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内蒙古月牙山幅 1∶50 000 地质图数据库

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摘要: 内蒙古月牙山幅（K47E015010）1∶50 000 地质图数据库是根据《区域地质调查技术要求（1∶50 000）》和《数字地质图空间数据库》技术标准，按照最新造山带填图思路，采用数字地质调查系统（DGSS），结合蛇绿构造混杂岩带 1∶10 000 大比例尺填图综合填绘而成。在充分利用 1∶200 000 区域地质、1∶50 000 矿产调查成果的基础上，结合 Spot、ETM、Aster 等多种遥感影像对构造及岩性边界不断验证，最终以构造格架为纲而成图，是北山地区以造山带理论指导填图的首批探索性成果图件之一。图件详细填绘了白云山蛇绿岩的物质组成和构造组合特点，对中–新元古界、震旦系、寒武系、奥陶系、泥盆系沉积建造类型进行了重新划分，把图幅内侵入岩划分为中志留世、早泥盆世、晚泥盆世与早二叠世 4 个序列，并构建了相对完善的构造演化序列。本数据库是月牙山幅配套的数据文件，包含 3 个非正式填图单位、8 个正式地层单位、4 期岩浆事件和 4 期构造变形，数据量为 26.7 MB。采集薄片分析样品 358 件，岩石全分析样品 84 件，锆石 U–Pb 年龄样品 14 件，矿化点 2 处。这些数据反映了 1∶50 000 造山带地质调查示范性成果，对后续造山带填图具有参考和借鉴意义，同时细化了俯冲过程的构造、岩浆演化规律，对北山造山带早古生代演化具有重要的科学研究价值。

关键词: 内蒙古；月牙山幅；1∶50 000；地质图；数据库；中亚造山带；地质调查工程
数据服务系统网址: http://dcc.cgs.gov.cn

1 引言

中亚造山带是世界上最显著的显生宙增生型造山带之一（Sengör et al., 1993；李继亮, 2004；Xiao WJ et al., 2010）。位于西伯利亚板块、哈萨克斯坦板块与塔里木板块的结合部位的北山造山带（图 1A），是研究中亚造山带演化的关键地区（左国朝等, 2003；何世平等, 2002；杨合群等, 2010；Xiao WJ et al., 2010；王国强等, 2014；Song DF et al., 2015；Zheng RG et al., 2018；Yuan Y et al., 2018；牛文超等, 2019）。自古生代以来，北山造山带经历了多期俯冲拼贴过程，物质组成与构造组合复杂,自南向北依次

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可识别 4 条主要构造带（何世平等, 2002；杨合群等, 2010；图 1B）：①辉铜山–帐房山–玉石山蛇绿构造混杂岩带（余吉远等, 2012）；②红柳河–牛圈子–洗肠井蛇绿构造混杂岩带；③石板井–小黄山深大断裂（陈超等, 2017）；④红石山–百合山蛇绿构造混杂岩带（Ao SJ et al., 2012；王国强等, 2014；牛文超等, 2019）。在牛圈子–洗肠井蛇绿岩中，虽有晚志留世–早泥盆世辉长岩的存在（Wang XY et al., 2018），但更多辉长岩与斜长花岗岩的年龄集中于晚寒武世–早奥陶世（530 ~ 516 Ma；张元元和郭召杰, 2008；侯青叶等, 2012；Tian ZH et al., 2014；胡新茁等, 2015；孙立新等, 2017），考虑斜长花岗岩的高 Sr、低 Y 的特征指示其可能晚于蛇绿岩的形成时间（彭银彪等, 2018），因此红柳河–牛圈子–洗肠井蛇绿岩的初始形成时限应不晚于早古生代，其形成与演化无疑是北山造山带研究的关键，但目前来看，其演化特别是晚古生代的演化过程还存在争议。

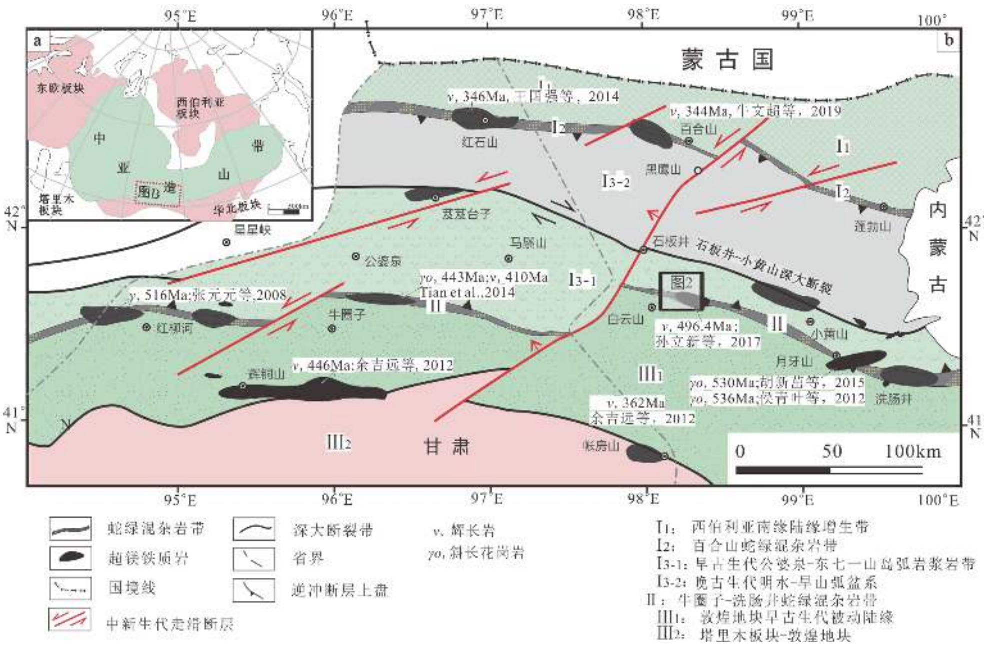

图 1　内蒙古北山造山带大地构造位置图（a）及北山地区蛇绿构造混杂岩带时空分布略图（b）（据杨合群等, 2010；Xiao WJ et al., 2010；牛文超等, 2019 改编）

北山南带早泥盆世 A 型花岗岩的发现（李舢等, 2009；Wang SD et al., 2018）及公婆泉早泥盆世花岗岩的地球化学研究揭示（郑荣国等, 2012），牛圈子洋的俯冲在早泥盆世已经结束；而对石板井晚泥盆世埃达克质花岗岩的研究（王鑫玉等, 2018），结合晚泥盆世墩墩山组陆缘弧火山岩的特征（Guo QQ et al., 2014；田健等, 2020b），显示该区晚泥盆世仍处在俯冲背景下，这样北山南带的晚古生代构造背景就存在矛盾。究其原因，一是目前缺乏对北山造山带结构的精细研究，另一是缺乏对造山带两侧沉积与构造变形研究认识（赵磊等, 2019）。

测区白云山蛇绿混杂岩位于红柳河–牛圈子蛇绿混杂岩中段，本次 1∶50 000 区域地质工作围绕白云山蛇绿混杂岩及其两侧古生代地质体展开调查，利用大比例尺填图、人工探槽及实测剖面等手段，详细揭示了白云山蛇绿混杂岩带的物质组成及构造组合样式，特别是对早泥盆世三个井组、晚泥盆世墩墩山组的厘定，填补了白云山地区晚泥盆世地层研究的空白。该数据集是该成果的集中体现，对研究北山造山带结构及古生代演化具有重要参考价值。

本区最早于 1971 年由甘肃省地质局第二区域地质测量队完成的 1：200 000 石板井幅区域地质测量❶，并对区内的地层格架、岩浆活动、构造演化等方面做了全面、系统地总结。2008–2010 年，中国地质调查局西安地质调查中心完成了内蒙古月牙山地区矿产远景调查的工作，工作区涉及本区月牙山幅❷；2014–2017 年，陕西省地质调查中心完成了邻区风化梁幅等 4 幅 1：50 000 区域矿产地质调查工作❸；2016–2018 年中国地质科学院地球物理地球化学勘查研究所开展内蒙古黑鹰山地区 4 幅 1：50 000 矿产地质调查项目的工作涵盖本区❹。这些调查工作为本文月牙山幅地质图的编制奠定了扎实基础。

月牙山幅 1：50 000 地质图作为北山造山带填图的探索性图件之一，力争在客观表达野外地质事实的基础上，结合前人地质调查、矿产勘查以及科研新成果，采用洋板块地层及造山带（蛇绿）构造混杂岩带填图思路（李荣社等, 2016；闫臻等, 2018），利用造山带构造解析手段（白瑾, 2003），精细刻画白云山蛇绿混杂岩早古生代地质构造演化过程，为野外地质调查和科研工作提供有益的参考资料。数据库（田健等, 2020a）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	内蒙古月牙山幅1：50 000地质图数据库
数据库（集）作者	田　健，中国地质调查局天津地质调查中心 辛后田，中国地质调查局天津地质调查中心 段霄龙，中国地质调查局天津地质调查中心 程先钰，中国地质调查局天津地质调查中心 张　永，中国地质调查局天津地质调查中心 任邦方，中国地质调查局天津地质调查中心 李　敏，中国地质调查局天津地质调查中心
数据时间范围	2017–2018年
地理区域	地理坐标：东经 98°15′ ~ 98°30′，北纬 41°30′ ~ 41°40′
数据格式	*.wp, *.wl, *.wt
数据量	26.7 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“阴山成矿带小狐狸山和雅布赖地区地质矿产调查”（项目编号：DD20160039）资助
语种	中文
数据库（集）组成	月牙山幅1：50 000地质图数据库包括：1：50 000地质图库和图饰。地质图库包括沉积岩、岩浆岩、变质岩、第四纪、脉岩、构造、地质界线、产状、矿化（点）、蚀变、岩性花纹、各类代号等。图饰包括：接图表、综合柱状图、图例、图切剖面、构造纲要图、地质演化史、大地构造位置图、责任表

