地球科学

中国岩石圈三维结构丛书之九

Series of Monographs on the Three-dimensional Structure of Lithosphere in China

中国大陆岩石圈物质组成及演化

邱瑞照 李廷栋 周 肃
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3D LITHOSPHERE

地质出版社

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·北　京·

内 容 提 要

本书为国土资源部“中国岩石圈三维结构”科技专项计划研究成果之一。作者通过中国大陆地形地貌、地热、地质历史、基底岩石组成、火成岩浆活动、深源包体、地震结构、实验岩石波速等多方面的研究，探索了解岩石圈深部物质组成的综合研究方法，首次构建出中国大陆岩石圈的岩石学结构初步模型，从岩石圈角度对中国大陆岩石圈的类型、物质形成时代和结构形成时代、岩石圈不均一性，以及岩石圈与金属矿产资源、能源的关系等进行了探讨。

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中国岩石圈三维结构丛书
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中国岩石圈三维结构丛书

Series of Monographs on the Three-dimensional Structure of Lithosphere in China

1 中国岩石圈三维结构
The three-dimensional structure of lithosphere in China

2 中国西部岩石圈三维结构及演化
The three-dimensional structure of lithosphere and its evolution in western part of China

3 中国兴蒙-吉黑地区岩石圈三维结构及演化
The three-dimensional structure of lithosphere and its evolution in the northeast part of China

4 中国华北地区岩石圈三维结构及演化
The three-dimensional structure of lithosphere and its evolution in north China

5 秦岭-大别-苏鲁地区岩石圈三维化学结构特征
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The three-dimensional structure of lithosphere and its evolution in south China and east China sea

8 中国南海海域岩石圈三维结构及演化
The three-dimensional structure of lithosphere and its evolution in the South China sea

9 中国大陆岩石圈物质组成及演化
The composition and evolution of lithosphere in China continent

序

地球是一个由多个圈层组成的复杂球体。岩石圈是地球浅部的刚性圈层，由地壳和地幔盖层组成。

地球科学的根本任务在于研究和认识地球，并利用这种认识去保障人类所需的自然资源的供给和人类居住环境的优化。岩石圈是近年来地球科学中发展起来的一个新的研究方向和前沿性研究课题。人们在生产和科学实践中逐渐认识到，研究岩石圈，认识岩石圈，不断充实岩石圈的科学知识，对于探讨地质规律、解析矿产成因、评估地质环境质量和地质灾害形成机理，以及洞察大陆演化的动力学过程等，都具有重要的意义。

正是由于以上的原因，自20世纪50年代以来，为了从整体上研究和认识地球，国际地学组织先后实施了“国际地球物理年”等国际合作研究计划。特别是从20世纪80年代开始，为了阐明岩石圈物质组成、结构构造、演化及动力学机制，国际组织实施了“国际岩石圈动力学和演化”及“国际岩石圈-生物圈计划”等大型国际合作研究计划；美国、加拿大、欧洲一些国家也实施了大规模的岩石圈研究计划。用地质、地球物理、地球化学相结合的方法，开展了全球地学断面以及重要造山带、地质区及沉积盆地岩石圈结构构造及深部作用过程的调查研究，取得了诸多创新性研究成果，深化了对岩石圈性质、成因的认识，为建立地球系统科学的知识体系奠定了良好基础。

几十年来，我国开展了规模宏大的地质调查、地球物理探测、地球化学勘查及岩石圈地质研究工作，中、小比例尺区域地质调查和航空磁测已覆盖全国陆地及毗邻海域的部分地区；以爆破地震为主的地球物理测深剖面已完成约50000 km，并完成了大量其他方法的地球物理探测工作。20世纪80年代以来，我国参与了国际岩石圈研究计划，进行了11条地学断面以及碰撞造山带超高压变质作用和动力学、沉积盆地成因及全球地震活动性等的研究，并在苏北实施了深度达5100余米的大陆科学钻探工程。多年来的地质调查研究积累了极为丰富的数据和资料。

为了系统总结我国深部地质、地球物理调查及岩石圈研究成果，国土资源部于2000年制定并实施了“中国岩石圈三维结构”专项研究计划。该计划包括3个重点研究项目：中国岩石圈三维结构数据库、重点区段岩石圈三维结构特征、中国大陆岩石圈三维结构及其演化与动力学。研究的任务和总目标是：以现代地学理论为指导，以新技术方法为手段，对已积累的岩石圈数据、资料进行多学科综合研究，揭示中国岩石圈三维结构及演化规律，为国土资源规划、管理、保护和合理利用提供科学依据，为国家经济社会可持续发展规划提供科学基础，为创建地球系统科学理论开辟科学的突破口。

