

成岩成矿理论与找矿

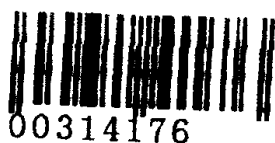
——中国主要类型矿床及花岗岩类岩石的
稳定同位素地质学

张理刚 著

北京工业大学出版社

40311

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SY21/04



200315747



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1989

内 容 简 介

作者根据最近十多年的稳定同位素研究成果,对中国金(银)矿、钨锡矿、铜钼矿、铅锌矿等矿床和中生代花岗岩类岩石的成岩成矿理论和找矿作了系统的论述。在成矿理论方面,强调了热液多成因的观点,论证了地壳浅层大气降水、再平衡岩浆水和海底海水的热液成矿作用及其成矿模式;在花岗岩类岩石理论方面,总结了我国东部中生代花岗岩类岩石来自各自基底岩石的深熔作用及其各自相应的成矿规律,并探讨了我国东部基底岩石分区及演化等。

此外,对稳定同位素地球化学研究方法;成矿流体的来源、性质判别及演化特征;运用稳定同位素地球化学标志开展找矿评价等,均有大量资料和实例进行系统的介绍。

本书可供金属与非金属矿产地质、地球化学、石油地质、海洋地质、环境地质、地理、气象、水文、冰川等方面的科研、生产、教学人员及高等院校有关专业的高年级学生和研究生阅读与参考。

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特约编辑 罗献林 刘宜河 罗春元

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北京工业大学出版社出版
新华书店北京发行所发行
桂林冶金地质学院印刷厂印刷

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787×1092毫米 16开本 印张: 13.5 字数: 335 000

1989年10月第1版 1989年10月第1次印刷

印数: 1~2000册

ISBN 7-5639-0022-5/TD·1

定价: 7.50元

Asso. Prof. Zhang Ligang
Yichang Institute of Geology
and Mineral Resources, CAGS
Yichang City, Hubei, 443003 China

PETROGENETIC AND MINEROGENETIC THEORIES AND PROSPECTING

**STABLE ISOTOPIC GEOCHEMISTRY OF MAIN TYPE
ORE DEPOSITS AND GRANITOIDS OF CHINA**

Press of Beijing University of Technology

1989

Abstract

According to the results of stable isotope studies of recent years or more, the author makes a systematic summarisation on the petrogeny and metallogeny as well as prospection of gold (silver), tungsten-tin, copper-molybdenum, lead-zinc deposits etc. and the Mesozoic granitoids of China. Metallogenetically, the ideal of polygenetic ore-forming hydrothermal fluids is emphasised, and the hydrothermal mineralizations and their minerogenic models of meteoric water in the shallow crust, re-equilibrium magmatic water and submarine hydrothermal (brine) solutions are demonstrated. Petrogenetically, the Mesozoic granitoids in eastern China resulting from the anatexis of their basement rocks are pointed out and the minerogenic regularities are put forward respectively. The distribution and evolution of the basement rocks of eastern China are discussed.

Moreover, a vast amount of data and examples about the research approaches of stable isotope geochemistry, the determination of the origin and nature of ore-forming fluids and their evolutionary characteristics, and the search and evaluation of ore deposits by using stable isotope geochemical criteria are systematically introduced.

The book may be available for the scientists, teachers and postgraduates in metallic and nonmetallic mineral deposit geology, geochemistry, petroleum geology, oceanic geology, environment geology, meteorology, hydrology, glaciology, geography etc. fields.

