PETROLOGY AND OXYGEN ISOTOPIC COMPOSITION OF TWO DIFFERENT UNGROUPED HIGHLY MAGNESIAN, REDUCED ULTRAMAFIC ACHONDRITES (NORTHWEST AFRICA 11562/ 12969 AND NORTHWEST AFRICA 13307): MORE SAMPLES FROM UNKNOWN PARENT BODIES

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Background: The most familiar achondrites rich in enstatite and other Mg-rich mineral phases are the aubrites [1]. Both these and other ungrouped enstatite achondrites (such as NWA 8173) have oxygen isotopic compositions which plot within uncertainty on the same trend as terrestrial and lunar rocks (as well as enstatite chondrites). Forsterite and diopside (containing slightly more iron than the corresponding phases in aubrites) are also major phases along with calcic plagioclase in the more mafic achondrites NWA 7325/8416/8509, NWA 11119/11558 and Caleta el Cobre 050, which have very different oxygen isotopic compositions [2-4].

Here we describe a unique diopside-rich ultramafic achondrite that may(?) have affinities to aubrites, and two paired highly magnesian achondrites, which do not have obvious affinities to any other known specimens.

Northwest Africa 11562 and 12969: Although these two specimens were made available by two different Moroccan dealers at different times, they exhibit such similar and unusual mineralogical and isotopic characteristics that they surely have to be paired specimens from a single ancient fall, or at least launch-paired specimens from the same parent body. Both harzburgitic specimens consist of coarser (mean grainsize 0.25 mm), protogranular regions composed of forsterite ($Fa_{1.0-1.1}$, FeO/MnO = 3-4) and enstatite ($Fs_{0.9-1.0}Wo_{1.0-2.3}$, FeO/MnO = 2-3) with some interstitial diopside ($Fs_{0.2-0.9}Wo_{36.3-40.5}$, Al_2O_3 = 2.0-3.6 wt.%, TiO_2 = 0.5-0.6 wt.%), altered kamacite and blade-like cohenite, plus much finer-grained, interstitial regions composed of finely exsolved pyroxene (see Figures 1,2). Plagioclase and sulfides are apparently absent in both specimens.

Northwest Africa 13307: This specimen is a protogranular, highly magnesian websterite (mean grain size ~1.2 mm) composed predominantly of subequal amounts of diopside ($Fs_{0.1\pm0.0}Wo_{39.7-40.5}$, FeO/MnO = 0.2) and enstatite ($Fs_{0.2\pm0.0}Wo_{1.7-4.5}$, FeO/MnO = 0.3) with minor accessory daubreelite, ferroan alabandite and Ti-Cr-bearing troilite (see Figures 3 and 4). Both pyroxenes exhibit fine, blebby and irrational exsolution of the other pyroxene phase, and also contain patchy, compositionally different domains (e.g., a homogeneous $Fs_{0.2}Wo_{8.3}$ low-Ca pyroxene domain is present within diopside). No metal, olivine or plagioclase was observed despite a diligent search.

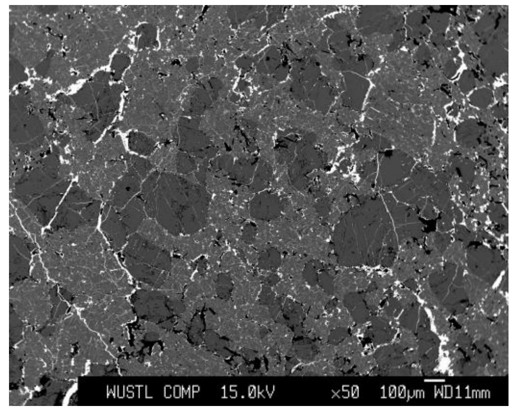
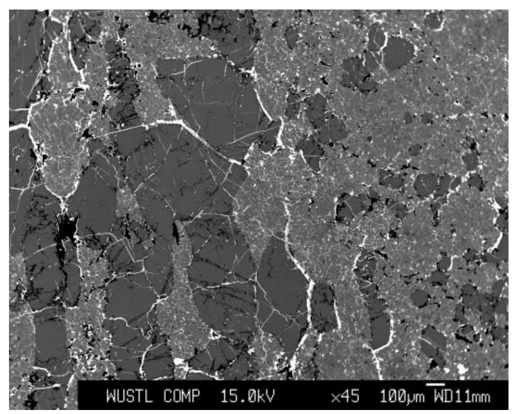


Figure 1. BSE images of NWA 11562 (above) and NWA 12969 (below). Forsterite and enstatite (dark gray), exsolved pyroxene (light gray), 'metal' (bright).



