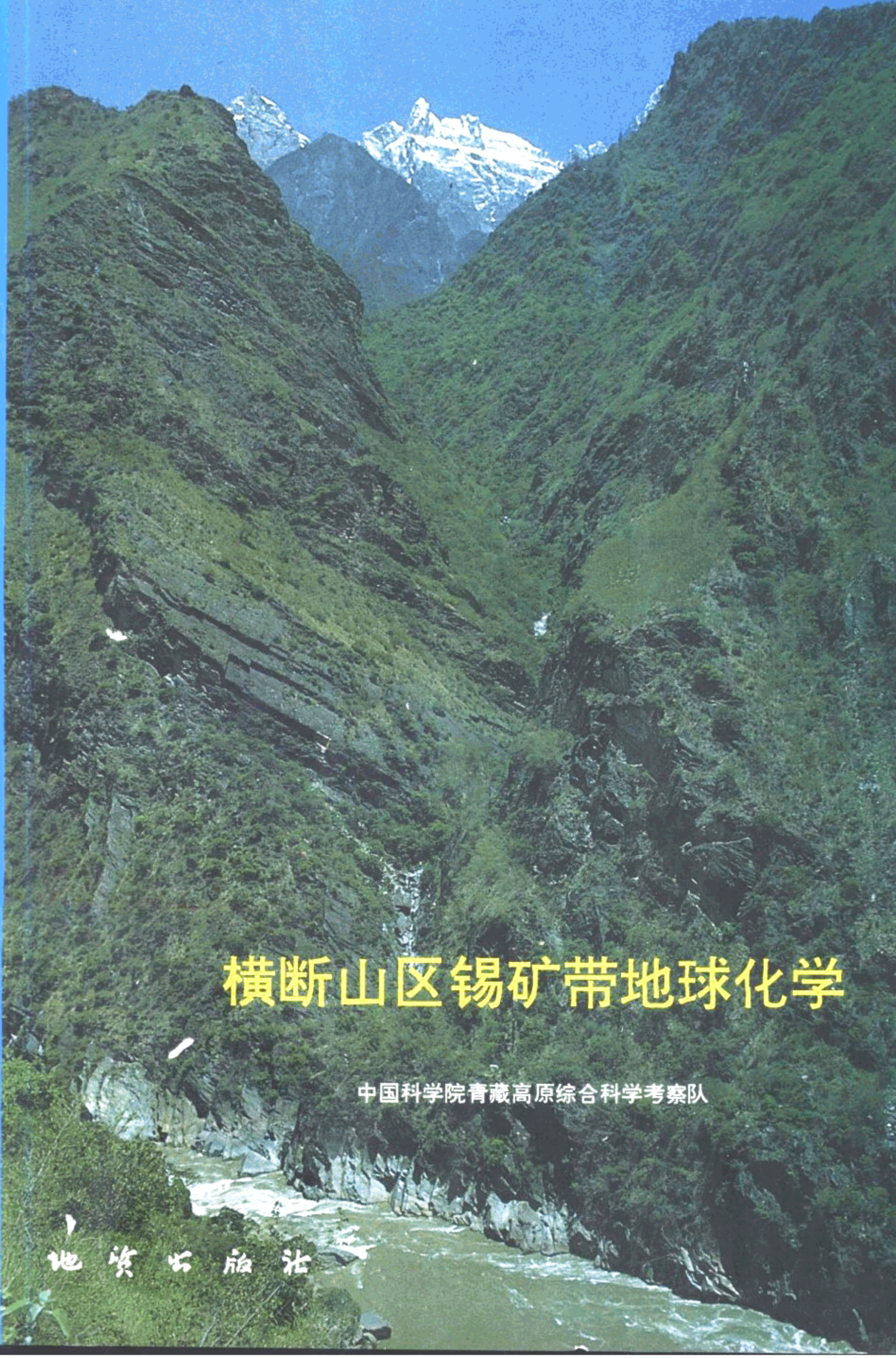

青藏高原横断山区科学考察丛书

横断山区锡矿带地球化学

中国科学院青藏高原综合科学考察队

地质出版社

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中国科学院青藏高原综合科学考察队

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内 容 简 介

本书是中国科学院青藏高原综合科学考察队花岗岩类地球化学专题组继《西藏南部花岗岩类地球化学》之后的一部锡矿带地球化学研究专著。作者在多年野外考察和室内研究的基础上，对康滇古陆、哀牢山-金沙江、临沧-左贡和潞西-腾冲四条锡矿带花岗岩地质、岩石学、岩石化学、微量元素和稀土元素地球化学、同位素地质年代学和同位素地球化学以及花岗岩的成因演化与锡成矿关系进行了较全面系统的综合论述。

