BASALTIC BRECCIA NWA 7034: NEW UNGROUPED PLANETARY ACHONDRITE

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Introduction: NWA 7034, purchased in Morocco in 2011, is a 319.8 gram single stone, with a shiny black surface. Saw cuts reveal a minimally weathered, porphyritic breccia with numerous dark and light colored phenocrysts and clasts of variable size, shape and texture, set in a dark gray groundmass, with many small reflective opaques visible (figure 1).

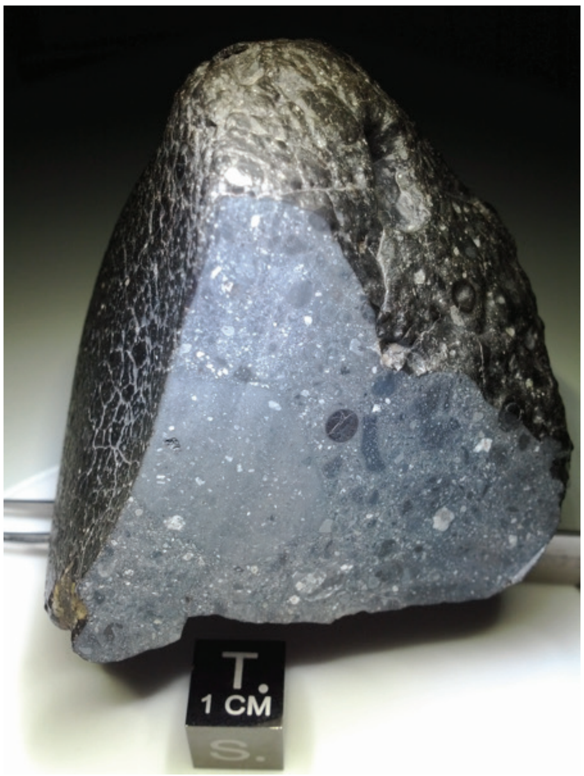

Figure 1. Main mass of NWA 7034 with saw-cut surface revealing heterogeneous, brecciated texture. White crystals are plagioclase phenocrysts, dark crystals are pyroxene phenocrysts. Clasts are plagioclase-pyroxene aggregates, melt pockets, and other domains resembling volcanic spherulites.

Petrography: Microprobe examination of three polished epoxy mounts shows a porphyritic, brecciated texture with many plagioclase and pyroxene phenocrysts up to 5 mm, accessory minerals include chlorapatite, chromite, ilmenite, magnetite, alkali-feldspar and pyrite, set in a very fine-grained groundmass (figure 2). Numerous poikilitic pyroxene-plagioclase clasts are also present and a 1-cm quench melt pocket with skeletal olivine and pyroxene was observed. No Fe-Ni metal was found in this meteorite.

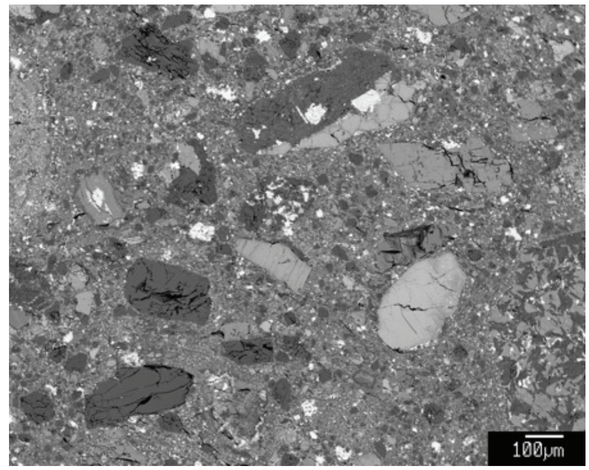

Figure 2. BSE image showing NWA 7034 pyroxene phenocrysts (light gray), plagioclase phenocrysts (dark gray), oxides and sulfides (white), and fine-grained matrix. Plagioclase-pyroxene clast is partially visible above the scale bar.

