INVESTIGATING THE HISTORY OF PROTO-BRECCIA CLASTS IN MARTIAN REGOLITH BRECCIA NORTHWEST AFRICA 7034.

G. M. Jacobs[1*], M. Anand[1,2], I.A. Franchi[1], and M.M. Grady[1,2], [1] Planetary and Space Sciences, The Open University, Milton Keynes, MK7 6AA, UK, [2] Department of Earth Sciences, Natural History Museum, London, SW7 5BD, UK. * George.jacobs@open.ac.uk.

Introduction: The polymict meteorite Northwest Africa 7034 [1,2] and its pairs are the first Martian breccia samples to be recovered [3]. NWA 7034 bears strong chemical and spectral similarities to the martian crust [3,4] and contains a wide variety of lithologies compared to the igneous martian meteorites, notably including possible sedimentary material [2].

One group of clasts with non-igneous textures has been described as proto breccia [2] with matrices within matrices textures [5]. The existence of different clast types matches observations by rovers and orbiters that show there is local and large scale heterogeneity of the martian soil [6,7,8]. Surface and sedimentary rocks will preserve a record of planetary climate [8] and surface processes during their residence within the regolith [4]. By studying the proto-breccia material in NWA 7034 we may learn about the variety and evolution of processes acting upon the martian regolith.

The analysis of clasts in two dimensions restricts our ability to study the geometry and spatial relationships of these clasts. Therefore, this study uses scanning electron microscopy (SEM) and X-ray Computed-Tomography (C-T) to study the proto-breccia clasts in 3-D.

Methods: A 1.2 g chip of NWA 7034 (~ 21 x 10 x 2 mm) was acquired from a dealer. The top surface was polished using diamond paste and aluminum oxide. A C-T scan (a series of virtual density-based 'slices' through the sample via X-ray) of the sample was performed at the Natural History Museum, London, with the Nikon HMXST 225 fitted with a Perkin-Elmer detector. An X-ray beam with 160 kV and 180 µA was used to ensure that features throughout the whole thickness of the irregularly shaped sample could be resolved clearly.

The FEI Quanta 3D dual beam SEM at the Open University, Milton Keynes was used to map the sample using both backscattered electron mode and energy dispersive spectroscopy (Figure 1), with an electron beam of 20 kV and 0.6nA. Because the sample was not coated it was analyzed under low vacuum using water for charge dispersion.

Results: Both SEM and C-T data confirm that the sample contains several large proto-breccia clasts which vary in composition, texture and shape (Figures 1 and 2).

The large clast B (~4.7 x 2.6 mm) appears to contain three different matrix components (Figure 3), enveloping several large (≤ 0.4 mm) highly rounded plagioclase fragments (Figures 3 and 4). Clast B has a rounded, elongate diamond appearance on its cut face. It extends through the thickness of the sample (Figure 4), as does clast E.

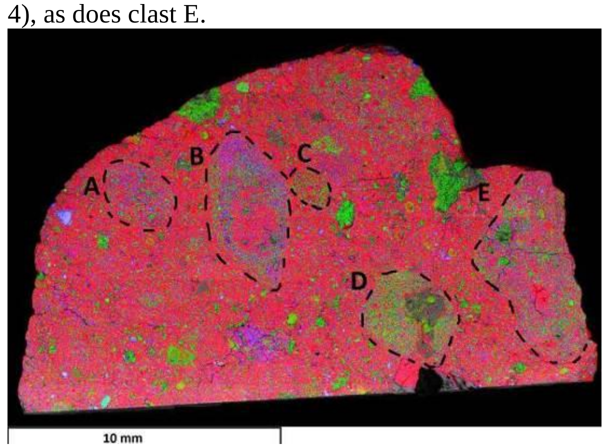

Figure 1 A false color X-ray map of the top surface from a chip of NWA 7034, Mg in red, Ca in green, Fe in blue, with proto-breccia clasts outlined in dashes.

The large plagioclase fragments have a 'halo' of Fe- and Mg-rich matrix, 0.1 to 0.15 mm thick, distinguished from surrounding material, with three having similar orientation (Figures 3 and 4).. These dense 'halos' can be seen in the C-T data, and partially envelop the plagioclase (Figure 4).

The elemental compositions of the 'halos' are similar to the matrix component that partially forms a ring (Figure. 3, green) within clast B. This component is more devoid of small mineral fragments than the bulk matrix (aside from Fe oxides), and its high density allows it to be distinguished in the C-T data. It extends as a narrow band encircling the inner portion of clast B throughout its thickness (Figure 4).

