Northwest Africa 8709: A rare but revealing type 3 ordinary chondrite melt breccia

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INTRODUCTION

NWA 8709 is classified as an L3-melt breccia [1], and may be important for understanding compaction and lithification of chondritic material. Chondrite melt breccias are rare, and type 3 melt breccias are rarer still, with only one other type 3 ordinary chondrite melt breccia known [1] (NWA 7120). We studied the petrography, chemistry and structure of NWA 8709 using optical microscopy, SEM, ICP-MS, X-ray computed microtomography (µCT), and oxygen isotope analysis to better understand the physical, chemical, and thermal processes affecting the rock.

Fig. 1 Optical scan of section 0109-2

Features:
- relatively well-defined chondrules (type 3)
- some large chondrules (e.g., A, B, C)
- chondrules squished together (e.g., cluster D, E, F, G)
- elongate chondrules form preferred orientation (NE-SW)
- dark section (blackened)
- chondrule olivine shock stage S4

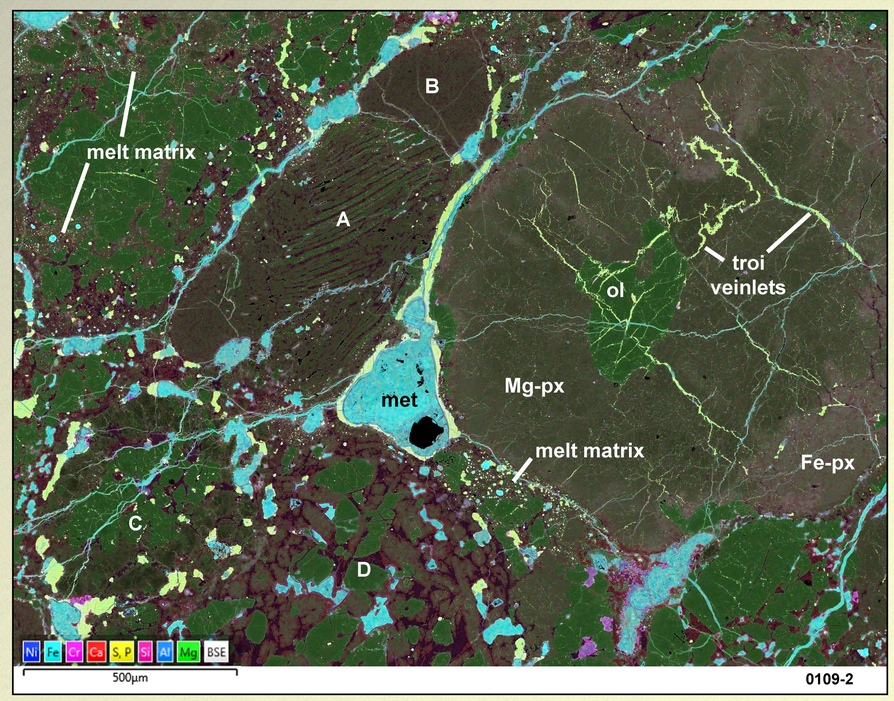
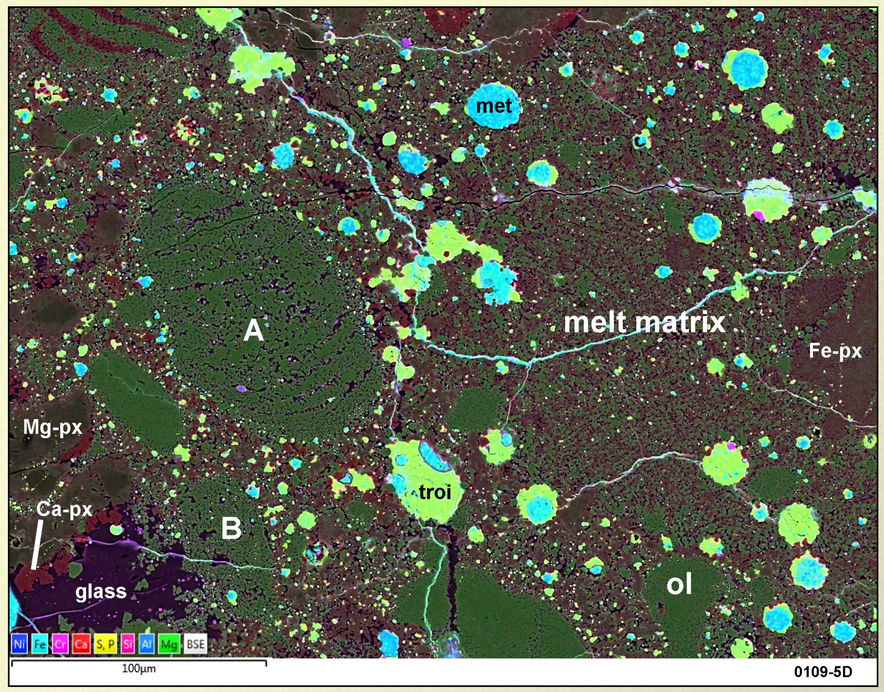