本书可供地球化学科学和资源科学界的广大科技工作者、高等院校教学工作者、高年级学生和研究生参考。

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《青藏高原横断山区科学考察丛书》序

辽阔的青藏高原，包括西藏全部、青海南部，以及四川西部和云南西北部，大部分地区海拔在4 000m 以上，四面以巨大的落差急剧下降，衬托出世界屋脊的磅礴气势，素有世界第三极之称。由于青藏高原独特的地质历史和自然条件，丰富的生物组成和生物群落类型，成为地球上一个独具特色的地理单元。青藏高原蕴藏着丰富的自然资源，又是许多少数民族生活和居住的地区，且地处边陲，合理保护和开发这一地区的自然资源，对发展经济，改善人民生活，以及巩固民族团结和加强国防建设都有重要的意义。

为了探索青藏高原形成和演变的历史，研究自然条件的特点及其对周围环境的影响，研究自然资源的数量和质量及其合理开发利用的途径。解放以后，中国科学院对这里进行了多次科学考察，特别是自1973年起组织了青藏高原综合科学考察队，对这一地区进行了更为全面、系统的综合性研究。

1973—1980年期间，考察队重点对西藏自治区进行了考察。其科学成果将集中反映在陆续出版的《青藏高原科学考察丛书》（西藏部分）及论文集和画册中。有些成果在实际生产中已得到推广和应用，在国际和国内产生了深远的影响。

考察队从1981年起将考察研究的重点转移到横断山区。横断山地处我国西南的藏东、川西和滇西北一带，是青藏高原的一个组成部分。在行政区域上包括西藏自治区的昌都地区，四川省阿坝、甘孜、凉山及云南省丽江、迪庆、怒江和大理等地（州）区，总面积约50万平方公里。

横断山脉在地质构造上处于南亚大陆与欧亚大陆镶嵌交接带的东翼，是我国东部环太平洋带与西部古地中海带间的过渡地带。地质构造复杂，新构造运动活跃。本区地势由西北向东南倾斜，大部为高山峡谷，山脉、河流南北纵贯，相间并列，高差很大，自然地理条件独具一格，生物区系绚丽多彩，且富含古老和孑遗类型，是研究生物和地学中许多重大理论问题的关键性地区。

横断山脉自然资源丰富，尤以多种矿产、水利、森林、草场等资源最为丰富。但是随着人口的增长和开发利用的加剧，自然资源承受的人类压力日益加大，有些地区生态平衡遭到了破坏。为了合理利用自然资源，必须研究本区的自然资源特点，探索其合理保护利用与开发的方向和途径。

横断山区科学考察工作主要围绕六个课题进行：(1) 横断山脉形成的原因和地质历史；(2) 横断山区自然地理特征及其与高原隆起的关系；(3) 横断山区自然垂直地带的结构及其规律；(4) 横断山区生物区系的组成；(5) 横断山区自然保护与自然保护区；(6) 横断山区自然资源的评价及其合理开发利用。

为了使科学考察研究更密切地与当地的经济开发工作结合起来，在自然资源评价与开发利用方面着重抓了农业自然资源条件与自然资源系列制图；亚高山暗针叶林采伐与更新；地方能源的综合利用；畜牧业发展战略及干旱河谷农业自然条件与开发利用等五项综合专

题的考察研究。

横断山区的综合科学考察研究工作由中国科学院-国家计划委员会自然资源综合考察委员会负责组织领导。参加此次考察研究的包括中国科学院有关研究所、高等院校和地方科研与生产部门等单位计40余个，约300多人，涉及40多个专业。

《青藏高原横断山区科学考察丛书》将系统地总结青藏高原综合科学考察第二阶段的成果。

《青藏高原横断山区科学考察丛书》计划由横断山区农业自然条件与农业自然资源评价、四川省金川县农业自然条件与农业自然资源评价、横断山区的地方能源资源、横断山区亚高山暗针叶林采伐与更新的研究、横断山区（川西部分）畜牧业战略发展的研究、横断山区干旱河谷、横断山区地质构造、横断山区的沉积岩及沉积盆地演化、横断山区基性超基性岩、横断山区富碱侵入岩带地球化学和成矿、横断山区花岗岩类地球化学、横断山区锡矿带地球化学、横断山区地层、横断山区古生物、横断山区哺乳动物化石与生活环境、横断山区地热与水热活动区名录、腾冲地热、横断山区自然地理、横断山区地貌与第四纪地质、横断山区气候、横断山区的冰川、横断山区泥石流、横断山区土壤地理、横断山区森林、横断山区草场、横断山区植被、横断山区沼泽与泥炭、横断山区湖泊综合研究、横断山区中小河流及水资源、横断山区自然垂直带结构特征及分布规律、横断山区植物、横断山区家畜种群生态、横断山区鱼类、横断山区哺乳动物、横断山区鸟类、横断山区两栖爬行动物志、横断山区甲壳动物、横断山区昆虫、横断山区土地资源开发与农业布局等专著组成。我们希望这些著作能在探索青藏高原的奥秘和我国社会主义建设中发挥积极的作用。

