Estimating the Chemical Composition of Alunite-Jarosite Group Minerals at MSL Drill Sites Using XRD Patterns from Synthetic Analogs

Chris Donaldson & Tom McCollom
LASP, Boulder, CO (tom.mccollom@lasp.colorado.edu)

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General formula for alunite-jarosite group:

$(Na,K,H_3O)(Al,Fe)_3(SO_4)_2(OH)_6$

Fe # = [Fe/(Fe+Al)] x 100

Introduction

The CheMin instrument on MSL's Curiosity rover has detected the presence of jarosite at several locations. The occurrence of jarosite provides an opportunity to place constraints on the chemical environment at the time the minerals precipitated, which, in turn, can provide insight into fluid-rock interactions during diagenesis of the sediments that compose the lower slopes of Mount Sharp. In addition, jarosite and other members of the alunite group can have considerable compositional variability, including Al-for-Fe and Na- or H_3O^+-for-K substitutions which, if quantified, would provide additional insight into the processes involved in these sediment's formation. Accordingly, our study investigated how XRD patterns and spectral features change in response to these variations, and our results allow preliminary constraints to be placed on the chemical composition of the jarosite at Mount Sharp.

Synthesis Experiments

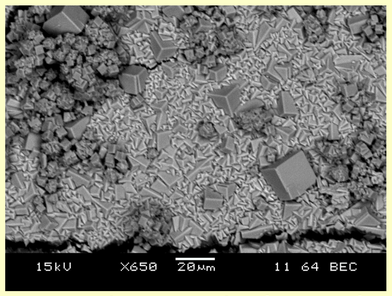
Temperature: 155 ± 5 °C

Pressure: ambient

Media: H_2O or 0.1 M H_2SO_4

Substrates: Al-Fe-and-$NaSO_4$ and KCl mixtures

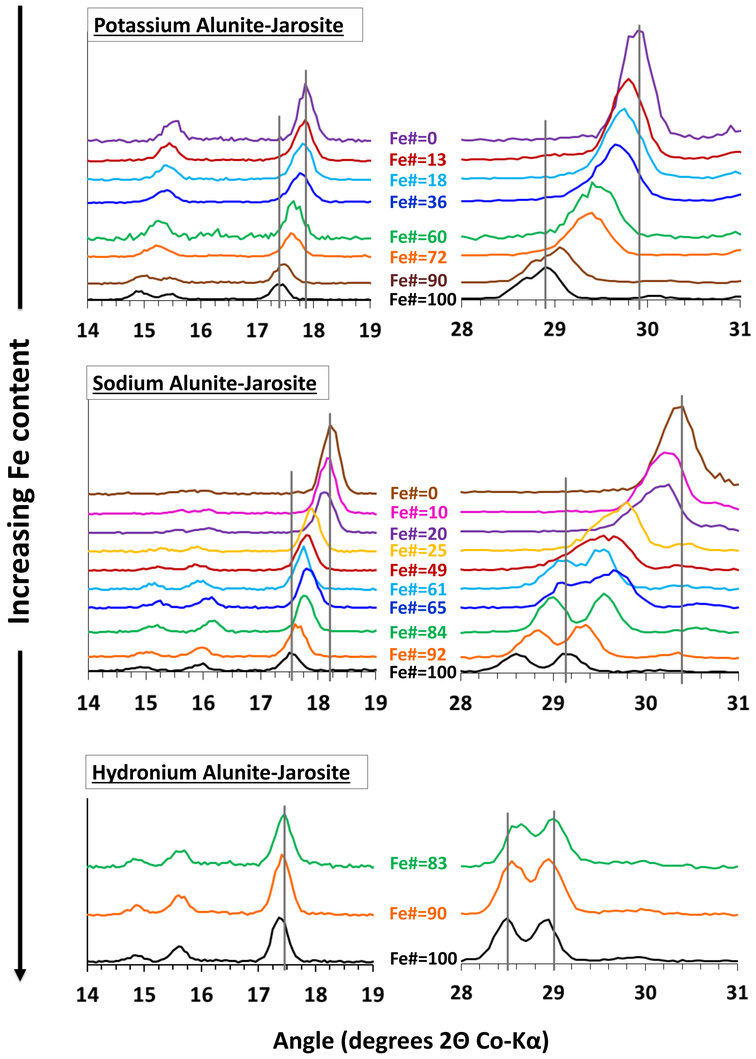
Products: rinsed with ethanol and dried at room temp.



