DIVERSE VARIANTS OF VOLATILE/REDOX DRIVEN LATE ALTERATION IN EUCRITES

Jason Utas, Junko Isa and Paul H. Warren, Dept. of Earth, Planetary, and Space Sciences, University of California, Los Angeles, CA 90095-1567, USA; jutas@ucla.edu.

Most eucrites have undergone an annealing process that equilibrated their pyroxene (px) into low-Ca and high-Ca components (exsolved) near a single compositional tie-line. Rare eucrites that avoided annealing offer more direct, "pristine" links to igneous origin. However, recent studies [esp. 1] suggest that even many unannealed eucrites feature secondary veining, typically dominated by an anomalous combination of fayalitic olivine and Na-poor plagioclase, within their px. Apparently [1, 2] secondary volatile-rich fluids precipitated these vein materials.

The unannealed NWA 11040 eucrite shows new varieties of secondary vein-alteration. NWA 11040 is unusual in having a relatively high proportion (0.5 vol%, partly oxidized by weathering) of Fe-metal; almost Ni-free (< 0.05 wt% by EPMA, with 0.15-0.23 wt% Co). In-situ reduction in NWA 11040 is suggested by: •••► high Fe-metal abundance; •••► the range in px *mg* is unusually truncated (nowhere less than 32 mol%), consistent with late diminution in [FeO]; •••► px composition does not exhibit the normal increase in FeO/MnO as crystallization caused diminution in *mg*. Also, •••► rims of many px grains, especially near Fe-metal, show a distinctive corrosion texture, with elongate silica-dominated inclusions oriented perpendicular to the rim, suggesting FeO reduction caused decomposition of rim px. We find similar corroded rims in unequilibrated eucrites QUE 94484 (for which [3] inferred late FeO reduction by fugitive SO_x) and NWA 5073, both of which show anomalous FeO/MnO trends.

In previous work on secondary veining in eucrites [1, 2], the near-total confinement of the olivine-rich veins to within px was emphasized. Veins formed by injection of melt would be similarly abundant within the other major phase, plagioclase. Also inconsistent with a melt-injection model is the contrast between the evolved (ferroan olivine) composition of the veins' dominant mafic silicate, and the extremely Na-poor composition of the vein plag; plus, in NWA 5738 [2], some locales have veins of Cr-spinel or Fe metal. In NWA 11040, secondary veins within large px grains are generally not olivine but anomalous-composition (Fe-rich, Ca-poor) "bleached" px. Even more extremely Ca-poor px is prevalent in scattered tiny enclaves (not clasts; the meteorite in unbrecciated) in which a silica phase (cristobalite?) is broken into polygonal subgrains by light veins of anomalous-composition px. We have also found similar objects in Pasamonte. The texture resembles grouted tiles, with px "grout" and silica "tiles". A typical composition of the grout px is En52Wo1.3. EPMA of less than 3 µm veins is difficult, but most analyses show fine pyroxene stoichiometry. In some grout areas a complementary high-Ca composition, ~ En39Wo44, is also (or instead) found. In NWA 11040 and other unannealed eucrites, the lowest Ca content for igneous px with *mg* near 53 mol% is Wo7. In order for grout px, with *mg* roughly 53 and Wo as low as 1 mol%, to develop out of normal igneous px by simple dry metamorphism (annealing), a low temperature of equilibration would be implied, roughly 550°C. But NWA 11040 is *not* an annealed eucrite. We infer that a late, reductive process corroded the px rims, added the "bleached" Ca-poor veins to the interiors of large px grains, and formed the grout pyroxenes.

In Pasamonte, grout-veins show a conspicuous void where they intersect a projection of plagioclase within a block of tiled silica. Evidently, the process that left the grout veins was host-phase selective. It was not merely a melt indiscriminantly filling available space. We infer that fluid was involved, and precipitation against the walls of cracks was favored, depending upon the suitability of the crack-wall matter as a site for nucleation and growth of the vein-fill phase(s). Where a eucrite-transiting fluid reacted with a pyroxene host with M/Si = 1 (M standing for divalent mafic cations MgO+FeO+CaO), the secondary depositions typically consist largely of olivine with M/Si = 2. But in the grouted-tile objects, where a similar fluid reacted with a silica host with M/Si = 0, the secondary depositions consist largely of pyroxene which has a more moderate M/Si of 1.

Although we infer that formation of the secondary veins (both olivine-dominated as in NWA 1000 and NWA 5738, and px-dominated as in NWA 11040) probably involved a fluid phase, important issues that warrant further study include: •••► the compositions of the fluids (in cases of major redox such as NWA 11040, largely H_2S?) [cf. 4]; •••► the detailed relationship between vein-filling alterations and late redox processing; •••► the possibility that fluid might have been involved with an accompanying melt (shock-melt?) component as part of the overall secondary processing; •••► the broader issue of whether the metasomatism was autometasomatism or distinctly post-igneous. Even if the fluids were H_2O-bearing, i.e., in a strict sense "aqueous", they were probably nothing like a typical terrestrial fluid, where H_2O dominates the composition.

References: [1] Barrat J. A. et al. (2011) *Geoch. Cosmoch. Acta* 75, 3839–3852. [2] Warren P. H. et al. (2014) *Geoch. Cosmoch. Acta* 141, 199–227. [3] Mittlefehldt D. W. and Peng Z. X. (2015) 78th MetSoc Meeting: abstract #5342. [4] Warren P. H. et al. (2017) *Meteor. Planet. Sci.*, in press.