

湘西发现镓超常富集铅锌矿床^{*}

吴涛¹, 黄智龙^{1**}, 叶霖¹, 周家喜³, 韦晨^{1,2}, 胡宇思¹, 向震中^{1,2}

(1 中国科学院地球化学研究所, 贵州 贵阳 550081; 2 中国科学院大学, 北京 100049;

3 云南大学 地球科学学院, 云南 昆明 650500)

摘要 分布于扬子地块东南缘的湘西铅锌成矿区是中国重要的铅锌生产基地, 累计探明铅锌资源量超过2000万t。近年来, 随着区内多个大型-超大型铅锌矿床相继被发现, 其成矿特征和找矿工作也受到地质工作者的关注。唐家寨矿床是分布于湘西洛塔矿田中的一个大型铅锌矿床, 文章通过电子探针(EPMA)和激光剥蚀等离子质谱(LA-ICPMS)发现唐家寨矿床闪锌矿中显著富集关键金属元素镓(Ga), 2种方法获得平均 $w(\text{Ga})$ 分别为 1320×10^{-6} 和 928×10^{-6} , 其富集程度之高全球罕见。另外, 结合 LA-ICPMS Mapping 分析发现, 唐家寨矿床中的 Ga 元素主要与 Cu 元素一起耦合替代 Zn 元素进入闪锌矿晶格之中。上述这些发现表明, 唐家寨铅锌矿床及其外围具有巨大的镓等战略性关键金属资源的找矿潜力。

关键词 地球化学; 关键金属; 镓超常富集; 唐家寨铅锌矿床; 湘西

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Discovery of Ga extremely enriched Pb-Zn deposit in western Hunan

WU Tao¹, HUANG ZhiLong¹, YE Lin¹, ZHOU JiaXi³, WEI Chen^{1,2}, HU YuSi¹ and XIANG ZhenZhong^{1,2}

(1 State Key Laboratory of Ore Deposit Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang 550081,

Guizhou, China; 2 University of Chinese Academy of Sciences, Beijing 100049, China; 3 School of Earth Sciences,

Yunnan University, Kunming 650500, Yunnan, China)

Abstract

The western Hunan lead-zinc metallogenic area, located in the southeast margin of the Yangtze block, is a significant Pb-Zn production base in China, with a cumulative proven metal resource of more than 20 million tons. In view of several large to super-large Pb-Zn deposits discovered in recent years, a great number of geologists pay attention to their mineralization and prospecting. The Tangjiazhai deposit is a large scale lead-zinc deposit in the Luota orefield of the western Hunan. Recently, the critical metal element gallium (Ga) was found extremely enriched in sphalerite of the Tangjiazhai deposit by electron microprobe (EPMA) and laser ablation plasma mass spectrometry (LA-ICPMS). The average content of Ga obtained by the two methods was 1320×10^{-6} and 928×10^{-6} , respectively, which is rare in the world. In addition, the LA-ICPMS Mapping analysis indicating that Ga is mainly coupled with Cu to replace Zn into sphalerite lattice. These findings show great prospecting potential for strategic critical metal gallium resources in the Tangjiazhai Pb-Zn deposit and its periphery.

Keywords: geochemistry, critical metal, gallium extremely enriched, Tangjiazhai Pb-Zn deposit, western Hunan

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第一作者简介 吴涛, 男, 1990年生, 博士后, 从事成矿规律与找矿预测研究。Email: wutao@mail.gyig.ac.cn

** 通讯作者 黄智龙, 男, 1967年生, 研究员, 从事成矿规律与找矿预测研究。Email: huangzhilong@vip.gyig.ac.cn

战略性关键金属是指对新材料、新能源、信息技术、航空航天、国防军工等新兴产业具有不可替代作用的金属,主要包括稀有、稀散、稀土和稀贵金属(蒋少涌等,2019;翟明国等,2019;胡瑞忠等,2020)。镓(Ga)是一种稀散金属(涂光炽等,2003),被广泛应用于半导体和太阳能电池等高科技领域和新兴产业,享有“电子工业脊梁”的美誉。镓的地壳丰度值为 15×10^{-6} (Wedepohl, 1995),很难形成独立矿床,主要伴生赋存于硫化物矿床的闪锌矿和铝土矿的一水铝石中(涂光炽等,2003;周家喜等,2009;George et al.,

