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Apatite Fission Track and (U-Th)/He data from deep boreholes and regional transects in South Africa: implications for the exhumation pattern and uplift of the southern African plateau

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Evolution of the southern African plateau remains contentious because of discrepancies between interpretations derived from geomorphic and stratigraphic evidence and quantitative, empirical estimates of the erosional history. Evidence of a large-scale seismic mantle anomaly suggests that the high elevation of the plateau might be related to active upward flow within the mantle. However, various published geodynamic models predict conflicting pictures of the vertical motion with Africa going up or down. These differences result from uncertainties on the viscosity and density structure of the mantle and also to how seismic velocity is finally scaled and used to drive deep mantle flow as well as how plate motions are incorporated into the models.

Whatever the process involved, the km-scale vertical motions predicted by from the models must have been accompanied by an increase in erosion rates and rock exhumation. In this study we use a combination of apatite fission-track (AFTA) and (U-Th)/He thermochronometry (AHe) to resolve thermal events occurring in the shallow part of the crust. We present analyses of transects crossing the Great Escarpment together with samples from deep boreholes (1-2 km depth). The borehole approach enables constraints to be placed on the timing and amount of cooling even in cases of relatively low amount erosion while outcrop samples enable discussion of the regional exhumation patterns.

A dozen deep boreholes from above and below the great escarpment have been sampled. We present fission track and AHe results for five of them. The AHe analyses are performed as single grain analyses with an average number of 15+ aliquots per sample for a total of 250+ single grain analyses in order to provide a high resolution chronology and to quantify the dispersion of single crystal ages. The shallowest borehole is 0.8 km and the deepest is 1.6 km, with most of them deeper than one kilometer. A spatial pattern is clearly evidenced with boreholes located above the escarpment showing older ages (AFT ages c. 300 Ma; AHe ages c. 110 Ma) than those located below (FT ages < 120 Ma; AHe ages < 90 Ma). We also present a new AHe transect from Johannesburg eastwards through Swaziland towards the Mozambique border.

Thermal history modelling was carried out by joint inversion of AHe and AFTA data. The data provide robust well-constrained evidence for a major period of cooling during the late Cretaceous (circa 90 Ma). From local measurement of the present geothermal gradient and estimation of palaeothermal gradient from the thermochronometry data we show that these data are best explained by spatially variable, km-scale erosion across the plateau. Palaeozoic AHe ages (c. 300 Ma or older) from the central part of the plateau suggest that the regional pattern of exhumation/uplift is probably more complex than previously thought. These preliminary results broadly agree with the offshore sedimentary records, and particularly well on the eastern craton margin.