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山东省臧家庄幅 1∶50 000 矿产地质图数据库

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摘要：山东省臧家庄幅 (J51E016004)1∶50 000 矿产地质图是根据《矿产地质调查技术要求 (1∶50 000)》(DD2019−02) 和《数字地质图空间数据库》(DD2006−06) 以及相关的行业标准和要求，充分利用 1∶50 000、1∶200 000 等区域地质调查工作成果资料，采用数字填图系统进行野外数据采集，并应用室内编图和重点工作区野外实测相结合的方法编制完成。图幅数据库通过基本要素类、综合要素类、对象类以及独立要素类对数据进行分别存储。本文提出栖霞高家—香夼—福山邢家山为一多金属成矿带的新认识，成矿岩体为中生代酸性侵入岩，成矿受东西向构造与北北东向构造交汇部位控制。针对香夼多金属矿典型矿床成矿岩体进行的锆石 LA−ICP−MS U−Pb 测年表明其成矿年龄为 127.91±0.58 Ma，为本区多金属成矿年龄和成矿规律研究提供了可靠的新数据。图幅数据库包含 5 个年龄数据，25 个矿产地数据，其中新发现铜矿 (化) 点 2 处、金矿化点 1 处,提交了 2 个找矿靶区并圈定 6 个最小预测区，预测了资源量，Au 10 962 kg、Ag 499.638 t、Pb 141 437 t、Zn 230 011 t。臧家庄幅 (J51E016004)1∶50 000 矿产地质图数据库为该区地质找矿工作提供了基础数据支撑，并将为地质科学的信息化、网络化建设提供数据源。

关键词：矿产地质图；数据库；1∶50 000；香夼多金属矿；矿产勘查工程；臧家庄幅；山东

数据服务系统网址：http://dcc.cgs.gov.cn

1 引言

胶东地区位于华北克拉通东南缘，是中国最重要的金矿集区 (王成辉等，2012；于学峰等，2012；杨立强等，2014)，并伴有钼、钨、铜、铅、锌等有色金属矿 (宋明春等，2015；李杰等，2013)。为查明胶东栖霞—蓬莱地区金及铜银多金属矿床，中国地质调查局实施了二级项目“胶东成矿区栖霞—牟平地区地质矿产调查”，以摸清区域成矿背景、成矿条件和成矿潜力。

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山东省臧家庄幅 (J51E016004)1∶50 000 矿产地质调查数据库属中国地质调查局二级项目“胶东成矿区栖霞—牟平地区地质矿产调查”的子项目之一“山东 1∶50 000 大辛店幅 (J51E015004)、岗嵛幅 (J51E015005)、臧家庄幅 (J51E016004)、高疃幅 (J51E016005) 矿产地质调查”的组成部分。图幅区位于胶东栖霞地区，大地构造位置属华北板块东南缘胶北隆起区 (张增奇等，2014)(图 1)，成矿区带上属于华北成矿省胶西北成矿亚带的栖霞—蓬莱—福山成矿区带 (图 2；丁正江等，2015a)。区内金矿发育，并赋存着其他重要的多金属矿，目前已发现 25 个矿产地（表 1），其中包括西林 (中型) 金矿以及山东省内规模最大的铅锌矿床——香夼铅锌矿 (王奎峰，2008)，该区地表及深部均具有进一步找矿勘探的潜力。

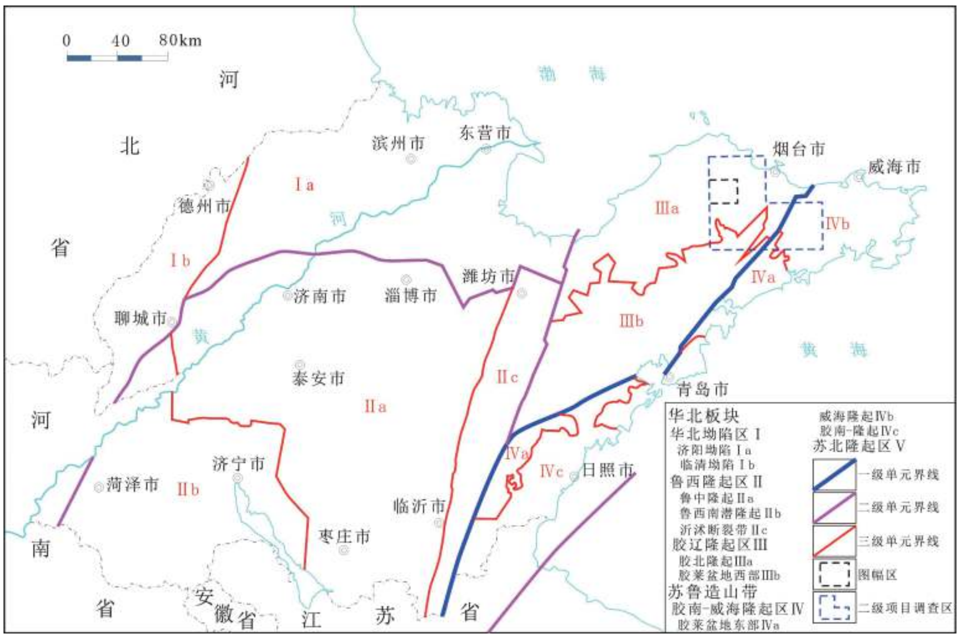

图 1　山东省臧家庄地区大地构造位置图 (据张增奇等，2014)

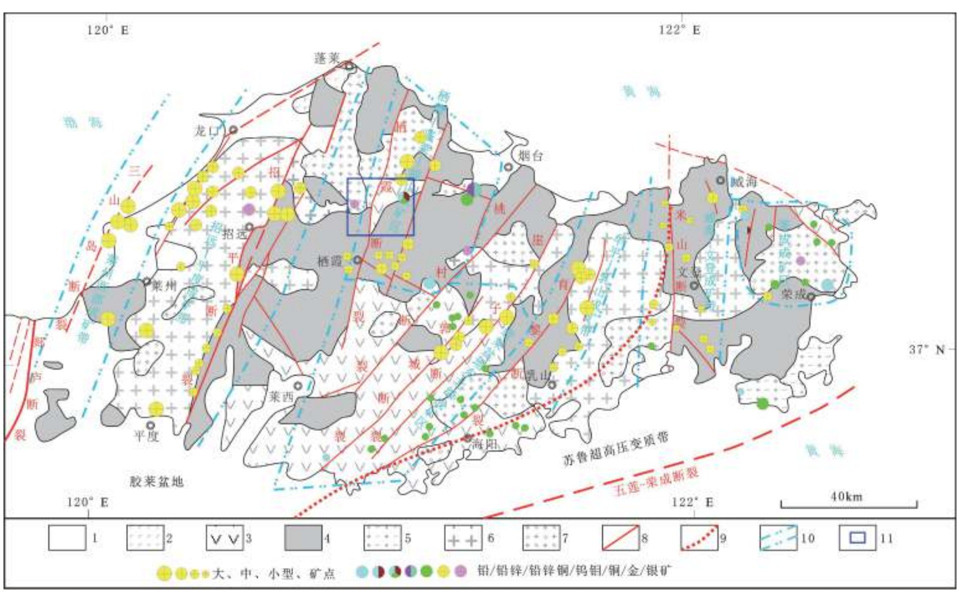

图 2　山东省臧家庄地区成矿区带位置图 (据丁正江等，2015a)

1—新生代沉积物；2—新生代玄武岩；3—白垩纪火山沉积岩；4—前寒武纪基底；5—三叠纪花岗岩；6—侏罗纪花岗岩；7—白垩纪花岗岩；8—主要断裂构造；9—推测变质带边界；10—成矿区带界线；11—图幅区位置

表 1　矿产地一览表

序号	名称	规模	类型	主要含矿建造构造
1	栖霞市臧家庄镇西林金矿	中型	潜火山热液裂隙充填交代型	近东西向断裂
2	栖霞市松山镇上艾口金矿	小型	石英脉型	近东西向糜棱岩带
3	蓬莱市村里集镇站马张家金矿	矿点	石英脉型	北东向断裂
4	蓬莱市村里集镇王格庄金矿	矿点	石英脉型	北北东向断裂
5	栖霞市臧家庄镇西尹家金矿	矿点	蚀变岩型	北东向断裂
6	栖霞市松山镇艾山汤金矿	矿点	石英脉型	北东向断裂
7	栖霞市松山镇下艾口金矿	矿点	石英脉型	北东向断裂
8	栖霞市庄园街道葛家沟金矿	矿点	石英脉型	北北东向断裂
9	栖霞城北张家沟金矿	矿点	石英脉型	北西西向糜棱岩带
10	栖霞市松山镇客落邹家金矿	矿点	石英脉型	北西西向糜棱岩带
11	栖霞市臧家庄镇蒙家金矿	矿化点	岩浆热液裂隙充填型	近东西向断裂
12	栖霞市松山镇金山泊子金矿	矿化点	石英脉型	北西向断裂
13	栖霞市庄园街道高家金矿	矿化点	石英脉型	北西向断裂
14	栖霞市亭口镇攻险顶金矿	矿化点	石英脉型	北东向断裂
15	栖霞市庄园街道和尚庄银矿	小型	岩浆热液充填型	粉子山群石墨二云片岩之北西西向断裂
16	栖霞市庄园街道高家北银矿	矿点	岩浆热液充填型	粉子山群石墨二云片岩之北西西向断裂
17	栖霞市臧家庄镇瓮留张家铜矿	矿点	岩浆热液充填型	白垩纪莱阳群砾岩
18	栖霞市臧家庄镇百佛院铜矿	矿化点	岩浆热液充填型	北北东向断裂
19	栖霞市臧家庄镇瓮留范家铜矿	矿点	岩浆热液充填型	白垩纪莱阳群砾岩
20	蓬莱市村里集镇小柱铜矿	矿化点	岩浆热液充填型	北北东向断裂
21	栖霞市臧家庄镇西山庄铅矿	矿点	岩浆热液充填型	近东西向断裂
22	蓬莱市村里集镇邓格庄铅矿	矿化点	岩浆热液充填型	白垩纪花岗岩之间的接触带
23	栖霞市臧家庄镇西林铅锌矿	矿化点	潜火山热液裂隙充填型	白垩纪花岗闪长斑岩与莱阳群接触带
24	栖霞市臧家庄镇香夼铜铅锌多金属矿	中型	矽卡岩–斑岩复合型	白垩纪花岗闪长斑岩与香夼组灰岩接触带
25	栖霞市松山镇郝家楼铜铅锌多金属矿	矿化点	矽卡岩型	白垩纪花岗闪长斑岩与豹山口组岩石接触带

