

滇中砂岩铜矿地质

DIANZHONG SHAYAN TONGKUANG DIZHI

郭远生 罗荣生 等著

云南出版集团公司
云南科技出版社

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图书在版编目(CIP)数据

滇中砂岩铜矿地质 / 郭远生, 罗荣生等著. —昆明: 云南科技出版社, 2008. 12

ISBN 978-7-5416-3098-9

I. 滇… II. ①郭…②罗… III. 砂岩—铜矿床—采矿地质学—云南省 IV. P618.410.2

中国版本图书馆CIP数据核字(2008)第197354号

云南出版集团公司

云南科技出版社出版发行

(昆明市环城西路609号云南新闻出版大楼 邮政编码:650034)

云南国浩印刷有限公司印刷 全国新华书店经销

开本:889mm×1194mm 1/16 印张:15.5 字数:448千字

2008年12月第1版 2008年12月第1次印刷

印数:1~1000册 定价:68.00元

序

滇中红盆中的铜矿,是我国著名的典型的陆相红层中的砂岩型铜矿。半个世纪以来,云南省有色地质局对该红层中的砂岩铜矿从未间断过地质找矿、勘探和科研工作。特别是大姚六苴和牟定郝家河两矿床的开采,获得的大量地表无法获取的地质资料已被利用到地质找矿和科研工作中,取得的成果对以往矿床成因的认识有了很大的更新。该书的特点是以当代沉积盆地分析理论为指导,把滇中红盆形成和发展演化的三个阶段,即前陆盆地、断陷盆地和山间盆地沉积的黑色含煤建造、红色含铜建造和白色含膏盐建造及其组合联系起来,认为这三色建造是成矿的先决条件,为成矿奠定了物质基础;把成盆构造动力学、湖盆水动力学、盆地中油气热演化动力学和卤水环流动力学的分析和铜矿的成生联系起来;把层序地层学的理论和方法引入到陆相湖盆层序地层与金属矿关系的研究中,把红盆内厚逾万米的红色岩系划分为七个层序,对三个主要容矿宿主岩的地层岩石体系组合及其走势进行了较详细的探讨分析,认为由于盆地构造动力学的影响,形成盆内三个主要容矿岩层三维空间的良好圈闭系统,而铜矿化(体)主要赋存于各体系域湖侵层序中的早期沉积层内;这些都是成矿预测的基础工作,把它们和其他成果联系起来,就可圈定找矿的远景地段。该书重点讨论了矿床成因、成矿规律、找矿标志、找矿方法和找矿方向。作者在研究和总结上述问题时,把与成矿作用有关的沉积作用、构造作用、有机质作用、油气及其运移作用、水岩反应作用、卤水环流作用、盆地动力学等都看成是砂岩型铜矿在地壳演化某阶段表现出来的各个侧面,在研究矿床成因、成矿规律、找矿标志和找矿方向时,把各个侧面进行综合、统一的分析,将各种作用的过程和环节都与“砂岩铜矿”联系起来,把局部与全区、宏观与微观、现象与本质、地表与地下综合分析研究,这样就可对资料得出较为符合客观实际的解析和预测,推动砂岩铜矿的找矿和科研工作。

在盆地分析和统一地质场理论指导下,作者提出了滇中红盆砂岩型铜矿“断陷盆地、三色建造、浅紫交互、矿物分带、鱼头鱼尾、六位一体、卤水环流、后生成矿、一型三式、唯物辩证”四十字的综合找矿方法。这一多学科结合、研究的成果,观点新颖,研究思路正确,实际资料丰富,分析深入、准确,结论可信,为我国陆相红盆砂岩型铜矿的地质找矿科研工作又增添了一份重要的文献资料。相信它的出版定会受到地质学界的欢迎,受到生产部门的重视。值此专著付印之际,作序以表祝贺。

中国科学院院士:

刘宝珺
2008年7月15日

Preface

The copper deposits in the Central Yunnan red – basin are famous and typical sandstone – type copper deposits in China, which occur in continental – facies red – bed. In the past half a century, Yunnan Nonferrous Metals Geological Bureau has continuously conducted geological prospecting, deposit exploration and research work of sandstone – type copper deposit. Owing to the development of especially Liuju copper deposit in Dayao County, and Haojiahe copper deposit in Mouding County, large amount of sub-surface geological information about sandstone – type copper deposit has been obtained, and those information has also been applied to prospecting and research of sandstone – type copper deposit. The accomplished achievements have updated the recognition on the genesis of sandstone – type copper deposit. This book is characterized by guiding with modern theories of sedimentary basin analysis. The authors of this book think that the formation and evolution of the Central Yunnan red – basin can be divided into three stages, i. e. , foreland basin stage, fault basin stage, and intermountain basin stage, in which black coal – bearing formation, red copper – bearing formation, and white gypsum – bearing evaporate formation were formed. The authors also think that the above – mentioned three kinds of formations are prerequisite for sandstone – type copper deposits, i. e. , they have laid material foundation for ore – forming process. The authors have also studied the metallogenesis of sandstone – type copper deposit by analyzing basin – forming tectonic dynamics, lake – basin hydrodynamics, oil – gas thermal evolution dynamics in basin, brine circulation dynamics, and by introducing the theory and method of Sequence Stratigraphy into the research on relations between metal deposits and continental lacustrine basin sequence stratigraphy. They have divided the red – basin red – bed series with a thickness of over 10 000 meters into seven sequences. More detailed analysis and discussion have also been made on the association and trend of the stratigraphy and rock within three main host rock units, and the conclusion is that, owing to the influence of basin tectonic dynamics, good 3 – dimensional trap systems were formed in each main host rock unit, and copper mineralization (ore – bodies) mainly occur in early – stage sedimentary layer of lake transgression sequence. The above – mentioned recognitions are the base for metallogenic prognosis, and prospecting targets can be outlined when other prospecting evidences have also been taken into consideration.

