Geological and Geochemical Characteristics of Skarn Type Lead-Zinc Deposit in Baoshan Block, Yunnan Province

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Abstract. Baoshan block is an important Pb-Zn-Fe-Cu polymetallic ore-concentration area which is located in southern of the Sanjiang metallogenic belt in western Yunnan. The article is studying about the geological and geochemical characteristics of the skarn type lead-zinc deposit in Baoshan block. The skarn-type lead-zinc deposit Baoshan block is characterized by skarn and skarn marble, and the orebodies are layered, or bedded along the interlayer fault, which are significantly controlled by structure. The research about Stable isotope S, H and O indicates that the ore-forming fluids are mainly derived from magmatic water, partly mixed with parts of metamorphic water and atmospheric precipitation. The initial Sr isotopic Sr\textsuperscript{87}/Sr\textsuperscript{86} ratio suggests that the ore-forming materials derived from deep concealed magmatic rock, age of Rb-Sr mineralization is similar to that of Yanshanian granite. In conclusion, the Yanshanian tectonic-magmatic-fluid coupling mineralization of Yanshan formation is the main reason for the skarn-type lead-zinc deposit in the Baoshan block.

1. Introduction
Baoshan block is located in the southern of the complex orogenic belt of Sanjiang (Nujiang, Lantsang and Jinshajiang) in Southwest China, belonging to the northern part of the Yunnan, Myanmar, Thailand, Malaysia block, which is an important ore-concentrated area of Pb, Zn, Fe, Cu, Au, Ag and Hg polymetallic, and a natural laboratory for the study of skarn-type Pb-Zn-Fe polymetallic deposits. In recent years, with the continuous investment in mineral exploration, Baoshan Hetaoping large-scale lead-zinc-copper mine, Jinchanghe large-scale iron-lead-zinc-copper mine, Zhenkang Luziyuan super-large lead-zinc-iron mine and Shuitoushan lead-zinc mine as well as over dozens of lead-zinc-polymetallic deposits have found in the study area, at the same time, Zhenkang Luziyuan is listed as one of the lead-zinc mine reconnaissance area in the national-level prospecting strategic breakthrough. Geologists have paid great attention to the prospecting breakthrough of this area, and a large number of scholars have studied the metallogenic geological background, regional tectonic evolution, geological and geochemical characteristics of ore deposits and metallogenic chronology, but the genesis of their mineral deposits still remained a controversy. In this paper, the genesis skarn-type Pb Zinc polymetallic deposit study combined with the geological characteristics of three Pb-Zn-polymetallic deposits in the Baoshan block, the typical Hetaoping, the Luziyuan and the Jinchanghe, and combined with the fluid geochemistry, stable isotope and metallogenic chronology studied the causes about the genesis of skarn type Pb Zn polymetallic deposits, in order to provide the basis for the establishment of regional metallogenic and ore-prospecting models.
2. Regional geological background

The eastern boundary of the Baoshan block is adjacent to Lancangjiang fault, the western boundary is adjacent to Nujiang fault, and the northern boundary is lost due to the convergence of the Lantsang and Nujiang faults, besides, the southern part extends to Myanmar, forming the northern extension of the Yunnan Myanmar, Thailand and Malaysia terrain. Before the Early Permian Epoch, Baoshan block and Tengchong, Qiangtang, Lhasa blocks were attached to the northeast part of Gondwanaland, at the end of Sakamarian Stage of the early Permian Epoch, Baoshan and Tengchong blocks began to split and drift from the Gondwanaland to the north, resulting in the entering of meso-tethys; during the late Triassic epoch to the Early Cretaceous Epoch, Lhasa block drifted to the north, and meso-tethys entered into the closing stage, resulting in the collision between Tengchong block and Baoshan block to form the Gaoligong collision structure belt [1, 2]. The Baoshan block experienced the early Paleozoic and Mesozoic-Cenozoic granite intrusion activities: the Paleozoic granitoid intrusion activity is mainly represented by the Pinghe granite base in the south of the block, and the zircon U-Pb is aged to be 502-466 Ma [2-4]. The Mesozoic Indosinian granitoids are mainly Muchang A-type granites, which are complex massif that composed of soda ash syenite, sodic granite and aegy granite. The age of cyrtolite and nepheline U-Pb is 253-241 Ma, with Sn, Zn, Ce comprehensive mineralization, but the ore-forming process is still not clear [5]. The rock bodies formed during the Mesozoic-Cenozoic magmatic activity mainly include Zhibenshan, Kejie and Caojian acid granites, of which, the Zhibenshan and Kejie granites are mainly formed in the late Yanshanian magmatic activity. The granite is composed of biotite granite, two-mica granite and light-colored granite. The age of zircon U-Pb is 126.7 ± 1.6 Ma and 93 ± 13 Ma, respectively, and the relevant mineralization include Pb, Zn, Fe, Cu that form polymetallic deposits, such as Baoshan Hetaoping and Zhenkang Luziyuan Pb-Zn-Fe(Cu); the rock bodies formed during the magmatic activity of the Himalayan period is mainly Caojian two-mica granite, and the age zircon U-Pb is 73 ± 0.19 Ma, which may be related to Yunlong Tiechang tin deposit [4, 6].

