热泉型金矿床成矿模式及成矿远景评价

郭光裕　侯宗林等著

天 津 科 学 技 术 出 版 社

热泉型金矿床
成矿模式及成矿远景评价

郭光裕　侯宗林　林卓虹
著
张俊苓　朱学文　丛桂新

天津科学技术出版社

内 容 简 介

本书是冶金部天津地质研究院数学地质组承担国家黄金管理局地质科研项目第89 A 9项成果的系统总结。作者在4年多的野外观测取样和室内分析测试基础上，通过地质学、矿床学、矿物学、地球化学、数学地质学等多学科综合研究，全面、系统地揭示了热泉型金矿床的地质特征、生成环境、赋存规律、成矿作用机制等。建立了完整的成矿模式，并通过实例介绍了应用该模式进行资源定量评价及预测的思路和方法。

本书可供从事金矿理论研究和地质找矿的人员、高等院校师生参考。

津新登字（90）003号

热泉型金矿床成矿模式及成矿远景评价

郭光裕 侯宗林 林卓虹
张俊苓 朱学文 从桂新 著

责任编辑 宗洁

天津科学技术出版社出版、发行
天津市张自忠路189号 邮编 300020
天津地质研究院印刷厂印刷

开本787×1092毫米 1/16 印张 17 插页8 字数409 000
1993年6月第1版
1993年6月第1次印刷

ISBN 7-5308-1388-9/P·1 定价：30.00元

前　言

热泉型金矿床——近年来发现的与热泉的发育有成因联系的新矿床类型，以其能为人类提供丰厚的金矿产资源而举世瞩目。至今已经开发出许多百吨以上的大型金矿床。因而，研究这类矿床的成矿控制条件和成矿作用机理是倍受人们关注的新课题。

我国藏南和滇西地区位于地中海–喜马拉雅贵金属成矿带东段，在那里发育大量古热泉群、现代热泉群及与之有关的金矿化。地处印度板块与欧亚板块碰撞接触带的腾冲地区，基性、中性、中酸性火山群广布，构造活动强烈频繁，气候温热多雨，植被浓郁繁茂。加上高山深谷地貌和成群、成带出现的热泉，构成了奇伟秀丽的自然景观。不但是令游客留连忘返的旅游胜地，而且以其丰富的地热资源而闻名于世。但是，该区的热泉分布空间发育强烈的金矿化，有可能成为热泉型金矿床找矿远景区却鲜为人知。据调查，该区出露热泉群 76 个，其中的温泉、沸泉、喷气孔、放热地面，形态各异的泉华堆积体，不同规模的水热爆炸角砾和爆炸坑，大面积出露的酸淋滤作用蚀变岩带和穿插于其中的脉状、网脉状、团块状黄铁矿、白铁矿硅质岩，以及异常含量的金、银、砷、锑、汞、铊等，与国外热泉型金矿床的空间几何模型有着一一对应的相似关系。对其进行详细的研究，会加深对热泉型金矿床控矿地质条件、成矿机理的认识和理解。

本书是国家黄金管理局下达的科研攻关项目《云南腾冲–梁河地区现代热泉型金矿床成矿模式及成矿远景评价》部分成果的总结。即在我国滇西构造火山地热活动区热泉型金矿床形成的地质构造环境、成矿控制条件、成矿作用机理、成矿模式等研究基础上，结合世界上一些典型的热泉型金矿床地质特征和成矿控制因素的统计分析成果，由郭光裕执笔编写而成。书中汇集了作者自 1987 年至 1991 年期间的野外地质观测和室内测试及综合研究成果。

全书包括 2 篇 8 章。第一篇是热泉型金矿床。共分 5 章。第一章是绪论，主要叙述两方面的问题，其一是介绍矿床模型和矿床模型法的概念、意义、理论基础、内容、用途、分类及建立的方法，应用概况和发展趋势等。其二是介绍热泉型金矿床的概念、一般特征、最有代表性的矿床模型，开发前景等。在这里我们给热泉型金矿床赋予了广义的概念，即成因上与热泉的发育密切相关的金矿床均属于热泉型金矿床。

