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Alkaline silicate magmas produced by carbonatite-induced melting: Evidence from experiments

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Carbonatites are commonly associated with alkaline silicate rocks, such as ijolites and nepheline syenites. In some complexes, e.g., Kovdor (Russia), these rocks are accompanied by ultramafic rocks, such as olivinites and clinopyroxenites. The alkaline silicate rocks in these complexes are considered to be the products of the fractionation of a carbonated alkaline ultrabasic magma, which generated cumulates (olivinites and clinopyroxenites), alkaline silicate rocks and eventually carbonatites (carbonatites also have been proposed to form by silicate-carbonate immiscibility). Our experiments suggest an alternative hypothesis, namely that the alkaline silicate rocks (ijolite and nepheline syenite) resulted from the melting of the host quartzo-feldspathic gneisses by mantle-derived carbonatitic magmas. To simulate this scenario, we reacted a silicate glass (having the composition of the Oka gneisses) with a Na_2CO_3-bearing dolomitic liquid (representing the carbonatitic magma) at 900-1000 ºC (the typical temperature range for carbonatitic magmas in the crust) and 2 kbar. This interaction produced a rind consisting mostly of fine-grained pyroxene (diopside with a small augite component) and/or melilite and phlogopite, a zone of coarse-grained calcite and olivine beyond the rind, and a domain of alkaline silicate liquid between the rind and the unreacted glass. The silicate liquid quenched to a glass close to nepheline syenite in composition, containing large crystals of wollastonite and aegirine-augite. We interpret the calcite-olivine zone to have crystallised from carbonate liquid that assimilated a small proportion of silica from the glass. The fine-grained rind is interpreted to be metasomatic and to have resulted from the initial interaction of the carbonate liquid with the glass (gneiss). As a result, calcium and magnesium were consumed and the sodium content of the residual carbonate liquid increased significantly adjacent to the unreacted glass. This and the high temperature of the experiments ensured melting of the latter to produce a silicate liquid of nepheline syenite composition and crystallisation of coarse-grained wollastonite and/or aegirine-augite. In nature, such a magma would produce cumulates of these minerals, leaving a residual liquid that would crystallise to nepheline syenite or ijolite. Thus, our experiments explain the formation of alkaline silicate rocks and their association with ultramafic rocks and carbonatites.