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荣誉证书

侯泉林同志：

在教育教学工作中成绩优异，授予北京市优秀教师称号。

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2022 年 9 月

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为了表彰 科学技术 出贡献，特决定发给政府特殊津贴并颁发证书。

您为发展我国事业做出的突

中华人民共和国国务院

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二〇〇五 年 八月 十 日

政府特殊津贴第(2004)481007l号

NO.Z 000083

河南省自然科学奖

证　书

为表彰河南省自然科学奖获得者，特颁发此证书。

项目名称：构造煤超微结构演化及甲烷吸附的变质变形机理

奖励等级：贰等奖

获 奖 者：侯泉林

河南省人民政府

2020年1月16日

证书号：2019-Z-012-R02/07

河北省科学技术奖

证 书

为表彰河北省科学技术奖获得者，特颁发此证书。

项目名称：幔枝构造与资源环境（幔枝构造与成矿规律找矿方向研究）

奖种类别：科技进步奖

奖种等级：一等

获 奖 者：侯泉林

二〇一一年[illegible]二十八日

2011 年度. 证书号：2011JB1017-6

为表彰在促进科学技术进步工作中做出重大贡献，特颁发此证书。

获奖项目：煤层气能量动态平衡系统及其控藏效应

获 奖 者：侯泉林(第6完成人)

奖励等级：自然科学奖二等奖

奖励日期：2015年2月

证 书 号：2014-083

中华人民共和国教育部

二〇一五年二月九日

安徽省科学技术奖

证　书

为表彰安徽省科学技术奖获得者，特颁发此证书。

项目名称：构造变形煤储层特征及地质控制机理

奖励等级：三等奖

获 奖 者：侯泉林

安徽省人民政府 2007年1月9日

证 书 号：2007-3-R3

SCIENCE CHINA Earth Sciences 2016年最佳论文奖

论文题目: Structure and coalbed methane occurrence in tectonically deformed coals

通讯作者: Hou QuanLin

出版时间: 2012, Vol. 55, Issue 11: 1755-1763

《中国科学》杂志社

二〇一七年一月

教材使用情况证明

中国科学院大学侯泉林教授编著的中国科学院大学研究生教材系列：《高等构造地质学　第一卷　思想方法与构架》（ISBN：9787030584588）于2018年8月由科学出版社（中国科技出版传媒股份有限公司）出版，截至2025年4月15日，累计印数2500册；《高等构造地质学　第二卷　新理论与应用》（ISBN：9787030588784）于2018年9月由科学出版社出版，累计印数2300册；《高等构造地质学　第三卷　专题知识与实践》（ISBN：9787030658555）于2020年9月由科学出版社出版，累计印数1900册；《高等构造地质学　第四卷　知识综合与运用》（ISBN：9787030697370）于2021年9月由科学出版社出版，累计印数1700册。

该系列教材内容丰富、体系完善、结构合理、图件精美，自出版以来，获得广大读者的认可与欢迎。该系列教材是主要为构造地质学研究生编写的系统性核心教材，内容涵盖思想方法、理论知识、专题应用及综合运用等多个方面，强调理论与实践结合，注重培养学生的创新能力和解决前沿问题的能力。教材内容系统全面，注重思想性、综合性、实用性和前沿性的结合，旨在培养研究生的创新能力、理性思维和脚踏实地的研究能力。侯泉林教授在编写过程中结合了多年的教学经验与科研积累，注重基本概念的深入解析和理论的创新性，同时借鉴国外教材特点，力求打造高水平教材，推动我国高等教育与国际接轨

目前，国内多所院校将该系列作为研究生教材或参考书，具体包括中国科学院大学、天津大学、西南大学、广东海洋大学、昆明理工大学、河北工业大学、西北大学、广东海洋大学、华南农业大学、广东石油化工学院、江西理工大学、河南理工大学等。

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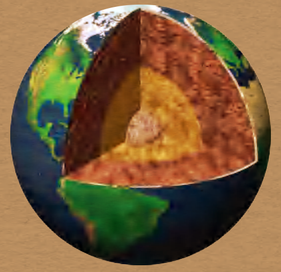

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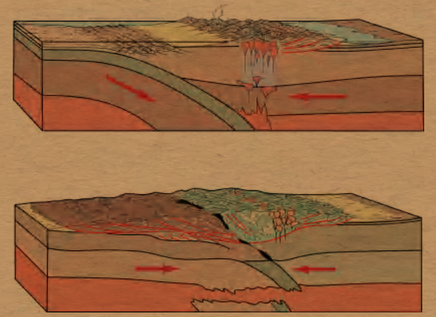

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主要读者对象为高等院校（研究所）地质学专业研究生，也可供本科生及大学教师和科研人员等地质工作者参考。

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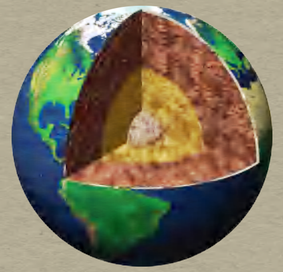

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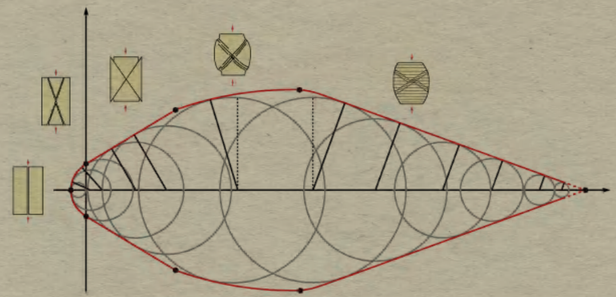

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本书主要读者对象为高等院校（研究所）地质学专业研究生，也可供本科生及大学教师和科研人员等地质工作者参考。

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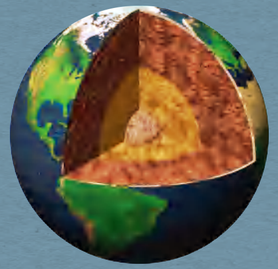

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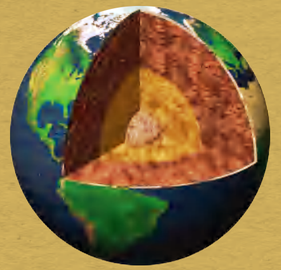

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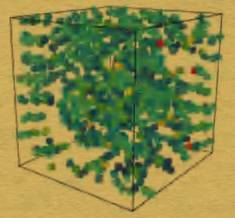

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主要读者对象为高等院校（研究所）地质学专业研究生，也可供高年级本科生及大学教师和科研人员等地质工作者参考。

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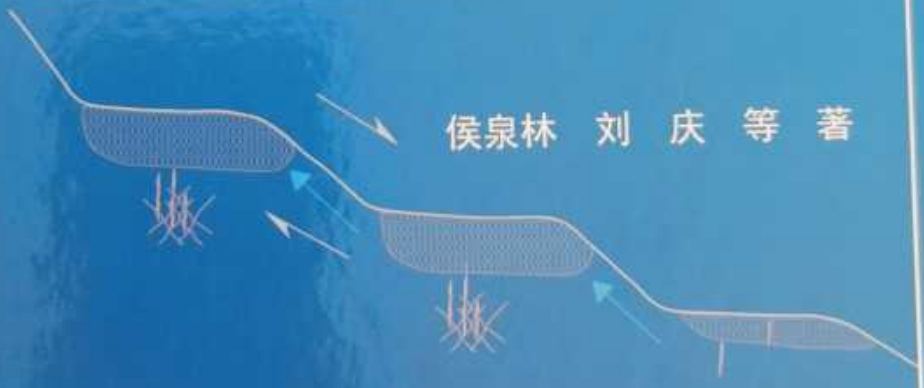
TECTONIC CONDITIONS AND MECHANOCHEMICAL PROCESS OF MINERALIZATION OF SHEAR ZONE TYPE DEPOSITS

剪切带型矿床成矿的岩石构造环境及力化学过程



侯泉林 刘 庆 等 著

科学出版社

内 容 简 介

剪切带与金属矿床之间具有密切的时空和成因联系，但成矿机理一直没有得到合理的解释。本书选取典型的金属矿床，以湘东钨锡矿床和胶东等金矿床为例，从岩石构造环境角度出发，对成矿元素析出沉淀的力化学过程进行了探讨，提出“多期岩体-热液流体-构造剪切-脆性破裂（R，R'，T）-应力骤降-流体闪蒸-元素析出”的成矿模式。

本书可供高校师生、地质学方面的研究人员，以及矿产勘查方面的专业人员参考。

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构造地质学课程虚拟教研室

教学研讨会　　2022年 第06期

主题：几个构造地质学问题思考

2022年5月27日 星期五 19：00-21：00

地点：虚拟教研室App在线会议（或钉钉）

入会口令：264 054 35630

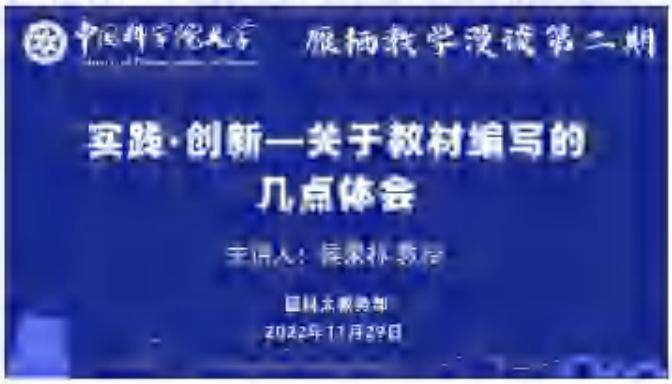
侯泉林，男，教授，博士生导师，中国科学院大学学术委员会副主任,原副校长，享受国务院政府特殊津贴，中国地质学会地质教育研究分会副会长，中国石油学会煤层气专业委员会委员，中国地质学会构造地质专业委员会委员。长期从事构造地质学教学科研工作，先后主持国家自然科学基金重点项目、中科院战略先导专项项目、国家重大研发计划项目课题、国家科技重大专项课题等20余项，在国内外刊物发表学术论文200余篇，一作专著和教材6部，合作专著3部。曾获省级科技进步奖一等奖和自然科学二等奖、中国青年地质科技奖“金锤奖”和中国科学院优秀青年称号。曾到英国Leicester大学、莫斯科大学、香港大学、澳大利亚Monash大学等大学访问和合作研究。

欢迎地学类高校教师踊跃参加讨论

"雁栖教学漫谈"第二期—侯泉林教授云端分享教材编写的体会

国科大教务部

11月29日上午，教务部主办的第二期"雁栖教学漫谈"系列讲座线上开讲，中国科学院大学侯泉林教授应邀为授课教师作题为"实践·创新—关于教材编写的几点体会"的精彩报告，报告由教务部副部长肖康主持。来自全校各院系和各培养单位的近200位教师参与。



