Nanoscale Analysis of Hydrous and Anhydrous Phosphates in Martian Samples

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**Figure 1:** Atom probe tomography data (100nm wide) for apatite in highly shocked martian meteorite NWA 5298 revealing nanoscale complexities in Fe, Mn, and Cl. An Fe-rich domain (arrow) reveals segregation of Fe and Cl, suggesting volatile mobilisation along the feature.

**Project highlights:**
- Explore a collection of martian meteorites to unravel the complex relationship between hydrous apatite and anhydrous merrillite, and provide vital new clues into the origin, evolution and fate of water on Mars
- Utilise cutting edge analytical equipment, including 3D-EBSD, FIB-SEM, NanoSIMS and atom probe tomography to develop new approaches to nanoscale planetary science
- Collaborate with colleagues in North America to integrate new datasets with observations from the Perseverance rover
- The successful candidate will develop skills in microscopy, meteoritics, nanoscale geochemistry and planetary science. Future career paths include within academia (with similarly focused research groups throughout the UK, Europe, the USA, Asia, and Australia) and industry (for example within microscopy and geochemistry focused companies), as well as with space organisations (e.g. ESA, NASA, JAXA).

**Project description:**
The history of water on Mars, and whether such aqueous environments would be capable of sustaining biological life, is a key question in planetary science. While rover and orbital missions to the red planet have yielded exciting discoveries [1], martian meteorites provide a unique insight into the formation and evolution of crustal rocks on Mars. For example, shergottites record nearly 500 million years of basaltic magmatism [2], placing empirical temporal constraints on the volcanic, volatile, and cratering histories of Mars.
Phosphate minerals are abundant within the shergottites, with hydrous apatite and anhydrous merrillite often coexisting throughout [3]. However, the presence of merrillite in an otherwise hydrous (OH-rich) magma is perplexing, as conditions should support crystallization of whitlockite, a hydrous form of merrillite. While the absence of whitlockite has been ascribed to the limited thermal stability of H within the phase [3], recent studies have revealed that shock compression of whitlockite can induce partial transformation to merrillite [4].

Given the high shock pressures experienced by most shergottites (> 30 GPa [2]), impact induced transformation of whitlockite to merrillite is a potentially critical mechanism that could dramatically alter our understanding of the volatile content of martian magmas. However, no diagnostic evidence of this transformation has been discovered in natural meteorite samples. Newly developed techniques, such as 3D-EBSD and atom probe tomography (APT), offer significant promise in the search for nanoscale structural, chemical and isotopic fingerprints of volatile mobility, diffusion and loss in phosphate minerals (Fig. 1), though are underexplored in the application to planetary materials.

In this project the student will carry out detailed micro to nanoscale structural (3D-EBSD, TEM) and chemical (EDS, APT) analysis of apatite and merrillite in a suite of martian meteorites to search for diagnostic evidence of shock-induced merrillite formation. Coupled analyses of the volatile composition (NanoSIMS) and age (SIMS) of associated apatite grains will provide further context to the suite of analysed meteorites.

Results from this study will yield new insights into the water content of martian magmas, and better constrain the history of water on Mars, whilst systematically ground truthing the application of state-of-the-art analytical techniques to planetary samples in preparation for future sample return missions.


Qualifications required:
A minimum of 2:1 BSc or a MSc in physics, geosciences or a related discipline.