Potassium Jarosite (Fe#=60)

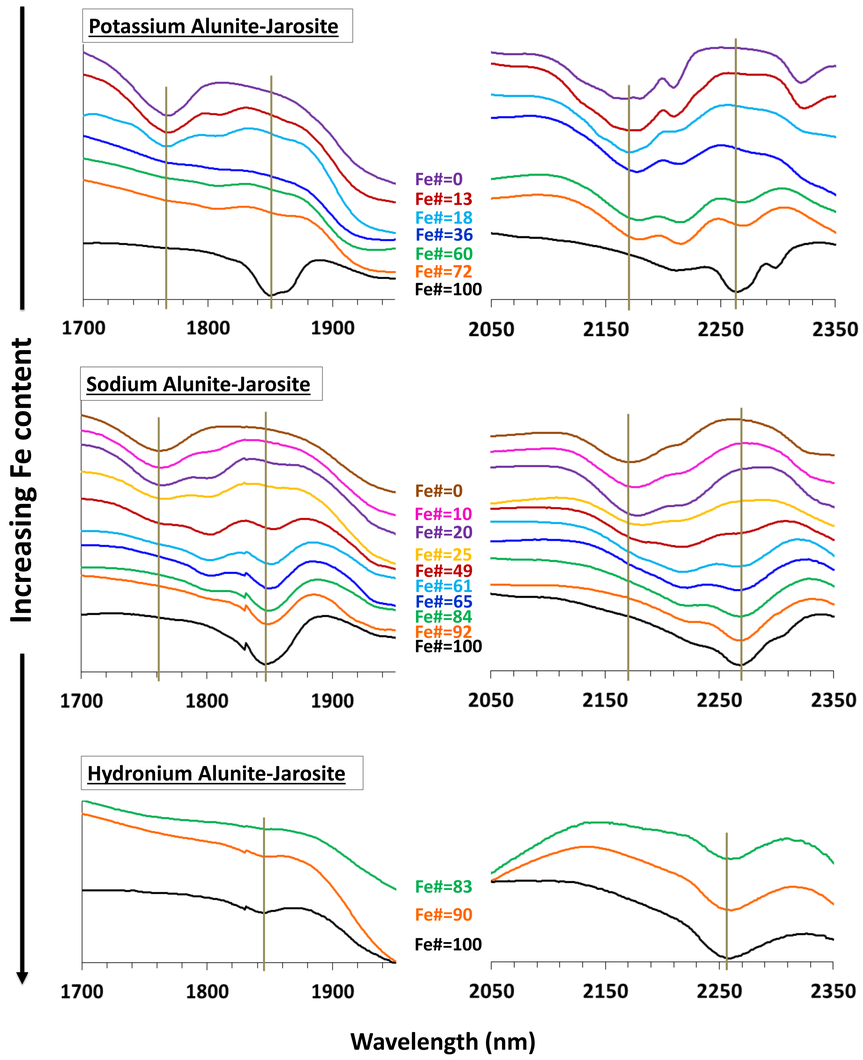
XRD

XRD peaks display systematic shifts with Fe-Al and Na-K-H_3O^+ substitutions.