侯泉林教授以自己编著出版的《高等构造地质学》四卷研究生系列教材为例，通俗且幽默地将其编撰过程及经历展示在大家面前。他谈到，由于内容形式和要求差异，在每一卷的编写中都采用不同的写作方法，同时针对其中容易混淆和误解的问题或概念，附录于每卷之后，以循序渐进的方式让学生准确理解、把握其中的知识要点。

侯泉林强调，教材是研究生培养的重要保障，教材内容既要满足一般学生的筑基要求，又能让拔尖的学生汲取充足养分。他提出，编写教材的关键在于思想与方法的系统构建，一定要有清晰明确的写作思路和深层次的科学思想，将实事求是的科学精神贯穿全书。教材不仅要给学生介绍专业知识，还要系统地讲学科史、讲证据和内在逻辑，在编撰的过程中要以培养研究生创新能力为编写原则，培养学生的理性思维和脚踏实地做学问的能力，同时，教材要体现出思想性、综合性、系统性、实用性和前沿性的有机结合。

"要用教材进行立德树人和励志教育"，侯泉林随后点明，"要培养研究生对科学研究的兴趣和解决前沿问题的能力，关键在于基本功训练和内涵式培养"。他强调，如果不能准确认识到教材在研究生培养中的关键地位，我们与他人的差距还会扩大，所以面对问题，不能做"跟跑者"，要奋起直追，尽可能激发学生的学习兴趣和创新意识，努力做"领跑者"。讲座最后，侯泉

高等构造地质学

侯泉林 等 燕山期重大地质事件 2020年10月22日 1:19

广义的"构造地质学"是地质学科的核心和基础，俗称地质学的三大件之一（三大件是指构造地质学、岩石学、地层古生物学）。构造地质学科本身有其独特的一面，它不仅具有很强的知识体系，而且具有明显的哲学色彩，其思想方法独特，涉及面宽，有较强的探索性。所以有人说"构造地质学"是地质学的统帅性学科。鉴于此，**《高等构造地质学》教材**的结构按照"**思想方法与构架-新理论与应用-专题知识与实践-知识综合与运用**"思路构思，分四卷先后出版，目前已出版三卷。

长摁识别二维码
购买本书

《高等构造地质学. 第一卷，思想方法与构架》
侯泉林编著. 北京：科学出版社，2018.7
ISBN 978-7-03-058458-8

燕山期重大地质事件

本书为第一卷，主要涉及科学哲学与地质学思维、地球科学革命的发展过程和启示及板块构造理论的基本框架、主要内容和发展趋势。并对一些前沿性和有争议的问题进行了深入剖析，同时注意与其他相关学科的衔接与延伸。"思想方法与构架"，顾名思义包括"思想方法"和"思想构架"两方面内容。前者主要涉及科学哲学、地质学思维、地球科学革命和启示；后者主要涉及板块构造理论的基本框架、主要内容和发展趋势。在章节安排上，按照科学哲学与地质学思维—地球科学革命与启示—板块构造学概论—板块构造学各论的顺序编排，体现从思想到内容、从抽象到具体的循序渐进原则。除参考文献外，第一章参阅了中国科学院地质与地球物理研究所李继亮研究员的部分手稿资料；第二章参阅了中国科学院地质与地球物理研究所孙枢院士的部分手稿资料；第三、四章重

侯泉林：当前研究生教育的关键问题是兴趣和能力的培养，而不是讲多少前沿"故事"

[illegible] 寰杰奥 [illegible]

二十余年的研究生教学经历告诉我，研究生与大学本科生的教学方式和培养内涵有着本质的不同。研究生阶段并不是大学本科的简单时间延续，即"**研一不是大五**"。研究生培养重点也不再只是传授知识，而是**培养其如何运用知识和创新知识，是能力的培养。**

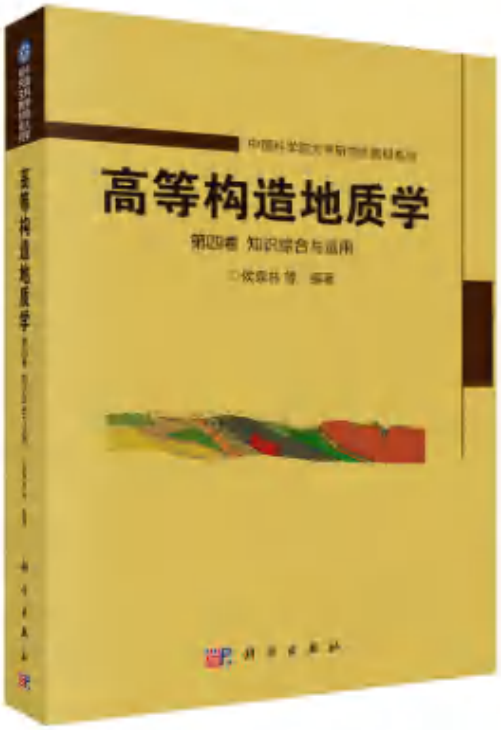
研究生阶段没有统一的教材，因此授课老师一般都会给学生指定大量的参考书和文献。从这个角度看，研究生阶段似乎可以没有，或者也没有必要有相应的教材。然而，研究生（尤其是硕士研究生）的知识结构和思维方式并没有随着其身份的改变而相应改变。面对老师推荐的大量参考书和参考文献往往感到既无从下手，读起来又困难重重。因缺乏适合自己程度的教材或参考教材，大多数同学只能通过课堂或文献阅读学习一些专业知识，了解一些前沿科学问题，但对基本概念的把握仍欠准确，对基本理论的理解仍欠深入。由此造成解决问题的能力和基本功并未达到相应的程度，后天发展缺乏后劲。我的体会是，**每门课程至少认真通读一本研究生教材或参考教材是搭建自身知识结构的基础。**因此，一本适合不同程度学生的教材或参考教材对研究生来说乃十分重要和必要。

鉴于此，我在撰写这套《高等构造地质学》教材，特别是第三卷时，**着重把握三个**

《高等构造地质学》收尾之作，第四卷：知识综合与运用

原创 侯泉林 赛杰奥 2021年10月29日 08:00

本书为《高等构造地质学》第四卷，是本套教材的收尾卷，以**造山带及其分析方法**为重点，同时注意**与成矿作用的结合**。内容包括**山脉与造山带、造山带的结构和组成、造山带的分析方法**——大地构造相、增生型造山带等传统大地构造学内容，以及**构造作用与成矿**，最后探讨了**应力化学**概念和有关问题。



本卷"知识综合与运用"是这套《高等构造地质学》教材的收尾卷，继续保持前面三卷的写作风格，主要包括以下内容：

（1）造山带及其分析方法。

四卷本《高等构造地质学》全部出版：夯实基础，真理至上

原创 侯泉林 赛杰奥 2021年11月09日 06:00

《高等构造地质学》按照"思想方法与构架—新理论与应用—专题知识与实践—知识综合与运用"思路构思，分四卷先后出版。该系列丛书为中国科学院大学研究生教材，旨在为地质相关专业的青年学生和教师夯实基础，明晰概念，为今后的科学道路打下坚实的基础。在丛书的结束语中，第一作者侯泉林讲述了他的科学道路和对科学精神的认识，希望能给读者有益的启示。

结束语

至此，《高等构造地质学》第四卷顺利收笔，也恰逢我年满五十八周岁，总算了却了自己多年的夙愿，下一步就是准备收拾行囊，进入人生的又一阶段，安度晚年了！然而，心里对这耕耘了几

夯实基础，真理至上

作者：李云虎 非常有李论 2021年1月12日 23:45

夯实基础，真理之上

—写在《高等构造地质学》出版之际

这几天，中国科学院大学的侯泉林教授完成了四卷的《高等构造地质学》，实在可喜可贺！一套书拿在手里沉甸甸的，翻读内容不仅感慨良多，这得花费多少时间和精力才能完成！侯老师是河南理工大学的著名校友，长期以来关心学校的发展，我也曾多次旁听侯老师授课，收获颇多，一直以来为侯老师渊博的学识和高尚的人格所折服。

《高等构造地质学》这套书按照“思想方法与构架—新理论与应用—专题知识与实践—知识综合与运用”的思路分四卷先后出版，里面不仅有构造地质学新进展的追踪和总结，也有学科发展前沿的思考和探究，同时也对年轻的科学家提出了谆谆期望。诚如侯老师所说的“夯实基础，真理至上”精神，应是当代科学家的毕生之追求。

书中序言摘选：

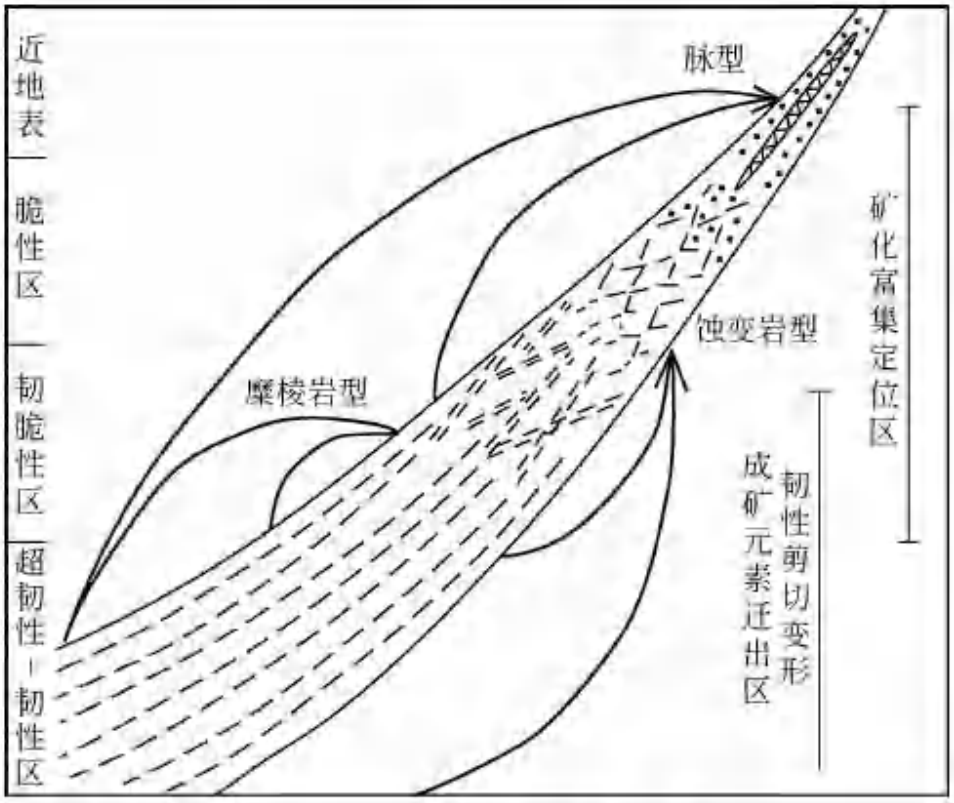
学术绝非仅是论文数量、影响因子、引用次数，也非获奖级别和多少，更非主持项目之多寡。学术应回归学术之本真，其实质是科学精神，是对学问的追求，是具有渊博的知识和强劲的创新能力，以及战略思想的综合衡量，简单地说，对学术水平的最好评价就是科学共同体的认可度，而绝非定量指标可衡量。