中国科学院青藏高原综合科学考察队

THE SERIES OF THE SCIENTIFIC EXPEDITION TO THE HENGDUAN MOUNTAINS OF THE QINGHAI-XIZANG PLATEAU

PREFACE

The vast Qinghai-Xizang Plateau, consisting of the Xizang (Tibet) Autonomous Region, the southern part of Qinghai, western part of Sichuan and northwestern part of Yunnan Provinces, is often eulogized as the third polar of the world. The major parts of the Plateau are 4 000 metres above sea level, while the areas around drop drastically setting off the tremendous monentum of the roof of the world. The particularities of the geological history and physical conditions, the variety of biological composition and the different types of bio-communities make the Qinghai-Xizang Plateau a unique geographical unit. As the Plateau, being rich in natural resources, lies on the border regions where inhabit many national minorities, the rational conservation and utilization of the natural resources in this region are of particular importance in developing economy, improving the local livelihood and consolidating national solidarity as well as strengthening national defence.

Ever since the foundation of new China, many scientific surveys have been carried out in this region so as to make a better understanding of the history of the formation and evolution of the Qinghai-Xizang Plateau, to study the characteristics of its natural conditions, their effects on the environment around and the quantity and quality of the natural resources and thus, to find a way of exploiting and utilizing them rationally. Especially after the forming of the Comprehensive Scientific Expedition to the Qinghai-Xizang Plateau in 1973, an even more comprehensive, systematic integrated research has being made on this region.

A survey was mainly carried out on the Xizang (Tibet) Autonomous Region during the period of 1973—1980. The scientific findings of the survey, part of which have already been extended and applied to actual production and have brought a far-reaching influence both in and outside China, will be concentratedly compiled in the series of the scientific expedition to the Qinghai-Xizang Plateau (Xizang Volume), proceedings and pictorials. Since 1981, the survey team has shifted its major researching area to the Hengduan Mountains Region which is a constitutional part of the Qinghai-Xizang Plateau and is located in the east of Xizang, west of Sichuan and northwest of Yunnan Provinces in southwest China. The total area of this region is about 0.5 million square kilometres and administratively speaking including the Qamdo district of Xizang, Erba, Cangzi, Liangshan of Sichuan and the Lijiang, Nujing and Dali districts of Yunnan.

The Hengduan Range is complicated in geological structure and active in new tectonic movements. It lies on the east flank of the juncture area where south Asia and Eurasia are mounted. It is the transition region between the east zones encircling the Pacific and the west zones of ancient mediterranian. The altitude of this area declines from northwest to southeast. Most parts of the area are characterised by a series of paralleled mountain ranges and rivers from south to north, and with a sharp altitudinal differentiation. Its unique physical conditions and variety ecosystems being rich in flora and funa with abundant relic species, give the area a critical nature for the fundamental research in the field of biology and earth science.

The Hengduan Mountains Region is abundant in natural resources, among which multi-mineral products, hydrological resources, forest and grasslands account for the great part. But with fast growth of the population and an extensive exploitation and utilization of the natural resources, the human pressure on natural resources has vastly increased which even caused ecologic equilibrium damagement in some part of the area. In order to make a more reasonable utilization of natural resources, it is necessary to study the characteristics of the resources in this region so as to work out certain ways and methods for protecting, utilizing and exploiting them rationally.

There are six major subjects in the research work being carried out in the Hengduan Mountains:

1. The geological history of the Hengduan Range;

2. The physiographical characteristics of the Hengduan Mountains and their relationship with the rise of the Plateau;

3. The structure and rule of the altitudinal belts of the Hengduan Mountains;

4. The composition of bio-communities in the Hengduan Mountains;

5. The natural conservation and nature reserves in the Hengduan Mountains;

6. Evaluation of the natural resources in the Hengduan Mountains and their rational development and conservation.

Five integrated projects have also been given special attention in the research on natural resources evaluation, exploitation and utilization. They include as following: compilation of a series of maps on the conditions of agricultural resources; deforestation and regeneration of subalpine coniferous forest in subalpine areas; the multiple utilization of local energy resources; strategy for the development of animal husbandry and finally the management of the natural resources in the arid valleys. This has been done in line with the purpose of linking scientific research closely to the development of the local economy.

The integrated survey on the Hengduan Mountains Region is organized by the Commission for Integrated Survey of Natural Resources, Chinese Academy of Sciences and the State Planning Commission. There are more than 300 people, coming from more than 40 institutions including different institutes of the Chinese Academy of Sciences, universities and local scientific research and production departments engaged in natural resources research. A series of scientific publications on the Hengduan Mountains will provide the results acquired from the second phase of the integrated scientific survey in the Qinghai-Xizang Plateau. It is designed that this series will be consisted of 39 volumes and 48 monographs. It is also expected that this series will play an important role in exploring the wonders of the Qinghai-Xizang Plateau and in the construction of China.

