

## Hyperspectral data analysis of martian meteorite alteration: A tool for constraining surface processes on Mars?

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### Introduction

Our information-base regarding *in situ* analysis of surface materials stems from a handful of spacecraft missions. Large areas of Mars are apparently coated with a layer of surface fines (dust) that are quite similar in composition, suggesting this material has been distributed globally. Knowledge of aqueous processes beneath the surface of Mars is severely restricted, however, preterrestrially altered portions of the Martian meteorites offer an opportunity to directly examine low temperature precipitates. Some have pointed-out the similarities between the major element chemistry of micrometer scale alteration products and Martian dust [1]. In this study, we have analyzed Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) data using multivariate statistical analysis (MVA) to compute the “local bulk composition” of secondary mineral veinlets to rigorously evaluate a chemical linkage to Martian dust. In doing so, we can also evaluate the possibility that Martian dust was processed aqueously.

### Approach and Results

Because the kinetics of low temperature reactions in the Martian crust are slow, the products have small grain sizes ( $\mu\text{m}$  to sub  $\mu\text{m}$ ), or are finely zoned amorphous phases [2]. As a result, ToF-SIMS and a pulsed  $\text{Ga}^+$  ion beam ( $\sim 300$  nm) were used to characterize these delicate secondary mineral assemblages. One advantage of ToF-SIMS is that all secondary ions are collected (effectively in parallel) at each pixel, producing a 3D hyperspectral data cube. We have processed several such mass-resolved data cubes using MVA (e.g. multivariate curve resolution) to compute the major, minor, and trace element compositions of “bulk” alteration. Our initial findings, based upon Si/Fe for example, suggest that aqueously altered silicates in meteorite alteration are distinct from soils analyzed by MER rover instrumentation. These findings suggest that Martian dust likely formed by a process distinct from low-T aqueous alteration.

### References

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## Carbonate-silicate assemblages in the Lafayette martian meteorite

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### Introduction

Some secondary mineral assemblages in Martian meteorites have long been interpreted as preterrestrial [1]. Poorly crystalline clay veinlets within nakhlitic olivines [1,2] and carbonate veinlets in Lafayette olivine [3-5] are probably the result of aqueous alteration in a near surface setting within the last 700 Ma [6]. Carbonate veinlets contain central silicates, zoned from the center outward, in the following way: amorphous Si-rich phase, amorphous Fe-rich phase, followed by poorly crystalline clays. Two microanalytical tools including full-spectrum X-ray mapping and time-of-flight secondary ion mass spectrometry (ToF-SIMS) were used to reveal the distribution of major, minor, and trace elements within these assemblages. ToF-SIMS has the unique capability of detecting a large suite of trace elements (e.g. Li, Be, B, Sc, V, Cr, Co, Ni, Cu, Rb, Sr, and Ba) in parallel on the sub micrometer scale, allowing one to evaluate different depositional models.

### Results

We examined five different carbonate-silicate assemblages in Nakhla olivine. The minor and trace element composition of different silicate phases is complex.

Poorly crystalline clays: Most element abundances differ only within a factor of two, suggesting clays are similar in all carbonate veinlets. However, Be, Ti, Cr, Cu, and Ba show distinctively greater variability. Fe-rich amorphous material: Compositional variation is more restricted relative to clays, including Ti abundances. Si-rich amorphous material: This phase exhibits the greatest variability between veinlets.

These findings are best explained by low and decreasing water/rock ratios during veinlet formation. Thus, the local mineralogy (100s of  $\mu\text{m}$ ) seemingly was increasingly important in determining veinlet fluid chemistry.

### References

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