AN INTRODUCTION TO SALINE LAKES
ON THE QINGHAI-TIBET PLATEAU

MONOGRAPHIAE BIOLOGICAE

VOLUME 76

Series Editors

H.J. Dumont and M.J.A. Werger

The titles published in this series are listed at the end of this volume.

An Introduction to Saline Lakes on the Qinghai–Tibet Plateau

by

ZHENG MIANPING

SPRINGER-SCIENCE+BUSINESS MEDIA, B.V.

A C.I.P. Catalogue record for this book is available from the Library of Congress.

ISBN 978-94-010-6295-4 ISBN 978-94-011-5458-1 (eBook)
DOI 10.1007/978-94-011-5458-1

Printed on acid-free paper

All Rights Reserved
© 1997 Springer Science+Business Media Dordrecht
Originally published by Kluwer Academic Publishers in 1997
No part of the material protected by this copyright notice may be reproduced or
utilized in any form or by any means, electronic or mechanical,
including photocopying, recording or by any information storage and
retrieval system, without written permission from the copyright owner.

The Author

—Research Professor Zheng Mianping

Zheng Mianping Male; born in Zhangzhou, Fujian Province, China in November 1934; graduated from the Department of Geology, Nanjing University, in 1956. Now he is chief of the R & D Center of Saline Lakes and Epithermal Deposit of the Chinese Academy of Geological Sciences, research professor of the Institute of Mineral Deposits and Chinese Academy of Engineering. He serves as member of the Standing Committee of the Society of the Qinghai-Tibet Plateau Research and Vice-Chairman of the International Association of Saline Lakes.

He has studied the geology of saline deposits, total utilization of saline lake resources and hydrothermal water deposits for 40 years, published 64 academic papers in Chinese and foreign journals and 4 monographs, made systematic and pioneering studies on saline lakes of the Qinghai-Tibet Plateau and the exploration and evaluation of saline deposits, and made outstanding contributions to the exploration, exploitation and utilization of K, B, Li and Cs resources. He has conducted an intensive study and prediction of the saline lake resources on the Qinghai-Tibet Plateau and thus directed mineral prospecting, exploitation and mining.

Contents

Preface	xi
Foreword	xiii
Part 1 General Overviews	(1)
Chapter 1 Introduction	(1)
Chapter 2 Saline Lakes and Lake Districts	(18)
Chapter 3 Evolution of Cenozoic Lake Basins and the Formation of Saline Lakes	(23)
3.1. Cenozoic Salt-bearing Strata and Salt-Forming Periods	(23)
3.1.1. Cenozoic Salt-bearing Strata	(23)
3.1.2. Quaternary Salt Forming Periods and Periodicity	(23)
3.2. Genesis and Classification of Lake Basins	(32)
3.2.1. Glacier Lakes	(32)
3.2.2. Silted-river Valley Lakes	(32)
3.2.3. Interbank Lakes	(33)
3.2.4. Dissolved-Salt Lakes	(34)
3.2.5. Hot Water Lakes	(34)
3.2.6. Volcanic Lakes	(35)
3.2.7. Tectonic Lakes	(35)
3.2.8. Meteorite Crater Lakes	(41)
3.3. Evolution of Lake Basins and Formation of Saline Lakes	(42)
3.3.1. Eocene-Miocene or Early Pliocene	(42)
3.3.2. Pliocene-early-middle Early Pleistocene	(44)
3.3.3. Middle-late Early Pleistocene to Early Late Pleistocene	(45)
3.3.4. Middle-Late Pleistocene to Holocene	(48)
Chapter 4 Hydrochemistry and Mineral Associations of Saline Lakes	(55)
4.1. Salinity and pH Values	(55)
4.2. Hydrochemical Types and Their Zoning	(59)
4.3. Chemical Compositions	(63)
4.3.1. Compositions of Lake Waters	(64)
4.3.2. Dominant Elements	(69)
4.3.3. Features of Distribution of B, Li and K	(69)
4.3.4. Correlation of Elements	(72)
4.3.5. The Rare Earth Elements	(75)
4.4. Hydrochemical Types and Their Corresponding Saline Mineral Associations	(75)
Chapter 5 Classification of Saline Lakes and Types of Mineral Deposit	(79)
Chapter 6 Tectonogeochemistry and Regional Geochemistry	(85)
6.1. Tectonogeochemical Characteristics	(85)