The Comprehensive Scientific Expedition to the Qinghai-Xizang Plateau,
Chinese Academy of Sciences

《横断山区锡矿带地球化学》序

许多知识界人士，包括地质工作者在内，当谈到我国的锡矿带时，首先或者只想到南岭锡矿带。这个闻名于世的东西向矿带，西部以产锡、东部以产钨为主。对此带之外的中国钨锡地质情况，人们便知之甚少了。

因此，相对来说，我国的另一条锡矿带，即本书所论述的横断山区锡矿带，就其知名度而论，远逊于前述的南岭锡矿带。但从不多的前人资料及本书所揭示和讨论的内容来看，横断山区锡矿带具有十分良好的成矿远景。只是由于人烟稀少、交通不便、地形陡峻、工农业不发达诸因素的制约，对它的了解、研究、勘查和开发的深度既远不如南岭成矿带，也逊于横断山区锡矿带的南延——泰国、缅甸、马来西亚、印尼成矿带。可以并不夸张地说，横断山区锡矿带在一定程度上还存在着不少薄弱环节，甚至空白领域。

本专著的特色在于它以前人的地质工作为基础，进行了大量第一手的地球化学研究。它所包含的丰富多采的岩石学、岩石化学、元素及同位素资料及数据，及由此而引申出来的对含锡花岗岩与锡矿化时空分布规律、含锡与不含锡花岗岩对比、花岗岩的演化与锡矿关系等方面的观点、看法与思考无疑将对横断山区锡资源的进一步普查、勘探、开发利用与科研提供重要依据。

同样重要的是本专著所强调的横断山区锡矿床具有多时代（晚前寒武纪、中生代、新生代）、多类型（锡石硫化物、锡石石英脉、含锡云英岩、伟晶岩和夕卡岩等）、多成因的论点。这就是本锡矿带具有与南岭锡矿带明显不同的特点。后者主要是中生代形成的，在类型上以锡石多金属硫化物为主，其他类型只占十分次要位置。可以说，横断山区锡矿带所具有的多时代、多类型、多成因特征，在其他国家和地区也是罕见的。

相信本专著的出版将有助于今后开拓我国西南的锡矿事业，并在锡的地球化学研究上有所建树。

涂 光 炽
1992.9.5

Geochemistry of Tin Ore Belts in Hengduan Mountains
Preface

What appears first or exclusively in their mind is the the Nanling tin mineralization belt whenever scholars of intellectual circles, including geological workers are talking about tin mineralization belts in China. That is because this EW-extending, world-known tin mineralization belt is abundant in Sn in the western part and in W in the eastern part. Little has been known about other Sn-W mineralization belts in China.

Comparatively speaking, another tin mineralization belt in China——the Mt. Henduanshan tin belt, documented in this book, is far less known than the Nanling tin mineralization belt. However, as viewed from the scarce previous data and those presented in this book, the Mt. Henduanshan tin belt has brilliant prospects in mineralization. Because of its sparse population, inaccessibility, great relief and agricultural and industrial backwardness the investigation, exploitation and development of the Mt. Henduanshan tin belt are far from enough as compared with the Nanling tin mineralization belt itself and its southward extensions in Thailand, Murma, Malaysia and Indonesia. It can be said with certainty that the Mt. Henduanshan tin mineralization belt needs to be further studied in many asepects.

Presented in this monograph are a great wealth of first-hand geochemical data based on the previous geological work. The abundant data on petrology, petrochemistry and element and isotope geochemistry are contained in this monograph, from which new ideas and viewpoints concerning the tempo-spacial distribution of Sn-bearing granites and Sn mineralizations, the correction between Sn-bearing and S-barren granites and the relationship between the evolution of granites and Sn mineralization are deduced, hence providing the important scientific grounds for the further survey, exploration, development and utilization of Sn resources in the Mt. Henduanshan region.

What is equivalently important is that the monograph places great emphasis on the multi-stage (Late Precambrian, Mesozoic, Cenozoic), multi-type (cassiterite-sulfide, cassiterite-quartz vein, Sn-bearing greisen, pegmatite and skarn) and multi-origin hypothesis of Sn ore deposits in the Mt. Henduanshan region. It is this feature that marks the difference between this tin belt and the Nanling tin mineralization belt. The latter was formed mainly during the Mesozoic, with the cassiterite-polymetallic sulfide type being predominated over the other types. It can be said that the Mt. Henduanshan tin mineralization belt is one that could rarely be found in other parts of the world with respect to its multi-stage, multi-type and multi-origin characteristics.

We are sure that the publication of this monograph will be benefitial to the exploration of Sn resources in southwestern China and contribute a lot to the geochemical study of Sn.

