



Achievements of CGS
CGS 2014-006

SALINE LAKES AND SALT BASIN DEPOSITS IN CHINA

—SELECTED WORKS OF ZHENG MIANPING

Zheng Mianping



SCIENCE PRESS
Beijing

Funded by Chinese Geological Survey's projects (1212011085524; 1212011085517)

SALINE LAKES AND SALT BASIN DEPOSITS IN CHINA

——SELECTED WORKS OF ZHENGMIANPING

Zheng Mianping

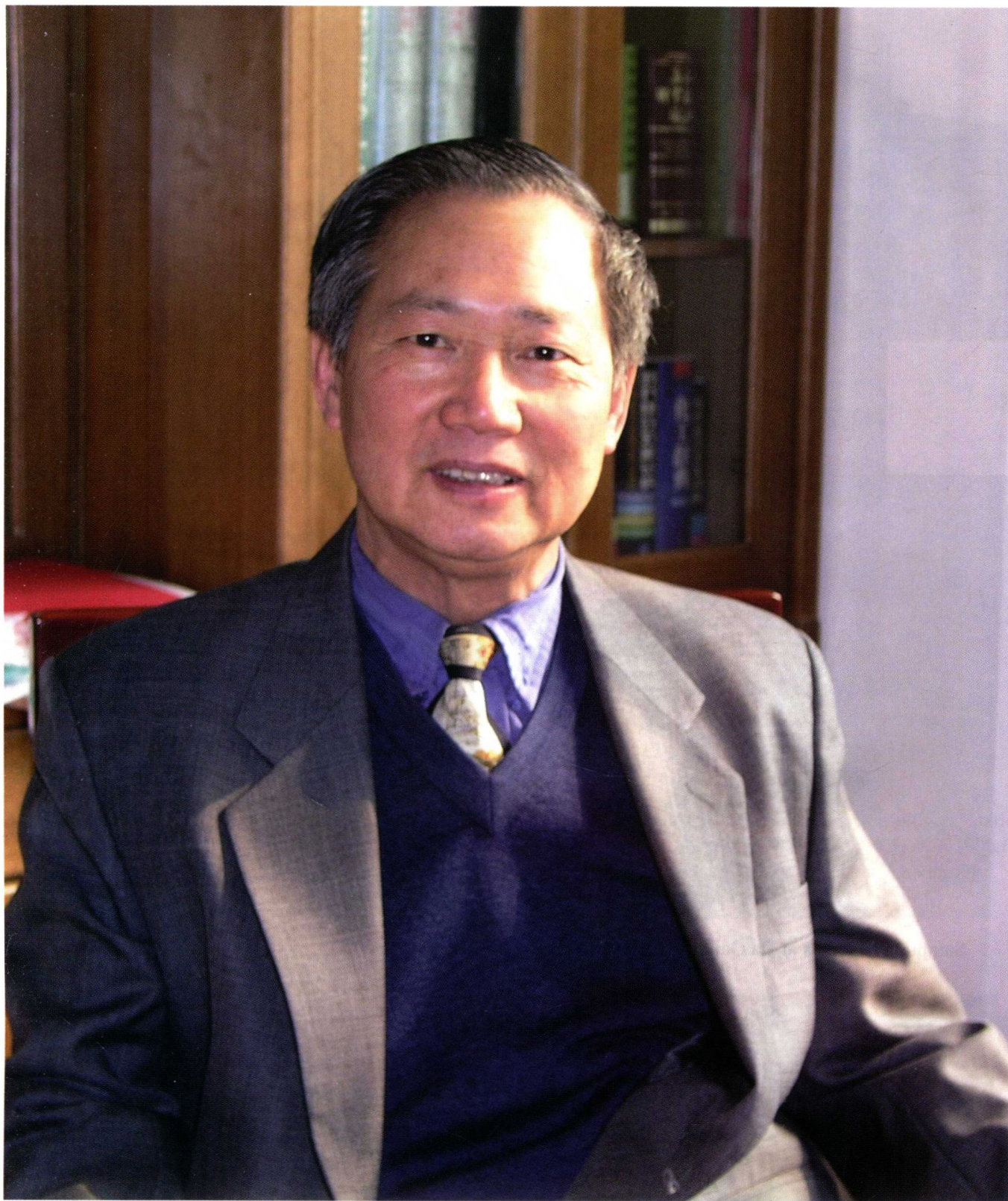
Responsible Editor: Zhang Jingfei

Copyright© 2014 by Science Press
Published by Science Press
16 Donghuangchenggen North Street
Beijing 100717, P. R. China