6.2. B, Li, Cs and Rb Contents	(86)
6.2.1. Boron Content in Rocks (Table 1.13)	(87)
6.2.2. Lithium Content in Rocks	(92)
6.2.3. Cesium Content in Rocks	(95)
6.2.4. Rubidium Content in Rocks	(97)
6.3. Boron Content in Plants	(98)
6.4. Regional Hydrochemistry	(100)
6.4.1. Hydrochemical Features of River Waters	(100)
6.4.2. B, Li and K Contents	(103)
6.4.3. Hydrogeochemistry of Groundwater	(104)
6.5. Origins of Hydrochemical Types and Their Zonation	(114)
6.5.1. Factors Controlling the Formation of Different Hydrochemical Lake Types	(114)
6.5.2. Formation of Various Water Types and the Hydrochemical Zones	(116)
6.5.3. Formation of the Chloride Type and Its Hydrochemical Zone.....	(121)
Chapter 7 Material Sources and Model of Salt Formation of Saline Lakes.....	(123)
7.1. Material Sources of Saline Lakes	(123)
7.1.1. Weathering of Rocks	(123)
7.1.2. Inherited Salt-bearing Rock Series.....	(124)
7.1.3. Deep-seated Recharge	(125)
7.1.4. Affinity between Dispersed Components in Special Saline Lakes and Geothermal Waters	(130)
7.2. Quatitative Estimate of Material Sources	(131)
7.2.1. Output of B, Li etc. from Geothermal Waters	(131)
7.2.2. Comparison between the Input and Geochemical Reserves of Lakes	(134)
7.2.3. Sources of Special Components	(136)
7.3. Salt Formation Models and Minerogenetic Series	(139)
7.3.1. Tectono-geomorphological Features and Genetic Models	(139)
7.3.2. Salt Formation Models and Minerogenetic Series	(141)
Chapter 8 Shoreline Deposits and Palaeoclimatic Analysis	(147)
8.1. The Paleoclimatic Evolution of the Qinghai-Tibet Plateau since the Late Part of the Late Pleistocene	(147)
8.1.1. Climatic Evolution since 40 Ka	(148)
8.1.2. Some Understandings of the Features of Climatic Evolution	(160)
8.1.3. Genetic Mechanism	(160)
8.2. Shoreline Deposits of the Zabuye Lake Area and Its	

Paleoclimatic Analysis	(164)
8.2.1. Differences between the Paleo-lake Shoreline and Structural Terraces	(164)
8.2.2. Deposits of the Zhaduixiong Spit Swarm and Their Ages	(169)
8.2.3. Evolution Characteristics of the Zhaduixiong	(174)
8.2.4. Paleoclimatic Analysis	(175)

Part 2 Study of Halophilic Organisms (181)

Chapter 9 Discovery and Study of Halobacteria and Halophilic Algae

in the Zabuye Caka	(181)
9.1. Introduction	(181)
9.2. Physiogeographic Conditions	(182)
9.3. Composition of Halobacteria and Halophilic Algae	(187)
9.4. Geological Conditions and Their Implications	(189)
9.5. Preliminary Study on the Practical Application and Culture Conditions of Halophilic Algae	(192)
9.5.1. Experimental Culture of Algae in Synthetic Culture Fluid	(194)
9.5.2. Experimental Culture of Algae in Culture Fluids with Different NaCl Concentrations	(195)
9.5.3. Experimental Culture of Algae with N- and P-Nutrients	(196)
9.5.4. Experimental Culture in Fluids with Different pH	(197)
9.5.5. Experimental Culture in the Concentrated Sea Water	(198)
9.6. Some Ideas of the Halobacteria and Halophilic Algae in Saline Lakes	(198)

Chapter 10 Biomineralization of Boron and Other Halotolerant

Organisms	(200)
10.1. Diversity of Boron Mineralization	(200)
10.2. Basic Facts	(200)
10.3. Preliminary Experimental Studies on Biomineralization of Boron	(202)
10.3.1. Experiments on the Solubility of Boron (Based on the Experiments Carried Out by Cheng Peng)	(202)
10.3.2. Preliminary Discussion on the Mechanism of Biomineralization of Boron	(203)
10.4. Halotolerant Organisms in Other Lakes	(205)
10.4.1. <i>Daphniopsis tibetana</i> Sars	(205)
10.4.2. <i>Artemia salina</i> Linneans	(208)

