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中国陆域 1∶25 万分幅建造构造图空间数据库

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摘要：依托全国矿产资源潜力评价专项（2006—2013 年），通过全面收集 1∶5 万、1∶20 万、1∶25 万区域地质调查资料（含 1999—2005 年获取的青藏高原 1∶25 万区域地质调查资料），地质研究成果、科研专著、重要文献等资料，以及地球物理、地球化学、遥感地质推断成果，在编制建立 1∶25 万分幅成矿地质背景研究实际材料图空间数据库基础上，应用建造构造分析法及编图技术，采用数据模型、质量控制模型、GIS 软件等现代信息技术手段，按 1∶25 万标准分幅编图、建库、汇总、集成，建立了中国陆域 1∶25 万分幅建造构造图空间数据库，包含图幅数 729 幅及其相应编图说明书和图件元数据等内容，空间范围基本覆盖中国陆域。明显优于以系或组级地层单位为表示单元的传统地质图数据库：主图图面要素是组级岩石地层单位的进一步细化、分解为不同的岩石建造，按产状表达建造花纹，客观表达岩石建造和地质构造实体形迹，系统反映地质作用及其演化特征，读图直观且便于应用。可为 1∶50 万尺度及以小大地构造图的编制提供基础资料，为 1∶25 万尺度及以小区域矿产预测直接提取矿产预测要素，为 1∶25 万尺度及以小成矿规律研究提供地质构造专题底图资料；在地质找矿、地质灾害防治、水工环地质调查、地热资源勘查、生态文明建设等方面具有广泛且长久可重复利用价值。

关键词：地质建造；地质构造；建造构造图；空间数据库；数据模型；质量控制模型；GIS 软件

数据服务系统网址：http://dcc.cgs.gov.cn

1　引言

全国矿产资源潜力评价专项是中国 2006 年至 2013 年部署完成的一项重要矿产资源国情调查，组织动员了全国、大区、省（直辖市、自治区）3 个层次地质科研力量，每个层次均设有成矿地质背景研究、成矿规律研究、重力资料应用、磁测资料应用、化探资料应用、遥感资料应用、自然重砂资料应用、矿产预测研究、综合信息集成 9 个专题（或项目、课题）组开展相应研究工作[1]，采用矿床模型综合地质信息预测方法，应用计

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算机与 GIS 技术手段，以实际资料为基础，采取自上而下统一技术要求、自下而上归纳分析综合方式，科学定量评价了中国煤炭、铀、铁、铜等 25 个重要矿种资源潜力和空间分布，摸清了中国重要矿产资源家底，取得了大量创新性成果，是目前中国最系统、最全面、最权威的一次矿产资源国情调查。

中国陆域 1：25 万分幅建造构造图空间数据库是全国矿产资源潜力评价专项系列成果之一，由全国、大区（包括华北、东北、华东、中南、西南、西北）、省（直辖市、自治区）（包括北京、天津、河北、山西、山东、河南、内蒙古、黑龙江、吉林、辽宁、江苏、安徽、浙江、江西、福建、湖北、湖南、广东、广西、海南、四川、重庆、云南、贵州、西藏、陕西、甘肃、宁夏、青海、新疆）3 个层次成矿地质背景专题组、综合信息集成专题组基于成矿地质背景研究技术要求、矿产资源潜力评价数据模型、数据集成建库技术要求完成的。中国陆域 1：25 万分幅建造构造图空间数据库的公开版已在全国地质资料馆数据服务系统网址（http://dcc.cgs.gov.cn）上发布，其基本信息见表 1，其中各 1：25 万分幅建造构造图采用的基础资料是对应 1：25 万分幅成矿地质背景研究实际材料图。

全国成矿地质背景专题组牵头制定了《成矿地质背景研究技术要求》(叶天竺等，2010)；全国综合信息集成专题组牵头研究制定了矿产资源潜力评价数据模型系列（左群超等，2011a，2011b，2011c，2011d，2011e，2012a，2012b，2013，2015a)、全国矿产资源潜力评价集成建库方法与技术（左群超等，2012，2013a，2015b，2015c)、全国矿产资源潜力评价编图与建库技术规范系列[❷~❾]，研发提供了 GeoMag、GeoTok、GeoDQC、GeoPEX、DipMopa 等建库软件（左群超等，2015b，2015c)；与大区成矿地质背景、综合信息集成专题组一起，对各省（直辖市、自治区）成矿地质背景专题组、综合信息集成专题组进行了编图技术要求、数据模型、建库技术要求及其软件系统等应用培训、现场指导、质量检查、验收汇总及集成建库等工作。各省（直辖市、自治区）的成矿地质背景专题组、综合信息集成专题组在编制完成跨本省（直辖市、自治区）范围 1：25 万分幅实际材料图库基础上，完成了跨本省（直辖市、自治区）范围 1：25 万分幅建造构造图库的研究编图、数据入库、质量自检、修改完善及成果提交等工作[❿]。

表 1　数据库（集）元数据简表

条目	描述
数据库（集）名称	中国陆域 1：25 万分幅建造构造图空间数据库
数据库（集）作者	左群超，中国地质调查局发展研究中心 叶天竺，中国地质调查局发展研究中心 冯艳芳，中国地质调查局发展研究中心 葛　佐，中国地质调查局发展研究中心 王英超，中国地质调查局发展研究中心
数据时间范围	编图、建库引用的基础数据资料截至到 2013 年底。
地理区域	中国陆域
数据格式	*.wl, *.wt, *.wp
数据量	16.6 GB

续表 1

条目	描述
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	全国重要矿产资源潜力评价综合信息集成（1212011121041） 全国重要矿产成矿地质背景研究（1212011121036）
语种	中文
数据库（集）组成	由基本覆盖中国陆域的 729 幅 1：25 万标准分幅建造构造图及其相应编图说明书和图件元数据文件构成，图件名称及图幅编号见附件《中国陆域 1：25 万分幅建造构造图图件名称、图幅名及编号检索一览表》。

2　数据采集和处理方法

2.1　基本概念及图件释义

2.1.1　地质构造

地球科学大辞典（2006）对地质构造的释义：第一，又称构造形迹，是地质体或岩石形成过程中产生的，或形成之后发生变形、变位所显现的中小型形迹，如褶皱、断层等。第二，泛指从全球构造到超显微领域的不同尺度地质体的结构特征及其内部组分或单元的相互配置关系和形貌特征。构造的规模一般分为巨型、大型、中型、小型、微型和超微型六类尺度。构造尺度的划分不仅与研究内容和侧重点相关，而且与研究方法和手段有关，各种尺度构造既表现在空间的组合和叠加，还表现在构造的主次控制关系。

为方便研究并更好服务于矿产预测评价实际，本次工作将地质构造从规模上和使用上分为三个层次，一是成（控）岩的构造，二是区域的构造，三是大地构造。

2.1.2　地质建造

地球科学大辞典（2006）对地质建造的释义：泛指在地壳发展的某一阶段，在特定的大地构造条件下所形成的具有成因联系的一套岩石共生组合。地质建造（以下简称建造）反映地壳演化和发展阶段特定的大地构造环境，区分和识别建造，为确定某一地区地壳演化和发展阶段提供重要依据。建造概念在不同地质学家中有不同的理解与命名，在不同学科及实际使用中，又有不同的含义及不同尺度的划分。

为方便研究并更好服务于矿产预测评价实际，本次工作对建造含义及划分统一厘定为三个层次：一是岩性或岩石组合，对应于成（控）岩的构造，指单一岩石或几种岩石的自然组合，一般在地质填图中可识别和可填图的，对其划分主要取决于填图精度。二是岩石的建造，对应于区域的构造，指表征形成环境的岩石组合，分为沉积岩建造、火山岩建造、侵入岩建造和变质岩建造四类，是建造构造图的基本编图单元。三是岩石构造组合，对应于大地构造，指表征大地构造环境的岩石组合，是成矿地质背景研究中大地构造相图的基本编图单元。

本次工作中的建造是指物质建造，是同一时代、同一地质作用（沉积、侵入、火山、变质）形成的一种岩石或几种岩石的自然组合。通常，建造划分应符合下列条件：一是岩性、岩相、变质程度一致；二是内部结构一致或相近；三是界线明显；四是有一定的规模和分布范围。

本次工作建造构造图中的沉积岩建造、火山岩建造、侵入岩建造、变质岩建造的含义统一厘定如下：

（1）沉积岩建造：同一时代、同一沉积作用下形成的同一沉积亚相（或微相）的一种或几种岩石的组合。

（2）火山岩建造：同一火山作用形成的一种或几种岩石的组合。按照岩性、岩相双重填图法的要求表示。多种岩相无法区分的，选择优势岩相表示，对于潜火山岩和沉积夹层则单独表示。

（3）侵入岩建造：是指同一时代、同一侵入作用形成的侵入体（不是深成岩体），在建造构造图中必须表达深成岩体解体以后的侵入体。在分析构造环境时，一般利用侵入岩岩石组合判断其构造环境，因此，在侵入岩建造综合柱状图中要表示反映构造环境的侵入岩岩石构造组合。

（4）变质岩建造：是由沉积岩、火山岩或侵入岩等原岩在同一期变质作用形成的，具有相对一致地质体结构类型的一种岩石或几种岩石组合。原则上，同一变质岩建造的岩石组合及变质程度应基本一致；在区域上有着一定规模和分布范围，可以在图面上合理表达；地质体结构类型和产状显示出一系列的共生特征，属于同一原岩系列；与其他变质岩建造之间应具有较清晰的边界，具有可分性。变质岩建造划分应注意以下几个方面：第一，应正确区分变质表壳岩和变质深成侵入体，在变质岩建造综合柱状图上一起表示；第二，变质岩建造一般是（岩）组级单位的进一步细分，变质深成侵入体应按岩性划分，各类片麻岩代号按国标表示，变质侵入体遵照侵入岩的规定；第三，变质岩建造划分尺度应适当，一般以原岩建造为基础，结合变质作用类型，当原岩建造不同而变质作用类型相同时，应分为两个变质岩建造。

本次工作认为，建造构造图不同于系级或组级地质图，建造不同于岩石地层单位的组，是对组级地层单位的进一步细分，这是本次建造构造图编图的核心。

2.1.3　分幅实际材料图

在本次工作中，1∶25 万分幅实际材料图（简称为分幅实际材料图），是专指 1∶25 万分幅成矿地质背景研究实际材料图，是成矿地质背景研究工作的资料基础，是全面反映成矿地质背景研究所依据实际资料的图件。分幅实际材料图是在分析整理区域地质调查、地质构造研究等原始材料基础上，按 1∶25 万标准分幅编制而成。

分幅实际材料图内容，主要包括岩性、地质界线、断裂、韧性剪切带、褶皱、蚀变带、产状要素、地质路线、地质点、地质剖面位置、钻孔、化石采样点、同位素年龄、岩石化学样品采样点、地球化学样品采样点、同位素样品采样点以及各类代号与标注等。

岩性内容是对原地质图内容的进一步细化，表示各类岩性或岩石组合分布情况及其相互关系。编制工作的核心是根据矿产预测和大地构造相研究需要，分解原地质图编图单元，查阅填图原始资料，主要是实测剖面和主干路线，补充岩性（组合）界线。

2.1.4　分幅建造构造图

在本次工作中，1∶25 万分幅建造构造图（简称为分幅建造构造图），是指在 1∶25 万分幅实际材料图基础上，通过建造与构造综合分析与研究，按 1∶25 万标准分幅编制

形成的图件。根据地质作用特征，分别按沉积作用、火山作用、侵入作用、变质作用、构造作用以及大型变形作用进行研究，并在分幅建造构造图上分别表达为沉积建造构造、火山岩性岩相构造、侵入岩浆构造、变质建造构造、变形构造、以及大型变形构造特征等；开展建造与构造综合分析研究，编制反映时空演化特征的综合柱状图。

分幅建造构造图内容，主要包括沉积岩建造、火山岩岩性岩相、火山构造、侵入岩、侵入岩浆构造带（构造岩浆带）、变质岩建造、大型变形构造、地质界线、断裂、韧性剪切带、褶皱、同位素年龄、产状、重力推断地质构造、磁法推断地质构造、地球化学推断地质构造、遥感推断地质构造、各类代号与标注，以及沉积、火山、侵入、变质建造综合柱状图和大型变形构造特征表等。

分幅建造构造图是反映地质作用及其演化特征的基础图件，是本次成矿地质背景研究工作的核心内容，也是本次大地构造相研究以及大地构造相图编制的“实际材料图”，同时，又可以在分幅建造构造图基础上，补充实际资料，细化成矿有关的岩石建造与构造内容，形成预测工作区地质构造专题底图。

2.2 资料收集与使用要求

2.2.1 资料收集内容

（1）全面收集了1∶5万、1∶20万、1∶25万区调资料（含1999—2005年获取的青藏高原1∶25万区域地质调查资料），包括区调成果报告、区调原始资料（实际材料图、野外记录本、实测剖面、钻孔剖面、地质路线信手剖面、图切剖面、前人科研论著发表剖面、各项测试分析成果等）以及区调地质图数据库和地质工作程度数据库。

（2）系统收集了以往区域地质研究报告、专著和重要文献（区域地质志、岩石地层清理成果等）以及网上专题学术论文等资料。

（3）全面收集了1∶5万、1∶20万、1∶25万、1∶50万物化遥原始数据及推断解释（译）地质构造或地质体成果等资料。

（4）不遗漏任何有用资料，全面掌握区域地质研究程度，编制了研究程度图。

（5）上述所收集资料原则上截至到2013年底。

2.2.2 资料使用要求

本次工作遵循了地质工作中一直沿用的使用地质资料原则，即有新资料不用旧资料，有大比例尺资料不用小比例尺资料，保证本次编图建库使用的是填图与研究的最新成果和精度更高的区域地质资料。全面应用建造构造分析法，岩石构造组合及时空演化谱系研究法。另外，对1∶5万区调资料的使用做出更明确规定：

（1）在编制1∶25万分幅实际材料图、1∶25万分幅建造构造图时，都必须使用1∶5万区调资料。

（2）在1∶25万区调与1∶5万区调发生重叠的地区，应利用1∶25万填图新资料对1∶5万填图内容进行补充。

（3）区别具体情况，合理、有效地使用1∶5万填图资料。由于不同年代和不同单位完成的1∶5万填图图幅质量和精度有较大差别，不应机械照搬和套用。在使用时，应对1∶5万填图资料的质量进行评估，区分填图质量的具体情况，全部使用、部分使用

或不使用 1∶5 万填图资料，以达到合理有效地使用为目的。

2.3 资料整理与综合研究

2.3.1 资料整理准备

在充分收集和利用已有各类资料、成果基础上，对各类原始资料、成果进行整理，消化原始资料，为开展各项研究与编图工作做好必要的技术准备，内容包括：

(1) 准备和整理地理底图及数据库。

(2) 准备和维护 1∶5 万、1∶20 万、1∶25 万地质图数据库和工作程度数据库。

(3) 初步分析和研究沉积作用、火山作用、侵入作用、变质作用及构造作用特征，初步建立岩石地层划分对比、火山喷发作用划分对比、侵入岩浆作用划分对比、变质地质单元划分、大地构造分区与演化阶段划分工作方案。

(4) 依据《成矿地质背景数据模型》(左群超等，2011a)，研究制定编图工作细则，统一图式、图例等编图工作方案。

2.3.2 综合研究工作

区域成矿地质构造研究，是以区域地质调查实际资料，以及区域地质研究等资料与成果为基础，通过区域地质构造的建造与构造特征研究与综合，分析区域大地构造环境，恢复其动力学演化过程。研究工作的目的是分析成矿的区域大地构造环境与演化过程，为通过成矿规律与矿产预测确定的具体矿产类型，提供成矿地质构造环境与构造演化阶段背景资料，是提供某类矿产预测类型的宏观前提。

按大地构造单元研究大陆地壳块体离散、汇聚、碰撞、造山等过程的地质作用特征，并说明其空间分布与演化特征。分别研究沉积作用（沉积岩建造及岩相与构造古地理)、火山作用（火山岩建造及火山岩相与火山构造)、侵入岩浆作用（侵入岩建造及侵入岩浆构造)、变质作用（变质岩及变质变形构造)、大型变形构造，综合物探、化探、遥感推断地质构造特征，分析研究地质构造演化及其时间、空间与物质组成特征，划分大地构造相。通过编制实际材料图、建造构造图、大地构造相图及数据库表达研究成果。

(1) 分析整理地质构造研究原始资料，分幅编制 1∶25 万分幅成矿地质背景研究实际材料图。

(2) 研究建造与构造及大型变形构造特征，分析地质构造演化，综合分析物探、化探、遥感推断地质构造内容，分幅编制 1∶25 万分幅建造构造图。

(3) 综合地质构造研究内容，开展沉积、岩浆、变质、大型变形构造等专题研究，按大地构造演化阶段分析地质构造演化与成矿地质背景，划分大地构造相及大地构造分区，编制全省 1∶50 万大地构造相图。

2.4 编图与建库技术流程

2.4.1 分幅实际材料图库编图建库

(1) 确定编图范围、比例尺、大地坐标系及地图投影：采用 1∶25 万比例尺、北京 54 坐标系、1956 黄海高程基准、高斯 6° 标准分带地图投影、投影原点纬度统一规定为 0°。

（2）资料利用重点范围：以 1∶25 万、1∶20 万、1∶5 万区调原始资料为基础，尽量收集有关专题研究的数据资料，收集网上有关专题学术论文资料，以弥补区调资料的不足。

（3）对使用 1∶5 万区调资料的要求。

在编制分幅实际材料图时，必须使用 1∶5 万区调资料。根据 1∶5 万区调覆盖面积的多少，分三种类型编制实际材料图。

第一类：1∶5 万区调面积基本覆盖的（覆盖面积大于 2/3 图幅），全部应用 1∶5 万原始资料编图。

1）实测剖面：全部利用。2）路线密度与观察点密度：按 1∶25 万精度，对 1∶5 万地质路线和地质观察点进行抽稀，原则上按 2.5 km×2.5 km 间距。地质路线和地质观察点的选择，应尽量选取主干地质路线以及有效地质点（地质界线与构造控制点、重要采样点等）。3）采样位置：以 1∶5 万资料为主，补充 1∶20 万、1∶25 万资料。4）地质内容：以 1∶5 万填图的地质内容进行缩编为主，少量未被 1∶5 万区调资料覆盖地区，应补充 1∶20 万、1∶25 万资料。

第二类：1∶5 万区调面积只占少量的（覆盖面积小于 1/3 图幅），全部应用 1∶25 万 /1∶20 万原始资料编图。

1）实测剖面：全部利用。2）路线密度与观察点密度：全部的 1∶25 万 /1∶20 万地质路线与地质观察点。3）采样位置：以 1∶25 万 /1∶20 万资料为主，补充 1∶5 万资料。4）地质内容：以 1∶25 万 /1∶20 万填图的地质内容为主，补充 1∶5 万填图地质内容。

第三类：1∶5 万区调覆盖面积占 1/3 ~ 2/3 图幅的编图，比照上述两类情况先分类处理，再综合即可。

（4）利用原地质图地质内容数据，矢量化原区调实际材料图内容，查阅和分析区调实测剖面、主干路线等实际材料，分解原地质图编图单元，补充岩性（组合）界线。

（5）分幅实际材料图应保持原区调资料的“原汁原味”，要求按原始地质内容表达，不进行地质连图。该图可由原区调实际材料图补充岩性（组合）内容后形成。分幅实际材料图为素图，不上颜色和花纹。区调资料中的实测剖面资料（包括剖面图和柱状图）应扫描成图像放在分幅实际材料图库中。

（6）对于公开发表文献资料上的岩石化学、地球化学和同位素年龄等数据，当有采样位置或地理坐标时应纳入分幅实际材料图库，采样位置数据不明的样品可以特殊图例标注在相关地质体上。