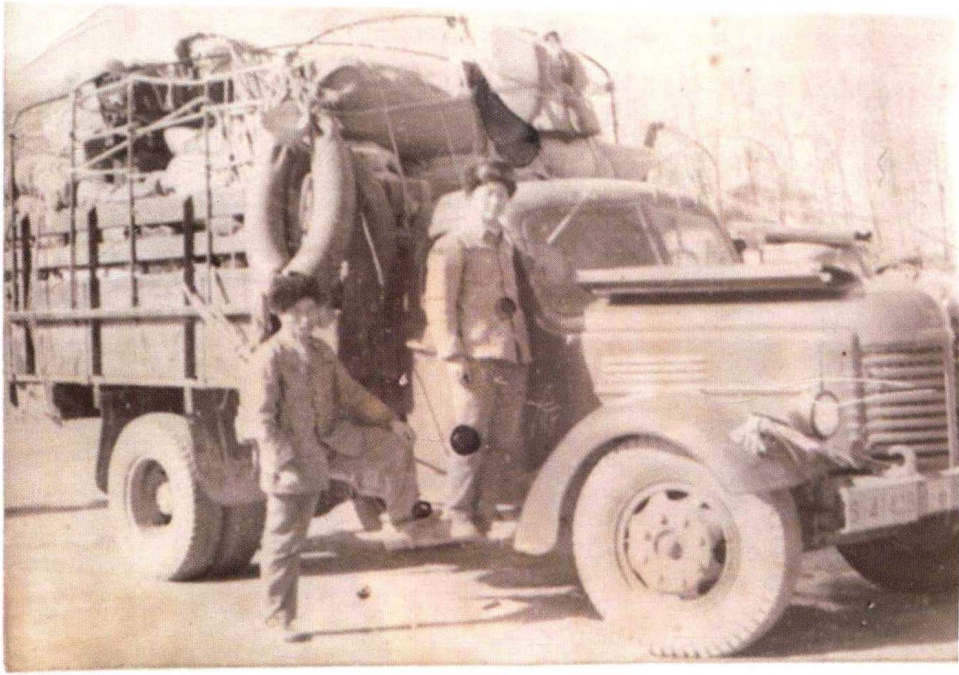
Printed in Beijing

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior written permission of the copyright owner.

ISBN 978-7-03-041144-0



Professor Zheng Mianping



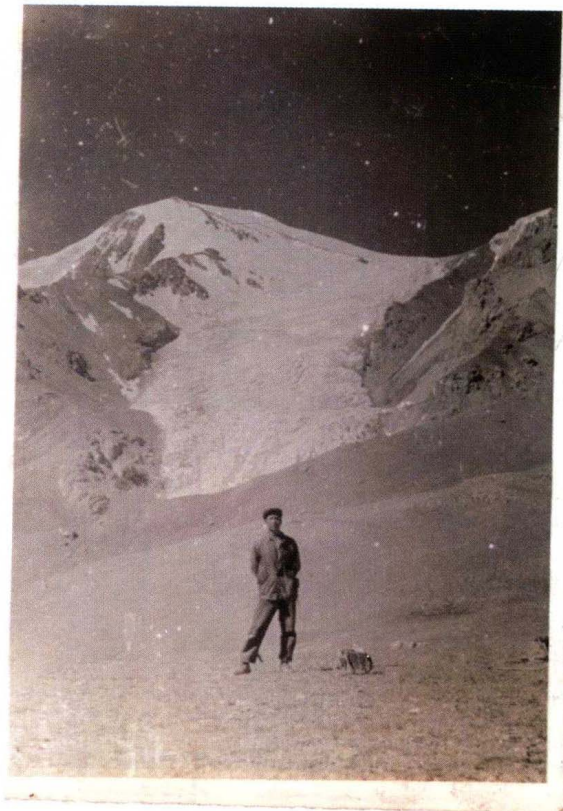
On the way to Qaidam basin for the first time in 1956 (right Zheng Mianping)



