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1∶500 000 二连–东乌旗成矿带西乌旗和白乃庙地区地质图空间数据库

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摘要: 1∶500 000 二连–东乌旗成矿带西乌旗和白乃庙地区地质图空间数据库的建设依托 2016–2018 年实施的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”开展。古生代、中生代、古近纪及新近纪地层以组为单位，侵入岩时代以最新获取的 777 个 LA-ICPMS 和 SHRIMP 锆石 U-Pb 年龄为依据，按照“岩性+时代”方法表达。地质图空间数据库的数据量为 210 MB，包括地层面图元 4682 个，侵入岩面图元 1938 个。所有地质图面图元和同位素年龄点均建立了相应的属性。在编图过程中主要取得了如下成果: 结合生物区系和重要构造边界重新划分了古生代地层分区，新建、重新厘定了关键地层单位，完善了古生代地层格架; 重新厘定了区内古生代侵入岩时空分布及性质，早、晚古生代 2 阶段岩浆作用是对早、晚古生代 2 期俯冲增生造山作用的响应; 新识别并在图上表达出早古生代萨音敖包、昌图及晚古生代二道井–迪彦庙、乌兰沟等蛇绿混杂岩，较为细致地刻画了早古生代大洋南北双向俯冲形成的增生造山带结构，对晚古生代洋盆的俯冲与封闭进行了限定，重新划分了构造单元。这些成果和资料对兴蒙造山带研究过程中的古生代构造单元划分、晚古生代构造背景等具有较大分歧的科学问题具有限定作用。该空间数据库是目前兴蒙造山带中段资料最齐全、最新的 1∶500 000 地质图数据库，反映了本区地质调查和科学研究的最新成果。

关键词: 兴蒙造山带中段；二连–东乌旗成矿带；1∶500 000地质图；数据库；古生代构造单元；蛇绿混杂岩

数据服务系统网址: http://dcc.cgs.gov.cn

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1 引言

二连–东乌旗成矿带大地构造位置属于兴蒙造山带中段。兴蒙造山带指华北板块北缘赤峰–白云鄂博断裂以北至中蒙边境的广大地区，位于中亚造山带东南部 (图 1)，其中分布有微陆块、蛇绿岩、岛弧、增生楔等大洋中具有不同构造属性的地质体 (Xiao WJ et al., 2003, 2015; Xu B et al., 2013; Liu YJ et al., 2017)，是增生造山带研究的热点和焦点地区，一直被国内外地质学界所关注。本区经历了早古生代以来俯冲导致的弧盆系发育、弧后扩张、弧–微陆块碰撞及最终碰撞造山等复杂的地质演化过程。二连–东乌旗成矿带是中国北方重要的成矿区带，包含国家级整装勘查区–内蒙古东乌旗地区铅锌矿整装勘查区，近年来在本区新近发现了乌兰德勒等大型斑岩钼矿、拜仁达坝及高尔其大型铅锌矿等矿床，具有丰富的资源找矿潜力。

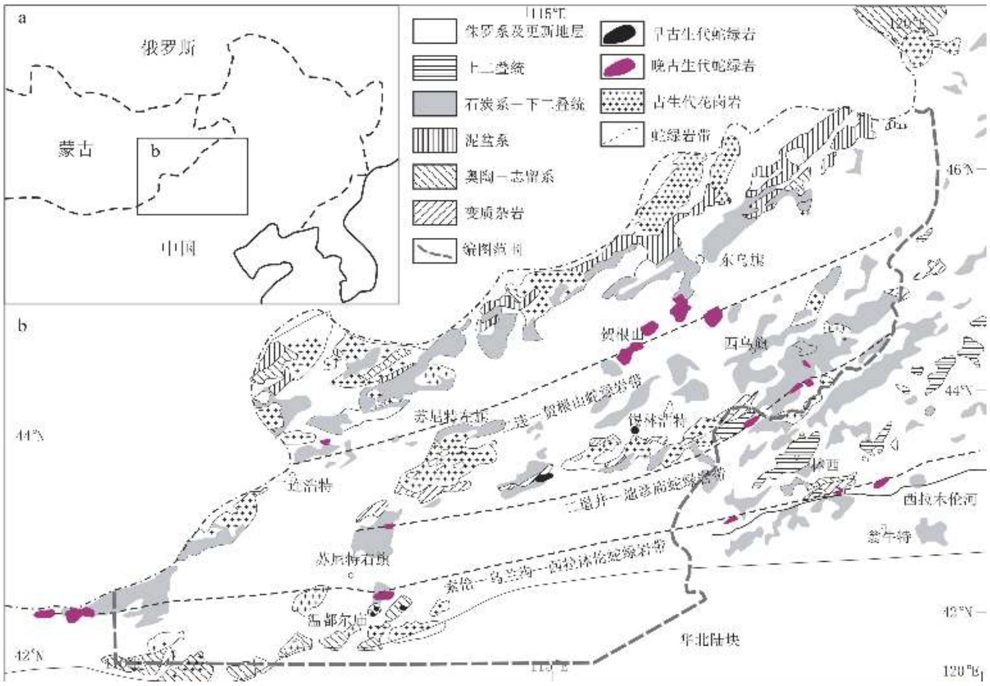

图 1 二连–东乌旗成矿带西乌旗和白乃庙地区地质简图（据 Miao LC et al.，2008）

近年来的研究在古生代构造格局 (Xiao WJ et al., 2003，2015, 2018; Li JY, 2006；Jian P et al., 2008, 2010; Chen B et al., 2009; Xu B et al., 2013, 2015; 徐备等，2014，2018；Wan B et al.，2018)、重要蛇绿岩带 (Miao LC et al., 2008；Jian P et al., 2012；Zhang ZC et al., 2015；Luo ZW et al., 2016；Liu YJ et al., 2017；Li YJ et al., 2018, 2020)、岩浆作用 (Zhang SH et al., 2007, 2009, 2014；何付兵等，2017；王金芳等，2018；Wei RH et al., 2018；郭喜运等，2019；王树庆等，2019)、微陆块 (Zhou JB et al.，2018；孙立新等，2017，2018) 等方面取得了许多重要成果和进展，这对于认识和理解本地区古亚洲洋中岛弧、微陆块等不同性质地质体的空间分布和相互作用、洋陆转换过程提供了重要的信息和约束。近年来蛇绿岩和岛弧岩浆作用研究表明，早在寒武纪大洋就开始俯冲 (Jian P et al., 2008；王树庆等，2016)，并经历了长期的俯冲、弧–弧和弧陆拼贴过程，但对于本区晚古生代的构造格局和演化，目前仍存在争议，主要有 2 种观点：一种观点认为大洋从早古生代–直演化到晚古生代，最终于晚二叠–早三叠世碰撞造山 (Xiao WJ et al., 2003, 2015, 2018；Li JY, 2006；Liu JF et al., 2013；Liu YJ et al., 2017；李锦轶等，

2019a，b；刘永江等，2010，2019)；另一种观点认为大洋于泥盆纪闭合，晚古生代为陆内演化阶段 (鲍庆中，2007；徐备等，2014，2018；Xu B et al., 2013, 2015；邵济安等，2014，2015)。上述科研工作多在局部地区开展较为精细的深入研究，但对于地层划分对比、区域构造–岩浆作用等方面的综合性资料报道相对较少，制约了区域构造分区和构造演化的研究。另外在区域编图方面，前人在本区编制的区域地质图件比例尺较小 (多小于 1∶2 000 000)，对于地层分区和构造单元划分也一直存在分歧，如内蒙古岩石地层 (李文国等，1996) 在划分地层分区时主要以生物地理区系为依据，并未考虑到蛇绿岩等板块构造边界的因素。

在兴蒙造山带中段实施的地质调查工作在古生代地层、岩浆作用、构造边界和造山带结构方面近年来获得了很多新资料，但公开发表的综合集成成果较少，特别是缺少公开发表的地质图数据库。本次主要以本区 2008–2018 年来完成的 1∶50 000 区域地质调查资料为主要数据来源，以板块构造理论为指导，编制了 1∶500 000 全区地质图空间数据库 (表 1，王树庆等，2020)。主要编图特色如下：重新厘定了温都尔庙群、白乃庙组、阿木山组等古生代关键地层的时代；重新表达了迪彦庙蛇绿混杂岩带；按照蛇绿岩带、关键地层对比及构造岩浆作用，重新划分了构造单元和地层分区，并将其边界统一，为造山带研究、成矿地质背景分析提供可靠的基础资料。