参加该专项研究和管理工作的包括来自中国地质科学院地质研究所、中国地质科学院矿产资源研究所、中国地质科学院机关、国土资源部国际合作与科技司、中国地质调查局、中国地质大学（北京）、中国地质大学（武汉）、吉林大学、成都理工大学、同济大学、中国地质调查局广州海洋地质调查局、中国石油化工集团上海石油规划设计研究院、中国地

质调查局天津地质矿产研究所、国土资源信息中心实物地质资料中心等14个单位100多位科研和科技管理专家。

在全体参研专家、学者们的辛勤劳作和精心研究下，圆满地完成了专项计划任务，达到了预期目标，各个项目和课题都在各自的研究领域取得了丰硕的科学成果。

“中国岩石圈三维结构数据库”是我国建立的第一个全国性的岩石圈结构数据库，它由9个原始数据库、3个成果数据库和2个总库共14个子库组成。该数据库收录的数据量大，学科涵盖面广；数据库软件先进，管理系统灵活实用；并可通过互联网实现信息的国际交换与数据共享，将成为我国岩石圈探测研究成果信息化和数据共享的范例。

各重点区段课题均以地学断面资料为基础，开展了地质、地球物理、地球化学等多学科综合研究，总结了区段内造山带、盆地和克拉通等构造单元岩石圈结构特征及相互间的时空联系，初步建立了岩石圈三维结构可视化模型。通过研究深化了对中国岩石圈物质组成及结构构造的认识，在中国东部，岩石圈与软流圈之间显示分层不明显的过渡带的存在，岩石圈呈现明显的“上老下新”年龄结构。在青藏高原近南北向巨型航磁异常带部位，在岩石圈深部也发现更为明显的近南北向的构造带，显示了岩石圈表层与深部构造的极端不均一性。

在岩石圈数据库及重点区段岩石圈结构研究的基础上，围绕“中国大陆岩石圈三维结构及其演化与动力学”这一主题，开展了综合研究和成果的集成，汇集编制了表达中国岩石圈结构和演化的系列图件；划分了中国大陆及其邻近海域岩石圈构造单元和岩石圈构造类型，总结了各岩石圈构造单元基本特点；论证了中国岩石圈地球物理场及地球化学场特征；探究了中国岩石圈物质结构及化学结构；进行了岩石圈三维结构的数值模拟，探讨了中国岩石圈的演化及动力学过程。

为了充分展现专项研究的成果，为有关部门和地学界奉献尽可能多的有关中国岩石圈的信息，除提交“中国岩石圈三维结构数据库”和“中国岩石圈三维结构特征图集”外，我们根据合同书的要求，在研究报告基础上编著了《中国岩石圈三维结构丛书》。这套丛书包括一部全国性论著和8部区域性专著，分别论述了全国和6个区段的岩石圈构造单元及秦岭、大别-苏鲁两个造山带岩石圈三维结构及其演化特征。

科研实践和科学成果说明，国土资源部实施“中国岩石圈三维结构”专项研究计划是一个有远见卓识之举。

通过专项研究计划的实施，建立了具有现代科学技术水平的“中国岩石圈三维结构数据库”，对我国积累的海量地质、地球物理、地球化学调查研究资料和数据进行了系统汇集；对一些面临散失和行将毁损的珍贵资料进行了抢救性收集、整理和转存；对大部分地球物理剖面进行了资料的再处理、再解释，挖掘出了更多地质信息。

通过专项研究计划的实施，取得了一批高水平的和创新性的科学成果，缩短了在岩石圈研究上与发达国家的差距。对中国岩石圈进行了地质、地球物理、地球化学相结合的综合研究，划分了中国岩石圈构造单元和类型，总结了中国岩石圈的若干特点和演化规律，揭示出若干新的事实和新的现象，深化了对中国岩石圈三维结构及其演化过程的认识，为解决资源、环境勘查、评价的一些重大科学问题奠定了基础。

