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The Laba Yanshanian Porphyry Mo(- Cu) Deposit in Shangri- La, NW Yunnan, China: Alteration, Mineralization and its Genesis

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1 Introduction

The Laba porphyry molybdenum (-copper) polymetallic deposit lies in the western margin depression belt of the Yangtze landmass and is adjacent to the southern connection part of Zhongdian island arc, which belongs to the southern part of the Late Triassic Yidun magmatic arc. The Zhongza block and Jinsha River suture are located in the northwest along the Geza faults zone, and the Garze- Litang suture zone to the northeast. The ore field covering an area of 10 square kilometres is located in Laba valley of Loji town in Shangri- La county, northwestern Yunnan province, southwestern China. Some little copper-, lead-, and zinc- polymetallic occurrence in the southeastern The deposit has two ore blocks termed the Tongchanggou ore block and the Laba ore block. Tongchanggou ore block has been discovered in 1985. Till to 2010, the No. KT1 Mo (- Cu) orebody was firstly explored by Geology Investigation Institute of Yunnan Bureau of Geological Survey sponsored by Yunnan Copper Industry Group Company(e.g., Li et al., 2012). After that, a number of Mo(- Cu) orebodies in the Laba ore block to the northwestern have been explored successively. The investigation confirmed that there is a superlarge porphyry- skarn hydrothermal type Mo (- Cu) polymetallic metallogenic system with resources reserves of 63.5 mt Mo @ 0.11%, associated with 33.7kt Co@ 0.22% and Au 14.7t @ 0.65ppm. The porphyry intrusions contributed to the mineralization closely, the superficial vein type Mo (- Cu, Pb, Ag) orebodies are usually located in faults and secondary fractures, and the deep porphyry type orebodies occurred in the granodiorite porphyries, the skarn type orebodies occurred in the contact zone intruded into limestone and/ or basalts in a certain range. Some intrusions have been wholly mineralized in the Laba deposit, show great prospecting potential.

The ore-bearing porphyry age measured by zircon SHRIMP U- Pb dating is from 83.0 Ma to 86.0 Ma(Li et al., 2012; and this study). It provides some clues for studying Yanshanian mineralization processes in this region. The ore- forming elements are rich in Mo mainly in the Laba deposit, however, the surrounding deposits are rich in Cu. Owing to these difference, it may be that they have different tectonic controlling, ore- bearing magma source and evolution, geological characteristics, ore-forming fluid source and evolution (Seedorff et al., 2005; Yang et al., 2008) and so on. The characterization about mineralization processes becomes extremely important. The alteration and mineralization, as the post- magmatic hydrothermal fluid flow record (Sillitoe, 1972), is also macroscopic performance of ore- bearing magma fluid evolution, its general characteristics and zonation studying is always the basic research of porphyry deposits.

2 Geology Background

In the Laba area, the main structure is a NS- trending Baihua Mountain anticline, with Upper Permian Dongba formation (P_2d) basalt in cores, and Middle Triassic Beiya formation (T_2b) limestone in limbs. The main fault belongs to the northern part of the Tongchang fault, and controls the distribution of the magmatic rocks. Many secondary faults are developed along both sides, which can be divided into three groups including EW-, NE- and NW- striking. The intersections of these secondary faults controls the distribution of the ore- bodies. Limestone, marbleization- limestone, marble, basalt are the main county rocks. As the main ore- bearing rocks, the Yanshanian magmatism includes quartz diorite porphyry, granodiorite porphyry and other intermediate- acid magmatic rocks. The outcrops as stock resulted from the marbleization, skarnization in the Middle Triassic Beiya formation. There are also local hornfels.