2　数据采集和处理方法

2.1　数据基础

内蒙古月牙山幅 1：50 000 地质图以《1：50 000 区域地质调查技术要求》（DD 2006-XX）为规范，在参考黑鹰山地区 4 幅 1：50 000 矿产地质调查项目原始资料（包括地质草图、遥感解译影像）的基础上，根据项目野外实际资料（实际材料图、剖面图）重新填图而成，代表月牙山幅 1：50 000 最新地质填图新成果。地理底图采用国家

测绘地理信息局最新地理数据。应用数字填图系统（DGSS）和 MapGIS 等计算机软件进行数据处理。

2.2 数据处理过程

2.2.1 预研究数据库

预研究数据库主要包括各类遥感影像、卫星影像、磁异常图件、化探异常图件，各类图件经核查可用后，校正配准套在 1∶50 000 标准图框及数字地形中，形成野外工作底图（投影系统为高斯–克吕格投影参数，坐标系统为西安 80 坐标系）。进一步结合收集的 MapGIS 版矿产地质图，编制预研究地质图，所有子图号、岩石代号均按照《1∶50 000 区域地质图图例》(GB 958–99) 进行标准化。在此基础上编制工作部署图，初步划分野外填图单位、编制数字填图字典库，供野外地质调查参考使用。

2.2.2 野外原始数据库

根据已有资料的综合分析和地质草图的编制，划分重点工作区和一般工作区，确定了重点填图内容为白云山蛇绿构造混杂岩带，并对复杂区部署了 1∶10 000 大比例尺填图区。原始数据库整体又可分为数字填图资料和数字剖面库。

数字填图资料以 1∶25 000 底图为基础，通过野外实际路线调查，在数字填图系统中采集地质点、界线点和地质界线及路线等点、线信息，观察并录入各点的性质、岩性、地质体产状等信息，形成野外手图。野外手图库存储野外地质路线各类地质数据，是最重要的野外第一手原始资料数据库。在野外手图库检查无误的基础上，对所有地质路线内容进行入库汇总整合，形成野外 PRB 总图库（野外数字地质路线调查过程分解为地质定点–P、分段路线–R、点和点间界线–B 过程，简称 PRB 填图过程（李超岭等, 2003）。对野外手图中存在问题的地方，适当进行野外补课，确保野外手图真实、客观。在此基础上将实体观测数据点、线采集层及标注图层进一步添加到实际材料图库中。对于特殊构造变形现象、接触关系等重要现象应进行简单的处理与描述，对测量的构造变形要素应分类统计，保证信息的完备性。

数字剖面库采用数字剖面测量方式进行，以野外工作手图为底图，在充分踏勘的基础上，选择出露完整的地段进行。野外逐层分层进行，记录岩性、样品、产状、照片、构造变形等信息，并在野外记录簿上相应做信手剖面图，均按系统自动生成的文件名及根据需要自定义文件名进行存储。一般在测量完整剖面后，由剖面的记录者进行剖面的初步整理和野外小结，结合室内薄片鉴定，画剖面图及剖面柱状图。

2.2.3 成果空间数据库

空间数据库包括基本要素类、综合要素类、对象类和独立要素类数据集。其中要素数据集是共享空间参考系统的要素类的集合，在地质图数据模型中，由地质点、面、线实体类构成。对象类是一个表，存储非空间数据，在地质图数据模型中，一般一个要素类对应多个对象类。地质图基本要素类、综合要素类和对象类各数据项属性齐全。

成果数据库建设内容和有关要求将依据《数字化地质图图层及属性文件格式》(DZ/T 0197–1997)、《地质图空间数据库建库工作指南（2.0 版）》等标准进行图形库和属性库等的建设，参照《地质图用色标准及用色原则》(DZ/T 0179–1997)、《区域地质图图例》(GB958–99)、《区域地质调查技术要求（1∶50 000）》(DD 2019–01) 等标准确定用色、图饰、图例和符号等的表达。为加强地质资料信息公开化建设，在参考已有出版地质图数据库的基础上（王春女等, 2019），去除地理底图等相关涉密信息（郑锦娜等, 2018），形成公开版的数据库（图 2）。

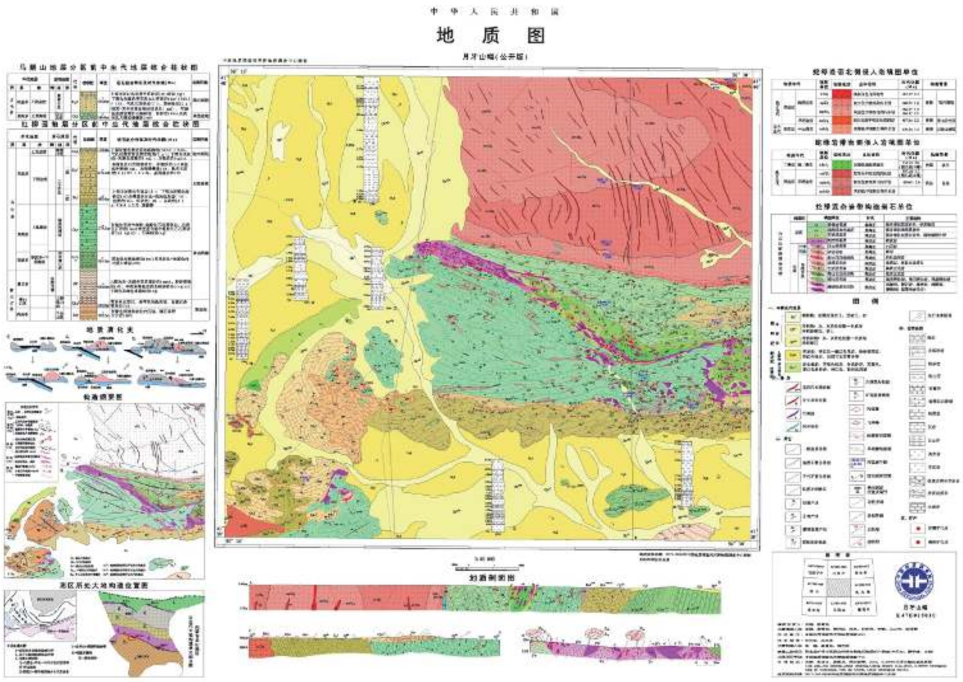

图 2　内蒙古月牙山幅 1：50 000 地质图（公开版）示意图

2.2.4　编制各类角图

（1）蛇绿混杂岩带构造岩石单位：不同于传统地层单位，蛇绿混杂岩整体无序、呈“岩块–基质”典型网结状分布特征，在填图实践中“岩块”和“基质”分别指弱变形变质、具刚性部分和强变形变质、具韧性部分，主要依据野外岩石类型（参考岩石地球化学）及构造变形特征来划分不同类型。

（2）综合柱状图：以蛇绿混杂岩带为界，分别对南、北 2 个地层分区内的岩石地层单元沉积建造特征进行详细表达。系统梳理图幅内各地层单元地层层序、沉积建造特征，结合锆石测年资料，综合反映其沉积背景及时代属性。

（3）侵入岩填图单位：以蛇绿混杂岩带为界，在北侧识别出 3 期岩浆演化序列：①中志留世以发育透入性片麻理的石英闪长岩为代表的俯冲期岩石（约 430 Ma）；②早泥盆世以块状正长花岗岩为代表的造山后伸展期岩石类型（约 407 Ma）；③晚泥盆世以块状花岗闪长岩及其专属岩脉（366 ~ 360 Ma）为代表的陆内裂陷期岩石类型；在南侧识别出早泥盆世以石英闪长岩、英云闪长岩及花岗闪长岩为代表的俯冲背景及晚二叠世（290 ~ 255 Ma）以辉绿岩为代表的板内伸展（Kang L et al., 2019）2 期岩浆岩浆演化序列。

（4）图切剖面：图幅内建造和构造的总体走向为近东西向，为直观表达区内各地质体接触关系及空间位态，提供 3 条图切剖面：①蛇绿岩大比例尺剖面，结合野外探槽编录，详细反映蛇绿构造混杂岩带物质组成及内部叠置特征；②纵贯全区的南北剖面，主要控制白云山蛇绿构造混杂岩及其两侧古生代地质体的空间位态；③西南部局部设置的剖面，主要反映中上元古界自南向北逆冲至蛇绿构造混杂岩带之上，三条图切剖面基本显示出本图幅内各地质体之接触关系。

（5）构造纲要图：构造混杂岩带的形成一般经历了俯冲增生、碰撞消减、碰撞后叠加改造等主要过程，在野外调查不同阶段的构造几何学、运动学特征及空间分布的基

础上，划分构造层，确定主要构造组合，建立构造变形序列，通过构造形成的动力学分析，推断构造混杂岩带的形成和就位过程，并在构造纲要图上借助不同符号和颜色将不同期构造形迹展现出来。

