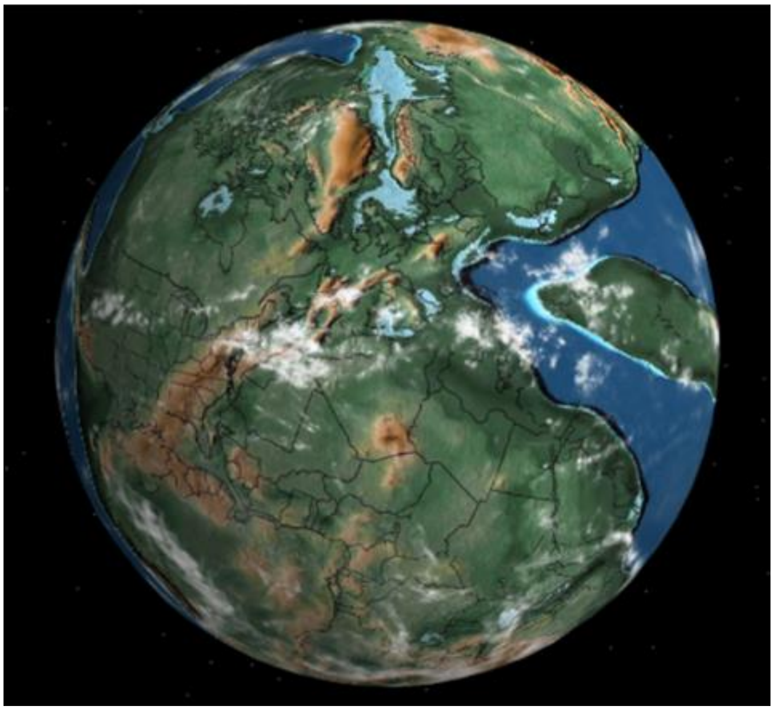
In Plate Tectonics, mantle plumes did not split continents



The strong outer shell of Earth is the lithosphere. In regions with continental crust, it is roughly 100 km (62 mi) thick, and very hard to break apart. What split the supercontinent Pangea in Plate Tectonics theory has been debated for decades. A common assumption has been that hot magma rising from the deep softened the lithosphere, weakening it so it could be pulled apart. The detailed study quoted here shows that did not happen. So some other powerful force must have divided the continents.

These are excerpts from a 2019 paper published in Earth-Science Reviews titled: A review of Pangaea dispersal and Large Igneous Provinces - In search of a causative mechanism*, emphasis added. A Large Igneous Province (LIP) is where there was an eruption of large quantities of basaltic magma in a relatively short time. On land they are flood basalt provinces; on the seafloor they are giant oceanic plateaus.

“The breakup of Pangaea was accompanied by extensive, episodic, magmatic activity. Several Large Igneous Provinces (LIPs) formed, such as the Central Atlantic Magmatic Province (CAMP) and the North Atlantic Igneous Province (NAIP). Here, we review the chronology of Pangaea breakup and related large-scale magmatism. We review the Triassic formation of the Central Atlantic Ocean, the breakup between East and West Gondwana in the Middle Jurassic, the Early Cretaceous opening of the South Atlantic, the Cretaceous separation of India from Antarctica, and finally the formation of the North Atlantic in the Mesozoic-Cenozoic. We demonstrate that throughout the dispersal of

Pangaea, major volcanism typically occurs distal [far] from the locus of rift initiation and initial oceanic crust accretion. **There is no location where extension propagates away from a newly formed LIP**."

"The processes that initiate the dispersal of these large continental accumulations remain controversial. The debate primarily revolves around whether continental dispersal is driven by deep-rooted thermal anomalies (Morgan-type mantle plumes) or shallow plate tectonic processes. The concept that plumes from the deep mantle are the main driver of continental rifting was originally proposed" in 1971. "[T]his hypothesis continues to be commonly invoked as a default to explain continental breakup and plate motions". "Plume impingement models predict uplift, LIP-emplacement and rifting in rapid succession. In such models, the bulk of the magmatic products are expected prior to and during the initial stages of rifting, shortly after plume impact." "Rifting is expected to initiate at, and propagate away from, the point of plume impact and LIP magmatism. The regions we reviewed, associated with the Pangaea breakup, do not display the features of this ideal model." These regions are the North, Central, and South Atlantic Ocean. "Less information is available from the Western Somali and Mozambique basins, which record the breakup of East and West Gondwana." "All the locations reviewed herein show evidence for prolonged phases of rifting prior to LIP magmatism and breakup." "In all cases reviewed here, the onset of LIP magmatism, and often eruption of the main volume, significantly overlapped with or postdated SDR [Seaward Dipping Reflector]- and initial-oceanic-crust production [that is, the start of spreading]. Such magmatism is inconsistent with plume impact driving sometimes long-lasting initial rifting. Instead, it suggests that **magmatism was a consequence of the same mechanism that triggered rifting and/or breakup**."

"Following plume arrival, widespread magmatism is predicted to occur in the region underlain by hot plume head material. This region is inferred to be circular, with a diameter of several 1000 km in an idealised model. Buoyant melt is expected to intrude the crust radially, governed by the circular stress field generated by the impinging plume, and to form radial dyke swarms and sills, again in an idealised model. Lithospheric structure is expected to impose only secondary control. The relatively small barriers presented by lithospheric inhomogeneities are expected to be overwhelmed by the much larger scale hot upwelling mantle material. These predictions are, however, not supported by observations of the disintegration of Pangaea. Instead, inherited lithospheric structure exerts a control, not only on the locus of breakup axes but also on the locations of magmatism including LIPs."

"None of the regions we review fit comfortably a plume-driven breakup model that predicts pre-breakup magmatism, plume tail eruptions producing ocean island chains, and rifting radiating from the point of plume impact. In contrast, most show multiple characteristics that are not fully compatible with this model, including a reverse chronology of uplift, magmatism and rifting, and rifting propagating towards LIPs. The idealised, generic plume-impingement model thus has difficulties fully explaining the dispersal of Pangaea and associated magmatism."

"Rifting and breakup driven primarily by far-field extensional forces, with magmatism occurring as a consequence, under strong lithospheric control, is much more consistent with observations that are common throughout the regions we review. These observations include:

- Evidence for pre-LIP uplift is lacking.
- Magmatism appears to have followed pre-existing structures that may have experienced magmatism previously.
- The source of magmas was distributed. Magmas did not arise from a single centre.
- Large-volume magmatism (LIP emplacement) occurred distal to [far from] simultaneous breakup-related rifting, which tended to migrate towards the new LIP.
- The geochemistry of LIP lavas, in particular their Ti contents, suggest a source in the lithospheric mantle."

"These observations suggest that a fundamental reappraisal of the causes and consequences of breakup-related LIPs is in order."

*Peace, A.L., J.J.J. Phethean, D. Franke, G.R. Foulger, C. Schiffer, J.K. Welford, G. McHone, S. Rocchi, M. Schnabel, A.G. Dore. 2019. A review of Pangaea dispersal and Large Igneous Provinces - In search of a causative mechanism. Earth-Science Reviews, published online 22 July 2019, 25 pages, DOI: 10.1016/j.earscirev.2019.102902

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