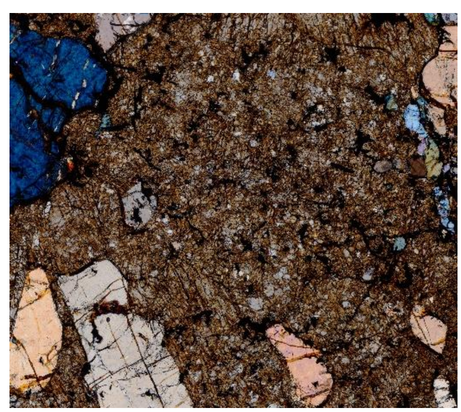


***Figure 2**. pXPL image of interstitial region*

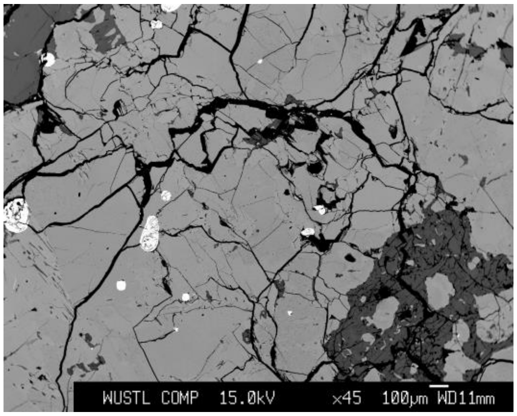


Figure 3. *BSE image of NWA 13307. Diopside (light gray), enstatite (dark gray), sulfides (bright).*

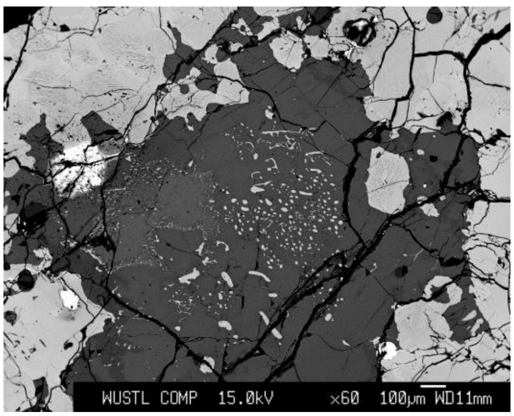


Figure 4. *Detail of exsolved diopside in NWA 13307*

Oxygen Isotopes: Oxygen isotopes were measured by laser fluorination on acid-washed subsamples. Results for NWA 11562 and NWA 12969 are given in [3]; results for NWA 13307 are as follows: $\delta^{17}O$ 2.794, 2.904, 2.811; $\delta^{18}O$ 5.374, 5.552, 5.405; $\Delta^{17}O$ -0.043, -0.027, -0.043 per mil. The latter plot just below the TFL, but within analytical uncertainty of values for aubrites and other enstatite achondrites (including Itqiy and Zakłodzie). In contrast, the results for NWA 11562 and NWA 12969 plot between the trends for CR and CV chondrites, far from values for most other achondrites, let alone highly magnesian ones (see Figure 5).

Discussion: An ongoing challenge in attempting to understand the increasing numbers of ungrouped achondrite specimens is trying to decipher which among them might possibly derive from common differentiated parent bodies, and which ones may be unique (at least until the next unusual specimen comes to light). Perhaps NWA 13304 and NWA 13307, despite being apparently metal-free, might be the first diopside-rich websterite

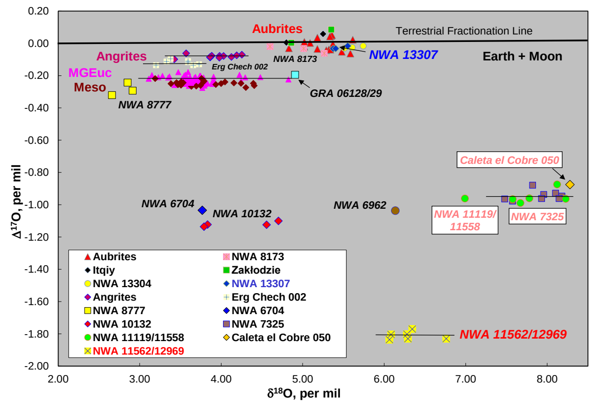


Figure 5. *Oxygen isotopic compositions of highly magnesian and other achondrites. Data are from this work and a literature compilation including [2-8]. Also shown are data for the recently recovered Erg Chech 002 ungrouped gabbroic achondrite [9, 10].*

specimens from the aubrite parent body, or alternatively ey might be from a separate parent body, which like Earth. Moon and enstatite chondrites happens to have oxygen isotope compositions close to the TFL. Perhaps NWA 7325, NWA 11119/11558 and Caleta el Cobre 050 are relatively magnesian, iron-poor mafic rocks from a common parent body, which still might possibly be Mercury (see [2], [11]). On the other hand, it is apparent that magnesian harzburgites NWA 11562 and NWA 12969 are the first known specimens from a distinct highly reduced but sulfur-poor parent body.

References: [1] Watters T. and Prinz M. (1979) *GCA* **84**, 186-203 [2] Koefoed P. et al. (2016) *GCA* **72**, 4874-4885 [3] *Meteorit. Bull.* (2018, 2020) [4] Srinivasan P. et al. (2018) *Nature Commun.* **9**, #3036 [5] Clayton R. and Mayeda T. (1996) *GCA* **60**, 186-203 [6] Irving A. et al. (2015) *76th Meteorit. Soc. Mtg.*, #5254 [7] Irving A. et al. (2013) *74th Meteorit. Soc. Mtg.*, #5249 [8] Irving A. et al. (2019) *Lunar Planet. Sci.* **L**, #2758 [9] Irving A. et al. (2020) *Fall AGU Mtg.*, #DI019-0004 [10] Carpenter P. and Irving A. (2021) *Lunar Planet. Sci.* **LII**, this conference [11] Weiss B. et al. (2017) *EPSL* **468**, 119-132.

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