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河北省张家口地区赵川幅 1∶50 000 矿产地质图数据库

白海军　缪建普*　许新成　袁矫龙　陶利鑫　邓佳

(河北省地矿局第三地质大队，河北 张家口 075000)

摘要: 赵川幅 (K50E020006) 位于河北省张家口—宣化地区东部, 华北克拉通北缘中段, 是中国重要的金矿产地之一。赵川幅 1∶50 000 矿产地质图数据库根据《固体矿产地质调查技术要求 (1∶50 000)》(DD 2019–02) 和行业其他规范要求进行系统编制, 完成专项地质填图 379.93 km^2、实测地质路线长度约 351 km、矿点检查及异常检查约 15 处、U–Pb 年龄样品数据 3 组 (390~370 Ma、~234 Ma 和 140~120 Ma) 和岩石全分析样品数据 6 组。本数据库在野外实测的地质点、地质路线、地质界线数据和收集的以往区域地质调查资料进行综合整理的基础上, 重新确定地质单元界线, 建立相应的要素图层, 对赵川幅中—新太古代、中元古代及中生代的地层进行重新划分, 对太古宙至中生代的岩浆岩进行归纳, 厘定了岩浆岩和成矿的时空演化序列, 建立了"三位一体"找矿预测地质模型及地、物、化、遥综合找矿预测模型。该数据库对区内矿产勘查部署具有重要的参考价值, 还可以为当地自然资源部门的国土空间规划和生态文明建设提供服务。

关键词: 数据库；1∶50 000；华北克拉通；矿产地质图；赵川幅；地质调查工程；河北

数据服务系统网址: http://dcc.cgs.gov.cn

1　引言

河北省赵川幅 (K50E020006) 研究区位于张宣地区东部, 华北克拉通北缘中段 (图 1a), 燕山山脉与太行山脉交汇部位, 北邻尚义—赤城深大断裂。区内地层发育广泛, 主要为太古宇桑干岩群和崇礼岩群变质岩系, 中—晚元古代发育海相沉积盖层, 寒武–奥陶系为浅海相沉积盖层, 侏罗—白垩系为陆相火山沉积岩, 第四系为河流冲洪积物 (图 1b; 崔盛芹等, 2000)。该地区构造活动频繁, 断裂极为发育, 且具有长期活动的特点, 区域性一级断裂包括尚义—崇礼—赤城断裂和上黄旗—乌龙沟断裂等。研究区岩浆岩具有多期次活动及岩石类型丰富的特点, 太古宙侵入岩主要为橄榄岩、辉长岩、闪长岩及花岗岩; 古生代岩浆岩以泥盆纪水泉沟碱性杂岩体为代表, 面积达 350 km^2 (图 1b; Miao LC et al., 2002);

第一作者简介：白海军，男，1984 年，高级工程师，从事矿产地质方面工作; E–mail: 304116131@qq.com。
通讯作者简介：缪建普，男，1986 年，工程师，从事矿产地质方面工作; E–mail: 279187068@qq.com。

中生代岩浆岩主要形成于三叠纪和晚侏罗–早白垩世, 三叠纪岩浆岩主要包括基性–超基性岩和花岗岩, 如小张家口基性–超基性岩体、红花梁花岗岩和谷嘴子花岗岩等 (Miao LC et al., 2002; Jiang N et al., 2007; 田伟等, 2007); 晚侏罗–早白垩世侵入岩主要为闪长岩和花岗岩, 包括上水泉花岗岩和转枝莲闪长岩等 (Jiang N et al., 2007, 2009)。区内火山岩发育广泛, 时代集中在侏罗纪—早白垩世。白垩纪张家口组火山岩在区内分布最广, 为一套中酸性的火山岩、火山碎屑岩, 岩性以英安岩、粗面岩和流纹岩为主 (图 1b)。

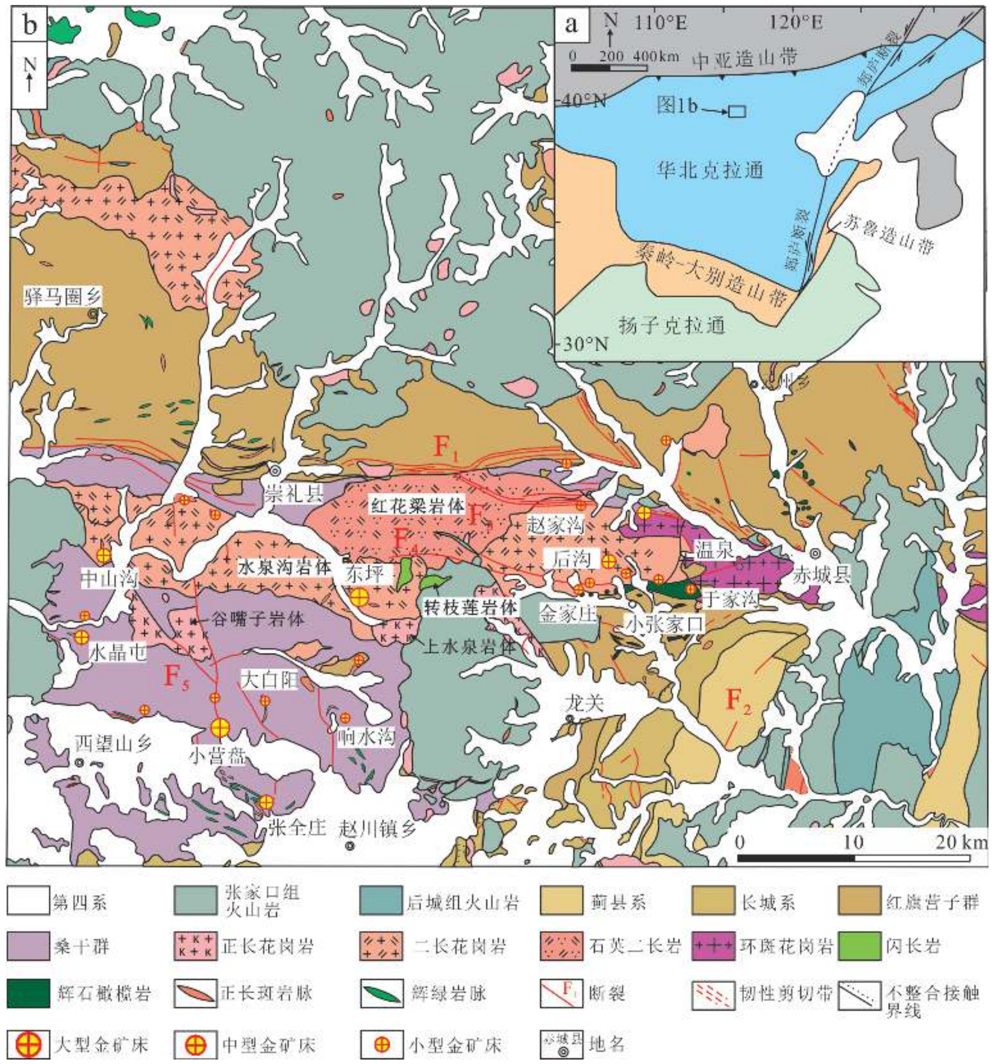

图 1　华北克拉通简图及研究区位置 (a) 与区域地质简图 (b)

F1—尚义—崇礼—赤城断裂; F2—上黄旗—乌龙沟断裂; F3—上太子城—温泉断裂; F4—西三间房—沃麻坑断裂; F5—韩家沟—谷嘴子—场地断裂

区内矿产十分丰富, 目前发现的金矿床 (点) 超过 100 处, 主要集中在赤城、崇礼和宣化地区, 被称为河北省的"金三角"(图 1b)。其中小营盘与东坪金矿床为大型矿床 (Wang DZ et al., 2020), 后沟、张全庄、大白阳和水晶屯等金矿床属于中型矿床 (Cook NJ et al., 2009; Shen JF et al., 2020), 赵家沟、金家庄、西坪、大营盘和中山沟等属于小型矿床。大量学者认为, 金矿床形成于海西期末—燕山期, 受控于内蒙古大洋板块南向俯冲 (Xiao W et al., 2003; Windley BF et al., 2007; 赵越等, 2017), 将已经在区域变质作用下初步活化富集的金活化萃取 (Bao ZW et al., 2014; Li H et al., 2018), 使金进一步富集, 燕山期的

