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The Origin and Melt Evolution of Massif-type Anorthosite Parental Magmas: Thermodynamically Controlled Major Element Constraints

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The parental magmas of massif-type anorthosites are suggested to originate from either the mantle or lower crust. If the source is the mantle, the magmas are presumed to have undergone crustal assimilation prior to plagioclase crystallization, which has produced melt compositions similar to anorthosite parental magmas (high-Al gabbros/basalts). If the source is the lower crust, the produced anorthosite parental melts are presumed to be monzodioritic (jotunitic) in composition. However, many studies have suggested that the monzodioritic rocks related to massif-type anorthosites rather represent residual melt compositions left after anorthosite fractionation. In this study, we have used the most recent thermodynamic modeling tools, Magma Chamber Simulator (MCS) and Rhyolite-MELTS to conduct partial melting, assimilation-fractional crystallization (AFC), and fractional crystallization (FC) models to address the unresolved questions about the source and compositional evolution of the anorthosite parental magmas.

AFC models were conducted at high lower crustal pressures (1000 MPa) by using MCS. In the models, we used four different sublithospheric mantle partial melt compositions and 11 different assimilants with representative average lower crustal compositions compiled from literature. In addition, equilibrium partial melting of the same lower crustal compositions was modeled separately by using rhyolite-MELTS. The melt major element compositions produced by both modeling tools were compared to suggested natural anorthosite parental magma compositions. Finally, to further study the evolution of these melts after their generation, FC models were run at different crustal pressures (1000-100 MPa) by using MCS. These differentiated melt compositions were compared to a global array of monzodioritic rocks presumed to represent residual melts left after anorthosite fractionation.

The preliminary modeling results point towards the mantle being a more suitable candidate for the source of the anorthosite parental magmas and that the parental magma compositions are better represented by high-Al gabbros than monzodioritic rocks: assimilation of mafic lower crustal material by mantle-derived magmas produces melts that are the most fitting analogues. Somewhat similar melts can also be produced by directly melting the lower crust, but this requires the crust to melt completely, which we consider improbable. The models further suggest fractional crystallization of high-Al gabbroic parental magmas produce residual melt evolution trends similar to the array of anorthosite-related monzodioritic rocks.