

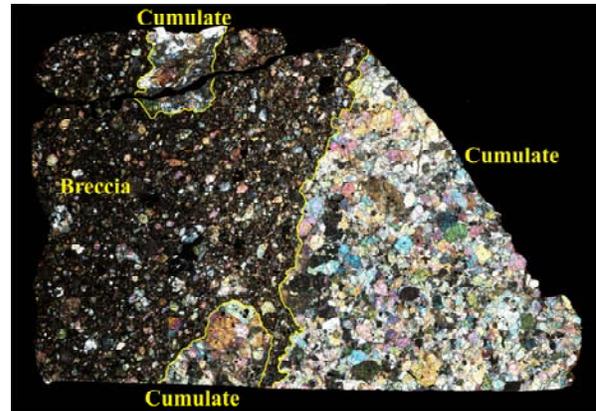
**3.1 GA CRYSTALLIZATION AGE OF MAGNESIAN AND FERROAN GABBRO LITHOLOGIES IN LUNAR METEORITES NORTHWEST AFRICA 773, 3170, 6950 AND 7007, AND EVIDENCE FOR 3.95 GA COMPONENTS IN NWA 773 POLYMICT BRECCIA.** B. J. Shaulis<sup>1</sup>, M. Richter<sup>1</sup>, T. J. Lapen<sup>1</sup>, A. J. Irving<sup>2</sup>. <sup>1</sup>Department of Earth and Atmospheric Sciences, University of Houston, Houston, Texas 77204-5007 (bshaulis@uh.edu), <sup>2</sup>Department of Earth and Space Sciences, University of Washington, Seattle, WA 98195.

**Introduction:** The NWA 773 clan of meteorites is a group of paired and/or petrographically related stones which includes: NWA 773, NWA 2700, NWA 2727, NWA 2977, NWA 3160, NWA 3333, NWA 6950, NWA 7007, and Anoual [1-4]. New U-Pb and <sup>207</sup>Pb-<sup>206</sup>Pb ages of baddeleyite in NWA 773, NWA 3170, NWA 6950 and NWA 7007 establish a chronologic link among members of the pairing group.

**Samples:** NWA 773 contains magnesian olivine gabbro cumulate and polymict breccia lithologies [5] (Figs. 1, 2). NWA 6950 is a monomict specimen of the magnesian olivine gabbro cumulate (Fig. 2). NWA 3170 is comprised of at least two different lithologies, ferroan olivine gabbro cumulate and breccia (Fig. 2). NWA 7007 is a monomict meteorite containing the ferroan olivine gabbro cumulate lithology (Fig. 2).

**Analytical Methods:** *In situ* dating of baddeleyite and zircon was conducted by LA-ICPMS at the University of Houston using a Varian 810 quadrupole mass spectrometer coupled with a Photon Machines Analyte.193 excimer laser ablation system. The laser ablation was performed using a 10 μm diameter laser spot size with a 7 Hz repetition rate over 20s and a fluence of 3 J/cm<sup>2</sup>. The Phalaborwa baddeleyite standard (2059.6 Ma[6]) was used as the external calibration standard and baddeleyite in FC5z (1099 Ma[7]) as the internal standard. The Plešovice zircon standard (337.1 Ma [8]) was used as the external calibration standard and the zircon in FC5z (1099 Ma [7]) as the internal standard. Data reduction followed methods outlined in [9].

**U-Pb and Pb-Pb results:** A total 28 analyses were conducted on 24 baddeleyite grains for NWA 773. The weighted average <sup>207</sup>Pb-<sup>206</sup>Pb age of these analyses is 3129 ± 11 Ma and the U-Pb concordia age is 3126 ± 26 Ma (all uncertainties are presented at the 2σ level). These ages are ~100 Ma older than previous age determinations on NWA 773 [10]. Analysis of a single large zircon grain in the breccia lithology of NWA 773 (Fig. 3) yielded a weighted average Pb-Pb age of 3948 ± 25 Ma and a U-Pb concordia age of 3953 ± 18 Ma (Fig. 4). Nineteen baddeleyite grains were analyzed from NWA 3170 and provided a weighted average age of 3118 ± 14 Ma and a U-Pb concordia age of 3104 ± 25 Ma. Results by [11] for NWA 6950 show a weighted average age for seven baddeleyite analyses of 3100 ± 16 Ma and a U-Pb concordia age of 3110 ± 22 Ma. A total of 12 analyses were performed on four baddeleyite



**Figure 1 - Photo mosaic of NWA 773 in cross polarized light showing both the magnesian olivine gabbro cumulate and breccia lithologies. Image roughly 3 cm across.**

grains from NWA 7007. The weighted average age of these analyses was 3106 ± 22 Ma and a U-Pb concordia age with an upper intercept age of 3111 ± 33 Ma.

