximately 0.75m³ was collected from Erlangjian near the southern bank of Qinghai Lake in the April of 1990. And then the natural evaporating experiment of the large-volume lake-water was carried out of laboratory in Xining city (from May to October at that year). On the basis of that, there were two experiments to be made in

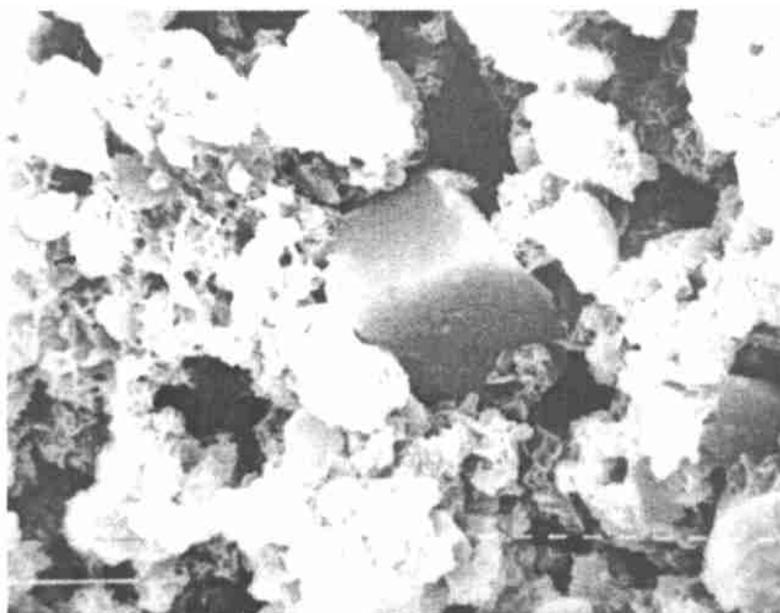


Photo. 1 SEM photograph of aragonite obtained from Qinghai Lake water (× 2500)

Table 1 Comparison of chemical composition between Qinghai Lake water and seawater^{1,4)}

Location	Qinghai Lake	Seawater	South China Sea	Huanghai Sea	Haiyan Bay	Gahai Lake
Density(g/ cm ³)	1. 011		1. 022	1. 022	1. 016	1. 024
pH	9. 15—9. 30		7. 52		8. 94	9. 02
Salinity($\times 10^{-3}$)	14. 23	34. 48	33. 20	31. 30	17. 83	31. 88
Main chemical components($\times 10^{-3}$):						
Na ⁺	3. 93	10. 56	10. 20	9. 67	5. 02	9. 46
K ⁺	0. 16	0. 38	0. 39	0. 33	0. 20	0. 44
Mg ²⁺	0. 79	1. 27	1. 33	1. 16	0. 97	1. 35
Ca ²⁺	0. 01	0. 40	0. 39	0. 37	0. 01	0. 01
Cl ⁻	5. 79	18. 98	18. 44	17. 15	7. 42	13. 37
SO ₄ ²⁻	2. 35	2. 65	2. 61	2. 37	2. 91	6. 04
HCO ₃ ⁻	0. 68	0. 14	0. 15	0. 13	0. 58	0. 53
CO ₃ ²⁻	0. 52	—	—	—	0. 71	0. 68
Trace elements($\times 10^{-6}$):						
B	11. 7	4. 6	4. 3	4. 3	14. 8	24. 7
Li	0. 84	0. 1	< 1	0. 17	1. 13	2. 10
Br	1. 50	65	72	61	2. 0	5. 5
I	0. 004	0. 05	<		0. 005	0. 011
Sr	0. 04	8	0. 01 9	7. 8	0. 05	0. 07
Ba	0. 02	0. 006			0. 03	0. 02
P	0. 503	0. 001—0. 06			0. 95	1. 20
Cu	0. 016	0. 001—0. 025			0. 03	0. 024
Fe	0. 067	0. 003			0. 09	0. 10
Ni	0. 092	0. 0015—0. 006			0. 20	0. 14
Mn	0. 016	0. 001			0. 019	0. 02
Ti	0. 01	0. 001—0. 009			0. 02	0. 018
U	0. 042	0. 003			0. 07	0. 064
Zn	0. 0021	0. 009—0. 021			0. 014	0. 004
Cr	0. 124	0. 001—0. 0025			0. 17	0. 20
Si	0. 925	0. 01—4			1. 32	2. 04
Al	0. 259	0. 003—2. 4			0. 46	0. 47
Characteristic coefficients:						
Na/K	24. 56	27. 79	25. 69	29. 30	25. 48	21. 50
Mg/K	4. 94	3. 34	3. 41	3. 52	4. 90	3. 07
Mg/Ca	79	3. 18	3. 41	3. 52	96. 5	135
(K/∑ salt) ° 1000	11. 24	11. 02	11. 75	10. 54	11. 22	13. 80
Cl ⁻ /∑ salt	0. 41	0. 55	0. 55	0. 55	0. 42	0. 42
SO ₄ ²⁻ /∑ salt	0. 17	0. 08	0. 08	0. 08	0. 16	0. 19
(HCO ₃ ⁻ +CO ₃ ²⁻ /∑ salt) ° 100	8. 43	0. 41	0. 45	0. 42	7. 24	3. 80
Hydrochemical type	Na ₂ SO ₄ - subtype	MgSO ₄ - subtype	MgSO ₄ - subtype	MgSO ₄ - subtype	Na ₂ SO ₄ - subtype	Na ₂ SO ₄ - subtype

