FLUID DEPOSITION PRODUCTS IN EUCRITES AND MOON ROCKS: A STUDY IN CONTRASTS.

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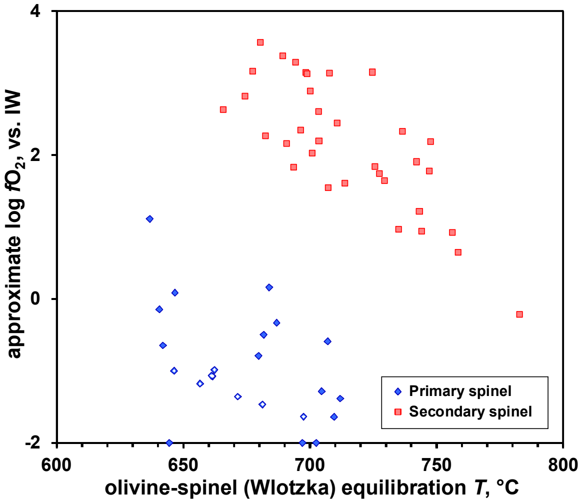
We continue to study the enigmatic variety of products of apparent fluid-metasomatism in the Northwest Africa 5738 eucrite [1]. We have also begun a companion study in search of analogous fluid deposition products in ancient lunar highland rocks.

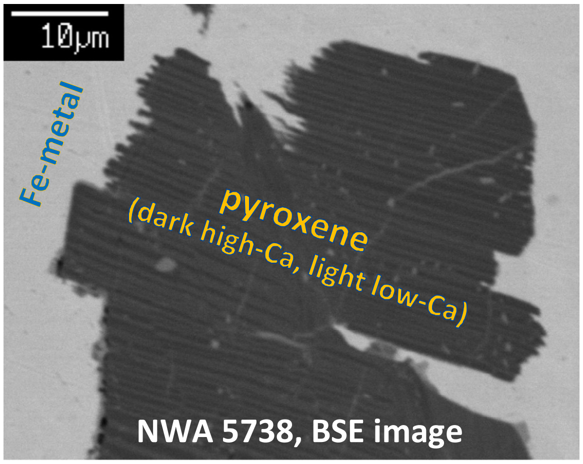
As described by [1, 2], NWA 5738 originated with a uniquely evolved (Stannern Trend) primary igneous composition, combining ultra-high bulk incompatible element and Na_2O concentrations with a relatively low *mg*. The meteorite's bulk oxygen-isotopic composition ($\Delta'^{17}O = -0.27$ ‰) [1], as well as its trace element composition (e.g., Ga/Al), are consistent with classification as a mildly anomalous eucrite. The rock includes scattered shock-glassy veins (i.e., injections from some distance beyond the confines of the present meteorite) that bear the same evolved compositional traits (e.g., Na-rich plagioclase). Most other eucrites with evidence of fluid metasomatism have uncommonly low grades of thermal metamorphism [3]. In the case of NWA 5738, *mg* equilibration, and exsolution of both augite lamellae and "cloudy" opaques, within the pyroxenes reflect a typical eucritic degree of thermal metamorphism [cf. 4]. However, the pyroxenes retain considerable heterogeneity of Ca (Wo) content.

The most common type of fluid-metasomatic vein deposits in NWA 5738 are curvy (fracture-fill) microveins, which consist dominantly of Ca-plagioclase (typically An_{95}, in stark contrast with the rock's $An_{68\text{-}78}$ primary-igneous plagioclase), with Fe-olivine (Fo_{14}) and Cr-spinel as additional major constituents. Likely related to these microveins are small masses of intergrown Ca-plagioclase (again roughly An_{95}) and silica (or high-Si glass), mostly taking the form of isolated equant masses but in some locales transitional toward the texture and mineralogy of a plagioclase-dominated curvy microvein. Analyses of the microvein Cr-spinels show stoichiometry that implies a significant Fe^{3+} content (Fe_2O_3 0.7-2.3 wt%; most of the distribution is spread rather evenly between 1.1 and 2.1 wt%), which in turn suggests, by the method of [5] with *T* from the method of [6], fO_2 up to roughly IW+3; clearly elevated in comparison to the normal HED fO_2 of about IW−1 [e.g., 7]. Determination of Fe^{3+} in spinel by our stoichiometric method [8] can be problematic if the spinels are dominated by the light elements, Mg and Al, that are most prone to systematic, corrections-linked inaccuracies in EPMA. However, the NWA 5738 spinels (both primary and secondary) are Cr- and Fe-dominated. Major systematic error is also unlikely because primary and secondary spinels were measured together, in the same thin sections, in tandem. The secondary spinel fO_2 results show an anti-correlation with both equilibration Mg/Fe and *T* (Fig. 1), which suggests the parent hydrothermal system evolved to become more oxidizing as it cooled.