Tu Guangzhi

5. 9. 1992

前　言

本专题是中国科学院制订的青藏高原横断山区综合科学考察五年规划的一部分，由中国科学院及国家计委自然资源综合考察委员会负责组织领导，中国科学院青藏高原综合科学考察队具体组织实施考察计划，中国科学院地球化学研究所承担研究任务。

横断山区锡矿带位于闻名于世的东南亚锡矿带北段。该区地处青藏高原东部的川西、藏东和云南广大地区，地质构造极其复杂，花岗岩岩浆侵入活动频繁、强烈，且呈带状分布。其时代从前寒武纪晋宁期到第三纪喜马拉雅期，并伴随同时代的锡成矿作用。该区又处在东南亚锡矿带所伴随的北北西向构造带与南岭钨锡成矿带所伴随的近东西向构造带的交会地区，在区域构造上处在特提斯-喜马拉雅构造区及其边缘地带，由于板块的多次俯冲、碰撞，为本区锡成矿作用提供了有利条件。因此，本区锡矿床具有多时代、多类型和多成因的特点。所以，通过锡矿带地球化学研究，对了解横断山区锡矿床的成因、富集规律，以及锡的找矿、勘探和开发利用，均具有重要的理论与实践意义。

70年代到80年代，中国有色金属工业总公司西南地质勘探公司和地质矿产部云南省地质矿产局、四川省地质矿产局等所属有关生产单位和科研单位，以及昆明工学院等，对该区广泛开展了锡找矿勘探和专题科学研究工作，揭示了锡矿床呈带状分布的规律，证实了锡矿床的潜在远景。1981年起，本考察队地球化学专题组，在前人工作基础上对横断山区锡矿带地球化学进行系统的研究，张玉泉、谢应雯、胡国相、战新志、董振生等22人次先后四度赴横断山野外地质考察，系统采集有关分析测试样品；1984年后则转为室内工作阶段，进行了Rb-Sr、K-Ar同位素地质年代学、氧、硫同位素地球化学、岩石学、岩石化学、微量元素和稀土元素地球化学等多学科的综合研究（成忠礼、张前锋和张鸿斌等参加部分同位素分析测试工作），经作者整理写成此书。具体分工情况为：谢应雯执笔第四、五章，张玉泉执笔第一、二、三章，谢应雯、张玉泉共同执笔前言与第七章，张玉泉、戴橦模、胡国相、蒲志平执笔第六章。

本项研究曾得到国家自然科学基金委员会的资助。在历年的野外考察研究过程中，曾得到西南地质勘探公司310队、308队，云南省地质矿产局第四地质大队、第五地质大队、第三地质大队，四川省地质矿产局攀西地质大队、402地质大队、108地质大队等单位的热情支持和鼎力相助。邹树、刘忠俊、汪志芬、李家和、李景略、张承佑等同志分别参加了有关锡矿床地质考察。涂光炽教授热情指导了本项目的野外、室内和总结等工作。作者一并致以最诚挚的谢意。

GEOCHEMISTRY OF TIN ORE BELTS IN HENGDUAN MOUNTAINS

Abstract

This research program is a part of the five-year project of Comprehensive Scientific Investigation of the Qinghai-Xizang Plateau-Hengduan Mountains Region, under the supervision of the Academia Sinica and the Committee of Natural Resources Survey of the State Planning Commission. The Qinghai-Xizang Exploitation Team of the Academia Sinica was responsible for its implement and the Institute of Geochemistry, Academia Sinica, undertook most of the field and laboratory work.

As the north extension of the well-known Southeast Asia Tin Belt, the Hengduan Mountains tin belt is localized in west Sichuan, east Xizang and Yunnan in the east part of the Qinghai-Xizang Plateau. The region is characterized by a highly complicated geology, with frequent, intensive and zonally distributed granitic intrusion, ranging in age from Precambrian (Jinning period) to Tertiary (Himalayan period), and coeval tin mineralization. Geographically roughly corresponding to the Tethys-Himalayan tectonic province, the region is also at the intersection of the NNW structures and the approximately EW structures with which the prominent Nanling W-Sn belt and the SE Asia Sn belt are associated respectively. The repeated subduction and collision of plates may have provided a favorable condition for the multicyclic and multigenetic tin mineralization in this region. A detailed geochemical study of this tin belt will be of important theoretical and pratical significance. It is expected to greatly improve our knowledge of the genesis of tin mineralization and thus to offer better prospecting techniques for new discovery.

The regularity of zonal distribution of tin deposits has been well established as a result of extensive studies carried out in the last two decades by many geological teams and institutes. Since 1981, systematic geochemical studies have been conducted by the Institute of Geochemistry. Detailed field investigations and sampling were made by, among others, Zhang Yuquan, Xie Yingwen, Hu Guoxiang, Zhan Xinzhi and Dong Zhensheng in their four field trips. Concerted laboratory researches began in 1984 by using various lines of approach including isotopic geochronology, stable isotope geochemistry, petrology, petrochemistry, trace element and REE geochemistry.

The book contains seven chapters.

