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# H-O-S-Pb isotopes for Sources of Ore-forming Material of Yinshuisi and Gongdongchong Pb-Zn Deposits in Eastern Dabie Orogen

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**Abstract.** The Yinshuisi and Gongdongchong are two important Pb-Zn deposits of the the eastern border of Qinling-Dabie metallogenic belt, Jinzhai County, Anhui Province.  $\delta D$  and  $\delta^{18}O$  values for the Yinshuisi and Gongdongchong deposits are -102.3‰ to -93.7‰ and -4.8‰ to -2.8‰, -85.7‰ to -74.0‰ and -1.7‰ to 0.1‰, respectively, indicating the ore-forming fluid is magmatic origin and mixed with the meteoric water.  $\delta^{34}S$  values of ore sulfides from the Yinshuisi and Gongdongchong deposits show a narrow interval of (1.7‰ to 4.4‰ and 2.4‰ to 5.3‰), suggesting sulfur in the these deposits was derived from magma. In the Yinshuisi and Gongdongchong deposit,  $^{206}Pb/^{204}Pb$ ,  $^{207}Pb/^{204}Pb$  and  $^{208}Pb/^{204}Pb$  values of sulfides point up the ore-forming metals from mixing source, mantle and crust, but not the same source. Pb isotopic compositions of the ore sulfides are close to the mineralization-related intrusions, indicating the intrusions provided major of the ore-forming material.

## 1. Introduction

The Dabie Orogen is a typical collisional orogenic belt between the Yangtze Craton (YC) and North China Craton (NCC). The extensive tectonic, magmatic and metallogenic events occurred in the Dabie belt in Mesozoic, making it become an important metallogenic belt for Mo, Pb, Zn, Au and Ag in China. The porphyry Mo deposits systems in the Dabie are Mesozoic in age. They were formed during the extension event following the collision of YC and NCC. However, the Pb-Zn deposits in the Dabie orogenic belt are not well constrained, such as their source, ages, origin of intrusions associated with the mineralization, ore-forming processes, and tectonic settings. Yinshuisi and Gongdongchong are two representative Pb-Zn deposits in the Dabie orogen, a systematic study on their ore-forming materials has not been understood yet. The aim of this paper is to make the comparison the mineralization and alteration and H-O-S-Pb isotopes from Yinshuisi and Gongdongchong, the result of which is the constraints on the source of ore-forming material and metallogenic evolution process.

## 2. Geological setting

The Dabie Orogen lies to the eastern end of the Central China orogenic belt between the YC and NCC, bounded by the Minggang-Lu'an fault to the north and Xiangfan-Guangji fault to the south (Fig. 1). The Tan-Lu fault made the Sulu orogen northward by about 500 km in the eastern end of the Dabie orogen. The Dabie metamorphic complex is composed of high-grade metamorphic rocks of Paleoproterozoic and Archean ages.



The Dabie orogen is divided into western and eastern parts by the S-N-trending Shang-Ma fault. The eastern part is composed of five main units from north to south: (1) the North Huaiyang zone (NHZ), (2) the North Dabie zone (NDZ), (3) the Central Dabie zone (CDZ), (4) the South Dabie zone (SDZ), and (5) the Susong zone (SZ) [1]. All these tectonic units were intruded by large volumes of Cretaceous magmatic rocks. The Yinshuisi and Gongdongchong Pb-Zn deposits are located in the eastern part of NHZ, which is composed of the Mid-Late Proterozoic Luzhenguan group and the Early Paleozoic Foziling group. They have generally experienced greenschist- and amphibolite-facies metamorphism.

The NW-trending faults are crosscut by NNE- to NE-trending faults in the Dabie orogen. Most of the Intrusions in the Dabie orogen are formed in the Yanshanian (Fig. 1), which widely developed along the NW- and NE-trending faults or at their intersections, consisting of intermediate to felsic granitoid plutons, with minor volcanic rocks and mafic or ultramafic intrusions. The volcanic-intrusive activities of these granitoids were from 143 to 110 Ma, which are associated with the porphyry Mo deposits in Dabie orogen.

