NORTHWEST AFRICA 11042: UNGROUPED ULTRAMAFIC CUMULATE ACHONDRITE: PETROLOGY, OXYGEN ISOTOPES, AND HIGH PRESSURE PHASES.

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Summary: We report here the discovery of a possibly unique ungrouped achondrite, Northwest Africa (NWA) 11042, that displays mineralogy, igneous textures, and shock characteristics that are reminiscent of ultramafic martian meteorites, however oxygen isotopes show $\Delta^{17}O$ values that are more similar to L-chondrites.


Fig. 1 NWA 11042 single stone, left shows fusion crust, right shows pale green fresh broken surface, small dark patches are shock melt pockets.

History and Physical Characteristics: NWA 11042 was purchased by Abdelhadi Aithiba in Morocco, in 2016. The specimen is a single stone, 90.1 grams, partially covered with black fusion crust. Broken surface reveals a phaneritic mix of pale yellow olivine grains, light green pyroxene grains, glassy maskelynite patches, and dark colored shock melt pockets (Fig. 1).

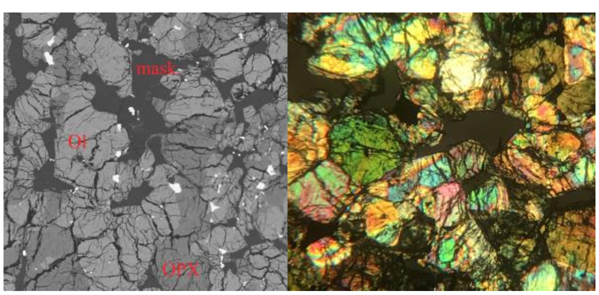

Fig. 2 (left) BSE image of typical textural relationships of olivine, pyroxene, and maskelynite. (right) Crossed polars of a similar section showing extinct (dark) maskelynite.

Mineralogy and Petrology: Microprobe examination of two polished mounts shows an ultramafic rock with approximately 46% olivine, 38% pyroxene, 15% maskelynite and 1% chromite. Fe-sulfide is a minor but ubiquitous phase. Trace amounts of Fe-Ni metal and chlorine-rich apatite are present. Dominant igneous texture consists of poikilitic olivine and pyroxene grains most in the size range 500-1000 µm. Plagioclase has been completely transformed to maskelynite. Maskelynite domains appear smooth and glassy, and are associated with radiating fractures into surrounding olivine and pyroxenes. Shock melt pockets are scattered throughout NWA 11042. These contain relict, partially melted phases mixed with glassy mesostasis. The assemblages are surrounded by reduction rims which are in disequilibrium with the surrounding minerals. These surrounding grains display exsolved metal grains, which are further evidence for reduction. Up to now we observed several grains of blue colored ringwoodite in one large melt pocket (Fig. 3). These grains have been identified as stoichiometric olivine by electron probe microanalysis.

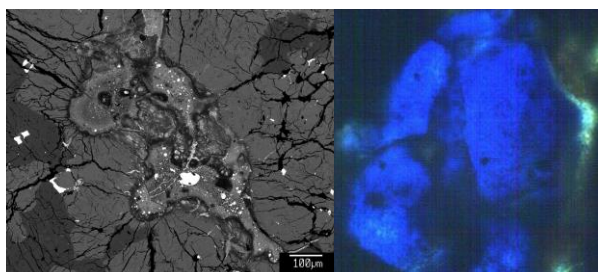

Fig. 3 (left). BSE image of a typical shock melt pocket with complex phase assemblage surrounded by olivine grains. Metal blebs are likely reduction byproducts. (right) Blue ringwoodite in plane polarized transmitted light, scale is approximately 0.5 mm across. Ringwoodite was ubiquitous in one large shock melt pocket (not shown).

Major Element Compositions: With the exception of the shock-transformed phases, the mineralogy of NWA 11042 is equilibrated, with olivines and pyroxenes showing uniform, unzoned compositions. Microprobe analyses: olivine Fa24.6±0.2, Fe/Mn = 50±2, n = 20; low-Ca pyroxene Fs20.2±0.4 Wo4.0±0.4, Fe/Mn = 30±2, n = 29; augite Fs10.5±0.1 Wo39.5±0.1, Fe/Mn = 22±1, n = 2; maskelynite Ab83.4±1.7 An11.9±1.8 Or4.8±0.4, n = 10.

