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Geology of the Jiama porphyry copper–polymetallic system, Lhasa Region, China

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ABSTRACT

The Jiama deposit, located in the eastern part of the well-known Gangdese Metallogenic Belt on the Tibetan Plateau, is the largest porphyry Cu–polymetallic system in the region, with the largest exploration budget, and is economically viable in the Gangdese Belt to undergo large-scale development. The deposit is well preserved and has experienced little erosion. The proven resources of the deposit are 7.4 Mt Cu, 0.6 Mt Mo, 1.8 Mt Pb + Zn, 6.65 Moz Au, and 360.32 Moz Ag. The results presented in this paper are based on geological and tectonic mapping, geological logging, and other exploration work performed by members of the Jiama Exploration Project Team over a period of 6 years. We propose that the Jiama porphyry Cu–polymetallic system is composed of skarn Cu–polymetallic, hornfels Cu–Mo, porphyry Mo ± Cu, and distal Au mineralization. The development of skarn Cu–polymetallic orebodies at the Jiama deposit was controlled mainly by the contact zone between porphyries and marbles, an interlayer detachment zone, and the front zone of a gliding nappe structure. The hornfels Cu–Mo and porphyry Mo ± Cu orebodies were controlled mainly by a fracture system related to intrusions, and the distal Au mineralization resulted from late-stage hydrothermal alteration.

On the basis of field geological logging, optical microscopy, and chemical analysis, we verify that the alteration zones in the Jiama deposit include potassic, phyllic, propylitic, and argillic alteration, with a local lithocap, as well as endoskarn and exoskarn zones. The endoskarn occurs mainly as epidote alteration in quartz diorite porphyry and granite porphyry, and is cut by massive andradite veins. The exoskarn includes garnet–pyroxene and wollastonite skarn, in which the mineralogy and mineral chemical compositions display an outward zonation with respect to the source porphyry. From the proximal skarn to the intermediate skarn to the distal skarn, the garnet/pyroxene ratio varies from >20:1 to ~10:1 to ~5:1, the garnet color varies from red-brown to brown-green to green-yellow, and the average composition of garnet varies from $Ad_{80.1}Gr_{18.9}(Sp + Py)_{1.0}$ to $Ad_{76.3}Gr_{23}(Sp + Py)_{0.7}$ to $Ad_{59.5}Gr_{39.5}(Sp + Py)_{1.0}$, respectively. The pyroxene is not as variable in composition as the garnet, and is primarily light green to white diopside with a maximum hedenbergite content of ~20% and an average composition of $Di_{88.6}Hd_{8.9}Jo_{2.5}$. From the proximal skarn to the intermediate skarn to the distal skarn, the mineralization changes from Cu–Mo to Cu ± Mo to Pb–Zn ± Cu ± Au ores, respectively. The wollastonite skarn displays no zonation and hosts mainly bornite mineralization. The Cu and Mo mineralization is closely related to the potassic and phyllic zones in the porphyry–hornfels.

Zircons from four mineralized porphyries yield U–Pb ages of 15.96 ± 0.5 Ma, 15.72 ± 0.14 Ma, 15.59 ± 0.09 Ma, and 15.48 ± 0.08 Ma. The Re–Os ages of molybdenite from the skarn, hornfels, and porphyry are 15.37 ± 0.15 Ma, 14.67 ± 0.37 Ma, and 14.66 ± 0.27 Ma, respectively. The present results are consistent with the findings of previous research on fluid inclusions, isotopes, and other such aspects. On the basis of the combined evidence, we propose a porphyry Cu–polymetallic system model for the Jiama deposit and suggest a regional exploration strategy that can be applied to prospecting for porphyry-skarn mineralization in the Lhasa area.

1. Introduction and exploration history

Porphyry Cu systems usually include porphyry deposits centered on intrusions, skarn, carbonate-replacement, and high- and intermediate-sulfidation epithermal deposits, which supply nearly three-quarters of the world's Cu, perhaps half the Mo and one-fifth of the Au, and minor amounts of Ag, Pb, Zn, and Bi (Sillitoe, 2010). There are extensive

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porphyry Cu systems in the Gangdese Metallogenic Belt which is the largest porphyry Cu belt in China.

The Jiama porphyry Cu–polymetallic system is located in Metrorkongka County, in the Tibet Autonomous Region of China, approximately 68 km east of Lhasa, the capital city of Tibet (Fig. 1). It is the largest porphyry Cu–polymetallic deposit in Tibet, with the most intensive exploration program, and is also economically viable in the region to be developed on a large scale. Some small-scale lead mining was undertaken in the Jiama area before the 1950s. Geological work conducted from 1951 to 1990, mainly surface trenching in the Jiama ore district, delineated a 3000-m-long belt of Cu–Pb–Zn mineralization. Subsequently, the Tibet Bureau of Mines and Geology conducted a 1:50,000-scale geochemical stream sediment survey and several 1:10,000-scale geophysical surveys (e.g., magnetic susceptibility, and electrical resistivity and polarizability) in the area. The surveys indicated a high potential for considerable Cu, Pb, and Zn ores in the form of skarn-type deposits, and the Lead Mountain area was targeted for exploration. Drilling (to a depth of 10,100 m) was conducted within an area of approximately 2 km^2, and at the end of 2000 a resource of 259 Kt of copper metal and 462.4 Kt of lead metal was estimated (indicated + inferred). Mining activities in the area commenced not long afterward.

