Forum Comment

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How local crustal properties influence the amount of denudation derived from low-temperature thermochronometry

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Łuszczak et al. (2017) apply apatite fission-track thermochronometry (AFTT) to the Cenozoic landscape development of northern Britain, including the Lake District (LD) of northwest England. Their main conclusion is that previous workers (e.g., Green, 2002; Green et al., 2012) have overestimated denudation by overestimating the thermal conductivity (k) of the rock column lost. However, Łuszczak et al. infer much more denudation than these other studies, although with much lower Late Cenozoic uplift rates, contradictions that require comment. Łuszczak et al. also dispute the inference by other workers of a higher-than-present paleo-geothermal gradient, ∇T_P, caused by transient heating of the shallow crust during the Paleocene British Tertiary Igneous Province (BTIP) magmatism.

Łuszczak et al. infer that the rock lost from the LD was Mesozoic mudstone and Chalk with k = 1.2–2.0 W/m/°C (cf. Green, 2002). Present outcrop in the LD is mostly Ordovician Borrowdale Volcanic Group (BVG), with offlapping Carboniferous and Permian-Triassic sediments (e.g., Holliday, 1993). For the BVG rocks, sampled by Green (2002), k is 2.51 ± 0.19 W/m/°C (±1s; Gunn et al., 2005). With a harmonic mean k of 1.6 instead of ~2.5 W/m/°C, the Cenozoic denudation estimated from Green's AFTT adjusts from ~700 to ~450 m. His arguments, and those by Green et al. (2012) and Westaway (2017), would not be significantly affected by this, but his original ~700 m value agrees better with Holliday's (1993) geological estimate of ~700–1750 m of denudation.

Łuszczak et al. partitioned their preferred 2250 m of Cenozoic uplift in the LD with 1650 m during 62–57 Ma, at 0.33 mm/yr, followed by ~500 m at 0.0088 mm/yr. However, uplands in northern England have maintained uplift rates of ~0.15–0.2 mm/yr since the Early Pleistocene, with uplift by ~150–200 m on this time scale and by ~300–400 m since the Mid Pliocene (e.g., Waltham, 2013; Westaway, 2017). These relatively high rates, established independently of AFTT, are evidently unrelated to the BTIP magmatism. The uplift history preferred by Łuszczak et al. is consistent with ~1250 m of denudation over the highest part of the LD (978 m above sea level [a.s.l.]), far above Green's (2002) estimate. However, they did not report any analyses with <2000 m of uplift assumed, and give no compelling reason for choosing their preferred solution, raising the possibility of significant overestimation. This is important, because 2250 m is roughly the uplift expected from isostatic modeling, after Brodie and White (1994), following the intrusion of ~5-km-thick underplating, as is observed (e.g., Barton, 1992). However, the Brodie and White modeling method is considered over-simplistic (e.g., Green et al., 2012; Westaway, 2017). As Łuszczak et al. present no analyses with ~450–700 m of denudation across the LD, their paper sheds no light on this key issue.

AFTT indicates that boreholes offshore of Britain record a 'pulse' of heating by the BTIP magmatism (e.g., Clift and Turner, 1998). Green's (2002) sampling of the BVG rocks up to 966 m a.s.l. in the LD provides an analogous vertical transect, with a ∇T_P of 61 °C/km, indicating paleo–heat-flow of 61 °C/km × 2.51 W/m/°C, or ~153 mW/m^2, ~60% above present, consistent with the offshore context. Green's analysis is not refuted by Łuszczak et al., whose sites are all too low (a.s.l.) to resolve ∇T_P. Łuszczak et al. also argue that the Green et al. explanation for the increased ∇T_P is wrong, stating "deep-seated magmatism has a negligible impact on the thermal structure of shallow crust" and citing Brown et al. (1994). However, Brown et al. assumed instantaneous underplating at the base of the crust, whereas the BTIP magmatism spanned millions of years (e.g., 61–52 Ma; Kent and Fitton, 2000). Following Clift (1999), many workers have realized that offshore thermal histories reflect prolonged underplating by many small intrusions. Green et al. (2012) thus assumed that the top of the underplate remained at 1100 °C, the freezing point of mafic magma, for up to 10 m.y., to mimic this scenario. The resulting calculated shallow geothermal gradient thus increased by ~60% within ~5 m.y. of the start of the magmatism, explaining the AFTT evidence. The assumption of instantaneous magmatism evidently led Łuszczak et al. to a mistaken conclusion.

Łuszczak et al. rightly emphasize the importance of basing AFTT modeling on site-specific, rather than nominal, data. Nonetheless (as for any modeling), judgment is required as to which details are key. Apart from the higher-than-present ∇T_P, their analysis also omits other aspects, including surface temperature fall (cf. Green et al., 2012), and causes of Cenozoic denudation and uplift other than the BTIP magmatism (cf. Green et al., 2012; Westaway, 2017). Aspects such as these, omitted from their modeling, have evidently led them to overestimate Cenozoic denudation; their analysis is thus not a sound basis for superseding the interpretation (e.g., Green, 2002; Green et al., 2012) of only modest (≤~700 m) Cenozoic denudation in uplands of northern England.

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