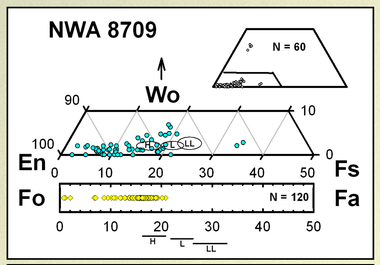
Fig. 2 False color phase map (EDS + BSE)

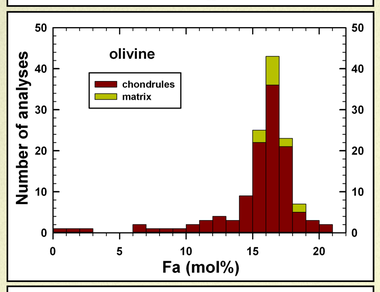
Features:
- troilite veins in chondrule at right, especially in olivine & Mg-rich low-Ca pyroxene (blackening in unmelted phases)
- chondrules (e.g., A, B, C, D) tightly packed, squeezed together
- melt matrix interstitial to chondrules

Fig. 3 False color phase map (EDS + BSE)– matrix close-up

Features:
- fine-grained (<5-10 µm) igneous matrix composed of olivine, low-Ca pyroxene (orthopyroxene - pigeonite), glass, high-Ca pyroxene (diopside - augite), and abundant somewhat irregular metal-troilite globules
- small (20-120 µm) clasts (e.g., A, B) partly melted and re-solidified







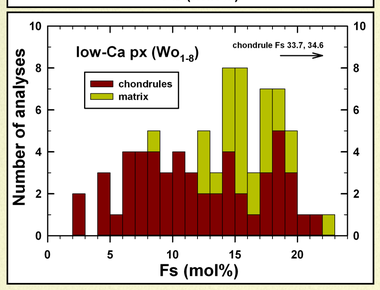


Fig. 4 Mineral chemistry

Features:
- variable ol Fa and low-Ca px Fs (type 3)
- does not have L composition
- Fa & Fs closest to H, but does not have typical spread for H3
- $Fa_{0.8-20.8}$, mainly Fa_{15-18} for chondrules & matrix
- $Fs_{2.2-34.6}$, matrix mainly Fs_{12-20}
- Anomalous mineral chemistry possibly caused by FeO-reduction during melting

