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Magma dynamics above the Karoo plume, South Africa

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Mantle plumes produce voluminous amounts of magma (10^6 km^3) during a short period of time (10^6 years). The heat input of such plumes into sedimentary basins has been proposed as a significant factor in several global climatic crises. Indeed heat transfer through conductive and advective processes is likely to bake organic matter-rich sediments, which in turn may release greenhouse gases (CO_2 and CH_4). One of the yet poorly understood aspects of this model is the regional pattern of magma flow. The objective of this study is to constrain magma dynamics in the Karoo Large Igneous Province (LIP) intruded in a continental basin of South Africa.

Magnetic fabrics provide an efficient and accurate mean to determine magma flow direction in gabbroic rocks. The anisotropy of magnetic susceptibility (AMS) is particularly suited for this type of study. A previous study had shown that the AMS fabric is a reliable proxy for magma flow as long as samples are collected from the upper chilled margin of a sill. The central part is more complex due to interference caused by thermal convection.

Oriented core samples were collected from 30 different sills and yielded 1598 specimens for AMS measurements. The low-field magnetic susceptibility K_m ranges widely from about 100 to 20,000 . 10^{-6} [SI], while the degree of anisotropy P' ranges from 1.01 to 1.10. Thermomagnetic experiments reveal that the main magnetic carrier is titanomagnetite with variable ulvöspinel content. This is confirmed by measurement of hysteresis properties that also indicate that titanomagnetite in general has a pseudo-single domain grain size.

The results of this study clearly indicate that magma flow followed a main NW-SE direction in the studied area. The AMS directional data is consistent with the nearly horizontal attitude of the sill in 23 out of 30 cases, with subvertical K_3 axes. In 5 out of 30 sills, K_3 axes are subhorizontal, characterized by scattered directional data and are considered anomalous AMS fabrics. K_1 axes are systematically subhorizontal and mark the magma flow direction. This regional scale flow pattern indicates that the Karoo plume head was not located under the Drakensberg basalts, the thickest part of the Karoo volcanic pile. Instead the plume head might have been located to the NW of the Karoo Basin, in Namibia. Overall these results show that magnetic fabrics are an efficient tool to analyze large-scale magma dynamics.