通过专项研究计划的实施，推动了科研单位、高等院校和地质勘查单位的结合，实现了岩石圈研究的强强联合，巩固和发展了一些岩石圈研究基地和科研群体，培养出一批年

轻的岩石圈研究人才，打造出一支老中青结合的、水平较高的岩石圈研究队伍，为我国今后较大规模的岩石圈研究提供了某些方面的组织和人才保障。

通过专项研究计划的实施，不但解决或深化了一批岩石圈研究中的重大科学技术问题；而且在岩石圈物质组成及结构构造上发现若干奇异的新现象，揭露出一批有待进一步深入研究的科学问题。同时，积累了一些岩石圈研究的经验。这些科学问题和经验可供日后岩石圈研究者借鉴。

这一专项研究计划的实施和成功，是与全体科技人员的辛勤劳作和刻苦钻研分不开的，是与上级各部门的领导、关怀和指导分不开的。同时，也是与各协作单位的支持和协同分不开的。这里需要特别指出的是，部国际合作与科技司和黄宗理司长、崔岩副司长、白星碧副处长，中国地质调查局和叶天竺原局长、孟宪来局长、张洪涛副局长、彭齐鸣主任，中国地质科学院及张彦英院长、董树文副院长，中国地质科学院地质研究所及许志琴前所长、汪东波所长、耿元生副所长等，自始至终给予该专项计划极大的关注指导和鼎力支持，对计划的顺利实施发挥了重要作用。在这里向支持该专项计划的各级领导部门、各协作单位以及有关领导和专家、学者表示衷心的感谢。

这套丛书连同“中国岩石圈三维结构数据库”和“中国岩石圈三维结构特征图集”，集中反映了“中国岩石圈三维结构”专项研究计划所取得的研究成果。我们期望这些成果能够对发展岩石圈的有关理论和实际应用方面发挥较大作用，对深入研究中国岩石圈结构构造及其演化作出较大贡献。我们真心诚意地期望地学界同仁们的批评指正。

李廷栋

2005 年 3 月

前　言

为了揭示中国岩石圈三维结构特征及其演化规律，深化对中国大陆形成、演化及大陆动力学的认识，查明岩石圈三维结构特征与矿产资源（含能源）形成、分布以及与地质灾害成因机理之间的内在联系，从而为国土资源规划与开发利用、为国民经济可持续发展提供深部地质科学依据，为地球科学的理论创新和发展做出贡献，国土资源部将“中国岩石圈三维结构”研究列入了“十五”期间的重点科技专项计划。

该专项计划由中国地质科学院地质研究所负责，中国地质大学、吉林大学、成都理工大学、广州海洋地质调查局和上海石油规划设计研究院等单位参加。专项计划包括三个项目、六个区段课题。

项目Ⅰ，建立中国岩石圈三维结构数据库。包括网络数据库、深地震反射与宽频地震数据库、大地电磁测深数据库、大地热流测量数据库等14个子库。由中国地质科学院地质研究所负责，吉林大学、同济大学等参加。

项目Ⅱ，六个地区（区段）的岩石圈三维结构研究。包括：

1. 青藏高原-西北盆山岩石圈三维结构研究。中国地质科学院地质研究所承担，中国地质科学院矿产资源研究所参加。

2. 兴蒙-吉黑地区岩石圈三维结构研究。吉林大学（地球科学学院）承担。

3. 华北地区岩石圈三维结构研究。中国地质大学（北京）承担。

4. 东秦岭-大别-苏鲁地区岩石圈三维结构研究。中国地质科学院地质研究所和中国地质大学（武汉）承担。

5. 华南地区（含东海）岩石圈三维结构研究。成都理工大学负责，天津地质矿产研究所和中国地质大学（北京）参加。其中东海海域岩石圈三维结构研究，由上海石油规划设计研究院承担。

6. 南海海域岩石圈三维结构研究。广州海洋地质调查局承担。

项目Ⅲ，中国大陆岩石圈三维结构及其演化和编图。由专项计划专家组负责，各项目、课题组的有关人员参加。

上述三个项目的实施计划，分别为：

项目Ⅰ，2000年9月—2005年12月；

项目Ⅱ，2000年9月—2004年6月；

项目Ⅲ，2004年6月—2006年7月。

为了确保上述专项计划的顺利实施，达到预期标准和实现预期目标，在国土资源部国际合作与科技司的领导下成立了专项计划专家组。专家组成员有：李廷栋（组长）、袁学诚、肖庆辉、黄宗理、叶天竺。部国际合作与科技司主管本项目专家为白星碧。由专家组负责专项计划实施过程中的全面技术指导、各阶段的计划落实与检查、组织召开各项技术业务会议和进行统一管理等工作，并直接承担项目Ⅲ的综合研究任务。