第二章是浅成热液循环系统。强调指出，一个热泉型金矿床的成生，决不仅限于矿床分布空间的热液作用，而是在更为广阔的区域上，热液迁移循环分异富集的结果。因而热泉型金矿床的形成有一个蕴育它不断成长的母体。这就是在区域上分布的，由地壳断裂、基底断裂、盖层断裂等配套构造体系形成的充满热液的"活"裂隙系统。热液在该系统中迁移循环，发展演化。在不同空间上有规律地与围岩发生各种形式的物质交换反应。也发生包括贵金属在内的各种物质的沉淀富集。我们称这种蕴育矿床成生的母体为浅成热液循环系统。金矿床就赋存在该系统的一定空间上。本章以腾冲浅成热液循环系统为例，结合

世界上一些典型的热泉型金矿床特征，详细地介绍了浅成热液循环系统的基本要素，空间分带，各分带的地质特征及显现的物理化学环境，热液在不同空间上的地球化学性质、演化方向、作用产物，特别是金矿化特征。

第三章是浅成热液循环系统形成的区域地质构造环境。指出，浅成热液循环系统是在特定的区域地质构造环境中形成的。尤其对具有贵金属矿化的浅成热液循环系统而言，它的形成必须具备：①热液赋存和迁移循环的空间——一个完备的裂隙系统；②使热液不断地发生迁移循环的动力；③充足的水源；④充足的热源；⑤充足的矿质来源；⑥充分的发育时间等条件。本章以腾冲浅成热液循环系统为例，探讨了热泉型金矿床成生的大地构造环境、构造和构造活动环境、水源、热源、物质来源，以及浅成热液循环系统发育的时间。指出，热泉型金矿床成生于聚合板块碰撞接触带上的扩容带，大陆火山沉积盆地中的热泉分布区。该区在长期不断的板块运动作用下，发育地壳断裂、基底断裂、盖层断裂配套构造体系，在区域上形成了完整的裂隙系统。强调指出，频繁不断发生的断裂构造活动是使裂隙系统内部空间结构发生改变，不断地形成减压空间，促使热液迁移循环的主要动力。板块运动产生的巨大能量所形成的各种热事件（岩浆侵入、火山喷发）和区域性高温状态（火山余热、近地表岩浆热）是浅成热液循环系统的主要热补给。在肯定大气水和围岩是热液主要补给源的同时，强调了来自深部地幔和（或）下部地壳岩浆的补给。指出，来自深部的挥发性组分、卤素、碱素等对围岩中金的活化转移以及在热液中迁移循环沉淀富集成矿等起着决定性的控制作用。

第四章是浅成热液循环系统中金的矿化作用。指出，热泉群的下面能否发育成金矿体，取决于浅成热液循环系统是否有深循环的热液存在。只有经历过深循环作用的热液才有可能在浅成热液循环系统的一定部位富集成金矿体。这种热液的金含量一般较高，并且有一组异常含量的特征元素与之相伴随。热液作用产物也会发生强烈的金矿化。本章以腾冲浅成热液循环系统为例，介绍了金及其伴生组分在热液及热液作用产物中的矿化特征。即通过区域上分布的主要岩系和浅成热液循环系统各种地表露头所含 29 种金属组分的定量对比研究，提炼出热泉型金矿床的最佳地球化学标志组合，确定了标志元素的垂直分带规律，建立了统计分布模型。指出，腾冲浅成热液循环系统的上部空间，已经有金的矿化显示。金品位大于 1μg／g 的矿石样品占 7.66%。这部分样品的金含量一般 1.06～5.02μg／g，平均 1.74μg／g。样品中出现的最大值为 7.16μg／g。温泉水也显示金的异常高含量，其平均值相当于世界温泉水金平均含量的 5.2 倍。金及其伴生组分银、砷、锑、汞、铊等与碱素、卤素、携矿组分硼、二氧化碳、硫化氢等存在线性相关关系，表明碱素、卤素、携矿组分等对金在热液中的迁移循环起着十分重要的作用。金及其伴生组分的垂直分带规律进一步表明金矿体在深部赋存的可能性。本章还对水热爆炸与金矿化的关系进行了定量研究，发现金含量对数值与水热爆炸次数之间存在着紧密线性相关关系。模拟的数学模型表明，当岩石反复爆破胶结 7 次时，沉淀的金含量可以达到 1.35μg／g。这一规律的发现，不仅定量地证明了该类型矿床金的沉淀

