Geophysical Research Abstracts
Vol. 21, EGU2019-17694, 2019
EGU General Assembly 2019

A terrestrial soil analogue for Martian mineralogy identified by the digital soil mineralogy concept applied to X-ray powder diffraction measurements on Earth and Mars

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Since landing on Mars in 2012 the CheMin instrument on board the Mars Science Laboratory (MSL) rover 'Curiosity' has analysed approximately 35 Martian soil and rock samples by X-ray powder diffraction (XRPD). The MSL XRPD measurements allow researchers to investigate the mineralogy of the Martian surface with particular focus on ancient aqueous environments that may once have provided the combination of factors required to sustain microbial life. A key part to this analysis is the identification and quantification of clay minerals since their presence is linked to the once hydrous geochemical conditions of Mars.

Qualitative and quantitative analysis of clay minerals can be a challenging undertaking, often requiring separation of the clay size fraction, its preparation as oriented specimen on a substrate such as a glass slide, and several ancillary treatments such as saturation with ethylene-glycol and heating. The MSL cannot separate the clay fraction from Martian samples and is limited to bulk sample analysis, where clay minerals are analysed in a randomly oriented powder along with all other crystalline and amorphous components within the sample. This limitation whereby the identification of clay minerals must rely solely on bulk random powder data has created some uncertainty and challenges in the identification of clay minerals from MSL XRPD data. Identification of Earth based analogues for Martian soil mineralogy therefore represent an opportunity to inform the interpretation of the clay mineralogy encoded within MSL XRPD data. Furthermore, understanding the development of mineralogically analogous soils on Earth has potential to aid the development of hypotheses for the environmental properties of aqueous systems on ancient Mars.

Here, by treating XRPD data as digital mineral signatures, the open access XRPD measurements from the MSL were compared to a dataset of approximately 1500 Scottish soils analysed as part of the National Soil Inventory of Scotland (NSIS). Initial correlation (Pearson; r) of each MSL sample to all NSIS samples yields a combined histogram dominated by correlation coefficients < 0.4. However, a distinct tail of the histogram extending to r = 0.87 was found to be associated with soils developed from basaltic parent material. Further inspection of these soils finds two sites, one on the Isle of Ulva (Mull) and one on the Isle of Skye to have the best correlations and similar XRPD signatures, to the Cumberland and Ogunquit sites analysed by the MSL. More detailed analysis of the clay minerals in these samples by classic clay mineralogy methods reveals further features, such as a notable resistance to collapse upon heating, which may be compared with features observed by the MSL in samples from the Cumberland site.