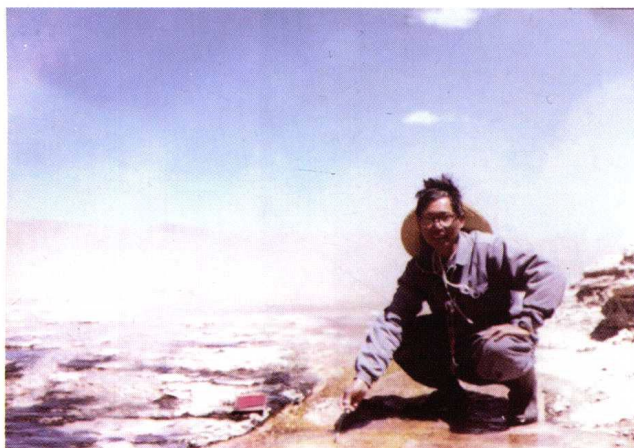
Sampling of brines at Da Qaidam salt lake



Sampling at Ascharite deposit at Fengcheng, Liaoning, in Nov. 1957 (second from left, professor Shchukin, former chief engineer of Ministry of Chemical Industry of USSR, third from left, Zheng Mianping)



Working at Xiagangjiang glacier, Ngari, 1960 at elevation of 5400m



1-1



1-2

Discovery of new type of Cesium-Bearing Gerserite at Tagejia, Tibet, in 1984



2-1 Observation of dunaliella salina at the Tufa island of the North Zabuye lake (from left, Zheng Yuan, Zheng Mianping, Xiang Jun)



2-2 The establishment of meteorological station in the middle part of Zabuye salt lake in 1990 (left Qi Wen, middle Zheng Mianping)



2-3 The research group lead by Zheng Mianping at Zabuye lake in 1995



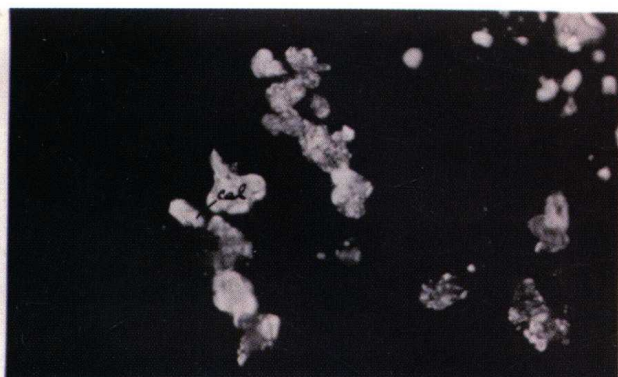
2-4 Working at the salt pan to build the research base for Li production (from left, Zheng Mianping, Yang Huipeng, Wang Gaoshang)



Chinese-America collaboration (expeditions of experts from both USA and China at Zabuye lake in 1988, 7th from left is Zheng Mianping, the leader of Chinese group, 9th from left is H. Holland, the leader of American group)



3-1 On the way to Daerduo depression of Lop Nor, along Kongque river in Oct. 1989



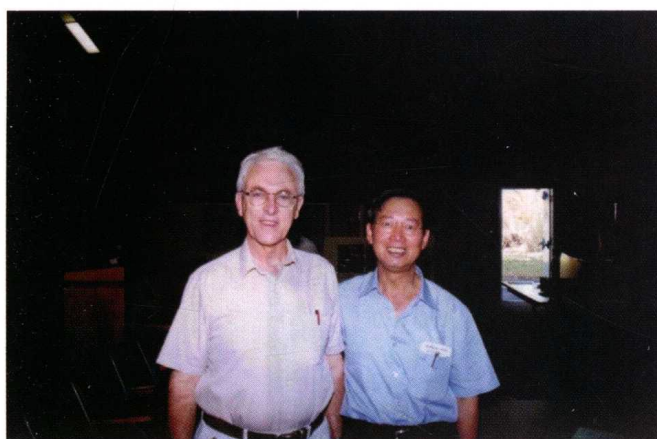
3-3 First discovery of carnalite at Lop Nor



3-2 Building the drilling rig on the salt crust of Lop Nor



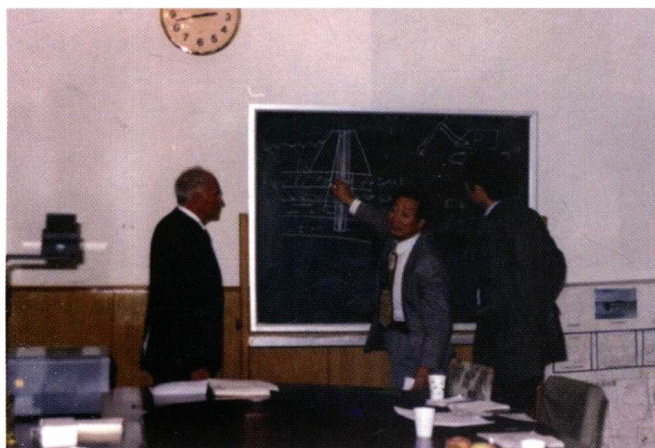
Vice Premier Zhou Jiahua with experts from China and overseas



