EXAMINING THE PETROLOGY OF “MARTIAN” METEORITE NWA 7034: A POLYMICT FRAGMENTAL BRECCIA N. R. Stephen1,2 & A. J. Ross1,3 (Email: n.stephen@nhm.ac.uk) 1Dept. of Earth Sciences, The Natural History Museum, London, SW7 5BD, UK, 2Dept. of Earth Science & Engineering, Imperial College London, London, SW7 2AZ, UK; 3Centre for Planetary Sciences, UCL/Birkbeck Research School of Earth Sciences, Gower St., London, WC1E 6BT, UK.

Introduction: NWA 7034 is a new class of brecciated meteorite found in 2011 and classified in 2012 [1]. It was initially described as a porphyritic basaltic monomict breccia and contains large clasts alongside phenocrysts of various phases within a fine-grained matrix [2]. It is one of five potentially paired stones referred to as Martian basaltic breccias [1, 3], containing Martian atmospheric noble gases [4].

Despite the presence of Martian atmospheric gases, there are distinct differences between NWA 7034 and the other Martian meteorites, previously SNCs. NWA 7034 does not exhibit a similar bulk mineralogy to any of the other Martian groups; shergottites, Chassignites and nakhlites or orthopyroxenite ALH 84001. Bulk chemistry analysed by [2] has a more similar composition to the Martian soils in Gusev Crater [5].

Texturally, there are no similar Martian meteorites, however, some of the clasts and phenocrysts within NWA 7034 exhibit features typical of those from other Martian samples, i.e. irregular zonation and/or exsolution [2, 6].

In this study we analyse various clasts and phenocrysts within the NWA 7034 meteorite in terms of both composition and texture, and compare them to similar occurrences in the other Martian meteorites. We present data to suggest that the meteorite is an example of a polymict fragmental breccia rather than a monomict breccia [7].

Samples & Analytical Techniques: 13 polished sections of Martian meteorites were available to this study; DaG 476 (BM2000, M7), EET 79001, Los Angeles (BM2000, M12), SaU 005 (BM2000, M40), Tissint (BM2012, M3), Zagami (BM1966, 54) and anomalous meteorite NWA 7034 on loan from UNM.

The polished thin sections were analysed in house at the Natural History Museum (NHM), London using the Zeiss EVO LS™ and the LEO 1455VP™ SEMs and on the Cameca SX-100™ electron microprobe. NWA 7034 was also analysed on the new FEI Quanta™ SEM in-house at the NHM. Element maps were extracted using the montage capabilities of Oxford Instruments INCA® software then combined to show the distribution of minerals within each thin section.

Results & Discussion: This study has identified various features of interest within the NWA 7034 thin section available. These have been classified as either ‘textural sites of interest’ (TSOIs) or ‘crystalline sites of interest’ (CSOIs). Large (up to 500 µm) homogenous crystals were found throughout the thin section, see figure 1; both clinopyroxenes were identified with little zonation, atypical of Martian specimens. Unshocked feldspars were also observed with varying alkali content; euhedral-subhedral plagioclase and anorthoclase remain with no evidence of maskelynisation. Accessory minerals include cubic pyrite, magnetite, ilmenite and chromite.

NWA 7034 exhibits a greater abundance of apatite than the other Martian meteorites within this study and initial pyroxene clast analyses match well with the shergottites studied here. Bulk ground mass composition from [2] match closely with the bulk major element compositions of basaltic shergottites summarized by [8]. The Gusev soils described in [5] typically contain 20-28 % olivine, and olivine is found within all sub-groups of the Martian meteorites, however, no olivine has been identified within NWA 7034.

Figure 1: CSOI’s within NWA 7034 (a) anorthoclase feldspar (dark grey) set within fine-grained groundmass; (b) large, euhedral clinopyroxene (grey) with apatite (white); (c) ~500 µm clinopyroxene crystal set within fine-grained groundmass; (d) possible breakdown product of feldspathic origin; (e) subhedral orthopyroxene exhibiting exsolution lamellae (light grey); (f) subhedral basal section pyroxene phenocryst
(grey) exhibiting core-rim zonation next to anorthoclase feldspar (black). Smaller clinopyroxenes (<35 µm) and chromite are poikilitically enclosed within the anorthoclase oikocryst.

Various growth textures were observed within NWA 7034; [2] reported ‘reaction spheres’, however, we would classify these as potential symplectite-like intergrowths of clinopyroxene, feldspars and oxide phases. ‘Basaltic clasts’ consist of feldspathic oikocrysts with pyroxenes and apatite, see figure 2.

![Figure 2: TSOI's within NWA 7034 (a) large feldspar (dark grey) poikilitically enclosing small clinopyroxenes, variety augite (light grey) and chromite (white); (b) fine-grained, Mg-rich spherical texture with Ca-rich rim; (c) Mg-depleted pyroxene with fine-grained rim and Fe-rich core; (d) enlarged image of the apatite/magnetite core observed in previous; (e) apatite (white) surrounded by feldspar fragments (dark grey) and pyroxene exhibiting exsolution lamellae (light grey); (f) cluster of anorthoclase feldspar (dark grey), clinopyroxene (grey), orthopyroxene (light grey) and apatite (white). A melt or symplectite-like breakdown product is also observed between the clinopyroxene.](image)

It is difficult to reconcile the lack of olivine in NWA 7034 compared to the other Martians within this study and rover data [5]. None of the current literature surrounding the NWA 7034 meteorite can account for the lack of olivine or maskelynitisation of feldspars within this sample compared to other Martian meteorites, despite the presence of “quench” [9] or impact-melt clasts. Gabbroic clasts require sampling of deeper-crust and subsequently a large impact event, which is not reflected in the meteorite’s mineralogy.

NWA 7034 and its potentially paired stones total ~480 g [3], however, a great variation is seen within this single thin section of the meteorite and within the multiple geochemical analyses performed in [2]. Bulk analyses of this meteorite may be biased by brecciated clasts or heterogeneous phenocrysts. The incorporation of chondritic material [6] has implications for the genesis of the sample. Greater care during analysis of the small scale mineralogical makeup is required before performing bulk analyses that conclude NWA 7034 is Martian in origin.

![Figure 3: BSE map (top) and false-colour image (bottom) of the NWA 7034 thin section. Colours used are: Mg=green, Si=blue, Ca=turquoise, Al=red. This combination highlights the following phases: orthopyroxene (green), clinopyroxene (blue-turquoise), K-feldspar (purple) and plagioclase (pink).](image)


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