为了加强专项计划实施过程中的项目管理，在专家组领导下，在中国地质科学院地质研究所建立了专项计划办公室，成员有：耿树方（主任）、范本贤、郝美英和姚培毅。办

公室承担专项计划的日常管理工作，协助专家组制定有关的统一技术标准，草拟各项文件，筹办各项会议及编写各项总结等等，以确保专项计划的顺利实施。

本专项计划建立的“中国岩石圈三维结构数据库”，以及专项计划各项研究成果构成的“中国岩石圈三维结构系列丛书”与相关“图集”，将为实行岩石圈信息资源共享，全面了解和认识中国大陆岩石圈三维结构特征，发展和创新地球科学理论，发挥重要作用；将为国土资源规划部署，矿产资源勘查、研究，地质环境与地质灾害评估等，提供深部地质资料依据。

“中国大陆岩石圈物质组成及演化”属于国土资源部科技计划专项“中国岩石圈三维结构”项目（编号：200010103）下设的创新性课题。该课题也是本书第一作者博士后期间的主要研究任务（合作导师李廷栋院士、肖庆辉研究员），研究目标是通过地质与地球物理相结合，探索了解岩石圈深部物质组成的综合研究方法；建立反映现今中国大陆三维岩石圈特点的深部物质模型；分析对比中国各岩石圈单元内不同类型岩石圈的岩石学结构差异，提出岩石圈构造单元划分建议；在代表性地学断面上或区域上表达反映中国主要岩石圈单元深部物质和结构的不均一性；根据岩石圈深部物质演化框架探讨岩石圈与金属矿产资源、能源矿产的关系。

岩石圈深部物质组成是一个极富挑战性的前沿课题，它是岩石圈的基本参数和大陆动力学研究的基础，对此各国地球科学家们竞相探索。这一学科也称为地球深部物质科学，在地球科学领域中是一个非常特殊的分支，需要把与地球深部有关的多个学科，如矿物学、矿物物理学、高压矿物物理学、岩石学、岩石力学、地质学、地球化学、地球物理学等学科的学术思想、研究成果和探测方法结合起来进行研究。因此，研究过程中需要广泛涉猎各学科的知识，吸收相关学科的研究成果。针对研究目标，作者开展了以下几个方面的研究：①根据既有实验波速数据又有岩石化学分析结果的样本，经过筛选、验证，建立了岩石成分与地震波速之间的关系方程，论述了其适用性；②厘定中国大陆主要地质事件序列，以及评估对各主要地质构造单元的影响；③按统一标准筛选和划分中国主要构造单元的典型地质地球物理剖面和地球物理柱；根据地质特征、现今地球物理深部结构特征、地热状态、地貌，分别区分了华北、东北、华南、西北和青藏高原地区的岩石圈类型；④采用综合岩石学结构研究方法，即出露的前寒武纪变质岩石、火成岩构造组合、深源包体、波速与岩石成分的关系、Sr－Nd 同位素示踪等资料和方法，结合壳幔演化、造山带演化模型，推断岩石圈的深部物质成分结构，建立了 18 个地区的不同岩石圈类型的壳-幔岩石结构和化学结构柱；⑤根据建立的岩石学结构柱，首次构建出中国大陆岩石圈岩石学结构模型；根据岩石圈动力学性质，区分出中国大陆由克拉通型（扬子、鄂尔多斯、塔里木）、造山带型（昆仑、天山、阿尔泰山、青藏高原、燕山、大兴安岭、南岭等）、裂谷型（中国东部平原、大陆架等）、岛弧型（台湾、日本列岛等）和边缘海洋壳型（南海中央海盆）等 5 类岩石圈构成；⑥根据岩石圈现今的特征，结合地质历史演化，详细论述了不同类型、不同地区岩石圈的物质形成时代和结构形成时代，展示了现今中国大陆岩石圈物质组成、结构和形成时代的不均一性；⑦根据中国大陆金属矿床、油气田产出的特点，结合岩石圈背景，探讨岩石圈与金属矿床大规模成矿作用、油气田产出的关系，提出大规模成矿作用的发生标志；⑧从岩石圈角度，对中新生代中国大陆动力学背景、中国东部燕山期花岗岩成因、大地构造单元划分和新生代以来中国大陆的旋转及其效应等若干问题进行了探讨。

