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New insights into the age of the first-order topography of southern Africa from apatite (U-Th)/He and fission track dating of a deep borehole sequence through the Kaapvaal craton

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The origin and timing of the >1km elevation increase of the South African plateau since the Palaeozoic is widely debated. The crux of the debate is whether the present day first-order topography of southern Africa represents the deeply eroded remnants of a previously elevated continental interior or that it is much younger and was created by regional dynamic uplift, linked to deep mantle flow beneath the continent, of a low relief surface with low mean elevation more than 100 Ma after continental break-up.

Here we present new low temperature thermochronology results using both apatite (U-Th)/He (AHe) and apatite fission track analysis (AFT) techniques applied to samples from a deep borehole in central South Africa. The key advantage of this borehole approach is that it enables constraints to be placed on the timing and amount of cooling resulting from relatively low amounts of erosion.

The samples were collected from the Bierskraal (BK1) borehole, located 100 km northwest of Johannesburg at an elevation of 1508 m. The 5 samples analysed are all from the Bushveld Igneous complex (gabbro norite and magnetite gabbro of the Main and Upper zones) and range from 434 m to 1401 m depth. Previously published AFT ages are between 321 $\pm$ 34 Ma and 278 $\pm$ 32 Ma with apparent age decreasing with sample depth and mean track lengths ranging between 12.7 $\pm$ 0.16 μm and 11.63 $\pm$ 0.18 μm. Between 13 to 22 apatite single grain or multi-grain apatite aliquots from each sample were analysed by AHe (n = 86). The ages range between 86 $\pm$ 31 Ma for the bottom sample to 125 $\pm$ 29 Ma for the shallowest sample and are everywhere less than the associated AFT ages.

Thermal history modelling was performed using QTQt that enables the AHe and AFT data from all samples in the vertical sequence to be jointly modelled. The thermal histories confirm the thermal history derived initially from the AFTA data alone and provide robust well-constrained evidence for a major period of cooling during the mid-Cretaceous at approximately 90 Ma. The data require $\simeq$3.5 km of denudation of the Bierkraal site during mid-Cretaceous time. This agrees with the offshore sedimentary records on the eastern craton margin and suggests that, far from being tectonically and geomorphically inert, the South African craton underwent a major uplift stage during late Mesozoic times. Whether this uplift was driven directly by dynamic uplift caused by buoyant flow within the deep mantle remains to be tested by compiling more data across the south-african plateau. This would allow constraint of a continental scale dynamic topography model and provide a better understanding of the relationship between mantle dynamics and the influence on topography.