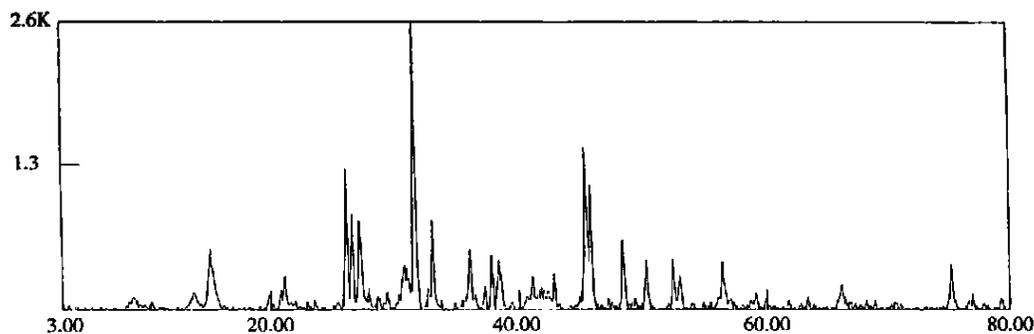


Fig 1 X-ray powder analysis of aragonite(contained a little calcite) separated from Qinghai Lake water^[5]

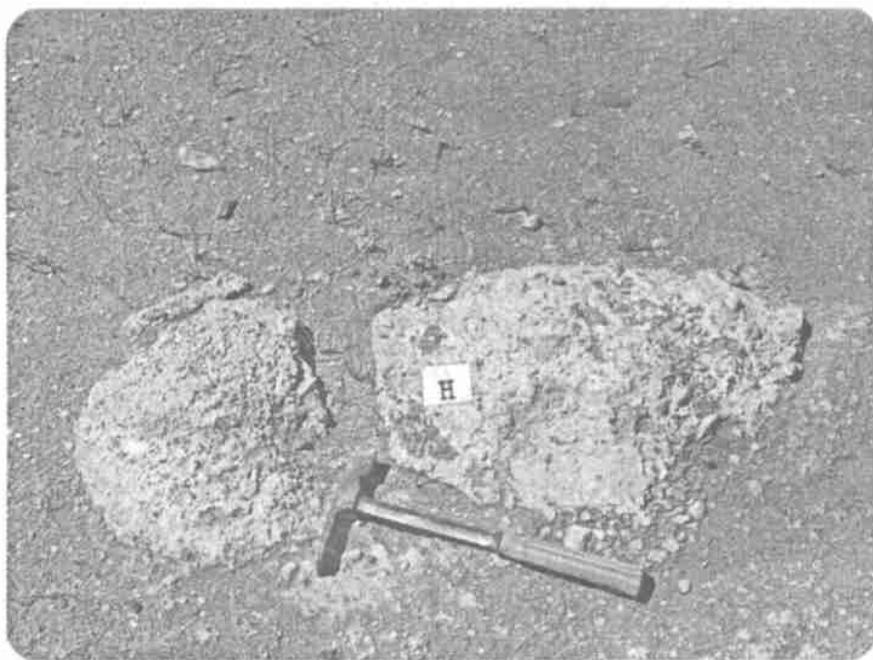


Photo. 2 Hydromagnesite deposits occurred on the eastern bank of Haiyan Bay

1991. One was the isothermal evaporating experiment at 25°C and the other was the natural freezing—evaporating experiment. The former was carried out in laboratory from the beginning of halite—separating stage to the end of carnallite—precipitating stage; the latter was made out of laboratory for freezing in spring (5°C — 17°C) and for evaporating in summer, and ended to the precipitation of bischofite in autumn of this year.