2016;温汉捷等,2020)。在铅锌矿床中,镓等稀散金属富集达到可工业回收利用的程度需要非常苛刻的地质条件(温汉捷等,2019;翟明国等,2019)。因此,在全球范围内,铅锌矿中镓超常富集现象的报道鲜见,镓被认识、重视和开发利用程度也远远低于其他矿产资源(USGS, 2015;王登红, 2019;侯增谦等, 2020;温汉捷等,2020;吴涛,2021)。

湘西铅锌矿集区是位于扬子地块东南缘的鄂西-湘西-黔东南铅锌成矿带的重要组成部分之一,由北至南可分为洛塔、保靖、花垣、凤凰4个铅锌矿田(图1a,b),

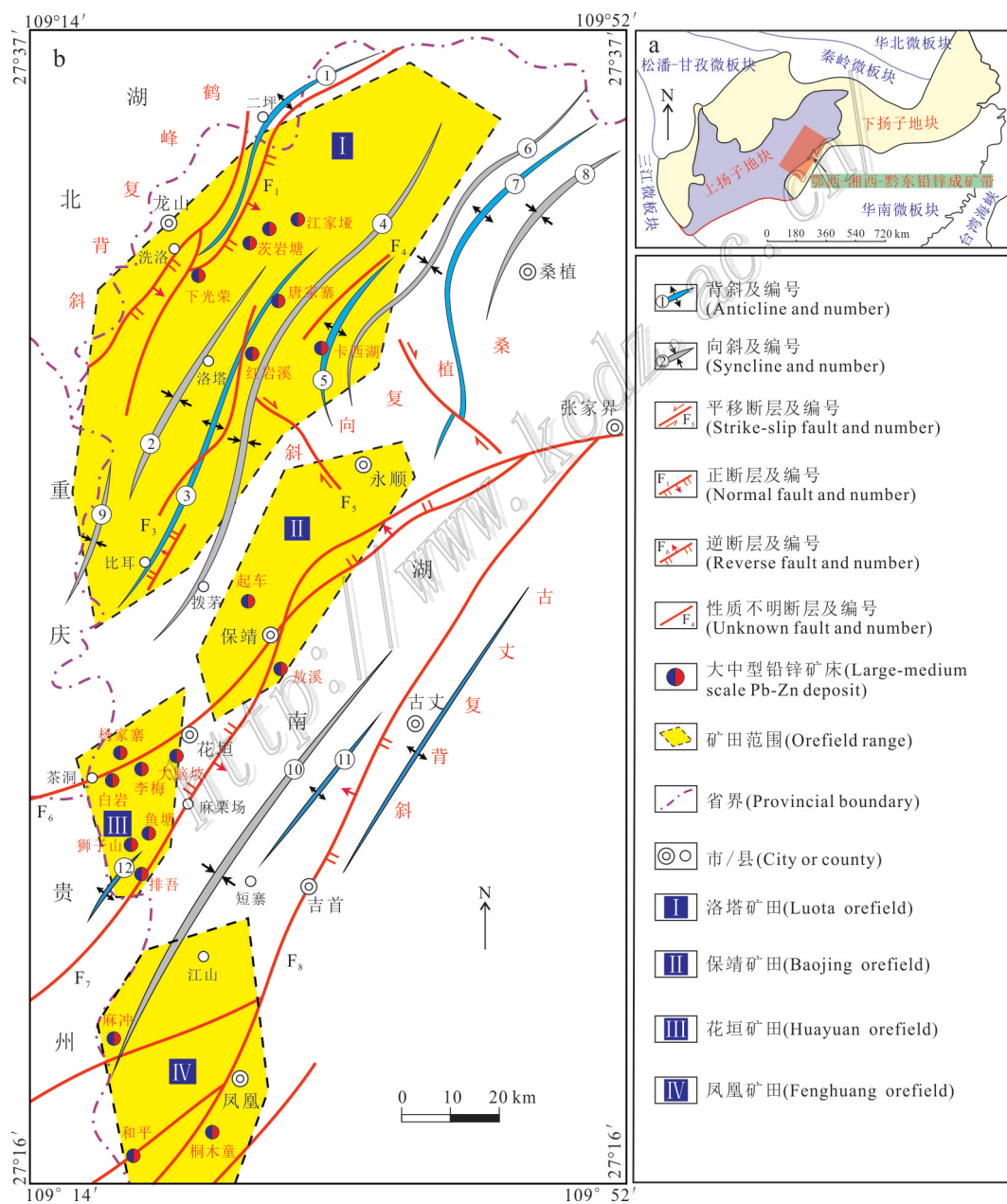


图1 鄂西-湘西-黔东南铅锌成矿带大地构造位置图(a,据李堃,2018修改)和湘西铅锌成矿区地质简图(b,据杨绍祥等,2007修改)
①—二坪背斜;②—洛塔向斜;③—红岩溪背斜;④—马蹄寨向斜;⑤—盐井背斜;⑥—龙溪寨向斜;⑦—二户溪背斜;⑧—桑植·官地坪向斜;

