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Plagioclase compositions give evidence for in situ crystallization under horizontal flow conditions in mafic sills

R. Latypov (1) and V. Egorova (1,2)

(1) Oulu University, Department of Geosciences, Oulu, Finland (rais.latypov@oulu.fi), (2) Institute of Geology and Mineralogy SP RAS, Novosibirsk, RUSSIA

The relative roles of crystal settling and in situ crystallization in the formation of mafic sills and layered intrusions are still a subject of active debate in igneous petrology. Despite the fundamental differences in these two processes, they both result in minerals that become more evolved in composition inwards. Our detailed study of mineral compositions across three dolerite sills from Siberia indicates, however, that this is not always the case. In particular, the ∼100 m thick Vavukansky dolerite sill shows a systematic inward increase in An-content of plagioclase across lower (from ∼An 63 to ∼An 82) and upper (from ∼An 63 to ∼An 80) marginal zones. This is followed by inward decreases in the An-content of plagioclase in the interior part of the sill that ends in a Sandwich Horizon (An 55-58). These trends in plagioclase composition are not consistent with either approach, but can be explained by in situ crystallization involving two distinct stages. During the initial stage the sill evolved as an open system that was continuously filled by magmas becoming more primitive with time. This gave rise to marginal zones with minerals showing reverse compositional trends (e.g. an inward increase in the An-content of plagioclase). During the subsequent stage the sill evolved as a closed system by fractional crystallization. This resulted in minerals showing normal compositional trends (e.g. an inward decrease in the An content of plagioclase). We believe that the proposed in situ crystallization model involving two distinct stages may represent a general mechanism for the origin of intrusive bodies since similar reverse trends in plagioclase composition are observed in many other mafic sills and layered intrusions. In particular, such trends are documented in marginal zones of the Koitelainen (Latypov et al., 2011), Imandra (Egorova and Latypov, 2011), Hasvik (Tegner et al., 1999) and Fongen-Hyllingen (Wilson and Engell-Sørensen, 1986) layered intrusions. Such trends are also evident in the basal parts of Greenland dolerite sills (Gisselø, 2001) and Golden Valley Sill, South Africa (Galerne et al., 2010). We should continue to document mineral compositions in mafic sills to make further progress in our understanding of the processes involved in magma differentiation.