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甘肃岷县寨上—马坞金矿锁龙幅1∶50 000 矿产地质图数据库

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摘要: 甘肃省岷县寨上—马坞金矿锁龙幅 (I48E010011)1∶50 000 矿产地质图是根据《固体矿产地质调查技术要求 (1∶50 000)》和行业的统一标准及要求，在充分利用 1∶50 000 区域地质调查、区域矿产调查等工作成果资料的基础上，采用数字填图系统进行野外地质专项填图，并应用室内与室外填编图相结合的方法完成的。本图对前泥盆系吴家山组、泥盆系大草滩组、石炭系巴都组、二叠系十里墩组的沉积建造类型进行了重新划分，并把图幅内侵入岩时代归纳为晚三叠纪、早二叠纪 2 期，建立了岩浆岩的演化序列。图幅内金成矿与二叠纪地层关系密切，大多矿床 (点) 产于十里墩组裂隙较为发育的碎屑岩中。本数据库包含 7 个地层单位和 2 期岩浆岩资料，光薄片 212 件，化学样 192 件，基岩光谱 486 件，土壤样 2793 件，Ar/Ar 测年 2 件，流体包裹体测温 8 件，岩石化学分析样 15 件，调查区内发现金矿体 3 条、矿化点 1 处，估算（334）金金属量 5.32 t。数据量约 17.4 MB，充分反映了 1∶50 000 矿产地质调查示范性成果，对该区矿产资源研究、能源勘探等具参考意义。

关键词: 整装勘查区；锁龙幅；找矿预测；数字填图；数据库；矿产地质调查工程；甘肃
数据服务系统网址: http://dcc.cgs.gov.cn

1　引言

西秦岭地区是甘肃省重要的铅、锌、金、银、锑、铜、铁、铀、汞等多金属成矿带，其中金矿和铅锌矿是该区的特色矿种 (刘建宏等，2006)。西秦岭造山带为秦岭造山带的西延部分，地处中央造山带的关键部位，同时横跨在中国中部北西向构造带上，是古亚洲构造域、特提斯构造域和滨太平洋构造域复合叠加部位 (冯益民等，2003；裴先治等，2005；詹艳等，2014；张德贤等，2015)。甘肃岷县寨上—马坞金矿整装勘查区属西秦岭造山带东段 (图 1)，北以武山–漳县区域断裂带与北秦岭–北祁连加里东造山带相邻，南以宕昌–岷县–合作区域性断裂带与南秦岭海西–印支构造带相接 (图 1)。出露地层

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有前泥盆系、泥盆系、石炭系、二叠系、白垩系、古近系、第四系。古生界为海相地层，中–新生界为陆相地层，其中泥盆系、二叠系为金矿主要赋矿地层 (喻万强，2014)。岩浆侵入作用强烈，形成海西末期中性岩、印支期中酸性岩 2 个构造侵入岩带，前者零星分布，后者呈北西向带状分布，与区内构造线间具明显的复合关系。变质作用主要发生在前泥盆系吴家山岩群中，以区域动力变质作用为主，叠加热液接触变质作用，依岩石中特征变质矿物石榴子石、白云母、黑云母、透辉石、石英等显示其具低绿片岩相—角闪岩相变质特征。构造变形极为强烈，多层次、多尺度、多体制下不同力学性质的构造形态广泛发育，主要构造形态有断层、褶皱、脆性剪切带、剥离构造、劈理等。构造组合有伸、聚、剪、滑等多个样式。

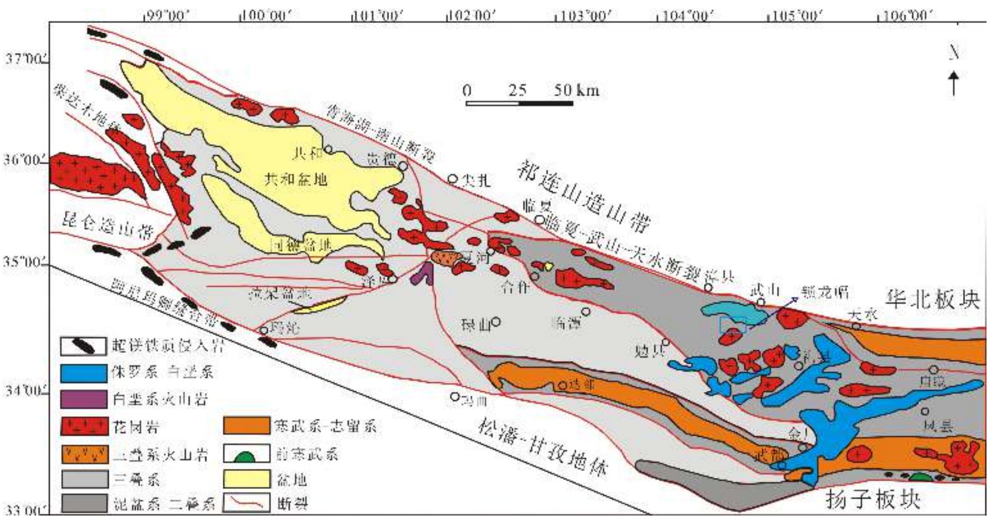

图 1　甘肃岷县寨上—马坞金矿区域地质图 (据李福林等，2015 修改)

甘肃岷县寨上—马坞金矿区域地质调查研究工作始于 20 世纪 30 年代，地质工作研究程度大致可分为 3 个阶段：①路线地质调查阶段 (1949 年前)；②1∶200 000 区域地质调查及路线地质调查阶段 (1950—1979 年)；③1∶50 000 区域地质调查及地质科学研究阶段 (1980 年—现在)。工作区先后完成了上洮坪幅、闾井幅、锁龙幅、马坞幅等 4 幅 1∶50 000 图幅填图工作，较详尽地提供了该地区基础地质资料。这些前期工作为锁龙幅 1∶50 000 矿产地质图数据库 (邓辉和赵得龙，2020；表 1) 的编制奠定了基础。本图幅作为新一轮矿产调查工作中取得的地质调查、矿产勘查以及科研新成果，可为该地区的矿产资源研究、能源勘探等提供基础地质图件，为地质调查和科学研究提供有益的参考资料。

2　数据收集与处理

2.1　数据基础

甘肃省锁龙幅 1∶50 000 矿产地质图以《1∶50 000 矿产地质调查工作指南 (试行)》(中地调函〔2016〕117 号) 为基本要求，以勘查区“三位一体”找矿预测理论 (叶天竺等，2014) 为指导，以锁龙幅 (I48E010011) 1∶50 000 区域地质图说明书[1](包括实际材料图、剖面图、记录本) 为基础，并充分结合了本次锁龙幅 1∶50 000 矿产地质填图新成果。地理底图采用国家测绘地理信息局最新地理数据。应用已有的技术标准和数字填图

表 1　数据库 (集) 元数据简表

条目	描述
数据库(集)名称	甘肃省锁龙幅1：50 000矿产地质图数据库
数据库(集)作者	沉积岩类：邓辉，甘肃省地矿局第二地质矿产勘查院 变质岩类：邓辉，甘肃省地矿局第二地质矿产勘查院 侵入岩类：赵得龙，甘肃省地矿局第二地质矿产勘查院
数据时间范围	2016—2017年
地理区域	经纬度：东经104°30′ ~ 104°45′，北纬34°20′ ~ 34°30′
数据格式	*.wl, *.wt, *.wp
数据量	17.4 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“整装勘查区找矿预测与技术应用示范” (项目编号：121201004000150017-32)资助
语种	中文
数据库(集)组成	锁龙幅1：50 000矿产地质图数据库包括1：50 000地质图库、角图和整饰。地质图库包括沉积岩、岩浆岩、变质岩、第四系、构造、地质界线、产状、矿床(点)、蚀变、岩性花纹、各类代号等。角图部分包括沉积岩建造、侵入岩建造、变质岩建造、脉岩、构造、图切剖面图、典型矿床(区)平面图、重要勘探线剖面图、地质剖面图及创新性角图、矿产图例、矿产地名录、矿化蚀变图例、成矿区(带)位置图。整饰部分包括接图表、中国地质调查局局徽、图名、比例尺、坐标参数、责任签等

