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内蒙古昌图希勒斯台幅 1∶50 000 矿产地质图数据库

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摘要：内蒙古昌图希勒斯台幅 (L50E015021)1∶50 000 矿产地质图数据库基于数字地质填图系统建立，实现了从前期资料准备→野外地质填图→室内综合整理→最终成果表达的全程数字化，有效开展了对各类数据的一体化描述、存储、组织和利用。数据库建立过程中采用“火山构造—岩性岩相—火山地层”填图方法，重新厘定了火山岩地层，详细划分了火山岩相、喷发旋回及其组合类型，重点查明了火山岩、火山构造、火山活动与成矿作用的关系，总结了中生代火山岩区金属矿产成矿地质条件和成矿规律。数据库的数据内容包含 8 个地层单位、4 期火山喷发旋回、8 处成矿远景区、6 处找矿靶区，此外，还包含有 1170 件化学样品数据、261 件土壤样分析数据、108 件岩石地球化学数据、222 件光薄片样品、35 件 S 和 Pb 同位素数据、10 件 H 和 O 同位素数据和 4 个锆石 U–Pb 年龄。初步查明图幅内新发现的昌图锡力银铅锌锰矿 334_1 银金属量为 1028.35 t，铅金属量为 11.25 万 t，锌金属量为 9.36 万 t，锰金属量为 55.24 万 t，达到大型银多金属矿床规模。本数据库内容详实、可利用度高，为大兴安岭中南段中生代火山岩区深入开展矿产资源调查评价和金属矿产勘探开发提供了重要基础性数据资料支撑。

关键词：昌图希勒斯台幅；1∶50 000；矿产地质图；数据库；资源勘查工程；内蒙古；大兴安岭

数据服务系统网址：http://dcc.cgs.gov.cn

1　引言

内蒙古昌图希勒斯台幅研究区位于西伯利亚板块和华北板块的结合部位 (Jahn BM et al.，2000；要梅娟等，2012；李俊建等，2016；杨海星等，2019；张海华等，2019)，大地构造位置上处于兴蒙造山带东段，位于二连−贺根山构造带南部，西拉木伦断裂以

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北 (图 1a)。古生代时期，华北板块北缘和西伯利亚板块之间经历了古亚洲洋的发生、发展和消亡，初步奠定了华北板块北缘以东西向为主的构造格局 (任纪舜等，1999；盛继福等，1999；刘光鼎等，2003；Meng QR，2003；Xiao WJ et al.，2003)。中生代以来经历了蒙古–鄂霍茨克构造体系与环太平洋构造体系的叠加与改造 (Xu WL et al.，2009；Wu FY et al.，2011；孟恩等，2011；仲米山等，2017)，调查区所处的内蒙古中东部及邻区的岩石圈遭受了伸展及减薄作用 (吴福元等，2003；毛景文等，2005)，促使发生强烈的构造岩浆活动，为区域成矿作用提供了热能及成矿物质来源，为大兴安岭地区成矿种类多、矿床类型丰富、成矿强度大提供了有利地质条件 (王京彬等，2000；刘建明等，2004；王长明等，2006；葛文春等，2007；陈良等，2009；邵积东等，2009；Zeng QD et al.，2011；武新丽等，2012；张万益等，2013；曾庆栋等，2016)。

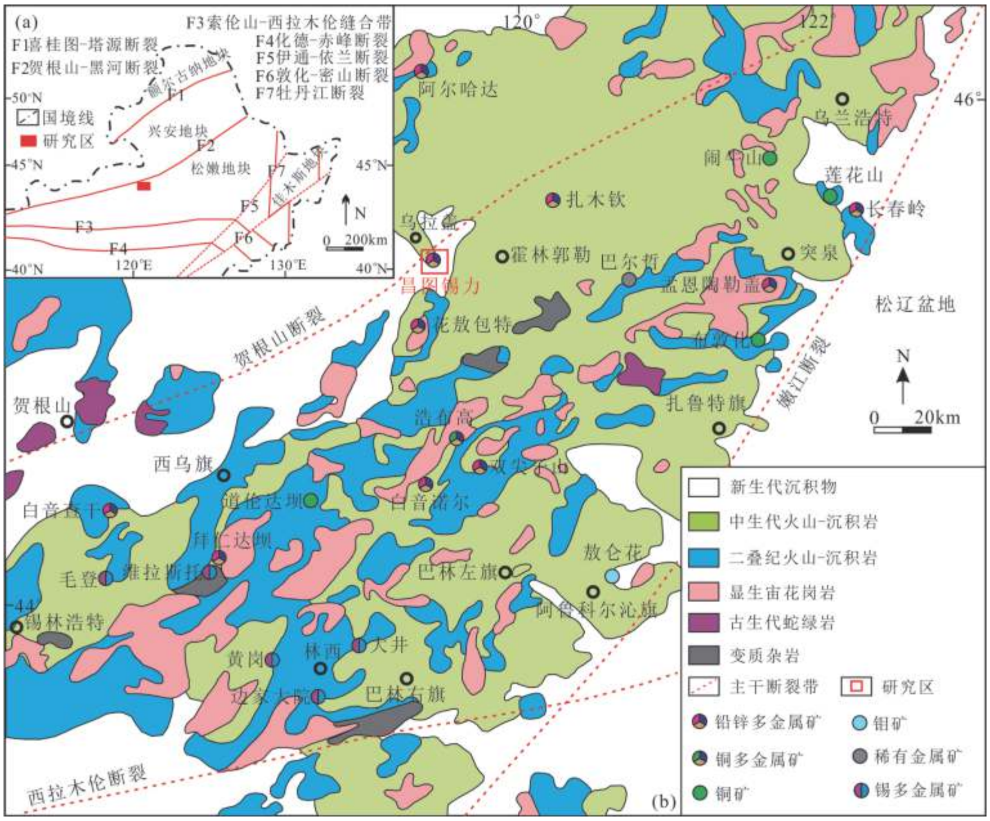

图 1　大兴安岭中南段地质矿产简图

(a) 大兴安岭地区大地构造简图 (据任纪舜等，1999 修改); (b) 大兴安岭中南段地质矿产简图 (据 Ouyang HG et al.，2014)

20 世纪 70 年代，前人在研究区内开展 1：200 000 区域地质矿产调查工作❶，2009—2011 年完成 1：250 000 区域调查修测工作❷，对地层、侵入岩、构造和矿产等进行系统调查。2013—2015 年中国地质调查局天津地质调查中心组织实施内蒙古布日都大队、马尼特、迪彦苏木、昌图希勒斯台等 4 幅 1：50 000 区域地质调查项目工作❸，对研究区的基础地质特征进行详细地调查研究，并完成昌图希勒斯台幅 1：50 000 土壤测量工作。以上资料的积累为昌图希勒斯台幅矿产地质图数据库的建立奠定了基础。通过编制数据库，将前人资料和新获取的地质调查成果进行全面数字化有利于保存和使用，不仅为查明研究区火山活动对金属成矿作用的制约、总结区域成矿地质条件提供详实矿产地质资料，也为该地区进一步进行地质调查和科学研究、矿产资源勘查等提供基础地

质图件。此外，昌图希勒斯台幅 1：50 000 矿产地质图已为研究区内的昌图锡力银铅锌锰矿开展预查工作起到良好的基础矿产地质资料支撑效果，该矿初步查明已达大型规模 (何鹏等，2019；郑全波等，2019)。内蒙古昌图希勒斯台幅 1：50 000 矿产地质图数据库（何鹏等，2020）的元数据简表如表 1 所示。

表 1　数据库 (集) 元数据简表

条目	描述
数据库(集)名称	内蒙古昌图希勒斯台幅1：50 000矿产地质图数据库
数据库(集)作者	何　鹏，中国地质调查局天津地质调查中心 郭　硕，中国地质调查局天津地质调查中心 苏　航，黑龙江省地质调查研究总院 王贵鹏，黑龙江省地质调查研究总院 张跃龙，黑龙江省地质调查研究总院
数据时间范围	2017—2018年
地理区域	东经119°00′～119°15′，北纬45°30′～45°40′
数据格式	MapGIS
数据量	6.27 MB
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	中国地质调查局地质调查项目“二连—东乌旗成矿带西乌旗和白乃庙地区地质矿产调查”(项目编号：DD2016041)资助
语种	中文
数据库(集)组成	昌图希勒斯台幅1：50 000矿产地质图数据库包括1：50 000矿产地质图库和图饰。地质图库包括火山岩、侵入岩、第四系、脉岩、构造、地质界线、产状、蚀变、岩性花纹、各类代号等；图饰包括接图表、图例、综合柱状图、图切剖面、矿化异常及编号、矿产远景区、所属成矿区带位置图、责任表

2　数据采集和处理方法

2.1　数据采集

2.1.1　数据采集准备

数据库的建立全程采用数字填图系统，遵循中国地质调查局地质调查技术标准《固体矿产地质调查技术要求 (1：50 000)》(DD 2019–02)、《数字地质图空间数据库》(DD 2006–06) 等规范要求。前期资料准备包括地理数据准备、前人资料数字化、物探和化探资料数字化等，并将已获取的昌图希勒斯台幅 1：50 000 区域地质调查路线、实测地质剖面等原始资料进行整理，结合《内蒙古自治区大兴安岭中南段、二连—东乌旗一带 1：50 000 航空物探综合站勘查报告》[4] 中的物化探图件等区域矿产地质资料，通过数字化处理过程编制建造—构造草图，作为矿产地质图的底图。

1：50 000 地理底图采用国家测绘地理信息局最新地理数据，坐标系统为西安 80，投影系统为高斯–克吕格投影参数。数据按 1：50 000 图幅所辖的 4 个 1：25 000 图幅进行组织和存储。填图全过程使用掌上机数字填图系统 (DGSS)，数据处理及矿产地质图的编制利用 MapGIS、DGSS 等计算机软件完成。

2.1.2　数据采集内容

数据采集以野外地质调查为主，依据本次工作的目标任务，明确调查工作重点为与成矿作用关系密切的中生代火山岩、构造、矿化蚀变等内容。野外路线 PRB 过程地质

信息数据采集模型主要包括地质点 (P)、地质路线 (R)、地质界线 (B)、GPS 点位、样品、产状、照片等，重点在调查路线中标绘出地质点 (P)、地质路线 (R)、地质界线 (B) 等基本地质信息，观察并记录地质点的岩性、矿化蚀变特征、产状、样品等属性信息。

