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Syn-magmatic deformation of the Upper Zone anorthosites of the Bushveld Complex, South Africa

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The Upper Zone of the Bushveld Complex is endowed with the world's largest Fe-Ti-V±P deposit. The origin of the Upper Zone (UZ) is attributed as the result of crystallisation from the last major injection of magma into the Bushveld magma chamber (Cawthorn et al. 1991; VanTongeren and Mathez 2013). A more recent study suggested that UZ formed from multiple batches of crystal-rich magmas derived from deeper chambers (Yuan et al. 2017). The striking, almost adcumulate, nature of many UZ anorthosites also pose the question of the origin of adcumulates. In order to improve the understanding of UZ magmatic history, we analysed the microstructure of UZ anorthosite and their associated magnetitite layers using electron backscatter diffraction (EBSD).

We analysed twelve samples from the western limb of the Complex, including three magnetitite layers and their margins, together with the underlying and overlying anorthosite. The magnetitite layers vary in thickness from 70 cm to 40 cm. Their lower contact with anorthosite is usually sharp, whereas the upper contact is diffuse. Plagioclase crystals within the magnetitite layers are often completely recrystallised, but their primary elongate shape is preserved. Independent of their position relative to the magnetitite layer, anorthosites show significant deformation. Plagioclase exhibits evidence for dislocation creep such as deformation twins, crystal misorientation and the formation of low angle grain boundaries. Most low angle boundaries are tilt boundaries formed by the operation of the slip system [010](001); (the most common high temperature slip system for plagioclase). Plagioclase has a bimodal grain size, with the larger grains representing original magmatic grains, whereas the smaller grains are neoblasts. The orientation of the large and small grains is remarkably similar, with (010) and [100] parallel to the foliation, but a random orientation of (001). This microstructure is a consequence of grain boundary migration and bulging recrystallisation. Anorthosites contain late-stage accessory phases such as biotite and interstitial quartz, together with reactive symplectites that have been linked to differential loss of immiscible conjugate interstitial liquids. While pyroxene records some crystal misorientation and rare low angle boundaries, none of the late-stage magmatic features show evidence of deformation. This implies that recrystallisation of plagioclase occurred early while melt was still abundant.

Recent work shows that the Bushveld mush at UZ times was only a few metres thick (Holness et al. 2017). This, together with the observation that the extent of deformation in the anorthosites under- and overlying magnetitite layers is the same, demonstrates that viscous compaction is not likely to have caused the deformation or resulted in adcumulate formation. However, the microstructural evidence is consistent with complex dynamics of a recent model where anorthosites and their associated magnetitites crystallised from multiple crystal-rich mushes (Yuan et al. 2017).

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