富集机制是反复不断的“沸腾—自封闭”作用，并且证明水热爆炸角砾岩的破裂次数可以作为评价金富集程度的宏观标志。

第五章是矿床模式。除建立世界上常见的空间几何模型外，还建立了描述性模型、区域环境模型、成矿过程模型、资源评价模型。对成矿机制的详细研究表明，来自地幔和（或）下部地壳岩浆的大量挥发分、卤素、碱素对热液的补给，不但促进了围岩中金的活化转移，而且保证金及其伴生组分在热液中的迁移循环。指出，下循环作用带的高温还原环境，不但含有大量卤素，也含有大量的硫（H_2S、HS^-、S^{2-}），更含有大量与金硫络阴离子和金氯络阴离子进行电性平衡的碱素，对金的活化转移迁移循环十分有利。还指出，“沸腾—自封闭”是热泉型金矿床金沉淀富集成矿的主要机制。进一步指出该机制的核心是热液大量汽化使大多数 H_2S 转化为气相而逃逸，为达成新的化学平衡，剩余热液中的 HS^-向 H_2S 转化，使金硫络合物解体而导致金的大量沉淀。热液汽化带走大量热能，使剩余热液的温度突然大幅度降低而导致氧化硅的大量沉淀。强调指出，“沸腾—自封闭”反复不断地进行，才有可能形成具有工业意义的金矿石。进一步指出，频繁不断的断裂构造活动和热液本身所具有的高温过压性质，是热液迁移循环和反复发生沸腾引起水热爆炸的动力。推断热液沸腾可能是所有热液型金矿床金沉淀富集成矿的重要机制。

第二篇是热泉型金矿床资源评价实例，共分 3 章，即第六、七、八章。第六章是腾冲一级浅成热液循环系统金矿资源评价，属于矿田规模的金矿产资源量估计和成矿远景区预测。在矿床模式指导下，应用有关的资源总量估计模型对腾冲地区的金矿产资源量进行了定量估计。依据 8 个判别标志对三级浅成热液循环系统的含矿性进行了统计对比，预测了成矿远景区。

第七章是热海三级浅成热液循环系统金矿资源评价。属于矿床规模的金矿产资源量估计和成矿远景区段预测。在矿床模式指导下，对热海三级浅成热液循环系统的金矿产资源量进行了估计。以 8 个判别标志为依据预测了有利找矿区段，确定了普查钻探工程的位置和见矿深度。

第八章是我国热泉型金矿床找矿前景浅析。以热泉型金矿床区域环境模型为样板，对我国的地质构造环境进行分析，指出我国的一些地区具有热泉型金矿成生的最佳条件和光明的找矿前景，划分出 8 个成矿带。

一个完整的矿床模型是在一定的地质理论指导下，根据大量多方面的实测资料和数据经提炼升华后建立起来的，涉及的知识面十分广泛。在完成本书过程中，除利用我们自己多年来实测的资料和数据外，还利用了中国科学院青藏高原综合科学考察队、云南省地矿局第十二地质队和地热地质队有关的一些调查材料和实测数据。昆明冶金地质调查所领导给我们的工作提供了方便条件。在开展野外地质调查中，腾冲县经委矿管会对我们的工作给予了很大的支持，特别瞿天相、毕戴周二位同志，不畏苦累艰险，和我们一起出没于峭壁悬崖沟壑林莽之中。涂光炽、周传新、吴悦斌教授，李文达、沈保丰研究员，寸圭、黄世杰、张涛、陈继明、冯建良、毛裕年、陈丙轼、黄佳展、罗镇宽高级工程师，李春富、张忠生、叶胜勇、洪永勇、李树良工程师等对研究成果进行了评