（7）分幅实际材料图基本图层的分层应符合《成矿地质背景研究数据模型》（左群超等，2011a）中分幅实际材料图图层分层规定。

（8）分幅实际材料图基本图层的属性数据应按《成矿地质背景研究数据模型》（左群超等，2011a）中分幅实际材料图图层数据表结构与填写规定录入相应的地质数据或信息。

分幅实际材料图库编图与建库主要流程及技术框架见图 1、图 2。

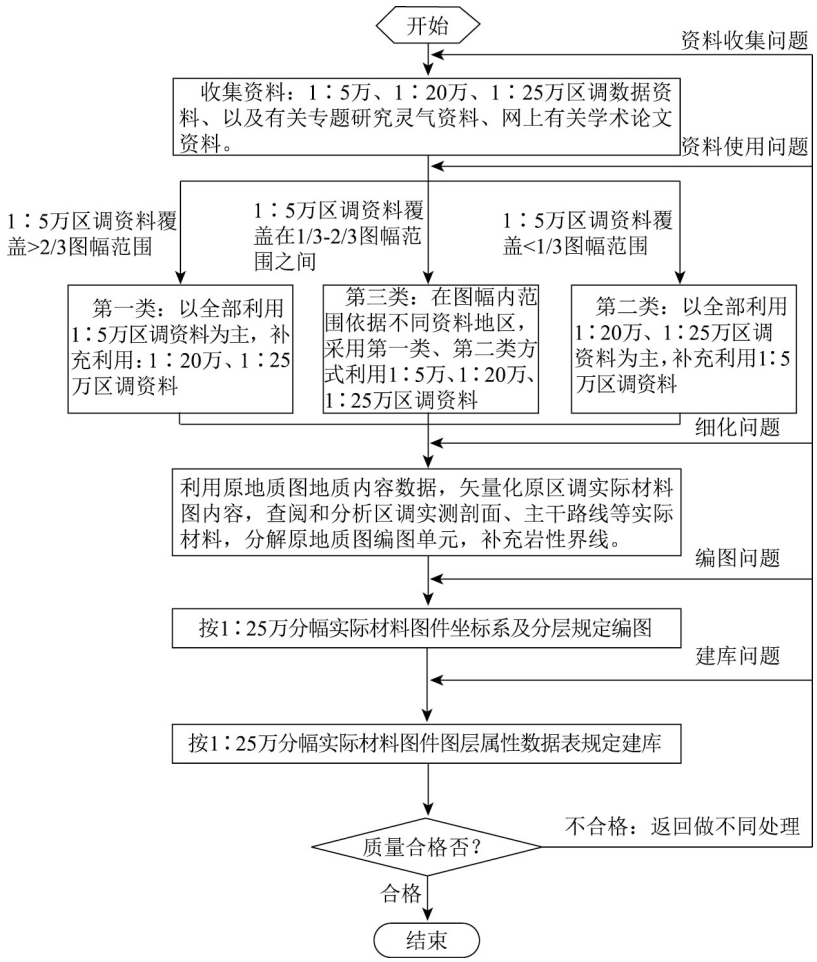

图 1　分幅实际材料图库编图与建库主要流程

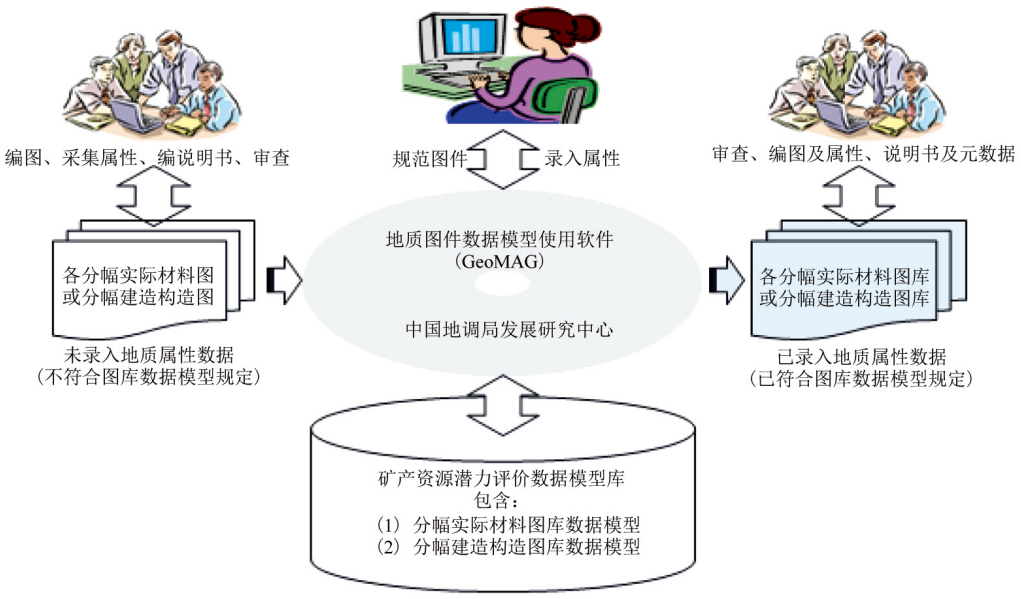

图 2　分幅实际材料图库或分幅建造构造图库建库技术框架

2.4.2　分幅建造构造图库编图建库

（1）确定编图范围、比例尺、大地坐标系及地图投影：采用 1：25 万比例尺、北京 54 坐标系、1956 黄海高程基准、高斯 6° 标准分带地图投影、投影原点纬度统一规定为 0°。

（2）以 1：25 万分幅实际材料图库为基础，编制分幅建造构造图，沉积岩区表达沉积建造构造内容，火山岩区表达火山岩性岩相构造内容（对海相火山岩区，如果难以识别原始火山构造时也可以直接表达沉积建造构造内容），侵入岩区表达侵入岩浆构造内容，变质岩区表达变质建造构造内容，构造变形表达褶皱、断裂、韧性剪切带等内容。同时，要求表达大型变形构造特征，以及以地质资料和地质研究为基础，综合物化遥推断地质构造内容，反映表达物化遥感推断地表新发现、隐伏或深部地质构造或地质体。

（3）通过建造与构造的综合分析与研究，编制反映时空演化特征的综合柱状图，可能包括沉积岩建造综合柱状图、火山岩建造综合柱状图、侵入岩建造综合柱状图、变质岩建造综合柱状图、大型变形构造特征表。

（4）通过建造与构造的综合分析与研究，编制反映各类建造的构造形态，按产状表达建造花纹、地质构造实体形迹。

（5）分幅建造构造图的图面精度：原则上应不低于原 1：25 万地质图的精度，在划分各类建造时，应对岩石地层组级单位进一步细分为建造，组一级单位不能进行归并，坚持地质信息优于图面表达的原则。当某些建造在图上太窄无法上岩性花纹时，可以不上花纹。

（6）分幅建造构造图基本图层的分层应符合《成矿地质背景研究数据模型》（左群超等，2011a）中分幅建造构造图图层分层规定。

（7）分幅建造构造图基本图层的属性数据应按《成矿地质背景研究数据模型》（左群超等，2011a）中分幅建造构造图图层数据表结构与填写规定录入相应的地质数据或信息。

分幅建造构造图库编图与建库主要流程及技术框架见上图 2、下图 3。

2.4.3　编图与建库总体技术流程

各省（直辖市、自治区）在地质资料收集、整理与编图建库等相关技术准备的基础上，首先按 1：25 万标准分幅编制 1：25 万分幅实际材料图并建库；然后以 1：25 万分幅实际材料图库为基础，开展建造与构造综合分析研究，编制 1：25 万分幅建造构造图并建库；最后，在各省（直辖市、自治区）提交的 1：25 万分幅建造构造图库基础上，汇总、集成、建立中国陆域 1：25 万分幅建造构造图空间数据库。在资料收集、整理、编图、建库、验收、汇总、集成等环节，均有相应质量控制要求。中国陆域 1：25 万分幅建造构造图空间数据库编图与建库总体技术流程（见图 4），分以下 7 个主要操作步骤简述：

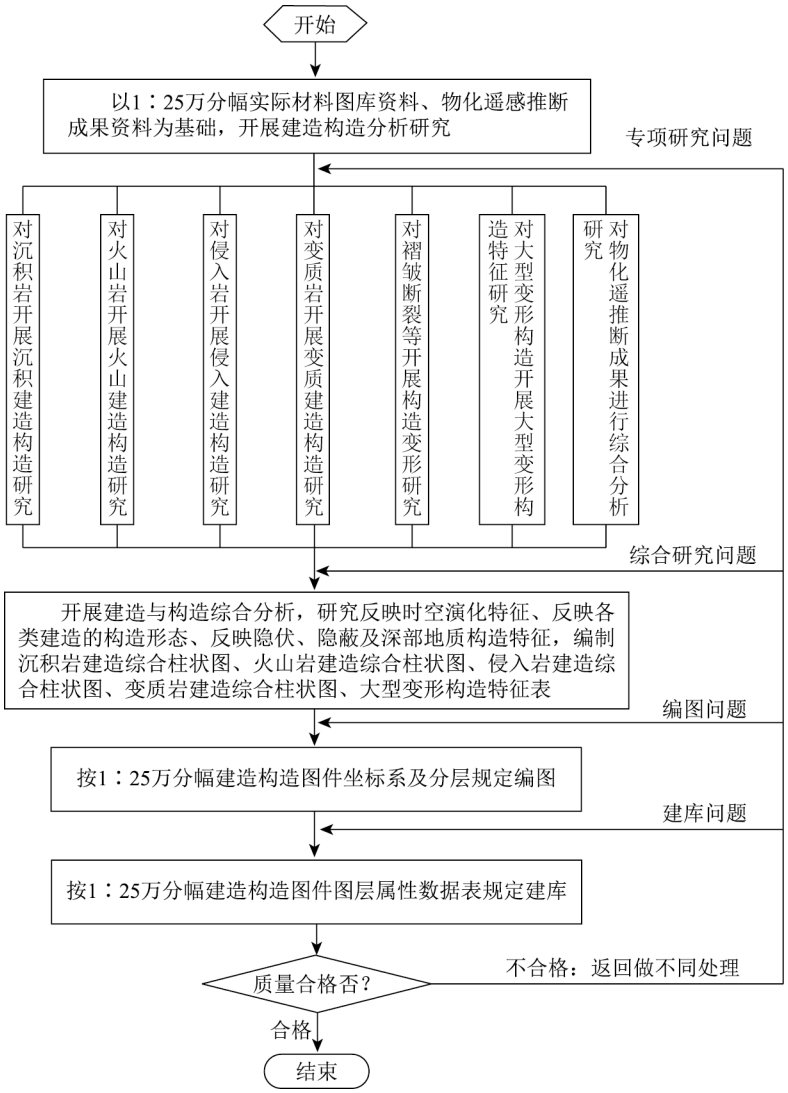

图 3　分幅建造构造图库编图与建库主要流程

（1）研究制定编图建库技术要求

全国成矿地质背景组研究制定成矿地质背景研究技术要求（内含 1∶25 万实际材料图、1∶25 万分幅建造构造图的编图研究技术要求）；全国综合信息集成专题组研究制定矿产资源潜力评价数据模型、建库技术要求、研发 GeoMag 等建库软件（内含支持 1∶25 万实际材料图、1∶25 万分幅建造构造图编图与建库内容）。

（2）开展典型示范完善技术要求

全国成矿地质背景组选择若干代表性地区，开展成矿地质背景研究技术要求典型示范，并完善编图技术要求；全国综合信息集成专题组与全国成矿地质背景组同地同步，开展数据模型、建库技术要求、建库软件等应用示范，并完善建库技术要求。

（3）开展编图建库技术要求培训

在典型示范成功并完善基础上，全国成矿地质背景与综合信息集成专题组，分别或协同，对各省（直辖市、自治区）成矿地质背景与综合信息集成专题组，开展编图与建库技术要求培训。

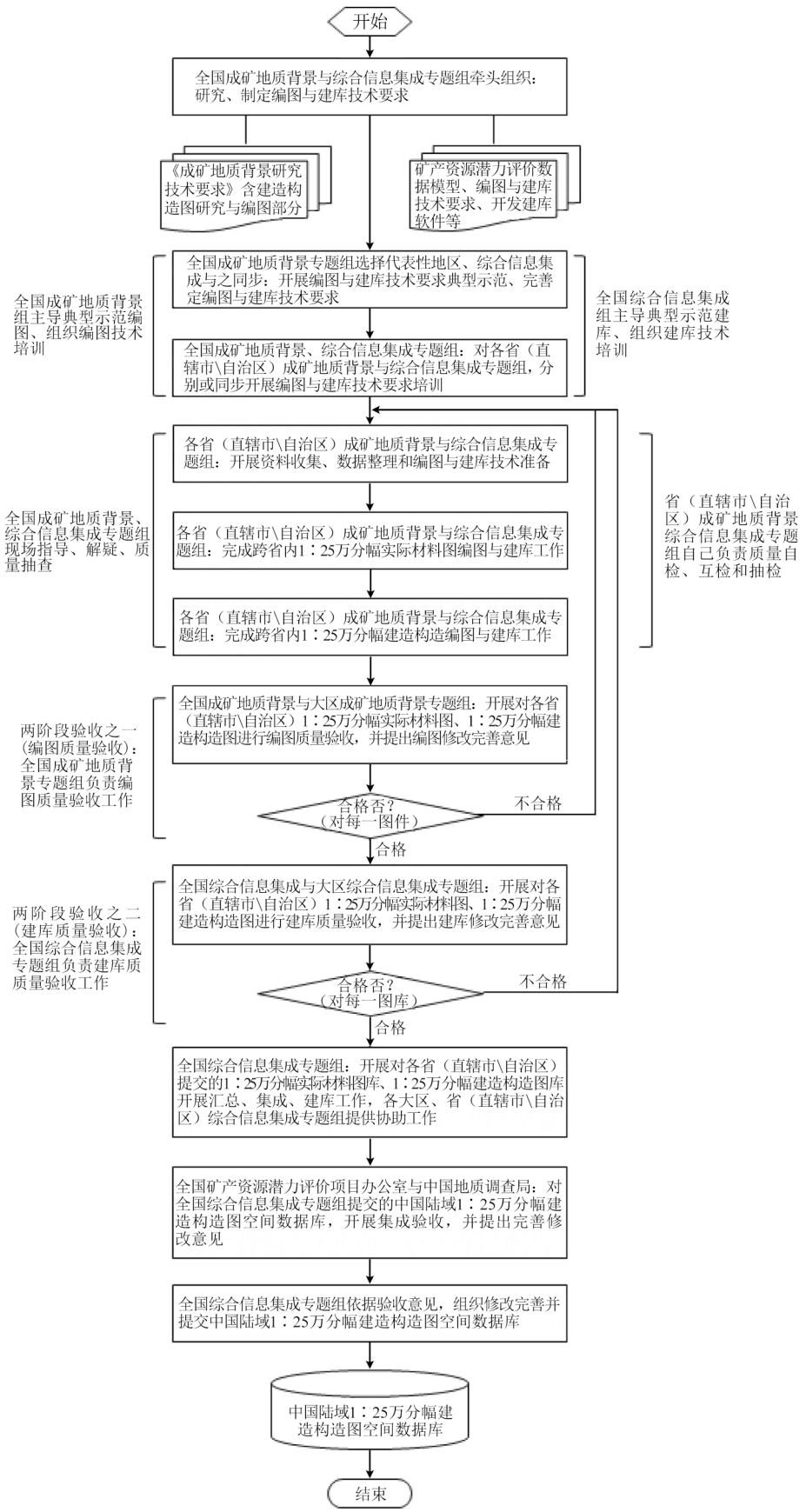

图 4　中国陆域 1：25 万分幅建造构造图空间数据库建设流程

（4）各省（直辖市、自治区）成矿地质背景与综合信息集成专题组开展编图与建库工作

首先，开展资料收集、数据整理和编图与建库准备；然后，完成跨省（直辖市、自治区）内 1：25 万分幅实际材料图编图与建库；再后，在 1：25 万分幅实际材料图库基础上，完成跨省（直辖市、自治区）内 1：25 万分幅建造构造编图与建库工作。

（5）“ 两阶段 ”验收各省（直辖市、自治区）编图建库成果

一阶段验收工作，称为编图质量验收。即：全国成矿地质背景与大区成矿地质背景专题组组织业内地质专家，对各省（直辖市、自治区）完成的每一幅 1：25 万分幅实际材料图、1：25 万分幅建造构造图进行编图质量验收，并提出编图修改完善意见。对存在编图质量问题的分幅实际材料图或分幅建造构造图，各省（直辖市、自治区）应按验收组地质专家意见修改、确认后，方可以转入阶段二验收流程。

二阶段验收工作，称为建库质量验收。即：全国综合信息集成与大区综合信息集成专题组组织业内数据库专家，对各省（直辖市、自治区）完成的每一幅 1：25 万分幅实际材料图库、1：25 万分幅建造构造图库进行建库质量验收，并提出建库修改完善意见。对存在建库质量问题的分幅实际材料图库或分幅建造构造图库，各省（直辖市、自治区）应按验收组数据库专家意见修改、确认后，方可以提交建库成果。若存在的建库质量问题，关联到因编图质量验收未发现或遗漏的编图质量问题而引起，则还应返回到编图质量问题处理过程。

（6）汇总集成各省（直辖市、自治区）提交编图建库成果

全国综合信息集成专题组组织对各省（直辖市、自治区）提交的 1：25 万分幅实际材料图库、1：25 万分幅建造构造图库等成果，开展汇总、集成，建立中国陆域 1：25 万分幅建造构造图空间数据库工作，并编写建库工作报告。在汇总、集成过程中，各大区综合信息集成专题组、省（直辖市、自治区）综合信息集成专题组提供协助工作。

（7）汇总集成建库成果验收完善工作

全国矿产资源潜力评价项目办公室与中国地质调查局，对全国综合信息集成专题组提交的中国陆域 1：25 万分幅建造构造图空间数据库，开展集成验收，并提出完善修改意见。全国综合信息集成专题组，依据验收意见，负责修改完善并提交最终数据库成果。

3　数据样本描述

3.1　分幅建造构造图结构

即分幅建造构造图数据结构，依据《成矿地质背景研究数据模型》（左群超等，2011a），由图件基本概要信息、图件主图图层分层信息、图件辅图信息（柱状图、剖面图、角图）、附表信息、以及其他必要整饰图层信息等 5 部分组成（表 2），每一部分简述如下。

（1）图件基本概要信息：包括图件中文名称命名模式、编图空间范围规定、编图比例尺规定、编图坐标系及地图投影参数规定、编图技术参数及流程要求、采用原始数据资料情况、采用图例规定、采用图式规定、图件数据格式规定、图件计算机命名模式、图件计算机代码模式、图件专业谱系及代码规定、编图说明书编写规定、图件元数据填

写要求。

（2）图件主图图层分层信息：包括逻辑图层即逻辑图层编号及逻辑图层名称，物理图层即物理图层编号及图层名称、图层空间特性（点、线、面、像元四者之一：即表示物理图层的空间特性为点、线、面、影像图层之一）、图层对应的数据表（有、无二者之一：即是否存在描述物理图层内图元特征的数据表）、图层计算机命名、图层计算机代码、图层数据来源。其中，逻辑图层包括：地理底图类图层、建造构造类图层、物化遥感推断构造或地质体类图层（地表新发现、隐伏或深部构造或地质体）、其他需要自行增加的逻辑图层四大类。

在分幅建造构造图中，地理底图类图层，包括主要行政境界、主要居民点、主要面状水系、主要线状水系等图层；建造构造类图层，包括沉积岩建造、火山岩性岩相、火山构造、侵入岩、构造岩浆带、变质岩建造、大型变形构造、地质界线、断裂、韧性剪切带、褶皱、同位素年龄、产状要素等图层；物探化探遥感推断构造或地质体类图层，包括重力、磁法、化探、遥感推断构造或地质体图层。

（3）图件辅图信息（柱状图、剖面图、角图）：包括沉积岩建造综合柱状图（沉积岩区）、火山岩建造综合柱状图（火山岩区）、侵入岩建造综合柱状图（侵入岩区）、变质岩建造综合柱状图（变质岩区）、图切地质剖面图、以及图幅所在大地构造位置角图、图幅所在位置地层分区角图等。

（4）附表信息：包括图幅所在位置大地构造分区表、图幅所在位置地层分区表、大型变形构造特征表、第四系成因类型划分表等。

（5）其他必要整饰图层信息：图件标题、比例尺表示（数字和线段）、图件方向标、图例说明、地图投影参数说明、编图技术参数及资料来源说明、编图责任表等。

3.2 主图图层数据表结构

沉积岩建造、火山岩岩性岩相、火山构造、侵入岩、侵入岩浆构造带（构造岩浆带）、变质岩建造、大型变形构造、地质界线、断裂、韧性剪切带、褶皱、同位素年龄、产状要素图层对应数据表结构及填写规定分别见《成矿地质背景研究数据模型》（左群超等，2011a）中关于沉积岩建造、火山岩岩性岩相、火山构造、侵入岩、侵入岩浆构造带（构造岩浆带）、变质岩建造、大型变形构造、地质界线、断裂、韧性剪切带、褶皱、同位素年龄、产状要素数据表结构及填写规定。

物探化探遥感推断构造及地质体图层对应数据表结构及填写规定分别见《重力资料应用数据模型》（左群超等，2011b）、《磁法资料应用数据模型》（左群超等，2011c）、《化探资料应用数据模型》（左群超等，2011d）、《遥感资料应用数据模型》（左群超等，2011e）中关于重力、磁法、化探、遥感推断构造及地质体（点、线、或面）数据表结构及填写规定。

3.3 图面重要辅图辅表结构

在分幅建造构造图编制中，依据图幅所在地区沉积作用及沉积岩建造与构造、火山作用及火山岩建造与构造、侵入作用及侵入岩建造与构造、变质作用及变质岩建造与构造发育演化及分布特征，分别编制沉积岩建造综合柱状图、火山岩建造综合柱状图、侵入岩建造综合柱状图、变质岩建造综合柱状图辅图、大型变形构造特征表，全面反映图

幅所在地区的区域地质作用及其演化特征。四类柱状图图头及大型变形构造特征表表头分别说明如下。

3.3.1　沉积岩建造综合柱状图结构

沉积岩建造综合柱状图综合反映图幅内沉积岩建造与构造时空演化特征，一般附在主图面的左或右侧，从左至右原则上包括（1）地层区划（区、分区、小区）；(2）年代地层单位（系、统、阶）；(3）岩石地层单位及代号（群、组、段）；(4）沉积岩建造类型；(5）厚度（单位：m）；(6）沉积岩建造柱；(7）岩性岩相简述；(8）含矿性；(9）化石组合或同位素测年方法与年龄值（单位：Ma）；(10）沉积亚相或微相；(11）沉积相；(12）大地构造环境等内容（见图 5），各项内容定义及表示要求见《成矿地质背景研究技术要求》（叶天竺等，2010）。