3. Geological and geochemical characteristics of typical deposits

3.1. Geological characteristics of the deposit

The geologic characteristics of the skarn-type lead-zinc deposits in the Baoshan block are very similar. The ore deposits in Hetaoping, Jinchanghe and Luziyuan are all produced in the Upper Cambrian strata. The ore bodies are produced in layers, strata, veins and stripes along the interlayer fracture zone. Skarn and skarn marble are the main ore-bearing lithology. Minerals mainly include sphalerite, galena, chalcopyrite and magnetite, which is semi-self-shaped and Hypediomorphic granular structure that produced in the massive, disseminated and vein structure. The skarn minerals are mainly composed of (Manganese) garnet, (Manganese) pyroxene, diopside, ilvaite, epidote, (Manganese) actinolite, quartz and calcite that form a typical Ca-Mn skarn structure, which is mostly represented by the rose pyroxene of Luziyuan deposit, and is considered an important symbol of searching for skarn-type lead-zinc deposits in Baoshan block. The skarn-type Pb-Zn deposits in the study area are characterized by obvious mineralized zonation, and the deep to shallow parts are garnet diopside skarns → magnetite, hematite → manganese skarn-type magnetite → pomegranate garnet skarn → manganese skarn type lead-zinc ore → epidote and actinolite from skarn → actinolite lead-zinc ore → actinolite and chlorite marble Pb-Zn ore, of which, chlorite can be observed in the whole area. The alteration mineralization features are controlled by the degree of metasomatism of deep hydrothermal fluids, the carbonate rocks and tectonic activities.

3.2. Geochemical characteristics of the deposit

The contents of major elements CaO and Fe2O3 in skarn lead zinc deposits in Baoshan block are the highest, followed by MgO, Al2O3, MnO, K2O and Na2O. The omega (CaO) shows the characteristics of marble > skarn ore rocks > >, the other major elements MgO, Al2O3, MnO, K2O, Na2O, TiO2 and Pb, Zn content of ore-forming elements as marble skarn rocks < tectonic rocks < ore occurrence law. CaO and other major elements showed negative correlation, this characteristic shows that the alteration process is a process of silicon and iron, magnesium, aluminum, manganese, calcium and
other elements to carry out, so that the content of CaO decreased gradually, formed a set of high manganese skarn composite rock mineral.

On the aspect of sulfur source, Ohmoto [9] studied the δ34S composition of some well-known deposits in the world, and concluded that there are four kinds of sulfur source in the hydrothermal deposit: (1) mantle sulfur, the δ34S value is close to 0, and its composition is close to sulfur isotopic, and the variation range is relatively small; (2) from the ocean water and seawater sulfate, featured by enrichment of 34S, and the value of δ34S = about +5 %; (3) mixed sulfur, the source is relatively complex, δ34S = +5 % ~+15‰, and the variation range is relatively large; (4) biogenic sulfur, biological reduction is characterized by enrichment of 34S, δ34S is mostly negative value, and the variation range is large. As shown in table 1 and figure 1, the δ34S value of the Hetaoping deposit is 0.99 ~7.20, and the range of variation is large. The δ34S value of the Luziyuan deposit is 9.23~10.17, and the variation range is small. Both of the δ34S values of the two deposits are in the range of mixed sulfur, which is consistent with magmatic sulfur, but it also mixed with metamorphic sulfur.

| Deposit                  | Hetaoping lead-zinc-copper deposit | Luziyuan lead - zinc - iron deposit |
|-------------------------|------------------------------------|-------------------------------------|
| δ34S isotope composition (%e) | 0.99~7.20                           | 9.23~10.17                           |
| H-O isotope composition  | δDV-SMOW: -108~100, average104; δ18O H2O: 6.1~7.6, average 6.7 [7] | δDV-SMOW: -81.7~73.3, average 75.4; δ18O H2O: 5.4~6.1‰, average 5.7 |
| Sr87/Sr86                | 0.7116~0.2720 [6]                   | 0.714 486~0.714 512 [8]              |
| Rb-Sr metallogenic age   | 116.1±3.1 [6]                       | 141.9± 2.6 Ma [8]                   |