This book mainly deals with deposit genesis, metallogenic regularity, prospecting criteria and target area selection for sandstone – type copper deposits. During the process of studying the above – mentioned questions, the authors have regarded sedimentation, tectonism, role of organic matter, oil – gas migration process, fluid – rock interaction, brine circulation and basin dynamics as different aspects of the metallogenesis of sandstone copper deposit in different stages of crustal evolution; have analyzed synthetically and unitedly all of those different aspects; have linked all courses and links of each kind of process with the formation of sandstone – type copper deposits; have linked part with region, macrosocsm with microscosm, phenomenon with essence, surface with subsurface. In fact, we have to do like that in order to obtain the explanations and predictions in accordance with objective reality, and to promote the prospecting and research of the sandstone – type copper deposits.

Under the guidance of modern theories of sedimentary basin analysis and universal geological process

field, the authors have proposed the integrated prospecting method for the Central Yunnan red – basin sandstone – type copper deposit with the key words of “Fault Basin, Three – colors Formation, Alternating of Light Color Bed with Purple Color Bed, Mineral Zoning, Ore – bodies Like Fish Head and Tail, Metallogenetic System Composed of Six Coupled Essential Factors, Brine Fluid Circulation, Epigenetic Mineralization, One Type Deposit and Three Styles of Mineralization, Materialistic and Dialectic”. This research achievement based on the study of multiple subjects, is new and original in viewpoint, right in research clue, rich in actual information, deep and accurate in analysis, and reliable in conclusion. This book is an important document for the prospecting and research of continental – facies red – basin sandstone – type copper deposits in China. I believe this book will be popular with geo – science circle, and exploration and mining branches will also pay attention to it. Before the publication of this book, I hereby write the preface to convey my congratulations to it.

Academician of Chinese Academy of Sciences: *Liu Baojun*

前 言

21 世纪是知识经济发展的时代,是一个经济和社会发展基于知识和科技创新的年代。我国经济社会高速发展,工业化进程加快的同时,矿产资源大量消耗,目前人们使用的 95% 以上的能源、80% 以上的工业原料和 70% 以上的农业生产资料都来自矿产资源。矿产资源仍然是人类生存的物质基础,所以保证矿物原料的充分供应是国家安全和经济社会稳定及可持续发展的关键。

在国外,砂(页)岩型铜矿,无论是历史还是现在,其储量和产量,均占有十分重要的地位。在 20 世纪 60 年代之前,其储量占铜总储量的第一位(占 51.4%)。60 年代之后,由于斑岩型铜矿的发现和开发,它才屈居第二位。我国砂(页)岩型铜矿分布也十分广泛,主要分布于云南、四川、湖南、广西、新疆、江西等十余个省区,并以云南规模最大。在时间上,从元古代到新生代均有产出。粗略统计,我国砂(页)岩型铜储量占整个铜储量的 3.2% 左右,而云南其储量却占全省铜储量的 18%~20%,主要分布于滇中红盆内,属易采选的优质矿石类型,所以总结滇中红盆陆相砂岩型铜矿成矿规律、找矿标志和指出找矿方向具有重要的理论意义和经济意义。

我局在 1977 年由刘昌辉等人编著出版的《砂岩铜矿地质》一书,是在滇中红盆开展砂岩铜矿地质找矿勘探初期(1971 年开始编写)所著,书中全面系统收集该历史阶段的找矿勘探和科研成果,从成矿地质条件、容矿岩石学特征、矿床地质概况、矿床成因和找矿勘探方法等方面进行了总结。无疑该书的出版对云南省乃至全国陆相砂岩型铜矿的地质找矿勘探起到了积极的推动作用。但随着地质找矿、矿床勘探和补充勘探工作的进行,特别是矿山开采和地质研究的进一步深入,勘探初期无法大量获取的深部地质现象和有关资料得以暴露和获取。这些资料的综合研究后认为,对以往的一些认识要深入、补充和修改(如三板斧中的水下地形)。正如叶连俊、李继亮教授审查《砂岩铜矿地质》一书时,在充分肯定该书成果基础上指出“……对滇中砂岩铜矿的认识并没有就此结束,而是开始了新的里程。我们还得在砂岩铜矿的地质勘探和成矿理论研究工作上不断地有所发现、有所发明、有所创造和有所前进,不断把工作推向新水平”。还认为“……从书中所列举的材料及所取得的成果来看,作者完全可以提出自己的完整的滇中矿床的形成理论,也恰恰是这一点上,我觉得本书应加以补充……”。20 世纪末原国家计委和地质矿产部联合相继开展了滇中红盆砂岩铜矿的“远景调查”和“成矿预测及靶区优选”为主要内容的第二轮^①、第三轮^②科技找矿项目,在地矿部组织验收和鉴定远景调查项目成果会上,与会专家认为:“该研究报告内容丰富、资料翔实、文图并茂、重点突出;对成矿背景、成矿条件及矿床地质特征的论述充分有据;远景预测依据较充分,可信度高,进一步肯定了滇中红盆砂岩铜矿还具有较大的找矿前景,是今后增长铜矿储量的重要类型和有利靶区;在成矿作用的认识上有了进一步的深化和新的进展,为在我国其他中生代陆相红盆中寻找同类型铜矿具有重要的借鉴意义。因此,与同类矿床的研究相比,从主体上达到了国际先进水平。”第三轮的“东川、楚雄地区铜矿成矿预测及靶区优选”项目的实施后,我局科委会在审查验收意见中写道:“研究报告运用新理论、新思路及先进的手段和方法,在大量新资料深入研究基础上进行了全面系统的总结与深化,

① 项目名称:康滇地轴及其西缘(滇中红盆)砂岩铜矿远景调查。

② 项目名称:东川、楚雄地区铜矿成矿预测及靶区优选(项目编号:JG9471906)。

内容丰富,资料翔实,图文并茂,观点有创新和发展,是目前云南砂岩铜矿的一份高水平的科研报告,就总体而言已达国际先进水平,同意验收上报。”在原国家计委和地矿部联合进行的该总结报告验收、鉴定会上与会专家认为:“报告资料齐全翔实、内容丰富、全面系统、重点突出、观点有创新、有发展,是我国砂岩铜矿方面高水平的研究报告,总体上达到了国内领先水平,建议修改补充后予以出版。”