表 1　数据库元数据简表

条目	描述
数据库名称	1∶500 000二连–东乌旗成矿带西乌旗和白乃庙地区地质图空间数据库
数据库作者	王树庆，中国地质调查局天津地质调查中心 胡晓佳，中国地质调查局天津地质调查中心 杨泽黎，中国地质调查局天津地质调查中心
数据时间范围	2014—2018年
地理区域	地理坐标为：东经110°00′ ~ 120°00′，北纬41°40′00″ ~ 46°40′00″
数据格式	MapGIS
数据量	210 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”(DD20160041)
语种	中文
数据库组成	本地质图空间数据库包括1∶500 000地质图库、地理图、系统库、字库。地质图库由主图、辅图及图饰组成；主图包括地层、侵入岩、脉岩、地质界线、断层、注记、断层性质及同位素年龄等；辅图包括构造单元划分和地层分区；图饰包括图例、图框、编图参数及责任表等

2　数据采集和处理方法

2.1　数据基础

二连–东乌旗成矿带西乌旗和白乃庙地区地质图空间数据库以板块构造理论为指导，以 2008–2018 年完成的 1∶50 000 地质图和地质矿产图为基础，部分 1∶50 000 区域地质调查空白区采用 1∶250 000 地质图，局部采用 1∶200 000 地质图，另外充分吸收了近年来科研工作研究成果。编图资料时间截至 2018 年 12 月。应用已有的技术标准以及国内和国际上通用的计算机软件进行数据处理和管理，按 1∶500 000 比例尺地质

图精度要求，建立地质图数据库。在编图建库采用的资料方面，本次地质图与前人在本区编制的地质图最大的区别有 2 点：①采用板块构造为指导思想，以蛇绿岩为构造边界统一地层及构造分区；②采用了最新的 1∶50 000 区域地质调查资料作为基础数据，目前 1∶50 000 是标准图幅地质填图的最大比例尺，数据精度最高；本次编图采用的基岩区数据 90% 以上都是来自 2008–2018 年以来完成 1∶50 000 区域地质调查，资料是最新的，特别是对侵入岩和火山岩开展了大量高精度锆石 U–Pb 测年 (LA-ICPMS 或 SHRIMP)，重新厘定了许多地质体，特别是有争议的地质体时代，重新建立了构造–岩浆作用时空格架。因此本次编制的本区地质图空间数据库的数据资料是相对较新和完整的。

2.2 数据处理过程

2.2.1 数据前处理

首先将研究区数字化 1∶50 000 地质图、1∶250 000 地质图投影到统一的 1∶500 000 比例尺，部分缺少 1∶50 000 和 1∶250 000 资料的区域应用 1∶200 000 地质图资料。1∶200 000 地质图处理过程为：先将图扫描成 TIFF 文件，在 MapGIS 平台图像分析模块应用标准图框进行空间信息校正后，再手动完成点、线文件的矢量化，再进行拓扑造区，生成 WT、WL、WP 文件，后再按统一参数投影。

2.2.2 投影并接图

将投影成 1∶500 000 比例尺的 1∶50 000、1∶250 000 和 1∶200 000 矢量化地质图，根据最新地质调查和科研成果，进行接图。重点将近年来新识别/新厘定的蛇绿–构造混杂岩、地层及岩浆岩在地质图图面上进行了表达：重点将二连–贺根山、二道井–迪彦庙、索伦–乌兰沟–西拉沐伦等蛇绿岩带进行了夸大表示，将小于 2 mm 的蛇绿岩放大到 5 mm；根据《内蒙古自治区岩石地层》（李文国等，1996）以及本区近年开展的地质调查工作资料和公开发表的科研论文，将地层进行重新梳理、修正和归并，并根据最新锆石年龄和古生物资料对其时代进行了修正；根据最新岩石学、地球化学资料对侵入体进行解体，并依据锆石 U–Pb 年龄重新厘定侵入岩时代。然后在 MapGIS 软件系统下进行线元矢量化编辑，生成.WL 文件；输入注记代号生成.WT 文件。在屏幕上修改、编缉、审查、输出，进行初审。拓扑造区，填色整饰，生成.WP 文件。编图流程见图 2。

2.2.3 编写属性表

在 MapGIS 6.7 平台上，输出属性表，应用 Excel 进行属性修改、补充，进行编码转换等，然后打印输出属性表，人工检查属性内容，之后再与图形数据进行关联。

2.2.4 属性数据检查

进行人工属性数据的检查，包括属性结构、属性类型、属性内容等，尽量将错误率降到最低。

3 数据样本描述

3.1 图面结构

二连–东乌旗成矿带西乌旗和白乃庙地区 1∶500 000 数字地质图由主图、辅图、图框及图例构成，其中主图和辅图放置在图框之中，图例在图框右侧。辅图包括二连–东乌旗地区古生代地层分区图和兴蒙造山带中段构造单元划分图。图例包括地层、岩浆岩、潜火山岩、脉岩和其他，地层断代和按照地层分区排列；岩浆岩以表格形式排列，

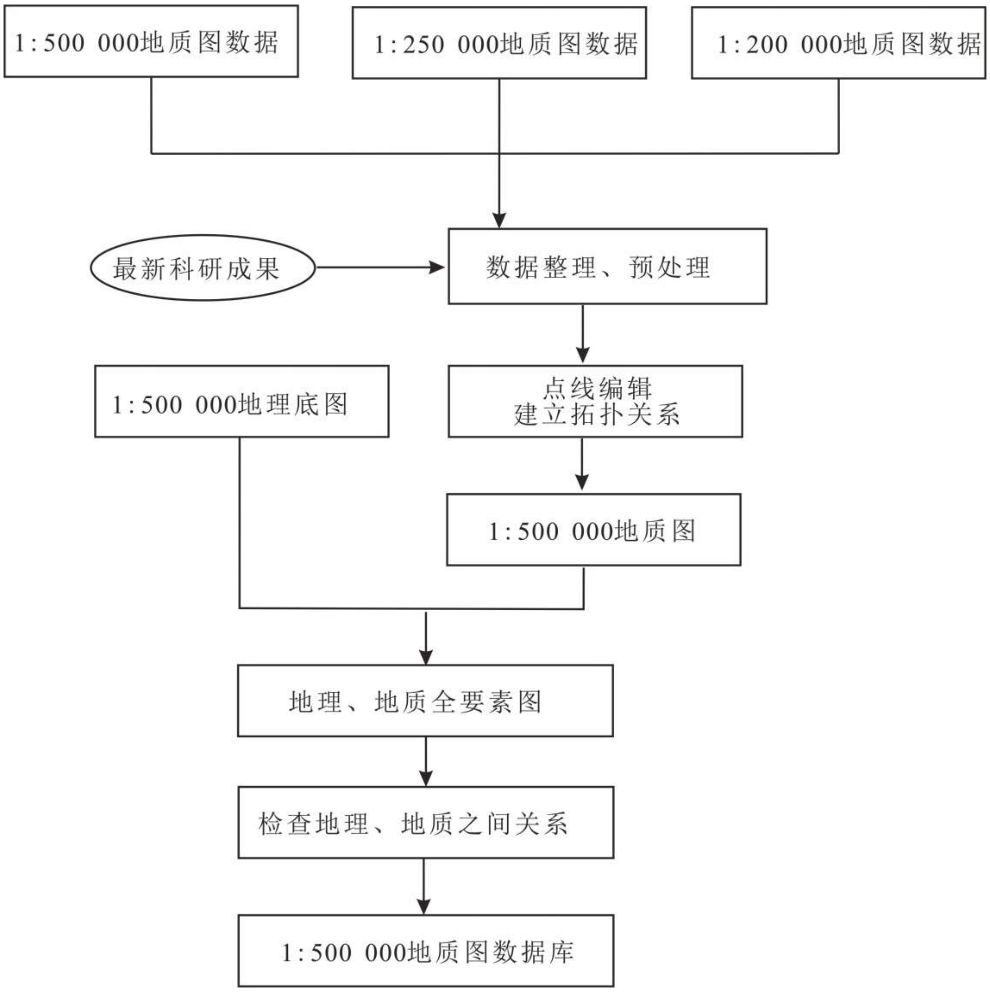

图 2　编图建库工作流程图

横坐标为岩石类型，纵坐标为时代。

3.2　图层名称

地质图和地理底图图层主要按要素类型划分，以文件的形式存放。

3.3　要素 (实体) 类型名称

实体类型名称：点、线、面。

点实体：地质体注记、同位素、断层性质、构造单元注记、地层分区注记、图例注记、地理、图框等。

线实体：地质界线、断层、引线、地理线、图框、构造单元线、地层分区线、图例线等。

面实体：地层、侵入体、岩脉及潜火山岩、地层分区及构造单元区文件、图例、地理区文件等。

3.4　属性列表

1∶500 000 数字地质图数据库包括地质实体要素信息和地理要素信息，地质实体主要为面元属性和同位素年龄属性。地质体面元属性表主要包括地层和侵入岩单位，其中地层面元属性结构如下：ID(标识码)、面积、周长、地质代号、地层名称、图层、面色