审，提出了宝贵的意见。连俊坚、孙树浩高级工程师等审阅了本书，提出了有益的意见。此外，李永明翻译，汪振彬、商木元、戴立军工程师等携助翻译了前言、目录及版图说明，全部英文部分由李永明审定。作者一并向他们表示崇高的敬意。

现今，我国尚未发现具有一定规模的热泉型金矿床，我们研究的实际范围仅限于浅成热液循环系统的上部，在建立成矿模式时，某些部分需要根据世界上的一些典型矿床特征来探寻。随着我国地质找矿事业的深入开展，热泉型金矿床的相继发现和深入研究，必将丰富和完善本书所建立的矿床模式。作者由衷地希望本书的面世能唤起同行们对热泉型金矿床的兴趣、思考和争论。如果能对我国寻找和开发这一类型矿床有所俾益，作者将会感到莫大的欣慰。因水平所限，文中错误一定不少，行文用字不恰之处在所难免，欢迎批评指正。

PREFACE

Gold deposit genetically related to hot spring is a new type discoverd in recent years supplying more and more gold to mankind. Megasized deposits (more than 100t for one deposit) belonging to the type are being developed in the world. Research on its controling factors and metallogenic mechanism is now a subject in great demount.

The studied area is situated in the east part of Mediterranean – Himalaya presiuos metal metallogenic belt, ie. Tibet – Dianxi area, concretely the Tengchong area where India Plate and Euroasia Plate collide. This area is only wellknown for its scenery, land – scape and geothermal resource. Its potential gold resource was overlooked.

Field and Lab work was done by the authors druing 1987–1991. It was found that hot springs occurred in belts and associated with strong gold mineralization spatially. 76 hot spring groups were located among which fumaroles of warm, boiling springs heat eruption surface, sinter deposits in different volume, thermal hydraulic exploded breccia and exploded pits in varied scales were recognized with extensive, acidic leaching and alterations. Veins, networks massive pyrite, marcasite, silicious rocks and anomal values of Au, Ag, As, Sb, Hg, Tl associated with the alterations were distributed in the similar to the spatial geometrical model of hot spring deposits abroad. Therefore, the authors determined to write a book for promoting development of hot spring type gold resource in China.

This book, written by Guo Guangyu, is based on the combination of above mentioned reseach outcomes and the geological features and metallogenic ore–controling features of statistical analysis of hot spring type gold deposits abroad. The book is divided into two sections and eight chapters.

The first section consists five chapters.

Chapter 1 introduces (1) the concept of ore deposit model and its method, significance, theoretic base, content, usage, classification and establishment method, practical application and developing trends; (2) concept of hot spring type gold deposit, general features, typical model and the prospect, and a broad – sensed concept is given that gold deposits genetically related to hot spring all belong to hot spring gold deposts.

The second chapter deals with circulation system of hydrothermal fluid. Such system is not only confined to the hydrothermal activity. around the hot spring gold deposits. It is constiuted by a complete fracture system including fractures in crust, basement and cover strata which are full of hydrothermal fluid. The fluid circulates, regularly reacts with wallrocks and evolves to bring about enrichment of some materials (presous metals included) and formation of Au deposits at certain positions in the system which this book calls the parental body of hot spring gold deposit. Taking the system developed in Tengchong as an example, together with typical hot spring gold deposits well–known in the world a detailed introduction of element, spatial zonation of the system are made; and the geological features, physiochemical conditions of varied zones, spatial geochemical behavour, evolution trends, resulting products, espect ially for the characteristics of Au mineralization.

