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Plume-generated LIPs and new ocean formation through time

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The Phanerozoic geological record shows clearly that plume-generated Large Igneous Provinces (LIPs) can be associated with major continental breakup and formation of new oceans. Prominent examples include the 62-55 Ma North Atlantic LIP, the 201 Ma Central Atlantic LIP, and the 132 Ma South Atlantic LIPs (including the Parana-Etendeka LIP), which are associated with formation of the North Atlantic, Central Atlantic and South Atlantic, respectively. In each case ocean opening began within a few million years following the arrival of the plume-generated LIP.

It is equally clear that some major plume-generated LIPs are not associated with breakup, such as the 251 Ma Siberian Traps LIP, which caused rifting (but no breakup) between Asia and Europe. A Proterozoic example is the 1106-1090 Ma Keweenawan LIP associated with the 2000 km long Mid-Continent Rift system in the Great Lakes region, but which failed to separate 'Canada' from the 'United States'. In both cases, coeval compressional stresses prevented ocean opening: assembly of Pangea in the case of the Siberian Traps LIP and the Grenville Orogeny in the case of the Keweenawan LIP.

We propose that formation of new oceans requires both a mantle plume and favourable extensional stresses in the plate at the time. It is further hypothesized that formation of every major ocean through geological history required the presence of a plume-generated LIP. In this present study, we provide an initial catalogue of plume-generated LIPs through time which can be linked with new ocean formation.

To demonstrate a link between a LIP and an ocean opening, it is key that the plume centre be located approximately along the new ocean boundary. We review criteria for locating plume centres of LIPs. The strongest constraint is giant mafic radiating dyke swarms which focus on the plume centre. Giant circumferential dyke swarm can also be important. Triple junction rifting can focus approximately on the plume centre, in some cases with offset of a few hundred km. Another criterion is variation in the thicknesses of flood basalts (as an indicator of proximity to the plume centre).