

## **Sulfur and Lead Isotopes of the No.3 Deposit in Xiongcu District, Tibet:**

### **Implications for Sources of Metals**

Yulin Deng<sup>1, a, \*</sup> and He Zhang<sup>1, b</sup>

<sup>1</sup>College of Earth Science, Chengdu University of Technology, Chengdu, China

<sup>a</sup>308061039@qq.com, <sup>b</sup>2287656362@qq.com

---

*Abstract: The Xiongcu district is located in the Gangdese porphyry copper belt (GPCB) in the southern margin of Lhasa terrane. To discuss the source of ore-forming material of No.3 deposit in Xiongcu district, here we report its sulfur and lead isotopes. Studies show that the  $\delta^{34}\text{S}$  values of ore sulfides vary from -1.3‰ to 1.4‰ with an average value of -0.85‰, and exhibit a tower distribution, which suggests a magmatic source. The  $^{206}\text{Pb}/^{204}\text{Pb}$ ,  $^{207}\text{Pb}/^{204}\text{Pb}$  and  $^{208}\text{Pb}/^{204}\text{Pb}$  ratios for metal sulfides vary in ranges of 18.204–18.468, 15.549–15.593 and 38.213–38.441, with the average value is 18.359, 15.567 and 38.351, respectively. The  $\mu$  values of lead isotope vary in ranges of 9.37–9.45, averaging 9.40. In the discrimination diagrams of the tectonic setting, all of the lead isotopic data points fall within the area between the mantle line and orogeny line, which suggesting the Pb materials were mainly from the mantle, and with little subducted sediments mixed.*

*Keywords: Gangdese, Xiongcu, sulfur isotope, lead isotope, sources of metals.*

---

## **1. INTRODUCTION**

The Gangdese porphyry copper belt (GPCB), which is 400 km long and 50 km wide, is situated at the southern margin of the Lhasa terrane. A number of porphyry and related skarn Cu (Mo, Au and Pb-Zn) deposits have been discovered in the GPCB, including Qulong, Jiama, Xiongcu, Zhunuo, Chongjiang, Pusanguo, Bangpu [1, 2]. The Xiongcu district is located in the western segment of the GPCB, 53 km west of Xigaze, which is composed of three individual deposits, i.e., the No. 1 (Xietongmen), No. 2 (Newtongmen), and No. 3 deposits. Previous studies have mainly focused on the geological characteristics, geochronology, and genesis of the No. 1 and 2 deposits [3-5]. However, the No. 3 deposit is a newly discovered porphyry Cu-Au deposit, there is a lack of information concerning sources of metals. In this study, S and Pb isotopic data were obtained to constrain the sources of metals of No.3 deposit in Xiongcu district.

## **2. GEOLOGICAL SETTING**

The Lhasa terrane, which can be divided into northern, central, and southern subterrane by the Shiquan River–Nam Tso Mélange Zone (SNMZ) and the Luobadui–Milashan Fault (LMF), is bounded to the north by the Banggong–Nujiang Suture Zone (BNSZ) and to the south by the

Yarlung–Zangbo Suture Zone (YZSZ, Fig. 1a). The Xiongcu district is located in the southern margin of the southern Lhasa subterrane. Three important deposits have been discovered in Xiongcu district, including No.1, No.2 and No.3 deposits. The Xiongcu district is structurally complex, containing Lower Jurassic to Eocene rock units (Fig. 1b). The Xiongcu Formation is exposed throughout the Xiongcu district, which consists of conglomerate, sandstone, siltstone, argillite, volcanic breccia, lava, and lesser limestone (165–195 Ma) [6]. Intrusive rocks include early Jurassic quartz diorite porphyry (171 Ma) [4], early–Middle Jurassic quartz diorite porphyry, Middle Jurassic quartz diorite (161–167 Ma) [4], late Jurassic granodiorite porphyry, diabase dykes (165 Ma), and Eocene biotite granodiorite, quartz diorite, granitic aplite dykes, and lamprophyre dykes. The F1 and F2 faults are the main structures in the Xiongcu district and they occur along the hangingwall and footwall of the No. 1 deposit. Other faults are post-mineralization structures and are distributed in bands, which are mainly NE-, N-, EW-, and NW-trending. The southern margin of the Xiongcu district has a developed EW-trending anticline (Fig. 1b). Constrained via Re–Os isotopic dating of molybdenite, the Xiongcu district includes two individual mineralization events, which are represented by the No. 1 ( $161.5 \pm 2.7$  Ma) and No. 2 deposit ( $172.6 \pm 2.1$  Ma). The No. 3 deposit is a newly discovered porphyry Cu–Au deposit.

