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Origin of mafic-ultramafic sills: new insights from M- and S-shaped mineral and whole-rock compositional profiles

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The origin of mafic and ultramafic sills exhibiting different whole-rock compositional profiles (e.g. I-, C-, D-, M- and S-shaped profiles) remains controversial. We have addressed this issue by revisiting three ∼100 m-thick Siberian dolerite sills (Vavukansky, Kuz'movsky and Vilyuysky) that display remarkable internal differentiation. The Vavukansky sill has an M-shaped profile with prominent basal and top reversals showing inward increases in whole-rock MgO, Mg-number (100*Mg/(Mg+Fe)) and normative An-content (100*An/(An+Ab)) followed by the Layered and Upper Border Series with inward decreases in these indices. The Kuz'movsky and Vilyuysky sills both show S-shaped profiles similar to the Vavukansky sill, but lack a top reversal. These whole-rock M- and S-shaped profiles are accompanied by similar profiles in mineral compositions. Plagioclase and, to a lesser extent, olivine show systematic inward increases in An-content and Mg-number, respectively, across basal and top reversals. These compositional trends are followed by inward decreases in these ratios in the interiors of the Vavukansky and Kuz'movsky sills. Currently accepted models attribute whole-rock M- and S-shaped compositional profiles to crystal settling, compositional convection or compaction operating in closed systems. Our observations challenge these traditional interpretations because variations in mineral compositions observed in marginal reversals cannot result from closed system fractionation. The studied dolerite sills are best explained by in situ crystallization in two distinct stages. Initially, the sills evolved as open systems that were flushed by magmas which became gradually more primitive with time. This gave rise to basal and top reversals with minerals becoming more primitive inwards. Subsequently, magma flow through the sills ceased and they evolved as closed systems by fractional crystallization. This resulted in the Layered and Upper Border Series with minerals becoming more evolved inwards. This novel model can be extended to explain other compositional profiles and petrological features in mafic and ultramafic sills.