本书是在第一作者的博士后研究报告《中国三维岩石圈深部物质模型研究》基础上

编写完成，研究工作得到国土资源部科技专项《中国岩石圈三维结构》综合研究项目（编号：200010103；2000—2006）、邓晋福教授负责的《中国岩石圈三维结构》项目下属专题——“华北地区岩石圈三维结构”（编号：200010202；2000—2003）和中国地质调查局《中国成矿体系与区域成矿评价》项目下属专题——“中国地球物理场特征及深部地质与成矿”（专题编号：K1.4－1－2；1999—2003）、肖庆辉研究员负责的中国地质调查局重大基础研究——《中国花岗岩与大陆地壳生长》综合研究项目（编号：200113900018；2001—2005），教育部“岩石圈构造、深部过程及探测技术”重点实验室基金——“西藏冈底斯造山带岩石圈壳幔岩石学结构研究”（编号：2003010；2004—2005）和国家自然科学基金——“印度—亚洲大陆起始碰撞时间穿时性研究的火成岩同位素年代学约束（编号：40572048）”等项目的联合资助。

全书共分9章，各章节编写如下：第一章：邱瑞照、李廷栋、邓晋福；第二章：邱瑞照、邓晋福、周肃、李廷栋；第三章：邱瑞照、李廷栋、邓晋福、周肃；第四章第一节：邱瑞照、周肃、李廷栋、邓晋福；第四章第二节：周肃、邱瑞照、邓晋福、李廷栋；第五章～第七章：邱瑞照、李廷栋、邓晋福、周肃、肖庆辉；第八章：邱瑞照、周肃、邓晋福；第九章：邱瑞照、李廷栋、周肃、邓晋福、肖庆辉；全书由邱瑞照统稿、编撰出版。

“中国大陆岩石圈物质组成及演化”为研究课题名称，作者认为“中国大陆岩石圈岩石学结构”作为本书名称比较合适。在完成本书之际，作者感谢国土资源部国际合作与科技司和中国地质调查局，由于它们设立的上述一些项目，使我们有机会参与中国大陆范围地质与地球物理相结合的前沿研究。感谢黄宗理研究员、张洪涛研究员、叶天竺研究员、肖序常院士、袁学诚研究员、白星碧研究员等在科研工作条件上的支持和研究方向、学术思想、工作方法上的具体指导。感谢《中国岩石圈三维结构》专项各专题、课题负责人和专家们在资料及研究工作上给予的真诚而有益的帮助；感谢中国地质科学院资源研究所彭聪研究员、地质研究所李秋生研究员、中国地质大学赵志丹教授等在地球物理资料、文献方面提供的帮助；感谢中国地质大学（北京）莫宣学教授、罗照华教授、赵海玲教授、喻学惠教授、苏尚国教授、赵国春博士、刘翠博士、成都地质矿产研究所潘桂棠研究员、天津地质矿产研究所陆松年研究员、中国科学院地质与地球物理研究所张旗研究员、美国芝加哥大学 Martin F. J. Flower 教授、罗马尼亚布加勒斯特大学 Victor Mocanu 教授等在研究过程中与作者进行的有益讨论；特别感谢中国地质科学院地质研究所各级领导、各有关研究室、以及办公室、科研处、财务处、图书馆、资料室、制图室等处室的同志们在许多具体事务上的帮助。

本书的编撰出版，还得到中国地质调查局发展研究中心姚华军副主任、严光生总工程师关心和境外地质矿产研究室同事连长云、刘大文、元春华、陈秀法、王靓靓、韩九曦、陈正，和职能处室的胡小平、张阳明、曹方、尤孝才、杨青、王军等同志在许多具体事务上给予的支持和鼓励；高歆、王玉巧帮助查阅了部分文献，刘勇、王明燕清绘了部分图件，特此致谢。

书中参考和引用了许多作者的资料和文献，特别是有些未公开发表的资料，在此谨向他们致以衷心的感谢！

中国岩石圈三维结构专项计划

办公室与本书作者

2004年7月13日

Foreword

The Earth is a complex multi-layered sphere, of which the lithosphere is the shallow rigid sphere made up of crust and the upper mantle.

The primary aim of geosciences is to study and recognize the earth, to guarantee the natural resources satisfy human needs and make human habitation comfort on the basis of these recognized rules. In current geosciences, the lithosphere is a newly-developed research subject. It is very important significance on the probing geological laws, analyzing mineral resource genesis, evaluating geological environment and catastrophes, apperceiving continental evolution to study lithosphere, recognize lithosphere, gradually extend the lithospheric data.