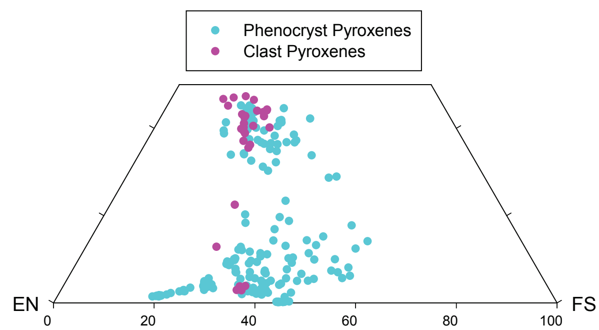

Figure 3. Pyroxene quadrilateral showing the compositional trends of the pyroxenes in NWA 7034.

Mineral composition and Geochemistry: Electron microprobe analyses using the UNM Cameca instrument gave the following average feldspar compositions; plagioclase phenocrysts: $Ab_{55.3\pm6.9}$ $An_{42.6\pm7.7}$ $Or_{2.2\pm1.1}$ n=46; K-feldspar: $Ab_{25.0\pm11.3}$ $An_{5.2\pm4.3}$ $Or_{69.8\pm13.0}$ n=6; alkali feldspar $Ab5_{7.2\pm12.5}$ $An_{5.7\pm1.4}$ $Or_{37.1\pm11.3}$ n=6. Average pyroxene phenocrysts compositions: low-Ca pyroxene $Fs_{32.9\pm8.8}$ $Wo_{2.7\pm1.4}$ Fe/Mn=37±4 n=98; pigeonite $Fs_{38.9\pm7.7}$ $Wo_{9.2\pm2.7}$ Fe/Mn=36±3 n=71; augite $Fs_{23.5\pm7.3}$ $Wo_{37.0\pm7.7}$ Fe/Mn=32±5 n=84. Skeletal olivine: $Fa_{46.6\pm5.7}$ Fe/Mn=48±7 n=28. Apatite: Cl=4.85±0.34 F=0.70±0.13 F+Cl=-O 1.38±0.06 (wt%) n=16.

Figure 3 shows magmatic iron-enrichment fractionation trends for phenocryst pyroxenes. In contrast, pyroxenes from poikilitic "plag-px-clasts" are highly equilibrated, suggesting the presence of at least two distinct basaltic lithologies in this meteorite. Plagioclase phenocrysts span a narrow compositional range similar to shergottite Ab-An values, while "plag-px-clast" feldspars show wider compositional ranges that include Ab-Or rich phases. The groundmass is a fine-grained mix of silicate, oxide, phosphate, and sulfide phases. Low microprobe totals on a significant number of these grains suggest the possible presence of hydroxides, carbonates, or sulfates, which we are currently exploring.

NWA 7034 Martian Basaltic Breccia?: Papike et al. [1] have shown that Fe/Mn, when used in combination with mineralogy, is an excellent diagnostic for classifying planetary basalts. Figure 4 shows that Fe-Mn of NWA 7034 pyroxenes most resemble the trend of the SNC meteorites from Mars.

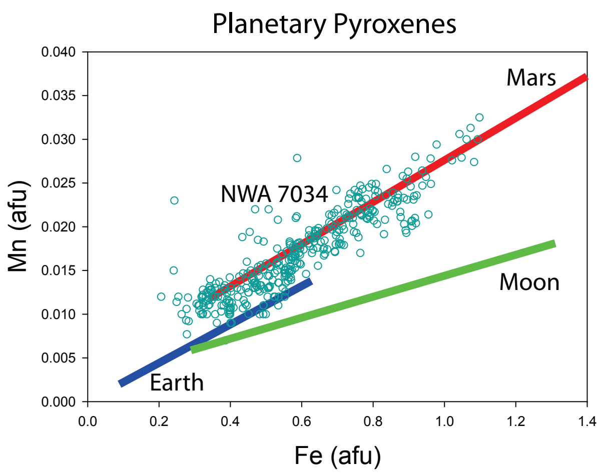

Figure 4. Fe versus Mn (atomic formula units) showing the trend for all NWA 7034 pyroxenes (cyan dots, 253 microprobe analyses) and for comparison pyroxene trends from Mars (red), Moon (green), and Earth (blue) [1].