The spatial shape of the No. 3 deposit is entirely stratiform or stratoid. The No. 3 deposit is mainly hosted in the early Jurassic quartz diorite porphyry (Fig. 1b). Extensive hydrothermal alteration is observed in the No.3 deposit. Four types of alteration zones, which are the potassic, sodic-calcic, phyllic and propylitic alteration zones were identified. The highest grade mineralization is associated with potassic alteration, rather than occurring in the transitional zone and outlying. The alteration comprises plentiful biotite and quartz, with variable concentrations of magnetite and minor K-feldspar. Sodic-calcic alteration is comprised of albite, actinolite, chlorite, epidote and quartz, with low to no sulfides, and overprints the mineralized potassic alteration. For phyllic alteration, quartz, sericite, and pyrite are the main alteration mineral assemblages with minor mineralization. This alteration event overprinted the potassic alteration. Propylitic alteration comprises chlorite, epidote, and quartz, calcite which mostly surrounds the deposit and is locally distributed within the deposit. The major types of the veins include quartz – sulfide veins, quartz – molybdenite – sulfide veins, magnetite – sulfide veins, biotite – sulfide veins, and chlorite – sulfide veins, pyrite veins, and chalcocopyrite – pyrite veins, actinolite veins (Fig. 2). The quartz – sulfide veins and chlorite – sulfide veins are main mineralized vein types in the No.3 deposit. The ore minerals are mainly chalcocopyrite and pyrite. The gangue minerals are mainly quartz, biotite, plagioclase, sericite, amphibole, chlorite and epidote.

### 3. SAMPLING AND METHOD

Selected samples in this study mainly originate from 3 diamond drill holes. Approximately 8 sulfide samples in main mineralized veins and alteration zones were chosen for S and Pb isotope analyses. The sulfur and lead isotopic compositions of sulfide were measured at the Analytical Laboratory, Beijing Research Institute of Uranium Geology, using Finnigan MAT 251 mass spectrometer and ISOPROBE-T Thermal Ionization Mass Spectrometer. The analytical precisions are higher than  $\pm 0.2\%$  for  $\delta S$ , and these values are reported relative to the PDB standard. The analytical precision for  $^{208}\text{Pb}/^{206}\text{Pb}$  and  $^{204}\text{Pb}/^{206}\text{Pb}$  are better than  $0.05\%$ .

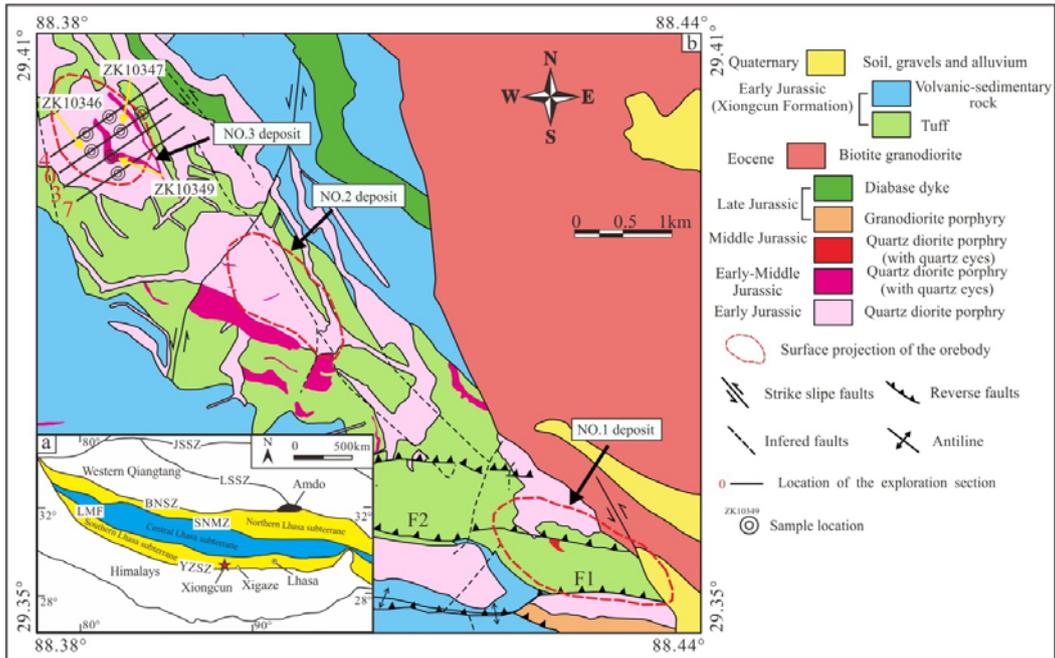


Fig 1. Simplified geologic map of the Xionggun district (modified after Tang et al [3])

