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新疆哈密卡拉塔格铜 (锌) 矿红石幅 1∶50 000 矿产地质图数据库

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摘要：新疆哈密卡拉塔格铜 (锌) 矿红石幅 (K46E009008)1∶50 000 矿产地质图数据库是根据《固体矿产地质调查技术要求 (1∶50 000)》(DD2019–02) 和行业其他标准及要求，在充分利用 1∶200 000、1∶50 000 等区域地质调查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。本数据库将中–上奥陶统荒草坡群大柳沟组、下志留统红柳峡组和卡拉塔格组的建造类型进行了重新划分，把图幅内侵入岩时代划分为志留纪、泥盆纪、二叠纪等 3 期，建立了岩浆岩演化序列。图幅区内有大中小型矿床和矿点共 8 个，成矿时代集中分布在志留纪、石炭纪，赋矿围岩为火山碎屑岩和次火山岩，该区优势矿产以铜锌金为主，矿床类型以 VMS 型和次火山热液脉型矿床为主，分布在图幅东南一带。除金属矿产外，尚有膨润土矿床产出，具有较好的找矿潜力。本数据库包含 5 个地层单位和 3 期岩浆岩资料，数据量约为 15.1 MB。这些数据充分反映了该图幅 1∶50 000 矿产地质调查示范性成果，对该区矿产资源研究和勘查等具有参考意义。

关键词：红石幅；矿产地质图；数据库；专项填图；卡拉塔格铜(锌)矿；矿产地质调查工程；哈密；新疆

数据服务系统网址：http://dcc.cgs.gov.cn

1　引言

东天山地区位于新疆东部小热泉子至甘肃与新疆交界，是中亚增生型造山带的重要组成部分，在古亚洲洋形成、演化和消亡过程中，经历多块体拼合、增生俯冲、碰撞造山等构造演化过程 (图 1a; Sengör et al., 1993; Xiao WJ et al., 2004)。从南向北包含 3 个构

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造单元，依次为中天山地块、觉罗塔格带、哈尔里克岛弧带 (秦克章等，2002)。觉罗塔格带主要由古生代火山岩和沉积岩组成，包括大南湖—头苏泉岛弧带、康古尔—黄山韧性剪切带和阿齐山—雅满苏构造带 (图 1b；王京彬等，2006)，蕴含了丰富多样的成矿系统，如土屋—延东斑岩型铜矿 (Han CM et al., 2006; Zhang LC et al., 2006; Shen P et al., 2014; Xiao B et al., 2018; Wang YF et al., 2018)、红海—小热泉子 VMS 铜锌矿 (He XH et al., 2020; Mao QG et al., 2020)、康古尔造山型金矿 (Du L et al., 2019)、彩霞山铅锌矿 (Li DF et al., 2016, 2019)、黄山—黄山东岩浆铜镍硫化物矿床 (Wu CZ et al., 2018)。工作区位于东天山卡拉塔格地区，大地构造位置属大南湖岛弧带 (图 1b)。

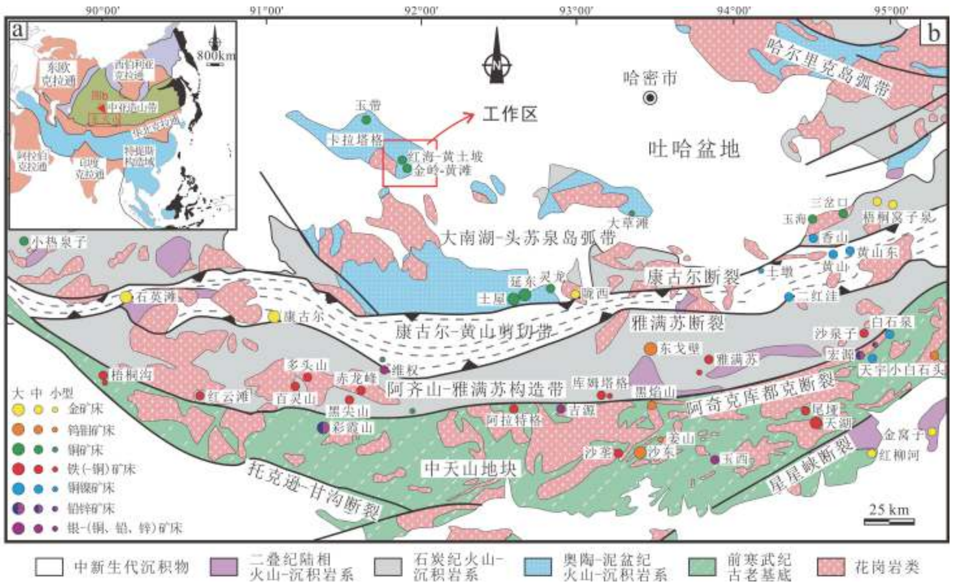

图 1　中亚造山带构造简图 (a，修改自 Sengor et al., 1993) 和东天山构造及矿床分布图 (b，修改自王京彬等，2006)

卡拉塔格地区 1∶50 000 区域地质调查工作始于 20 世纪 90 年代，红石幅 1∶50 000 区域地质矿产调查于 2014—2017 年由有色金属矿产地质调查中心完成，同时期还完成了 1∶50 000 重力测量、1∶50 000 激电测量。2014—2015 年北京矿产地质研究院完成了 1∶50 000 岩屑地球化学测量、1∶50 000 磁法测量。此外，前人对该地区的构造环境、岩石特征、成矿规律等方面也进行了大量研究 (秦克章等，2001；唐俊华等，2006；毛启贵等, 2010, 2017；龙灵利等，2019；Mao QG et al., 2019；Sun Y et al., 2019; Deng XH et al., 2016, 2020)。这些研究工作为红石幅地质矿产图的编制奠定了基础。红石幅 1∶50 000 矿产地质图作为中国地质调查局矿产地质调查的示范图件，力争反映新一轮矿产地质调查工作中取得的地质调查、矿产勘查以及科研新成果，为该地区的矿床研究、矿产勘查等提供基础地质图件，为科研和野外地质调查提供有益的参考资料。新疆红石幅 1∶50 000 矿产地质图数据库（王丰丰等，2020）的元数据简表如表 1 所示。

2　数据采集和处理方法

2.1　数据基础

新疆哈密市卡拉塔格红石幅 1∶50 000 矿产地质图以《固体矿产地质调查技术要求 (1∶50 000)》(DD2019−02) 为基本要求，以勘查区找矿预测理论为指导，系统收集和综

表 1　数据库 (集) 元数据简表

条目	描述
数据库(集)名称	新疆红石幅1∶50 000矿产地质图数据库
数据库(集)作者	王丰丰，北京矿产地质研究院 邓小华，北京矿产地质研究院 李德东，北京矿产地质研究院 卫晓锋，北京矿产地质研究院 吕晓强，北京矿产地质研究院 王燕超，北京矿产地质研究院
数据时间范围	2017—2018年
地理区域	东经91°45′ ~ 92°00′，北纬42°30′ ~ 42°40′
数据格式	*.wl, *.wt, *.wp; *.pm, *.lm, *.tm
数据量	15.1 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: 121201004000160901–66)
语种	中文
数据库(集)组成	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、侵入岩、火山岩、构造、地质界线、产状、矿床(点)、矿化蚀变、同位素地质年龄取样点及取样点测年数据、岩性花纹、各类岩性代号等；角图包括综合建造柱状图、沉积岩建造柱状图、侵入岩建造柱状图、火山岩建造柱状图、构造、火山岩相、地质剖面图、图切剖面、典型矿床(区)平面图、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

合分析原有的地质、物探、化探、遥感、矿产等资料，充分结合本次红石幅 1∶50 000 矿产地质专项填图新成果。地理信息坐标系采用国家 2000 大地坐标系。应用已有技术标准和数字填图系统 (DGSS)、MapGIS 等计算机软件进行数据处理。

2.2　数据处理过程

2.2.1　数据准备

分析研究调查区沉积、火山、岩浆侵入、构造活动等成矿地质条件，系统收集和综合分析已有地质、物探、化探、遥感、矿产等资料，将收集的地质图件进行矢量化处理，形成 MapGIS 点、线、面文件。分析调查区矿产特征与建造构造的关系，划分出区内主要含矿建造。根据红石幅图幅号生成 1∶50 000 标准图框，投影系统为高斯—克吕格投影参数，坐标系统为国家 2000 大地坐标系。