The most perplexing aspect of NWA 5738 is that it also contains an additional variety of apparent fluid-deposited secondary matter: iron metal. The Fe-metals are remarkably pure, with Ni consistently below the EPMA detection limit (0.07 wt%). The vein-like shapes of roughly 1/3 of the largest metals strongly suggest origin by deposition from a fluid. Deposition from a fluid is also suggested by one low-weathering area in which Fe-metal surrounds an exsolved medium-Ca pyroxene, and the ~1-µm scale exsolution lamellae show clear control of (or else, implausibly, by) the detailed, denticular shape of the metal (Fig. 2).

The control of the exsolution over that denticular Fe-metal shape, and the survival of Fo_{14} olivine in a

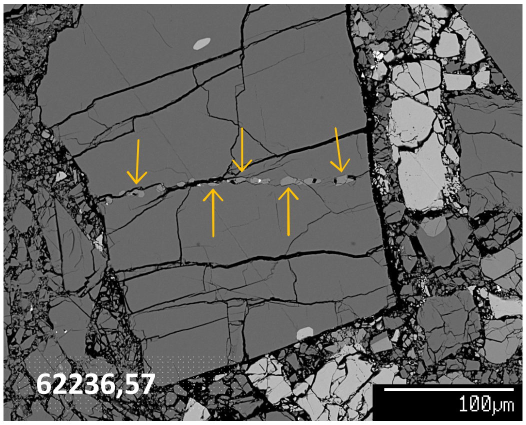


rock with abundant silica and a far higher bulk *mg*, suggest that thermal metamorphism peaked prior to the secondary alteration. The denticluar structure most likely formed as a result of etch-corrosion of the pyroxene (cf. [9]) at an early stage of the fluid-metasomatic processing of the rock.

Near-complete lack of spatial association suggests that the Fe-metals formed during a time period distinct from that in which the curvy microveins formed. The proximal cause of the Fe-metal deposition was most plausibly (or anyway, least implausibly) an abrupt downshift in the fluid fO_2. Considering the extremely evolved bulk composition, the fluid(s) may have been largely deuteric. However, more likely the main source of fluid was a nearby buried mass of volatile-rich impactor matter, such as carbonaceous chondrite (cf. [10]), that hit the asteroid (Vesta?) at a moderate velocity, so that it remained mostly intact. We further speculate that the abrupt drop in fluid fO_2 may have been caused by a process of carbon-fueled "smelting" (cf. ureilites [11]), triggered by an impact-effected shift of the carbonaceous material to a changed environment, with higher T and/or lower P. One way to possibly constrain such models is by *in-situ* measurement of oxygen isotopes. We have obtained some very preliminary data, using the UCLA Cameca 1270 ion microprobe, which suggest the secondary Cr-spinel may contain oxygen with $\Delta^{17}O$ below the normal eucrite fractionation line [12].

These and other recent eucrite results [e.g., 3, 13], point to a need for greater scrutiny regarding the apparent absence of comparable alteration-veining in rocks from the lunar highland crust, a curious lack given the recent evidence for abundant lunar water [e.g., 16-17]. Apatites of suspected fluid-metasomatic origin have been described in an Apollo 17 granulite [14], but no vein-like depositions have been described. Regions of pronounced reverse-zoning have been noted in plagioclase from ferroan anorthosites, by Nord [15]. However, despite our new awareness of lunar water, Nord's interpretation of these complexities as "subsolidus overprint" still seems sound. Anomalies linked with twin boundaries and low-angle subboundaries (in contrast to the fracture-linked deposits of NWA 5738 and other eucrites) probably originated under extremely fluid-poor conditions, and/or before the rocks experienced any significant fracturing, i.e., soon after igneous crystallization. But features such as these in lunar intrusive rocks warrant much more detailed study.

We have recently begun a search for veins or other secondary alterations among ancient lunar highland rocks. To date, other than confirming the reverse zoning in plag reported by [15], our most intriguing discovery is a discontinuous (structurally NWA 5738-reminiscent) train of augite, with minor FeS, that extends across a plag grain from ferroan anorthosite 62236 (Fig. 3; arrows). This augite is incongruously magnesian, $En_{43.1}Wo_{46.0}$, in the ferroan anorthosite context [cf. 18]. Even so, it is conceivably a by-product of some vagary in the primary igneous crystallization.



Water of late-accretionary origin, analogous to our proposed NWA 5738 water source, is probably not as abundant on the Moon as on Vesta. A considerable fraction, roughly 10%, of all Vestan impacts [19-20] occur at specific impact energy less than half that of the most gentle impact on the Moon, as the far higher lunar escape velocity leads to a minimum of 3.9 MJ/kg.

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