ASSESSING THE FORMATION OF UNGROUPED ACHONDRITE NORTHWEST AFRICA 8186: RESIDUE, CRYSTALLIZATION PRODUCT, OR RECRYSTALLIZED CHONDRITE? P. Srinivasan[12], F. M. McCubbin[2], and C. B. Agee[1]. [1]Institute of Meteoritics and Dept. of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, USA. [2]NASA Johnson Space Center, Mail Code XI2, 2101 NASA Parkway, Houston TX 77058. Email: psrinivasan@unm.edu.

Introduction: The recent discoveries of primitive achondrites, metachondrites, and type 7 chondrites challenge the long held idea that all chondrites and achondrites form on separate parent bodies. These meteorites have experienced metamorphic temperatures above petrologic type 6 and have partially melted to various degrees [1-8]. However, because of their isotopic and compositional similarities to both undifferentiated and differentiated groups [6-8], the provenance of these 'type 6+' meteorites remains largely unknown.

CK and CV chondrites have recently been linked to a few achondrites due to their strong compositional, mineralogical, and isotopic similarities [1-3,6,8,9], suggesting a common origin between these meteorites. Although CVs have generally undergone low degrees of alteration near petrologic type 3, CKs have experienced a wide range of thermal alteration from petrologic type 3 to 6 [10-11]. Thermal evolution models on early accreting bodies predict that an early forming body can partially differentiate due to radiogenic heating, and, as a result, form radial layers of material increasing in thermal grade (types 3 to 6+) from the unmelted chondritic surface towards the differentiated core [4,12-16].

Northwest Africa (NWA) 8186 is an ungrouped achondrite that provides compelling evidence for higher degrees of thermal processing and/or melting and differentiation on some CK/CV parent bodies [8]. NWA 8186 plots on the CCAM line on a 3-oxygen isotope diagram directly with CK and CV chondrites and also plots with the CKs in regards to Cr isotopes. This meteorite is dominated by NiO-rich olivine (>80%), lacks iron metal, and contains four oxide phases, indicating a high fO_2 (above FMQ) similar to the CKs [8]. Additionally, NWA 8186 does not contain chondrules. We have further investigated the origins of NWA 8186 by examining and comparing the bulk composition of this CK-like achondrite with CK and CV chondrites, allowing us to assess the various scenarios in which NWA 8186 may have formed from CK/CV precursor material.

Methodology: A 1 x 0.5 cm thin section of NWA 8186 was used for quantitative electron-beam procedures. A FEI Quanta 3D FEG SEM was used to obtain EDS X-ray maps, and EPMA analyses on all phases, including the fusion crust, were obtained using a JEOL 8200 superprobe. We processed the X-ray maps with ImageJ to determine modal abundances, and then we calculated the bulk composition of NWA 8186 by factoring in a density correction to the mineral modes.

Results: EPMA and SEM analyses showed that NWA 8186 is composed of >94% silicate phases, including olivine (Fo_{65}), plagioclase (An_{48-51}), and augite ($Fs_{8-12}Wo_{48-50}$). Compositions of all silicates are homogeneous, and zonation was not observed in any grains. Plagioclase and pyroxene occur as discrete and segregated particles (Figure 1). There is also a heterogeneous distribution of plagioclase grains in the section.

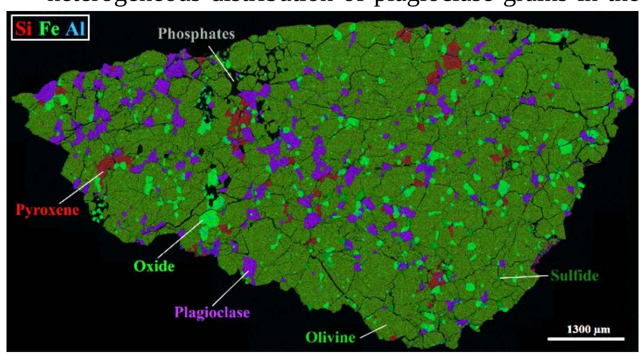

***Figure 1**. False colored Si, Fe, and Al X-ray maps showing various phases in NWA 8186.*

Table 1 shows the calculated bulk composition from NWA 8186 along with EPMA data from the fusion crust. Bulk compositions from CK and CV chondrites have been recalculated to oxides from [17] and normalized for comparison. Overall, the bulk compositions of NWA 8186, CK, and CV chondrites are similar, with minor differences in some elements. Fe, Mn, and P are nearly identical between the three meteorites, but Al, Ti, and Na are all lower in NWA 8186 than in the CKs and CVs.

Discussion: NWA 8186 is isotopically and geochemically similar to CK and CV chondrites. However, the provenance of this meteorite is unknown. We now further explore the possibilities for the origin of NWA 8186 from a chondritic precursor.