臧家庄幅已在 20 世纪 90 年代完成 1∶50 000 区域地质调查❶以及化探普查❷工作。进入 21 世纪，山东省第三地质矿产勘查院、山东正元地质资源勘查有限公司等地勘单位在该区完成了一系列矿产普查与勘探工作❸❹，同时吸引了较多学者对该区金及典型多金属矿床 (胡品三，1987；张乾，1990；王奎峰等，2008；孙丰月等，2011；薛玉山等，2014；丁正江等，2015a、2015b；宋明春等，2015；卢文姬等，2016) 和前寒武纪地质体 (汪山，1984；薛志忠，1999；周喜文等，2004；Zhao GC et al., 2005；Li XH et al., 2007；Zhou JB et al., 2008；Tam PY et al., 2011；梁凤华等，2011；Li SZ et al., 2012) 进行科学研究。这些前期工作为臧家庄幅矿产地质图的编制奠定了基础。臧家庄幅 1∶50 000 矿产地质图作为中国地质调查局在山东省实施的首批 1: 50 000 矿产地质调查图幅之一，以不断更新的《矿产地质调查技术要求 (1∶50 000)》(DD2019-02) 为矿产

地质调查的基本纲领开展工作，以中国地质调查局示范图幅 (王春女等，2019) 为参考，综合反映图幅区地质、勘查及科研成果，为该区矿产资源研究、潜力评价、找矿勘探等提供了基础地质图件，为后续矿产地质调查起到了示范作用。山东省臧家庄幅 1∶50 000 矿产地质图数据库 (朱学强等，2020) 在此基础上形成，元数据简表列于表 2。

表 2　数据库元数据简表

条目	描述
数据库(集)名称	山东省臧家庄幅1∶50 000矿产地质图数据库
数据(集)作者	朱学强，山东省地质调查院 戴广凯，山东省地质调查院 郭　晶，山东省地质调查院 刘　丽，山东省地质调查院
数据时间范围	2016—2018年
地理区域	东经120°45′ ~ 121°00′，北纬37°20′ ~ 37°30′
数据格式	MapGIS
数据量	36.5 MB
数据服务系统网址	http://dcc.cgs.gov.cn
基金项目	中国地质调查局矿产地质调查项目“山东1∶50 000大辛店幅、岗嵛幅、臧家庄幅、高疃幅矿产地质调查”(编号：DD20160044-1)
语种	中文
数据集组成	本数据集包括1∶50 000地质图库和图饰。地质图库包含基本要素类、综合要素类、对象类和独立要素类。其中基本要素类包括：地质体面实体、地质界线、矿产地、产状、样品、照片、同位素年龄、火山口、河、湖、海、水库岸线。综合要素类包括：构造变形带、蚀变带、变质相带、火山岩相带、标准图框。对象类包括：沉积(火山)地层单位、侵入岩岩石年代单位、断层、变质岩地(岩)层单位、特殊地质体、脉岩(面)、面状水域与沼泽、图幅基本信息。独立要素类主要包括图例、柱状图、图切剖面、接图表、典型矿床解剖图、矿产地名录、矿种及规模、所处成矿区带位置图、责任表等角图

2　数据采集和处理

利用数字地质调查系统 (DGSS) 对 1∶50 000 地理底图进行数字化，投影系统为高斯—克吕格投影，坐标系统为 1980 年西安坐标系，1985 年国家高程基准。图幅范围：东经 120°45′ ~ 121°00′，北纬 37°20′ ~ 37°30′。数据格式：通过点.tm、线.lm、区.pm 3 种数据类型表示。使用统一规定的 Slib 系统库 (陈安蜀等，2008)。

2.1　编制建造—构造草图

将收集到的 1∶50 000 臧家庄幅区域地质调查资料进行数字化处理，并在综合分析已有资料的基础上，以原区调实际材料图为底图，补充岩性 (组合) 界线，并按照不同建造类型 (沉积岩建造、火山岩建造、侵入岩建造和变质岩建造) 对应的岩性花纹表达在实际材料图上形成建造—构造草图。

2.2　矿产地质专项填图及整理

根据对已有 1∶50 000[1] 和 1∶200 000 地质[2]、物探[3]、化探[4]、遥感[5] 资料的综合分析和建造–构造草图的编制，以及对香夼铜铅锌斑岩–矽卡岩型多金属典型矿床的解剖，确定成矿围岩主要为白垩纪浅成酸性斑岩体和新元古代蓬莱群香夼组与南庄组碳酸

盐岩与钙质板岩，矿体主要受东西向构造与北北东向构造交汇部位控制，蚀变类型主要为矽卡岩化、黄铁矿化、黄铜矿化、青磐岩化等。按照成矿有利程度划分臧家庄盆地南北缘为重点工作区，以臧家庄盆地南缘与多金属矿有关的新元古代蓬莱群香夼组碳酸盐岩建造和白垩纪浅成酸性斑岩建造以及北缘与金矿有关的白垩纪郭家岭花岗岩建造为重点填图内容。一般工作区主要根据《1∶50 000 大辛店幅、臧家庄幅区域地质调查报告》进行编图。

野外路线地质调查过程中的数据采集使用基于 Android 操作系统的野外数字填图系统 AoRGMap，以 1∶25 000 建造–构造草图为底图，采集地质点 (P)、地质路线 (R) 和地质界线 (B) 以及相关的岩性、构造、矿化、样品、产状等信息，形成野外手图库，并在此基础上建立图幅 PRB 库，其中包括野外路线数据入库、野外剖面数据投影、样品数据库建立以及勘探 (探槽、钻孔等) 工程的投影，所有的要素均按照规范进行数据整理及批注。其中，实测剖面 9 条，实测路线 33 条 (长度 158 km)，收集路线 373 km，探槽编录 3 条，地质点数 323 个，薄片鉴定样品 45 个，基本分析样品 65 个，锆石 U–Pb 测年样品 5 个 (其中实测 2 个，表 3)，产状 138 个，照片 417 张。总体精度达到 1∶50 000 矿产地质填图的具体要求。

表 3　同位素年龄数据一览表

序号	岩性	测试方法	年龄/Ma	数据来源
1	安山岩	黑云母K–Ar法	123	收集❶
2	片麻状黑云二长花岗岩	锆石U–Pb法	2447	收集❶
3	斜长角闪岩	Sm–Nd法	2938	收集❶
4	花岗闪长斑岩	锆石LA-ICP-MS U–Pb法	127.91±0.58	中国地质调查局天津地质调查中心实验室
5	流纹斑岩	锆石LA-ICP-MS U–Pb法	114.14±0.78	中国地质调查局天津地质调查中心实验室

更新图幅 PRB 库至实际材料图库，编辑地质区文件 (GEOPOLY.PM)、地质线文件 (GEOLINE.LM)、地质点文件 (GEOLABEL.TM)，并根据 PRB 内容提取相应的属性数据，形成实际材料图。

2.3　编制成果图件

在编制建造—构造草图时的实际材料图的基础上，根据本次实测的实际材料图的内容进行更新，对地质界线、建造类型及花纹、矿化蚀变特征进行修正，形成臧家庄幅建造构造图，并编制完善建造柱状图、图切剖面、所处成矿区带位置图、图例等角图。

在建造–构造图的基础上，按照《矿产地质调查技术要求 (1∶50 000)》(DD2019-02) 的图饰要求编制矿产地质图。图层内容主要包括：地理底图 (HYDNT.WP、HYDNT.WL、A_HYDNT.WT、)、地质区 (_GEOPOLYGON.WP)、地质界线 (_GEOLINE.WL)、地质代号 (A_GEOPOLYGON.WT)、岩性花纹 (A_GEOPOLYGON.WL)、产状 (_ATTITUDE.WT)、矿点 (_MINERAL_PNT.WT)、矿化蚀变 (A_ALTERATION_POLYGON.WT) 等，角图内容包括接图表、柱状图、图例、图切剖面、典型矿床解剖图、矿产地名录、矿种及规模、所处成矿区带位置图、责任表等。

该矿产地质图是在深入研究本图幅内沉积岩建造、火山岩建造、变质岩建造、侵入

岩建造、构造、矿产的基础上，结合本次 1∶50 000 矿产地质专项填图成果编制形成的，通过建造、构造与矿产的关系进行综合分析与研究，划分了 8 个沉积 (火山) 岩建造，21 个侵入岩建造、8 个变质岩建造，其中早白垩世花岗闪长斑岩侵入岩建造和新元古代蓬莱群香夼组碳酸盐岩变质岩建造是多金属矿含矿建造、早白垩世斑状中粒含角闪二长花岗岩侵入岩建造是金矿含矿建造，是本次工作的重点工作对象。

3 成果数据库数据描述

以《数字地质图空间数据库》(DD2006-06) 为矿产地质图数据库建设的基本要求，臧家庄幅 (J51E016004)1∶50 000 矿产地质图数据库通过基本要素类、综合要素类、对象类以及独立要素类对数据进行分别存储。

基本要素类包括：地质体面实体 (_GEOPOLYGON.PM)，地质界线 (_GEOLINE.LM)，矿产地 (_MINERAL_PNT.TM)，产状 (_ATTITUDE.TM)，样品 (_SAMPLE.TM)，照片 (_PHOTOGRAPH.TM)，同位素年龄 (_ISOTOPE.TM)，火山口 (_CRATER.TM)，河、湖、海、水库岸线 (_LINE_GEOGRAPHY.LM)。