据上述情况,云南省有色地质局局长郭远生在听取汇报后指出:要总结半个世纪来对砂岩铜矿的实践和认识。在原有基础上收集、补充近年来深部找矿的资料和研究成果,出版专著向局庆五十五周年献礼。

时已至此,本书就在上述两期科技找矿项目基础上,收集近几年危机矿山深边部找矿的新情况、新认识后修改、补充的。书中所引用资料除作者的研究成果外,其余均来自我局所属队、所,大姚、牟定两矿山和有关大专院校多年积累的资料,所以这本书的许多成果是集滇中红盆工作过的广大职工,特别是地学工作者集体智慧的结晶。应当说是集体的成果。

纵观全书,看点、想点和究点是:

1. 通过总结研究认为:滇中红盆位于扬子古板块西部边缘,西临古特提斯洋,属攀西裂谷的南延部分。攀西裂谷拉伸拗陷于海西早期,回返封闭于印支期。从广义上讲滇中红盆可视为攀西裂谷回返期产物,但又有其独特的发展演化过程。滇中红盆自晚三叠世至第四纪可划分为三个发展演化阶段,即前陆盆地、裂陷盆地和山间盆地阶段,经历了海侵海退、湖进湖退的变化,形成下部含煤建造(黑)、中部含铜建造(红)和上部含膏盐建造(白),人们简称为黑、红、白三色建造。这三色建造被视为滇中红盆砂(页)岩型铜矿成矿的先决条件,为成矿奠定了雄厚的物质基础,也是找矿的建造组合标志。所以滇中红盆中的砂(页)岩型铜矿可视为裂谷成矿系列的组成部分。

2. 书中首次在红盆砂(页)岩型铜矿地质找矿研究中引进了层序地层学的理论和方法,并将厚逾万米的红色岩系划分为七个层序地层系统,并对三个主要容矿宿主岩的地层、岩石体系组合及其走势进行较详细的探讨分析后认为:由于构造运动的影响,造成盆地内三个主要容矿岩层及其上(覆)下(伏)层系的层序地层系统沉积期处于湖进湖退的变迁,形成地层剖面结构上的山麓洪积相、河流相、河湖交替相和湖泊相的反复更迭,亦即形成三个主要容矿岩系(石)在三维空间上良好的圈闭系统。而铜矿化主要赋存于各体系域中湖进层序中的早期沉积层内,为找矿增添了新的标志。

3. 滇中红盆内的砂岩型铜矿床,既有共性又有个性,通过研究总结出“一型三式”的成矿模式,“一型”是共性,“三式”是个性。概括起来其过程大致是这样:在下部热能驱动和地质构造等动力的驱动下,下部含煤建造向上输送烃(裂)解物、单环烷族等有机络合物与上部含膏盐建造淋滤下渗和地层中的卤水共同对含铜建造岩石进行长期的水岩反应,形成含矿热卤水循环系统,最终在断褶构造动力的沟通和影响下,结果在向斜构造中的湖滨相、河湖交替相中的细砂岩、含砾砂岩、砾岩和粉砂岩中形成顺层稳定的大村式砂(砾、页)岩铜矿床;在大雪山背斜倾伏端部位的河流相中的中细粒砂岩、含砾砂岩中形成富、厚、大的六苴式铜矿床;在河湖交替相、河流相中的中细粒砂岩,含砾砂岩和断裂带、复式背斜之次级小断褶带中形成改造强烈的郝家河式砂岩铜矿床。故含铜的油田热卤水环流方式在不同的岩相带和不同的构造部位形成大村式、六苴式和郝家河式的整个矿床模式,我们称之为滇中红盆砂岩型铜矿的“一型三式”成矿模式。在成矿作用的认识上有了进一步的深化和新的进展,在我省我国其他陆相红盆中寻找同类型铜矿具有重要的借鉴意义。

4. 滇中红盆红色岩系中浅色体(层)的成因及其与铜矿体的关系,是砂岩铜矿极为重要而地质工作者都十分关切、苦思和不断研究的难题。盆内砂岩型铜矿体(床)均产出于浅紫交互

带靠浅色层一侧,表现出铜矿化与岩石颜色有十分密切的亦步亦趋的依存关系。因此,研究浅紫岩石产出的类型、特征及成因就成了寻找砂岩铜矿的关键问题之一,因为它关系到矿体的圈定、连接、矿床的评价和砂岩铜矿的寻找和预测。根据浅色体(层)产出的特征,本书从成因上把浅色层(岩石)划分为同生沉积成因、成岩成因和改造成因三大类型。在此基础上,结合赋存于浅色体中的矿床地质特征,把改造型浅色体进一步划分为面型、带型和混合型三种浅色体,而与其相对应的矿床类型亦为大村式、六苴式和郝家河式铜矿床,我们称之为滇中红盆砂岩型铜矿“一型三式”的综合成矿模式。这样看起来比较符合客观实际,想起来也可能是这个理,考究起来也较能经得住推敲。

5. 盆地动力学的提出和应用:滇中红盆自形成至结束,经历了印支、燕山、喜山三期构造运动,并产生了巨大的影响,对盆地的形成和演化中起着决定性的控制作用,同时也对砂(页)岩型铜矿的成生起着直接和间接的作用;盆地动力学从成盆前、成盆期、盆地萎缩和成盆后的动力学分析认为:盆地的构造格局是基底控制盖层、盖层继承基底,成盆前控制成盆期,成盆后部分继承、部分改造了成盆期构造,形成盆地构造上的多期活动、多方向构造继承复合叠加格局;湖盆水动力学着重分析研究早、晚白垩世水动力学特征,认为白垩世湖盆水动力的变化是随盆地及其周边的构造升降强度、幅度、水流注入方向、湖盆水面升降、气候的变化而改变的。一般早期动力较强,中期时强时弱,而晚期则处于停滞、静止蒸发至最后消失;盆地中油气热演化动力学,研究分析了烃源岩热演化与气化和矿物流体包裹体的特征之后认为,盆内砂岩铜矿的分布,不但与有利的成油、成气带有空间上的联系,而且与含铜热卤水的形成、运移、淀积的作用中,也有不容忽视的直接成因联系;卤水环流动力学,从卤水的来源、性质及其环流系统和动力研究分析后认为“牟定斜坡”和渡口—大姚—南华及姚安前场—郝家河两条隐伏断裂的结合是形成团山—六苴—郝家河—石板河弧形矿集带的重要原因,这就是滇中砂岩铜矿形成的最佳时空耦合。因此,在滇中红盆内寻找砂岩铜矿,该带是最有远景的矿化集中带。

