

Zircon from Mount St. Helens: Implications for magma storage

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What lies beneath active volcanic edifices? Is magma stored in the crust beneath active volcanoes as long-lived crystal mush or as solid rock, or does it travel from lower crustal/upper mantle depths with no significant residence time in the crust prior to eruption? Uranium-Th and U-Pb geochronology of zircons from units that span the 300,000 years eruptive history of Mount St. Helens reveal crystal ages ranging from 10,000s to over 100,000 years before eruption, indicating that eruptions often extract crystals from previous episodes of crystallization. Periods of significant crystallization coincide with periods of eruptive quiescence. Preliminary data from analyses of surfaces of zircons did not reveal ages different from the main populations for each sample. Careful application of the Ti-in-zircon thermometer (Watson *et al.*, 2005; Ferry and Watson, 2007) indicates that zircons crystallized at relatively low temperatures, commonly lower than eruption temperatures of their final host magma. Absence of zircon or presence of only small, rounded grains in rocks that record hotter histories attests to the instability of zircon at these conditions; survival of the grains suggests rapid transport from the storage zone to the surface. Elemental compositions (Hf and REE) demonstrate crystallization from variable, evolved melt compositions. Whether a solid plutonic complex or a long-lived mush stockpiles these zircons, the apparent accumulation of numerous batches of magma of various ages at relatively low temperatures documents the construction of a complex magmatic storage zone in the crust beneath Mount St. Helens.

The great collapse of methane: Rethinking the rise of Oxygen

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The oxygenation of the atmosphere approximately 2.4 billion years ago stimulated biologic evolution and fundamentally altered chemical processes in Earth's atmosphere, crust, and oceans [1]. A consensus of theoretical and experimental work has implicated a key environmental role for atmospheric CH₄ prior to this redox transition. Photochemically stable atmospheres after the advent of oxygenic photosynthesis consist of trace levels of O₂ (~ 1ppbv) and CH₄ levels of 10² – 10³ ppmv [2, 3].

Environmental conditions on the early Earth would have supported larger fluxes of reducing gases from the solid planet than in the modern world [4, 5]. These extra reducing gases would have supplemented CH₄ fluxes from the biosphere leading to a net CH₄:O₂ flux ratio greater than 1:2, which supports a reducing atmosphere. Over long timescales, the net CH₄:O₂ flux ratio into the atmosphere should decline below 1:2 given predictions of volcanic [4] and metamorphic flux [5, 6] evolution. Similar evolution in biological CH₄:O₂ flux ratios are expected as trace amounts of atmospheric O₂ [7] enable sulfate fluxes to the ocean that stimulate microbial anaerobic oxidation of methane [8]. We present photochemical model results showing that the primary atmospheric response to a declining CH₄:O₂ flux ratio is a substantial decline in methane concentrations, while oxygen concentrations remain below 1 ppmv. As CH₄ levels drop, the signature of mass-independent fractionation of sulfur isotopes disappears prior to any significant rise in oxygen levels [3].

Our models indicate that only when CH₄ levels drop to tens of ppmv can the photochemical lifetime of O₂ exceed one day, allowing O₂ to persist over Archean nights and grow in abundance. We posit that the events leading up to the Paleoproterozoic redox transition are better described as a “decline in methane and its consequences” than the more simplistic “rise in oxygen”

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