Magma ascent and fragmentation in a silica-undersaturated monogenetic volcanic field: evidence from textural analysis of pyroclasts from the Gregory Rift (East African Rift System)

Hannes B Mattsson

Institute of Geochemistry and Petrology, ETH Zurich, Switzerland

E-mail: hannes.mattsson@erdw.ethz.ch

Pyroclasts formed in eruptions involving high CO_2, silica-undersaturated, magmas in the Gregory Rift of northern Tanzania show distinct textural and morphological characteristics when compared to the more common basaltic equivalents. Overall the shape of all pyroclasts (independent of size) is sub-rounded to near spherical and evidence of broken bubble walls or blocky fragments is extremely rare. This applies to all melilititic eruptions, but do also occur in the eruptions of more primitive nephelinitic magmas erupted in the area. Many of the volcanic landforms within this monogenetic field would classify as maars and tuff rings/cones based on morphology alone, yet the availability of external water required to drive phreatomagmatic fragmentation is scarce as most of these "phreatomagmatic" landforms are located on a horst structure 200-300 meters above the surrounding sedimentary basins and in an arid climate (where evaporation greatly exceeds rainfall on an annual basis). The melilititic pyroclasts are moderately vesiculated (around 30-40%), which is a considerably higher value than what would be expected in phreatomagmatic deposits. Analysis of vesicle size distributions and vesicle number densities also show minor differences between melilititic pyroclasts in scoria cones and those found within tuff rings as well as maar-diatreme volcanoes. From this, in combination with the observed morphologies, it is clear that there is no clear difference between inferred "magmatic" and "phreatomagmatic" pyroclasts of melilititic compositions.

The ascent rate must have been high for the melilititic magmas, and calculations show that these magmas probably ascended with a rate of 8-35 ms^{-1} from an upper-mantle source to the surface (i.e., less than one day), with an absolute minimum speed of <1 ms^{-1} required in order to keep the mantle debris entrained with the rising magma. This essentially excludes any possibility of long-time ponding, and associated degassing, of the melilititic magmas during ascent. Previous studies have shown that melilititic melts can hold >18 wt.% of CO_2 dissolved within the melt structure at upper-mantle pressures, and it is here proposed that the sub-rounded to spherical melilititic pyroclasts form as a result of rapid exsolution of CO_2 during ascent, and that this fragmentation level (controlled by the increasing gas fraction-volume) is located at depth within the conduit. A deep fragmentation level and transport as an aerosol-type gas jet would imply significant cooling of pyroclasts (also within the conduit itself) and this may explain the absence of agglutination/welding even at the crater rim of the melilititic deposits.