（6）大地构造位置图：展现了月牙山幅在区域大地构造中所处的位置及其大地构造单元划分情况。本图是在在阴山成矿带二级项目北山 1∶250 000 地质图基础上，根据地层、岩浆岩及蛇绿混杂岩带展布情况，重新梳理划分而成，表达白云山蛇绿混杂岩带是测区一级构造单元界线，两侧同期沉积的古生代地层不同的大地构造相，体现了北山洋早古生代北向俯冲的弧–盆沉积体系建造。

（7）地质演化史：根据区内的地层、岩浆岩、变质岩和构造特征，结合区域地质对比编制而成，主要包括古生代大洋形成（Є）、初始俯冲（O_1–S_1）、俯冲峰期（S_2）、白云山洋闭合拼贴（S_3–D_1）、南侧洋俯冲（D_1）、陆缘弧（D_3）等 6 个完整演化阶段，直观反映出古生代不同地质体的时空演化与产出背景。

（8）其他：对脉岩、地质代号、地质符号及岩性花纹进行梳理，编制图例、责任表及引文格式。

3　数据样本描述

3.1　数据的命名方式

地质面.wp，地质线.wl，地质点.wt。

3.2　图层内容

主图内容包括蛇绿构造混杂岩、沉积岩、火山岩、侵入岩、第四系、构造形迹、地质界线、产状、各类代号等。

角图内容包括地层综合柱状图、侵入岩填图单位、图切剖面、构造纲要图、大地构造位置图及地质演化史。

其他内容包括图例、接图表、责任表及引文格式等。

3.3　数据类型

实体类型名称：点、线、面。

点实体：各类地质体符号及标记、地质花纹、矿化蚀变。

线实体：断裂构造、地质界线、岩相界线、构造界线及特殊标志层花纹等。

面实体：沉积岩、火山岩、变质岩、侵入岩、第四系等。

3.4　数据属性

月牙山幅（K47E015010）1∶50 000 地质图数据库包含地质实体要素信息、地理要素信息和地质图整饰要素信息。地理要素信息属性沿用国家测绘地理信息局收集数据的属性结构。地质实体要素信息属性按照 1∶50 000 区域地质调查专项地质填图数据库建库要求分四大岩类（沉积岩、火山岩、侵入岩、变质岩）、断裂构造、产状要素、矿产地等分别建立数据库属性。

沉积岩建造数据属性主要有：年代地层单位、岩石地层单位、建造名称、建造代码、岩性组合、地层时代、建造厚度、建造含矿性、岩石结构、沉积构造、岩石颜色、沉积作用类型、沉积相类型、同沉积构造。

火山岩建造数据属性主要有：年代地层单位、岩石地层单位、建造名称、建造代码、地层时代、地层分区、岩性组合、建造厚度、建造含矿性、火山喷发旋回、火山喷发类型、火山岩成因类型、特殊岩性夹层、火山岩相类型、同位素年龄。

侵入岩建造数据属性主要有：建造名称、建造代码、岩性组合、建造含矿性、岩石结构、岩石构造、侵入期次、岩体产状、平面形态、剖面形态、岩体侵位构造特征、接触带特征、成因类型、同位素年龄。

变质岩建造数据属性主要有：年代地层单位、岩石地层单位、建造名称、建造代码、岩性组合、地层时代、建造厚度、建造含矿性、岩石结构、岩石构造、原岩建造、变质相、变质作用类型。

断裂构造数据属性主要有：断裂名称、断裂类型、断裂延长、断裂延深、断裂宽度、断裂走向、断裂面倾向、断裂面倾角、断距、断裂面形态、构造岩特征、运动方式、活动期次、力学性质。

产状数据属性有：产状类型、倾向、倾角。

4　数据质量控制和评估

填图精度总体按照《区域地质调查技术要求（1∶50 000）》（DD2006–XX）标准进行，野外填图工作围绕造山带等关键地质问题重点开展。项目组对基岩区采取加密地质路线调查，对中新生代地层区采取遥感解译为主、野外验证为辅的方式进行，在蛇绿混杂岩带布设了1∶10 000大比例尺填图，取得了很好的成果。其中地质点布设以充分控制地质体接触关系、重大构造边界、构造变形、特殊岩性等重要地质界线为原则。

为填绘月牙山幅1∶50 000地质图，野外实测入库路线389.75 km，地质点数598个，地质界线数1 873个，薄片鉴定样品358件，岩石全分析样品84件，锆石U–Pb年龄样品14件（9件岩浆锆石测年样品，5件碎屑锆石测年样品），照片1 400张，实测1∶2 000地层剖面约30 km。平均651.76 m路线含1个地质点，平均157.73 m路线含1个地质点或点间界线，填图总体精度达到1∶50 000区域地质专项填图的具体要求。

图面表达一般只表达直径大于100 m的闭合地质体，宽度大于50 m、长度大于250 m的线状地质体，以及长度大于250 m的断层、褶皱构造。对蛇绿构造混杂岩带中特殊地质体，则采取适当放大、同类岩块合并的方式予以表达。一般地质点在野外手图上所标定的点位与实地位置误差不得大于25 m。

实验测试方面，薄片制片及鉴定、岩石粉末碎样及锆石挑选由廊坊河北区域地质调查院实验室完成，阴极发光（CL）图像在北京锆年领航科技有限公司的日本电子JSM–6510型扫描电镜上完成。锆石U–Pb测年在天津地质调查中心实验室利用激光剥蚀多接收器电感耦合等离子体质谱仪（LA–MC–ICPMS）完成（李怀坤等，2010）。同位素比值及元素含量数据处理采用软件ICPMSData–Cal 9.2完成（Liu YS et al., 2010），U-Pb年龄谐和图绘制和年龄加权平均值计算采用Isoplot/3.0完成（Ludwig KR et al., 2003）。全岩地球化学元素分析在天津地质调查中心实验室完成。主量元素在样品制成熔片后通过X射线荧光光谱法（XRF）测试，相对误差在元素丰度大于1.0%时约为1%，元素丰度小于1.0 %时约为10%；FeO采用氢氟酸、硫酸溶样、重铬酸钾滴定容量法，分析误差优于2%，微量元素测试在7500型感应耦合电浆质谱仪上采用ICP–MS法完成，样品测定值和推荐值的相对误差小于10 %，绝大多数值在5%以内。

数据质量方面，填图路线自检、互检达100%，项目组抽检30%，符合地质调查项目质量管理要求。中国地质调查局天津地质调查中心分别于2017年9月、2017年12月、2018年6月组织有关专家，在野外及室内对原始资料、成果进展进行了质量检查；于2018年9月底组织专家采用室内与野外现场相结合的方法对项目进行了验收，评定为优秀级，并推荐月牙山幅参加全国区域地质调查优秀图幅展评（毛晓长, 2018）；于2019年1月组织数据库专家对内蒙古1∶50 000月牙山幅（K47E015010）空间数据库进行了评审，综合评分90分，为优秀级。

5 数据价值

内蒙古月牙山幅（K47E015010）1∶50 000地质图是中国地质调查局开展新一轮地质调查工作的代表性图幅之一。该地质图在深入研究本图幅内岩石组合、层序及构造变形的基础上，以最新的造山带填图思路为指导（李荣社等, 2016；闫臻等, 2018），按照最新《区域地质调查技术要求（1∶50 000）》（DD 2019–01）要求，不断完善图面结构与布局。以岩块–基质形式精确表达了白云山蛇绿岩带的物质组成，识别出纯橄岩、二辉橄榄岩、辉石岩、异剥辉石橄榄岩、辉长岩、玄武岩及硅质岩大洋岩石圈岩块和灰岩、砂岩等外来岩块。特别是在白云山中部一带识别出保留较好、层序向北依次变新的堆晶橄榄岩、堆晶辉石岩、堆晶辉长岩、斜长花岗岩、枕状玄武岩、硅质岩构成的洋壳残块。

主要特色是以造山带古生代结构为纲，以白云山蛇绿构造混杂岩一级构造单元为界，对两侧古生代地层（表2）、侵入岩（表3）进行了重新梳理划分，详细划分了沉积建造与岩石组合类型。通过两侧沉积建造、岩浆岩岩石组合及时代并结合构造变形组合特征，综合建立了白云山蛇绿岩带晚奥陶世–早志留世的俯冲期（450～430 Ma）、晚志留世–早泥盆世的拼贴碰撞期（415～407 Ma）、晚泥盆世的陆内（缘）裂陷局部伸展期（370～360 Ma）及晚三叠世（290～255 Ma）板内伸展4期构造–岩浆演化序列。

综上，本数据集为北山造山带中南带的地质工作提供基础数据支撑，发挥科技创新引领作用，以相对完善的造山带结构解析，提升了地质调查工作服务重大科学问题与资源安全的能力。

6 数据使用方法和建议

1∶50 000地质图空间数据库包括基本要素类、综合要素类、对象类和独立要素类数据集。需在数字地质调查系统（DGSS）中配套使用，利用DGSS新建1∶50 000标准分幅，然后将数据集放置于图幅下的空间数据库文件夹即可，所用系统库（Slib）为DGSS标准库。

需要说明的是，要素数据集是共享空间参考系统的要素类的集合，在地质图数据模型中，由地质点、面、线实体类构成；对象类是一个表，存储非空间数据，在地质图数据模型中，一般一个要素类对应多个对象类。地质图基本要素类、综合要素类和对象类各数据项属性齐全，现就本数据集对应的要素类和对象类列表如下（表4）。

除上述各要素图层外，另有断层符号（A_GEOLINE.wt）、地质体面实体引线（A_GEOLINE.wl）、地质体代号与岩性花纹（A_GEOPOLYGON.wt）、产状标注（A_ATTITUDE.wt）、同位素年龄值（A_ISOTOPE.wt）、图切剖面线（A_PROFILE）、

