TRACE ELEMENT GEOCHEMISTRY OF A LUNAR GRANULITE: EVIDENCE FROM NORTHWEST AFRICA 3163. J. T. Shafer[1,2], A. D. Brandon[1], T. J. Lapen[1], A. H. Peslier[3], A. J. Irving[4] [1]University of Houston, Dept. of Earth and Atmospheric Sciences, Houston TX, 77204, USA, [2]Lunar and Planetary Institute, Houston TX, 77059, USA, [3]Jacobs Technology, ESCG, Mail Code JE23, Houston TX, 77058, USA, [4]University of Washington, Dept. of Earth & Space Sciences, Seattle WA, 98195.

Introduction: Northwest Africa (NWA) 3163 is a feldspathic lunar meteorite that may be an example of nearly pristine lunar crust. NWA 3163 is likely a genomict breccia (i.e., composed of lithic fragments that are genetically related) and is contaminated only by a minor meteoritic component as evidenced by highly siderophile element concentrations (~2 ppb Ir [1]). NWA 3163 is unique amongst lunar meteorites by having low incompatible trace element concentrations (ITEs) (e.g., ~0.04 ppm Th, ~0.4 ppm Sm) and being relatively mafic and ferroan (~5.8 wt.% FeO) [1].

Shock History: Plagioclase has been nearly completely converted to maskelynite although domains of birefringent plagioclase remain [1]. We examined a polished slab of NWA 3163 with BSE images and we were unable to precisely determine if all of the plagioclase was converted into maskelynite in our sample. However, textural evidence supporting conversion into maskelynite includes the absence of cleavage and intragranular cracks, melting of pyroxene and olivine as schlieren in maskelynite (Fig. 1), and lack of chemical zoning. Furthermore, some highly fractured mafic phases have cracks filled with maskelynite (Fig. 2) and there are fragments of mafic silicates "floating" in maskelynite. These detached fragments may have been derived from neighboring mafic silicates. Cracks filled with maskelynite are often found with cracks not filled by maskelynite (Fig. 2), which suggests multiple impact events may be recorded. This supports the interpretation of [1] that the maskelynization event was related to much earlier impacts than the ejection event. Melting of plagioclase to form maskelynite and localized impact melt veins seen in the hand sample [1] indicate peak shock pressures in excess of 45 GPa [2,3].

Methods: Major element concentrations of mineral phases in a polished slab of NWA 3163 were determined via electron probe micro analysis (EPMA) at the NASA-Johnson Space Center. ITE concentrations of the same phases were determined by *in situ* laser ablation ICP-MS (LA-ICP-MS) using major element concentrations as internal standards at the University of Houston. These are the first *in situ* laser ablation ITE results for this meteorite.

Results: In general, there is little variation in major element concentration in the dominant mineral phases and our results are consistent with [1]. No melt

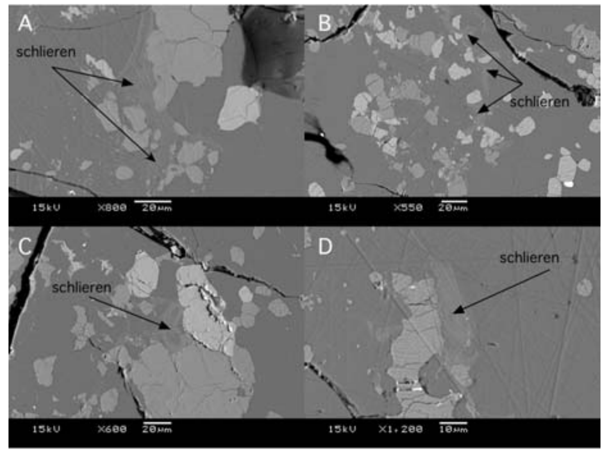

Figure 1: Schlieren of pyroxene and olivine within maskelynite, indicating melting of mafic phases during conversion of plagioclase to maskelynite.

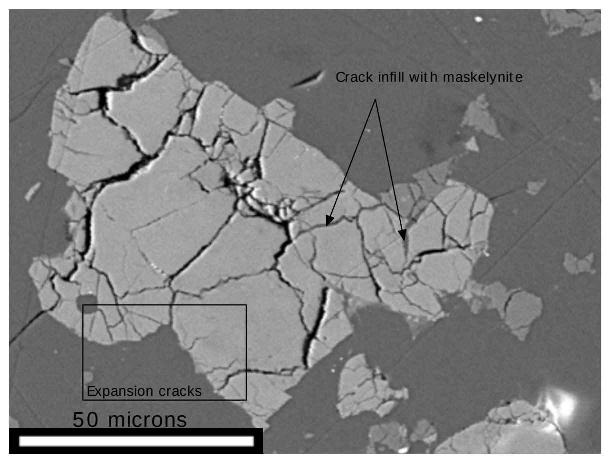

Figure 2: Fractured olivine crystal. Maskelynite fills some cracks indicating melting of plagioclase. Other cracks are not filled, which indicates multiple impact events are being recorded.

glass globules or agglutinates were observed in our slab.