岩浆活动使金进入成矿流体随岩浆同时向地表迁移, 在有利位置沉淀富集, 形成了张宣地区密集的金矿和金矿化点 (Zhen SM et al., 2020)。

虽然前人对区内金矿床的地球化学特征及矿床成因进行了大量研究, 但赵川幅内尚未系统开展过 1：50 000 矿产地质调查工作, 尤其对成矿地质体、成矿构造及成矿构造面、成矿作用特征标志等未开展过系统调查研究。成矿规律研究总结不足严重制约了本区的进一步找矿勘查。本次 1：50 000 赵川幅矿产地质图的编制提高了区内矿产地质调查程度, 对揭示金矿床的区域成矿规律和资源潜力具有重要意义, 并有利于区内矿产资源的保护及生态文明的建设。

2 数据采集与处理方法

2.1 数据基础

张宣地区 1：50 000 区域地质调查工作主要开展于 20 世纪 80 年代到 90 年代, 赵川幅 (西半幅) 已在 20 世纪 80 年代完成区域地质调查工作, 这些前期工作为赵川幅地质矿产图的编制奠定了基础。

赵川幅 (K50E020006) 1：50 000 矿产地质图以 1：250 000 和 1：50 000 常峪口幅、崇礼幅、镇宁堡幅区域地质调查为基础[❶❷], 以赵川幅 1：50 000 矿产地质专项填图成果为主要资料来源, 对存在“同物异名”或“异物同名”现象的岩石、地层单位等信息进行统一梳理, 重新对幅内岩体分类、测年等, 对大白阳金矿进行实地勘查、编录 (坑道、钻孔), 对成矿年龄厘定。以最新的《勘查区找矿预测理论与方法》(叶天竺等, 2014) 成矿理论和《固体矿产地质调查技术要求 (1：50 000)》(DD 2019–02) 为基本参照, 充分利用已有区域地质调查成果资料, 深入分析研究, 紧密结合成矿规律和成矿预测目的有选择、有重点地开展, 最终编制而成。地理信息底图采用国家 2000 大地坐标系 (CGCS 2000), 数据处理利用数字填图系统 (DGSS) 和 MapGIS 等计算机软件进行, 地形图采用国家测绘地理信息局最新地理数据 (韩坤英等, 2005)。

数据库的元数据按照《地质信息元数据标准》(DD2006–05) 进行编制, 标定与成矿理论有密切联系的信息要素 (成矿地质体、成矿结构面和成矿作用特征标识), 以不同的形式 (点、线、面) 体现出来, 同时赋予其相应的属性和数值 (宋相龙等, 2017; 朱群等, 2018; 党学亚等, 2018), 最终形成矿产地质图数据库 (白海军等, 2020; 表 1)。

为编制赵川幅 (K50E020006)1：50 000 矿产地质图, 收集、修编 1：50 000 区域地质调查路线长度约 612 km, 路线约 94 条, 地质点约 1 064 个; 利用前人锆石 U–Pb 年龄样品数据约 2 组、岩石全分析样品数据约 6 组; 实测地质路线长度约 351 km, 路线 105 条, 地质点 1 154 个, 矿点检查及异常检查约 15 处, 实测锆石 U–Pb 年龄样品数据 1 组, 填 (编) 图总体精度达到 1：50 000 矿产地质专项填图的具体要求。

2.2 数据采集

根据预研究成果, 赵川幅找矿预测的矿床类型为岩浆热液型金矿, 按照国土资源部矿产勘查技术指导中心的矿集区找矿预测技术要求 (试行)[❸], 有选择、有重点的开展数据采集工作, 避免基础研究、矿产研究与采集数据脱节的现象 (张庆合等, 2002)。数据来源分为文献收集与实测 2 类 (表 2), 文献收集类数据包括整理以往区调、勘探、科研报告和已发表论文中的数据, 实测类数据包括路线勘查、物化探测量和探矿工程等取得的数据。

表 1　赵川幅 1∶50 000 矿产地质图数据库基本信息

条目	描述
数据库名称	河北省张家口地区1∶50 000赵川幅矿产地质图数据库
数据库作者	白海军, 河北省地矿局第三地质大队 缪建普, 河北省地矿局第三地质大队 许新成, 河北省地矿局第三地质大队 袁矫龙, 河北省地矿局第三地质大队 陶利鑫, 河北省地矿局第三地质大队 邓　佳, 河北省地矿局第三地质大队
数据时间范围	2017—2018年
地理区域	河北省宣化区。经纬度范围为: 东经115°15′00″～115°30′00″, 北纬40°40′00″～40°50′00″, 采用1∶50 000地形图的国际标准分幅编号
数据格式	MapGIS
数据量	11.3 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(DD20160052)
语种	中文
数据库(集)组成	该系统库由1∶50 000国际标准分幅的地理地图库, 1∶50 000全国资源潜力评价地质图库、属性库、点性库、线性库、色标库、花纹库、符号库等构成。地质图库由建造柱状图、成矿构造信息表、(矿产)图例、矿产地名录、所属成矿区带位置图、大地构造分区划分表、地质剖面图、责任签8个辅图(附表)和1个主图构成。每幅图由不同的专题层组成(例如: 地理网格、居民地、矿产地、构造、侵入岩、蚀变岩等)

表 2　河北赵川幅火山岩和侵入岩样品采集地及锆石年龄

序号	样品采集地	岩石类型	锆石U–Pb年龄/Ma	数据来源
1	青羊沟	张家口组粗面岩–流纹岩及二长花岗岩	128～141	杨进辉等, 2006; Jiang et al., 2009; 李创举和包志伟, 2012
2	水泉沟—大南山	辉石角闪二长岩–辉石–二长岩–角闪二长岩–正长岩	372～390	Jiang N et al., 2007; Li H et al., 2018; Zhang QQ et al., 2018
3	响水沟	似斑状花岗岩	233.7±2.3	Miao LC et al., 2002; 陈茜, 2013
4	小蛤蟆口	花岗岩	136.4±3	实测

2.3　数据处理

赵川幅 1∶50 000 矿产地质图地质体目标层为变质岩 (特别是谷咀子岩组) 和燕山期侵入岩, 基本层为沉积岩、火山岩和侵入岩等; 地质构造专题底图分为基本层 (成矿前、后断裂) 和目标层 (成矿期断裂); 蚀变特征目标层 (钾化、硅化、绢英岩化、黄铁矿化、绢云母化)。最终矿产地质图要全面反映与本区岩浆热液型金矿有关的建造、构造和矿化蚀变信息等内容 (李超岭等, 2012)。

在野外实测的地质点 (P)、地质路线 (R)、地质界线 (B) 数据和收集的以往区域地质调查资料进行综合整理的基础上, 重新确定地层单元界线、岩体范围界线, 划分各类建造类型、补充岩性 (组合) 界线, 绘制岩性建造花纹, 勾绘蚀变范围、标注探矿工程等, 同时建立相应的要素图层, 以点.WT、线.WL、面.WP 形式表达, 制作流程见图 2。

