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Evolution of the East Greenland passive continental margin: new evidence from single-grain-age low-temperature thermochronology

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Neogene uplift has been widely used to explain the present high topography of many North Atlantic continental margins, but a contrary view exerts that such landscapes developed by protracted exhumation of topography since the Caledonian Orogeny as a result of gravitational collapse, continental rifting and erosion (e.g. Nielsen et al., 2009). We have obtained a single-grain apatite (U-Th)/He age dataset for East Greenland to test and refine theories of passive continental margin evolution in this region. Furthermore, multiple single-grain ages (up to 20 per sample) were obtained to enable investigation of (U-Th)/He age reliability and the factors that influence age reproducibility. We have focussed on East Greenland because stratigraphical evidence demonstrates unambiguously that the first-order topography, which consists of a series of deeply dissected quasi-planar high-level surfaces that are separated by well-defined escarpments, evolved prior to the onset of flood volcanism that coincided with lithospheric breakup at $\sim$ 57 Ma. The maximum age of this ancestral topography is constrained by our (U-Th)/He age dataset, which consists of eighteen samples from four topographic profiles located in the inner fjord-system and spanning elevations from sea-level to $\sim$ 1100 m. Importantly, the data demonstrates a rapid period of exhumation at $\sim$ 60–70 Ma that indicates that the first-order topography formed rapidly in response to a single erosional event stimulated either by climatic change or the renewed onset of rifting. However, many individual samples exhibit poor single-grain age reproducibility, with standard deviations (calculated over the arithmetic mean of the corrected single-grain age) approaching 40%. Such variability has been presumed to indicate either ‘excess He’ arising from the presence of undetected fluid and/or mineral inclusions, or the anomalous He retention as a result of radiation damage that affects He diffusivity. Nevertheless, statistical analysis of the dataset has demonstrated no clear systematic pattern behind the wide age variation. Notably, analysis of three Caledonian Basement samples from one particular topographic profile, each of which has > 15 age determinations, demonstrated that: (1) age variation was normally distributed, indicating that age variability cannot be ascribed to ‘excess He’; and (2) ages demonstrated only weak correlation with [eU] for high-[eU] samples ($r2 = 0.17$; $p = 0.05$; $n = 19$), whilst many low-[eU] and high-[eU] samples demonstrate similarly weak reproducibility, indicating that the samples may be insufficiently old for radiation damage to have influenced He diffusivity. Furthermore, inverse modelling of sample cooling histories using the uncorrected AHe age, the AFT age and the AFT track length distribution supports an age close to the weighted-mean age as being the most plausible. The single-grain age data therefore supports our previously-published conclusions based on multiple-grain age data from the same topographic profiles (Swift et al., 2008) that the East Greenland topography formed rapidly between $\sim$ 70 and $\sim$ 55 Ma. Furthermore, though further work is needed to understand the causes of the observed age variation and how such ages should be interpreted, it is possible that single-grain (U-Th)/He age variation could contain important information that can be further used to constrain thermal histories. We therefore advocate that non-reproducible samples should not be discounted on the basis of an inferred poor quality of the picking procedure or suspected radiation damage without rigorous analysis of a reasonable number of single-grain age determinations.