The natural evaporating experiment of the large—volume lake water was carried out in plastic troughs ($100\times 100\times 40\text{cm}^3$, each one) under sunlight. The isothermal evaporating experiment (25°C)

for the lake water was carried out in an isothermal plant of the laboratory, putting the halite—separating stage brine into a glass trough and heating with 4 bulbs, and the temperature is controlled by a contact temperature meter and a relay (precision: $25^{\circ}\text{C}\pm 0.5^{\circ}\text{C}$). For the entire experiment we adopted the continuously separating method of the liquid and solid phases.

The liquid—phase samples obtained from those experiments were determined by the chemical analysed method and the AAS method. The solid samples were identified by the chemical, microscope and X—ray powder analysis, and part by scanning elec-

tron microscopy.

2.2 Experiment Results

(1) Natural evaporating experiment for a large volume of Qinghai Lake water

The original lake water is 1.010 in specific gravity(S. G.) and 14.07 g/l salinity. It is saturated by CaCO₃ and aragonite is separating. With the evaporation and concentration, the salt-separating sequence is as follows(Table 2):

a. As S. G. is 1.015 and salinity 22.21 g/l, nesquehonite begins to precipitate(Fig. 2). At that time, the concentration of the mother liquid is similar to that of the Haiyan Bay water(Table 1).

b. S. G. reaches 1.025, salinity 33.94 g/l, hydromagnesite (contained a little calcite) begins to separate(Fig. 3, Photo. 3). At that time, the concentration of the liquid phase is similar to that of the Gahai water(Table 1).

c. S. G. = 1.237, salinity = 352.52 g/l, halite begins to precipitate.

With the evaporation and concentration of the

lake water, the crystallization pathway is: the chemical composition point of the original lake water is situated at the bloedite field of the metastable phase diagram (25 °C) for Na⁺, K⁺, Mg²⁺//Cl⁻, SO₄²⁻-H₂O system (Fig. 4), and then drops to the thenardite field with the separation of nesquehonite and hydromagnesite. This point is just the beginning of halite precipitation.

(2) Isothermal evaporating experiment(25 °C) for Qinghai Lake water

The original sample is the brine of the halite-separating stage with a specific gravity of 1.256 and a salinity of 379.07 g/l. With the evaporation and concentration of the brine, its salt-separating sequence is as follows(Table 3):

a. As the specific gravity of the brine reaches 1.266, the salinity 380.17g/l, and thenardite began to precipitate. Its mineral group: Halite + Thenardite.

b. As S. G. reaches 1.285, salinity 404.54 g/l, and bloedite began to separate. Its mineral group: Halite + Thenardite + Bloedite.

Table 2 The result of natural evaporating experiment for a large volume of Qinghai Lake water^[5]

Samples	S. G.	Salinity	pH	Chemical composition of liquid phase ρ/(g/l)											Indx/(mol/100mol)			Solid phase	
				Na	K	Mg	Ca	Cl	SO ₄	HCO ₃	CO ₃	B ₂ O ₃	Li	Br	I	K ⁺	Mg ²⁺		SO ₄ ²⁻
/t °C	(g/l)			(mg/l)											(mg/l)	(μg/l)			
QE-OWL 010		14.07	9.31	4.13	0.15	0.75	0.0	5.64	2.29	0.53	0.56	0.04	0.88	2.97	4.2	3.50	54.4	42.11	Aragonite
QE-1	1.015/17 °C	22.21	9.27	6.40	0.25	1.15	0.01	9.21	3.7	0.83	0.67	0.06	1.3	4.5	6.5	3.4	53.05	43.5	Nesquehonite
QE-2	1.025/28 °C	33.9	9.03	9.88	0.39	1.67	0.02	14.1	5.70	1.23	0.94	0.10	1.9	6.7	14.4	3.77	51.5	44.73	Hydromagnesite
QE-3	1.071/25 °C	102.1	n.d.	31.7	1.27	4.07	0.05	44.9	17.9	1.16	1.09	0.31	5.4	19.4	53	4.39	45.2	50.4	Hydromagnesite
QE-4	1.237/17 °C	352.5	n.d.	110.0	4.32	12.5	0.20	159.3	63.4	2.84		0.78	13.8	n.d.	90	4.50	41.80	53.7	Halite
QE-5	1.256/14 °C	379.1	n.d.	120.0	4.68	13.4	0.18	170.1	68.16	2.54		0.86	14.5	n.d.	n.d.	4.55	41.75	53.75	Halite