⑨—八面山向斜;⑩—涂乍-禾库向斜;⑪—万岩溪背斜;⑫—摩天岭背斜; F_1 —二坪断层; F_2 —洗洛断层; F_3 —砂坪-热水洞断层;
 F_4 —万民岗断层; F_5 —大车-儒家寨断层; F_6 —花垣-张家界断层; F_7 —麻栗场断层; F_8 —古丈-吉首断层

Fig. 1 Geotectonic location of the western Hubei-western Hunan-eastern Guizhou lead-zinc metallogenic belt (a, modified after Li, 2018) and geological map of western Hunan lead-zinc ore concentration district (b, modified after Yang et al., 2007)

①—Erping anticline; ②—Luota syncline; ③—Hongyanxi anticline; ④—Matizhai syncline; ⑤—Yanjing anticline; ⑥—Longxizhai syncline;
 ⑦—Erhuxi anticline; ⑧—Sangzhi-Guandiping syncline; ⑨—Bamianshan syncline; ⑩—Tuzha-Heku syncline; ⑪—Wanyanxi anticline;
 ⑫—Motianling anticline; F_1 —Erping fault; F_2 —Xiluo fault; F_3 —Shaping-Reshuidong fault; F_4 —Wanmingang fault;
 F_5 —Dache-Rujiadong fault; F_6 —Huayuan-Zhangjiajie fault; F_7 —Malichang fault; F_8 —Guzhang-Jishou fault

其中,花垣铅锌矿田内已探明多个大型-超大型矿床,如李梅、杨家寨、大脑坡等(杨绍祥等,2007;隗含涛,2017;吴涛,2021)。唐家寨铅锌矿床位于洛塔矿田中部,由唐家寨、头车湖和打溪3个矿段组成,矿体赋存于奥陶系碳酸盐岩中,矿石矿物90%以上为闪锌矿,平均品位5.2%,铅锌资源储量约55万t,达大型规模。电子探针(EPMA)分析发现,唐家寨铅锌矿床闪锌矿中 $w(\text{Ga})$ 很高,58个测点平均 $w(\text{Ga})$ 为 1320×10^{-6} ,约是其地壳丰度的100倍,超过铅锌矿床中镓工业回收利用最低标准(100×10^{-6} ;徐靖中,2007)10倍以上。为验证这一发现的可靠性,笔者进行了闪锌矿原位激光剥蚀等离子质谱(LA-ICPMS)分析结果显示,273个测点平均 $w(\text{Ga})$ 为 928×10^{-6} ,进一步证实唐家寨铅锌矿床闪锌矿中镓的显著超常富集,最高相对地壳丰度超过400余倍富集(图2)。

已报道的欧洲东南部 Rosia Montana 矿床闪锌

矿中平均 $w(\text{Ga})$ 为 334×10^{-6} (Cook et al., 2009),法国 Noailhac-Saint-Salvy 矿床闪锌矿中平均 $w(\text{Ga})$ 为 264×10^{-6} (Belissont et al., 2014),中国凡口矿床中闪锌矿的 $w(\text{Ga})$ 为 $75 \sim 550 \times 10^{-6}$ (邓卫等,2002),均明显比笔者发现的唐家寨铅锌矿床闪锌矿中平均 $w(\text{Ga})$ 低(图2)。此外,除凡口铅锌矿床外,中国其他铅锌矿床闪锌矿中镓超常富集鲜有报道,如会泽铅锌矿床闪锌矿中平均 $w(\text{Ga})$ 仅为 3.9×10^{-6} (Ye et al., 2011),花垣铅锌矿田闪锌矿中的平均 $w(\text{Ga})$ 仅为 6.9×10^{-6} (胡宇思,2020),大宝山铅锌矿床闪锌矿中平均 $w(\text{Ga})$ 仅为 29.2×10^{-6} (Ye et al., 2011),芦子园铅锌矿床闪锌矿中平均 $w(\text{Ga})$ 更低,仅为 0.3×10^{-6} (Ye et al., 2011)。