综合要素类包括：构造变形带 (_TECTZONE.PM)，蚀变带 (_ALTERATION_POLYGON.PM)，变质相带 (_METAMOR_FACIES.PM)，火山岩相带 (_VOLCA_FACIES.PM)，标准图框 (_MAP_FRAME.LM)。

对象类包括：沉积 (火山) 地层单位 (STRATA)，侵入岩岩石年代单位 (INTRU_LITHO_CHEONO)，断层 (FAULT)，变质岩地 (岩) 层单位 (METAMORPHIC)，特殊地质体 (SPECAIL_GEOBODY)，脉岩(面)(_DIKE_OBJECT)、面状水域与沼泽(_WATER_REGION)，图幅基本信息 (_SHEET_MAPINFO)。

独立要素类主要包括图例、柱状图、图切剖面、接图表典型矿床解剖图、矿产地名录、矿种及规模、所处成矿区带位置图、责任表等。

其中基本要素类、综合要素类、对象类数据分别对应 BASE_FCLS.mdb、DSGMAP.mdb、SYNTH_FCLS.mdb 具有相应属性结构的数据表，具体要素类信息见表 4。

同时，对形成的地球化学数据、地球物理数据、遥感数据建立相应的数据库，最后形成包括异常查证结果表、矿点检查结果表、找矿靶区、矿产预测远景区等信息的综合成果库。

4 数据质量

矿产地质填图过程中，按照《矿产地质调查技术要求 (1∶50 000)》(DD2019-02)，选择重点工作区进行实测，一般工作区根据区域地质调查报告进行编图，采用填编结合的方法进行。

该项目工作全过程使用数字填图系统 DGSS 完成。野外调查中首次使用基于 DGSS 的安卓操作系统野外数据采集仪，提高了工作效率和精度。矿产地质图空间数据库是对前一阶段原始资料数据库的继承与综合；建库流程严格遵循数字填图系统数据库建设流程，使用数字填图统一的系统库，有效实现了对各类数据的一体化描述、存储和组织。

实际材料图及编稿原图各图幅先进行接边再以内图框裁剪分幅，在拓扑造区之前反复进行自动剪断线—线拓扑错误检查直至没有任何错误后才进行线工作区提区弧段—拓

表 4 臧家庄 (图幅号: J51E016004) 幅基本要素类、综合要素类和对象类数据表

数据集	实体名称	文件名	文件数/个	数据类型
基本要素类	地质体面实体	_GEOPOLYGON.PM	904	Area
	地质(界)线	_GEOLINE.LM	2 550	Line
	矿产地	_MINERAL_PNT.TM	25	Point
	产状	_ATTITUDE.TM	138	Point
	同位素测年	_ISOTOPE.TM	5	Point
	火山口	_CRATER.TM	1	Point
	河、湖、海、水库岸线	_LINE_GEOGRAPHY.LM	231	Line
综合要素类	构造变形带	_TECOZONE.PM	6	Area
	蚀变带(面)	_ALTERATION_POLYGON.PM	66	Area
	变质相带	_METAMOR_FACIES.PM	230	Area
	火山岩相带	_VOLCA_FACIES.PM	20	Area
	标准图框(内图框)	_MAP_FRAME	4	Line
对象类	沉积(火山)岩岩石地层单位	_STRATA	8	ACCESS
	侵入岩岩石年代单位	_INTRU_LITHO_CHRONO	21	ACCESS
	断层	_FAULT	10	ACCESS
	变质岩地(岩)层单位	_METAMORPHIC	8	ACCESS
	特殊地质体	_SPECIAL_GEOBODY	6	ACCESS
	脉岩(面)	_DIKE_OBJECT	17	ACCESS
	面状水域与沼泽	_WATER_REGION	4	ACCESS
	图幅基本信息	_SHEET_MAPINFO	1	ACCESS

扑重建，系统节点/裁剪搜索半径为 10^{-9}。通过以上程序，图形精度符合数据库建设质量要求。

图面地层接触关系按照标准进行，不同地质体的压盖关系、断层与地质界线的压盖关系按实际情况排列，不同图层在统一空间的整合处理正确。

地质图空间数据库文件种类齐全，文件命名及属性结构符合相关规范要求；数据库各数据集 (基本要素类、综合要素类、独立要素类、对象类) 数据项与地质图图面表达内容吻合，真实反映原地质图及文字报告资料的实际情况，符合建库要求。

原始资料自检、互检达到 100%，项目抽检 30%，单位抽检 10%，符合单位质量管理体系和地质调查项目管理要求。在年度质量检查和野外验收过程中，中国地质调查局天津地质调查中心组织专家经室内检查和野外抽查相结合方式对原始资料数据库进行检查。2019 年 6 月，中国地质调查局天津地质调查中心组织专家对臧家庄幅数据库完成了最终验收。

5 数据价值

通过本次 1∶50 000 臧家庄幅矿产地质填图工作，提出栖霞高家—香夼—福山邢家山为一多金属成矿带的新认识，成矿岩体为中生代酸性侵入岩，矿体主要受东西向构造与北北东向构造交汇部位控制。对香夼斑岩–矽卡岩型铜铅锌多金属典型矿床成矿岩体进行了锆石 LA–ICP–MS U–Pb 测年，成矿岩体香夼花岗闪长斑岩年龄为 127.91±0.58 Ma，与宋英昕等 (2019) 测年结果 130.4±1.2 Ma 相当，对多金属成矿年龄和成矿规律研究提

供了可靠的新数据。同时，在香夼多金属矿外围发现了隐爆—侵入角砾岩，丰富了找矿模式，有助于探寻斑岩型隐伏矿体 (郭晶等，2019)。本次工作新发现铜矿点 2 处、金矿化点 1 处，提交了 2 个 A 类找矿靶区，即高家银矿找矿靶区和香夼铅锌矿深部预测靶区，并圈定 6 个最小预测区，分别为艾山汤金最小预测区、金山金最小预测区、车夼金最小预测区、高家银最小预测区、香夼铅锌最小预测区和东龙夼最小预测区，预测了资源量，其中 Au 10 962 kg、Ag 499.638 t、Pb 141 437 t、Zn 230 011 t。

臧家庄幅 (J51E016004)1：50 000 矿产地质图及其数据库为该区地质找矿工作提供了基础数据支撑，对该区矿产资源研究、找矿勘探等具有参考意义，并为地质科学的信息化管理、网络化建设和社会化服务提供数据源 (马明等，2017；李晨阳等，2019；刘翠辉等，2019)。

6 结论

(1) 山东省臧家庄幅 (J51E016004)1：50 000 矿产地质图是中国地质调查局在山东开展的首批矿产地质调查的图幅之一，是按照不断完善的《矿产地质调查技术要求 (1：50 000)》(DD2019-02) 为矿产地质调查的基本纲领逐步调整工作思路开展的，形成了臧家庄幅矿产地质图，对全省开展矿产地质调查起到了示范作用。

(2) 该矿产地质图是在深入研究本图幅内沉积岩建造、火山岩建造、变质岩建造、侵入岩建造、构造、矿产的基础上，结合本次 1：50 000 矿产地质专项填图成果，突出对成矿有关要素的表达，系统编制而成，并建立了空间数据库。

(3) 形成栖霞高家—香夼—福山邢家山为一多金属成矿带的新认识，成矿岩体为中生代酸性侵入岩，矿体主要受东西向构造与北北东向构造交汇部位控制。对香夼多金属矿成矿岩体进行了锆石 LA−ICP−MS U−Pb 测年，香夼花岗闪长斑岩年龄为 127.91±0.58 Ma，对多金属成矿年龄和成矿规律研究提供了可靠的新数据。新发现矿 (化) 点 3 处，提交了 2 个找矿靶区并圈定 6 个最小预测区，预测了资源量。

(4) 臧家庄幅 (J51E016004)1：50 000 矿产地质图及其数据库为该区地质找矿工作提供了基础数据支撑，对该区矿产资源研究、找矿勘探等具有参考意义，并为地质科学的信息化管理、网络化建设和社会化服务提供数据源。

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注释：

❶ 山东省地质矿产局第三地质队. 1996. 1：50 000 大辛店幅、臧家庄幅区域地质调查报告.

❷ 山东省地质矿产局物化探大队. 1992. 山东省 1：50 000 大辛店幅、臧家庄幅化探普查成果报告.

❸ 山东省第三地质矿产勘查院. 2008. 山东省栖霞市西林矿区深部及外围金矿详查报告.

❹ 山东正元地质资源勘查有限责任公司. 2010. 山东省栖霞市香夼矿区铜、铅、锌多金属硫化物矿床外围普查报告.

❺ 山东省地质矿产局区域地质调查队. 1991. 1：200 000 烟台、蓬莱幅区域地质调查报告.

参考文献

Li S Z, Zhao G C, Santosh M, Liu X, Dai L M, Suo Y H, Tam P Y, Song M C, Wang P C. 2012.

Paleoproterozoic structural evolution of the southern segment of the Jiao-Liao-Ji Belt, North China Craton[J]. Precambrian Research, 200: 59−73.

Li X H, Chen F K, Guo J H, Li Q L, Xie L W, Siebel W. 2007. South China provenance of the Lower-grade Penglai Group north of the Sulu UHP orogenic belt, eastern China: evidence from detrital zircon ages and Nd-Hf isotopic composition[J]. Geochemical Journal, 41: 29−45.

Tam P Y, Zhao G C, Liu F L, Zhou X W, Sun M, Li S S. 2011. Timing of metamorphism in the Paleoproterozoic Jiao-Liao-Ji Belt: new SHRIMP U−Pb zircon dating of granulites, gneisses and marbles of the Jiaobei massif in the North China Craton[J]. Gondwana Research, 19: 150−162.

Zhao G C, Sun M, Wlide S A, Li S Z. 2005. Late Archean to Paleoproterozoic evolution of the North China Craton: key issues revisited[J]. Precambrian Research, 136: 177−202.

Zhou J B, Wilde S A, Zhao GC, Zheng C Q., Wei J, Zhang X Z, Cheng H 2008. SHRIMP U−Pb zircon dating of the Neoproterozoic Penglai Group and Archean gneisses from the Jiaobei Terrane, North China, and their tectonic implication[J]. Precambrian Research, 160: 323−340.