In 2007, China National Gold Group Corporation began to acquire and integrate exploration licenses, and commissioned the Institute of Mineral Resources, CAGS, to conduct general geological exploration in the ore district. The Jiama Exploration Project Team first studied the geology, geophysics, and geochemistry of the area, and interpreted the hornfels alteration (over an area of 10 km^2 to the north of Copper Mountain) at the Jiama deposit (Fig. 1) to be closely associated with porphyry emplacement. The ZK1616 drill hole was bored approximately 1 km northeast of the Lead Mountain exploration area (Fig. 1) to search for possible porphyry at depth. The porphyry–hornfels orebody above the ZK1616 drill hole is 490 m thick, with an average copper grade of 0.25% and an average molybdenum grade of 0.05%. The skarn orebody below is 252 m thick and has an average grade of 0.75% Cu, 0.1% Mo, 0.24 g/t Au, and 12.3 g/t Ag. The grade of both Pb and Zn is less than 0.1%. Subsequent exploration work confirmed that the ZK1616 drill hole is near the porphyry–skarn contact zone.

By the end of 2013, drilling in the Jiama ore district had reached a depth of 200,000 m. Four hundred drill holes were completed, and the exploration area was extended to 7 km^2. The exploration results show that the porphyry Cu–polymetallic system is composed mainly of skarn Cu–polymetallic orebodies, and hornfels Cu–Mo and porphyry Mo ± Cu orebodies (Tang et al., 2010, 2013a; Zheng et al., 2010, 2012a). The skarn ore resource accounts for ~60% of the entire deposit, the hornfels ore for ~35%, and the porphyry ore for ~5%. The deposit contains six elements (Cu, Mo, Au, Ag, Pb, and Zn) that can be extracted, and it is highly economical (Table 1).

On the basis of geological–tectonic mapping, geological logging, and other work done by the Jiama Exploration Project Team, the present study describes the geological setting, alteration, and mineralization of the Jiama porphyry Cu–polymetallic deposit, assesses the timing of diagenesis and metallogenesis, establishes a geological model for the system, and proposes a strategy for regional exploration.

2. Regional geological and metallogenic setting

Studies of the tectonics, magmatic rocks, and mineralization of the Gangdese Metallogenic Belt in Southern Tibet have made an

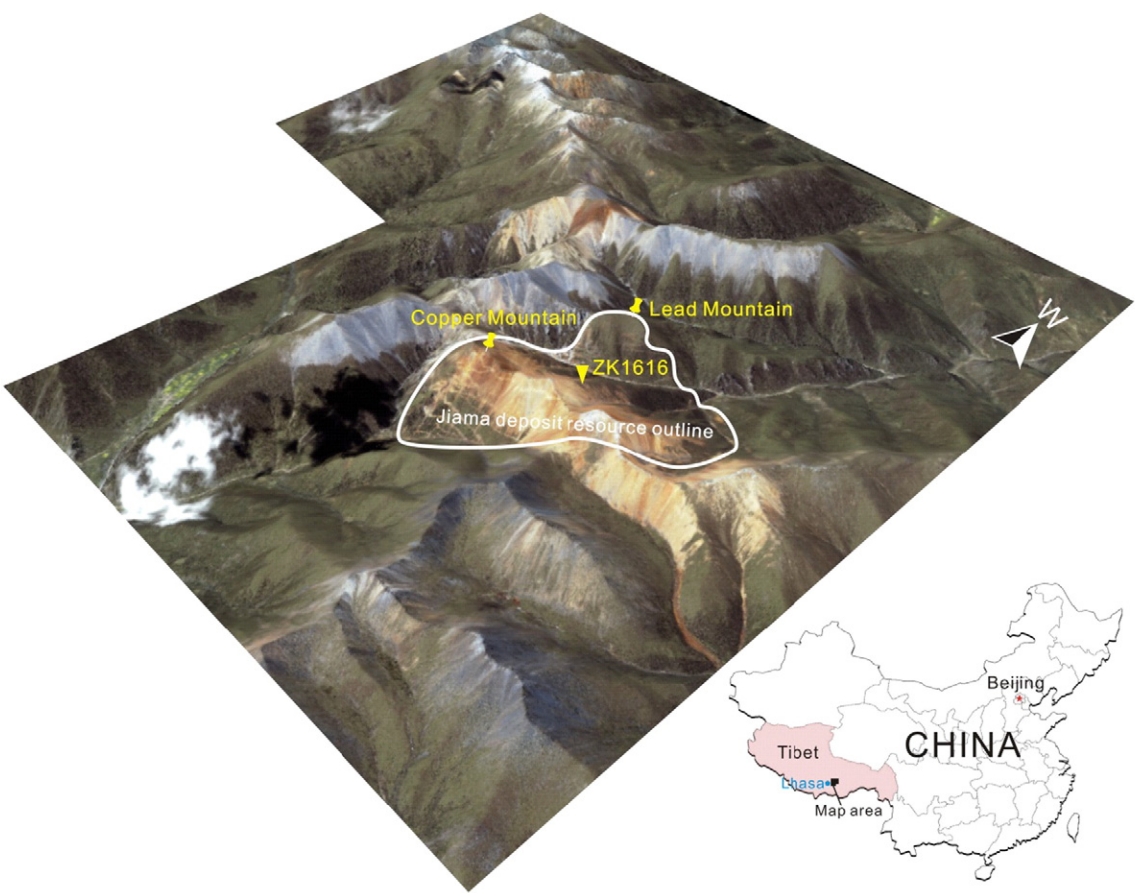

Fig. 1. IKONOS remote-sensing image of the Jiama area. The hornfels alteration zone, which exceeds 10 km^2 in size, is a significant indicator of porphyry systems, and the ZK1616 drill hole has made an important contribution to prospecting in the Jiama deposit.