Seismic imaging of a hot upwelling beneath the British Isles: Comment

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Arrowsmith et al. present a three-dimensional model for the crust and mantle beneath Britain, which resolves lateral variations in seismic velocity of ~±1.5%, corresponding to temperature anomalies of ~±100 °C. Despite the distance of up to ~2000 km from Iceland, they assert that these anomalies are being maintained by hot material from the Iceland mantle plume, which they thus regard as the cause of the Cenozoic epeirogenic uplift, gravity anomalies, and intraplate seismicity within Britain.

Their results indicate that at depths of <~100 km temperatures are up to ~200 °C hotter beneath N and SW England than beneath SE England. They attribute this variation to the presence of hot material from the plume in the north and west. However, the boundary between these hot and cold model regions follows that between relatively old (Proterozoic) and cold (surface heat flow, q_s, <~50 mW m^{-2}) crust of the London Platform in the southeast and the younger (Paleozoic) and hotter (q_s locally >90 mW m^{-2}) crust elsewhere (data from Ziegler, 1990; Rollin, 1995; Jackson, 2004). Much of this heat flow variation is due to the distribution of radiogenic Paleozoic granite in the crust. Extrapolation of the observed geothermal gradients, taking account of the expected decrease of heat production with depth, indicates that the Moho (at ~30–35 km; Chadwick and Pharaoh, 1998) is ~200 °C hotter in the north and west than in the southeast (~700 against ~500 °C). This indicates that the lateral variation in temperature and seismic velocity deduced by Arrowsmith et al. (2005) results from lateral variations in crustal properties inherited from the ancient geological past, rather than being dynamically maintained by the Iceland plume.

Regarding epeirogenic uplift, I see no problem with the suggestion, made previously (e.g., Nadin and Kusznir, 1995), that the Iceland plume caused significant early Cenozoic uplift in the north and west of Britain, when these regions overlay the head of this plume. However, oceanic spreading at the Mid-Atlantic Ridge has subsequently taken each part of Britain ~800 km farther away from the plume. One should thus expect any plume effect to have weakened over time; so if it was the only factor operating, then early Cenozoic uplift would have been followed by late Cenozoic subsidence. The fact that this has not occurred makes it clear that the Iceland plume is just part of the Cenozoic vertical crustal motion story within Britain. However, there is a strong correlation across Britain between rates of vertical crustal motion and the thermal state of the crust. Typical middle-late Pleistocene uplift rates in SE England have been ~0.05–0.1 mm yr^{-1} from dated fluvial terraces and marine deposits (e.g., Bridgland, 1994; Bridgland and Thomas, 1999; Bridgland et al., 2004). In northern England, raised beaches and karstic systems indicate uplift rates of >~0.2 mm yr^{-1} on equivalent time scales (e.g., Waltham et al., 1997; Bridgland and Austin, 1999). However, rates of this order are thought to be characteristic only of time since the middle Pliocene, after which most of the present topography developed (e.g., Westaway et al., 2002). Furthermore, numerical modeling suggests that this uplift is being caused by coupling between surface processes (such as erosion) and induced flow in the lower crust, and is thus a consequence of the pattern of post-middle-Pliocene climate regimes (e.g., Westaway et al., 2002). The colder crust in the southeast has a higher effective viscosity, thus it flows less readily in response to a given magnitude of forcing, leading to lower rates of crustal-thickness change and surface uplift. The present pattern of topographic relief, and thus the associated pattern of free-air gravity anomalies, therefore has nothing to do with the Iceland plume.

Regarding the intraplate seismicity of Britain, Arrowsmith et al. (2005) suggest that this is concentrated along the boundary between the hot region to the northwest and the cold region to the southeast, citing Bott and Bott (2004) as a supporting reference. In fact, the analysis by Bott and Bott (2004) argued instead that this seismicity is concentrated in the hottest model region, not at its edge. However, both earthquake populations are dominated by very small events, so their apparent distributions are influenced by spatial and temporal variations in detection thresholds as seismograph coverage has changed. In terms of significance for coseismic crustal deformation, the largest known onshore earthquakes in Britain, from a historical record exceeding 700 yr (Colchester, Essex, 22 April 1884, M_L 4.6; and South Hayling, Hampshire, 15 October 1963, M_L 4.7; Musson, 1994), both occurred in SE England, near the North Sea and English Channel coasts. They thus provide no basis for any direct cause-and-effect relationship between seismicity and the thermal state of the crust, let alone any relationship involving the Iceland plume.

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