2.2.2　编制建造构造草图

通过查阅和分析红石幅区域地质调查成果中的野外路线记录，初步划分区域内出露地层，将野外记录以岩性建造花纹点或线的形式表示在图件上。

以 1∶50 000 区域地质调查资料为基础，结合区域矿产资料、红石幅内矿床专题研究资料进行综合分析，初步划分建造填图单元，编制建造构造草图。制作数字地质调查 (DGSS) 的背景图层，初步确定重点工作区与一般工作区，并布设踏勘路线和剖面位置等。

(1) 建造

根据《地质图用色标准及用色原则 (1∶50 000)》(DZ/T 0179−1997)，使用建造花纹及颜色表示建造类型，用相近的颜色表示同一组地层单位中的不同段岩石建造类型，用

不同颜色表达时代含义。

(2) 构造

按照统一的用色标准使用红色表示，用不同线型表达断裂性质。

(3)“三位一体”找矿模型

通过收集前人资料进行整合分析，确定总体工作思路，初步建立 VMS 型矿床、次火山热液型矿床找矿模型。

2.2.3 野外专项地质填图

整理前人地质、物探、化探、遥感资料，在建造构造草图上划分 3 类调查区 (重点工作区、一般工作区和修编工作区)、2 个层次 (1：50 000 矿产地质专项调查和 1：10 000 综合检查) 部署工作。基于工作区矿床类型是以 VMS 型矿床和次火山热液脉型矿床为主攻矿床类型，部署和开展卡拉塔格找矿预测工作。以《数字地质图空间数据库》(DD2006−6) 为基本要求，使用数字地质调查 (DGSS) 的地质调查 GIS 平台进行图件绘制，按照编制建造构造草图、实际材料图、建造构造图、矿产地质图的流程建立数字填图成果数据库。

2.2.4 室内数据整理

按照收集整理和野外实测相结合的方式，将地质点、地质路线和地质界线成图。根据相应的规范进行数据整理。通过专项填图，在已划分的岩石地层单位基础上，进一步划分其岩相及岩石组合，大致查明流纹斑岩等次火山岩的岩石类型、矿物成分、结构构造、岩石地球化学特征、产状与接触关系、空间分布。

将本次收集和野外实际采集的路线数据汇编 1：50 000 实际材料图，在实际材料图的基础上对地层单元、建造花纹和构造形态进行修正编图，完成 1：50 000 建造构造图。图件包括主图、综合建造柱状图和各类建造柱状图及构造、矿化蚀变图例等内容。主图包括火山岩建造、与成矿有关的建造与构造、地质界线、断裂、面状与线状地质要素等构成的地质图和建造花纹。

2.2.5 各类角图编制

(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。柱状图以花纹、建造类型、岩石组合等方面表达建造特征，明确地层所包含的各种岩性，确定地层接触关系。对地表无出露与成矿有关的建造，根据钻孔资料在柱状图中突出表示矿化蚀变、含矿元素、含矿层建造，明确含矿层位。编制综合建造柱状图、沉积岩建造柱状图、侵入岩建造柱状图、火山岩建造柱状图。

(2) 典型矿床

该部分图件包括红海 VMS 型矿床剖面图、红石次火山热液型矿床剖面图及红海−红石南北向地质剖面图。明确指出工作区存在的矿床类型和矿体形态，对于地表无出露 VMS 型含矿层位，结合钻孔资料，在矿床剖面图中突出表示，并指出构造对 VMS 型矿床的控制作用。

(3) 地质剖面图

利用 1 条北东 30°的地质剖面显示中二叠统卡拉岗组、志留纪花岗闪长岩、志留纪闪长岩、泥盆纪正长花岗岩、中−上奥陶统荒草坡群大柳沟组 ($O_{2-3}hd$)、下志留统卡拉塔格组 (S_1k) 组合顺序。使用“标准剖面线型+标准代号”表达位置，用相应的花纹表达各层岩性，同时标注矿点位置。

(4) 图切剖面

为了能有效地反映图幅内总体建造、构造特征及与矿化的关系，利用 2 条图切剖面反映图幅内总体建造和构造与矿化的关系，这 2 条图切剖面穿切了图幅区内主要地层及梅岭铜矿、红石铜矿，反映各地层矿化蚀变特征，显示出成矿条件与地表岩石之间关系。

(5) 矿产地名录

为显示红石幅内的矿产情况，把本区的矿产地按照矿产地名称、规模、类型和主要含矿建造等呈现在图面，标记为矿产地名录（表 2）。

表 2　红石幅矿产地名录

序号	名称	规模	类型	主要含矿建造构造
1	新疆维吾尔自治区哈密市卡拉塔格红山铜金矿	小型	次火山热液	次火山岩
2	新疆维吾尔自治区哈密市卡拉塔格红山东铜金矿	矿点	次火山热液	次火山岩
3	新疆维吾尔自治区哈密市卡拉塔格梅岭铜锌矿	中型	次火山热液	次火山岩
4	新疆维吾尔自治区哈密市卡拉塔格红石铜矿	小型	次火山热液	次火山岩
5	新疆维吾尔自治区哈密市卡拉塔格碧玉山铜金矿	矿点	次火山热液	次火山岩
6	新疆维吾尔自治区哈密市卡拉塔格红海铜锌矿	大型	VMS型	火山碎屑岩
7	新疆维吾尔自治区哈密市卡拉塔格金岭金锌铜矿	中型	VMS+次火山热液	火山碎屑岩
8	新疆维吾尔自治区哈密市卡拉塔格沙尔湖膨润土矿	中型	风化蚀变	次火山岩

(6) 成矿区带位置图

为宏观表示所属成矿区带内构造位置及与成矿有关构造，在收集新疆维吾尔自治区 1：500 000 矿产方面资料基础上，根据本次图幅确定区域轮廓范围并进行裁剪，保留 II–IV 级成矿单元和主要地名和矿床，并投影罗布泊野骆驼国家级自然保护区坐标位置，用线段在图面内表示，然后进行缩放生成红石幅所属成矿区带位置图 (图 2)。

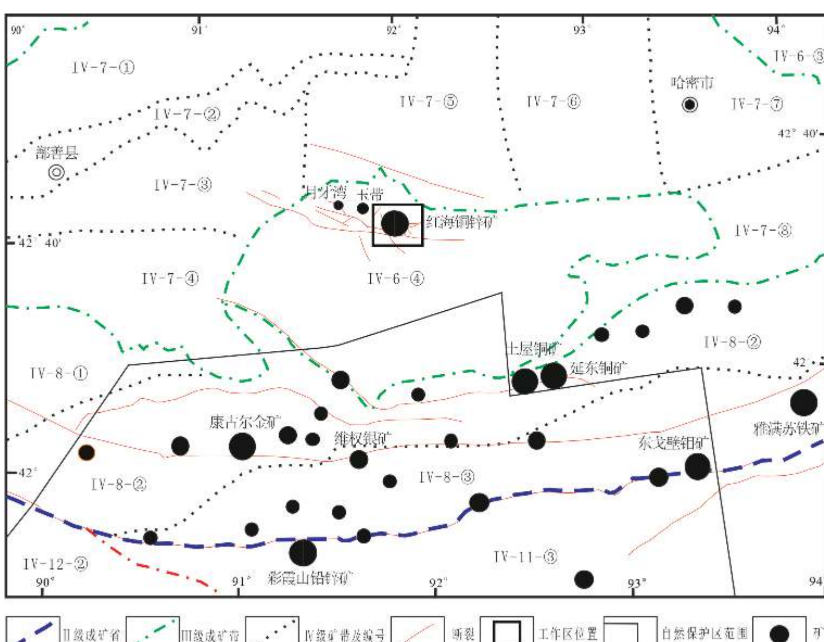

图 2　所属成矿区带位置图

(7) 其他

对大地构造、火山岩相、矿化蚀变和其他图例进行图面整饰。

3 数据样本描述

3.1 数据的命名方式

地质区: *.wp、*.pm；地质线: *.wl、*.lm；地质点: *.wt、*.tm。

3.2 图层内容

主图内容包括沉积岩建造、侵入岩建造、火山岩建造、第四系、构造、地质界线、产状、矿产地、同位素地质年龄取样点及测年年龄等。

角图内容包括接图表、建造柱状图、图例、地质剖面、图切剖面、典型矿床图、矿产地名录、成矿区带位置图、图签等。

3.3 数据类型

文件类型名称：点、线、面。

点实体：各类地质体符号及标记、地质花纹、矿产地、矿化蚀变等。

线实体：断裂构造、地质界线、矿化蚀变带等。

面实体：沉积岩、侵入岩、火山岩、第四纪沉积物等。

3.4 数据属性

红石幅 1：50 000 矿产地质图数据库包含地质实体要素信息、地理要素信息和地质图整饰要素信息。地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、火山岩、侵入岩)、断裂构造、产状要素、矿产地等分别建立数据库属性；地理要素信息沿用国家测绘地理信息局收集数据的属性结构；地质图整饰要素信息按照《固体矿产地质调查技术要求 (1：50 000)》(DD2019−02) 附录 I 矿产地质图参考图示整理。