2.2 数据处理

数据处理包括野外路线数据室内整理→建立实际材料图→建立编稿原图→建立矿产图空间数据库等 4 个主要步骤。

2.2.1 野外路线数据室内整理

由于野外工作的环境与时间限制，掌上机采集的路线数据往往比较粗糙、不完整，需要将野外路线数据导入电脑中，对 PRB 过程按照规范进行修改完善。

(1) 首先对野外路线中地质点、地质路线、地质界线、产状点、照片点等图元的空间位置进行适当调整，统一颜色、线型及线宽等参数，使其表达更准确、图面更美观。

(2) 补充整理地质点 (P)、地质路线 (R)、地质界线 (B) 中的属性信息，岩石名称根据样品薄片鉴定结果进行定名，并添加批注信息。

(3) 导入路线照片并补充照片点、产状点、采样点的属性信息。

(4) 填写路线小结，并对路线内容进行复查与补充。

2.2.2 建立实际材料图

野外路线资料整理完毕后，汇总到 1：25 000 野外总图库中，在该阶段连接地质界线，拓扑造区形成地质体，完善地质线、面要素的属性和图饰图例等内容，建立实际材料图。

(1) 由野外总图库更新到实际材料图

实际材料图比野外总图库新增了 3 个文件，分别为：GEOPOLY.WP(地质面要素文件)、GEOLINE.WL(地质线要素文件)、GEOLABEL.WT(地质面要素标注文件)。

(2) 连接地质界线

在 GEOLINE.WL 图层中将地质界线连接在一起，并进行地质界线的拓扑，通过多次拓扑检查逐一排除各类错误。

(3) 建立地质面实体

①将拓扑后的地质界线转化为地质面的弧段并拓扑造区，建立地质面实体；②为地质面实体赋属性、参数：在添加“填图单位”和“岩石名称”等关键属性信息后，可以利用程序中的工具批量处理地质界线赋属性、地质面实体赋颜色等操作，从而提升数据处理效率；③为地质界线赋属性：当完成所有的地质面实体属性添加之后，可以利用程序功能为相关的地质界线赋左、右地质体代号的关键字段。

(4) 地质面实体批量标注

建立图例文件并为图例点添加属性，图例标注赋在对应地质区的实体上。

(5) 实际材料图质量检查与拓扑重建

实际材料图的建立并不是一次性完成的，需要进行多次质量检查消除错误，相应地经过多次拓扑重建最终形成实际材料图。

2.2.3 建立编稿原图

通过以上步骤分别完成昌图希勒斯台幅 4 幅 1：25 000 的实际材料图之后，建立编稿原图。

(1) 利用昌图希勒斯台幅 1：50 000 的图框 (L50E015021) 建立图幅工程，将 1：25 000

实际材料图投影到 1∶50 000 编稿原图。

(2) 完成 4 幅 1∶25 000 图幅的接边工作、1∶50 000 图幅拓扑工作以及图框外的各种图饰图例的整理工作，最终形成完整的编稿原图。

2.2.4 建立空间数据库

(1) 空间数据库基本要素

昌图希勒斯台幅 1∶50 000 矿产地质图数据库包括基本要素类、对象类、综合要素类、独立要素类四类内容：①基本要素类指在野外地质调查过程中获取的地质数据，包括野外采集的地质体面实体、地质界线、蚀变点、矿化点、火山口、产状、样品、同位素、照片等地质内容；②对象类包括：沉积 (火山) 岩岩石地层单位、脉岩、断层等；③综合要素类是在野外调查的基础上，通过室内的综合研究和样品测试分析的基础上确定的，包括火山岩相带、蚀变带等；④独立要素类主要为图例及图饰部分，包括：接图表、图例、综合柱状图、图切剖面、矿化异常及编号、矿产远景区、所属成矿区带位置图、责任表等。

(2) 空间数据库建立步骤

编稿原图完成后，转入最终空间数据库建立阶段。①在空间数据库建库环境生成标准属性结构的要素类和对象类文件；②从编稿原图的相关文件中提取信息到基本要素类，并编辑完善要素类属性；③建立综合要素类并完善属性信息；④从要素类提取信息到对象类，并完善对象类属性；⑤图件整饰，增加接图表、综合柱状图、图切剖面等独立要素类信息，形成完整的空间数据库。

3 数据样本描述

昌图希勒斯台幅 (L50E015021)1∶50 000 矿产地质图数据库按照 1∶50 000 矿产地质调查地质填图数据库建库要求，分为基本要素类、对象类、综合要素类、独立要素类数据建立数据库 (表 2)。

3.1 基本要素类

(1) 地质体面实体 (_GEOPOLYGON.WP)

地质体面实体包括火山岩、沉积岩、侵入岩、第四系等地质体，其数据属性主要包括：地质体面实体标识号、原编码、地质体面实体类型代码、地质体面实体名称、地质体面实体时代、子类型标识。

(2) 地质界线 (_GEOLINE.WL)

地质界线数据属性主要包括：地质界线 (接触) 代码、地质界线类型、界线左侧地质体代号、界线右侧地质体代号、界面走向、界面倾向、界面倾角、子类型标识。

(3) 蚀变点 (_ALTERATION_PNT)

蚀变点数据属性主要包括：蚀变类型名称代码、蚀变类型名称、蚀变矿物组合及含量、被蚀变的地质代号、蚀变带所含矿种。

(4) 矿化点 (_MINERAL_PNT.WT)

矿化点数据属性主要包括：矿种代码、矿种名称、共生矿、伴生矿、矿产地数、矿石品位、规模、成矿时代、矿产地名、矿化类型、工业类型。

(5) 火山口 (_CRATER.WT)

火山口数据属性主要包括：火山口类型、火山口名称、火山口大小、火山口产出的地质体单位及代号、火山口岩石类型、火山口形成时代。

表 2　内蒙古昌图希勒斯台幅 (L50E015021)1∶50 000 矿产地质图数据库一览表

基本要素类		对象类		综合要素类		独立要素类
名称及标准编码	实体个数	名称及标准编码	说明	名称及标准编码	说明	名称及标准编码
地质体面实体(_GEOPOLYGON.WP)	82	沉积(火山)岩岩石地层单位(_STRATA)	包括第四系全新统冲积层(Qh^{al})，第四系全新统冲湖积层(Qh^{all})，第四系全新统冲洪积层(Qh^{alp})，第四系全新统湖积层(Qh^{l})，上侏罗统玛尼吐组一段(J_3mn^1)，下白垩统白音高老组一段(K_1b^1)，下白垩统白音高老组二段(K_1b^2)，下白垩统大磨拐河组(K_1d)，新近系上新统宝格达乌拉组(N_2b)，新近系上新统五叉沟组(N_2w)共10个	标准图框(_MAP_FRAME.WL)	标准图框内图框4条线，属性相同	接图表(MAP_SHEET)
地质界线(_GEOLINE.WL)	101					综合柱状图(COLUMN)
蚀变点(_ALTERATION_PNT.WT)	63					图切剖面(PROFILE)
矿化点(_MINERAL_PNT.WT)	2					图例(LEGEND)
火山口(_CRATER.WT)	6	脉岩(_DIKE_OBJECT)	包括晚侏罗世安山岩脉(αJ_3)，早白垩世安山岩脉(αK_1)，晚侏罗世安山玢岩脉($\alpha\mu J_3$)，晚侏罗世闪长玢岩脉($\delta\mu J_3$)，晚侏罗世英安岩脉(ζJ_3)，早白垩世流纹岩脉(λK_1)，早白垩世流纹斑岩脉($\lambda\pi K_1$)共7个	火山岩相带(_VOLCA_FACIES)	主要有喷溢相(EFF)、爆发空落相(FOF)、火山碎屑流相(PRF)、火山通道相(VNF)、火山爆发崩塌相(VECF)	责任表(DUTY_TABLE)
产状(_ATTITUDE.WT)	30					
样品(_SAMPLE.WT)	568	断层(_FAULT)	共18条			
同位素(_ISOTOPE.WT)	4	面状河和水库(_WATER_REGION)	从地理底图中提取	蚀变带(_ALTERATION_POLYGON)	主要有铅锌矿化、褐铁矿化、硅化、碳酸盐化	其他(OTHER)主要包括火山岩相构造图、侵入岩单位划分及其他图廓外整饰
照片(_PHOTOGRAPH.WT)	186					
河湖水库岸线(_LINE_GEOGRAPHY.WL)	50					

(6) 产状 (_ATTITUDE.WT)

产状数据属性主要包括：产状类型名称代码、产状类型名称、走向、倾向、倾角。

(7) 样品 (_SAMPLE.WT)

样品数据属性主要包括：样品编号、样品类型代码、样品类型名称、样品岩石名称。

(8) 同位素 (_ISOTOPE.WT)

同位素数据属性主要包括：样品编号、样品名称、年龄测定方法、测定年龄、被测定地质体单位及代号、测定分析单位、测定分析日期。

(9) 照片 (_PHOTOGRAPH.WT)

照片数据属性主要包括：要素标识号、照片编号、照片题目、照片说明。

3.2 对象类

(1) 沉积 (火山) 岩岩石地层单位 (_STRATA)

沉积 (火山) 岩岩石地层单位数据属性主要包括：要素分类、地层单位名称、地层单位符号、地层单位时代、岩石组合名称、岩石组合主体颜色、岩层主要沉积构造、生物化石带或生物组合、地层厚度、含矿性。

(2) 脉岩 (_DIKE_OBJECT)

脉岩数据属性主要包括：脉岩分类代码、脉岩名称、脉岩符号、岩性、颜色、结构、构造、主要矿物及含量、次要矿物及含量、与围岩接触面走向、与围岩接触面倾向、与围岩接触面倾角、形成时代、含矿性。

(3) 断层 (_FAULT)

断层数据属性主要包括：断层类型、断层名称、断层编号、断层性质、断层上盘地质体代号、断层下盘地质体代号、断层破碎带宽度、断层走向、断层倾向、断层面倾角、估计断距、断层形成时代、活动期次。

3.3 综合要素类

(1) 火山岩相带 (_VOLCA_FACIES.WP)

火山岩相带数据属性主要包括：火山岩岩相类型及代码、产出的地层单位及代号、火山岩相岩石类型、岩石结构、岩石构造、流面产状、流线产状、形成时代、含矿性。

(2) 蚀变带 (_ALTERATION_POLYGON)

蚀变带数据属性主要包括：蚀变类型名称代码、蚀变类型名称、蚀变矿物组合及含量、含矿性、蚀变地质体代号。

(3) 内图框 (_MAP_FRAME.WL)

内图框数据属性主要包括：图名、图幅代号、比例尺、坐标系统、高程系统、左经度、下纬度、图形单位。

3.4 独立要素类

(1) 接图表 (MAP_SHEET)

接图表数据属性主要包括：接图表点、接图表线、接图表面。

(2) 图例 (LEGEND)

图例数据属性主要包括：图例点、图例线、图例面。

(3) 综合柱状图 (COLUMN)

综合柱状图数据属性主要包括：综合柱状图点、综合柱状图线、综合柱状图面。

(4) 图切剖面 (PROFILE)

图切剖面数据属性主要包括：图切剖面点、图切剖面线、图切剖面面。

(5) 责任表 (DUTY_TABLE)

责任表数据属性主要包括：责任表点、责任表线、责任表面。

(6) 其他 (OTHER)