6. 在找矿标志和找矿方法之后,增写了与找矿标志和找矿方法既有密切联系,又有明显区别的“找矿方法问题的探讨研究”,它是我局半个世纪以来在砂(页)岩铜矿地质找矿勘探中的经验和教训的总结。说它与找矿标志有联系,是因为它所讨论和要解决的问题都要应用找矿标志。说它有区别,是因为单纯应用某项或若干项找矿标志又难于直接解决的问题。它要求地质工作者根据暴露的地质现象和掌握的相关资料(包括全部的找矿标志),遵循认识的规律,从已知到未知,从现象到本质,由表及里,由点到面去探寻和研究才能得出比较接近客观实际的认识。说它不同于一般的找矿方法,是因为它涉及到对所讨论方面的认识问题,而认识问题又是需要通过充分的讨论才能达到统一,通过实践才能证实的,从这个意义上讲,它又是找矿标志和找矿方法的补充,所以说它又是找矿标志和找矿方法的升华。

7. 全书以刘宝珺院士提出的统一地质作用场理论为指导,把与砂(页)岩型铜矿成矿作用有关的沉积作用、构造作用、有机质作用、油气运移作用、水岩反应作用、卤水环流作用、盆地动力学作用等都看成是砂(页)岩铜矿在地壳演化某个阶段表现出来的各个侧面。这就使我们在研究分析砂(页)岩铜矿成生过程中,把上述各个侧面综合统一考虑,把各种作用的过程和关联与“砂岩铜矿”四个字联系起来,从宏观到微观、从现象到本质、从局部到全区、从地表到深部进行综合分析,这样就可能得出较符合客观实际的解释和预测,推动砂(页)岩型铜矿的地质找矿和预测。

8. 书中在研究和探讨了找矿标志、找矿方法和滇中红盆砂岩铜矿时空配置结构之后,指出了在滇中红盆中寻找砂岩铜矿的“时间和空间”的方向。在时间上:盆地从侏罗纪至第三纪地层中有16个含铜层位,几乎遍及中生代到新生代岩系的每一个层位,但又不是凡有这些层位出露的地方都有铜的工业矿化(体)。工业矿化特别是中大型工业矿床,只局限在白垩系凹地苴

段、六苴段和大村段三个层位中。据统计,这三个主要含铜地层的厚度和只占红盆红色岩系厚度的1.16%,而这三个段地层中探明的铜金属却占全红盆探明铜金属量总和的93.72%;在面积36 000平方千米的红盆内,白垩系地层出露地层面积约占红盆总面积的42.78%,而白垩系地层中探明的铜金属储量约136万吨,占红盆探明铜金属总量的94.34%;在空间上,距元谋古陆10千米至30千米的盆地范围内,从北至南,即由团山—六苴—郝家河—石板河的弧形矿集带,南北长165千米,东西宽24千米至36千米,面积约5 000平方千米,占红盆总面积的13.88%,该带内已知矿床(点)145处,占全盆地矿床(点)总数的54%,盆内4处中型以上的矿床和绝大部分小型矿床均分布在该带内。带内探明铜金属总量的134.6万吨,占全盆地探明铜金属的93.47%。上述情况表明红盆内的砂岩型铜矿床具有十分明显的“时控和空控”,为今后找矿指明了“时间和空间”。

9. 关于“三板斧”的问题:所谓找矿“三板斧”,简而言之是指浅紫交互、矿物分带和水下地形。其内涵是指砂岩铜矿赋存于容矿岩石中的浅(色)紫(色)交互带靠浅色层一侧;组成砂岩铜矿体(床)中的矿石矿物存在矿物分带现象;砂岩铜矿体赋存于容矿地层沉积期相对凹陷的部位。在半个世纪的实践过程中证实浅紫交互和矿物分带是砂岩铜矿找矿中的两把“利斧”。找矿勘探初期借鉴国外砂(页)岩型铜矿的地质资料和找矿经验认为滇中红盆内的砂岩铜矿赋存于湖相地层中,为了寻找湖相地层沉积期能有硫化铜矿物淀积的地球化学条件环境,水下靠低洼的地形也就很自然地“浮出水面”(作者也是当年的实践者和总结三板斧的参与者)。到20世纪70年代,我局与原成都地质学院刘宝珺院士、余光明教授、张锦泉教授等合作,对红盆中砂岩铜矿的赋矿围岩进行沉积相与砂岩铜矿关系等方面的研究,大量的资料和成果证实^[8,31],盆内砂岩铜矿赋矿地层是河流相,河湖交替,而不是湖泊相。河流和河湖交替环境不可能有硫化铜淀积的地球化学条件,更不可能有几万吨、几十万吨铜金属淀积的环境。因此“三板斧”中的第三板——水下地形也随实践证实是一把“废斧”。这也就是作者在书中提及的,在地质找矿实践中要辩证唯物论的、坚持实践是检验真理的唯一标准这一原则,对前人(包括自己)总结的认识或规律,要在实践中经受检验,证实凡是符合客观地质实际的是可行的可用的,凡是不符合客观地质实际的,要敢于摒弃,这就是在实践中要敢于否定“前人”也要敢于否定“自己”。在实际工作中践行科学发展观。