对年轻学子寄语：

剪切带型矿床成矿模式新探

[illegible] 文庆 等 裴杰奥 2020年[illegible]月[illegible]日 [illegible]

剪切带与金属矿床之间具有密切的时空和成因联系，这种成矿机制与控矿因素均与剪切带关系紧密的矿床，称为剪切带型矿床。该类矿床在世界范围内广泛发育，对其进行深入研究能够揭示成矿系统中构造与成矿的成因关系。**传统观点**认为剪切带为构造薄弱带，为流体的迁移提供了有利的空间和通道，驱使成矿物质活化迁移，在有利部位富集成矿。但是，即使在矿集区，也不是每一条剪切带中都有矿体产出；即使是同一条剪切带，也并不是处处都发育良好的矿化带。可见，**剪切带型矿床的成矿过程与成矿机理仍有待深入研究。**



▲ 剪切带构造层次与矿化类型关系图(引自陈柏林等，1999)

为此，本研究（《**剪切带型矿床成矿的岩石构造环境及力化学过程**》，侯泉林、刘庆等著. 北京：科学出版社，2020. 5）选取典型的剪切带型金属矿床，以湘东钨锡矿床和胶东等金矿床为例，从岩石构造环境角度出发，运用断层阀模式和力化学理论，对剪切带型矿床中成矿元素的析出沉淀机制和成矿机理进行了深入探讨

获国科大“李佩奖”，他说自己总算没辜负老师

赛杰奥 2022年07月26日 06:00 北京

以下文章来源于中国科学报，作者韩扬眉

中国科学报
关注科教重要事件，网罗学术新鲜趣闻。

※四卷，200万字。这套教材，是认识侯泉林的最好方式。一位院士看完此书后说：我们课题组的老师和学生，要人手一套！

※为了一个地质构造，他带领师生，在考察现场从上午争辩到下午，面红耳赤；为了后辈的一个选题方向咨询，他放在心里反复考量，一年后郑重给出最终答案。

※李佩先生对侯泉林影响很大，他记得学生有任何困难，“不需要张口”，先生都会帮。所以，对于学生，无论是学术研究还是就业方面，甚至是结婚成家，侯泉林的关心事无巨细。

10月的北京云蒙山，险山幽谷，层林尽染。

从北京城区出发，大约行驶70公里，就可到达云蒙山的主体区。万里晴空，从北东到南西展布的不规则穹窿形态山体清晰可见。

“云蒙山存在几期构造运动？云蒙山发育有我国最早发现的变质核杂岩，变质核杂岩内部和外部构造有什么区别？大家注意观察。”

一个浑厚有力的声音吸引了大家的目光。走在最前面的侯泉林，在考察前先提出了一些基本问题。

侯泉林：当前研究生教育的关键问题是兴趣和能力的培养，而不是讲多少前沿“故事”

龚杰奥

今日是我国第36个教师节。本号编发从教二十多年的侯泉林教授的《高等构造地质学》编后感，分享其对当下研究生教育与培养的深刻思索与拳拳情怀。在此也向所有的老师们道一声辛苦，祝[illegible]教师节快乐！

二十余年的研究生教学经历告诉我，研究生与大学本科生的教学方式和培养内涵有着本质的不同。研究生阶段并不是大学本科的简单时间延续，即“**研一不是大五**”。研究生培养重点也不再只是传授知识，而是**培养其如何运用知识和创新知识，是能力的培养。**

研究生阶段没有统一的教材，因此授课老师一般都会给学生指定大量的参考书和文献。从这个角度看，研究生阶段似乎可以没有，或者也没有必要有相应的教材。然而，研究生（尤其是硕士研究生）的知识结构和思维方式并没有随着其身份的改变而相应改变。面对老师推荐的大量参考书和参考文献往往感到既无从下手，读起来又困难重重。因缺乏适合自己程度的教材或参考教材，大多数同学只能通过课堂或文献阅读学习一些专业知识，了解一些前沿科学问题，但对基本概念的把握仍欠准确，对基本理论的理解仍欠深入。由此造成解决问题的能力和基本功并未达到相应的程度，后天发展缺乏后劲。我的体会是，**每门课程至少认真通读一本研究生教材或参考教材是搭建自身知识结构的基础。**因此，一本适合不同程度学生的教材或参考教材对研究生来说乃十分重要和必要。

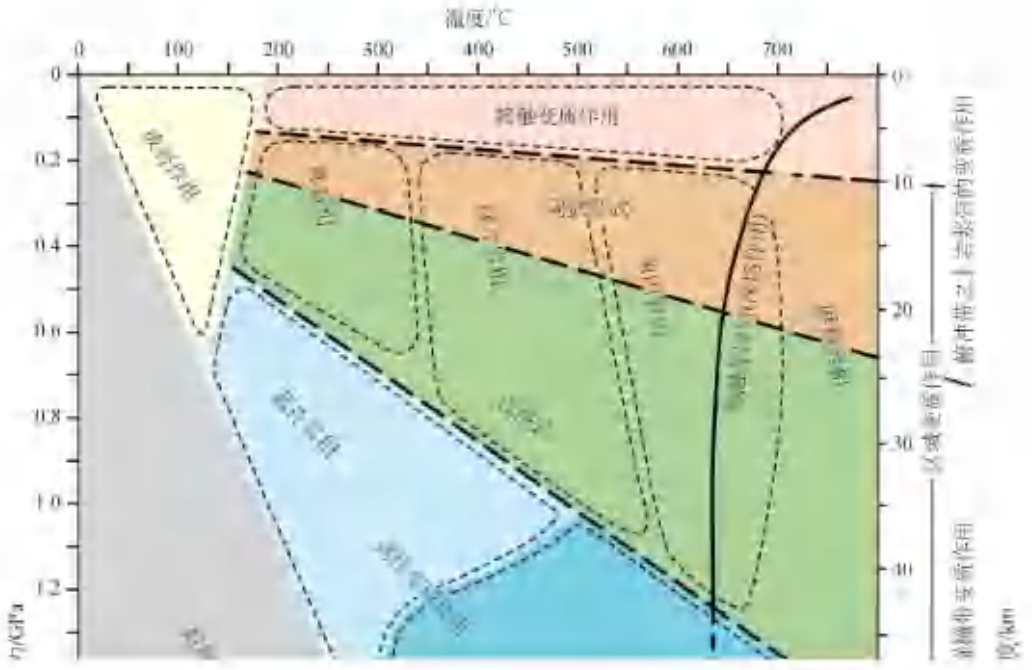
鉴于此，我在撰写这套《高等构造地质学》教材，特别是第三卷时，**着重把握三个**

高压- 超高压构造岩及其意义

[illegible] 等 赛杰奥 2020年09月29日 06:00

高压- 超高压构造岩与高压- 超高压变质岩一样，是个非常重要的命题，然而与高压-超高压变质岩不同的是，**高压- 超高压构造岩的存在与否长期以来饱受争议。**这里进行讨论，旨在引起读者重视，并能针对有关问题开展进一步研究工作。

大陆物质的深俯冲与折返是20 世纪后期固体地球科学的重大进展之一。它表明，不仅洋壳可以俯冲到上地幔深度，而且密度相对较小的大陆地壳物质也可以俯冲到上地幔深度，并且折返回地表。**超高压变质岩是大陆地壳岩石俯冲到上地幔深度，在超高压变质环境下（2.5 ~ 4.5GPa，600 ~ 900℃）形成的。**在此环境下，陆壳岩石的主要造岩矿物，如石英、斜长石、角闪石、辉石和云母等，转化为柯石英、石榴子石、绿辉石/ 硬玉、蓝晶石和多硅白云母等在上地幔环境下稳定存在的高压-超高压变质矿物。这些矿物的转化导致俯冲陆壳物质的结构、构造、物理化学和流变学性质的转变，从而为研究大陆物质深俯冲过程、物质的交换和转化、流体的活动与性质、岩石的流变学特征及其对深俯冲的影响，以及超高压变质岩的折返机理等提供了基础。



任务艰巨，他给自己下了"死命令"

关注 中国科学院大学 2025年02月20日 21:47 北京

编者按

中华民族尊师重教、尊师重道的传统源远流长。每一个时代都赋予了教师特殊的使命，新时代更是对教育工作者提出了新的要求与期冀。习近平总书记多次殷殷嘱托，要做好老师、做"大先生"，大力弘扬教育家精神。他指出："一个人遇到好老师是人生的幸运，一个学校拥有好老师是学校的光荣，一个民族源源不断涌现出一批又一批好老师则是民族的希望。""教师要成为大先生，做学生为学、为事、为人的示范，促进学生成长为全面发展的人。"

为大力弘扬教育家精神，中国科学院大学（以下简称"国科大"）党委宣传部推出《大先生的科学课》系列微视频，聚焦国科大教师队伍中的"两院"院士、全国优秀教材编写者、全国教材建设先进个人、教育部课程思政示范课程教学名师、国科大"李佩教学名师奖"获得者、学科带头人等，让更多的人了解国科大躬耕教坛、潜心育人的科学家"大先生"风采。

本期，国科大官微推出《大先生的科学课》系列微视频第二季第二集，走近国科大地球与行星科学学院教授侯泉林，聆听这位"大先生"的科学课。

“燕山期重大地质事件科研-教学基地”揭牌仪式成功举行

燕山期重大地质事件 2021年05月07日 20:18

2021年4月28日，早上9点30分，在中国科学院大学雁栖湖东校区教二楼东侧，隆重举行了“燕山期重大地质事件科研-教学基地”的揭牌仪式，出席仪式的主要人员有：项目首席科学家孙卫东教授，中国科学院大学科研处林晓处长，中国科学院大学地球与行星科学学院党委书记周元泽教授，课题负责人侯泉林教授以及其他课题骨干和学生。

项目首席科学家孙卫东教授发言

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The impact of tectonic stress chemistry on mineralization processes: A review

