

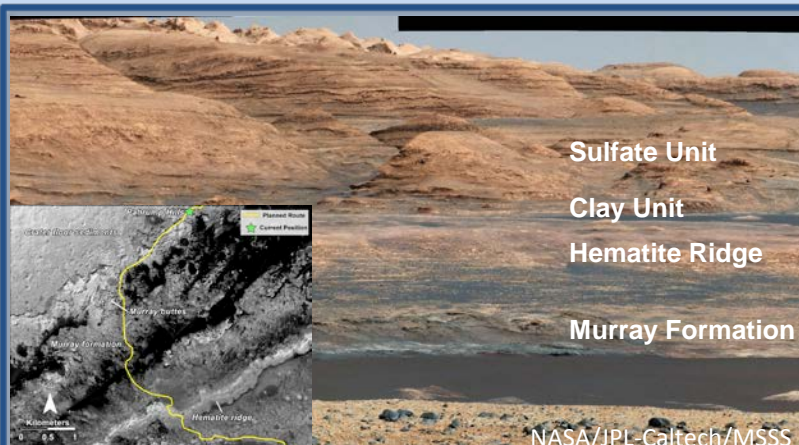
HEMATITE INDICATOR OF HIGH WATER/ROCK RATIO ALTERATION IN GALE CRATER

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Introduction

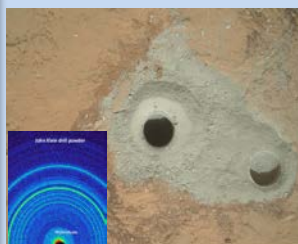
In the Sheepbed mudstone of Yellowknife Bay in Gale Crater, diagenetic mineral assemblages have been found by the Curiosity Rover [1] which are the result of intermediate to low water/rock W/R diagenesis [2]. However, at Hematite Ridge on the north, lower slopes of Mt. Sharp (Aeolis Mons) which Curiosity is expected to reach within the current Extended Mission, a different assemblage is predicted. Hematite Ridge is a 200 m wide protruding feature extending 6.5 km NE-SW [3], identified by CRISM as having a hematite-rich signature, contrasting with the clay- and sulfate-rich mineralogy dominating other parts of the Gale Crater Floor and Mt. Sharp [4,5]. Here we propose a model to explain the formation of Hematite Ridge and the associated environmental conditions.



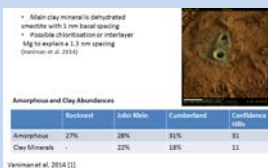
▲ The Hematite Ridge is a 6.5 km, 200m wide layer [3,4] above the Murray Formation of Aeolis Mons, Gale Crater

Methods and Results

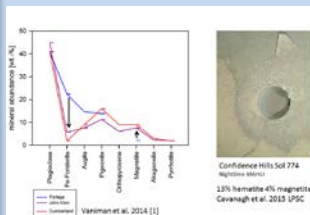
We use CHIM-XPT (M. H. Reed, U. Oregon) to model the different alteration conditions expected at Gale (details see [2]). Dissolution of approximately 70:20:10 % amorphous material, olivine, and basaltic material in an open system within the Sheepbed Member mudstone leads to the smectite and magnetite abundances identified by CheMin XRD at the John Klein and Cumberland sites [2]. These conditions are low-T diagenetic with intermediate W/R, as expected from reactions between pore water and rock, and predominantly form Fe-silicates and magnetite. For the formation of Hematite Ridge, oxidation of an inflowing Fe²⁺-rich groundwater has been suggested [3]. Our models show that other options are possible.



▲ John Klein drill hole (1.5 cm wide) and CheMin XRD pattern showing presence of ~ 1 nm d-spacing smectite.



▲ Clay (smectite) and amorphous contents mudstone and Rocknest soil [1]

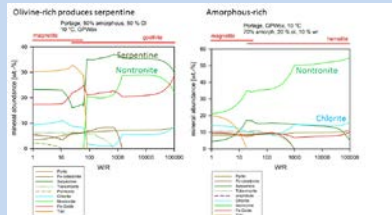


▲ Mineral abundances from CheMin [1] in Sheepbed member mudstone. Reaction and loss of olivine is linked to an increase in magnetite

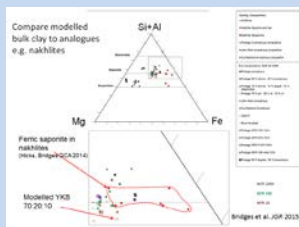
Water to Rock Ratio and Temperature

Water to rock ratio and temperature. High W/R ratio favours Fe-oxide (or hydroxide) formation alongside either Al-oxide/-hydroxide, silica, and/or kaolinite, while more soluble elements (e.g. K, Mg) stay in solution. Thus, especially under exposure to fresh water (i.e. precipitation, surface water) repeated dissolution-precipitation cycles will enhance the Fe-oxide content of the resi-due. In just one re-dissolution cycle the hematite abundance at very high W/R reaches 50 wt%. Accompanying minerals are Fe-clays (smectite and chlorite). If redox is solely controlled by rock alteration, pyrite would not be present. By this model Hematite Ridge could be explained as the result of near surface, high W/R weathering. However, elevated temperatures, e.g. from a hydrothermal system, could also lead to enhanced Fe-oxide pre-cipitation. In contrast though to the low-T case, pure hematite precipitates would require extremely high W/R.

▲ Model results for olivine-rich and amorphous reactions with a dilute brine. The closest correspondence to Sheepbed mineralogy occurs with 70% amorphous, 20% olivine, 10% whole rock reactants.

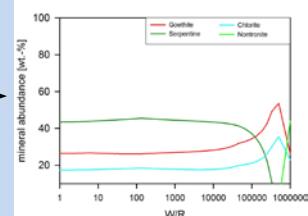


▲ Sheepbed Member mudstone showing Mg-rich ridges. This is the location of the John Klein and Cumberland drill holes. MastCam image, fov 3 m.



▲ Bulk clay composition from the model compared to nakhilite ferric saponite [2, 6]

Hematite Ridge Model. Re-dissolution of alteration mineral assemblage at W/R 100 from the model runs. Original weathering products were dissolved in a new batch of the dilute diagenetic brine. Repeated weathering cycles in open system (high W/R) will lead to enrichment of ferric oxide



Summary – Hematite Ridge Predictions

• Hematite Ridge is an important point in Curiosity's investigations and may reveal a new type of weathering palaeo-environment previously unidentified in Gale

• Reaction of basaltic composition sediment with dilute brine
➢ Initial dilute brine is oxidising, near neutral, HCO₃-poor

• A mixture of 70 % amorphous, 20 % olivine and 10 % basaltic whole rock satisfies the observations
➢ Olivine dissolves and magnetite is produced
➢ Average phyllosilicate is similar to ferric saponite identified in nakhilites

• Diagenetic fluid composition characteristic of basaltic terrains e.g. Deccan
➢ MgFe depletion due to early precipitation of clay (Mg-rich ridges) from early olivine dissolution
➢ Active groundwater flow
➢ Some detrital clay is possible

• Hematite enrichment from repeated alteration-weathering cycles in Gale