Chapter Ⅰ deals with the distribution of tin deposits in this region. Four belts of tin mineralization have been well recognized based on structural features, ages of magmatic rocks and

ore deposits as well as deposit type: (1) The Precambrian Kangdian Ancient Land Tin Belt. The distribution of tin-bearing granites is controlled by the approximately SN striking Anninghe-Yuanmou deep fault in the basement. Tin mineralization seems to be related to granites of the Jinning—Chengjiang period, with isotopic ages between 860 and 637 Ma. Major tin deposits and prospects, including cassiterite-sulfide, cassiterite-quartz vein and cassiterite-greisen, are known, from the north to the south, in Lugu, Chahe, Pingdi and Jiudaowan. (2) The Mesozoic Ailaoshan-Jinshajiang Tin Belt. Distributed along the east side of the Ailaoshan-Jinshajiang ancient sutured zone, the tin-bearing granites are of Middle—Late Yanshanian (Jurassic—Cretaceous) period, with isotopic ages between 147—80 Ma. Deposit types include cassiterite-sulfide, cassiterite-quartz vein, cassiterite-greisen, cassiterite-pegmatite and tin-bearing skarns, with deposits known, from the north to the south, in Dengke, Hailong, Yidun, Xiangcheng, Mahuaping, Gejiu, Bozhushan and Laojunshan (Dulong). This belt extends southeastwards into the north and central Vietnam. (3) Precambrian—Paleozoic Lincang-Zogang Tin Belt. Instrusives related to tin mineralization are distributed along the ancient sutured zone from the upper reach of Nujiang River to Lancang, with tin deposits (and prospects) found in Lengshuigou, Shiganghe, Zhibenshan, Tiechang, Haobadi, Jingmenkou, Taiyingong, Yunling, Ximeng, Mengsong and Bulangshan. The mineralization is of Chengjiang—Hercynian age (648—250Ma). Major ore types include cassiterite-quartz vein, cassiterite-greisen, cassiterite-pegmatite and cassiterite sulfides. As the east branch of the SE Asia Tin Belt, it extends northwards to Changdu and Leiwuqi in east Xizang and southwards, through Burma, into Thailand and Malaysia. Tin mineralization is related to granite and granodiorite, which are always gneissic as a result of later thermal metamorphism. What is striking is that tin mineralization is much younger than the intrusion. For example, the Zhibenshan two-mica alkali-feldspar granite has a whole rock Rb-Sr isochron age of 648 Ma in comparison with the $^{40}Ar/^{39}Ar$ age of Sn-W quartz vein of only 69—32 Ma. (4) The Mesozoic—Cenozoic Luxi-Tengchong Tin Belt. Tin-bearing granites flank the east side of the ancient sutured zone along the Yarlung-Zangbo River-Mizhina. Tin deposits (cassiterite-quartz vein, cassiterite-greisen, cassiterite-pegmatite, cassiterite-quartz-sulfide, tin-polymetallic sulfides, tin-rare-metal-bearing pegmatite) are distributed in Lailishan, Dasongpo, Xiaolonghe, Tieyaoshan, Zhenan and Pinghe. The mineralization is of Late Yanshanian—Himalayan period (Cretaceous—Tertiary) with isotopic age of 112—13 Ma. Corresponding to the west branch of the SE Asia Tin Belt, this belt extends along the Gaoligong Mountain northwards to Zayu and Langxian in Xizang and southwards, through Zoushan, Zhefang, into Burma and Indonesia.

In Chapter Ⅱ, Granite Petrology, classification of the granites has been attempted on a chemical and mineralogical basis (Strecheisen A., 1976). The Or-Ab-An plots of 220 data of CIPW norms from 43 granites in the four tin belts show that the majority of them (including porphyritic biotite-monzonitic granite, biotite-monzonitic granite, porphyritic biotite-potash-feldspar granite, prophyritic two-mica-potash-feldspar granite, biotite-potash-feldspar granite, two-mica-potash-feldspar granite, biotite-alkali-feldspar granite, two-mica-alkali-feldspar granite and muscovite-alkali-feldspar granite) fall in the fields of monzonitic granite, potash-feldspar granite and alkali-feldspar granite with rare exceptions (the porphyritic biotite-granites from Longcahe (Gejiu) and Kelunpo) which plot onto the granodiorite field.

In most cases these tin-bearing granites occur as composite batholiths consisting of multi-stage intrusions. In general, the earlier intrusions are more basic than the later ones. For example, the Moshaying mass in Kangdian Ancient Land Tin Belt is composed of Precambrian porphyritic biotite-monzonitic granite, equigranular biotite-potash-feldspar granite, porphyritic two-mica-potash-feldspar granite and equigranular two-mica-alkali-feldspar granite, and the Lailishan mass in Luxi-Tengchong Tin Belt comprises Cretaceous hypersthene-bearing porphyritic biotite-monzonitic granite, biotite-potash feldspar granite and Tertiary equigranular biotite-potash-feldspar granite and equigranular two-mica-alkali-feldspar granite. The alkali-feldspar granite or potash-feldspar granite emplaced in later times show more close association with tin mineralization.