沉积岩建造数据属性主要有：年代地层单位、岩石地层单位、建造名称、建造代码、厚度、建造类型、岩性组合等。

火山岩建造数据库属性主要有：年代地层单位、岩石地层单位、建造名称、建造代码、地层时代、厚度、岩性组合、矿化蚀变特征、同位素年龄、火山机构等。

侵入岩建造数据特征主要有：建造名称、建造代码、厚度、岩性组合、同位素年龄等。

断裂构造数据属性主要有：断裂名称、断裂类型、断裂延长、断裂走向、断裂面倾向、断裂面倾角等。

产状数据属性有：产状类型、倾向、倾角。

矿产地数据属性主要有：矿产地编号、矿产地名称、矿产地规模、矿产地类型、主要含矿建造等。

4 数据质量控制和评估

按照 1：50 000 矿产地质调查专项填图细则要求，一个图幅内实测和修测地质观察路线的总长度原则上不少于 500 km，其中实测路线长度不少于 300 km。本次填图按照《固体矿产地质调查技术要求 (1：50 000)》(DD2019−02) 规范要求，采用填编结合方

式，一般工作区以《新疆哈密市卡拉塔格铜 (锌) 矿整装勘查区 1∶50 000 (K46E008007、K46E008008、K46E008009、K46E009007、K46E009008、K46E009009) 六幅区域地质矿产调查》[1] 原始资料编图为辅。地质点采集以充分控制与成矿有关的地质体、矿化蚀变带、重要地质界线为原则。在编制红石幅 1∶50 000 矿产地质图中，总路线长度 594 km，其中收集前人资料 248 km；实测路线 272 km (40 条)，大比例尺填图路线 73.2 km (24 条)，地质界线 796 条，地质点 949 个，样品点 478 个。填 (编) 图总精度达到 1∶50 000 矿产地质图专项填图的具体要求。

图面表达一般只表达直径大于 100 m 的闭合地质体，宽度大于 50 m、长度大于 250 m 的线状地质体，以及长度大于 150 m 的断层。对矿化蚀变构造带及其他矿化地质体规模不论大小，均在图上表示；厚度较小者，用适当的花纹、符号放大或归并表示。一般地质点在野外手图上所标定的点位与实地位置误差不大于 25 m。

数据质量方面，填图路线自检、互检达 100%，项目组抽检 40%，并及时修正路线中的错误，提出填图中的注意事项，符合地质调查项目质量管理要求。

5　数据价值

新疆哈密卡拉塔格红石幅 (K46E009008)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。图幅研究区所在的区域成矿背景意义大，成矿区带划分见表 3。该矿产地质图在深入研究本图幅内火山岩岩相的基础上，结合本次 1∶50 000 专项地质填图成果，按照《矿产地质调查技术要求 (1∶50 000)》(DD 2019–02) 中的要求，以建造为划分原则，通过建造与构造综合分析与研究，将泥盆系、二叠系、侏罗系重新归类划分，对火山岩地层进行了重新划分 (表 4)，将下志留统划分为卡拉塔格组和红柳峡组；划分出图幅内侵入岩时代分为志留纪、泥盆纪、二叠纪 3 期（表 5)，建立了岩浆岩的演化序列，为该地区地质找矿工作提供基础数据支撑，发挥科技创新引领作用。

表 3　成矿区带划分一览表

	二级成矿省及编号	三级成矿区带及编号	四级矿带及编号
古亚洲成矿域Ⅰ–1	准噶尔成矿省Ⅱ–2	Ⅲ–6准噶尔南缘(复合岛弧带) Cu–Mo–Au–Ag–Pb–Zn–W–Fe–Cr–Mn–RM–Pt–Sb–U–Ni–高岭土–硫铁矿–膨润土–重晶石–玉石–石墨–钠硝石–泥炭–盐类–重晶石成矿带	Ⅳ–6–③哈尔里克(复合岛弧带) Cu–Au–Ag–Pb–Zn–W–RM–Mo–多金属–石墨–钠硝石–芒硝–泥炭–白云母–重晶石矿带
		Ⅲ–7吐哈盆地(地块) U–Fe–石油–天然气–煤–耐火黏土–钠硝石–盐类–膨润土成矿带	Ⅳ–7–①胜金口–小草湖(凹陷)石油–天然气–煤–钠硝石–石膏矿带
			Ⅳ–7–②中央隆起带Fe–Mn–U–煤–石油–天然气–钠硝石矿带
			Ⅳ–7–③托克逊–鄯善(凹陷) Fe–Mn–石油–天然气–煤–钠硝石–岩盐矿带
			Ⅳ–7–④艾丁湖(斜坡) U–石油–天然气–煤–石盐–芒硝矿带
			Ⅳ–7–⑤了墩(隆起)煤–钠硝石矿带(区)
			Ⅳ–7–⑥三道岭(凹陷) U–煤–耐火黏土矿带(区)
			Ⅳ–7–⑦哈密–骆驼圈子(隆起)芒硝矿带(区)
			Ⅳ–7–⑧大南湖–卡特卡尔(凹陷) Fe–U–煤矿带

续表 3

	二级成矿省及编号	三级成矿区带及编号	四级矿带及编号
古亚洲成矿域Ⅰ–1	准噶尔成矿省Ⅱ–2	Ⅲ–8觉罗塔格(裂陷槽) Cu–Ni–Fe–Mn–V–Ti–Au–Ag–Mo–W–RM–钠硝石–石膏–硅灰石–煤–硫铁矿–玉石成矿带	Ⅳ–8–①小热泉子(夭折裂谷) Cu–Pb–Zn–Au矿带 Ⅳ–8–②康古尔–土屋–黄山(裂陷槽) Cu–Ni–Ti–Au–Ag–Mo–Pb–Zn–RM–硫铁矿–硅灰石–玉石矿带 Ⅳ–8–③阿齐山–雅满苏–沙泉子(裂陷槽) Fe–Mn–Co–V–Ti–Au–Cu–石膏–煤–硫铁矿矿带
	塔里木成矿省Ⅱ–4	Ⅲ–11那拉提–巴伦台–卡瓦布拉克(微陆块群/结合带) Fe–Pb–Zn–Ag–Cu–Ni–Pt族–Cr–V–Ti–REE–MR–U–W–硅灰石–水晶–滑石–萤石–盐类–白云母–磷灰石–宝玉石–煤矿带	IV–11–③卡瓦布拉克–星星峡(地块/结合带) Fe–Pb–Zn–Ag–Cu–Ni–Cr–V–Ti–REE–MR–U–W–硅灰石–盐类–白云母–磷灰石–宝玉石矿带
		Ⅲ–12塔里木板块北缘(复合沟弧带) Fe–Ti–Mn–Cu–Ni–Mo–Pb–Zn–Sn–Pt族–菱镁矿–铝土矿–石墨–硅灰石–红柱石–磷灰石–石油–天然气–煤–硫铁矿–盐类–宝玉石–滑石–石棉–蛇纹岩–萤石–重晶石–泥炭成矿带	IV–12–②艾尔宾山(残余海盆) Fe–Mn–Cu–Au–W–Sn–Pb–Zn–U–菱镁矿–石墨–硅灰石–红柱石–石棉–滑石–蛇纹岩–硫铁矿–盐类矿带

