Plumes do that

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The plate tectonic paradigm profoundly changed the way geologists viewed and understood our planet. Elegant and powerful as the paradigm was, geologists still had a need to explain volcanism located away from plate boundaries, i.e. volcanism that could not readily be related to processes to do with continental break-up or subduction. Thus the term 'hotspot' was coined by Tuzo Wilson in the early 1960s. Classic examples of such volcanism are the islands of Hawaii, situated within an oceanic plate, and Yellowstone, situated within a continental plate.

Given that hotspots could not easily be related to plate tectonics, another explanation was sought. In the early 1970s Jason Morgan provided the concept of mantle plumes — roughly 3000 km-tall columns of abnormally hot mantle rising from the core–mantle boundary and eventually inducing hotspot magmatism on the overriding plate. Conceptually this is a bit like moving your hand over a burning candle. This concept was not plucked from thin air, since it was well understood that convective turnaround of the earth's mantle was needed to explain the cooling of the earth. The failure to appreciate heat loss via convection is, for example, blamed for Lord Kelvin's underestimate of the age of the earth. So given that convection was accepted, Morgan's plume concept was well received. The number of such plume features was originally estimated to be 20 or so. These rising columns of molten rock were also suggested to be stationary with respect to the earth's core, and so the concept was quickly embraced by researchers reconstructing plate motions, since it provided an absolute reference frame.

The plume concept became so popular that before long there were about 5000 proposed hotspots and associated plumes! Hotspots were no longer restricted to plate interiors and the term was also applied to plate-boundary volcanism. More remarkable still, is the flexibility granted the plume concept.

I recall a geological conference where I met an eminent professor, a world authority on plumes, and asked about his recently proposed plume model. This particular plume was first expressed as a 2000 km-long sub-vertical mantle sheet, inducing an equally long magmatic province. Some 5–10 Ma later, the sub-vertical mantle sheet swung around by 90 degrees, produced another 2000 km-long magmatic province at right angles to the first, and while doing so broke the plate. Following this neat acrobatic trick the plume collapsed into a Morgan-type cylindrical-shaped plume. I asked if such unlikely acrobatics were not artificially tailored to match surface observations, and received the firm reply 'plumes do that.'

Such malleable concepts are useful. We should have more of them in geoscience. Fortunately for us geoscientists, the plume concept has been expanded and can now explain far more than the original idea could. Take the case of Iceland, a commonly cited super plume, supposedly rooted at the core–mantle boundary and by chance intersecting the mid-Atlantic plate boundary. Unlike Hawaii, Iceland does not have a hotspot track, but that is OK, because one can calculate the plume's paleo-position since it is fixed to the earth's core. And lo and behold, the Iceland plume can be followed on quite a journey through time and space. Some 250 Ma ago, this plume was apparently responsible for the Siberian traps, after which it took a 120 Ma break before emerging in the Alpha Ridge area of the Arctic Ocean. And guess what? After another 60 Ma pause in the magmatic activity the plates had moved such that the plume again caused basalt extrusion, this time in the Disco Island area of West Greenland. Somehow the plume shortly thereafter sent off a tentacle to the incipient northeast Atlantic, or alternatively the plate moved quickly over the plume. In any event, the plume emerged from beneath Greenland and induced northeast Atlantic break-up, in a magma-rich manner. This magma-rich break-up is itself a true sign of plumes, for what else could cause it? Surely not the plate tectonic break-up process itself? That would just be too easy. The idea that there could be a genetic relationship between rate of plate separation and the amount of adiabatic melting is actually quite appealing to some of us. But no, let's introduce a plume instead. After all, plumes being fixed to the earth's core and remaining so for hundreds of millions of years within a simultaneously convecting mantle is a sign of a robust concept, right? Plumes do that.

More recently it has been suggested that plumes are not strictly fixed with respect to the core, but sway in the mantle wind. That's OK. One has to be a bit flexible.

A concept that is granted the freedom of perpetual *ad hoc* amendments has the ability to explain anything, and is hence attractive to some people. But such a concept can neither be falsified nor be used predictively. In the long run it may be wiser to ask yourself 'Is there an alternative explanation?' rather than simply shrugging, 'Plumes do that.'