其他图廓内容包括：矿化异常及编号、矿产远景区、所属成矿区带位置图。

4 数据质量控制和评估

内蒙古昌图希勒斯台幅矿产图数据库建立的整个过程依据《固体矿产地质调查技术要求 (1∶50 000)》(DD 2019-02)、《数字地质图空间数据库建库标准》(DD 2006−06) 等规范要求进行。充分参考利用最新研究区区域地质调查成果资料，依据本次工作的目标任务有针对性地重点调查与成矿作用密切相关的火山岩、火山机构、构造、矿化蚀变带等成矿因素，在地质构造复杂区、矿化异常区、成矿有利区按 1∶10 000 比例尺加密了调查路线的网度。在昌图希勒斯台幅 1∶50 000 矿产地质图编制过程中，共收集前人路线资料 660 km，实测路线 185 km，地质点数 336 个，地质界线 566 条，光薄片鉴定样品 31 个，锆石 U–Pb 同位素样品 4 个，照片 186 张。

本次工作依托“二连—东乌旗成矿带西乌旗和白乃庙地区地质矿产调查”地质调查项目完成。项目组定期进行三级质量检查，野外地质路线自、互检率为 100%，项目组检查率为 30%。项目承担单位分阶段进行了野外实地检查及室内资料检查，2017 年 10 月、2018 年 7 月中国地质调查局天津地质调查中心分别组织专家对项目进行了原始资料质量抽查和野外现场检查，各项成果符合质量要求。2018 年 10 月对本次工作进行了野外验收，专家一致认为项目较好地完成了目标任务和主要实物工作量，各项工作成果符合设计及规范要求，顺利通过野外验收。

5 数据价值

(1) 内蒙古昌图希勒斯台幅 (L50E015021)1∶50 000 矿产地质图位于大兴安岭中南段成矿带中生代大规模火山岩区，编制过程中对与成矿关系密切的火山岩采用“火山构造—岩性岩相—火山地层”填图方法进行了研究，通过火山岩岩石组合划分、同位素年代数据限定将地层重新厘定为侏罗系上统玛尼吐组 (J_3mn)，白垩系下统白音高老组 (K_1b)、梅勒图组 (K_1m)，新近系上新统宝格达乌拉组 (N_2b)、五叉沟组 (N_2w)(表 3)，划分出了玛尼吐期、白音高老期、梅勒图期、五叉沟期等 4 期火山喷发旋回 (表 4)。本数据库样品测试分析数据见表 5，土壤样、化学样等样品分析数据为圈定矿带、划分矿体、确定矿体品位提供数据支持，共圈定矿带 6 处；光薄片鉴定结合野外调查将成矿期划分为表生期及热液成矿期，其中热液成矿期可划分为 4 个成矿阶段，银矿物及金属硫化物阶段为主成矿阶段；岩石地球化学、S、Pb、C、O 同位素数据结果指示成矿物质来源于深源岩浆，为今后的矿产勘查工作提供了新的工作思路。

(2) 结合航磁、遥感综合解译成果，重点针对化探综合异常区进行路线检查，加强了对火山岩含矿性与成矿专属性的调查研究，查明白音高老组是重要赋矿地层，北西向断裂及火山机构是重要的容矿构造，在昌图锡力地区圈定 6 处与构造–岩浆作用有关的银、铅、锌多金属矿化蚀变带。总结了中生代火山岩区金属矿床成矿地质条件、成矿规

表 3 内蒙古昌图希勒斯台幅 (L50E015021) 岩石地层单位划分一览表

界	系	统	组(段)	代号	岩石组合	同位素测年/Ma
新生界	新近系	上新统	五叉沟组	N_2w	深灰、灰黑色、紫红色气孔状玄武岩、致密块状玄武岩、安山玄武岩、玄武质集块角砾岩、砂砾岩	
			宝格达乌拉组	N_2b	砖红色(含砾)泥岩、含砾中粒长石岩屑杂砂岩、中粒岩屑长石杂砂岩、灰黑色泥岩、砂砾岩	
中生界	白垩系	下统	大磨拐河组	K_1d	以泥岩、粉砂岩为主，夹中、细粒砂岩、含砾砂岩，在泥岩、粉砂岩内夹煤层	
			梅勒图组	K_1m	灰黑色、灰褐色、紫红色气孔状、杏仁状、致密块状玄武岩、安山岩、凝灰质(长石)岩屑砂岩、凝灰质砾岩、凝灰质砂砾岩、晶屑玻屑沉凝灰岩	
			白音高老组二段	K_1b^2	灰褐色、灰色、浅紫色流纹岩、流纹质(角砾)晶屑(玻屑、岩屑)凝灰岩、流纹质(角砾)晶屑熔结凝灰岩、球粒流纹岩，英安质晶屑凝灰岩、沉凝灰岩、松脂岩、珍珠岩、英安岩等	130±1 128.2±2.8
			白音高老组一段	K_1b^1	深灰、灰黑色、灰褐色英安质凝灰岩、流纹质(含角砾)晶屑凝灰岩、流纹质玻屑凝灰岩、英安质沉火山角砾岩、中、细粒岩屑长石砂岩、细砾岩、中、中粗砾砾岩、凝灰质砾岩、流纹岩、英安岩等	134.2±1 141.1±2.7
	侏罗系	上统	玛尼吐组二段	J_3mn^2	深灰、灰、灰紫、灰红、紫红色辉石粗面安山岩、石英粗安岩、粗安岩、粗面岩、粗面质英安岩、英安岩的岩石组合，火山机构附近可见粗面质、粗安质火山角砾岩、火山角砾集块岩	
			玛尼吐组一段	J_3mn^1	灰色、灰褐色、褐色、紫色安山岩、杏仁状安山岩、气孔状安山岩、英安岩、安山质集块火山角砾岩、安山质(含角砾)晶屑熔结凝灰岩、安山质晶屑凝灰岩、英安质晶屑熔结凝灰岩	154.7±1.3

表 4 内蒙古昌图希勒斯台幅 (L50E015021) 火山喷发旋回划分表

时代	火山喷发旋回	岩石地层	岩石组合	构造环境
上新世	4	五叉沟组	气孔杏仁状、致密块状玄武岩	
早白垩世	3	梅勒图组	气孔杏仁状、致密块状玄武岩	大陆溢流玄武岩
	2	白音高老组	流纹质晶屑凝灰岩、流纹质熔结凝灰岩、流纹岩、松脂岩、英安质晶屑凝灰岩、砾岩	活动大陆边缘
晚侏罗世	1	玛尼吐组	安山岩、气孔杏仁状安山岩、粗面岩、粗面英安岩、火山角砾岩、安山质晶屑熔结凝灰岩、安山质晶屑凝灰岩	

律，控制研究区内成矿作用的主要地质因素包括构造、火山岩浆活动、火山岩等，构造决定了成矿运移通道、成矿淀积场所及其成矿的空间展布形式，岩浆活动为成矿提供了热源及成矿物质来源，火山岩为矿物质来源、矿体赋存提供了有利的空间与环境。归纳了中生代火山岩区找矿标志：北西向断裂及其与火山机构叠加部位；铁锰矿化、硅化、碳酸盐化蚀变带；Ag、Mn、Pb、Zn、Cd 元素异常强度高、套合好异常区；高极化、中高阻激电异常区；弱的负磁异常和正负磁梯度带区域。

表 5　内蒙古昌图希勒斯台幅 (L50E015021) 样品测试分析数据表

数据类型	数据量	数据属性
化学样	1 170件	Ag、Pb、Zn、Mn、Cd等5项化学样分析
原岩光谱样	597件	Au、Ag、Cu、Pb、Zn、As、Sb、Sn、W、Mo、Cd、Mn共12种元素分析
岩石地球化学	108件	火山岩的11种主量元素、31种微量元素
光薄片	222件	透明矿物及金属矿物鉴定
S、Pb同位素	35件	金属矿物的S、Pb同位素分析
H、O同位素	10件	透明矿物的H、O同位素分析
同位素年龄数据	12件	火山岩的锆石U–Pb同位素年龄

(3) 经初步计算昌图锡力银铅锌锰矿 334_1 银金属量为 1 028.35 t，铅金属量为 11.25 万 t，锌金属量为 9.36 万 t，锰金属量为 55.24 万 t，达到大型银多金属矿床规模。深入研究总结成矿规律，建立了成矿模式，认为昌图锡力银铅锌锰多金属矿床是受断裂构造、火山岩浆活动等多种地质因素控制的陆相火山热液型银铅锌锰多金属矿床，推测成矿期为 130 ~ 140 Ma。

(4) 通过矿产地质图的编制为研究区内新发现的昌图锡力银铅锌锰矿的勘探工作提供基础地质资料支撑，共划分成矿远景区 8 处，其中Ⅰ级成矿远景区 2 处，Ⅱ级成矿远景区 1 处，Ⅲ级成矿远景区 5 处，进一步圈定找矿靶区 6 处。对不同成矿远景区及找矿靶区的成矿地质背景、成因类型、物化探异常特征进行了总结，提高了工作区矿产地质研究程度，为下一步矿产工作打下良好的基础。

6　结论

(1) 系统编制了内蒙古昌图希勒斯台幅 (L50E015021)1：50 000 矿产地质图并建立了空间数据库，实现了从前期资料准备→野外地质填图→室内综合整理→最终成果表达的全程数字化，便于对各类数据的一体化描述、存储、组织和利用。

(2) 矿产地质图的编制中采用“火山构造—岩性岩相—火山地层”工作方法，详细划分了火山岩相、喷发旋回及其岩石组合类型，重点查明了火山活动与成矿作用的关系，总结了中生代火山岩区金属矿产成矿地质条件和成矿规律，归纳了中生代火山岩区找矿标志。

(3) 在昌图希勒斯台幅内新发现的昌图锡力银铅锌锰矿经初步计算 334_1 银金属量为 1 028.35t，铅金属量为 11.25 万 t，锌金属量为 9.36 万 t，锰金属量为 55.24 万 t，达到大型银多金属矿床规模。通过总结成矿规律、建立成矿模式，认为昌图锡力银铅锌锰多金属矿床是受断裂构造、火山岩浆活动等多种地质因素控制的陆相火山热液型银铅锌锰多金属矿床。

(4) 本次工作中划分成矿远景区 8 处，圈定找矿靶区 6 处，并对成矿远景区及找矿靶区的成矿地质背景、成因类型、物化探异常特征进行了总结，为大兴安岭中南段中生代火山岩区多金属矿产的勘查及研究提供地质资料支撑。

致谢：内蒙古昌图希勒斯台幅 1：50 000 矿产地质图是在中国地质调查局天津地质调查中心和黑龙江省地质调查研究总院项目工作人员的共同努力之下编制的，同时，矿产地质图数据库建设中得到 2 个单位领导、专家的多次指导，在此对各位专家和项目组成员表示衷心感谢。

注释：

❶ 内蒙古自治区区域地质测量队. 1977. 哈拉盖图幅 1：200 000 区域地质调查报告 [R].

❷ 福建省地质调查院. 2011. 宝格达山林场分场幅、霍林郭勒市幅 1：250 000 区域地质调查修测 [R].

