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Magmatic haggertyite in olivine lamproites of the West Kimberley region, Western Australia

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Abstract

We report the first occurrence of magmatic haggertyite ($BaFe_6Ti_5MgO_{19}$) from the Miocene lamproites of the West Kimberley region of Western Australia. This contrasts with the metasomatic formation reported in an olivine lamproite host at the type locality, Prairie Creek, Arkansas. Haggertyite occurs in the groundmass of a diamondiferous olivine lamproite pipe in the Ellendale field, and within the large zoned Walgidee Hills lamproite where it forms part of an extensive suite of Ba- and K-bearing titanate and Ti-rich silicate minerals. The haggertyite co-exists with chromian spinel, perovskite, and ilmenite in the Ellendale lamproite, and with priderite and perovskite and, in one locality, with priderite, jeppeite, ilmenite, and perovskite, in the Walgidee Hills lamproite. Unlike priderite and perovskite, which are common groundmass phases in the Ellendale olivine lamproites and present throughout the Walgidee Hills lamproite, haggertyite appears restricted in its occurrence and crystallization interval, with sparse ilmenite apparently mostly crystallizing as an alternative phase. In the Walgidee Hills lamproite the haggertyite-bearing assemblage is succeeded by the Ba-titanate assemblage priderite plus jeppeite in the evolved central part of the body.

The haggertyite in the main zone of the Walgidee Hills lamproite has an average composition of $(Ba_{0.7}K_{0.3})_{1.0}(Ti_{5.0}Fe^{3+}_{2.1}Cr_{0.1}Fe^{2+}_{3.8}Mn_{0.2}Mg_{0.6}Na_{0.1})_{12}O_{19}$ and is thus very similar to the original haggertyite described from xenoliths in the Prairie Creek lamproite apart from being poorer in Cr and Ni. Haggertyite in the groundmass of the Ellendale olivine lamproite and the central zone of the Walgidee Hills lamproite, in addition to variations in Mg and Cr, show significant variation in Ti and Fe contents and in calculated Fe^{3+} and Fe^{2+}. A linear inverse relationship between Ti and Fe, and Ti and Fe^{3+}, indicates that Fe^{3+} is accommodated by the coupled substitution $Ti^{4+} + Fe^{2+} \leftrightarrows 2\,Fe^{3+}$. A marked trend to higher Fe^{3+} in the haggertyite in Ellendale 9 olivine lamproite is ascribed to increasing oxidation during crystallization, with f_{O_2} estimated from the olivine-spinel thermometer and oxygen barometer at Δlog FMQ = –1 to +3 at temperatures of 790–660 °C. The haggertyite in the central zone of the Walgidee Hills lamproite, in contrast, shows a marked trend to Fe^{2+} enrichment, which is associated with decreasing Fe in perovskite. This is inferred to indicate formation under more reducing conditions, but sufficiently oxidized to permit Fe^{3+} in co-existing priderite and jeppeite.

Trace-element analysis by LA-ICP-MS shows the Walgidee Hills haggertyite contains minor amounts of Na, Si, Ca, V, Co, Zn, Sr, Zr, Nb, and Pb, and only traces of Al, P, Sc, Rb, REE, Hf, and Ta. Moreover, the haggertyite is preferentially enriched in certain lithophile (Ba, Sr), siderophile (Mn, Fe, Co, Ni), and chalcophile (Zn, Pb) elements relative to co-existing priderite. Haggertyite crystallization appears to be a consequence not only of the very high Ba, Ti, and K contents of the lamproite, but of relatively high-Fe concentrations and low temperatures in evolved olivine lamproite magma with the Fe^{3+}/Fe^{2+} ratio determined by the prevailing f_{O_2}. The new data suggest that haggertyite might also be present but previously unrecognized in the evolved groundmass of other olivine lamproites. Haggertyite is one of an increasing number of new minerals in upper mantle rocks and volcanics derived from the upper mantle hosting large-ion-lithophile and high field strength cations.

Keywords: Haggertyite, titanate, ultrapotassic, lamproite, priderite, magneto-plumbite, ilmenite