序

近20年来, 固体地球科学研究中引人注目的进展之一是各种稳定同位素的应用。它的表现形式是: 同位素分析所获得的成果在解释岩石、矿床成因、成岩成矿物质来源等方面十分有力地冲击了一、二百年来形成的各种传统理论(岩浆热液形成高温、中温、低温、远温的各种金属及非金属矿床), 绝对对立的内生成矿与外生成矿观点都被提出了各种各样的质疑。若干新的理论和见解正在逐渐形成。

在这方面我国学者也作出了他们应有的贡献, 其中之一便是本书的作者张理刚同志。继《稳定同位素在地质科学中的应用——金属活化热液成矿作用及找矿》(1985)之后, 张理刚同志又写成了本书《成岩成矿理论与找矿——中国主要类型矿床及花岗岩类岩石的稳定同位素地质学》。10多年来, 张理刚同志对我国东部中生代花岗岩类, 金(银)矿、铜铅矿、钨锡矿、铅锌矿等矿床作了大量稳定同位素工作, 进行了剖析与解释, 为更接近客观实际地阐述成岩成矿机理提出了重要依据。在这些方面, 作者的工作在国内是领先的。作者在某些领域, 如石英-锡石-黑钨矿-水-盐体系氧同位素分馏作用实验研究方面的成果, 目前在国外也尚属空白。

这里, 我想强调一下当前微观实验与测试手段对解决固体地球科学重大实际与理论课题的必要性。20年前, 板块构造的提出得力于对海底扩张现象的认识, 但当时人们尚不能潜入深海对洋中脊进行洋底观察。海底扩张这一理论的确立归功于平行洋中脊的磁极倒转观测及海底岩石同位素年龄随距洋中脊越远而越大的这两项测试成果。20多年前, 人们根本还不了解大气降水对成岩成矿的重要性(除对一些风化矿床外)。现在, 主要是通过氢、氧同位素及成矿实验、微量元素、气液包体等研究, 人们已经认识到大气降水或海水下渗、形成环流、活化运移某些成矿元素, 对后者在一定构造部位富集成矿, 具有不可忽视的作用。当然, 对固体地球科学来说, 野外现场的细微观察与剖析, 始终具有头等重要意义。但时至今天, 若仅靠野外工作, 是很难解决重大的实际及理论课题的。张理刚同志的成果, 从一个侧面阐明了微观实验测试工作的重要意义。

祝愿这本书的出版, 能使中华大地上稳定同位素在成岩成矿问题上的应用迈入一个新的时期。

1. 李亮书

1989.2.9

Preface

In recent twenty years or more, one of the noticeable spectacular developments of the studies on solid earth science is the appliance of each kind of stable isotopes. Its form of expression is that the results got from isotope analyses have lashed at each kind of traditional theories formed in one or two hundred years in the respect of explaining the geneses of rocks and mineral deposits and the origins of materials of petrogenesis and minerogenesis etc.. The omnipotent theories of magmatic mineralization (magmatic hydrothermal fluids forming each kind of metal and nonmetal ore deposits with high-, mid-, low- and telemagmatic- temperatures) which have governed geological ideas for half a century long, the view-points of absolutely opposed endogenetic mineralization and epigene mineralization have all been questioned with varied kinds of problems. Several new theories and opinions are forming gradually.

In this aspect the scholars in our country have made their due contributions, one of whom is the author of this book—Asso. Prof. Zhang Ligang. Following the book «The Application of the Stable Isotope to Geology—The Hydrothermal Mineralization of Metal Activation and Its Prospection» (1985), this book about «Petrogenetic and Minerogenetic Theories and Prospecting—Stable Isotope Geochemistry of Main Type Mineral Deposits and Granites of China» has then been written out. In recent ten years or more, Asso. Prof. Zhang Ligang has carried out a great number of stable isotopic studies on the Mesozoic granitoids, Au-Ag, Cu-Mo, W-Sn, Pb-Zn deposits etc. of eastern China. Many important bases have been given in order to expound the mechanism of petrogenesis and minerogenesis much closely to objective reality. In these aspects the author's study works are in the lead in China. In some fields, the studies of oxygen isotope fractionation in the quartz-cassiterite-wolframite-water-salt system are still a gap at both home and abroad.

