Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.15108

Skaergaard: Catastrophic growth of a magma chamber in months to years

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The ca. 55 Ma Skaergaard layered mafic intrusion (Greenland) is characterized by an onion skin-like lithological structure. Cumulus phases appear and disappear, and mineral compositions evolve in the same way from the vertical side walls, horizontal roof, and floor of the intrusion, which indicates that the ~300 km^3 of the Skaergaard magma body differentiated from a parental liquid under closed system conditions. This implies that the Skaergaard intrusion was a large, fully liquid magma chamber before it started to crystallize.

We ran numerical simulations which show that the Skaergaard magma chamber must have been emplaced in years to decades, with a vertical growth rate of a few 100 m/yr. Slower emplacement rates result in the formation of a crystal-rich magma chamber or partial solidification of the magma body before the end of emplacement. The robustness of the results and the validity of the approach are supported by a good fit between modelled temperature profiles in the country rock and temperature estimates obtained from rocks in the contact metamorphic aureole of the Skaergaard intrusion reported in the literature.

According to the model, the volumetric flow rate of magma into the Skaergaard magma chamber must have been 10s to 100s of km^3/yr, which is several orders of magnitude faster than emplacement rates reported for other intrusive bodies. This suggests that magma emplacement events like the Skaergaard intrusion are rare and catastrophic. Such rapid accumulations of magma can be accommodated by subsidence of the floor rocks along faults that may have been lubricated by magma.

Despite differences in magma compositions and tectonic context, some aspects of the Skaergaard intrusion are similar to caldera-forming super-eruptions, in that they represent rare, catastrophic events involving rapid transfer of magma along faults. The high intrusion rate of the Skaergaard magma chamber at a depth of a few kilometers is commensurate with the high eruptive fluxes of basalts observed at the surface in Large Igneous Provinces. We conclude that some layered mafic intrusions are the plutonic equivalent of LIP-related volcanoes, which rapidly erupt large volumes of basaltic magma on the Earth's surface.