地层区划			年代地层单位			岩石地层单位及代号			沉积岩建造类型	厚度(单位：m)	沉积岩建造柱	岩性岩相简述	含矿性	化石组合或同位素测年方法与年龄值（单位：Ma）	沉积亚相或微相	沉积相	大地构造环境
区	分区	小区	系	统	阶	群	组	段									
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

图 5　沉积岩建造综合柱状图图头结构

3.3.2　火山岩建造综合柱状图结构

火山岩建造综合柱状图综合反映图幅内火山岩建造与构造时空演化特征，一般附在主图面的左或右侧，从左至右原则上包括（1）构造岩浆岩带（带、亚带、喷发带）；(2）地质时代（火山岩建造的时代，以代、纪、世表示）；(3）岩石地层单位（火山岩建造所属的群、组）；(4）岩石组合或建造；(5）岩性花纹柱；(6）岩相代号；(7）厚度（单位：m）（以柱状图形式列出编图区内不同地质时期火山岩建造之岩性岩相及其厚度，综合反映火山岩建造的特征）；(8）岩性描述；(9）含矿性；(10）喷发旋回；(11）同位素年龄与测试方式（单位：Ma）；(12）火山构造；(13）岩石系列；(14）岩石成因类型；(15）大地构造属性等内容（见图 6），各项内容定义及表示要求见《成矿地质背景研究技术要求》（叶天竺等，2010）。

构造岩浆岩带			地质时代			岩石地层单位		岩石组合或建造	岩性花纹柱	岩相代号	厚度(单位：m)	岩性描述	含矿性	喷发旋回	同位素年龄与测试方法（单位：Ma）	火山构造	岩石系列	岩石成因类型	大地构造属性
带	亚带	喷发带	代	纪	世	群	组（代号）												
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

图 6　火山岩建造综合柱状图图头结构

表 2　1：25 万分幅建造构造图数据结构

		图件基本概要信息
1	图件中文名称模式	×× 幅 1：25 万建造构造图
2	编图空间范围规定	×× 分幅经纬度范围（左上角经度：DDDMMSS.SS、左上角纬度：DDMMSS.SS；右下角经度：DDDMMSS.SS、右下角纬度：DDMMSS.SS）
3	编图比例尺规定	1：25 万
4	编图坐标系及地图投影参数规定	选用北京 54 坐标系、1956 黄海高程基准、高斯 - 克吕格投影、6° 标准分带、投影原点维度统一规定为 0°，具体地图投影参数依据《全国矿产资源潜力评价编图空间坐标系统及其参数规定》[7]
5	编图技术参数及流程要求	依据《成矿地质背景研究技术要求》（叶天竺等，2010）
6	采用原始数据或资料情况	基于相应分幅 1：25 万分幅成矿地质背景研究实际材料图（库）以及物化遥感推断成果等资料
7	采用图例规定	依据《全国矿产资源潜力评价编图统一图例规定》[3]成矿地质背景研究编图图例和其它相关图例规定
8	采用图式规定	依据《全国矿产资源潜力评价编图统一图式规定》[2]成矿地质背景研究编图图式规定（即分幅建造构造图图式）
9	图件数据格式规定	MapGIS6.7 格式
10	图件计算机命名	MDZJZGZC×××× （×××× 按矿产资源潜力评价数据模型丛书《通用代码规定》（左群超等，2012b）“ 图件命名规定 ”关于图件中文名称取四位汉语拼音首字母的规则填写）
11	图件计算机代码	OFBB000C1A××××××××××0（×××××××××× 按矿产资源潜力评价数据模型丛书《通用代码规定》（左群超等，2012b）“ 图件代码规定 ”的 1：25 万标准分幅空间范围码填写）
12	图件专业谱系及代码规定	地质填图—地质图件—专题地质图件—建造构造图—0—00
13	编图说明书编写规定	依据《全国矿产资源潜力评价编图说明书编写提纲》[4]成矿地质背景研究编图说明书编写规定：即分幅建造构造图编图说明书编写规定
14	图件元数据填写要求	依据《全国矿产资源潜力评价图件元数据规定》[6]要求填写并提交分幅建造构造图图件元数据文件

续表 2

图件主图分层信息							
逻辑图层		物理图层（空间特性：限定为【点 | 线 | 面 | 像元】之一；数据表：限定为【有 | 无】之一）					
	编号及名称	图层编号及名称	空间特性	数据表	图层计算机命名	图层计算机代码	图层及数据来源
1	地理图层	主要行政境界图层	线	无			
		主要居民点地图层	点	无			
		主要面状水系图层	面	无			
		主要线状水系图层	线	无			
2	沉积岩建造图层	沉积岩建造图层	面	有	LDZOFBB001	OFBB001C1A××××××××0	(1) 说明：将相应分幅实际材料图中的岩性图层转换为建造图层，即通过综合研究将实际材料图中自然岩石组合归并上升为建造（沉积建造、火山岩岩性岩相单位、变质建造、深成侵入岩单元），同时，要将各类建造进行系统分析进一步上升，沉积岩区要进一步归纳出沉积建造序列，陆相火山岩区要综合归纳出火山构造内容（成矿地质构造预测要素）、侵入岩区要归纳出侵入岩浆构造带内容（成矿地质构造预测要素）。因此，建造构造图的编制主要是依据相应分幅实际材料图及数据库等资料。 (2) 间接引用相应分幅实际材料图中同名图层及属性数据。说明：由于分幅建造构造图的图幅之内要求连图，因此，若在分幅实际材料图之内未连图时（注意：分幅实际材料图之内，工作技术要求未规定必须连图），则在编制分幅建造构造图时有必要进行连图处理，所以，此处的引用涉及直接引用或间接引用两种情况。
		火山岩性岩相图层	面	有	LDZOFBB002	OFBB002C1A××××××××0	
		火山构造图层	面	有	LDZOFBB011	OFBB011C1A××××××××0	
		侵入岩图层	面	有	LDZOFBB003	OFBB003C1A××××××××0	
		构造岩浆带图层	面	有	LDZOFBB010	OFBB010C1A××××××××0	
		变质岩建造图层	面	有	LDZOFBB004	OFBB004C1A××××××××0	
		大型变形构造图层	面	有	LDZOFBB009	OFBB009C1A××××××××0	
		地质界线图层	线	有	LDZOFBA002	OFBA002C1A××××××××0	
		断裂图层	线	有	LDZOFBA003	OFBA003C1A××××××××0	
		韧性剪切带图层	面	有	LDZOFBA004	OFBA004C1A××××××××0	
		褶皱图层	线	有	LDZOFBA005	OFBA005C1A××××××××0	

续表 2

图件主图分层信息							
逻辑图层		物理图层（空间特性：限定为【点 | 线 | 面 | 像元】之一；数据表：限定为【有 | 无】之一）					
	编号及名称	图层编号及名称	空间特性	数据表	图层计算机命名	图层计算机代码	图层及数据来源
2	沉积岩建造图层	同位素年龄图层	点	有	LDZOFBA008	OFBA008C1A×××××××0	若在编制分幅实际材料图时已连图，则此处为直接引用；若在编制分幅实际材料图时未连图，则此处为间接引用
		产状要素图层	点	有	LDZOFBA016	OFBA016C1A×××××××0	
3	物探（重、磁）化探遥感推断隐伏构造及地质体图层（地表新发现、隐伏、或深部）	重力推断构造及地质体图层	点线面	有			以地质资料和地质研究为基础，综合分析引用重力资料推断隐伏构造及地质体（主要指地表新发现、隐伏、深部等）图层及其属性数据。
		磁法推断构造及地质体图层	点线面	有			以地质资料和地质研究为基础，综合分析引用磁法资料推断隐伏构造及地质体（主要指地表新发现、隐伏、深部等）图层及其属性数据。
		化探推断构造及地质体图层	点线面	有			以地质资料和地质研究为基础，综合分析化探资料推断隐伏构造及地质体（主要指地表新发现、隐伏、深部等）图层及其属性数据
		遥感推断构造及地质体图层	点线面	有			以地质资料和地质研究为基础，综合分析遥感资料推断隐伏构造及地质体（主要指地表新发现、隐伏、深部等）图层及其属性数据
4	其他图层		点线面				

续表 2

图件辅图、辅表信息	
柱状图	1. 沉积岩建造综合柱状图【可选】;2. 火山岩建造综合柱状图【可选】;3、侵入岩建造综合柱状图【可选】;4、变质岩建造综合柱状图【可选】等
剖面图	1. 图切地质剖面图 1【必要】;2. 图切地质剖面图 2【可选】等
角图	1. 所在位置大地构造分区图【必要】;2. 所在位置地层分区图【可选】等
附表	1. 所在位置大地构造分区表【必要】;2. 所在位置地层分区表【可选】;3. 大型变形构造特征表【可选】;4. 第四系成因类型划分表【可选】等
图件其他必要整饰信息	
1. 图件标题 ;2. 比例尺表示（数字和线段）;3. 图件方向标 ;4. 图例说明 ;5. 地图投影参数说明 ;6. 编图技术参数及资料来源说明 ;7. 编图责任表等	

注：在图件的图层信息中，只列出了建造构造类图层，但物（重、磁）化遥感推断构造及地质体类图层（地表新发现、隐伏或深部）、地理底图类图层、整饰类图层、非整饰类图层均未具体列出，可依据相关工作技术要求、实际表达需要、以及相应图式规定等，自行设置并建立所需要的地理、整饰、非整饰图层，但所设置的地理、整饰、非整饰图层命名及图层代码，严格按矿产资源潜力评价数据模型丛书《重力资料应用数据模型》（左群超等，2011b）、《磁测资料应用数据模型》（左群超等，2011c）、《化探资料应用数据模型》（左群超等，2011d）、《遥感资料应用数据模型》（左群超等，2011e）、《全国矿产资源潜力评价编图地理信息规定》[8]规定图层命名执行，其它可能的图层按自增命名方式处理。

3.3.3 侵入岩建造综合柱状图结构

侵入岩建造综合柱状图综合反映图幅内侵入岩建造与构造时空演化特征，一般附在主图面的左或右侧，从左至右原则上包括（1）构造岩浆岩带名称（一、二、三级）;（2）地质时代（代、纪、世、期）;（3）侵入岩建造（岩性、岩性花纹柱、代号、结构、岩性描述）;（4）同位素年龄（单位：Ma）及测定方法 ;（5）侵位深度 ;（6）剥蚀深度 ;（7）包体特征 ;（8）含矿性 ;（9）岩石系列 ;（10）岩石成因类型 ;（11）岩石构造组合 ;（12）大地构造环境等内容（见图 7），各项内容定义及表示要求见《成矿地质背景研究技术要求》（叶天竺等，2010）。

构造岩浆岩带名称			地质时代				侵入岩建造					同位素年龄（单位：Ma）及测定方法	侵位深度	剥蚀深度	包体特征	含矿性	岩石系列	岩石成因类型	岩石构造组合	大地构造环境
一级	二级	三级	代	纪	世	期	岩性	岩性花纹柱	代号	结构	岩性描述									
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

图 7　侵入岩建造综合柱状图图头结构

3.3.4 变质岩建造综合柱状图结构

变质岩建造综合柱状图综合反映图幅内变质岩建造与构造时空演化特征，一般附在主图面的左或右侧，从左至右原则上包括（1）变质地质单元名称（Ⅰ、Ⅱ、Ⅲ级）;

（2）地质时代（变质岩建造的原岩的形成时代，以代、纪表示）；（3）岩石地层单位及代号（变质岩建造所属的地层单位：岩群、岩组、群、组、代号）；（4）变质岩建造类型；（5）变质岩建造花纹柱；6）岩性描述；（7）含矿性；（8）原岩建造；（9）变质矿物组合；（10）变质作用类型；（11）变质相；（12）变质相系；（13）变质温压条件；（14）变质时代；（15）大地构造环境等内容（见图 8），各项内容定义及表示要求见《成矿地质背景研究技术要求》（叶天竺等，2010）。

变质地质单元名称			地质时代		岩石地层单位及代号			变质岩建造类型	变质岩建造花纹柱	岩性描述	含矿性	原岩建造	变质矿物组合	变质作用类型	变质相	变质相系	变质温压条件	变质时代	大地构造环境
Ⅰ	Ⅱ	Ⅲ	代	纪	群	组	代号												
–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

图 8　变质岩建造综合柱状图图头结构

3.3.5 大型变形构造特征表结构

大型变形构造特征表，综合反映图幅内大型变形构造物质组成、规模、产状、形成时代、组合、变形、运动、演化等多种特征信息，一般附在主图面的左或右侧，从左至右原则上包括（1）大型变形构造名称；（2）代号；（3）类型；（4）规模；（5）产状；（6）组合形式；（7）物质组成；（8）构造层次；（9）运动方式；（10）力学性质；（11）形成时代；（12）变形期次；（13）大地构造环境；（14）含矿特征等内容（见图 9），各项内容定义及表示要求见《成矿地质背景研究技术要求》（叶天竺等，2010）。

大型变形构造名称	代号	类型	规模	产状	组合形式	物质组成	构造层次	运动方式	力学性质	形成时代	变形期次	大地构造环境	含矿特征
–	–	–	–	–	–	–	–	–	–	–	–	–	–

图 9　大型变形构造特征表（或图）表头结构

3.4　分幅建造构造图样本

本文以青海省布喀达坂峰幅 1：25 万分幅建造构造图为代表，向读者展示一个分幅建造构造图实际样本（见图 10），该图件除了主图及必要整饰信息外，配有重要辅图辅表：沉积岩建造综合柱状图、火山岩建造综合柱状图、侵入岩建造综合柱状图、变质岩建造综合柱状图、大型变形构造特征表。另外，还有所在位置大地构造分区图、蛇绿（混杂）岩综合柱状图、第四系成因类型划分表、图切剖面图等。

4　数据质量控制和评估

4.1　利用原始资料质量评估

1：25 万分幅建造构造图编图建库使用的原始地质数据资料全面、系统、可靠。

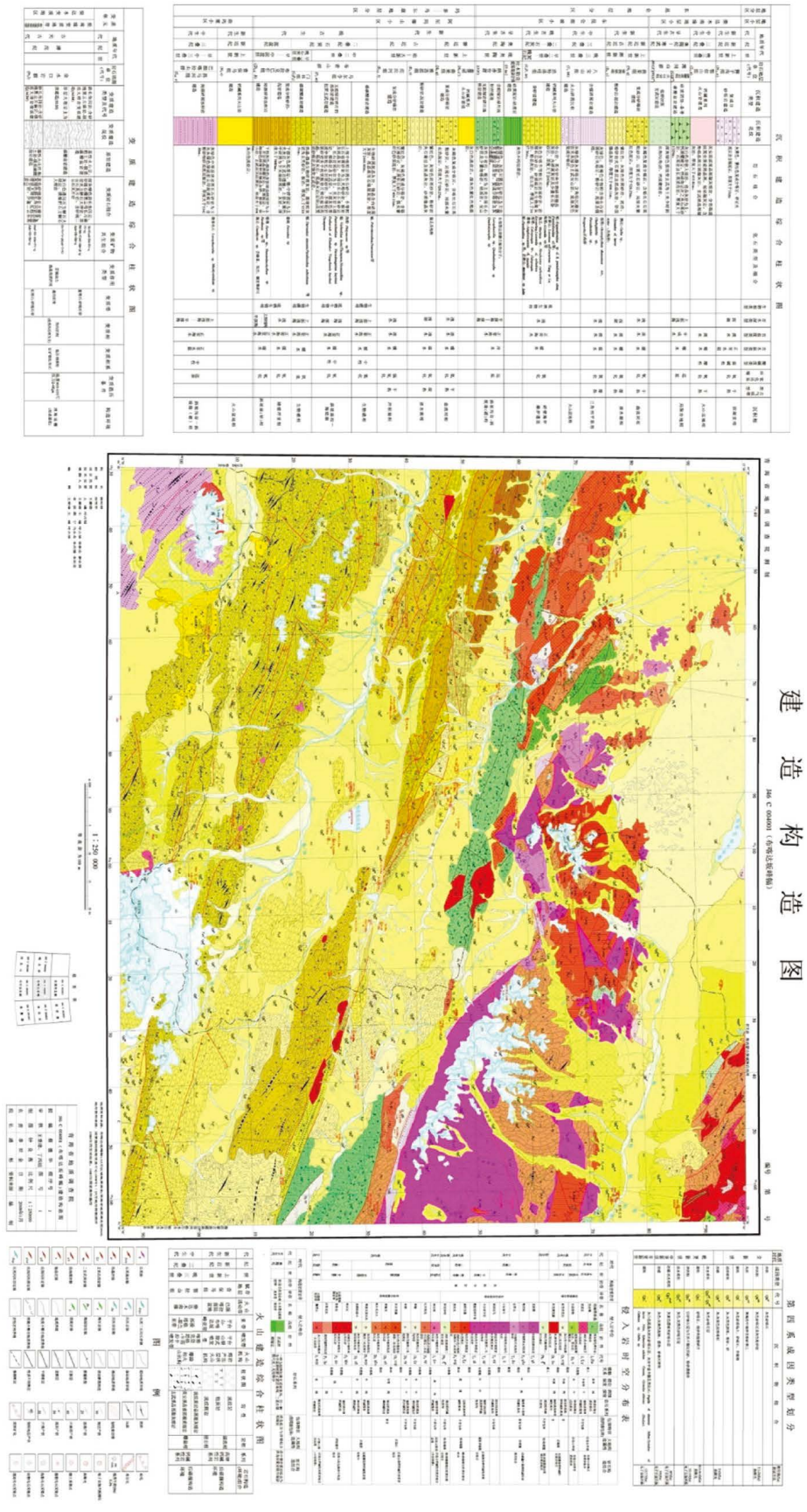

图 10　1：25 万分幅建造构造图样本

（1）全面、系统收集了本次研究尺度所需的以往所有地质区调数据资料，即1∶5万、1∶20万、1∶25万区调资料（含1999—2005年获取的青藏高原1∶25万区域地质调查资料），包括区调成果报告、区调原始资料（实际材料图、野外记录本、实测剖面、钻孔剖面、地质路线信手剖面、图切剖面、前人科研论著发表剖面、各项测试分析成果等）以及区调地质图数据库和地质工作程度数据库。

（2）全面、系统收集了以往区域地质研究成果、专著和重要文献（区域地质志、岩石地层清理成果等）以及网上专题学术论文资料等。

（3）全面、系统收集了1∶5万、1∶20万、1∶25万、1∶50万区域物探、化探、遥感解释（译）推断地质构造或地质体（包括地表新发现、隐伏或深部）等成果资料。在利用物化遥成果资料方面，坚持以地质资料和地质研究为基础，准确评价物化遥成果精度和可靠性，综合适度应用。

（4）严格遵循有新资料不用旧资料、有大比例尺资料不用小比例尺资料的地质资料使用原则，在综合研究与编图建库工作中，尽可能利用了最新1∶5万、1∶25万资料和最新专题研究成果等。本次收集利用的原始数据资料均是我国历年按统一行业标准形成的，质量可靠，所收集资料原则上要求截至到2013年底。

4.2 编图建库质量控制情况

4.2.1 严格控制编图质量

在编图质量控制方面，制定了严格、有序、有效、可控、可行的编图技术路线、工作方法和编图质量保障措施，保障了全国各省（直辖市、自治区）编图质量，简述如下。

（1）编制编图技术要求：全国成矿地质背景专题组组织业内权威专家、学者，研究编制《成矿地质背景技术要求》（叶天竺等，2010）。

（2）开展编图技术示范：针对中国地质情况复杂特点，选择了10个以上代表地区，结合《成矿地质背景技术要求》开展编图技术典型示范，在典型示范基础上多次研讨、修改、完善编图技术要求。

（3）开展编图技术培训：在示范完善成熟编图技术要求基础上，组织专家编写专门培训教材，多次集中培训各省（直辖市、自治区）成矿地质背景编图人员，并巡回到现场指导，随时组织专题研讨，专门解决编图中遇到的问题。

（4）资料全面系统可靠：严格要求各省（直辖市、自治区）编图使用的原始资料全面、系统、可靠；要求全国综合信息专题组编制相关基础地质数据库维护更新技术要求，统一下发全国掌握的有关基础地质数据库；动用有关行政力量，帮助有关省（直辖市、自治区）收全、收准、收到所需地质资料，保障编图所需原始资料全面系统可靠。

（5）先编分幅实际材料图，再编分幅建造构造图：要求各省（直辖市、自治区），严格按照《成矿地质背景技术要求》（叶天竺等，2010），先编制分幅实际材料图，在完成分幅实际材料图并符合质量要求之后，再以分幅实际材料图为基础，编制分幅建造构造图并符合质量要求，不得逾越和缺省，保障编图符合技术要求。

4.2.2 严格控制建库质量

在建库质量控制方面，制定了严格、有序、有效、可控、可行的建库技术路线、工作方法和建库质量保障措施，保障了全国各省（直辖市、自治区）建库质量，简述如下。

（1）编制建库技术要求：全国综合信息集成专题组组织业内权威专家、学者，研究编制矿产资源潜力评价数据模型等系列建库技术要求。

（2）开展建库技术示范：与编图技术示范同步开展建库技术示范，在示范基础上多次研讨、修改完善建库技术要求。

（3）开展建库技术培训：在示范完善成熟建库技术要求基础上，组织专家编写专门培训教材，多次集中培训各省（直辖市、自治区）成矿地质背景编图人员、建库人员，并巡回到现场指导，随时组织专题研讨，专门解决建库时遇到的问题。

