EXPERIMENTAL WEATHERING OF METEORITES UNDER TERRESTRIAL AND MARTIAN CONDITIONS IN ENVIRONMENTAL CHAMBERS. C. Mansell[1] and H. Downes[1], [1]Dept. of Earth and Planetary Science, Birkbeck, University of London, Malet Street, London WC1E 7HX, UK (candice.mansell@uclmail.net; h.downes@bbk.ac.uk).

Introduction: Twenty-three confirmed and candidate meteorites have been discovered on the surface of Mars by remote and direct sensing instrumentation placed on the NASA planetary rovers, Opportunity and Spirit (Mars Exploration Rovers, MERs) and Curiosity (Mars Science Laboratory, MSL [1]. On Mars, iron meteorites are more abundant than stony meteorites. This may be due to the sampling methods and limited ranges of the rovers, or because stony meteorites contain more reactive minerals, subjecting them to disintegration accelerated by exposure to fierce dust storms and UV radiation on the martian surface. Here we investigate how meteorites on Mars may have weathered in the acid fog environment, and how this differs from weathering on Earth.

Method: Simple glass vacuum desiccators were used as Earth and Mars environmental chambers and kept at ambient pressures and temperatures (Figure 1(a)). A basaltic substrate from a young scoria cone in the Canary Islands was used (Figure 1(b)). Distilled water was introduced into the Earth chamber and 10 % HCl and 10 % H_2SO_4 into the Mars chamber along with dry ice to create a CO_2 atmosphere.

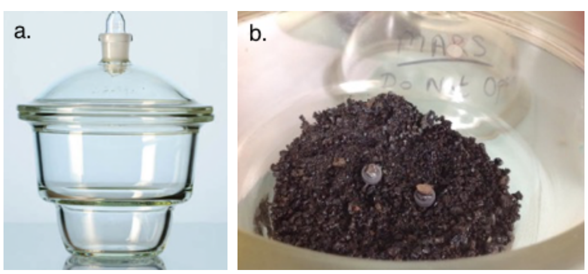


Figure 1. (a) Glass vacuum desiccator used as an environmental chamber. (b) The Mars environmental chamber after introduction of the basaltic substrate and insertion of the meteorite samples (Sikhote-Alin, left and NWA X, right).

A stony and an iron meteorite were used in this study: NWA X, an unclassified recrystallized L6 chondritic meteorite containing melt veins and showing evidence of shock, and Sikhote-Alin, a widely-known IIAB iron meteorite, a piece of each of which was placed in each of the chambers. A thin-section of NWA X and a mount of Sikhote-Alin in their initial forms were analyzed by electron microprobe (EMPA) and the artificially weathered samples were analyzed by environmental scanning electron microscope (SEM) and electron microprobe after 149 days (Figure 2).

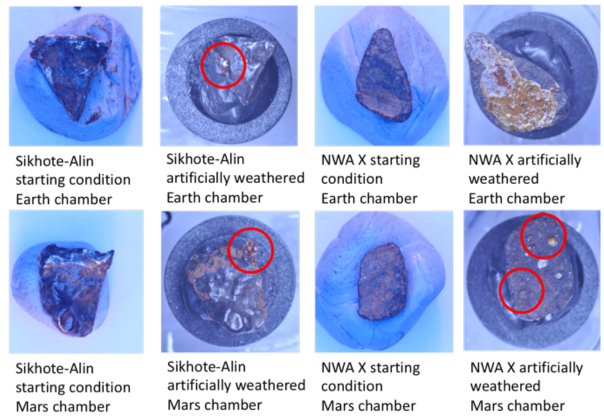


Figure 2: Microscope images showing starting conditions of the divided meteorites and after artificial weathering. Red circles show where globular structures appeared. Weathered meteorites are mounted on 12.5 mm carbon stubs using conductive carbon cement.