❸ 黑龙江省地质调查研究总院. 2015. 内蒙古 1：50 000 布日都大队、马尼特、迪彦苏木、昌图希勒斯台幅区域地质调查 [R].

❹ 中国地质科学院地球物理地球化学勘查研究所. 2008. 内蒙古自治区大兴安岭中南段、二连东乌旗一带 1：50 000 航空物探综合站勘查报告 [R].

参考文献

Jahn BM, Wu FY, Chen B. 2000. Grantitoids of the central Asian orogenic belt and continental growth in the Phanerozoic[J]. Earth and Environmental Science Transactions of the Royal Society of Edinburgh, 91(1-2): 181−193.

Meng QR. 2003. What drove late Mesozoic extension of the northern China-Mongolia trace?[J]. Tectonophysics, 369(3): 155−174.

Ouyang HG, Wu XL, Mao JW, Su HM, M Santosh, Zhou ZH, Li C. 2014. The nature and timing of ore formation in the Budunhua Copper Deposit, southern great Xingan range: evidence from geology, fluid inclusions, and U-Pb and Re-Os geochronology[J]. Ore Geology Reviews, 63: 238−251.

Wu FY, Sun DY, Ge WC, Zhang YB, Grant M L, Wilde SA, Jahn BM. 2011. Geochronology of the phanerozoic granitoids in northeastern china[J]. Journal of Asian Earth Sciences, 41(1): 1−30.

Xiao WJ, Windley BF, Hao J, Zhai MG. 2003. Accretion Leading to Collision and the Permian Solonker sutute, Inner Mongolia, China: termination of the Central Asian Orogenic Belt[J]. Tectonic, 22(6): 1484−1505.

Xu WL, Ji WQ, Pei FP, Meng E, Yu Y, Yang DB, Zhang XZ. 2009. Triassic volcanism in eastern Heilongjiang and Jilin provinces, NE China: Chronology, geochemistry, and tectonic implications[J]. Journal of Asian Earth Sciences, 34(3): 392−402.

Zeng QD, Liu JM, Yu CM, Ye J and Liu HT. 2011. Metal deposits in the Da Hinggan Mountains, NE China: Styles, characteristics, and exploration potential[J]. International Geology Review, 53(7): 846−878.

陈良, 张达, 狄永军, 徐俊, 王策, 宛胜, 来守华. 2009. 大兴安岭中南段区域成矿规律初步研究 [J]. 地质找矿论丛, 24(4): 267−271, 281.

盛继福, 付先政. 1999. 大兴安岭中段成矿环境与铜多金属矿床地质特征 [M]. 北京: 地震出版社: 1–216.

葛文春, 吴福元, 周长勇, 张吉衡. 2007. 兴蒙造山带东段斑岩型 Cu, Mo 矿床成矿时代及其地球动力学意义 [J]. 科学通报, 52(20): 2407−2417.

何鹏, 郭硕, 张阔, 张天福, 苏航, 马一行. 2019. 大兴安岭中南段昌图锡力银铅锌锰多金属矿床成矿物质来源及矿床成因: 来自 S-Pb-C-O 同位素的制约 [J]. 地质学报, 93(8): 2037−2054.

何鹏, 郭硕, 苏航, 王贵鹏, 张跃龙. 2020. 内蒙古昌图希勒斯台幅 1：50 000 矿产地质图数据库

[DB/OL]. 地质科学数据出版系统. (2020-12-30).DOI: 10.35080/data.C.2020.P24.

李俊建, 付超, 唐文龙, 李惠民, 林源贤, 张彤, 王守光, 赵泽霖, 党智财, 赵丽君. 2016. 内蒙古东乌旗沙麦钨矿床的成矿时代 [J]. 地质通报, 35(4): 524−530.

刘光鼎, 涂光炽, 刘东生. 2003. 大兴安岭中南段——一个重要的有色金属资源基地 [J]. 中国科学院院刊, 18(5): 324−325.

刘建明, 张锐, 张庆洲. 2004. 大兴安岭地区的区域成矿特征 [J]. 地学前缘, 11(1): 269−277.

毛景文, 谢桂青, 张作衡, 李晓峰, 王义天, 张长青, 李永峰. 2005. 中国北方中生代大规模成矿作用的期次及其地球动力学背景 [J]. 岩石学报, 21(1): 169−188.

孟恩, 许文良, 杨德彬, 邱昆峰, 李长华, 祝洪涛. 2011. 满洲里地区灵泉盆地中生代火山岩的锆石 U-Pb 年代学、地球化学及其地质意义 [J]. 岩石学报, 27(4): 1209−1226.

任纪舜, 牛宝贵, 刘志刚. 1999. 软碰撞、叠覆造山和多旋回缝合作用 [J]. 地学前缘, 6(3): 85−93.

邵积东, 陶继雄, 李四娃, 尚恒胜, 武利文, 巩智镇, 李甫. 2009. 大兴安岭成矿带找矿工作新进展 [J]. 地质通报, 28(7): 955−962.

王京彬, 王玉往, 王莉娟. 2000. 大兴安岭中南段铜矿成矿背景及找矿潜力 [J]. 地质与勘探, 36(5): 1−4.

王长明, 张寿庭, 邓军. 2006. 大兴安岭南段铜多金属矿成矿时空结构 [J]. 成都理工大学学报 (自然科学版), 33(5): 478−484.

吴福元, 葛文春, 孙德有, 郭春丽. 2003. 中国东部岩石圈减薄研究中的几个问题 [J]. 地学前缘, 10(3): 51−60.

武新丽, 毛景文, 周振华, 欧阳荷根. 2012. 大兴安岭中南段布敦化铜矿床 H-O-S-Pb 同位素特征及成矿指示 [J]. 中国地质, 39(6): 1812−1829.

杨海星, 高利东, 高玉石, 隋海涛, 赵志飞, 吕晶, 张维宇, 赵胜金, 柳志辉, 周颖帅. 2019. 大兴安岭中南段梅勒图组层型剖面锆石 U-Pb 年龄、地球化学特征及其地质意义 [J]. 地质通报, 38(5): 845−857.

要梅娟, 刘家军, 翟德高, 王建平, 邢永亮. 2012. 大兴安岭南段多金属成矿带硫、铅同位素组成及其地质意义 [J]. 吉林大学学报 (地球科学版), 42(2): 362−373.

曾庆栋, 刘建明, 褚少雄, 郭云鹏, 高帅, 郭理想, 翟媛媛. 2016. 大兴安岭南段多金属矿成矿作用和找矿潜力 [J]. 吉林大学学报 (地球科学版), 46(4): 1100−1123.

张海华, 张健, 黄欣, 邱亮, 苏飞, 郑月娟, 张德军. 2019. 大兴安岭中部乌兰浩特地区林西组碎屑岩锆石 U-Pb 年龄、地球化学特征及其构造意义 [J]. 地质通报, 38(9): 1484−1500.

张万益, 聂凤军, 刘树文, 左力艳, 陕亮, 姚晓峰. 2013. 大兴安岭南段西坡金属矿床特征及成矿规律 [J]. 中国地质, 40(5): 1583−1599.

郑全波, 苏航, 何鹏, 张跃龙, 郑涛. 2019. 内蒙古昌图锡力地区锰银铅锌多金属矿的找矿标志 [J]. 地质调查与研究, 42(1): 37−44.

仲米山, 王忠江, 敖光, 翟富荣, 王粉丽, 王岐, 谭超, 杨运来. 2017. 张广才岭二浪河组火山岩的锆石 U-Pb 年代学及地球化学特征 [J]. 地质调查与研究, 40(3): 161−168.

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Database of 1∶50 000 Mineral Geological Map of Changtuxilesitai Map-sheet, Inner Mongolia

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Abstract: In this paper, the database of 1∶50 000 mineral geological map of Changtuxilesitai Map-sheet (L50E015021), Inner Mongolia (also referred to as the Database) was established on the basis of digital geological mapping system, achieving the digitalization of the whole process of early data preparation → field geological mapping → indoor comprehensive data collation → the presentation of final results. Meanwhile, various relevant data were effectively described, stored, organized and utilized in an integrated way. The mapping method of “volcanic structure–lithology and lithofacies–volcanic strata” was adopted during the establishment of the Database. As a result, the volcanic strata were determined again, and the volcanic lithofacies as well as eruption cycles and their association types were classified in detail. Furthermore, the relationship of volcanics, volcanic structures and volcanic activities with mineralization were ascertained, and the geological conditions and metallogenic rule of metal minerals in Mesozoic volcanic areas were summarized. The Database contains eight stratigraphic units, four phases of volcanic eruption cycles, eight mineralization prospecting areas and six prospecting target areas. In addition, it also contains analytical data on 1 170 pieces of rock samples and 261 pieces of samples for geochemistry, 108 pieces of samples for petrochemistry, 222 pieces of thin slice samples for petrography, 35 pieces of S and Pb isotopes, ten pieces of H and O isotopes, as well as four zircon U–Pb ages. The newly discovered Changtuxili Ag-Pb-Zn-Mn deposits in the map-sheet area have a roughly identified resource of 1 028.35 tonnes of 334_1 Ag, 112 500 tonnes of Pb, 93 600 tonnes of Zn and 552 400 tonnes of Mn, belonging to a large-scale silver polymetallic deposit. The Database is detailed and accurate in contents and boasts high utility, providing important basic data for further survey and assessment of mineral resources, as well as the exploration and development of

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metal minerals in the area of Mesozoic volcanic rocks in the middle–southern section of the Da Hinggan Mountains.