（4）制定质量控制模型：依据地质图件数据特点、矿产资源潜力评价数据模型和地质数据质量检查与评价基本原理，建立了以“单个图件编图质量模型 + 单个图件空间数据质量模型 + 单个图件属性数据质量模型 + 单个图件元数据质量模型 + 单个图件质量模型 + 图件子集质量模型 + 图件集合质量模型”（简称“地质图件七层质量控制模型”）为核心的地质图件数据质量检查与评价方法技术体系（左群超等，2013b），并研发提供了支持软件（GeoMag、GeoTok、GeoDQC 等），方便图库数据质量自检、互检、抽检、修改。统一检查标准，实现定量评估自动化，极大提高了质量检查与评价效率，降低了工作成本，保证了建库质量符合技术要求（见图 11、图 12）。

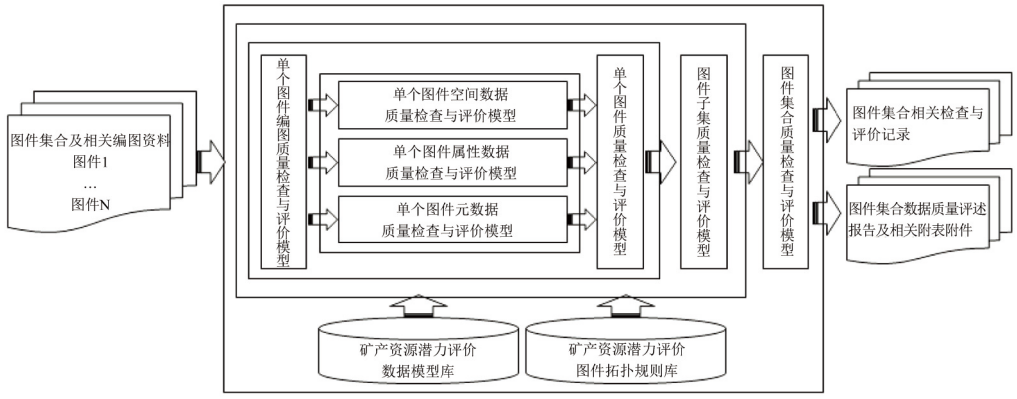

图 11　地质图件七层质量控制模型

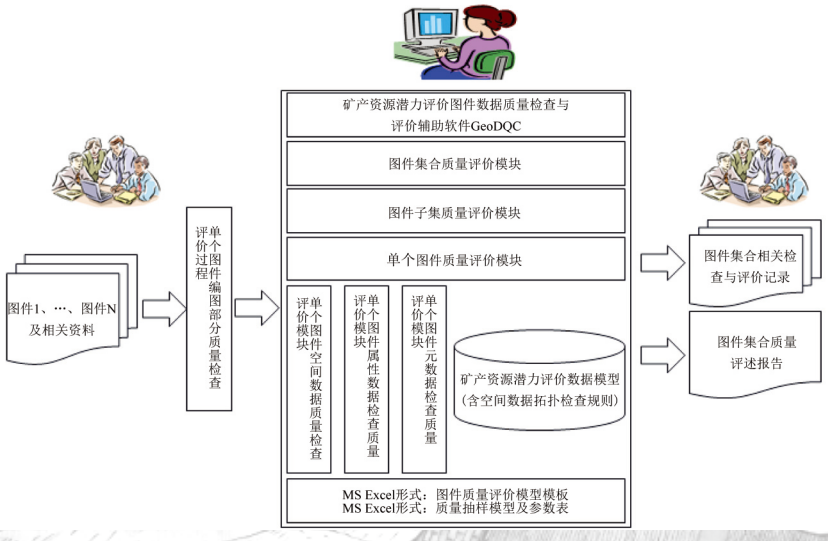

图 12　“地质图件七层质量控制模型”软件实现框架

4.2.3 建库验收质量控制

在本次建库成果质量验收方面，实现“两阶段验收”技术方法，保障了编图与建库数据质量统一，简述如下：

在建库成果质量验收之前，先由编图专家验收组进行编图成果质量验收，只有每一图件的编图质量验收通过，或对存在编图质量问题的图件，各省（直辖市、自治区）已按编图专家验收组意见修改、确认后，方可以转入建库成果质量验收流程。

建库成果质量验收，即由建库专家验收组进行建库成果质量验收，只有每一图库的建库质量验收通过，或对存在建库质量问题的图库，各省（直辖市、自治区）已按建库专家验收组意见修改、确认后，方可以用于汇总、集成建库。

若某分幅图库存在的建库质量问题，关联到因编图成果质量验收阶段未发现或遗漏的编图质量问题而引起，则还必须回到编图成果质量问题处理过程，这样循环直至每一分幅图库的建库质量验收合格为止[9]。

4.3 编图建库质量总体评述

本次编图建库工作利用的地质数据资料全面、系统、可考；采用建造构造分析法研究编图，客观表达了岩性或岩石的自然组合和地质构造实体形迹，系统反映了地质作用及其演化特征，明显优于传统的系级、组级地质图；采用全程应用 GIS 技术、以“地质图件七层质量控制模型”为核心的地质图件数据质量检查与评价方法技术体系、以及两阶段（编图质量验收 + 建库质量验收）质量验收方法，使得本次建立的中国陆域 1：25 万分幅建造构造图空间数据库质量完全符合技术要求[10]。

本次编图建库工作也存在如下两点局限：

其一，由于中国陆域存在少数地质调查工作空白区，没有合适的地质数据资料可用于开展 1：25 万分幅建造构造图编图与建库，因此，本次建立的中国陆域 1：25 万分幅建造构造图空间数据库，只能算基本覆盖中国陆域。本次已编图建库图幅清单详见附件《中国陆域 1：25 万分幅建造构造图图件名称、图幅名及编号检索一览表》。

其二，由于本次工作利用的地质数据资料，特别是区调地质图、区调地质空间数据库等资料，其空间坐标描述，主要采用北京 54 坐标系、1956 黄海高程基准，因此，编图与建库工作为了编图方便并提高工作效率，也采用了北京 54 坐标系、1956 黄海高程基准。自中国已法定要求全部采用 2000 国家大地坐标系、1985 国家高程基准之后，本次建立的中国陆域 1：25 万分幅建造构造图空间数据库，在今后提供服务过程中，还需完成从北京 54 坐标系、1956 黄海高程基准转换到 2000 国家大地坐标系、1985 国家高程基准，方便重复利用。

5 结论

依托全国矿产资源潜力评价专项（2006—2013 年），通过开展 1：25 万分幅建造构造图的编图与建库工作，取得如下 5 方面重大成果与技术创新：

（1）首次建立了中国陆域 1：25 万分幅建造构造图空间数据库，数据量达 16.6 GB，包含 729 幅 1：25 万标准分幅的图库及其相应图幅的编图说明书、图库元数据文件，其中每一图库数据为 MapGIS6.7 格式、编图说明书为 MS Word97-2003 格式、图库元数据

文件为 TXT\XML 两种格式。

（2）编图建库利用的基础地质数据资料系统、全面、可靠。所收集资料全部要求截至到 2013 年底，包括区域地质调查（1：5 万、1：20 万、1：25 万）、地质科研、专著文献等数据资料，地球物理、地球化学、遥感地质综合推断成果资料（1：5 万、1：20 万、1：25 万、1：50 万）、以及网上专业学术文献等。

（3）编图采用了建造构造分析法，编制的 1：25 万分幅建造构造图，主图图面要素是组级岩石地层单位的进一步细化与分解，客观表达岩石建造和地质构造实体形迹，按产状表达建造花纹，读图直观且便于应用，系统反映地质作用及其时空演化特征，明显优于以系级或组级地层单位为表示单元的传统地质图。可为 1：50 万尺度及以小大地构造图的编制，1：25 万尺度及以小区域矿产预测、成矿规律研究所用地质构造专题底图的编制等提供基础资料；在地质找矿、地质灾害防治、水工环地质调查、地热资源勘查、生态文明建设等方面具有广泛且长久可重复利用价值。

（4）研究形成了一整套编图、建库技术要求，一整套用于编图与建库的地质数据模型、质量控制模型、成果两阶段验收的方法技术体系，同时研发了一套与之方法技术体系配套的操作简单、适用有效的计算机软件或系统。这些方法技术或软件已产生广泛的影响和效益。

（5）形成了一整套多方参与、联动、合作、创新的工作机制，完成了中国陆域 1：25 万分幅建造构造图编图与建库的复杂、浩大工程。本次工作以实际资料为基础，采用自上而下统一技术要求、自下而上归纳分析综合的工作方式，将 30 个省（直辖市、自治区）、6 个大区、以及全国三层次的地质背景、信息专业、科技管理等多方面技术人员融为一体，从规范制定、技术培训、资料收集、数据整理、研究编图、质量控制、验收汇总，直至集成建库，每一环节、每一步骤，均非常协调、精准、规范、有效、可靠。

致谢：在中国陆域 1：25 万分幅建造构造图空间数据库建设过程中，北京、天津、河北、山西、山东、河南、内蒙古、黑龙江、吉林、辽宁、江苏、安徽、浙江、江西、福建、湖北、湖南、广东、广西、海南、四川、重庆、云南、贵州、西藏、陕西、甘肃、宁夏、青海、新疆共 30 个省（直辖市、自治区）矿产资源潜力评价项目组的成矿地质背景专题组、综合信息集成专题组对跨本省（直辖市、自治区）范围内的 1：25 万分幅建造构造图编图与建库，做出了基础而重要的贡献，致以衷心感谢。华北、东北、华东、中南、西南、西北片区矿产资源潜力评价项目组的成矿地质背景专题组、综合信息集成专题组，对本片区范围内 1：25 万分幅建造构造图编图与建库工作，全力协助指导应用、质量检查、成果验收、汇总集成，致以衷心感谢。全国成矿地质背景专题组、全国综合信息集成专题组的专家精心编制技术要求、精心组织技术示范、精心培训指导应用，取得了实实在在效果，致以崇高敬礼。对国土资源部地勘司、中国地质调查局、全国项目办以及发展研究中心的精心领导、精心策划、精准组织，致以衷心感谢。

注释：

❶ 叶天竺 , 陈毓川 , 张洪涛 . 2006. 全国矿产资源潜力评价总体实施方案 . 全国矿产资源潜力评价项目办公室 .

❷ 左群超 , 杨东来 . 2008a. 全国矿产资源潜力评价编图统一图式规定 . 全国矿产资源潜力评价项目办公室 .

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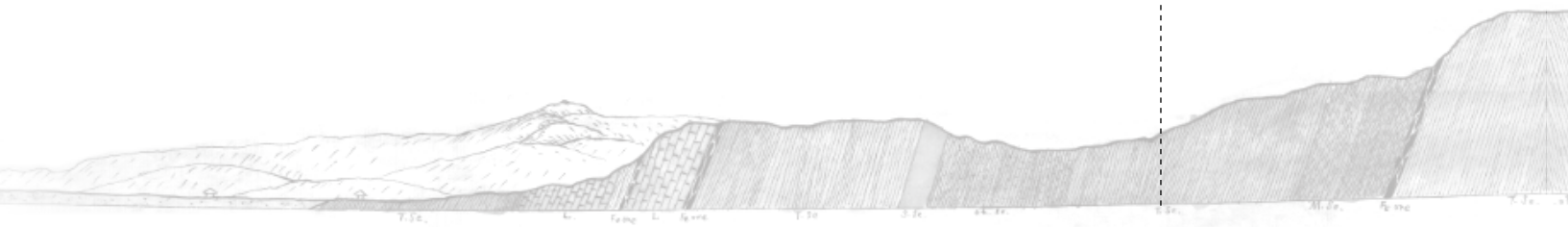

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Spatial Database of Serial Suite-Tectonic Map-sheets of Mainland China (1:250, 000)

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Abstract: For the thematic Program on China's national mineral resources' potentials assessment (2006—2013), the research group has collected such abundant references as 1:50, 000, 1:200, 000 and 1:250, 000 regional geological survey data (including the 1:250, 000 regional geological survey results from the Qinghai-Tibet plateau in 1999—2005), geological research results, scientific research monographs and important geological literatures as well as geophysical, geochemical, and remote sensing prospecting inferred results. Having digested all these data, the group has compiled serial first-hand data map-sheets at scale of 1:250, 000 and created the spatial database for the metallogenic geological setting researches. Applying the suite-tectonic analysis method and map-compiling techniques with such modern information technologic means as data models, quality-controlling models, and GIS software, the group has further compiled multiple map-sheets, created new databases, and summarized and integrated all these results in line with standard serial map-sheets, and has established the spatial database of serial suite-tectonic map-sheets of mainland China (1:250, 000). The database has included 729 map-sheets as well as their corresponding compilation explanatory notes and map-compiling metadata, roughly covering the entire mainland China. Compared with the traditional edition of the geological maps database which is characterized by using the stratigraphic units of System and Formation as the basic map-compiling units, this database has some outstanding advantages. Firstly, the essential mapping elements in the principal map are as fine as lithological units (quasi-Member), which are actually the finest mapped lithological components under the litho-stratigraphic unit 'Formation'. Secondly, different occurrences of the lithological units are expressed with the respective lithological patterns, objectively presenting the physical tracks and lineaments of lithological suites and geological structures, systematically reflecting the geological processes and their evolutionary characteristics, and being convenient for direct map reading and utilization. In general, this database can provide fundamental information for the compilation of 1:500, 000 or smaller scaled tectonic map-sheets, can directly offer essential factors for 1:250, 000 and smaller scaled regional mineral resources prediction, and can supply thematic base maps of geological structures for 1:250, 000 and smaller scaled minerogenetic regularity researches. It has also held extensive and long-term values for duplicative utilizations in geological survey and ore-prospecting, geo-hazard mitigation, hydrological, engineering and environmental geological surveying, geothermal resources exploration, and ecological conservation.

Key words: geological suite; geological structure; suite-tectonic map; spatial database; data model; quality-controlling model; GIS software

Data service system URL: http://dcc.cgs.gov.cn

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1 Introduction

Executed during 2006—2013, the thematic Program of China's national mineral resources' potentials assessment is a nationwide survey of key mineral commodities. In the Program, the geological scientific research forces are mobilized at such 3 levels as national, regional (referring particularly hereinafter to the 6 regional or multi-provincial subordinate branches of China Geological Survey, see the immediate next paragraph for details) and provincial levels (including 4 municipalities directly under the central government, and 5 autonomous regions) of China, and such 9 research groups (projects or subjects) as geological settings of metallogenesis, minerogenetic regularity study, application of gravity data, application of magnetic survey data, application of geochemical exploration data, application of remote sensing prospecting data, application of natural heavy mineral survey, mineral resources' prediction research, and comprehensive information integration [1] are set up respectively for the aforementioned each level. The research group has adopted the prediction methodology of deposit modeling plus integrated geological information, and has applied computer and GIS technologies to process the first-hand geological data. Administratively, the group has standardized the same technical requirements for all the aforementioned 3 levels of research forces from national level downwards, and has meanwhile academically concluded and synthesized the basic research results from provincial level upwards; this two-way mechanism has greatly contributed to the accomplishments of a quantitative potentials assessment of China's 25 key mineral commodities (e.g., coal, uranium, iron, and copper) as well as their spatial distributions. The results of this Program have perfectly portrayed a comprehensive picture of China's whole mineral resources potentials, and have yielded out a big quantity of creative achievements, and have further actually fixed this Program firmly to the position of a most systematic, most comprehensive, and most authoritative national-level survey of China's general situation of mineral resources' potentials.

The Spatial Database of Serial Suite-Tectonic Map-sheets of Mainland China (1:250, 000) (hereinafter, SDSSTMMC) is one of the fruits of the thematic Program of China's national mineral resources' potentials assessment. It has been carried out by research groups on geological settings of metallogenesis and research groups for comprehensive information integration at the national, regional (including North China, Northeast China, East China, South Central China, Southwest China, and Northwest China; i.e., the aforementioned 6 subordinate multi-provincial regional branches of China Geological Survey), and provincial levels (including municipalities and autonomous regions: Beijing, Tianjin, Hebei, Shanxi, Shandong, Henan, Inner Mongolia, Heilongjiang, Jilin, Liaoning, Jiangsu, Anhui, Zhejiang, Jiangxi, Fujian, Hubei, Hunan, Guangdong, Guangxi, Hainan, Sichuan, Chongqing, Yunnan, Guizhou, Tibet, Shaanxi, Gansu, Ningxia, Qinghai, and Xinjiang). The research groups have completed their tasks based on the technical requirements of research on geological settings of metallogenesis, the data models of mineral resources' potentials assessment, and data integration database construction technologies. The public version of SDSSTMMC has been issued on the website (http://dcc.cgs.gov.cn). The basic information is shown in Table 1, wherein the base data used for individual 1:250, 000 serial suite-tectonic map-sheets corresponds to 1:250, 000 serial first-hand data map-sheets on geological settings of metallogenesis.

Moreover, the national research group on geological settings of metallogenesis has facilitated the formulation of Technical Requirements of Researches on Geological Settings of Metallogenesis (Ye Tianzhu et al., 2010). And the national research group for comprehensive information integration has led in studying and formulating the data model series of mineral resources' potentials assessment (Zuo Qunchao et al., 2011a, 2011b, 2011c, 2011d, 2011e, 2012a, 2012b, 2013, 2015a), integrated database-construction methods and technologies of national mineral resources' potentials assessment (Zuo Qunchao et al., 2012, 2013a, 2015b, 2015c), and map compilation and database-construction technical specifications series of the national mineral resources' potentials assessment [2~9]; meanwhile, it has also facilitated the research and development of such database construction software as GeoMag, GeoTok, GeoDQC, GeoPEX and DipMopa (Zuo Qunchao et al., 2015b, 2015c); in addition, this national research group joined hands with regional research groups on geological settings of metallogenesis and comprehensive information integration so as to provide provincial research groups with training courses about map compilation technical requirements, data models, database construction technical requirements and relevant software systems, on-the-spot guidance, and quality inspection and acceptance checks. Later on, they have summarized all the results and completed the integration and database construction work. Furthermore, the provincial research groups on geological settings of metallogenesis and comprehensive information integration have completed their work on 1:250, 000 serial first-hand data map-sheet databases in the range of intra- and trans-provincial boundary. In this way, they have also completed the compilation of 1:250, 000 serial suite-tectonic map-sheet databases in the range of intra- and trans-provincial boundary, and has realized data in-putting, quality self-inspection, revising, and result submission [10].

Table 1 Metadata table of Database (Dataset)

Items	Description
Database (dataset) name	Spatial Database of Serial Suite-Tectonic Map-sheets of Mainland China (1:250, 000)
Database (dataset) authors	Zuo Qunchao, Development and Research Center of China Geological Survey Ye Tianzhu, Development and Research Center of China Geological Survey Feng Yanfang, Development and Research Center of China Geological Survey Ge Zuo, Development and Research Center of China Geological Survey Wang Yingchao, Development and Research Center of China Geological Survey
Data acquision time	The base data cited in map compilation and database construction is as of the end of 2006, and some information is as of the beginning of 2013.
Geographic area	Mainland China
Data format	*.wl, *.wt, *.wp
Data size	16.6 GB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	Comprehensive information integration on China's important mineral resources' potentials assessment (1212011121041) Research on the geological settings of metallogenesis of China's important mineral resources (1212011121036)
Language	Chinese

Continued table 1

Items	Description
Database (dataset) composite	It consists of 729 sheets of 1:250, 000 scaled standard serial suite-tectonic map-sheets (covering the entire mainland area of China) and their corresponding compilation explanatory notes and map metadata documents.

2 Data Collection and Processing Methods

2.1 Definitions of Basic Concepts and Maps

2.1.1 Geological Structures

According to A Dictionary of Earth Sciences (2006), Geological Structures, also named as structural lineation, are defined in 2 different visions: the first is as small- and medium-sized tracks and traces that occur during the genesis of geological bodies (rocks), or, those are resulted from the deformation or displacement of them after genesis, such as folds and faults; the second is, in a more general sense as narrated in the Dictionary, as the constructional assemblages of the geological bodies and the reciprocal allocating mosaics and general lineation features of their internal units or components at sizes from global to ultra-microscopic. In a common sense, geological structures are classified as 6 scales: gigantic, large, medium, small, microscopic, and ultra-microscopic. The classification of structure scales is related not only to the research fields and focuses, but also to the research methods and means. Geological structures at different scales are embodied, on the one hand, through their spatial assemblages and superimpositions, and on the other hand, through the predominating ones' controlling over the secondary ones.

However, for convenience of researches and better services to the practices of mineral resources assessment, geological structures in this paper have been classified simply into 3 scales based on their sizes and applications instead of the aforementioned 6-scale scheme: diagenetic (rock-controlling) geological structures, regional geological structures, and geo-tectonics.

2.1.2 Geological Suite

According to A Dictionary of Earth Sciences (2006), a geological suite generally refers to a set of genetically-related rock paragenetic associations formed under specific geotectonic conditions in a certain stage of the earth's crust development. It is believed that geological suites reflect specific geotectonic settings in the earth's crust evolution and development stage and that therefore the efforts of differentiating and identifying suites provide an important basis for determining the evolution and development stage of the crust in a certain area. Conceptually, geological suites mean different understanding and nomenclatures among different geologists and also varied implications and scale division for different disciplines and practical uses.

