DISCOVERY OF A GARNET-BEARING CLAST IN MARTIAN POLYMICT BRECCIA NORTHWEST AFRICA 8171. T. V. Kizovski[1], L. F. White[2], A. Černok[2], K. T. Tait[3,4], V. E. Di Cecco[3,4], R. I. Nicklin[5], B. C. Hyde[6], and J. R. Darling[7]. [1]Brock University (St. Catharines, ON L2S 3A1 Canada, tkizovski@brocku.ca), [2]Open University, UK, [3]University of Toronto, Canada, [4]Royal Ontario Museum, Toronto, Canada, [5]University of Western Ontario, London, Canada, [6]Queen's University, Kingston, Canada, [7]University of Portsmouth, UK.

Introduction: The martian polymict breccia meteorites are composed of a variety of clast types, representing a diverse group of martian lithologies [1-4]. The clast types typically range from basalts to more evolved alkali igneous rocks, impact melts, and proto-breccias [1-4]. However, due to their polymict nature, some rare clast types have only been found in one or two of the 18 paired samples (i.e. the pyrite-ilmenite-zircon clast only found in Northwest Africa (NWA) 7034 [5], and the siltstone clasts found in NWA 7475 [2]). As such, the detailed petrological analysis of under-studied pairs like NWA 8171 is essential for the discovery of new rock types on Mars, expanding our knowledge of martian geological processes.

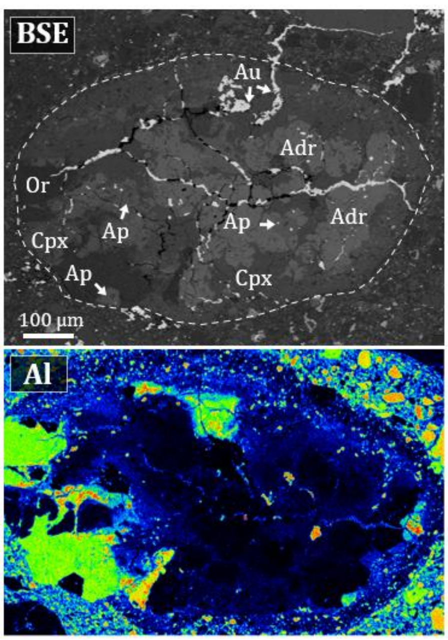

Figure 1: BSE image of the garnet-bearing clast in NWA 8171. (Adr = Andradite Garnet, Ap = Apatite, Au = remnant gold coat, Cpx = Clinopyroxene, Or = Orthoclase).

Our analysis of NWA 8171 revealed the presence of a new clast type not previously identified in martian samples. The clast notably contains clusters of garnet up to ~380 µm in size embedded in a fine-grained matrix of clinopyroxene, with alkali feldspar and plagioclase (Figure 1). Since garnet is known as a common metamorphic mineral (i.e. [6]), the clast may represent the first endogenous metamorphic sample from Mars. Garnets are not exclusively metamorphic minerals however, and are also known to occur in igneous rocks [6]. In order to classify this clast and its petrogenesis, we have conducted a variety of preliminary chemical and structural analyses on the garnet-bearing clast.

Methods: Wavelength Dispersive Spectroscopy (WDS) point analyses and maps were acquired using JEOL JXA-8230 Electron Probe Micro-Analyzers (EPMAs) at Queen's University and at the University of Toronto.

Raman spectra were collected using a Horiba LabRAM ARAMIS Raman Spectrometer, housed at the Royal Ontario Museum. A 532 nm wavelength, 50 mW laser was used with a spot size of ~1.3 µm. Each point spectrum was collected for 200 seconds (10 s x 20 repetitions).

EBSD maps were collected using an Oxford Instruments Nordlys-Nano EBSD detector equipped on the Zeiss EVO MA10 LaB_6-SEM at Portsmouth University.

Results & Discussion: The garnet-bearing clast is a rounded 540 µm x 830 µm clast embedded in the clastic matrix of the breccia. The clast contains approximately 35 % garnet, 45 % pyroxene, 12 % feldspar, 8 % chlorapatite, and comprises two domains: a coarse-grained domain of zoned augite and K-rich feldspar, and a garnet-bearing domain with subhedral to anhedral embayed garnets embedded in a fine-grained diopside-rich matrix. The garnets also contain numerous diopside inclusions ~5 µm in size. The garnet has been identified by Raman (Figure 2), EBSD (Figure 3), and microprobe analyses (Table 1), and has been classified as the Ca- and Fe^{3+}- rich garnet, andradite ($Ca_3Fe^{3+}_2(SiO_4)_3$).

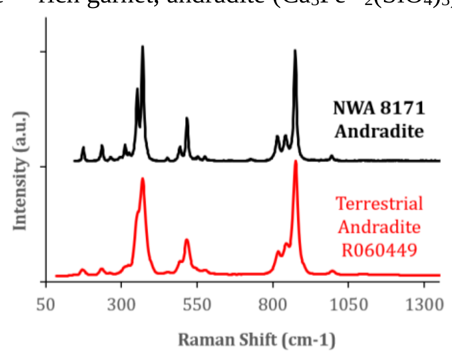

Figure 2: Representative Raman spectra for andradite in the garnet-bearing clast compared with a terrestrial andradite sample (RRUFF database ID R060449, Namibia).