Key words: Changtuxilesitai Map-sheet; 1∶50 000; mineral geological map; database; resource exploration engineering; Inner Mongolia; Da Hinggan Mountains

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

1 Introduction

The survey area of the Changtuxilesitai Map-sheet, Inner Mongolia (also referred to as the study area) is situated at the junction of the Siberian Plate and North China Plate (Jahn BM et al., 2000; Yao MJ et al., 2012; Li JJ et al., 2016; Yang HX et al., 2019; Zhang HH et al., 2019). It lies in the eastern segment of Xing'an Mongolian orogenic belt, in the south of Erenhot–Hegenshan tectonic zone, and to the north of Xar Moron fault (Fig. 1a). During the Paleozoic, the Paleo-Asian Ocean was formed, developed and disappeared between the northern margin of the North China and Siberian Plates, which preliminarily set up the tectonic framework in mainly EW-trending of the northern margin of North China Plate (Ren JS et al., 1999; Sheng JF et al., 1999; Liu GD et al., 2003; Meng QR, 2003; Xiao WJ et al., 2003). Owing to the superposition and transformation caused by the Mongol–Okhotsk tectonic system and Circum-Pacific tectonic framework since the Mesozoic (Xu WL et al., 2009; Wu FY et al.,

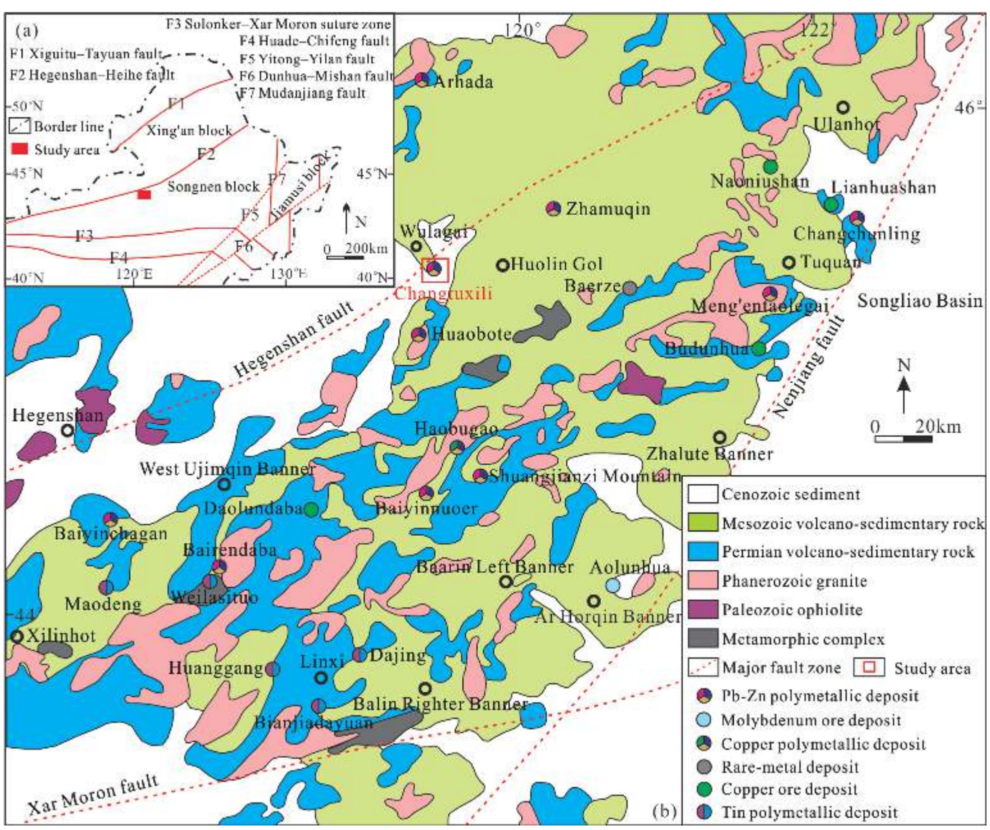

Fig. 1 Geological and mineral map of the middle–southern section of Da Hinggan Mountains

(a) Geotectonic map of Da Hinggan Mountains (modified from Ren JS et al., 1999); (b) Geological and mineral map of the middle–southern section of Da Hinggan Mountains (modified from Ouyang HG et al., 2014)

2011; Meng E et al., 2011; Zhong MS et al., 2017), the lithosphere in the middle and eastern part of Inner Mongolia, where the study area stands and its adjacent areas underwent extension and thinning (Wu FY et al., 2003; Mao JW et al., 2005). As a result, intense tectonic magmatic activities occurred, providing sources of heat and metallogenic materials for regional mineralization and creating favorable geological conditions for various deposits with high intensity of mineralization in Da Hinggan Mountains (Wang JB et al., 2000; Liu JM et al., 2004; Wang CM et al., 2006; Ge WC et al., 2007; Chen L et al., 2009; Shao JD et al., 2009; Zeng QD et al., 2011; Wu XL et al., 2012; Zhang WY et al., 2013; Zeng QD et al., 2016).

In the 1970s, previous researchers conducted regional geological and mineral surveys on a scale of 1∶200 000 in the study area[❶]. From 2009 to 2011, the regional amendment survey on a scale of 1∶250 000 was completed[❷], during which the strata, intrusions, structures and minerals in the study area were systematically surveyed. From 2013 to 2015, Tianjin Center of China Geological Survey organized the implementation of the regional geological survey project of four map-sheets named Buridu Village, Manite, Diyansumu and Changtuxilesitai in Inner Mongolia on a scale of 1∶50 000[❸]. During this project, the basic geological characteristics in the study area were surveyed and researched in a detailed way, and a soil survey of Changtuxilesitai Map-sheet on a scale of 1∶50 000 was completed. The data accumulated in the above-mentioned geological surveys laid a foundation for the establishment of the Database. By setting up the Database, previous data and newly obtained geological survey results were comprehensively digitalized, which contributes to the preservation and use of the data and results. The Database will provide detailed and accurate data of minerals and geology for ascertaining the restrictions of volcanic activities on metallic mineralization in the study area and for summarizing geological conditions of mineralization in the area. It will also provide fundamental geological maps for further geological surveys, scientific research and exploration of mineral resources in the study area. In addition, the 1∶50 000 mineral geological map of Changtuxilesitai Map-sheet have played a good supporting role as fundamental mineral and geological data in pre-survey of Changtuxili Ag–Pb–Zn–Mn deposits in the study area, which has been proved to be a large-scale deposit (He P et al., 2019; Zheng QB et al., 2019). The brief metadata table of the Database (He P et al., 2020) is shown in Table 1.

2 Method for Data Acquisition and Processing

2.1 Data Acquisition

2.1.1 Preparation for Data Acquisition

The Database was set up in accordance with the technical standards on geological surveys issued by the China Geological Survey such as DD 2019-02 *Technical Requirement of Solid Mineral Geological Survey* (1∶50 000) and DD 2006-06 *Spatial Database for Digital Geological Maps*, during which a digital mapping system was adopted. Data preparation in the early stages includes the preparation of geographical data, the digitalization of previous data, and the digitalization of the data obtained from geochemical and geophysical exploration.

Table 1 Metadata Table of Database (Dataset)

Item	Description
Database (dataset) name	Database of 1∶50 000 Mineral Geological Map of Changtuxilesitai Map-sheet, Inner Mongolia
Database (dataset) authors	He Peng, Tianjin Center, China Geological Survey Guo Shuo, Tianjin Center, China Geological Survey Su Hang, Heilongjiang Institute of Geological Survey and Research Wang Guipeng, Heilongjiang Institute of Geological Survey and Research Zhang Yuelong, Heilongjiang Institute of Geological Survey and Research
Data acquisition time	from 2017 to 2018
Geographical area	119°00′–119°15′E, 45°30′–45°40′N
Data format	MapGIS
Data size	6.27 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	China Geological survey project entitled *Geological and Mineral Survey of Erenhot-East Ujimqin Banner Metallogenic Belt, West Ujimqin Banner, and Bainaimiao Area* (No.: DD2016041)
Language	Chinese
Database (dataset) composition	The Database consists of a library of 1∶50 000 mineral geological map and map decorations. The former includes volcanics, intrusions, Quaternary strata, dikes, structures, geological boundaries, attitude, alteration, lithologic pattern and all kinds of symbols. The latter includes an index map, legends, synthetic histograms, transverse cutting profiles, mineralization anomalies and their numbers, mineral prospect areas, maps of locations of their metallogenic belts and a duty table

Furthermore, the original material was collated, including geological routes and measured geological sections acquired from a regional geological survey of Changtuxilesitai Map-sheet on a scale of 1∶50 000. Based on this, as well as regional mineral and geological data such as the geochemical and geophysical exploration maps in the 1∶50 000 -*Scale Aero-Geophysical Integrative Survey Report of Middle–southern Section of Da Hinggan Mountains and Erlianhot-East Ujimqin Banner*[4], the formation-tectonic geological sketch map was plotted based on digitalized processing. It was used as the base map of the geological and mineral map.

The geographical base map on a scale of 1∶50 000 was plotted with the latest geographical data from National Administration of Surveying, Mapping and Geoinformation of China, with Xi'an 1980 as the coordinate system and Gauss–Kruger projection parameters as the projection system. Relevant data were organized and stored according to the four 1∶25 000-scale map-sheets under the 1∶50 000-scale map-sheet. The mapping was totally conducted using a digital mapping system (DGSS) for palm-sized personal digital assistants. The data were processed and mineral and geological maps were prepared by using the software such as MapGIS and DGSS.

2.1.2 Data Acquisition

The data were mainly collected through field geological surveys. Based on the goals and tasks of this project, it was ultimately determined to survey metallogenic factors including Mesozoic volcanics, structures, and mineralization alteration. The data used to acquire a geological model for the PRB process of field routes mainly includes geological observation points (P), geological routes (R), geological boundaries (B), GPS point locations, samples, attitude, and photos.

2.2 Data Processing

Data processing mainly consisted of four successive steps, namely indoor collation of field route data, establishment of primitive data maps, establishment of primitive maps for compilation, and establishment of the spatial database of mineral maps.

2.2.1 Indoor Collation of Field Route Data

Field route data acquired by using palm-sized personal digital assistants tend to be rough and incomplete owing to restrictions of environment and time in fieldwork. Therefore, it is necessary to import the data into computers and then to modify and improve the PRB process as per relevant specifications, as follows:

(1) First, properly adjust the spatial positions of primitives such as geological observation points, geological route, geological boundaries, attitude points, and photo taking points in the field routes to harmonize their parameters such as colors, line types, and line width. In this way, the primitives can be expressed more accurately and the maps will be more aesthetically pleasing.

(2) Complement and collate attributes of geological observation points (P), geological routes (R), and geological boundaries (B). Denominate rocks based on the results of thin section identification of rock samples and add comments.

(3) Import route photos and complement attributes of photo taking points, attitude points, and sampling points.

(4) Fill in field route summary, and recheck and complement the contents along the route.

2.2.2 Establishment of Primitive Data Maps

This step aims to establish primitive data maps. Firstly, gather the field route data obtained through the preceding steps into the general library of 1:25 000-scale field geological maps. Then successively connect geological boundaries, construct geological bodies by topological area creation, and improve the attributes of geological line features and geological plane features as well as map decorations and legends.

(1) Update of primitive data maps with the general library of field geological maps

Compared with the general library of field geological maps, the primitive data maps have three new files, namely Geopoly.wp (a file of geological polygon features), Geoline.wl (a file of geological line features), and Geolabel.wt (a file of labels of geological polygon features).

(2) Connection of geological boundaries

Connect geological boundaries in the map layer of Geoline.wl. Establish topological relationship for geological boundaries and eliminate various errors one by one by multiple topological checks.

(3) Construction of geological polygon entities

① Convert the geological boundaries determined by the preceding step into arcs of geological polygons, and then conduct topological area creation. In this way, geological polygon entities can be built;

② Assign attributes and parameters to geological polygon entities: After adding critical attributes such as "Mapping unit" and "Rock name", it is practicable to use the tools in the software to conduct operations such as adding attributes to geological boundaries and adding colors to geological polygon entities in batches, thus increasing the efficiency of data processing;

③ Assign attributes to geological boundaries: After adding attributes to all geological polygon entities, it is practicable to use the functions of the software to assign key fields such as the codes of left and right geological bodies to relevant geological boundaries.

