Magma composition, and architecture of the active deep plumbing system at Oldoinyo Lengai carbonatite volcano, Tanzania

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Carbonatite magmas, the main rare earth element reservoir on Earth, are unique in that they contain almost no silica, but >50% primary carbonate. Although more rare than silicate magmas, carbonatites have been produced throughout Earth's history, and on all continents. Their genesis and evolution has been studied for decades, but an integrated model has not yet been presented. Characterization of the magma supply system architecture, and of the composition of the magma being transferred, is required to reconstruct the magmatic conditions and processes that ultimately produce carbonatite. Here, we quantify the pressure, temperature, and compositional evolution of magmas during their transfer through the plumbing system of the single active carbonatite volcano on Earth, Oldoinyo Lengai (Tanzania). We characterize the major element compositions and volatile (H_2O and CO_2) contents of cognate xenoliths erupted during the most recent explosive eruptions (2007–2008); these cognate xenoliths document igneous processes occurring within the active magma chamber at the time of eruption. Clinopyroxene-hosted melt inclusions allow us to identify that a phonolitic recharging melt triggered the sub-Plinian eruption. Experimentally determined mixed H_2O-CO_2 solubility models and recalculation of clinopyroxene-melt inclusion equilibrium indicate a main crustal magma chamber at 11.5 ± 3.5 km depth, consistent with geophysical surveys performed during the eruption. The phonolite melt contained ≥ 3.2 and ≥ 1.4 wt.% H_2O and CO_2, respectively. It was equilibrated at ~1060°C, and followed, within the identified magma chamber, a liquid line of descent producing alkaline-nephelinite compositions equilibrated at 880 °C. The identified liquid line of descent is consistent with Oldoinyo Lengai eruptive products from previous eruptions, suggesting that the plumbing system architecture has remained stable over the volcano's lifetime.