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Cosmogenic ^{3}He and ^{21}Ne concentrations in olivines and pyroxenes from a Pleistocene basalt flow, western Grand Canyon National Park, Arizona, USA

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The Bar Ten lava flow is a Pleistocene basalt flow that erupted 94 $\pm$ 20 ka (weighted mean; two ^{40}Ar/^{39}Ar ages) in the Uinkaret Volcanic Field in western Grand Canyon National Park (AZ, USA). It was chosen as a CRONUS-EU calibration site for the production of cosmogenic ^{21}Ne/^{3}He (^{21}Ne$_c$ /^{3}He$_c$) in olivine and pyroxene because it has more than 600 m of elevation gain, and has likely experienced little erosion due to a regional desert climate. Eruption age and erosion should have no effect on the ratio, if ^{3}He$_c$ and ^{21}Ne$_c$ are produced at constant rates relative to each other and relative to time, latitude, and elevation. In this study, 14 samples were collected from stable, primary surfaces at elevations from 1180 to 1820 m above sea level along a vertical transect on the Bar Ten flow between 36.2239˚ and 36.2417˚ N. He, Ne, and Ar were analyzed by stepwise heating of olivine and pyroxene separates under vacuum at 600˚, 900˚, and 1750˚ C, and ^{3}He$_c$ and ^{21}Ne$_c$ components have been determined. ^{21}Ne$_c$ /^{3}He$_c$ varies from 0.27 to 0.47 in the olivines, with an average of 0.35, and from 0.19 to 0.22 in pyroxenes. Variation may be due to differences in mineral composition affecting production of ^{21}Ne$_c$; He is less sensitive to such variations. Olivine and pyroxene separates were analyzed for Al, Ca, K, Na, Ti, Fe, Mg, and Si with an electron microprobe and with ICP-AES. Elemental production rates were calculated for each sample using methods derived by Kober et al. (2005) and Masarik (2002). Production rates calculated based on ICP-AES bulk-sample elemental analyses were

within 0.2 to 2.8% of those calculated using microprobe elemental analyses. Neon analyses in olivine can be used to determine the spallation line for this mineral in the neon three-isotope diagram. An error-weighted regression defines a spallation line [y = (1.0834 $\pm$ 0.0348)x + (0.09835 $\pm$ 0.00037)] which is similar to that for pyroxene (Schäfer et al., 1999). Using the combination of Dunai's (2000) scaling factors and Kober et al.'s (2005) production-rate model, $^{3}He_{c}$ ages are 63-110 ka and $^{21}Ne_{c}$ ages are 73-91 ka for olivine; pyroxene yields $^{3}He_{c}$ ages of 75-97 ka and $^{21}Ne_{c}$ ages of 65-80 ka. Likewise, Dunai's (2000) scaling factors and Masarik's (2002) model yield $^{3}He_{c}$ ages of 96-134 ka and $^{21}Ne_{c}$ ages of 79-99 ka for olivine and $^{3}He_{c}$ ages of 99-128 ka and $^{21}Ne_{c}$ ages of 75-92 ka for pyroxene. These values are generally consistent with the mean $^{40}Ar/^{39}Ar$ age of the Bar Ten lava flow. Ages calculated similarly using Lal's (1991) scaling factors yield $^{3}He_{c}$ and $^{21}Ne_{c}$ ages that are 5-8% lower than those calculated with the scaling factors of Dunai (2000).