(4) Labeling of geological polygon entities in batches

Create a legend file and add attributes to legend points. Legend labels should be assigned to the entities in corresponding geological areas.

(5) Quality inspection and topologic reconstruction of primitive data maps

Primitive data maps cannot be established at any one time. Rather, they can be finally formed only after multiple quality inspection to eliminate errors and accordingly multiple topologic reconstruction.

2.2.3 Establishment of primitive maps for compilation

The primitive maps for compilation were established by the following steps after four 1:25 000-scale primitive data maps of Changtuxilesitai Map-sheet were completed.

(1) Build the map sheet project by using the 1：50 000-scale map-frame of Changtuxilesitai Map-sheet (L50E015021). Then project the 1:25 000 primitive data maps to the 1：50 000 primitive maps for compilation.

(2) Complete the edge match of the four 1:25 000-scale map sheets, define topology for the 1：50 000-scale map sheet, and arrange various map decorations and legends outside the map frame. In this way, complete primitive maps for compilation can be finally formed.

2.2.4 Establishment of spatial database

(1) Features of spatial database

The Database includes four types of classes, namely feature classes, object classes, complex classes, and independent feature classes. ① Feature classes refer to the geological data obtained during field geological surveys, including geological polygon entities, geological boundaries, alteration points, mineralized points, craters, attitude, samples, isotopes, and photos. ② Object classes include lithostratigraphic units of sedimentary (volcanic) rocks, dikes and faults. ③ Complex classes refer to those determined through indoor comprehensive research and sample testing and analysis based on field surveys, including volcanic lithofacies zones and alteration zones. ④ Independent feature classes mainly refer to legends and decorations, including an index map, legends, synthetic diagrams, transverse cutting profiles, mineralization anomalies and their codes, mineral prospect areas, location map of metallogenic zones/belts of the mineral prospect areas, and duty table.

(2) Steps to establish spatial database

The final spatial database was established according to the following steps after the primitive maps for compilation were completed. ① Generate files of feature classes and object classes with standard attribute structures. ② Extract information from relevant files of primitive maps for compilation and assign the information to feature classes. Then edit and improve the attributes of the feature classes. ③ Build complex classes and improve their attributes. ④ Extract information from complex classes and assign the information to object classes. Then improve the attributes of the object classes. ⑤ Finish maps by adding information of independent feature classes such as the index map, synthetic diagrams, and transverse cutting profiles. As a result, a complete spatial database was established.

3 Description of Data Samples

According to the requirements for setting up a database for 1：50 000-scale mineral and geological surveys and geological mapping, the Dataset was established according to feature classes, object classes, complex classes, and independent feature classes (Table 2).

3.1 Feature classes

(1) Geological polygon entities (_GEOPOLYGON.WP)

Geological polygon entities include geological bodies such as volcanics, sedimentary rocks, intrusions, and Quaternary rocks. Their data attributes mainly consist of ID, original code, type code, name, era, and subtype ID.

(2) Geological boundaries (_GEOLINE.WL)

The data attributes of a geological boundary mainly include code of the geological boundary (contact), type of the geological boundary, codes of geological bodies on the left and right side of the geological boundary, the strike, dip, and dip angle of the interface, and subtype ID.

(3) Alteration points (_ALTERATION_PNT)

The data attributes of an alteration point mainly include name code and name of alteration type, altered mineral associations and their content, altered geological code, and mineral types in the alteration zone.

(4) Mineralized points (_MINERAL_PNT.WT)

The data attributes of a mineralized point mainly include code and name of mineral type, paragenetic ore, associated ore, number of mineral deposits, ore grade, scale, metallogenic epoch, name of ore locality, type of mineralization, and industrial type.

(5) Craters (_CRATER.WT)

The data attributes of a crater mainly include: the type, name and size of the crater, the unit and code of geological bodies produced in the crater, and the rock types and formation era of the crater.

(6) Attitude (_ATTITUDE.WT)

The data attributes of attitude mainly include name code and name of attitude type, and

Table 2 Information list of the database of 1：50 000 mineral geological map of Changtuxilesitai Map-sheet (L50E015021), Inner Mongolia

Basic feature class		Object class		Complex class		Independent feature class
Name and standard code	Entity quantity	Name and standard code	Description	Name and standard code	Description	Name and standard code
Geological polygon entity (_GEOPOLYGON.WP)	82	Lithostratigraphic unit of sedimentary (volcanic) rocks (_STRATA)	Including ten strata, namely Quaternary Holocene alluvial deposit (Qh^{al}), Quaternary Holocene alluvial-lacustrine deposit (Qh^{all}), Quaternary Holocene alluvial-diluvial deposit (Qh^{alp}), Quaternary Holocene lacustrine deposit (Qh^{l}), the first member of Upper Jurassic Manitu Formation (J_3mn^1), the first member of Lower Cretaceous Baiyingaolao Formation (K_1b^1), the second member of Lower Cretaceous Baiyingaolao Formation (K_1b^2), Lower Cretaceous Damoguaihe Formation (K_1d), Neogene Pliocene Baogedawula Formation (N_2b), and Neogene Pliocene Wuchagou Formation (N_2w)	Standard map frame (_MAP_FRAME.WL)	Four lines of inner map frame (standard frame), with same attributes	Map index (MAP_SHEET)
Geological boundary (_GEOLINE.WL)	101					Comprehensive histogram (COLUMN)
Alteration point (_ALTERATION_ PNT.WT)	63					Transverse cutting profile (PROFILE)
Mineralized point (_MINERAL_PNT.WT)	2					Legend (LEGEND)

Continued table 2

Basic feature class		Object class		Complex class		Independent feature class
Crater (_CRATER.WT)	6	Dike (_DIKE_OBJECT)	Including seven dikes, namely late Jurassic andesitic dike (αJ_3), early Cretaceous andesitic dike (αK_1), late Jurassic andesitic porphyrite dike ($\alpha\mu J_3$), late Jurassic diorite porphyrite dike ($\delta\mu J_3$), late Jurassic dacite dike (ζJ_3), early Cretaceous rhyolite dike (λK_1), early Cretaceous rhyolite porphyry dike ($\lambda\pi K_1$)	Volcanic lithofacies zone (_VOLCA_FACIES)	Mainly including effusive facies (EFF), fallout facies (FOF), pyroclasic flow facies (PRF), volcanic vent facies (VNF), and volcanic explosion-collapse facies (VECF)	Duty table (DUTY_TABLE)
Attitude (_ATTITUDE.WT)	30					
Sample (_SAMPLE.WT)	568	Fault (_FAULT)	18 in total			
Isotope (_ISOTOPE.WT)	4	Planar river and reservoir (_WATER_REGION)	Extracted from geographical base map	Alteration zone (_ALTERATION_POLYGON)	Mainly including Pb–Zn mineralization, limonitization, Silicification, and carbonatization	Other (OTHER) mainly includes volcanic lithofacies tectonic map, units of intrusions and other map decorations outside map border
Photo (_PHOTOGRAPH.WT)	186					
Bank line of river, lake, and reservoir (_LINE_GEOGRAPHY.WL)	50					

the strike, dip and dip angle of attitude.

(7) Samples (_SAMPLE.WT)

The data attributes of a sample mainly include: sample number., code and name of sample type, and names of rocks in the sample.

(8) Isotopes (_ISOTOPE.WT)

The data attributes of an isotope mainly include number and name of the sample, dating method, age dated, the unit and code of the geological body dated, and the unit and date of dating analysis.

(9) Photos (_PHOTOGRAPH.WT)

The data attributes of a photo mainly include feature ID, and the No., title, and notes of the photo.

3.2 Object Classes

(1) Lithostratigraphic units of sedimentary (volcanic) rocks (_STRATA)

The data attributes of a lithostratigraphic unit of sedimentary (volcanic) rocks mainly include feature type, the name, symbol, and era of the stratigraphic unit, the name and dominant color of rock association, and the main sedimentary structure, biofossil zone or biotic association, thickness, and ore-bearing features of the lithostratigraphic unit.

(2) Dikes (_DIKE_OBJECT)

The data attributes of a dike mainly include the type code, name, symbol, lithology, color, texture, and structure of the dike, the primary minerals and secondary minerals in the dike and their content, the strike, dip, and dip angle of the contact surface between the dike and its surrounding rocks, and the formation era and ore-bearing features of the dike.

(3) Faults (_FAULT)

The data attributes of a fault mainly include the type, name, number, and characteristics of the fault, codes of geological bodies in the hangingwall and footwall of the fault, and the fractured zone width, strike, dip, and dip angle, estimated fault throw, formation era, and active stages of the fault.

3.3 Complex Classes

(1) Volcanic lithofacies zones (_VOLCA_FACIES.WP)

The data attributes of a volcanic lithofacies zone mainly include the type and code of volcanic lithofacies, units and codes of strata produced, and the rock type, rock structure, and petrotectonics of volcanic lithofacies, attitude of planar flow structure, attitude of streamlines, formation era, and ore-bearing features.

(2) Alteration zones (_ALTERATION_POLYGON)

The data attributes of an alteration zone mainly include the name code and name of alteration type, altered mineral associations and their content, ore-bearing features, and codes of altered geological bodies.

(3) Inner map frame (_MAP_FRAME.WL)

The data attributes of an inner map frame mainly include map name, code of the map sheet, scale, coordinate system, elevation system, left longitude, lower latitude, and map units.

3.4 Independent feature classes

(1) Index map (MAP_SHEET)

The data attributes of an index map mainly include the points, lines, and polygons in the index map.

(2) Legends (LEGEND)

The data attributes of a legend mainly include points, lines, and polygons of the legend.

(3) Synthetic histograms (COLUMN)

The data attributes of a synthetic histogram mainly include points, lines, and polygons in the synthetic histogram.

(4) Transverse cutting profiles (PROFILE)

The data attributes of a transverse cutting profile mainly include points, lines, and polygons in the transverse cutting profile.

(5) Duty table (DUTY_TABLE)

The data attributes of a duty table mainly include points, lines, and polygons in the duty table.

(6) Others (OTHER)

Others in a map border include mineralization anomalies and their numbers, mineral prospect areas, and location map of metallogenic zones/belts of the mineral prospect areas.

4 Data Quality Control and Assessment

The Database was set up in accordance with the requirements of technical specifications such as DD 2019-02 *Technical Requirement of Solid Mineral Geological Survey* (1 ∶ 50 000) and DD 2006-06 *Spatial Database for Digital Geological Maps*. Meanwhile, the results of the latest regional geological surveys in the study area were fully referred to and used. Based on the goals and tasks of this project, metallogenic factors including volcanics, volcanic edifices, structures, and mineralized alteration zones were surveyed. The grid density of survey routes was increased on a scale of 1 ∶ 10 000 in areas with complex geological structure, anomalous areas of mineralization and favorable mineralization areas. During the preparation of the 1 ∶ 50 000 mineral and geological maps of Changtuxilesitai Map-sheet, previous data from 660 km survey routes were collected, 185 km survey routes were surveyed, and 336 geological observation points, 566 geological boundaries, 31 samples for thin section identification, four zircon U–Pb isotope samples and 186 photos were taken.