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Abstract

Tectonism often plays an important role in the mineralization process, which is generally thought to be the main controlling factor in the accumulation of economic materials (e.g., gold, coal, oil and gas) through deformation. However, numerous experimental and theoretical studies have suggested that tectonic stress not only causes deformation (physical changes) in rocks and minerals but also promotes their chemical changes by acting directly on chemical bonds and causing bond scission or regeneration, called tectonic stress chemistry (TSC). In recent years, TSC actions caused by tectonic activities have provided new ideas and evidence for explaining the chemical structural evolution of coal, hydrocarbon formation, organic (coal-derived) and inorganic graphitization and hydrothermal mineralization under shear stress. These background studies have provided incentives and insights into how tectonic stress affects the chemical structures of minerals, rocks and even ore-forming fluids in the process of mineralization. In this paper, we briefly review: (1) the concept of TSC; (2) the TSC process in the formation of shear zone type gold deposits from stress concentration, brittle fracturing, sudden reduction of fluid pressure, and flash vaporization to gold precipitation; (3) mechanisms of the macromolecular structural evolution of coal and gas generation under shear stress from deformation experiments and molecular dynamic simulations; (4) coal-derived graphitization caused by preferred orientation and extension of the basic structural units (BSUs) under shear stress; and (5) some preliminary experimental explorations on inorganic graphitization in carbonate-hosted shear zones. In addition, some existing problems and possible solutions for these processes are also discussed. Finally, we propose additional potential TSC processes in extensive geological processes, e.g., the relationship between deformation and metamorphism and trigger mechanisms of slow-slip earthquakes. To further explore these processes, a combination of experiments and molecular dynamic simulations should be undertaken by researchers.
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Keywords: Tectonic stress chemistry; Mineralization; Shear zone type gold deposits; Macromolecular structure of coal; Graphitization

1. Introduction

Tectonism often plays an important role in geological activities, especially in mineralization processes. It is generally considered that the accumulation of economic materials (e.g., gold, coal, oil and gas) is mainly controlled by tectonism through deformation, including brittle deformation and ductile deformation at different structural levels (Chai et al., 2016; Eisenlohr et al., 1989; Pan et al., 2012; Sun et al., 2016). In addition to these physical deformations, can tectonism cause chemical changes in minerals and rocks? Or what role does tectonism play in these chemical changes? How does it work? These questions have been debated for centuries. More and more numerous experimental and theoretical studies have suggested that the influence of tectonism includes not only physical changes but also chemical changes in rocks, minerals

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“构造地质学”发展方向的一些思考*

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Abstract Structural geology/tectonics is a fundamental discipline in geoscience. Over the past few decades, theoretical advances and technological innovations have brought new frontiers of exploration in structural geology. This paper discusses future research opportunities in structural geology and tectonics. The primary goal of structural geology is to understand how rocks or mineral aggregates respond to the applied stress field, including the physical and chemical actions happened in this process, and mathematical methods developed to describe them, which can be further demonstrated as follows: (1) The physical process is primarily rock deformation, including brittle and ductile deformations. The mechanical properties of rocks (rock rheology) vary across various spatial and temporal scales, and rheology controls the rock deformation pattern. To combination of observations derived from field and experiments, rock mechanics and rheology studies, and a multi-scale simulation approach enables us to understand multi-scale deformations of rocks and lithosphere rheology. (2) The chemical process refers to chemical reactions modulated by stress (stress chemistry). Stress chemistry may play an important role in the many chemical processes, such as the metamorphism in deforming rocks, shear zone-related gold mineralization, shear-induced graphitization, and gas and hydrocarbon generation under shear stress. However, the exact mechanisms of these processes remain unclear and need further investigation. (3) Proper mechanical descriptions of the individual or coupled physical and chemical processes by using numerical simulation and perhaps quantum computing are also an important tendency for the development of structural geology in the future. In general, structural geology/tectonics is remarkably interdisciplinary. Geologists need to use a broad spectrum of tools and approaches assimilated from the fields of physics, chemistry and mathematics to understand the processes operating in solid-Earth in future research.

Key words Structural geology/Tectonics; Rock rheology; Stress chemistry; Numerical simulation

摘 要 构造地质学是地质学的核心基础学科,其发展方向是目前构造地质学家面临的挑战之一。本文从构造作用的本质出发,试图对构造地质学的发展方向进行思考。构造作用本质上是岩石和矿物对应力作用的响应,包括物理响应和化学响应,进而用数学方法进行表达:(1)物理响应主要表现为变形,包括脆性变形和韧性变形。岩石的力学性能决定了其变形特征。岩石圈力学性能在时间和空间上的不均一性一直是研究岩石圈变形行为的巨大挑战。需要结合野外观测、岩石力学和流变学研究,并借助多尺度模拟方法来建立不同时间尺度和空间尺度下岩石的变形行为和变形准则。(2)化学响应主要指构造应力作用下岩石和矿物发生化学变化的过程,即应力化学作用。变形变质作用、剪切带成矿作用、剪切带石墨化、应力生气和生烃等方面都可能存在应力化学过程,但其详细过程和反应机理还需要进一步探究。(3)运用数值模拟、量子计算对以上

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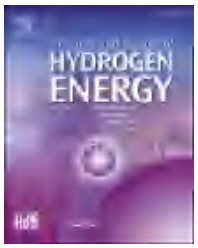

Mechanisms of methane generation from anthracite at low temperatures: Insights from quantum chemistry calculations

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abstract

For a long time, it has been debated if coals, especially the anthracite, could produce methane or other hydrocarbons under a temperature lower than pyrolysis temperature. In this study, to discuss the mechanism of methane production by anthracite under stress, we perform quantum chemistry calculations to investigate the dissociation mechanism of three different types of aliphatic structures. The following results are obtained: (1) The Gibbs free energy calculation shows it is the stress rather than the pyrolysis that produces methane in the deformation experiments at 200 °C; (2) For low-rank anthracite, the hydrogen atom contained in the coal can promote the dissociation of aliphatic carbon bonds and stress prefers to concentrate on aliphatic carbon bonds rather than other macromolecular structures of coal, which facilitate the gas generation; (3) For medium-rank anthracite, the hydrogen atom added to the aromatic ring can lead to more ordered and parallel orientation of the aromatic layers. Considering that the aromatic rings can rotate more easily than the bond stretching under stress, we think medium-rank anthracite may tend to enhance the degree of metamorphism, reducing the production of hydrocarbons. The gas and hydrocarbon generation under stress may be an important complement for the traditional hydrocarbon generation theory.

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Introduction

Whether chemical changes can occur in coals under tectonic stress, i.e. whether gas or hydrocarbon can be generated from coal, especially anthracite, by stress at low temperature conditions (lower than pyrolysis temperature) has been a long-standing controversy in coal geology and petroleum geology. Previous studies suggested that pressure only affects the physical structures of the coals (such as the pore structure) and has little influence on the chemical changes [1,2].

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Review

The impacts of stress on the chemical structure of coals: a mini-review based on the recent development of mechanochemistry

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abstract

The chemical structure evolution of coal, which is important for understanding coalification and the accompanying volatile and possible oil generation, is generally thought to be influenced by temperature, time and confining pressure. Though evidence concerning the impacts of stress on the chemical structure has accumulated for many years and some hypotheses have been proposed, the mechanism remains controversial. Recent years have seen a breakthrough in mechanochemistry, which proves that stress can act on the molecule directly to initiate or accelerate reactions by deforming the chemical bonds. The progress in mechanochemistry gives researchers incentive to consider how stress works on the chemical structure of coals. Preliminary quantum chemical calculations have been performed on the macromolecule of anthracite to explain the mechanism of gas generation during the deformation experiments at low temperatures. This paper briefly reviews the evidence regarding the impacts of stress on the chemical structure of coals and introduces the recent achievements in the mechanism research. To further investigate this problem, more work should be undertaken by researchers from both geology and quantum chemistry fields.

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1. Introduction

Coals mainly consist of aromatic layers where aromatic rings are surrounded by peripheral aliphatic chains and functional groups [1]. The chemical structure transformation is important for understanding coalification and the accompanying volatile [2] and possible oil [3] generation, which are the key issues in coal geology. These chemical reactions are naturally thought to be governed by, like any chemical reaction, temperature [4,5], time [6], pressure [7–9] and possible catalysis [10]. Since tectonic stress occurs extensively in geological settings, the influence of stress on the chemical structure of coals has long been an important but debated problem [11]. Though papers concerning the impacts of stress on the chemical structure of coals have been published on and off, most geologists tend to consider the impacts of stress are in fact thermal impacts, which is resulted from the transformation of mechanical work into heat. This conclusion parallels the research level of chemical reaction mechanism. Compared with the way of chemical activation by heat or light, chemical reactions initiated by stress, i.e. mechanochemistry, are not well accepted [12,13]. Nevertheless, recent years have seen a big breakthrough in the field of single-molecule mechanochemistry with the application of atomic force microscopy (AFM) and molecular dynamic simulation, which demonstrates that stress can work on the molecule directly to initiate or accelerate reactions by deforming the chemical bonds [14–22]. The advanced development of mechanochemistry encourages researchers to reconsider the effects of stress on the chemical structure and its mechanism. For example, Xu et al. [23] suggested that mechanical energy could transform into strain energy during the deformation of coals, and the strain energy can promote the deformation and breakage of chemical bonds, resulting in gas generation. Liu et al. [24,25], when studying the chemical properties of superfine pulverized coal particles, considered that the mechanochemical effects during the coal grinding resulted in the free radicals and carbon structure variations. However, most other researchers have not been aware of this progress. This paper briefly reviews the evidence regarding the impacts of stress on the chemical structure of coals and introduces the progress in the mechanism research. Though our investigation is focused on coals, it has implications for other kerogens as well. We hope it can attract more attention and discussions from our colleagues.

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Full Length Article

The role of structure defects in the deformation of anthracite and their influence on the macromolecular structure

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highlights

- The correlation between structure defects and deformation was established.
- The role of SW defect in the deformation of anthracite was studied by calculation.
- The SW defect reduces the energy needed to produce CO gas from anthracite.

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abstract

The impacts of stress on the physical and optical properties of coals are well recognized, while the influence on the chemical structure is seldom considered. In the light of mechanochemistry research that mechanical force can act on the molecule directly to initiate or accelerate reactions by deforming the chemical bonds, it is meaningful to consider how stress works on the macromolecule of coals. In this work, some insights are given based on anthracites with different tectonic deformation from Qinshui Basin, Shanxi Province, China. The deformation degree was measured by bireflectance ($R_{o,max} - R_{o,min}$), and the macromolecular structure was characterized by Raman spectroscopy. For samples from the same colliery, there is a positive relationship between Raman area ratio A_D/A_G and bireflectance, suggesting that the deformation of anthracite is related with the generation of structure defects at the atomic scale. Further quantum chemistry calculations demonstrate that accompanying the generation of one Stone-Wales (SW) defect (induced via in-plane rotation of C-C bond by 90°), the molecular geometries of anthracite, such as chemical bonds and angles, change. The deviation of atoms from their equilibrium geometries reflects the local force distribution and transfers 303.48 kJ/mol mechanical energy into chemical energy. These changes allow chemical bonds to adjust to the applied stress without breakage, so that anthracite will accommodate plastic deformation. Additionally, the existence of SW defect slightly reduces the energy needed to produce carbon monoxide from carbonyl in anthracite. The current study helps to understand the potential influence of stress on the chemical structure evolution of coals.