Professor W.D. Willams and Professor Mianping Zheng during the seventh International Conference on Salt Lake Research in 1998



Some representatives during seventh International Conference on Salt Lake Research in 1998



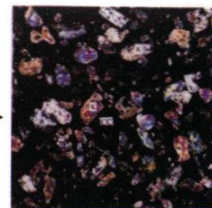
Discussing with David S. Butts, an American experts on salt pans, in 2000



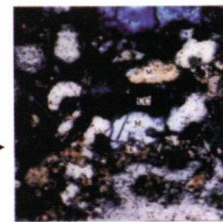
Professor Zheng visiting the Washington University for joint research on Mars salts in 2009 (From left, Wiens Douglas; Zheng Mianping; Arvidson Raymond)



General exploration of boron deposits at Chagcam caka, Tibet, 2002 (A new type of boron deposits was discovered by Zheng Mianping in 1961), left panel: primary euhedral kurnakovite and euhedral pinnoite surrounded by mirabilite, subsumption structure $4 \times 10(+)$



$6.3 \times 6.3(+)$



Observation of magnesium borates bearing sections by Zheng Mianping (right) and colleagues at the primary terraces of Nie'er Co, Tibet, in 2000



Field work at Mengyejing potassium deposit (left Zheng Mianping)

Introduction

Academician Zheng Mianping has been working on salt lakes and ancient salt deposits for more than half century, and this book is a selection of his works covering almost all the aspects in salt science. The 12th international conference, convened by Academician Zheng, will be held in China this year, and this book is written in English to serve reference for foreign colleagues who study salt lakes and salt bearing deposits.

Most of the materials in this book have been published with some minor errors corrected, and some new materials are added as supplements. Five chapters are organized based on disciplines of selected works. The first chapter gives the concept of salinology and saline systems, which is a high level systematic summary of salt sciences. Chapter 2 introduces the Saline Lakes and their resources in China. Chapter 3 includes some studies on palaeoclimate through detailed investigation of salt lake sediments. Chapter 4 focuses on the geoecology aspect of salt lakes, and introduces the concept of “Salt lake agriculture” proposed by Academician Zheng. Chapter 5 introduces salt basins and the new progresses in potassium exploration in China.

The publishing of this book was greatly supported by Science Press, and was greatly helped by the editors Zhang Jingfei and Bu Xin. Special thanks to Professor Fei Zhenbi for translating most parts of this book. During the organization of this book, Kong Weigang, Hu Yun, Chang Huilin, Wang Hailei, Zhang Xuefei, Wang Yunsheng, Zhang Zhen, Yan Lijuan and many other colleagues have helped on editing and translation. All these support and help make this book get published on time.

All maps in this book are sketch maps, and they may have historical limitations.

“Selected Works of Zheng MianPing” editorial group
June 2014

Contents

Introduction

Chapter 1 Thoughts on Salinology and Saline Systems Research	1
1.1 On Salinology	1
1.1.1 Introduction	1
1.1.2 Trends of scientific and technological development	1
1.1.3 Salinology	6
1.2 Expansion of Salt Science—Thoughts on Saline Systems Research	8
1.3 Salinology: Research and Prospects	13
1.3.1 A review of research and utilization of saline lakes	13
1.3.2 Salinology and great saline lake industry	17
1.3.3 Investigation of salt resources and prospects of salinology	18
1.3.4 Conclusions	21
1.4 A Comparative Analysis of Evaporate Sediments on Earth and Mars: Implications for the Climate Change on Mars	22
1.4.1 Introduction	22
1.4.2 Observations of Martian salts	22
1.4.3 The formation of evaporate salts on Mars	25
1.4.4 Primary discussion on the evolution of Martian atmosphere indicated by the evaporate salts	28
1.4.5 Potential potassium salts deposits on Mars	31
1.4.6 Future works	34
References	35
Chapter 2 Chinese Saline Lakes and Their Resources	41
2.1 On Chinese Saline Lakes	41
2.1.1 Introduction	41
2.1.2 Salt lake regions	42
2.1.3 Chemical typology	46
2.1.4 Palaeolimnology	47
2.1.5 Halophilic organisms and biological mineralogenesis	51
2.2 On Saline Lakes in Xizang (Tibet), China	52
2.2.1 Origin of lake basins and classification of lake systems	52
2.2.2 Lake basin evolution and salt sedimentary cycles	55
2.2.3 Chemical types of salt-lake water and their distribution	59
2.2.4 Source of mineral materials	60
2.3 Hydrochemistry of Salt Lakes of the Qinghai-Tibet Plateau, China	62
2.3.1 Introduction	62
2.3.2 Salinities and pH values of salt lake brine	62
2.3.3 Hydrochemical types of brine	64
2.3.4 Hydrochemical zoning and mineral assemblages of salt lakes on the Qinghai-Tibet plateau	65

