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The largest volcanic eruptions on Earth

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ABSTRACT

Large igneous provinces (LIPs) are sites of the most frequently recurring, largest volume basaltic and silicic eruptions in Earth history. These large-volume (>1000 km^3 dense rock equivalent) and large-magnitude (>M8) eruptions produce areally extensive (10^4–10^5 km^2) basaltic lava flow fields and silicic ignimbrites that are the main building blocks of LIPs. Available information on the largest eruptive units are primarily from the Columbia River and Deccan provinces for the dimensions of flood basalt eruptions, and the Paraná–Etendeka and Afro-Arabian provinces for the silicic ignimbrite eruptions. In addition, three large-volume (675–2000 km^3) silicic lava flows have also been mapped out in the Proterozoic Gawler Range province (Australia), an interpreted LIP remnant. Magma volumes of >1000 km^3 have also been emplaced as high-level basaltic and rhyolitic sills in LIPs. The data sets indicate comparable eruption magnitudes between the basaltic and silicic eruptions, but due to considerable volumes residing as co-ignimbrite ash deposits, the current volume constraints for the silicic ignimbrite eruptions may be considerably underestimated. Magma composition thus appears to be no barrier to the volume of magma emitted during an individual eruption. Despite this general similarity in magnitude, flood basaltic and silicic eruptions are very different in terms of eruption style, duration, intensity, vent configuration, and emplacement style. Flood basaltic eruptions are dominantly effusive and Hawaiian–Strombolian in style, with magma discharge rates of ~10^6–10^8 kg s^{-1} and eruption durations estimated at years to tens of years that emplace dominantly compound pahoehoe lava flow fields. Effusive and fissural eruptions have also emplaced some large-volume silicic lavas, but discharge rates are unknown, and may be up to an order of magnitude greater than those of flood basalt lava eruptions for emplacement to be on realistic time scales (<10 years). Most silicic eruptions, however, are moderately to highly explosive, producing co-current pyroclastic fountains (rarely Plinian) with discharge rates of 10^9–10^{11} kg s^{-1} that emplace welded to rheomorphic ignimbrites. At present, durations for the large-magnitude silicic eruptions are unconstrained; at discharge rates of 10^9 kg s^{-1}, equivalent to the peak of the 1991 Mt Pinatubo eruption, the largest silicic eruptions would take many months to evacuate >5000 km^3 of magma. The generally simple deposit structure is more suggestive of short-duration (hours to days) and high intensity (~10^{11} kg s^{-1}) eruptions, perhaps with hiatuses in some cases. These extreme discharge rates would be facilitated by multiple point, fissure and/or ring fracture venting of magma. Eruption frequencies are much elevated for large-magnitude eruptions of both magma types during LIP-forming episodes. However, in basalt-dominated provinces (continental and ocean basin flood basalt provinces, oceanic plateaus, volcanic rifted margins), large magnitude (>M8) basaltic eruptions have much shorter recurrence intervals of 10^3–10^4 years, whereas similar magnitude silicic eruptions may have recurrence intervals of up to 10^5 years. The Paraná–Etendeka province was the site of at least nine >M8 silicic eruptions over an ~1 Myr period at ~132 Ma; a similar eruption frequency, although with a fewer number of silicic eruptions is also observed for the Afro-Arabian Province. The huge volumes of basaltic and silicic magma erupted in quick succession during LIP events raises several unresolved issues in terms of locus of magma generation and storage (if any) in the crust prior to eruption, and paths and rates of ascent from magma reservoirs to the surface.

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