表 2　白云山蛇绿混杂岩带两侧地层沉积建造一览

时代			本数据集			厚度/m	建造
代	纪	世		塔里木地层大区	兴蒙–天山地层大区		
新生代	第四纪	全新世	天山地层区	冲积物、冲洪积物、风积物（$Qh^{al+alp+l}$）		>2.82	松散堆积物
	新近纪	上新世		苦泉组（N_2k）		>9.6	陆内湖泊沉积建造
中生代	白垩纪	早白垩世		赤金堡组（$K_1\hat{c}$）		>7.12	陆内拉分盆地沉积建造
古生代	泥盆纪	晚泥盆世		墩墩山组（D_3d）		>575.0	陆内裂陷盆地火山岩建造
		早泥盆世		三个井组（D_1s）		>445.6	大陆斜坡火山岩+碎屑岩建造
	奥陶纪	晚奥陶世		a.晚奥陶世锡林柯博组（O_3x）	b.晚奥陶世白云山组（O_3b）	a.>1374.1 b.>146.9	a被动陆缘碎屑岩建造 b弧前盆地碎屑岩+碳酸盐岩建造
		中奥陶世					
		早奥陶世		罗雅楚山组（O_1l）		>471.9	被动陆缘碎屑岩建造 上部被动陆缘硅质岩+碳酸盐岩建造
	寒武纪	中–晚寒武世		西双鹰山组（ϵO_1x）		>518.5	
		早寒武世					底部被动陆缘深水硅质岩建造
元古代	震旦纪			洗肠井群（Z*X*）		>984.9	底部冰碛砾岩建造；上部细碎岩屑建造
	青白口纪			大豁落山组（Qb*d*）		>93.9	陆表海碳酸盐岩建造

表 3　白云山蛇绿构造混杂岩带两侧侵入岩演化序列一览

时代	区域分带	填图单位	岩石类型	同位素年龄/Ma	构造背景
晚二叠世	全区	$x\beta\mu P_3$	灰绿色细粒辉绿岩	255.2±2.9	板内伸展
晚泥盆世	北侧	$z\gamma\delta D_3$	中粒花岗闪长岩	360.7±1.6	陆缘弧
		$zx\gamma\delta D_3$	中细粒花岗闪长岩	366.2±1.8；366.2±2.1	
	中部		白云山蛇绿构造混杂岩		
	南侧	$zx\xi\gamma D_3$	中细粒正长花岗岩	375.4±3.5	陆内局部裂陷
早泥盆世	北侧	$xz\xi\gamma D_1$	细中粒正长花岗岩	407.4±2.2	造山后拉张
	中部		白云山蛇绿构造混杂岩		
	南侧	$zx\gamma\delta D_1$	中细粒花岗闪长岩	397.0±1.7	岛弧
		$x\gamma\delta o D_1$	细粒英云闪长岩	404.6±2.6	
		$zx\delta o D_1$	中细粒石英闪长岩		
中志留世	全区	$zx\delta o S_2$	中细粒石英闪长岩	430.2±3.5	俯冲大陆边缘弧

表 4　内蒙古 1：50 000 月牙山幅地质图空间数据库要素类和对象类一览

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）	738	沉积（火山）岩岩石地层单位（_STRATA）	包括平头山组等14个地层单位	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）	2006					综合柱状图（COLUMN_SEC）
产状（_ATTITUDE.wt）	411	侵入岩岩石年代单位（_INTRU_LITHO_CHRONO）	志留纪、泥盆纪等8个填图单元	构造变形带（_TECTZONE.wp）	韧性断层	图切剖面（CUTTING_PROFILE）
样品（_SAMPLE.wt）	115	脉岩（_DIKE_OBJECT）	不同岩性脉岩共计4类	火山岩相带（_VOLCA_FACIES.wp）	三个井组墩墩山组火山岩	责任表（DUTY_TABLE）
照片（_PHOTOGRAPH.wt）	1400					图例（LEGEND）
素描（_SKETCH.wt）	6	断层（_FAULT）	本图幅共44条	变质岩相带（_METAMOR_FACIES.wp）	区域变质带	构造辅图（TECTONIC_MAP）
化石（_FOSSIL）	0					
同位素测年（_ISOTOPE.wt）	14					垂向剖面图（VERTICAL_PROFILE）
火山口（_CRATER.wt）	1	图幅基本信息（_SHEET_MAPINFO）	从标准图框中提取			

构造辅图（TECTONIC_MAP）及标注等没有属性内容的地质整饰图层，读者可自行选择打开或关闭相应图层。

7 结论

（1）内蒙古月牙山幅（K47E015010）1：50 000 地质图是中国地质调查局新一轮地质调查的代表性图幅之一，以造山带结构及蛇绿（构造）混杂岩带填图理论为指导，采用构造-岩性填图方式提升成果表达方式，对区域地质调查特别是造山带填图起到了示范作用。

（2）以中国地质调查局最新技术要求为标准，全面系统编制了月牙山幅（K47E015010）1：50 000 地质图并建立了空间数据库，完善并规范了各类地质信息的表达。

（3）结合前人资料和本次研究成果，明确白云山蛇绿混杂岩带为北山地区早古生代一级大地构造单元边界。通过野外沉积建造、构造变形序列研究，结合岩石地区化学及年代学测试资料，系统建立了白云山蛇绿岩带晚奥陶–早志留世的俯冲期（450 ~ 430 Ma）、晚志留–早泥盆世的拼贴碰撞期（415 ~ 407 Ma）、晚泥盆世的陆内裂陷局部伸展期（370 ~ 360 Ma）3 期造山带相关构造岩浆演化序列。

致谢：内蒙古月牙山幅 1：50 000 地质图是一项集体成果，项目组一线地质工作人员付出了辛勤的努力。在地质图填绘及数据库建立过程中，得到谷永昌教授级高工、李承东研究员等多位专家辛勤指导，河北省区域地质调查院王占立与赵泽南参加部分野外工作，在此对各位专家和野外工作人员表示最诚挚的感谢。

注释:

❶ 甘肃省地质局第二区域地质测量队. 1972. 甘肃省石板井幅 1：200 000 区域地质测量报告.

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1∶50 000 Geologic Map Database of Yueyashan Map Sheet, Inner Mongolia

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Abstract: The 1∶50 000 geologic map database of Yueyashan map sheet (K47E015010), Inner Mongolia (also referred to as the Database) was comprehensively mapped and prepared according to the technical standards *Technical Requirements for Regional Geological Survey (Scale: 1∶50 000)* and *Spatial Database Establishment Code of Digital Geologic Maps*. In this case, the latest mapping ideas of orogenic belts were followed, a digital geological survey system (DGSS) was adopted, and the 1∶10 000 large-scale mapping of ophiolitic melange belts were combined. Furthermore, the structural and lithologic boundaries in Yueyashan map sheet were continually verified by making full use of the results of 1:200 000-scale regional geological surveys and 1∶50 000-scale mineral surveys as well as the remote sensing images of multiple types such as Spot, ETM, and Aster. As a result, the geologic maps in the Database were finally prepared according to the structural framework of the map sheet, and serve as part of the first-batch exploratory results mapped under the guidance of orogeny theory in Beishan area. In this Dataset, the material composition and structural association characteristics of the Baiyunshan ophiolites were plotted in the maps in detail, the sedimentary formations of the middle Neoproterozoic, Sinian, Cambrian, Ordovician, and Devonian were reclassified, the intrusions in the map sheet were divided into four sequences (i.e., the middle Silurian sequence, early Devonian sequence, late Devonian sequence, and early Permian sequence), and a comparatively complete tectonic evolution sequence was also established. This Database consists of the data and files of Yueyashan map sheet, including the data of three informal mapping units, eight formal stratigraphic units, four stages of magmatic events, and four stages of tectonic deformation, with a size of 26.7 MB. In addition, three hundred fifty-eight samples for thin slice petrographic observation, eighty-four samples for whole-rock geochemistry

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analysis and fourteen samples for zircon U–Pb dating were collected, and two mineralized sites were discovered in this work, all of which were also integrated into the database. These data reflect the demonstrative results of a 1 : 50 000-scale geological survey of an orogenic belt, and can be used as a reference for subsequent mapping of orogenic belts. In addition, tectonic and magmatic evolutionary history of the subduction process was highlighted in the data, which is of scientific research value for the early Paleozoic evolution of Beishan orogenic belt.