CLR(色标号)、图案号 (填充图案号)、图案高 (填充图案高度)、图案宽 (填充图案宽度)、图案颜色 (填充图案颜色号) 等；侵入岩面元属性结构为：ID(标识码)、面积、周长、地质代号、面色 CLR(色标号)、图案号 (填充图案号)、图案高 (填充图案高度)、图案宽 (填充图案宽度)、图案颜色 (填充图案颜色号)、图层、时代、同位素年龄等。同位素年龄属性结构为：年龄、测试方法、岩性、岩体。

3.5 投影参数

二连–东乌旗成矿带西乌旗和白乃庙地区地质图空间数据库地图参数见表 2。

表 2 二连–东乌旗成矿带西乌旗和白乃庙地区地质图空间数据库地图参数

坐标系类型	投影类型	椭球参数	比例尺分母	坐标单位	参数比例
投影平面直角	兰伯特等角圆锥投影坐标系	北京54/克拉索夫斯基1940年椭球	500 000	mm	1∶1
第一标准经纬度	第二标准经纬度	中央子午线经度	投影原点纬度	图框经度范围	图框纬度范围
42°50′00″	45°40′00″	114°00′00″	41°30′00″	109°56′00″ ~ 119°56′00″	41°33′00″ ~ 46°53′00″

4 数据质量控制和评估

二连–东乌旗成矿带西乌旗和白乃旗地区 1∶500 000 地质图主要以新近完成的 1∶50 000、1∶250 000 数字地质图库为基础，吸收前人近年在兴蒙造山带对于蛇绿岩、构造岩浆作用及造山带演化的研究成果，重新梳理了地层分区和构造单元划分，编绘了地质图及数据库。

在地质图空间数据编制过程中，编图组始终把数据质量放在首位，主要从 2 个方面加强数据质量控制和评估：源数据和数据处理加工。①在源数据部分，本次编图主要利用的是 2008–2018 年完成的 1∶50 000 和 1∶250 000 地质图及地质矿产图，这些 1∶50 000 地质图均按照《区域地质调查总则》(1∶50 000)、《1∶50 000 区域地质调查技术要求》、《数字地质图空间数据库标准》、《1∶25 万区域地质图空间数据库建设技术要求及实施细则》、《地质信息元数据标准》(DD2006–05)、《区域地质图图例》(GB/T958–2015) 等标准进行数据采集、整理、入库并建立空间数据库，其中对于野外采集原始数据均进行了 100% 的自检和互检，并且数据库均经过由具高级职称的专家组验收，这些均可保障编图采用源数据的质量。②在数据加工处理部分，首先检查所有用于编图的源数据的空间信息准确性，对于空间位置偏离和丢失的数据，用标准图框校正到正确位置；其次投影拼贴后，对于部分由不同团队完成的 1∶50 000 和 1∶250 000 地质图在接图时不一致无法接图的地质体，通过野外工作进行验证；另外在数据处理方面，编图组对处理完的数据特别是人工输入的属性表进行 100% 的自检和互检，并且在数据库验收时经专家验收后又进行了修改。以上措施从源数据和处理过程 2 个方面保证了数据库的质量。

5 编图主要进展及数据价值

5.1 主要进展

本次编图工作以 2008 年以来在本区开展的 1∶50 000 区域地质调查资料和科研资料为基础，以板块构造理论为指导，在造山带岩浆作用、古生代地层划分及构造单元划

分等方面取得了一些新认识和资料。基于现代测试分析技术特别是高精度原位锆石同位素年龄，重新厘定了本区 (兴蒙造山带中段) 侵入岩时空格架、岩浆性质和构造背景；新建和重新厘定了一些关键地层单位，除生物区划外，结合重要构造边界，重新划分了地层分区，完善了古生代地层格架；新识别并在图上表达出早古生代萨音敖包、晚古生代二道井–迪彦庙、乌兰沟等蛇绿岩带，较为精细的刻画了早、晚古生代沟弧盆体系，以板块构造理论和增生造山带理论为指导，重新划分了构造单元。具体进展见表 3。

5.2　数据价值

1：500 000 二连–东乌旗成矿带西乌旗和白乃庙地区地质图空间数据库基于本区最新的 (2008–2018 年)1：50 000 地质调查数据，在板块构造理论和俯冲–增生造山带等地学理论指导下，充分吸收了国内外最新研究进展。本数据库的使用主要有：①用于编制更小比例尺的地质图数据库，也可用于岩浆岩图等专题图件编制；②用于编制区域地质矿产调查规划、管理等工作；③基础地质调查资料编图集成可为成矿地质背景和成矿条件总结提供基础。本次编图在造山带地层、构造–岩浆作用、重要构造边界等方面提供了可靠翔实的成果和资料，可用于本区造山带演化、成矿地质背景和成矿条件等研究，解决前人由于对区域资料掌握不全面而造成的对本区造山带研究特别是晚古生代构造背景 (大洋/陆内) 认识的分歧。

6　结论

1：500 000 二连–东乌旗成矿带西乌旗和白乃庙地区地质图空间数据库，是以近年来在本区完成区域地质调查和专题研究的新成果资料，以板块构造理论为指导，应用地理信息系统和地质制图等新技术和新方法，开展的综合研究与数字地质图编制工作，展示了近年来在兴蒙造山带开展的地质调查和科学研究的新资料，是目前兴蒙造山带中段资料较为齐全、最新的 1：500 000 地质图数据库，对于兴蒙造山带、成矿地质背景研究和编制国土资源规划等提供基础资料，可为实现基础性公益性地质工作社会化服务奠定基础。

(1) 本地质图数据库新建和重新厘定了二连–东乌旗成矿带古生代关键地层单位：新建早泥盆世吉林宝力格组、晚泥盆世汗乌拉巴格组、早石炭世汗敖包组，重新厘定了奥陶纪温都尔庙群、晚石炭世阿木山组；以二连–贺根山和索伦–西拉沐伦蛇绿岩带为界重新划分了洪格尔–东乌旗、锡林浩特、包尔汗图–白乃庙等 3 个古生代地层分区，完善了古生代地层格架。

(2) 梳理了古生代岩浆岩时空演化规律，重新厘定了区内古生代侵入岩时空分布及性质，早、晚古生代 2 阶段岩浆作用是对早、晚古生代 2 期俯冲增生造山作用的响应。

(3) 新识别并在图上表达出早古生代萨音敖包、昌图及晚古生代二道井–迪彦庙、乌兰沟等蛇绿混杂岩，较为细致地刻画了早古生代大洋南北双向俯冲形成的增生造山带结构，对晚古生代洋盆的俯冲与封闭进行了限定，重新划分了构造单元。

致谢：本项目地质图编制及数据库建库工作是项目组全体同志集体工作的成果，在编图过程中，得到了天津地质调查中心李承东教授级高工、辛后田教授级高工、谷永昌教授级高工及孙立新研究员的指导和帮助，在此一并表示衷心的谢意。

