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Multiple broadly synchronous km-scale exhumation episodes on different continents: implications for controlling processes

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Numerous low temperature thermochronology studies have defined regional cooling episodes which imply removal of several km of section over areas of several 104 km2. The origin of such events has long been the subject of debate, while their reality has sometimes been questioned because of the lack of a viable mechanism. Kilometre-scale denudation at rifted margins has traditionally been interpreted as related to rifting and breakup, magnified by the flexural response to denudation of the uplifted rift flanks. But it is now clear that at many margins the post-breakup history is more complex, with km-scale uplift and erosion commonly post-dating breakup by 10s of Myr and often affecting regions many 100s of kilometres inland of the margins (Green et al., 2013; Brown et al., 2014). Numerous examples around the world of km-scale exhumation affecting regions distant from continental margins, including cratonic regions traditionally regarded as stable over Phanerozoic time (e.g. Ault et al., 2009; Flowers & Kelley, 2011), cannot be explained by margin-related mechanisms.

It has also become clear that periods of exhumation are separated by episodes of burial, defining a series of positive and negative vertical movements. Previous studies have defined a broad synchroneity of Early, Middle and Late Cenozoic exhumation events in regions from Alaska to Greenland, Norway and Svalbard (Green and Duddy, 2010). New results from SE Australia define a series of exhumation episodes ranging in time from Carboniferous to Cenozoic which are broadly synchronous with similar events previously defined in Brazil and South Africa (Green et al. 2013). While estimates of the timing of exhumation in different areas are subject to some uncertainty, data across three southern hemisphere continents show a broad synchronicity in similar fashion to the northern hemisphere examples cited above.

Dynamic topography has been invoked as a possible mechanism for producing uplift, the effects of which might be magnified by the isostatic response to denudation, but until recently the vertical motions expected from this mechanism were thought to be restricted to 100s of metres while expected timescales of 100s of Myr are not consistent with observations. Braun et al. (2014) showed that movement of plates over areas of areas of mantle upwelling could produce much more rapid uplift and also much larger-scale vertical movements, but the predicted diachroneity of uplift across southern Africa differs from the apparent synchroneity across three continents described here. The processes described by Braun et al. are also specific to one location and one event. Japsen et al. (2012) suggested that broadly synchronous exhumation events on divergent continents resulted from lateral resistance to plate motion driven by forces transmitted in the asthenosphere, while Colli et al. (2014) proposed that dynamic topography caused by pressure-driven mantle flow could produce synchronous uplift (and erosion) in separate continents. Such processes appear to offer more viable mechanisms for producing broadly synchronous episodes of kilometre-scale exhumation and intervening burial in regions separated by large distances. Further geodynamic modelling is needed to develop and test likely mechanisms.