Key words: Inner Mongolia; Yueyashan map sheet; 1 : 50 000; geologic map; database; CAOB; geological survey engineering

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

1 Introduction

The Central Asian Orogenic Belt (CAOB) is one of the world's most prominent Phanerozoic accretion-type orogens (Sengör et al., 1993; Li JL, 2004; Xiao WJ et al., 2010). The Beishan orogenic belt, which is located at the junction of the Siberian plate, Kazakhstan plate, and Tarim plate (Fig. 1A), is a key area for studying the evolution of CAOB (Zuo GC et al., 2003; He SP et al., 2002; Yang HQ et al., 2010; Xiao WJ et al., 2010; Wang GQ et al., 2014; Song DF et al., 2015; Zheng RG et al., 2018; Yuan Y et al., 2018; Niu WC et al., 2019). It has undergone multiple stages of subduction and amalgamation processes since the Paleozoic, leaving complex material compositions and tectonic association. Four major tectonic zones can be successively identified in it from south to north (He SP et al., 2002; Yang HQ et al., 2010; Fig.1b): (i) Huitongshan-Zhangfangshan-Yushishan ophiolitic melange belt (Yu JY et al., 2012); (ii) Hongliuhe-Niujuanzi-Xichangjing ophiolitic melange belt; (iii) Shibanjing-Xiaohuangshan deep fault (Chen C et al., 2017); (iv) Hongshishan-Baiheshan

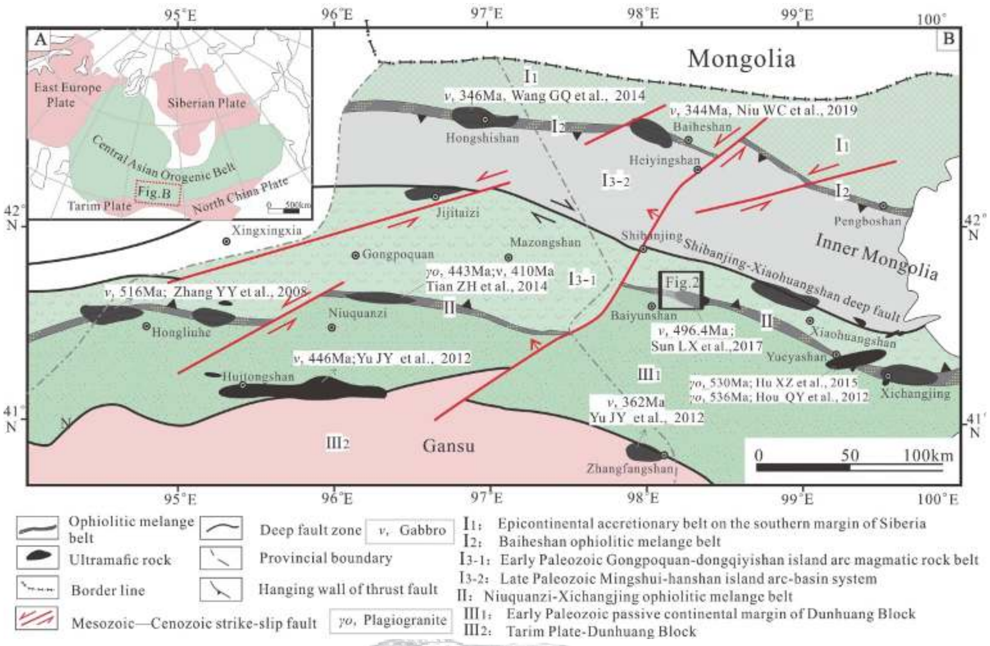

Fig. 1 Geotectonic location map of the Beishan orogenic belt (a) and generalized map of temporal and spatial distribution of ophiolitic melange belts in Beishan area (b) in Inner Mongolia (modified after Yang HQ et al., 2010; Xiao WJ et al., 2010; Niu WC et al., 2019)

ophiolitic melange belt (Ao SJ et al., 2012; Wang GQ et al., 2014; Niu WC et al., 2019). In Niujuanzi-Xichangjing ophiolite, although there exists late Silurian-early Devonian gabbros (Wang XY et al., 2018b), more gabbros and plagiogranites were mainly formed during the late Cambrian-early Ordovician (530–516 Ma; Zhang YY et al., 2008; Hou QY et al., 2012; Tian ZH et al., 2014; Hu XZ et al., 2015; Sun LX et al., 2017). The plagiogranites feature high Sr content and low Y content, indicating that they may be formed later than the ophiolites (Peng YB et al., 2018). Therefore, the initial formation time of Hongliuhe-Niujuanzi-Xichangjing ophiolites should not be later than the early Paleozoic, and thus the formation and evolution of this ophiolite belt certainly serve as the key to the study of Beishan orogenic belt. However, its evolution—especially the evolution process in the late Paleozoic—is still controversial at present.

As revealed by the discovery of early Devonian A-type granites in the south Beishan orogenic belt (Li S et al., 2009; Wang SD et al., 2018) and geochemical study of the early Devonian granites in Gongpoquan area (Zheng RG et al., 2012), the subduction of the Niujuanzi Ocean had ended in the early Devonian. In contrast, as indicated by the study of the late Devonian adakitic granites in Shibanjing area (Wang XY et al., 2018a), as well as the characteristics of the epicontinental-arc volcanics of the late Devonian Dundunshan Formation (Guo QQ et al., 2014; Tian J et al., 2020b), the south Beishan orogenic belt was still in the subduction background in the late Devonian. Therefore, the late Paleozoic tectonic background of the south Beishan orogenic belt is contradictory. One reason is the current lack of detailed research on the structure of the Beishan orogenic belt, and another reason is lack of research and understanding of sediments and tectonic deformation on both sides of the orogenic belt (Zhao L et al., 2019).

The Baiyunshan ophiolitic melange belt in the survey area is located in the middle section of Hongliuhe-Niujuanzi ophiolitic melanges. This ophiolitic melange belt and the Paleozoic geologic blocks on its two sides are the focus of the 1 ∶ 50 000-scale regional geological survey in this paper. With the aid of large-scale mapping, artificial trenching, and section (profile) surveying, the material composition and structure of the Baiyunshan ophiolitic melange belt were revealed in a detailed way. In particular, the early Devonian Sangejing Formation and late Devonian Dundunshan Formation were determined. All these fill in some blanks of the research on late Devonian strata in Baiyunshan area. The Database contains all these results and will serve as an important reference for future research on the structure and Paleozoic evolution of the Beishan orogenic belt.

Early in 1971, the 2nd Regional Geological Survey Team of Geological Exploration Bureau of Gansu Province conducted a 1:200,000-scale regional geological survey in Shibanjing map sheet❶, during which the stratigraphic framework, magmatic activities, and tectonic evolution in Shibanjing map sheet were summarized comprehensively and systematically. During 2008–2010, Xi'an Center of China Geological Survey completed a mineral prospect survey in Yueyashan area, Inner Mongolia, which covered Yueyashan map sheet❷. From 2014–2017, Shaanxi Mineral Resources and Geological Survey completed a

1∶50 000-scale regional mineral and geological survey in four neighboring map sheets including Fenghualiang map sheet[3]. During 2016–2018, the Institute of Geophysical and Geochemical Exploration of Chinese Academy of Geological Sciences carried out a 1∶50 000-scale mineral and geological survey project in four map sheets of Heiyingshan area, Inner Mongolia, which also covered Yueyashan map sheet[4]. All these surveys laid a solid foundation for the preparation of the geologic maps of Yueyashan map sheet in this paper.

The 1∶50 000 geologic map of Yueyashan map sheet is one of the exploratory maps of the Beishan orogenic belt. Besides making it objectively reflect field geological facts, great efforts were also made to finely depict the tectonic evolutionary process of early Paleozoic Baiyunshan ophiolitic melanges in the map by following mapping techniques of the strata of oceanic plates and (ophiolite) melanges of orogenic belts (Li RS et al., 2016; Yan Z et al., 2018). A structural analysis of orogenic belts (Bai J, 2003) is also employed based on previous geological survey results, mineral exploration results, and new findings. This will provide useful reference data for field geological surveys and scientific research. The brief metadata table of the Dataset (Tian J et al., 2020a) is shown in Table 1.

Table 1 Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	1∶50 000 Geologic Map Database of Yueyashan Map Sheet, Inner Mongolia
Database (dataset) authors	Tian Jian, Tianjin Center, China Geological Survey Xin Houtian, Tianjin Center, China Geological Survey Duan Xiaolong, Tianjin Center, China Geological Survey Cheng Xianyu Center, China Geological Survey Zhang Yong, Tianjin Center, China Geological Survey Ren Bangfang, Tianjin Center, China Geological Survey Li Min, Tianjin Center, China Geological Survey
Data acquisition time	2017–2018
Geographic area	Geographical coordinates: 98°15′–98°30′E, 41°30′–41°40′N
Data format	*.wp, *.wl, *.wt
Data size	26.7 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	A geological survey project titled *Geological and Mineral Survey of Xiaohulishan and Yabulai Areas, Yinshan Metallogenic Belt* initiated by China Geological Survey (No.: DD20160039)
Language	Chinese
Database (dataset) composition	The Database consists of 1∶50 000-scale geologic map databases and map decorations. A geologic map database includes sedimentary rocks, magmatic rocks, metamorphic rocks, the Quaternary, dikes, structures, geologic boundaries, attitude, deposits (mineralized points), alteration, lithologic patterns, and various codes. The map decorations consist of index map, synthetic histograms, legends, transverse cutting profiles, a geological structure outline map, geological evolutionary history, geotectonic location maps, and duty tables

2 Methods for Data Acquisition and Processing

2.1 Data Basis

The 1∶50 000 geologic map of Yueyashan map sheet, Inner Mongolia was remapped in accordance with *Technical Specification on 1∶50 000 Regional Geological Survey* (DD 2006-XX) based on field data obtained from this project (primitive data maps and profiles), during which the original data obtained from the 1∶50 000-scale mineral geological survey project of four map sheets in Heiyingshan area (including geologic draft maps and remote sensing interpretation and images) were referred to. It represents the latest 1∶50 000-scale geologic mapping results of Yueyashan map sheet. The geographic base map was prepared with the latest geographical data from National Administration of Surveying, Mapping and Geoinformation of China. The data were processed by using software such as DGSS and MapGIS.