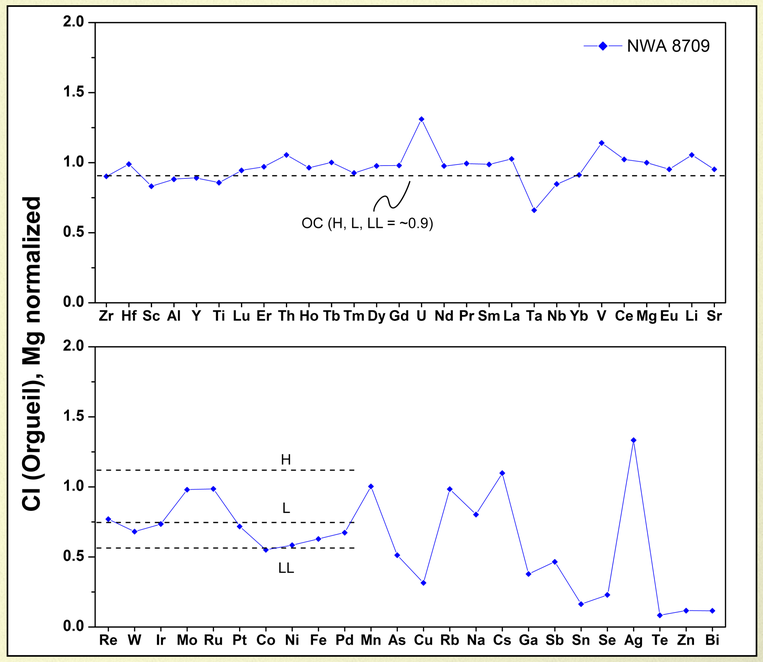


Fig. 5 ICP-MS data for whole-rock aliquot

Features:
- refractory lithophile (Zr-Sr) abundances flat, similar to ordinary chondrites
- refractory siderophile (Re-Pd) abundances best matched by L chondrite
- volatile elements (Mn-Bi) not strongly depleted by heating effects
- high U likely reflects weathering; high Ag is suspect

Fig. 6 µCT stereoplots showing orientations of chondrule and metal grain shapes in 3D

Features:
- data for individual chondrules & grains in parts a & c, contoured data in parts b & d
- chondrules and grains show similar preferred orientations, likely caused by shock compaction
- µCT data confirm generally large chondrules: 0.6-1.2 mm diameter most common, up to 2.5 mm, more like LL than L

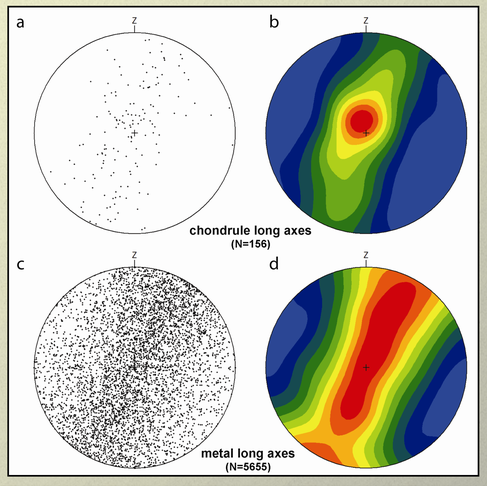
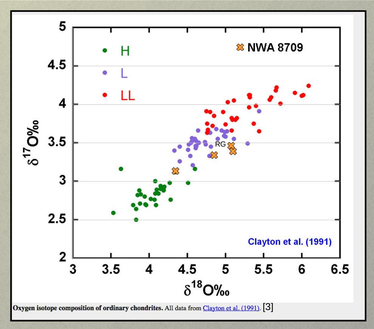


Fig. 7 Oxygen isotope data for bulk aliquots

Features:
- 1-3 mg aliquots, three acid-treated (K. Ziegler), one untreated (R. Greenwood "RG"), no obvious difference between the two sets
- average ± standard deviation $\delta^{18}O = 4.833 \pm 0.340$, $\delta^{17}O = 3.337 \pm 0.147$
- most closely resembles L chondrites



CONCLUSIONS

1) Although classified as an L3 melt breccia, NWA 8709 is an anomalous L: mineral chemistry is unlike L chondrite, and chondrule sizes are larger than most L chondrites.
2) NWA 8709 conforms to the predictions of hydrocode models [2], which show that shock heating effects will be concentrated in the porous matrix of chondritic agglomerates.
3) The rarity of chondrite melt breccias could be explained if most chondrites experienced a series of weaker initial shock compactions; NWA 8709 evidently differs in having been affected by a strong early shock compaction.

References: [1] Meteoritical Bulletin Database, accessed May 13 2015. [2] Bland P.A. et al. (2014) Nature Communications 5:5451, doi 10.1038/ncomms6451. [3] Clayton et al. (1991) GCA 55, 2317-2337.

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