

## POSSIBLE ALTERATION OF ROCKS OBSERVED BY CHEMCAM ALONG THE TRAVERSE TO GLENELG IN GALE CRATER ON MARS.

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**Introduction:** The possibility that the rocks and soils along the traverse during the 90 first SOLs have been altered is evaluated through the large number of ChemCam observations and through theoretical considerations on water-rock interactions. ChemCam [1,2] uses laser-induced breakdown spectroscopy (LIBS) to produce atomic emission spectra of small (350-550  $\mu\text{m}$ ) observation points on rocks and soils within 7 m of the rover. In the first 90 sols, 359 such observations were made on Mars targets.

**Bulk chemistry:** LIBS peak ratios, normalized to silica, have been used as a first level quantification tool for the assessment of chemical input or output fluxes. The dust (1<sup>st</sup> laser shot on 30 to 50 per observation), and the soils and rocks (average of all shots excluding the first five) are evaluated separately. Alkali elements (Fig.1A) in rocks and soils display a trend towards enriched compositions consistent with the alkali feature of rocks such as Jake Matijevic [3], unusual for Martian basalts, but confirmed by APXS analyses [4]. However, the data do not suggest any sign of leaching of these labile elements. Alkaline earth elements (not shown) have sporadic values radically enriched in Ca with respect to silica suggesting the presence of a non silicate Ca-phase, but a significant fraction of the overall observations are depleted in Ca and Mg. These latter targets correspond to rocks enriched in alkali elements, thus with correspondingly lower concentrations in ferromagnesian and alkaline earth element concentrations. The dust displays less diverse values than rocks, the smaller grain size - smaller than the laser beam - making the LIBS analysis an average composition of the particles.

Fig. 1B highlights the distinction between felsic and mafic mineral constituents. Peak ratios ( $\text{Al}_{494+496}/\text{Si}_{288}$  and  $(\text{Fe}_{438}+\text{Mg}_{285})/\text{Si}_{288}$ ) have been converted to approximate element ratios using measurements on eight on-board calibration targets. Data for rocks are scattered but when examined rock by rock a mixing trend between felsic and mafic can be distinguished in many cases, most visible in soils, with a felsic end-member having the composition of andesine ( $\text{Al}/\text{Si} \sim 0.55$ ) and consistent with the mineral characterization by CheMin [e.g., 5]. Besides this mixing trend, rocks display incursions towards either a silica-rich composition or a trend showing Fe+Mg enrichment. This does not correspond directly to any typical silicate minerals, but it may indicate a mixture of silicates and oxides.

**Modeling:** Here we modeled the alteration of a mineral mixture representative of the composition encountered at Gale, using the JChess simulator [6] with realistic kinetic constraints. We considered a mixture of olivine, andesine and pyroxene on the basis of the CheMin soil determination [7], with the addition of 10% K-feldspar as suggested by the K content measured by APXS on Jake Matijevic. The alteration is assumed to be driven by fluids from acidic composition [8] under low water-rock ratios ( $\text{H}_2\text{SO}_4$  brines, in the continuation of [9], assuming a  $\text{SO}_2$ -rich atmosphere [10]) to less acidic and higher water/rock ratios. The calculations indicated that strong leaching would generate a siliceous by-product accompanied by Ca-rich salts (sulfates in this case). By contrast to similar calculations using the Adirondack basalt as a model, the precipitation of Mg-salt is not found. Under a weaker leaching scenario, olivine and magnetite feed the precipitation of a mixture of Fe,Al-oxyhydroxides and nontronite, the composition of which corresponds to the observed trend in rocks in Fig.1B.

**Interpretation:** These results, compared to the absence of clays, sulfate or other hydrated alteration phases in the scooped soil analyzed by CheMin, suggest that the Ca-rich spots observed in several soils, as well as the silica rich compositions encountered [7] at Rocknest, may result instead from the sporadic evaporation of a Ca-enriched fluid and not from an intensive alteration of the soils as suspected elsewhere on Mars [11]. For rocks, the few silica-rich spots are more problematic. Local Ca-rich salt contamination may also be envisaged, as for the soils, rather than a strong leaching which is not reflected in the alkali content of rocks. However, the slight alteration of the mafic rock constituents into oxides and nontronite remains perhaps possible, as modeled in Fig.2, although no sign of alteration is detected in the neighboring soils. Given the likely volcanic context for some of the analyzed rocks [12], such a partial alteration of the mafic constituents and the precipitation of Si- and Ca-rich phase can be compared with numerous occurrences in lava flows and volcanic edifices on Earth, suggesting that an early, local and ephemeral alteration stage by the degassing volatiles affected these rocks during or just after their formation, as suggested by [13], making the alteration history of the local rocks different from the soils.