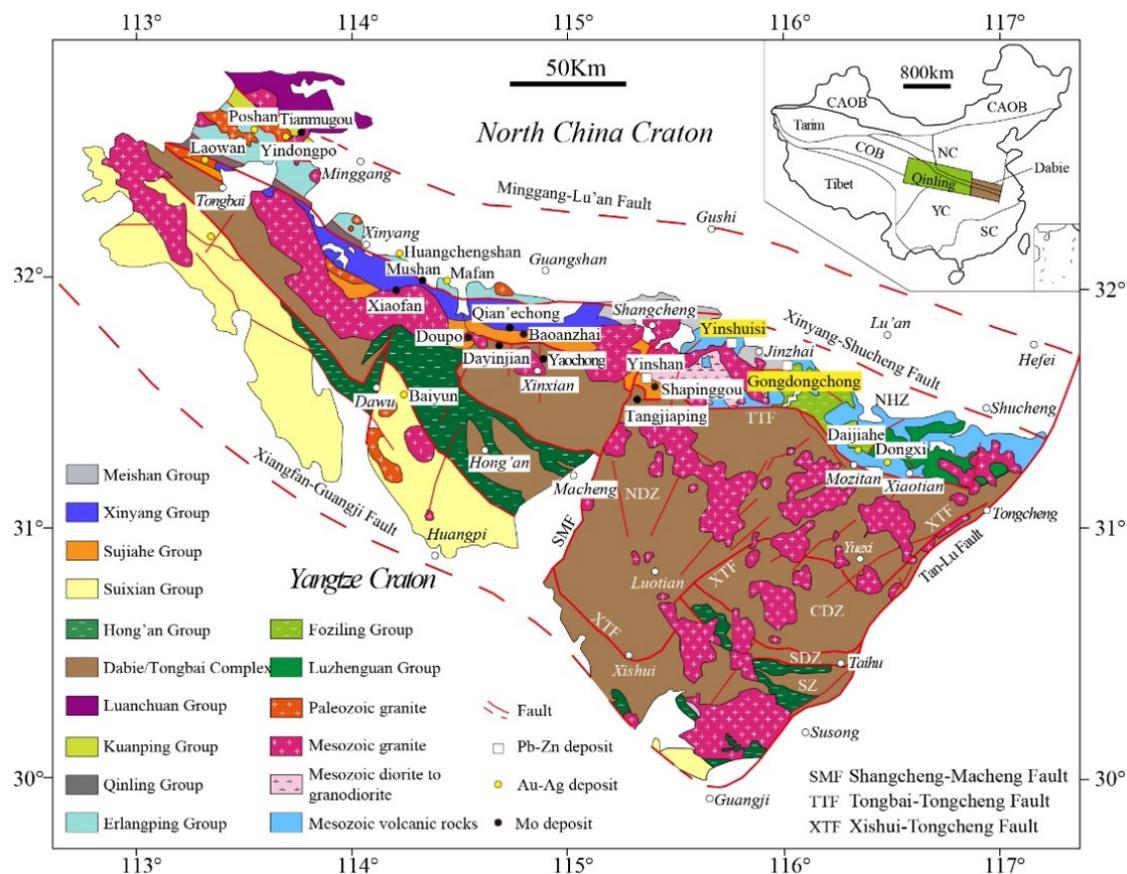


Figure 1. Geological sketch map of the Dabie orogen (based on Ref. [2]).

### 3. Local and ore geology

#### 3.1. Yinshuisi deposit

The Yinshuisi Pb-Zn deposit is the largest Skarn deposit in Dabie orogen. Orebodies mainly occur in the fracture zones between the marble of the Xianrenchong Formation and phyllites of Zhengtangzi Formation, Luzhenguan Group, or in the contact zones between syeno-granite porphyry and marble. Most of the orebodies are lense-like and stratiform-like. NW-trending and NE-trending faults are the main structures in the Yinshuisi deposit. The Xianrenchong and Zhengtangzi Formations were intruded by the syeno-granite porphyry, which has caused the skarn and mineralization.

Skarn (epidote, actinolite, and chlorite) is the most important wall-rock alteration in the Yinshuisi deposit, followed by silicification, and carbonate. The epidote, actinolite and chlorite alteration are closely related to magnetite-mineralization, however galena- and sphalerite-mineralization is associated with silicification in Yinshuisi. The Pb-Zn ore textures are mainly disseminated and massive. Ore minerals include galena, sphalerite, magnetite and chalcopyrite, with minor pyrite and pyrrhotite. Gangue minerals include epidote, actinolite, chlorite, quartz, calcite, and fluorite.

