EXPERIMENTALLY SHOCKED AND ALTERED BASALT: LABORATORY ANALOGS FOR CALIBRATION OF MARS REMOTE SENSING AND *IN SITU* DATA.

M. S. Bell[1], [1]Jacobs, NASA Johnson Space Center , Houston, TX 77058, mary.s.bell@nasa.gov.

Introduction: Major occurrences of hydrous alteration minerals on Mars have been found in Noachian impact craters formed in basaltic targets and detected using visible/near infrared (VNIR) spectroscopy. The MER (Mars Exploration Rovers) rovers previously reported results of *in situ* measurement indicating the presence of alteration minerals on Mars [1,2] and it was recently reported that the Mars Curiosity rover has detected alteration phases *in situ* at Yellowknife Bay in Gale crater [3,4]. Understanding the alteration assemblages produced by a range of conditions is vital for the interpretation of spectral signatures and to decipher the environment and evolution of early Mars, and especially for identifying habitable niches in which life could be initiated and sustained. No experimentally controlled and well characterized analog materials that simulate martian shock metamorphism and alteration conditions currently exist for calibrating either remote sensing or *in situ* measurements of Mars. A series of laboratory shock and alteration experiments was initiated to assess the effects of systematic changes in physico-chemical conditions on Mars analog materials thereby providing samples to ground-truth Mars remote sensing observations from CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) and *in situ* measurements from Opportunity's Mössbauer and Curiosity's CHEMIN (Chemistry and Mineralogy X-Ray Diffraction/XRay Fluorescence) instruments.

Experimental Methods: The material chosen for the experiments is a well characterized natural sample of basaltic tephra (HWMK725) from Mauna Kea, Hawaii that has a composition similar to the average Mars basaltic soil and Meridiani compositions inferred on a S-, Cl-, and Br-free basis [1,5,6]. The relative abundance of phases in HWMK725 is glass > plagioclase feldspar > olivine > titanomagnetite [13]. The < 75μm size fraction has been used for the experiments. Four alteration experiments utilizing 100 mg aliquots of material each were conducted to alter the samples under neutral and acidic (0.1M H_2SO_4) conditions at 80°C and 160°C for 21 days. Three experiments utilizing 80 mg each of the same material were shocked in fansteel holders in the Johnson Space Center Experimental Impact Laboratory to 35, 40, and 45 GPa. The 45 GPa sample was chosen for alteration experiments to compare with altered samples that were not shocked. This pressure experiment was chosen because a combination of solid-state and melt reactions are manifest in plagioclase, a major constituent of the sample. Four experiments utilizing 40 mg aliquots each of shocked material were altered under the same conditions as the unshocked starting material. Results of shock and alteration experiments as analyzed by Secondary Electron Microscopy –Energy Dispersive Spectroscopy) and X-ray Diffraction (XRD) analysis are reported here.

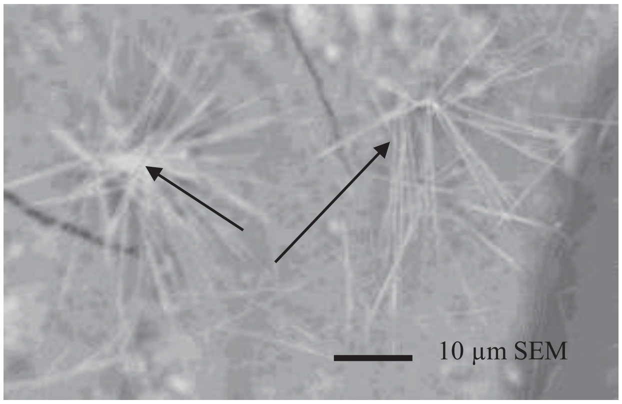

Fig.1. SEM image of the unshocked sample altered at 160°C. An alteration phase in the form of white radiating needles on the surface of the sample heated to 160°C and present in SEM images is ca-phosphate (at arrows).