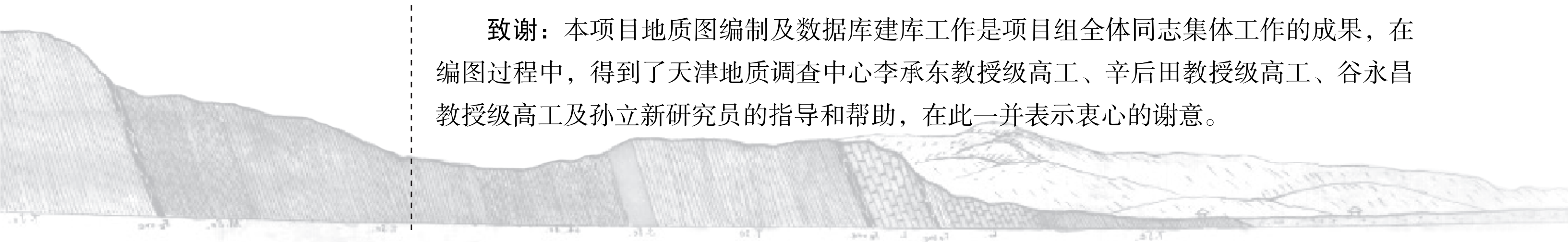

表 3　编图工作主要进展

进展	前人观点	具体内容	意义
重新划分了古生代地层分区	以贺根山蛇绿岩带为界划分为天山兴蒙和华北地层大区	以贺根山、索伦–西拉沐伦蛇绿岩带为界将兴蒙造山带中段的古生代地层划分为洪格尔–东乌旗、锡林浩特和包尔汗图–白乃庙3个地层区	与前人地层分区方案相比，本次除考虑生物区系划分外，结合蛇绿岩等重要构造边界的分区意义，与构造单元划分统一起来
在洪格尔–东乌旗地层分区新建早泥盆世吉林宝力格组(D_1j)、晚泥盆世汗乌拉巴格组(D_3h)、早石炭世汗敖包组(C_1h)	本次新建	新发现的*Monograptus uniformis*笔石组合指示吉林宝力格组为早泥盆世早期半深海沉积；含有斜方薄皮木等植物化石的晚泥盆世晚期汗乌拉巴格组为海陆交互相沉积；早石炭世汗敖包组为陆相火山岩建造	进一步完善了东乌旗地区晚古生代地层格架。本区从顶志留世卧都河组以来进入泥盆纪连续的被动陆缘沉积，直到晚泥盆世向陆相转变
重新厘定了温都尔庙群、白乃庙组、阿木山组及寿山沟组	温都尔庙群(长城系–蓟县系)：下部桑达来呼都格火山岩，上部为哈尔哈达组碎屑岩；白乃庙组(青白口系):长英质及基性片岩；阿木山组:塔林宫地区建组	将温都尔庙群原划桑达来呼都格组重新厘定为二叠纪蛇绿混杂岩和洋岛海山建造，原划哈尔哈达组保留，时代为奥陶纪；将白乃庙组时代重新厘定为早奥陶世–中志留世；根据新识别出的植物化石，将达茂旗北塔林宫地区阿木山组下部与赤峰地区白家店组对比，上部与酒局子组对比；明确西乌旗地区寿山沟为半深海相浊积岩沉积	早古生代温都尔庙群为弧前增生楔，白乃庙组代表岩浆弧，与早古生代蛇绿岩共同代表了南部沟弧盆体系；晚古生代阿木山组的重新厘定，解决了地层分区与构造单元划分的不一致，使之统一起来。寿山沟组沉积环境表明晚古生代洋盆并未封闭
重新厘定了古生代侵入岩时空分布及性质	部分年龄为K–Ar、Rb–Sr方法测定	本次编图根据锆石U–Pb年龄更新了兴蒙造山带中段古生代侵入岩时代，全区大部分侵入体都有精确年龄限定。在二连–东乌旗地区，将大量原划二叠纪侵入岩重新厘定为石炭纪和白垩纪，将泥盆纪侵入岩重新厘定为奥陶纪；将白音宝力道地区泥盆纪侵入岩重新厘定为奥陶纪和志留纪	兴蒙造山带中段古生代岩浆作用主要分为奥陶纪–早志留世和晚石炭–早二叠世两期，分别代表了早、晚古生代大洋俯冲及弧陆碰撞和碰撞造山过程。与前人相比，汇聚了大量高精度锆石年龄，明确了岩浆作用时空分布及构造背景及对造山过程的约束
在早古生代北部造山带/弧盆系新识别出萨音敖包蛇绿混杂岩	本次工作新厘定	在阿巴嘎旗南部萨音敖包地区新识别出早古生代(519 Ma)蛇绿岩，并在其中识别出代表初始俯冲的玻安质岩石，其北侧为岛弧型侵入岩(485～493 Ma)，南侧为温都尔庙群哈尔哈达组增生楔，指示大洋向北的俯冲极性	进一步明确了早古生代大洋向南北双向俯冲的构造格局，较为细致的刻画了增生造山带结构–由洋向两侧分别为增生楔、蛇绿岩、岛弧及弧后盆地
在图上表达出二道井–迪彦庙蛇绿岩带	本次工作新厘定	分布于苏右旗南部二道井(298 Ma)、达青牧场(314～318 Ma)和迪彦庙(340 Ma)地区，位于石炭纪白音宝力道–西乌旗岛弧南侧，代表了石炭纪大洋板片向北俯冲。时代介于贺根山与索伦–西拉沐伦蛇绿岩之间	与苏尼特左旗–西乌旗岛弧及沉积建造共同代表了西拉沐伦蛇绿岩北侧发育的石炭纪增生带，反映了由北向南逐次拼贴增生的过程

续表 3

进展	前人观点	具体内容	意义
新识别出乌兰沟早二叠世蛇绿岩	原划为温都尔庙群桑达来呼都格组	乌兰沟地区原划温都尔庙群桑达来呼都格组中识别出早二叠世蛇绿混杂岩，辉长岩年龄为292±10 Ma，其中还发育洋岛海山建造(包括OIB型玄武岩和盖帽碳酸盐岩)。蛇绿岩类型为SSZ型	进一步明确了索伦–乌兰沟–西拉沐伦蛇绿岩带的空间分布、时代及分区意义，对构造单元划分及地层分区具有重要约束作用。同时二叠纪SSZ型蛇绿岩的确定也表明晚古生代洋盆未封闭
重新划分了构造单元	以贺根山蛇绿岩带为界划分为北部西伯利亚板块和南部华北板块	以索伦–西拉沐伦蛇绿岩带为界将兴蒙造山带中段划分为北部的西伯利亚板块和南部的华北板块2个一级构造单元，再以贺根山蛇绿岩带为界将北部西伯利亚板块划分为西伯利亚东南缘陆缘增生带和锡林浩特复合增生带2个二级构造单元，南侧华北板块以赤峰–白云鄂博断裂划分为华北北缘增生带和华北陆块2个二级构造单元	考虑到增生造山带的生长方式，将蛇绿岩作为一级构造单元–板块的界线，其他都是拼贴在板块边缘的岛弧、微陆块、增生楔等地体。与前人划分方案相比，未将造山带作为独立构造单元来划分

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1∶500 000 Geological Map Spatial Database of the Xiwuqi and Bainaimiao Areas in the Erlian– Dongwuqi Metallogenic Belt

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Abstract: The 1∶500 000 Geological Map Spatial Database of the Xiwuqi and Bainaimiao Areas in the Erlian-Dongwuqi Metallogenic Belt is developed as part of China Geological Survey's project 'Geological and Mineral Survey of the Xiwuqi and Bainaimiao Areas in the Erlian-Dongwuqi Metallogenic Belt' during 2016 to 2018. The stratum of the Paleozoic, Mesozoic, Paleogene and Neogene are divided into different formations, while the intrusive rocks are expressed in the form of 'lithology + era' based on 777 LA-ICPMS and SHRIMP zircon U–Pb ages. The geological map spatial database is rich in geological information with a data size of 210 MB, including 4682 stratigraphic and 1938 intrusive rock surface entities, all of which are associated with their corresponding attributes. The following achievements have been made during the mapping process: the Paleozoic stratigraphic division has been revised considering biota and key tectonic boundaries, with newly established and re-defined important stratigraphic units and an improved Paleozoic stratigraphic framework; the temporal-spatial distribution and properties of Paleozoic intrusive rocks have been clarified, with the Early and Late Paleozoic two-stage magmatism being responses to corresponding subduction-accretion orogeny; newly identified ophiolitic mélanges, such as Early Paleozoic Sayin Aobao, Changtu and Late Paleozoic Erdaojing-Diyanmiao and Wulangou, have been expressed on the map, which shows the structure of the accretionary orogeny formed by the Early Paleozoic North and South bi-direction subduction. The final closure of the Paleo Asian ocean at the end of the Late Paleozoic was constrained and the tectonic units were re-divided. These achievements and data may shed light on scientific issues with diverging views regarding the Xing'an–Mongolian

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orogeny, such as the division of the Paleozoic tectonic units and late Paleozoic tectonic setting. As the latest and most complete 1：500 000 geological map database in the middle part of the Xing'an–Mongolian orogeny so far, this spatial database reflects the latest achievements of geological surveys and research in this area.