此外,通过测试研究和数据分析发现,唐家寨铅锌矿床中闪锌矿的Ga和Cu具有显著的正相关性($R^2=0.68$;图3d),并且在LA-ICPMS Mapping 图解

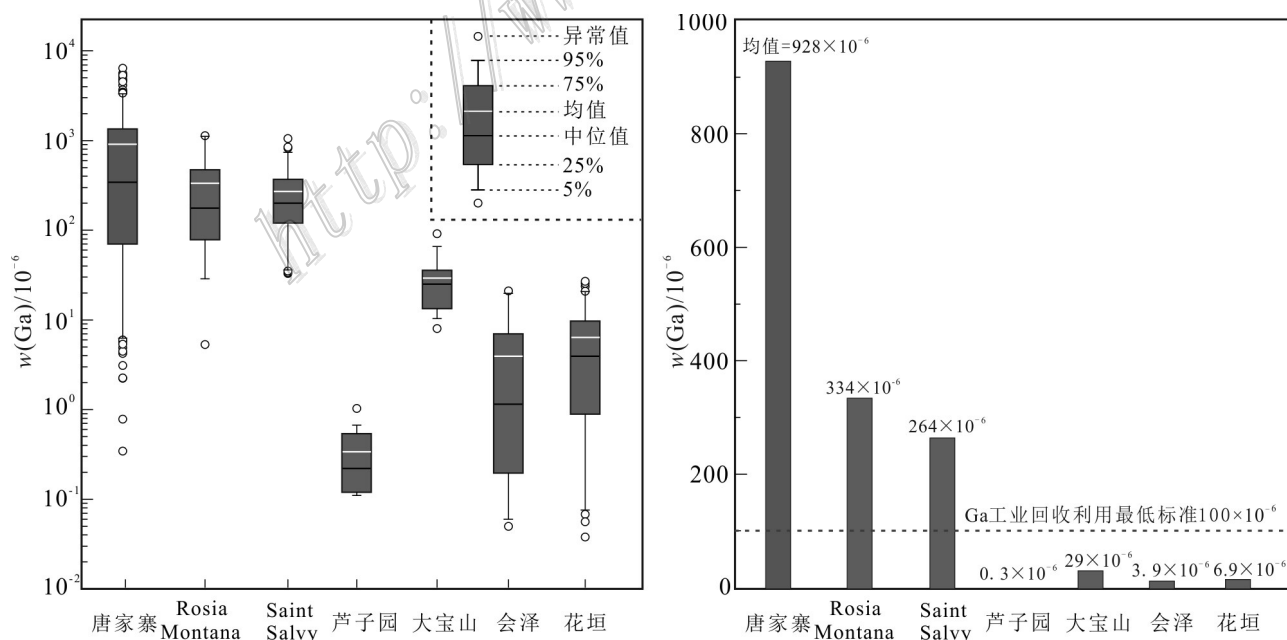


图2 唐家寨铅锌矿床与全球典型铅锌矿床闪锌矿中 $w(\text{Ga})$ 对比图

Fig. 2 Comparison of Ga contents in sphalerite between the Tangjiazhai and global typical Pb-Zn deposits