Results: The basaltic substrate had reacted with the acidic atmosphere in the Mars chamber to produce gypsum and an unknown salt (Figure 3) and the meteorite samples were all found to have formed thin-walled globular structures composed of FeO: flat cracked surfaces on NWA X in the Earth chamber and discrete FeO globular structures in varying states of disintegration in the Mars chamber (Figure 4).

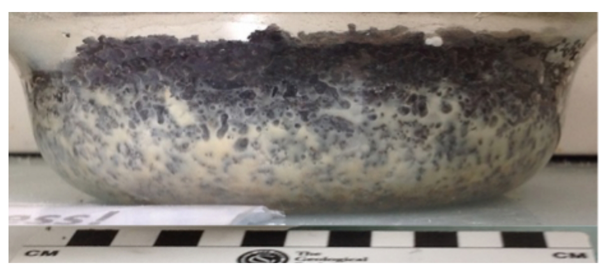
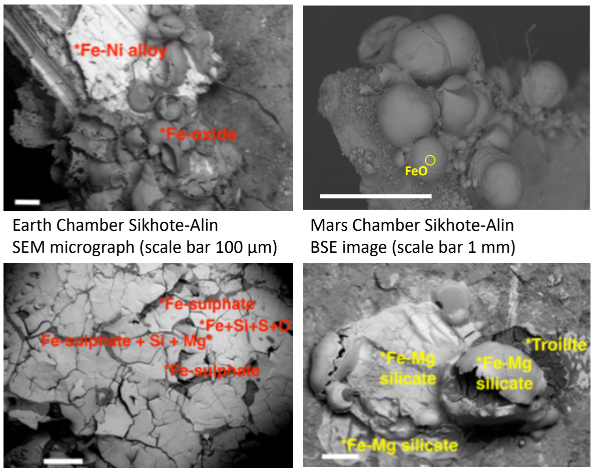


Figure 3: The white reaction product in the Mars chamber.

Sikhote-Alin in the Earth chamber showed clusters of FeO globules breaking down into lace-textured shells, and extensive areas of rust-bubble-like structures in the Mars chamber (Figure 4). NWA X globules in the Earth chamber also contained Fe-sulfate, Mg-sulfate and FeS; in the Mars chamber they also contained Fe-sulfate, Cl and troilite (Figure 4). Clay minerals formed on Sikhote-Alin in the Earth chamber.

The wide range of weathering products in NWA X is the result of its more complex initial mineralogy. In the Mars chamber sulfate and chloride minerals formed on NWA X (Figure 5) while FeO and FeS formed on Sikhote-Alin (Figure 6).



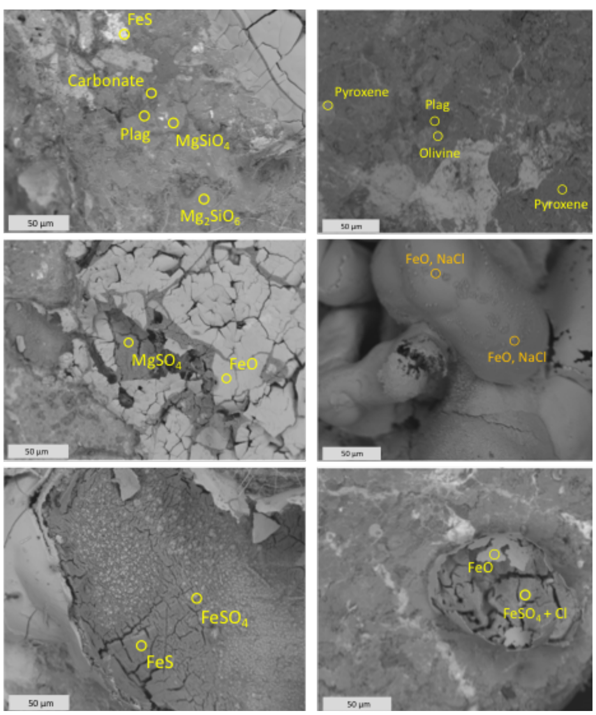
Earth Chamber Sikhote-Alin
SEM micrograph (scale bar 100 µm)