### 3.2. Gongdongchong deposit

The Gongdongchong Pb-Zn deposit is one of the important breccia-type lead-zinc polymetallic deposits in the east end of Qinling-Dabie metallogenic belt. Ore bodies are controlled by the breccia bodies and situated in the Early Palaeozoic Zhufoan Formation of Foziling Group, which is composed of mica quartz schist and phyllite.

The Gongdongchong breccia pipe is hosted in the mica quartz schist of Foziling Group, and is cylindrical shape in cross-section view. The breccia pipe extends >775 m vertically, dipping NW, the dip angle is 70°~90°. Mineralization in the Gongdongchong deposit is mainly disseminated in the breccia matrix with minor stockwork veinlets. The ore minerals are galena, sphalerite, chalcopyrite, pyrite, with minor native gold, cervelleite and silver-bearing tetrahedrite. Gangue minerals are quartz, calcite, dolomite, siderite, sericite, and chlorite. Quartz and carbonate form euhedral associated with sulfides in the breccia matrix.

There are no intrusions in the Gongdongchong deposits, but field investigations and Liu et al. (2018) demonstrate that Pb-Zn mineralization and cryptoexplosion have a genetic link with the quartz syenite porphyry cropped out in the Sunchong area [3], which is the periphery of Gongdongchong deposit.

## 4. Results

### 4.1. Hydrogen-oxygen isotopes

The  $\delta D$  and  $\delta^{18}O$  values of eight quartz samples of ore-forming stage from Yinshuisi and Gongdongchong vary from -102.3‰ to -93.7‰, -85.7‰ to -74.0‰, and 2.1‰ to 4.1‰, 5.2‰ to 7.0‰ respectively. The  $\delta^{18}O$  values of fluids in quartz samples calculated by the equation  $1000\ln\alpha_{\text{quartz-water}} = 3.38 \times 10^6 T^{-2} - 3.40$  [4] vary from -4.8‰ to -2.8‰ and -1.7‰ to 0.1‰ respectively.

### 4.2. Sulfur isotopes

$\delta^{34}S$  values of three sphalerite samples from the Yinshuisi deposit vary from 3.7‰ to 4.4‰; three galena samples have  $\delta^{34}S$  values from 1.7‰ to 2.2‰;  $\delta^{34}S$  value of one chalcopyrite is 3.4‰.  $\delta^{34}S$  values of two sphalerite samples from the Gongdongchong deposit range from 3.6‰ to 4.7‰;  $\delta^{34}S$  values of two galena samples vary from 2.4‰ to 2.9‰;  $\delta^{34}S$  values of two pyrite samples vary from 4.8‰ to 5.3‰;  $\delta^{34}S$  values of two chalcopyrite samples vary from 4.1‰ to 4.5‰.

### 4.3. Lead isotopes

The  $^{206}Pb/^{204}Pb$  ratios of seven ore sulfides from the Yinshuisi deposit range from 16.550 to 16.705,  $^{207}Pb/^{204}Pb$  range from 15.369 to 15.459, and  $^{208}Pb/^{204}Pb$  range from 37.463 to 37.767.  $^{206}Pb/^{204}Pb$ , The  $^{206}Pb/^{204}Pb$  ratios of eight ore sulfides from the Gongdongchong deposit range from 17.804 to 17.868,  $^{207}Pb/^{204}Pb$  range from 15.567 to 15.621, and  $^{208}Pb/^{204}Pb$  range from 38.496 to 38.669.

## 5. Source of ore-forming fluids and metals

$\delta D_{\text{water}}$  and  $\delta^{18}O_{\text{water}}$  values of four quartz samples from Yinshuisi deposit vary from -102.3‰ to -93.7‰ and -4.8‰ to -2.8‰, respectively. Four quartz samples of Gongdongchong deposit have  $\delta D_{\text{water}}$  of -85.7‰ to -74.0‰, and  $\delta^{18}O_{\text{water}}$  values of -1.7 to 0.1. The  $\delta^{18}O_{\text{water}}$  values are much lower than the primary magmatic water ( $\delta^{18}O = 5.5\sim 10\%$ , [5]). And all the data points distribute in the field between the meteoric water line and primary magmatic water in the  $\delta D_{\text{water}}$  vs.  $\delta^{18}O_{\text{water}}$  diagram (Fig. 2), suggesting the ore-forming fluid is derived from a mixing source of magmatic water and meteoric water during the

main mineralization stage. From the perspective of a single deposit, the data points of Yinshuisi deposit are more close to the meteoric water line, indicating that the ore-forming hydrothermal fluid of Yinshuisi deposit has more meteoric water ingredient.