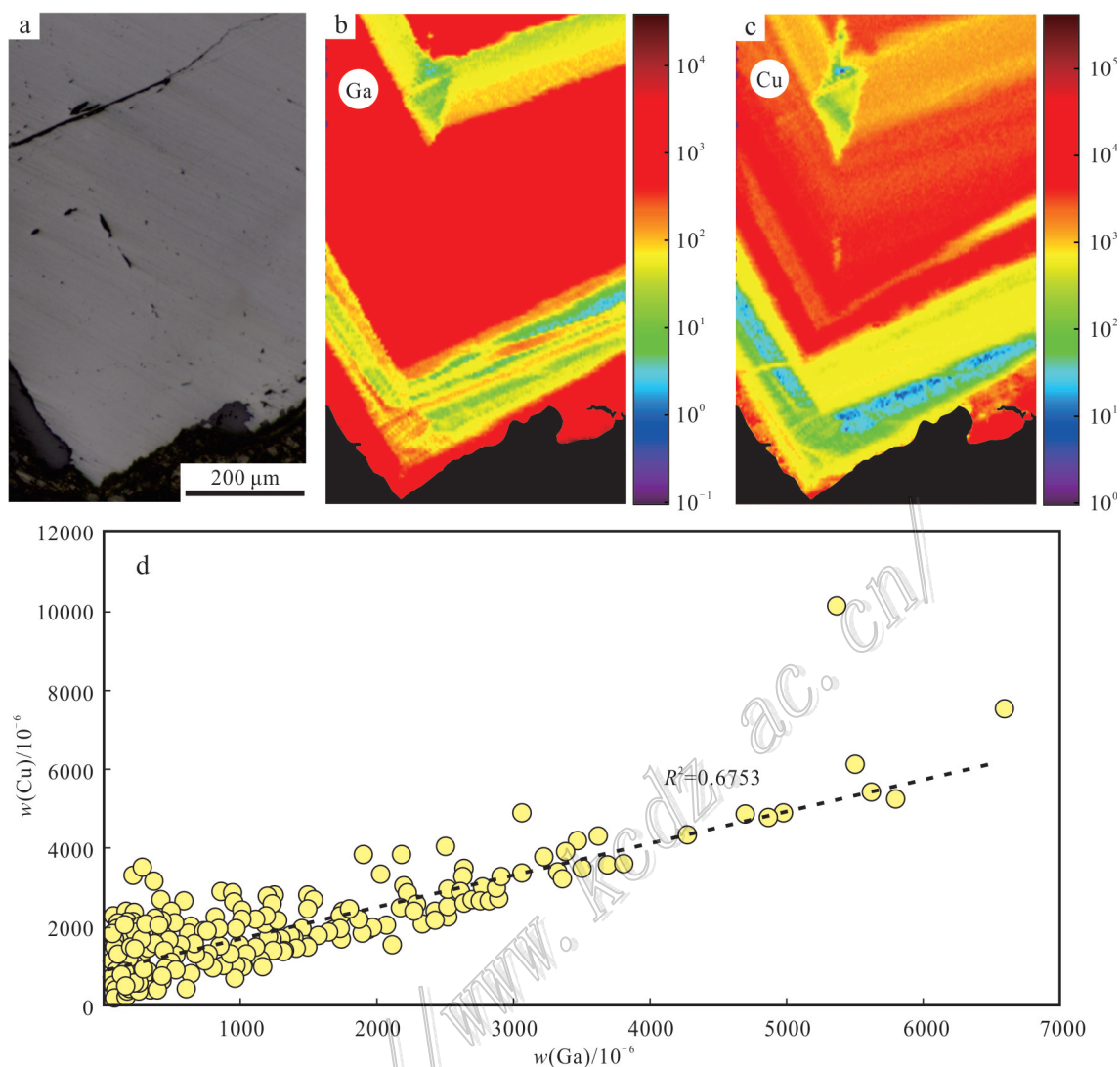


图3 唐家寨铅锌矿床闪锌矿 Cu-Ga LA-ICPMS Mapping(a~c)和含量相关性图解(d)

Fig. 3 LA-ICPMS Mapping (a~c) and relationship diagram of Ga-Cu content (d) of the sphalerite in the Tangjiazhai Pb-Zn deposit

(图3b~c)中,Ga和Cu也呈现出高度匹配的协变关系,另外,在扫描电镜下也未发现微米级Ga独立矿物的存在,因此,唐家寨矿床中Ga很可能与Cu一起耦合替代Zn进入到闪锌矿晶格之中($2\text{Zn}^{2+} \leftrightarrow \text{Ga}^{3+} + \text{Cu}^{+}$)。

根据唐家寨铅锌矿床规模和品位,笔者初步估算其中蕴含镓金属资源储量超过500 t,达中型共伴生镓矿床规模。此外,洛塔矿田铅锌金属远景资源量超过200万t,镓金属资源储量远景有望达到大型规模,潜在经济价值巨大。因此,面对镓等稀散金属激烈的国际竞争形势和高科技领域、新兴产业的迫切需求,笔者建议运用新的研究视角和研究方法开

展整个洛塔矿田内镓超常富集机制和资源综合利用研究,这对丰富和完善中国华南大面积低温系统稀散金属超常富集成矿理论具有重要意义,同时,也可作为铅锌矿床中稀散金属资源高效清洁利用提供理论支撑。

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