陈安蜀, 李效广, 高晓红. 2008. 1∶25 万区域地质图空间数据库建设——以 1∶25 万都兰县幅建库为例 [J]. 地质调查与研究, 31(1): 64−69.

丁正江, 孙丰月, 刘福来, 刘建辉, 彭齐鸣, 纪攀, 李碧乐, 张丕建. 2015a. 胶东中生代动力学演化及主要金属矿床成矿系列 [J]. 岩石学报, 31(10): 3045−3080.

丁正江, 孙丰月, 李国华, 纪攀, 孔彦. 2015b. 胶东邢家山地区燕山早期钼钨成矿母岩锆石 U−Pb 年龄及其意义 [J]. 中国地质, 42(2): 556−569.

郭晶, 朱学强, 任天龙, 戴广凯. 2019. 山东栖霞香夼地区多金属硫化物矿床外围隐爆——侵入角砾岩的发现及意义 [J]. 山东国土资源, 35(1): 19−24.

胡品三. 1987. 山东香夼多金属硫化物矿床分带特征和成矿机制的探讨 [J]. 唐山工程技术学院学报, (3): 25−33.

李晨阳, 王新春, 何春珍, 吴轩, 孔昭煜, 李晓蕾. 2019. 全国 1∶200 000 数字地质图 (公开版) 空间数据 [J]. 中国地质, 46(S1): 1−10.

李杰, 宋明春, 王美云, 李世勇, 周明岭, 倪师军, 张成江, 丁正江, 岳跃破. 2013. 胶东尚家庄钼矿床 Re−Os 同位素年龄及其地质意义 [J]. 中国地质, 40(5): 1612−1621.

梁凤华, 许志琴, 李忠海, 陈方远. 2011. 胶北地体中的深层次拆离构造: 扬子板片折返的板上响应 [J]. 岩石学报, 27(4): 969−979.

刘翠辉, 于长琦, 贺根文, 李伟, 刘孝斌. 2019. 赣南宁都地区 1∶50 000 青塘幅矿产地质图数据集 [J]. 中国地质, 46(S1): 75−83.

卢文姬, 孔祥超, 蓝信杰, 张丽君, 连舒婷, 辛魏. 2016. 山东栖霞香夼矿床深部地球化学成矿机理 [J]. 地质与勘探, 52(6): 1095−1106.

马明, 吴涵宇, 陈刚. 2017. 华东地区 1∶5 万区域地质图空间数据库建设及应用 [J]. 华东地质, 38(3): 228−233.

宋明春, 宋英昕, 李杰, 李世勇. 2015. 胶东与白垩纪花岗岩有关的金及有色金属矿床成矿系列 [J]. 大地构造与成矿学, 39(5): 828−843.

宋英昕, 宋明春, 李世勇, 李杰, 丁正江, 谭现峰. 2019. 胶东晚中生代三期成矿岩体和 3.5 Ga 锆石的发现及成矿动力学背景 [J]. 地质学报, 93(2): 440−458.

孙丰月, 丁正江, 刘殿浩, 张丕建, 于晓飞. 2011. 初论胶东福山北部地区斑岩成矿系统 [J]. 黄金, 32(1): 14−19.

汪山. 1984. 山东栖霞香夼古火山机构及其成矿特征 [J]. 吉林地质, 3(2): 31−40.

王成辉, 王登红, 黄凡, 徐钰, 陈郑辉, 应立娟, 刘善宝. 2012. 中国金矿集区及其资源潜力探讨 [J]. 中国地质, 39(5): 1125−1142.

王春女, 杜泽忠, 于晓飞, 李永胜, 吕鑫, 孙海瑞, 杜轶伦. 2019. 甘肃省花牛山幅 1∶50 000 矿产地质图数据库 [J]. 中国地质, 46(S1): 55−65.

王奎峰. 2008. 胶东栖霞香夼铅锌多金属矿床地质特征及成因 [J]. 地质调查与研究, 31(2): 89−96.

薛玉山, 柳振江, 成少博, 朱保霖. 2014. 胶东邢家山大型钼矿地质地球化学特征及成因意义 [J]. 中国地质, 41(2): 540−561.

薛志忠. 1999. 胶北臧家庄盆地中生代火山岩及火山活动特征 [J]. 山东地质, 15(4): 11−17.

杨立强, 邓军, 王中亮, 张良, 郭林楠, 宋明春, 郑晓礼. 2014. 胶东中生代金成矿系统 [J]. 岩石学报, 30(9): 2447−2467.

于学峰, 李洪奎, 单伟. 2012. 山东胶东矿集区燕山期构造热事件与金矿成矿耦合探讨 [J]. 地质学报, 86(12): 1946−1956.

张乾. 1990. 山东香夼斑岩型铅锌矿床的地球化学特征及成因探讨 [J]. 地质找矿论丛, 5(2): 12−19.

张增奇, 张成基, 王世进, 刘书才, 王来明, 杜胜贤, 宋志勇, 张尚坤, 杨恩秀, 程光锁, 刘凤臣, 陈军, 陈诚. 2014. 山东省地层侵入岩构造单元划分对比意义 [J]. 山东国土资源, 30(3): 1−23.

周喜文, 魏春景, 耿元生, 张立飞. 2004. 胶北栖霞地区泥质高压麻粒岩的发现及其地质意义 [J]. 科学通报, 29(14): 1424−1430.

朱学强, 戴广凯, 郭晶, 刘丽. 2020. 山东省臧家庄幅 1∶50 000 矿产地质图数据库 [DB/OL]. 地质科学数据出版系统. (2020-12-30). DOI: 10.35080/data.C.2020.P27.

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1∶50 000 Mineral and Geological Map Database of Zangjiazhuang Map-sheet, Shandong Province

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Abstract: The 1∶50 000 mineral and geological map of Zangjiazhuang Map-sheet (J51E016004), Shandong Province was prepared according to applicable industry standards such as *Technical Requirement of* 1∶50 000 *Solid Mineral Geological Survey* (DD 2019-02) and *Spatial Database for Digital Geological Map* (DD 2006-06), during which the results of relevant 1∶50 000- and 1∶200 000-scale regional geological surveys were fully adopted. In addition, a digital mapping system was applied to acquire data in the field, and indoor map preparation was conducted in combination with field survey of key survey sites. The data in the 1∶50 000 mineral and geological map database of Zangjiazhuang Map-sheet, Shandong Province (also referred to as the Database) was individually stored according to four types of classes, namely feature classes, complex classes, object classes and independent feature classes. In this paper, a new polymetallic metallogenic belt located in Qixia, Yantai City was proposed, i.e., the Gaojia–Xiangkuang–Xingjiashan polymetallic metallogenic belt. This metallogenic belt, with Mesozoic acid intrusions as metallogenic intrusions, is under the control of the intersection of the EW- and NNE-trending faults. LA-ICP-MS zircon U-Pb dating of the metallogenic intrusions in typical Xiangkuang polymetallic deposits indicates that the metallogenic age of the metallogenic intrusions is 127.91±0.58 Ma, providing new credible data for research into the metallogenic ages and rules of the polymetallic deposits in Zangjiazhuang Map-sheet. The Database covers the data of five ages and 25 mineral deposits, including two copper ore occurrences and one gold mineralized point that were newly discovered. Meanwhile, two prospecting target areas were determined and six predicted minimum prospecting target areas were delineated. Furthermore, the resources of Au, Ag, Pb and Zn in the new polymetallic metallogenic belt were predicted to be 10 962 kg, 499.638 t, 141 437 t and 230 011 t, respectively. The Database could provide basic data for the geological prospecting in Zangjiazhuang Map-sheet, as well as data sources for information- and network-

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oriented construction of geology.

Key words: mineral and geological map; database; 1∶50 000; Xiangkuang polymetallic deposit; mineral resource exploration engineering; Zangjiazhuang Map-sheet; Shandong Province

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

1 Introduction

Jiaodong area is located on the southeastern margin of North China Craton. It is one of the most important gold ore concentration areas in China (Wang CH et al., 2012; Yu XF et al., 2012; Yang LQ et al., 2014), accompanied by nonferrous mineral deposits such as Mo, W, Cu, Pb, and Zn deposits (Song MC et al., 2015; Li J et al., 2013). To figure out the polymetallic (Au, Cu, and Ag) deposits in Qixia–Penglai area, Jiaodong, the China Geological Survey implemented a secondary project entitled *Geological and Mineral Survey of Qixia–Muping Area, Jiaodong Metallogenic Province* to get a clear picture of regional metallogenic background, conditions, and potential.

The Database is a part of the project named *1∶50 000-scale Mineral and Geological Survey of Daxindian Map-sheet (J51E015004), Gangyu Map-sheet (J51E015005), Zangjiazhuang Map-sheet (J51E016004), and Gaotong Map-sheet (J51E016005), Shandong Province*, which is one of the sub-projects of the aforementioned secondary project. Zangjiazhuang Map-sheet is located in Qixia City, Jiaodong area, lies in the Jiaobei uplift on the southeastern margin of North China Plate (Zhang ZQ et al., 2014; Fig. 1), and is located in Qixia–Penglai–Fushan metallogenic belt, northwest Jiaodong metallogenic sub-belt, North China metallogenic province (Ding ZJ et al., 2015a; Fig. 2). In this map-sheet area, the gold deposits were developed and other important polymetallic deposits also occurred, with 25 mineral deposits (Table 1) recently discovered including Xilin (medium-scale) gold deposit and Xiangkuang lead–zinc deposit, of which the latter is the largest lead–zinc deposit in Shandong Province (Wang KF, 2008). Both ground and deep parts in the map-sheet area boast the potential for further prospecting and exploration.