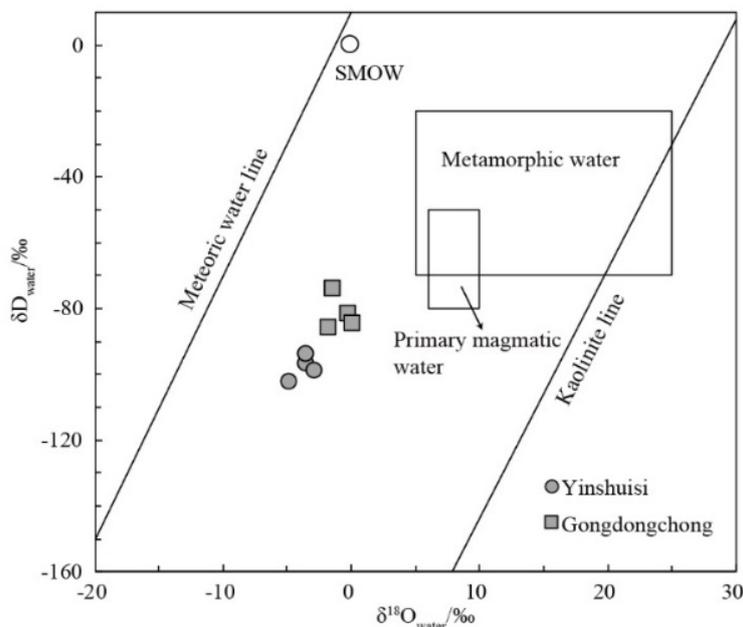


Figure 2.  $\delta D$ - $\delta^{18}O$  diagram of water from the Yinshuisi and Gongdongchong Pb-Zn deposits (based on Ref. [5]).

The  $\delta^{34}S$  values of sulfide samples from Yinshuisi and Gongdongchong deposits show a relatively narrow range of 1.7‰ to 4.4‰ and 2.4‰ to 5.3‰ respectively (Fig. 3). The paragenetic relationship of the galena, sphalerite, chalcopyrite and pyrite, and the value of  $\delta^{34}S$  (Py) >  $\delta^{34}S$  (Sp) >  $\delta^{34}S$  (Cpy) >  $\delta^{34}S$  (Gn) suggesting an overall equilibrium of sulfur isotopes among sulfides during the evolution of the mineralization [6]. In general,  $\delta^{34}S$  has three different origin in nature, including the sulfur in seawater (almost +20‰), the sulfur in sediments (approximately low to -40‰, [7]) and the mantle source of sulfur ( $0 \pm 3$ ‰, [8]). In fact, as shown in Figure 3, our obtained  $\delta^{34}S$  values of sulfides in the these two Pb-Zn deposits give a very uniform and narrow range, excluding the possibility of a multiple sulfur sources. The  $\delta^{34}S$  values of these two deposits in the Dabie orogen are similar to typical magma-derived fluids (-3 to +7‰, [9]), and most magmatic hydrothermal deposits [7], indicating that sulfur in the Pb-Zn deposits in the Dabie orogen are of magmatic origin.