表 4　火山岩建造柱状图一览表

岩石地层单位					建造单元特征					
系	统	群	组	代号	建造类型	厚度/m	岩性组合	矿化蚀变特征	同位素年龄/Ma	火山机构
二叠系	中二叠统		卡拉岗组	P_2k^{2a} P_2k^{2b} P_2k^{2c}	中基性—中酸性火山岩建造	1451.4	英安岩–玄武岩–杏仁状安山岩	膨润土矿、蒙脱石化、高岭石化、碳酸盐化	253±1.2	破火山口
				P_2k^{1a} P_2k^{1b} P_2k^{1c}	火山碎屑岩建造		晶屑岩屑凝灰岩–集块岩–玄武质晶屑岩屑凝灰岩			
泥盆系	下泥盆统		大南湖组	D_1d^{3a} D_1d^{3b} D_1d^{3c}	碎屑岩夹安山质火山岩建造	1995.71	晶屑岩屑凝灰岩–角砾凝灰岩–火山灰凝灰岩	含锰菱铁矿化		
				D_1d^{2a} D_1d^{2b} D_1d^{2c}	玄武质角砾熔岩、火山碎屑岩建造		凝灰岩–玄武质角砾熔岩夹砂岩			
志留系	下志留统		卡拉塔格组	S_1k^{2a}	流纹斑岩建造	300～600	英安质凝灰岩–含角砾晶屑岩屑凝灰岩–晶屑岩屑凝灰岩–英安岩	次火山岩热液型铜金矿床	439±7	
				S_1k^{2b}	(黄铁)霏细岩建造					
				S_1k^{1a}	含角砾晶屑岩屑凝灰岩建造					
				S_1k^{1b}	英安质凝灰岩建造					
				S_1k^{1c}	英安岩建造					
				S_1k^{1d}	晶屑岩屑凝灰岩建造					
				S_1k^{1e}	火山角砾岩建造					

续表 4

岩石地层单位					建造单元特征					
系	统	群	组	代号	建造类型	厚度/m	岩性组合	矿化蚀变特征	同位素年龄/Ma	火山机构
志留系	下志留统		红柳峡组	S_1h^a	含矿沉凝灰岩建造	0～>400	沉凝灰岩–条带状凝灰岩	VMS型铜锌金多金属矿床	440.4±2.9	
				S_1h^b	黄铁绢英岩化凝灰岩建造					
				S_1h^c	条带状凝灰岩建造				434.2±3.9	
奥陶系	中–上奥陶统	荒草坡群	大柳沟组	$O_{2-3}Hd^a$	安山岩建造	>800	安山岩–玄武岩		446.4±4.6	
				$O_{2-3}Hd^b$	玄武岩建造					

表 5　侵入岩建造一览表

时代				建造单元特征			
代	纪	世	期	代号	建造类型	岩性组合	同位素年龄/Ma
晚古生代	二叠纪			$\psi\nu$P νP $\beta\nu$P $\beta\mu$P	基性–超基性侵入岩	辉长岩–辉绿岩–橄榄辉石岩	280～270
	泥盆纪			δD $\delta\mu$D $\xi\gamma$D $\eta\gamma$D	中酸性侵入岩	正长花岗岩–二长花岗岩–闪长岩–石英闪长玢岩	390～380
早古生代	志留纪			γS $\gamma\delta$S δoS $\gamma\delta o$S	中酸性侵入岩	英云闪长岩–花岗闪长岩–石英闪长岩组合	450～426

6　结论

(1) 根据新疆红石幅 (K46E009008)1∶50 000 矿产地质图专项填图，提出了 VMS 型与热液脉型矿床同时异相的叠加成矿模式，完善典型矿床找矿预测模型，为成矿预测和资源潜力评价奠定了基础。

(2) 新疆红石幅 (K46E009008)1∶50 000 矿产地质图及数据库，表现了含矿建造的空间分布和蚀变矿化特征，厘清了含矿建造形成的地质条件，查明了成矿地质背景，提出了下一步找矿工作部署建议。

(3) 新疆红石幅 1∶50 000 矿产地质图及数据库是中国地质调查局新一轮地质矿产调查的示范图幅，通过积极探索创新矿产地质专项填图成果表达方式，形成了红石幅矿产地质图，对矿产地质调查起到了示范作用。

致谢：新疆红石幅 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 有色金属矿产地质调查中心. 2016. 新疆哈密市卡拉塔格铜 (锌) 矿整装勘查区 1：50000 (K46E008007、K46E008008、K46E008009、K46E009007、K46E009008、K46E009009)6 幅区域地质矿产调查 [R].

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Database of 1∶50 000 Mineral Geological Map of the Hongshi Map-sheet in Kalatage Copper (-Zinc) Deposit, Hami, Xinjiang

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Abstract: The database of 1∶50 000 mineral geological map of Hongshi Map-sheet (K46E009008) in Kalatage Copper (-Zinc) Deposit, Hami, Xinjiang (also referred to as the Database) was developed through field geology-specific mapping using the digital mapping system in accordance with the *Technical Requirements of Solid Mineral Geological Survey* (1∶50 000) (DD2019-02) and other standards and requirements in the geological industry. Meanwhile, the results of previous 1∶200 000 and 1∶50 000 regional geological surveys were fully utilized, and indoor and outdoor mapping/compilation was also carried out during database building. In this database, the suites of the Daliugou Formation of Middle-Upper Ordovician Huangcaopo Group as well as Lower Silurian Hongliuxia and Kalatage formations were reclassified. Moreover, the formation time of intrusive rocks in the map-sheet area was determined as Silurian, Devonian, and Permian, and the evolutionary sequence of magmatic rocks was established. There are eight large, medium and small mineral deposits and ore occurrences in the map-sheet area, the metallogenic epoch of which is concentrated in the Silurian and Carboniferous. The ore-hosted wall rocks are pyroclastic and subvolcanic rocks. The dominant mineral resources in this area are copper, zinc and gold, and their deposit types are mainly VMS type and subvolcanic hydrothermal vein type, which are distributed in the southeastern zone of the map-sheet area. In addition to metallic minerals, there are bentonite deposits with good prospecting potential. With a data size of about 15.1 MB, this database

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contains the data of five stratigraphic units and three stages of magmatic rocks. These data fully reflect the demonstration results of 1∶50 000 mineral geological survey of this map-sheet and provide references for the research and exploration of mineral resources in the survey area.

Key words: Hongshi Map-sheet; mineral geological map; database; special mapping; Kalatage Copper (-Zinc) Deposit; mineral geological survey engineering; Hami; Xinjiang
Data service system URL: http://dcc.cgs.gov.cn

1 Introduction

The East Tianshan Mountains extend from Xiaorequanzi in eastern Xinjiang to the border between Gansu and Xinjiang. It is an important part of the accretion-type Central Asian Orogenic Belt and experienced the tectonic evolution such as multi-block splicing, accretion-subduction, and collisional orogenesis during the formation, evolution, and extinction of the Paleo-Asian Ocean (Fig. 1a; Sengör et al., 1993; Xiao WJ et al., 2004). It consists of three tectonic units, namely the Central Tianshan Block, Jueluotage Orogenic Belt, and Harlik Island Arc Belt from south to north (Qin KZ et al., 2002). Among them, the Jueluotage Orogenic Belt is mainly composed of Paleozoic volcanic rocks and sedimentary rocks, including Dananhu–Tousuquan island arc belt, Kanggur–Huangshan ductile shear zone, and Aqishan–Yamansu tectonic belt (Fig. 1b; Wang JB et al., 2006). It bears rich and diverse metallogenic systems, such as Tuwu–Yandong Porphyry Copper Deposit (Han CM et al., 2006; Zhang LC et al., 2006; Shen P et al., 2014; Xiao B et al., 2018; Wang YF et al., 2018), Honghai-Xiaorequanzi Volcanogenic Massive Sulfide (VMS) Copper-Zinc Deposit (He XH et al., 2020; Mao QG et al., 2020), orogenic Kanggur Gold Deposit (Du L et al., 2019), Caixiashan Lead-Zinc Deposit (Li DF et al., 2016, 2019), and Huangshan–East Huangshan Magmatic Copper-

