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Magma supercooling as a cause of mineral reverse trends in mafic dykes?

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Magma differentiation processes that operate in conduits delivering basaltic magmas towards the Earth's surface still remains poorly understood. To get insight into this problem we have studied whole-rock geochemistry and mineral composition of rock-forming minerals (plagioclase and clinopyroxene) in one section across a large dolerite dyke (21 m thick) and three sections across its narrow apophysis (69 cm, 29 cm and 17 cm thick) from the Lupchinga Island, Russian Karelia. Chemical zonation is found to systematically change with a decreasing thickness of studied sections. In particular, a tendency to become more evolved inwards in narrow apophysis sections (e.g. a decrease in MgO, Mg-number, normative An content and an increase in P2O5) gradually gives way to an opposite tendency to become more primitive inwards in a large dyke (e.g. an increase in MgO, Mg-number, normative An content and a decrease in P2O5). Our study shows that the observed spatial chemical zonation can be attributed to a gradual change from rocks mostly produced by quenching of progressively more evolved magmas (an apophysis) towards those predominantly formed by in situ cumulate growth of these magmas (a large dyke) (Chistyakova & Latypov, 2012). This model implies the filling of a dolerite dyke and its apophysis with magmas that become increasingly more evolved with time. However, composition of plagioclase in a master dyke shows a systematic inwards increase in An-content. Also, plagioclase and clinopyroxene become higher in An-content and Mg-number from the thinnest profile of an apophysis towards that of a master dyke. A question arises as to why these rock-forming minerals become more primitive inwards if they crystallize from inflowing magmas that become more evolved with time. The most logical answer to this paradox is that these changes in mineral compositions result from the decreasing extent of magma supercooling. There are three lines of evidence that provide support to this interpretation. Firstly, clinopyroxene shows a significant decrease in $Al2O_3$ and TiO_2 as the sections become thicker apparently reflecting a decrease in the rate of magma cooling (and the degree of supercooling) moving from an apophysis towards a master dyke. It is logical to suggest that a tendency for clinopyroxene and plagioclase to become higher in An-content and Mg-number in this direction is also due to the same reason. Secondly, an inward increase in An-content of plagioclase in the master dyke is correlated with an increase in the average length of plagioclase crystals apparently reflecting an inward decrease in a rate of magma cooling. Thirdly, the zonation pattern of plagioclase crystals in the master dyke is consistent with their crystallization from magmas that become inwards increasingly more evolved and less supercooled. It remains to be understood whether magma supercooling is a general reason for reverse trends in rock-forming minerals in mafic dykes.