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Volatiles, redox, and mantle attenuation in the East African Rift

MARYJO BROUNCE[1], HEATHER FORD[2], TOBIAS P FISCHER[3], JOSEPH BYRNES[4], SARA SCOGGINS[2], SEAN JARAMILLO[2], GILLIAN GOLDHAGEN[2] AND JEN HUMPHREYS[2]

[1]900 University Drive
[2]University of California Riverside
[3]University of New Mexico
[4]Northern Arizona University

Presenting Author: mbrounce@ucr.edu

The volatile contents of magmas erupted along the East African Rift are constrained in few locations, complicating efforts to interpret slow and attenuated seismic waves observed under Afar and the role of the Afar mantle plume and melt generation in continental rifting. We present measurements of major and volatile elements and S and Fe oxidation states of Gulf of Aden pillow glasses and melt inclusions from Erta Ale in the Afar and from Paka, Suswa, and Eburru farther south. We use these data to place constraints on the volatile compositions and fO_2s of least degassed magmas and together with new models of mantle attenuation, assess the role of volatiles and melt in slowing and attenuating seismic waves in the mantle under the rift.

Gulf of Aden glasses are basaltic (6.7-11.7 wt% MgO); glassy melt inclusions are basaltic to trachybasaltic (Paka: 2.7-7.91 wt% MgO; Erta Ale: 3.8-7.3 wt% MgO) and phonolitic (Eburru: 62.2-66.2 wt% SiO_2; Suswa: 53.1-57.1 wt% SiO_2). The compositions in each suite are consistent with fractionation of one or more mineral phases and CO_2±H_2O±S degassing. After accounting for these processes, we compile the H_2O and fO_2 of the least differentiated samples and place constraints on H_2O and fO_2 of the sources of melts along the rift –DMM, Afar plume, and Pan-African lithosphere. The DMM, Afar plume, and Pan-African lithosphere contaminated magmas are reduced (δQFM ≈ 0). Afar plume (H_2O ~0.8 wt% H_2O) and Pan-African lithosphere contaminated (H_2O ~ 2 wt%) magmas are more hydrous than those from DMM (H_2O ~ 0.2 wt%). Paka magmas record higher fO_2s (δQFM ≈ +1) and intermediate H_2O (~0.7 wt%). The slowest and most attenuated seismic waves are under Afar (δVp ~-6%, δt* ~0.19) where fO_2 is low and H_2O is elevated. Wave speeds increase and attenuation decreases towards Paka, while fO_2 increases and H_2O remains elevated. These combined results suggest that high fO_2 may not strongly attenuate seismic waves. The similarity in H_2O contents of Afar and Kenyan magmas suggests that H_2O does not independently strongly attenuate. Instead, a combination of temperature, melt, and H_2O may produce the anomalous mantle in this region.