A COMPARATIVE STUDY OF THE ZAKLODZIE AND NORTH WEST AFRICA 4301 ANOMALOUS ENSTATITE ACHONDRITES. D.D. Uribe[1*], P.J.A. McCausland[1], M.R.M. Izawa[1,2,3], R.L. Flemming[1] [1]Dept. of Earth Sciences, Western University, London, ON, N6A 5B7 **duribelo@uwo.ca*, [2] Dept. of Earth Sciences, Brock University, 1812 Sir Isaac Brock Way, St. Catharines's, ON, L2S 3A1, [3] Planetary Science Institute, 1700 E Fort Lowell Rd #106, Tucson, AZ 85719, USA

Introduction: Enstatite achondrites are amongst the more reduced meteorites and their precursors, an enstatite chondrite protolith, is believed to be similar to the material that formed Earth [1]. The Zaklodzie meteorite has been proposed by [2] as a primitive enstatite achondrite and so may provide information about the processes that occurred during early planetary differentiation. In this study we compare the Zaklodzie meteorite with North West Africa (NWA) 4301 to determine if they are paired, as classification of NWA 4301 in [3] describes it as being texturally and chemically similar to Zaklodzie.

Both Zaklodzie and NWA 4301 are enstatite-rich, chondrule free meteorites with textural features suggestive of high temperature metamorphism and substantial recrystallization. Boesenberg et al. [4] report that both meteorites have similar mineral chemistry and both show a distinctive granular texture in the enstatite grains with interstitial plagioclase. The only differences found amongst samples were the slightly more calcic feldspar and small plagioclase inclusions in NWA 4301. In this study, we revisit the proposed pairing and investigate some key differences between Zaklodzie and NWA 4301 which may indicate that they represent different evolutionary histories.

Methods: Chemical analysis of silicates, sulphide and metal grains was performed using the JEOL JXA-8530F field emission electron microprobe at the Earth and Planetary Materials Analysis laboratory at Western University. The probe was operated at an accelerating voltage of 15 kV and a beam current of 20 mA. Elemental maps were also acquired at resolutions of 4, 2 and 0.5 µm in order to assess spatial element distribution and variation between samples.

In situ X-ray diffraction analysis was done with the Bruker D8 Discover µXRD at Western University, operating with Co Kα radiation (λ = 1.78897 Å) at 35 kV and 45 mA with a 60 mm Göbel mirror, with a nominal incident beam diameter of 300 µm [5]. The instrument operates in theta-theta geometry, delivering diffracted X-rays to a 2D detector. Targets from both meteorites were investigated in omega scan mode at two frames of 30 minutes each. Textural analysis can be performed on the 2D diffraction images, and mineral structures can be identified by integrating the image to produce a standard intensity versus 2theta diffraction pattern, which can then be searched for matches with the International Centre for Diffraction Data (ICDD) Database [e.g., 5].

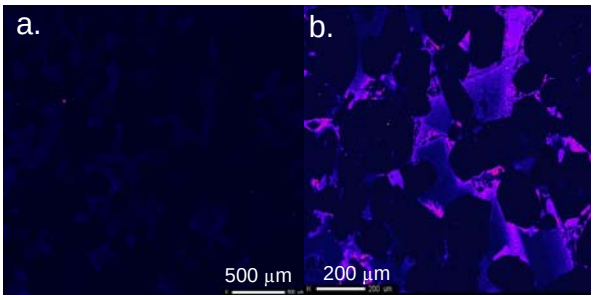

Fig 1. Potassium Kα X-ray map in a) NWA 4301 b) Zaklodzie, illustrating myrmekitic intergrowth of alkali feldspar with enstatite. Note that zoning is more prominent in Zaklodzie than in NWA 4301.

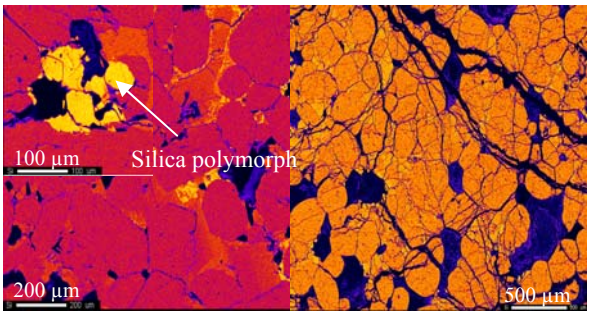

Fig 2. Kα X-ray maps for Silicon in a) Zaklodzie and b) NWA 4301. Note. Silica polymorphs are readily detectable in Zaklodzie, but not as prevalent in NWA 4301.