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1. Introduction

The chemical structure evolution of coals is the foundation for understanding coalification and the accompanying volatile [1] and possible oil generation [2]. These chemical transformations are generally thought to be influenced by, like any chemical reaction, temperature [3], time [4], pressure [5], and possible catalysis [6]. Most researchers recognize that stress, which occurs extensively in geology, can impact the physical [7–9] and optical [10,11] structure of coals and do not consider its possible influence on the chemical structure. Recent years have seen a breakthrough in the single molecule mechanochemistry, which proves that stress can act on the molecule directly to initiate or accelerate reactions by deforming the chemical bonds [12–15]. This background provides incentive to further explore the possible impacts of stress on the chemical structure of coals. Xu et al. [16] suggested that the bond breakage in anthracite during deformation experiments could result in gas generation. Liu et al. [17,18], in a comprehensive study of the chemical properties of superfine pulverized coal

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剪切带型金矿中金沉淀的力化学过程与成矿机理探讨*

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Cheng NN, Liu Q, Hou QL, Wei W, Shi MY, He M and Guo QQ. 2018. Discussions on the stress-chemical process of gold precipitation and metallogenic mechanism in shear zone type gold deposits. *Acta Petrologica Sinica*, 34(7):2165-2180

Abstract Most gold deposits in the world are related to shear zones, and the genesis of shear zones type gold deposits has long been a major concern in the geological study, while the precipitation mechanism of gold remains controversial and the cause at the ore-localized portions is seldom considered. This paper firstly sorts out and analysis the research progress of mineralization in recent years combining with the case studies of Jiaodong gold deposits. Using fault-valve model and stress-chemical theory, this paper finds that the ore-localized portions have close links to brittle fractures or joints (especially R, T and R' joints) and (multi-stage) pluton emplacement whether in brittle or ductile shear zones or vein type or altered rock type gold deposits, which are resulted from stress concentration. And the stress-chemical process, which is associated with the extreme decrease of fluid pressure and flash vaporization during the abrupt rupture, may be the effective mechanism of gold precipitation. In addition, fluids derived from multi-stage pluton emplacement are material basis of mineralization. Hence, this paper proposes that the stress-chemical process is the key process for gold precipitation in shear zones, which is from stress concentration, brittle fracturing, sudden reduction of fluid pressure, flash vaporization to gold precipitation. Additionally, the structural level of fracturing is not limited to brittle or brittle-ductile shear zones found from cases in domestic and overseas study, it can also occur in ductile shear zones though the concrete reason is not clear, which may be the critical metallogenic mechanism to ductile shear zones. Depending on above characteristics, the metallogenic mechanism in shear zones can be summarized as (multi-stage) pluton emplacement, hydrothermal fluid action, shearing action, brittle fracturing, sudden reduction of fluid pressure, flash vaporization and (gold) mineralization, which is a cycling process making large deposits eventually. And from this mechanism we suggest that the relatively concentrated portions of stress in shear zones, like the striking-turning positions in strike-slip faults, the dip turn-to-gentle positions in normal faults and turn-to-steep positions in thrust faults, are favorable areas for mineralization.

Key words Shear zone type gold deposits; Stress concentration; Boiling; Flash vaporization; Stress-chemistry; Metallogenic mechanism

摘 要 剪切带型金矿是一种重要的金矿床类型,有关该类型金矿的成因问题已开展了大量研究,但对于剪切带中金的沉淀析出机制和成矿过程仍存在较大争议,对于赋矿部位的构造属性与矿床关系的研究尚显薄弱。对此笔者整理分析了近年来国内外有关剪切带型金矿的研究进展,并结合我国胶东金矿的研究实例,运用断层阀和力化学理论分析发现,无论是脆性还是韧性剪切带,无论是脉型还是蚀变岩型金矿,其成矿的关键部位均与构造应力集中而导致的脆性破裂(特别是 R、T、R'破

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Article

New Insight into the Genetic Mechanism of Shear Zone Type Gold Deposits from Muping-Rushan Metallogenic Belt (Jiaodong Peninsula of Eastern China)

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Abstract: Most gold deposits are genetically controlled by shear zones, which are called shear zone type gold deposits (SZTGD). A better understanding of kinematics of shear zones and its constraint on the ore-forming process is critical to reveal the genetic mechanism of the SZTGD and favorable to mineral exploration. By conducting detailed structural analysis including field and microscopic observations and electron backscatter diffraction (EBSD) and fractal dimension analysis in the Muping-Rushan shear zone (MR) as well as several gold deposits, the kinematic characteristics of the MR are well recognized and the metallogenic process of the SZTGD are discussed. The main conclusions are as follows: (1) petrology, geometry, kinematics, macro- and micro-structures imply that the MR has experienced a progressive shearing history exhumed via middle crust to subsurface level under the NW-SE extensional regime from late Jurassic to early Cretaceous; (2) in the MR, gold may precipitate both in the brittle fractures at middle crust level and brittle deformation part at shallow crust level during the stress-chemical process and (3) comparison of gold deposits between the MR and other areas show that the SZTGD has a uniform metallogenic mechanism, which is from (multi-stage) pluton emplacement, hydrothermal fluid action, shearing action, brittle fracturing, sudden reduction of fluid pressure, flash vaporization to (gold) mineralization.

Keywords: shear zone type gold deposits; Jiaodong Peninsula; Muping-Rushan metallogenic belt; EBSD analysis; fractal dimension

1. Introduction

Shear zones are one type of strain localization structures [1], which are widely developed in various structural environments. As weak zones in regions, shear zones are always concentrated for intense magma activities, fluid actions and metamorphism, hence provide favorable transport channels and precipitation spaces for ore-forming elements, e.g., Au, Ag, Cu, Pb, Zn, W, Sn and Mo [2–7]. Many gold deposits are host in, or spatially associated with first- and second-order shear zones [8–15], which we call the shear zone type gold deposits (SZTGD). In the SZTGD, the formation, transport and precipitation of gold are strictly controlled by shearing activities [16,17]. This kind of gold deposit has a wide distribution in the world, e.g., Abitibi greenstone belt in Canada, the Norseman-Wiluna

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不同构造层次岩石变形准则的融合与发展*

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Hou QL, Cheng NN, Shi MY and Lu X. 2018. The union of various rock deformation criteria at different structural levels and its further development. *Acta Petrologica Sinica*, 34(6):1792-1800

Abstract The study of rock deformation criteria, including brittle and ductile deformation criteria, has important theoretical value and practical significance for structural geology and engineering safety. The classic brittle deformation (failure) criteria include Tresca criterion, Coulomb criterion and Griffith criterion, which are horizontal line, oblique line or parabola, and parabola envelope in Mohr diagram, respectively. In recent years the maximum effective moment (MEM) criterion has become one important ductile deformation criteria, which is supported by increasingly solid evidence from both observed examples in nature and laboratory experiments. However, we find that it is unfeasible for applying these criteria to actual geological practices. For instance, there are no reasonable explanations for some of the criteria in theory; though the MEM criterion is well functioned in explaining the origin of obtuse conjugate angle (usually ~110°), it is not yet resolved for the accurately corresponding envelope of MEM criterion in Mohr diagram; the applicable limitations of some criteria are unclear which make certain contradictions. Combining with field practices and theoretical analyses, we hold that: (1) It cannot be done for the Tresca criterion with horizontal envelope (the equation is $\tau = \tau_0$, τ_0 is the cohesive strength) in geological processes. Because in compressive regime, the normal stress is positive ($\sigma_n > 0$) on the planes in $\theta = 45°$ direction (θ is the angle between the maximum principal stress σ_1 and the potential share planes), the failures will not form in this direction until the shear stress overcomes not only cohesive strength but also internal friction of the rock. Namely the shear stress cannot make rocks fracturing when it just achieves cohesive strength. The case of conjugate shear failures with 90° in the field is merely a coincidence, which is more likely to be the end tip of Coulomb criterion with parabola envelope tending to be horizontal in high confining pressure. (2) We propose that the Mohr envelope equation of the MEM criterion is $\tau = -0.35(\sigma_n - \sigma_d)$, which is corresponding to an anti-oblique line in Mohr diagram. Then we can combine the brittle deformation criteria (the Coulomb criterion and the Griffith criterion) and the ductile criterion (the MEM criterion) in Mohr diagram and make them coordinate with each other. (3) No clear distinctions among the applied conditions (namely the corresponding structural levels) of different criteria are the basic reasons for the contradictions above. For rocks in crust, there are various microscopic deformation mechanisms from brittle to ductile domain, which correspond to frictional sliding and crystal-plasticity (such as dislocation and diffusion creep), respectively. So the transformation of different deformation mechanisms requires the adjustment of corresponding criteria at different structural levels. To cover the full range of critical stress states in the crust, we try to give an unified interpretation to the mechanism of rock deformation at different structural levels and express it in Mohr diagram: the Griffith criterion with a parabola envelope is more appropriate at the tensile settings such as superficial crust and artificial settings like hydraulic fracturing where tensile fractures ($\theta = \sim 0°$) or hybrid fractures ($\theta = 0° \sim 30°$) form; the Coulomb criterion with an oblique line envelope is proper at upper crust with axial compressive stresses where acute conjugate shear fractures form ($\theta = \sim 30°$); it is common for the envelope to flatten as the depth increases to the middle crust, and the Coulomb criterion with parabola envelope is suitable at brittle-ductile transition zone where acute conjugate ductile shear bands form ($\theta = 30° \sim 45°$); at lower crust and below, the MEM criterion with an anti-oblique envelope is befitting where

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敦煌造山带南部红柳峡混杂带基质的沉积学、地球化学和年代学特征及其大地构造意义*

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Shi MY, Hou QL, Wu CM, Wang YCH, Cheng NN, Zhang WLQ and Pham VT. 2018. Sedimentology, geochemistry, geochronology, and tectonic implication of the matrix in Hongliuxia mélange, southern Dunhuang Orogenic Belt. *Acta Petrologica Sinica*, 34(7): 2099 – 2118