2.2 Data processing

2.2.1 Pre-research Database

The pre-research database mainly includes various remote sensing images, satellite images, maps of magnetic anomalies, and maps of geochemical anomalies. After being verified as available, these maps were corrected and then were made to overlap a 1∶50 000-scale standard frame and digital terrain to form a field survey base map (projection system: Gauss-Kruger projection parameters, coordinate system: Xi'an 1980). Then the pre-research geologic maps were developed based on collected minerals and geologic maps in MapGIS format, with all sub-map numbers and rock codes being standardized in accordance with *Geological Symbols Used for Regional Geologic Maps (1∶50 000)* (GB 958-99). The pre-research database serves as the base for latter preparation of work deployment maps, preliminary division of field mapping units, and the development of digital mapping dictionary bases, thus providing references for the field geological survey.

2.2.2 Database of Original Field Data

Based on the comprehensive analysis of existing data and the preparation of geologic draft maps, the study area was divided into key survey sites and minor survey sites. Meanwhile, the key mapping zone was determined to be the Baiyunshan ophiolitic melange belt, and 1:10 000 large-scale mapping zones were deployed for complex areas. The database of original field data can be further divided into digital mapping data and digital profile databases as a whole.

Based on the 1∶25 000 base maps, the information of points and lines including geological points, boundary points, geological boundaries, and survey routes were collected through field route surveys. Meanwhile, information such as the features and lithology of the points as well as the attitude of geological blocks were observed and recorded. This information was input into the digital mapping system and thus freehand field maps were formed. The freehand field map database is used to store various geological data of field geological routes, and therefore, it is the most important database of first-hand original field data. After being verified correct, all the data from geological survey routes were input into a database for data gathering and integration. In this way, the general field PRB map database was formed. The field geological route survey process by digital means comprises three parts, namely determination of geological points (P), determination of segmented route (R), and formation of boundaries between points (B), and thus the process is abbreviated as PRB mapping process (Li CL et al., 2003). The freehand field maps should be made authentic and objective, and a supplementary field survey should be appropriately conducted in case of any problems with the maps. Then the layers of point and line data of geological blocks observed and the label layers were further added to the draft data map database. Important phenomena such as special structural deformation and contact relation should be processed and described, and statistics should be made for measured structural deformation factors according to their categories, in order to ensure full comprehension.

The digital profile database was established by means of digital profile surveys of the areas with complete outcrops selected after a full reconnaissance survey, with the freehand field maps as the base map. The field survey was conducted according to strata, during which information on the lithology, samples, attitude, photos, and structural deformation of each stratum was recorded. Meanwhile, freehand profiles were correspondingly prepared in field record books. All of these data were saved into files, with the filenames being automatically generated by the system or self-defined. Generally, after the survey of a complete profile, the recorder of the profile should conduct preliminary organization and field summary of the profile, and prepare profiles and histograms of the profile by combining indoor thin section identification.

2.2.3 Spatial Database of Results

The spatial database of results is composed of a feature class dataset, a complex class dataset, an object class dataset, and an independent feature class dataset. The feature class dataset is the collection of feature classes that share the same spatial reference system. In the data model of geological maps, it is composed of geological points, polygons, and lines. The object class dataset is a table used to store non-spatial data. One feature class corresponds to multiple object classes in general in the data model of geological maps. The attributes of the data items of the feature classes, complex classes, and object classes in geological maps should be filled in completely.

The spatial database was created as follows. The graphic databases and attribute databases in the spatial database were established in accordance with the standards including *Specification for Layers and Attributes Formats of Digital Geologic Maps* (D/Z 0197–1997) and *Guidelines for the Construction of Geologic Map Spatial Database* (Version 2.0). The colors, legends, and symbols in the geological maps were determined by referring to the standards such as *Standard and Principle of Coloring in Geologic Maps* (DZ/T 0179-1997), *Geological Symbols Used for Regional Geologic Maps(1：50 000)* (GB 958−99), and *Technical Requirements for Regional Geological Survey (Scale: 1：50 000)* (DD 2019−01). A public database (Fig. 2) was developed by referring to published geological databases (Wang CN et al., 2019) and deleting relevant confidential information such as geographic base maps

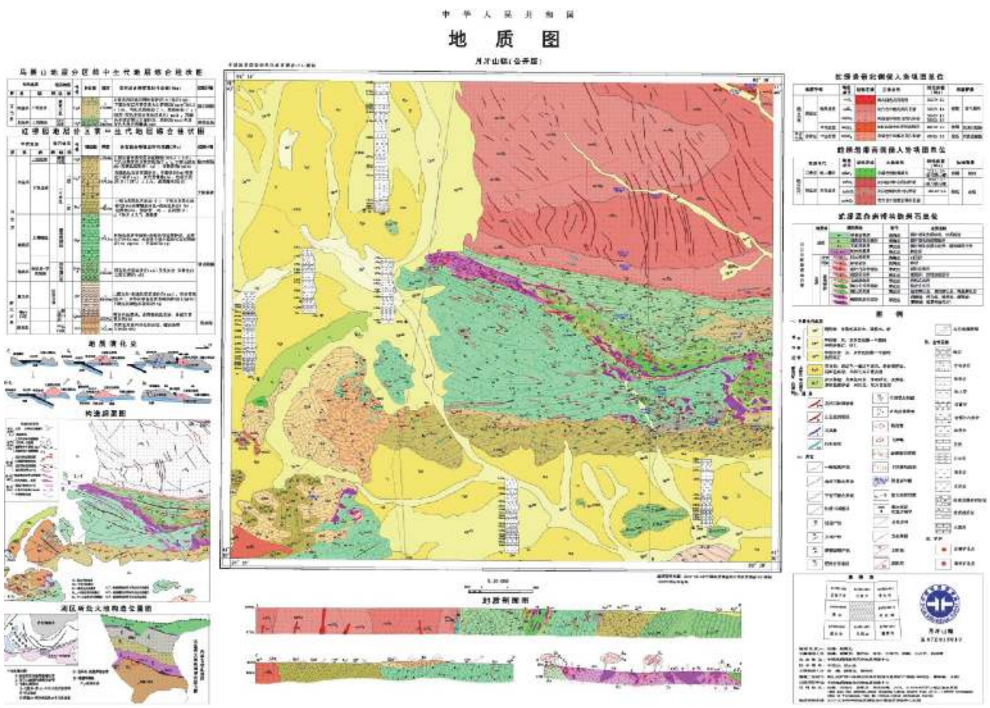

Fig. 2 1：50 000 geological map of Yueya map sheet, Inner Mongolia (for public)

(Zheng JN et al., 2018).

2.2.4 Preparation of Various Corner Maps

(1) Rock units of ophiolitic melange belts: Different from a traditional stratigraphic unit, the ophiolitic melanges are in disorder as a whole and are distributed in the form of the typical network of “rock blocks–matrix”. In mapping practice, the “rock blocks” refers to the rigid part with weak deformation and metamorphism, while the “matrix” refers to the ductile part with strong deformation and metamorphism. They are mainly classified according to field rock types (referring to petrogeochemistry) and structural deformation characteristics.

(2) Synthetic histograms: used to present in detail the sedimentary formation characteristics of the lithostratigraphic units in two stratigraphic zones, namely the northern part and southern part of the Baiyunshan ophiolitic melange belt. The stratigraphic sequences and sedimentary formation characteristics of individual stratigraphic units in the map sheet were systematically sorted. Furthermore, the sedimentary background and the eras were comprehensively reflected by combining zircon dating data.

(3) Mapping units of intrusions: The magmatic evolution sequences on the two sides of the Baiyunshan ophiolitic melange belt were identified as follows. Three stages of magmatic evolution sequences were identified on the northern side: ① the subduction period in the middle Silurian represented by the quartz diorites of which penetrative gneissic schistosity developed (about 430 Ma); ② the post-orogenic extensional period in the early Devonian represented by massive syenite granites (about 407 Ma); ③ the intracontinental rifting period in the late Devonian represented by massive granodiorites and their exclusive dikes (366–360 Ma). Two stages of magmatic evolution sequences were identified on the southern side, namely the subduction background in the early Devonian represented by quartz diorites,

tonalities, granodiorites and the intraplate extension period in the late Permian represented by diabases (290–255 Ma) (Kang L et al., 2019).

(4) Transverse cutting profiles: The formations and structures in the map sheet are generally in a nearly EW trend. Three transverse cutting profiles were provided to intuitively present the contact relationship and spatial positions of the geological blocks in the map sheet: ① a large-scale ophiolite profile, used to reflect in detail the material composition and internal superimposition characteristics of the ophiolitic melange belt based on field trenching records; ② a SN-trending profile passing through the whole map sheet, mainly used to control the spatial positions of Baiyunshan ophiolitic melange belt and Paleozoic geological blocks on the two sides of the belt; ③ a profile in the southwest, mainly used to reflect the middle-upper Proterozoic strata that was thrust onto the ophiolitic melange belt from south to north. These three transverse cutting profiles can basically represent the contact relationship of geological blocks within the map sheet.

(5) Geological structure outline map: a tectonic melange belt is generally formed as a result of subduction accretion, collision reduction, and post-collision superposition. Based on field surveys of the structural geometric and kinematic characteristics and spatial distribution of different stages in the map sheet, the structural layers were determined, main tectonic associations were determined, and the tectonic deformation sequences were established. Furthermore, the formation and emplacement process of the tectonic melange belt were inferred from dynamic analysis of tectonic formation. The tectonic traces at different stages were exhibited with different symbols and colors on the structure outline map.