3 Alteration and Mineralization

Based on systematic field observation and detailed cataloging of drilling core rocks, the alteration includes

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three types, that is the early potassic alteration, skarnization and hornfels, the middle propylitic alteration and the late feldspar- destructive alteration. The veins associated with early potassic alteration are irregular K-feldspar- quartz veins, a little anhydrite in the porphyry and chlorite- epidote veins, a little quartz in the wall rocks; the veins associated with propylitic alteration are mainly irregular chlorite- epidote- calcite, chlorite- ferrocalcite and calcite- quartz veins; the minerals associated with late feldspar- destructive alteration are mainly sericite, chlorite, quartz, clay minerals and so on. Quartz runs through all kinds of the alteration described as above. The potassic alteration is located in the granodioritic porphyry; the propylitic alteration lies in the outside of the potassic alteration; the feldspar- destructive alteration is strongly pervasive in the interior of the porphyry and occurs as vein halos away from the porphyry, between the potassic and the propylitic alteration, and has overprinted most of the potassic and part of the propylitic alteration. The sequences of the alteration zone from the porphyry to the wall rocks are respectively, these are potassic zone, quartz- sericite- chlorite zone, argillic zone and propylitic zone.

Based on field observation, the mineralization types are mainly porphyry type. In the skarn and wall rocks, there is a little ore body. Compared with the Cu ore body, the location of the Mo ore body is deeper in the Laba area. From deep to shallow, from porphyry to wall rocks, the sequences of the mineralization zonation have the following trends: strong Mo mineralization, Mo and Cu mineralization, weak Mo and Cu mineralization, a small amount of Cu mineralization, pyrite runs through all kinds of the mineralization described as above.

4 Discussion

The alteration and mineralization have experienced a multi-stage evolution, the late alteration has often overprinted most of the early alteration. In the early stage, K- feldspar occurs in the granodioritic porphyry, skarn occurs in the carbonate wall rocks. With the K metasomatism continuing, there are K- feldspar- quartz veins, anhydrite. While the hydrolytic action starts to work, porphyry internal with Na＋, Ca2＋, Fe2＋, Mg2＋ are leached out away from the contact zone, and reacted with wall rocks, resulting in the formation of the propylitic alteration. With the further hydrolytic action, the pre-formed K-feldspar turned into sericite, the plagioclase phenocryst in the porphyry also turned into sericite and the hornblende phenocryst turned into chlorite. In these processes, there produced a large amount of quartz. Subsequently, part of the pre- formed chlorite and epidote turned into clay minerals, resulting in the weak argillic alteration. With the hydrolytic action continuing, overprinted the pre- formed alteration and produced a lot of clay minerals, resulting in the intermediate argillic alteration and advanced argillic alteration. The alteration zonation is controlled by the location of the porphyry and texture. Mo sulfide- bearing assemblages are mainly produced in the granodioritic porphyry, and occurred closely during the stage between the early potassic alteration and the late feldspar- destructive alteration, characterized by quartz- molybdenite viens, may be related to the temperature and pressure declining suddenly. Cu mineralization is associated with the feldspar-destructive alteration, may be related to the releasing of the Ca2＋, Fe2＋ in the processes of hydrolytic action.

Zhongdian area located in the southern segment of Yidun island arc of the eastern Tethyan metallogenic domain, outcrop a series of porphyry deposits. From a regional perspective, the Zhongdian arc is a significant Triassic porphyry and skarn Cu- polymetallic district(e.g., Hou et al., 2003; 2007), hosting several large deposits, such as Pulang, Xuejiping, Hongshan, Gaochiping and Chundu, as well as many smaller deposits and occurrences under the setting of the Mesozoic arc. The porphyry metallogenic belt includes two porphyry belts, that is the western part (249.0~ 237.5 Ma) and the eastern part (223.8~ 203 Ma) (Zeng et al., 2006).

But recently, the Late Cretaceous monzonitic granite to granodiorite porphyries with porphyry and skarn Mo (-Cu) mineralization (e.g., Li et al., 2012; Peng et al., 2014; and this study) and lamprophyre has also been identified in Laba area. They exposed diabase dikes and sporadically in local area. Acid intrusions in the area extend from north to south, and the belt passes through Yidun arc and enters the western margin of Yangtze landmass. Differed from the Himalayan Yulong porphyry belt and the Indosinian Zhongdian island arc porphyry belt, the Laba deposit is formed during the Late Yanshanian. In that time, Zhongza block and Yangtze landmass collided intensively, and gradually turned into post- collision stage (Li et al., 2012), which is under the collisional orogen setting (Hou et al., 2007; Yang et al., 2008). The metallogenic materials is mainly Mo, may be due to the melting of continental crust. The source of the metallogenic materials is continental crust.

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