系统 (DGSS)、MapGIS 等计算机软件进行数据处理。图幅内完成野外路线 60 条，1：50 000 矿产地质专项填图 410 km^2，1：10 000 构造剖面 22.77 km，1：2 000 实测地质剖面 28.27 km，1：10 000 土壤剖面测量 25 km，光薄片样品 212 件，化学样品 192 件，基岩光谱样品 486 件，土壤样品 2 793 件，Ar/Ar 测年样品 2 件，流体包裹体测温样品 8 件，岩石化学分析样品 15 件。

2.2　数据处理过程

2.2.1　数据准备

将收集到的区域地质调查成果和实际材料图进行数字化处理，形成 MapGIS 点、线、面文件。根据锁龙幅范围生成 1：50 000 标准图框，投影系统为高斯−克吕格投影参数，坐标系统为 2000 国家大地坐标 (CGCS 2000)。

2.2.2　编制建造−构造草图

通过查阅和分析《锁龙幅 (I48E010011) 1：50 000 区域地质图说明书》[1] 中涉及的野外实测剖面、数字化野外路线等实际材料，分解组及段一级编图单元，补充岩性或岩性组合界线，并将野外记录以岩性建造花纹点或线的形式表达在实际材料图上，形成建造–构造草图，其包括了建造、脉岩、构造、地质剖面、化石采样点、岩石化学样品采样点、地球化学样品采样点、同位素样品采样点等。

2.2.3　野外专项地质填图

根据已有资料的综合分析整理和建造−构造草图的编制，划分重点工作区和一般工作区，确定专项地质重点填图内容为二叠系十里墩组、矿化蚀变、构造、脉岩等。以数字填图掌上电脑中 1：250 000 实际材料图为底图，通过野外实际路线地质调查，在掌上机中标绘出地质点、地质界线及点间路线等点、线信息，观察并录入各点的岩性、性质、产状等信息，初步建立数字填图 (PRB) 数据库。

地质点 (P)：分为界线点和岩性控制点。野外工作过程中，在系统中填写了简单的属性，包括点性、点号、露头情况、微地貌、风化程度、位置说明、填图单元及接触关系，坐标数据是由系统自动读取。

地质路线 (R)：野外工作过程中在系统中填写的属性包括地质点号、路线编号、方向 (度)、分段距离、累计距离、填图单位和岩石名称。其中，方向 (度)、分段距离、累计距离均为系统自动计算的。

地质界线 (B)：野外工作过程中在系统中填写的属性包括路线号、地质点号、R 编号、B 编号、界线类型、右侧填图单位、左侧填图单位、接触关系、界线走向、界面倾向及倾角。对沿途所见的地质产状和采集的标本信息，在系统中及时定位并录入了相关的信息，填写了属性数据。

2.2.4　室内相关数据整理

(1) 将野外采集到的地质点 (P)、地质路线 (R)、地质界线 (B) 数据资料导入电脑中，并根据相应规范进行数据整理。

地质点 (P) 过程基本要求：路线号、风化程度、接触关系等信息按照实际情况填写完整，填图单位填写相应填图单元代号，岩石名称与地质描述对话框中的内容保持一致 (包括颜色、结构、构造等)，批注信息为薄片鉴定结果，并按照实际情况综合定名后填写。

地质路线 (R) 过程基本要求：R 在室内按照“光滑曲线–修改线参数 (线性 1，颜色 1，线宽 0)–点间路线计算– (统计工作量)”进行。补充完善 R 属性数据库，并在进行路线地质描述前重新计算方位和距离。

地质界线 (B) 过程基本要求：在室内计算机上用剪短线、延长线或者重新画线的方法按照接触情况对地质界线进行美化，统一颜色、线性及线宽等参数。补充地质界线描述信息，用“左侧为 xxx，右侧为 xxx”来说明界线两侧岩性，默认左侧为先观察的岩性，右侧为后观察到的岩性，并对 2 种岩性的接触关系及其证据加以表述。

路线中的产状、采样、照片要求：补充产状、采样等相应属性描述信息。产状编号在换地质点后重新从 1、2、3 等开始编号，照片按照要求导入后在照片详细描述中对照片内容及所反映地质现象进行描述。

(2) 将以本次野外实际采集的 PRB 数据为主的实际材料图与收集前人区调资料编制建造–构造草图时整理的区域地质调查实际材料图进行对比分析，对地质单元界线、建造花纹及反映各类建造的构造形态进行修正，对新形成的地质单元的界线进行勾连。

2.2.5　编制各类角图

(1) 建造柱状图：对主图中岩石地层单元的建造特征进行详细表达。通过对图幅内各类建造、构造及其与矿的关系进行对比分析研究，编制沉积岩建造柱状图、侵入岩建造柱状图、变质岩建造柱状图。

(2) 典型矿床角图：包括典型矿床锁龙中低温热液型矿床成矿要素图及 123 线勘探线剖面图❷，为本区的找矿预测工作提供参考。在收集以往资料成果的基础上，充分借鉴本次典型矿床野外实地调查与综合研究的成果，编制了典型矿床的角图。

(3) 图切剖面：图幅内建造和构造的总体走向为北西向，为了能有效反映图幅内总体建造和构造特征及其与矿化的关系，布置了 2 条贯穿全区的北西向和北东向的图切剖面，分别反映二叠系十里墩组、三叠纪花岗岩建造。表达方式主要使用了“标准剖面线型+标准代号”表达位置，并以地质点及编号表达实际控制点情况，以相应的花纹表达

各层岩性，同时在地质剖面上表达产状要素。

(4) 矿产地名录：对本区的矿产地按照矿产地名称、规模、类型、主要含矿建造等方面进行了分析，编制矿产地名录，有利于对整个锁龙幅区域内矿产情况的了解。

(5) 所处成矿区带位置图（图 2）：表达了锁龙幅在区域大地构造中所处的位置及其区域地质背景情况。在收集甘肃省 1∶500 000 区域成矿规律图[3] 的基础上，根据图幅位置确立的区域轮廓范围对本图进行裁剪，保留 I–IV 成矿区带和主要的地名、矿床。然后进行缩放，生成锁龙幅所属成矿区带的角图部分。区域轮廓范围必须满足以下 3 个条件：①以工作图幅为中心位置；②以能包括工作区预测矿产的完整区域为成矿带范围；③以能包括预测矿产区域所属成矿带的相关区域为构造带完整范围。

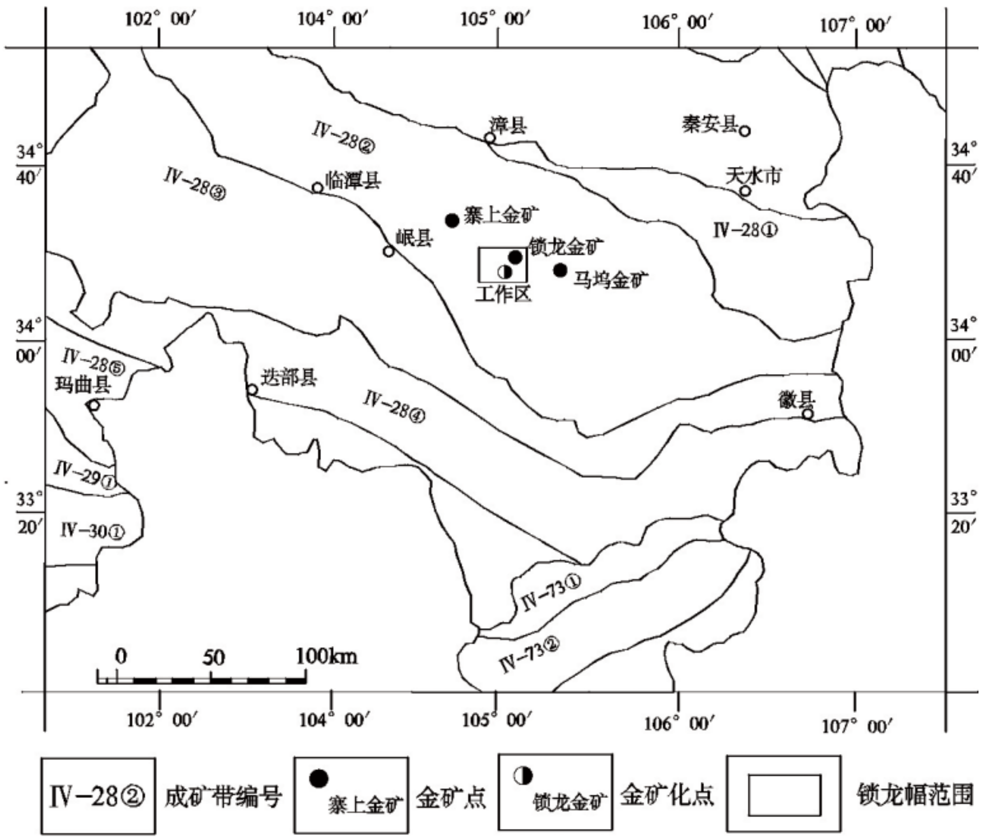

图 2　甘肃省南部成矿带划分图 (修改自张新虎等，2013；余超等，2017)