(6) Geotectonic location map: used to present the location of Yueyashan map sheet in the regional geotectonic structure and the division of geotectonic units in the map sheet. It was prepared by re-sorting and division based on the 1:250,000 geological map of Beishan area, a secondary project of a project entitled *Geological and Mineral Survey of* Xiaohulishan *and Yabulai Areas, Yinshan Metallogenic Belt,* as well as the distribution of strata, magmatic rocks, and the ophiolitic melange belt. It shows that Baiyunshan ophiolitic melange belt is the boundary of the first-order tectonic units in the map sheet, and the Paleozoic strata contemporaneously deposited on both sides of the belt are of different geotectonic facies. These reflect the arc-basin sedimentary system as a result of the northward subduction of Beishan Ocean in the early Paleozoic.

(7) Geological evolution history: This was prepared according to the strata, magmatic rocks, metamorphic rocks, and tectonic characteristics in the map sheet as well as regional geological comparison. It mainly includes six complete evolutionary stages, namely the formation (Є), initial subduction (O_1–S_1), and subduction peak period (S_2) of Paleozoic oceans, the closing and splicing (S_3–D_1) of Baiyunshan Ocean, the subduction of the southern oceans (D_1), and epicontinental arc (D_3). Therefore, it intuitively reflects the spatio-temporal background of different Paleozoic geological blocks.

(8) Others: dikes, geological codes, geological symbols, and lithologic patterns were sorted out, and legends, duty tables, and citation formats were prepared.

3 Description of Data Samples

3.1 Naming of Data

.wp,.wl, and.wt are the suffixes of the files of geological polygons, geological lines, and geological points, respectively.

3.2 Contents in Maps

The contents in the master map include ophiolitic melanges, sedimentary rocks, volcanics, intrusions, the Quaternary, tectonic traces, geological boundaries, attitude, and various codes.

The corner maps include synthetic histograms, mapping units of intrusions, transverse cutting profiles, geological structure outline map, geotectonic location map, and geological evolution history.

Other contents include legends, index map, author information table, and citation formats.

3.3 Data Types

Entity types: points, lines, and polygons.

Point entities: symbols, labels, geological patterns, and mineralized alteration of various geological blocks.

Line entities: fault structures, geological boundaries, lithofacies boundaries, tectonic boundary, patterns of special label layers, etc.

Polygon entities: sedimentary rocks, volcanics, metamorphic rocks, intrusions, the Quaternary, etc.

3.4 Data Attributes

The Database includes data for geological entity elements, geographical elements, and decoration elements of geological maps. As for the attributes of the geographical elements, the attribute structure used for data collection by National Administration of Surveying, Mapping and Geoinformation of China was followed. The attributes of geological entity elements were created according to rocks of four major types (sedimentary rocks, volcanics, intrusions, and metamorphic rocks), fault structures, attitude elements, and mineral deposits according to the requirements for establishing databases of special geological mapping of 1：50 000-scale regional geological survey.

The data attributes of sedimentary rock formation mainly include: chronostratigraphic units, lithostratigraphic units, formation name, formation code, lithological association, stratigraphic eras, formation thickness, formation-related ore-bearing features, rock texture, sedimentary structure, rock colors, sedimentation type, sedimentary facies type, and synsedimentary structure.

The data attributes of volcanic rock formation mainly include: chronostratigraphic units, lithostratigraphic units, formation name, formation code, stratigraphic eras, stratigraphic division, lithological association, formation thickness, formation-related ore-bearing features, volcanic eruption cycle, volcanic eruption type, volcanic rock genesis type, special lithologic intercalations, volcanic facies type, and isotopic age.

The data attributes of intrusion formation mainly include: formation name, formation code, lithological association, formation-related ore-bearing features, rock texture, rock structure, intrusion stages, rock mass attitude, plane morphology, profile morphology, rock mass emplacement, tectonic features, contact zone characteristics, genetic type, and isotopic age.

The data attributes of metamorphic rock formation mainly include: chronostratigraphic units, lithostratigraphic units, formation name, formation code, lithological association, stratigraphic eras, formation thickness, formation-related ore-bearing features, rock texture, rock structure, protolith formation, metamorphic facies, and metamorphism type.

The data attributes of a fault structure mainly include: fault name, fault type, fault length, fault depth, fault width, fault strike, fault surface dip, fault surface dip angle, fault plane dip angle, fault throw, fault surface morphology, tectonic rock features, movement modes, activity stages, and mechanical properties.

The data attributes of attitude include: attitude type, dip, and dip angle.

4 Data Quality Control and Evaluation

The mapping accuracy was generally determined in accordance with *Technical Requirements for Regional Geological Survey (1∶50 000)* (DD 2006—XX). The field mapping focused on the key geological issues such as orogenic belts. Bedrock areas were surveyed along denser geological routes. The Mesozoic and Cenozoic strata were investigated primarily by remote sensing interpretation and secondarily by field verification. As for the ophiolitic melange belt, 1:10 000 large-scale mapping was arranged. The geological points were arranged on the principle that important geological boundaries including contact relationship between geological bodies, major tectonic boundaries, tectonic deformation, and special lithology were fully controlled.

The mapping and preparation of the 1∶50 000 geological map of Yueyashan map sheet involved 389.75 km of routes that were measured in the field and input to the database, 598 geological points, 1 873 geological boundaries, 358 samples for thin section identification, 84 samples for whole rock analysis, 14 samples for zircon U-Pb dating (nine for igneous zircons and five for detrital zircons), 1400 photos, and about 30 km of 1:2 000-scale strata profiles subjected to field survey. There was a geological point every 651.76 m along the routes and a geological point or boundary between points every 157.73 m on average. The overall mapping accuracy met the specific requirements for 1∶50 000-scale regional geology-specific mapping.

Generally, the contents to be presented on the map sheet only include sealed geological blocks with a diameter greater than 100 m, linear geological blocks with a width greater than 50 m and a length greater than 250 m, and fault and fold structures with a length greater than 250 m. Special geological blocks in the ophiolitic melange belt were expressed by appropriately zooming in or combining rock masses of similar type. Error in the location of a geological point (i.e., the difference between its location marked on the freehand field map and its actual location) should not exceed 25 m in general.

Relevant testing and analyses were conducted as follows. The preparation and identification of thin sections, crushing of rock samples, and zircon selection were completed at Hebei Institute of Regional Geological Survey, Langfang. Cathodoluminescence (CL) imaging was completed using a JSM-6510 scanning electron microscope (manufactured by JEOL of Japan) in Beijing GeoAnalysis Co., Ltd. The zircon U-Pb dating was completed at Tianjin Center, China Geological Survey using a laser ablation multiple collector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) (Li HK et al., 2010). Data processing of isotope ratios and element content was conducted using the software ICPMSData-Cal 9.2 (Liu YS et al., 2010), and the program Isoplot/3.0 was adopted to prepare U-Pb concordia diagram and to calculate the weighted average of the U-Pb zircon age (Ludwig KR et al., 2003). The whole rock geochemical analysis was completed at Tianjin Center, China Geological Survey. The major elements were determined by X-ray fluorescence (XRF) spectrometry after the samples were prepared as fused glass discs. The relative errors for major elements were about 1% when the element abundance was greater than 1.0%, and otherwise, they were about 10%. FeO was determined as follows. The rock samples were firstly dissolved using hydrofluoric acid and sulfuric acid. Then FeO was measured by titration —a type of volumetric analysis—using potassium bichromate, with the error lower than 2%. The trace elements were tested by using Agilent 7500 inductively coupled plasma mass spectrometer (ICP-MS), with relative errors between the measured values and recommended values generally smaller than 10% and mostly less than 5%.

As for the data quality, the self-check rate and mutual check rate of the survey routes for geological mapping were both up to 100%, and the rate of spot inspection conducted by the project team was 30%, meeting the requirements of quality management of geological survey projects. In September 2017, December 2017, and June 2018, Tianjin Center of China Geological Survey organized experts to conduct quality inspection on the original data and results in the field and indoor. At the end of September 2018, it organized experts to conduct acceptance checks on this project through indoor inspection combined with field inspection and the project was ranked excellent. Furthermore, Yueyashan map sheet was recommended to be included in a national exhibition and review of excellent map sheets of regional geological survey (Mao XC, 2018). In January 2019, it organized database experts to review the 1：50 000-scale spatial database of Yueyashan map sheet (K47E015010). As a result, the spatial database obtained a comprehensive score of 90 points, and was ranked excellent.

5 Data Value

The 1：50 000 geological map of Yueyashan map sheet (k47E015010) in Inner Mongolia is one of the representative maps prepared during a new round of geological surveys initiated by China Geological Survey. It was prepared based on in-depth research on the rock association, sequences, and tectonic deformation in this map sheet, during which the structure and layout of the map face had been continually improved according to the requirements of *Technical Requirements for Regional Geological Survey (Scale: 1：50 000)* (DD 2019-01) and the guidance of the latest mapping ideas of orogenic belts (Li RS et al., 2016; Yan Z et al., 2018). The material composition of the Baiyunshan ophiolitic melange belt was accurately presented in the form of the typical network of "rock blocks–matrix" in this map. Furthermore, the oceanic lithosphere rocks and exotic rocks were identified. The former includes dunites, lherzolites, pyroxenites, diallage peridotites, gabbros, basalts, and siliceous rocks, while the latter includes limestones and sandstones. Most especially in the central part of Baiyunshan ophiolitic melange belt, well-preserved oceanic crust residual blocks were identified. They consist of cumulate peridotites, cumulate pyroxenites, cumulate gabbros, plagiogranites, pillow basalts, and siliceous rocks and their sequences are increasingly new from south to north.