Trace element concentrations determined by LA-ICP-MS also show very limited variation between individual crystals. The overall major and trace element systematics of the major phases in NWA 3163 suggest that groundmass olivine and pyroxene are from the same source rock as the larger, more heavily fractured olivine and pyroxene mineral clasts. Maskelynite shows very little trace element variation, which again indicates homogenization due to metamorphism or shock melting. REE profiles of the maskelynite, olivine, pigeonite, and augite are shown in Fig. 3.

Our slab of NWA 3163 is composed primarily of maskelynite, pyroxene (~90% pigeonite), and olivine with minor oxide phases. Importantly, our slab does not contain minor phases such as phosphate minerals that are rich in REE and Th. Therefore, the bulk rock composition can be estimated by performing a modal recombination using the trace element composition of maskelynite, pyroxene, and olivine (Fig. 3). REE and other incompatible trace elements should be well estimated by this technique (Fig. 4). Metal and oxide compatible elements like Cr, Ti, and Ni, however, are strongly influenced by the estimated modal abundance of oxides. Our slab may not have representative abundances of oxides compared to the whole meteorite.

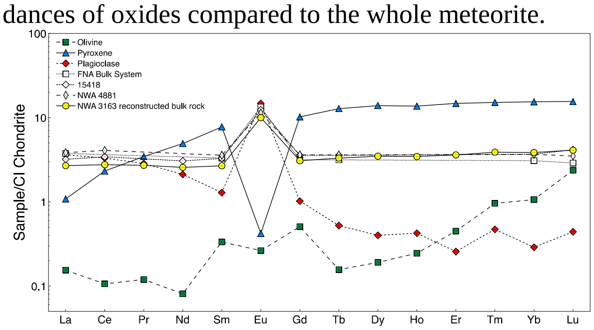

Figure 3: LA-ICP-MS REE composition of major mineral phases, reconstructed bulk rock composition based on modal proportions, and a comparison of NWA 3163 to sample 15418, paired sample NWA 4881 [9], and the proposed FNA system bulk of [6].

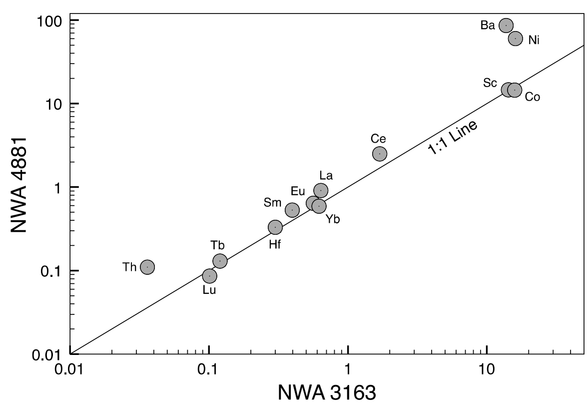

Figure 4: Correlation diagram of NWA 3163 constructred bulk rock vs. measured bulk of paired sample NWA 4881 [9] in ppm. In general, a good 1:1 correlation is observed for REE, Sc, and Co. Ba and Ni are higher in NWA 4881 most likely due to lack of terrestrial contamination and non-modal oxide distribution in NWA 3163. Low Th concentrations in NWA 3163 vs NWA 4881 may be due to small Th rich clasts present in NWA 4881 that were not in our slab of NWA 3163.

The homogeneous incompatible trace element concentrations indicates that NWA 3163 is composed of lithic and mineral fragments from a suite of genetically related anorthositic gabbro/norite and gabbroic anorthosites.

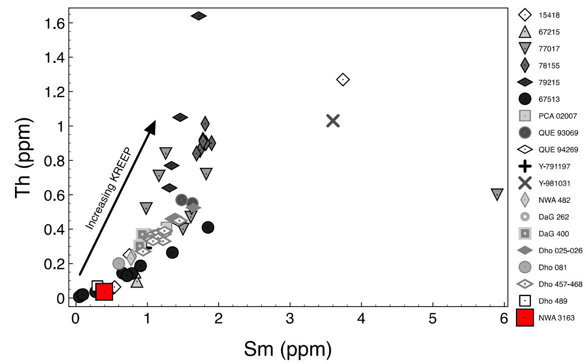

Figure 5: Discrimination plots showing unique composition of NWA 3163 compared to other FLM. Meteorite and Apollo data from multiple sources, many of which can be found in [12].

Origin of NWA 3163: The low Th and REE concentrations (Fig. 5) indicate that NWA 3163 originated far from the Procellarum KREEP terrain. Pyroxene equilibration temperatures and the observed granulitic texture argue for a deep origin, perhaps in excess of 50 km [1,7]. This interpretation is in contrast to the contact metamorphism hypothesis of lunar granulite formation [10, 11].

The lack of regolith melt glass and agglutinates, homogeneous mineral major and trace element concentrations, and relatively low meteoritic siderophile contamination suggest that the NWA 3163 source rock formed deep in the lunar crust and that the brecciation event largely occurred in situ. At least for NWA 3163, these characteristics suggest burial metamorphism rather than contact metamorphism from impact-melt sheets or ejecta blankets.

Exposure to the surface and resulting ejection may have occurred due to serial impacts slowly exposing deeper sections of the crust or in a single larger basin forming impact. NWA 3163 is likely from the farside of the Moon, away from potential KREEP and mare basalt contamination and likely represents the same source as the FNA suite proposed by [1] (Fig. 3).

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