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Qualitative and quantitative analyses of magmatic stoping in the roof of the Proterozoic Åva ring complex

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Daly (1903) defined magmatic stoping as magma emplacement due to the detachment of blocks of magma-chamber roof- and wall rocks and their incorporation into the magma chamber. Stoping itself involves a number of interrelated processes, e.g. hydraulic fracturing, partial melting, and explosive exfoliation, that are a product of the complex thermal, mechanical, and chemical interaction of magma and the country rocks. However, the individual processes, as well as the influence of the main controlling parameters, are poorly understood. This makes it difficult to quantify the contribution of magmatic stoping as a magma-emplacement process, which has resulted in vigorous debates about its efficiency and overall significance. To resolve this controversy, detailed, qualitative and quantitative studies to better understand the involved processes and the interaction of forces are essential.

We studied strongly foliated amphibolite-facies volcaniclastic metasedimentary rocks that were intruded by granitic magmas of the Åva ring complex (Finland), a 1.76 Ga intrusion which formed at 5 to 6 km depth (Eklund and Shebanov, 2005). In the roof region of the main intrusion, the country rock is strongly fragmented and incorporated into the granite as xenoliths ranging in size (area) from tens of m2 to mm2. We systematically recorded subhorizontal, glacially polished coastal outcrops that contain thousands of xenoliths. The xenoliths show signs of brittle deformation resulting in intense fragmentation caused by the intrusion of granitic veins and dyklets, i.e. the fragments are angular. Bigger blocks are often split along the foliation and are surrounded by a cloud of smaller blocks. In many places, the blocks still fit to each other like a jig saw puzzle, while in other domains, they appear to have tumbled around. In contrast, some outcrops contain rounded xenolithic blocks that show signs of ductile deformation.

From the outcrop maps, we carefully recorded all xenoliths to determine their size, orientation, and shape. In addition, we measured the strike of the internal foliation in relation to the undisturbed country rock for each individual xenolith.

The spatial xenolith distribution pattern and the close assemblage of fragments of a wide range of sizes indicate that stoping is a rapid and efficient process. The size distribution closely resembles a power-law distribution over several orders of magnitude, even if modified by stereographic effects. The results of the shape analysis indicate that the fragmentation process is strongly controlled by the host-rock foliation, expressed in alternating aspect ratios with respect to the xenolith size. First fragmentation occurs parallel to the foliation, resulting in high aspect ratios of large xenoliths. Further fragmentation reduces block aspect ratios cracking the blocks perpendicular to their long axis, before fragmentation parallel to the foliation becomes dominant again, producing small blocks with high aspect ratios.

References
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