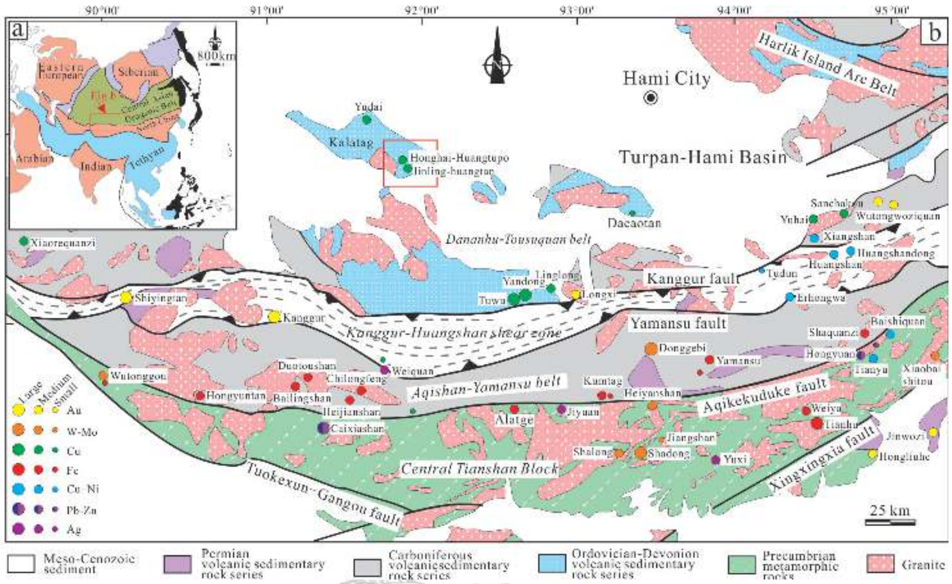

Fig. 1 Sketch of Central Asian Orogenic Belt (a, modified from Sengör et al., 1993) and the distribution of structures and deposits in East Tianshan Mountains (b, modified from Wang JB et al., 2006)

Nickel Sulfide Deposit (Wu CZ et al., 2018). The study area in this paper is located in the Kalatage area of East Tianshan Mountains and belongs to the Dananhu island arc belt (Fig. 1b).

The 1∶50 000 regional geological surveys of the Kalatage area began in the 1990s, and the 1∶50 000 regional mineral and geological surveys of Hongshi Map-sheet were conducted by the China Non-ferrous Metals Resource Geological Survey in 2014–2017, during which 1∶50 000 gravity surveys and 1∶50 000 induced polarization (IP) surveying were also completed. In 2014–2015, the Beijing Institute of Geology for Mineral Resources conducted 1∶50 000 debris geochemical surveys and 1∶50 000 magnetic surveys in this area. In addition, the tectonic environment, rock characteristics, and metallogenic regularity in Kalatage area were extensively studied (Qin KZ et al., 2001; Tang JH et al., 2006; Mao QG et al., 2010, 2017; Deng YF et al., 2017; Long LL et al., 2019; Mao QG et al., 2019; Sun Y et al., 2019; Deng XH et al., 2016, 2020). All these surveys and studies lay a basis for the preparation of the mineral geological maps of Hongshi Map-sheet. As a demonstration map of mineral geological surveys initiated by the China Geological Survey, the 1∶50 000 mineral geological map of Hongshi Map-sheet was prepared in order to reflect the new achievements made in geological survey, mineral exploration, and scientific research in the new round of geological surveys. In addition, it is to provide basic geological maps for deposit research and mineral exploration in this area, and to offer useful references for scientific research and field geological surveys. The brief metadata table of the Database (Wang FF et al., 2020) is shown in Table 1.

2 Methods for Data Acquisition and Processing

2.1 Data Bases

In accordance with the *Technical Requirements of Solid Mineral Geological Survey* (1∶50 000) (DD 2019-02) and under the guidance of prospecting prediction theory of exploration areas, the 1∶50 000 mineral geological map of Hongshi Map-sheet in Kalatage, Hami, Xinjiang was developed through the systematical collection and comprehensive analysis of previous geological, geophysical, geochemical, remote sensing, and mineral data. This also involves the full utilization of new results obtained from the 1∶50 000 mineral geology-specific mapping of Hongshi Map-sheet conducted in this study. The geographic coordinate system adopted is the National Geodetic Coordinate System 2000, and relevant data were processed by applying existing technical standards and computer software such as the digital mapping system (DGSS) and MapGIS.

2.2 Data Processing

2.2.1 Data Preparation

The data preparation was conducted as follows: (1) The metallogenic geological conditions such as sedimentation, volcanic activities, magmatic intrusion, and tectonic activities in the Hongshi Map-sheet were analyzed and studied; (2) Previous data on geology, geophysics, geochemistry, remote sensing, and mineral resources were systematically collected and comprehensively analyzed; (3) The geological maps collected were vectorized to form the

Table 1 Metadata Table of Database (Dataset)

Item	Description
Database (dataset) name	Database of 1∶50 000 Mineral Geological Map of the Hongshi Map-sheet in Xinjiang
Database (dataset) authors	Wang Fengfeng, Beijing Institute of Geology for Mineral Resources Deng Xiaohua, Beijing Institute of Geology for Mineral Resources Li Dedong, Beijing Institute of Geology for Mineral Resources Wei Xiaofeng, Beijing Institute of Geology for Mineral Resources Lyu Xiaoqiang, Beijing Institute of Geology for Mineral Resources Wan Yanchao, Beijing Institute of Geology for Mineral Resources
Data acquisition time	2017–2018
Geographical area	91°45′−92°00′E, 42°30′−42°40′N
Data format	*.wl, *.wt, *.wp; *.pm, *.lm, *.tm
Data size	15.1 MB
Data service system URL	http://dcc.cgs.gov.cn
Fund project	The project entitled *Prospecting Prediction and Technological Application Demonstration of Integrated Exploration Areas* (No.: 121201004000160901–66) initiated by the China Geological Survey
Language	Chinese
Database (dataset) composition	The Database consists of a map library, corner maps, and map decorations of 1∶50 000 geological map. The map library covers sedimentary rocks, intrusive rocks, volcanic rocks, structures, geological boundaries, attitude, mineral deposits (ore occurrences), mineralized alternation, samples for isotopic dating and their dated ages, lithologic patterns, and various lithologic codes. The corner maps include histograms of comprehensive suites, sedimentary rock suites, intrusive rock suites, and volcanic rock suites. Besides, they cover structures, volcanic rock facies, geological sections, cross-sections, plans of typical deposits (mining areas), mineral legends, mineral deposit list, mineralized alternation legends, and the map of metallogenic zone/belt location. The map decorations include an index map, the logo of the China Geological Survey, map name, scale, coordinate parameter, and signature

files of geological points, lines, and polygons in the format of MapGIS; (4) The relationships between the mineral characteristics and suites in the study area were analyzed, based on which main ore-bearing suites in the study area were determined; (5) The 1∶50 000-scale standard map frame was created according to the range of Hongshi Map-sheet, with the Gauss–Kruger projection serving as the projection system and the National Geodetic Coordinate System 2000 (CGCS 2000) adopted as the coordinate system.

2.2.2 Preparation of Suite-structure Draft Map

The outcrops in the Hongshi Map-sheet area were primarily classified by referring to and analyzing the field route records in the regional geological survey results of the map-sheet. Then the field records were presented on the map in the forms of lithologic suite pattern points or lines.

The mapping units of the suites in the map-sheet were primarily determined according to a comprehensive analysis of 1∶50 000 regional geological survey data along with the regional mineral resources data and the study data specific to the deposits in the Hongshi Map-sheet.

Then the suite-tectonic draft map was complied accordingly. Moreover, the background map layers of DGSS were prepared, the study area was preliminarily divided into major survey sites and minor survey sites, and the reconnaissance routes and section locations were arranged.

