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Zircon U-Pb dating and Sr-Nd-Pb-Hf isotopes of the ore-associated granite porphyry at the Chagele Pb-Zn deposit, Tibet

Yong-Chao Zhang*, You-Ye Zheng, Shun-Bao Gao, and Shu-Zhi Zhang

Institute of Geological Survey, China University of Geosciences, Wuhan, China, *e-mail, dzzhych@163.com

Chagele is a typical Pb-Zn skarn deposit formed in the western part of the Nyainqentanglha Pb-Zn-Fe-Ag metallogenic belt (NMPB) that is located immediately north of Gangdese porphyry copper belt, Tibet. Copper-lead-zinc mineralization mainly occurs as vein or lenticular ores in the external contact of skarn developed in limestone. Primary ore minerals at Chagele are sphalerite, galena, and chalcopyrite, with minor pyrite, magnetite, and pyrrhotite. Gangue minerals are quartz, calcite, diopside, garnet, epidote, and chlorite. The deposit has 0.38 Mt Pb, 0.6 Mt Zn, and 110.1 t Ag, with average grades of 2.08 %, 3.29 % and 6.07 g/t, respectively, representing a huge potential ore deposit in the belt. However, studies of the petrology, geochemistry, isotope systematics, and genesis of the granite porphyry at the deposit are lacking. In addition, the metallogenic geodynamic setting of the belt and the age of the initial collision of Indian and Asian continents are still controversial. We report new data for the granite porphyry related to Pb-Zn mineralization, including major and trace element data and zircon U-Pb, zircon Hf, and Sr-Nd-Pb isotope composition, and thereby, comprehensively define the ages and genesis of the granite porphyry, discuss the tectonic setting of Chagele skarn Pb-Zn system, and relationship to the time of India–Asia initial collision. Granite porphyries yield a weighted average zircon $^{206}Pb/^{238}U$ age of 62.7±0.9 Ma, slightly older than the molybdenite Re-Os isochron age of 61.5±0.6 Ma from the mineralized rocks. Granite porphyries show high contents of SiO_2, K_2O and CaO, low contents of TiO_2 and P_2O_5, and peraluminous high-K calc-alkaline composition typical of S-type granite, with obvious LREE enrichment and negative Eu anomalies. They have low $(^{87}Sr/^{86}Sr)_i$ ratios of 0.71595 to 0.72313, εNd(t) values of -11.1 to -9.7, and T_{DM2}(Nd) ages of 1.66 to 1.77 Ga. Their $(^{206}Pb/^{204}Pb)_t$, $(^{207}Pb/^{204}Pb)_t$ and $(^{208}Pb/^{204}Pb)_t$ values are 18.663-19.058, 15.643-15.664, and 39.002-39.559, respectively. Zircon εHf(t) values range from -3.5 to -0.2, with T_{DM2}(Hf) ages of 1.02-1.19 Ga. These geochemical and isotopic data imply that the Chagele granite porphyry originated mainly from partial melting of ancient continental crust of the Gangdese micro-continent accompanied by fractional crystallization during the main collision between India and Asia. Dynamic modeling of slab detachment predicts that there are 10 to 20 myr delay times between the initiation of continental collision and the occurrence of slab break-off. Linzizong volcanic rocks were formed during the break–off of the subducted Neo–Tethyan slab. The Pana Group, which includes the upper Linzizong Formation, was formed at 53.9–47.1 Ma. Thus, the break-off of the Neo-Tethyan slab occurred no later than that time range. Abundant magmatic rocks were produced during collision between India and Asia. These magmatic rocks formed between 68.8 and 51.5 Ma and are associated with the Pb-Zn (Fe-Cu) polymetallic ores, such as at the Narusongduo Pb-Zn, Yaguila Pb-Zn-Ag, Dongzhongsongduo Cu-Pb-Zn, Dongzhongla Pb-Zn-Cu-Ag, Mengya'a Pb-Zn-Ag, Chagele Pb-Zn-Cu, Jialapu Fe, Lietinggang Fe polymetallic, and Silongduo Fe polymetallic deposits. Therefore, we conclude that the initial India–Asia continental collision started no later than 65 Ma