The central matrix component (Figure 3, orange) has a fine-grained appearance and is largely free of mineral fragments. The rest of the clast (Figure 3, purple) is made up of a matrix enriched in Ca and poor in Mg. It is relatively enriched in small mineral fragments compared to the other components of the proto-breccia, and similar to the bulk matrix.

Clast D is highly rounded with a fine-grained matrix enriched in Ca. Within the proto-breccia is a large (~ 2.6 x 1.5 mm), irregular shaped igneous clast. This proto-breccia is not readily distinguishable in the C-T data because of its similar density to the bulk matrix.

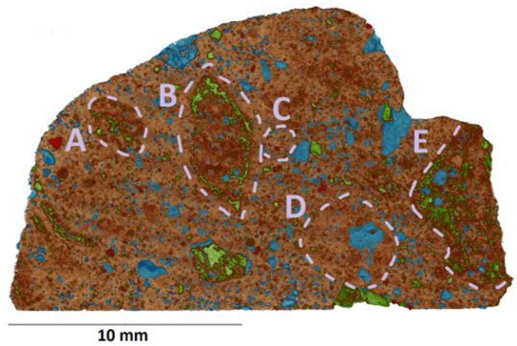

Figure 2 C-T image of chip of NWA 7034. High density (Fe oxides) in red, mid-high density (pyroxene, Fe-rich matrix) in green, mid density (bulk matrix) in brown, low density (feldspar) in blue, with proto-breccia clasts highlighted with dashes.

Discussion: The variety in composition and shape of proto-breccia clasts suggests that NWA 7034 has sampled proto-breccias from multiple source regions that have experienced variable weathering and transportation conditions. Proto-breccia clast B appears to have incorporated several generations of proto-breccia clasts, each in turn entraining regolith. If the large plagioclase fragments have the same origin as the Fe-, Mg-rich (Figure 3, green) matrix then a processes is required to account for their presence in the clast's interior. This could indicate that layering in clast B developed prior to lithification, perhaps as damp compacted regolith rolled along a stream bed picking up material, with the matrix-coated plagioclase fragments intruding into the pre-lithified sediment. Alternatively the plagioclase fragments could have the same parent rock as the green-labelled matrix, but represent the product of earlier weathering. Volatile analysis may fingerprint their relationship.

All the components have a very rounded appearance, suggesting transport over long distances or otherwise significant weathering. Clast B's layered appearance suggests that regardless of whether or not NWA 7034 is an impact or sedimentary breccia, clast B is likely to be sedimentary in origin.

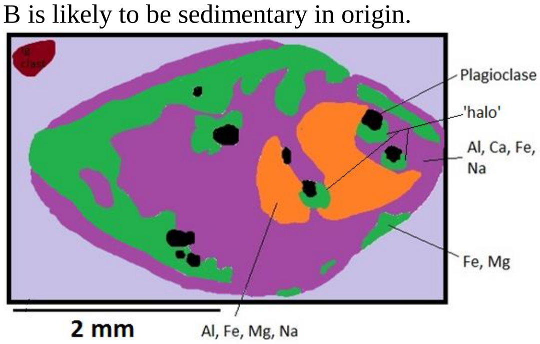

Figure 3 A representation of clast B with enriched elements of matrix components and 'halos' labelled.

The rounded appearance of clast D, along with the irregular shape of its internal igneous clast, suggest that there was a relatively short time between the erosion of the igneous parent, and the incorporation of the resulting fragment into the proto-breccia, which was subsequently transported (and so abraded) before being incorporated into the breccia of NWA 7034.
Clasts A, B, and E are all Fe-enriched relative to the bulk matrix, suggesting that either they sampled a separate Fe bearing rock (whether igneous or alteration Fe) compared to the NWA 7034 bulk matrix, or that Fe-rich fluids affected the proto-breccias prior to their incorporation into NWA 7034.

Further textural and mineralogical work on individual matrix components, as well as more in depth shape analysis, will further determine the history of each clast and how each interacted with the martian surface.

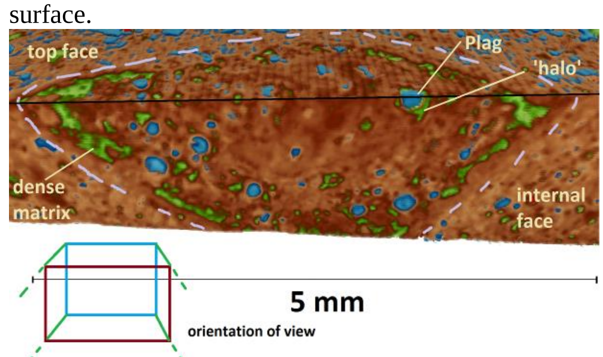

Figure 4 A cross section of proto-breccia B (outlined in dashes) in C-T image.

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