Part 3 Division of Minerogenic Zones, Prediction of Resource Potential and Prospects of Development of Saline Lakes on the Qinghai–Tibet Plateau (211)

Chapter 11 Division of Minerogenic Zones and Prediction of Resource Potential (211)

- 11.1. First–Class Minerogenic Zone of B, Li, K, Cs (Rb, Halite, Soda and Mirabilite)–bearing Carbonate–type Saline Lakes (A) (212)
 - 11.1.1. Gangbei (North of the Gangdisé) Principal Minerogenic Subzone of B, Li, Cs, Br and Rb–Bearing Brine–Borax (Halite, Soda and Mirabilite) (A₁) (214)
 - 11.1.2. Gangnan (South of the Gangdisé) Subordinate Minerogenic Subzone of Borax–B and Li–bearing Brine (A₂) (218)
- 11.2. First–Class Minerogenic Zone of B, Li, K, (Cs Rb, Halite and Mirabilite)–Yielding Saline Lakes of Sodium (Magnesium) Sulfate Type (B) (218)
- 11.3. Second–Class Minerogenic Zone of Li, B, K, Halite and Mirabilite–bearing Saline Lakes of Magnesium Sulfate Subtype (C) (222)
- 11.4. First–Class Minerogenic Zone of K, Mg, (B and Li)–bearing Saline Lakes of Sulfate–Chloride Type..... (223)
- 11.5. Third–Class Minerogenic Area of Halite and Mirabilite –bearing Saline Lakes of Sodium Sulfate Subtype (E) (230)

Chapter 12 Prospects of Development of Resources of Saline Lakes and Their Environmental Protection (231)

- 12.1. Problems in Exploitation of Saline Lakes (232)
- 12.2. Suggestions about the Utilization of Resources of Saline Lakes and Environmental Protection (234)

Concluding Remarks (237)

References (243)

Appendix 1 Rules for Translating Geographic Names Related to Saline Lakes on the Qinghai–Tibet Plateau (251)

Appendix 2 List of Lakes on the Qinghai–Tibet Plateau (253)

Appendix 3 Index of the Place Names (273)

Appendix 4 Explanation of Plates (290)

Appendix 5 Map of Hydrochemical Zones of Lakes on Qinghai–Xizang (Tibet) Plateau

Preface

As the senior author, I wrote the book "Saline Lakes on the Qinghai-Tibet Plateau" in Chinese in 1989. The present book has been written on the basis of that book, with all the case histories of saline lakes omitted and the latest research results supplemented. In fact, it is a summary of my long-term study on saline lakes of the Qinghai-Tibet Plateau undertaken since 1956 and appears in the English language. The main purpose in publishing this book is to introduce my colleagues and other scholars who are interested in saline lakes to saline lakes on the world's roof and promote the exchange between the Chinese scientists studying saline lakes and their colleagues of other countries. This book was translated into English by Mr. Jiang Minxi, Mr. Fei Zhenbi and I, and the whole English version was checked, revised and proofread by Fei Zhenbi and me. Mrs. Liu Yuxia carefully prepared the camera-ready typescript, and Mrs. Fu Ziji and Mrs. Wang Qingxin fair-drew all the text-figures. During the 39 years of field investigations of the Qinghai-Tibet Plateau, the author has been accorded great support and provided with various conveniences by the Geological Bureaus and Parties of Qinghai and Tibet as well as local governments at all levels and local people. The Institute of Rock and Mineral Analysis, Institute of Hydrogeology and Engineering Geology and Institute of Mineral Deposits under the Ministry of Geology and Mineral Resources and the Institute of Saline Lakes of Qinghai of the Chinese Academy of Sciences assisted in analyzing the chemical composition of solid and liquid phases, the Institute of Geology of the State Seismological Bureau and the Institute of Vertebrate Paleontology and Paleoanthropology of the Chinese Academy of Sciences assisted in determining the ^{14}C ages of the samples, the Beijing Institute of Botany of the Chinese Academy of Sciences and the Institute of Geology of the Chinese Academy of Geological Sciences assisted in sporopollen analysis, and related divisions and groups of the Institute of Mineral Deposits assisted in stable isotope study, section grinding and chemical analysis. Zhang Fasheng and Liu Shuqin helped the author with some work in different periods of time; especially Xiang Jun, Liu Wengao, Wei Xinjun, Xu Guowen, Zheng Yuan, Zhou Taiguang, Shen Jinming, Min Linsheng, Lu Defu, Gao Shiyang, Chen Bingmu, Jing Xuqing and Qian Jun had conducted field surveys or participated in laboratory work together with the author in the fifties, sixties and eighties. My grateful thanks are due to all of them. I would also like to express my heartfelt thanks to the older generation of geologists such as the late academicians Liu Dagang, Yuan Jianqi and Meng Xianming, Chief Engineer Li Yueyan and Academicians Guo Wenkui,

