CLUES TO THE ORIGIN OF GABBROIC LUNAR METEORITE NORTHWEST AFRICA 5000.

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Introduction: Northwest Africa 5000 (Fig. 1), the largest lunar meteorite found so far at ~11kg, was recovered in Morocco in 2007 by Tony Irving [1]. It is a feldspathic gabbroic polymict breccia sample composed of mostly plagioclase, pyroxene and lesser olivine, with kamacite (Fe-Ni alloy), merrillite, ilmenite, chromite, baddeleyite, troilite and K-feldspar as accessory minerals [1]. Here we present major and trace element concentration data for mineral separates that were prepared by Amy Gaffney and Lars Borg. These separates consist of magnetic fractions of 100-200 and 200-325 mesh size obtained from ~1g of the meteorite. Representative minerals were handpicked from each split under binocular microscope, mounted in epoxy, then polished with diamond paste and carbon coated for electron imaging and quantitative microbeam analyses.

Previous petrographic observations of NWA 5000 show evidence of impact melt: most coarse grained gabbroic clasts as well as the less abundant black vitreous clasts contain metal grains (up to 4mm) whereas other gabbro clasts are injected with shock veins composed of glass, troilite and mineral fragments [1]. Siderophile element compositions of the larger metal grains indicate meteoritic contamination of the main gabbroic lithology and suggest that “the dominant gabbroic lithology in NWA 5000 was a product of large-scale impact melting” [2]. As lunar meteorites may sample regions of the Moon that are distant from the Procellarum-KREEP terrane, which was over-sampled by the Apollo missions, the composition and crystallization age of NWA 5000 should provide additional constraints on lunar impact history and crustal compositions.

Fig 1. Photograph of ~4mm long chip of NWA 5000

Mineralogy and Major Element Compositions. Backscattered electron (BSE) images were obtained for every grain and quantitative Energy Dispersive X-ray Spectroscopy (EDS) data were obtained for a selection of grains. The grains were mostly Ca-rich plagioclase (An_{92-96}) and clinopyroxene (augite and pigeonite, $Wo_{9-43}En_{42-67}Fs_{11-24}$), with a smaller amount of low-Ca pyroxene ($Wo_{3-5}En_{71-74}Fs_{22-26}$). One grain was a clinopyroxene with low-Ca pyroxene exsolution, and a low-Ca pyroxene had exsolution of clinopyroxene. Other phases include olivine (Fa_{25-31}), phosphate, troilite, and chromite. Many grains show petrographic evidence of shock such as finely dispersed inclusions of sulfide and metal, and clastic textures (Fig. 2).

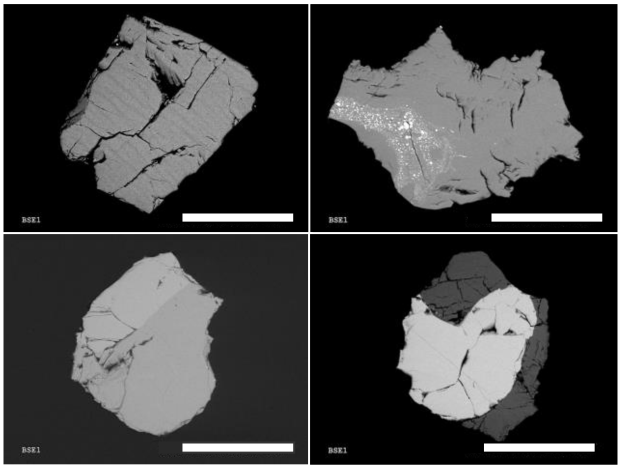

Fig 2. BSE images, from top left corner, clockwise: cpx with exsolution of low-Ca px; plagioclase with shock vein; mixed grain of cpx and olivine (darker grey); phosphate and troilite (light grey). Scale bar is 100 µm

Co-existing compositions of low-Ca pyroxene and plagioclase show that NWA 5000 has mineral compositions that span the gap between the Mg-suite and the Ferroan Anorthosite suite (Fig. 3). Similar compositions are often found in lunar granulitic breccias and feldspathic lunar meteorites [3]. By comparison with recently studied lunar melt rock 67955, which yielded a crystallization age of 4.2 Ga [4], NWA 5000 has somewhat more calcic plagioclase and more ferroan pyroxene.