Oxygen Isotopes: Figure 4 shows our results for laser fluorination analyses of five acid-washed fragments of bulk sample with values of $\delta^{18}O$= 4.33, 4.45, 4.36, 4.54, 4.64, 4.42, 4.49, 4.46; $\delta^{17}O$= 3.33, 3.38, 3.34, 3.42, 3.52, 3.35, 3.41, 3.36; $\Delta^{17}O$= 1.04, 1.04, 1.04, 1.03, 1.07, 1.02, 1.03, 1.00 (linearized, all per mil, TFL slope=0.528); weighted average $\delta^{18}O$ = 4.46; $\delta^{17}O$ = 3.34; $\Delta^{17}O$ = 1.03. The values plot in the field of the L ordinary chondrites suggesting that NWA 11042 is derived from an ordinary chondrite-like precursor. The oxygen isotope composition of NWA 11042 plots close to two other ungrouped achondrites, NWA 4284 and 6698. NWA 4284 has an overall similar mineralogical composition to NWA 11042, but less of its plagioclase has been altered to maskelynite. In addition, shock melt pockets and ringwoodite are absent. Additional analyses will reveal whether these meteorites are genetically related and constitute a unique achondrite group.

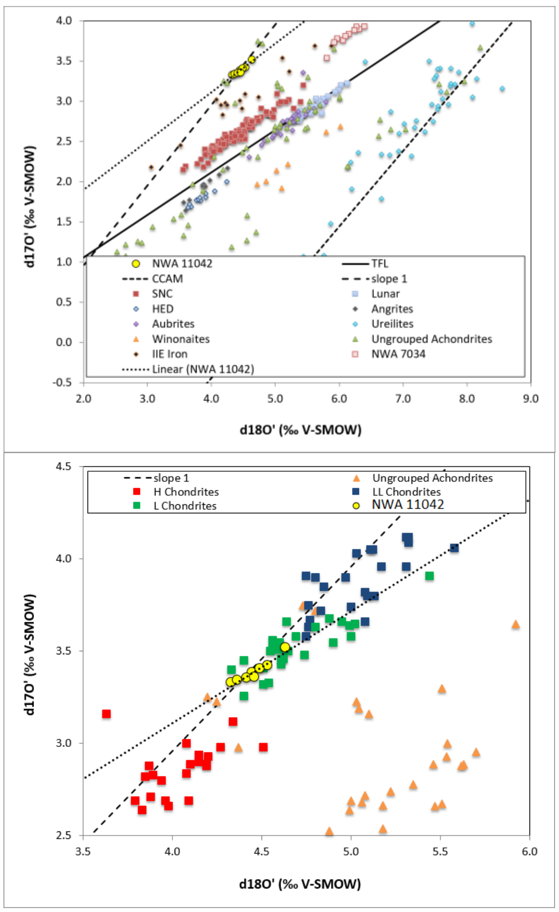

Figure 4 showing triple oxygen plots for NWA 11042 relative to other achondrites, including ungrouped achondrites (top), and relative to the ordinary chondrites [2] and some ungrouped achondrites (bottom). The slope of the best-fit trend line for NWA 11042 (dotted line) is 0.69.

Discussion: NWA 11042 displays textural features similar to lherzolitic shergottites, in particular the complete transformation of all plagioclase to maskelynite, as well as the presence of shock melt pockets and radial shock fractures. Fa, Fs, and Fe/Mn are similar to SNC, however Ab composition of maskelynite is higher than known shergottites. $\Delta^{17}O$ values are well outside the documented range of SNC and coincide with the L-chondrite field. The O isotopes of the silicate inclusions in the group IIE iron meteorites also plot somewhat close to NWA 11042. However, the measured Fe/Mn ratios in these phases are all significantly lower (<20). Therefore they probably are not related in origin.

While a Martian origin cannot be ruled out at this time, it is more likely NWA 11042 originated from an L-chondrite-like source and thus preserved its oxygen isotopic signature. The L chondrites can have Fe-Ni metal contents as high as 10%, and the extremely low (<<1%) Fe-Ni metal content of NWA 11042 could provide evidence of magmatic differentiation on the L chondrite parent body. Our companion abstract [3] on the trace elements and noble gases in NWA 11042 provide additional constraints on the origin of this ungrouped achondrite.

NWA 11042 reflects a complex history that must have had several discrete steps. First, its parent body underwent a heating event from an unknown source which caused melting. Next, olivine, pyroxene, plagioclase, and minor phases crystallized with some of the melt possibly removed, resulting in a rock with cumulate characteristics. There must have been an extreme shock event that produced the melt pockets and transformed all of the original plagioclase to maskelynite and some of the olivine to ringwoodite. This event likely contributed to the oxidation-reduction reactions responsible for the alteration rims around the melt pockets. The parent body underwent an impact event ~30 Ma ago; whether this was the same shock event remains to be seen. As the meteorite retains fresh fusion crust and shows no evidence of terrestrial carbonate veining, its residence time in the Sahara desert is assumed to be relatively short.

References: [1] C.B. Agee et al. (2013) *Science, 339*, 780-785. [2] R.N. Clayton et al. (1991) *Geochimica, 55*, 2317-2337.