Previous geological surveys of Zangjiazhuang Map-sheet are described as follows. Early in the 1990s, a 1∶50 000-scale regional geological survey[1] and a geochemical reconnaissance survey[2] had been completed for this map-sheet. In the 21st century, geological exploration organizations, such as the *No.3 Exploration Institute of Geology and Mineral Resources of Shandong Province* and *Geological Exploration Institute of Shandong Zhengyuan Co. Ltd.*, completed a series of reconnaissance surveys and exploration of the mineral resources for this map-sheet[3,4]. Meanwhile, many scholars conducted scientific research on gold deposits and typical polymetallic deposits (Hu PS, 1987; Zhang Q, 1990; Wang KF et al., 2008; Sun FY et al., 2011; Xue YS et al., 2014; Ding ZJ et al., 2015a, 2015b; Song MC et al., 2015; Lu WJ et al., 2016) and the Precambrian geological bodies (Wang S, 1984; Xue ZZ, 1999; Zhou XW et al., 2004; Zhao GC et al., 2005; Li XH et al., 2007; Zhou JB et al., 2008; Tam PY et al., 2011; Liang FH et al., 2011; Li SZ et al., 2012) in this map-sheet. All these lay a foundation

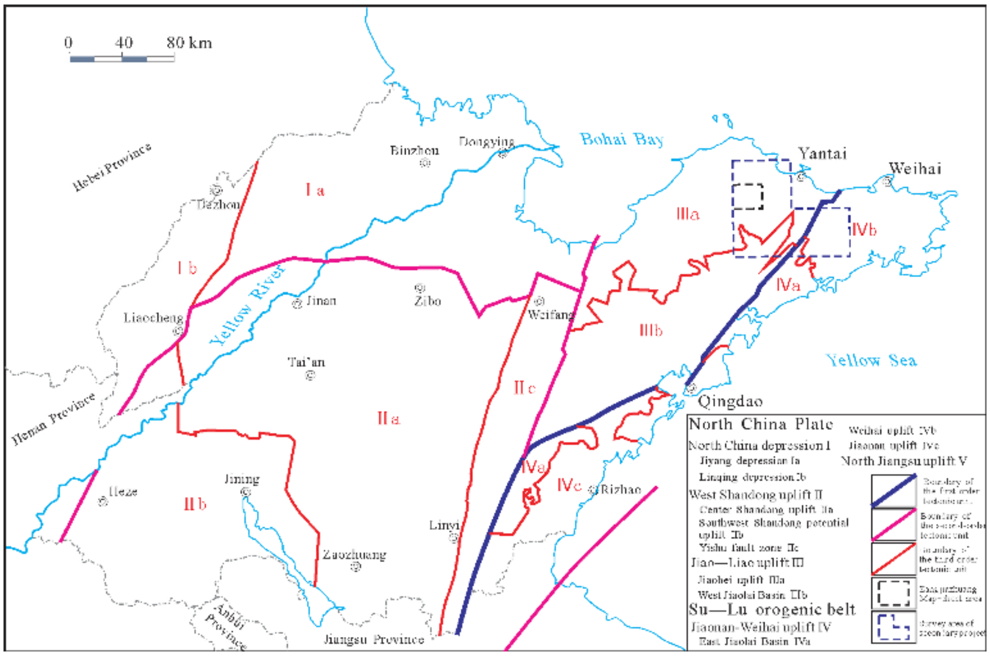

Fig. 1　Tectonic location map of Zangjiazhuang area, Shandong Province (modified from Zhang ZQ et al., 2014)

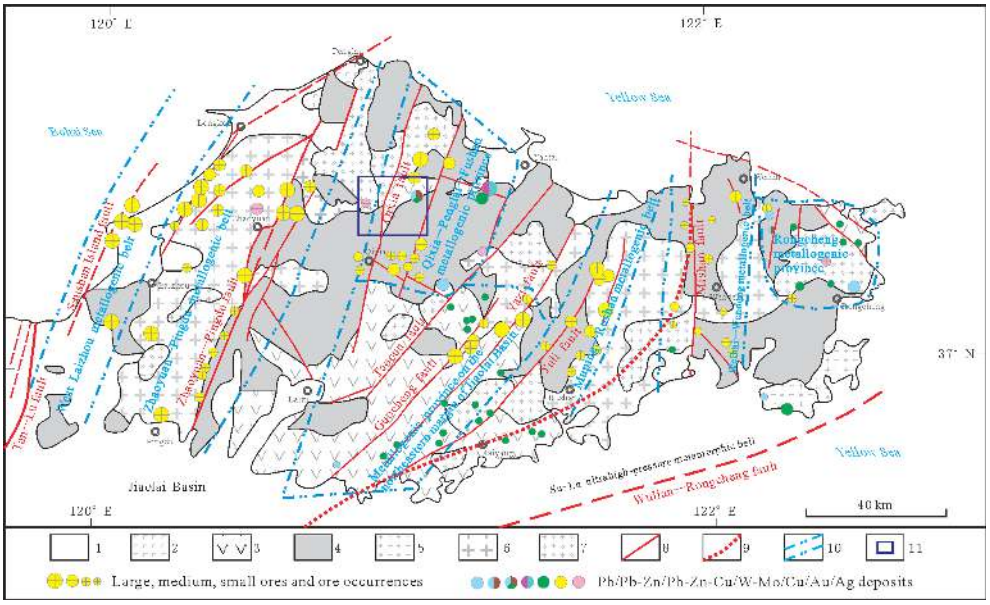

Fig. 2　Metallogenic belt location of Zangjiazhuang area, Shandong Province (modified from Ding ZJ et al., 2015a)

1—Cenozoic sediments; 2—Cenozoic basalt; 3—Cretaceous volcanogenic sedimentary rock; 4—Precambrian basement; 5—Triassic granite; 6—Jurassic granite; 7—Cretaceous granite; 8—main fault; 9—Inferred boundary of metamorphic zone; 10—boundary of metallogenic belt; 11—scope of Zangjiazhuang Map-sheet

for the preparation of mineral and geological maps of the Zangjiazhuang Map-sheet. As one of the first batch of 1：50 000 mineral and geological maps implemented by the China Geological Survey in Shandong Province, the 1：50 000 mineral and geological survey map of the Zangjiazhuang Map-sheet was prepared by taking the continually updated *Technical Requirement of* 1：50 000 *Solid Mineral Geological Survey* (DD 2019-02) as basic guidelines

Table 1 List of 25 mineral deposits recently discovered in the Zangjiazhuang area

Code	Mineral deposit name	Scale	Deposit type	Main ore-bearing suites and structures
1	Xilin gold deposit in Zangjiazhuang Town, Qixia City	Medium	Subvolcanic hydrothermal fracture-filling and metasomatic type	Near EW-trending fault
2	Shangaikou gold deposit in Songshan Town, Qixia City	Small	Quartz vein type	Near EW-trending mylonite zone
3	Zhanmazhangjia gold deposit in Cunliji Town, Penglai City	Ore occurrence	Quartz vein type	NE-trending fault
4	Wanggezhuang gold deposit in Cunliji Town, Penglai City	Ore occurrence	Quartz vein type	NNE-trending fault
5	Yinjia gold deposit in Zangjiazhuang Town, Qixia City	Ore occurrence	Altered rock type	NE-trending fault
6	Aishantang gold deposit in Songshan Town, Qixia City	Ore occurrence	Quartz vein type	NE-trending fault
7	Xia’aikou gold deposit in Songshan Town, Qixia City	Ore occurrence	Quartz vein type	NE-trending fault
8	Gejiagou gold deposit, Zhuangyuan Street, Qixia City	Ore occurrence	Quartz vein type	NNE-trending fault
9	Zhangjiagou gold deposit, northern Qixia	Ore occurrence	Quartz vein type	NWW-trending mylonite zone
10	Keluozoujia gold deposit in Songshan Town, Qixia City	Ore occurrence	Quartz vein type	NWW-trending mylonite zone
11	Mengjia gold deposit in Zangjiazhuang Town, Qixia City	Mineralized point	Magmatic hydrothermal fracture-filling type	Near EW-trending fault
12	Jinshanbozi gold deposit in Songshan Town, Qixia City	Mineralized point	Quartz vein type	NW-trending fault
13	Gaojia gold deposit, Zhuangyuan Street, Qixia City	Mineralized point	Quartz vein type	NW-trending fault
14	Gongxianding gold deposit, Tingkou Town, Qixia City	Mineralized point	Quartz vein type	NE-trending fault
15	Heshangzhuang silver deposit in Zhuangyuan Street, Qixia City	Small	Magmatic hydrothermal fracture-filling type	NWW-trending fault of the graphite-two mica schist of the Fenzishan Group
16	Gaojiabei silver deposit in Zhuangyuan Street, Qixia City	Ore occurrence	Magmatic hydrothermal fracture-filling type	NWW-trending fault of the graphite-two mica schist of the Fenzishan Group
17	Wengliuzhangjia copper deposit in Zangjiazhuang Town, Qixia City	Ore occurrence	Magmatic hydrothermal fracture-filling type	Cretaceous Laiyang Group conglomerate

Continued table 1

Code	Mineral deposit name	Scale	Deposit type	Main ore-bearing suites and structures
18	Baifoyuan copper deposit in ZangjiazhuangTown, Qixia City	Mineralized point	Magmatic hydrothermal fracture-filling type	NNE-trending fault
19	Wengliufanjia copper deposit in Zangjiazhuang Town, Qixia City	Ore occurrence	Magmatic hydrothermal fracture-filling type	Cretaceous Laiyang Group conglomerate
20	Xiaozhu copper deposit in Cuoliji Town, Penglai City	Mineralized point	Magmatic hydrothermal fracture-filling type	NNE-trending fault
21	Xishanzhuang lead deposit in Zangjiazhuang Town, Qixia City	Ore occurrence	Magmatic hydrothermal fracture-filling type	Near EW-trending fault
22	Denggezhuang lead deposit in Cunliji Town, Penglai City	Mineralized point	Magmatic hydrothermal fracture-filling type	Contact zone between Cretaceous granites
23	Xilin lead–zinc deposit in Zangjiazhuang Town, Qixia City	Mineralized point	Subvolcanic hydrothermal fissure filling and replacement	Contact zone between Cretaceous granodiorite porphyry and Laiyang Group
24	Xiangkuang copper–lead–zinc polymetallic deposit in Zangjiazhuang Town, Qixia City	Medium	Skarn–porphyry complex type	Contact zone between Cretaceous granodiorite porphyry and the limestone of Xiangkuang Formation
25	Haojialou copper–lead–zinc polymetallic deposit in Songshan Town, Qixia City	Mineralized point	Skarn type	Contact zone between Cretaceous granodiorite porphyry and Baoshankou Formation

for mineral and geological survey, and the Huaniushan Map-sheet (Wang CN et al., 2019) issued by the China Geological Survey as references. As a result, the results of geology and the results of exploration and scientific research for the Zangjiazhuang Map-sheet are comprehensively presented in the map, thus providing basic geological maps for mineral resource research, potential assessment, and mineral prospecting and exploration in the map-sheet area and also setting an example for subsequent mineral and geological surveys. The Database (Zhu XQ et al., 2020) was accordingly built, and its brief metadata table is shown in Table 2.