This project was completed with thanks to a geological survey project entitled *Geological and Mineral Survey of Erenhot-East Ujimqin Banner Metallogenic Belt, West Ujimqin Banner, and Bainaimiao Area*. Three-level quality inspection was regularly conducted. The self-check rate and mutual check rate of field geological routes were both 100%, and the inspection rate conducted by the project team was 30%. The project undertaker conducted field inspection and indoor information inspections by stages. Tianjin Center, China Geological Survey organized experts to conduct quality spot checks of original data and field inspection in October 2017 and

July 2018, respectively, and all results were found to meet quality requirements. A field acceptance check of this project was conducted in October 2018, during which experts unanimously argued the goal and tasks and the main physical workloads of the project were successfully completed and all work results met the requirements of design and relevant specifications. As a result, the project passed the field acceptance smoothly.

5 Data Value

(1) The 1：50 000-scale mineral geological map of Changtuxilesitai Map-sheet (L50E015021), Inner Mongolia covers large-scale Mesozoic volcanic rock areas in the metallogenic belt of the middle–southern section of Da Hinggan Mountains. During the preparation of the map, volcanic rocks closely related to mineralization were studied by using the mapping method of “volcanic structure - lithology and lithofacies – volcanic strata”. According to rock association division of the volcanics and restrictions of isotopic dating data, it was determined again that the strata in the map sheet include the upper Jurassic Manitu Formation (J_3mn), Baiyingaolao Formation (K_1b) and Meiletu Formation (K_1m) of the lower Cretaceous, and the Baogedawula Formation (N_2b) and Wuchagou Formation (N_2w) of the Neogene Pliocene (Table 3). Meanwhile, four stages of volcano eruption cycles were identified in the map sheet, namely Manituian, Baiyingaolaoian, Meiletuian, and Wuchagouian (Table 4). The analytical data of the samples collected in this Database are shown in Table 5. The geochemistry data of soil and rock samples are used for delineating ore belts, dividing ore bodies, and determining ore grades, and then a total of six ore belts are delineated. Combining optical thin slice identification with field surveys, the mineralization period is divided into epigenetic period and hydrothermal mineralization period, and the latter could be subdivided into four stages with silver minerals and metal sulfides being the main mineralization stages. The petrochemical data and isotopes of S, Pb, C and O indicate that the ore-forming materials are derived from deep-source magma, providing innovative ideas for future mineral exploration.

(2) The inspection conducted focused on the survey routes in comprehensive geochemical anomalous areas according to comprehensive interpretation results of aeromagnetic surveys and remote sensing. Meanwhile, the ore-bearing features and metallogenic specialization of the volcanics were intensively surveyed and researched. As a result, it was ascertained that Baiyingaolao Formation is an important ore-bearing stratum, and NW-trending faults and volcanic edifices are important ore-hosting structures. Meanwhile, six polymetallic mineralized alteration zones of Ag, Pb and Zn related to tectonic magmatism were delineated in the Changtuxili area. The geological conditions and metallogenic rule of metal deposits in Mesozoic volcanic rock areas were summarized, and the geological tectonic evolution and metallogenic process in the study area were systemically concluded. The geological factors controlling the ore-forming process in the study area include structure, volcanic magma activities and volcanic rocks. The structures control the migration channel, depositional site and spatial distribution form of the ore-forming materials, the magmatic activities provide

Table 3 Lithostratigraphic units in Changtuxilesitai Map-sheet (L50E015021), Inner Mongolia

Erathem	System	Series	Formation (member)	Code	Rock association	Isotopic dating /Ma
Cenozoic	Neogene	Pliocene	Wuchagou Formation	N_2w	Dark-gray, grayish-black and amaranthine vesicular basalt, dense massive basalt, andesitic basalt, basaltic agglomeratic breccia, sandy conglomerate	
			Baogedawula Formation	N_2b	Brick-red (pebbly) mudstone, pebbly medium-grained feldspathic lithic greywacke, medium-grained lithic feldspathic greywacke, grayish dark mudstone, and sandy conglomerate	
Mesozoic	Cretaceous	Lower Cretaceous	Damoguaihe Formation	K_1d	Mainly consisting of mudstone and siltstone, interbedded with medium- and fine-grained sandstone and pebbly sandstone as well as coal seams	
			Meiletu Formation	K_1m	Grayish-black, grayish-brown, and amaranthine vesicular, amygdaloidal, and dense massive basalt, andesite, tuffaceous (feldspathic) lithic sandstone, tuffaceous conglomerate, tuffaceous sandy conglomerate, and crystal vitric sedimentary tuff	
			The second member of Baiyingaolao Formation	K_1b^2	Grayish-brown, gray, light purple rhyolite, rhyolitic (brecciaceous) crystal (vitric, lithic) tuff, rhyolitic (brecciaceous) crystal ignimbrite, pelletized rhyolite, dacitic crystal tuff, sedimentary tuff, pitchstone, perlite, dacite, etc.	130±1 128.2±2.8
			The first member of Baiyingaolao Formation	K_1b^1	Dark-gray, grayish-black, and grayish-brown dacitic tuff, rhyolitic (brecciaceous) crystal tuff, rhyolitic vitric tuff, dacitic tuff sendimentary volcanic breccia, medium- and fine-grained lithic feldspathic sandstone, fine-grained conglomerate, medium-grained and medium-coarse grained conglomerate, tuffaceous conglomerate, rhyolite, dacite, etc.	134.2±1 141.1±2.7
	Jurassic	Upper Jurassic	The second member of Manitu Formation	J_3mn^2	Consisting of dark-gray, gray, grayish-purple, grayish-red, and amaranthine pyroxene-bearing trachyandesite, quartz trachyandesite, trachyandesite, trachyte, trachydacite, and dacite. Trachytic and trachyandesitic volcanic breccia and volcanic brecciaceous agglomerate are visible near volcanic edifice	
			The first member of Manitu Formation	J_3mn^1	Gray, grayish-brown, brown, and purple andesite, amygdaloidal andesite, vesicular andesite, dacite, andesitic agglomeratic volcanic breccia, andesitic (brecciaceous) crystal ignimbrite, andesitic crystal tuff, and dacitic crystal ignimbrite	154.7±1.3

Table 4 Volcanic eruption cycles in Changtuxilesitai Map-sheet (L50E015021), Inner Mongolia

Era	Volcanic eruption cycle	Rock stratum	Rock association	Tectonic environment
Pliocene	4	Wuchagou Formation	Vesicular, amygdaloidal, and dense massive basalt	
Early Cretaceous	3	Meiletu Formation	Vesicular, amygdaloidal, and dense massive basalt	Continental flood basalts
	2	Baiyingaolao Formation	Rhyolitic crystal tuff, rhyolitic ignimbrite, rhyolite, pitchstone, andesitic crystal tuff, and conglomerate	Active continental margin
Late Jurassic	1	Manitu Formation	Andesite, vesicular and amygdaloidal andesite, trachyte, trachydacite, volcanic breccia, andesitic crystal ignimbrite, andesitic crystal tuff	

Table 5 Analytical data list of the samples collected in the Changtuxilesitai Map-sheet (L50E015021) area, Inner Mongolia

Data type	Number of samples	Data description
Samples for chemistry	1 170	Five metal elements of Ag, Pb, Zn, Mn, Cd
Samples for rock spectroscopy	597	12 elements of Au, Ag, Cu, Pb, Zn, As, Sb, Sn, W, Mo, Cd, Mn
Samples for petrochemistry	108	11 main elements and 31 trace elements of volcanic rocks
Samples for thin slice identification	222	Microscopic petrography identification of the transparent and metallic minerals
Samples for S and Pb isotopes	35	S and Pb isotopic analysis on the metallic minerals
Samples for H and O isotopes	10	H and O isotopic analysis on the transparent minerals
Samples for isotopic dating	12	Zircon U–Pb dating ages of the volcanic rocks

thermal power and metallogenic materials for the formation of polymetallic deposits, and the volcanic rocks provide favorable space and environment for the source of minerals and occurrence of orebodies. The prospecting indicators in the Mesozoic volcanic rocks are thus generalized as follows: ① NW-strike faults and their superimposed position with volcanic structure. ② Iron and manganese mineralization, silicification, carbonated alteration zone. ③ Ag, Mn, Pb, Zn and Cd elements have high anomalous intensity and fit well in anomalous areas. ④ High polarization, medium and high resistance induced polarization (IP) abnormal area. ⑤ Weak negative magnetic anomaly and positive and negative magnetic gradient zone.

(3) The Changtuxili Ag-Pb-Zn-Mn deposits have a roughly identified resource of 1 028.35 tonnes of 334_1 Ag, 112 500 tonnes of Pb, 93 600 tonnes of Zn and 552 400 tonnes of Mn, belonging to a large-scale silver polymetallic deposit. Through in-depth studying metallogenic rule and establishing the metallogenic model, it is believed that the Changtuxili Ag-Pb-Zn-Mn polymetallic deposit is a terrestrial volcanic hydrothermal one controlled by various geological factors such as fault and volcanic magmatic activities. The mineralization period is estimated to be 130–140 Ma.

(4) The mineral geological map of Changtuxilesitai Map-sheet has provided basic geological data for the exploration of Changtuxili Ag–Pb–Zn–Mn deposit newly discovered in

the study area. As a result, a total of eight metallogenic prospects are divided, including two Ⅰ-level prospects, one Ⅱ-level prospect and five Ⅲ-level prospects, and six prospecting target areas are further delineated. The mineralization geological features, mineralization types, and geophysical and geochemical anomaly characteristics of different mineralization prospects and prospecting target areas were summarized, which improved the mineral geological research level, and laid a good foundation for the future mineral exploration.

6 Conclusions

(1) The 1∶50 000 mineral geological map of Changtuxilesitai Map-sheet (L50E015021), Inner Mongolia was systemically plotted and a spatial database was established, achieving digitalization of the whole process of early data preparation → field geological mapping → indoor comprehensive data collation → the presentation of final results. This contributes to the integrated description, storage, organization, and utilization of various data.

(2) The mineral geological map of the Changtuxilesitai Map-sheet were plotted by using the method of “volcanic structure – lithology and lithofacies – volcanic strata”. As a result, the volcanic lithofacies as well as eruption cylces and their association types were classified in detail, the relationship between volcanic activities and mineralization was ascertained, the geological conditions and metallogenic rules of metal minerals in the Mesozoic volcanic rock area were summarized, and the prospecting indicators in the Mesozoic volcanic rocks were generalized.

(3) The Changtuxili Ag-Pb-Zn-Mn deposits newly discovered in the map of Changtuxilesitai Map-sheet have a roughly identified resource of 1 028.35 tonnes of 334_1 Ag, 112 500 tonnes of Pb, 93 600 tonnes of Zn and 552 400 tonnes of Mn, belonging to a large-scale silver polymetallic deposit. Through summarizing metallogenic rule and establishing the metallogenic model, it is believed that the Changtuxili Ag-Pb-Zn-Mn polymetallic deposit is a terrestrial volcanic hydrothermal one controlled by various geological factors such as fault and volcanic magmatic activities.

