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Martian Chemical Weathering at Hematite Ridge, Gale Crater

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Abstract

A likely origin of Hematite Ridge, Gale Crater is from the in-situ weathering of precursor silicates under oxidizing conditions: it might represent an ancient sub aerially exposed horizon. High W/R associated with FeMg mineral alteration and hematite enrichment is envisaged within a near surface aquifer.

1. Introduction

Secondary minerals identified by Mars Science Laboratory (MSL), together with their sedimentological context, provide an unprecendented opportunity to constrain the nature of martian fluids and habitability. One of the main targets for MSL Mission is the Hematite Ridge on the north, lower slopes of Mt. Sharp (Aeolis Mons). Hematite Ridge is a 200 m wide protruding feature extending 6.5 km northeast-southwest [3], identified by CRISM as having a hematite-rich signature, contrasting with clay- and sulfate-rich mineralogy dominating other parts of Mt. Sharp [1,2].

After landing in August 2012, Curiosity has identified clay and Fe oxides within sediments along the traverse to Hematite Ridge. ChemCam analyses show the overall basaltic composition of the sediments (Fig. 1). The Sheepbed member is a mudstone of basaltic chemical composition with ~15% smectite, ~50% igneous minerals, and ~35% amorphous material [4]. The observed magnetite is considered to be authigenic [5]. In previous work we showed that dissolution of approximately 70:20:10 % amorphous material, olivine, and basaltic material in an open system within the Sheepbed Member mudstone can explain the smectite and magnetite abundances identified by CheMin XRD at the John Klein and Cumberland sites [6]. More recently, at the Kimberley drill site, CheMin has identified ~10% magnetite with some hematite [7].

Here we show thermochemical models for the formation of Fe oxide enrichments, and the ferric oxide hematite in particular, within Gale sediments. This provides an insight into the formation conditions of the Hematite Ridge layer during diagenesis or other alteration stages. An alternative model has been suggested by [3] who suggested exposure of a Fe^{2+} rich groundwater to an oxidizing environment, leading to precipitation of hematite or its precursors. These models will be tested once we have a full mineral assemblage from Hematite Ridge.

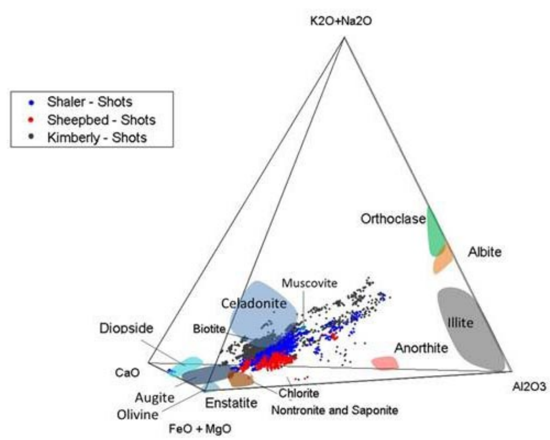

Figure 1: ChemCam LIBS data (PLS1) of the Sheepbed Member mudstones. The sedimentary horizons show an overall basaltic mixing trend between pyroxene and feldspar. The more alkali-rich Kimberley and Shaler units are shown for comparison.

2. Methods

We use ChemCam (PLS1), APXS and CheMin analyses and sedimentological observations of the

Gale sediments [4,8,9] to guide the input parameters of our thermochemical model. We have used CHIM-XPT [10] to perform the model runs for a variety of compositional, T, W/R values and initial fluid compositions. The bulk composition is assumed to be basaltic (Fig. 1). Here Water/Rock ratio W/R is the ratio of incoming fluid to reacted rock.

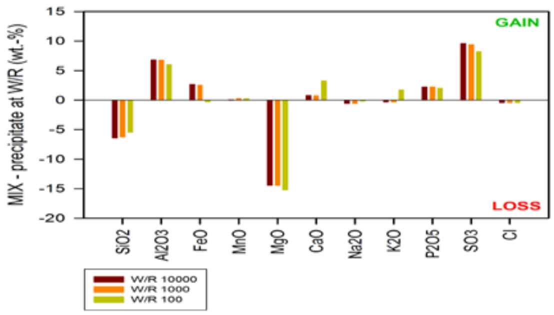

Figure 2: Element gain/loss in precipitate relative to the dissolving host rock (incongruent dissolution of Portage soil, see [6])

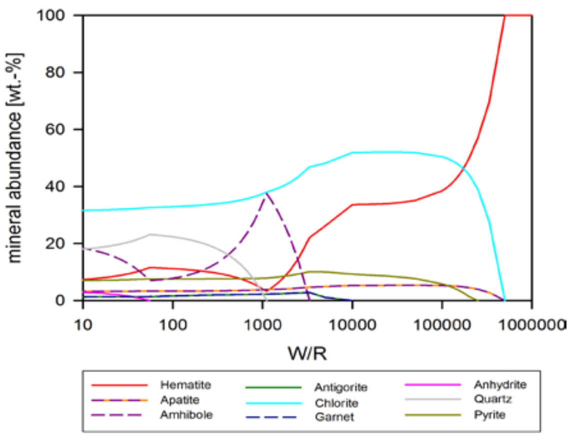

Figure 3: The effect of temperature on ferric oxide abundance. Higher T, here 150 °C, is associated with more hematite relative to magnetite and other oxides; particularly at the very highest W/R [6].

3. Results

In general, the model based on dissolution of 70% amorphous phase, 20 % olivine and 10 % whole rock [6], produces precipitates that are enriched in Fe, Al, and S compared to the original rock. This effect can be more pronounced at higher W/R (Fig. 2). High W/R runs, e.g. >1000, and higher temperature (Fig. 4) also predict the precipitation of ferric oxide at the expense of ferric silicates or other Fe oxides. Repeated weathering/leaching cycles such as can occur at the surface or along fluid conduits, will increase the effect. For example, if the alteration assemblage formed by incongruent dissolution of Portage soil (with 70 % amorphous phase, 20 % olivine and 10 % whole rock), is subject to another fluid event, the newly precipitated assemblage (at W/R 1000) contains 27 % goethite, 44 % serpentine, and 22 % clay with minor pyrite and apatite (Fig. 4).

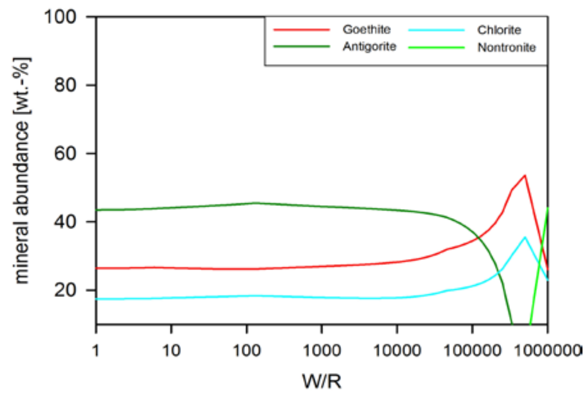

Figure 4: Re-dissolution of an alteration mineral assemblage at W/R 100 from the model runs for the 70:20:10 amorphous:olivine:bulk rock mixture. The original weathering products were dissolved in a new batch of the dilute diagenetic brine (see [6]). This shows that repeated weathering cycles will lead to enrichment of ferric oxide (goethite here, though this can readily transition to hematite).

References

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