CHEMICAL ENGINEERING TRANSACTIONS

VOL. 62, 2017

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Fei Song, Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216

DOI: 10.3303/CET1762080

Geological Features and C-H-O-S-Pb Isotopes at the Zhazixi Sb-W Deposit

Liangliang Jia[a,b], Tagen Dai[a], Chaozhuang Xi[a,c,d*], Dexian Zhang[a]

[a] MOE Key Laboratory of Metallogenic Prediction of Nonferrous Metals, School of Geosciences and Info-Physics, Central South University, Changsha, China
[b] Hunan Institute of Coal Geological Exploration, Changsha, China
[c] Geological Survey Institute for Nuclear resources, Guizhou Geological Exploration Bureau for Nonferrous Metals and Nuclear Industry, Guiyang, Guizhou
[d] Hunan gold group Co.,Ltd.,Changsha, China
xczcsummmmmm@126.com

The Zhazixi Sb–W deposit in the Xuefeng arc metallogenic belt, South China, is one of the Sb deposits in Precambrian strata. The sources of the ore-forming fluid and the metallogenic material, as the bone of contention in geochemical field, are researched by means of geological features and C-H-O-S-Pb isotopes. According to the isotope analysis of carbon, hydrogen and oxygen, most of the fluids derived from magmatic water and meteoric water in the Zhazixi Sb–W deposit. The result of sulfur and lead isotopes shows that the metallogenic material of Sb derived from Banxi group strata, and W derived from deep magmatic rock in the Zhazixi Sb–W deposit. The Zhazixi Sb–W deposit is a Yanshanian polygenetic compound deposit.

1. Introduction

The Zhazixi Sb–W deposit in the Xuefeng arc metallogenic belt, South China, is one of the Sb deposites in Precambrian strata. The Zhazixi Sb–W deposit, where Sb and W mineral coexist in different orebodies, exhibits a unique metal association of W and Sb. The Zhazixi Sb–W deposit is located in the intersection part of the Xuefeng arc metalloenic belt with the NW Xinhua-Lianshao regional fault, and the research for the Zhazixi Sb–W deposit is important to Sb deposits and Sb-Au deposits in both the Xuefeng arc metallogenic belt and the middle area of Hunan.

Since the company was constructed in 1906, the main exploration object at present time is Sb orebodies.

Previous research about the Zhazixi Sb–W deposit mainly concentrated on geologic characteristics, ore control factors, and metallogenic epoch, and seldom showed ore-forming material source, and the study about each source of Sb and W was almost blank in the past. Based on the previous research, combined with field observations and regional mineral geologic characteristic, this study summarizes the lithology and Sb element contents of the strata of the mine filed, wall rock alteration, mineralization characteristics, orebody characteristics etc, fluid inclusion and carbon, hydrogen, oxygen, sulfur and lead isotopic compositions to reveal the ore-forming process, explore control factors of mineralization and each source of Sb and W, and provide new reference for ore-search breakthrough in the Xuefeng arc metallogenic belt, South China.

2. Regional Geological Background

The Zhazixi Sb–W deposit is located in the northeastern part of the Xuefeng arc metallogenic belt (Figure 1), where The Xuefeng uplift trends to the northeast from the east. The majority of outcropping strata are Banxi group strata, Cambrian strata, and Devonian strata. Banxi group strata is a suit of clastic rocks containing volcanic material and is the principal ore-host strata.

This region passed through Xuefeng movement, Jinning movement, Caledonian movement, Hercynian movement, Indo-China movement, and Yanshannian movement. The regional geologic structure trends to the northeast in region, The NE folds and faults arrange in imbrication together form the fault-block modes. The regional faults and Banxi group strata together control the distribution of the deposits (pits) in region.

Please cite this article as: Liangliang Jia, Tagen Dai, Chaozhuang Xi, Dexian Zhang, 2017, Geological features and c-h-o-s-pb isotopes at the zhazixi sb-w deposit, Chemical Engineering Transactions, 62, 475-480 DOI:10.3303/CET1762080

The magmatic rocks distribute unevenly in the Xuefeng arc metallogenic belt. Granite bodies and dikes are located in north and east side. Few mafic-ultramafic dikes appear in other area.

