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Evolution of the ore-forming fluid in the Chagele distal Pb-Zn skarn deposit, Tibet

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The Chagele Pb-Zn deposit (0.38 Mt Pb at 2.08%, 0.60 Mt Zn at 3.29%, and 110.1 t Ag at 6.07g/t) is located in the western segment of the Nyainqentanglha copper polymetallic belt within the Central Lhasa terrane. The Permian Xiala Formation, consisting of limestone, calc-slate and quartz sandstone, was intruded by a granite porphyry dated at 62.1±1.1Ma. The area mainly comprises NE- and NW-trending faults and a NW-trending brittle-ductile shear zone. The Zn-Pb-Cu orebodies are layered or lenticular and controlled by a normal fault in hornfels, whereas Zn-Pb orebodies occur as veins or lenticular bodies mainly in skarn between wallrock and the granite porphyry. Ore minerals are dominated by sphalerite, galena, chalcopyrite, pyrite, pyrrhotite, and malachite. Gangue minerals are dominated by diopside, actinolite, tremolite, epidote, wollastonite, quartz, and calcite, followed by garnet. The ores primarily show hypidiomorphic-xenomorphic granular, metasomatic relict, and exsolution textures, and mainly involve massive, veined, banded, and disseminated structures.

The homogenization temperatures of fluid inclusions are 300-400°C in the pre-ore hydrothermal stage associated with a tremolite-actinolite-epidote-fluorite skarn mineral assemblage, 200-370°C in the early syn-ore stage with a quartz-sphalerite association, 170-300°C in the later syn-ore stage with quartz-sphalerite mineralogy, and 120-220°C in the post-ore stage with quartz-calcite. During the evolution of the skarns, the corresponding salinities show a decreasing trend but the change is not significant(7.6 → 6.5→ 7.1→ 5.9 wt.% NaCl equiv). In the early syn-ore stage, both vapor-rich and liquid-rich fluid inclusions were observed in sphalerite and quartz and these display similar homogenization temperatures, indicating the fluid was boiling. The estimated average trapping pressure is 120 bar, and the depth of the hydrostatic pressure is estimated to be 1.2 km, suggesting shallow ore formation. The fluid evolution can be defined in the Chagele Pb-Zn deposit as: (1) a high temperature, low salinity, near neutral (pH = 6.67), and reducing (Eh = -0.16 V) fluid in the pre-ore stage; (2) sulfide deposition then occurred when fluid boiling occurred during the early syn-ore stage; (3) this was followed by a rapid decrease of temperature and a change of redox conditions (Eh=0.08V), with some lead-zinc sulfides continuing to precipitate in the late-ore stage; and (4) finally, the fluid evolved into a low temperature, low salinity, weakly acid, and oxidized (Eh = 0.20V) system.