Mars Chamber Sikhote-Alin
BSE image (scale bar 1 mm)

Earth Chamber NWA X
SEM micrograph (scale bar 500 µm)

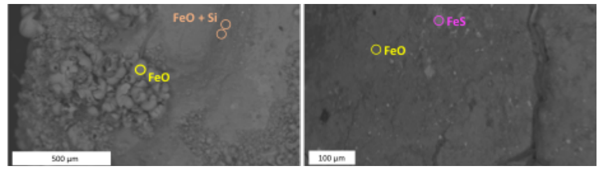
Mars Chamber NWA X
SEM micrograph (scale bar 100 µm)

Figure 4: Globular structures appeared on all the samples in both the Earth and Mars chambers. On NWA X in the Earth chamber, areas of extensive cracking developed.



BSE images (scale bars 50 µm)
Earth chamber Mars chamber

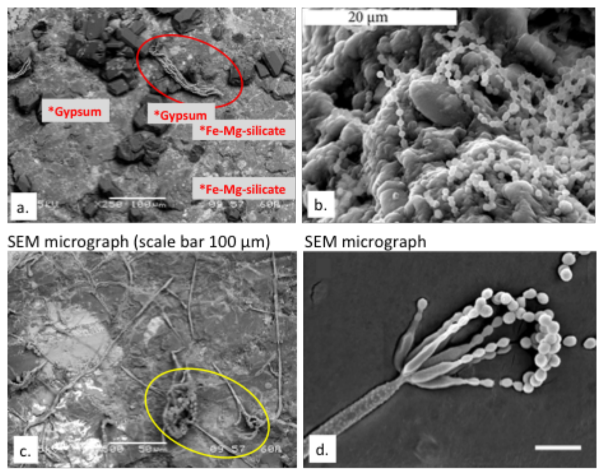
Figure 5: The simulated weathering of NWA X produced Mg-sulfate, iron oxide, carbonate and gypsum from Ca-plagioclase in the Earth chamber and fewer sulfates, more chloride minerals (salt) and iron oxide in the Mars chamber.



BSE images (scale bars 500 µm and 100 µm)

Figure 6: The Mars chamber weathered sample of Sikhote-Alin contains FeO, FeS, Fe metal and extensive FeO globular structures.

Fungi- and bacteria-like biological structures appeared on NWA X in the Earth chamber from contamination in the unsterilized basaltic substrate (Figure 7). The susceptibility of NWA X to weathering leads to the conclusion that preferential disintegration of stony meteorites takes place over the more robust iron meteorites on Mars.



SEM micrograph (scale bar 100 µm) SEM micrograph

SEM micrograph (scale bar 50 µm) SEM micrograph (scale bar 10 µm)

Figure 7: 'String-of-bead-structures' (a) (red oval) are associated with gypsum crystals and are similar in appearance to chains of spherical bacteria (cocci) found in a cave on the biofilm from a microbial mat [2] (b). Broccoli-like structures (c) (yellow oval) associated with the filament-like structures resemble fungi (d) *Penicillium viticola* [3].

Future work: Glass reaction vessels with attached apertures for access would include an analogue atmosphere of the present martian atmosphere, with exposure to freeze-thaw conditions. Sterilization of the substrate would also be desirable. In addition to EMPA and SEM analysis, Raman spectroscopy, XRD, micro XRD and micro Raman would be employed for a more targeted approach. Where Mars chamber facilities are available and acid can be introduced by some process avoiding damage to the pumps, exposure to UV radiation and simulated surface airflow would be desirable.

References: [1] Ashley J.W. (2015) *Elements, 11*(1), 10-11. [2] Lavoie K. H. et al. (2017) *PLoS One 12*(2), p.e0169339. [3] Nonaka K. et al. (2011) *Mycoscience 52*(5), 338.