2.3.5	Chemical composition of brine and origins of boron and rare alkali elements	73
2.3.6	Conclusions	77
2.4	A New Lithium Mineral—Zabuyelite	78
2.4.1	Introduction	78
2.4.2	Occurrence	78
2.4.3	Physical properties	78
2.4.4	Chemical compositions	80
2.4.5	X-ray diffraction analysis	81
2.4.6	IR spectrum analysis	82
2.4.7	Crystal structure	83
2.4.8	Description and discussion of the crystal structure	84
2.5	25°C-Isothermal Evaporation of Autumn Brines from the Zabuye Salt Lake, Tibet, China	85
2.5.1	Experiment	85
2.5.2	Result and discussion	86
2.5.3	Summary	95
2.6	Preliminary Discussion of Low-salinity Hydrothermal Fluid Mineralization	96
	References	98
Chapter 3	Saline Lakes Deposition and Palaeoclimate	102
3.1	Salt Lake Sediments as Indicators for Palaeoclimates	102
3.1.1	Introduction	102
3.1.2	Saline sediments as climatic indicators	102
3.1.3	Zoning of hydrochemical types of saline lake waters and their response to the climates	106
3.2	Palaeoclimate Events and the Quaternary Salt Deposits in China	106
3.3	Trend of Salt Lake Changes in the Background of Global Warming and Tactics for Adaptation to the Changes	110
3.3.1	Introduction	110
3.3.2	Case histories of geological hazards in the salt lake areas	112
3.3.3	Analysis of rising and shrinking of salt lake water in western China	116
3.3.4	Some suggestions for adaptation to the changes of salt lakes	120
3.3.5	Conclusions	122
3.4	Evidence of the Pan-Lake Stage in the Period of 40-28 ka BP on the Qinghai-Tibet Plateau	123
3.4.1	Palaeoclimatic evolution of the pan-lake stage in the period of 40-28 ka BP	123
3.4.2	Palaeoclimatic analysis	127
3.5	The Quaternary Pan-lake (Overflow) Period and Paleoclimate on the Qinghai-Tibet Plateau	128
3.5.1	Introduction	128
3.5.2	Evidence of Quaternary pan-lakes on the Qinghai-Tibet plateau	130
3.5.3	Timing and extent of high lake levels of pan-lakes on the Qinghai-Tibet plateau	139
3.5.4	Pan-lakes and paleoclimate on the Qinghai-Tibet plateau	143
3.5.5	Conclusions	147
3.6	Sedimentary Characteristics and Palaeoenvironmental Records of Zabuye Salt Lake, Tibetan Plateau, since 128 ka BP	147
3.6.1	Introduction	147