EBSD analysis of the clast reveals significant crystal plastic deformation in the garnet, with ~60° of misorientation observed across an area ~350 µm in length. Typically, ~3–5° of misorientation are measured across each garnet fragment. No obvious signs of directional strain were observed. The fine-grained diopside matrix contains <5 µm randomly orientated fragments, with ~1.2–3.5° of misorientation measured across each fragment.

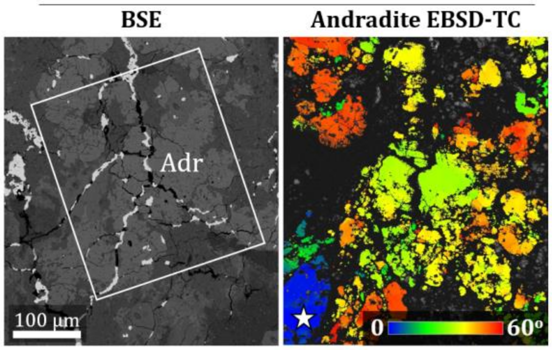

Figure 3: BSE and EBSD Texture Component (TC) maps for andradite (garnet) in NWA 8171. EBSD-TC maps display crystallographic misorientation (deformation) relative to a defined point of reference (denoted by the white star).

WDS analysis reveals slight zoning across the clast, with an Mg-rich core, and Al-rich rim. Zoning is also observed in the coarser-grained Ca-poor pyroxenes with Mg-poor cores and Mg-rich rims (Figure 1). Zoning profiles in garnet were of particular interest as they can be used to identify evolving tectonometamorphic pressure and temperature conditions, and constrain metamorphic grade [6]. However, no significant zoning was noted.

Table 1: Electron Microprobe Point Analysis Results

	Garnet (n = 38)
Oxide wt %	
SiO_2	35.64
TiO_2	0.03
Al_2O_3	0.68
Cr_2O_3	0.00
V_2O_3	0.01
FeO*	-
Fe_2O_3	30.75
MnO	0.17
MgO	0.18
CaO	32.40
Na_2O	0.01
K_2O	0.00
NiO	0.01
Total	99.89

Notes: All Fe assumed to be Fe^{3+}.

More detailed analyses of the other minerals in the garnet-bearing clast revealed two separate compositional groups for both the pyroxenes and feldspars, which correspond to the two petrographic domains in the clast (Figure 4). In the coarse-grained zone the pyroxenes are richer in Fe and contain slightly less Ca, with K-rich feldspars. The fine-grained pyroxenes in the garnet-bearing domain are richer in Ca and Mg, and are intergrown with more Ca/Na-rich, K-poor plagioclase. The pyroxene and feldspar compositions are very similar to the evolved clasts in other martian polymict breccia meteorites, such as monzonites [6].

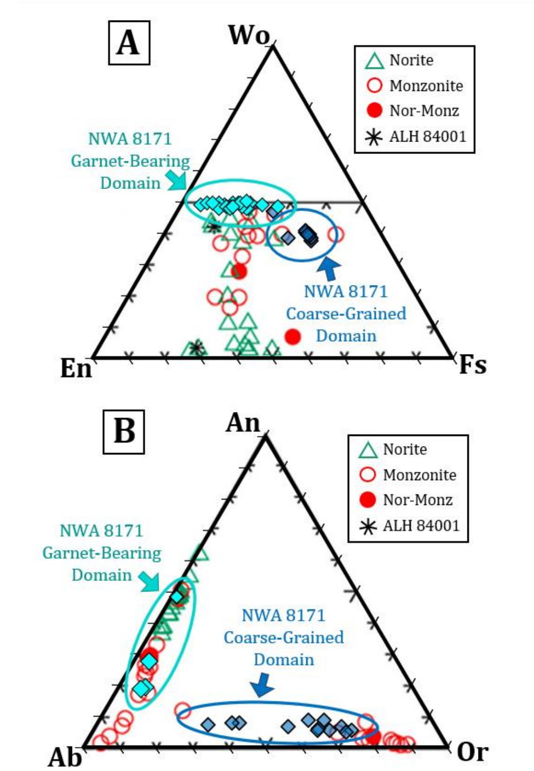

Figure 4: Summary of the electron microprobe point analyses for pyroxenes (A) and feldspars (B) in NWA 8171 in comparison to other martian polymict breccia pairs. After [6].

Summary & Future Work: More detailed analysis is needed to determine the true origin and petrogenesis of the garnet-bearing clast. Detailed trace element mapping (to determine if any garnet zoning is present in these less mobile elements) and quantitative point analyses (to determine if the clast is genetically related to one of the shergottite reservoirs) are planned for the near future.

This study illustrates the importance of detailed examination of the martian polymict breccia meteorites. As they contain a diverse suite of martian rock types, the discovery of new clast types like the garnet-bearing clast can provide new insights into geological processes on Mars.

References: [1] Santos A. R. et al. (2015) *GCA* 157. [2] Wittmann A. et al. (2015) *MAPS* 50. [3] McCubbin F. M. et al. (2016) *JGR Planets* 121. [4] Hewins R. H. et al. (2017) *MAPS* 52. [5] Liu Y. (2016) *EPSL* 451. [6] Baxter E. F. et al. (2017) *Rev. Min. Geochem.* 83.