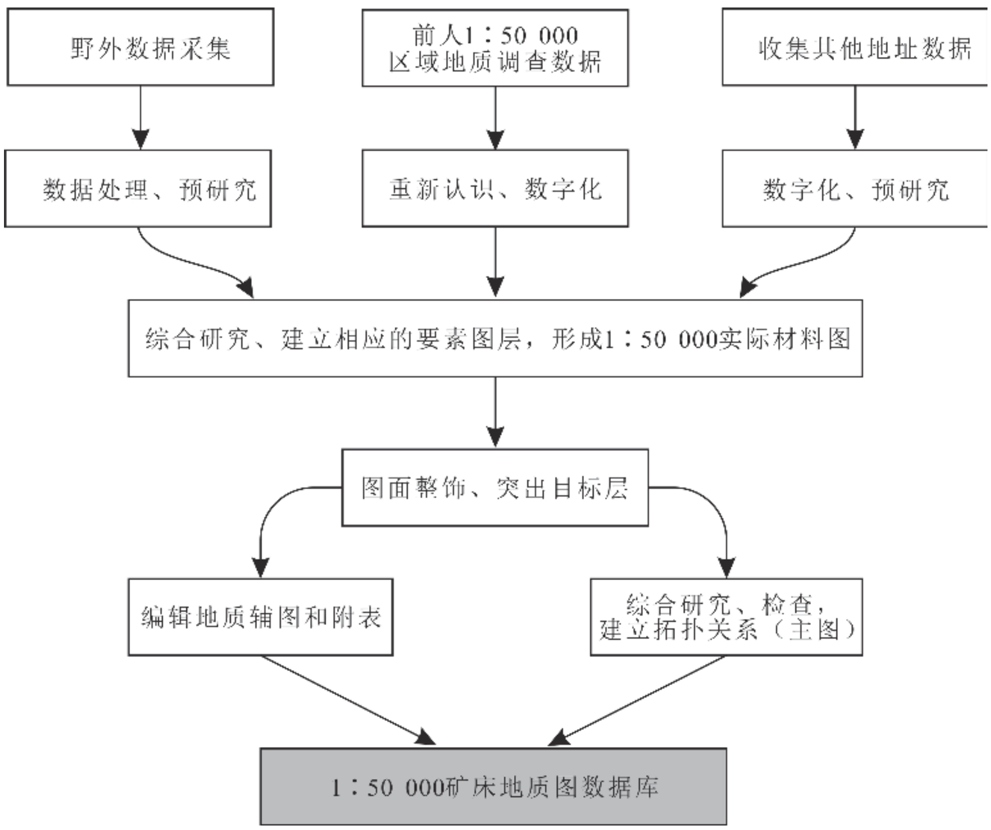

图 2　1：50 000 矿产地质图数据库制作流程图

图面表达形式按照中国地质调查局《1：50 000 矿产地质调查工作指南 (试行)》(中地调函〔2016〕117 号) 相关要求和规范执行, 例: ①沉积地层和变质岩采用“时代+岩石地层单位”表示, 如 Ar_2g^b 表示中太古界谷咀子岩组的条纹、条带状黑云角闪斜长片岩建造, 上下标代号不反映建造内容; ②侵入岩代号为“岩性+时代”, 如 γK_1 代表早白垩世花岗岩; ③建造构造图面色调按时代、岩性给出, 参考《地质图用色标准及用色原则》(D/ZT0179–1997) 统一色标设置, 特殊意义的地质体选用突出的颜色表示, 基本层的颜色淡化处理; ④地理信息底图采用 2 000 国家大地坐标系 (CGCS 2000) 等。

3　数据内容描述

地质图是将沉积岩层、火成岩体、地质构造等的形成时代和相关的各种地质体、地质现象, 用一定图例表示在某种比例尺地形图上的一种图件, 是以全面反映在最新矿产调查工作中取得的各项成果为导向, 最终为该地区的矿产资源规划、勘查提供基础性地质图件, 为野外地质调查和科研工作提供有益的参考资料。河北省赵川幅 1：50 000 矿产地质图分为主图、辅图、附表 3 部分, 图面内容由地理信息和地质信息组成。

主图部分地理要素信息主要为居民地属性表; 地质要素信息包含有: 建造数据表、岩性花纹数据表、地质界线数据表、断裂数据表、蚀变类型数据表、同位素年龄数据表、岩石化学样品数据表、同位素样品采样点数据表、地质点数据表、地质剖面数据表、产状要素数据表、火山构造数据表等 (表 3)。

主图的底图分为基本层和目标层, 目标层用来表达不同地质体建造类型、岩石组合在平面上的分布和变化, 对基本层进行简化。河北省赵川幅 1：50 000 矿产地质图的目

标层为变质岩和燕山期侵入岩，基本层为沉积岩、火山岩和其它时期的侵入岩等，以全面反映与本区岩浆热液型金矿有关的建造、构造和矿化蚀变信息等内容（表 4）。

表 3 赵川幅地质图主图数据库

序号	字段名称	数据格式	数据类型	实例
1	村镇名称	.WT	点文件	大白阳、涧沟河等
2	矿产地	.WT	点文件	大白阳金矿、小白阳银矿等
3	地层	.WP	区文件	张家口组火山岩、谷咀子组变质岩
4	断裂	.WL	线文件	张全庄–和尚窑断裂
5	岩体	.WP	区文件	响水沟岩体、象山岩体
6	建造	.WP	区文件	二辉斜长麻粒岩建造
7	脉岩	.WP	区文件	辉绿岩脉、闪长玢岩脉等
8	矿化蚀变	.WT	点文件	褐铁矿化、黄铜矿化
9	地质界线	.WL	线文件	角度不整合界线、整合界线
10	地层产状	.WT	点文件	节理、面理、片麻理

表 4 目标层不同地质体建造类型

目标层建造	岩性代号	建造类型	岩石组合	矿化蚀变特征
变质岩建造	Ar_2g^d	二辉斜长麻粒岩建造	二辉斜长麻粒岩、混合岩化含辉石麻粒岩、含透辉石斜长麻粒岩	碳酸盐化、高岭土化
	Ar_2g^c	石榴子石角闪斜长变粒岩–混合岩化角闪斜长变粒岩建造	角闪斜长变粒岩、黑云角闪斜长变粒岩、含辉石黑云角闪斜长变粒岩	碳酸盐化、高岭土化
	Ar_2g^b	条纹、条带状黑云角闪斜长片麻岩建造	褐灰色黑云斜长片麻岩、混合岩化黑云角闪斜长片麻岩	碳酸盐化、高岭土化
	Ar_2g^a	石榴子石角闪透辉石斜长变粒岩–混合岩化透辉石斜长变粒岩建造	角闪透辉斜长变粒岩、混合岩化透辉石斜长变粒岩、含辉石黑云斜长变粒岩	硅化、钾化、绢云母化
侵入岩建造	γK_1	花岗岩建造	花岗岩	

辅图则是对主图的进一步说明、解释，是综合研究的产物，地质要素信息有沉积岩建造数据表、侵入岩数据表、火山岩性岩相数据表、变质岩建造数据表、大地构造分区数据表等，相应地绘制了大地构造位置图、建造柱状图、地质剖面图、典型矿床平面图、典型矿床重要勘探线剖面图、矿体水平投影图及矿体垂直纵投影图等。

附表部分地质要素信息有成矿构造信息表、矿产地名录、责任签、接图表等。

赵川幅 1∶50 000 矿产地质图数据库由 1∶50 000 国际分幅的数据库和 1∶50 000 矿产地质调查的属性库、线型库、色标库、子图库（花纹、注释）库、符号库等组成，包含地质要素信息和地理要素信息。由于要素信息类别不同，其数据项名称也有所差异（左群超，2011）。

4 数据质量及监控

4.1 数据精度

地质体图面表示精度，面积≥1 mm^2，每个地质体单位都建立相应的属性，有些重要的

地质体面积较小, 但在图面上均予以夸大表示。

精度方面, 地质时代表示到世, 地层单位表示到组 (岩组), 个别到段或群 (岩群), 侵入岩以“岩性+年代”表示, 如 γK_1(早白垩世花岗岩)。构造变形分褶皱、脆性断裂和韧性剪切带进行表示, 其中褶皱分为基底褶皱和盖层褶皱, 断裂分为 I 级区域深大断裂、II 级主干断裂和 III 级次级断裂。每个地质体单位都建立相应的属性。