Ⅳ–28①—武山–天水 Au–Ag–Cu–Pb–Zn–Sn–Cr–硫铁成矿带 (PZ1;MZ); Ⅳ–28②—临潭–徽县 Pb–Zn–Cu(Fe)–Au–Hg–Sb–Ag–Mo–W–Sn 成矿带 (PZ;MZ); Ⅳ–28③—夏河–两当 (崖湾)Au–Sb–Hg–Ag–Pb–Zn–Cu–Fe–Mo–W–Sn 成矿带 (MZ); Ⅳ–28④—碌曲–舟曲–广金坝 Au–Fe–Mn–Cu–Sb–Hg–As–Se–P–硫铁矿成矿带 (MZ;CZ) ; Ⅳ–28⑤—玛曲 (西倾山)Au–Hg 成矿带 (MZ); Ⅳ–29①—布青山–积石山 Cu–Co–Au–Sb 成矿带 (PZ2); Ⅳ–30①—加给龙洼–昌马河 Au–Sb–REE–W–Sn–Hg 成矿带 (MZ); Ⅳ–73①—新天–阳山 Au–Fe 成矿带 (MZ); Ⅳ–73②—文县东–康县 Mn–Au(Mo–Co) –重晶石成矿带 (PZ;MZ;CZ)

(6) 其他角图：对脉岩、构造、矿化蚀变图例进行梳理，统一编制相应图例。

3　数据样本描述

甘肃省锁龙幅 (I48E010011)1∶50 000 矿产地质图数据库包括地质体要素信息、地理要素信息和地质图整饰要素信息。地理要素信息属性沿用国家测绘地理信息局收集数

据的属性结构。地质实体要素信息属性按照 1：50 000 矿产地质调查专项地质填图数据库建库要求分 3 大岩类 (沉积岩、侵入岩、变质岩)、断裂构造、产状要素、矿产地等分别建立数据库属性。

矿产地质图沉积岩建造数据属性（表 2）包含如下内容：图幅号、岩性名称、地层代号、时代、地质体代码、符号代码。

表 2　锁龙幅矿产地质图沉积岩建造数据属性表

序号	数据项名称	标准编码	数据类型	实例
1	图幅号	Mapcode	字串符	I48E010011
2	岩性名称	Litho	字串符	土黄—黄褐色石英砂岩，黄褐色泥质板岩
3	地层代号	Strapha	字串符	P_1sl^1qu
4	时代	Geoname	字串符	二叠系下统十里墩组下段
5	地质体代码	Type_Code	字串符	YSAC2
6	符号代码	Sign_Code	字串符	0404

矿产地质图侵入岩建造数据属性（表 3）包含如下内容：图幅号、岩性名称、地质代号、时代、地质体代码、符号代码。

表 3　锁龙幅矿产地质图侵入岩建造数据属性表

序号	数据项名称	标准编码	数据类型	实例
1	图幅号	Mapcode	字串符	I48E010011
2	岩性名称	Litho	字串符	中细粒含斑黑云二长花岗岩
3	地质代号	Strapha	字串符	TL$\eta\gamma\beta$
4	时代	Geoname	字串符	中生代三叠纪
5	地质体代码	Type_Code	字串符	YSAC1
6	符号代码	Sign_Code	字串符	0401

矿产地质图变质岩建造数据属性（表 4）包含如下内容：图幅号、岩性名称、地层代号、时代、地质体代码、符号代码。

表 4　锁龙幅矿产地质图变质岩建造数据属性表

序号	数据项名称	标准编码	数据类型	实例
1	图幅号	Mapcode	字串符	I48E010011
2	岩性名称	Litho	字串符	灰黑—灰色板岩
3	地层代号	Strapha	字串符	P_1sl^1sl
4	时代	Geoname	字串符	二叠系下统十里墩组下段
5	地质体代码	Type_Code	字串符	YSAC2
6	符号代码	Sign_Code	字串符	0404

矿产地质图断裂构造数据属性（表 5）包含如下内容：图幅号、断层编号、左侧填图单位、右侧填图单位、断层性质、断层走向、断层倾向、断层面倾角、接触关系。

表 5　锁龙幅矿产地质图断裂构造数据属性表

序号	数据项名称	标准编码	数据类型	实例
1	图幅号	Mapcode	字串符	I48E010011
2	断层编号	Line_Code	字串符	F25
3	右侧填图单位	Right_Body	字串符	P_1sl^1ssl
4	左侧填图单位	Left_Body	字串符	P_1sl^1ssl
5	断层性质	Type	字串符	正断层
6	断层走向/°	Trend	字串符	61
7	断层倾向/°	Dip	字串符	151
8	断层面倾角/°	Dip_Ang	字串符	80
9	接触关系	Relation	字串符	断层接触

矿产地质图产状数据属性（表 6）包含如下内容：路线号、地质点号、产状类型名称、产状走向、产状倾向、产状倾角。

表 6　锁龙幅矿产地质图产状数据属性表

序号	数据项名称	标准编码	数据类型	实例
1	路线号	Routecode	字串符	L5001
2	地质点号	Geopoint	字串符	D5003
3	产状类型名称	Type	字串符	层理
4	产状走向/°	Trend	字串符	80
5	产状倾向/°	Dip	字串符	350
6	产状倾角/°	Dip_Ang	字串符	75

矿产地质图矿产地数据属性（表 7）包含如下内容：矿种名称、矿产地数、矿石品位、规模、成矿时代、矿产地名、矿化类型、成因类型。

表 7　锁龙幅矿产地质图矿产地数据属性表

序号	数据项名称	标准编码	数据类型	实例
1	矿种名称	Commodities_Name	字串符	Au
2	矿产地数	Ore_Sums	整数型	1
3	矿石品位	Ore_Grade	字串符	Au 1.44 g/t
4	规模	Deposite_Size	字串符	中型矿床
5	成矿时代	Metallogenetic_Epoch	字串符	三叠纪
6	矿产地名	Placename	字串符	锁龙金矿
7	矿化类型	Genesis_Types	字串符	中低温热液型
8	成因类型	Industrial_Types	字串符	构造蚀变岩型

4　数据质量控制和评估

本数据库建设过程中数据采集以实测为主，地质点采集以充分控制与成矿有关的地质体、矿化蚀变带、重要地质界线等为原则。为编制锁龙幅 1∶50 000 矿产地质图，野外实测调查涉及总路线长度为 507 km，地质点数 495 个。

填图精度符合《1∶50000矿产地质调查工作指南(试行)》(中地调函〔2016〕117号)的具体要求，数据来源可靠，属性库建设完善。地质图中的符号、图式图例等遵照《区域地质图图例》(GB/T 958−2015)中规定的进行表示。

数据库建设过程中严格按照班组、项目组、院级“三级质量管理体系”，进行数据质量的控制，其中班组自检、互检比例100%，项目组检查比例83%，院级检查50%，符合中国地质调查局项目的质量管理要求。2017年9月上旬，中国地质调查局发展研究中心(自然资源部勘查技术指导中心)组织专家采用室内、现场两者相结合的检查方法对锁龙幅2016年野外工作进行了验收，结论为通过野外验收。

5　数据价值

甘肃省锁龙幅(I48E010011)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工作的示范图幅之一。该矿产地质图按照《固体矿产地质调查技术要求(1∶50 000)》(DD2019–02)要求，在深入研究本图幅内沉积序列的岩石组成和结构构造(陈义兵等，2010)的基础上，依据宏观岩性特征、准层序类型及叠置规律、相对地层位置，结合区域地层延伸稳定性与本次1∶50 000专项地质填图成果，对比《甘肃省岩石地层》(杨雨等，1997)，将图幅内地层由下至上确定为黄家沟组(D_1h)、大草滩组(D_3dc)、巴都组(C_1b)、下加岭组(C_2x)、十里墩组(P_1sl)、大关山组(P_2dg)等组级正式岩石地层单位。依据沉积岩建造的岩性层类型、岩性层形态、成分及界面特点进一步划分编图单元，其地层单位划分见表8。