Results: Both meteorites are comprised of subhedral to anhedral enstatite crystals, with a texture suggestive of having experienced recrystallization. The enstatite in NWA 4301 has a composition of $Fs_{0.31\text{-}1.38}$ and $Ws_{0.35\text{-}0.76}$. Both orthorhombic (Pbca) and monoclinic ($P2_1/c$) enstatite structures were detected in NWA 4301 by µXRD, similar to XRD results of [6]. Both forms were also found in Zaklodzie, as also reported by [2]. Chondrules, CAIs and other 'nebular' features were not observed in NWA 4301. Metal compositions in NWA 4301 were 5.6-5.7 wt% Ni, and 1.23-1.27 wt% Si, similar to those of Zaklodzie. NWA 4301 has 0.46-0.47% Co in the metal grains, similar to that reported for Zaklodzie.

Discussion: Although the Zaklodzie and NWA 4301 meteorites show mineral, chemical and textural similarities [2], there are some differences that may count against pairing them. The interstitial plagioclase in Zaklodzie exhibits myrmekitic intergrowth texture

of the higher potassium content feldspars and silica in the rim areas where potassium content is higher (Fig 1). These K and Si rich zones may represent late-stage crystallization products of localized melting. Plagioclase zoning is more prominent in Zaklodzie, whereas in NWA 4301, the increase in potassium and sodium toward the rims of plagioclase grains appear to be more gradual and lack the myrmekitic intergrowth texture seen in Zaklodzie. These textural and chemical differences may indicate that NWA 4301 underwent a slower cooling rate than Zaklodzie (Fig 2).

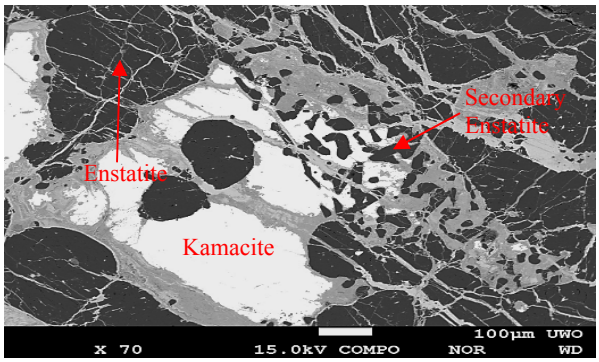

Fig 3. BSE image of NWA 4301 showing first generation, sub-rounded enstatite grains and small anhedral "secondary" enstatite grains contained within metal and oxides.

NWA 4301 and Zaklodzie have very similar petrographic features. However, NWA 4301 contains small enstatite grains engulfed in a metal matrix resembling a graphic texture (Fig 3). These small enstatite crystals may have cooled quickly and may have been the result of an impact-related process that partially melted and quickly recrystallized the second generation enstatite grains.

Moreover, the silicon Kα X-ray map for Zaklodzie exhibits a higher modal proportion of silica polymorph than in NWA 4301. Graphite was observed in Zaklodzie [6] and NWA 4301, implying that both experienced high pressure and temperatures during metamorphism. NWA 4301 and Zaklodzie may have fragments of the same parent body, but could have experienced distinct pressure-temperature-time paths (P-T-p). Both meteorites also appear to have experienced different weathering histories as shown by [7] where NWA 4301 has pervasive weathering and its metal grains appear to be more interconnected than in Zaklodzie. Sulphides in NWA 4301 are not abundant as these have been affected by the degree of weathering.

Summary: NWA 4301 is an anomalous enstatite achondrite that formed by high degree melting of an EL-like precursor, which then experienced extensive annealing. The heat source for initial melting may have been impact related or endogenic (^{26}Al radiogenic heating) or perhaps a mixture of both processes. Comparison of petrology, mineralogy and chemistry of the Zaklodzie and NWA 4301 meteorites may indicate that both objects originated from a common parent body, but experienced different metamorphic histories.

Future Work: ^{26}Al/^{26}Mg isotopic study of NWA 4301 and Zaklodzie will be performed to help constrain heating source for the meteorite samples. Shock assessment of enstatite via µXRD would provide a comparison of their shock histories. Sulphide thermometry of NWA 4301 would be useful to determine temperature of sulfide crystallization in and compare it with available Zaklodzie data.

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