A large number of gold deposits(pits), antimony deposits(pits) and tungsten deposits(pits), including some super large deposits, even world-class deposits, have been found in region, where antimony deposits were divided into three types: the single Sb deposits(the world-class Xikuangshan Sb deposit), Sb-W deposits(the Zhazixi Sb–W deposit), Sb-Au-W deposits(the super large Woxi Sb-Au-W deposit) .

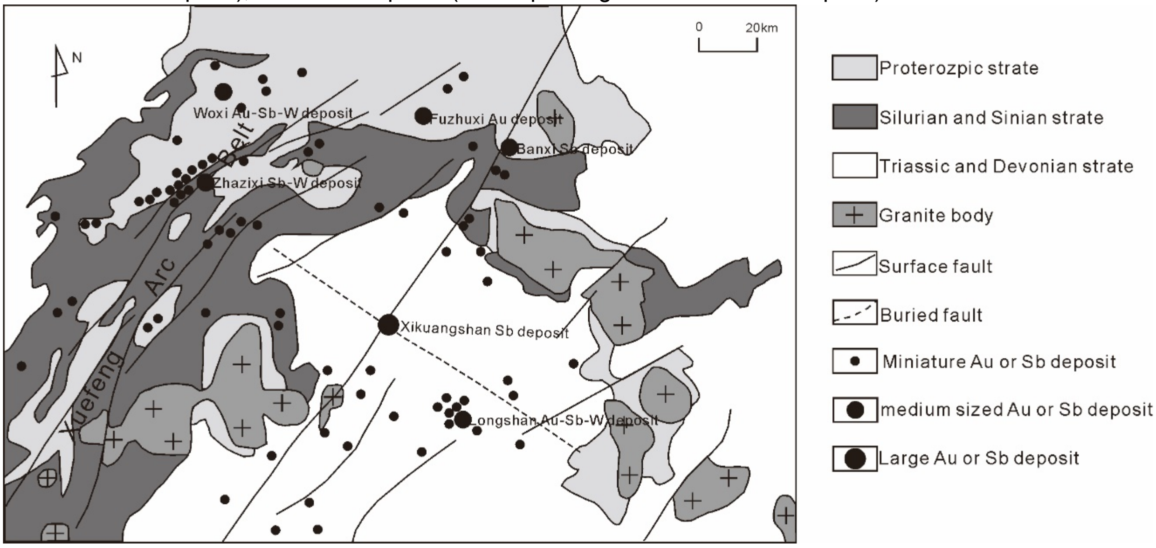

Figure 1: Regional geological map of the Zhazixi Sb-W deposit

3. Results

3.1 Carbon, Hydrogen and oxygen isotopes

The $\delta^{13}C_{PDB}$ values of quartz-stibnite veins are −5.1‰ to 2.1‰ with an average of −1.84‰.. The δD_{H2O} values of quartz-stibnite veins are −49‰ to −78‰ with an average of −61.6‰. The quartz–stibnite veins had $\delta^{18}O_{quartz}$ values varying from 15.2 to 18.2‰ (average of 17.54‰), respectively. The quartz–stibnite veins had $\delta^{18}O_{H2O}$ values varying from 3.5 to 7.4‰ (average of 5.84‰), respectively (Table 1).

Table 1: Carbon, Hydrogen and oxygen isotopes in the Zhazixi Sb(W) deposit

Sample Serial No.	Simple Mineral	$\delta^{13}C_{PDB}$‰	$\delta D_{V\text{-}SMOW}$‰	$\delta^{18}O_{V\text{-}SMOW}$‰	$\delta^{18}O_{H2O}$‰
ZZX01	Quartz	-5.1	-68	17.9	6.2
ZZX02	Quartz	-4.7	-57	19.1	7.4
ZZX03	Quartz	-2.3	-49	15.2	3.5
ZZX04	Quartz	2.1	-56	17.3	5.6
ZZX05	Quartz	0.8	-78	18.2	6.5

3.2 Sulphide and lead isotopes

The $^{34}S_{V\text{-}CDT}$ values of stibnite ranged from -2.6‰ to 3.5‰ (average of 1.1‰) (Table 2). Pb isotopic data of stibnite (Table 2) show that the $^{208}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and$^{206}Pb/^{204}Pb$ ratios were 38.167~38.928 (mean of 38.553), 15.616~15.674 (average of 15.632), and 18.079~18.815 (mean of 18.362), respectively