(1) Suites

Suites were expressed on the suite-tectonic draft maps according to the *Standard and Principle of Coloring in Geological Map* (1∶50 000) (DZ/T 0179-1997). In detail, they were represented using suite patterns and colors, with similar colors being used to denote the rock suites in different members of the same stratigraphic unit and different colors being used to denote eras.

(2) Structures

Structures were expressed in red color according to the unified standard of coloring, and fault properties were represented by different line types.

(3) "Trinity" prospecting model

Previous data were collected and comprehensively analyzed, based on which the overall working idea was determined and the prospecting models of VMS deposits and subvolcanic hydrothermal deposits were preliminarily built.

2.2.3 Field Geology-specific Mapping

According to previous geological, geophysical, geochemical, and remote sensing data, three types of survey sites (i.e., major, minor, and amendment survey sites) and two levels of surveys (i.e., 1∶50 000 mineral geology- specific survey and 1∶10 000 comprehensive inspection) were determined on the suite-tectonic draft map. Meanwhile, prospecting predication was deployed and carried out in Kalatage area on the premise that VMS deposits and subvolcanic hydrothermal deposits serve as the main prospecting deposits in the Hongshi Map-sheet. Taking the *Standard on Spatial Databases for Digital Geological Maps* (DD 2006−06) as the basic requirements, the database of digital mapping results was built by successively compiling the suite-tectonic draft map, draft data map, suite-tectonic map, and mineral geological map using the geological survey GIS platform of the DGSS.

2.2.4 Indoor Data Collation

The geological points, routes, and boundaries were plotted through indoor data collection and collation along with field survey, with the data being collated according to relevant specifications. The lithofacies and rock associations of the lithostratigraphic units once divided were further classified through specific mapping, and the attributes of subvolcanic rocks such as rhyolite porphyry were roughly figured out, including rock types, mineral composition, structure, texture, geochemical characteristics, occurrence and contact relationships, and spatial distribution.

The 1∶50 000 draft data map was compiled using the route data that were collected indoor and in the field in this study. The stratigraphic units, suite patterns, and structural morphology were amended and plotted according to the draft data map. As a result, the 1∶50 000 suite-tectonic map was formed, which consisted of a master map, comprehensive suite histogram, histograms of various suites, and legends of structures and mineralized alteration.

The master map contains volcanic rock suites, suites and structures related to metallogenesis, geological boundaries, faults, polygon features, line features, and suite patterns.

2.2.5 Preparation of Various Corner Maps

(1) Histograms of suites

This type of histogram is used to reflect detailed characteristics of the suites in the lithostratigraphic units on the master map. The suite characteristics were denoted with patterns, suite types, rock associations to specify the lithology of the lithostratigraphic units and determine the contact relationships between the lithostratigraphic units. In the case of the suites that are not exposed but related to metallogenesis, they were highlighted in the histograms according to the borehole data (including mineralized alteration, ore-bearing elements, and suites of ore-bearing layers) and their ore-bearing horizons were specified. The histograms of comprehensive suites, sedimentary rock suites, intrusive rock suites, and volcanic rock suites were individually prepared.

(2) Typical deposits

The corner maps of typical deposits include sections of Honghai VMS Deposit, sections of Hongshi Subvolcanic Hydrothermal Deposit, and NS-trending geological sections from Honghai deposit to Hongshi deposit. On these maps, the deposit types and ore body morphology in the area are clearly presented. Meanwhile, the VMS ore-bearing horizons that are not exposed are highlighted according to borehole data, and the control of structures over VMS deposits is denoted.

(3) Geological section

A geological section with a strike of 30° north by east was employed to express the association of Middle Permian Kalagang Formation, Silurian granodiorite, Silurian diorite, Devonian syenogranite, the Daliugou Formation of Middle-Upper Ordovician Huangcaopo Group ($O_{2-3}hd$), and lower Silurian Kalatage Formation (S_1k). On the geological section, the positions and lithology of these strata are represented with "standard section line type + standard code" and proper patterns, respectively. Meanwhile, the locations of ore occurrences are labeled.

(4) Cross-sections

Two cross-sections were used to effectively reflect the relationships of overall characteristics of suites and structures with mineralization in the Hongshi Map-sheet area. They run across the main strata in the map-sheet area and Meiling Copper Deposit and Hongshi Copper Deposit, and thus can reflect the characteristics of mineralized alternation of various strata in the area and show the relationships between metallogenic conditions and surface rocks.

(5) List of mineral deposits

To reflect the mineral resources in the Hongshi Map-sheet area, list of the mineral deposit information in the area is presented in the corner part of the map face, including the name, scale, type, and main ore-bearing suites of the deposits. This content was named as the list of mineral deposits in the Hongshi Map-sheet area (Table 2).

Table 2 List of mineral deposits in the Hongshi Map-sheet area

No.	Mineral deposit name	Scale	Type	Main ore-bearing suite
1	Hongshan copper-gold deposit in Kalatag region, Hami, Xinjiang	Small	Subvolcanic hydrothermal	Subvolcanic rocks
2	East Hongshan copper-gold deposit in Kalatag region, Hami, Xinjiang	Ore occurrence	Subvolcanic hydrothermal	Subvolcanic rocks
3	Meiling copper-zinc deposit in Kalatag region, Hami, Xinjiang	Medium	Subvolcanic hydrothermal	Subvolcanic rocks
4	Hongshi copper deposit in Kalatag region, Hami, Xinjiang	Small	Subvolcanic hydrothermal	Subvolcanic rocks
5	Biyushan copper-gold deposit in Kalatag region, Hami, Xinjiang	Ore occurrence	Subvolcanic hydrothermal	Subvolcanic rocks
6	Honghai copper-zinc deposit inKalatag region, Hami, Xinjiang	Large	VMS	Pyroclastic Rocks
7	Jingling gold-zinc-copper deposit in Kalatag region, Hami, Xinjiang	Medium	VMS+Subvolcanic hydrothermal	Pytoclastic Rocks
8	Shaerhu bentonite deposit in Kalatag region, Hami, Xinjiang	Medium	Weathering alteration	Subvolcanic rocks

(6) Map of metallogenic zone/belt location

The corner map of this type is used to macroscopically present the location of structures in the metallogenic zone/belt where the Hongshi Map-sheet lies, including the structures related to metallogenesis. It was prepared as follows. The 1：500 000 mineral map of Xinjiang collected was clipped according to the regional outline range of the Hongshi Map-sheet to retain metallogenic belts of levels II–IV and main place names and mineral deposits. Meanwhile, the coordinates of Lop Nur Wild Camel National Nature Reserve were projected and represented with line segments on the map. Then the map was scaled to generate the map of metallogenic zone/belt location (Fig. 2).

(7) Others

Map decorations were made for geotectonic legends and the legends of volcanic rock facies, mineralized alteration, and others.

3 Description of Data Samples

3.1 Data Naming

File names of geological polygons: *.wp, *.pm; file names of geological lines: *.wl, *.lm; file names of geological points: *.wt, *.tm.

3.2 Contents on Map Layers

The maser map include the layers of sedimentary rock suites, intrusive rock suites, volcanic rock suites, Quaternary, structures, geological boundaries, attitudes, mineral deposits, samples for isotopic dating and their dated ages.

The corner maps include an index map, suite histograms, legends, geological sections, cross-sections, typical deposit maps, a list of mineral deposits, map of metallogenic zone/belt locations, signatures.