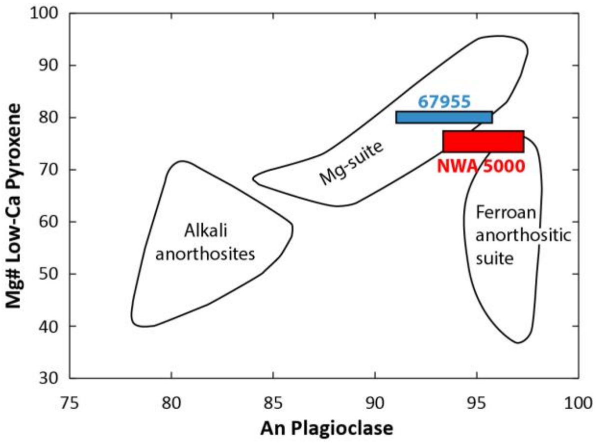

Fig 3. Mg# of low-Ca pyroxene vs. An content in plagioclase of NWA 5000 compared to igneous lunar highlands rock suites [5] and Apollo 16 lunar melt rock 67955 [4]

Trace Element Compositions. Trace element concentrations were obtained on plagioclase, pyroxenes and olivine by laser ablation ICPMS using the procedure described by [4]. Figure 4 shows a diagram of Sr/Ba vs La (ppm) for NWA 5000 plagioclase compared to plagioclase from 67955 [4]. The NWA 5000 plagioclase has generally lower concentrations of highly incompatible elements like Ba and La, and higher Sr/Ba ratios compared to 67955.

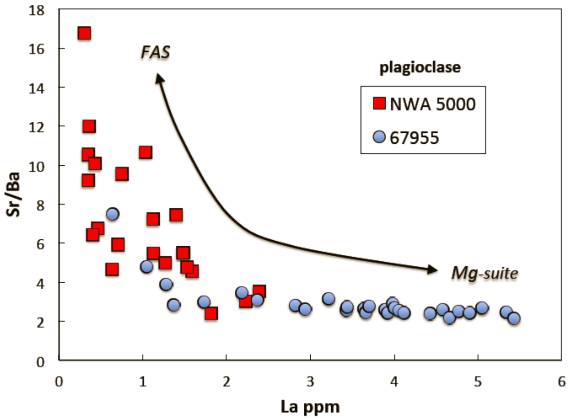

Fig 4. Sr/Ba vs La (ppm) in NWA 5000, compared to 67955 [4] affiliated to the Mg-suite.

Because plagioclase from Ferroan Anorthosite suite rocks tend to have higher Sr/Ba (typically >10) and low La contents (typically <1 ppm) relative to plagioclase from Mg-suite rocks [4], we interpret the NWA 5000 data as indicating a greater proportion of lithologies compositionally similar to Ferroan Anorthosite suite in this meteorite compared to 67955, which is interpreted as crystallizing from a KREEP-rich parental impact melt [4].

Interestingly, however, NWA 5000 also contains abundant high-Ca pyroxene, which distinguishes it from the more noritic affinities of typical FAS rocks. A variety of previous studies have shown that gabbroic lithologies are more abundant in the lunar highlands than implied by the typical mineralogy of FAS rocks [e.g., 6-9], although some trace element-enriched varieties of FAS do contain relatively abundant clinopyroxenes (e.g., noritic anorthosite clasts in North Ray crater breccias such as 67016 and 67215 [10-11]).

Further Work: Mineral fractions are being prepared for isotope (Rb/Sr and Sm/Nd) analyses. Preliminary results will be presented during this conference.

References: [1] Irving A. J. et al. (2008) 39th LPSC, Abstract #2168. [2] Humayun M. and Irving A. J. (2008) Goldschmidt Conference Abstract A402. [3] Gross et al. (2014) EPSL 388, 318-328. [4] Norman M. D. et al. (2016) GCA 172, 410-429. [5] Warren P. H. (1993) Am. Mineral. 78, 360-376. [6] Pieters C. M. (1986) Rev. Geophys. 24, 557-578. [7] Lucey P. G. and Hawke B. R. (1988) Proc. 18th LPSC, 355-363. [8] Tompkins S. and Pieters C. M. (1999) MAPS 34, 25-41. [9] Ryder G. et al. (1997) GCA 61, 1083-1105. [10] Norman M. D. et al (1995) GCA 59, 831-847. [11] Norman M. D. et al. (2003) MAPS 38, 645-661.