10. 在找矿标志中提出:“层、岩、相”标志,意在滇中红盆中寻找砂岩铜矿,首先要在盆内找到白垩系凹地苴段、六苴段和大村段三个主要含矿层位,其次是在这些层位中寻找浅紫交互带中的浅色中—细粒长石石英砂岩、含砾砂岩,最后利用原生沉积构造进一步确认这些砂砾岩是否属河流相、河湖交替相。在此基础上提取矿化信息后,即有可能找到铜的矿化或工业矿化。研究发现,岩相古地理不仅控制着沉积层状矿床的形成和分布规律,而且也制约着许多层控金属矿床的形成和富集。这里要说明的是:在滇中红盆中并不是凡有河流相、河湖交替相的浅色砂(砾)岩中都有铜的工业矿化;在河流和河湖交替环境下,不可能有硫化铜沉积的地球化学条件,更没有淀积几万吨、几十万吨铜金属的地球化学环境;换句话说,不是岩相古地理条件控制着滇中红盆砂岩铜矿的形成和分布规律,而是滇中红盆中的砂岩铜矿的成生选择了有利的岩相条件,因为控制矿质富集的物理化学因素与一定的地质环境有关,一定的古地理环境不仅控制了同生期地质、物理化学条件,而且在沉积物埋藏之后,仍能在沉积物(岩)中产生一种或数种有利于矿质聚集的溶液的地球化学环境和障壁,这就是沉积期后形成的层控金属矿床也与一定的岩相古地理有密切关系的重要原因。

作者从滇中红盆中层控砂岩铜矿岩相古地理条件的研究中联想到研究以沉积岩为宿主岩的层控金属矿产的岩相古地理条件,如同研究沉积层状金属矿产中岩相古地理具有同等重要的意义,为寻找以沉积岩为宿主岩的层控金属矿床拓宽了思路,拓宽了找矿空间。

11. 本书对滇中红盆的砂(页)岩型铜矿,提出了“断陷盆地、三色建造、浅紫交互、矿物分带、鱼头鱼尾、六位一体、卤水环流、后生成矿、一型三式、唯物辩证”四十字的综合找矿方法。这也要在今后地质找矿、科研工作中接受实践的检验、补充和修改。

12. 关于“硅桥”的问题,书中提及在矿体前端或尾端,即“鱼头”、“鱼尾”部位,常见容矿岩层延展的无矿岩石中,见较多无规律可循的石英脉穿层或沿层理产出,一线地质工作者称之为“冷水石英脉”。作者提出,通过进一步工作,它可能是近矿的找矿标志。曾与丁悌平研究讨论过这一问题,丁悌平研究员曾提出是否可以“利用硅同位素的研究,帮助解决石英脉中的硅源问题”。作者也曾对凹地苴矿床、六苴矿床中的这类石英脉及矿体和矿体上(覆)下(伏)岩层采过硅同位素的样品,欲求解决石英脉中硅源和含矿热卤水循环体腔和相关成分的问题,以便进一步探求砂岩铜矿后生成因的另类证据和正式提出该石英脉可作近矿的找矿标志的理论依据。由于种种原因,这一工作未能如愿,在此提出来,希望来者去想、去究。

13. 在国外砂(页)岩型铜矿,占有十分重要的地位。据王少波统计,砂(页)岩型铜矿的铜储量占各类型铜矿总储量的31%,开采的铜也有20%来自此类矿床,其主要产地为非洲的赞比亚—扎伊尔铜带,前苏联的乌多坎铜矿和美国的怀特派恩铜矿等。我国砂(页)岩铜矿分布也十分广泛,其储量占铜总储量的3.2%。而云南省的砂(页)岩铜矿的储量占全省铜总储量的18%~20%,主要分布在滇中红盆其次是兰坪—思茅红盆。国外的这类铜矿主要赋存于海相碎屑岩、泥灰岩中,而我国目前所知主要赋存于陆相碎屑岩中。我国幅员辽阔,成矿条件多种多样。在云南省的易门、东川地区的元古代因民组地层中有砂岩型铜矿点,震旦统陡山沱组中有陆源沉积的滥泥坪中型铜矿床。该类矿床东起东川的汤丹,向西至牛奶厂—滥泥坪—石将军—九龙一带均有分布^[2];滇中玉溪地区震旦系下部和底部澄江砂岩中有多个铜矿点,滇西丽江地区、滇东北和滇东地区的三叠纪地层中也有砂岩型铜矿点多处。上述各铜矿点多赋存于海相地层中。涂光炽院士曾在地化专刊中撰文:青海省兴海县在海相地层中有砂岩铜矿床,其中鄂拉山地区的兴海县铜峪沟铜矿床为大型,赛代塘铜矿床达中型。李大民等报道甘肃省天鹿志留纪海相地层中赋存有砂岩铜矿。在长13千米,宽2.5千米范围内,有十多个矿化层位。矿体规模悬殊,长一般在50厘米至600米,最长达6130米,厚0.1米至3.5米。平均品位0.2w%至1.21w%。矿体出露高差达670米。上述表明在我国寻找砂(页)岩型的铜矿有广阔的前景,在继续寻找陆相砂(页)岩铜矿的同时,要着力寻找海相砂(页)岩、泥灰岩型铜矿,在现有资料不多的情况下,借鉴国外找矿的经验和运用同类型铜矿的成矿规律和找矿方法,特别是岩相古地理的研究,根据矿产伴生关系注意综合找矿,一旦突破一点,前景是比较乐观的。

14. 为了让读者了解云南省砂(页)岩型铜矿概况,在书的后记部分简略地介绍了全省砂(页)岩铜矿情况。其目的是让读者看了《滇中砂岩铜矿地质》之后,就想着在云南38.3万平方千米范围内有494个砂(页)岩铜矿点,其中有63.56%的矿点尚未作较深入的地质工作,从而考虑着这300多个矿点中哪些还值得进一步工作。为此我们在编写本书的同时,也把数百个砂(页)岩铜矿点汇编成卡片(另册,内容包括矿点位置,容矿地层名称及时代,矿化特征、矿石矿物、远景评价和工作程度等),供读者使用参考。

在编写本书过程中,我们力求做到对地质资料的收集齐全或比较齐全,分析准确或比较准确,既要承前启后,又要避免材(资)料的重复堆砌,尽可能做到立论要有据,逻辑推理要适度。但由于作者水平不高,加之时间仓促,书中会有缺点、错误,请读者批评指正。

