Origin of ultramafic rocks associated with carbonatites and their bearing on the formation of HFSE-deposits

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Many carbonatites occur together with large amounts of ultramafic rocks, melilitolites, foidolites and (foid)syenites. There is an ongoing debate if and how these contrasting lithologies were formed by differentiation of a common, mantle-derived silicate magma or rather by metasomatic processes between carbonatite and country rocks (Vasyukova & Williams-Jones, 2022). In order to find petrological evidence for one or the other, two key examples, the Gardiner (E Greenland) and Kovdor (Russia) complexes are compared in this study (Fig. 1). Despite their similar tectonic setting and succession of rock types, they show significant differences in the texture and mineral composition of ultramafic rocks.

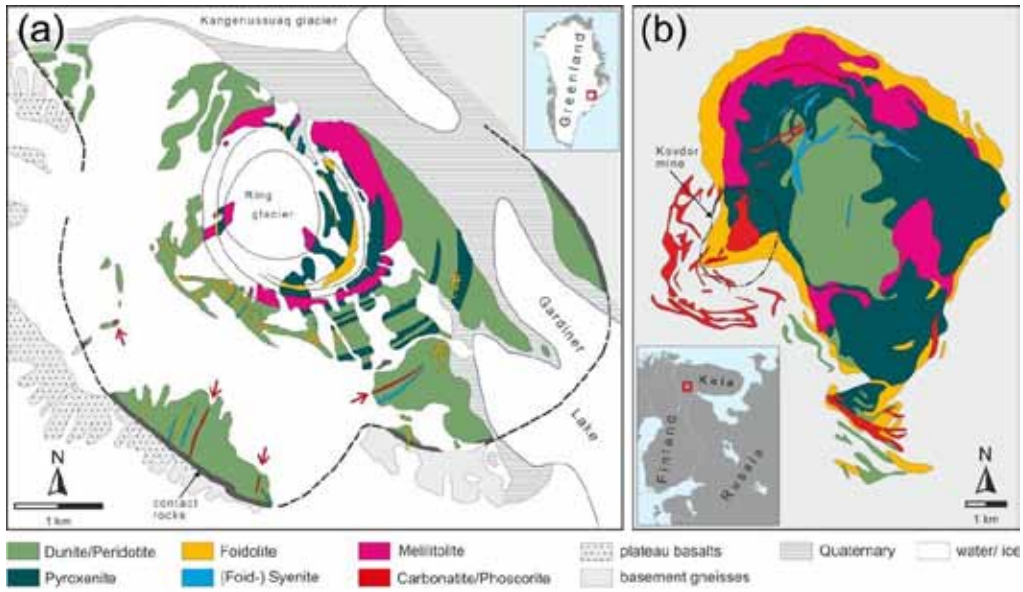

Figure 1: Geological maps of (a) Gardiner (E Greenland) and Kovdor (Russia), taken from Gudelius et al. (2023).

Ultramafic rocks from Kovdor include calcite- and biotite-rich dunites and pyroxenites without typical cumulate textures. They partly consist of Ni-poor forsterite (Fig. 2), Cr-poor diopside and Ni-Cr-poor spinel and are therefore interpreted as metasomatic reaction products between mantle-derived carbonatite melts and silicic host rocks. Similar ultramafic rocks are associated with carbonatites (e. g. at Palabora - South Africa, Afrikanda - Russia, and Salitre - Brazil). In contrast, the ultramafic rocks from Gardiner show well-preserved cumulate textures and consist

of Ni-rich forsterite, Cr-rich diopside as well as Cr-Ni-Ti-rich spinel and also contain F-Cl-rich apatite.

