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Maruyamaite, a new K-dominant tourmaline coexisting with diamond: Significance of tourmaline in UHP rocks

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Maruyamaite is a new end-member species of the tourmaline supergroup (IMA 2013-123, Lussier et al., 2014). The ideal chemical formula of maruyamaite is $K(MgAl_2)(Al_5Mg)(BO_3)_3(Si_6O_{18})(OH)_3O$, which is the K-analog of oxy-dravite. This new mineral was first reported as a K-dominant tourmaline coexisting with microdiamond inclusions from the Kokchetav Massif, Kazakhstan (Shimizu & Ogasawara, 2005) and named in honor of Professor Shigenori Maruyama (Earth-Life Science Institute, Tokyo Institute of Technology, Japan), who led the Japan-U.S.-Kazakhstan cooperative project on Kokchetav ultrahigh-pressure (UHP) metamorphism. The K content in maruyamaite is up to 0.576 apfu (2.76 wt% K_2O). Currently, the occurrence of maruyamaite has been reported exclusively from the type locality (the Kokchetav Massif) and maruyamaite is a unique K-dominant tourmaline species. Moreover, no K-rich dravitic tourmaline has been found from other UHP terranes (Marschall et al., 2009). The rarity of K-dominant tourmaline is probably due to the large ionic radius of K with respect to the X-site of magnesian tourmalines.

The systematic chemical analysis of various tourmalines including maruyamaite in diamond-bearing Kokchetav UHP rocks combined with detailed inclusion mineralogy demonstrated that K in tourmaline decrease with pressure (and temperature) decrease (Shimizu & Ogasawara, 2013). For instance, the figure shows that microdiamond occurs only in K-dominant core (maruyamaite) and the surrounding low-K parts (K-bearing dravite or oxy-dravite) contain low-pressure minerals such as graphite and quartz. Maruyamaite or "K-dravite" component can form continuous solid solutions with other magnesian tourmalines up to ~58% of K in the X-site, with a close relationship to pressure. In particular, the limited occurrence of microdiamond in maruyamaite strongly indicates that K-dominant tourmaline is a UHP phase. Ota et al. (2008) concluded that partial melting of gneisses under UHP condition had formed the maruyamaite-bearing tourmaline-rich quartzofeldspathic rock from the high δ^{11}B values of maruyamaite, which is quite unusual for high-grade metamorphic tourmaline.

There had been no experimental constraint on K-incorporation in tourmaline until fairly recently, however, K-dominant tourmaline (up to 0.71 K apfu) has been synthesized for the first time by Berryman et al. (2014). They showed that K-dominant tourmaline is stable at UHP conditions (2-4 GPa). It means that K-dominant tourmaline including maruyamaite can be a new UHP indicator. K in tourmaline also is a potential geobarometer once partition coefficient of K and Na between tourmaline and mica or feldspar is experimentally determined. Another important constraint is that K-incorporation in tourmaline structure requires not only high-pressure but also very high K/Na conditions (Berryman et al., 2014). A number of studies (e.g., Hwang et al., 2005) have shown that K-rich fluid had been present at the Kokchetav UHP stages and played an important role for the formation of metamorphic diamond and other UHP minerals such as K-rich clinopyroxene. The experimental results were consistent with the interpretation of the occurrence and chemical analyses of the natural maruyamaite-bearing rock.

Four generations of tourmaline from K-dominant maruyamaite to K-free low-grade tourmalines were recognized in the Kokchetav UHP gneisses based on their chemical compositions and inclusion contents. The tourmalines record the retrograde history from a diamond-grade partial melting to the latest greenschist facies overprint. This interpretation further emphasizes the feature of tourmaline for an excellent geochemical recorder of metamorphic events and a sink of light element such as boron in deeply subducted crustal materials.

Figure captions: (A) Photomicrograph of K-bearing tourmaline showing maruyamaite as domains rounded by red broken lines; (B) K zoning of tourmaline; and (C) Microdiamond inclusions in maruyamaite.

Keywords: maruyamaite, tourmaline, diamond, ultrahigh-pressure metamorphism, Kokchetav Massif, inclusion

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