**4. RESULT**

The S and Pb isotopic compositions of the sulfides from the No.3 deposit measured are presented in Table 1. The  $\delta^{34}\text{S}$  values of pyrite range from -0.6‰ to 1.4‰, with an average value of -0.07‰. The  $\delta^{34}\text{S}$  values of chalcopyrite have a range from -1.3‰ to -0.4‰, with an average value of -0.85‰. The  $^{206}\text{Pb}/^{204}\text{Pb}$ ,  $^{207}\text{Pb}/^{204}\text{Pb}$ , and  $^{208}\text{Pb}/^{204}\text{Pb}$  ratios of the eight sulfides vary from 18.204 to 18.468, 15.549 to 15.593, and 38.213 to 38.441, averaging 18.359, 15.567 and 38.351, respectively. The  $\mu$  value varies from 9.37 to 9.45, with an average value of 9.40.

Table 1. Sulfur and lead isotope compositions of ore sulfides from the No.3 deposit in Xionggun district

Sample No.	Mineral	$\delta^{34}\text{S}\text{-CDT}/\text{‰}$	$^{206}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{204}\text{Pb}$	$^{208}\text{Pb}/^{204}\text{Pb}$	$\mu$ <sub>a</sub>
10346-222	Pyrite	-0.6	18.468	15.578	38.352	9.41
10349-105.5	Pyrite	-0.6	18.320	15.549	38.333	9.37
10346-240.2	Pyrite	-0.2	18.374	15.568	38.404	9.40
10347-287.6	Pyrite	-0.6	18.204	15.555	38.320	9.40
10346-402.4	Pyrite	1.4	18.367	15.593	38.213	9.45
10349-84.8	Pyrite	0.2	18.320	15.566	38.404	9.41
10349-105.5	Chalcopyrite	-1.3	18.405	15.553	38.344	9.37
10346-240.2	Chalcopyrite	-0.4	18.416	15.571	38.441	9.41

a  $\mu = ^{238}\text{U}/^{204}\text{Pb}$ .

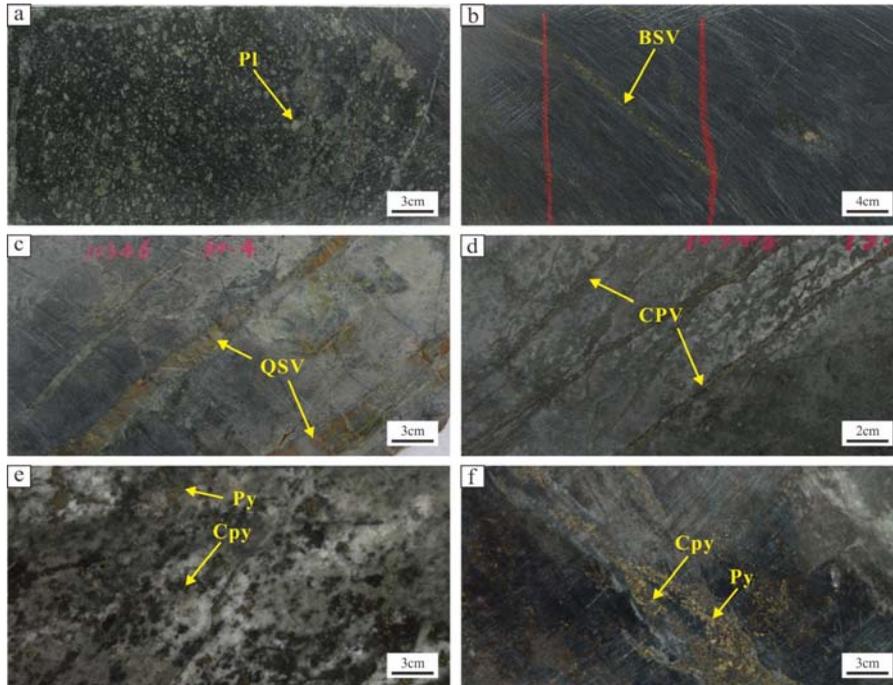


Fig 2. Photographs showing ore minerals, alteration and veins in the No.3 deposit in Xionggun district: (a) strong potassic alteration in quartz diorite porphyry; (b-d) the major veins distribute in the potassic alteration; (e-f) pyrite and chalcopyrite in the veins and alteration zone. Pl = plagioclase, Cpy = chalcopyrite, Py = pyrite, QSV = quartz – sulfide veins, CPV = chlorite – sulfide veins, BSV = biotite – sulfide veins