表8　早泥盆世—晚二叠世陆表海盆地构造演化阶段岩石地层单位

年代地层		岩石地层单位		地层代号	岩石组合特征
二叠系	上统	大关山组	下段	$P_2dg^1(sl+mls)$	黄褐色粉砂质板岩与青灰色微晶灰岩互层，偶见浅黄色泥质板岩、灰色结晶灰岩
				P_2dg^1ss	灰白色含砾石英砂岩、砂砾岩
				P_2dg^1qu	黄褐色石英砂岩，偶见浅灰色石英细砂岩
	下统	十里墩组	上段	P_1sl^2ssl	粉砂质板岩
				P_1sl^2sl	泥质板岩、硅质板岩，偶夹薄层微晶灰岩
			下段	P_1sl^1qu	土黄—黄褐色石英砂岩，偶见黄褐色泥质板岩
				P_1sl^1ds	灰色岩屑石英砂岩，偶夹灰白色石英砂岩
				P_1sl^1ssl	黑色粉砂质板岩，该层是构造蚀变岩型金矿主要的赋矿岩性层
				$P_1sl^1(ds+sl)$	灰白—灰黑色岩屑石英砂岩与灰黑色板岩互层，该层是构造蚀变岩型金矿主要的赋矿岩性层
				P_1sl^1sl	灰黑—灰色板岩
石炭系	上统	下加岭组	上段	C_2x^2ls	砂屑灰岩、含生物碎屑砂屑灰岩夹泥灰岩、含炭质板岩组成的韵律层
			下段	C_2x^1st	褐灰色钙质岩屑砂岩、钙质粉砂岩、石英砂岩
	下统	巴都组		$C_1b(ss+sl)$	深灰色中层长石石英砂岩、石英砂岩、粉砂质板岩等
泥盆系	上统	大草滩组	上岩段	D_3d^2st	紫红色中薄层状粉砂岩、泥岩夹灰绿色中层状含细砾长石石英砂岩、石英砂岩互层
			下岩段	D_3d^1fq	灰绿色中厚层状长石石英砂岩、粉砂岩夹紫红色粉砂质泥岩或泥岩互层
	下统	黄家沟组	二段	D_1h^2qu	灰白色中厚层状石英砂岩建造

通过 1∶50 000 专项地质填图，总结出图幅内金成矿与二叠纪地层关系密切，调查区内发现的榜黑路西金矿点、上岭沟南金矿点、上岭沟北金矿点及大黑山金矿化点，都处于教场坝岩体与二叠系下统十里墩组下段外接触带中，主要岩性为二叠系十里墩组下段黑色碎裂状岩屑石英细砂岩，其矿化蚀变主要为硅化、褐铁矿化、黄钾铁钒化，共同点在于发现的这些金矿（化）点对岩性建造有一定的选择性，大多矿 (化) 点产于十里墩组裂隙较为发育的碎屑岩中，矿体主要受轴向北东的褶皱构造及北东向的断裂构造控制，金矿成矿结构面主要为软硬岩层接触界面、砂岩与灰岩接触界面、断裂裂隙面及褶皱节理面等。

6 结论

(1) 在系统收集调查区内地、物、化、遥、矿产勘查等资料的基础上，结合本次 1∶50 000 专项地质填图成果，以建造单元为划分原则，对沉积岩地层重新进行了划分，对金矿成矿规律进行了总结，认为调查区内金成矿与二叠纪地层关系密切，调查区内的金矿床及金矿点主要分布在二叠纪十里墩组中，金矿床对岩性建造有一定的选择性，大多矿床（点）产于十里墩组裂隙较为发育的碎屑岩中，且大多数金矿床（点）均分布于三叠纪花岗岩体外接触带 0 ~ 5 km 范围内。甘肃省锁龙幅 (I48E010011)1∶50 000 矿产地质图是中国地质调查局新一轮地质矿产调查的示范图幅，本次工作通过积极探索创新矿产地质专项填图成果表达方式，形成了锁龙幅矿产地质图，对矿产地质调查起到了示范作用。

(2) 全面系统编制了 1∶50 000 锁龙幅 (I48E010011) 地质矿产图并建立了空间数据库，突出了成矿信息的表达，如矿化带、蚀变带、成矿构造、成矿结构面等。通过充分利用先进的数据库信息管理技术和手段，实现地质矿产信息管理的数据化、系统化和标准化，有效提高了地质数据信息使用的效率和水平。

致谢：甘肃省锁龙幅 1∶50 000 矿产地质图是一项集体成果，野外一线地质工作人员付出了辛勤的努力。在矿产地质图数据库的建立过程中，得到了刘家军、张新虎、蒙轸、尤关进、白斌、陈化奇等多位地质矿产专家的辛勤指导，在此对各位专家和野外项目组所有成员表示最诚挚的感谢。

注释

❶ 甘肃地勘局地质一队. 1999. 锁龙幅 (I48E0100111) 1∶50 000 区域地质图说明书.

❷ 甘肃省地矿局第二地质矿产勘查院. 2016. 甘肃省岷县锁龙金矿深部普查报告.

❸ 甘肃地质调查院. 2012. 甘肃省 1∶500 000 区域成矿规律图及编图说明书.

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Database of 1∶50 000 Mineral Geological Map of the Suolong Map-sheet in Zhaishang–Mawu Gold Deposit, Minxian County, Gansu Province

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Abstract: The 1∶50 000 mineral geological map of the Suolong Map-sheet (I48E010011) in Zhaishang–Mawu Gold Deposit in Minxian County, Gansu Province was developed in accordance with the *Technical Requirements of Solid Mineral Geological Survey* (1∶50 000) and other unified standards and requirements in the geological industry, during which the results obtained from previous 1∶50 000-scale regional geological surveys and 1∶50 000-scale regional mineral surveys were fully utilized. Meanwhile, the digital mapping system was adopted for field geology-specific mapping, and indoor map compilation was conducted along with field mapping. In this map, the sedimentary suite types of the pre-Devonian Wujiashan and Dacaotan Formations, Carboniferous Badu Formation, and Permian Shilidun Formation are reclassified, the formation epochs of the intrusions are classified into Late Triassic and Early Permian, and the evolutionary sequence of magmatic rocks is established. The gold metallogenesis in this Map-sheet is closely related to Permian strata, and most deposits (ore occurrences) occurred in clastic rocks of the Shilidun Formation with relatively developed fissures. The database of the 1∶50 000 mineral geological map (also referred to as the Database) includes the data of seven stratigraphic units and two stages of magmatic rocks, and covers 212 polished thin sections, 192 chemical samples, 486 bedrock spectra, 2 793 soil samples, two samples for Ar/Ar dating, eight samples for fluid inclusion thermometry, and 15 samples for petrochemical analysis. Meanwhile, three gold ore bodies and one gold mineralized point were newly discovered in the study area, with estimated (334) gold of 5.32 tonnes. Having a data size of about 17.4 MB, the Database fully reflects the demonstration results of 1∶50 000 mineral geological surveys, and could provide references for mineral resource research and energy exploration in this Map-sheet area.

