ESPÉRANCE: EXTREME AQUEOUS ALTERATION IN FRACTURE FILLS AND COATINGS AT MATIJEVIC HILL, MARS.

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Introduction: Intensive investigations of a boxwork structure located in an area called Matijevic Hill on the eastern side of the Cape York rim segment surrounding Endeavour Crater, resulted in the discovery of fracture-fill material and coating of unique compositions. After major efforts resulting in partial RAT abrasion of the target subsequently named Espérance6, APXS analyses obtained the lowest values of FeOT (4.4 wt.%) and CaO (2.1 wt.%), and the highest values of SiO2 (62.5 wt.%) and Al2O3 (15.4 wt.%) measured on martian materials during the past ten year mission by the Opportunity rover at Meridiani Planum [1].

Context: Boxwork structures (Fig. 1) in the Matijevic formation were analyzed in two separate visits to the area, originally during investigation of other, apparently unrelated outcrop. Exposed Espérance fracture fill (substrate) is lighter than host rock, but a patchy, coating is darker (colorized MI mosaic, Fig. 2).

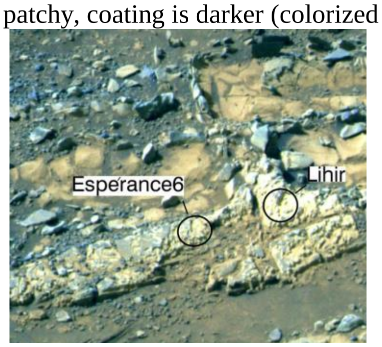

Fig. 1. Espérance /Lihir are part of the boxwork seen in this Pancam false-color image.

Composition and Trends: Even though the coating is discontinuous, the field of vie w (FOV) of APXS is too large to individually analyze coated vs uncoated material. However, with progressive RAT grinding we have been able to artificially vary the proportions of coated and uncoated material. Extrapolation of trends indicate a mixing line between two end-members, although how close the substrate and coating match the two end-members could not be analyzed because of the intrinsic patchiness of the coatings and incomplete grinding through all patches with coating.

Substrate. Element trends in this series of analyses conducted on Espérance show unusually strong correlations and anti-correlations between most elements, which cluster into two major groups (Table 1). Trends indicate the substrate contains mainly Si, Al, and Cr (Fig. 3, 4), and the coating is rich in a medley of the remaining elements. Both end-member compositions are significantly different from martian soils [2], typical basalts, or martian meteorites. While the fracture-filling substrate is mainly an aluminosilicate, extrapolation of the Al vs Si trend in Fig. 4 reveals a second, non-Al phase of Si alone, possibly silica.

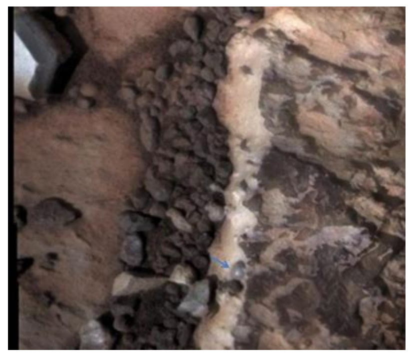

Fig. 2. Espérance fracture fill (white) and with dark coatings (patchy areas to right). Scale: ~5 x 5 cm.

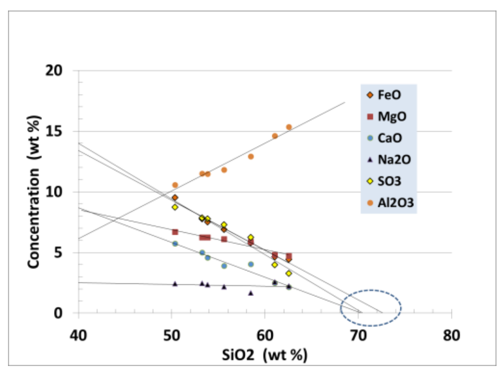

Fig. 3. Most elements anti-correlate with Si.

Pancam images of the brightest regions of Espérance reveal a drop in reflectance over the spectral region 0.934-1.009 μm, consistent with the presence of one or more hydrated mineral phases. Ratios of the backscatter peaks in APXS constrain the water content to be ~5 wt. % or less [1].

The aluminosilicate portion is implied to be a smectite [1], Fig. 5. Elemental compositions implicating montmorillonite have also been observed by the Spirit rover in the Independence samples on Husband Hill

[3], which also include Cr enrichment, albeit with no obvious evidence for accompanying silica or coatings.