However, for convenience of researches and better services to the practices of mineral resources assessment, geological suites in this paper have been calibrated simply as 3 grades. The first grade is as lithological or rock association, which, corresponding to diagenetic (rock-control) structures, refers to a single kind of natural rock or an association of several kinds of rocks, being generally identifiable and describable in geological mapping, and depending upon the mapping accuracy. The second grade is as rock suite,

which, corresponding to regional structures, refers to rock associations that characterize the suite settings and are classified into such 4 types as sedimentary rock suite, volcanic rock suite, intrusive rock suite, and metamorphic rock suite, serving as the basic mapping unit of suite-tectonic map-sheets. The third grade is as petro-tectonic associations, which, corresponding to tectonic structures, refers to the rock associations that characterize the geotectonic settings, serving as the basic mapping unit of geotectonic facies maps in research on geological settings of metallogenesis.

The suites in this work refer to material suites, which are natural associations of one or more types of rocks formed at the same age and under the same geological process (sedimentation, intrusion, volcanism, or metamorphism). Therefore, the division of suites should be generally subject to the following conditions: 1) consistent lithologies, lithofacies and degree of metamorphism; 2) same or similar internal structures; 3) clear boundaries; and 4) a certain large scale and distribution range.

The definitions of sedimentary rock suite, volcanic rock suite, intrusive rock suite, and metamorphic rock suite in the suite-tectonic maps of this work are unitarily determined as follows:

(1) Sedimentary Rock Suite: It refers to the associations of one or more types of rocks of the same sedimentary sub-facies (or micro-facies) formed under the same sedimentation process at the same age.

(2) Volcanic Rock Suite: It refers to the associations of one or more types of rocks formed under the same volcanism. It is represented as per the requirements of lithology-lithofacies two-factor mapping method; for those with multiple indistinguishable lithofacies, the prevailing one is chosen to be mapped, while the subvolcanic rock and the sedimentary interlayer are mapped separately.

(3) Intrusive Rock Suite: It refers to the intrusive bodies (excluding the plutonic rock masses) formed under the same intrusion at the same age. Intrusive bodies resulted from the differentiation of plutonic rock masses must be represented in the suite-tectonic maps. Since rock-structure associations of intrusive rocks are generally used to trace back their tectonic settings, it is necessary to represent the rock-structure associations in the establishment of composite columnar section of intrusive rock suites.

(4) Metamorphic Rock Suite: It refers to the associations of one or more types of rocks with relatively unified geological structural-type formed from the primitive sedimentary rock, volcanic rock, and/or intrusive rock by metamorphism of the same age. In principle, the rocks and their metamorphic levels in a same metamorphic suite should be roughly consistent with each other; they should widely occur in a certain large ranges so that they can be reasonably represented in the map; their structural types and occurrences show a series of similarities in characteristics, and belong to the same protolith families; moreover, they should be distinguishable with the other ones by their clear boundaries.

Furthermore, the followings should be noted in the classification of metamorphic rock suites. Firstly, metamorphic supracrustal rocks and metamorphic plutonic intrusive bodies should be correctly distinguished, and both should be represented on the composite columnar section of metamorphic rock suites. Secondly, as metamorphic rock suites are generally further subdivision of (Rock) Formation-level unit, metamorphic plutonic intrusive bodies should be divided by lithology; various gneisses should be denoted with codes as per the national standard, while the metamorphic intrusive bodies should be

denoted as per the specifications of intrusive rocks. Thirdly, the division of metamorphic rock suites should be reasonable, according generally to the balance of the protolith suite and the type of metamorphism: the rock associations of the same metamorphic types with different protolith suites should be distinguished as different metamorphic rock suites.

The research group of this paper confirms that the suite-tectonic map-sheets are different from the System- or Formation-level geological maps, and that Suite, different from the "litho-stratigraphic unit Formation" is the further subdivision of the Formation-level stratigraphic unit. This is the core of this suite-tectonic map compilation.

2.1.3 Serial first-hand Data Map-sheets

In this Project, the 1:250, 000 serial first-hand data map-sheets refer particularly to those used in the research on geological settings of metallogenesis, serving as the main original data sources of the research. They are compiled on the basis of 1:250, 000 standard serial geological map-sheets, being integrated with such original data as the analysis results of regional geological surveys and studies of geological structures obtained from this circle of the mapping.

The contents of serial first-hand data map-sheets mainly include lithologies, geological boundaries, faults, ductile shear zones, folds, alteration zones, occurrence elements, traverses and points of geological reconnaissance, positions of geological sections, boreholes, fossil sampling points, isotopic ages, petrochemical, geochemical and isotopic sampling points, various codes and annotations.

Lithology information is a detailed supplement to the original geological maps, mainly indicating the distribution of various lithological associations or rock associations and their interrelations. The core of this compilation work is, concerning the needs of mineral resources prediction and geotectonic facies research, to further subdivide the map-compiling stratigraphic units of the original geological maps, and check in detail the first-hand mapping data, mainly including the measured sections and trunk traverses, so as to supplement the lithologic (association) boundaries.

2.1.4 Serial Suite-Tectonic Map-sheets

In this work, the 1:250, 000 serial suite-tectonic map-sheets, refer to the maps compiled according to 1:250, 000 standard map-sheets after the integrated analysis and study of suites and structures based on 1:250, 000 serial first-hand data map-sheets. The research group has studied the geological processes by sedimentation, volcanism, intrusion, metamorphism, tectonism, and macro-deformation according to their characteristics, and has then represented them on the serial suite-tectonic map-sheets respectively as sedimentary suite structure, volcanic lithology-lithofacies structure, intrusive magmatic structure, metamorphic suite structure, deformed structure, and large-scale deformed structure. Following these steps, an integrated analysis and study of suites and structures is carried out to prepare composite columnar sections reflecting the characteristics of spatial-temporal evolution.

The contents of serial suite-tectonic map-sheets mainly include sedimentary rock suites, volcanic lithology-lithofacies structures, volcanic structures, intrusive rocks, intrusive magmatic tectonic belts (tectonic magmatic belts), metamorphic rock suites, large-scale deformed structures, geological boundaries, fractures, ductile shears belts, folds, isotopic age, occurrence, and inferred geological structures by gravity, magnetic, geochemical

and remote sensing prospecting, various codes and annotations, as well as composite columnar sections of sedimentary, volcanic, intrusive and metamorphic suites, and table of characteristics of large-scale deformed structures.

The serial suite-tectonic map-sheets are basic maps that have reflected geological processes and their evolutionary characteristics. As the core of this research on geological settings of metallogenesis, they are also the "first-hand data maps" of the geotectonic facies research and stepping-stones for the preparation of geotectonic facies maps. Meanwhile, the serial suite-tectonic map-sheets can be further supplemented with the first-hand data so as to better materialize the rock suites and structures that are related to mineralization, and consequently to form the thematic base map of geological structures in the mineral resources prediction area.

2.2 Data Collection and Data-use Regulations

2.2.1 Data Collection

(1) The research group for this paper has comprehensively collected 1:50, 000, 1:200, 000, 1:250, 000 regional geological survey data (including the 1:250, 000 regional geological survey results from the Qinghai-Tibet plateau in 1999—2005), including regional geological survey result reports and regional geological survey first-hand data (first-hand data maps, field-trip paper-back notebooks, measured sections, drilling sections, freehand sketch sections along geological reconnaissance, cutting sections, sections and analysis results issued in previous research works), regional geological survey map database, and geological exploration coverage database.

(2) The group has systematically collected previous regional geological research results, monographs and key literatures (such as the regional geological memoirs, the finely calibrated litho-stratigraphic data), and on-line thematic academic papers.

(3) The group has completely collected 1:50, 000, 1:200, 000, 1:250, 000 and 1:500, 000 geophysical, geochemical, and remote-sensing first-hand data, as well as inferred interpretation results of geological structures or geological bodies.

(4) Without missing any valuable information, the group has thoroughly understood the depths of the regional geological researches, and has consequently compiled the research maturity map.

(5) Generally, all the collected data are as of the end of the year 2013.

2.2.2 Data-use Regulations

The utilization of geological data in this Program has also followed the conventional practice, i.e., the newer data are more likely adopted rather than the older; the larger-scaled data are more often used instead of the smaller; the regional geological data that are used in the map-compilation and database construction are ensured to be the most recently obtained from the up-to-date mapping and thematic researches with the highest accuracies. Moreover, the suite-tectonic analysis, the petro-tectonic associations, and the spatial-temporal evolutional hierarchy are fully applied in the whole process of this Program.

In addition, the data-use of 1:50, 000 regional geological survey results is more explicitly stipulated as the followings:

(1) The compilation of 1:250, 000 serial first-hand data map-sheets and 1:250, 000 serial suite-tectonic map-sheets is indispensable to use the 1:50, 000 regional survey data.

(2) In the mapping areas where the 1:250, 000 regional geological survey data overlaps that of 1:50, 000, the new data from the former should be used to supplement the latter.

(3) The 1:50, 000 mapping data should be used reasonably and effectively according to the specific circumstances. As the 1:50, 000 maps are issued by different explorers in different years, their mapping qualities and precisions vary remarkably; consequently, they should not be indiscriminately copied and mechanically applied. Therefore, the 1:50, 000 mapping data should be evaluated before use so as to distinguish the specific mapping quality, and then decide whether fully or partly to use, or even to abandon the 1:50, 000 data, and thereby reach the target of rationality and effectiveness.

2.3 Data Processing and Integration

2.3.1 Preparation of Data Processing

Based on the thorough collection, deep digestions, and effective utilization of all the existing first-hand data and comprehensive results, the research teams have well prepared for the necessary technical requirements of the further researches and map-compilations, which are mainly as follows:

(1) Geographical base maps and related databases;

(2) Geological map databases at 1:50, 000, 1:200, 000, 1:250, 000 scales as well as geological exploration coverage databases;

(3) Preliminary analyses on the sedimentation, volcanism, intrusion, metamorphism, and tectonism; and the classification and correlation working schemes on lithological stratigraphy, volcanic eruption, magmatic intrusion, metamorphic geological units, and tectonic divisions and evolutional stages; and

(4) Calibration of detailed regulations for map-compilation (including unified symbols and patterns), based on the Data Models of Researches on Geological settings of Metallogenesis (Zuo Qunchao et al., 2011a).

2.3.2 Data Integration

The research on regional metallogenic geological structures, which is based on first-hand geological data and research results from regional geological field surveys, is aimed at analyzing regional geotectonic settings and re-constructing their dynamical evolution through integrating the suite-tectonic characteristics of regional geological structures. It targets at offering the macroscopic prerequisites for the forecasting of a certain kind of mineral commodity, with supports from the analysis of ore-forming regional tectonic evolution and metallogenic regularity.

The characteristics of such geological processes as divergence, convergence, collision, and orogeny among the continental crustal blocks are studied on the basis of geotectonic units; their spatial distribution and evolution characteristics are consequentially described. Moreover, sedimentation (sedimentary rock suites, lithofacies, and tectonic paleogeography), volcanism (volcanic rock suites, volcanic rock facies, and volcanic structures), intrusive magmatism (intrusive rock suites and intrusive magmatic structures), metamorphism (metamorphic rocks and metamorphic deformed structures), and large-sized deformed structures are studied respectively; meanwhile, the geotectonic characteristics inferred through geophysical, geochemical and remote sensing prospecting results are used to analyze the temporal-spatial evolution of geological structure and their material

composition characteristics, based on which the geotectonic facies are classified. Research results are expressed by compilation of first-hand data maps, suite-tectonic map-sheets, geotectonic facies maps, and related databases. The comprehensive research is roughly divided as the following steps.

(1) The research group systematizes and analyzes the first-hand data on geo-tectonics, and compiles the 1:250, 000 scaled serial map-sheets for metallogenic geological settings researches.

(2) The group studies the characteristics of suites and structures and large-scale deformed structures to analyze the evolution of geological structures. With supports from the inferred results of the geological structures by means of comprehensive geophysical, geochemical and remote sensing prospecting analysis, the group compiles the 1:250, 000 scaled serial suite-tectonic map-sheets.

(3) Combining the geologic structure research, the group carries out thematic researches on sedimentation, magmatism, metamorphism and large-scale deformed structures so as to analyze geotectonic evolution and metallogenic geological settings by tectonic evolution stages. After the classification of geotectonic facies and geotectonic divisions, the provincial-sized 1:500, 000 scaled geotectonic facies maps are compiled.

2.4 Technical Flow in Map Compilation and Database Construction

2.4.1 Map Compilation and Database Construction of Serial first-hand Data Map-sheet Databases

(1) Selecting mapping ranges, scale, geodetic coordinate system and map projection: 1:250, 000 scale, Beijing-1954 Coordinate System, Huanghai-1956 Elevation System, Gaussian-6° standard zoning map projection, and projection origin latitude to be uniformly defined as 0°.

(2) Key data used in the compilation/construction: the first-hand data of 1:250, 000, 1:200, 000, and 1:50, 000 scale regional geological surveys besides the collections of the thematic research results in the mapped areas, with supplements of on-line academic papers.

(3) Technicalities for utilizing 1:50, 000 scale regional geological survey data.

The 1:50, 000 regional geological survey data should be used in the preparation of serial first-hand data map-sheets. According to the coverage percentage of 1:50, 000 scale regional geological surveys in the mapped area, the first-hand data map-sheets are compiled in 3 ways with respect to the data utilization:

The First Way: If the coverage percentage of 1:50, 000 scale regional geological surveys is between 100% and 2/3, all the 1:50, 000 scale first-hand data will be adopted for the map compilation.

1) Measured sections: All should be used.

2) Densities of routes and observation points: towards the precision of 1:250, 000 scale, the densities of the geological reconnaissance route and observation points in the 1:50, 000 scale maps are rarefied principally at a spacing square by 2.5 km × 2.5 km. The trunk routes and valid points should, to the most extent, be selected (i.e., geological boundaries, structural control points, and important sampling points).

3) Sampling locations: the 1:50, 000 scale data is the first choices, with the supplements from the 1:200, 000 and 1:250, 000 scale data.

4) Geological data: the downscaling from the 1:50, 000 scale geological mapping results should be the main sources, with some data being cited from 1:200, 000 and 1:250, 000 scale geological surveys so as to remedy those areas without the covering of 1:50, 000 geological survey data.

The Second Way: If the 1:50, 000 regional geological surveys is only finished in a smaller percentage (e.g., less than 1/3), all the 1:250, 000/1:200, 000 first-hand data should be used for the map compilation.

1) Measured sections: All should be adopted.

2) Densities of routes and observation points: All in the 1:250, 000/1:200, 000 surveys should be adopted.

3) Sampling locations: That from the 1:250, 000/1:200, 000 surveys are the main sources, with that from the 1:50, 000 surveys being the supplements.

4) Geological data: That from the 1:250, 000/1:200, 000 surveys are the main sources, with that from the 1:50, 000 surveys being the supplements.

The Third Way: If the coverage percentage of 1:50, 000 regional geological surveys is between 1/3 and 2/3, the utilization of the 1:50, 000 data would be flexible with references from the above two ways: classifying firstly and synthesizing secondly.

(4) Supported with the geological data on the former-edition geological maps, the geological data on the former-edition first-hand data map-sheets of the former regional geological surveys are vectorized; and the first-hand data such as the measured sections and trunk geological reconnaissance routes are then referred to and are thoroughly analyzed; the original map-compiling geological units of the former-edition geological maps are further subdivided; the lithological (association) boundaries are completed.

(5) The serial first-hand data map-sheets should keep the authenticities of the original regional geological survey data, with the primary geological data being expressed, and the maps being not adjoined. These map-sheets can be finished on the base of the former-edition first-hand data map-sheets of the former geological surveys with additions of the newly-supplemented lithological (association) data. These serial first-hand data map-sheets are of black-and-white style without coloring and legend patterns. The measured sections of the regional geological surveys (such as the cross sections and columnar sections) should be scanned as digital images and be stored in the serial first-hand data map-sheets databases.

(6) As for the isotopic ages and other important lithochemical and geochemical data issued on the public academic literatures, if they are attached with sampling locations or geographical coordinates, they should be adopted into the serial first-hand data map-sheet databases; those without clear sampling locations could be annotated on the relevant geological bodies with special legends.

(7) The stratifying of the basic layers of the serial first-hand data map-sheets should comply with the relevant regulations calibrated in the Data Models of Researches on Geological Settings of Metallogenesis (Zuo Qunchao et al., 2011a).

(8) The attribute data of the basic layers of the serial first-hand data map-sheets should be input in accordance with the framework of the data table and in-filling regulations calibrated in the Data Models of Researches on Geological Settings of Metallogenesis (Zuo Qunchao et al., 2011a).

The main flowchart and the technical framework of map compilation and database construction of the serial first-hand data map-sheet databases are shown in Fig. 1 and Fig. 2.

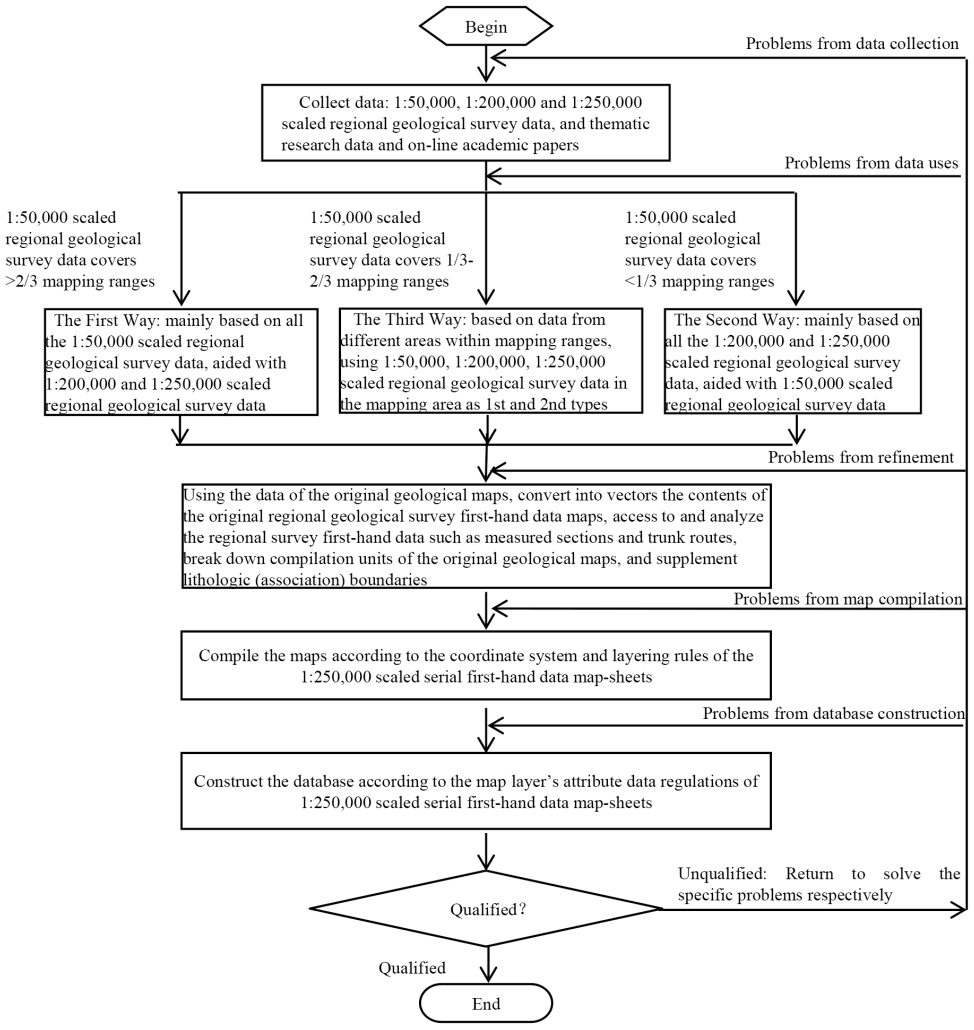

Fig. 1 A Flowchart of Map Compilation and Database Construction of the Serial First-hand Data Map-sheet Databases

2.4.2 Map Compilation and Database Construction of Serial First-hand Data Map-sheet Databases

(1) The research group calibrates the compiling coverage, scale, geodetic coordinate system and map projection: the 1:250, 000 scale, Beijing-1954 Coordinate System, Huanghai-1956 elevation system, Gaussian 6° standard zone-dividing map projection, and projection origin latitude uniformly defined as 0°.

(2) Based on the 1:250, 000 serial first-hand data map-sheet databases, the group compiles serial suite-tectonic map-sheets. Therein, the sedimentary rock area depicts the sedimentary suites and sedimentary structures; the volcanic rock area presents the volcanic lithology, volcanic lithofacies, and volcanic structures (for the marine volcanic rock area, sedimentary suite and sedimentary structures could be the main expressions especially if the original volcanic structures are hard to be identified); the intrusive rock area describes the magmas and their intrusive structures; the metamorphic rock area mainly draws the

metamorphic suite and metamorphic structures; and the tectonic deformation area shows the folds, faults, and ductile shear zones. Meanwhile, the characteristics of large-scale deformed structures need to be expressed on the map. Furthermore, based on geological data and geological research results, the map needs to express the newly discovered, buried or deep-rooted geological structures or geological bodies inferred by geophysical, geochemical and remote sensing prospecting.

(3) Through integrated analysis and research on suites and structures, the group aims to compose a series of comprehensive columnar sections so as to reflect the characteristics of spatial-temporal evolution, which may include the composite columnar sections respectively of sedimentary, volcanic, intrusive, and metamorphic suites, and table of characteristics of large-scale deformed structures.