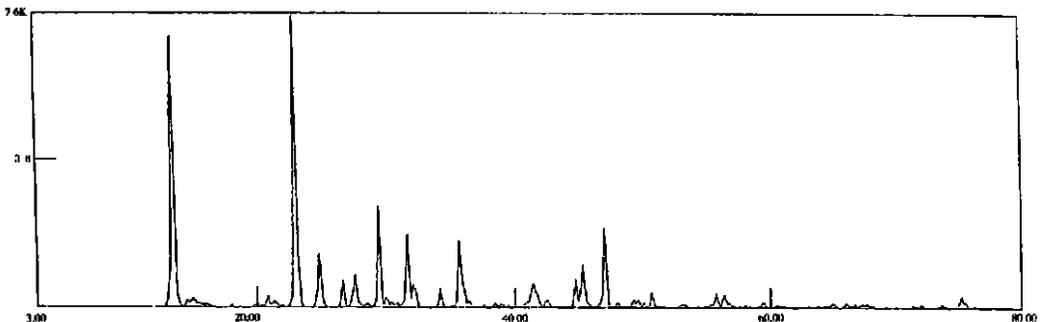


Fig 2 X-ray powder analysis of nesquehonite obtained from the natural evaporating experiment

of Qinghai Lake water^[5]

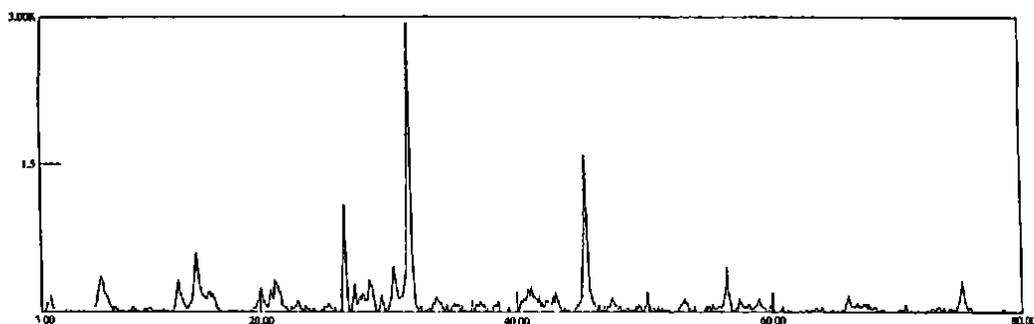


Fig 3 X-ray powder analysis of hydromagnesite obtained from the natural evaporating experiment of Qinghai Lake water^[9]



Photo. 3 SEM photograph of hydromagnesite obtained from the natural evaporating experiment of Qinghai Lake water($\times 5000$)

c. S. G. — 1.303, salinity — 403.84g/l, picromerite began to separate. Its mineral group: Halite + Bloedite + Picromerite.

d. S. G. — 1.309, salinity — 426.34g/l, epsomite began to precipitate. Its mineral group: Halite + Bloedite + Picromerite + Epsomite.

e. S. G. — 1.346, salinity — 436.66g/l, carnallite began to separate. Its mineral group: Halite + Epsomite + Carnallite.

f. Finally, the specific gravity reached 1.350, salinity 446.90 g/l, and the salt-separating group: Halite + Hexasahydrate + Epsomite + Carnallite.

The remained mother liquid contains 9.42 g/l B_2O_3

and is reserved for a month, and borate is precipitated(Photo. 4).

In the experimental process, the original brine point was situated at the upper part of thenardite field of the metastable phase diagram ($25^\circ C$) for Na^+ , K^+ , $Mg^{2+} // Cl^-$, $SO_4^{2-} - H_2O$ system (Fig. 5). With the evaporation and concentration, this point moved upwards, passing bloedite field and entering epsomite field. And finally it only closed to the eutectic point of halite + epsomite + picromerite + sylvite when the carnallite, hexasahydrate, epsomite and halite were separated (Fig. 5).

Obviously, the crystallization pathway is not consis-

tent with that of the metastable phase diagram. This is mainly because the chemical components of the natural brine are complicated and its evaporation is rapid during the process of the experiment.

In the process of evaporating experiment, the sylvite-separating stage should exist between point

11 and point 12. Unfortunately, we could not take the sample in time.

