PYRITE TRACKS LATE HYDROTHERMAL ALTERATION IN MARTIAN REGOLITH BRECCIA NWA 7533

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Highlands regolith breccias (NWA 7533 and paired stones) containing pieces of the early terrains of Mars are unique among Martian meteorites in showing widespread crystallization of accessory pyrite (up to 0.6+/-0.1 vol %) instead of pyrrhotite-rich magmatic sulfides. Pyrite crystals (30-40µm across; up to 120-150µm in maximum dimensions) combine cubes, truncated cubes and octahedra, all showing microstructural features (PDF; fracture networks) of soft shock-induced deformation. These fractures acted as preferential pathways for terrestrial weathering. Pyrite is partly replaced by Fe oxy-hydroxides indicating terrestrial D/H values (NanoSIMS analyses). This alteration resulted in significant S losses, as suggested by the low whole-rock S contents (<0.1 wt.%) so far published [1][2].

Pyrite is a late mineral, perhaps the latest in the martian chronology of NWA 7533. It is present in all of the lithologies, i.e. the fine-grained matrix (ICM), clast laden impact melt rocks (CLIMR), melt spherules, microbasalts, lithic clasts and mineral clasts [2]. Low-Ca pyroxene clasts show partial replacement by pyrite that infiltrates cleavage planes in the pyroxene. Some pyrite crystals obstruct open fracture planes cutting across the whole meteorite. All these features indicate that pyrite crystallized after the final assembly of the breccia. One-third of the 350 pyrite analyses (SEM and EMP) show Ni > 0.5 wt.% with occasional peaks up to 4.5 wt.% tracing random meteoritic Ni contamination that accumulated in the regolith breccias. Other modified projectile debris are nanometric Ir-(Os)-As-S and Os-S-rich compounds. EMP analyses of chalcophile trace elements suggest minimum S/Se ratios of ca 7,000 for the Ni-free pyrite, as expected for hydrothermal sulfides.

Pyrite is almost invariably intergrown with micron-sized Fe-(Ti) oxides (magnetite-maghemites) that served as nuclei for crystallization. The maximum T for pyrite crystallization is fixed at 400-500°C from the maximum Ni contents. This elevated temperature is supported by Fe-depletion halos in mafic minerals enclosed in pyrite or surrounding that mineral. Pyrite grew from just-saturated sulfurous fluids under near-neutral (6<pH<10) oxidizing conditions (FMQ + 2 log units). The morphologies of pyrite crystals argue for moderate to slow growth rate consistent with a reheating event perhaps related to the late (1.4 Ga) disturbance identified in several isotope systematics [2][3] and contemporaneous with a sintering event identified in ICM [4]. The polymict martian breccias NWA 7533 and paired stones shed some new light on links between impact events, hydrothermal alteration and sulfide cycling in the early Martian crust.

References: [1] Agee C.B. et al. (2013) *Science* 339, 780–785. [2] Humayun M. et al. (2013) *Nature* 503, 513-516. [3] Goderis, S. et al., (2014) *LPSC* XLV, Abstract #2200. [4] Muttik et al.(2014) *LPSC* XLV Abstract #2768.