3.6.2	Natural environment and geology of the study area	148
3.6.3	Brief account of hole SZK02	150
3.6.4	Chronology of lacustrine sediments	150
3.6.5	Sedimentary features	153
3.6.6	Oxygen isotope study	157
3.6.7	Discussion and conclusions	162
3.7	Carbon and Oxygen Stable Isotope Values and Microfossils at 41.4-4.5 ka BP, in Tai Co, Tibet, China, and Their Paleoclimatic Significance	162
3.7.1	Introduction	162
3.7.2	Regional setting	163
3.7.3	Sedimentary characteristics of the sections	164
3.7.4	Chronological study	167
3.7.5	Carbon and oxygen stable isotope features of P ₁	171
3.7.6	Conclusions	181
3.8	Some Characteristics of Stratigraphic Sequences and Lacustrine Sediments of Main Quaternary Lakes on the Qinghai-Tibet Plateau	182
3.8.1	Introduction	182
3.8.2	Quaternary lacustrine stratigraphic areas of the Qinghai-Tibet plateau	183
3.8.3	Division of Quaternary lacustrine sequences of the Qinghai-Tibet plateau	184
3.8.4	Brief description of stratigraphic sequences of Quaternary stratigraphic areas of the Qinghai-Tibet plateau	184
3.8.5	Several characteristics of Quaternary lacustrine sediments on the Qinghai-Tibet plateau	189
3.8.6	Conclusions	190
3.9	Lake Basin Evolution and Plateau Uplifting	192
3.9.1	Evolution stage of lake basins on Qinghai-Xizang plateau	192
3.9.2	Time of large-scale uplifting of Qinghai-Xizang plateau	198
3.9.3	Uplift form of Qinghai-Xizang plateau	200
	References	201
Chapter 4	Saline Lake Geoecology and “Saline Lake Agriculture”	212
4.1	Preliminary Study on the Geoecology of Halophilic Algae and Halobacteria Found in Zabuye Salt Lake, Xizang (Tibet)	212
4.1.1	Physiographic condition	212
4.1.2	The composition of halobacteria and halophilic algae	215
4.1.3	Geological condition and its signification	217
4.1.4	Conclusions	218
4.2	On “Saline Lake Agriculture”	219
4.2.1	Introduction	219
4.2.2	Some organisms in saline lake that have been commercialized or have economic and scientific significance—resources of “saline lake agriculture”	220
4.2.3	Concept and character of “saline lake agriculture”	226
4.2.4	The importance of developing “saline lake agriculture”	227
4.2.5	Research contents of “saline lake agriculture”	229
4.2.6	Conclusions	230

4.3	Biological Investigation of Salt Lakes in Tibet	232
4.4	Salt Lake Resources and Eco-environmental Protection in China	236
4.4.1	Introduction	236
4.4.2	Distribution of salt lakes and brief account of salt lake resources in China	236
4.4.3	Present situation of exploitation and utilization of salt lake resources and environmental problems	239
4.4.4	Rational utilization of resources and protection of the eco-environment in salt lake regions	243
4.4.5	Conclusions	245
	References	246
Chapter 5 Distribution of Salt Basins and Potash Exploration in China as well as New Understanding and Progresses		
5.1	Regional Distribution and Prospects of Potash in China	250
5.1.1	Introduction	250
5.1.2	Regional geological setting of salt and potash formation in China	251
5.1.3	Characteristics of major salt-forming basins and analysis of potash-forming conditions	254
5.1.4	Analysis of potash prospects	279
5.1.5	Conclusions	283
5.2	Potash Exploration Characteristics in China: New Understanding and Research Progress	285
5.2.1	Introduction	285
5.2.2	Regional geological setting of salt formation in China	286
5.2.3	New understanding and research progress in potash exploring in China	289
5.3	A New View Concerning the Formation of the Mengyejing Potash Deposit in Jiangcheng, Yunnan, China	296
5.3.1	Introduction	296
5.3.2	Characteristics of salt-bearing strata and potassium-bearing sequences	199
5.3.3	Jurassic salt-and potash-forming environments	301
5.3.4	New view of potash deposit formation	303
5.3.5	Preliminary analysis of the mechanism of potash formation	311
5.3.6	Conclusions	312
5.4	Preliminary Study on Sedimentary Environment of the Lop Nor Salt Lake and Its Prospect for Potassium	313
5.4.1	Division of salt sedimentary phases	313
5.4.2	Depositional environment	314
5.4.3	Preliminary discussion on perspective in search for potassium	315
	References	316

Chapter 1 Thoughts on Salinology and Saline Systems Research

1.1 On Salinology*

1.1.1 Introduction

Saline lakes are an important type of lake, *viz.* one where water-bodies contain a relatively high concentration of dissolved salts. According to recent advances in the study of saline lake geology, biology and other fields, I suggest that the lower limit of salinity for saline lakes *sensu stricto* be defined as $>3.5\%$, while that for saline lakes *sensu lato* $\geq 0.30\%$ or in excess of $3\text{ g}\cdot\text{l}^{-1}$ (Williams, 1996). Saline lakes can contain important raw materials for industry, agriculture, and medicine, e.g. halite, mirabilite, lithium, magnesium, boron, gypsum calcium chloride, tungsten, cesium, rubidium, strontium, hydromagnesite and zeolite. Considerable amounts of biological resources, such as halophilic algae, *Artemia*, *Spirulina*, of economic and scientific value, occur in saline lakes. Moreover, saline lakes are important for tourism. The heat-storing features of lake brine solar evaporation ponds have also been used in electricity. Finally, saline lakes are sensitive indicators of the past and important for reconstructing paleoclimatic, paleoenvironmental and tectonic events.