From the above mentioned, it might be seen that the whole salt-separating sequence during the evaporation and concentration of Qinghai Lake water is described as follows:

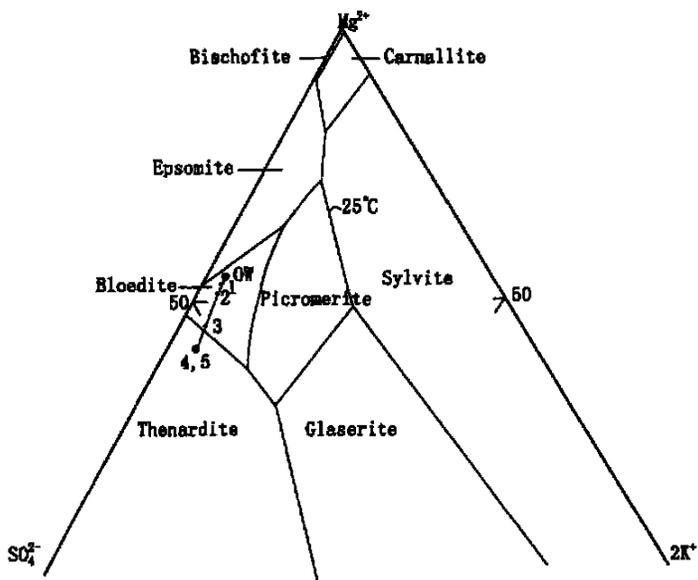


Fig 4 Crystallization path of the natural evaporating experiment for a large-volume of Qinghai Lake water



photo. 4 SEM photograph of borate obtained from the final mother liquid of evaporating experiments for Qinghai Lake water (× 5000)

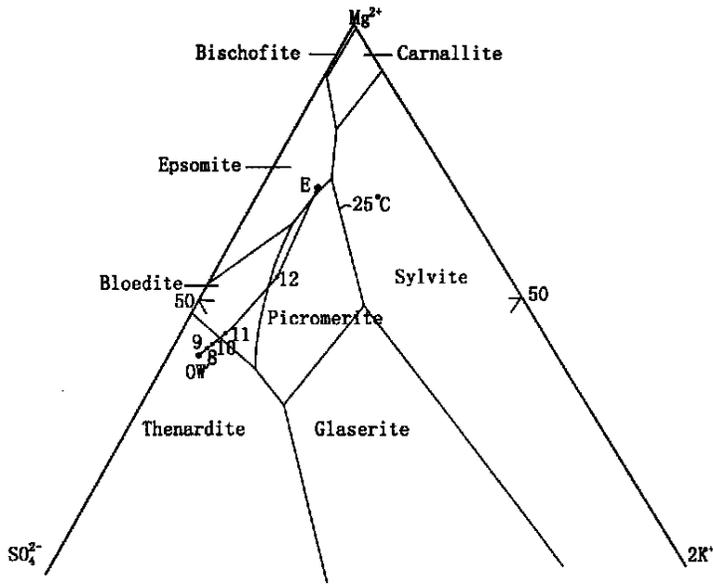


Fig 5 Crystallization path of the isothermal evaporating experiment(25 °C)
for Qinghai Lake water

Table 3 The result of isothermal evaporating experiment(25 °C) for Qinghai Lake water

Samples	S. G.	Salinity (g/l)	pH	Chemical composition of liquid phase ρ_l (g/l)											Indx (mol/100mol)			Solid phase		
				Na	K	Mg	Ca	Cl	SO ₄	HCO ₃	CO ₃	B ₂ O ₃	Li	Br	I	2K ⁺	Mg ²⁺		SO ₄ ²⁻	
														(mg/l) (mg/l) (μg/l)						
QE-OW	1.256	379.1	n.d.	120.0	4.68	13.42	0.18	170.1	68.16	2.54		0.8	14.5				4.55	41.7	53.75	Halite
QE-6	1.266	380.2	8.04	108.1	5.82	16.65	0.07	169.9	85.82	0.95	0.82	0.83	17.47	237	0.03	4.85	41.2	54.2	Halite+	
																				Thenardite+
																				Hydro-glauberite(?)
QE-7	1.285	404.5	7.94	99.84	7.84	22.31	0.06	156.3	115.98	1.13	1.04	1.09	23.1	309	0.03	4.62	41.04	54.34	Halite+	
																				Thenardite+
																				Bloedite
QE-8	1.303	408.8	8.00	94.72	9.94	25.21	0.02	153.7	117.6	1.06	1.53	1.33	43.1	370	0.04	5.40	42.7	51.9	Halite+Bloedite+	
																				Picromerite
QE-9	1.301	416.3	7.94	97.70	10.67	26.15	0.07	155.8	123.4	1.12	1.54	1.38	43.1	399	0.05	5.20	42.93	51.89	duo	
QE-10	1.306	416.8	7.87	84.50	12.7	29.68	0.06	151.8	135.04	1.13	1.98	1.73	52.8	483	0.05	5.63	43.7	50.7	duo	
QE-11	1.309	426.24	7.84	84.43	15.43	32.86	0.06	151.8	137.7	1.93	2.80	2.05	64.1	525	0.06	6.61	45.4	51.9	Halite+Bloedite+	
																				Picromerite+
																				Epsomite
QE-12	1.346	436.7	7.24	46.7	31.8	55.7	0.04	164.2	138.3			5.07	160.5	562	n.d.	9.79	55.35	34.86	Halite+Epsomite	
																				+Carnallite
QE-E	1.350	446.9	6.52	15.0	31.37	84.83		216.3	99.40			9.42	425	1250	n.d.	8.11	70.8	21.06	Halite+	
																				Hyxhydrate+
																				Epsomite+
																				Carnallite