4.2 数据质量监控

全面系统收集了研究区 1∶50 000、1∶200 000、1∶250 000 区域调查数据资料, 严格遵循用新不用旧、用大不用小 (比例尺) 的原则进行数据资料收集工作。野外调查工作依照中国地质调查局《1∶50 000 矿产地质调查工作指南 (试行)》(中地调函〔2016〕117 号) 和《固体矿产地质调查技术要求 (1∶50 000)》(DD 2019–02) 执行, 严格执行“三级质量检查制度”, 其中原始资料自检、互检比例均为 100%, 项目组检查比例大于 50%, 质检组抽查比例大于 15%, 保证了资料数据的质量 (万常选等, 2009)。

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

建库工作依据地质图件数据特点、矿产资源潜力评价数据模型和地质数据质量检查与评价, 建立以“单个图件编图质量模型+单个图件空间数据质量模型+单个图件属性数据质量模型+单个图件元数据质量模型+单个图件质量模型+图件子集质量模型+图件集合质量模型”(简称“地质图件 7 层质量控制模型”) 为核心的地质图件数据质量检查与评价方法技术体系 (左群超等, 2013), 并研发提供了支持软件 (GeoMag、GeoTok、GeoDQC 等), 方便图库数据质量自检、互检、抽检、修改。统一检查标准, 实现定量评估自动化, 极大提高了质量检查与评价效率、降低了工作成本, 保证了建库质量符合技术要求。

建库成果质量验收以“两阶段验收法”进行, 即先由编图专家验收组进行编图成果质量验收, 通过验收后再由建库专家验收组进行验收, 验收专家确认无质量问题后方可以用于汇总、集成建库。

5 数据价值

赵川幅 1∶50 000 矿产地质图是中国地质调查局开展新一轮矿产地质调查的图幅之一。本次工作按照《矿产地质调查技术要求 (1∶50 000)》(DD2019–02) 要求, 在深入研究图幅内建造构造的基础上, 以 1∶50 000 专项地质填图成果为主, 结合图幅及周边图幅不同时期、不同比例尺的地质资料, 对太古宇变质岩、元古宇长城系、中生界白垩系张家口组建造类型进行了重新划分; 建立了赵川幅岩浆岩的时空演化序列, 由老到新分别为①中太古代变质二长花岗岩建造 ($\eta\gamma Ar_2$), ②新太古代花岗片麻岩建造 ($ggAr_3$), ③海西期辉石角闪二长岩–辉石二长岩–角闪二长岩建造 ($v\eta D_2$–$\varphi\eta D_2$–$\psi\eta D_2$)、二长岩–正长岩–石英二长岩建造 (ηD_2–ξD_2–$\eta o D_2$), ④印支期二长花岗岩建造 ($\eta\gamma T_3$), ⑤燕山期黑云母花岗岩建造 ($\gamma\beta K_1$)、辉石闪长岩建造 ($\varphi\delta K_1$)、黑云母二长花岗岩建造 ($\eta\gamma\beta K_1$); 总结了区域成矿时空演化序列, 为①中太古代的沉积变质型铁矿, ②早–中侏罗世的岩浆热液型金矿, ③早白垩世的陆相次火山岩型铅锌矿和金铜矿; 厘定本区金矿的目标层为燕山期侵入岩、太古宇变质岩 (特别是谷咀子岩组), 为后续矿产资源潜力评价和找矿预测工作打下了良好

的基础; 建立了成矿地质体、成矿构造及成矿结构面、成矿作用特征标志的“三位一体”找矿预测地质模型及地、物、化、遥综合找矿预测模型。

数据库由地质图库、属性库、点性库、线性库、色标库、花纹库、符号库等构成, 具有信息量大、功能齐全、实用性强等特点。本次工作不仅是对找矿工作理论探索, 也是对矿产地质调查成果图面表达方式和内容的创新, 对该区今后矿产勘查部署具有重要的参考价值。

6 结论

(1) 赵川幅 1：50 000 矿产地质图数据库, 不仅是对找矿理论工作的探索, 也是对矿产地质专项调查成果图面表达方式和内容的创新。

(2) 赵川幅 1：50 000 矿产地质图数据库具备信息量大、功能齐全、实用性强等特点, 同时具备有动态更新的接收端。不仅可以及时完成基础图件的更新与完善, 还可以为当地自然资源部门合理规划提供常态化服务, 对降低勘查风险、保障地质勘查有着重要的现实意义。

(3) 本次工作对赵川幅地层进行了重新划分, 建立了岩浆岩和成矿的时空演化序列, 建立了“三位一体”找矿预测地质模型及地、物、化、遥综合找矿预测模型。赵川幅 1：50 000 矿产地质图数据库为该区矿产资源潜力评价和找矿预测工作提供了基础数据支撑, 对后续矿产勘查部署具有重要的参考价值。

致谢：河北省赵川幅 1：50 000 矿产地质图是一项集体成果, 野外一线和室内制作人员都付出了辛勤的汗水。在矿产地质图数据库的建立过程中, 得到叶天竺、庞振山、程志中、薛建玲、左群超等多位专家的辛勤指导, 在此对各位专家和项目组所有成员表示最诚挚的感谢。

注释：

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❷ 河北省区域地质矿产调查研究所. 2008. 张家口市幅 1：250 000 区域地质调查成果报告 [R].

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1∶50 000 Mineral Geological Map Database of the Zhaochuan Map-sheet in Zhangjiakou area, Hebei Province

BAI Haijun, MIAO Jianpu*, XU Xincheng, YUAN Jiaolong, TAO Lixin, DENG Jia

(*No.3 Geological Brigade of Hebei Provincial Geology and Mineral Exploration Bureau*, *Zhangjiakou* 075000, *Hebei*, *China*)

Abstract: The Zhaochuan Map-sheet (K50E020006) area is located in the eastern part of Zhangjiakou–Xuanhua region of Hebei province and the middle section of the northern margin of the North China craton. It is one of the important gold fields in China. The 1∶50 000 mineral geological map database of the Zhaochuan Map-sheet was compiled in accordance with the *Technical Requirements of Solid Mineral Geological Survey* (1∶50 000) (DD 2019−02) and other applicable industrial standards. The survey work involves specific geological mapping covering an area of 379.93 km^2, measured geological routes totaling approximately 315 km in length, ore spot checks and anomaly checks at about 15 points, three groups of U–Pb ages (390–370 Ma, 234 Ma and 140–120 Ma), and six groups of whole-rock analytical data. Through comprehensively analysing field measurement data of geological points, geological routes and geological boundaries, and previous regional geological survey records, the boundaries of geological units were redelineated, and the corresponding feature layers were established. Meanwile, the Meso–Neoarchean, Mesoproterozoic and Mesozoic strata in the Zhaochuan Map-sheet were redivided, the Archean to Mesozoic magmatic rocks were generalized, the spatio-temporal evolution sequence of the magmatic rocks and metallogenesis was determined, and a "three-in-one" ore prospecting prediction geological model and an integrated geological, geochemical, geophysical and remote-sensing ore prospecting prediction model were then established. The database has a high reference value for the deployment of mineral exploration activities in the area, and could also provide service

About the first author: BAI Haijun, male, born in 1984, senior engineer, engages in mineral geological survey and research; E-mail: 304116131@qq.com.
The corresponding author: MIAO Jianpu, male, born in 1986, engineer, engages in mineral geological survey and research; E-mail: 279187068@qq.com.

for the local natural resource departments in the field of the land space planning and ecological civilization.

