TESTING PETROGENETIC RELATIONSHIPS OF THE LUNAR NWA773 METEORITE CLAN WITH NICKEL & COBALT IN OLIVINE. K. E. Gibson, B. L. Jolliff, R. A. Zeigler, R. L. Korotev, Department of Earth and Planetary Sciences and the McDonnell Center for the Space Sciences, St. Louis, Missouri 63130 (kegibson@levee.wustl.edu)

Introduction: Chemical evidence indicates a petrogenetic relationship between the volcanic and cumulate lithologies of Northwest Africa (NWA) 773 and paired meteorites, which we refer to here as the NWA 773 clan. Currently, a total of six stones have been paired with NWA773: NWA 2700, NWA 2727, NWA 2977, NWA 3160, NWA 3333, and Anoual [1]. The NWA773 clan has a unique geochemical signature among lunar meteorites and Apollo samples [2]. These meteorites contain three prominent lithologies; olivine gabbro cumulate (OGC), olivine phyric basalt (OPB), and breccia (Bx). The compositions of all lithologies within the clan have low plagiophile-element concentrations (e.g., Na, Eu, Sr), an enrichment of light rare earth elements (REE), and a high Th/REE ratio [5]. The OPB clasts in these meteorites have very low Ti (VLT) compositions. The unique geochemical signature suggests the lithologies are related and share a common source, which has been hypothesized to be similar to the Apollo 14 green volcanic glasses [3,4,5].

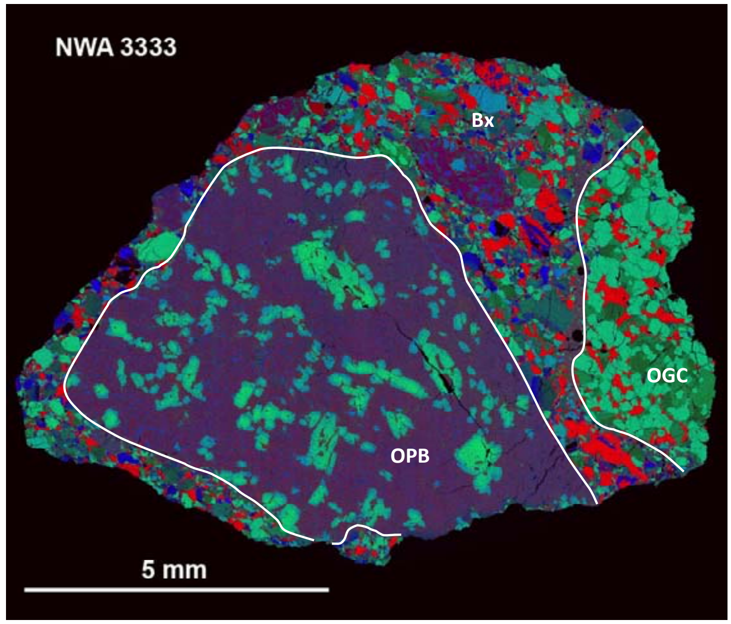

Figure 1: In this x-ray composite image made with the electron microprobe, red represents aluminum, green, magnesium, and blue, iron. A glassy impact-melt vein with several large vesicles cuts through the breccia on the right side. Bx=Breccia, OPB=Olivine Phyric Basalt, OGC=Olivine Gabbro Cumulate

In this abstract, we test the apparent petrogenetic relationships using bulk compositions and compositions of olivine phenocrysts in OPB and cumulus olivine in OGC, including high precision electron microprobe analyses of Ni and Co.

Methods: Electron-probe microanalysis (EPMA) was performed on the Washington University JEOL JXA-8200 microprobe. Ni and Co concentrations were measured simultaneously using LiF and LiFH WDS with summed intensities using the Probe for EPMA aggregate intensity method. Measurements were made with a 150 nA probe current. Standards included synthetic fayalite, Ni-olivine, Corning 95IRW and 95IRX glass, Co metal, and natural standards San Carlos and Boyd olivine. Corrections for peak overlap of Fe kβ on Co kα and Co kβ on Ni kα were included.

OPB: In this abstract, we report on basaltic clasts in three of the four NWA 773 clan members which contain the OPB lithology. The basalt lithology is a VLT olivine phyric basalt (lithic clasts average 0.86 wt% TiO_2), best exemplified by a 7x7 mm clast in NWA 3333 (Fig. 1). In NWA 3333 the OPB clast contains ~16 vol. % olivine phenocrysts, many of which exhibit variation in Mg/Fe between cores and rims. Zoned olivine phenocrysts reach a few mm in length. Olivine also occurs as spinifex-textured crystals in areas of relatively coarse groundmass and as equant to acicular and dendritic grains in areas of fine-grained groundmass, along with pyroxene, plagioclase, and mesostasis. Chromite forms small equant grains ~10 µm or less, and are found as inclusion within the olivine phenocrysts.

NWA 2727 and NWA 3160 OPB clasts vary in the groundmass texture from the OPB lithic clast in NWA 3333. NWA 2727 and NWA 3160 have spinifex-textured and hopper olivine crystals randomly oriented with skeletal pyroxene and plagioclase in the interstices of the olivine. In addition to the lithic OPB clast in NWA 2727, there is a basaltic vitrophyre.

Olivine generations: The OPB clast contains distinct generations of olivine, consistent with textural relationships. Zoned phenocrysts have the most magnesian cores (~Fo_{73}) (Fig. 2) and get progressively richer in iron towards the rims (~Fo_{56}). Smaller phenocrysts average Fo_{54}. In matrix olivine compositions, Fe-enrichment extends to Fo_{36}.