Key words: integrated exploration area; Suolong Map-sheet; prospecting prediction; digital

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mapping; database; mineral geological survey engineering; Gansu Province
Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

The west Qinling area serves as an important polymetallic metallogenic belt of lead, zinc, gold, silver, antimony, copper, iron, uranium, and mercury in Gansu Province, among which gold and lead-zinc deposits are the distinct minerals of this area (Liu JH et al., 2006). The West Qinling orogen, the westward extension of the Qinling Orogen, is located in the key part of the Central Orogenic Belt of China. It stretches across the NW-trending tectonic zone in central China, and lies on the part where the Paleo-Asian, Tethyan, and Circum-Pacific tectonic domains overlap each other (Feng YM et al., 2003; Pei XZ et al., 2005; Zhan Y et al., 2014; Zhang DX et al., 2015). The integrated exploration area of Zhaishang–Mawu gold deposit in Minxian County, Gansu Province is located in the eastern section of the West Qinling orogen (Fig. 1). It is adjacent to the North Qinling–North Qilian Caledonian orogenic belt in the north with the Wushan–Zhangxian regional fault zone as the boundary, and is connected to the South Qinling Hercynian–Indosinian tectonic zone in the south with the Tanchan–Minxian–Hezuo regional fault zone as the boundary (Fig. 1). The outcrops in the integrated exploration area consist of the strata of pre-Devonian, Devonian, Carboniferous, Permian, Cretaceous, Paleogene, and Quaternary, among them the Paleozoic strata are of marine facies, the Mesozoic-Cenozoic strata are of continental facies, and Devonian and Permian strata serve as the main host strata of gold deposits (Yu WQ, 2014). The integrated exploration area suffered strong magmatic intrusion, leading to the formation of Late Hercynian intermediate and Indosinian intermediate-acid rock zones. The former is sparsely distributed, while the latter is distributed in a banded form in NW trending and obviously overlaps with structural lines of the area. The metamorphism in the area mainly occurs in pre-Devonian Wujiashan Group, which is dominated by regional dynamic metamorphism and superimposed by hydrothermal contact metamorphism. Meanwhile, it has the characteristics of the metamorphism of low greenschist facies–amphibolite facies according to the presence of characteristic metamorphic minerals in rocks such as garnet, muscovite, biotite, diopside, and quartz. In addition, the integrated exploration area experienced extremely strong tectonic deformation, which is reflected by extensively developed structural features with different mechanical properties at multiple levels, on multiple scales, and under multiple tectonic regimes. The tectonic morphology mainly includes faults, folds, brittle shear zones, detachment structures, and cleavage, and the tectonic associations consist of stretch, convergence, shear, and slip.

The regional geological surveys of Zhaishang-Mawu gold deposit in Minxian County, Gansu Province date from the 1930s. They can be roughly divided into three stages in terms of geological exploration level: ① geological route surveys (before 1949); ② 1：200 000 regional geological surveys and geological route surveys (1950–1979); ③ 1：50 000 regional geological surveys and geological scientific research (1980–present). The geological mapping has been successively completed for four 1：50 000 map-sheets in the study area, namely

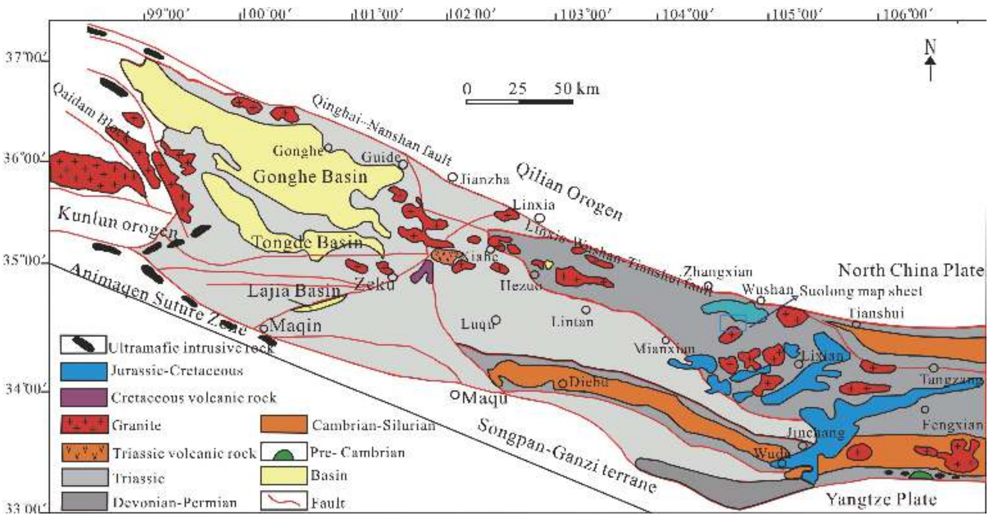

Fig. 1 Regional geological map of Zhaishang–Mawu Gold deposit in Minxian County, Gansu Province (modified from Li FL et al., 2015)

Shangtaoping, Lyujing, Suolong, and Mawu. This provides detailed basic geological data of the study area. All these lay the foundation for the building of the Database (Deng H and Zhao DL, 2020; Table 1). As the results of geological survey, mineral exploration, and scientific research made in Suolong Map-sheet in the new round of mineral survey, the Database can provide basic geological maps for mineral resource research and energy exploration in this Map-sheet area. In addition, it can provide useful references for geological survey and scientific research.

2 Methods for Data Acquisition and Processing

2.1 Data Bases

The Database was completed following the “trinity” prospecting prediction theory of exploration areas that integrates metallogenic geological bodies, metallogenic structures, metallogenic structural planes, and metallogenic characteristics and indicators (Ye TZ et al., 2014) according to the *Guidelines for* 1∶50 000 *Mineral & Geological Survey (Trial)* issued by China Geological Survey in 2016. To this end, new results obtained from the 1∶50 000 mineral and geology-specific mapping of the Suolong Map-sheet in this study were fully combined with the *Instructions for* 1∶50 000 *Regional Geological Map of Suolong Map-sheet* (I48E010011)❶(including draft data maps, sections, and records). The geographic base map consists of the latest geographic data issued by the National Administration of Surveying, Mapping and Geoinformation of China, and the data were processed by applying existing technical standards and computer software such as the digital mapping system (DGSS) and MapGIS. The geological survey of the Suolong Map-sheet in this study covered field survey of 61 routes, 1∶50 000 mineral and geology-specific mapping of 410 km^2, 1∶10 000 structural sections of 22.77 km, 1∶2 000 surveyed geological sections of 28.27 km, and 1∶10 000 soil profile survey of 25 km. Meanwhile, the samples collected include 212 polished thin sections, 192 chemical samples, 486 bedrock spectral samples, 2 793 soil samples, two samples for

Table 1 Metadata Table of Database (Dataset)

Item	Description
Database (dataset) name	1：50 000 Mineral Geologic Map of the Suolong Map-sheet, Gansu Province
Database (dataset) authors	Sedimentary rocks: Deng Hui, The Second Geological Mineral Exploration Institute of Gansu Provincial Geology and Mineral Bureau Metamorphic rocks: Deng Hui, The Second Geological Mineral Exploration Institute of Gansu Provincial Geology and Mineral Bureau Intrusive rocks: Zhao Delong, The Second Geological Mineral Exploration Institute of Gansu Provincial Geology and Mineral Bureau
Data acquisition time	2016–2017
Geographical area	104°30′−104°45′E; 34°20′−34°30′N
Data formats	*.wl, *.wt, *.wp
Data size	17.4 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	The project titled *Prospecting Prediction and Technological Application Demonstration of Integrated Exploration Areas* (No.: 121201004000150017-32) initiated by the China Geological Survey
Language	Chinese
Database (dataset) composition	The mineral geological map database of the Suolong Map-sheet consists of a map library, corner maps, and map decorations. The map library covers sedimentary rocks, magmatic rocks, metamorphic rocks, the Quaternary, structures, geologic boundaries, attitude, deposits (ore occurrences), alternation, lithologic patterns, and various geologic codes. The corner maps involve the sedimentary rock suites, intrusion suites, metamorphic rock suites; vein rocks, structures, cross-sections, plans of typical deposits (mining areas), major exploration line sections, geological sections, innovative corner maps, mineral legends, deposit list, mineralized alternation legends, and the map of metallogenic zone/belt locations. The map decorations include an index map, the logo of the China Geological Survey, map name, scale, coordinate parameters, and signatures

Ar/Ar dating, eight samples for fluid inclusion thermometry, and 15 samples for petrochemical analysis.

2.2 Data Processing

2.2.1 Data Preparation

Data digitization was conducted for the regional geological survey results and draft data maps collected to form the files of geological points, lines, and polygons in the format of MapGIS. Then the 1：50 000-scale standard map frame was created according to the range of Suolong Map-sheet, with the projection system of Gauss–Kruger projection and coordinate system of the National Geodetic Coordinate System 2000 (CGCS 2000).