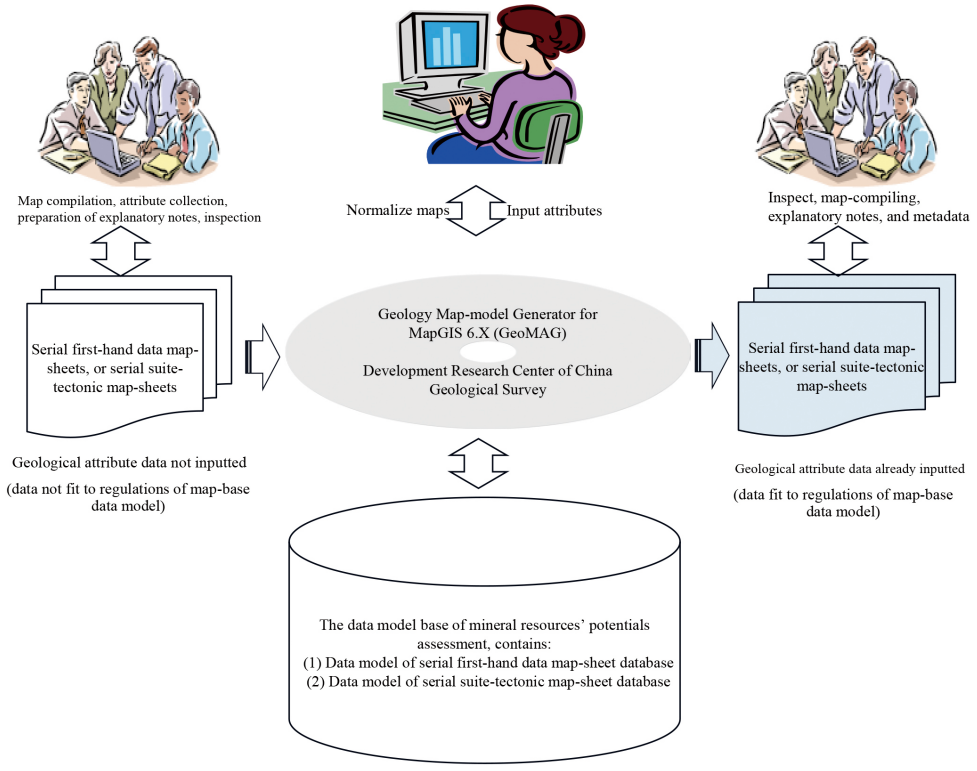

Fig. 2 Technical Framework of Database Construction of the Serial First-hand Data Map-sheet Database or Serial Suite-Tectonic Map-sheet Database

(4) Through integrated analysis and research on suites and tectonics, the group also aims to figure out various structural shapes representing different suites so as to express the suite patterns by occurrence and physical trails of geological structures.

(5) The drawing precision of the serial suite-tectonic map-sheets is, by principle, calibrated as being not lower than that of the original 1:250, 000 geological maps. Meanwhile, to classify the various suites, the Formation-level lithological stratigraphic units are further subdivided into suites; and the Formation-level lithological stratigraphic units are not incorporated with each other. The principle to be obeyed is that the geological information is always superior to mapping expressions. If some suites are too narrow in the map to be clearly expressed with lithological patterns, these patterns are then allowed to be omitted.

(6) The basic layers of the serial suite-tectonic map-sheets are stratified in accordance with the specifications calibrated in the Data Models of Researches on Geological Settings of Metallogenesis (Zuo Qunchao et al., 2011a).

(7) The attribute data of basic layers of the serial suite-tectonic map-sheets should be input or infilled in accordance with the data table framework and specifications that are calibrated in the Data Models of Researches on Geological Settings of Metallogenesis (Zuo Qunchao et al., 2011a).

The main flowchart and the technical framework of map compilation and database construction of the serial suite-tectonic map-sheets are shown in Fig. 2 and Fig. 3.

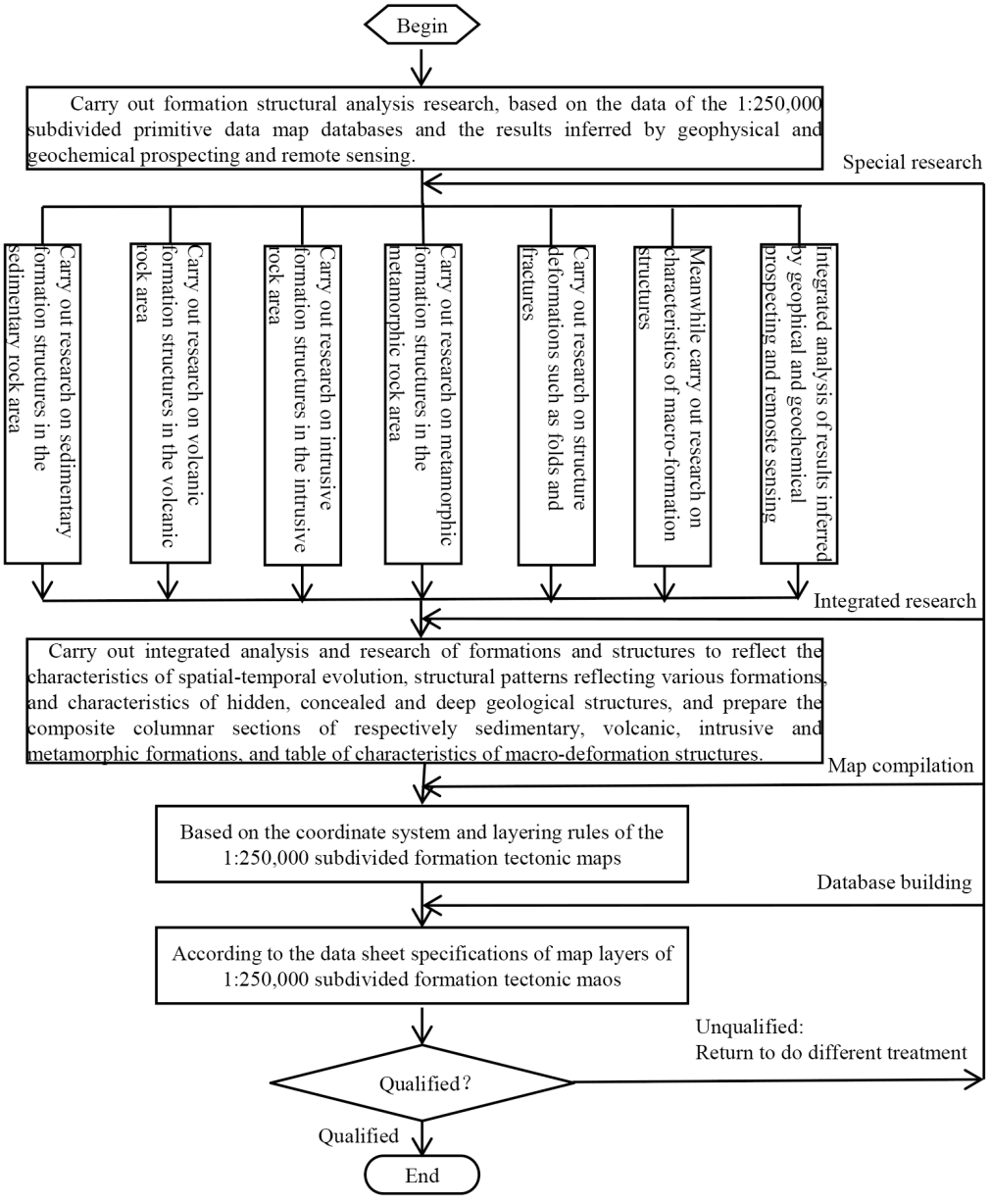

Fig. 3 Main Flowchart of Map Compilation and Database Construction of the Serial Suite-Tectonic Map-sheet Database

2.4.3 General Technical Process of Map Compilation and Database Construction

Based on such technical preparations as geological data collection, data sorting, map compilation, and database construction, the provincial research groups firstly compile the 1:250, 000 serial first-hand data map-sheet databases. The comprehensive analyses and researches on suites and tectonics are, as the second step, launched aiming at the construction of the 1:250, 000 serial suite-tectonic map-sheet databases. Thirdly, the provincial-level 1:250, 000 serial suite-tectonic map-sheet databases are finally integrated as the general Spatial Database of Serial Suite-Tectonic Map-sheets of Mainland China (1:250, 000).

Meanwhile, the quality control measurements are successively adopted for each episode of the data collection, data sorting, map compilation, database construction, data-pooling, database integration, and quality acceptance checking. The general technical process could be classified as the following 7 major steps (see Fig. 4):

(1) Formulating the technical requirements for map compilation and database construction

The national research group calibrates the technical requirements for research on geological settings of metallogenesis (including that for the compilation of 1:250, 000 serial first-hand data map-sheets and 1:250, 000 serial suite-tectonic map-sheets); meanwhile, it also issues technical requirements for data models and database-construction aiming at mineral resources' potentials assessment, and programs such database-construction software series as GeoMag (including supporting software for the map compilation and database construction of 1:250, 000 first-hand data map and 1:250, 000 serial suite-tectonic map-sheets).

(2) Pilot demonstrations aiming to improve technical requirements

The national research group on geological settings of metallogenesis has held several times of field pilot demonstrations at selected representative areas; it meanwhile improves the technical requirements for map compilation from the results of the demonstrations. To be in pace with the above, the national research group on comprehensive information integration simultaneously offers application demonstrations of the technical requirements on data models and database construction as well as related software, and achieves the isochronous technical requirements improvements for database construction.

(3) Training courses on technical requirements for map compilation and database construction

Based on the successful pilot demonstrations of the technical requirements and their secondary improvement, the national research group has independently or jointly provided training courses on the technical requirements for map compilation and database construction for provincial research groups respectively on geological settings of metallogenesis and comprehensive information integration.

(4) Provincial research groups launching map compilation and database construction

Firstly, the research groups complete data collection, data sorting, and preparations of map compilation and database construction. Secondly, the research groups finish the compilation and database construction of 1:250, 000 serial first-hand data map-sheets in the range of intra- and trans-provincial (or municipality and autonomous region) boundary. Thirdly, the research groups complete the map compilation and database construction of 1:250, 000 serial suite-tectonic map-sheets in the range of intra- and trans-provincial (or

municipality and autonomous region) boundary.

(5) "Two-stepped" acceptance checking

The first step is called the Map Compilation Quality Acceptance. In this step, the national and regional research groups on geological settings of metallogenesis respectively organize specialized geologists to carry out quality acceptance checking of every 1:250, 000 serial first-hand data map-sheet and serial suite-tectonic map-sheet completed by the provincial research groups, and to offer evaluation remarks on how to revise and improve the map qualities. For those maps with quality defects, the provincial research groups need to revise and attain to be qualified according to the evaluation remarks; only when the revision quality are confirmed, can the acceptance checking be continued to the second step.

The second step is called Database Construction Quality Acceptance. In this step, the national and regional research groups on comprehensive information integration respectively organize database construction specialists to carry out quality acceptance checking of every 1:250, 000 serial first-hand data map-sheet database and serial suite-tectonic map database completed by the provincial research groups, and to offer evaluation remarks on how to revise and improve the map database qualities.

For those databases with quality defects, the provincial research groups need to revise and attain to be qualified according to evaluation remarks; only when the revisions are confirmed, can the database construction results be formally submitted. If any of the defects can be traced back to the afore steps, as are occasionally failed to be detected in the Map Quality Acceptance Checking step, or are unintentionally omitted in the map compilation process, these defects should be send back to the afore step or even to the original map compilation process and be re-treated till qualified.

(6) Integration of provincial map compilation and database construction results

The national research group on comprehensive information integration organizes the integration of the results of the 1:250, 000 serial first-hand data map-sheet databases and the 1:250, 000 serial suite-tectonic map databases submitted by the provincial research groups; it still constructs the SDSSTMMC and composes the final research report on database construction. During the process of results-pooling and integration, the regional and provincial research groups provide necessary assistance.

(7) Final Promotion and General Acceptance Checking

China National Mineral Resources' Potentials Assessment Program Office and China Geological Survey jointly launch a special acceptance check on the SDSSTMMC, and offer an evaluation remark; while the national research group on comprehensive information integration need to correct and improve the final results of the database construction according to the evaluation remarks, and submit the whole completion of the Program.

3 Description of Data Sample

3.1 Digital Framework of Serial Suite-Tectonic Map-sheets

In accordance with the Data Models of Researches on Geological settings of Metallogenesis (Zuo Qunchao et al., 2011a), the digital framework of serial suite-tectonic map-sheets consists of 5 parts, namely the outlines of map-sheet, map-layers of the

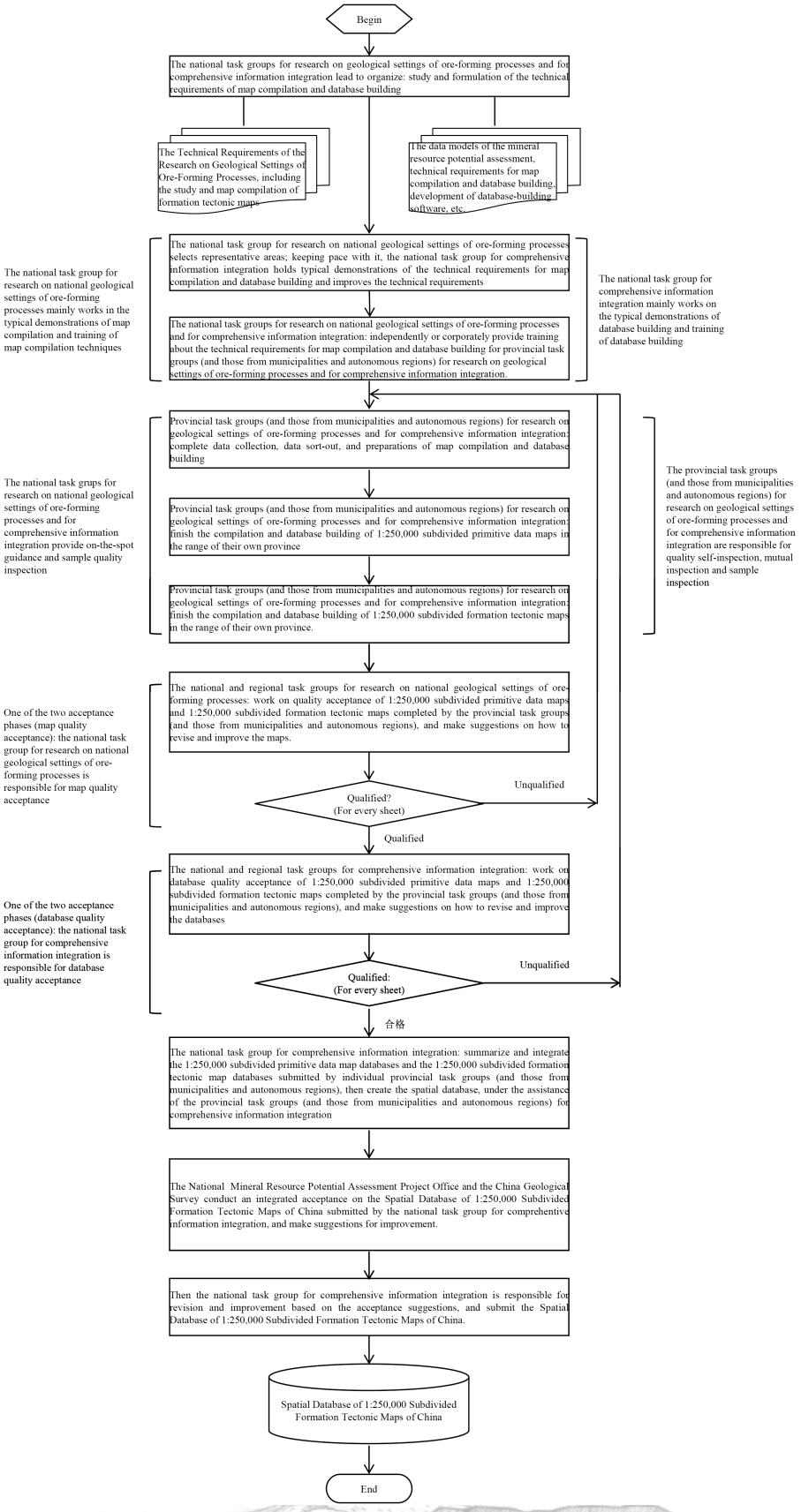

Fig. 4 Construction Flowchart of Spatial Database of Serial Suite-Tectonic Map-sheets of Mainland China (1:250, 000)

principal map, auxiliary diagrams (columnar sections, cutting sections, and location index sketch), annexed tables, and necessary decoration layers (Table 2), each of which is briefly described below.

(1) Outlines of Map-sheet: Containing the naming pattern of the map's Chinese name; provisions on spatial dimensions, scale, coordinate system and projection parameters; map-compilation technical parameters and process requirements; the first-hand data utilization; provisions on utilization of legends, symbols and data formats; map's computing naming pattern; map's computing code mode; provisions on map's professional hierarchy and code; provisions on map's compilation explanatory notes; and requirements for in-filling map's metadata.

(2) Map-layers of the Principal Map: Containing the logical map-layer (serial numbering and names); the physical layer (serial numbering and names); spatial characteristics of layer (either point feature, polyline feature, polygon feature, or image - the spatial characteristic of the physical layer belongs to one of the following four elements: point feature, polyline feature, polygon feature, or image); the layer's corresponding data table (yes-or-naught: whether there is a data table describing the features of the physical layer); computing naming of the layers; computing code of the layers; and data source of the layers. Among them, the logical layers include such 4 types as respectively of geographical base map layer, suite-tectonic map layer, structures or geological bodies map layer (i.e., the newly discovered, buried or deep-rooted structures or geological bodies) inferred by geophysical, geochemical and remote sensing prospecting, and other necessary logical layers.

In the serial suite-tectonic map-sheets, the geographical base map layer depicts major administrative boundaries, residential sites, and planar/linear drainage systems; meanwhile, the suite-tectonic layer predominately draws the sedimentary rock suites, volcanic rocks' lithofacies, volcanic structures, intrusive rocks, tectonic-magmatic belts, metamorphic rock suites, large-scale deformed structures, geological boundaries, fractures/faults, ductile shear zones, folds, isotopic ages, and occurrences; while the inferred structures/geological bodies layer mainly focuses on the gravity, magnetic, geochemical and geophysical prospecting results, which can roughly delineate the outlines of the structures and geological bodies.

(3) Auxiliary Diagrams: (Columnar Sections, Cutting Sections, Location Index Sketch): Referring to the composite columnar sections, according to the features of the mapped areas, respectively of sedimentary suites, volcanic rock suites, and intrusive rock suites, metamorphic rock suites, as well as the geological cutting sections, and location index sketches which indicate the geotectonic and/or stratigraphic location(s) of the mapped area.

(4) Annexed Tables: Including the tables of geotectonic and stratigraphic divisions where the mapped area is located, the characteristics table of large-scale deformed structures, and the table of Quaternary genetic type classification.

(5) Necessary Decoration Layers: Including map titles, scales (numerical scale or segment scale), map direction indicator, explanations of the legends, description of map projection parameters, explanations of technical parameters and data sources of map compilation, and table of map-compilation contributors.

3.2 Data Table Framework of Map Layers of Principal Map

The Data Models of Researches on Geological Settings of Metallogenesis (Zuo Qunchao et al., 2011a) has respectively given the provisions for the data table's framework and the in-filling specifications separately for the sedimentary rock suites, volcanic lithology-lithofacies, volcanic structures, intrusive rocks, intrusive magmatic tectonic belts (tectonic-magmatic belts), metamorphic rock suites, large-scale deformed structures, geological boundaries, faults, ductile shears belts, folds, isotopic ages, and occurrences.

The Application Model of Gravity Prospecting Data (Zuo Qunchao et al., 2011b), the Application Model of Magnetic Prospecting Data (Zuo Qunchao et al., 2011c), the Application Model of Geochemical Prospecting Data (Zuo Qunchao et al., 2011d), and the Application Model of Remote Sensing Prospecting Data (Zuo Qunchao et al., 2011e) have respectively given the provisions for the data table framework and the in-filling specifications separately for the inferred structures and geological bodies (point feature, polyline feature, polygon feature) by gravity and magnetic prospecting, geochemical and remote sensing prospecting data.

3.3 Frameworks of Essential Auxiliary Sections and Tables

In the compilation of serial suite-tectonic map-sheets, the auxiliary serial composite columnar sections respectively of sedimentary, volcanic, intrusive, and metamorphic rock suites as well as the table of characteristics of large-scale deformed structures, have been separately compiled according to the evolution and distribution of the sedimentation and sedimentary rock suites vs tectonism, volcanism and volcanic rock suites vs tectonism, intrusion and intrusive rock suites vs tectonism, and metamorphism and metamorphic rock suites vs tectonism in the mapped area; these essential auxiliary sections and tables have fully reflected the regional geological processes and their evolutionary characteristics in the mapped area. The headers of the 4 types of columnar sections and the table are described as below.

