CHROMIUM AND OXYGEN ISOTOPIC COMPOSITIONS OF ULTRAMAFIC ACHONDRITES: IMPLICATIONS FOR THE MISSING MANTLE PROBLEM IN THE ASTEROID BELT

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Introduction: Achondrites Northwest Africa (NWA) 12217, 12319, 12562, and 13954 are monomict fragmental breccias with >85 modal % olivine. It has been suggested that these rocks represent ultramafic material associated with the howardite-eucrite-diogenite (HED) clan (e.g. [1]). However, combining nucleosynthetic chromium isotopic anomalies with mass independent oxygen isotopic data reveals that these meteorites are not associated with the main-group HED meteorites. Instead, they are sourced from at least two unique parent bodies potentially associated with one of the "anomalous" HED [2,3]. The discovery of these ultramafic breccias suggests that the "Missing Mantle Problem" in the asteroid belt is a result of the obliteration of olivine-rich material by impacts [4].

Oxygen Isotopes: Oxygen isotopic analysis are reported as $^{18}O/^{16}O$ and $^{17}O/^{16}O$ ratios that are expressed in δ-notation (parts per 1,000 deviations from the measured standard) and Δ-notation (deviation from the terrestrial fractionation line [TFL]). Results for laser fluorination of acid-washed bulk fragments of NWA 12217 ($\delta^{18}O$ = 3.475, 3.558, 3.526, 3.552; $\delta^{17}O$ = 1.639, 1.698, 1.661, 1.673; $\Delta^{17}O$ = -0.196, -0.181, -0.201, -0.203; weighted average $\delta^{18}O$ = 3.523; $\delta^{17}O$ = 1.665; $\Delta^{17}O$ = -0.195), NWA 12562 ($\delta^{18}O$ = 3.496, 3.613, 3.521, 3.778; $\delta^{17}O$ = 1.161, 1.686, 1.629, 1.783; $\Delta^{17}O$ = -0.230, -0.222, -0.230, -0.211; weighted average $\delta^{18}O$ = 3.605; $\delta^{17}O$ = 1.680; $\Delta^{17}O$ = -0.223), NWA 12319 ($\delta^{18}O$ = 3.613; $\delta^{17}O$ = 1.681; $\Delta^{17}O$ = -0.227), and NWA 13954 ($\delta^{18}O$ = 3.039, 3.405, 3.194; $\delta^{17}O$ = 1.392, 1.587, 1.446; $\Delta^{17}O$ = -0.213, -0.211, -0.240; weighted average $\delta^{18}O$ = 3.175; $\delta^{17}O$ = 1.451; $\Delta^{17}O$ = -0.226) are shown in Figure 1A. The new values overlap with those of [5] and plot in the field of the HED meteorites. The dunite NWA 12217 diverges due to ~+0.03‰ higher $\Delta^{17}O$ values, similarly to the anomalous eucrites that diverge from the mass-dependent fractionation line defined by HED meteorites [2].

Chromium Isotopes: Results for chromium isotopic anomalies are reported as mass fractionation corrected $^{54}Cr/^{52}Cr$ ratios that are expressed in ε-notation (parts per 10,000 deviations from the measured standard) and shown in Figure 1B. In the $\varepsilon^{54}Cr$-$\Delta^{17}O$ isotope diagram, NWA 12217 plots near the oxygen- and chromium-anomalous HED meteorites Pasamonte and PCA 91007, suggesting that they could have originated on the same parent body. NWA 12319 and 12562 plot in a unique region as they have a heavier chromium isotopic composition, where NWA 12562 could be associated with PCA 91007. No mixture with any known chondritic compositions are capable of producing these values in oxygen-chromium isotopic space.

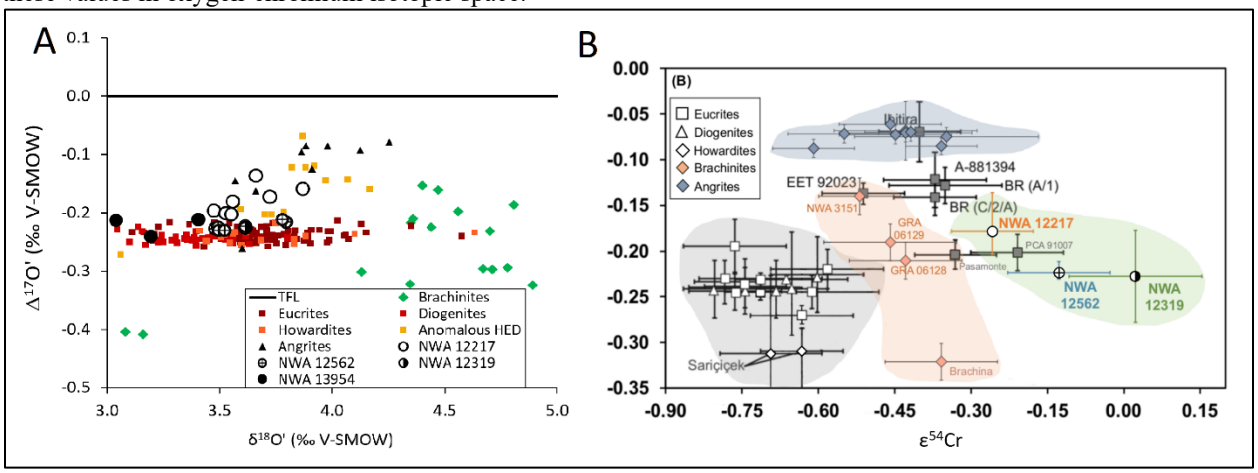

Figure 1. (A) Triple oxygen diagram showing the ultramafic achondrites in relation to other achondrite groups and the terrestrial fractionation line (TFL). (B) $\Delta^{17}O$ vs. $\varepsilon^{54}Cr$ diagram showing ultramafic achondrites and other achondrite groups.

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