2.2.2 Preparation of Suite-Tectonic Draft Maps

The suite-tectonic draft maps were prepared as follows. Firstly, by referring to and analyzing draft data such as sections surveyed in the field and digitized field routes involved in the *Instructions of* 1：50 000 *Regional Geological Map of Suolong Map-sheet* (I48E010011)[❷], the mapping units of formations and members were divided and lithologic boundaries or the boundaries of lithologic associations were supplemented. Then the field records were presented on the draft data maps in the forms of lithologic suite pattern points or lines. In this way, the suite-tectonic draft maps were formed, which cover suites, vein rocks, structures, geological sections, and the sampling points of fossil, petrochemical samples, geochemical samples, and isotopic samples.

2.2.3 Field Geology-specific Mapping

The study area was divided into key survey sites and minor survey sites based on comprehensive analysis and collation of existing data as well as the preparation of suite-tectonic draft maps. Meanwhile, the focus of geology-specific mapping was determined to be the Permian Shilidun Formation, mineralized alteration, structures, and vein rocks. The points and lines (e.g., geological points, geological boundaries, and survey routes between geological points) were labeled and marked in the digital mapping system according to the filed geological survey along actual routes, with 1：25 000 draft data maps in palm-sized personal digital assistants (PDAs) for digital mapping serving as base maps. Meanwhile, the information such as the lithology, site, and occurrence of each point were observed and input. In this way, the digital mapping database (PRB) was preliminarily created.

Geological points (P): including boundary points and lithologic control points. Simple attributes of a geologic point were filled in the digital mapping system in the field, such as site, geologic point no., outcrops, micro-landform, weathering degree, location description, mapping unit, and contact relationships. The coordinates were automatically read from the system.

Geological routes between geologic points (R): the attributes of a geological route that were filled in the digital mapping system in the field include geological point nos., route no., direction (°), the distance of current workstation, cumulative distance, mapping unit, and rock names. Among them, the direction (°), the distance of current workstation, and the accumulative distance were automatically calculated by the system.

Geological boundaries (B): the attributes of a geological boundary that were filled in the digital mapping system in the field include route no., geological point nos., boundary code, route code, boundary type, mapping units on the left and right sides, contact relationships, strike, dip, and dip angle. For the geological occurrence and specimen observed and collected along the geological boundaries, they were timely positioned and the relevant information was input. Meanwhile, their attributes were filled in the system.

2.2.4 Indoor Data Collation

(1) The data of geological points (P), routes (R) and boundaries (B) collected in the field were imported into the digital mapping system and were sorted out according to applicable specifications. The basic requirements are as follows.

Inputting process of geological points (P): Fill in the information such as the route no., weathering degree, and contact relationship completely according to actual conditions. Fill the mapping units with the codes of corresponding mapping units and make the rock names consistent with those input into the dialogue box of geological description (including color, tectonics, and structure). Describe thin section identification results of rocks in annotation after naming the rocks comprehensively according to actual conditions.

Inputting process of routes between points (R): Input geological routes indoor following the order of "smoothing curve → modifying line parameters (line type: 1; color: 1; line width: 0) → calculating routes between points → (make statistics of workload)". Then supplement and improve the databases of route attributes, and re-calculate the orientations and distance of the routes before describing the geological conditions of the routes.

Inputting process of geological boundaries (B): Make the geological boundaries aesthetically pleasing by cutting, extending, or redrawing lines on visual software according to contact relationships. Select the parameters such as color, line type, and line width in a uniform way. Then supplement the description of geological boundaries by expressing the lithology of both sides of a geological boundary with consistent terminology such as "the left side consists of xxx and the right side consists of xxx". By default, the lithology of the left side is observed earlier than that of the right side. Additionally, describe the contact relationships between the lithology of two sides and its evidence.

Inputting process of attitude, sampling, and photos along geological routes: Supplement descriptive information of the attributes such as attitude and sampling. Number the attitudes of a new geological point from "1" again. As for a photo, describe its contents and the geological phenomena it reflects in a detailed way after importing the photo.

(2) A comparative analysis was conducted on two types of draft data maps. One type mainly consists of field PRB data obtained in this study, while the other type is regional geological survey maps that were collated during collecting previous regional survey data to prepare the suite-tectonic draft maps. Then corrections were performed for boundaries of stratigraphic units, suite patterns, and tectonic morphology reflecting various suites, and the boundaries of newly formed geological units were connected.

2.2.5 Preparation of Various Corner Maps

(1) Histograms of suites

The corner maps of this type are used to reflect detailed characteristics of the suites in the lithostratigraphic units on the master map. Specifically, the histograms of sedimentary rock suites, volcanic rock suites, intrusive rock suites, and metamorphic rock suites were prepared based on the comparative analysis and research of various suites and structures within the Map-sheet and their relationship with mineralization.

(2) Corner maps of typical deposits

These maps include the metallogenic factor map[❷] of Suolong low-medium-temperature hydrothermal deposit and the exploration line section of line No. 123, aiming to provide references for the prospecting prediction of the Map-sheet. These corner maps of typical deposits were compiled by collecting previous data and outcomes and fully referring to the results of the field survey and comprehensive research of typical deposits in this study.

(3) Cross-sections

The suites and structures within the Suolong Map-sheet are in NW trending in general. To effectively reflect the overall characteristics of these suites and structures and their relationship with mineralization, one NW-trending and one NE-trending cross-sections that run across the whole Map-sheet were arranged. They are used to reflect the Permian Shiliudun Formation and the Triassic granite suite, respectively. On these cross-sections, the positions of the suites and structures are expressed with standard section line type and standard code, the actual controlling points with geological points and their nos., and the lithology of each stratum with proper patterns. Meanwhile, the occurrence elements were expressed on cross-sections.

(4) List of mineral deposits

The list of mineral deposits within the Map-sheet was established by analyzing the mineral deposits from the aspects of name, scale, type, and main ore-bearing suites. This assists in the understanding of the minerals in the whole Map-sheet.

(5) Map of metallogenic zone/belt locations

This map (Fig. 2) is used to reflect the regional geotectonic position and regional geological setting of the Suolong Map-sheet. It was prepared by clipping the collected 1：

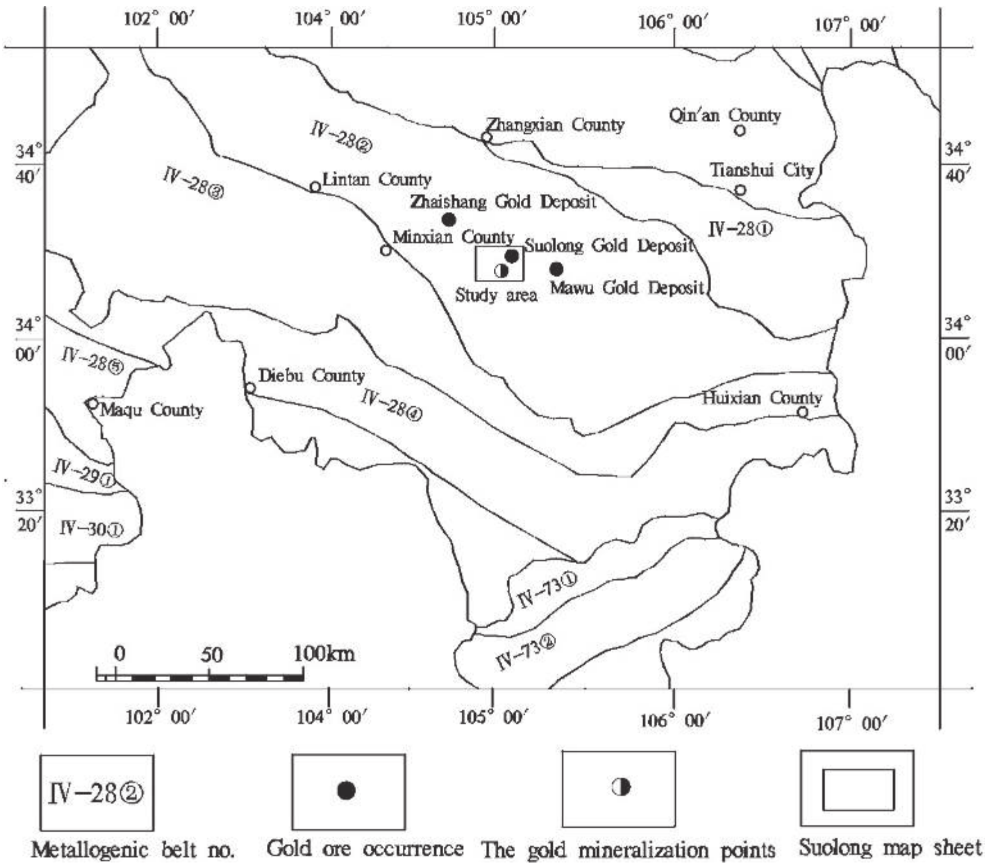

Fig. 2 Division of metallogenic belts in southern Gansu Province (modified from Zhang XH et al., 2013; Yu C et al., 2017)