Key words: database; 1∶50 000; North China craton; mineral geological map; Zhaochuan Map-sheet; geological survey engineering; Hebei

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

1 Introduction

The Zhaochuan Map-sheet (K50E020006) study area is located in the eastern part of Zhangjiakou–Xuanhua region, Hebei province, and in the middle section of the northern margin of North China craton (Fig. 1a) where the Yanshan range joins with the Taihang range, neighboring the Shangyi–Chicheng deep large fault to the north. The strata in the area are widely developed, primarily the Archean Sanggan Group and Chongli Group metamorphic complex, Middle to Late Proterozoic marine sedimentary overlying strata, Cambrian–Ordovician shallow-sea sedimentary strata, Jurassic–Cretaceous continental volcanic sedimentary rocks, and Quaternary fluvial alluvial-diluvial sediments (Fig. 1b; Cui SQ et al., 2000). Tectonic activities in the area could be frequent, as the faults are extremely developed, showing constantly active. Regional first-order faults include the Shangyi–Chongli–Chicheng fault and Shanghuangqi–Wulonggou fault. The magmatic rocks in the study area are characterized by multiple stages and various rock rypes. Archean intrusive rocks include peridotite, gabbro, diorite, and granite. Paleozoic magmatic rocks, typically the Devonian Shuiquangou alkaline composite plutons, covers an area of 350 km^2 (Fig. 1b; Miao LC et al., 2002). The Mesozoic magmatic rocks were mainly developed in Triassic and Late Jurassic–Early Cretaceous. The Triassic magmatic rocks mainly consist of mafic–ultramafic rocks and granite, such as the Xiaozhangjiakou mafic–ultramafic pluton, Honghualiang granite, and Guzuizi granite (Miao LC et al., 2002; Jiang N et al., 2007; Tian W et al., 2007). The Late Jurassic–Early Cretaceous intrusive rocks are mainly diorite and granite, including the Shangshuiquan granite and Zhuanzhilian diorite (Jiang N et al., 2007, 2009). Volcanic rocks are widely present throughout the area and they were mainly developed in the Jurassic–Early Cretaceous. The Cretaceous Zhangjiakou Formation volcanic rocks, which are the most widely found rocks in the area, are a series of intermediate-acidic volcanic and pyroclastic rocks, mainly consisting of dacite, trachyte, and rhyolite (Fig. 1b).

The area is home to very rich minerals. So far more than 100 gold deposits (spots) have been discovered. They are mainly located in Chicheng, Chongli, and Xuanhua, known as the “golden triangle” of Hebei province (Fig. 1b). Among them, the Xiaoyingpan and Dongping gold deposits are large-sized (Wang DZ et al., 2020), the Hougou, zhangquanzhuang, Hanjiegou, and Shuijingtun gold deposits are medium-sized (Cook NJ et al., 2009; Shen JF et al., 2020), and the Zhaojiagou, Jinjiazhuang, Xiping, Dayingpan, and Zhongshangou are small-sized. Many authors deem that the gold deposits formed in the late Hercynian–Yanshanian and are controlled by the southward subduction of the Inner Mongolia oceanic plate (Xiao W et al., 2003; Windley BF et al., 2007; Zhao Y et al., 2017), which extracted out the gold that had

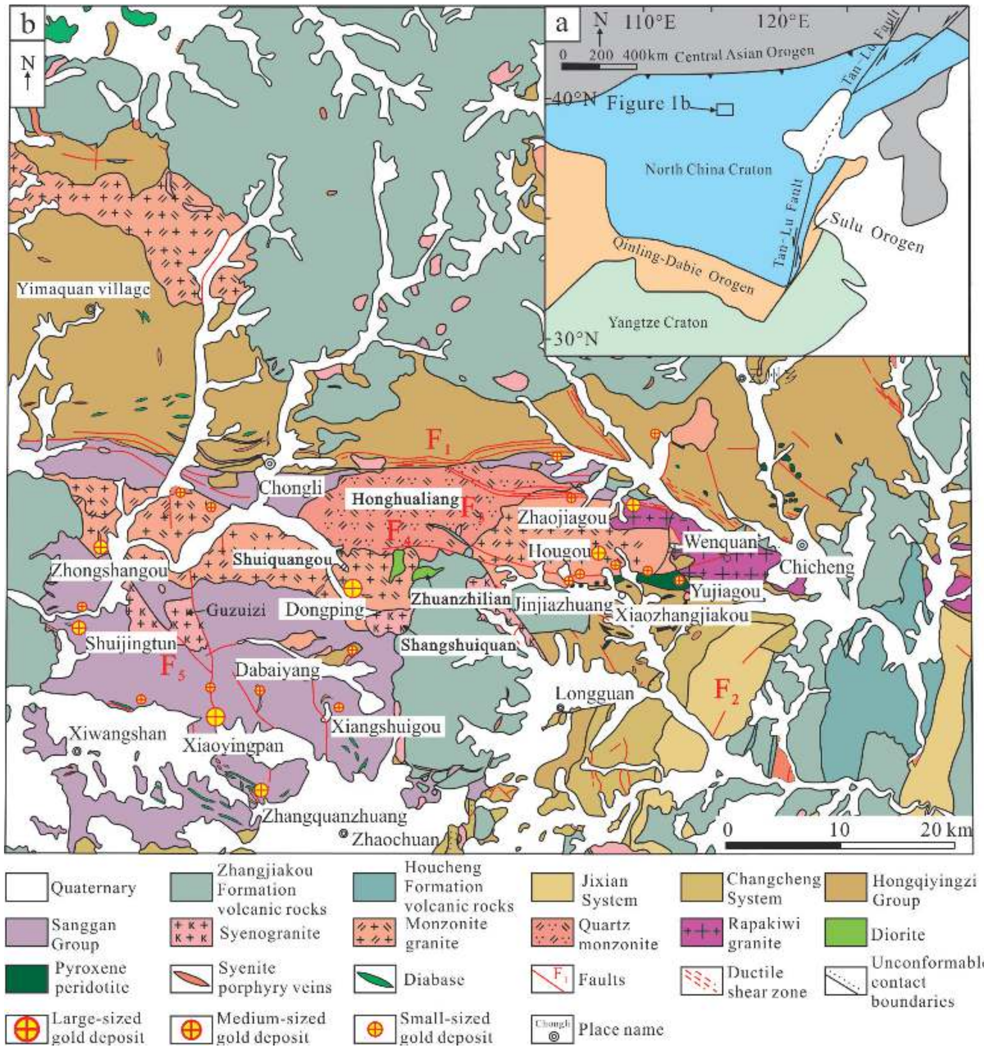

Fig. 1 Brief map of the North China Craton showing the location (a) and regional geology of the study area (b)

F1—Shangyi–Chongli–Chicheng fault; F2—Shanghuangqi–Wulonggou fault; F3—Shangtaizicheng–Wenquan fault; F4—Xisanjianfang–Womakeng fault; F5—Hanjiagou–Guzuizi–Changdi fault

already been preliminarily activated and enriched under regional metamorphosis (Bao ZW et al., 2014; Li H et al., 2018), causing gold to be further enriched. The magmatic activity in the Yanshanian caused the gold to come into ore-forming fluids and migrate up to ground surface along with the magma, deposit and enrich at favorable locations, giving rise to the densely distributed gold deposits and gold mineralization spots in Zhangxuan (Zhen SM et al.2020).

The mineral resources in the area are abundant, and more than 100 gold ore deposits (ore occurrences) have been discovered, mainly distributed in Chicheng, Chongli and Xuanhua areas, which are known as the “Golden Triangle” of Hebei province (Fig. 1b). Among them, the Xiaoyingpan and Dongping gold ore deposits are large-sized (Wang DZ et al., 2020), the Hougou, Zhangquanzhuang, Dabaiyang and Shuijingtun gold ore deposits are medium-sized (Cook NJ et al., 2009; Shen JF et al., 2020), and the Zhaojiagou, Jinjiazhuang, Xiping, Dayingpan and Zhongshangou gold ore deposits are small-sized. Lots of scientists believe that the gold deposits were formed in the end-Hercynian–Yanshanian period, and were controlled by the southward subduction of the Inner Mongolia oceanic plate (Xiao W et al., 2003; Windley BF et al., 2007; Zhao Y et al., 2017), extracting the gold elements that had been preliminarily activated and enriched under regional metamorphism (Bao ZW et al., 2014; Li H et al., 2018), making the gold further concentrated. The Yanshanian magmatic activities promoted the entry of gold into the ore-forming fluid, and thus the gold elements were migrated to the surface along with the magma, and then precipitated and enriched in favorable positions, forming the intensive gold deposits and mineralized spots in the Zhangxuan region (Zhen SM et al., 2020).