(4) In this work, a total of eight metallogenic prospects are divided, and six prospecting target areas are delineated. The mineralization geological features, mineralization types, and geophysical and geochemical anomaly characteristics of different mineralization prospects and prospecting target areas were summarized, providing basic data for the exploration and research of polymetallic minerals in the area of Mesozoic volcanic rocks in the middle–southern section of the Da Hinggan Mountains.

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Notes:

❶ Regional Geological Survey Team of Geological Exploration Bureau of Inner Mongolia Autonomous Region. 1977. 1 : 200 000-Scale Regional Geological Survey Report of Halagai Map-sheet[R].

❷ Fujian Institute of Geological Survey. 2011. 1 : 250 000-Scale Regional Geological Amendment Survey of Baogedashanlinchangfenchang and Huolinguoleshi Map-sheets[R].

❸ Heilongjiang Institute of Geological Survey and Research. 2015. 1 : 50 000-Scale Regional Geological Survey of Map-sheets of Buridu Village, Manite, Diyansumu and Changtuxilesitai, Inner Mongolia[R].

❹ Institute of Geophysical and Geochemical Survey, Chinese Academy of Geological Sciences. 2008. 1 : 50 000-Scale Aero-Geophysical Integrative Survey Report of Middle-southern Section of Da Hinggan Mountains and Erlianhot–East Ujimqin Banner[R].

References

Chen Liang, Zhang Da, Di Yongjun, Xu Jun, Wang Ce, Wan Sheng, Lai Shouhua. 2009. A study on the regional metallogenic regularity in the mid-southern segment of Da Hinggan Mountains, China[J]. Contributions to Geology and Mineral Resources Research, 24(4): 267−271, 281 (in Chinese with English abstract).

Ge Wenchun, Wu Fuyuan, Zhou Changyong, Zhang Jiheng. 2007. Metallogenic age of the porphyry Cu, Mo deposit in the eastern Xingmeng orogenic belt and its geodynamic significance[J]. Chinese Science Bulletin, 52(20): 2407−2417 (in Chinese).

He Peng, Guo Shuo, Zhang Kuo, Zhang Tianfu, Su Hang, Ma Yixing. 2019. The sources of ore-forming materials and genesis of the Changtuxili Ag-Pb-Zn-Mn polymetallic deposit in the middle–southern segment of Da Hinggan Mountains: Constraints from S-Pb-C-O isotope geochemistry[J]. Acta Geologica Sinica, 93(8): 2037−2054 (in Chinese with English abstract).

He Peng, Guo Shuo, Su Hang, Wang Guipeng, Zhang Yuelong. 2020. Database of 1 : 50 000 Mineral Geological Map of Changtuxilesitai Map-sheet, Inner Mongolia[DB/OL]. Geoscientific Data & Discovery Publishing System. (2020-12-30). DOI: 10.35080/data.C.2020.P24.

Jahn BM, Wu FY, Chen B. 2000. Grantitoids of the central Asian orogenic belt and continental growth in the Phanerozoic[J]. Earth and Environmental Science Transactions of the Royal Society of Edinburgh, 91(1–2): 181−193.

Li Junjian, Fu Chao, Tang Wenlong, Li Huimin, Lin Yuanxian, Zhang Tong, Wang Shouuang, Zhao Zelin, Dang Zhicai, Zhao Lijun. 2016. The metallogenic age of the Shamai wolframite deposit in Dong Ujimqin Banner, Inner Mongolia[J]. Geological Bulletin of China, 35(4): 524−530 (in Chinese with English abstract).

Liu Guangding, Tu Guangchi, Liu Dongsheng. 2003. Middle–southern segment of Da Hinggan Mountains—an important non-ferrous metal resource base[J]. Bulletin of the Chinese Academy of Sciences, 18(5): 324−325 (in Chinese).

Liu Jiamin, Zhang Rui, Zhang Qingzhou. 2004. The reginal metallogeny of Da Hinggan Ling, China[J]. Earth Science Frontiers, 11(1): 269−277 (in Chinese with English abstract).

Mao Jingwen, Xie Guiqing, Zhang Zuoheng, Li Xiaofeng, Wang Yitian, Zhang Changqing, Li Yongfeng. 2005. Mesozoic large-scale metallogenic pulses in North China and corresponding geodynamic settings[J]. Acta Petrologica Sinica, 21(1): 169−188 (in Chinese with English abstract).

Meng En, Xu Wenliang, Yang Debin, Qiu Kunfeng, Li Changhua, Zhu Hongtao. 2011. Zircon U-Pb chronology, geochemistry of Mesozoic volcanic rocks from the Lingquan basin in Manzhouli area, and its tectonic implications[J]. Acta Petrologica Sinica, 27(4): 1209−226 (in Chinese with English abstract).

Meng QR. 2003. What drove late Mesozoic extension of the northern China-Mongolia trace?[J]. Tectonophysics, 369(3): 155−174.

Ouyang HG, Wu XL, Mao JW, Su HM, M Santosh, Zhou ZH, Li C. 2014. The nature and timing of ore formation in the Budunhua Copper Deposit, southern great Xingan range: evidence from geology, fluid inclusions, and U-Pb and Re-Os geochronology[J]. Ore Geology Reviews, 63: 238−251.

Ren Jishun, Niu Baogui, Liu Zhigang. 1999. Soft collision, superposition orogeny and polycyclic suturing[J]. Earth Science Frontiers, 6(3): 85−93 (in Chinese with English abstract).

Shao Jidong, Tao Jixiong, Li Siwa, Shang Hengsheng, Wu Liwen, Kong Zhizhen, Li Fu. 2009. The new progress in ore prospecting within Daxing'anling mineralization belt, China[J]. Geological Bulletin of China, 28(7): 955−962 (in Chinese with English abstract).

Sheng Jifu, Fu Xianzheng. 1999. Metallogenic environment and geological characteristics of copper-polymetallic deposits in the middle segment of Da Hinggan Mountains[M]. Beijing: Seismological Press. 1–216 (in Chinese).

Wang Jingbin, Wang Yuwang, Wang Lijuan. 2000. Copper metallogenic setting and prospecting potential in the middle-southern part of Da Hinggan Mountains[J]. Geology and Prospecting, 36(5): 1−4 (in Chinese with English abstract).

Wang Changmin, Zhang Shouting, Deng Jun. 2006. The metallogenic space-time structure of copper-polymetallic deposits in the southern segment of Da Hinggan Mountains, China[J]. Journal of Chengdu University of Technology (Science & Technology Edition), 33(5): 478−484 (in Chinese with English abstract).

Wu Fuyuan, Ge Wenchun, Sun Deyou, Guo Chunli. 2003. Discussions on the lithospheric thinning in eastern China[J]. Earth Science Frontiers, 10(3): 51−60 (in Chinese with English abstract).

Wu FY, Sun DY, Ge WC, Zhang YB, Grant M L, Wilde SA, Jahn BM. 2011. Geochronology of the phanerozoic granitoids in northeastern China[J]. Journal of Asian Earth Sciences, 41(1): 1−30.

Wu Xinli, Mao Jingwen, Zhou Zhenhua, Ouyang Hegen. 2012. H-O-S-Pb isotopic components of the Budunhua Cu deposit in the middle-south part of the Da Hinggan Mountains and their implications for the ore-forming process[J]. Geology in China, 39(6): 1812−1829 (in Chinese with English abstract).

Xiao WJ, Windley BF, Hao J, Zhai MG. 2003. Accretion Leading to Collision and the Permian Solonker sutute, Inner Mongolia, China: termination of the Central Asian Orogenic Belt[J]. Tectonic, 22(6): 1484−1505.

Xu WL, Ji WQ, Pei FP, Meng E, Yu Y, Yang DB, Zhang XZ. 2009. Triassic volcanism in eastern Heilongjiang and Jilin provinces, NE China: Chronology, geochemistry, and tectonic implications[J].

Journal of Asian Earth Sciences, 34(3): 392−402.

Yang Haixing, Gao Lidong, Gao Yushi, Sui Haitao, Zhao Zhifei, Lü Jing, Zhang Weiyu, Zhao Shengjin, Liu Zhihui, Zhou Yingshu. 2019. Zircon U-Pb age and geochemistry of the stratotype section of the Meiletu Formation in middle southern Da Hinggan Mountains and its geological significance[J]. Geological Bulletin of China, 38(5): 845−857 (in Chinese with English abstract).

Yao Meijuan, Liu Jiajun, Zhai Degao, Wang Jianping, Xing Yongliang. 2012. Sulfur and lead isotopic compositions of the Polymetallic deposits in the southern Daxing'anling: Implications for metal sources[J]. Journal of Jilin Unviersity (Earth Science Edition), 42(2): 362−373 (in Chinese with English abstract).

Zeng QD, Liu JM, Yu CM, Ye J and Liu HT. 2011. Metal deposits in the Da Hinggan Mountains, NE China: Styles, characteristics, and exploration potential[J]. International Geology Review, 53(7): 846−878.

Zeng Qingdong, Liu Jianming, Chu Shaoxiong, Guo Yunpeng, Gao Shuai, Guo Lixiang, Zhai Yuanyuan. 2016. Poly-Metal Mineralization and Exploration Potential in Southern Segment of the Da Hinggan Mountains[J]. Journal of Jilin Unviersity (Earth Science Edition), 46(4): 1100−1123 (in Chinese with English abstract).

Zhang Haihua, Zhang Jian, Huang Xin, Qiu Liang, Su Fei, Zheng Yuejuan, Zhang Dejun. 2019. Zircon U-Pb age, geochemical characteristics and tectonic implications of detrital zircon from Linxi Formation in the Wulanhaote area, central Da Hinggan Mountains[J]. Geological Bulletin of China, 38(9): 1482−1500 (in Chinese with English abstract).

Zhang Wanyi, Nie Fengjun, Liu Shuwen, Zuo Liyan, Shan Liang, Yao Xiaofeng. 2013. Characteristics and metallogenic regularities of ore deposits on the western slope of the southern section of the Da Hinggan Mountains metallogenic belt[J]. Geology in China, 40(5): 1583−1599 (in Chinese with English abstract).

Zheng Quanbo, Su Hang, He Peng, Zhang Yuelong, Zheng Tao. 2019. The prospecting criteria of Mn-Ag-lead-zinc polymetallic ore in Changtuxili area of Inner Mongolia[J]. Geological Survey and Research, 42(1): 37−44 (in Chinese with English abstract)

Zhong Mishan, Wang Zhongjiang, Ao Guang, Zhai Furong, Wang Fenli, Wang Qi, Tanchao, Yang Yunlai. 2017. Zircon U-Pb chronology and geochemical characteristics of the volcanic rocks from Erlanghe formation in Zhangguangcai range[J]. Geological Survey and Research, 40(3): 161−168 (in Chinese with English abstract).