Table 1. Correlation Coefficients (R^2)

	SiO2		SO3
SiO2	1	SO3	1
Al2O3	0.9795	MgO	0.9917
Cr2O3	0.9419	K2O	0.9765
TiO2	-0.066	CaO	0.9681
Na2O	-0.208	FeO	0.9524
Cl	-0.255	Zn	0.9521
Ni	-0.262	Br	0.9404
P2O5	-0.627	MnO	0.7867
MnO	-0.877	P2O5	0.5655
K2O	-0.927	Ni	0.3602
Zn	-0.948	TiO2	0.2309
MgO	-0.957	Cl	0.1713
Br	-0.96	Na2O	0.025
CaO	-0.971	Cr2O3	-0.895
SO3	-0.974	SiO2	-0.974
FeO	-0.992	Al2O3	-0.999

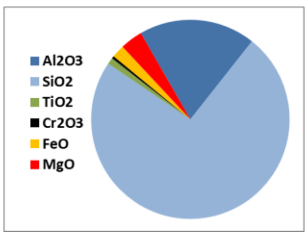

Fig. 4. Fracture fill is dominated by Si and Al.

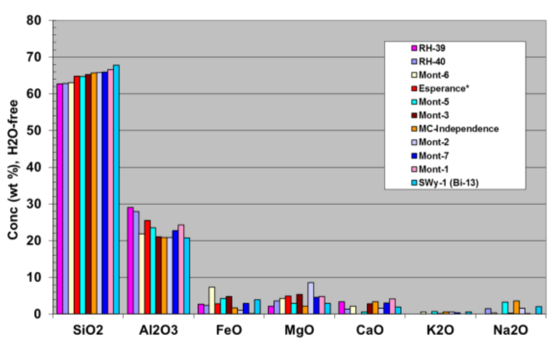

Fig. 5. The aluminosilicate end-member (red bars, after extrapolated silica is subtracted) has Si and Al in the common range for montmorillonites, with appropriately low values for other elements.

Coating. As shown in Fig. 6, the coating hosts many elements, possibly in a variety of mineralogic or amorphous forms. The elements iron and sulfur dominate, but large amounts of Mg and Ca are also present. Sulfate salts of Mg, Fe, and Ca have all been found at various locations on Mars, but in this case charge balance calculations show there is insufficient S to accommodate all cations. Elements invisible to APXS, including O and C must be present to form species such as carbonates or iron oxides. Although APXS can indirectly detect the presence of light elements via the ratio of incoherent to coherent scattering from a sample, this technique cannot be applied to a thin coating because the high penetrating power of the source x-rays reflects the characteristics of mainly the bulk material.

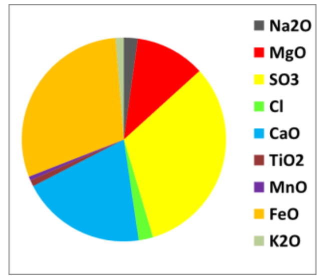

Fig. 6. An excess of cation elements in the coating end-member implies sulfates, but also Fe-oxides, and possibly carbonates.

Astrobiological Significance: The Esperance assemblage suggests past environmental conditions favorable for habitability, in view of the large amount of H_2O needed to derive silica as well as mortmorillonite, which forms best under moderately alkaline conditions.

The coating is a separate potential habitat for lithobionts [4]. Its relatively low albedo would increase peak diurnal temperatures, favoring formation of transient liquid-like films from nighttime frosts; the accompanying salts depress freezing points for transport of nutrients and waste products; and the high Fe can be an effective shield against EUV on Mars [5].

Conclusions: Extreme aqueous alteration in multiple events to produce filling of fractures and surficial coating has occurred at this location, as evidenced by a mineral assemblage that includes substantial amounts of a likely Al-rich smectite plus a siliceous phase, and coatings that also depart strongly from compositions of dust, soils, or surrounding rocks. Formation of the low-Fe phases implies the fracture filling fluid was reducing and at moderate pH values, whereas the coating could have been produced subsequently, under different conditions involving oxidation and acid sulfate solutions.

References: [1] Arvidson, R. et al. (2014), *Science*, Jan. 14th, in press. [2] Yen, A., et al. (2005), *Nature*, *436*, 49– 54. [3] Clark, B.C. et al. (2006). *JGR*, *112*, doi:10.1029/2006JE00. [4] Dorn, R.I. (2009). In: Parsons, A.J.(ed). Geomorph. of Desert Environ. Springer, p. 153. [5] Phoenix,V.R., Geology(2001), 29, 823-826.

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