For above-mentioned reasons, since 1950s, in order to study and recognize completely the earth, the International Geoscience Organization have implemented some international cooperation research projects, such as "International Geophysical Year". Especially from 1980s on, to make out the lithospheric constitutes, texture and structure, evolution and dynamical mechanism, the International Geoscience Organization have implemented such large-scaled international cooperation research projects as "International Lithospheric Dynamic and Evolution Program" and "International Lithosphere-Biosphere Program". In addition, USA, Canada, some states In Europe have implemented some large-scaled lithospheric research projects. By using of combination of the geological, geophysical, geochemical methods, the research and survey on the lithospheric texture and structure and deep processes of the global geoseience transect, important orogenic belts, and the sedimentary basins have done, and many innovative research results have been obtained, which make the lithospheric property and genesis be deeply recognized. That becomes the good basis for establishing the systemic geosciences.

During several tens of years, in China, some magnificent geological survey, geophysical detection, geochemical prospecting, and lithospheric research have been accomplished. The mid-scaled, small-scaled regional geological survey and aeromagnetic survey have covered with the continent of all over the country and abut part sea area; about 50000 km geophysical detection sections by explosion seismic method have been finished, a great lot of geophysical detection sections by other methods been finished. Since 1980s, China have taken part in the international lithospheric research project, such as 11 global geoscience transect, ultra-high pressure metamorphism and dynamics in orogenic belts, genesis of sedimentary basin, seismic activity all over the earth have been carried out. Additionally, the 5000 m deep Continental Scientific Drilling Project has been performed. The geological survey of multi-year accumulates and enriches the documents and data about the earth.

To systemically review and summarize the deep geology, geophysical survey and lithospheric

studying result, the Ministry of Land and Resource (MLR) constituted and performed a specialized research project of "3 - D Structure of China Lithosphere", which is composed of three emphasis research programs: Database on 3 - D Structure of China Lithosphere, 3 - D Structure of Lithosphere in Some Key Areas and Segments, 3 - D Structure , Evolution and Dynamics of China Continental Lithosphere. The task and aim are: based on current geosciences theory, new method and technique, to comprehensively study the accumulative lithospheric data and documents by multi - knowledge, to make out 3 - D structure and the evolution laws of China lithosphere, to supply scientific foundation for planning, managing, protecting and utilizing land & resource with reason, to supply scientific base for sustainable development of society and economy, to pioneer and breakthrough for establishing systemically geoscience theory.

There are 14 units that participate in the specialized research project as follows: Institute of Geology, CAGS, Institute of Mineral Resources, CAGS, Chinese Academy of Geological Sciences, International Cooperative and Technological Bureau, MLR, China Geology Survey, China University of Geosciences (Beijing), China University of Geosciences (Wuhan), Jilin University, Chengdu University of Technology, Tongji University, Guangzhou Marine Geology Survey, Shanghai Oil Institute of Planning and Devising, Sinopec, Tianjin Institute of Geological and Mineral Resources; Field geological data Center, Information Center of Land and Resources.

All the experts and scholars do their best effort to accomplish the task, and the plentiful and substantial results have been acquired in each study field.

The Database of 3-D Structure of China Lithosphere, the first one established all over country, is composed of 9 primary databases, 3 result databases, 2 total databases, 14 sub-databases. The database has the following characteristics: large data volume, wide knowledge, advanced database software, agile and applied management system. In addition, the data may be shared and transferred on line, which will be the successful example of the lithosphere research of our country.

Based on the data of global geoscience transect, the subject group of each key area and segment has performed the comprehensive research on geology, geophysics, and geochemistry, and summarized the temporal-spatial relationship of structural characteristics of orogenic belt, sedimentary basin, craton, finally, basically established the visual model of the 3-D lithosphere structure. The above-mentioned study makes us more deeply recognize the lithospheric constitutes and structural feature. In east China, between lithosphere and asthenosphere there is a transitional zone with unconspicuous layer. The lithosphere shows the obvious age feature of upper-older and lower-younger. In the nearly NS-direction aeromagnetic anomaly area of Qinghai - Tibet plateau, to the deep section of lithosphere, the nearly NS-direction structural belt is found, which shows extreme inhomogeneity between the surface and deep section of lithosphere.