Recrystallized chondrite? NWA 8186 has experienced a high degree of thermal alteration, above

	NWA 8186		CK	CV
	Bulk Comp.	Fusion Crust	Av. Bulk Comp.*	Av. Bulk Comp.*
SiO_2	35.95	38.25	33.68	33.18
Al_2O_3	2.84	2.84	5.57	6.32
TiO_2	0.06	0.12	0.16	0.14
Cr_2O_3	0.29	0.08	1.03	1.01
FeO_{total}	29.91	25.26	29.59	29.97
MnO	0.20	0.22	0.19	0.19
MgO	26.21	28.22	24.29	23.42
CaO	2.34	2.87	2.37	2.54
Na_2O	0.50	0.45	0.83	0.91
K_2O	0.05	0.08	0.04	0.05
P_2O_5	0.55		0.50	0.51
CoO	0.01		0.08	0.08
NiO	1.07	1.61	1.66	1.66
ZnO	0.00		0.01	0.01
CuO	0.00		0.01	0.01
S	0.49	0.01	0.03	0.03
F	0.00		0.00	0.00
Cl	0.05	0.01	0.01	0.01
O=S+F+Cl	0.54	0.02	0.04	0.04
Total	100.00	100.00	100.00	100.00

Table 1. *Calculated bulk composition and fusion crust data from NWA 8186. *CK and CV average bulk compositions are recalculated from [17]. Values have been normalized for comparison.*

petrologic type 6. This meteorite lacks chondrules and matrix, two features that are present in all CK chondrites, regardless of petrologic type [10-11]. NWA 8186 also contains 120° triple junctions between mineral phases. Plagioclase grains in NWA 8186 are homogeneous and occur as discrete particles. This is unlike the petrologic type 3-6 CKs, which contain heterogeneous silicates that are closely interconnected with one another [9-11]. Texturally, NWA 8186 resembles a recrystallized chondrite. It experienced high enough heating that partial melting (or melting) occurred and was subsequently followed by slow cooling.

Residue or crystallization product? The Fe-Mn-Mg system has previously been used to determine the relationship between chondrites, primitive achondrites, and evolved achondrites [7]. Figure 3 shows a schematic diagram of this system. Evolved achondrites (i.e. SNC, HED) have superchondritic Mn/Mg ratios and may have formed from fractionated melts and cumulates. Primitive achondrites tend to have chondritic-like Mn/Mg ratios and may have formed as residues [7]. NWA 8186 has chondritic-like Mn/Mg, so we will explore a residue formation with this system. If the bulk composition of a rock starts with chondritic Mn/Mg and experiences low degrees of melting, the resulting residue will barely differ from the bulk composition. At higher degrees of melting, the resulting liquid will move towards the bulk composition and the residue will move towards a lower Mn/Mg. Figure 3 shows the bulk composition of NWA 8186, along with the average bulk compositions of CK and CV chondrites [17]. The Mn/Mg ratio of NWA 8186 barely differs from CK and CV, only slightly differing by a lower Fe/Mg ratio.

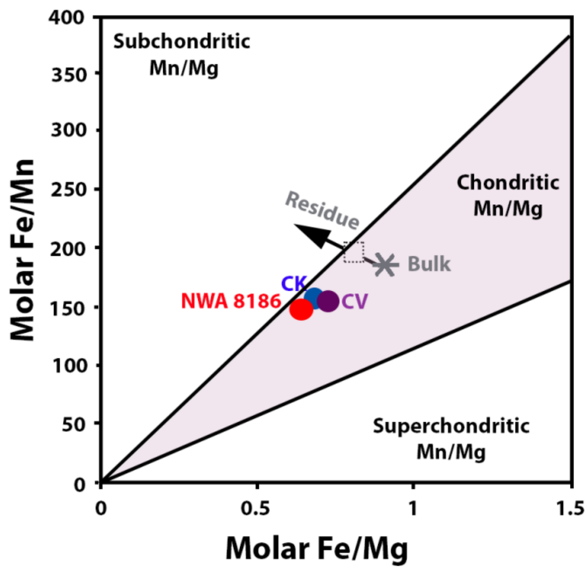

Figure 3. *Simplified Fe-Mn-Mg diagram modified from [7]. CK and CV data are compiled from [17]. NWA 8186 has a similar bulk composition and Mn/Mg ratio compared to CK and CV chondrites.*

Because the bulk composition of NWA 8186 is so similar to CK and CV chondrites, it is difficult to determine whether or not this meteorite formed as a residue from low degrees of chondritic melting or as a highly metamorphosed, recrystallized chondrite. Future U-Pb dating and trace element analysis will be able to clear this issue.

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