1.1.2 Trends of scientific and technological development

If we consider that research on saline lakes started from an analysis of the brines of the Karabugaz Lagoon in the mid-nineteenth century, saline lake research has experienced three stages. The first stage lasted from the middle of the nineteenth to the beginning of the twentieth century (the Van't-Hoff school and N.S. Kurnakov school). Research during this period was dominated by physical-chemical analysis. The second stage, from the early-twentieth century to the 1960s, can be referred to as the stage of traditional geological, biological and chemical disciplinary research. Since the 1970s, research on saline lakes has developed into a stage with multidisciplinary research (Matter and Tucker, 1978; Kushner, 1978; Eugster and Hardie, 1978; Smith, 1979; Brock, 1979; Dietor, 1979; Gwynn, 1980; Nissenbaum, 1980; Borowitzka et al., 1981; Hammer, 1981; Williams, 1981; Yuan, 1982; Javor, 1989; Hurlbert, 1993; Zheng, 1995, 1996; Oren, 1999).

1. Development and expansion of the scope of research on saline lakes

Saline lakes are valuable natural resources. With continued reconnaissance, exploration and development of their resources, research on them has deepened and its scope expanded, with progress in experimental studies of their values and uses. The concept of saline lakes as mainly solid mineral resources has been outdated. Large amounts of important raw materials for the chemical industry, agriculture, metallurgical industry and medicine are now obtained from saline lakes. In some brines, biological resources are present in large amounts. In addition, the heat-storing features of saline lake brines have been used in “solar energy salt pond” electricity and playas have been used to build highways, railways and even airfields.

2. Value and use of saline lake brines

Mineral resources of saline lakes and their applications are shown in Table 1.1.1. In saline lakes, there are

* Zheng Mianping. 2001. On salinology. *Hydrobiologia*, 466: 339-347.

usually complex ores with solid and liquid states. Significant advances in the investigation, valuation and uses have been made with considerable economic benefits. For example, in Great Salt Lake, long-term fundamental and applied research has focused on mineral and biological resources, hydrochemistry, and engineering and includes meteorological and hydrological observations over 140 years (Gwynn, 1980). The annual gross value of the potash, magnesium, sodium sulfate and halite reaches about one billion dollars. Another example is the Atacama Salt Lake in Chile, where the Cyprus-Foot Company and SQM Company invested 60 million dollars for feasibility studies of development of lithium production and then established a lithium plant that is now the largest in size and produces lowest cost lithium. Simultaneous production of lithium salt, potash salt, borate and sodium sulfate occur with an annual gross product of more than one billion dollars. Since 1997, SQM has greatly reduced the cost of Li_2CO_3 and eliminated many hard rock lithium ventures (McCracken and Mike, 1998).

Table 1.1.1 Summary of types, magnitudes and uses of saline lake resources

Type			Magnitude and occurrence		Uses
Classic material			Clay, sand, gravel, volcanic ash	Large quantities available; economic-geographic conditions appropriate; exploitable	Used in building and road paving, and especially clay used in brick-making; volcanic ash used as absorbents for automobiles, ship docks and factories
Solid-state minerals	Dominant evaporites	Carbonates	1. Calcite, aragonite, dolomite, magnesite	Commonly dispersed; low purity; but calcite occurs as large accumulations	Calcite can be used as lime
			Hydromagnesite	A few thousand tons discovered in Tibet, China	Can be used for refractory magnesium bricks
			2. Trona, soda and other alkali-bearing materials	Vary in magnitude from several hundreds tons and several hundred million tons (in U.S.A., Russia, Inner Mongolia of China, Kenya)	Widely applied in glass, textile, paper-making, dye, rubber, synthetic rubber, medicine, battery, detergent and chemical industries
			3. Li-bearing magnesite, Zabuyaite (Li ₂ CO ₃)	Commonly contain a few per mil to a few hundred ppm Li ₂ CO ₃ (Zubuye Lake and Bangkog Lake, Tibet)	Mainly used in special glass, ceramic, aluminium smelting, chemical products, synthetic rubber, medicine, batteries, lubricant, air purifier
		Sulfates	1. Gypsum and anhydrite	Mostly dispersed and locally occur as a few million tons of gypsum accumulations	Used in light building materials, agriculture, gypsum products and other daily life products
			2. Thenardite and mirabilite	Mirabilite deposits and part of thenardite deposits have large magnitude and high purity, larger ones attain a few hundred million to a few billion tons (e.g. in Karabujiaz Gulf, Russia)	Used in glass, paper-making, detergent, dynamite, medicine and metallurgical industries
			3. Epsomite and kieserite	Range from a few hundred to a few hundred thousand tons	Medicine and chemical Industries
			4. Bloedite	Generally dispersed, and in some areas reserves attain few tens of million tons (e.g. in Russia)	Used in manufacturing magnesium glass for laboratory use yielding good effects
			5. Aphthitalite, picromerite, kainite, polyhalite, syngenite, and hanksite	Dispersed and locally picromerite occurs as potash layers (Dalang P. and Da Qaidam L., China); can be mined for multi-purpose uses	Mainly used in agriculture and chemical industry
		Halides	1. Halite	Ranges from a few hundreds of thousands of tons to a few hundreds of billions of tons (e.g. Qarhan P., China); widely distributed in world	Mainly used in edible salt and basic chemical industry; those used for edible salt and fodder make up to 65%–70%
			2. Potash	Commonly dispersed; in places reserves up from $n \times 10^4$ to $n \times 10^7$ tons (Potash Lake of Qaidam and Potash Valley of Red Sea)	About 90% used in agriculture, and the rest in the chemical and military industries