Here, I want to emphasize the necessity of micro-experimental and analytical means in solving great practical and theoretical subjects of solid earth science. The theory of plate structure raised twenty years ago was based on the knowledge of submarine expansion. But at that time, the human being was still not able to submerge into deep sea to have ocean ridges observed. The foundation of this theory was owed to the two

observational results of the magnetic pole inversion of parallel ocean ridges and the isotopic ages of rocks which become older with the distance away from ocean ridge. Twenty years or more ago, people still notice the importance of meteoric water to petrogenesis and minerogenesis (except to some weathering ores). Now mainly through the studies on O and H isotope analyses, mineralization experiments, trace elements, vapor-liquid inclusions etc., it is known that the infiltration of meteoric or sea water forms circular current which activates and transports some kinds of useful elements and plays an unignorable role in the formation of mineral deposits at specified positions. Of course, as solid earth science is concerned, the detail observation and analysis in the field have all the time the most important significance. But till today, it is very difficult to solve great practical and theoretical problems if only base on field work. The achievements of Asso. Prof. Zhang Ligang have indicated from an indirect source the importance of micro-experimental and analytical works.

I wish the publication of this book would make the application of stable isotope to problems of petrogenesis and minerogenesis step into a new period.

February 9, 1989.

Tu Guangzhi

前 言



近代,随着H、O、S、C、Pb、Sr、Nd、Si等稳定同位素广泛应用于研究各种各样岩石和矿床物质组成以后,从根本上动摇了万能的岩浆期后含矿热液和原始岩浆(分异)说,促使人们再实践、再认识,去探索和创立新的成岩成矿理论。作者通过近几年的深入研究,对稳定同位素地质应用中的成岩成矿等许多基本理论问题有了较深的认识,研究方法和研究途径也渐趋完善。为此,写成本书,以飨对这一问题感兴趣的广大同行,并期望能起到抛砖引玉的作用。

作者在《稳定同位素在地质科学中的应用》(1985)一书中,强调在地壳表层岩石的热液矿床中,大气降水热液成因是占第一位的;在大洋底岩石体系热液(沉积)矿床中,海底海水热液成矿作用是占第一位的。而在本书中,除了第一章就中国近代大气降水、地表水、地下水、地热水、地热资源及其矿床的H、O同位素地球化学作了概要总结外,第二章较系统论述了我国各类金(银)矿床稳定同位素地球化学特点,特别是对大气降水热液金(银)矿床稳定同位素地球化学及其找矿问题作了较深入研究;第三章对我国三大类型钨锡矿床中除了再平衡岩浆水和大气降水热液钨锡矿床外,海底热泉沉积(变质)钨-铋-金矿床(层)的稳定同位素地球化学特征作了广泛的研究和探讨;第四章就我国两大类型——再平衡岩浆水和大气降水热液斑岩型铜(钼)矿床稳定同位素资料进行了系统的归纳,指出了两类斑岩矿床的区别标志及找矿方法;第五章就南岭和秦岭地区泥盆系层控铅锌矿床的稳定同位素组成作了系统的对比研究,并着重探讨其成因差异。上述各章均有典型的矿床实例,阐明具体的研究途径及方法;第六章较全面地总结了我国东部大气降水热液成矿作用稳定同位素地球化学基本特征。本书另一重点是第七章,该章揭示了我国东部中生代花岗岩及其有关矿石稳定同位素组成变化规律,并探讨了我国东部基底岩石的性质、组成和差异,花岗岩类岩石的物质来源、分类及其与成矿省之间的关系,并初步尝试建立我国区域铅构造两阶段模式。

本书的附录系作者等在国家自然科学基金资助项目(4860149)——“石英-锡石-黑钨矿-水体系氧同位素分馏作用研究”方面的研究成果。

作者由衷感谢我国著名矿床地球化学家、中国科学院地学部主任、学部委员涂光炽教授经常给予的关心和帮助;国家自然科学基金局所给予的财政资助。此外,对桂林冶金地质学院学报编辑部罗献林高级工程师及其同事为本书的编辑、出版与发行所付出的辛勤劳动深致谢忱!对陈振胜同志为本书收集整理部分资料表示谢意。