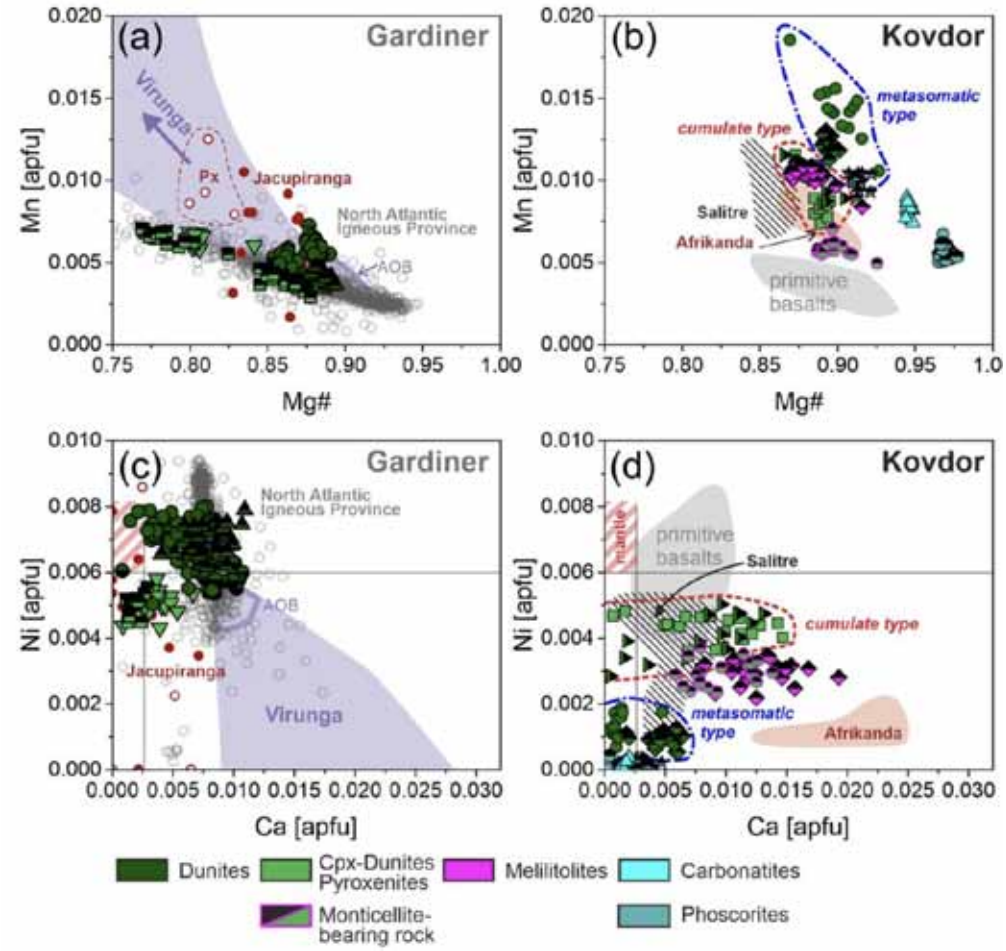

Figure 2: Comparison of olivine compositions from Gardiner (left column) and Kovdor (right column) with literature data (taken from Gudelius et al. 2023)

This indicates that these rocks represent cumulates of an evolving, mafic melt derived from Ti-rich mantle source, similar to other rocks of the North Atlantic igneous province (Fig. 2). In contrast to systems dominated by carbonatite metasomatism like Kovdor, Ti-rich parental silicate magmas can abundantly crystallize Ti phases, as recorded by massive perovskite cumulates in Gardiner melilitolites. This can effectively scavenge HFSE from the magmatic system early in its evolution and likely explains HFSE-barren carbonatites at Gardiner, while those from Kovdor are highly HFSE-enriched. In summary, ultramafic rocks in alkaline complexes can be of both cumulate and metasomatic origin; the specific type has an important bearing on their HFSE enrichment and on the types of ores present in such complexes.

Gudelius, D., Marks, M. W., Markl, G., Nielsen, T. F., Kolb, J., Walter, B. (2023): The origin of ultramafic complexes with melilitolites and carbonatites: a petrological comparison of the Gardiner (E Greenland) and Kovdor (Russia) intrusions. - J Petrol, egad036

Vasyukova, O.V. & Williams-Jones, A.E. (2022): Carbonatite metasomatism, the key to unlocking the carbonatite–phoscorite–ultramafic rock paradox. - Chem Geol 602, 120888