Despite the extensive studies already made on the geochemical characteristics and genesis of the gold deposits in the area, no 1：50 000 mineral geological survey has ever been carried out in the Zhaochuan Map-sheet, especially with respect to the ore-forming geobodies, ore-forming structures and ore-forming structural planes, and metallogenetic characteristic signatures there. Insufficient metallogenic research and summary has heavily restrained further ore prospecting exploration in the area. The compilation of the 1：50 000 mineral geological map of the Zhaochuan Map-sheet improves the degree of mineral geological survey in the area, and is of great significance to revealing the regional metallogenic law and resource potential of the gold deposits in the area, and contributes to the mineral resource protection and ecological civilization there.

2 Data Acquisition and Processing Method

2.1 Data Base

In the Zhangxuan region, 1：50 000 regional geological survey was conducted from the 1980s to 1990s. Regional geological survey of the Zhaochuan Map-sheet (the western half) was first completed in the 1980s. These previous efforts have laid foundation for the compilation of the present geological mineral map of the Zhaochuan Map-sheet.

The 1：50 000 mineral geological map of the Zhaochuan Map-sheet (K50E020006) relies on the 1：250 000 and 1：50 000 regional geological survey of the Changyukou, Chongli, and Zhenningbao Map-sheets as the basis[1,2], and the 1：50 000 mineral geology-specific mapping result as the main source of data. During the compilation, lithostratigraphic unit information that is "synonym" or "homonym" was reviewed altogether. Rocks in the map-sheet were reclassified and redated. Field exploration and logging (pits and drillholes) was made to the Dabaiyang gold deposit, and the ore-forming age was determined. Against the latest metallogenic theory in the *Theory and Method of Prospecting Prediction in Exploration Area* (Ye TZ et al., 2014) and the *Technical Requirements of Solid Mineral Geological Survey* (1：50 000)" (DD 2019–02) as the reference, in-depth research was made on the existing regional geological survey results and selective, emphatic work was carried out in light of the metallogenic law and metallogenic prediction objective before the map database was eventually compiled. The geographic information base map uses the National Geodetic Coordinate System 2000 (CGCS 2000). Data is processed using computer software such as the

Digital Geological Survey System (DGSS) and MapGIS. Topographic maps are based on the latest geographic data of the National Administration of Surveying, Mapping and Geographic Information (Han KY et al., 2005).

Metadata of the database are compiled in accordance with the *Metadata Standard of Geological Information* (DD2006–05). Information features closely related to metallogenetic theory (metallogenic geobodies, metallogenic structural planes, and metallogenetic characteristic signatures) are marked and presented in different forms (points, lines, areas), and assigned corresponding attributes and values (Song XL et al., 2017; Zhu Q et al., 2018; Dang XY et al., 2018), before they finally compound into a mineral geological map database (Bai HJ et al., 2020; Table 1).

Table 1 Basic information of the 1∶50 000 mineral geological map database of the Zhaochuan Map-sheet

Item	Description
Database name	1∶50 000 Mineral Geological Map Database of the Zhaochuan Map-sheet in Zhangjiakou, Hebei Province
Database authors	Bai Haijun, No.3 Geological Brigade of Hebei Geology and Mineral Exploration Bureau Miao Jianpu, No.3 Geological Brigade of Hebei Geology and Mineral Exploration Bureau Xu Xincheng, No.3 Geological Brigade of Hebei Geology and Mineral Exploration Bureau Yuan Jiaolong, No.3 Geological Brigade of Hebei Geology and Mineral Exploration Bureau Tao Lixin, No.3 Geological Brigade of Hebei Geology and Mineral Exploration Bureau Deng Jia, No.3 Geological Brigade of Hebei Geology and Mineral Exploration Bureau
Data acquisition time	2017–2018
Geographical area	Xuanhua, Hebei, located at 115°15′00″–115°30′00″E, 40°40′00″ – 40°50′00″N, numbered per international standard for 1∶50 000 topographic maps
Data format	MapGIS
Data size	11.3 MB
Data service system URL	http://dcc.cgs.gov.cn/
Fund project	The geological survey project (No.: DD20160052) initiated by the China Geological Survey
Language	Chinese
Database (Dataset) composition	This system database is composed of a 1∶50 000 international standard sheet-division geographic map database, a 1∶50 000 national resource potential evaluation geologic map database, the attribute library, pointed library, linear library, color code library, pattern library, and symbol library. The geological map database is composed of eight auxiliary maps (attached tables)—a formation columnar section, an ore-forming structure information table, (mineral) legend, a mineral deposit directory, a metallogenic zone location map, a geotectonic zoning table, a geological profile map, and a duty table—and one master map. Each map is composed of different thematic layers (e.g., geographic grid, settlement, mineral deposit, structure, intrusive rock, and altered rock)

In order to compile the 1∶50 000 mineral geological map of the Zhaochuan Map-sheet (K50E020006), the authors collected and revised 1∶50 000 regional geological routes totaling about 612 km in length, involving about 94 routes and about 1 064 geological points; utilized about two groups of previous zircon U–Pb ages and about six groups of whole-rock analytical geochemical data; measured geological routes totaling about 351 km in length, involving 105 routes and 1 154 geological points; performed ore spot checks and anomaly checks at about 15 spots, and measured one group of zircon U–Pb age. The mapping satisfies the accuracy required for 1∶50 000 mineral geology-specific mapping.

2.2 Data Acquisition

According to the pre-study result, the deposit type covered by the ore prospecting prediction of the Zhaochuan Map-sheet is magmatic hydrothermal gold deposit. As required by the *Technical Requirements for Prospecting Prediction in Ore Concentration Areas (for trial implementation)*[3] issued by the MNR Mineral Exploration Technical Guidance Center, data acquisition should be performed selectively and emphatically to avoid disconnection between basic research or mineral research from data acquisition (Zhang QH et al., 2002). Data sources include literature collection and measurement (Table 2). The former includes reorganizing data from previous regional survey, exploration, science research reports and published papers. The latter includes data from route survey, geophysical and geochemical measurement, and ore exploration projects.

2.3 Data Processing

For the geobodies of the 1∶50 000 mineral geological map of the Zhaochuan Map-sheet, the target layers are the metamorphic rocks (especially Guzuizi Formation) and the Yanshanian intrusive rocks; the basic layers are the sedimentary rocks, volcanic rocks and intrusive rocks. The geotectonic-specific base map is divided into the basic layer (pre-/post-metallogenetic faults) and the target layer (metallogenic period faults); and the alteration characteristic target layer (potassium alteration, silicification, phyllic alteration, pyritization, sericitation). The final mineral geological map should give a full presentation of the formations, structures, and mineralization alterations related to the magmatic hydrothermal gold deposits in the area (Li CL et al., 2012).

Table 2 Sampling sites and zircon ages of volcanic and intrusive rocks in the Zhaochuan Map-sheet, Hebei

SN	Sampling Site	Rock Type	Zircon U–Pb age/Ma	Data Sources
1	Qingyanggou	Zhangjiakou Fm trachyte−rhyolite and monzonitic granite	128–141	Yang JH et al., 2006; Jiang N et al., 2009; Li CJ and Bao ZW, 2012
2	Shuiquangou–Dananshan	Pyroxene hornblende monzonite−pyroxene monzonite−hornblende monzonite−syenite	372–390	Jiang N et al., 2007;Li H et al., 2018;Zhang QQ et al., 2018
3	Xiangshuigou	Porphyritic granite	233.7±2.3	Miao LC et al., 2002; Chen Q, 2013
4	Xiaohamokou	Granite	136.4±3	Measured

After reorganizing field measurement data at geological points (P), geological routes (R), and geological boundaries (B), and collecting previous regional geological survey records, the authors redelineated the boundaries of the stratigraphic units and rock extents, identified the types of various formations, added necessary lithological (combination) boundaries, drew lithological formation patterns, outlined the alteration extents, and marked the prospecting projects. Meanwhile, the corresponding feature map layers were also established and presented in the form of point.WT, line.WL, and area.WP. Fig. 2 shows the preparation flowchart.