2 Data Acquisition and Processing

The digital geological survey system (DGSS) was applied to digitalize the 1：50 000 geographical base map, with Gauss-Kruger projection as the projection system, Xi'an 1980 as the coordinates system, and National Height Datum 1985 as the height datum. The geological

Table 2 Metadata Table of Database (Dataset)

Items	Description
Database (dataset) name	1：50 000 Mineral and Geological Map Database of Zangjiazhuang Map-sheet, Shandong Province
Database (dataset) authors	Zhu Xueqiang, Shandong Institute of Geological Survey Dai Guangkai, Shandong Institute of Geological Survey Guo Jing, Shandong Institute of Geological Survey Liu Li, Shandong Institute of Geological Survey
Data acquisition time	From 2016 to 2018
Geographical area	120°45′–121°00′E, 37°20′–37°30′N
Data format	MapGIS
Data size	36.5 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	Mineral and geological survey project entitled *1：50 000-scale Mineral and Geological Survey of Daxindian Map-sheet, Gangyu Map-sheet, Zangjiazhuang Map-sheet and Gaotuan Map-sheet, Shandong Province* (No.: DD20160044-1) initiated by the China Geological Survey
Language	Chinese
Database (dataset) composition	The Database consists of 1：50 000 geological map library and map decorations. The geological map library includes feature classes, object classes, complex classes and independent feature classes. The feature classes include geological polygon entities, geological boundaries, mineral deposits, attitude, samples, photos, isotopic ages, craters, shorelines of rivers, lakes, seas, and reservoirs. Complex classes include tectonic deformation zone, alteration zones, metamorphic facies zones, volcanic facies zones, standard map frames. Object classes include sedimentary (volcanic) rocks, chronologic unit of intrusions, faults, petrostratigraphic units of metamorphic rocks, special geological bodies, dike (sections), planar waters and swamps, basic information of the map-sheet. Independent feature classes include the corner maps such as legends, diagrams, transverse cutting profiles, an index map, profiles of typical deposits, the name list/mineral types/scale of mineral deposits, location map of metallogenic belt the map-sheet is located, and duty table

scope of the Map-sheet is 120°45′–121°00′E and 37°20′–37°30′N. The data formats include.tm (for geological observation points),.lm (for geological lines), and.pm (for geological polygons). The system databases of Slib were used in the whole Database (Chen AS et al., 2008).

2.1 Preparation of suite-tectonic Draft Map

The suite-tectonic draft map was compiled using the following steps. First, digitalize the data collected from the 1：50 000-scale regional geological surveys of the Zangjiazhuang Map-sheet. Secondly, based on a comprehensive analysis of existing data, complement lithologic (association) boundaries and present lithologic patterns according to different types of suites (sedimentary rocks, volcanics, intrusions and metamorphic rocks) in the draft data map formed by previous regional surveys. In this way, the suite-tectonic draft map was prepared.

2.2 Mineral and geology-specific mapping and collation

Based on the comprehensive analysis of existing 1：50 000[❶] and 1：200 000-scale geological[❷], geophysical[❸], geochemical[❹] and remote sensing[❺] data, preparation of the suite-tectonic draft map, and the dissection of typical Xiangkuang porphyry-skarn polymetallic Cu-Pb-Zn deposit, it was determined that (i) the metallogenic surrounding rocks mainly include Cretaceous hypabyssal acid porphyry and the Neoproterozoic carbonate rock and calcareous slate in Xiangkuang and Nanzhuang formations, Penglai Group; (ii) the orebodies are mainly controlled by the junction of EW-trending structures and NNE-trending structures; (iii) main alteration types include skarnization, pyritization, chalcopyritization and propylitization. The southern and northern margins of Zangjiazhuang basin were classified as key survey sites according to metallogenic favorability degree, and the mapping focus was determined to be (i) Neoproterozoic carbonate rock formation of Xiangkuang Formation, Penglai Group and Cretaceous hypabyssal acid porphyry that are related to polymetallic deposits on the southern margin of Zangjiazhuang basin; (ii) Cretaceous Guojialing granites that are related to gold deposits on the northern margin of Zangjiazhuang basin. The mapping of the minor survey sites were mainly prepared according to the *1：50 000-scale Regional Geological Survey Report of Daxindian and Zangjiazhuang Map-sheets.*

During the field route geological survey, the data were acquired using the field digital mapping system AoRGMap based on Android OS. Then with the 1：25 000 suite-tectonic draft map as base map, the freehand field map databases were established by acquiring data for geological points (P), geological routes (R), and geological boundaries (B) as well as relevant information such as lithology, structures, mineralization, samples, and attitude. After that, the PRB databases of the Zangjiazhuang Map-sheet were established by inputting field route data into the database, projecting field section (profile) data, creating sample databases, and projecting exploration engineering (such as trenching and borehole drilling). All features in the databases were collated and labeled in accordance with relevant specifications. The field route geological survey involves nine surveyed profiles, 33 surveyed routes (158 km long), routes of 373 km for data acquisition, records of three trenches, 323 geological points, 45 samples for thin section identification, 65 samples for basic analysis, five samples for isotopic dating (including two surveyed, Table 3), 138 attitudes, and 417 photos. The overall accuracy meets the specific requirements of 1∶50 000-scale mineral and geological mapping.

Afterwards, the draft data maps were prepared in the following steps. First, update the draft data map databases with the PRB databases. Then, edit the geological polygon file (GEOPOLY.PM), geological line file (GEOLINE.LM) and geological point file (GEOLABEL.TM), and extract appropriate attributes from the PRB databases. In this way, the draft data maps of the map-sheet were prepared.

2.3 Preparation of Result Maps

The previous draft data maps used as the base map of the suie-tectonic draft map were updated based on the contents of the draft data maps surveyed in this project. The geological boundaries, formation types and their patterns, and characteristics of mineralized alteration were corrected. In this way, the suite-tectonic map of the Zangjiazhuang Map-sheet was formed. Meanwhile, the corner maps were prepared or improved, including formation histograms, transverse cutting profiles, location map of metallogenic belt the map-sheet is located, and legends.

The mineral and geological map was prepared based on the suite-tectonic map according to the *Technical Requirement of* 1∶50 000 *Solid Mineral Geological Survey* (DD 2019-02). The contents of map layers mainly include geographical base maps (HYDNT.WP、HYDNT.WL, A_HYDNT.WT), geological polygons (_GEOPOLYGON.WP), geological boundaries (_GEOLINE.WL), geological codes (A_GEOPOLYGON.WT), lithologic patterns (A_GEOPOLYGON.WL), attitudes (_ATTITUDE.WT), ore occurrences (_MINERAL_PNT.WT), and mineralized alteration (A_ALTERATION_POLYGON.WT). The contents of corner maps include an index map, histograms, legends, transverse cutting profiles, typical deposit profiles, the name list/mineral types/scale of mineral deposits, location map of the metallogenic belt the map-sheet is located, and duty table.

The mineral and geological map was prepared based on in-depth research into the formations of sedimentary rocks, volcanics, metamorphic rocks, and intrusions, the structures, and the minerals in the Zangjiazhuang Map-sheet, as well as the results of the 1∶50 000-scale mineral and geology-specific mapping in this project. After comprehensive analyses and

Table 3 List of isotopic dating samples and related information

Code	Lithology	Datig method	Age/Ma	Data source
1	Andesite	Biotite K–Ar dating	123	Collected from the reference[1]
2	Gneissic biotite monzonitic granite	Zircon U–Pb dating	2447	Collected from the reference[1]
3	Plagioclase amphibolite	Sm–Nd dating	2938	Collected from the reference[1]
4	Granodioritic porphyry	Zircon LA-ICP-MS U–Pb dating	127.91±0.58	The laboratory of Tianjin Center, China Geological Survey
5	Rhyolitic porphyry	Zircon LA-ICP-MS U–Pb dating	114.14±0.78	The laboratory of Tianjin Center, China Geological Survey

investigation of how the formations and structures are related to the deposits, eight sedimentary (volcanic) rock formations, 21 intrusion formations, and eight metamorphic rock formations were identified. Among them, the granodiorite-porphyry formation of the early Cretaceous and the Neoproterozoic metamorphic carbonate rock formation of Xiangkuang Formation, Penglai Group are polymetallic ore-bearing formations, and the porphyritic medium-grain hornblende-bearing monzonitic granite intrusion formation is the gold-bearing rock formation, all of which are the main focus of this study.

3 Data Description of Result Database

With the *Spatial Database for Digital Geological Map* (DD 2006-06) as the basic requirements of the establishment of mineral and geological map databases, the data in the Database were individually stored according to four types of classes, namely feature classes, object classes, complex classes, and independent feature classes.

The feature classes include geological polygon entities (_GEOPOLYGON.PM), geological boundaries (_GEOLINE.LM), mineral deposits (_MINERAL_PNT.TM), attitudes (_ATTITUDE.TM), samples (_SAMPLE.TM), photos (_PHOTOGRAPH.TM), isotopic ages (_ISOTOPE.TM), craters (_CRATER.TM), shorelines of rivers, lakes, seas, and reservoirs (_LINE_GEOGRAPHY.LM).

The complex classes include tectonic deformation zones (_TECTZONE.PM), alteration zones (_ALTERATION_POLYGON.PM), metamorphic facies zones (_METAMOR_FACIES.PM), volcanic facies zones (_VOLCA_FACIES.PM), and standard map frames (_MAP_FRAME.LM).