Continued

		Type	Magnitude and occurrence		Uses
Solid-state minerals	Dominant evaporites	Halides	3. Carnallite	$n \times 10^4$ to $n \times 10^7$ tons KCl, and $n \times 10^4$ to 10^7 tons MgCl; low grade; generally difficult to mine as an independent mineral (e.g. Qarhan P., Qaidam, China)	(1) Use of KCl same as above; (2) magnesium salt used in producing metal magnesium and its alloy and medicine
			4. Bischofite	Locally forms separate accumulations, up to a few million tons (Dalangtan P., China)	Same as above
		Borates	Borax	B ₂ O ₃ ranges from a few tens to a few millions tons; high-grade boron ores (e.g. W. U.S.A., plateau of S. America, Tibet of China)	Widely applied in more than 100 industries, such as glass, glass fiber, porcelain glaze, detergent and steel smelting
			Mg borate	B ₂ O ₃ ranges from $n \times 10^4$ to $n \times 10^6$ tons; acid-soluble boron ore (e.g. Zacang Caka and Da Qaidam L. of China, Argentina)	Same as above
			Ulexite	B ₂ O ₃ , a few tens to a few tens of thousand tons; can be partly decomposed in hot water (e.g. N. Chile and W. U.S.A.)	Same as above
			Colemanite	B ₂ O ₃ , a few tens to a few tens of thousand tons; acid-soluble boron ores	Same as above
		Nitrates	Soda niter	About a few tens to a few millions tons (e.g. desert area in N. Chile)	Used in dynamite, chemical industry, agriculture
			Niter	Smaller in magnitude than soda niter (e.g. N. Chile and Uzong Bulak of Xinjiang, China)	Used in chemical industry, dynamite and fire-works
		Iodates	Lautarite, Bruegggenite	Dispersed in niter ore; can be mined as a by-product (e.g. N. Chile)	Mainly used in medical industry, chemical industry, agriculture and environmental hygiene
		Uranates	Pitchblende, Urasilite, Carnotite, Autunite	Can form accumulations of commercial value (e.g. W. Australia, W. U.S.A.)	Used in nuclear power station and military aspects
		Calcium chloride	Antarcticite and other CaCl ₂ minerals	Can form commercial mineral deposits; known ones dispersed (e.g. N. Antarctic and Qaidam); can form commercial ore beds (e.g. Bristol Lake, W. U.S.A.)	Used in driers, chemical Reagents
		Silicates Others, Iron minerals	Hydroglass, Magadiite, Goethite, limonite, pyrite, marcasite	Mostly dispersed; locally occur as thin beds (Magadi Lake) Occur in a few acid saline lakes; goethite and limonite can make up modern deposits with over a few millions tons (e.g. Tyrrell L., Australia); high grade	Not yet used Possible use in iron smelting
	Sedimentary minerals	Silicates	Zeolite	Can form industrial ore beds (e.g. salt lakes in W. U.S.A.)	Environmental protection, metal recovery and agriculture
			Bedded chert, opal	Bedded cherts may have larger magnitude (e.g. Magadi Lake, Kenya)	Not yet used
		Organic ooze		Locally contains large amount of organic ooze and may form large bedded accumulations	Liquid fuel can be extracted Through heat treatment