3.3.1 The Header of Composite Columnar Section of Sedimentary Rock Suites

The composite columnar section of sedimentary rock suites comprehensively reflects the characteristics of spatial-temporal evolution of sedimentary rock suites and tectonics within the map. It is generally attached to the left or right side of the principal map and includes the followings (from left to right): (1) stratigraphic division (stratigraphic Region, stratigraphic Sub-region, and stratigraphic Area); (2) chronostratigraphic units (System, Series, and Stage); (3) lithostratigraphic units and codes (Group, Formation, and Member); (4) sedimentary rock suite type; (5) thickness (unit: m); (6) sedimentary rock suite column; (7) brief description of lithology and lithofacies; (8) ore-bearing potentials; (9) Ages by fossil associations or isotopic dating methods (unit: Ma); (10) sedimentary sub-facies or micro-facies; (11) sedimentary facies; and (12) geotectonic settings (see Fig. 5). In addition, more and further details are described in the Technical Requirements of Researches on Geological Settings of Metallogenesis (Ye Tianzhu et al., 2010).

Stratigraphic division			Chronostratigraphic unit			Lithostratigraphic unit and code			Sedimentary rock formation type	Thickness (m)	Sedimentary rock formation column	Brief description of lithology and lithofacies	Ore-bearing potential	Ages by Fossil association or isotopic dating methods (Ma)	Sedimentary subfacies or microfacies	Sedimentary facies	Geotectonic settings
Region	Sub-region	Area	System	Series	Stage	Group	Formation	Member									
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Fig. 5 Figure Header of the Composite Columnar Section of Sedimentary Rock Suites

3.3.2 The Header of Composite Columnar Section of Volcanic Rock Suites

The composite columnar section of volcanic rock suites comprehensively reflects the characteristics of spatial-temporal evolution of volcanic rock suites and tectonics within the map. It is generally attached to the left or right side of the principal map and includes the followings (from left to right): (1) tectonic magmatic belts (belt, subbelt, and eruptive belt); (2) geological age (the age of volcanic rock suite, represented by Era, Period and Epoch); (3) lithostratigraphic units (Group and Formation that the volcanic rock suite belongs to); (4) rock assemblages or suites; (5) lithological pattern column; (6) lithofacies code; (7) thickness (unit: m) (i.e., the columnar section is aimed to list the lithology and lithofacies and thickness of various volcanic rock suites at different geological periods in the mapped area, comprehensively reflecting the characteristics of volcanic rock suites); (8) lithological description; (9) ore-bearing potentials; (10) eruption cycles; (11) isotopic ages and dating methods (unit: Ma), (12) volcanic structures, (13) rock series; (14) rock genetic types; and (15) geotectonic attributes (see Fig. 6). In addition, more and further details are given in the Technical Requirements of Researches on Geological Settings of Metallogenesis (Ye Tianzhu et al., 2010).

Tectonic magmatic belt			Geological age			Lithostratigraphic unit		Rock assemblage (suite)	Lithological pattern column	Lithofacies code	Thickness (m)	Lithological description	Ore-bearing potential	Eruption cycles	Isotopic age and dating method (Ma)	Volcanic structure	Rock series	Rock genetic type	Geotectonic attribute
Belt	Sub-belt	Eruptive belt	Era	Period	Epoch	Group	Formation (code)												
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Fig. 6 Figure Header of the Composite Columnar Section of Volcanic Rock Suites

3.3.3 The Header of Composite Columnar Section of Intrusive Rock Suites

The composite columnar section of intrusive rock suites comprehensively reflects the characteristics of spatial-temporal evolution of intrusive rock suites and tectonics within the map. It is generally attached to the left or right side of the principal map and includes the followings (from left to right): (1) names of tectonic magmatic belts (Level I, II, and III); (2) geological age (Era, Period, Epoch, and Stage); (3) intrusive rock suites (lithology, lithological pattern column, code, structure, and lithology description); (4) isotopic age (Ma) and dating method; (5) emplacement depth; (6) denudation depth; (7) characteristics of inclusions; (8) ore-bearing potential, (9) rock series; (10) rock genetic type; (11)

petrotectonic assemblage; and (12) geotectonic settings (see Fig. 7). More and further details are given in the Technical Requirements of Researches on Geological Settings of Metallogenesis (Ye Tianzhu et al., 2010).

Name of tectonic magmatic belt			Geological age				Intrusive rock suite					Isotopic age (Ma) and dating method	Emplacement depth	Denudation depth	Characteristics of inclusions	Ore-bearing potential	Rock series	Rock genetic type	Petrotectonic assemblage	Geotectonic settings
Level I	Level II	Level III	Era	Period	Epoch	Stage	Lithology	Lithological pattern column	Code	Structure	Lithological description									
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Fig. 7 Figure Header of the Composite Columnar Section of Intrusive Rock Suites

3.3.4 The Header of Composite Columnar Section of Metamorphic Rock Suites

The composite columnar section of metamorphic rock suites comprehensively reflects the characteristics of spatial-temporal evolution of metamorphic rock suites and tectonics within the map. It is generally attached to the left or right side of the principal map and includes the followings (from left to right): (1) names of metamorphic geological units (Level I, II, and III); (2) geological age (the age of metamorphic rock suite, represented by Era, and Period); (3) lithostratigraphic units (stratigraphic units that the metamorphic rock suites belong to Rock Group, Rock Formation, Group, and Formation) and their codes; (4) types of metamorphic rock suites; (5) pattern column of metamorphic rock suites; (6) lithological description; (7) ore-bearing potential; (8) protolith suites; (9) metamorphic mineral associations, (10) type of metamorphism; (11) metamorphic facies; (12) metamorphic facies series; (13) temperature and pressure of metamorphism; (14) metamorphism age; and (15) geotectonic settings (see Fig. 8). More and further details are given in the Technical Requirements of Researches on Geological Settings of Metallogenesis (Ye Tianzhu et al., 2010).

Name of metamorphic geological units			Geological age		Lithostratigraphic unit and code			Type of metamorphic rock suites	Pattern column of metamorphic rock suites	Lithological description	Ore-bearing potential	Protolith suites	Metamorphic mineral associations	Type of metamorphism	Metamorphic facies	Metamorphic facies series	Temperature and pressure of metamorphism	Metamorphism age	Geotectonic settings
I	II	III	Era	Period	Group	Formation	Code												
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Fig. 8 Figure Header of the Composite Columnar Section of Metamorphic Rock Suites

Table 2 Digital Framework of 1:250, 000 Scaled Serial Suite-Tectonic Map-sheets

		Outlines of Map-sheets
1	Naming pattern of map-sheet's Chinese name	×× 1:250, 000 Serial Suite-Tectonic Map-sheets
2	Provision on compilation's spatial dimensions	Latitude and longitude ranges of ×× serial map-sheet (longitude in the upper left corner: DDDMMSS.SS, latitude in the upper left corner: DDMMSS.SS; longitude in the lower right corner: DDDMMSS.SS, latitude in the lower right corner: DDMMSS.SS).
3	Provision on compilation's scale	1:250, 000 scale.
4	Provision on coordinate system and projection parameter in map-compilation	Use the Beijing-1954 Coordinate System, the Huanghai-1956 Elevation System, Gauss-Krüger projection, 6° standard zone-division, and projection origin latitude to be uniformly defined as 0°. The specific map projection parameters are based on the Specifications for Cartographic Space Coordinate System and Its Parameters in China's National Mineral Resources' Potentials Assessment.[7]
5	Technical parameters and process requirements for map-compilation	Based on the corresponding 1:250, 000 serial first-hand data map-sheets (map base) on geological settings of metallogenesis and results inferred by geophysical, geochemical and remote sensing prospecting.
6	First-hand data utilization	Based on the corresponding 1:250, 000 subdivided primitive data maps (database) for research on geological settings of ore-forming processes and results inferred by geophysical and geochemical prospecting and remote sensing
7	Provision on legend utilization	According to the provisions on map compilation legends on geological settings of metallogenesis, which are calibrated in the Specifications for Cartographic Legends in China's National Mineral Resources' Potentials Assessment[3] and other relevant legend provisions.
8	Provision on utilization of map symbols	According to the provisions on map compilation symbols (i.e., map symbols of the serial suite-tectonic map-sheets) on geological settings of metallogenesis, which are calibrated in the Specifications for Cartographic Symbols in China's National Mineral Resources' Potentials Assessment.[2]
9	Provision on utilization of map data formats	MapGIS6.7 format.
10	Map's computing naming pattern	MDZJZGZC×××× (×××× is the first four Pinyin initials of the Chinese name of the map according to the "provisions on map naming" in the Specifications for Universal Codes (Zuo Qunchao et al., 2012b) in the book series of data models of mineral resources' potentials assessment)
11	Map's computing code mode	OFBB000C1A××××××××××0 (×××××××××× is filled in accord with the spatial range code of 1:250, 000 standard map-sheet systems in the "provisions on map's code" in the Specifications for Universal Codes (Zuo Qunchao et al., 2012b) in the book series of data models of mineral resources' potentials assessment)
12	Provisions on map professional hierarchy and code	Geological mapping-Geological maps-Thematic geological maps-Suite-tectonic map-sheets-0-00

Continued table 2

Outlines of Map-sheets		
13	Provisions on map's compilation explanatory notes	According to the provisions on preparation of map-compilation explanatory notes in the research on geological settings of metallogenesis in the Preparation Outline of Map-compilation Explanatory Notes in China's National Mineral Resources' Potentials Assessment [4]: i.e., the provisions on preparation of map-compilation explanatory notes of the serial suite-tectonic map-sheets
14	Requirements for in-filling of map's metadata	Map metadata documents of the serial suite-tectonic map-sheets should be filled in and submitted according to the Specifications for Map Metadata in China's National Mineral Resources' Potentials Assessment [6]

Map-Layer Information of Principal Map

Logic Layer		Physical Layer (spatial characteristics: limited to one of the [point|polyline|polygon|image] alternatively; data table: limited alternatively to [yes/no])					
Serial Number	Serial Number and Name	Layer Serial Number and Name	Spatial Characteristic	Data Table	Layer's Computing Naming	Layer's Computing Code	Layer and Data Source
1	Geographic Map-Layer	Layer of major administrative boundaries	Polyline	No			
		Layer of major residential sites	Point	No			
		Layer of major planar drainage systems	Polygon	No			
		Layer of major linear drainage systems	Polyline	No			
2	Map-Layer of Suite-Tectonics	Layer of sedimentary rocks suites	Polygon	Yes	LDZOFBB001	OFBB001C1A ××××××××0	(1) Description: convert the lithological layer in the corresponding serial first-hand data map-sheet into a suite layer, i.e., after comprehensive studies, the natural rock associations in the first-hand data map are merged and upgraded as various suites (sedimentary suites, volcanic lithologies and lithofacies units, metamorphic suites, and plutonic intrusive units); meanwhile, all sorts of suites are systematically analyzed and further upgraded, i.e., the sedimentary rocks areas are further concluded as the sedimentary suite sequences; the continental volcanic rocks areas are further comprehensively concluded as volcanic tectonics (or, the essential prediction factors of the metallogenic geological structures); while the intrusive rocks areas are further concluded as intrusive magmatic-tectonic zones (or, the essential prediction factors in the metallogenic geological structures). Therefore, the compilation of the suite-tectonic map-sheets is mainly based on the corresponding serial first-hand data map-sheets and databases.
		Layer of volcanic lithologies and lithofacies	Polygon	Yes	LDZOFBB002	OFBB002C1A ××××××××0	
		Layer of volcanic structures	Polygon	Yes	LDZOFBB011	OFBB011C1A ××××××××0	
		Layer of intrusive rocks	Polygon	Yes	LDZOFBB003	OFBB003C1A ××××××××0	
		Layer of tectonic-magmatic belts	Polygon	Yes	LDZOFBB010	OFBB010C1A ××××××××0	
		Layer of metamorphic rock suites	Polygon	Yes	LDZOFBB004	OFBB004C1A ××××××××0	
		Layer of large-scale deformed structures	Polygon	Yes	LDZOFBB009	OFBB009C1A ××××××××0	

Continued table 2

Map-Layer Information of Principal Map							
Logic Layer	Physical Layer (spatial characteristics: limited to one of the [point|polyline|polygon|image] alternatively; data table: limited alternatively to [yes/no])						
Serial Number and Name	Layer Serial Number and Name	Spatial Characteristic	Data Table	Layer's Computing Naming	Layer's Computing Code	Layer and Data Source	
	Layer of geological boundaries	Polyline	Yes	LDZOFBA002	OFBA002C1A ××××××××××0	(2) Indirectly cite the eponymous layer data and attribute data in the corresponding serial first-hand data map-sheets for the compilation of the suite-tectonic maps. Description: when the suite-tectonic map is to be compiled, the serial first-hand data map-sheets, in the suite-tectonic map's covering ranges, should be linked with each other (which are not necessarily linked by the technical requirements) in case of no link among the serial first-hand data map-sheets; therefore, the citation here involves both direct and indirect ways. If the first-hand data map-sheets are already linked in the preparation stage, we call it as direct citation; otherwise, it is called an indirect citation.	
	Layer of faults	Polyline	Yes	LDZOFBA003	OFBA003C1A ××××××××××0		
	Layer of ductile shear zones	Polygon	Yes	LDZOFBA004	OFBA004C1A ××××××××××0		
	Layer of folds	Polyline	Yes	LDZOFBA005	OFBA005C1A ××××××××××0		
	Layer of isotopic ages	Point	Yes	LDZOFBA008	OFBA008C1A ××××××××××0		
	Layer of occurrences	Point	Yes	LDZOFBA016	OFBA016C1A ××××××××××0		
3 Map-Layer of structures and geological bodies inferred by geophysical (gravity and magnetic), geochemical and remote sensing prospecting (the newly discovered, buried, or deep-rooted ones)	Layer of structures and geological bodies inferred by gravity exploration data	Point | polyline | polygon	Yes			Based on geological data and geological researches, comprehensively analyze and cite the layer data and attribute data of the buried structures and geological bodies (mainly referring to the newly-discovered, buried or deep-rooted ones) which are inferred by gravity prospecting data.	
	Layer of structures and geological bodies inferred by magnetic prospecting data	Point | polyline | polygon	Yes			Based on geological data and geological researches, comprehensively analyze and cite the layer data and attribute data of the buried structures and geological bodies (mainly referring to the newly-discovered, buried or deep-rooted ones) which are inferred by magnetic prospecting data.	
	Layer of structures and geological bodies inferred by geochemical prospecting data	Point | polyline | polygon	Yes			Based on geological data and geological researches, comprehensively analyze and cite the layer data and attribute data of the buried structures and geological bodies (mainly referring to the newly-discovered, buried or deep-rooted ones) which are inferred by geochemical prospecting data.	
	Layer of structures and geological bodies inferred by remote sensing prospecting	Point | polyline | polygon	Yes			Based on geological data and geological researches, comprehensively analyze and cite the layer data and attribute data of the buried structures and geological bodies (mainly referring to the newly-discovered, buried or deep-rooted ones) which are inferred by remote sensing prospecting data.	
4 Other map-layers		Point | polyline | polygon					

Continued table 2

Map-Layer Information of Principal Map						
Logic Layer	Physical Layer (spatial characteristics: limited to one of the [point|polyline|polygon|image] alternatively; data table: limited alternatively to [yes/no])					
Serial Number and Name	Layer Serial Number and Name	Spatial Characteristic	Data Table	Layer's Computing Naming	Layer's Computing Code	Layer and Data Source
Information of Auxiliary Figures and Tables						
Columnar section	1. Composite columnar section of sedimentary rock suites [optional]; 2. Composite columnar section of volcanic rock suites [optional]; 3. Composite columnar section of intrusive rock suites [optional]; 4. Composite columnar section of metamorphic suites [optional].					
Cutting sections	1. Geological cutting section-1 [mandatory]; 2. Geological cutting section-2 [optional].					
Location index sketches	1. Geotectonic Division Map where the mapped area is located; [mandatory]; 2. Stratigraphic Division Map where the mapped area is located [optional].					
Annexed table	1.Geotectonic Division Table of the mapped area [mandatory]; 2. Stratigraphic Division Table of the mapped area [optional]; 3. Table of characteristics of large-scale deformed structures [optional]; 4. Table of Quaternary genetic type classification [optional].					
Other Necessary Decoration Information						
1. Map title; 2. Scales (numerical scale and segment scale); 3. Map direction indicator; 4. Legend; 5. Description of map projection parameters; 6. Explanation of technical parameters and data sources of map compilation; 7. Table of map-compilation contributors.						

Note: The layer information of maps only lists the suite-tectonic layers, without the layers of structures and geological bodies inferred by geophysical (gravity and magnetic), geochemical and remote sensing prospecting (the newly discovered, buried or deep-rooted ones), the layer type of geographical base maps, the decoration layer, and non-decoration layer. It is allowed to set up and establish necessary geographical, decoration and non-decoration layers according to relevant technical requirements, actual representation needs and corresponding symbol specifications. However, the naming of set geographical, decoration and non-decoration layers with layer codes should be strictly in accordance with the Application Model of Gravity Prospecting Data (Zuo Qunchao et al., 2011b), the Application Model of Magnetic Prospecting Data (Zuo Qunchao et al., 2011c), the Application Model of Geochemical Prospecting Data (Zuo Qunchao et al., 2011d), the Application Model of Remote Sensing Prospecting Data (Zuo Qunchao et al., 2011e), and the Specifications for Cartographic Geographic Information in China's National Mineral Resources' Potentials Assessment[5]. Meanwhile, other possible layers should be added with independent names.

3.3.5 The Header of Table of Characteristics of Large-scale Deformed Structures

The table of characteristics of large-scale deformed structures comprehensively reflects various characteristics, such as material composition, scale, occurrence, age, association, deformation, movement and evolution of large-scale deformed structures within the map. It is generally attached to the left or right side of the principal map and includes the followings (from left to right): (1) name of large-scale deformed structure; (2) code; (3) type; (4) scale; (5) occurrence; (6) assemblage form; (7) material composition; (8) structural hierarchy; (9) movement mode, (10) mechanical property; (11) age; (12) phase of deformation; (13) geotectonic settings; and (14) ore-bearing characteristics (see Fig. 9). More and further details are given in the Technical Requirements of the Researches on Geological Settings of Metallogenesis (Ye Tianzhu et al., 2010).

Name of large-scale deformed structure	Code	Type	Scale	Occurrence	Assemblage form	Material composition	Structural hierarchy	Movement mode	Mechanical property	Age	Phase of deformation	Geotectonic settings	Ore-bearing characteristics
-	-	-	-	-	-	-	-	-	-	-	-	-	-

Fig. 9 Figure Header of Characteristics of Large-scale Deformed Structures

3.4 Sample of Serial Suite-Tectonic Map-sheets

In this paper, the 1:250, 000 scaled Bukadaban Peak suite-tectonic map-sheet in Qinghai Province is taken as a real sample (see Fig. 10). In addition to the principal map and necessary decoration information, the map-sheet is well matched with key auxiliary figures and tables, including the composite columnar sections respectively of sedimentary, volcanic, intrusive (temporal-spatial distribution table), and metamorphic (rock) suites; besides, it also offers the Table of Quaternary Genetic Type Classification.

4 Data Quality Control and Assessment

4.1 Quality Assessment by First-hand Data

The first-hand data used in map compilation and database construction of the 1:250, 000 scaled serial suite-tectonic map-sheets is comprehensive, systematic, and reliable.

(1) The research group has comprehensively and systematically collected all the previous regional geological survey data (including the 1:250, 000 regional geological survey results from the Qinghai-Tibet plateau in 1999—2005) required in this research, i.e., 1:50, 000, 1:200, 000, 1:250, 000 scaled regional geological survey data, including regional geological survey result reports and regional geological survey first-hand data (first-hand data maps, field-trip paper-back notebooks, measured sections, drilling sections, freehand sketch sections along geological reconnaissance, cutting sections, sections and analysis results issued in previous research works), geological survey map database, and geological exploration coverage database.

(2) The group has comprehensively and systematically collected previous regional geological research results, monographs and key literatures (such as the regional geological memoirs, the finely calibrated litho-stratigraphic data), and on-line thematic academic papers.

(3) The group has comprehensively and systematically collected 1:50, 000, 1:200, 000, 1:250, 000, and 1:500, 000 scaled regional results about geological structures or geological bodies (the newly discovered, buried or deep-rooted ones) inferred by geophysical and geochemical prospecting and remote sensing interpretation. Such geophysical, geochemical and remote sensing prospecting results should be correctly assessed based on the previous geological data and geology researches to ensure their accuracy and reliability and for appropriate application.

