MINERALOGY AND SHOCK EFFECTS IN MARTIAN REGOLITH BRECCIAS

F. Cao[1], R. L. Flemming[1], D. E. Moser[1], M. R. M. Izawa[1,2], [1]Department of Earth Sciences/ Centre for Planetary Science & Exploration, University of Western Ontario, London ON, Canada (fcao23@uwo.ca), [2]Institute for Planetary Materials, Okayama University, Misasa, Tottori, Japan.

Introduction: Nicknamed "Black Beauty", NWA 8171 and its pairings (e.g., NWA 7475 and NWA 11220) are pieces of a polymict regolith breccia with a basaltic composition [1,2] and represent the very ancient Martian crust [3,4]. Martian brecciated samples contain multiple lithologies in the fine-grained matrix, and chemically resembles outcrops sampled by Spirit and Curiosity rovers [1,5]. Moreover, these samples are relatively hydrous and contain secondary alteration components related to aqueous activities that may have occurred on the near-surface of Mars [1,6-8]. The brecciation is the consequence of bombardment of Mars' crust [3,9]; during which fragments with a range of shock histories were incorporated in lithic breccias [10,11]. Currently, there is some research about shock-metamorphic effects in the suite of "Black Beauty" meteorites using qualitative petrographic methods [8,12], and quantitative methods on accessory phases [13] which demonstrate that the Martian regolith breccia meteorites experienced low-level shock effects. *In situ* microXRD (μXRD) provides a quantitative approach to assessing shock metamorphism in the rock-forming minerals [14-16]. Many of the grains in NWA 8171 show shock-metamorphic features, such as line broadening, strain-related mosaicity (streaking), and asterism in their XRD patterns [17]. Our goal is to assess the degree of cumulative shock experienced by this ancient Martian crust, as preserved by rock-forming minerals. Cross-cutting relationships enable assessment of relative timing of shock events.

Samples and methods: Four slabs of Martian breccia, NWA 8171_medium, NWA 11220, NWA 7475, and NWA 8171_large, have been studied using μXRD, SEM and in most cases Raman spectroscopy. μXRD was performed using a Bruker-AXS D8 Discover diffractometer with a 300 μm nominal beam diameter, using CoKα radiation (λ=1.7889 Å) (operating at 35 kV and 45 mA) and a Vantec-500 Area Detector. 2D images were integrated to produce intensity vs. 2θ plots over 2θ range 25°-95°, with step size 0.04°, or intensity vs. χ plots, to measure strain-related mosaicity. Backscattered electron (BSE) images and distributions of Al, Mg, Ca were conducted at Zircon and Accessory Phase Laboratory (ZAPLab), Western University, using a Hitachi SU6600 FEG-SEM with a five-sector solid-state BSE detector at the accelerating voltage of 10 kV [18]. Raman spectra were collected in the range of 150-1200 cm^{-1} with a spectral resolution of 2 cm^{-1}. Spectra of various minerals with different shock effects were analyzed for comparison with μXRD data. Care was taken to analyze domains away from launch-related fractures/ strain effects.

Results: Combined mineralogical and chemical investigation by μXRD and SEM on various clasts yielded similar results for these samples. Lithic clasts in four slabs contain coarse- to fine-grained mixtures of primary orthopyroxene (opx), clinopyroxene (cpx), plagioclase, and magnetite, as well as occasional pyrite, hematite, and ilmenite in the matrix and opx, cpx, plagioclase as single crystal clasts. Cl-rich apatite is widely distributed in NWA 8171 and NWA 7475 and has some OH substitutions of Cl in the site, which means apatite should be a significant reservoir of both H and Cl in the Martian regolith. μXRD provides a quantitative measurement of shock metamorphism of single clasts through measuring strain-related mosaicity (SRM). Most medium-grained clasts in four slabs have shown streaking to varying degrees - presumably due to impact activities on Mars. The higher SRM of the crystal clasts in NWA 11220 compared to those in the other pairings suggests that it has probably experienced a relatively higher shock pressure.

Discussion and Conclusions: Preliminary μXRD, SEM and Raman results confirmed that four Martian breccias contain the same dominant mineralogy. Many lithic and crystal grains show streak characteristics in the 2D XRD images and the ones in NWA 11220 exhibit more extended streak lengths along χ. Future work will involve powder X-ray diffraction, and Rietveld refinement/modal analysis of NWA 11220, to quantitatively determine the major and minor phase abundances, especially the representative secondary phases (including hydrous phases) on the Martian surface. The study of the mineralogical composition, shock-induced deformation mechanisms, and spectral features of Martian breccia meteorites will contribute significantly to deciphering the evolution of regolith on Mars.

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