IV–28①—Wushan−Tianshui Au–Ag–Cu–Pb–Zn–Sn–Cr–pyrite metallogenic belt (PZ1; MZ);
IV–28②—Lintan−Huixian Pb–Zn–Cu(Fe)–Au–Hg–Sb–Ag–Mo–W–Sn metallogenic belt (PZ; MZ);
IV–28③—Xiahe−Liangdang (Yawan) Au–Sb–Hg–Ag–Pb–Zn–Cu–Fe–Mo–W–Sn metallogenic belt (MZ);
IV–28④—Luqu−Zhouqu−Guangjinba Au–Fe–Mn–Cu–Sb–Hg–As–Se–P–pyrite metallogenic belt (MZ; CZ);
IV–28⑤—Maqu (Xiqingshan) Au–Hg metallogenic belt (MZ); IV–29①—Buqingshan−Jishishan Cu–Co–Au–Sb metallogenic belt (PZ2); IV–30①—Jiageilongwa−Changmahe Au–Sb–REE–W–Sn–Hg metallogenic belt (MZ); IV–73①—Xintian−Yangshan Au–Fe metallogenic belt (MZ); IV–73②—Eastern Wenxian−Kangxian Mn–Au (Mo–Co)–barite metallogenic belt (PZ; MZ; CZ)

50 000 regional metallogenic regularity map of Gansu Province❸, according to the regional outline range of the sheet area to retain metallogenic belts of levels I–Ⅳ and main place names and deposits, and then scaling the map slipped to form the corner map of the metallogenic zone/belt locations where Suolong Map-sheet lies. The regional outline range must be determined in accordance with the following three criteria: (i) the Suolong Map-sheet serving as the center; (ii) including the complete regional metallogenic belt scope of predicated mineral resources in the Suolong Map-sheet; (iii) including the complete range of the regional tectonic belts that are related to the metallogenic belt covering the predicated mineral resource area.

(6) Other corner maps

The legends of vein rocks, structures, and mineralized alteration were collated to prepare the legends in a unified way.

3 Description of Data Samples

The Database includes the data of geological entity elements, geographical elements, and geological map decorations. The attributes of geographical elements follow the attribute structures used by the National Administration of Surveying, Mapping and Geoinformation of China to collect data. In terms of the geologic entity elements, database attributes were individually established for three major types of rocks (sedimentary rocks, intrusions, and metamorphic rocks), fault structures, occurrence, and mineral deposits according to the requirements for establishing of specific geologic mapping database of 1∶50 000 mineral geological surveys. The data attributes of these geologic entity elements are described as follows.

The data attributes of a sedimentary rock suite (Table 2) include map-sheet no., lithologic name, stratigraphic code, era, geologic block code, and symbol code.

The data attributes of an intrusive rock suite (Table 3) include map-sheet no., lithologic name, stratigraphic code, era, geologic block code, and symbol code.

The data attributes of a metamorphic rock suite (Table 4) include map-sheet no., lithologic name, stratigraphic code, era, geologic block code, and symbol code.

Table 2 Data attributes of sedimentary rock suites on the 1∶50 000 mineral geological map of Suolong Map-sheet

No.	Data item	Standard code	Data type	Example
1	Map-sheet no.	Mapcode	string	I48E010011
2	Lithologic name	Litho	string	Earth yellow−yellowish brown quartz sandstone, and yellowish brown argillaceous slate
3	Stratigraphic code	Strapha	string	P_1sl^1qu
4	Era	Geoname	string	Lower member of Lower Permian Shilidun Formation
5	Geologic block code	Type_Code	string	YSAC2
6	Symbol code	Sign_Code	string	0404

The data attributes of a fault structure (Table 5) include map-sheet no.; mapping units of the left and right sides; the no., nature, strike, and dip of the fault; the dip angle of fault surface; contact relationship.

Data attributes of an attitude (Table 6) include route no.; geological point no.; the type, strike, dip, and dip angle of attitude.

Main data attributes of a mineral deposit type (Table 7) include mineral type name, mineral deposit sum, ore grade, scale, metallogenic epochs, deposit name, mineralization types, and genetic types.

Table 3 Data attributes of intrusive rock suites on the 1：50 000 mineral geological map of Suolong Map-sheet

No.	Data item	Standard code	Data type	Example
1	Map-sheet no.	Mapcode	string	I48E010011
2	Lithologic name	Litho	string	Medium-fine grained porphyritic biotite monzonitic adamellite
3	Stratigraphic code	Strapha	string	TL$\eta\gamma\beta$
4	Era	Geoname	string	Triassic (Mesozoic)
5	Geologic block code	Type_Code	string	YSAC1
6	Symbol code	Sign_Code	string	0401

Table 4 Data attributes of metamorphic rock suites on the 1：50 000 mineral geological map of Suolong Map-sheet

S. No.	Data item	Standard code	Data type	Example
1	Map-sheet no.	Mapcode	string	I48E010011
2	Lithologic name	Litho	string	Greyish black – gray slate
3	Stratigraphic code	Strapha	string	P_1sl^lsl
4	Era	Geoname	string	Lower member of Lower Permian Shilidun Formation
5	Geologic block code	Type_Code	string	YSAC2
6	Symbol code	Sign_Code	string	0404

Table 5 Data attributes of fault structures on the 1：50 000 mineral geological map of Suolong Map-sheet

S. No.	Data item	Standard code	Data type	Example
1	Map-sheet no.	Mapcode	string	I48E010011
2	Fault no.	Line_Code	string	F25
3	Mapping units of the right side	Right_Body	string	P_1sl^lssl
4	Mapping units of the left side	Left_Body	string	P_1sl^lssl
5	Fault nature	Type	string	Normal fault
6	Fault strike /°	Trend	string	61
7	Fault dip /°	Dip	string	151
8	Dip angel of fault surface/°	Dip_Ang	string	80
9	Contact relationship	Relation	string	Fault contact

Table 6 Data attributes of attitude on the 1：50 000 mineral geological map of Suolong Map-sheet

S. No.	Data item	Standard code	Data type	Example
1	Route no.	Routecode	string	L5001
2	Geological point no.	Geopoint	string	D5003
3	Attitude type name	Type	string	Bedding
4	Attitude strike/°	Trend	string	80
5	Attitude dip/°	Dip	string	350
6	Attitude dip angle/°	Dip_Ang	string	75

Table 7 Data attributes of mineral deposits on the 1：50 000 mineral geological map of Suolong Map-sheet

S. No.	Data item	Standard code	Data type	Example
1	Mineral type name	Commodities_Name	string	Au
2	Mineral deposit sum	Ore_Sums	int	1
3	Ore grades	Ore_Grade	string	Au 1.44 g/t
4	Scale	Deposite_Size	string	Medium-sized deposit
5	Metallogenic epochs	Metallogenetic_Epoch	string	Triassic
6	Deposit name	Placename	string	Suolong gold deposit
7	Mineralization types	Genesis_Types	string	Medium-low temperature hydrothermal type
8	Genetic types	Industrial_Types	string	Tectonic altered rock type

4 Data Quality Control and Assessment

The Database was mainly build based on the data collected through field surveys and the geological points were collected on the principle of fully controlling the geologic blocks related to mineralization, mineralized alteration zones, and major geological boundaries. To prepare the 1：50 000 mineral geological map of Suolong Map-sheet in this study, the field survey covered 507 km of geological routes in total and 495 geological points.

The Database enjoys reliable data sources and completely constructed attribute databases, with the mapping precision meeting the specific requirements of the *Guidelines for* 1：50 000 *Mineral & Geological Survey (Trial)* issued by Chine Geological Survey in 2016. Meanwhile, the symbols, formats, and legends in the geological map are presented according to the *Geological Symbols Used for Regional Geological Map* (GB/T 958−2015).