Song Shuhe, Ye Lianjun, Zhang Bingxi and Zhang Zonghu for their help. I thank especially, Dr Porman for revising Chapters 1–8 of this book in English rhetoric. I also wish to extend my appreciation to Prof. W.D. Williams for writing a foreword for the book and recommending it to the publisher so that the book can be published abroad and more colleagues of mine can gain knowledge of saline lakes on the “world’s roof”. Finally, I am especially grateful to my wife Liu Junying, associate research fellow of the Chinese Academy of Geological Sciences, who made a lot of sacrifices for the successful completion of this book.

Zheng Mianping
June 1995

Foreword

Until recent decades, the secrets of the Qinghai–Tibet plateau’s natural environment, the wonders of its landscapes, remained mostly beyond the reach of science and scientists. Located at high altitude, inaccessible, and with a forbidding climate, the plateau was visited by few with a scientific interest in its environment. Even mountaineers were generally confined to regions of very high altitude in the southern periphery of the area. The situation has changed rapidly in the recent past and continues to evolve. Now, thanks largely to several expeditions involving Chinese scientists (and in a few cases also, non–Chinese scientists), supported by an increasingly important and active regional scientific community, we are beginning to tease out the secrets and more fully appreciate the wonders.

Amongst the most noteworthy and significant features of the Qinghai–Tibet plateau are its lakes. But these are no ordinary lakes: contrary to what cursory and unknowing glances at any atlas may suggest, the lakes on the plateau are – for the most part – saline, with salinities from less than 3 to over 500 parts per thousand (the latter value, 14 times greater than that of the sea!), include some of the world’s largest lakes (with almost 40 lakes of area greater than 50 km²), and certainly include some to the world’s highest lakes (e.g. Nam Co, area 1,961 km², lies nearly 4,600 m above sea–level). Without doubt, the lakes of the plateau are unique.

My friend and distinguished colleague, Professor Zheng Mianping, has played a significant role in the scientific investigation of these lakes. He has participated in many expeditions, promoted the development of regional scientific efforts, and written widely on scientific matters. Thanks largely to Professor Zheng and his colleagues, we are now in a much stronger position than we were with regard to our knowledge of the limnology of the Qinghai–Tibet plateau. In this connection, it is salutary to place their endeavours within familiar perspectives. Note, then, that the plateau is larger than the whole of western Europe, that access to most lakes involves many hundreds of kilometres of remote travel on unsealed roads, and that prolonged exposure to low oxygen concentrations at high altitudes is not a healthy pastime for those who live normally at altitudes not far above sea–level. Winter temperatures of –40°C, intense solar radiation, and high winds must also be contended with. The sheer physical efforts of Professor Zheng and his colleagues in their limnological investigations are surely

orders of magnitude greater than those needed by most limnologists. I speak from slight experience in this matter because after the Sixth International Symposium on Salt Lakes, hosted by Professor Zheng and his colleagues in Beijing in 1994, I and several other colleagues were able to join him on a short expedition to some of his more accessible lakes in Tibet. Even to an Australian, the expedition was a salutary lesson in practical limnology!

Unfortunately, much of the work of Professor Zheng and his colleagues so far remains largely unknown to many limnologists who do not read Chinese (and of whom I am one). This is indeed a great pity. I am glad therefore that the pleas of many of these limnologists, including my own pleas, have at last been acceded to: behind this foreword lies summarised in English the results of many years of Professor Zheng's work, which, together with that of others, represents a masterly review of the Qinghai–Tibetan limnology so far as present data permit. Of course, much remains for discovery, but the present text provides a magnificent basis for future labours. Professor Zheng deserves not only our congratulations on his efforts and achievements but also our thanks. I am pleased to write this foreword and so by a small shaft of reflected illumination be associated with this volume.

W.D. Williams
Adelaide, Australia, September 1995