The map face presentation was implemented in accordance with the requirements and standards of the *Guide for* 1∶50 000 *Mineral Geological Survey Work (for trial implementation)* initiated by the China Geological Survey in 2016. For examples, ① sedimentary strata and metamorphic rocks are presented with "era + lithostratigraphic unit", such as Ar_2g^b, which represents the stripped or banded biotite hornblende plagioclase schist formations in the Mesoarchean Guzuizi Formation, where the superscript or subscript code does not reflect the formation content; ② intrusive rocks are coded as "lithology + era", such as γK_1, which represents the Early Cretaceous granite; ③ the map face tone of formations and structures is given by era and lithology, and set against the uniform color code defined in the *Color Standard and Color Use Principle of Geological Maps* (D/ZT0179–1997). The geobodies of special significance are presented with striking color while the color of the basic layer is lightened; ④ the geographic information base map is based on China Geodetic Coordinate System 2000 (CGCS 2000).

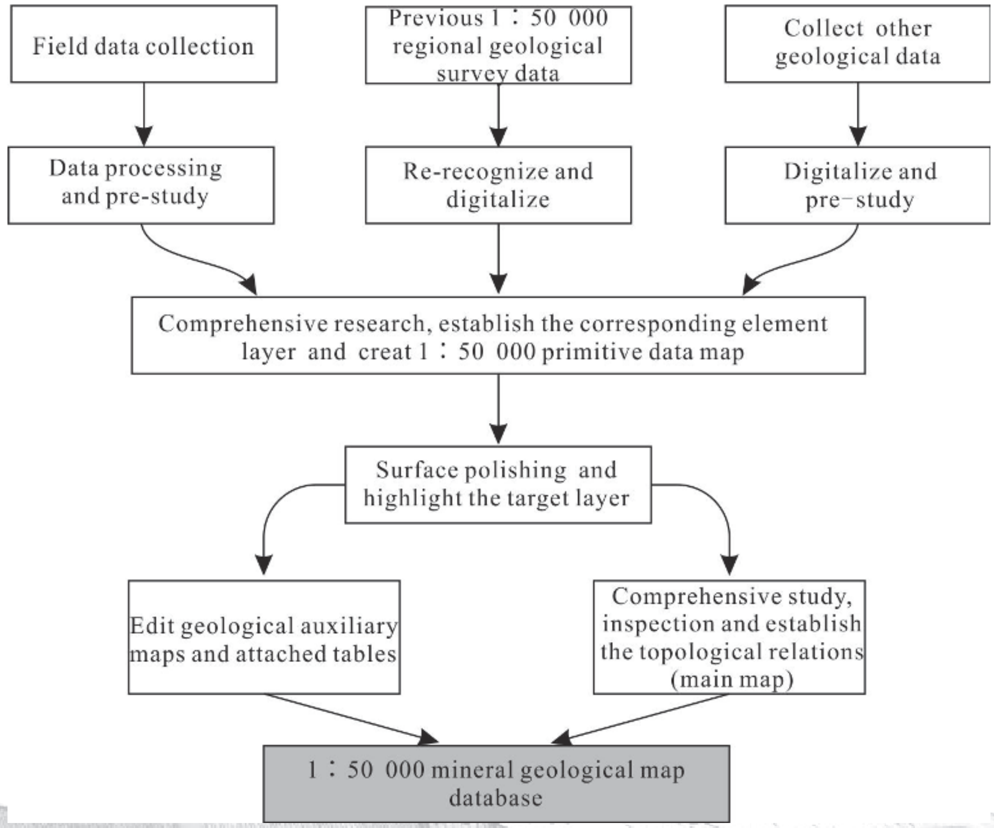

Fig. 2 Preparation flowchart of the 1∶50 000 mineral geological map database

3 Data Content Description

A geological map is a map that shows the forming era of sedimentary rock formations, igneous rock bodies and geological structures, and various related geobodies and geological phenomena on a given scale of topographical map. It aims to give a full reflection of the various achievements made in the latest mineral survey efforts and eventually provide a basic geological map for mineral resource planning and exploration of the area, as well as useful reference material for field geological survey and science research. The 1：50 000 mineral geological map of the Zhaochuan Map-sheet, Hebei consists of three parts: the master map, auxiliary maps, and attached tables. The map face content is composed of geographic information and geological information.

In the master map, the geographic feature information mainly includes the formation attribute table. The geological feature information includes the formation datatable, lithologic pattern datatable, geological boundary datatable, fault datatable, alteration type datatable, isotopic age datatable, petrochemical sample datatable, isotopic sampling point datatable, geological point datatable, geological profile datatable, attitude feature datatable, and volcanic structure datatable (Table 3).

The base map of the master map is divided into the basic layer and the target layer. The target layer is used to present the plane distribution and variation of the formation type and rock combination of different geobodies, as well as a simplification of the basic layer. For the 1：50 000 mineral geological map of the Zhaochuan Map-sheet, the target layer includes the metamorphic rocks and the Yanshanian intrusive rocks. The basic layer includes the sedimentary rocks, volcanic rocks and other intrusive rocks. This gives a full presentation of the formations, structures, and mineralization alterations related to the magmatic hydrothermal gold deposits in the area (Table 4).

The auxiliary maps are further description or explanation of the master map. They are the product of comprehensive research. The geological feature information includes the

Table 3 Master map database of the geological map of the Zhaochuan Map-sheet

SN	Field Name	Data Format	Data Type	Example
1	Village/town name	.WT	Point file	Dabaiyang, Jiangouhe
2	Mineral site	.WT	Point file	Dabaiyang Au deposit, Xiaobaiyang Ag deposit
3	Stratum	.WP	Zone file	Zhangjiakou Fm volcanic rock, Gujyuzi Fm meta-rock
4	Fault	.WL	Line file	Zhangquanzhuang–Heshangyao fault
5	Rock body	.WP	Zone file	Xiangshuigou rock body, Xiangshan rock body
6	Formation	.WP	Zone file	Websterite plagioclase granulite formation
7	Dyke	.WP	Zone file	Diabase dyke, diorite porphyrite dyke
8	Mineralization alteration	.WT	Point file	Limonitization, pyritization
9	Geological boundary	.WL	Line file	Angular unconformable boundary, conformable boundary
10	Stratigraphic attitude	.WT	Point file	Joint, foliation, gneissosity

Table 4 Formation types of different geobodies in the target layer

Target Layer Formation	Lithology Code	Formation Type	Rock Combination	Mineralization Alteration
Meta-rock formation	Ar_2g^d	Websterite plagioclase granulite formation	Websterite plagioclase granulite, migmatized pyroxene-bearing granulite, diopside-bearing plagioclase granulite	Carbonatization, kaolinization
	Ar_2g^c	Garnet hornblende plagioclase granulite–migmatized hornblende plagioclase granulite formation	Hornblende plagioclase granulite, biotite hornblende plagioclase granulite, pyroxene-bearing biotite hornblende plagioclase granulite	Carbonatization, kaolinization
	Ar_2g^b	Striated/banded biotite hornblende plagioclase gneiss formation	Brownish gray biotite plagioclase gneiss, migmatized biotite hornblende plagioclase gneiss	Carbonatization, kaolinization
	Ar_2g^a	Garnet hornblende diopside plagioclase granulite–migmatized diopside plagioclase granulite formation	Hornblende diopside plagioclase granulite, migmatized diopside plagioclase granulite, pyroxene-bearing biotite plagioclase granulite	Silicification, potassium alteration, sericitization
Intrusive rock formation	γK_1	Granite formation	Granite	

sedimentary rock formation datatable, intrusive rock datatable, volcanic rock lithology and lithofacies datatable, metamorphic rock formation datatable, and geotectonic division datatable, along with the corresponding geotectonic location map, formation columnar section, geological profile map, typical deposit plane map, profile map of important exploration lines of typical deposits, orebody horizontal projection map, and orebody vertical longitudinal projection map.