Nickel and Cobalt Systematics: Ni and Co were measured in olivine in the OPB and OGC lithic clasts. In OPB, Ni and Co concentrations in Mg-rich phenocryst cores are ~400-500 ppm (Ni) and 50-100 ppm (Co), and Ni decreases toward the rims within zoned phenocrysts (Fig. 2). Cobalt concentrations are less systematic than Ni and, on average, remain roughly constant throughout zoned phenocrysts, but appear to decrease slightly in matrix olivine. The flat Co pattern in olivine can be explained as a balance between an increasing D_{Co} during crystallization with a depletion of cobalt in the melt [9]. The ratio of Co/Ni in the olivine in OPB increases with crystallization. The Ni and Co trends are consistent with expected behavior during fractional crystallization [9,10]. Core Ni values are high in OPB compared to those in OGC (~200 ppm Ni). In addition to higher Ni content, the OPB cores have a higher Mg # (avg. 0.72) than the OGC olivine (Mg # avg. 0.68).

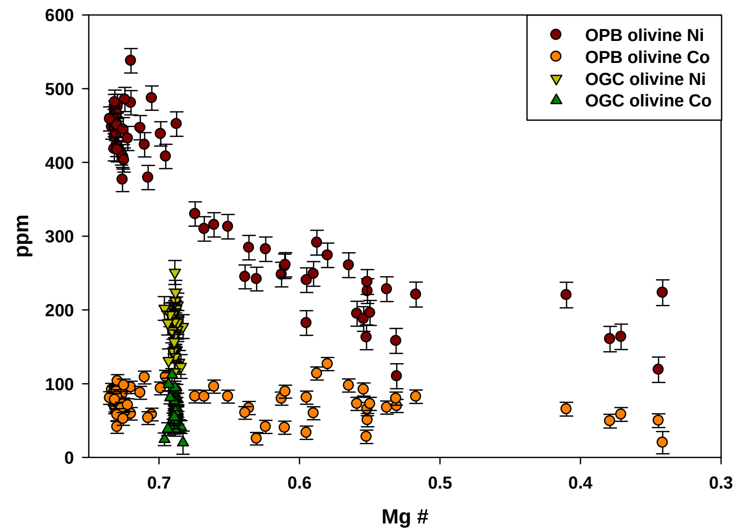

Figure 2: Ni and Co concentrations (ppm) in OPB and OGC olivine grains in NWA 3333 plotted versus Mg# (Mg/(Mg+Fe)). There is a prominent correlation of nickel decreasing with increasing Mg# in the OPB olivine.

Jolliff et al. [3,4] suggested that Apollo 14 green glass B1 (Ni: 185 ppm, Co: 54 ppm [11]) could be a potential parent melt for the petrogenesis of OPB and OGC. Equilibrium crystallization and Rayleigh fractionation calculations were made using the constraints of the previously mentioned model [3,4] and the Ni and Co concentrations in the olivine analyses from OPB and OGC. The calculations indicate the common melt capable of deriving OPB and OGC would have lower Ni content (70-90 ppm) than the Apollo 14 green glass B1. Measured Ni concentrations in phenocrysts in OPB in NWA 3333 are consistent with a D_{Ni} of ~8, which is in the family of lunar distribution coefficients for Ni in olivine [12]. The cumulus olivine in OGC has lower Ni concentrations than would be the case if the Apollo 14 green glass composition was the parent melt. The highest concentrations of Ni in OGC olivine are in the range 200-260 ppm, so if we take the concentrations in OGC olivine to represent equilibrium with the body of melt from which they crystallized, then the melt would have lower Ni and similar Co concentrations than the OPB parent melt.

Apollo 14 green glass compositions range in Ni concentration from 115–185 ppm and Co from 57–111 ppm [11]. Apollo 15 green glass has lower Ni (90-170 ppm) and lower cobalt (41-71 ppm) concentrations than Apollo 14 green glass [11]. The lower Ni content in Apollo 15 green glass is closer to the concentration required for a potential parent melt of OPB. However, the major-element concentrations (including Mg/Mg+Fe) are more consistent with a parent melt similar to Apollo 14 green glass [3,4].

Conclusions: Results of this study support the conclusion [4] that OPB is likely to represent derivation from a similar but more primitive parent melt than that of OGC. The olivine in the OPB has prominent zoning of Fe and Mg, which is consistent with petrography. The concentrations of Ni and Co in olivine in the olivine-phyric basalt and olivine gabbro cumulate indicate a parental melt for the basaltic lithologies with a lower Ni content than Apollo 14 green glass B1.

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References: [1] Weisberg, M.K. et al. (2008) *Meteoritics & Planet. Sci.*, 43, Nr9, p. 1551-1588. [2] Korotev, R. L. et al. (2002) *Meteoritics & Planet. Sci.*, Abstract #5259. [3] Jolliff, B.L. et al. (2003) *Geochimica*, 67, 4857-4879. [4] Jolliff, B.L. et al. (2007) *LPS XXXVIII*, Abstract #1489. [5] Zeigler, R. A. et al. (2007) *LPS XXXVIII*, Abstract #2109. [6] Fernandes et al. (2003) *Meteoritics & Planet. Sci.*, 38, Nr 4, p. 555-564. [7] Borg et al. (2004) *Nature*, 432, p. 209-211. [8] Burgess, R. et al. (2007) *LPS XXXVIII*, Abstract #1603. [9] Papike et al. (1999) *Amer. Min.*, 84, p. 392-399. [10] Herd, et al. (2009) *Amer. Min.*, 94, p. 244-255. [11] Shearer, C.K. and J.J. Papike (1993) *Geochimica*, 57, p. 4785-4812. [12] Shearer, C.K., et al. (2006) *Reviews in Min. and Geochem.*, 60, p. 365-518.