Key words: middle part of Xing'an-Mongolian orogenic belt; Erlian-Dongwuqi metallogenic belt; 1：500 000 geological map; geological database; Paleozoic tectonic unit; ophiolitic mélange

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

1 Introduction

The Erlian–Dongwuqi metallogenic belt is situated in the middle part of the Xing'an–Mongolian orogeny, which refers to the vast area between the north of the Chifeng-Bayan Obo fault, which lies on the northern margin of the North China plate, and the China–Mongolia border, which is situated on the southeastern part of the Central Asian Orogenic Belt (CAOB) (Fig. 1). There are terranes of different tectonic affinities such as micro-continents, ophiolites, island arcs and accretionary wedges (Xiao WJ et al., 2003, 2015; Xu B et al., 2013; Liu Y J et al., 2017), attracting significant attention for studying accretive orogenic belts. As an important metallogenic belt in northern China, the Erlian–Dongwuqi metallogenic belt has undergone complicated geological evolution processes including arc-basin system development, back-arc expansion, arc-micro-continent collision and final collision orogeny caused by subduction since the Early Paleozoic. It comprises the lead-zinc ore exploration area in Dongwuqi of Inner Mongolia, which is a National Integrated Exploration Area. In recent

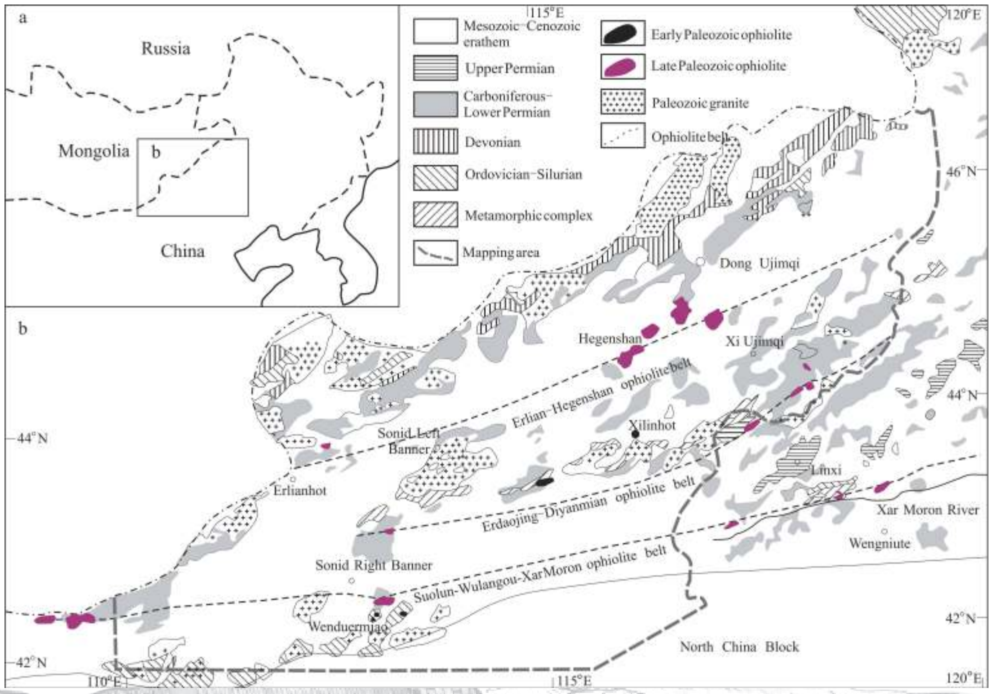

Fig. 1 Geological map of the Xiwuqi and Bainaimiao areas in the Erlian-Dongwuqi metallogenic belt (modified from Miao LC et al., 2008)

years, large porphyry-type Mo deposits, such as the Wulandele Porphyry Molybdenum Deposit, and large lead-zinc deposits, such as the Bayern Daba and Goerqi, have been newly discovered in this area providing rich potential for future prospecting.

Important findings have been made in recent studies on Paleozoic tectonic evolution (Xiao WJ et al., 2003, 2015, 2018; Li JY, 2006; Jian P et al., 2008, 2010; Chen B et al., 2009; Xu B et al., 2013, 2015; Xu Bei et al., 2014, 2018; Wan B et al., 2018), important ophiolitic belts (Miao LC et al., 2008; Jian P et al., 2012; Zhang ZC et al., 2015; Luo ZW et al., 2016; Liu YJ et al., 2017; Li YJ et al., 2018, 2020), Paleozoic magmatism (Zhang SH et al., 2007, 2009, 2014; He FB et al., 2017; Wang JF et al., 2018; Wei RH et al., 2018; Guo XY et al., 2019; Wang SQ et al., 2019) and micro-continents (Zhou JB et al., 2018; Sun LX et al., 2017, 2018). These findings have provided important information and constraints for understanding the spatial distribution and interaction of terranes with different properties, such as Paleo-Asian oceanic island arcs and micro-continents in this region, as well as the ocean-continent transition process. Recent studies on ophiolite and island arc magmatism show that subduction was initiated as early as the Cambrian (Jian P et al., 2008; Wang SQ et al., 2016) and experienced a long period of subduction in addition to arc-arc and arc-continent collision. However, there are still controversies about tectonic setting and evolution in the Late Paleozoic. There are now two competing views: one is that the ocean evolved from the Early Paleozoic all the way to the Late Paleozoic, with final ocean closure and collision in the Late Permian-Early Triassic (Xiao WJ et al., 2003, 2015, 2018; Li JY, 2006; Liu JF et al., 2013; Liu YJ et al., 2017; Li JY et al., 2019a, b; Liu YJ et al., 2010, 2019); other researchers argued that the ocean was closed in the Devonian era and experienced an intracontinental evolution stage in the Late Paleozoic (Bao QZ, 2007; Xu B et al., 2014, 2018; Xu B et al., 2013, 2015; Shao J’A et al., 2014, 2015). Most of the above studies represent in-depth studies of local areas, but lack relative comprehensive analysis about stratigraphic division and correlation, regional tectonic-magmatism and the understanding of tectonic evolution. In addition, in terms of regional mapping, the scale of previous regional geological maps was relatively small (mostly less than 1∶2 000 000). Views also differ on stratigraphic division and tectonic division. For example, lithostratigraphic in Inner Mongolia (Li WG et al., 1996) is largely based on biogeographic flora and does not take into account much of tectonic boundaries-ophiolite.