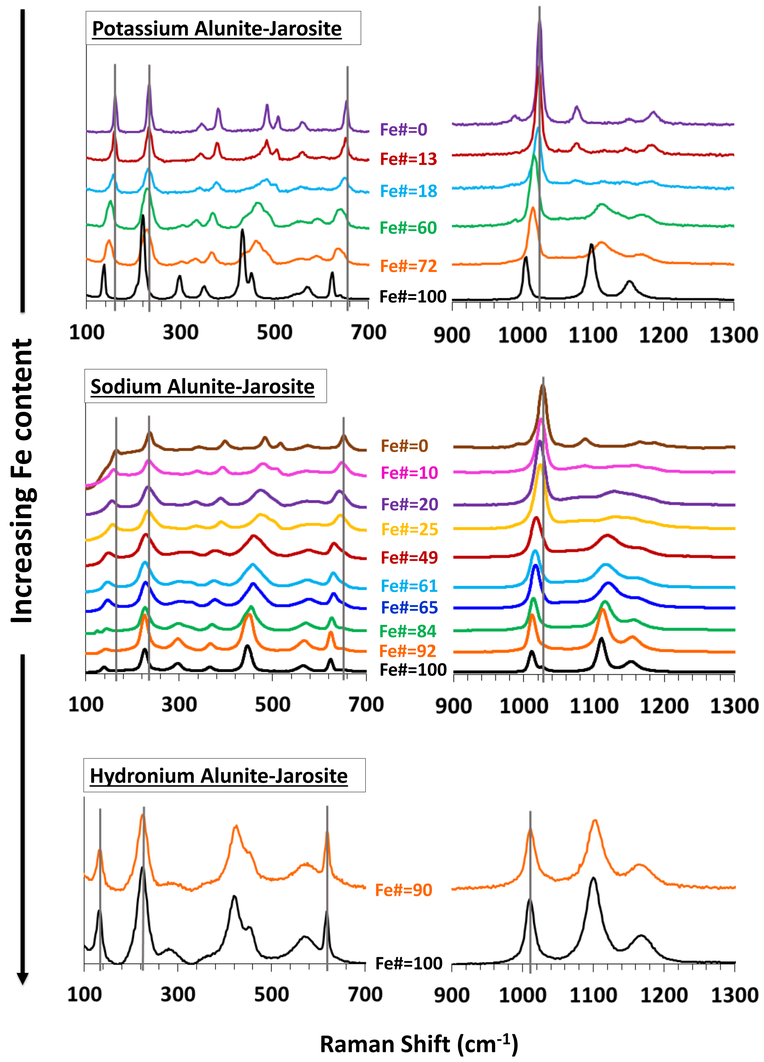
VNIR

VNIR spectral features show systematic shifts with Fe-Al substitutions, but little variation with Na-K-H_3O^+ substitutions.

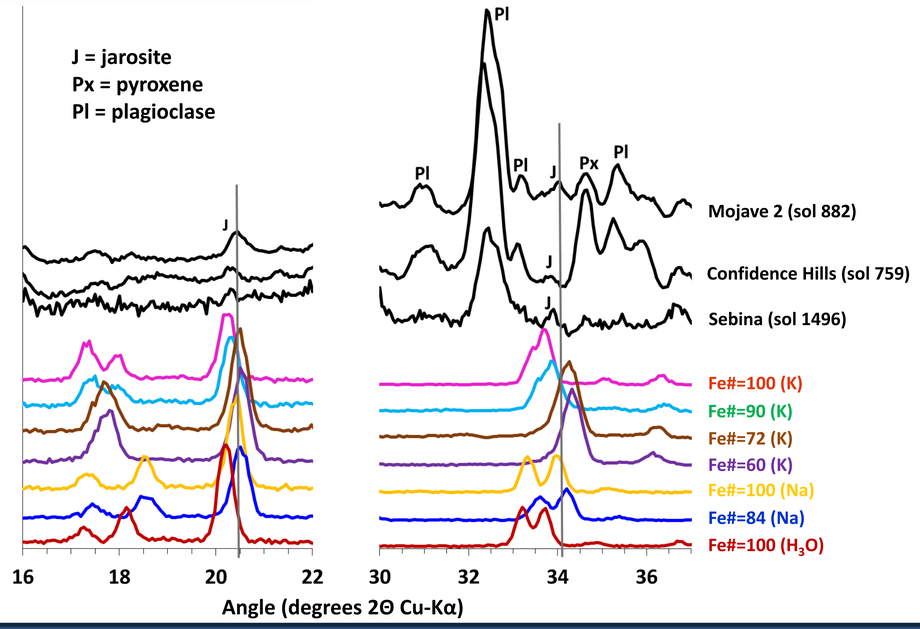


Raman

Raman peaks also display systematic shifts with Fe-Al and Na-K-H_3O^+ substitutions.



Mount Sharp Jarosite



Comparison of our synthetic samples with CheMin results from three Murray Formation drill sites on Mount Sharp.

Single diffraction peak at ~34° rather than a doublet is indicative of K dominated alunite or jarosite with little to no Na or H_3O^+.

The position of both the peak at ~34° and the peaks at 17-21° indicate that Mount Sharp jarosite minerals have significant Al-for-Fe substitution (Fe# between 75 to 90) with a possible slight increase in Al contents from Confidence Hills to Sebina to Mojave2.

Conclusions

The noticeable shifts in XRD patterns and spectral features with varying composition suggests that using these indicators to infer chemical composition is feasible. With that said, our results indicate that the jarosite on the lower slopes of Mount Sharp has significant Al for Fe substitution and is dominated by K as opposed to Na or H_3O^+. Moreover, using our inferred composition and an estimated 3.1 wt% jarosite in the Mojave sample [2], we estimate that the jarosite can account for ~30 wt% K_2O, approximately half of the total amount of K_2O measured in the sample (0.72 wt%) [3]. Also, in many terrestrial settings, jarosite forms by oxidative weathering of Fe-sulfide minerals, and sulfides have been identified in small amounts in other samples within Gale crater [4]. However, it is not clear that this process could account for the inferred presence of substantial Al in the jarosite observed in the Murray formation samples, and may instead point to formation of the jarosite by interaction of acidic, sulfate-rich fluids with K-, Fe-, and Al-bearing silicate minerals.

References: [1] McCollom et al., 2014, Am Min 99, 948-964. [2] Rampe et al.,2017, EPSL 471, 172-185. [3] APXS data downloaded from Planetary Data System (PDS). [4] Vaniman D. T. et al. (2014) Science, 343, DOI: 10.1126/science.1243480. [5] Curiosity data downloaded from: odr.io/chemin.