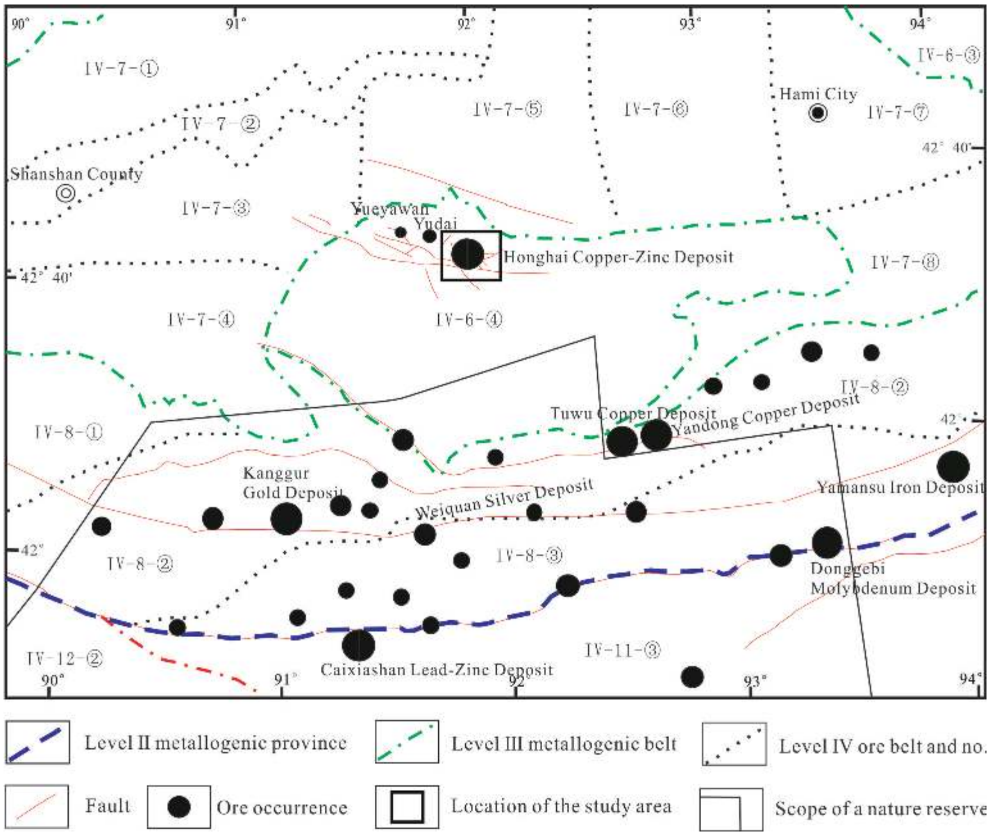

Fig. 2 Map of metallogenic zone/belt location where the Hongshi Map-sheet lies

3.3 Data Types

Names of geological entity features: points, lines, and polygons.

Geological points include symbols and labels of various geologic blocks, geological patterns, mineral deposits, and mineralized alteration.

Geological lines include fault structures, geological boundaries, and mineralized alteration zones.

Geological polygons include sedimentary rocks, intrusive rocks, volcanic rocks, and the Quaternary sediments.

3.4 Data Attributes

The Database includes the data of geological entity features, geographical elements, and geological map decorations. For the data of geological entity features, the database attributes were individually established for three major types of rocks (sedimentary rocks, volcanic rocks, and metamorphic rocks), fault structures, attitudes, and mineral deposits according to the requirements for the establishment of geology–specific mapping database of 1：50 000 mineral geological surveys. The attributes of geographical elements follow the attribute structures used by the National Administration of Surveying, Mapping and Geoinformation of China to collect data. The geological map decorations were collated by referring to the mineral geological map example in Annex I of the *Technical Requirements of Solid Mineral Geological Survey* (1：50 000) (DD 2019-02).

Main data attributes of a sedimentary rock suite include chronostratigraphic unit, lithostratigraphic unit, suite name, suite code, thickness, suite type, and lithologic associations.

Main data attributes of a volcanic rock suite include chronostratigraphic unit, lithostratigraphic unit, suite name, suite code, stratigraphic era, thickness, lithologic associations, mineralized alteration characteristics, isotopic ages, and volcanic edifices.

Main data attributes of an intrusive rock suite include suite name, suite code, thickness, lithologic associations, and isotopic ages.

Main data attributes of a fault structure include the name, type, extension, and strike of the fault; the dip and dip angle of fault surface.

Main data attributes of an attitude include the type, dip, and dip angle of the attitude.

Main data attributes of a mineral deposit include the no., name, scale, type, main ore-bearing suites of the mineral deposit.

4 Data Quality Control and Assessment

According to the detailed requirements on 1∶50 000 mineral geology-specific mapping, the surveyed geological routes and the geological routes for amendment survey in a map-sheet should not be less than 500 km in total, among which the surveyed geological routes should not be less than 300 km. The map in this study was prepared through field mapping and indoor compilation according to the *Technical Requirements of Solid Mineral Geological Survey* (1∶50 000) (DD 2019-02). In addition, minor survey sites were mapped based on the primary data in the 1∶50 000 *Regional Mineral and Geological Survey of Six Map-sheets* (K46E008007, K46E008008, K46E008009, K46E009007, K46E009008, and K46E009009) *in Kalatage Copper (-Zinc) Deposit Integrated Exploration Area in Hami, Xinjiang*[❶]. Meanwhile, geological points were collected on the principle of fully controlling the geologic blocks related to mineralization, mineralized alteration zones, and major geological boundaries. The preparation of the 1∶50 000 mineral geological map of Hongshi Map-sheet involved 594 km of geological routes in total, 796 geological boundaries, 949 geological points, and 478 sample points. The geological routes consist of 248 km of geological routes obtained by collecting previous data, 272 km (40 lines) of surveyed routes, 73.2 km (24 lines) of routes achieved by large-scale mapping. Therefore, the total mapping precision met the specific requirements of 1∶50 000 mineral geological mapping.

In general, the contents on a geological map only include sealed geologic blocks with a diameter greater than 100 m, linear geologic bocks with a width greater than 50 m and a length greater than 250 m, and faults with a length greater than 150 m. Meanwhile, all mineralized geologic blocks such as mineralized alteration tectonic zones are all presented in the map, regardless of size. Among them, those with a small thickness are presented with proper patterns or symbols by zooming in or incorporating with each other. The errors in the location of a geological point (i.e., the difference between its location marked on the freehand field map and its actual location) should not exceed 25 m in general.

As for the data quality, the self-check rate and mutual check rate of the survey routes for geologic mapping were both 100% and the errors on the routes were corrected in time. Meanwhile, the rate of spot inspection conducted by the project team was 40%, and precautions for mapping were proposed during the spot inspection. In this way, the requirements of quality management of geological survey projects were satisfied.

5 Data Value

The 1∶50 000 mineral geological map of Hongshi Map-sheet in Kalatage, Hami, Xinjiang (K46E009008) is a demonstration map in the new round of geological surveys initiated by the China Geological Survey. The metallogenic background of the survey area is of great significance, and the division of metallogenic zones is shown in Table 3. On this map, according to the *Technical Requirements of Solid Mineral Geological Survey* (1∶50 000) (DD 2019-02), the strata in Hongshi Map-sheet is divided into suites based on comprehensive analysis and research of suites and structures, in-depth research on volcanic rock facies, and the 1∶50 000 geology-specific mapping results of this study. In detail, the Devonian, Permian and Jurassic strata in the map-sheet area were reclassified and the volcanic rock stratawere re-divided (Table 4). The Lower Silurian was divided into Kalatage Formation and Hongliuxia Formation, three stages of volcanic rocks were defined, namely Silurian, Devonian and Permian (Table 5), and the evolutionary sequence of magmatic rocks was established. All these could provide basic data for geological prospecting in the map-sheet area and play a leading role in scientific and technical innovation.

6 Conclusions

(1) With the specific mapping of 1∶50 000 mineral geological map of Hongshi Map-sheet (K46E009008) in Xinjiang, the metallogenic model of synchronous superimposition of VMS deposits and hydrothermal vein-type deposits was put forward and the prospecting prediction models of typical deposits were improved. This lays a foundation for metallogenic prediction and resource potential assessment.

(2) The 1∶50 000 mineral geological map and database of Hongshi Map-sheet (K46E009008) in Xinjiang reflect the spatial distribution and altered mineralization characteristics of ore-bearing suites. Accordingly, the geological conditions for the formation of ore-bearing suites were ascertained, the metallogenic geological setting was identified, and the suggestions on the deployment of further prospecting were proposed.

(3) The 1∶50 000 mineral geological map and database of Hongshi Map-sheet (K46E009008) in Xinjiang are the demonstration results in the new round of mineral and geological survey projects initiated by China Geological Survey. The geological map was prepared by actively exploring and innovating the presentence of mineral geology-specific mapping results. This will serve as a demonstration in mineral and geological surveys.