7/11 理明
O + 2H₂O = 2H₂ + O₂
2H₂O = 2H₂ + O₂

Author's Preface

In modern times, with the wide application of stable isotopes of H, O, S, C, Pb, Sr, Nd, Si etc. to study of the material components of various kinds of rocks and ore deposits, the omnipotent theory of deuteric ore-bearing hydrothermal fluids and primary magmatic (differentiation) has been shaken fundamentally. It impels us to search and found new theories of petrogenesis and minerogenesis through re-practic and re-understanding.

Through studies of recent years, the author has a rather profound knowledge of many basic theories and problems of the application of stable isotopes to petrogenesis and minerogenesis, and the study approaches and means are being gradually perfected. For this reason, this book is written out for the vast numbers of colleagues who are interesting in the subject. The author hopes that this book can take an effect of casting a brick to attract jades.

In the book about «The Application of the Stable Isotope to Geology» (1985), the author emphasized that among the hydrothermal deposits in the continental surface rocks, meteoric hydrothermal genesis is the most important one; among the hydrothermal (brine) ore deposits in the sea floor rock system, the ocean water hydrothermal fluid (brine) mineralization came in first. While in this book, except Chapter 1, which makes a summary on H₂O isotope geochemistry of modern times meteoric water, surface water, subsurface water, terrestrial heat water and its heat resources and related ore deposits in China; in Chapter 2, the characteristics of stable isotope geochemistry of various types of Au-Ag deposits have been systematically expounded, especially on meteoric hydrothermal Au-Ag deposits and their prospecting; in Chapter 3, the stratabound (or stratiform) W-Sb-Au deposits of submarine hot spring (brine) deposition have been discussed on their stable isotopes. Except this, re-equilibrated magmatic and meteoric hydrothermal W-Sn deposits have been studied too. In Chapter 4, a systematical induction on the stable isotope data of the two porphyry Cu-Mo deposits in China—the re-equilibrated magmatic and meteoric hydrothermal deposits has been made, and the distinguished marks and prospecting means of these two types have been pointed out; a systematical contrast study on stable isotope compositions of Devonian stratabound Pb-Zn deposits in Nanling and Qinling areas has been shown in Chapter 5, and the genetic difference between these two areas has been discussed in particular. There

are typical ore deposits examples in each chapter mentioned above to clarify the specific method of study. Chapter 6 makes a relatively complete summary on the basic characteristics of stable isotope geochemistry for meteoric hydrothermal mineralization in East China. Another focal point in this book is Chapter 7, in which the varied patterns of stable isotope compositions in eastern China Mesozoic granitoids and their related ore deposits have been revealed. The nature, components and difference of the basement rocks in eastern China, the materials source, classification of granitoids and their relationships with metal provinces have also been discussed. In the end of this chapter, the author tries to found the regional plumbotectonic two-stage model.

The appendix in this book is part of the study achievements of the subject "Oxygen isotope fractionation in quartz-cassiterite-wolframite-water system" which is supported by National Nature Science Foundation (4860149).

The author is sincerely grateful to the famous mineral deposit geochemists, the director and member of the Division of Earth Science, Academia Sinica, Prof. Tu Guangzhi for his help and concern and National Nature Science Bureau for giving financial support. Moreover, thanks to the Editorial Office of Journal of Guilin College of Geology for investigating this manuscript. Special thanks to Senior Engineer Luo Xianlin and his colleagues for their hardworking for the edition, publication and distribution of this book. Thanks to comrades Chen Zhensheng for compiling and sorting out the part of data of this book.

