Oldoinyo Lengai natrocarbonatites derive from classical calciocarbonatites: a melt inclusion approach

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Carbonatites are rare magmas containing almost no silica; their igneous counterparts represent the main rare earth element deposits inoperation. No consensus exists on their origin, genesis and evolution. Oldoinyo Lengai (Tanzania) is the only active carbonatite volcano, but the alkali-rich natrocarbonatites it erupts are unique among the >500 reported fossil carbonatite occurrences. Here, we use three-phase melt inclusions hosted in minerals from cognate cumulates (clinopyroxene, nepheline, Ti-garnet, interstitial melt)— which sampled the active Oldoinyo Lengai magma chamber during the 2007–08 sub-Plinian explosive eruption—to track the carbonatite presence within the plumbing system, and to eventually quantify its composition at depth. We show that although natrocarbonatites are emitted at the Oldoinyo Lengai summit, more classical calciocarbonatites are present at magma chamber depth (~3.5 kbar, 1050 to 900°C), which is consistent with the model of rare natrocarbonatites deriving from calciocarbonatites by further magma differentiation. We also show that those calciocarbonatites are not isolated but rather conjugated with alkali-rich silica melt suggesting a joint evolution. We eventually present the first direct measurements of major and trace element partition coefficients between natural coexisting carbonate and silicate melts. Partitioning behaviour and recent experiments support our conclusion that natrocarbonatites derive from calciocarbonatites by fractionating Ca-rich, Na-poor phases. As natrocarbonatites are highly unstable at surface conditions, they were likely erupted but not preserved in association with fossil calciocarbonatites worldwide. Oldoinyo Lengai can then be considered as representative of other carbonatite systems, and provide us with the unique opportunity to observe the plumbing system architecture, and to constrain the protracted differentiation path of a carbonatite system.