Summary and Future Work: Calcium-phosphate (likely chloroapatite) is formed in the alteration experiments and is more abundant in the altered *and* shocked sample probably due to increased surface area exposed to alteration fluids resulting from shock damage in the form of both brittle and structural deformation to the starting material (Figs 1 & 3). Apatite forms in basic conditions so the closed system alteration experiment

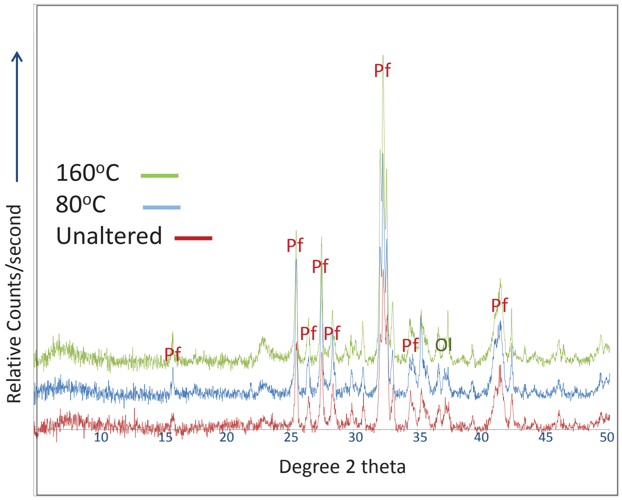

Fig.2. XRD patterns for the sample heated to 80°C and 160°C in neutral baths remain unchanged from the starting material. Alteration on the surface of the sample heated to 160°C that can be detected in SEM images is below the detection limit of the XRD technique (~2 vol. %). Pf = plagioclase feldspar, Ol = Oliveine, Uv = ulvospinel.

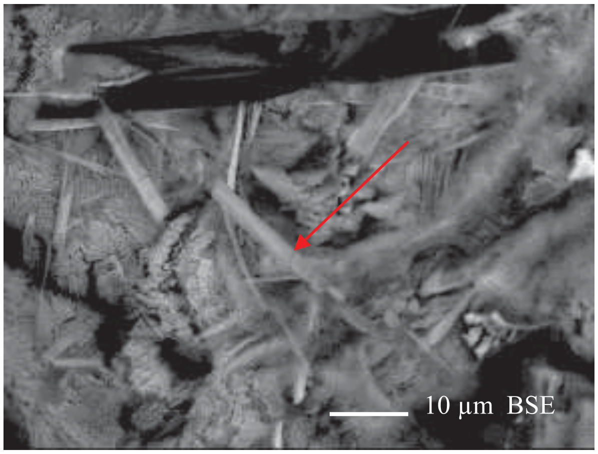

Fig.3. The same calcium phosphate needles found on the surface of the sample heated to 160°C are present in Back-Scattered Electron (BSE) images of the shocked and altered sample (red arrow). The “etched” surfaces have compositions similar to an An_{50} feldspar and reflect the plagioclase feldspar composition present in the basalt starting material.

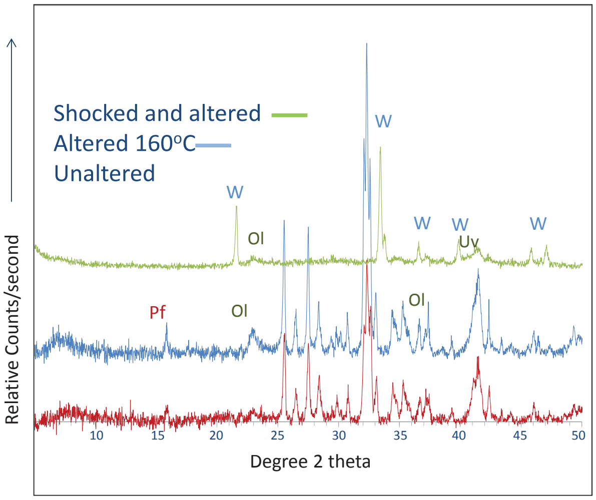

Fig.4. XRD diffractograms of the unaltered starting material, the sample altered in de-ionized water at 160°C and the sample shocked to 45 GPa then altered at 160°C. The abundance of the calcium phosphate alteration phase that can be detected by EDS on the surface of both the unshocked and shocked samples remains below the detection limit of the XRD technique (~2 vol%).

must be buffered by the basalt starting material to create a fluid chemistry environment evolving from neutral at the start to alkaline after 21 days at 160°C. Plagioclase feldspar in the unshocked sample (Fig. 2) has undergone a solid-state transformation to maskelynite, a disordered phase that is not manifest in the XRD pattern of the shocked sample (Fig.4). Olivine and ulvospinel that are present in the starting material can be detected by XRD in the shocked and altered sample (Fig. 4). Tungsten from the sample holder used in the shock experiments dominates the XRD pattern of the shocked and altered sample (Fig. 4).

Samples were weighed after the alteration experiments to determine mass loss and predict the amount of material available for the planned analyses from the shock experiments. Within the constraints of these experiments, mass loss is negligible. The samples will next be characterized by Mössbauer and Vis-Near IR spectroscopy, the results of which will be compared to the Mars Exploration Rovers and Mars Reconnaissance Orbiter data sets respectively.

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