Furthermore, the NWA 7034 feldspar compositions are SNC-like. Presence of ubiquitous chlorapatite, magnetite, and pyrite in NWA 7034 are all consistent with common martian accessory phases, and a relatively high magmatic oxidation state expected in terrestrial planet volcanism. Interestingly, there are no martian meteorite breccias such as frequently seen in meteorites from the Moon and the HED parent body. If NWA 7034 is a martian meteorite, then it would probably form a new group distinct from the shergottites, nakhlites, chassignites, and orthopyroxenite. On the other hand, we performed oxygen isotope analyses on NWA 7034 whole rock and found a fractionation trend distinct from the SNC fractionation array (fig.5).

Oxygen Isotopes: Oxygen isotopes were performed at the UNM Stable Isotope Laboratory on acid-washed material analyzed in replicate by laser fluorination on three different day-sessions. (see table 1, all per mil). The precision on San Carlos olivine standard for $\Delta^{17}O=\pm0.03$ per mil. The best fit to the NWA 7034 data is a fractionation line with slope 0.52 (black line, fig.5), and average value $\Delta^{17}O=0.57\pm0.05$. This value is significantly higher than the average value for SNC meteorites $\Delta^{17}O=0.28\text{-}0.32$ [3,5], note also that both $\delta^{18}O$ and $\delta^{17}O$ are higher in NWA 7034 than SNC.

Table 1: Bulk oxygen isotope results of NWA 7034.

$\delta^{17}O$	$\delta^{18}O$	$\Delta^{17}O$
4.14	6.61	0.65
3.94	6.42	0.55
3.79	5.99	0.63
3.55	5.82	0.47
4.31	7.21	0.51
3.90	6.33	0.56
3.84	6.18	0.59
3.77	6.08	0.56
3.94	6.30	0.61
3.82	6.12	0.59

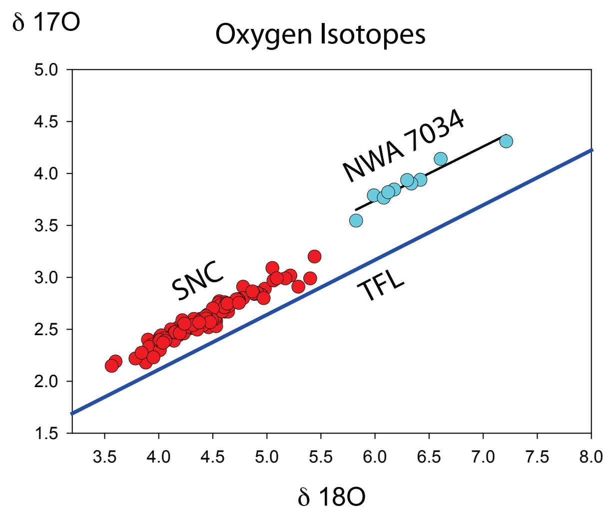

Figure 5. Oxygen isotope plot showing the values of NWA 7034 from this study (cyan dots, 10 analyses, UNM) compared to SNC meteorites from the literature (red dots) [2-5]. TFL=terrestrial fractionation line, slope 0.528.

If NWA 7034 is a martian meteorite, then its oxygen isotope values are anomalous compared to other martian meteorites, perhaps due to martian aqueous alteration, introduction of an exotic isotopically heavy component during impact brecciation, or other unknown processes. On the other hand, NWA 7034 may be a unique basaltic breccia from a yet unsampled planetary body, derived from a different oxygen isotopic reservoir than Mars. Future work on NWA 7034 will hopefully elucidate this enigma.

References: [1] Papike J. J. et al. (2009) *GCA, 73,* 7443-7485. [2] Meteoritical Bulletin Database (2012). [3] Franchi I. A. et al. (1999) MAPS 34, 657-661. [4] Mars Meteorite Compendium (2011) Meyer C., NASA JSC. [5] Rumble D. III et al. (2009) 40th LPSC, Abstract #2293.