Table 2: Sulphide and lead isotopes in the Zhazixi Sb(W) deposit

Sample Serial No.	Simple Mineral	$\delta^{34}S_{VCDT}$‰	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
ZZX01	Stibnite	2.1	18.575	15.619	38.753
ZZX02	Stibnite	3.5	18.079	15.624	38.591
ZZX03	Stibnite	2.2	18.157	15.625	38.167
ZZX04	Stibnite	0.3	18.815	15.674	38.928
ZZX05	Stibnite	-2.6	18.186	15.616	38.324

4. Discussion

4.1 Sources of mineralization fluids

In order to study the ore forming fluid, the predecessors have done much works by means of Sm-Nd isotope and Sr isotope in scheelite and He and Ar isotope in stibnite, but the results are different, for example, Peng et al. (2008) found high radio genic Sr, classified Nd isotope initial compositions of the samples of scheelite into two groups, and thought the ore forming fluid remainly derived from two sources: one probably originating from the prototerozoic sequence or underlying terrigenous basement clastic rocks and the other probably related to the basic/ultrabasic rocks of the lengjiaxi group. Wang et al.(2012) found Nd isotope initial compositions of the samples of scheelite was consistent with Nd isotope initial compositions of Banxi group strata, and thought the ore forming fluid came from proterzoic strata or the older strata. Zeng et al. (2017) studied He and Ar isotope in stibnite and thought the ore forming fluid came from the crust.

The carbon isotope remains almost the same during the diagenetic process, thus has been used as the tracer of the ore-forming fluids. Previous studies have suggested that the carbon isotope in ore-forming solution derives from three sources(Zhang et al. 2012): (1) the first kind comes from the upper mantle or magmatic rocks, and ranges from -5‰~-2‰ and -9‰~-3‰(Taylor, 1986); (2) the second kind comes from degassing of carbonate rocks or the interactions of brine with pelite, and range from -2‰~+3‰ (Veizer et al. ,1980); (3) the last kind comes from the organic carbon in rocks, ranges from -30‰~-15‰ (Ohmoto, 1972. Ohmoto and Rye, 1979; Zheng et al., 2000). The analysis of carbon isotopes shows that carbon isotopes of the Zhazixi Sb–W deposit are similar to the carbon isotopic compositions of the upper mantle and magmatic rocks, In the contrast diagram of carbon isotopes (Figure 2), the carbon isotopic fluid inclusions in quartz are similar to the carbon isotopic compositions of the diamond and carbonatite rocks, and are obviously different from the organic carbon. So the carbon in the Zhazixi Sb–W deposit should come from the deeper magmatic rocks.

Diagram of $\delta^{18}O_{H2O}$-$\delta^{13}C_{PDB}$ isotopes compositions (Figure 3), shows the range of oxygen and carbon isotope from the upper mantle or magmatic rocks, marine carbonates and organic carbon, and the change trend from the three sources by the arrow (Liu et al., 2000). Figure 3 shows carbon isotopes in the ore-forming fluids of the zhazixi Sb-W deposit mostly came from the mantle, a little was formed by the dolomitization of marine carbonate. In the diagram of δD_{SMOW}-$\delta^{18}O_{SMOW(H2O)}$ isotopes compositions (Figure 4) , the samples of the Zhazixi deposit are mostly plotted as magmatic water.

Liu (2009) and Chen et al. (2015) found concealed rock bodies in deep part of the region, consistent with the analysis of carbon , hydrogen and oxygen isotopes, thus this study think the thermal fluids associated with mineralization derived from magmatic water and metamorphic water.