- a. Aragonite,
- b. Nesquehonite,
- c. Hydromagnesite,
- d. Halite,
- e. Halite+Thenardite+Hydroglauberite(?)
- f. Halite+Thenardite+Bloedite,
- g. Halite+Bloedite+Picromerite+Epsomite,
- h. Halite+Picromerite+Epsomite,
- i. Halite+Picromerite+Epsomite+Sylvite,
- j. Halite+Epsomite+Sylvite+Carnallite,
- k. Halite+Epsomite+Carnallite,
- l. Halite+Epsomite+Hyxahydrate+Carnal-
lite.

The whole crystallization path is also rather complicated. At first, the original point was situated at bloedite field, and then moved down to the thenardite field with the precipitation of nesquehonite and hydromagnesite, and finally rised to epsomite field passing through bloedite field. That is, the final constituting point of them other liquid still fell into epsomite field of the metastable diagram for Na^+ , K^+ , $\text{Mg}^{2+}/\text{Cl}^-$, $\text{SO}_4^{2-}-\text{H}_2\text{O}$ five-component system(Fig. 5).

In addition, we have carried out the natural evaporating experiment for Gahai Lake water. The salt-separating sequence and crystallization path are similar to those of Qinghai Lake water.

In the above whole experimental process for Qinghai Lake water, with the precipitation of various salts, B and Li elements are further concentrated in the mother liquid, and they finally reach 9.42g/l and 425 mg/l, respectively (Table 3). It sufficiently shows the characteristics of B-rich and Li-rich in the saline lakes of the Qinghai-Xizang(Tibet) Plateau of China.

(3) Natural freezing-evaporating experiment for Qinghai Lake water

During the process of natural evaporating experiment for a large volume of Qinghai-Lake water in 1990, we took a concentrated water-sample(S. G. -1.100, salinity -120.74g/l, separating hydromagnesite) as the original brine of the experiment.

In the winter, the freezing experiment was carried out of laboratory under the temperature of 5°C - 17°C for a month (Table 4). A large amount of mirabilite and nesquehonite was precipitated, and then the remained mother liquid was separated from those and reserved in laboratory at that time. In the summer of next year, the natural evaporating experiment was made under sunlight using that sample. The salt-separating sequence is described as follows (Table 4):

a) As S. G. reached 1.129, salinity 193.86g/l, nesquehonite was separated,

b) As S. G. -1.204/ 35°C , salinity -306.38g/l, halite began to precipitate. Its mineral group: Halite + Nesquehonite,

c) As S. G. -1.266, salinity -370.18 g/l, epsomite began to separate. Its mineral group: Halite + epsomite,

d) As S. G. -1.345, salinity -441.63 g/l, carnallite began to precipitate. Its mineral group: Halite + Epsomite + Carnallite,

e) Finally, when the mother liquid reached 457.08 g/l in salinity, bischofite began to precipitate. Its mineral group: Halite + epsomite + carnallite + bischofite. Sylvite should be separated between the stages of epsomite and carnallite separation. Unfortunately, we were unable to take that sample in time.

In the whole experimental process, the original brine point was situated at thenardite field of the metastable phase diagram (25°C) for Na^+ , K^+ , $\text{Mg}^{2+}/\text{Cl}^-$, $\text{SO}_4^{2-}-\text{H}_2\text{O}$ system (Fig. 6). Passing through freezing experiment of low-temperature, mirabilite and nesquehonite were separated and the brine point moved upwards to the epsomite field. With the evaporation and concentration of mother liquid, nesquehonite was precipitated and the brine point moved down. Carnallite and bischofite were separated respectively after epsomite began to precipitate, the brine point moved upwards gradually from point 3 to 4, 5(Fig. 6). However, finally it has not reached to the eutectic point of halite + epsomite

+ carnallite + bischofite on the metastable phase diagram. This is mainly because the chemical compo-

ments of natural brine are complicated and its evaporating rate is rapid during the experimental process.

