AQUEOUS ALTERATION PROCESSES ON MARS
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Introduction: The search for life beyond Earth is the driving motivation for present and planned missions to Mars by both NASA and ESA. Developing a full understanding of the aqueous history of the Martian surface and sub-surface is essential because of the key role water plays in the history of life. In lieu of a sample return mission, and assuming that such a mission will excavate samples from only near-surface lithologies, martian meteorites continue to provide unique records of sub-surface aqueous activity on Mars.

As part of a continuing investigation of aqueous flow on Mars, we have undertaken systematic analyses of the secondary mineral assemblages within nakhlites. These assemblages are complex mixtures of clay minerals, carbonates, sulphates, oxides and iron oxy-hydroxides [1-3], and are indicative of alteration sequences that may be related to different fluid flow regimes (groundwater, hydrothermal, crater lake) including evaporation of fluids and interaction with the atmosphere and bedrock [2,3].

Samples and methods: The alteration assemblages are very fine grained mixtures of several minerals and poorly crystalline 'gels' which lack resolvable crystal structure. Advances in analytical instruments (FIB extraction, TEM, NanoSIMS, AFM, Tip-Enhanced Raman Spectroscopy) allow more detailed mineralogical, chemical and isotopic analyses than has been possible in earlier studies of these mineral assemblages.

Terrestrial analogues: Detailed petrologic, chemical and isotopic analyses of martian meteorites will only provide an accurate picture of Mars' history if the results can be reliably interpreted. For this reason it is essential to analyse a range of suitable terrestrial analogues for comparison. The detailed geologic and climate history of terrestrial samples can be defined in a way that is impossible for meteorites excavated from unknown localities on Mars. Characterisation of systematic structural, chemical and isotopic variations associated with analogous terrestrial environments will enable us to discriminate between putative aqueous systems on Mars e.g. hydrothermal cells, groundwater seepage, transient/seasonal melt waters, crater-floor lakes and brines.

Implications: Accurately identifying the geological setting of aqueous alteration of martian meteorites will not only elucidate Mars' geologic and climate history but will also provide valuable input for current and future Mars missions. For example, if aqueous activity in nakhlites was identified as resulting from long-term ambient conditions suitable for liquid water ~1.3Ga this would have significant implications for the habitability of Mars and the evolution of life. Alternatively, the identification of transient, impact-related, aqueous activity would suggest that outcrops of phyllosilicates identified by recent orbiter missions [4-6] do not require a warm and wet climate late in Mars' history.

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