Mineralogical Indicators of the Degree of Evolution of Rare-Metal Pegmatites, Chinese Altai, Xinjiang

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Granitic pegmatite dikes result from crystallization of granitic magma that is rich in fluxes and H_2O and are commonly enriched in the so-called critical or rare-elements (REL). The REL mineralization in pegmatites is mostly controlled by fractional crystallization and immiscibility of liquids. In comparison with the barren pegmatites, the REL-mineralized pegmatites have a higher degree of evolution, and pegmatites with diverse REL-mineralization types show different degrees of evolution. Thus, previous studies have focused on identifying the degree of evolution of pegmatites to evaluate REL mineralization potential.

There are approximately 100,000 pegmatite dikes located in the Chinese Altai. They belong to muscovite, REL-muscovite, and REL pegmatites. Some of the REL pegmatite dikes are Be, Be-Nb-Ta, Nb-Ta, Li-Nb-Ta, Li-Be-Nb-Ta, and Li-Be-Nb-Ta-Cs-Hf deposits. Among these pegmatites, the Koktokay No. 3 pegmatite is the largest rare-metal deposit in China is the most highly evolved pegmatite. The REL pegmatites in the Chinese Altai are good examples for the study of indicators of the degree of evolution for REL pegmatites. In comparison with the accepted indicators, we found that with increasing degree of evolution, the contents of Sn of muscovite; Y of columbite-tantalite, garnet, and apatite; Sc of garnet; and Ti of tourmaline decrease, whereas the contents of Sc and W of columbite-tantalite; Li of garnet; Pb, Th, and Y/Ho values of apatite; and Ca of tourmaline increase. On the other hand, the zones from different pegmatite dikes that have the same REL mineralization mostly display a consistent degree of evolution. The Koktokay No.3 pegmatite, which is composed of nine concentric internal zones, experienced REL mineralization evolution from Be-Nb-Ta (slightly evolved), to Be-(Li)-Nb-Ta (moderately evolved), and to (Be)-Li-Ta-Cs-Hf (highly evolved). We take the Koktokay No.3 pegmatite as the standard and summarize the mineralogical characteristics of different degrees of evolution corresponding to different REL mineralization types. In zones of limited evolution (Be-Nb-Ta), the occurrences of graphic pegmatites and aplites accompanied by homogeneous muscovite, beryl, Nb-rich oxides, almandine-spessartine, and dravite-schorl are common. Zones of moderate evolution (Be-(Li)-Nb-Ta) mainly display coarse to huge crystal assemblages of (Li)-muscovite, Na-(Li)-beryl, columbite-tantalite, spessartine, and schorl with oscillatory structures and replacement rims. In zones of high degrees of evolution ((Be)-Li-Ta-Cs-Hf), medium to coarse grained crystals of lepidolite, white-pink Na-Li-Cs beryl, tantalite-tapiolite, elbaite-rossmanite, and pollucite are observed, and the internal structures of minerals are complex, including patchy structures, irregular or reverse replacement rims, reverse zoning structures, and veinlets. Also, from slightly to highly evolved pegmatites, the contents of Li, Ta, Cs, Mn, F, Pb, and Th, and the tetrad effects of REEs and Y/Ho values increase, whereas the concentrations of Fe, Mg, Ti, Y, and REEs decrease for most minerals in pegmatites. These are

possible mineralogical indicators of the degree of evolution and newly recognized REL mineral occurrences.