Yichang, Feb. 9, 1989 (49 birth day)

Zhang Ligang

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第一章 中国现代大气降水及其资源

氢、氧同位素地球化学

“水生万物，万物皆源于水”。这个发端于古希腊哲学中的观点，曾是十八世纪国外地质学家们在关于地球成因的争论中以维尔纳为代表的水成学派的核心思想。诚然，当时这场关于地球成因的长久争论最后是以赫屯为首的火成学派的胜利而结束。但是，水为地球生命的催化剂和万物之源是没有疑问的。如果没有水，人类赖以生存的地球就会和月球一样，成为一个没有生命的死寂的星球，且也不可能赋存众多复杂的热液矿床。

地球上几种水？究竟有多少重量呢？除了地幔岩浆水和岩石结构水以外，据估计，地球上水的总量大致有14亿多立方公里。如果把这些水平均分布在地球表面，那么，每平方厘米地球表面上可以分摊到274公斤水。这些水包括地球表面无边无际的海洋，它占地球上总水量的96.98%以上，大约有137亿亿吨；在高山上和南北两极，有大量的冰盖、冰川与积雪，水量约2.9亿亿吨，占地球总水量的2.0%；在离地面5~16公里以内的大气层中，又有以水蒸气、雨、雪、冰雹组成的大气水，水量有12.9万亿吨，约占地球总水量的0.002%；陆地上分布着众多的江河湖泊，水量约220万亿吨，约占地球总水量的0.017%；除此之外，在地球上具有举足轻重地位的“地下海洋”，即地下水，它们的水量也很可观，数量可达8300万亿吨，约占地球总水量的1%。上述各种水及其分配状况如图1-1所示。

众所周知，水是由氢和氧组成的。但是，氧有三种天然同位素，即 ^{16}O 、 ^{17}O 和 ^{18}O ；氢也有三种天然同位素，即 ^1H （氕）、 ^2H 即D（氘）和 ^3H 即T（氚）。这些同位素的平均丰度为： ^{16}O 为99.760%， ^{17}O 为0.042%， ^{18}O 为0.198%； ^1H 为99.9844%， ^2H 为0.0156%， ^3H 为 $1 \times 10^{-15}\%$ 。每 10^6 水分子中，平均有320个HDO分子，420个 H_2^{17}O 分子和2000个左右 H_2^{18}O 分子。由于这些水分子的质量不同，它们的物理和化学性质也有微小的差别。图1-1中各种天然水之间在转变过程中，如在凝聚和蒸发过程中，由于同位素分馏作用，必然出现各种天然水中氢、氧同位素组成有规律地变化。下面，我们讨论我国现代大气降水、地下水和地热水氢、氧同位素组成及其变化。

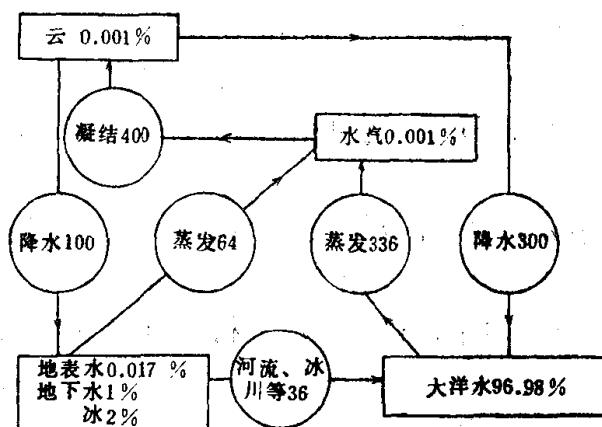


图1-1 地球上天然水组成及分配状况图示
(方框内数字表示各种天然水占地球总水量的分比；圆圈内的数字表示地球天然水循环过程的速度，万吨/年)
Fig. 1-1 Distribution pattern and compositions of natural water on the earth

一、大气降水、地表水和地下水

大气降水的氢、氧同位素组成变化规律，是稳定同位素地球化学中最基本、最重要的基础