The third chapter makes a description of the regional tectonic setting of the circulation system. Hot spring Au deposits only occur in specific setting which can supply (1)space for large volume hydrothermal fluid to stay and circulate, ie.a complete set of fracture system, (2)dynamics to drive circulation of fluid, (3)enough water and heat sources, (4) enough ore material source, (5) enough time for ore formation. Exactly hot spring Au deposits are located in dilatant zones of convergent plate margins, and areas abundant with hot springs in continental subvolcanic basins. Tengchong– lianghe area is situated in the colliding zone of India Plate and Euroasia Plate. Plate movement have resulted in a complete set of fracture system in crust, basement and cover strata and structure modification to cause pressure – reduced space. thus dynamics to drive circulation is produced. Huge energe generated by the movement leads to various heat events (intrusion, eruption and the related high regional temperature at depth and near the surface) supplying heat source. Meteoric water and formation water penetrated down and magma water moved up along the fracture system together with the metamorphic water from the plate movement emerge to form water source. Volatiles, halagen and alkline elements from depth of the system evolved with the fluid can extract gold from wallrock and transfer it to the system, then control the enrichment and deposition. Thus Tengchong area is a prospect for hot spring gold deposits.

The fourth chapter analyses gold mineralization in the system. whether gold ore body is developed under hot spring group depends on incorporation of deep – circulated hydrothermal fluid into the epithermal fluid. Only can the deep – circulated fluid enrich gold to form ore bodies at certain positions in the system. Such fluid contains generally high values of gold which often acompanied by a group of elements in anomal content and strong gold mineralization appears in its resultant product.

During the project the group made a systematic investigation of main rocks regionally distributed and the various outcrops of Tengchong epithermal system, mainly concentrated on the quantitative comparison of 29 elements by which this book establishes geochemical associations, vertical zonations of indicating elements and statistical model of the element distribution. The results reveal clues of gold mineralization in upper part of the system, such as samples (more than 1mg / g) acounting for 7.66 of the whole samples with a general range of 1.06–5.02mg / g. Warm spring water has as high gold values as 5.2 times of average for the warm spring water in the world.

Au is in linear relation to Ag, As, Hg, Sb, Tl, alkline elements, halogen gold – carriers of B, $CO_2$and H_2S indicating that alkline elements, halogen and the gold – carriers played an importamt role in gold transportation and circulation within the fluid. Vertical zonation of Au and the related elements imply possibility of ore bodies at depth. Quantitative study shows that log values of gold is in good linear relation to times of explosion. Math model established is that explosion comes to seven times when gold deposited can be as high as 1.35mg / g. The result manifests not only that "boiling – self closing" is the enrichment mechanism for hot spring gold deposit but also that times of explosion can be used as a megscale marker for gold mineralization of a hydrothermal system.

The fifth chapter deals with metallogenic modeling. Models of description, regional setting, ore– forming process, gold resource assessment and spatial geometry are included. Volatiles, halogen and alkline elements stem from mantle or the lower crust. The lower zone of the hydrothermal fluid system is a high temperature–reduced environment which involves large volume of halogen, S(H_2S, HS^-, S^{2-}) AuS, AuCl complexed ions. The ions can balance the valence charge of alkline elements to keep activation, transportation and circulation of gold. In the process of boiling – self closing pneumatolysis of fluid turns most of H_2S to be gas released. To get further balance of the residual fluid $HS^-$is transfered to H_2S causing decomposition of Au complexec and deposition Sudden drop of temperature after pneumatolysis leads to SiO_2deposition in large volume. It is necessary to stress that only repeated boiling–self closing can make econmic Au ore deposits. The frequent structure activity and overpressure of fluid create dynamics for mobilization, circultaion and explosion. The author refer boiling to be the most possible enrichement and deposition mechanism of gold to all hydrothermal type deposits.

The second section is divided into three chapters.

