Comparing Clays From Mars and Earth

Highlights Article for American Mineralogist

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Abstract: A terrestrial analogue of the saponite identified by Mars Science Laboratory in the mudstone of Yellowknife Bay, Gale Crater has been identified. It is griffithite, from Miocene volcanic and sedimentary rocks in Griffith Park, Los Angeles. This is a ferrian, trioctahedral saponite with all the Fe^{3+} in a distorted octahedral site.

Since August 2012 the Mars Science Laboratory rover Curiosity has been studying ancient, clay-bearing sedimentary rocks of basaltic composition in Gale Crater. During sols (the Mars term for a day) 57-100, 180-292, Curiosity analysed soil and drilled fine grained sediment at the Rocknest sand shadow, then the John_Klein and Cumberland outcrops of the 1.5 m thick Sheepbed unit.

The presence of CheMin – a novel transmission X-ray Diffraction instrument with a Co Kα source [Blake et al. 2012] – in the body of the rover has allowed mineralogists to determine what the fine grained sediments of Yellowknife Bay are made of. The results of that work showed the presence of a saponite and magnetite-bearing assemblage in the mudstone and also amorphous material in both the scooped aeolian and drilled samples. In a remarkable step forward in our understanding of Mars, the clay-bearing assemblage was interpreted as diagenetic rather than detrital and forming in a circum-neutral, habitable, fluvio-lacustrine environment [McLennan et al. 2014; Grotzinger et al. 2014].

However, as Treiman et al. [2014] point out in their paper in this issue, even Curiosity has its limitations, the 2θ range of the CheMin detector 5-50^{o}, doesn't allow for the identification of all features normally used to help distinguish between di and trioctahedral structures. For instance, an 060 peak, or 06l band which is present when there is rotational disorder between clay lattice layers, occurs at 61^{o} in saponite (Moore and Reynolds, 1997). Accurate estimations of the proportion of ferric iron and associated redox conditions are also challenging.

Studying Mars' mineralogy *in situ* sharpens the need for suitable terrestrial analogues that can provide detailed structural and compositional information to feed back into the martian studies. To this purpose, Treiman et al. have gathered such data on a saponite from Griffith Park, Los Angeles, found in basaltic amygdales of Miocene age and adjacent volcaniclastic sediments. This 'griffithite' [Larsen and Steiger, 1917] is a Mg-Fe^{3+}-Fe^{2+} trioctahedral smectite with all of the ferric iron ($Fe^{3+}/\Sigma Fe$ = 64 to 93%) considered on the basis of Mössbauer spectra, to be present in a distorted octahedral site. The griffithite has an 02l band at 4.59 Å, indicating some disorder resulting from rotations

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between layers in the clay lattice, as does the saponite identified in the John_Klein and Cumberland samples of the Sheepbed mudstone [Vaniman et al. 2014]. Vaniman et al. have already put this work to good use by showing that in one model of the Sheepbed saponite its composition is similar to the Griffith Park clay. By analogy between the two clays, this might mean that the Sheepbed saponite experienced oxidation after formation, in a late diagenetic event, to create its current ferrian composition.

Supporting evidence that such a saponite could be widespread in areas that have preserved alteration of the martian basaltic composition crust, comes from the Lafayette member of the nakhlite martian meteorite group. This meteorite contains hydrothermal veins including saponite of similar composition to the griffithite, though with greater iron content and some tetrahedral Fe^{3+} site occupancy [Changela and Bridges, 2011; Hicks et al. 2014].

Treiman et al. also note that their infrared spectroscopy of the griffithite may help refine the identification of clay minerals by the OMEGA and CRISM spectrometers on the Mars Express and Mars Reconnaissance Orbiter spacecraft. The identification of clay from orbit was a key reason for the selection of Gale Crater as the Curiosity landing site [Milliken et al. 2010], and clays are high priority targets for the upcoming ExoMars 2018 and Mars2020 rover missions. Analogue studies like the one presented by Treiman et al. will be essential in the ongoing identification and characterisation of habitable environments on Mars.

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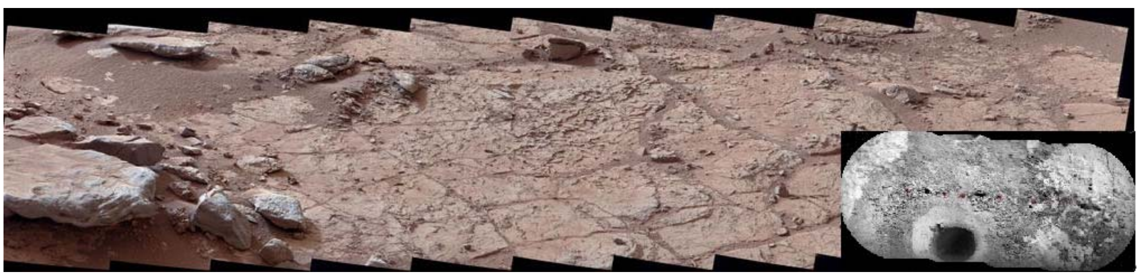

Figure 1. The Sheepbed fluvio-lacustrine mudstone unit of Yellowknife Bay, Gale Crater showing characteristic flat bedding and raised ridges (Field of View 3.5 m, MastCam mosaic Sol 167, NASA/JPL-Caltech/MSSS). Inset shows a ChemCam Remote Micro-Imager view (Width of drillhole 1.6 cm, Sol 183, NASA/JPL-Caltech/LANL/CNES/IRAP/LPGNantes/CNRS/IAS) of the John Klein drill hole, with laser spots visible, that was made within Sheepbed. The material from this drillhole, and the one in Cumberland, which was also in the Sheepbed unit, were analysed by the CheMin XRD instrument and found to contain a saponite which Treiman et al. 2014 argue is similar to terrestrial griffithite from Griffith Park, Los Angeles.

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