**Discussion:** The <sup>207</sup>Pb-<sup>206</sup>Pb and <sup>206</sup>Pb-<sup>238</sup>U baddeleyite ages for NWA 773/3170/6950/7007 are identical (Fig. 5) within error to both a <sup>207</sup>Pb-<sup>206</sup>Pb baddeleyite age of 3116 ± 7 Ma [12] (data of [12] were recalculated with the U decay constants of [13]) and a Sm-Nd age of 3100 ± 50 Ma [14] for NWA 2977. The U-Pb, Pb-Pb and Sm-Nd ages are 300-400 Ma older than the 2.7-2.8 Ga Ar-Ar ages found in NWA 773/2977/3160 [15, 16].

The <sup>207</sup>Pb-<sup>206</sup>Pb ages of baddeleyite from the breccia and cumulate gabbro lithologies in NWA 773 are 3114 ± 32 Ma and 3131 ± 12 Ma, respectively. For NWA 3170, the <sup>207</sup>Pb-<sup>206</sup>Pb ages of baddeleyite from the breccia and cumulate lithologies are 3115 ± 15 Ma and 3139 ± 37 Ma, respectively. These data indicate 1) that the magnesian and ferroan olivine gabbro cumulate lithologies are nearly identical in age and 2) the breccia lithologies contain material predominantly derived from the larger clast lithologies.

The cumulate lithologies of both NWA 773 and 3170 tend to be older than the breccia lithology, but all have identical ages within error of each other. Based on the resolution of the data, it would be difficult to make any distinction among these ages. Also, the Pb-Pb ages from [11, 12] are from monomict meteorites with cumulate textures whose reported Pb-Pb ages are younger than those reported separately here for NWA 773 and NWA 3170. The 3.95 Ga age of the single large zircon grain found in the breccia lithology of

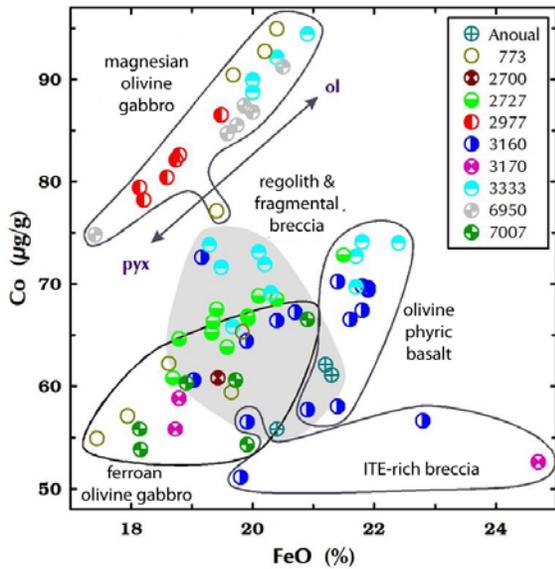


Figure 2 - FeO-Co variation between members of the NWA 773 pairing group. Modified from [4].

NWA 773 adds complexity to the chronology of the NWA 773 pairing group. The inclusion of this grain within NWA 773 suggests that both a 3.1 Ga and 3.95 Ga terrane be proximal to the impact site from which the NWA 773 polymict meteoroid was ejected.

**Conclusions:** The chronologic data from NWA 773/3170/6950 and 7007 suggest a genetic link amongst group members, and establish that both the magnesian and ferroan olivine gabbros formed at similar times. The data further suggest that the target region on the Moon that yielded these specimens had 3.95 Ga and 3.1 Ga terranes in close proximity to each other. Further isotopic work is underway by the authors to understand potential petrologic links among NWA 773 clan members.

**Acknowledgements:** Special thanks to Ted Bunch for providing the thin section of NWA 773 used in this study. Funding provided by NASA Cosmochemistry Grant (TJL) and NLSI (TJL).