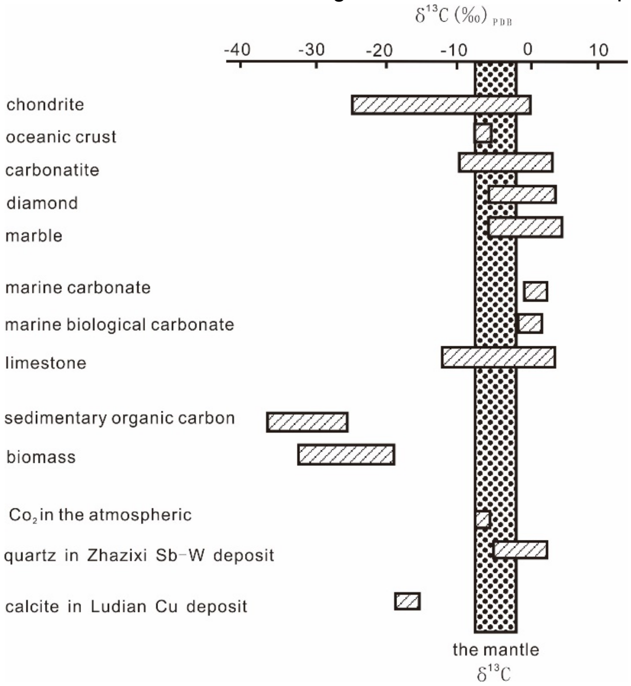

Figure 2: Composition of carbon isotopes in the Zhazixi Sb(W) deposit

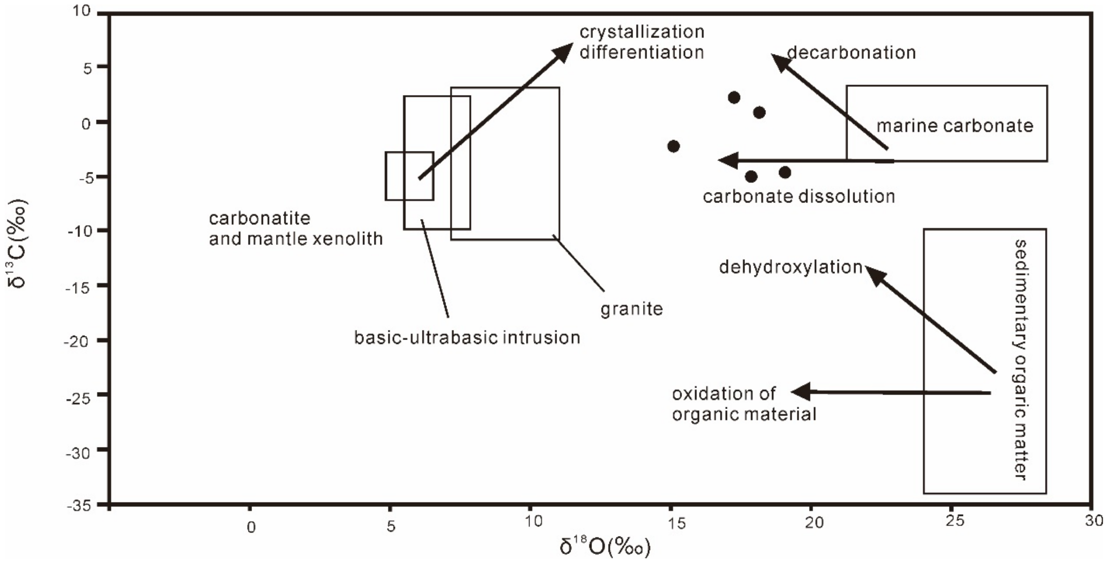

Figure 3: Diagram of $\delta^{18}O_{H2O}$-$\delta^{13}C_{PDB}$ isotopes compositions in granite vein fluid of Zhazixi Sb(W) deposit