## 5. DISCUSSION

Sulfur isotopes have been proven to be highly effective resources with which to establish the source of ore-forming metals [7]. The phenomenon that all of the  $\delta^{34}\text{S}$  values of pyrite are greater than those of chalcopyrite is consistent with the  $\delta^{34}\text{S}$  enrichment condition of  $\delta^{34}\text{S}_{\text{pyrite}} > \delta^{34}\text{S}_{\text{chalcopyrite}}$  at isotopic equilibrium, indicating that the S isotopes of pyrite and chalcopyrite had reached equilibrium [7]. The  $\delta^{34}\text{S}$  values of the eight sulfide samples vary from -1.3‰ to 1.4‰, with an average of -0.26‰. The  $\delta^{34}\text{S}$  histogram reveals a tower distribution and the  $\delta^{34}\text{S}$  values are close to 0‰ (Fig. 3), which suggests a magmatic source [8].

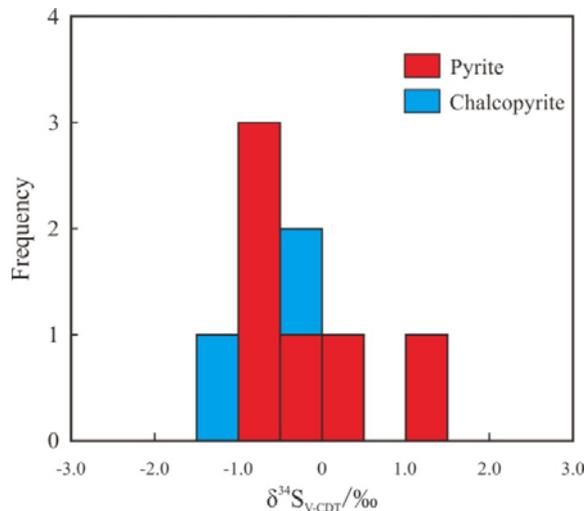


Fig 3. Histogram of  $\delta^{34}\text{S}$  value from No.3 deposit in the Xionggun district

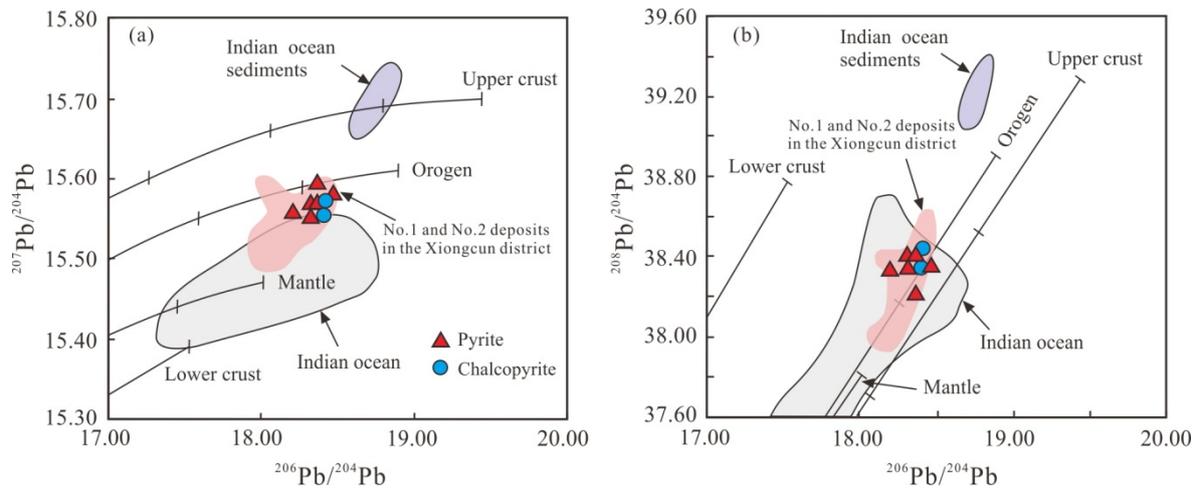


Fig 4. Lead isotope diagrams of the ore sulfides from No.3 deposit in the Xiongcu district (modified after Zartman and Doe [7]). Indian ocean MORB are from Sun [9] and Indian ocean sediments from Edwards et al. [10].

The lead isotopic compositions of sulfides can provide constraints on the sources of ore-forming Pb and deposit genesis [11]. As shown in Fig. 4, all of the lead isotopic data points fall within the area between the mantle line and orogeny line, which may suggest that the lead was derived mainly from mantle mixed with a small component of subducted sediments. The results obtained are similar to those from No.1 and No.2 deposits in the Xiongcu district (Fig. 4). Meanwhile, the high  $\mu$  values ( $>9.58$ ) reflect a crustal source for Pb sources [8]. The average  $\mu$  value of the sulfides in the No.3 deposit is 9.40 (Table 1), showing that the lead was mainly derived from the mantle source.

