EXAMINATION OF LITHOLOGIC CLASTS IN MARTIAN METEORITE NWA 7034. A. R. Santos[1], C. B. Agee[1], F. M. McCubbin[1], C. K. Shearer[1], P. V. Burger[1], and K. Ziegler[1], [1]Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131 (asantos5@unm.edu).

Introduction: The martian meteorite NWA 7034 has been classified by [1] to be a monomict brecciated porphyritic basalt, the first of its kind discovered from Mars. As such, this meteorite consists of several different types of mineral grains and lithologic clasts set in a fine-grained matrix. The meteorite and its individual components provide a unique and different view of Mars than has been seen before. For example, the mineral apatite has been found throughout the meteorite and can provide information about magmatic volatiles [1, 2]. Oxide phases are also ubiquitous and can provide information about martian alteration processes (if secondary phases) or f_{O2} (if primary phases) (see [3]). This study examines three types of lithologic clasts found throughout this meteorite and their associated minerals that are present throughout the meteorite matrix. We define a clast as a polymineralic fragment and a "matrix mineral" as individual mineral grains surrounded by matrix material. The three clast types investigated are gabbroic clasts, phosphate clasts, and melt clasts, which have been distinguished from each other by mineral-textural relationships. Using major, minor, and trace element geochemistry along with oxygen isotope data, we hope to gain further insight into the processes that formed these lithologies and determine how they relate to each other and the matrix minerals present in this meteorite. We will then apply these results to better understand the petrogenesis of NWA 7034 and martian igneous processes in general.

Methods: Multiple sections from NWA 7034 were examined using the JEOL 8200 electron microprobe at UNM to classify different clast types and determine major and minor element compositions of phases. The Cameca IMS 4f Ion Microprobe (SIMS) at UNM was then used on selected minerals to obtain REE data (see also [2]). Further oxygen isotope analyses will also be conducted at UNM using laser fluorination techniques.

Results: Representative images of the three clast types examined are shown in Figure 1.

Gabbroic Clasts: Gabbroic clasts consist of interlocking sub- to anhedral pyroxene, feldspar and minor phosphates (apatite) and oxides (primarily magnetite and ilmenite). The clast sizes are variable, as are the sizes of their associated minerals. Oxides appear to be some of the last phases to form due to their frequent anhedral shape that seems to fill the space between previously formed minerals. In the sections examined so far, gabbroic clasts are the most abundant clast type. The pyroxenes of gabbroic clasts fall into both the or-

thopyroxene and augitic clusters in the pyroxene quadrilateral (Figure 2). Feldspars are plagioclase with most being in the range of An_{30}-An_{55} (Figure 3).
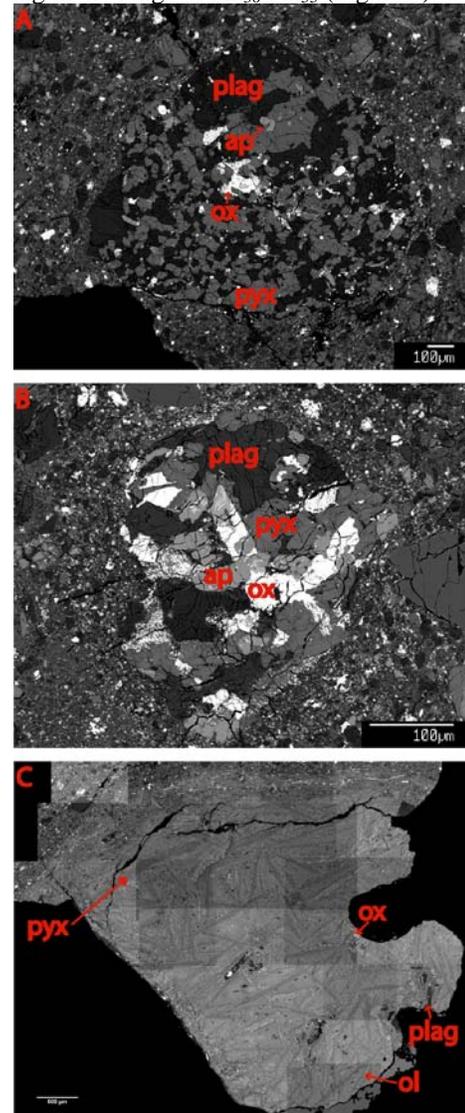

Figure 1: Backscattered electron images of examples of the three clast types identified. A: Gabbroic clast B: Phosphate clast C: Mosaic image of a melt clast. Plag-plagioclase, ap-apatite, ox-oxide phase, pyx-pyroxene, ol-olivine.

Phosphate Clasts: Phosphate clasts are composed of similar phases to the gabbroic clasts (pyx, feldspar, apatite, oxides), but the textural relationships between the phases are different. Oxide minerals tend to be larger in the phosphate clasts and tend to be more lath-like. Apatites also tend to be larger and are either lath shaped or sub- to euhedral with hexagonal shapes.