In the attached tables, the geological feature information includes the metallogenic structure information table, mineral site directory, duty tag, and index map.

The 1∶50 000 mineral geological map database of the Zhaochuan Map-sheet is composed of the 1∶50 000 international division database, and the attribute library, line type library, color code library, submap library (patterns, annotations), and symbol library for 1∶50 000 mineral geological survey, covering geological feature information and geographical feature information. As the feature information is of different varieties, the names of the data items may also differ (Zuo QC, 2011).

4 Data Quality and Control

4.1 Data Accuracy

The map face presentation accuracy is ≥1 mm^2 in terms of area. Corresponding attributes are established for each geobody unit. For some important geobodies with small area, they are all exaggerated on the map face.

In terms of accuracy, geological eras are presented down to the epoch. Stratigraphic units are presented down to formation (rock formation), or to member or group (rock group) for a few of the units. Intrusive rocks are presented by lithology + era, such as γK_1 (Early Cretaceous granite). Tectonic deformation is shown as folds, brittle faults and ductile faults. Folds are shown as basement folds and caprock folds. Faults are shown as first-order regional deep large faults, second-order major faults and third-order secondary faults. Corresponding attributes are established for each geobody unit.

4.2 Data Quality Control

All 1 ∶ 50 000, 1 ∶ 200 000, and 1 ∶ 250 000 regional survey data of the study area were collected and reorganized by selecting the latest and largest (scale) data as far as possible. Field survey work was carried out in accordance with the CGS *Guide for* 1 ∶ 50 000 *Mineral Geological Survey Work (for trial implementation)* initiated by the China Geological Survey in 2016, and *Technical Requirements of Solid Mineral Geological Survey* (1 ∶ 50 000) (DD 2019–02). Data collection was performed by strictly following the three-level quality check procedure, with 100% self-check and mutual check for primitive data. The check ratio at the project team level was greater than 50%, and that at the quality check group level is greater than 15%, which helped guarantee the quality of all data (Wan CX et al., 2009).

Map compilation was carried out in strict accordance with the *Technical Requirements for Metallogenic Geological Background* (Ye TZ et al., 2010). First, primitive data map of the subsheet was prepared to the specified quality standard. Then, based on this primitive data map, formation and structure maps were prepared to the specified quality standard. Measures were taken to ensure that there is no overstepping or default and the map was compiled in compliance with the technical requirements.

Database building was carried out according to the data characteristics of geological maps, mineral resource potential evaluation data model, and geological data quality inspection and evaluation. A geological map data quality inspection and evaluation method technical system cored around “single map mapping quality model + single map space data quality model + single map attribute data quality model + single map metadata quality model + single map quality model + map subset quality model + map set quality model” (abbreviated as the “seven-layer geological map quality control model” was established (Zuo QC et al., 2013). Supporting software programs (e.g., GeoMag, GeoTok, GeoDQC) were also developed to facilitate quality self-check, mutual check, spot check and correction of the library database data, and allow automatic quantitative evaluation. This greatly improved the quality inspection and evaluation efficiency, saved the working cost, and guaranteed the database building quality.

The quality of the database building result was accepted in two steps. First, the quality of the mapping result was accepted by a mapping expert acceptance panel. Then it was reaccepted by a database-building expert acceptance panel. After the quality was conformed by the experts, the result was used for summarizing and integrating into the database.

5 Data Value

The 1∶50 000 mineral geological map of the Zhaochuan Map-sheet represents one of the Map-sheets covered by the new round of mineral geological survey. The present work is performed in accordance with the *Technical Requirements for Mineral Geological Survey* (1∶50 000) (DD2019–02). After intensive research on the formations and structures within the Map-sheet, on the basis of the 1∶50 000 geology-specific mapping results, as well as the geological data of different times and different scales in and around the Map-sheet, we redivided the formation type of the Archean metamorphic rocks, Proterozoic Changchengian, and Mesozoic Cretaceous Zhangjiakou formations; established the spatio-temporal evolution sequence of the magmatic rocks in the Zhaochuan Map-sheet, which chronologically is ① Mesoarchean metamorphic monzonite granite formations ($\eta\gamma Ar_2$), ②Neoarchean granite gneiss formations ($gg Ar_3$), ③ Hercynian pyroxene hornblende monzonite–pyroxene monzonite–hornblende monzonite formations ($\nu\eta D_2$–$\varphi\eta D_2$–$\psi\eta D_2$), monzonite–syenite–quartz monzonite formations (ηD_2–ξD_2–$\eta o D_2$), ④ Indosinian monzonite granite formations ($\eta\gamma T_3$), ⑤ Yanshanian biotite granite formations ($\gamma\beta K_1$), pyroxene diorite formations ($\varphi\delta K_1$), biotite monzonite granite formations ($\eta\gamma\beta K_1$); summarized the regional metallogenic spatio-temporal evolution sequence, which is ① Mesoarchean sedimentary metamorphic iron deposits, ② Early to Middle Jurassic magmatic hydrothermal gold deposits, ③ Early Cretaceous continental subvolcanic lead zinc deposits and gold deposits; determined the gold ore target layer of the area to be Yanshanian intrusive rocks and Archean metamorphic rocks (especially Guzuizi rock formation), laying good foundation for subsequent mineral resource potential evaluation and ore prospecting prediction efforts; and established a “three-in-one” ore prospecting prediction model and integrated geological, geophysical, geochemical, remote-sensing ore prospecting prediction model for metallogenic ore bodies, metallogenic structures, and metallogenic structural planes.

The database is composed of the geological map library, attribute library, pointed library, linear library, color code library, pattern library, and symbol library. It features large information volume, all necessary functions, and high practicability. The present work is not only an exploration on the ore prospecting theory work, but also an innovation on the presentation method and content of mineral geological survey result maps. It has great reference value for the deployment of future mineral exploration efforts.

6 Conclusions

(1)The 1∶50 000 mineral geological map database of the Zhaochuan Map-sheet is not only an exploration on the ore prospecting theoretical work, but also an innovation on the presentation method and content of mineral geology-specific survey result maps.

(2)The 1∶50 000 mineral geological map database of the Zhaochuan Map-sheet features large information volume, all necessary functions, and high practicability. It also provides a dynamically updated receiving end. This database not only allows for the timely update and refinement of the basic maps, but also provides normalized service for the rational planning of the local natural resource department. It plays an important realistic role in mitigating exploration risks and guaranteeing geological exploration.

(3)The present work redivided the strata in the Zhaochuan Map-sheet, established a spatio-temporal evolution sequence of the magmatic rocks and metallogenesis there, and established a "three-in-one" ore prospecting prediction model and integrated geological, geophysical, geochemical, remote-sensing ore prospecting prediction model for metallogenic ore bodies, metallogenic structures, and metallogenic structural planes. The 1 ∶ 50 000 mineral geological map database offers basic data support for the mineral resource potential evaluation and ore prospecting prediction work of the area. It has great reference value for the deployment of future mineral exploration.

Acknowledgments: The 1 ∶ 50 000 mineral geological map of the Zhaochuan Map-sheet, Hebei is the result of the collective effort of both field workers and indoor staff. The authors thank Ye Tianzhu, Pang Zhenshan, Cheng Zhizhong, Xue Jianling, Zuo Qunchao and other experts for their kind instructions in the building of the mineral geological map database. Thanks also to all experts and all project team members for their hard work and great contribution.

Notes:

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❷ Hebei Institute of Regional Geology and Mineral Survey. 2008. The 1 ∶ 250 000 Regional Geological Survey Result Report of the Zhangjiakou Map-sheet[R].

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