## 6. CONCLUSION

The  $\delta^{34}\text{S}$  values of the ore sulfides indicate that sulfur originated from a magmatic source. The lead isotopic compositions of sulfide indicate that the ore-forming metals were mainly derived from the mantle, with little subducted sediments mixed.

## ACKNOWLEDGEMENTS

This paper was supported by the China Geological Survey Programs (grant numbers: DD20160346).

## REFERENCES

- [1] Zengqian Hou, Zhiming Yang, Xiaoming Qu, Xiangjin Meng, Zhenqing Li, G. Beaudoin, Zongyao Rui, Yongfeng Gao and K. Zaw, "The Miocene Gangdese porphyry copper belt generated during post-collisional extension in the Tibetan Orogen", *Ore Geology Reviews*, 2009, Vol. 36, p25-51.
- [2] Youye Zheng, Xiang Sun, Shunbao Gao, Song Wu, Jing Xu, Junsheng Jiang, Xin Chen, Zhongying Zhao and Yan Liu, "Metallogenesis and the minerogenetic series in the Gangdese polymetallic copper belt", *Journal of Asian Earth Sciences*, 2015, vol. 103, p23-39.
- [3] Juxing Tang, Xinghai Lang, Fuwei Xie, Yiming Gao, Zhijun Li, Yong Huang, Feng Ding,

- Huanhuan Yang, Li Zhang, Qin Wang and Yun Zhou, “Geological characteristics and genesis of the Jurassic No. 1 porphyry Cu–Au deposit in the Xiongcu district, Gangdese porphyry copper belt, Tibet”, *Ore Geology Reviews*, 2015, vol. 70, p438-456.
- [4] Xinghai Lang, Juxing Tang, Zhijun Li, Yong Huang, Feng Ding, Huanhuan Yang, Fuwei Xie, Li Zhang, Qin Wang, Yun Zhou, “U-Pb and Re-Os geochronological evidence for the Jurassic porphyry metallogenic event of the Xiongcu district in the Gangdese porphyry copper belt, southern Tibet, PRC”, *Journal of Asian Earth Sciences*, 2014, vol. 79 (2), p608-622.
- [5] Qing Yin, Xinghai Lang, Zhiwei Cui, Zongyao Yang, Fuwei Xie and Xuhui Wang, “Geology and geochemistry constraints on the genesis of the No.2 porphyry copper-gold deposit in the Xiongcu District, gangdese porphyry copper belt, Tibet, China”, *Applied Ecology & Environmental Research*, 2017, vol. 15 (3), p477-508.
- [6] Xinghai Lang, Dong Liu, Yulin Deng, Juxing Tang, Xuhui Wang, Zongyao Yang, Zhiwei Cui, Yongxin Feng, Qing Yin, Fuwei Xie, Yong Huang and Jinshu Zhang, “Detrital zircon geochronology and geochemistry of Jurassic sandstones in the Xiongcu district, southern Lhasa subterrane, Tibet, China: implications for provenance and tectonic setting”, *Geological Magazine*, 2018, In press. Doi: 10.1017/S0016756818000122.
- [7] R. E. Zartman and B. R. Doe, “Plumbotectonics: the model (in the evolution of the upper mantle)”, *Tectonophysics*, 1981, vol. 75 (1), p135-162.
- [8] H. Ohmoto and R.O. Rye, Isotopes of sulfur and carbon. In: Barnes, H.L. (Ed.), *Geochemistry of Hydrothermal Ore deposits*, second ed. John Wiley and Sons, New York. 1979, p509-567.
- [9] S. S. Sun, “Lead isotopic study of young volcanic rocks from mid-ocean ridges, ocean islands and island arcs”, *Philosophical Transactions of the Royal Society Series A*, 1980, vol. 297 (1431), p409-445.
- [10] C. M. H. Edwards, M. A. Menzies, M. F. Thirlwall, J. D. Morris, W. P. Leeman and R. S. Harmon, “The transition to potassic volcanism in island arcs: the Ringgit-Beser complex, east Java, Indonesia”, *Journal of Petrology*, 1994, vol. 35 (6), p1557-1595.
- [11] F. P. Bierlein and N. J. McNaughton, “Pb isotope fingerprinting of mesothermal gold deposits from central Victoria, Australia: implications for ore genesis”, *Minerium Deposita*, 1998, vol. 33 (6), p633-638.