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Experimental melting of a hydrous websterite source: constraints on the genesis of Cenozoic leucitites in eastern Australia

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Cenozoic alkaline volcanism is widespread in eastern Australia. The majority of the volcanism occurs in areas with thin lithosphere (<100 km) and shows sodic character, whereas a few potassium-rich leucitites occur in regions with thicker lithosphere (120–140 km) [1]. The leucitites have extremely high TiO_2 (3.4–5.5 wt.%) and K_2O (reaching 7.3 wt.%) contents with K_2O/Na_2O up to 9.0, high MgO (6.3–15.2 wt.%), and relatively uniform CaO (7.0–10.8 wt.%) and Al_2O_3 (7.5–11.6 wt.%) contents.

A mantle source containing phlogopite is generally invoked to account for the origin of leucitites. However, experimental melts from phlogopite-bearing peridotites have high Al_2O_3 and those from phlogopite clinopyroxenites have high CaO for a given K_2O content: both are distinct from the leucitite compositions. We have performed melting experiments on a phlogopite websterite, which is a potential source rock for leucitites.

The experiments show that the melting reaction is Phl + Cpx + Opx = Ol + melt at 1.5 GPa, whereas at ≥ 3.0 GPa the reaction becomes Phl + Cpx = Opx + Grt + melt. The latter differs from the melting reactions in phlogopite-bearing peridotite and clinopyroxenite in that the formation of garnet keeps the CaO content of the melt relatively uniform, comparable to the leucitite compositions. Therefore, we suggest that the source rock of the leucitites probably consists of phlogopite websterite.

The eastern Australian leucitites can be explained by a two-stage process: firstly, thermal perturbation along the Cosgrove hotspot track induced low-degree melting in the thick continental lithosphere, producing melts that ponded close by at the base of slightly shallower lithosphere and crystallized to form phlogopite websterite. Secondly, continued northward movement of Australia caused these phlogopite websterites to be re-melted shortly afterwards to form the leucitites. This is consistent with the unradiogenic $^{87}Sr/^{86}Sr$ ratios of the leucitites, with experiments showing that alkali-rich incipient melts should react with peridotite to form phlogopite websterite [2], and with the high mobility of magma at 150–120 km depth [3].

[1] Davies et al., 2015, Nature [2] Förster et al., 2019, Journal of Asian Earth Sciences [3] Sakamaki et al., 2013, Nature Geoscience