Table 4 The result of natural freezing—evaporating experiment for Qinghai Lake water

Samples	S.G./t/°C	Salinity (g/l)	pH	Chemical composition of liquid (g/l)										Solid phase	
				Na	K	Mg	Ca	SO ₄	Cl	HCO ₃	CO ₃	B ₂ O ₃	Li		Br
QFOW-1	1.100/24	120.74	n.d.	22.4	1.21	5.49	0.06	26.02	63.42	0.59	1.54	n.d.	n.d.	n.d.	Hydromagnesite
QFOW-2	n.d.	104.93	n.d.	31.9	1.29	5.04	0.05	5.30	59.36	0.84	1.20	n.d.	n.d.	n.d.	Nesquehonite + Mirabilite
QFE-1	1.129/34	193.86	7.98	55.77	2.99	9.02	0.06	12.77	111.05	1.21	0.48	0.34	11.18	143	Nesquehonite
QFE-2	1.204/35	306.38	7.83	85.60	4.80	14.06	0.05	20.80	178.55	0.96	0.60	0.75	16.0	198	Halite + Nes.
QFE-3	1.266/31	370.18	7.38	52.03	15.40	44.63	0.05	65.33	186.10	2.07	1.98	2.01	66.21	524	Halite + Epsomite
QFE-4	1.345/26	441.63	6.15	4.36	19.54	94.55	—	63.74	253.26	n.d.	n.d.	5.45	204.44	859	Halite + Epsomite + Carnallite
QFE-5	n.d.	457.08	5.89	4.67	6.34	107.96	—	51.17	278.64	n.d.	n.d.	7.20	275.4	829	Halite + Epsomite + Carnallite + Bischofite

* Brine removed mirabilite from QFOW-1 under low temperature (5 °C—17 °C).

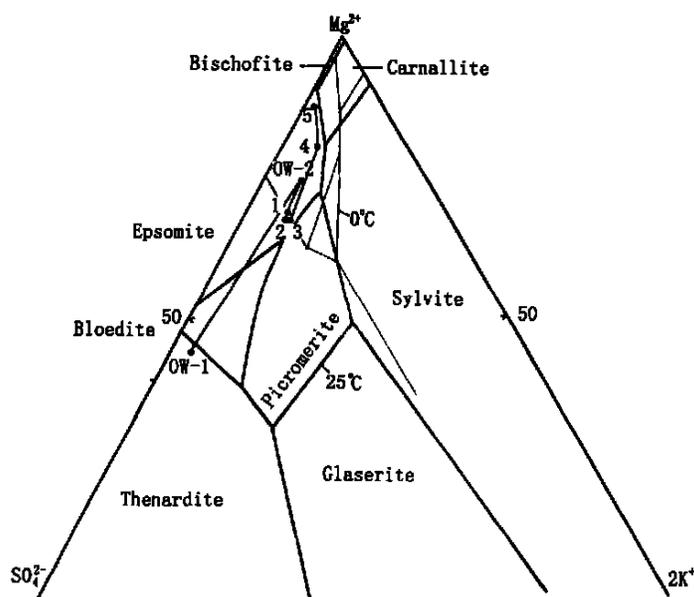


Fig 6 The crystallization pathway of natural freezing—evaporating experiment for Qinghai Lake water

The salt—separating sequence of natural freezing—evaporating experiment differs from that of the above isothermal evaporating experiment and is described as follows:

- Hydromagnesite,
- Mirabilite + Nesquehonite,
- Nesquehonite,
- Halite + Nesquehonite,

- Halite + Epsomite,
- Halite + Epsomite + Sylvite,
- Halite + Epsomite + Sylvite + Carnallite,
- Halite + Epsomite + Carnallite,
- Halite + Epsomite + Carnallite + Bischofite,

In the final remained mother liquid, B and Li content reached highly enrichment and the borate

was precipitated after 1—2 months.

3 DISCUSSION

1) The result of evaporating experiments for Qinghai Lake water reflects the whole process of the evolution of the sulphate—type water—bodies in the continental lake basins. At the same time, it also reveals the further evolving tendency of Qinghai Lake in the future geological age under the arid climate. At present, hydromagnesite is depositing in the Haiyan Bay and Gahai Lake at the northeast of Qinghai Lake. It shows that Qinghai Lake is slowly developing towards the direction of saline lake.