The main feature of the Database is that, with the Paleozoic structure of Beishan orogenic belt as the outline, the Paleozoic strata (Table 2) and intrusions (Table 3) on the two sides of the Baiyunshan ophiolitic melange belt (the first-order tectonic unit in the map sheet) were re-sorted and classified. As a result, the sedimentary formation and rock association types on the two sides were classified in detail. Furthermore, based on the sedimentary formations, magmatic rock associations on the two sides and their eras, as well as the characteristics of structural deformation associations, four stages of tectonic and magma evolution sequences of the Baiyunshan ophiolitic melange belt were comprehensively established, namely a subduction period in the late Ordovician–early Silurian (450–430 Ma), a splicing and collision period in the late Silurian–early Devonian (415–407 Ma), a local extension period of intracontinental (epicontinental) rifts in the late Devonian (370–360 Ma), and an intraplate extension period in the late Triassic (290–255 Ma).

To sum up, this Database will provide basic data for geological surveys in the south-central part of the Beishan orogenic belt and will play a leading role in terms of scientific and technological innovation. Furthermore, it will enhance the ability of geological surveys to serve major scientific issues and resource security with comparatively complete structural analysis of the orogenic belt.

6 Methods and Suggestions for Data Use

The spatial database of the 1：50 000 geological map consists of a feature class dataset, complex class dataset, object class dataset, and independent feature class dataset. It should be used together with DGSS through the following steps. Create a new 1：50 000-scale standard map sheet in DGSS, and then place the datasets into the folder of the spatial database of the map sheet. The system database (Slib) used is a standard database of DGSS.

Special attention should be paid to the following. The feature class dataset is a collection of feature classes that share the same spatial reference system. In the data model of geological maps, it is composed of geological points, polygons, and lines. The object class dataset is a table used to store non-spatial data. One feature class corresponds to multiple object classes in general in the data model of geological maps. The attributes of the data items of the feature classes, complex classes, and object classes in geological maps should be filled in completely. The feature classes and object classes in the Database are listed below (Table 4).

Table 2 List of sedimentaty formations on the two sides of Baiyunshan ophiolitic Melange belt

Age			This database		Thickness/m	Sedimentary formation
Era	Period	Epoch	Tarim strata superregion	Xingmeng-Tianshan strata superregion		
Cenozoic	Quaternary	Holocene	Tianshan strata region	Alluviums, alluviums-proluviums, aeolian sediments ($Qh^{al+alp+l}$)	>2.82	Loose sediments
	Neogene	Pliocene		Kuquan Formation (N_2k)	>9.6	Intracontinental lacustrine sedimentary formation
Mesozoic	Cretaceous	Early Cretaceous		Chijinpu Formation ($K_1\hat{c}$)	>7.12	Sedimentary formation in an intracontinental pull-apart basin
aleozoic	Devonian	Late Devonian		Dundunshan Formation (D_3d)	>575.0	Volcanic formation deposited in an intracontinental rift basin
		Early Devonian	Sangejing Formation (D_1s)		>445.6	Formation of volcanic rocks and clasolites deposited on a continental slope
	Ordovician	Late Ordovician	a. Late Ordovician Xilinkebo Formation (O_3x)	b. Late Ordovician Baiyunshan Formation (O_3b)	a.>1 374.1 b.>146.9	a Clasolite formation deposited on a passive continental margin b Formation of clasolites and carbonate rocks deposited in a forearc basin
		Middle Ordovician				
		Early Ordovician	Luoyachu Formation (O_1l)		>471.9	Clasolite formation deposited on a passive continental marginUpper part: formation of siliceous rocks and carbonate rocks deposited on a passive continental margin
	Cambrian	Middle-late Cambrian Early Cambrian	Xishuangyingshan Formation ($\text{Є}O_1x$)		>518.5	Lower part: formation of deep-water siliceous rocks deposited on a passive continental margin
oterozoic	Sinian		Xichangjing Group (ZX)		>984.9	Moraine gravel formation deposited in the lower part; fine cuttings formation deposited in the lower part
	Qingbaikou		Dahuoluoshan Formation (Qbd)		>93.9	Carbonate rock formation deposited in an epicontinental sea
	Jixianian		Pingtoushan Formation (Jxp)		>343.3	Carbonate rock formation deposited in an epicontinental sea

Table 3 List of evolution sequences of intrusions on the two sides of Baiyunshan ophiolitic melange belt

Age	Zone	Mapping unit	Rock type	Isotopic age/Ma	Tectonic setting
Late Permian	Whole map sheet	x$\beta\mu P_3$	Grayish-green fine-grained diabases	255.2±2.9	Intraplate extension
Late Devonian	Northern side	z$\gamma\delta D_3$	Medium-grained granodiorites	360.7±1.6	Epicontinental arc
		zx$\gamma\delta D_3$	Medium-fine grained granodiorites	366.2±1.8; 366.2±2.1	
	Middle part		Baiyunshan ophiolitic melanges		
	Southern side	zx$\xi\gamma D_3$	Medium-fine grained syenogranites	375.4±3.5	Intracontinental local rifting
Early Devonian	Northern side	xz$\xi\gamma D_1$	Fine-medium grained syenogranites	407.4±2.2	Post-orogenic extension
	Middle part		Baiyunshan ophiolitic melanges		
	Southern side	zx$\gamma\delta D_1$	Medium-fine grained granodiorites	397.0±1.7	Island arc
		x$\gamma\delta o D_1$	Fine-grained tonalites	404.6±2.6	
		zx$\delta o D_1$	Medium-fine grained quartz diorites		
Middle Silurian	Whole map sheet	zx$\delta o S_2$	Medium-fine grained quartz diorites	430.2±3.5	Epicontinental arc formed owing to subduction

Beside the feature layers listed above, there are geological decoration layers without attributes, including fault symbols (A_GEOLINE.wt), lines from geological polygon entities (A_GEOLINE.wl), geological block codes and lithologic patterns (A_GEOPOLYGON.wt), attitude labels (A_ATTITUDE.wt), isotopic age values (A_ISOTOPE.wt), transverse cutting profile lines (A_PROFILE), tectonic mosaic maps (TECTONIC_MAP), and labels. It is up to the readers to either open or close the corresponding layers.

7 Conclusion

(1) The 1：50 000 geological map of Yueyashan map sheet (k47E015010) in Inner Mongolia is one of the representative maps prepared during a new round of geological surveys initiated by China Geological Survey. It was prepared under the guidance of the latest mapping theory of orogenic belt structure and ophiolitic melange belts, during which the tectonic-lithology mapping method was adopted to improve the presentation effects of the results. In this way, it serves as a good example for regional geological survey, especially for orogenic belt mapping.

(2) The 1：50 000 geological map of Yueyashan map sheet (K47E015010) was comprehensively and systematically prepared and a spatial database was established according to the latest technical requirements issued by China Geological Survey, improving and standardizing the presentation of various geological information.

Table 4 List of feature classes and object classes of the 1：50 000 geological map spatial database of Yueyashan map sheet

Feature Class		Object Class		Complex Class		Independent feature class
Name and standard code	Number of entities	Name and standard code	Description	Name and standard code	Description	Name and standard code
Geological polygon entity(_GEOPOLYGON.wp)	738	Lithostratigraphic units of sedimentary (volcanic) rocks(_STRATA)	14 stratigraphic units including Pingtoushan Formation	Standard map frame(_MAP_FRAME.wl)	Four lines of inner map frame (standard frame), with same attributes	Index map(MAP_SHEET)
Geological line (boundary)(_GEOLINE.wl)	2006					Synthetic histogram(COLUMN_SEC)
Attitude(_ATTITUDE.wt)	411	Chronological units of intrusions(_INTRU _LITHO_CHRONO)	Eight mapping units including the Silurian and Devonian units	Tectonic deformation zone(_TECTZONE.wp)	Ductile fault	Transverse Cutting profile(CUTTING_PROFILE)
Sample(_SAMPLE.wt)	115	Dike(_DIKE_OBJECT)	Four types of dikes of different lithologies	Zone of volcanic rock facies (_VOLCA_FACIES.wp)	Volcanic rocks of Sangejing Formation and Dundunshan Formation	Duty table(DUTY_TABLE)
Photo(_PHOTOGRAPH.wt)	1400					Legend(LEGEND)
Sketch(_SKETCH.wt)	6	Fault(_FAULT)	44 faults in this map sheetExtracted from standard map frames	Belt of metamorphic rock facies(_METAMOR_FACIES.wp)	Regional metamorphic belt	Tectonic mosaic map(TECTONIC_MAP)
Fossil(_FOSSIL)	0					
Isotopic dating(_ISOTOPE.wt)	14					Vertical profile(VERTICAL_PROFILE)
Crater(_CRATER.wt)	1	Basic information of map sheet(_SHEET_MAPINFO)				
Mineral depositMineral land(_MINERAL_PNT.wt)	2					

(3) The Baiyunshan ophiolitic melange belt was ascertained to be the boundary of the early Paleozoic first-order geotectonic unit in Beishan area according to previous data and the results of this project. Furthermore, based on field research of sedimentary formation and tectonic deformation sequences as well as petrogeochemical data and chronological tests, three stages of tectonic and magmatic evolutionary sequences of Baiyunshan ophiolitic melange belt were systematically established, namely a subduction period in the late Ordovician–early Silurian (450–430 Ma), splicing and collision period in the late Silurian–early Devonian (415–407 Ma), and a local extension period of intracontinental rifts in the late Devonian (370–360 Ma).

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Notes:

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