全书共分七章:其中第一章由郭远生、豆松、张红英、徐金祥执笔;第二章由罗荣生、张道红、李伟中、贺胜辉执笔;第三章由郭远生、陈明伟、俞国芬、张淑芸、王维贤执笔;第四章由王维贤、贺胜辉、张淑芸、张红英执笔;第五章由罗荣生、俞国芬、王维贤、贺胜辉执笔;第六章由张道红、罗荣生、郭远生、王维贤执笔;第七章由徐金祥、张道红、罗荣生、王维贤执笔。

全书由郭远生、罗荣生、王维贤汇总编纂。

同时，在本书的编写过程中，我们还得到了局领导和各处、室同志的大力支持和帮助，使本书能够顺利完成。在此表示衷心的感谢！

应特别提出的是：本书初稿出来之后，承蒙任祖传高工进行初审，并提出了宝贵的修改、补充意见；在编写过程中一些重大问题又常与郑庆鳌高工讨论；书中序和前言由豆松高工翻译、吴鹏博士校审；书中照片是由梁秉强高工帮助拍摄；初稿插图、附表和有些文稿打印由张淑芸高工及张红英、俞国芬两位工程师完成，在此一并致谢！

Foreword

The 21st century is an era in which knowledge economy develops, and economic and social development depends on knowledge and innovation of science and technology. With the rapid development of economics and society, and the speed – up of industrialization process in China, large amount of mineral resources has been consumed. At present, more than 95% of energy, 80% of industrial raw material, and 70% of agricultural means of production come from mineral resources. Because mineral resources is still the material base for human existence, it is key for national security, economic and social stability, and sustainable development to guarantee the sufficient supply of mineral resources.

The reserves and production abroad were, and are still of high position. The reserves of sandstone (shale) copper deposits ranked first (accounting for 51.4% of total copper reserves) before 1960s, and second after 1960s owing to the discovery and exploitation of porphyry copper deposits. In China, sandstone (shale) copper deposits are widely distributed, mainly in Yunnan, Sichuan, Hunan, Guangxi, Xinjiang, Jiangxi, etc., and Yunnan ranks first in terms of deposit scale. They occur in rocks of from Proterozoic to Cenozoic. According to rough statistics, the reserves of sandstone (sandshale) copper deposits accounts for about 3.2% of total copper reserves in China, and 18% ~ 20% in Yunnan. Sandstone copper deposits are chiefly distributed in Central Yunnan Red – basin in Yunnan, belonging to high quality ore which is very easy for mining and dressing. So it is of important theoretical and economic significance to summarize the metallogenic regularity, prospecting criteria and prospecting direction of continental – facies sandstone copper deposit in Central Yunnan Red – basin.

The book of *《Geology of Sandstone Copper Deposit》* published in 1977 were compiled by Liu Changhai et al. with Yunnan Nonferrous Metals Geological Bureau. The authors began compiling the book since 1971, at the initial stage of prospecting for sandstone copper deposit in Central Yunnan Red – basin. On the basis of overall and systematically collecting the achievements of prospecting and exploration, and scientific research, they summarized ore – forming geological conditions, characteristics of ore – hosting rocks, deposit geology, deposit genesis, and prospecting method, and so on. No doubt, the publication of that book had played a positive pushing role in prospecting and exploration of continental – facies sandstone copper deposit in Yunnan and even in China. However, with the development of geological prospecting, deposit exploration, and deposit supplementary exploration, especially the progress of mining and the deepening of geological research, a lot of deep – seated geological phenomena and relevant information that could not be observed or acquired in initial exploration stage, had been exposed or acquired. So the formerly understandings (for example, underwater topography was once believed to be one of the three key ore – control factors) need to be deepened, supplemented, or modified. Just as Professor Ye Lianjun and Li Jiliang said in the preface of *《Geology of Sandstone Copper Deposit》*, “the understandings on sandstone copper deposits in Central Yunnan don’t end with this book, but begin a new course; We need to make more new discovery, invention, creation and progress in the work of geological exploration and metallogenetic – theory research of sandstone copper deposit, and continually push the work to a new high level.”, and “Judging from the data and accomplished achievements listed in the book, the authors absolutely could have come up with a complete metallogenic theory on sandstone copper deposits in Central Yunnan, so the book should be supplemented in future.”

In the end of last century, "State planning commission" and "Ministry of Geology and Mineral Resources" united to conduct the second round and the third round prospecting projects, the chief working contents of which are "prospective survey" and "metallogenic prognosis and target optimization" of Central Yunnan Red - basin sandstone copper deposit. At the meeting (organized by the Ministry of Geology and Mineral Resources) of checking and appraising the achievements of "prospective survey project", the experts present said: "the research report is rich in contents, full and accurate in data, outstanding on key points, excellent in both pictures and literary compositions; is full and with good grounds in expounding metallogenic setting, ore - forming conditions, and deposit geology; the prospective prognosis is relatively ample in foundation, and high in reliability, further affirming that the prospects of prospecting for sandstone copper deposits in Central Yunnan Red - basin is good, and sandstone copper deposit is an important type of copper deposit, Central Yunnan Red - basin is a favorable prospecting target in the future; new progress and further deepening have been made in the aspect of understanding of metallogenesis, which is copper mineralizing and very useful for finding same type copper deposits in other Mesozoic continental red - basins in China. It achieved international advanced level." After conducting project of "Copper Deposit Mineralizing Prediction and Target optimization in Dongchuan and Chuxiong", Science and Technology Committee of Yunnan Nonferrous Metals Geological Bureau said "The report gave us new theories, new method to summarize perfectly mineralization with rich information, real data, illustrations and innovative opinions. It was a advanced level research report on sandstone copper deposit in Yunnan and achieved international advanced level". On the meeting, Guo Yuansheng, director of Yunnan Nonferrous Metals Geological Bureau, indicated that it is necessary to summarize the opinions and practices on sandstone copper deposit in past half century and compile monograph for the 55th anniversary of the bureau.