The object classes include sedimentary (volcanic) stratigraphic units (STRATA), petrostratigraphic units of intrusions (INTRU_LITHO_CHEONO), faults (FAULT), stratigraphic (lithostratigraphic) units of metamorphic rocks (METAMORPHIC), special geological bodies (SPECAIL_GEOBODY), dikes (area) (_DIKE_OBJECT), planar waters and swamps (_WATER_REGION), and basic information of the map-sheet (_SHEET_MAPINFO).

The independent feature classes mainly include legends, histograms, transverse cutting profiles, index map, analytical graph of typical deposits, name list/mineral species/scale of mineral deposits, location map of the metallogenic belt the map-sheet is located, and duty table.

Among these classes, the feature classes, complex classes, and the object classes correspond to the data table with following attribute structure in BASE_FCLS.mdb, DSGMAP.mdb and SYNTH_FCLS.mdb, respectively. The specific information about these classes is shown in Table 4.

Databases were individually established for geochemical, geophysical, and remote-sensing data generated during the survey. Based on these databases, a comprehensive result database was finally formed, which includes anomaly verification result tables, ore occurrence inspection result tables, prospecting target areas, and predicted mineral prospect areas.

Table 4 Data Tables of the Feature Classes, Complex Classes, and Object Classes of Zangjiazhuang Map-sheet (J51E016004)

Dataset	Entity name	File name	File number	Data type
Feature classes	Geological polygon entity	_GEOPOLYGON.PM	904	Area
	Geological (boundary) line	_GEOLINE.LM	2 550	Line
	Mineral deposit	_MINERAL_PNT.TM	25	Point
	Attitude	_ATTITUDE.TM	138	Point
	Isotopic dating	_ISOTOPE.TM	5	Point
	Crater	_CRATER.TM	1	Point
	Shoreline of river, lake, sea, or reservoir	_LINE_GEOGRAPHY.LM	231	Line
Complex classes	Tectonic deformation zone	_TECOZONE.PM	6	Area
	Alteration zone (section)	_ALTERATION_POLYGON.PM	66	Area
	Metamorphic facies zone	_METAMOR_FACIES.PM	230	Area
	Volcanic facies zone	_VOLCA_FACIES.PM	20	Area
	Standard map frame (inner map frame)	_MAP_FRAME	4	Line
Object classes	Petrostratigraphic unit of sedimentary (volcanic) rocks	_STRATA	8	ACCESS
	Chronologic unit of intrusions	_INTRU_LITHO_CHRONO	21	ACCESS
	Fault	_FAULT	10	ACCESS
	Petrostratigraphic unit of metamorphic rocks	_METAMORPHIC	8	ACCESS
	Special geological body	_SPECIAL_GEOBODY	6	ACCESS
	Dike (section)	_DIKE_OBJECT	17	ACCESS
	Planar waters and swamp	_WATER_REGION	4	ACCESS
	Basic information of the Map-sheet	_SHEET_MAPINFO	1	ACCESS

4 Data Quality

The mineral and geological mapping in this paper was conducted according to the *Technical Requirement of* 1：50 000 *Solid* Mineral *Geological Survey* (DD 2019-02), during which the key survey sites were mainly mapped based on field survey, while the maps of minor general survey sites were prepared according to previous regional geological reports.

The digital mapping system DGSS was used throughout the project. The field data acquisition instruments equipped with Android OS-based DGSS was used for the first time during the field survey, improving work efficiency and accuracy. The spatial database of the mineral and geological map inherited and integrated previous databases of original data. It was established by strictly following the database establishment processes of the digital mapping system, and uniform system databases of DGSS were adopted, thus effectively achieving uniform description, storage, and organization of various data.

Edge match was conducted for all draft data maps and original maps for compilation, and then the maps were clipped according to the inner map frame. After that, automatic cutting and line-line topological checks were repeatedly carried out until there was no error. Then topological area creation was performed by extracting arcs from geological lines and conducting topologic reconstruction. The search radius of the system nodes/clipping was 10^{-9}. Through these procedures, the map precision met the quality requirements of the database.

The contact relationships between strata on the map face were determined in accordance with applicable standards. The underlying/overlying relationships between different geological bodies and between faults and geological boundaries were arrayed as per actual conditions. Different map layers were correctly integrated into a uniform space.

The files of the geological map spatial database feature complete file types, with filenames and attribute structures meeting the requirements of applicable specifications. The data items in all datasets of the database (feature classes, complex classes, independent feature classes, and object classes) coincide with contents presented on the map face, and authentically reflect the actual conditions in the original geological maps and text reports, thus meeting the requirements of the database.

The self-check rate and mutual check rate of original data were both 100%, and the rate of spot inspection conducted by institutions of the project was 30%, meeting the requirements of quality management system of the institutions of the project and the requirements of geological survey project management. During the annual quality inspection and field acceptance check, the Tianjin Center of China Geological Survey organized experts to check the original data by indoor inspection combined with field spot inspection. In June 2019, it organized experts to complete the final acceptance check of the Database.

5 Data Value

During the 1：50 000-scale mineral and geological mapping of the Zangjiazhuang Map-sheet, a new polymetallic metallogenic belt located in Yantai City was proposed, i.e., the Gaojia–Xiangkuang–Xingjiashan polymetallic metallogenic belt. This metallogenic belt, with Mesozoic acid intrusions as metallogenic intrusions, is mainly controlled by the junction of EW- and NNE-trending structures. As indicated by LA-ICP-MS zircon U-Pb dating of the metallogenic intrusions in typical Xiangkuang porphyry-skarn polymetallic Cu-Pb-Zn deposits, the age of the granodiorite porphyry of Xiangkuang deposit is 127.91±0.58 Ma, which approximates to the dating results (130.4±1.2 Ma) of Song Yingxin (2019). Therefore, the dating of this project provided new credible data for research into the metallogenic ages and rules of the polymetallic deposits in the Zangjiazhuang Map-sheet. Meanwhile, cryptoexplosive-intrusive breccia was discovered in the periphery of Xiangkuang polymetallic deposit, enriching the prospecting model and contributing to the exploration of porphyry-type concealed ore bodies (Guo J et al., 2019). Two copper ore occurrences and one gold mineralized point were newly discovered. Two prospecting target areas were determined, namely the prospecting target area of Gaojia silver deposit and the predicted deep prospecting target area of Xiangkuang lead–zinc deposit. Six predicted minimum prospecting target areas were delineated, namely Aishantang gold area, Jinshan gold area, Chekuang gold area, Gaojia gold area, Xiangkuang lead–zinc area, and Donglongkuang area. The resources of Au, Ag, Pb and Zn in the new polymetallic metallogenic belt were predicted to be 10 962 kg, 499.638 t, 141 437 t and 230 011 t, respectively.

The 1∶50 000 mineral and geological map and the database of the Zangjiazhuang Map-sheet (J51E016004) will provide basic data for the geological prospecting in the map-sheet area, can be used as references for the research, prospecting, and exploration of the mineral resources in the Map-sheet, and provide data sources for information- and network-oriented geological construction (Ma M et al., 2017; Li CY et al., 2019; Liu CH et al., 2019).

6 Conclusions

(1) The 1∶50 000 mineral and geological map of the Zangjiazhuang Map-sheet (J51E016004), Shandong Province is one of the first batch of maps surveyed by the China Geological Survey in Shandong Province. It was prepared by taking the continually updated *Technical Requirement of* 1∶50 000 *Solid Mineral Geological Survey* (DD 2019-02) as basic guidelines for mineral and geological survey, during which research techniques were gradually adjusted. As a result, the mineral and geological map of the Zangjiazhuang Map-sheet was formed, setting an example for mineral and geological surveys in the whole Shandong Province.

(2) The mineral and geological map was systematically prepared based on in-depth research into the formations of sedimentary rocks, volcanic rocks, metamorphic rocks and intrusives, the structures, and the minerals in the map-sheet area, as well as the results of the 1∶50 000-scale mineral and geology-specific mapping in this project. The presentation of metallogenic factors was highlighted in the map. Furthermore, a spatial database was established.

(3) A new polymetallic metallogenic belt located in Yantai City was proposed, i.e., the Gaojia–Xiangkuang–Xingjiashan polymetallic metallogenic belt. This metallogenic belt, with Mesozoic acid intrusions as metallogenic intrusions, is mainly controlled by the junction of EW-trending structures and NNE-trending structures. The LA-ICP-MS zircon U-Pb dating of the metallogenic intrusions of Xiangkuang polymetallic deposit indicates that the metallogenic age of the granodiorite porphyry in the Xiangkuang deposit is 127.91±0.58 Ma, providing new credible data for research into the metallogenic ages and rules of the polymetallic deposits in the Zangjiazhuang Map-sheet. Furthermore, three ore occurrences (mineralized points) were newly discovered, two prospecting target areas were determined, six predicted minimum prospecting target areas were delineated, and the resources of the new polymetallic metallogenic belt were predicted.

(4) The 1∶50 000 mineral and geological map and the database of Zangjiazhuang Map-sheet (J51E016004) could provide basic data for geological prospecting in the map-sheet area, can be used as references for research, prospecting, and exploration of the mineral resources in the Map-sheet, and provide data sources for information- and network-oriented geological construction.

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Zangjiazhuang Map-sheet (J51E016004), Shandong Province was established through hard field work of all project members. The authors hereby extend sincere gratitude to all of them. Thanks also go to the reviewers for their valuable comments on this paper.

Notes:

❶ No.3 Geological Brigade of Shandong Provincial Bureau of Geology & Mineral Resources. 1996. 1：50 000-scale Regional Geological Survey Report of Daxindian and Zangjiazhuang Map-sheets.

❷ Geophysical and Geochemical Exploration Brigade of Shandong Provincial Bureau of Geology and Mineral Resources. 1992. 1：50 000-scale Geochemical Reconnaissance Survey Result Report of Daxindian and Zangjiazhuang Map-sheets.

❸ No.3 Exploration Institute of Geology and Mineral Resources of Shandong Province. 2008. Detailed Survey Report of Deep and Peripheral Gold Deposits of Xilin Mining Area, Qixia City, Shandong Province.