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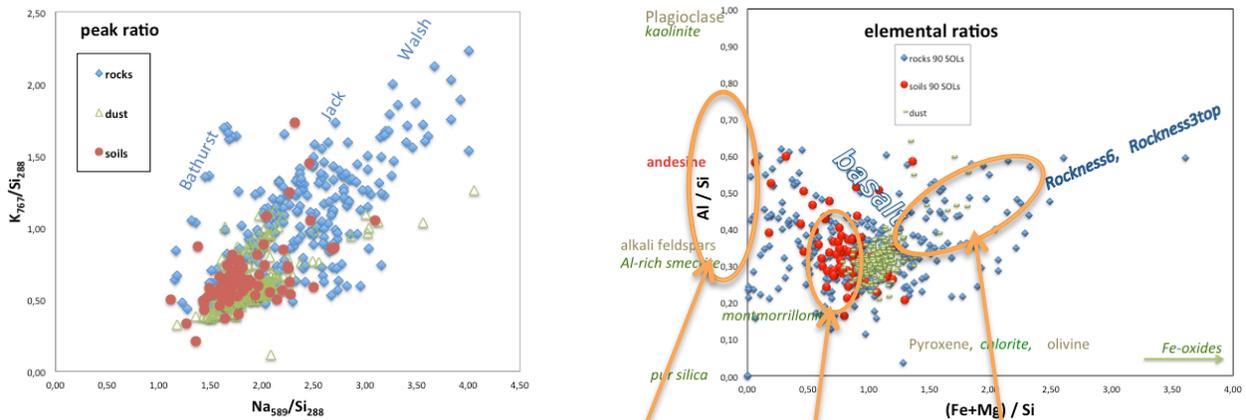


Figure 1: A) Peak ratio of alkali of rock, soil and dust during the first 90 SOLs. B) Elemental ratio compared to compositional field of some mineral references.

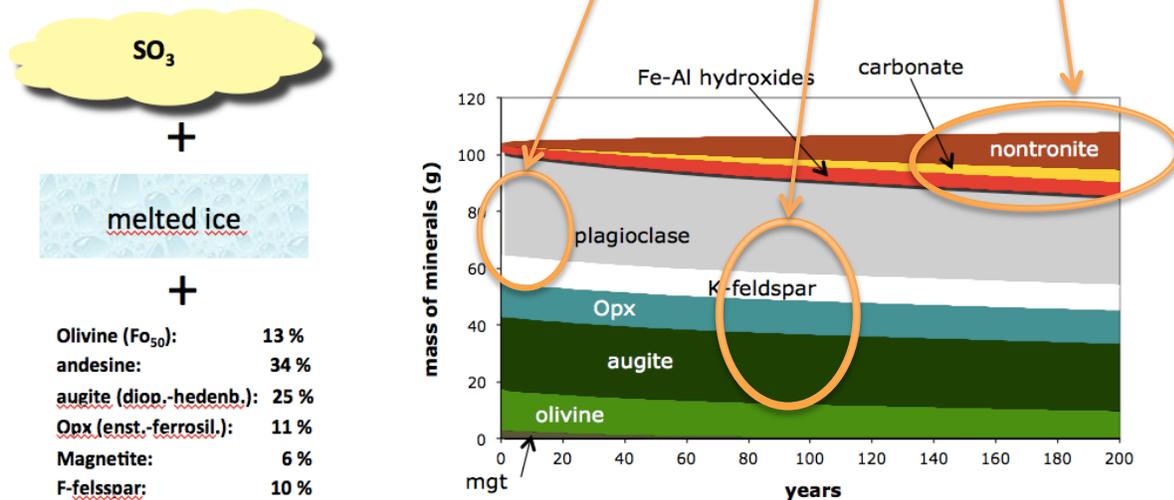


Figure 2: Modeling a moderate alteration of the Gale basalt. The starting mineral composition is based on the CheMin evaluation for soils and the assumption of the occurrence of K-feldspar. The W/R ratio is 100 with a cold  $10^{-2}$  m  $H_2SO_4$  fluid produced by the dissolution of an acid fog in melting ice. The atmosphere composition is the modern one. The other parameters can be found in [7].