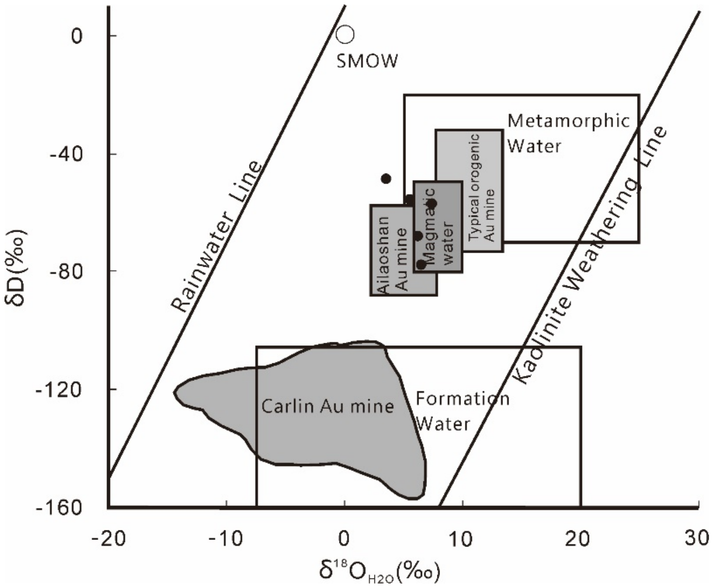

Figure 4: Diagram of δD_{SMOW}-$\delta^{18}O_{SMOW(H2O)}$ isotopes compositions in granite vein fluid of Zhazixi Sb(W) deposit. Carlin-type gold deposit from Field et al., 1985; Formation water from Sheppard., 1986; Ailaoshan gold mine from Sun et al., 2009; Gold deposit with specific orogenesis from Goldfarb et al., 2004

4.2 Sources of mineralization materials

In order to study the ore-forming material source, the predecessors have done much works by means of trace rare earth elements in ores and sulphide and lead isotope in stibnite, but the results are different, For example, Deng et al. (2008) analysised rare earth elements and trace elements in ores and host wall-rocks and thought the source materials were mainly derived from the crust and the mantle; Zeng et al. (2017) thought sulphide come from the Wuqiangxi Formation of the Banxi group, and lead are upper- lower crust mixed lead by means of sulphide and lead in stibnite. Previous studies are based on the geochemical data, and deduce the ore-forming material source from metallogenic hydrothermal. The Zhazixi Sb-W deposit is a special deposit, where antimony orebodies and tungsten orebodies coexist in different orebodies, but not a unique deposit. The Xuefeng arc metallogenic belt is a great Au-Sb-W polymetallic metallogenic belt, where Au deposits, Sb deposits and W deposits present a definite rule of distribution, thus it is more scientific that the ore-forming material source are researched through geochemical characteristics, geological features of the ore deposit and regional geological characteristics.

Restricted by the source of ore-forming fluid, the metallogenic material of the Zhazixi Sb-W deposit could derive from three sources: (1) The first kind comes from buried igneous rocks, (2) The second kind comes from many geological strata, which ore-forming fluid cross, (3) The last kind comes from buried igneous rocks and the strata.

According to testing result, sulfur isotopes have a wide range. Figure 5 shows the covariation diagram of $^{206}Pb/^{204}Pb$~$^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$~$^{208}Pb/^{204}Pb$ lead isotopes ratios. In the figure, Zhazixi Sb-W deposit fall on the area of the lower crust and the area of the orogenic belt. So the testing result of sulfur isotope and lead isotope shows the ore-forming material derived from the source of igneous rocks and strata mixed, which is similar to the result of C, H and O isotopes.

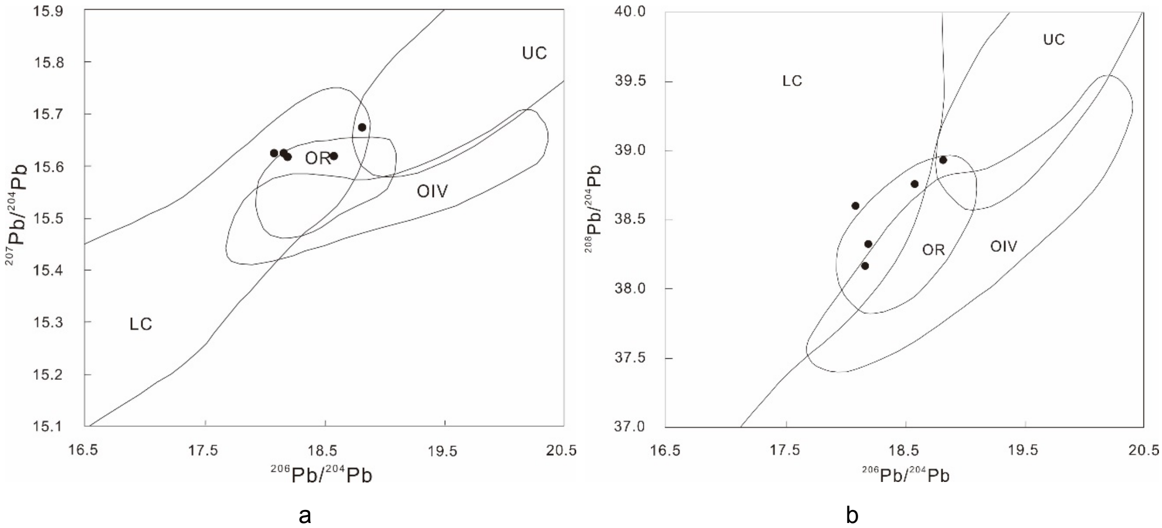

Figure 5: Covariation diagram of $^{206}Pb/^{204}Pb$~$^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$~$^{208}Pb/^{204}Pb$ in the Zhazixi Sb(W) deposit. UC-upper crust; LC-lower curst; OR- orogenesis belt; OIV-mantl