The sixth is a gold resource assessment for I–scale hydrothermal system (ore field scale resouce) in Tengchong area. Deposit modeling and estimation modeling of total resource are applied to make a prediction for the area. 8 discrimination markers are used to make statistical comparison prediction of ore – forming prospect areas for III – scale hydrothermal system. The seventh is an assessment for the Rehai hydrothermal system (III – scale corresponding to ore deposit gold resource). The same methods are used as in the first to make the resource prediction. Locations of drilling are designed and depth at which ore bodies could be encountered is determined. The eighth analyses briefly the propect of hot spring type gold deposit in China. The tectonic settings in China are correlated to regional setting model of typical hot spring Au deposit in the world. Several areas are optimun in metallogeny for hot spring Au deposit. 8 ore–forming belts are picked out.

Models established in the book are based on data obained by many geological branches as well as those of the authors and many geologists and enginerrs give their hands to the authors in both of field and lab researches. Here, whole – hearted thanks are expressed to all of them, such as colleagues of the Comprehensive Scientific Expedition to the Qinghai–Xizang Plateau, the Chinese Academy of Scienes, 12th geological Team and Geothermal Team of Yunnan Bureau of Geology Kunming, Geological survy, professor Tu Guangzhi, Wu Yuebin, Li Wenda, Shen Baofeng, Zhou Chuanxin, Cun Gui ect. On addition to those, Li Yongming, Wang Zhenbin, Sang Muyuan and Dai Lijun translated the preface, contents, photo description and Li Yongming determined the version.

The authors are limited in their academic levels and experiences which must resul[illegible]rors in the book. Correction and critisizations are welcome.

目　录

CONTENT

第一篇　热泉型金矿床

第一章　绪　论

第一节　矿床模型法及其发展前景

一、矿床模型和矿床模型法

地球科学研究的中心课题之一，是如何适应人类对矿产资源的需求。大量统计资料表明，在人类社会发展进程中，随着人们对矿产资源需求量的不断增长，发现矿产的实际数量逐年增加，但距离人的聚居区较近的和近地表的矿产越来越少，找矿难度越来越大。为适应这一严峻的形势，一方面用于预测和找矿的新技术、新方法不断涌现。另一方面，预测和找矿工作越来越需要成矿理论的指导。在新形势下，各种找矿方法的地位发生了很大的变化：传统普查找矿方法的地位不断下降；物、化探方法的地位稳步提高；以类比为基础的地质推断法的地位大幅度上升，成了找矿工作中最重要的方法。尤其近年来，随着遥感地质、数学地质、电子计算机技术的应用，以及各种分析测试技术的提高，至今已经发展成为应用矿床模型来进行预测和找矿。该工作在研究对象方面，已经从单纯的矿石、矿床研究，发展成为整个成矿环境的研究。在方法和途径上，也从单一的地质信息研究，发展为地质、矿物、地球化学、地球物理、遥感地质、数学地质等多学科、多信息、多方法的综合研究。在研究深度上，正在从定性描述和经验推断向定量研究方向发展。

矿床模型法的理论基础是："一定类型的矿床具有一定的特点，并赋存于一定的地质构造环境中"。该方法把矿床模型作为预测和找矿的"标样"，通过评价区地质特征与矿床模型的相似性对比，对评价区进行定量、定位预测。不难看出，矿床模型法是一种类比的方法。

应用矿床模型法开展矿产资源评价和预测工作，包括下列三方面内容：

（1）建立矿床模型。

（2）评价区与矿床模型的相似性对比。

（3）矿床的定量、定位预测。

矿床模型是对一定类型矿床的矿体和矿产特征、围岩条件、成矿因素、成矿机制、成矿过程，以及矿床所处的三维地质构造环境的一种概括。是地质工作者对一系列同类型的已知矿床开展以控矿地质条件为重点的矿床特征及成因研究成果加以综合和提炼而建立起来的。矿床模型是应用矿床模型法对评价区进行预测时赖以类比的依据。不但能为地质类比或地质研究开拓思路，而且，对一定类型矿床而言，能够指出哪些地质、物理、化学资料和数据对矿石的产出是至关重要的。在一个具体的区域地质构造环境中，能指出应当找