Among the 20 typical tin-bearing granites in this region (Gejiu, Laojunshan, Lailishan and Dasongpo) and South China (Dachang and Limu in Guangxi; Sizhuyuan, Hunan; and Keshuling, Yunshan, Zhangtiantang, Zongshukeng in Jiangxi), including medium—coarse grained porphyritic granite, biotite granite, two-mica granite, muscovite granite and etc. , 75% of them plot in alkali-feldspar granite field in the Strecheisen diagram and only 25% falls in potash-feldspar granite. It is clear that tin mineralization is mostly associated with alkali-feldspar granite and, to a lesser extent, potash-feldspar granite, and monzonitic granite is notably devoid of tin deposit. This is an important criterion for distinguishing tin-bearing granite from barren granite.

Chapter Ⅱ, Petrochemistry of Granite, presents petrochemical data of 206 samples from 43 granite masses in the four tin belts. The results show that, in comparison with those in south Xizang, South China and in other places of China and the world, granites in this region are characterized by higher contents of SiO_2 and lower contents of TiO_2, Fe_2O_3 and MgO. It is also noticed that SiO_2 increases, while TiO_2, Al_2O_3, Fe_2O_3 and FeO decrease, progressively in going westwards from the Kangdian Ancient Land Tin Belt, through the Ailaoshan-Jinshajiang Tin Belt and the Lincang-Zogang Tin Belt to the Luxi-Tengchong Tin Belt.

While very similar chemical compositions are observed for the same type of granite in different belts and of different ages, there are apparent differences between different rock types, with SiO_2 increasing (69. 15%→73. 42%→74. 97%) and TiO_2 (0. 45%→0. 24%→0. 14%), Al_2O_3 (14. 86%→13. 38%→12. 73%), FeO (2. 42%→1. 52%→1. 17%), MgO (0. 85%→0. 28%→0. 21%) and CaO (2. 37%→1. 18%→0. 68%) decreasing from the earlier intruded monzonitic granite through potash-feldspar granite to the later intruded alkali-feldspar granite. Additionally, Acidity (82. 77%→84. 29%→84. 27%), alkalinity (2. 19%→2. 51%→3. 26%) and differentiation index (78. 68%→88. 11%→91. 91%) all tend to increase following the same sequence.

As can be seen from the SiO_2-FeO+MgO+CaO-Na_2O+K_2O+Al_2O_3 diagram (Juniper,

D. N. et al., 1979), most tin-bearing granites in this region as well as in adjacent areas are alkali-feldspar granite and, to a lesser extent, potash-feldspar granite, with the character of $Si_2O \geqslant 73\%$, $R^{2+}O \leqslant 3.2\%$, $DI \geqslant 86$, $Si_2O/TiO_2 \geqslant 340$, $(Na_2O+K_2O)/TiO_2 \geqslant 30$, $SiO_2/(MgO+CaO) \geqslant 40$.

In Chapter Ⅳ, Trace Element Geochemistry, the distinction between tin-bearing and barren granites is further discussed based on trace element data of 169 samples from 20 mineralized and 26 barren granites in this region. As has been revealed, in comparison with the average acid intrusives in the crust, granites in this region contain lower Ga, V, Cu, Ba, Sr, Be and Zr but higher W, Sn, Mo, Li, Rb, Th, Nb, Ta, F, B, Pb, Sc and Ni, with a particularly attractive feature of the apparent enrichment (3 times over the Clarks) of W and Sn.

From the early monzonitic granite, through potash-feldspar granite, to the late alkali-feldspar granite, Be, Nb, Ta, Li, Rb, Cs, W, Sn, Th, V, Ga, Pb, F and B are found increasing while V, Ni, Sr, Ba, Sc and Zr decreasing with magmatic evolution. The monzonitic granite has the lowest tin content (7.33 ppm) and the alkali-feldspar granite the highest (17.99 ppm), with potash-feldspar granite showing the intermediate tin abundance (10.32 ppm). This is consistent with the conclusions reached in the previous chapters that the alkali-feldspar granite is the most important tin-bearing rock while the monzonitic granite is generally barren.

Tin-bearing granite can be better distinguished from barren ones by using Li+Rb+Cs-F-Sr+Ba diagram, and some ratios of elements are of particular significance. It has been found that Sn content is inversely related to Mg/Li, K/Rb, Ba/Rb, (Sr+Ba) / (Li+Rb+Cs) and TiO_2/Ta, and is positively related to 1000Li/K, Rb/Sr and F. In the sequence of monzonitic granite→potash-feldspar granite→alkali-feldspar granite, Rb/Sr and 1000 Li/K increase progressively while Mg/Li, K/Rb, Ba/Rb, (Sr+Ba) / (Li+Rb+Cs) and TiO_2/Ta decrease. Tin-bearing granite is characterized by Rb/Sr>3.5, 1000 Li/K>1.8, K/Rb<130, Ba/Rb<0.85, Mg/Li<30, TiO_2/Ta<550, (Sr+Ba) / (Li+Rb+Cs) <1, among which the first four criteria are usually of critical importance.

