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CATASTROPHIC VOLCANISM

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Since primitive times, catastrophes due to volcanic activity have been vivid in the mind of man, who knew that his activities in many parts of the world were threatened by lava flows, mudflows, and ash falls. Within the present century, increasingly complex interactions between volcanism and the environment, on scales not previously experienced historically, have been detected or suspected from geologic observations. These include enormous hot pyroclastic flows associated with collapse at source calderas and fed by eruption columns that reached the stratosphere, relations between huge flood basalt eruptions at hotspots and the rifting of continents, devastating laterally-directed volcanic blasts and pyroclastic surges, great volcanic-generated tsunamis, climate modification from volcanic release of ash and sulfur aerosols into the upper atmosphere, modification of ocean circulation by volcanic constructs and attendent climatic implications, global pulsations in intensity of volcanic activity, and perhaps triggering of some intense terrestrial volcanism by planetary impacts. Complex feedback between volcanic activity and additional seemingly unrelated terrestrial processes likely remains unrecognized. Only recently has it become possible to begin to evaluate the degree to which such large-scale volcanic processes may have been important in triggering or modulating the tempo of faunal extinctions and other evolutionary events. In this overview, I examine such processes from the viewpoint of a field volcanologist, rather than as a previous participant in controversies concerning the interrelations between extinctions, impacts, and volcanism.

Particularly relevent are explosive eruptions of silicic pyroclastic material from large calderas related to shallow batholithic magma chambers and eruptions of basaltic lava at high discharge rates to form basaltic plateaus. Several Quaternary ash-flow eruptions (75-ka Toba, 600-ka Yellowstone) and many Tertiary eruptions have each released several thousand km^3 of magma within periods of a few days or weeks. The largest historic eruptions (1883 Krakatau, 1912 Katmai) are 2 orders of magnitude smaller than Toba, impeding confidence in extrapolating effects to the largest prehistoric ash-flow eruptions. Such eruptions are the most catastrophic events on earth, other than large planetary impacts. Convective eruptive columns readily reach stratospheric levels during major ash-flow activity, and as much as a third of the total erupted volume may be dispersed globally as wind-born ash and dust. Eruptions as such as Toba seemingly released dust and sulfur aerosols capable of producing climatic effects comparable to those inferred for nuclear warefare and major planetary impacts. In contrast to the probable climatic effects, reports of shocked minerals from such eruptions--though tantalizing--have been nonrigorous and unconvincing, and inferences of large overpressures during explosive eruptions are based on controversial models.

Lava discharges during some large flood basalt eruptions, such as on the Columbia River plateau at 14-17 Ma, appear to have exceeded 100 km^3/day, with volumes of 500-1000 km^3 erupted within a few weeks. Sulfur releases as great or greater than during the largest ash-flow events have been postulated, based on extrapolation from the climate-modifying 1783 Laki basalt eruption in Iceland (12 km^3 within a few weeks), and major global climatic effects seem likely, especially if associated thermal convection reached stratospheric levels. In addition, for both basaltic effusions and more silicic explosive eruptions, sulfur release estimated on the basis of S loss from erupted rocks may be much to low. Gas emissions measured during recent eruptions at Mount St. Helens and Kilauea document that several times more sulfur was degassed from magma that remained within the subvolcanic reservoir than from the volcanic material actually erupted. Recent studies also indicate probable regional or even global pulses of intensified volcanic activity during brief times in the geologic record, suggesting possible occasional cumulative effects of atmospheric loading from several near-simultaneous eruptions. Studies of partitioning of rare metals between magmas and volatiles during volcanic activity are in their infancy, but surprising results have already emerged, as exemplified by high Ir contents in gases from relatively small Hawaiian eruptions.

Another topic involves interrelations between growth of large volcanic features, such as island arcs or oceanic basalt ridges, and global oceanic circulation patterns. Quaternary climatic fluctuations are increasingly recognized to have been importantly influenced by changes in deep ocean circulation resulting from subtle geologic processes. Such effects on global patterns of ocean circulation due should be expected from events such as initial construction of the Scotia volcanic arc that would impede deep ocean flow between South America and Antartica, initial opening of the Atlantic and formation of the mid-ocean basaltic spreading center, or closing of the Tethys Sea and extinction of the associated spreading center. On a more modest scale, giant Quaternary landslides on submarine flanks of the Hawaiian Ridge, only recently recognized, have generated tsunami waves that washed as much as 300 m high on adjacent islands. What effects would such disturbances have on the specialized coastal eccosystems of oceanic archipelagoes?

Finally, what consequences for terrestrial volcanism might result from planetary impacts? In orogenic regions, high geothermal gradients and intermittent surface volcanism indicate that the lower crust and lithospheric mantle widely contain partial melt or are near melting threshholds. Recent studies increasingly point toward generation of large-scale volcanism when the impacts were sufficiently great, even within cratonic areas, as suggested for the Sudbury and Bushveld complexes. In orogenic regions, smaller impacts could likely generate voluminous magmatism, and the surface volcanic deposits might largely obscure evidence for an impact. Could some "hotspot" basaltic plateaus associated with continental separations be triggered by impacts? How about the geometrically peculiar Snake River Plain-Yellowstone hotspot that was initiated abruptly at 15 Ma in southwestern Idaho?