Abstract The integrated investigation of the matrix in Hongliuxia mélange, southern Dunhuang Orogenic Belt (DOB), provides new evidences for understanding the formation and evolution of the DOB. In this contribution, sedimentological, geochemical, and geochronological studies were undertaken on the matrix for constraining its tectonic setting formed. The matrix in Hongliuxia mélange dominantly consists of sheared metapelite (mica-quartz schists) and meta-sandstones. Locally, some of the matrix preserves the original sedimentary structures (such as T_{ab}, T_{de}, T_{bde} divisions of Bouma sequence). This indicates the protolith of the matrix is turbidite flysch. In detrital composition, the matrix are composed of predominate feldspar, quartz, and lithic fragment. High proportion of feldspar (47%) and lithic fragment (27%) indicate abundant magmatic-derived clasts were involved. The clasts are poorly sorted and rounded, suggesting a short distance before deposited. Geochemically, Low CIA values (49 ~ 67) of the matrix indicate low-degree of weathering in the provenance. High ICV values (mostly > 0.8) and the Zr/Sc-Th/Sc diagram reflect the sediments were not significantly recycled before deposited. The matrix show low Sc, Cr, Co, Ni contents, and similar Eu/Eu^*, La/Sc, Th/Sc, La/Co, Th/Co, and Cr/Th ratios with the clasts shed from the felsic rocks provenance. This indicates the source rocks comprise dominant intermediate-acidic rocks, though few mafic rock clasts involved. The La/Sc-Ti/Zr and Th-Sc-Zr/10 plotting of the matrix suggest they form in the continental arc or active continental margin tectonic setting. Framework modes of slightly deformed and low-grade metamorphosed sandstones indicate the clasts of matrix predominantly derive from the "dissected-transitional arc" provenance. To some up, the composition of low recycled, near sourced "dissected-transitional arc" derived clasts, accompanied by the sedimentary structure of mass-transport deposit (MTD), manifest the matrix deposit in the trench associated with the subduction zone along continental arc or active continental margin. The detrital zircons from the matrix show three age groups: 2300Ma, 1850Ma, and 423Ma. Combined with the regional geological background, we preliminary speculate the clasts probably shed from the Paleozoic granitoid and exhumed metamafic rocks in the Sanweishan arc and Dongbatu-Mogutai arc, north to the Hongliuxia mélange. The meta-sandstones of the flysch matrix yield the youngest magmatic detrital zircon age of 389Ma, indicating the protolith (sandstone) formed after Middle Devonian. This further indicates the ocean basin of the Hongliuxia area had not been closed at Middle Devonian and the collision hadn't initiated at that time.

Key words Dunhuang Orogenic Belt; Hongliuxia mélange; Matrix in mélange; Turbidite; Detrital zircon geochronology

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造山带研究中有关复理石和磨拉石的几个问题*

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Hou QL, Guo QQ and Fang AM. 2018. Discussions on some basic problems in the research of orogenic belts concerning on flysch and molasse. *Acta Petrologica Sinica*, 34(7):1885 – 1896

Abstract The pattern and timing of collision are long-term controversies in orogenic research. Flysches and molasses, as one of the most important recorder, have been applied to constrain the collision timing. In this paper, we review research history and their different tectonic meaning in geosyncline-plat-form theory and plate tectonic theory, and then followed by an effort to anatomize their tectonic implications. Flysches in passive margins, active margins or arcs related tectonic settings are deposited before collision, and molasses in peripheral foreland basin after the collision. The youngest flysch could provide information on the maximum collision timing while the oldest molasses in peripheral foreland basin provide information on them-in-collision timing. The transition of sedimentary succession from flysches to molasses indicates that the sedimentation may be continuous during huge tectonic events and thus the collision orogeny is a uniformitive process after the collision event.

Key words Timing of collision; Molasses; Flysch; Peripheral Foreland molasse basin; Turbidite

摘 要 在造山带研究中,碰撞方式和时限的争议是全球造山带研究中的一个共同现状或面临的难题。利用复理石和磨拉石时代来限定碰撞时限是造山带研究的一项重要内容。本文首先综述了复理石和磨拉石从提出到广泛应用以及不同历史时期被赋予的构造含义;其次,根据其可能发育的构造环境,指出复理石和磨拉石纪录造山带的相关信息及其演变过程。被动陆缘复理石可能纪录了参与碰撞拼贴块体的亲缘性,而且被动陆缘、活动陆缘或者岛弧环境的复理石均形成于碰撞作用之前,因此最年轻的复理石时代可提供碰撞时间的下限;(周缘)前陆盆地的磨拉石形成于碰撞造山作用过程中,因此其最早的磨拉石沉积时代可用于限定碰撞时间的上限。从复理石到磨拉石地层的渐变过程(连续沉积)指示了碰撞构造事件的发生、以及之后的碰撞造山作用是均变过程,会发育不同尺度规模的不整合。因此,造山带中的不整合未必代表有重大构造事件的发生,而连续沉积并不表明没有大的构造事件。

关键词 造山带碰撞时限;复理石;磨拉石;(周缘)前陆磨拉石盆地;浊积岩

中图法分类号 P542

造山作用是大陆形成与增生的最基本地球动力学过程,关于碰撞造山方式和时限的争议是全球造山带研究中的一个共同现状(肖文交等,2017)。自板块构造理论创立以来,不同学者根据造山带的结构对碰撞造山带的类型先后进行过不同的划分,具有代表性的有Şengör(1992)把碰撞造山带分为三种类型,即阿尔卑斯型、喜马拉雅型和阿尔泰型(即增

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ORIGINAL ARTICLE

Timing and structural controls on skarn-type and vein-type mineralization at the Xitian tin-polymetallic deposit, Hunan Province, SE China

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Abstract Xitian tin-polymetallic deposit, located in the eastern Hunan Province, SE China, hosts quartz vein and skarn in the contact zone between carbonate and two stages granites. Critical geodynamic questions for South China are whether different types of mineralization form in the same time and how the magmatism–tectonic system controls the ore-forming process. Based on the distribution of the orebodies, six cassiterite samples from different types of mineralization are collected for dating. In-situ LA-MC-ICP-MS U–Pb isotopic data yielded concordia low intercept ages between 154 and 157 Ma, indicating that different types of mineralization belong to the same magmatism–mineralization system. Coupled with the study of the kinematic indicators, it suggests that the structural control of the wall rocks constrain the types of mineralization. These results provide further evidence of a close temporal link between the structure and the tin-polymetallic mineralization in Xitian deposit. Considering the structure in the district, granite dome plays an important role in the ore-forming process. The age and structural signatures in Xitian deposit are the response to the subduction of Pacific Plate.

Keywords LA-MC-ICP-MS U–Pb dating · Structure control · Tin-polymetallic deposit · SE China

1 Introduction

The Nanling Range, located in the southern part of the South China Block, is famous for the numerous W–Sn deposits that are closely associated with voluminous Mesozoic granitic magmatism (Wang et al. 2014b; Zhang et al. 2015; Zhao and Zhou 2015). Extensive studies have been performed that reveal the genetic relationship between ore deposits and granites in the Nanling Range (Chen et al. 2013b; Liu et al. 2007; Ma et al. 2008; Wang et al. 2014a; Yuan et al. 2011). The peak of mineralization in the Nanling Range is deemed to be Yanshanian according to massive geochronology studies of the tin-polymetallic deposits (Guo et al. 2011; Hu and Zhou 2012; Mao et al. 2008; Peng et al. 2006). However, with increasing geochronology studies in the Nanling Range recently, the Indosinian tin-polymetallic mineralization that is genetically related to Indosinian granites is also widespread and more common than previous thought (Cai et al. 2006; Liu et al. 2008b; Wu et al. 2012a; Yang et al. 2009; Zhang et al. 2015). Additionally, based on the distribution of the skarn-type orebodies, which are spread in the outer contact zone of the Indosinian granites, the potential of Indosinian mineralization in the Xitian deposit attracts a group's attention (Cai et al. 2006; Liu et al. 2016; Mao et al. 2013; Zhang et al. 2015). The Xitian tin-polymetallic deposit located at the central of the Nanling Range is one of the representatives (Fig. 1). It has multi-phase intrusions and complex types of mineralization. However, previous geochronology studies have revealed that rocks of different episodes cannot be adequately classified by

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Full Length Article

Mechanolysis mechanisms of the fused aromatic rings of anthracite coal under shear stress

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ABSTRACT

The fused aromatic rings (FARs) of coal are considered to be relatively stable during coalification. However, it is speculated that defects may form in FARs during the deformation of coals under tectonic stress. In order to investigate the possibly existed mechanolysis reactions of FARs, we performed molecular dynamics simulations with the reactive force field to study an anthracite coal model under shear stress. The results show that the FAR rupture reactions occur much more efficiently than expected. There are two important ways to initiate FAR rupture: attacked rupture and direct rupture. Among the mechanisms, two types of rearrangement reactions play crucial roles. The first type is intra-ring rearrangement where the FAR forms a three-membered ring and a five-membered ring before rupture. The second type is extra-ring rearrangement where the location of substituent group changes. Both rearrangement reactions determine which bond in the FAR preferentially breaks but in different manners, and then promote the subsequent reactions. Comparing to pyrolysis mechanism, mechanolysis mechanism follows completely different reaction pathways and result in different products. This research will aid in understanding the reaction mechanisms of coal mechanochemistry, and it opposes the traditional standpoint that the FARs of coal are relatively stable and very hard to be destroyed during coalification.

1. Introduction

The macromolecular structure of coal consists of two essential components: fused aromatic rings (FARs) and aliphatic structures (or functional groups) [1]. The breakdown mechanisms of coal structures are important for coalification process, mining security, climate change, and comprehensive utilization of coal [2]. Temperature is a major influence factor in coalification, where aliphatic structures (or functional groups) are removed and the aromatic materials condense into larger cluster [3,4]. Stress is considered to play an important role in changing the physical properties of coal, such as the pore structures [5,6]. Fourier transform infrared spectroscopy and ^{13}C nuclear magnetic resonance results indicate that tectonic stress can also influence the chemical structure by promoting dissociation of labile aliphatic structures into free radicals or small molecules and enhancing the size of the aromatic layers [7–14], following a similar evolution pathway to thermal coalification. However, this process does not reveal the difference between mechanolysis and pyrolysis [15], and there has been little discussion about the possibility of FAR rupture.