Chapter Ⅴ: REE Geochemistry. REE analyses of 173 granite samples in this region show wide range of variation (22—537 ppm). REE contents of same rock type differ from batholith to batholith, and in the same batholith, earlier intrusions contain higher REE than the later intrusions. From monzonitic granite through potash-feldspar granite to alkali-feldspar granite, REE_2O_3 decreases from 270.9 ppm to 231.6 ppm to 219.4 ppm. A negative correlation is apparent between Sn and REE_2O_3 in granites, with a correlation coefficient of −0.2885.

In the sequence of monzonitic granite→potash-feldspar granite→alkali-feldspar granite, total REE (314.7 ppm→270.9 ppm→263.9 ppm) and LREE (226.1 ppm→198.5 ppm→118.6 ppm) decrease, HREE (51.9 ppm→59.8 ppm→94.9 ppm) increases, accompanied by increasing Eu depletion (δEu 0.38→0.23→0.1). Three types of REE patterns can be distinguished in major rock types of this region. (1) The (porphyritic) biotite-monzonitic granite is characterized by LREE enrichment (LREE/HREE=4.36) and intermediate Eu depletion (δEu

=0.38), with a right-declined V-shaped curve (La/Yb=14). (2) The biotite (two mica) potash-feldspar granite is less LREE-enriched (LREE/HREE=3.32), with strong Eu depletion (δEu=0.25) and a right-declined steep V-shaped cruve (La/Yb=9.6). (3) Biotite (two-mica) alkali-feldspar granite has about equal amounts of LREE and HREE (LREE/HREE=1.25), a very obvious Eu depletion (δEu=0.10) and a symmetric V-shaped curve (La/Yb=3.7), similar to that observed in the Sn-W-bearing granites in South China (Zhu Jinchu, 1989). This symmetric V-shaped REE pattern may be taken as a criterion of tin-mineralization. Tin tends to increase with decreasing LREE and increasing HREE in the granite, and the most favorable condition for tin mineralization is LREE<150 ppm and HREE>100 ppm or 150 ppm.

In Chapter Ⅵ, Geochronology and Isotopic Geochemistry, Rb-Sr and K-Ar ages and Sr, Rb, O, S isotopic compositions are presented and evaluated for granites in the four tin belts. Based on 11 whole rock Rb-Sr isochrons and 74 mica K-Ar datings, it is concluded that mineralization-associated granites in Moshaying, Jiudaowan and Lugu in Kangdian Ancient Land Tin Belt were formed in Precambrain Jinning—Chengjiang period (860—637 Ma); those in Hagala, Cilinchuo, Gejiu, Bozhushan and Laojunshan (Dulong) in the Ailaoshan-Jinshajiang Belt is of Middle—Late Yanshanian (Jurassic—Cretaceous) age (147—80 Ma); those in the Lincang-Zogang Belt range from Precambrian to Paleozoic (648—250 Ma, corresponding to the Chengjiang—Hercynian Period); and the granites in the Luxi-Tengchong Belt are dated as Late Yanshanina (112—46 Ma, corresponding to Cretaceous-Tertiary). It is worth noting that the Lincang-Zogang Belt is characterized by: (1) Tin mineralization is associated with not only granites but also granodiorites; (2) The intrusives are gneissic as a result of subsequent thermal metamorphism; and (3) Mineralization is much later (69—32 Ma) than the emplacement of plutonic rocks (648—296 Ma).

Pyrites for sulfur isotope measurements are selected from 10—20 kg rock samples (porphyritic biotite-monzonitic granite, gneissic biotite-monzonitic granite, biotite-monzonitic granite and biotite-potash-feldspar granite) and from ores of cassiterite-quartz vein, cassiterite-sulfide and cassiterite-skarn types. The results show that $\delta^{34}S$ values range from −6.87‰ to +10.37‰ in rocks and from −7.84‰ to +7.01‰ in ores. Sulfur isotopic compositions differ, to varying extent, from area to area, but for a give mining district rather consistent results are obtained, suggesting syngenetic character. Whole rock $\delta^{18}O$ values are between +8.99‰ and +10.38‰, and $\delta^{18}O$ values of quartz range from +9.71‰ to +11.52‰ in rocks and from +10.08‰ to +12.03‰ in ores. The close similarity in $\delta^{34}S$ and $\delta^{18}O$ values between ores and rocks strongly indicates the dominance of magmatic water in the ore-forming solutions as well as the close relationship, in terms of time, space and genesis, of tin mineralization and granitism.

Chapter Ⅶ, Genesis and Evolution of Granite and the Criteria of Tin-Bearing Granite. The genesis of granites in the region is discussed in detail based on various lines of evidence of geology, temporal and spatial relationship, petrology and geochemistry. The magmatic origin of gran-