In term of data quality control of the Database, a three-level quality management system consisting of the shifts, project team, and the Second Geological Mineral Exploration Institute of Gansu Provincial Geology and Mineral Bureau was strictly implemented during database building. 100% self-check and 100% mutual check were conducted by the shifts, and the check rates obtained by the project team and the institute were 83% and 50%, respectively, thus meeting the requirements of quality management for geological survey projects. In early September 2017, the Development and Research Center of China Geological Survey (i.e., the Exploration Technical Guidance Center of the Ministry of Natural Resources of the People's Republic of China) organized experts to conduct acceptance check on 2016 fieldwork of

Suolong Map-sheet by indoor inspection combined with field inspection. As a result, the fieldwork passed the acceptance check.

5 Data Value

The 1∶50 000 mineral geological map of Suolong Map-sheet (I48E010011) in Gansu Province is one of the demonstration maps of the new round of mineral geological survey initiated by the China Geological Survey. Based on the *Technical requirements of solid mineral geological survey* (1∶50 000) (DD2019–02) and deep research on the composition, texture, and structure of the rocks of the sedimentary sequence in the Map-sheet (Chen YB et al., 2010), the strata in the Map-sheet were divided according to their macroscopic lithologic characteristics, parasequence types, overlapping regularity, and relative stratigraphic positions along with regional stratigraphic extension stability, the 1∶50 000 spatial geological mapping results in this study, and comparison with the *Lithostratigraphy of Zhejing Province* (Yang Y et al., 1997). In detail, the strata in the Map-sheet were determined as formal formation-level lithostratigraphic units, namely Huangjiagou Formation (D_1h), Dacaotan Formation (D_3dc), Badu Formation (C_1b), Xiajialing Formation (C_2x), Shilidun Formation (P_1sl), and Daguanshan Formation (P_2dg) from bottom to top. These formations were further divided into other mapping units according to characteristics of sedimentary rock suites such as lithological layer types, lithological layer morphology, composition, and interface characteristics. The details are shown in Table 8.

It can be summarized from the 1∶50 000 geology-specific mapping that: (1) the gold metallogenesis in the Map-sheet area is closely related to Permian strata, and the gold deposits and gold ore occurrences in the study area, including West Bangheilu, South and North Shanglinggou gold ore occurrences and Daheishan gold mineralization spot, are mainly distributed in the external contact zone between the Jiaochangba pluton and the lower member of Permian Shilidun Formation; (2) the gold deposits (ore occurrences) select lithologic suites to some extent, and most of the gold deposits (ore occurrences) occur in clastic rocks of the Shilidun Formation with relatively developed fractures, mainly in black fine-grained cataclastic lithic quartz sandstone in the Permian Shilidun Formation, showing alteration of silicification, ferritization and jarosite; (3) the ore bodies are mainly controlled by fold structures with axial direction of NE trending and NE-trending fault structures; (4) the metallogenic structural planes of the gold deposits mainly include contact interfaces between soft and hard strata, contact interfaces between sandstone and limestone, surfaces of faults and fractures, and joint surfaces of folds.

6 Conclusions

(1) Based on the systematic collection and collation of geological, geophysical, geochemical, remote-sensing, and mineral-exploration data of the study area along with the 1∶50 000 geology-specific mapping results in this study, the sedimentary rock strata in Suolong Map-sheet were re-divided and the gold metallogenic regularity was summarized. It is

Table 8 Lithostratigraphic units in the tectonic evolutionary stage of epicontinental-sea basins from Early Devonian to Late Permian

Epoch		Lithostratigraphic unit		Stratum code	Rock association
Permian	Upper	Daguanshan Formation	Lower member	P_2dg^1 *(sl+mls)*	Alternating layers consisting of yellowish brown silty slate and caesious micrite, with light-yellow argillaceous slate and gray crystalline limestone occasionally visible
				P_2dg^1ss	Hoary gravel-bearing quartz sandstone and sandy conglomerate
				P_2dg^1qu	Yellowish brown quartz sandstone, with light gray fine-grained quartz sandstone occasionally visible
	Lower	Shilidun Formation	Upper member	P_1sl^2ssl	Silty slate
				P_1sl^2sl	Argillaceous and siliceous slate, occasionally interbedded with thin laminated microcrystalline limestone
			Lower member	P_1sl^1qu	Earth yellow–yellowish brown quartz sandstone, with yellowish brown argillaceous slate occasionally visible
				P_1sl^1ds	Gray lithic quartz sandstone, occasionally interbedded with grayish-white quartz sandstone
				P_1sl^1ssl	Black silty slate, serving as the main ore-hosting lithologic layers of tectonic altered rock type of gold deposits
				P_1sl^1 *(ds+sl)*	Alternating layers consisting of grayish-white–grayish-black lithic quartz sandstone and grayish-black slate, serving as the main ore-hosting lithologic layers of tectonic altered rock type of gold deposits
				P_1sl^1sl	Grayish-black−gray slate
Carboniferous	Upper	Xiajialing Formation	Upper member	C_2x^2ls	Rhythmites composed of calcarenite and bioclastic calcarenite interbedded with marl and carbonaceous slate
			Lower member	C_2x^1st	Brownish-gray calcareous lithic sandstone, calcareous siltstone, and quartz sandstone
	Lower	Badu Formation		C_1b *(ss+sl)*	Dark gray medium laminated feldspar-quartz sandstone, quartz sandstone, silty slate, etc.
Devonian	Upper	Dacaotan Formation	Upper member	D_3d^2st	Amaranthine medium-thin laminated siltstone and mudstone interbedded with grayish-green medium laminated alternating layers consisting of quartz sandstone and feldspar-quartz sandstone bearing fine gravel
			Lower member	D_3d^1fq	Mainly grayish-green medium-thick laminated feldspar-quartz sandstone and siltstone, interbedded with alternating layers consisting of amaranthine silty mudstone or mudstone
	Lower	Huangjiagou Formation	Second member	D_1h^2qu	A grayish-white medium-thick laminated quartz sandstone suite

considered that (ⅰ) the gold mineralization in Suolong Map-sheet is closely related to Permian strata, and the gold deposits and gold ore occurrences in the survey site are mainly distributed in the Permian Shilidun Formation; (ⅱ) the gold deposits select lithologic suites to some extent, and most of the gold deposits (ore occurrences) occur in clastic rocks of the Shilidun Formation with relatively developed fractures and are distributed within 0–5 km of external contact zones of Triassic granite plluton. The 1∶50 000 mineral geological map of Suolong Map-sheet (I48E010011) in Gansu Province is a model map-sheet of the new round of mineral geological survey initiated by the China Geological Survey. In this study, the presentation of mineral and geology-specific mapping results was actively explored and innovated, based on which the mineral geological map of Suolong Map-sheet was formed. This plays a demonstration role in mineral geological surveys.

(2) The 1∶50 000 mineral geological map of Suolong Map-sheet (I48E010011) was prepared in a comprehensive and systematic way and a spatial database was established. All of them highlight the expression of metallogenic information, such as mineralized zones, alteration zones, metallogenic structures, and metallogenic structural planes. The full utilization of advanced database management technology and means contributes to the digital, systematic, and standardized management of geological and mineral data, thus effectively improving the utilization efficiency and level of geological data and information.

Acknowledgements: The 1∶50 000 mineral geological map of Suolong Map-sheet, Gansu Province is a collective achievement, for which the field geological workers have made great efforts. Meanwhile, multiple experts in geology and mineral resources provided diligent guidance during the establishment of the mineral geological map database, including Liu Jiajun, Zhang Xinhu, Meng Zhen, You Guanjin, Bai Bin, and Chen Huaqi. The authors hereby extend sincere gratitude to all the experts and filed project members.

Notes:

❶ No.1 Geology and Mineral Exploration Team of Gansu Provincial Bureau of Geology and Mineral Exploration and Development. 1999. Instructions of 1∶50 000 Regional Geological Map of Suolong Map-sheet (I48E010011).

❷ The Second Geological Mineral Exploration Institute of Gansu Provincial Geology and Mineral Bureau. 2016. Report on Reconnaissance of Deep Parts of Suolong Gold Deposit, Minxian County, Gansu Province.

❸ Gansu Institute of Geological Survey. 2012. 1∶500 000 Regional Metallogenic Regularity Map of Gansu Province and Its Preparation Instructions.

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