The geological survey carried out in the middle part of the Xing’an–Mongolian orogeny has obtained, in recent years, a lot of new data on Paleozoic stratigraphy, magmatism, tectonic boundary and orogeny structure. However, integrated publications remain lacking, particularly in geological map databases. With data mainly derived from the 1∶50 000 regional geological survey completed in the area from 2008 to 2018, and guided by plate tectonics theory, we compiled a 1∶500 000 spatial database of the geological maps of the whole region (Table 1, Wang SQ et al., 2020). The main conclusions of the present project are as follows: the era of key stratum such as the Wenduermiao Group, Bainaimiao and Amushan formations have been re-defined; and the Diyanmiao ophiolitic mélange belt is re-expressed. By considering the ophiolitic belt, key stratum correlation and tectonic magmatism, we revised the tectonic units

Table 1 Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	1：500 000 Geological Map Spatial Database of the Xiwuqi and Bainaimiao Areas in the Erlian-Dongwuqi Metallogenic Belt
Database (dataset) authors	Wang Shuqing, Tianjin Center, China Geological Survey Hu Xiaojia, Tianjin Center, China Geological Survey Yang Zeli, Tianjin Center, China Geological Survey
Data acquisition time	2014—2018
Geographic area	110°00'–120°00' E, 41° 40'00"–46°40'00" N
Data format	MapGIS
Data size	210 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	China Geological Survey project named 'Geological and Mineral Survey of the Xiwuqi and Bainaimiao Areas in the Erlian-Dongwuqi Metallogenic Belt' (DD20160041)
Language	Chinese
Database (dataset) composition	This geological map spatial database includes a 1：500 000 geological map database, geographical map, system database and font database. The geological map database consists of a main map, auxiliary map and map appearance. The main map includes strata, intrusive rocks, dikes, geological boundaries, faults, annotations, fault properties and isotopic age. The auxiliary map includes tectonic unit division and stratigraphic division. The map appearance includes a legend, drawing frame, drawing parameters and the author information.

and strata with unified boundaries, thus providing reliable basic data for the study of orogenic belts and the analysis of metallogenic geological background.

2 Data Acquisition and Processing Methods

2.1 Data Source

Guided by plate tectonics theory, the *Geological Map Spatial Database of the Xiwuqi and Bainaimiao Areas in the Erlian-Dongwuqi Metallogenic Belt* made use of data derived from the 1：50 000 geological and mineral resources surveys between 2008 and 2018. For areas without a 1：50 000 regional geological survey, 1：250 000 geological maps were adopted in some parts, and 1：200 000 geological maps in others, while fully incorporating research progress from recent years. The data for the compilation were updated to December 2018. The existing technical standards and the commonly used computer software were applied for data processing and management in order to build the geological map database, whilst keeping in line with the accuracy requirements on a scale of 1：500 000. In terms of the data used, this geological map database differs from previously compiled geological maps for this area in two major ways: ① guided by plate tectonics theory, the ophiolite was taken as the main and consistent boundary for stratigraphic and tectonic divisions; ② the latest 1：50 000 regional geological surveys were adopted as the basic data source. At present, 1：50 000 is the largest scale of standard geological mapping that has the highest data accuracy. More than 90% of the data of the bedrock area in our mapping are derived from the 1：50 000 regional geological surveys that have been completed over the last ten years, containing the most up-to-date information; in particular, a lot of efforts in high-precision zircon U-Pb dating (LA-ICPMS or SHRIMP) were made for intrusive and volcanic rocks with the aim of re-determining the era of many terranes, especially controversial ones. Moreover, the temporal-spatial framework of tectonic-magmatism is now re-established. Therefore, the data of this geological map spatial database is relatively new and complete.

2.2 Data Processing

2.2.1 Data Pre-processing

The vectorized 1∶50 000 and 1∶250 000 geological maps of the study area were firstly projected to an unified 1∶500 000 scale, while 1∶200 000 geological maps were adopted for areas lacking 1∶50 000 and 1∶250 000 geological maps. The processing of 1∶200 000 geological maps was done according to the following steps: the paper maps were firstly scanned and saved as.TIFF files; and point and line files were manually vectorized, after correcting spatial information using the standard map frame in the image analysis module of the MapGIS platform; then a topological area was created to generate WT, WL and WP files, before applying projection using unified parameters.

2.2.2 Dovetailing of Projected Maps

The 1∶50 000, 1∶250 000 and 1∶200 000 vectorized geological maps, which were projected to a scale of 1∶500 000, were dovetailed based on latest geological survey and research results. In particular, data acquired in recent years of the ophiolite-tectonic mélange, strata and magmatic rocks in the orogenic belt were expressed on the geological map. Ophiolitic belts such as Erlian–Hegenshan, Erdaojing–Diyanmiao and Suolun–Wulangou–Xilamulun were highlighted; and ophiolites with a diameter less than 2 mm were amplified to 5 mm. The strata were re-sorted, revised and merged according to '*Lithostratigraphy of Inner Mongolia Autonomous Region*' (Li et al., 1996) in addition to recent geological surveys and publications, and their age was revised according to the latest zircon age and paleontological data. The intrusive bodies were classified into different stages using the latest petrographic and geochemical data, and the era of the intrusive rocks was re-determined according to zircon U–Pb aging. Then, line elements were vectorized under the MapGIS software system to generate.WL files. The annotation code was entered to generate.WT files, which were modified, edited, reviewed and output on the screen before preliminary examination. After topological area creation, color filling and trimming,.WP files were generated, using the editing process shown in Fig. 2.

2.2.3 Preparation of Attribute Sheet

The attribute table was output on the MapGIS 6.7 platform and Excel was used for the modification, supplementation and code conversion of attributes. Then the attribute table was printed out and manually checked before being correlated with graphic data.

2.2.4 Attribute Data Check

Attribute data, including attribute structure, type and content, were manually checked to minimize error rate to the largest extent possible.

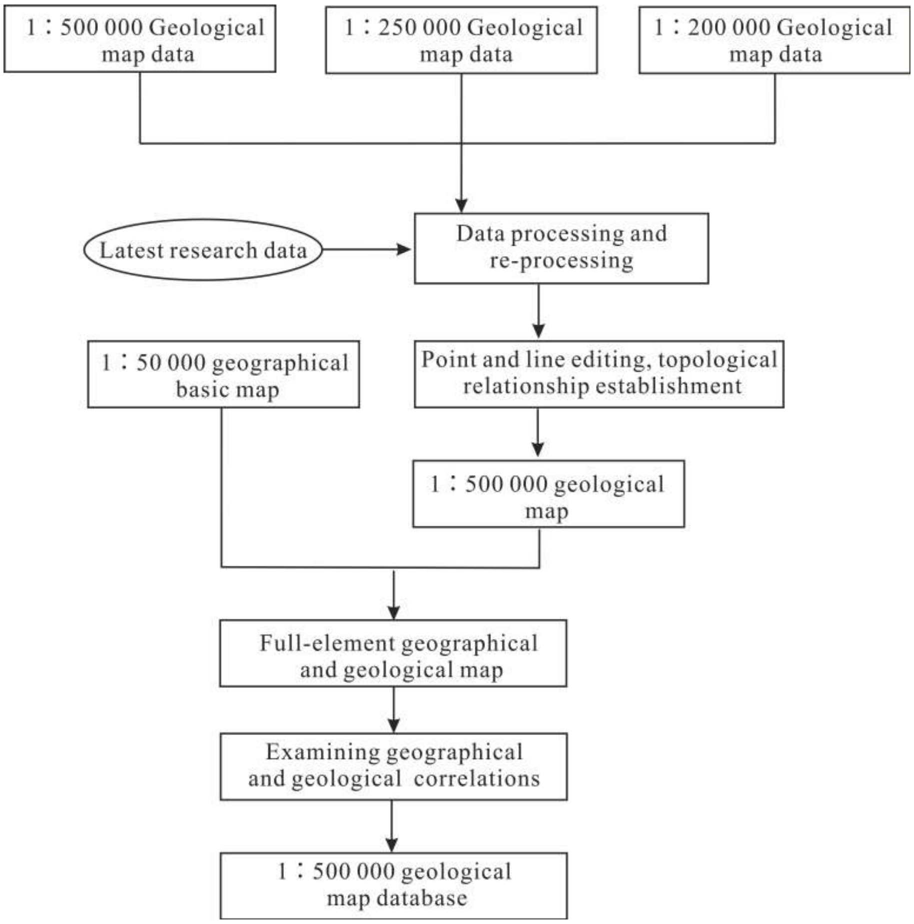

Fig. 2 Work flow of map compilation and database construction

3 Data Sample Description

3.1 Map Surface Structure

The 1∶500 000 digital geological map database of the Xiwuqi and Bainaimiao areas in the Erlian–Dongwuqi metallogenic belt is comprised of master map, auxiliary maps, map frames and legends. The master map and the auxiliary maps are placed in the map frame, with the legend on the right side of the map frame. The auxiliary map includes the Paleozoic stratigraphic and tectonic division maps of the middle part of the Xing'an–Mongolian orogeny. The legend includes strata, magmatic rocks, sub-volcanic rocks, dike rocks, among others. Strata is arranged according to era and stratigraphic sub-region. Magmatic rocks are arranged in the form of tables, with horizontal coordinates representing rock type and vertical coordinates representing era.