With the development of metamorphic grade coals, the level of aromaticity plays a crucial role in the thermal stability of the FARs and more thermal energy is required to dissociate the bonds of the aromatic rings [16]. Therefore, higher temperature will promote the condensation reactions to generate larger aromatic layers rather than destroy them [1,17] until formation of graphite (the final coalification product) [18,19]. FARs can react in different ways under mechanical force. Hou and co-workers suggested that ductile deformation can produce structural defects in FARs which can reduce the active energy barrier and affect or break the chemical bonds of the macromolecular structures and even FARs. Meanwhile, they speculated that mechanical force can directly act on the coal molecules [20–23]. It has also been reported that the aromatic hexagons of graphite or carbon nanotubes are destroyed during the milling process, and the hybridization of some of the carbon atoms transforms from the sp^2 configuration to the sp^3

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RESEARCH ARTICLE

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Origins of the meta-mafic rocks in the southern Dunhuang Block (NW China): Implication for tectonic framework of the southernmost Central Asian Orogenic Belt

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The Central Asian Orogenic Belt (CAOB) is one of the largest accretionary orogenic collages in the world with prominent juvenile crust addition, where the southernmost margin of the CAOB located is one hot topic in the international studies. The Dunhuang Block located to the south of the Beishan Orogen is a key position for outlining the tectonic framework of the south margin of the CAOB. However, at present, the tectonic attribution of the Dunhuang Block is still controversial. In this paper, we focus on the origins and protoliths of the meta-mafic rocks from the Hongliuxia complex in the southern Dunhuang Block for determining the tectonic attribution of the Dunhuang Block. In the field, the meta-mafic rocks are mainly exposed as tectonic blocks within the metasedimentary rocks displaying the "block-in-matrix" fabrics or as tectonic slices juxtaposed by faults. Geochemically, the meta-mafic rocks could be divided into three groups based on the rare earth elements (REE) and trace elements: the group 1 samples are depleted in the LREE relative to HREE and show flat HREE patterns, similar to the mid-oceanic ridge basalt; the group 2 samples show flat REE patterns without obvious differentiation between the LREE and HREE, like the oceanic plateau basalt; the group 3 samples are enriched in LREE relative to LREE, and have negative Nb, Ta, and Ti anomalies, similar to the island arc basalt. Conclusively, the protoliths of the meta-mafic rocks dominantly belong to the oceanic plate components. They were metamorphosed during Early Silurian to Middle Devonian in different depths of the subduction zone documented in previous studies. So, we suggest the Hongliuxia complex is an exhumed Palaeozoic subduction–accretion complex (SAC) formed during the oceanic plate subduction. This result confirms the Palaeozoic subduction event occurred in the Dunhuang region and indicates that the Dunhuang Block is a Palaeozoic Orogen rather than a part of Precambrian continent block. Considering the regional geology context, we speculate the Dunhuang Orogen belongs to the southernmost margin of the CAOB.

KEYWORDS
Central Asian Orogenic Belt, Dunhuang Block, meta-mafic rocks, subduction–accretion complex

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中国东部中生代构造格局与演化

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摘　要：中国东部早中生代以挤压构造为主，如大别造山带的逆冲推覆构造，而晚中生代伸展构造十分显著，表现为大量发育的变质核杂岩、同构造岩浆岩、拆离断层带以及穹隆构造等，这些伸展构造使地壳深部的岩石折返至地表，从而使中下地壳结构发生了强烈的改造。拟通过对中国东部晚中生代构造发育的典型地区：北部的燕山构造带、中-东部的大别-苏鲁构造带和东部的东南沿海构造带进行系统的研究、分析、归纳和总结，恢复燕山运动启动前的构造体制，研究中国东部对多幕次燕山运动中地壳变形对板块相互作用及其深部过程的响应，阐明中国东部燕山期构造体制转折的期次、时限、动力学演变机制及其与板块运动的关系，进而探讨其对成矿作用的制约。

关　键　词：晚中生代；伸展构造；变质核杂岩；动力学机制
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Mesozoic Tectonic Framework and Evolution of Eastern China

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Abstract: Eastern China was dominated by compressional structures in early Mesozoic but vast extensional structures in the Late Mesozoic. A large number of extensional structures, such as metamorphic core complexes, syntectonic plutons, detachments and domes, have exhumed the middle to lower crust into surface, and changed the structure of middle-lower crust dramatically. This paper aims to investigate the late Mesozoic structures in typical areas of Eastern China that include Yanshan tectonic belt in the north, Dabie-Sulu tectonic belt in the central and the coastal tectonic belt in the southeast. This project will also try to reconstruct the tectonic framework before Yanshanian period for its critical role to know how crust deformation responded to interaction and deep process of plates during the Yanshanian period. The purpose of this project is to illuminate the tectonic phase, activity time, dynamic mechanism, and relationship to relevant plates in Eastern China during Yanshanian period, and discuss the constraint on the metallic mineralization.

Key words: late Mesozoic; extensional structures; metamorphic core complexes; dynamic mechanism

中生代是欧亚大陆的基本构造格架发生重大转折的阶段，强烈的地壳收缩和增厚，形成了大规模走滑构造的形成，加厚岩石圈垮塌和大规模地壳伸展减薄均发生在这一阶段。特别是中国东部中生代发生的燕山运动，形成了大规模的褶皱、逆冲和推覆，并广泛发育同构造花岗岩(165～145 Ma)，是欧亚大陆一次重要的构造活动。到早白垩世中期，中国东部以华北克拉通为代表经历了岩石圈垮塌和地壳伸展过程，主要表现为广泛发育的变质核杂岩(峰期在125 Ma左右)和相的伸展盆地体系，并

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Paleozoic Sanweishan arc in the northern Dunhuang region, NW China: The Dunhuang block is a Phanerozoic orogen, not a Precambrian block

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ABSTRACT

The Dunhuang region is located to the south of the Central Asian Orogenic Belt and connecting the Tarim Craton westerly and North China Craton easterly, respectively. It is an important position for understanding the geodynamics and tectonic framework of Central Asia. However, the issue about whether it is a Phanerozoic orogen or a Precambrian block is still controversial. Magmatic arcs are the most prominent and laterally persistent structural elements of orogenic belts and used to reconstruct now-disrupted orogenic belts. This paper concerns the petrogenesis and tectonic setting of andesitic-dacitic-rhyolitic volcaniclastic rocks and dacitic porphyries in the Sanweishan area, northern Dunhuang region. Volcaniclastic rocks overlie the metasedimentary rocks by fault and dacitic porphyries intrude into the metasedimentary rocks. The calc-alkaline signature and relative enrichment of large-ion lithophile elements of volcaniclastic rocks and dacitic porphyries seemingly favor a subduction setting. Zircon U-Pb dating results reveal the deposition at 424–414 Ma for volcaniclastic rocks and emplacement at ca. 364 Ma for dacitic porphyries. The coeval granitoid plutons in the Sanweishan area show arc geochemical signature and are originated from partial melting of the subducted sediments based on the available data. Paleozoic volcanic-subvolcanic rocks and plutons in this area probably represent a magmatic arc developed on the accretionary complex, resembling the arc magmatic rocks formed in the Nankai complex, SW Japanese Island arc. Our results provide constraints on the existence of the Paleozoic magmatic arc in the northern Dunhuang region and suggest the so-called "Dunhuang block" is virtually a Phanerozoic orogen rather than a Precambrian block.

1. Introduction

The Central Asian Orogenic Belt (CAOB) is located to the south of the East Europian Craton and Siberian Craton, and the north of the Tarim Craton (TC) and North China Craton (NCC), respectively. It is considered as the relic of the Paleo-Asian Ocean and one of the largest accretionary orogenic systems in the world with a long evolutionary history from ca. 1000 Ma to ca. 250 Ma (Sengor et al., 1993; Sengor and Natal'in, 1996; Windley et al., 2007; Xiao et al., 2008, 2009a, 2015). It is a crucial tectonic position to shed light on the geodynamics of Central Asia and is a window for understanding the process of continental growth and mantle-crust interaction.

The Dunhuang region is bordered by the CAOB to the north and connecting the TC westerly and NCC easterly, respectively (Fig. 1a). It's traditionally considered as a stable Precambrian continental block with crystalline basement belonging to the TC or NCC, termed the "Dunhuang block" (Huang et al., 1980; Long et al., 2014; Lu et al., 2008; Mei et al., 1998; Zhang et al., 2012, 2013; Zhao et al., 2013, 2015a, 2015b; Zong et al., 2013). Some researchers considered that the "Dunhuang block" was incorporated into the Beishan orogenic collage as a micro-continental block (e.g., He et al., 2014b). But, the recent studies reveal that the Paleozoic magmatic and high-pressure metamorphic rocks are widely exposed in the Dunhuang region (Bao et al., 2017; He et al., 2014a; Meng et al., 2011; Peng et al., 2014; Pham et al., 2018; Wang et al., 2016a, 2016b; Wang et al., 2016c, 2017a, 2017b, 2018a, 2018b; Zhang et al., 2009; Zhao et al., 2015c, 2016, 2017; Zhu et al., 2014; Zong et al., 2012). These rocks are considered as products of the Paleozoic subduction-collision events. Additionally, the field structural, sedimentary, metamorphic and geochronological studies suggest that the Hongliuxia area (southern Dunhuang region) is possible a Paleozoic subduction mélange formed in the oceanic lithosphere subduction process (Shi et al., 2017, 2018; Wang et al., 2017a, 2017b,

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The Late Jurassic extensional event in the central part of the South China Block – evidence from the Laoshan'ao shear zone and Xiangdong Tungsten deposit (Hunan, SE China)

Wei Wei, Chao Song, Quanlin Hou, Yan Chen, Michel Faure, Quanren Yan, Qing Liu, Jinfeng Sun & Haofeng Zhu

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北京云蒙山变质核杂岩大水峪韧性剪切带的应变特征及构造意义*

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Zhao TG, Hou QL, Shi MY and Ding L. 2021. Strain characteristics and tectonic significance of Dashuiyu ductile shear zone in Yunmengshan metamorphic core complex, Beijing. *Acta Petrologica Sinica*, 37(8): 2483 – 2501, doi: 10.18654/1000-0569/2021.08.14

Abstract The study of the Dashuiyu ductile shear zone on the southeastern margin of the Yunmengshan metamorphic core complex in Beijing provides a new basis for understanding the tectonic evolution process of the Yunmengshan metamorphic core complex. This paper systematically analyzes the strain characteristics of the Dashuiyu ductile shear zone by means of deformation temperature interval estimation, finite strain measurement and kinematic vorticity calculation and further explores the structural significance of its changes. The results of feldspar quartz thermometer and EBSD quartz fabric analysis show that the deformation temperature range of shear zone is 480 ~ 650℃. The deformation temperature of the southwest section of the shear zone gradually decreases from north to south, and the deformation temperature of the northeast section first decreases from the rock base to the fault and then increases. The finite strain measurement results indicate that the deformation of the shear zone is affected by flattening as a whole, and the flattening degree and ductile displacement of the southwestern section are greater than those of the northeastern section. The kinematic vorticity calculation results show that the shear band is mainly controlled by pure shear during the formation process. The kinematic vorticity in the southwestern section gradually increases from N to S, and the kinematic vorticity in the northeastern section first decreases and then increases from the rock base to the fault direction. Combined with the previous research results of Yunmengshan metamorphic core complex, comprehensive analysis shows that magmatism is the dominant factor leading to the formation of the Yunmengshan metamorphic core complex, and the detachment process of the northeast segment of the Dashuiyu ductile shear zone is blocked by the eastern rock mass.