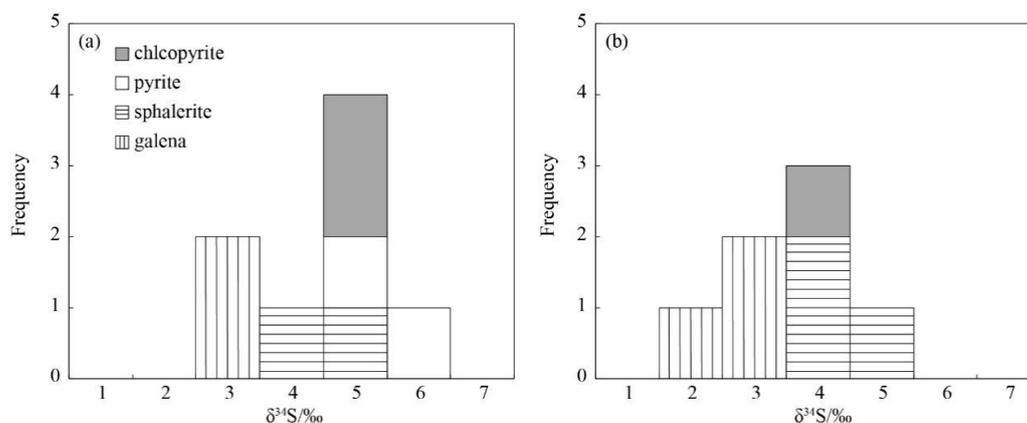


Figure 3. Histograms of  $\delta^{34}S$  values of ore sulfides from the Yinshuisi and Gongdongchong deposits. (a) Yinshuisi, (b) Gongdongchong.

All the sulfides samples of the Yinshuisi and Gongdongchong deposits have narrow range of  $^{206}\text{Pb}/^{204}\text{Pb}$ ,  $^{207}\text{Pb}/^{204}\text{Pb}$ , and  $^{208}\text{Pb}/^{204}\text{Pb}$  ratios. In the  $^{207}\text{Pb}/^{204}\text{Pb}$  vs  $^{206}\text{Pb}/^{204}\text{Pb}$  diagram (Fig. 4), ore sulfides data points of Yinshuisi deposit show an approximate linear distribution, which suggest a mixing source of two different Pb reservoirs [10]. The sulfides data points distribute between the mantle and orogen curves, suggesting that mantle components could be involved in the Yinshuisi mineralization. The sulfides data points of Gongdongchong are plotted close to the orogen curve, indicating that the majority of ore-forming materials are also derived from a mixing source of mantle and crust. In addition, most of the ore sulfides data points overlap closely related to the Pb isotopic compositions for the porphyry in Yinshuisi and Gongdongchong deposits (Fig. 4), suggesting that mineralization-related porphyries supplied the major materials of the Pb-Zn deposit in Debie orogen. However the mineralization-related porphyries are not the same source.

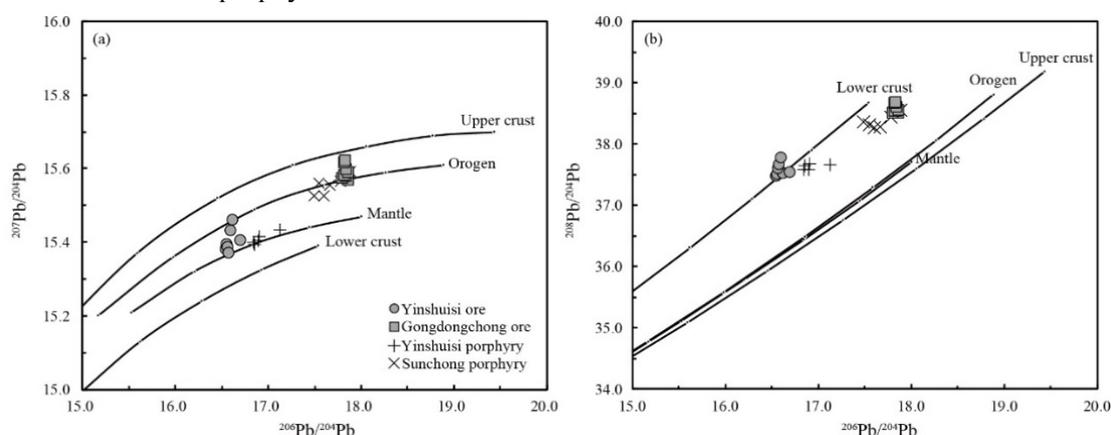


Figure 4. Pb isotopes of ore sulfides from the Yinshuisi and Gongdongchong (based on Ref. [11]). Pb isotope of the Sunchong porphyry are sourced from Ref. [3].

## 6. Conclusions

- (1). Hydrogen-oxygen isotopes show that ore-forming fluids in the Yinshuisi and Gongdongchong deposits were magmatic origin and mixed with mounts of the meteoric water
- (2). Sulfur isotopes show that sulfur in Yinshuisi and Gongdongchong deposits were of magmatic origin.
- (3). Lead isotopes show that ore-forming materials in Yinshuisi and Gongdongchong deposits were derived from mixing source of two different Pb reservoirs, mantle and crust. The mineralization-related porphyries supplied the major materials of the Pb-Zn deposit in Debie orogen.

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