3.2 Map Layer Name

Geological and geographical maps are divided mainly according to element types and stored as documents.

3.3 Element (Entity) Type Name

Entity type name: point, surface and arc segment.

Point entities: geological body annotation, isotope, fault nature, tectonic unit annotation, stratigraphic division annotation, legend annotation and geographical map frame.

Line entity: geological boundary, fault, lead, geographical map frame, tectonic unit line, stratigraphic division line and legend line.

Surface entities: documents and legend regarding strata, intrusive bodies, dikes and sub-volcanic rocks, stratigraphic zones and tectonic unit area, and geographical area documents.

3.4 Attribute List

The 1：500 000 digital geological map database includes information on geological entity elements and geographical elements. Geological entities are mainly surface element attributes and isotopic ages.

The geobody surface element attribute table includes stratigraphic and intrusive rock units, of which the stratigraphic surface element is structured as follows: ID (identification code), area, circumference, geological code, formation name, layer, surface color CLR (color label), pattern number (fill pattern number), pattern height (fill pattern height), pattern width (fill pattern width) and pattern color (fill pattern color number).

The surface element attribute of intrusive rocks is structured as follows: ID (identification code), area, perimeter, geological code, surface color CLR (color number), pattern number (fill pattern number), pattern height (fill pattern height), pattern width (fill pattern width), pattern color (fill pattern color number), map layer, era and isotope age.

The isotope attribute is structured as follows: age, testing method, lithology and intrusion name.

3.5 Projection Parameters

The map parameters of the *Geological Map Spatial Database of the Xiwuqi and Bainaimiao Areas in the Erlian-Dongwuqi Metallogenic Belt* are shown in Table 2.

4 Data Quality Control and Evaluation

The 1：500 000 geological maps of the Xiwuqi and Bainaimiao Areas in the Erlian-Dongwuqi Metallogenic Belt are mainly based on the newly completed 1：500 000 and 1：250 000 digital geological map databases. Incorporating research results in recent years regarding ophiolite tectonic magmatism and orogenic belt evolution in the Xing'an–Mongolian

Table 2 Parameters of the geological map spatial database of the Xiwuqi and Bainaimiao areas in the Erlian-Dongwuqi metallogenic belt

Coordinate system type	Projection type	Ellipsoid parameter	Scale denominator	Coordinate unit	Parameter proportion
Projection rectangular coordinates	Coordinate system of Lambert isometric conical projection	Beijing 54/Ellipsoid Krasovski 1940	500 000	mm	1：1
First standard longitude and latitude	Second standard longitude and latitude	Longitude of central meridian	Latitude of projection origin	Frame longitude range	Frame latitude range
42°50′00″	45°40′00″	114°00′00″	41°30′00″	109°56′00″–119°56′00″	41°33′00″–46°53′00″

orogeny, the strata and tectonic units are re-divided, and geological maps and databases are compiled.

Whilst compiling the spatial data of the geological maps, the team prioritized data quality, with data quality control and evaluation ensured in two primary aspects: source data and data processing.

(1) In terms of source data, this project mainly uses the 1：50 000 and 1：250 000 geological maps and geological and mineral maps completed from 2008 to 2018. All 1：50 000 geological maps are in accordance with '*General Provisions for Regional Geological Surveys*' (1：50 000), '*1：50 000 Technical Requirements for Regional Geological Surveys*', '*Standards for Digital Geological Map Spatial Databases*', '*Technical Requirements and Detailed Rules for Implementation of 1：250 000 Regional Geological Map Spatial Database Construction*', '*Standards for Geological Information Metadata*' (DD2006–05), '*Legend of Regional Geological Maps*' (GB/T958–2015), among other standards for data collection, collation, storage and establishment of spatial databases. Furthermore, 100% self-checks and mutual checks were carried out on the original data collected from the field, and the database has been checked and accepted by an expert group with senior professional titles, which helps to ensure the quality of the source data used in mapping.

(2) In terms of data processing, firstly, the spatial information of all source data used for mapping is checked for accuracy, and data that had a spatial position which deviated or were lost were then revised to the correct position with a standard map frame; secondly, following dovetailing of projected maps, geobodies that failed to dovetail as a result of inconsistencies in certain 1：50 000 and 1：250 000 geological maps completed by different teams were verified in field work. In addition, in terms of data processing, the team carried out 100% self-checks and mutual checks on the processed data, especially the manually input attribute table, and modified the database after being checked and accepted by experts. The above measures ensure the quality of the database regarding source data and processing.

5 Main Achievements and Data Value

5.1 Main Achievements

New understandings and data have been obtained based on the 1：50 000 regional geological data and research results for this area since 2008, guided by plate tectonics theory, on the magmatism of orogenic belts, Paleozoic stratigraphic division and tectonic unit division. Also, the temporal-spatial framework, magmatic properties and tectonic background of intrusive rocks in this area (the middle part of the Xing'an–Mongolian orogeny) have been re-determined based on reliable isotopic ages obtained by high-precision in-situ zircon dating Xing'an–Mongolian. Certain key stratigraphic units have been newly built and re-defined. In addition to biological zoning, stratigraphic sub-regions have been re-divided, taking into consideration important structural boundaries, and the Paleozoic stratigraphic framework has been improved. The ophiolitic belts of the Early Paleozoic Sayin Aobao and Late Paleozoic Erdaojing-Diyanmiao, Wulangou are newly identified and expressed on the map, with more details of the trench-arc-basin system of the Early and Late Paleozoic. Guided by plate tectonic theory and accretionary orogeny theory, the tectonic units have been re-divided. The specific achievements in map compilation are shown in Table 3.

5.2 Data Value

The 1：500 000 Geological Map Spatial Database of the Xiwuqi and Bainaimiao Areas in the Erlian-Dongwuqi Metallogenic Belt is based on the latest (2008–2018) 1：50 000 geological survey data in this area. Guided by plate tectonic theory and geoscientific theories regarding subduction-accretion orogenic belts, we have fully incorporated the latest research achievements at home and abroad. This database may be applied in the following ways: (1) it may be used to compile geological map databases on smaller scales and thematic maps such as magmatic rock maps; (2) it may be used for the planning and management of regional geological and mineral resources survey; (3) the compilation and integration of basic geological survey data can provide a basis for the summary of metallogenic geological background and conditions. This project provides reliable and detailed results, data in the aspects of stratigraphic tectonic-magmatism and important tectonic boundaries of orogenic belts. Thus, it can be used to promote the study of orogenic belt evolution, metallogenic geological background and conditions in this area, and to reconcile current differences in the understanding of the orogenic belt in this area, especially the Late Paleozoic tectonic background (oceanic/intracontinental), as a result of incomplete data prior to this project.

6 Conclusion

The 1：500 000 Geological Map Spatial Database of the Xiwuqi and Bainaimiao Areas in the Erlian-Dongwuqi Metallogenic Belt, based on the latest regional geological survey and research work completed in this area in recent years, and guided by plate tectonic theory, was compiled using new technologies and methods such as GIS and geological mapping. With comprehensive research and compilation of digital geological maps, this database presents the latest data from geological surveys and research in the Xing'an–Mongolian orogeny from recent years. It also represents the most complete and up-to-date 1：500 000 geological map database for the middle part of the Xing'an–Mongolian orogeny. It provides basic data for the study of the Xing'an–Mongolian orogeny and metallogenic geological background, as well as national land and resource planning, paving the way for realizing the social value of basic geological work.

(1) Several key Paleozoic stratigraphic units have been newly established and re-determined in the Erlian–Dongwuqi metallogenic belt, including the newly established Early Devonian JilinBaolige Formation, Late Devonian Hanwulabage Formation, Early Carboniferous Hanaobao Formation, and re-determined the Ordovician Wenduermiao Group and Late Carboniferous Amushan Formation; it has re-divided three Paleozoic stratigraphic sub-regions, including Xilinhot, Baoerhantu and Bainaimiao, by placing the Erlian-Hegenshan and Suolun-Xilamulun ophiolitic belts as boundaries, thus improving the Paleozoic stratigraphic framework.