Nowadays, based on the results of two prospecting projects conducted in the past 50 years, this book was edited by modifying and renewing new information and ideas collected from exploration of crisis mines. All information used in the book, besides research results of author, came from geological teams and institutes of Yunnan Nonferrous Metals Geological Bureau, Dayao copper mine, Mouding copper mine and academies, so it was a crystallization of the collective wisdom of bureau's employee, especially geologists, whose worked in the Central Yunnan Red - basin.

In this book, the important opinions were following:

1. The Central Yunnan Red - basin located at west edge of Yangtze paleo - plate, faced Paleo - Tethys ocean in the west and belong to southern part of Panxi Rift. The Panxi Rift tensiled and depressed in early Hercynian Epoch and closed in Indo - China period. Generally, the Central Yunnan Red - basin could be considered as production at return stage of Panxi Rift but it had its special process of development and evolution. The basin could be divided to three stages that were foreland basin, rift basin and intermountane basin, those experienced the movement of transgression - regression, aggression and withdraw of lake regression. It formed lower Coal - bearing Formation (black), middle Copper Formation (red) and upper Evaporite Formation (white) simply called Three Color Formation that was considered as pre - condition of mineralization of the basin Copper Deposit. It provided material base for mineralization and combinatorial indicators of prospecting from late Triassic Period to Quaternary Period, so the Central Yunnan Red - basin Copper Deposit was the part of rift mineralizing series.

2. It is the first time to use the theory and method of sequence stratigraphy to research prospecting on red - basin sandstone copper deposit, divide red - rock system, 10 to 7 sequence systems, discuss on the combination and their trend of three main sequence systems with ore hosted rock. It considered that sedi-

mentary stage of three main stratum and their overlying and underlying stratum was transitional stage of lake transgression and lake regression in the basin, formed rock systems alternated of torrential facies, fluvial facies, stream – lake alternated facies and lacustrine in stratum profile and also formed good trap system in three – dimensional space. The copper mineralization hosted early sedimentary rocks of lake transgression sequence in each stratum system and that was new indicator for prospecting.

3. Central Yunnan Red – basin Sandstone Copper Deposits have both generality and individuality. Its metallogenic model is summarized as “ One Type and Three Styles”, of which Type is generality, and Style is individuality. The metallogenic model can be generally explained as follows: lower coal – bearing Formation transferred organic complex of hydrocarbon products and single cycloparaffin up by driving of deep heat energy and geological tectonic movement, with brine in the stratum and leached down from upper Gypsiferous Formation, then made water – rock reaction and formed hot ore brine circle system, with influence of power of faults and folds movement, finally formed stable and bedding Dacun Style sandstone copper deposit hosted at fine sandstone, gravel sandstone, conglomerate and siltstone of lake – shore facies and stream – lake alternated facies in synclines, rich – thick – large Liuzuo Styles sandstone copper deposit hosted at middle – fine sandstone and gravel sandstone of stream facies in plunging part of Daxueshan anticline and hardly changed Haojiahe Style sandstone copper deposit hosted at middle – fine sandstone and gravel sandstone of stream – lake alternated facies and stream facies and located at fault zones and sub – folds of multiple anticlines. It was a new progress on understanding of copper mineralization and very useful and important to find same style copper deposit in other continental red – basins.

4. The relationship between copper deposit and the cause of gray bed in red rock system at the – basin was very important to sandstone copper deposit. The ore bodies of sandstone copper deposit in red – basin all occurred at gray side of gray – purple alternated zone that showed very close relationship between copper mineralization and colors of rocks, so the research on characters and cause of gray and purple rocks became one of keys for prospecting sandstone copper deposit because it was related to ore – bodies, evaluation of deposit and prospecting. Based on characters of gray beds occurred, the author divided gray beds to three types of syngensis, diagenesis and alteration according to their causes, then combined the characters of deposit hosted in gray strata, further divided gray strata of alternation type to three styles of cover, zone and commix that comparatively hosted Dacun Style sandstone copper deposit, Liuju Style sandstone copper deposit and Haojiahe Style sandstone copper deposit, called metallogenic model of “ One Type and Three Styles” of the Central Yunnan Red – basin Copper Deposit. The model awords with facts.

5. Used basin dynamics to explain that the Central Yunnan Red – basin experienced Indosinian Movement, Yangshan Movement and Himalaya Movement which controlled the form and evolvement of the basin and effected mineralization of sandstone copper deposit. By dynamics analysis, considered basin structure was that basement controlled capping bed and capping bed come to basement, structures before basin formed controlled structures in stage of basin formed, structures after basin formed partly inherited and rebuild structures in stage of basin formed, produced structure system consisted of multiphase activity and multi – direction structures inherited, composite and superimpose. Lake – basin hydrodynamics mainly analysed hydrodynamic characters in early and late Cretaceous Period and considered that the hydrodynamic change of lake – basin was related to the intension and extent of tectonic movement at basin and its close area, direction of stream flowed, change of lake – basin surface and climate change in Cretaceous Period and the hydrodynamic power commonly was strong in early, sometime strong and sometime weak in middle and stagnant, still, vaporized and disappeared finally in late. Used oil – gas thermal dynamics in the basin to discuss the characteristics of heat evolvement and gasification of hydrocarbon rock and miner-

al hydro - inclusion, then thought that the distribution of sandstone copper deposit in basin was related to advantageous zones of gas and oil formed in space and also directly related to the producing, movement and settlement of hot brine with copper in cause. Brine circumfluence dynamics conducted the discussion on source and character of brine and its circumfluence system and motivity, then considered that combined zones of Mouding Incline with two buried faults of Dukou - Dayao - Nanhua fault and Yaoan - Qianchang - Haojiahe fault were important area of forming Tuanshan - Liuju - Haojiahe - Shibanghe mineral concentration arc zone which is best one for prospecting sandstone copper deposit in the Central Yunnan Red - basin.

