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Origin of gem-quality turquoise associated with quartz-barite veins in western Hubei Province, China: Constraints from mineralogical, fluid inclusion, and C-O-H isotopic data

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Abstract

Two types of turquoise, including homogeneous Cu-rich turquoise and oscillatory zoned turquoise-planerite series, are recognized in association with quartz-barite veins hosted by Cambrian carbonaceous slates from western Hubei Province of China. Combined fluid inclusion and Raman micro-spectroscopic data reveal that turquoise-bearing barite-quartz veins contain three types of fluid inclusions (pure CH_4-N_2, carbonic-aqueous, and aqueous), suggesting the responsible fluid is of carbonic-aqueous composition with low oxygen fugacity. Pressure-corrected homogenization temperatures in quartz and barite show a range from 325 to 485 °C and 186 to 391 °C, respectively. Carbon, oxygen, and hydrogen isotopic data suggest that the mineral-forming fluids have a mixed metamorphic-organic affinity, in which the fluids have $\delta^{18}O$ and δD values of 15.0 to 18.8‰ and –111 to –93‰, respectively. Generally, the formation of quartz-barite-turquoise veins could be triggered by prior metamorphic devolatilization, followed by the interaction of fluids with country rocks enriched in carbonaceous material, which resulted in the leaching of Cu, Fe, P, and Al from chalcopyrite, pyrite, magnetite, monazite, xenotime, apatite, feldspar, and muscovite in the wall rocks. Decomposition of the organic matter in the carbonaceous slates, caused by regional metamorphism and deformation, could also promote the concentration and transportation of necessary metals for the turquoise. Thus, we propose a new model and suggest that the turquoise gem deposits in western Hubei Province of China belong to the non-magmatic hydrothermal vein type deposit, not the previously proposed supergene origin. The turquoise-forming fluids were characterized by the coexistence of two immiscible fluids of non-magmatic affinity (i.e., moderate to high-temperature and low-salinity aqueous fluid and pure CH_4-N_2 fluid formed by interaction with carbonaceous slates). The bluish green homogeneous turquoise in the metamorphic quartz-barite-turquoise veins evolved toward the turquoise-planerite solid solution series as the metal-leaching capability of the aqueous fluids decreased.

Keywords: Turquoise, fluid inclusions, H-O-C isotopes, metamorphic hydrothermal origin, western Hubei Province