There is great difference in ore-controlling structure, ore type and fabric between antimony orebodies and tungsten orebodies of the Zhazixi Sb–W deposit. Sb orebodies contain almost no tungsten minerals. All shows antimony orebodies and tungsten orebodies have different ore-forming material sources. In Region, W deposits occur in a magmatic rock region in the southern of the Xuefeng arc metallogenic belt, are in close relationship with the granite, and occur in or close to rock mass, such as Xingfengshan Au-W deposit, Shaxi W deposit, Lishanpo W deposit, Shangchasha W deposit, Zhongcun W deposit, Zhaixishan W deposit, Darongxi W deposit, Situpu W deposit (Su et al. 2016). Even the intermediate-acid magmatic veins have been found in the Woxi Au-Sb-W deposit (Kuang et al. 2004; Peng et al. 2006). Wang et al., (2012) found the Metallogeneti age is 227.3± 6.2Ma, similar to the age of some magmatic rocks in region. On the other hand, Sb deposits have been found in the total Xuefeng arc metallogenic belt, are in close relationship with Banxi group. According to assessment of mineral resources potential in Hunan Province (Hunan Institute of Geological Survey. 2013), 44 of 71 Sb deposits occur in Banxi group (the ratio 62%). Ma et al. (2000) investigated 4 long geochemical sections of unaltered rocks in Madiyi Formation, Banxi Group, and put the Sb background value at 1.0ppm and the average Sb content of two lithologic members at 7.4ppm and 25ppm, respectively. The results far exceed the concentrations in the upper crust (0.2ppm) (Taylor et al., 1995). Therefore, Banxi Group acts as a potential source of mineralization materials for Sb deposits.

Comprehensive analysis of above all, this study think Sb in the Zhazixi Sb-W deposit came from Banxi Group, but W came from the concealed rock body.

5. Conclusions

Through Geological features and Carbon (C)-Hydrogen (H)-Oxygen (O)-sulphur (S)-lead (Pb) isotope analysis, the sources of mineralization materials and mineralization fluids at the Zhazixi Sb-W deposit in Xuefeng Belt are identified as follows:

(1) Sulphur and lead isotopes in the Zhazixi Sb-W deposit primarily originate from deeper places in the earth.

(2) The thermal fluids associated with mineralization derived from magmatic water and metamorphic water.

(3) The Zhazixi Sb–W deposit is a Yanshanian polygenetic compound deposit.

Acknowledgments

This paper is made possible by the generous support from the National Natural Foundation of Science of China (Grant No.: 41672082), Hao Li Fuchu and two anonymous reviewers.

Reference

Chen F., Xia F., 2015. Study on the fluid inclusions of Jiangdongwan Au-Sb deposit Western Hunan. Energy research and management, (2), 25-29

Deng H., Xi C., Xia H., Lu Z., 2016, Characteristics of trace elements in Zhazixi Antimony Deposit in Anhua, Hunan Province. Gold. 37(5), 21-25

Field, C.W., Fifarek, R.H., 1985, Light stable-isotopic systematics in the epithermal environment: Reviews in Economic Geology, 2, 99-128.