On the basis of the lithospheric database and the study of lithospheric structure, focusing on the subject of "Dynamics of 3-D structure and evolution of China continental lithosphere", the comprehensive research and result integration have been preformed——a series of maps showing 3-D structure and evolution of China lithosphere have been compiled; lithospheric structural unit

and structural type of China continent and about sea area have been divided; basic characteristics of every lithospheric structural unit have been summarized; geophysical and geochemical fields of China lithosphere have been discussed; substance and chemical structure of China lithosphere have been studied; numerical modeling of 3-D structure of lithosphere has been done; evolution and dynamical process of China lithosphere have been discussed.

For adequately displaying specialized research result, and supplying the information about China lithosphere for related sectors and geological field, we not only have submitted the database of 3-D structure of China lithosphere, the Atlas of 3-D Structural Characteristic of China lithosphere, but also compiled the series books of 3-D structure of China lithosphere based on the research report. These series books include a nationally work, and 8 regional monographs, in which the lithospheric structural units of all over country and six regional segments, 3-D structure and evolution of Qinling and Dabie-Sulu orogenic belts are studied.

The scientific research practice and results show that it is a very far-sight for MLR to carry out the specialized research project of "3-D Structure of China Lithosphere".

Through carrying out the specialized research project, the database of 3-D structure of China lithosphere with the current scientific and technique level has been established; the accumulated great number data about geology, geophysics, geochemistry have been collected; some data that may be lost or ruined have been collected, neatened, and displaced; most of the geophysical section data have been re-disposed and re-explained to make more geological information exhibit to us.

Through carrying out the specialized research project, a batch of high quality and innovative scientific results have been obtained to decrease the difference of lithosphere research with other developed states. Through systemically studying the geology, geophysics and geochemistry, the structural unit and type of China lithosphere have been divided, several characteristics and evolution laws of China lithosphere reviewed and summarized, several new facts and phenomena found, 3-D structure and evolution processes of China lithosphere deeply recognized. That will become the basis of some important scientific problems such as resources, environment.

Through carrying out the specialized research project, the scientific research units, universities and colleges, and geological survey institutes have been combined together, some research base of lithosphere and scientific research groups have been consolidated and developed, a batch of young research personnel have been trained. A research team, which is composed of high-leveled aged, mid-aged, and young personnel, must contribute to the large-scaled lithospheric research project in the future.

Through carrying out the specialized research project, a series of important science and technology problems have been solved and recognized more deeply, some new fantastic phenomena about substance constitutes and structure of lithosphere have been found, a batch of scientific problems need to be studied further in the future. In addition, we have accumulated some experiences on lithospheric research. In the future, these problems and experiences will be used for researchers to study the related subject.

The specialized research project being preformed successfully is related to the whole scientific personnel's effort, to every superior sector's guiding and attention, to every cooperative unit's supporting. It specially points out that Huang Zongli, Cui Yan, Bai Xingbi from Bureau of International Cooperative & Technology, MLR, Ye Tianzhu, Meng xianlai, Zhang Hongtao and Peng Qiming from China Geology Survey, Zhang Yanying, Dong Shuwen from Chinese Academy of Geological Sciences, and Xu Zhiqing, Wang DongPo, Geng yuansheng from Institute of Geology, CAGS, have played a important role in the project performing. Here we honestly express our acknowledgments to them.

These series books with "Database of 3-D Structure of China Lithosphere" and "Atlas of 3-D Structural Characteristic of China Lithosphere" mainly reflect the research results of the specialized project. We expect that these results may play an important role in developing related theory and practice about lithosphere, and contribute to study structure and evolution of China lithosphere. In meantime, we honestly expect that the readers make suggestion to us.

Li Tingdong
December 2004

Extended Abstract

The "Composition and Evolution of the Lithosphere In Continental China" is an innovative subject under the special project of the Scientific and Technological Plan of the Ministry of Land and Resources "3D Lithospheric Structure of China" (grant 200010103, 2000—2006). The aim of the study was to explore an integrated method for understanding the composition of deep-seated material of the lithosphere in continental China by combining the geological approach with the geophysical one, construct a model of the deep-seated material composition that can reflect the characteristics of the 3D lithosphere in present continental China, analyze and compare the petrological structures of different types of lithosphere in lithospheric units of China, propose a suggestion about the division into lithospheric tectonic units, show the inhomogeneity of the structures and deep-seated material compositions of the major lithospheric units of China along typical geoscience transects or regional geological sections and discuss the relations of the lithosphere with the metallic mineral resources and energy resources according to the frame of the evolution of lithospheric deep-seated material.