These two minerals are major phases in the phosphate clasts, making up a substantial portion of the mineral mode. Pyroxenes in the phosphate clasts are restricted to the orthopyroxene cluster, though they do have around 10% Ca. Additionally, pyroxene was only present in one of the three phosphate clasts identified thus far. Phosphate clast feldspars have the widest variation in compositions of the three clast types, with most feldspars falling between An_{45}-An_{20}. A few potassium-rich feldspars were also found; no other clast type has been found to have potassium feldspar as of yet.
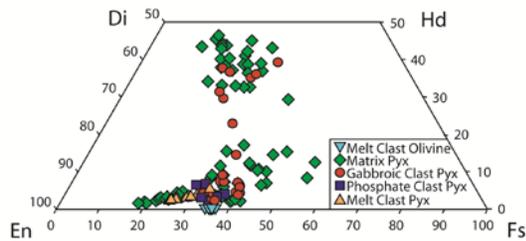

Figure 2: Pyroxene and olivine compositional data from matrix minerals the three different clast types. The data show two clusters of pyroxene compositions as found by [1] (matrix mineral data from [1]).
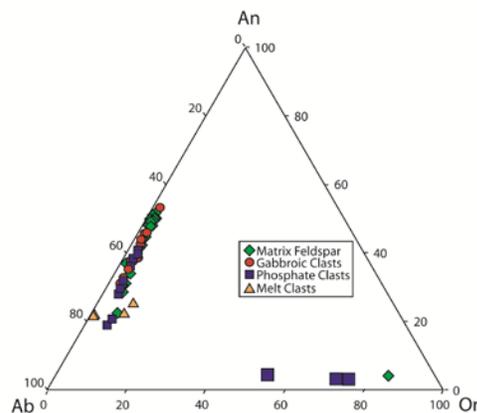

Figure 3: Feldspar ternary showing compositions of matrix feldspar and feldspars within the different lithologic clasts. Matrix feldspar data is from [1].

Melt Clasts: Unlike the other two clast types, melt clasts preserve a magmatic quenching process with mineral phases that may have formed rapidly, some of which may even be metastable. Several small spherules of quenched melt were found by [1], but a large melt clast was also observed in one section of the meteorite (shown in Figure 1C). The melt clasts consist of skeletal and possibly resorbed mineral grains surrounded by a glassy matrix, all indicative of a rapidly cooled system. The minerals that are present include pyroxene, olivine, and feldspar. The pyroxenes are only found in the orthopyroxene field, and include some of the most En-rich pyroxenes out of the three clast types. They also have some of the lowest Ca contents, but tend to

be higher in Al_2O_3 than the other pyroxenes. The feldspars have some scatter, mostly clustering around An_{20}-An_{30}. Olivines have Mg# between 63 and 65. Almost all minerals in the melt clast show zoning, with fairly consistent compositions in their centers and more evolved compositions along the edges, consistent with relatively fast cooling. The glassy portions of the clast have an Mg# around 24 with around 4 wt% total alkalis and around 0.1 wt% P_2O_5.

Interpretations: The olivine in the melt clast seems to be undergoing resorption at the time of quench. Given the absence of olivine in the matrix of the breccia, the elevated Mg#'s, and the abundance of melt, the melt clasts could represent a snapshot of a less evolved melt closer to that of the parental liquid than any of the other clast types identified. Alternatively, the melt clasts could be unrelated to the breccia and other lithologic clasts. Further analyses are needed before any conclusions regarding the petrogenesis of the melt clasts can be reached.

Based on geochemical data, the gabbroic clasts and phosphate clasts do not seem to be from genetically related magmas. Although there are significant compositional overlaps between minerals from both clast types including pyroxene (Fig. 2), feldspar (Fig. 3), and apatite [2], there are important differences that suggest they are not directly related by equilibrium magmatic differentiation. For example, the potassium feldspars in the phosphate clasts coexist with pyroxene that has a higher Mg# than any pyroxene found in the gabbroic clasts, indicating the phosphate clasts formed from a more K-rich magma. Additionally, only the gabbroic clasts contain augitic pyroxene. Further analyses of trace and minor elements in these clasts are needed to determine if any genetic links can be made among the clast types investigated and how they relate to the population of matrix phenocrysts that are ubiquitous in NWA 7034.

Despite the mineral compositions that are unique to certain clast types, there is enough major element overlap to make it difficult to determine for certain if matrix phenocrysts originated from specific clast types. For example, there are a significant number of matrix augitic pyroxenes, and these are likely disaggregated from gabbroic clasts, but there are also a number of matrix orthopyroxenes, which may have come from phosphate or gabbroic clasts. Further study of trace elements and oxygen isotopes may provide better ways to more definitively determine the origin of these matrix minerals.

References: [1] Agee C. B. et al. (2013) *Sciencexpress,* 10.1126/science.1228858. [2] Santos A. R. et al. (2013b) *LPSC XLIV.* [3] Agee C. B. et al. (2013) *LPSC XLIV.*