Goldfarb, R.J., Ayuso, R., Miller, M.L., Ebert, S.W., Marsh, E.E., Petsel, S.A., Miller, L.D., Bradley, D., Johnson, C., and McClelland, W., 2004, The late cretaceous Donlin Creek gold deposit, Southwestern Alaska: Controls on epizonal ore formation: Economic Geology, 99, 643-671. DOI: 10.2113/99.4.643

Hunan Institute Of Geological Survey. 2013. Assessment of mineral resources potential in Hunan Province. Hunan Institute Of Geological Survey, 877-916

Kuang W., Gu D., Liu X., 2004. Discussion on the mineralization geological features and metallogenetic model of Woxi Au-Sb-W deposit in west Hunan. Gold, 25(6), 10-15

Liu J., Li C., Pan J., Hu R., Liu X., Zhang Q.. 2000. Isotopic geochemistry of copper deposits in sandstone and shale of Lanping-Simao basin, Western Yunnan. Mineral deposits, 19(3), 223-234

Liu B., 2009. Features and evolution of deep structures in the Xuefeng intracontinental tectonic system. Qingdao: Ocean university of China, 12-79

Ma, D.S. and Bernd, L., 2000, The Multi-peak Structure of the stibium content in Ma Diyi Formation of West Hunan Gold deposit and its region: Application of the cumulative probability ruled form for gold deposit genesis and exploration: Bulletin of Mineralogy, Petrology and Geochemistry, 19, 218-220.

Ohmoto H. 1972. Systematics of sulfur and carbon isotopes in hydrothermal ore deposits. Econ. Geol., 67, 551-578. DOI: 10.2113/gsecongeo.67.5.551

Ohmoto, H. and Rye, R.O., 1979, Isotopes of sulfur and carbon. In: Barnes HL (ed.). Geochemistry of Hydrothermal Ore Deposits: New York, John Wiley, 509-567.

Peng J., Zhang D., Hu R., Wu M., Lin Y., 2008. Sm-Nd and Sr Isotope Geochemistry of Hydrothermal Scheelite from the Zhazixi W-Sb Deposit,Western Hunan, Acta geologica sinica, 82(11), 1514-1520

Peng B., Robert F.I., Tu X., 2006. Nd-Sr-Pb Isotopic Geochemistry of Scheelite from the Woxi W-Sb-AuDeposit, Western Hunan: Implications for Sources and Evolution of Ore-forming Fluids. Acta geologica sinica, 80(4), 561-570

Su K., Lu S., Kong L., Yang F., Xiang J., 2016. Geological characteristics, metallogenetic regularity and model of quartz vein type tungsten deposits in Chongyangping, Hunan Province. Mineral deposits, 35(5), 902-912. DOI: 10.16111/j.0258-7106.2016.05.002

Sheppard, S.M.F., 1986, Characterization and isotopic variations in natural waters: Reviews in Mineralogy & Geochemistry, 16, 165-183

Sun, X.M., Zhang, Y., Xiong, D.X., Sun, W.D., Shi, G.Y., Wei, Z., Wang, S.W., 2009, Crust and mantle contributions to gold-forming process at the Daping deposit, Ailaoshan gold belt, Yunnan, China: Ore Geology Reviews, 36, 235-249. DOI: 10.1016/j.oregeorev.2009.05.002

Taylor BM. 1986. Magmatic volatiles: Isotope variation of C, H, S. In: Stable isotopes in high temperature geological progress. Mineralogical society of America. Reviews in mineralogy, 16: 185-226

Taylor, S.R. and McLennan, S.M., 1995, The geochemical evolution of the continental crust: Reviews of Geophysics, 33, 241-265. DOI: 10.1029/95RG00262

Veizer J, Holser WT and Wilgus CK. 1980. Correlation of 13C/12C and 34S/32S secular variation. Geochimica et Cosmochimica acta, 44, 579-588. DOI: 10.1016/0016-7037(80)90250-1

Wang Y., Chen Y., Wang D., Xu J., Chen Z., 2012. Scheelite Sm-Nd dating of the Zhazixi W-Sb deposit in Hunan and its geological significance. Geology in China, 39(5), 1339-1344

Zhang J., Wen H., Qin C. and Wang J., 2012. Fluid inclusion and stable isotopes study of Liancheng Cu-Mo polymetallic deposit in Lanping basin, Yunan Province. Actor petrologica sinica, 28(5), 1373─1386

Zheng, Y.F. and Chen, J.F., 2000, Stable Isotope Geochemistry: Beijing, Science Press, 1-316

Zeng G., Gong Y., Hu X., Xiong S., 2017. Geology, fluid inclusions, and geochemistry of the Zhazixi Sb–W deposit, Hunan, South China. Ore Geology Reviews, 80, 2298-2360. DOI: 10.1016/j.oregeorev. 2017.08.001