The Lost World: Environmental Effects During the Formation of a Giant Volcanic Province

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Large igneous provinces (LIPs) form when extraordinary amounts of mantle-derived magma enter regions of the Earth's crust. The intense igneous activity during their creation temporarily increases the flux of mass and energy from the mantle to the crust, hydrosphere, biosphere, and atmosphere, with many possible global environmental effects.

During Mesozoic and Cenozoic time, LIPs have typically formed in geologically brief (1-10 million year) episodes. The youngest LIP formed ~15 million years ago. On continental lithosphere, LIPs are also known as continental flood basalts, which are relatively well studied. Several are associated with mass extinctions and environmental changes, although causal relationships and feedback loops are not well understood. On transitional and oceanic lithosphere, respectively, divergent volcanic margins and oceanic plateaus are relatively understudied, with drilling being the primary means of sampling. Ocean drilling at the two most voluminous LIPs on Earth, the Kerguelen Plateau/Broken Ridge in the southern Indian Ocean and the Ontong Java Plateau in the western Pacific, has provided information on the processes that form LIPs and their potential environmental consequences.

The uppermost crust of both the Kerguelen Plateau and Broken Ridge is dominated by the products of massive magmatism. Physical characteristics of the LIP lava flows together with wood fragments, charcoal, pollen, spores and seeds in the shallow water sediments overlying igneous basement, show that large portions of the Kerguelen Plateau and Broken Ridge formed islands. After their formation, the islands gradually subsided by as much as several thousand meters to their present water depths.

The large volume and long duration of subaerial basaltic volcanism on the Kerguelen Plateau and Broken Ridge, combined with the high latitude of the plateau, would all have contributed to potential global environmental changes involving climate, sea level, oceanic anoxia, seawater composition, biological radiations, and extinctions. The eruption of enormous volumes of basaltic magma during their formation released volatiles such as carbon dioxide (CO_2), sulfur (S), chlorine (Cl), and fluorine (F). Because the LIP formed at high latitudes, where the tropopause is relatively low, the effects of these eruptions could have been intensified because large basaltic eruption plumes can transport SO_2 and other volatiles into the stratosphere. Sulfuric acid aerosol particles that form in the stratosphere after such eruptions have a longer residence time and greater global dispersal than if the SO_2 remains in the troposphere; therefore they have greater effects on climate and atmospheric chemistry. During the final stages of plateau construction, highly explosive felsic eruptions likely injected both particulate material and volatiles (SO_2, CO_2) directly into the stratosphere. Significant volume of explosive, subaerial felsic volcanism, undiscovered until 1999, would have further contributed to the effects of this plume volcanism on the global environment.

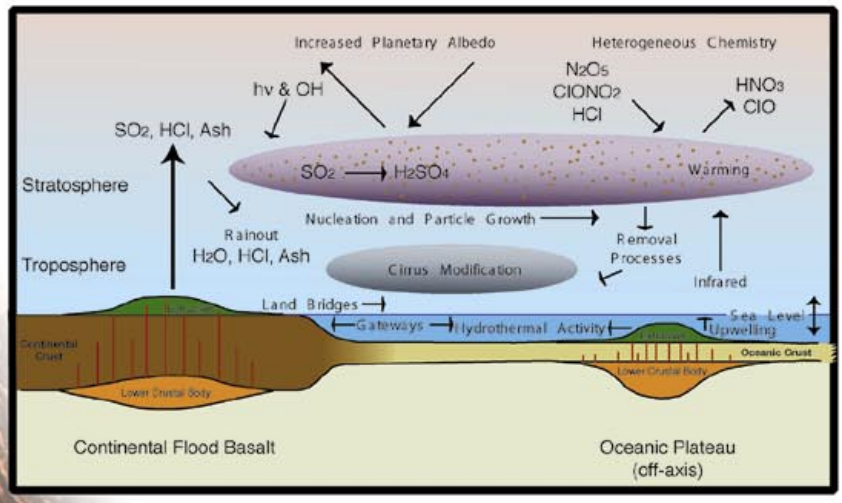

Figure 1. Environmental effects of LIP formation. LIP eruptions can perturb the Earth-ocean-atmosphere system significantly. Note that many oceanic plateaus form at least in part subaerially.