2) The salt—separating sequence and crystallization pathway in the process of the evaporating experiment(25 °C) for Qinghai Lake water are similar to those of Zhacang Caka Salt Lake(Tibet)^[6], and obviously different from those of sea water. According to the data of the isothermal evaporating experiment at 25 °C for the Huanghai Sea water of China^[7], the salt—separating sequence is as follows: a) Aragonite, b) Gypsum, c) Halite + Gypsum, d) Halite + Epsomite, e) Halite + Epsomite + Sylvite, f) Halite + Epsomite + Carnallite and g) Halite + Epsomite + Carnallite + Bischofite. Such a salt—separating sequence is more different from that of Qinghai Lake water.

3) The salt—separating sequence and paragenetic mineral groups obtained from the above experiment of the Qinghai—Lake water are very similar to those in the Tertiary salt—bearing basins of Dawenkou and Jiangnan in the eastern China. However, these lake—basin water—bodies were concentrated only up to the stages of bloedite and picromerite precipitation at that time. These salt deposits belong to the products of the dry—hot climate.

4) The result of natural freezing—evaporating experiment for Qinghai lake water basically reflects the evolution process of Dalongtan Salt Lake in the western Qaidam Basin since the Quaternary period.

In the early—mid Pleistocene epoch, a large amount of mirabilite deposits occurred; in the Late—Pleistocene and Holocene epoch, a lot of halite, epsomite and potash deposits appeared; and up to now bischofite is separating in the brine pits on the salt crust. This is a set of salt—separating sequence of the sulphate—type water—body under the dry—cold climate.

5) The borate obtained from the final mother liquid of those experiments of Qinghai Lake water is similar to that from the concentrated brine of Da—Qaidam Salt Lake^[8]. It illustrates that the potash—separating stage brine is beneficial to the formation of borate. Therefore, borate can be found in the potash zones of some ancient marine salt deposits in Europe.

4 CONCLUSIONS

1) The result of the evaporating experiments for Qinghai Lake water reveals the whole process of the evolution of sulphate—type water—body in the continental lake basins, and also illustrates the evolving processes of the recent salt lakes and ancient Tertiary salt—bearing basins in China, as well as the genetic mechanism of those various salt deposits. At the same time, it also reveals the further evolving pathway of Qinghai Lake under dry climate in the future. At present, the occurrence of hydromagnesite in Haiyan Bay and Gahai Lake shows that the Qinghai Lake is slowly development towards the direction of saline lake.

2) The salt—separating sequence and crystallization pathway during the evaporation process of Qinghai Lake water are obviously different from those of seawater. However, part of the salt—separating sequence and crystallization pathway of the Qinghai Lake concentrated brine after mirabilite was removed is similar to those of seawater. Thereby, some salt—separating sequences and paragenetic mineral assemblages found in the normal concentrated process of seawater also appear in some recent salt lakes, such

as Dalongtan Salt Lake in Qaidam Basin etc.

3) Hydromagnesite obtained from the above experiments can be found in many salt lakes on Qinghai-Xizang(Tibet) plateau.

4) Some paragenetic mineral groups related to mirabilite, bloedite, picromerite, epsomite and potash salts obtained from the above experiments can be found in many recent salt lakes and ancient Tertiary lake basins in the east of China.

5) The appearance of high-B-Li content in the final remained mother liquid also shows the characteristic of B-Li-rich of the salt lakes on Qinghai-Xizang(Tibet) Plateau.

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青海湖湖水蒸发实验研究

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摘要: 青海湖位于青藏高原的东北部, 是一个典型的大陆微咸水湖。其湖水盐度为 14.07g/L, 水化学类型为硫酸钠亚型, 化学组成不同于海水。该湖水为 CaCO₃ 所饱和, 正在析出文石。为了揭示其湖水演化的趋势、析盐顺序和各种盐类形成的条件, 曾在湖的南岸采集了大量湖水进行了蒸发实验和冷冻-蒸发实验。蒸发实验的结果表明: 首先析出水菱镁矿, 随着湖水继续浓缩进一步析出石盐、无水芒硝、白钠镁矾、软钾镁矾、泻利盐、钾石盐和光卤石。冷冻-蒸发实验的结果是: 首先析出水菱镁矿, 然后是芒硝、三水菱镁矿、石盐、泻利盐、光卤石和水氯镁石。这些实验的最终母液在室内保存了 1-2 月, 均析出了硼酸盐。上述实验的析盐顺序和结晶途径与海水明显不同, 而与某些青藏高原盐湖和我国东部某些第三纪古湖盆相似, 如柴达木盆地的大浪滩干盐湖和山东的大汶口盆地等。因此, 这些实验结果对于阐明青海湖湖水的演化趋势、青藏高原盐湖的形成和演化, 以及大陆湖盆钾盐和其它盐类矿产资源的形成都是非常重要的。

关键词: 青海湖; 蒸发实验; 析盐; 干盐湖