**References:** [1] Bunch et al., (2006) *LPSC XXXVII* #1375, [2] Zeigler et al., (2006) *LPSC XXXVII* #1804, [3] Weisberg et al., (2008) *Met. Bull.* 94, *MAPS* 43, 1551-1588. [4] Kuehner et al., (2012) *LPSC XVIII* #1519 [5] Fagan et al., (2003) *EPSL*, 38, 529-554. [6] Heaman et al., (2009) *Chem. Geol.*, 261, 43-52. [7] Paces and Miller, (1993) *JGR*, 98, B8, 13997-14018. [8] Slama et al., (2008) *Chem. Geol.*, 249, 1-35. [9] Shaulis et al., (2010) *G<sup>3</sup>*, 11, Q0AA11. [10] Borg et al., (2009) *GCA*, 73, 3963-3980. [11] Shaulis et al., (2012) *LPSC XVIII* #2236. [12] Zhang et al., (2011) *MAPS*, 45, 1929-1947. [13] Schoene et al., (2006), *GCA*, 70, 426-445. [14] Nyquist et al., (2009) *MAPS*, 44, A159. [15] Burgess et al., (2007) *LPSC XXXVIII* #1603. [16] Fernandes et al., (2003) *MAPS*, 38, 555-564.

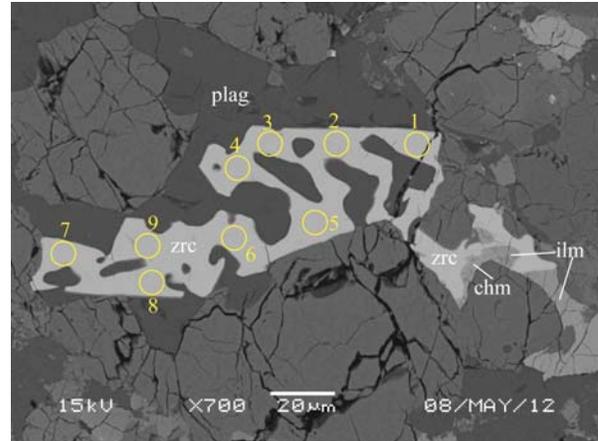


Figure 3 - BSE image of the large zircon found in the breccia lithology of NWA 773. Yellow circles represent individual laser spots (10 µm). [plag - plagioclase, zrc - zircon, chm - chromite]

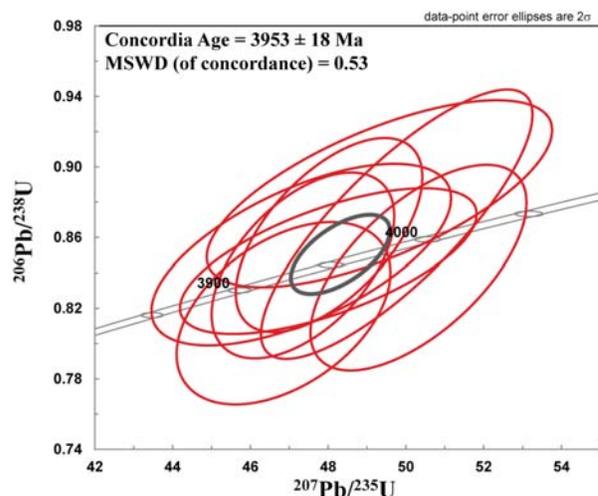


Figure 4 - U-Pb concordia plot of nine zircon analyses from NWA 773.

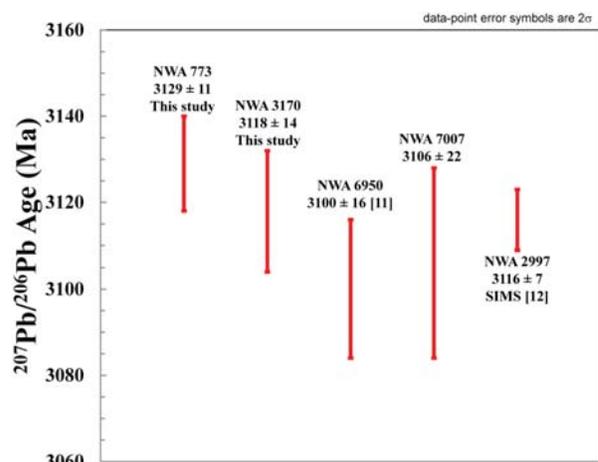


Figure 5 - Pb-Pb age comparison among NWA 773, 3170, 6950 [11], 7007 and 2977 [12].