The lithospheric deep-seated material composition is a highly challenging frontier topic, which is a basic parameter of the lithosphere and the foundation for the study of continental dynamics, and Earth scientists of various countries are exploring it competitively. This discipline is also called material science of the deep interior of the Earth and is a very special branch of Earth sciences. Its research calls for the combination of academic thoughts, research outcomes and survey methods of multiple disciplines relating to the deep Earth's interior, such as mineralogy, mineral physics, high pressure mineral physics, petrology, rock mechanics, geology, geochemistry and geophysics. Therefore, in the course of the study, one must widely hunt through knowledges of various disciplines and assimilate the research outcomes of relevant disciplines. In regard to the study objectives, we have carried out the following aspects of study.

1. Based on the experimental rock data, including both the chemical composition of rocks and seismic wave velocities (v_P), regression equations of seismic wave velocities and petrochemistry have been derived and their applicability discussed.

2. The sequence of the main geological events in continental China has been defined and their influences on the major tectonic units in continental China evaluated.

3. Typical geophysical sections and geophysical columns for defining major tectonic units of China have been screened and chosen according to the unified standards and the lithospheric types of North China, South China, northwestern China and the Qinghai-Tibet Plateau have been identified according to the geological characteristics, present geophysical deep structure, geothermal regimes and geomorphological features.

4. The compositional structures of lithospheric deep-seated material have been deduced and crust-mantle petrological structures and chemical structure columns of eighteen lithospheric types in continental China have been established by using the integrated petrological structure method, i. e. the data of exposed Precambrian metamorphic rocks, igneous rocks, deep-seated xenoliths, relations between seismic wave velocities and rock composition and Sr and Nd isotopes, combined with the models of the evolution of the crust and mantle and evolution of orogenic belts.

5. A petrological structure model of the lithosphere in continental China has been constructed for the first time on the basis of the established petrological structure columns and five types of lithosphere, namely, cratonic type (Yangtze, Ordos, Tarim), orogenic type (the Kunlun Mountains, Tianshan Mountains, Altay Mountains, Qinghai-Tibetan Plateau, Yanshan Mountains, Da Hinggan Mountains, Nanling etc.), rift type (plains and continental shelve of eastern China etc.), island-arc type (Taiwan, the Japanese Islands chain etc.) and marginal-sea oceanic-crust type (the South China Sea), are distinguished in continental China according to their dynamic natures.

6. According to the present features of the lithosphere, combined with the geological evolution, the ages of formation of materials and structures of lithospheres of different types and different areas are discussed in details and the inhomogeneity of temporal-spatial distribution of the crust-mantle petrological structure of the present lithosphere in continental China is displayed.

7. According to the modes of occurrences of metallic deposits and oil-gas fields in continental China, combined with the lithospheric setting, the relationships of the lithosphere to large-scale metallogenesis and occurrence of oil-gas fields have been discussed and the indicators of large-scale metallogenesis are proposed.

8. Some problems such as the Meso-Cenozoic dynamic background and tectonic units in continental China are discussed.

The main preliminary conclusions in this monograph are as follows.

1. Based on the experimental rock data, including both the chemical composition of rocks and seismic wave velocities (v_P) and an analysis of the factors affecting the seismic velocities of rocks, data features and data screening, the regression equations of seismic wave velocities vs. SiO_2, quartz, quartz + feldspar and the differentiation index (DI) have been derived. The composition calculated by the dada of seismic velocities of geoscience transects indicates that the average petrochemical composition of continental crust of continental China is granodioritic with its acidity higher than that of the global average crustal value, which is because the lithosphere in continental China has undergone repeated orogenies. The average crustal compositions in western and eastern China are both granodiorite, and comparison shows that the acidity ($SiO_2 = 65.12\%$) of the crust of eastern China is a little higher than that ($SiO_2 = 64.32\%$) of western China. In eastern China, the highest acidity ($SiO_2 = 65.98\%$) of the crust is recorded in South China, next comes that ($SiO_2 = 64.88\%$) in North China, and the lowest value ($SiO_2 = 63.18\%$) is found in Northeast China. In western China, the acidity ($SiO_2 = 65.43\%$) of the average crustal composition in the southwest is a little higher than that ($SiO_2 = 64.88\%$) in the northwest. The cause of