(4) The utilization principles of geological data (i.e., using new data rather than old data, and large-scaled data rather than small-scaled data) are strictly followed. The latest 1:50, 000

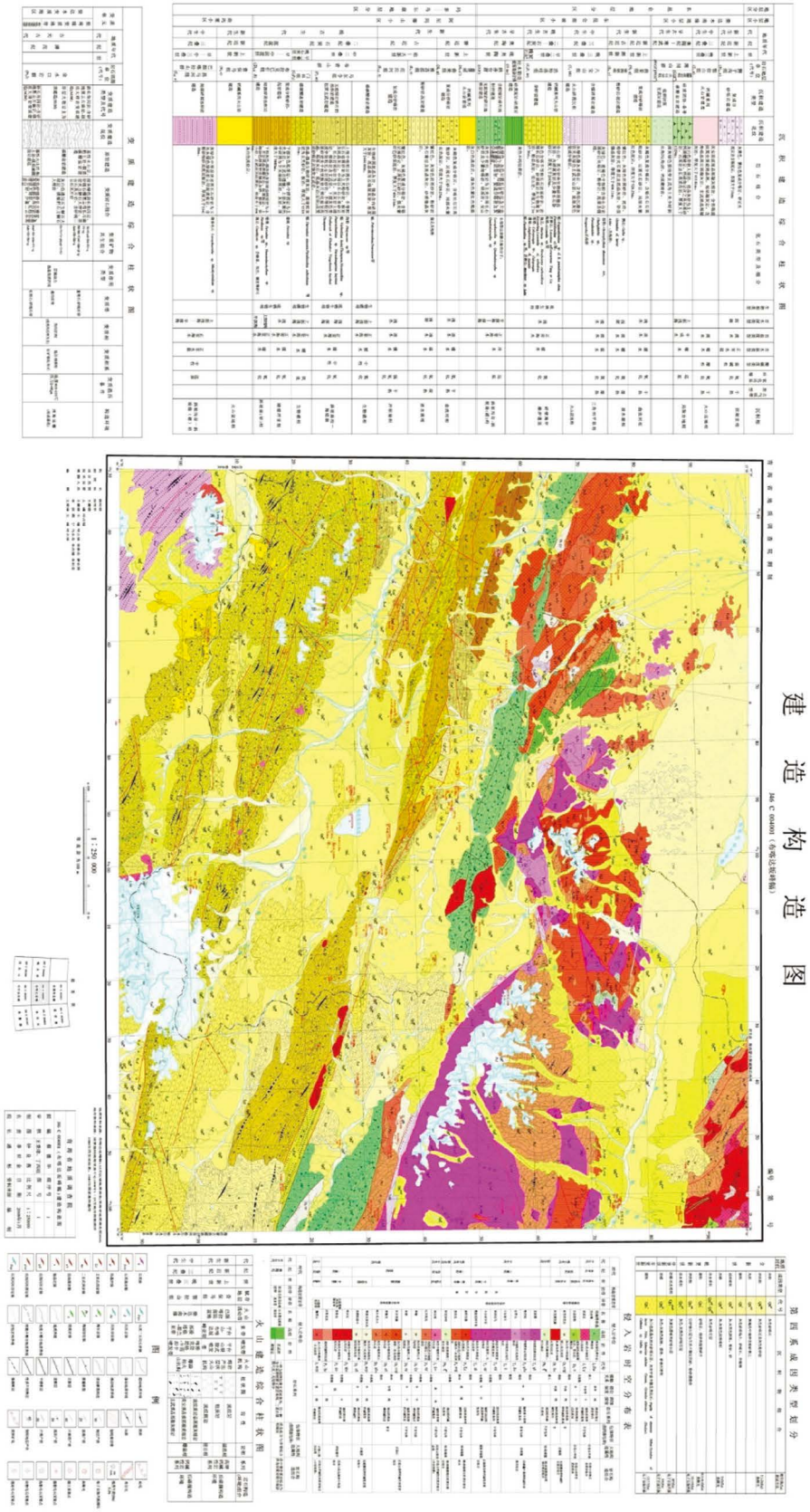

Fig. 10 A Sample of 1:250, 000 Scaled Serial Suite-Tectonic Map-sheets

and 1:250, 000 scaled geological survey data and the latest thematic research results are used in the integrated research, map compilation, and database construction. Moreover, the first-hand data collected and used in this work are all credibly produced under the uniform industry standards over the years in China; and all the data collected are, in principle, as of the end of 2013.

4.2 Quality Control over Map Compilation and Database Construction

4.2.1 Strict Quality Control over Map-Compilation

In terms of quality control over map compilation, the strictly-executed, well-organized, highly-effective, controllable, and practical compilation technical routes and working methods as well as quality assurance measures are calibrated and adopted. In this way, the research group ensures the quality of map compilation by provincial researching groups. A brief description of the quality control measures is as follows.

(1) Calibrating the Technical Requirements for Map Compilation: The national research group on geological settings of metallogenesis has organized authoritative experts and scholars to study and calibrate the Technical Requirements of Researches on Geological Settings of Metallogenesis (Ye Tianzhu et al., 2010).

(2) Sponsoring Field Technical Demonstrations of Map Compilation: With respects to the complex characteristics of China's geological conditions, more than 10 representative areas are selected to exemplify the typical operating processes of map compilation under the guidance of the Technical Requirements of Researches on Geological Settings of Metallogenesis. In this way, the technical requirements are further improved after several rounds of discussions and revisions based on typical demonstrations.

(3) Hosting Training Courses on Map Compilation Techniques: On the basis of the aforementioned demonstrations, the research group has compiled thematic training textbooks, and offered centralized training to provincial-level research groups. In addition, the experts have further paid numerous on-the-spot visits to organize seminars and solve problems encountered in filed map compilation.

(4) Acquiring Comprehensive, Systematic and Reliable Data: The research group has strictly required that all first-hand data used by provincial-level research groups should be comprehensive, systematic, and reliable. Moreover, the national research group on comprehensive data integration has compiled relevant technical requirements for maintaining and updating basic geological databases, and issued unified relevant basic geological database for nationwide application. Furthermore, the research group has mobilized the relevant administrative forces to help to collect the essential geological data as completely and correctly as possible, thus ensuring the first-hand data's being comprehensive and reliable.

(5) Compiling Serial First-hand Data Map-sheets Before Compiling Serial Suite-Tectonic Map-sheets: The provincial groups are required to strictly follow the Technical Requirements of Researches on Geological Settings of Metallogenesis (Ye Tianzhu et al., 2010); the serial first-hand data map-sheets which should meet quality requirements should be firstly compiled, based on which the serial suite-tectonic maps also beyond quality requirements are then compiled, with no exception and omission; thereby the technical requirements of map compilation are credibly ensured.

4.2.2 Strict Quality Control over Database Construction

In terms of quality control over database construction, the research group has formulated strict, well-organized, effective, controllable and feasible database-construction technical routes, working methods and quality assurance measures, thus ensuring the quality of database construction by provincial research groups. A brief description of the measures taken therein is as follows:

(1) Preparing Technical Requirements for Database Construction: The national research group for comprehensive information integration has organized authoritative industry experts and scholars to study and formulate database-construction technical requirements, involving data model of mineral resources' potentials assessment.

(2) Sponsoring Field Technical Demonstrations of Database Construction: Field technical demonstrations of database construction have been held while that of map compilations are sponsored. Based on such demonstrations, the technical requirements for database construction are improved after several rounds of discussions and revisions.

(3) Hosting Technical Training Courses on Database Construction: On the basis of demonstrations of improved and mature technical requirements of database construction, the research group has organized experts to prepare thematic training materials and has offered multiple technical-intensive training courses to provincial-level research groups on geological settings of metallogenesis. Besides, the experts have paid on-the-spot visits to organize seminars and solve problems encountered in database construction.

(4) Developing a Quality Controlling Model: In line with the data characteristics of geological maps, data models of mineral resources' potentials assessment, and basic principles of geological data quality inspection and evaluation, the research group has established a technical system of data quality inspection and assessment (Zuo Qunchao et al., 2013b). The core of this technical system features "singular map compilation quality model + singular map spatial data quality model + singular map attribute data quality model + singular map metadata quality model + singular map quality model + map subset quality model + map set quality model" (i.e., "Seven-stepped Quality Controlling Model" in short). Meanwhile, supporting software (GeoMag, GeoTok, GeoDQC) has also been developed to facilitate data self-inspection, mutual inspection, sample inspection and revision of map databases. The unified inspection standards for automatic quantitative assessment have greatly improved the efficiency of quality inspection and evaluation, reduced operational costs, and ensured that the quality of database construction meets the technical requirements (see Fig. 11 and Fig. 12).

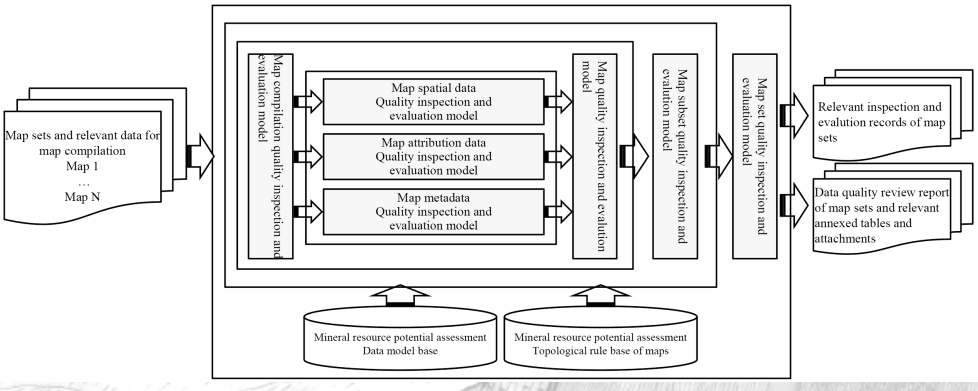

Fig. 11 Seven-stepped Quality Controlling Model of Geological Maps

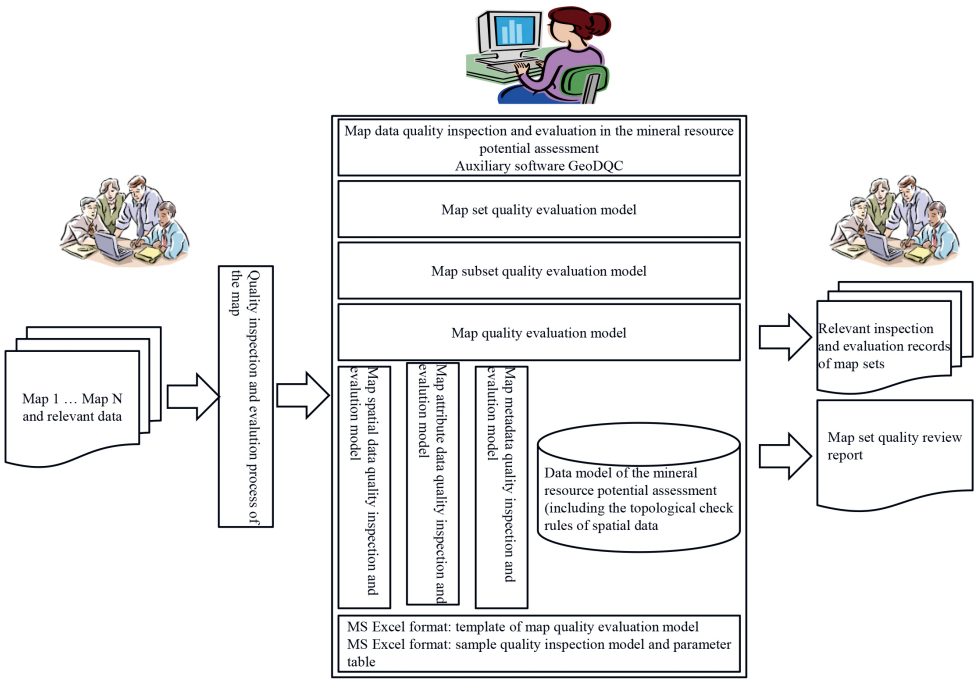

Fig. 12 Framework of the "Seven-stepped Quality Controlling Model" of Geological Maps

4.2.3 Quality Control in Acceptance Checking for Database Construction

The method of "two-stepped acceptance checking" has been applied in quality acceptance checking of database construction, ensuring that the data used in map compilation is consistent with that in database construction. The process is briefly described as follows:

Prior to the quality acceptance checking for database construction, the expert group has firstly checked the map compilation results to ensure that each map can pass the quality acceptance checking. The maps being identified as with quality problems are not allowed to the process of database-construction quality acceptance checking until they are properly revised and confirmed by the provincial-level research groups, who need to follow the modification instructions issued by the map-compilation acceptance checking expert group.

Later on, database construction results have been checked by the exclusive acceptance checking expert group to ensure that each map-sheet database can pass the quality acceptance checking of database construction. The map-sheet databases being identified as with quality problems cannot be used for database collection and integration until they are properly revised and confirmed by the provincial-level research groups, who need to follow the modification instructions issued by the database-construction acceptance checking expert group.

If a quality problem in a certain serial map-sheet base can be traced back to the map-compilation quality problem which is failed to be detected or unintentionally omitted in the process of map-compilation quality acceptance checking, this quality problem should be returned to the first step (i.e., the map-compilation quality acceptance checking) and be well solved; all these problems should be re-treated recurrently till each of the serial map-sheet base is qualified[9].

4.3 Overall Quality Review of Map Compilation and Database Construction

The geologic data used for map compilation and database construction is comprehensive, systematic, and traceable. In addition, the suite-tectonic analysis method used to study map compilation objectively represents the original lithology or rock assemblages and the physical tracks and lineaments of geological structures, and systematically reflects the geological processes and their evolutionary characteristics; it is undoubtedly better than the traditional System- and Formation-level geological maps. Furthermore, aided by the GIS technology, the technical system of data quality inspection and evaluation methods for geological maps with the core of "Seven-stepped Quality Controlling Model", as well as the two-stepped quality acceptance checking (map compilation + database construction acceptance checking) method are used effectively. In this way, the research group ensures that the quality of the SDSSTMMC meets the technical requirements completely[10].

However, there are still 2 deficiencies in this round of map compilation and database construction:

Firstly, Only Partial Coverage. There are still some vacant regions without any geological mapping data in Mainland China; hence, the research group has no way to obtain the necessary data for this round of 1:250, 000 scaled map compilation and database construction. In this sense, the maps and databases can only be reckoned as "have almost completely covered" the Mainland China.

Secondly, Coordinate System. For the sake of the source data, the Beijing-1954 Coordinate System and the Huanghai-1956 Elevation System are adopted in this map compilation and database construction; as defined by China's laws, the China-2000 Geodetic Coordinate System and the China-1985 Vertical Datum are the legal regulations, the SDSSTMMC should be updated (transformed to the newly issued standards) in the near future so as to better service the national economic growth.

5 Conclusion

Relying on the thematic program of China's national mineral resources' potentials assessment (2006-2013), the research group has finished the map compilation and database construction of serial suite-tectonic map-sheets (at scale of 1:250, 000), mainly with the following 5 fundamental results and technical innovations:

(1) For the first time, the SDSSTMMC has been established with a total data volume of 16.6 GB, including 729 sheets of 1:250, 000 scaled standard serial suite-tectonic map-sheets as well as their corresponding compilation explanatory notes and mapping metadata documents. The data of each individual map's database is in MapGIS 6.7 format; the compilation explanatory notes are in MS Word 97-2003 format, and mapping metadata documents in TXT\XML format.

(2) The basic geological data used for map-compilation and database construction are systematic, comprehensive, and reliable. In addition, all the collected data have been ensured to be as of the end of 2013. The data include those from regional geological surveys (scales at 1:50, 000, 1:200, 000, and 1:250, 000 respectively), geological scientific research results and monographs, integrated inferred results from geophysical, geochemical and remote sensing prospecting (1:50, 000, 1:200, 000, 1:250, 000, and 1:500, 000), and online professional academic literatures.

(3) The suite-tectonic analysis method has been adopted in map compilation. In the compiled 1:250, 000 serial suite-tectonic map-sheets, the basic mapping elements in the principal map are the quasi-Member lithological units that are under the Formation-level unit, which objectively represent the real physical tracks and lineaments of rock suites and geological structures; the mapping methodology of using different patterns to represent different rock suite according to their occurrences, has greatly excelled the traditional System or Formation-predominated mapping ways, which is convenient for direct map-reading and has meanwhile systematically reflected the multiple geological processes and their temporal-spatial evolution. In general, this database can provide fundamental information for the compilation of 1:500, 000 or smaller scaled tectonic map-sheets, can directly offer essential factors for 1:250, 000 and smaller-scaled regional mineral resources prediction, and can supply thematic base maps of geological structures for 1:250, 000 and smaller scaled minerogenetic regularity researches. It has also held extensive and long-term values for duplicative utilizations in geological survey and ore-prospecting, geo-hazard mitigation, hydrological/ engineering/ environmental geological surveying, geothermal resources exploration, and ecological conservation.

(4) The research group has developed a complete series of technical requirements for comprehensive research, map compilation, and database construction, and a logically integrated set of such methods and technical systems as geological data models, quality controlling models, and two-stepped acceptance checking procedure. Meanwhile, the group has also developed a set of supporting computer software or systems that are simple, flexible, and effective. These methods, technologies, and software have exerted extensive influence and achieved multiple benefits.

(5) The research group has also developed an effective mechanism of innovative cooperation that activated all the nation's research organizations and agencies to participate in the Program, under which the group has guided and finished the complicated and gigantic engineering of compiling and constructing the Spatial Database of Serial Suite-Tectonic Map-sheets of Mainland China (1:250, 000). The Program has based itself on the first-handed data, adopted the administrative approach of standardizing technical requirements from national level downwards, and meanwhile executed the academic measures of concluding and synthesizing the basic research results from the provincial level upwards. In this bi-directional way, the geological experts and IT professionals and scien-tech managers from China's 30 provinces and municipalities and autonomous regions as well as the 6 regional branches of China Geological Survey, are organically assembled as a union; this powerful talent group has experienced the whole processes of calibrating the map-compiling regulations, technical training, data collecting, data processing, map compilation researching, quality-controlling, result accepting-and-pooling, and finally to the results integration and database construction; each of the steps and links is highly harmonized, which has greatly helped to yield the precise, standard, effective, and reliable accomplishment.

Acknowledgments: During the development of Spatial Database of Serial Suite-Tectonic Map-sheets of Mainland China (1:250, 000), the research groups on geological settings of metallogenesis and comprehensive information integration from Beijing, Tianjin, Hebei, Shanxi, Shandong, Henan, Inner Mongolia, Heilongjiang, Jilin, Liaoning, Jiangsu, Anhui, Zhejiang, Jiangxi, Fujian, Hubei, Hunan, Guangdong, Guangxi, Hainan,

Sichuan, Chongqing, Yunnan, Guizhou, Tibet, Shaanxi, Gansu, Ningxia, Qinghai, and Xinjiang (30 provinces, municipalities, and autonomous regions), working under the China National Mineral Resources' Potentials Assessment Program Group, have made fundamental and important contributions to map compilation and database construction in the range of their respective provinces (or municipalities and autonomous regions). We would like to express our sincerest gratitude to all of them. In addition, the research groups on geological settings of metallogenesis and comprehensive information integration at the regional level (including North China, Northeast China, East China, South Central China, Southwest China, and Northwest China), working under the China National Mineral Resources' Potentials Assessment Program Group, have completed map compilation and database construction of 1:250, 000 scaled serial suite-tectonic map-sheets in their own regions. They are very supportive in application guidance, quality inspection, result acceptance checking, and summary and integration. We are thankful to all of them. Moreover, we would like to express our utmost regard and gratitude for the experts of the national research groups on geological settings of metallogenesis and comprehensive information integration. They have made great efforts to formulate technical requirements, sponsor technical demonstrations, and offer training and application guidance, thereby achieving effective results. Furthermore, we specially thank the Geological Exploration Department of Ministry of Land and Resources, China Geological Survey, the National Program Office, and Development and Research Center of China Geological Survey for their leadership, planning, and organization.

Notes:

❶ Ye Tianzhu, Chen Yuchuan, Zhang Hongtao. 2006. The Overall Implementation Scheme of China's National Mineral Resources' Potentials Assessment. China National Mineral Resources' Potentials Assessment Program Office.

❷ Zuo Qunchao, Yang Donglai. 2008a. Specifications for Cartographic Symbols in China's National Mineral Resources' Potentials Assessment. China National Mineral Resources' Potentials Assessment Program Office.

❸ Zuo Qunchao, Yang Donglai. 2008b. Specifications for Cartographic Legends in China's National Mineral Resources' Potentials Assessment. China National Mineral Resources' Potentials Assessment Program Office.

❹ Zuo Qunchao, Yang Donglai. 2008c. Preparation Outlines of Cartographic Explanatory Notes in China's National Mineral Resources' Potentials Assessment. China National Mineral Resources' Potentials Assessment Program Office.

❺ Zuo Qunchao, Yang Donglai. 2008d. Specifications for Cartographic Geographic Information in China's National Mineral Resources' Potentials Assessment. China National Mineral Resources' Potentials Assessment Program Office.

❻ Zuo Qunchao, Yang Donglai. 2008e. Specifications for Map Metadata in China's National Mineral Resources' Potentials Assessment. China National Mineral Resources' Potentials Assessment Program Office.

❼ Zuo Qunchao, Yang Donglai. 2008f. Specifications for Cartographic Space Coordinate System and Its Parameters in China's National Mineral Resources' Potentials Assessment. China National Mineral Resources' Potentials Assessment Program Office.

❽ Zuo Qunchao, Yang Donglai. 2008g. Technical Requirements for Map Spatial Topology in China's National Mineral Resources' Potentials Assessment. China National Mineral Resources' Potentials

Assessment Program Office.

❾ Zuo Qunchao, Yang Donglai. 2010. Technical Schemes on Inspection and Pooling of Informative Phasic achievements Maps and Attribute Databases in China's Provincial Mineral Resources' Potentials Evaluation Projects. China National Mineral Resources' Potentials Assessment Program Office.

❿ Zuo Qunchao, Yang Donglai. 2013. Research Report on Results of Comprehensive Information Integration in China's National Mineral Resources' Potentials Assessment. Comprehensive Information Integration Project Group of China National Mineral Resources' Potentials Assessment Program.

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Zuo Qunchao, Ye Yaqin, Wen Hui, Song Yue, Ge Zuo, Wang Yingchao, Zuo Zejun, Yang Donglai. 2013a. The Integrated Database Model for Mineral Resources Potential Evaluation in China [J]. Geology in China, 2013, 40 (6): 1968−1981 (in Chinese with English abstract).

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