ANNIVERSARY RETROSPECTIVE

Mantle signatures in the surface

Yellowstone National Park is awe-inspiring. Towering mountain ranges flank a high plateau spattered with explosive geysers and hydrothermal springs of swirling orange, green and blue. Powerful rivers carve canyons through uplifted peaks and open downstream to peaceful lakes, while thick forests provide canopy for the wolves, grizzly bears, bison and elk that roam freely. And all of this beauty sits atop a supervolcano.

To understand what fuels this supervolcano helped inspire my PhD research. That Yellowstone's geysers and springs are powered by volcanism is unquestionable, but the source driving this volcanism is unclear. The North American plate could be moving slowly across a stationary plume of upwelling, hot mantle. Such a mechanism could explain the trail of volcanic centres that stretch northeastwards across Idaho and Montana, into Wyoming, decreasing in age until they reach Yellowstone — the postulated present-day site of the mantle plume. Yet, tomographic data have so far failed to provide a clear image of a plume extending from the shallow mantle into the deep Earth.

Mantle plumes are often invoked to explain chains of volcanism that cross the ocean floor, with the Hawaiian–Emperor chain in the Pacific Ocean an oft-cited type example. The seabed surrounding Hawaii bulges upwards in a dome-shape that is thought to be the surface expression of an underlying mantle plume. So, writing in the *Journal of Geophysical Research* in 2000, Lowry and colleagues attempted to see if Yellowstone was characterized by a similar swell (Lowry et al. *J. Geophys. Res*. **105**, 23371–23390; 2000). Using a range of geophysical data, they identified an anomalous dome, up to 2-km high and 1,000-km wide, centred on Yellowstone. Simulations with a numerical model then showed that this swell was consistent with deformation of the continental lithosphere induced by a potential Yellowstone plume.

Credit: Amy Whitchurch

Motivated by these quantitative constraints on what might be a hallmark signature of plume activity at Yellowstone, I set about testing whether the regional landscape preserved a record of such dramatic uplift. In theory, this hotspot swell should have migrated in tandem with plate motion across a stationary mantle heat source, disrupting river drainage patterns along the way. Rivers should steepen and incise in response to uplift, gaining more power to erode and transport large pebbles and sediment downstream. Indeed, analysis of ancient river deposits preserved in Montana revealed a transition from a gentle, meandering river system to an energetic, braided system at about the same time the region would have passed across the hotspot swell. However, fluvial systems reflect the complex influences of local tectonics and climatic changes, too. To isolate the signature of a plume-induced hotspot swell proved no simple task, but I loved the idea that surface geomorphic features that are so familiar in our present lives could provide windows into processes operating deep and hidden within the Earth.

Seventeen years down the line, the debate about the existence of a mantle plume beneath the western US still has not closed. Revised estimates of the size of the Yellowstone hotspot swell are smaller. It now seems possible that the volcanic activity in this region is linked to hot mantle drawn out from beneath the Pacific Ocean basin and under the western US by mantle flow induced by sinking of the ancient subducted Farallon slab into the deeper mantle (Zhou et al. p70; Keane p8).

If this scenario stands the test of time, a Yellowstone plume could only have a limited role. But it cannot be ruled out completely. ❐

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Published online: 2 January 2018
https://doi.org/10.1038/s41561-017-0050-z