Table 3 Main achievements in map compilation

Achievement	Previous study	Specific Content	Significance
Paleozoic stratigraphic sub-regions are re-divided	The Xing'an–Mongolian Orogeny is divided into the Tianshan-Xingmeng and North China stratigraphic regions by the Hegenshan ophiolitic belt	With the Hegenshan-Suolun-Xilamulun ophiolitic belt as the boundary, the Paleozoic strata in the middle part of the Xing'an–Mongolian orogeny are divided into three stratigraphic areas, namely, Hongeer-Dongwuqi, Xilinhaote and Baoerhantu-Bainaimiao	Compared with previous stratigraphic zoning schemes, besides considering the division of biota, we considered important tectonic boundaries, such as ophiolitic belts, in stratigraphic division
The Early Devonian Jilin Baolige Formation (D_1j), the Late Devonian Hanwulabage Formation (D_3h) and the Early Carboniferous Hanaobao Formation (C_1h) have been newly established in the Honge'er-Dongwuqi stratigraphic sub-region	Newly established in this project	The newly discovered *Monograptus uniformis* graptolite assemblage indicates that the Jilinabolige Formation is a semi-deep-sea deposit in the Early Devonian. The Hanwulabage Formation in the late Devonian, which contains plant fossils such as *Schizocarpus orbicularis*, is a set of marine-terrigenous facies sediments. The Hanaobao Formation in the Early Carboniferous is a continental volcanic rock formation	The Late Paleozoic stratigraphic framework in the Dongwuqi area has been further improved. This area had continuous passive continental margin deposit since the Woduhe Formation in the Pridoli series and has transitioned to continental facies in the Late Devonian, ending the oceanic evolution
The Wenduermiao Group, Bainaimiao Formation, Amushan Formation and Shoushangou Formation have been redefined	The Wenduermiao Group (Changcheng System-Jixian System): the lower part consists of Sangdalaihuduge volcanic rock and the upper part consists of clastic rocks of the Haarhadda Formation; the Bainaimiao Formation (Qingbaikou System): felsic and basic schist; Amushan Formation: established in the Talinggong area	The original Wenduermiao Group, Sangdalaihuduge Formation, is redefined as a Permian ophiolitic mélange and ocean island seamount formation, while the original Haarhadda Formation is preserved as an Ordovician formation. The era of the Bainaimiao Formation is redefined as Early Ordovician-Middle Silurian. According to the newly identified plant fossils, the Amushan Formation in the northern Talingong area of Damaoqi is correlated with the Baijiadian Formation in the Chifeng area in the lower part, and with the Jiujuzi Formation in the upper part. It is clear that Shoushangou in the Xiwuqi area is a turbidite deposit with semi-deep-sea facies.	The Early Paleozoic Wenduermiao Group is a pre-arc accretionary wedge, and the Bainaimiao Formation represents magmatic arc, which together with the Early Paleozoic ophiolite represents the southern trench-arc basin system. The redefinition of the Late Paleozoic Amushan Formation has reconciled the inconsistencies between stratigraphic division and tectonic unit division in an effort to unify them. The sedimentary environment of the Shoushangou Formation indicates that the Late Paleozoic ocean basin has not closed

Continued table 3

Achievement	Previous study	Specific Content	Significance
The temporal-spatial distribution and properties of Paleozoic intrusive rocks have been re-determined	The era is partially determined by the K-Ar, Rb-Sr method.	According to zircon in-situ U-Pb aging, this map updates the era of the Paleozoic intrusive rocks in the middle part of the Xing'an–Mongolian orogeny. Most of the intrusive bodies in the study area are of precise ages. In the Erlian-Dongwuqi area, a large number of intrusive rocks originally classified as Permian are redefined as Carboniferous and Cretaceous, and the Devonian intrusive rocks in Baiyinbaolidao area are redefined as Ordovician and Silurian	Paleozoic magmatism in the middle part of the Xing'an–Mongolian orogeny is divided into two main stages: Ordovician-Early Silurian and Late Carboniferous-Early Permian, respectively representing the Early and Late Paleozoic ocean subduction, arc-continent collision and final closure of the ocean. Compared with previous compilation efforts, we have gathered a large number of high-precision zircon ages, and have clearly defined the temporal-spatial distribution of magmatism, tectonic background and constraints on the orogeny processes
The Sayin Aobao Ophiolitic Mélange is newly identified in the Early Paleozoic Northern Orogenic Belt/Arc Basin System	Newly determined in this map compilation	The Early Paleozoic (519 Ma) ophiolite is newly identified in the Sayin Aobao area in the south of Abaga Banner, in which Bininitic rocks representing initial subduction were identified. The north side features island arc intrusive rocks (485–493 Ma), and the south side features accretionary wedge of the Haarhadda Formation of the Wenduermiao Group, indicating the northward subduction polarity	The tectonic pattern of bi-direction subduction of the Early Paleozoic ocean is further clarified and the accretionary orogenic belt structure is described in detail; namely, accretionary wedge, ophiolite, island arc and back-arc basin on both sides from the ocean
The Erdaojing-Diyanmiao ophiolitic belt is expressed on the map	Newly determined in this project.	Distributed in the Erdaojing (298 Ma), Daqingmuchang (314–318 Ma) and Diyanmiao (340 Ma) areas in the south of the Sunidyou Banner; located on the south side of the Carboniferous Baiyinbaolidao-Xiwuqi Island Arc, representing northward subduction of the Carboniferous ocean; age is between Hegenshan and Suolun-Xilamulun ophiolite	Together with the Sunitezuoqi-Xiwuqi island arc and sedimentary formation, it represents the Carboniferous accretion zone developed on the northern side of the Xilamulun ophiolite, reflecting the process of successive collision and accretion from north to south

Continued table 3

Achievement	Previous study	Specific Content	Significance
The Early Permian ophiolite in Wulangou is newly identified	Originally included in the Sandalaihuduge Formation of the Wenduermiao Group	The Early Permian Ophiolitic Mélange is identified in the Sandalaihuduge Formation of the Wenduermiao Group in the Wulangou area. Gabbro age is 292± 10 Ma and ocean island seamount formation (including OIB basalt and cap carbonate) is also developed. The ophiolite is of SSZ type	The spatial distribution, age and zoning significance of the Suolun-Wulangou-Xilamulun ophiolitic belt are further clarified, which is conducive to more precise tectonic unit division and stratigraphic division. Meanwhile, the determination of the Permian SSZ ophiolite also indicates that the Late Paleozoic ocean basin has not closed
Tectonic units are re-divided	Bounded by the Hegenshan ophiolitic belt, it is divided into the northern Siberian plate and North China plate	With the Suolun-Xilamulun ophiolitic belt as the boundary, the middle part of the Xing’an–Mongolian orogeny is divided into two first-order tectonic units: the northern Siberian plate and the North China plate in the south. The northern Siberian plate is divided into two secondary tectonic units, specifically, the continental margin accretion zone and the Xilinhot composite accretion zone. While the North China plate on the south side is divided into two secondary tectonic units, namely, the northern margin accretion zone and the North China continental block, with the boundary of the Chifeng–Bayan Obo fault	Considering the growth mode of accretionary orogenic belts, ophiolite is adopted as a main boundary of the first-class tectonic unit (plate), while the others are geobodies attached at the edge of the plate, such as island arcs, micro-continents and accretionary wedges. In contrast with previous division schemes, the orogenic belt is not taken as an independent tectonic unit

(2) The present work has summarized the temporal-spatial evolution of Paleozoic magmatic rocks, and re-determined the temporal-spatial distribution and properties of Paleozoic intrusive rocks in the area. The Early and Late Paleozoic two-stage magmatism represents a response to the Early and Late Paleozoic subduction and accretion orogeny.

(3) The Early Paleozoic Sayin Aobao, Changtu and Late Paleozoic Erdaojing-Diyanmiao, and Wulangou Ophiolitic Mélange are newly identified and expressed on the map. The structure of the accretive orogenic belt formed by the bi-direction subduction of the Early Paleozoic ocean is described in detail; this project has also prescribed constraints to the subduction and final closure of the late Paleozoic ocean basin, and re-divided the tectonic units.

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