Key words Yunmengshan; Ductile shear zone; Finite strain measurement; Kinematic vorticity

摘 要 北京云蒙山变质核杂岩东南缘的大水峪韧性剪切带是认识云蒙山变质核杂岩构造演化的关键。本文通过变形温度区间估算、有限应变测量以及运动学涡度计算等手段对大水峪韧性剪切带的应变特征进行了系统分析。长石石英温度计

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山脉与造山带及有关问题讨论*

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Hou QL, Guo QQ, Chen YC, Cheng NN, Shi MY and Li JL. 2021. Discussions on the mountains and orogenic belts and related issues. *Acta Petrologica Sinica*, 37(8): 2287 – 2302, doi: 10.18654/1000-0569/2021.08.02

Abstract A good grasp of the distinctions between mountains and orogenic belts is crucial to the understanding of plate tectonics. The greatest innovation must be based on the inheritance of previous researches, therefore, this paper first reviews the research history from mountains to orogenic belts in Earth Science, and then concludes the distinctions between them, and lists some common questions in the study of orogenic belts. The research history of mountains, from morphology and the interpretation of uplifting to the internal structure, tectonics and the universal dynamics, follows the whole process of modern geology, from the birth to the geosyncline theory and finally the plate tectonics theory. The plate tectonics theory gives a more definite definition to orogenic belts and defines the tasks and objects of structural geology. As a topographic term, mountains only represent landmasses conspicuously above surroundings. The key point of mountains is the elevations and steep slops. They can be resulted from any horizontal stresses of extensional, compressional and shearing, or from vertical stresses governed by mantle plume or exoteric body impact. Orogen is a collective term and represents structures constructed by the collective work of convergent plate margin processes. Orogenic belts contain subductional and collisional orogenic belts. The key characteristics of orogenic belts are the subduction-controlled rock-structure associations. Orogenic belts emphasize the dynamic process while mountains emphasize the static form and the present morphology. Mountains and orogenic belts are two entirely different concepts. In the end, we outline some confused and misunderstood issues, as well as some unclear concepts, that remain to be discussed.

Key words Orogenic belts; Mountains; Subduction metamorphism; Mélange; Accretionary arc

摘 要 正确处理山脉和造山带之间的关系,是深刻理解和准确把握板块构造理论的内涵本质和理论体系的基础和前提。最伟大的创新必然是建立在最深刻的继承基础之上。本文详细回顾了从山脉到造山带的研究历史,梳理了两者的关系,并在此基础上简单总结了一些目前造山带研究中的共性问题。山脉的研究历史,从形态描述和隆升成因探索的形貌学研究阶段,到内部构造、形成机制的研究和普适性成因的探索,伴随了现代地质学从诞生到槽台学说并最终形成板块构造理论的整个过程。板块构造理论对造山带做出了更为明确的限定,明确了山脉研究中构造地质学的任务和对象。山脉是地貌学/地理学名词,强调的是现时形态和形貌特征,关键是具有一定的高程和陡坡,它可以形成于引张、挤压、剪切等不同的水平应力作用下,也可以形成于垂向应力作用范畴的地幔柱、地外体冲击作用等。然而,造山带是汇聚板块边缘大地构造作用形成的带状地质体,是地质学名词,强调的是动态过程,包括俯冲造山带和碰撞造山带,关键是具有汇聚板块边缘的岩石-构造组合。山脉和造山带是既有交集,又彼此不可包容的两个概念。文中最后列举的一些造山带研究中容易混淆和误解的问题,以及有些不太清

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新疆南天山阿沙哇义金矿床的成因与找矿启示：来自流体和硫化物成分的限定*

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Chen B, Hou QL, Feng HY, Guo H and Xu YX. 2019. Fluid and sulfide component constraints on the genesis and prospecting implications of the Ashawayi gold deposit, South Tianshan, Xinjiang, NW China. *Acta Petrologica Sinica*, 35(7):2086-2104, doi:10.18654/1000-0569/2019.07.09

Abstract The Ashawayi gold deposit is located in the eastern part of South Tianshan Sb-Hg-Au metallogenic belt which is one of the important sources of gold in China. This deposit is characterized by typical disseminated pyritization and arsenopyritization, and its distribution is controlled by faults. Three stages of hydrothermal alteration have been identified, including: (1) the early stage with no mineralization or quartz-growth; (2) the middle stage with occurrences of quartz polymetallic sulfide; and (3) the late stage with quartz and carbonatization. Among them, the middle stage is the main period for mineralization. The gas phase compositions of the fluid from the middle stage ores are mainly H_2O (75% ~93%), and subordinately followed by CO_2 (6% ~25%), and the rests are CH_4, C_2H_6, H_2S, N_2 and Ar. The cations are mainly Na^+ with minor K^+ and Ca^{2+} while the anions are mainly Cl^-, followed by SO^{2-}. The Au content in the ore is inversely correlated with the CO_2 content, and is positively correlated with the K^+ content of the fluid from the ore. The analytical results of the sulfide compositions show that: (1) The pyrite and arsenopyrite in the wall rocks and ores are mainly auriferous minerals. The Au contents in pyrite and arsenopyrite are 0 ~0.09% (0.03% on average) and 0 ~0.28% (0.07% on average), respectively; (2) There is no obvious correlation between Au content and crystal morphology of the pyrite and arsenopyrite; (3) Cyclic zonal pyrite contains higher Au contents than the pyrite having homogeneous structure; (4) Au rarely occurs in the pyrite from magmatic rocks. Many factors, such as ore-forming structural environments, properties and evolution of ore-forming fluids, the mechanism of gold enrichment and the estimation for ore-forming *P-T* conditions, are similar with ones of most orogenic gold deposits in the world. Thus we suggest that the Ashawayi gold deposit is an orogenic gold deposit with relatively shallow denudation. The possible mechanism for mineralization is associated with the fault healing and fracturing which induced the immixing process of fluids. The fluid mixing mechanism also plays a role in gold enrichment and precipitation. As a result, we proposed that the development and coexistence of pyrite, arsenopyrite and carbonaceous material is the most favorable marks for the exploration of high-grade ores in the Ashawayi gold deposit.

Key words Orogenic gold deposit; Ashawayi; Fluid inclusion; Pyrite; South Tianshan

摘 要 阿沙哇义金矿位于中国新疆南天山造山带，属于著名的中亚南天山锑-汞-金成矿带的东延部分。该矿床严格受断

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Molecular dynamics simulation of quartz deformation under slow earthquake background

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Abstract Slow earthquakes are the primary mechanism of slow energy release, and research on the focal mechanism has been inconclusive. Studies have primarily focused on the friction law based on physical mechanisms and have suggested that slow earthquakes are caused by brittle faults. However, the focal strength and structural characteristics of slow earthquakes in subduction zones provide evidence of plastic deformation. What is the role of plastic deformation in the focal mechanisms of slow earthquakes? Mechanochemical study have shown that mechanical forces can directly affect chemical bonds. In this study, we examine the storage and release of chemical energy during plastic deformation and consider a mechanochemical process in the focal mechanism of slow earthquakes. Combined with the Tersoff potential, molecular dynamics simulation on the shear deformation process of two α-quartz crystals show that the shear modulus of α-quartz is 18 GPa, and that the crystal model primarily exhibits atoms flowing and changing in the direction of chemical bonds during the steady-state flow stage. The molecular potential energy and stress vary in an oscillating up-and-down curve during shear, indicating that chemical energy can be stored and released during plastic deformation. This is consistent with the energy variation during slow earthquakes. Under the initial simple-shear loading condition, α-quartz crystals undergo general shear deformation instead of plane strain and the angle between the longest instantaneous stretching axis (ISA_1) and the shearing direction is approximately 30°, not 45°. Both the deformation type and direction of ISA_1 are contrary to basic deformation theory, which may provide clues for future research. This study reveals the process of quartz elastic-plastic shear deformation on an atomic scale. This information is useful for understanding focal mechanisms of slow earthquakes. This study is part of a series of investigations on tectonic stress chemistry.

Keywords Slow earthquake, α-quartz, Plastic strain energy, Tectonic stress chemistry, Tersoff potential

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1. Introduction

Slow earthquakes, a popular topic in the research on earthquake physics and subduction zone dynamics, are a type of slow energy release closely related to ordinary earthquakes. Studies on slow earthquakes began with observations and identification of seismic signals and later expanded to the geophysical detection of focal areal structures and mechanisms (Sacks et al., 1978; Costello and Tullis, 1999; Dragert et al., 2001; Kodaira et al., 2004; Shelly et al., 2006; Bell et al., 2009; Shelly and Hardebeck, 2010; Gao and Wang, 2017; Wei et al., 2021). Studies on elastic-plastic mechanics suggest that brittle deformation releases elastic strain energy, whereas plastic deformation cannot be recovered and can only consume energy. The study of the slow-earthquake focal mechanism began primarily with brittle deformation and considered the rheological and frictional properties of the fault zone. Researchers have conducted many laboratory experiments and numerical simulations on rock mechanical properties and have developed various models and me-

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综 述

构造应力化学
——慢地震震源机制解的一种可能途径*

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摘 要 慢地震震源机制研究主要建立在脆性变形基础上。然而高纵、横波速度比、异常高泊松比等特征表明其震源区物质黏度较大,更易发生塑性变形。固体力学研究认为塑性变形的起点是位错,塑性应变能无法释放。分子尺度上,原子通过化学键结合形成矿物结构。应力化学研究显示机械力可以直接作用于化学键,化学键断裂时体系位于能量高位。塑性变形的位错机制可能始于化学键的变化,再通过断裂、重组,形成亚颗粒、细粒化,能量的转化过程可能是机械能首先转化为体系内能,即原子势能;随着加载继续,原子势能突破化学键的束缚,转化为塑性应变能。化学键的重建会释放能量,塑性变形过程中可能会释放一部分化学能,这是否与慢地震有关,是个值得探索的科学问题。

关键词 慢地震;震源机制;塑性变形微观机理;塑性应变能;构造应力化学

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Tectonic stress chemistry: a possible perspective on focal mechanism of slow earthquakes

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Abstract Research on the slow-earthquake focal mechanism was mainly based on brittle deformation. However, high ratios of P-wave to S-wave velocity, and anomalously high Poisson's ratios indicate that the source material of slow earthquakes is more viscous and more prone to plastic deformation. Traditional studies suggest that plastic deformation begins with dislocation, and is permanent. Therefore, the plastic strain energy cannot be released. However, it may be different when talked about on a microscopic molecular scale. The lithosphere is mainly constructed of silicate

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