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# Ordovician syn-ore high Sr/Y and pre-ore normal arc igneous rocks of the Tongshan porphyry Cu deposit in the eastern CAOB

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The Tongshan large porphyry Cu deposit (0.9Mt Cu @0.48%) is located in the famous Duobaoshan Cu-Au metallogenic belt, Heilongjiang Province. The mineralization age is ca. 475 Ma. It isadjacent to the Duobaoshan gold-rich porphyryCu deposit and Zhengguang epithermal Au(Zn) deposit also in thebelt. They are the oldest porphyry andepithermal deposits (~480 to ~475 Ma) within the eastern part of the CAOB.

A relative complete sequence of Ordovician igneous rocks within the Tongshan deposit was established relying on their field contact relationships and zircon U-Pb dating results. It comprises andesite (~482 Ma), tonalite(~475 Ma), granodiorite porphyry (~474 Ma) and post-ore diorite porphyrite (~453 Ma). Whole rock chemicaldata show that all these rocks have typical magmatic arc signatures, including calc-alkaline series, enrichment in LREE and LILE elements, and depletion in HFSE elements. TheREE, trace element, and zircon Hf isotope characteristics of the Ordovician Duobaoshangranodiorite and Ordovician Zhengguang dacite porphyry are consistent with those of the Tongshan Ordovician igneous rocks, which indicates that they have been derived from a common source and tectonic setting. The Th/Yb-Ta/Yb of andesite and Th/Yb-Nb/Yb of granitoids suggest they were formed in a continental arc setting. Zircon εHf (t) values of+9.0 to +14.3 and young zirconTDM(Hf) values (495~697 Ma) suggest the involvement of mantle-derived material in their genesis.

Although they share many similar features, Ordovician igneous rocks in the Duobaoshan belt still have some differences. In the Tongshan orefield, syn-ore granodiorite porphyry, and most granodiorite and tonalite exhibit high Sr/Y and (La/Yb)N, and low Y and YbNfeatures, whereasall pre-ore andesites show low Sr/Y and (La/Yb)Nvalues that are normal arc-related magmatic features. The two groups can be identified assyn-ore high Sr/Y rocks and pre-ore normal arc volcanic rocks.Most major elements (e.g., $Fe_2O_3$, $Al_2O_3$and $TiO_2$) and some trace elements (e.g., Co and Yb) forf these rocks decrease smoothly with increasing $SiO_2$. The (La/Sm)Nratios increase with increasing $SiO_2$, whereas(Dy/Yb)Nratios decrease weakly with increasing $SiO_2$. These trends support fractionation of amphibole during magma evolution. Amphibole fractionation and plagioclase suppression, which is indicated by lack of Eu anomaly, suggest a $H_2O$-rich environment. The apatite $SO_3$and MnO contents in the Tongshan granodiorite porphyry are relatively higher than those of the tonalite, which suggests an increase in $fO_2$during the petrogenesis of the mineralized porphyries. Relative high oxygen fugacity and a high $H_2O$ content of the magma that formed the granodiorite porphyry are favorable for mineralization.

Hence, we propose that the Tongshan porphyry deposit is associated with igneous rocks formed from ~482 Ma to ~453 Ma. They were formed in a continental arc setting. Among them, syn-ore intrusions belong to high Sr/Y rocks, whereaspre-ore volcanics are normal arc igneous rocks. The origin of high Sr/Y rocks may be attributed to amphibole fractional crystallization of

parental arc basaltic magmas stalled in the middle-lower crust. Relatively highoxygen fugacity of the magma, and a high $H_2O$ content are favorable conditions for porphyrymineralization in the Tongshan deposit.