The H and O isotopic composition in fluid inclusions of Augite at Luziyuan deposit: δ DV-SMOW is -81.7 ‰ ~ -73.3 ‰, δ18O H2O is 5.4 ‰ ~ 6.1 ‰, the variation ranges of δ18O H2O is narrow and δ DV-SMOW is relatively large; The H and O isotopic composition in fluid inclusions of marble at Hetaoping deposit: δ DV-SMOW ranges from -108‰ to -100 ‰, with wide variation range, and δ18O H2O ranges from 6.1‰ to 7.6‰, and the variation range is narrow (table 1). In the H-O diagram (figure 2), the throwing-dots at Luziyuan deposit are located in the lower left side of the original magmatic water, and close to the metamorphic water area; throwing-dots at Hetaoping are located on the magma underwater side, compared with Luziyuan deposit, δ18O H2O composition is close, but δ DV-SMOW value drifts downwards. It may be because the test minerals in the Luziyuan mining area are skarn early-altered mineral rose-pyroxene, which is not mixed with the atmospheric precipitation, and the test minerals in the Hetaoping mining area are mineralization of quartz, so the value of δ DV-SMOW is decreased due to the atmospheric precipitation and the construction water mixture. The composition of the stable isotopes S, H and O shows that the ore-forming fluids of the lead-zinc deposits on the Baoshan block are mainly derived from magmatic water and mixed with some metamorphic fluids and precipitation.
3.3. Age of Rb-Sr mineralization
The skarn-type ore-bearing stratum of lead-zinc deposit in Baoshan block is Cambrian strata, probably formed before 500 Ma. The zircon U-Pb diagenesis age of the granite body exposed to the block is 126.7 ± 1.6 Ma, with the initial Sr isotopic Sr\textsuperscript{87}/Sr\textsuperscript{86} ratio to be 0.716810. The ore-forming age of Rb-Sr isochron of the metal sulfides in the Hetaoping deposit is 116.1 ± 3.9 Ma, with the initial Sr isotopic Sr\textsuperscript{87}/Sr\textsuperscript{86} ratio to be 0.711850. The ore-forming age of Rb-Sr isochron of the metal sulfides in the Luziyuan deposit is 141.9 ± 2.6 Ma, and the Sr isotopic Sr\textsuperscript{87}/Sr\textsuperscript{86} ratio is 0.714479. The above results indicate that the age of the skarn-type Pb-Zn deposits in the Baoshan block is close to that of the Yanshanqi Zhibenshan granite, which is very different from that of the Yanshanian granitoids. Therefore, it can be seen that the genesis of mineral deposit is related to the Yanshanian tectonic-magmatic rocks activities, belonging to sedimentary deposit. The initial Sr isotope ratio of the two deposits is similar to that of the Zhubenshan granite, suggesting that the ore-forming materials are mainly derived from deep buried magmatic rocks.

4. Conclusion
(1) The ore-bearing stratum of skarn-type lead-zinc ore deposits in Baoshan block belong to the upper Cambrian Hetaoping and Shahechang groups. The ore-bearing rocks are mainly skarn and skarn marble with high manganese content. The ore minerals are sphalerite, galena, chalcopyrite, magnetite and pyrite, while gangue minerals are a set of manganese skarn construction consisting mainly of the garnet, diopside, rose pyroxene, epidote, chlorite, quartz and calcite.

(2) The ore bodies are stratified and appear to be layered along the interlayer faults, and the tectonic control is obvious. The mineralization shows the zoning characteristics of magnetite mineralization→ Pb-Zn-Cu mineralization →Pb-Zn mineralization from the deep to the shallow.

(3) Stable isotopes of S, H and O indicate that the ore-forming fluids are mainly derived from magmatic water, and some metamorphic water and meteoric water are mixed at the later stage.

(4) The initial Sr isotopic Sr\textsuperscript{87}/Sr\textsuperscript{86} ratio suggests that the ore-forming materials originate from deep concealed magmatic rocks. In conclusion, the Yanshanian tectonic-magmatic-fluid coupling mineralization is considered to be the main reason for the formation of the skarn-type Pb-Zn deposit in the Baoshan block based on the Rb-Sr mineralization age.

5. References
[1] Metcalfe I, 2011 Gondwana Res. 19(1) 3-21.
[2] Deng J, Wang Q F, Li G J, Li C S and Wang C M 2014 Gondwana Res. 26 419-37.
[3] Wang X F, Metcalf I, Jian P, He I Q and Wang C S 2000 J. Asian Earth Sci. 18(6) 675-90.
[4] Yu L, Li G J, Wang Q F and Liu X F 2014 Acta Petrol. Sin. 30(9) 2709-24.
[5] Gu Y Q, Qan T H and Ye Z S 1998 *Acta Petrol. ET Miner.* 7(1) 38-48.
[6] Tao Y, Hu R Z, Zhu F L, Ma Y S, Ye L and Cheng Z T 2010 *Acta Petrol. Sin.* 26(6) 1760-72.
[7] Xue C D, Han R S, Yang H L, Yang Z M, Tian S H, Liu Y Q and Hao B W 2008 *Miner. Depos.* 27(2) 243-52.
[8] Zhu F L, Tao Y, Hu R Z, Liao M Y, Wang Y X and Li Y B 2011 *Bull. Mineral. Petrol. Geochem.* 30(1) 73-9.
[9] Ohmoto H and Rye R O 1979 *Isotopes of sulfur and carbon.* In Barnes H L, ed. Geochemistry of Hydrothermal Ore Deposits, New York: Wiley-Interscience, 509-67.