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Estimating the Initial Volume of Large Igneous Provinces: Approaches and Applications

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Precise age-dating techniques, and advanced geochemical and geological modelling are leading to a better understanding of the origin, and environmental, economic and geotectonic significance of Large Igneous Provinces (LIPs). Still poorly known, however, is the precise areal extent and volume of LIPs (continental and oceanic). Here we attempt to make an accurate estimate of LIP volumes and examine the significance for studies of the lithosphere, climate-environment, tectonics and ore genesis.

The main barrier to accurate calculation of the original volume of LIPs is the extent of erosion and tectonic fragmentation. Areal extent (i.e. a boundary that surrounds all the magmatic components of a LIP) is often used as a proxy for LIP scale, but has limitations. For instance, it is uncertain whether the areal extent of flood basalts (best preserved for Mesozoic/Cenozoic LIPs) matches the areal extent of the dyke/sill plumbing system (typically exposed through erosion in Proterozoic LIPs). In addition, although the magmatic underplate likely dominates volumetrically, it is unknown how its scale correlates with the areal extent of flood basalts or with the magnitude of the dyke/sill plumbing system. Another consideration is that different geospheric implications may require different types of scale estimates. For instance, climatic effects depend mainly on gas release from the volcanic component, plus thermogenic release from sill complexes interacting with volatile-rich sedimentary rocks.

Here we catalogue the natural range and peak values in the scale of each component, using just well-preserved examples for each. For flood basalts, the best candidates are young LIPs and for dyke swarms, we use eroded LIPs for which extensive high-quality aeromagnetic data are available. Geophysics (particularly seismics and gravity) can determine the size of the underplate. Geochemical proxies include the degree of differentiation estimated using Mg #, or Ni, Cr, which can be used to estimate the volume of fractionated material remaining at deeper levels of the plumbing system. A further proxy approach is to estimate the extent of the uplift using radiating and circumferential dyke swarms, in order to interpret the size of the underlying flattened mantle plume head and then estimate the total partial melt volume produced.