❹ Geological Exploration Institute of Shandong Zhengyuan Co. Ltd. 2010. Reconnaissance Survey Report of the Periphery of Xiangkuang Cu-Pb-Zn Polymetallic Sulfide Deposit, Qixia City, Shandong Province.

❺ Regional Geological Survey Brigade of Shandong Provincial Bureau of Geology and Mineral Resources. 1991. 1：200 000-scale Regional Geological Survey Report of Yantai and Penglai Map-sheets.

References

Chen Anshu, Li Xiaoguang, Gao Xiaohong. 2008. 1：250 000-scale regional geological map spatial database[J]. Geological Survey and Research, 31(1): 64−69 (in Chinese with English abstract).

Ding Zhengjiang, Sun Fengyue, Liu Fulai, Liu Jianhui, Peng Qiming, Ji Pan, Li Bile, Zhang Peijian. 2015a. Mesozoic geodanamic evolution and metallogenic series of major metal deposits in Jiaodong Peninsula, China[J]. Acta Petrologica Sinica, 31(10): 3045−3080 (in Chinese with English abstract).

Ding Zhengjiang, Sun Fengyue, Li Guohua, Ji Pan, Kong Yan. 2015b. Accurate zircon U-Pb dating of early Yanshanian molybdenum-tungeten mother rocks in Xingjiashan area of Jiaodong Peninsula and its significance[J]. Geology in China, 42(2): 556−569 (in Chinese with English abstract).

Guo Jing, Zhu Xueqiang, Ren Tianlong, Dai Guangkai. 2019. Discovery and significance of cryptoexplosive intrusive breccia in Xiangkuang polymetallic sulfide deposit in Qixia area of Shandong Province[J]. Shandong Land and Resources, 35(1): 19−24 (in Chinese with English abstract).

Hu Pinsan. 1987. A study of zoning character and metallogenetic mechanism of the polymetallic sulfide deposit in Xiangkuang, Shandong[J]. Journal of Tangshan Institute of Engineering and Technology, (3): 25−33 (in Chinese with English abstract).

Li Chenyang, Wang Xinchun, He Chunzhen, Wu Xuan, Kong Zhaoyu, Li Xiaolei. 2019. China national digital geological map (public version at 1：200 000 Scale) spatial database[J]. Geology in China, 46(S1): 1−14.

Li Jie, Song Mingchun, Wang Meiyun, Li Shiyong, Zhou Mingling, Ni Shijun, Zhang Chengjiang, Ding

Zhengjiang, Yue Yuepo. 2013. The molybdenite Re-Os age and genetic analysis of the Shangjiazhuang Mo Deposit in Jiaodong area[J]. Geology in China, 40(5): 1612−1621 (in Chinese with English abstract).

Li Sanzhong, Zhao Guochun, Santosh M., Liu Xin, Dai Liming, Suo Yanhui, Tam Pui Yuk, Song Mingchun, Wang Peicheng 2012. Paleoproterozoic structural evolution of the southern segment of the Jiao-Liao-Ji Belt, North China Craton[J]. Precambrian Research, 200: 59−73.

Li Xianghui, Chen Fukun, Guo Jinghui, Li Qiuli, Xie Liewen, Wolfgang Siebel. 2007. South China provenance of the lower-grade Penglai Group north of the Sulu UHP orogenic belt, eastern China: evidence from detrital zircon ages and Nd-Hf isotopic composition[J]. Geochemical Journal, 41: 29−45.

Liang Fenghua, Xu Zhiqin, Li Zhonghai, Chen Fangyuan. 2011. Deep-level ductile detachment system in the Jiaobei terrain, eastern China: deformation response of the overlying plate during the exhumation of Yangtze Plate[J]. Acta Petrologica Sinica, 27(4): 969−979 (in Chinese with English abstract).

Liu Cuihui, Yu Changqi, He Genwen, Li Wei, Liu Xiaobin. 2019. The 1：50 000 mineral geological map dataset of the Qingtang Map-sheet, Ningdu, south Jiangxi[J]. Geology in China, 46(S1): 1000−111.

Lu Wenji, Kong Xiangchao, Lan Xinjie, Zhang Lijun, Lian Shuting, Xin Wei. 2016. Geochemical metallogenic mechanism of the deep Xiangkuang deposit in the Qixia area of Shandong Province[J]. Geology and Exploration, 52(6): 1095−1106 (in Chinese with English abstract).

Ma Ming, Wu Hanyu, Chen Gang. 2017. Construction of 1：50 000 regional geological map database in East China and its application[J]. East China Geology, 38(3): 228−233 (in Chinese with English abstract).

Song Mingchun, Song Yingxin, Li Jie, Li Shiyong. 2015. Metallogenic series of gold and nonferrous metal deposits related to Cretaceous granites in eastern Shandong Peninsula, China[J]. Geotectonica et Metallogenia, 39(5): 828−843 (in Chinese with English abstract).

Song Yingxin, Song Mingchun, Li Shiyong, Li Jie, Ding Zhengjiang, Tan Xianfeng. 2019. The discovery of three-stage late Mesozoic metallogenic granitic bodies and 3.5 Ga zircon in the Jiaodong terrane and their metallogenetic geodynamical setting[J]. Acta Geologica Sinica, 93(2): 440−458 (in Chinese with English abstract).

Sun Fengyue, Ding Zhengjiang, Liu Dianhao, Zhang Pijian, Yu Xiaofei. 2011. Discussion on the porphyry metallogenic system in north Fushan Area, Jiaodong Peninsula[J]. Gold, 32(1): 14−19 (in Chinese with English abstract).

Tam Pui Yuk, Zhao Guochun, Liu Fulai, Zhou Xiwen, Sun Ming, Li Sisui. 2011. Timing of Metamorphism in the Paleoproterozoic Jiao-Liao-Ji Belt: New SHRIMP U-Pb Zircon Dating of Granulites, Gneisses and Marbles of the Jiaobei Massif in the North China Craton[J]. Gondwana Research, 19: 150−162.

Wang Chenghui, Wang Denghong, Huang Fan, Xu Yu, Chen Zhenghui, Ying Lijuan, Liu Shanbao. 2012. The major gold concentration areas in China and their resource potentials[J]. Geology in China, 39(5): 1125−1142 (in Chinese with English abstract).

Wang Chunnyu, Du Zezhong, Yu Xiaofei, Li Yongsheng, Lyu Xin, Sun Hairui, Du Yilun. 2019. 1：50

000 mineral geological map database of the Huaniushan Map-sheet, Gansu[J]. Geology in China, 46(S1): 72−86 (in Chinese with English abstract).

Wang Kuifeng. 2008. Geochemical characteristics and origin of the Xiangkuang lead-zinc polymetallic deposit in Qixia City, eastern Shandong Province[J]. Geological Survey and Research, 31(2): 89−96 (in Chinese with English abstract).

Wang Shan. 1984. Paleovolcanic mechanism and metallogenic characteristics of Xiangkuang, Qixia, Shandong Province[J]. Jilin Geology, 3(2): 31−40 (in Chinese).

Xue Yushan, Liu Zhenjiang, Cheng Shaobo, Zhu Baolin. 2014. Geological-geochemical characteristics of the Xingjiashan Mo deposit in Jiaodong and their geological significance[J]. Geology in China, 41(2): 540−561 (in Chinese with English abstract).

Xue Zhizhong. 1999. Characteristics of Mesozoic volcanic rocks and volcanic activities in Zangjiazhuang Basin in Jiaobei[J]. Shandong Geology, 15(4): 11−17 (in Chinese with English abstract).

Yang Liqiang, Deng Jun, Wang Zhongliang, Zhang Liang, Guo Linnan, Song Mingchun, Zheng Xiaoli. 2014. Mesozoic gold metallogenic system of the Jiaodong gold province, eastern China[J]. Acta Petrologica Sinica, 30(9): 2447−2467 (in Chinese with English abstract).

Yu Xuefeng, Li Hongkui, Shan Wei. 2012. Study on coupling between Yanshannian tectonic thermal events and gold mineralization in Jiaodong ore concentrating area in Shandong Province[J]. Acta Geologica Sinica, 86(12): 1946−1956 (in Chinese with English abstract).

Zhang Qian. 1990. Lead-zinc deposit in Shandong Province and discussion on its genesis[J]. Contributions to Geology and Mineral Resources Research, 5(2): 12−19 (in Chinese).

Zhang Zengqi, Zhang Chengji, Wang Shijin, Liu Shucai, Wang Laiming, Du Shengxian, Song Zhiyong, Zhang Shangkun, Yang Enxiu, Cheng Guangsuo, Liu Fengchen, Chen Jun, Chen Cheng. 2014. Views on classification and contrast of tectonic units in strata in Shandong Province[J]. Shangdong Land and Resources, 30(3): 1−23 (in Chinese with English abstract).

Zhao Guochun, Sun Min, Simon A.Wlide, Li Sanzong 2005. Late Archean to Paleoproterozoic Evolution of the North China Craton: Key Issues Revisited[J]. Precambrian Research, 136: 177−202.

Zhou Jianbo, Simon A.Wilde, Zhao Guochun, Zheng Changqing, Wei Jin, Zhang Xingzhou, Cheng Hong 2008. SHRIMP U-Pb zircon dating of the Neoproterozoic Penglai Group and Archean gneisses from the Jiaobei Terrane, North China, and their tectonic implication[J]. Precambrian Research, 160: 323−340.

Zhou Xiwen, Wei Chunjing, Geng Yuansheng, Zhang Lifei. 2004. Discovery of the high-pressure pelitic granulite from the Jiaobei and its implications[J]. Chinese Science Bulletin, 29(14): 1424−1430 (in Chinese).

Zhu Xueqiang, Dai Guangkai, Guo Jing, Liu Li. 2020. 1：50 000 Mineral and Geological Map Database of Zangjiazhuang Map-sheet, Shandong Province[DB/OL]. Geoscientific Data & Discovery Publishing System. (2020-12-30). DOI: 10.35080/data.C.2020.P27.