# EUCRITE-LIKE SECONDARY METASOMATISM IN APOLLO 14 MARE BASALT 14072

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The two large samples of mare basalt acquired by Apollo 14, 14053 (251 g) and 14072 (45 g), show many similarities, including an unusual extent of subsolidus reduction; and they have been regarded as a "pair" [1], albeit they were found at a separation of 250 meters, and 46 degrees apart in terms of radials from nearby Cone Crater (diam. 350 m) [2]. For comparison with secondary alterations in eucrite meteorites [3-6] we have studied these two "most reduced" lunar basalts, including a newer 14072 thin section, 14072,69. Within 14072 pyroxene (px), especially in 14072,69, we found widespread narrow veins of dominantly olivine, analogous to the eucritic secondary veining.

Secondary veins in 14072 are up to 0.5 mm long but seldom much more than 3 µm wide; 1 µm is typical. Within any one large 14072,69 px there are typically ~ 10 olivine veins, with mildly curvy shapes but a statistical tendency to be near-perpendicular to the long axis of the host px. A shock melt origin for the veins is unlikely given that 14072 is a low-shock sample, with no hint of maskelynite and only weak undulose extinction. A melt-injection origin would lead to indiscrimate, near-random siting for the veins. Instead, deposition of vein matter appears to have involved a fluid that was selectively reactive vis-à-vis the surrounding material; cf. eucrites [5]. Veins tend to thin out as they near more evolved (Fe- and Ca-rich) margins of the host igneous px grains. The major mineral plagioclase is virtually devoid of veins. The peridotitic composition of the veins is also an unlikely result for selective impact melting. In one locale in 14072,10, additional secondary veins, px-like in composition, were deposited within cristobalite, after a cool-down to below ~ 250°C, the *T* at which distinctive "fish-scale" texture develops by contraction-cracking as volcanic cristobalite transitions from β to α structure; cf. analogous textures in eucrites [5].

Another similarity with eucrites [4] is that the veins include a minor Cr-spinel component, and in this case, as in eucrite NWA 5073 [6], the Cr-spinel tends to occur as a discontinuous median near the center of the vein. Like the eucrite secondary spinels [5-9], these are rich in Ti, Al and especially Cr. Unlike eucrites, 14072 has a component of coarse, early igneous olivine, up to Fo79 [7]. The 14072 secondary olivines are likewise far more magnesian than their eucrite counterparts. Among olivines analyzed in 70 veins Fo42 is the lowest *mg* (the maximum, Fo62, is likely a byproduct of close proximity to a primary-igneous olivine). Where a secondary olivine vein transected one of the early igneous olivines, the vein is discernible as an extra-thin and discontinuous vein of Cr-spinel accompanied by minute voids (bubbles). In one such locale, a tight cluster of sharp-bounded <8 µm blebs of olivine(?) with ~9 wt% CrO formed within the igneous olivine. In some places the surrounding px has a reaction zone extending up to (rarely) ~ 6 µm from the olivine. The px in these reaction zones has lower *mg* by as much as 15 mol% versus the original core/host px (typical *mg* ~ 71 mol%). Some olivine veins are studded with tiny grains of kamacite. Although the vein-like metals associated with eucritic metasomatism [4, 5] are remarkably Ni-free pure iron, the 14072,69 metals consistently have sufficient Ni to be detected even by SEM-EDS spectroscopy (i.e., not << 1 wt%).

We prepared a focused ion beam (FIB) section from one of the larger veins and obtained chemical and microstructural data using transmission electron microscopy (TEM). The prelimnary TEM results show that the vein is dominated by equant olivine grains (Fo45) that share equilibrium grain boundaries with each other and with minor augite and Cr-spinel. The pyroxene host has exsolved augite from pigeonite adjacent to the vein at a temperature of <900°C, and augite exsolution lamella become more numerous and more Mg-rich away from the vein. The augite exsolution lamella are compositionally distinct from the augite grains within the vein.

The analogy to the eucrite secondary veins [3-6], and the related(?) issue of unusually extensive reduction, both warrant careful study. As with the eucrites, the heating event associated with the 14072 metasomatism was not protracted. Exsolution is ubiquitously hard to detect at SEM scale. Equilibrium among *mg* ~ 50 olivine, px and iron metal would suggest [8, 9, assuming ~ 800°C] an $fO_2$ of IW−1, far above what [1] inferred for 14053. Assuming the $H_2O/H_2$ ratio was set by dissociation in a compositionally simple, low-*P* fluid, at 800°C this ratio would have been ~ 0.3 [9]. Transport of the olivine cations (and admittedly, the distances may have been short) implies at least moderate solubility, which suggests polar molecules were important in the fluid. Molecules such as $H_2$, $CO_2$, $CH_4$, CO, all have very low polarity. The requisite polarity is possessed by $H_2O$, or conceivably some mix of $H_2S$, HF and HCl.

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