6. Following section of criterias and methods of Prospecting, added section of Discussion on criterias and methods of Prospecting and was summarizing on experiences and lessons for Yunnan Nonferrous Metals Geological Bureau carried out prospecting and exploration works on sandstone copper deposit since the half of century. The relationship between Discussion on Prospecting methods and prospecting criterias was that it had to use the prospecting criterias, and difference was that only used one or some criterias to resolve problem was very difficult, so geologist had to basing on geological information exposed and related data (including all prospecting indicators), following geological rules known, from phenomenon to essence, from surface to inside, from point to cover for discussion and research, then could got the ideas that was close to the fact relatively. Discussion on Prospecting methods was quite difference with common prospecting means because that referred to ideas which could be achieved by fully discussion and proven by practice, so it was complementarity and sublimation to criterias and methods of Prospecting.

7. Under the theories of unitive geological process field put forward by academician Liu Baojun, the author thought sedimentary processes, tectonic processes, organic processes, oil - gas movement, water - rock reactions, brine circumfluence processes, basin dynamics related to mineralizing process as different sides of sandstone copper deposit put up in different stage of crustal evolution. When we discuss mineralizing process of sandstone copper deposit, we can synthetically and uniformly analyse all sides above and connect all processes with sandstone copper deposit from macro - data to micro - data, phenomenon to essence, local to global, surface information to underground information, then can explain and predict the information in accordance with the facts and promote prospecting and prediction works on sandstone copper deposit.

8. After studying and discussion on marks and methods of prospecting and investigation of allocation structure in space and time of sandstone copper deposit in Yunnan, the author indicated the way of sandstone copper deposit prospecting at the basin in Time and Space. For Time, there were 16 copper stratum from Jurassic Period to Tertiary Period, almost covered each strata from Mesozoic Era to Cenozoic Era, but did not exist always industrial copper ore - bodies in these stratum exposed. Industrial copper ore - bodies, especially large scale deposits, only occurred at Wadizuo Member, Liuju Member and Dacun Member of Cretaceous. By statistic data, the area of Cretaceous strata exposed was 42.78% of whole red - basin area of 36 000 km², but the copper metal reserves proven at Cretaceous strata was about 1 360 000 tons that was 94.34% of total copper metal reserves proven in the basin and the thickness of three copper stratum of Cretaceous system was 1.16% of thickness of whole red rock system in the basin, but the copper metal reserves proven at these three stratum was 93.72% of total copper metal reserves proven in the basin. For Space, the area in the basin scope around Yuanmou ancient land from 10 km to 30 km, that was Tuanshan - Liuju - Haojiahe - Shibanghe mineral concentration arc zone, 165 km long in South - north and 24 to 36 km wide in east - west, with area of 5 000 km² was 13.88% of total red - basin area, there were 145 mineral occurrences, included 4 middle - large scale deposits and most small

scale deposits, that was 54% of total occurrences in whole red – basin, and copper metal reserves proven in the zone was 1 346 000 tons that was 93.47% of total copper metal reserves proven in the basin. It shows that sandstone copper deposit in red – basin had obvious characteristics of Time and Space Control which point out the way of Time and Space for further prospecting.

9. The idea of Three features, gray – purple zone alternated, mineral zoning and underwater landform, meant that sandstone copper deposit occurred at gray side of gray – purple zone alternated in hosted rocks, there were mineral zoning in ore – bodies of sandstone copper deposit and the ore – bodies of sandstone copper deposit located at depression of hosted strata in their sedimentary stages. The prospecting practice had proven that features of gray – purple zone alternated, mineral zoning were two sharp axes in past half century. In the early of exploration on sandstone copper deposit, it was considered that sandstone copper deposit hosted at strata of lacustrine using geological information and prospecting experiences on sandstone copper deposit over the world, so cupped area of underwater landform became a geo – chemical condition (environment) for sediment of sulfide copper minerals in the sedimentary stage of lacustrine strata (the author was participant summarizing the idea of Three features). At the early 1970's, the Bureau made cooperation with academician Liu Baojun, professor Yu Guangming and Zhang Jinqian from primary Chengdu Geology College to research sandstone copper deposit relationship on sedimentary facies of hosted rocks of sandstone copper deposit and then lots of datum and results proven that hosted strata of sandstone copper deposit were fluvial facies and stream – lake alternated facies which did not exist geo – chemical condition for sulfide copper sediment with several ten thousands or hundred thousands tons of copper metal but not lake facies and it was proven that the third features, underwater landform, was a useless by practice. So in the book, author said that we had to persist in materialistic dialectic and the rule of Practice is Aalone Standard for Checking Truth, all ideas or rules summarized by former person (included ourself) had to be proved by practice, it was available and useful to all things proven were accordant to facts and we had to be dare throwing away all things proven were not accordant to facts, that was dare to negate Primary Person and Self in practice and practice Scientific Development Conception in the work.

10. In the prospecting criterias, Strata, Rocks and facies meant that firstly found three main copper hosted strata of Wadizuo member, Liuju member and Dacun member, secondly found gray fine – middle feldspathic sandstone and gravel sandstone in gray – purple alternated zone and finally confirmed the rocks were products of fluvial facies and stream – lake alternated facies, then mineralizing information was acquired and it was possible to find copper mineralization or copper deposits. The research showed that lithofacies – paleogeography controlled forming and distributing of sedimentary bedded deposit and also restricted forming and concentrating of many metal stratabound deposits. Specially explained that did not all exist industrial copper mineralization in all gray sandstone (conglomerate) of fluvial facies and stream – lake alternated facies in the basin, under the stream environment and stream – lake alternated environment, it was impossible to exist geo – chemical conditions for sediment of sulfide copper minerals with several ten thousands to hundred thousands tons copper metal. In other word, it was not the conditions of lithofacies – paleogeography controlled forming and distributing of Dianzhong Red – basin sandstone deposit, but sandstone deposit choose advantageous lithofacies conditions for sediment. Because the physical and chemical factors made mineral materials concentrating must be related to their geological environments, one paleogeographic environment controlled its geological, physical and chemical conditions of same stage and could create the geochemical environment and boundary that could form one or several kind of solutions were useful to concentrate mineral materials in sedimentary rock after the sediments bur-