Acknowledgements: The 1∶50 000 mineral geological mapping of Hongshi Map-sheet in Xinjiang is a collective achievement, for which the frontline geological workers have paid many industrious efforts in the field. In the process of establishing the mineral geological map

Table 3 Classification of metallogenic zones/belts

	Level Ⅱ metallogenic province and no.	Level Ⅲ metallogenic belt and no.	Level Ⅳ ore belt and no.
Paleo-Asian metallogenic domain I–1	Junggar metallogenic province II–2	III–6:Cu–Mo–Au–Ag–Pb–Zn–W–Fe–Cr–Mn–RM–Pt–Sb–U–Ni–kaolin–pyrite–bentonite–barite–jade–graphite–nitratine–peat–salts–barite metallogenic belt on the southern margin of Junggar (composite island arc belt)	IV–6–③: Halierke (composite island arc belt) Cu–Au–Ag–Pb–Zn–W–RM–Mo–polymetal–graphite–nitratine–mirabilite–peat–muscovite–barite metallogenic belt
		III–7: U–Fe–petroleum–natural gas–coal– chamotte–nitratine–salts–bentonite metallogenic belt in Turpan–Hami Basin (Block)	IV–7–①: Shengjinkou–Xiaocaohu (sag) petroleum–natural gas–coal–nitratine–gypsum ore belt
			IV–7–②: Fe–Mn–U–coal–petroleum–natural gas–nitratine ore belt of central uplift belt
			IV–7–③: Toksun–Shanshan (sag) Fe–Mn–petroleum–natural gas–coal–nitratine–rock salt ore belt
			IV–7–④: Aydingkol (slope) U–petroleum–natural gas–coal–rock salt–mirabilite ore belt
			IV–7–⑤: Liaodun (uplift) coal–nitratine ore belt (zone)
			IV–7–⑥: Sandaoling (sag) U–coal–chamotte ore belt (zone)
			IV–7–⑦: Hami–Luotuojuanzi (uplift) mirabilite ore belt (zone)
			IV–7–⑧: Dananhu–Katekar (sag) Fe–U–coal ore belt
		III–8: Jueluotage (rift trough) Cu–Ni–Fe–Mn–V–Ti–Au–Ag–Mo–W–RM–nitratine–gypsum–wollastonite–coal–pyrite–jade metallogenic belt	IV–8–①: Xiaorequanzi (failed rift) Cu–Pb–Zn–Au ore belt
			IV–8–②: Kanggur–Tuwu–Huangshan (rift trough) Cu–Ni–Ti–Au–Ag–Mo–Pb–Zn–RM–pyrite–wollastonite–jade ore belt
			IV–8–③: Aqishan–Yamansu–Shaquanzi (rift trough) Fe–Mn–Co–V–Ti–Au–Cu–gypsum–coal–pyrite ore belt
	Tarim metallogenic province II–4	III–11: Nalati–Baluntai–Kawabulake (microcontinental group/junction zone) Fe–Pb–Zn–Ag–Cu–Ni–Pt family–Cr–V–Ti–REE–MR–U–W–wollastonite–crystal–talc–fluorite–salts–muscovite–apatite–gem–coal metallogenic belt	IV–11–③: Kawabulake–Xingxingxia (block/junction zone) Fe–Pb–Zn–Ag–Cu–Ni–Cr–V–Ti–REE–MR–U–W–wollastonite–salt–muscovite–apatite–gem ore belt
		III–12: Fe–Ti–Mn–Cu–Ni–Mo–Pb–Zn–Sn–Pt group–magnesite–bauxite–graphite–wollastonite–andalusite–apatite–petroleum–natural gas–coal–pyrite–salts–gem–talc–asbestos–serpentine–fluorite–barite–peat metallogenic belt on the northern margin of Tarim plate (composite trench arc belt)	IV–12–②: Aierbin (residual basin) Fe–Mn–Cu–Au–W–Sn–Pb–Zn–U–magnesite–graphite–wollastonite–andalusite–asbestos–talc–serpentine–pyrite–salt ore belt

Table 4 Histogram of volcanic rock suites

Lithostratigraphic unit				Characteristics of a suite unit						
System	Series	Group	Formation	Code	Suite type	Thickness/m	Lithologic association	Mineralized alteration characteristics	Isotopic age/Ma	Volcanic edifice
Permian	Middle Permian		Kalagang	P_2k^{2a} P_2k^{2b} P_2k^{2c}	Intermediate-basic – intermediate-acid volcanic rock suites	1451.4	Dacite-basalt-amygdaloidal andesite	Bentonite ore, montmorillonitization, kaolinitization, and carbonation	253±1.2	Calderas
				P_2k^{1a} P_2k^{1b} P_2k^{1c}	Volcanic clastic rock suites		Crystal lithic tuff-agglomerate-basaltic crystal lithic tuff			
Devonian	Lower Devonian		Dananhu	D_1d^{3a} D_1d^{3b} D_1d^{3c}	Suites consisting of clastic rocks interbedded with andesitic volcanic rocks	1995.71	Crystal lithic tuff-breccia tuff - lapilli tuff	Manganese-bearing sideritization		
				D_1d^{2a} D_1d^{2b} D_1d^{2c}	Suites consisting of basaltic breccia lava and pyroclastic rocks		Tuff - basaltic breccia lava interbedded with sandstone			
Silurian	Lower Silurian		Kalatage	S_1k^{2a}	Rhythmic porphyry suites	300–600	Dacitic tuff-breccia-bearing crystal lithic tuff-crystal lithic tuff-dacite	Subvolcanic hydrothermal copper-gold deposit	439±7	
				S_1k^{2b}	(Pyrite) felsite suites					
				S_1k^{1a}	Suites consisting of crystal lithic tuff bearing breccia					
				S_1k^{1b}	Dacitic tuff suites					
				S_1k^{1c}	Dacite suites					
				S_1k^{1d}	Crystal lithic tuff suites					
				S_1k^{1e}	Volcanic breccia suites					

Continued table 4

Lithostratigraphic unit				Characteristics of a suite unit						
System	Series	Group	Formation	Code	Suite type	Thickness/m	Lithologic association	Mineralized alteration characteristics	Isotopic age/Ma	Volcanic edifice
Silurian	Lower Silurian		Hongliuxia	S_1h^a	Ore-bearing sedimentary tuff suites	0–>400	Sedimentary tuff-banded tuff	VMS copper-zinc-gold polymetallic deposit	440.4±2.9	
				S_1h^b	Beresitized tuff suites					
				S_1h^c	Banded tuff suites				434.2±3.9	
Ordovician	Middle–Upper Ordovician	Huangcaopo	Daliugou	$O_{2-3}Hd^a$	Andesite suites	>800	Andesite-basalt		446.4±4.6	
				$O_{2-3}Hd^b$	Basalt suites					

Table 5 Histogram of intrusive rock suites

Time				Characteristics of a suite unit			
Era	Period	Epoch	Stage	Code	Suite type	Lithologic association	Isotopic age/Ma
Late Paleozoic	Permian			$\psi\nu$P	Mafic-ultramafic intrusive rocks	Gabbro-diabase-olivine pyroxenite	280–270
				νP			
				$\beta\nu$P			
				βμP			
	Devonian			δD	Intermediate-acid intrusive rocks	Orthogranite-monzogranite-diorite-quartz diorite porphyrite	390–380
				$\delta\mu$D			
				$\xi\gamma$D			
				$\eta\gamma$D			
Early Paleozoic	Silurian			γS	Intermediate-acid intrusive rocks	Tonalite-granodiorite-quartz diorite association	450–426
				$\gamma\delta$S			
				δoS			
				$\gamma\delta o$S			

database, the authors have been guided by several geological and mineral experts. Thanks to all the experts and all members of the field project team.

Notes:

❶ China Non-ferrous Metals Resource Geological Survey. 2016. 1：50 000 Regional Mineral and Geological Survey of Six Map-sheets (K46E008007, K46E008008, K46E008009, K46E009007, K46E009008, and K46E009009) in Kalatage Copper (-Zinc) Deposit Integrated Exploration Area in Hami, Xinjiang[R].

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