NEGATIVE EU ANOMALIES IN PLAGIOCLASE: KREEP-LIKE CONTAMINANT OF IMPACT MELT? A. L. Fagan[1] and C.R. Neal[2], [1,2]Dept of Civil Engineering and Geological Sciences, University of Notre Dame, Notre Dame, IN, 46556, USA (abacasto@nd.edu; neal.1@nd.edu).

Introduction: Igneous-textured basaltic samples from the Apollo 16 (A16) site are considered to be impact melts of lunar highlands target rocks due to their high alumina and calcium contents (~25-28 wt% Al2O3; 14-17 wt% CaO), reflected in high modal abundances of plagioclase. This study uses crystal stratigraphy in order to understand the petrogenesis of these unique impact melts by focusing on individual analyses of plagioclase and pyroxene crystals. 18 impact melts from the A16 site were examined to study their crystallization conditions. This study has uncovered a unique phenomenon amongst a portion of the plagioclase populations in 5 samples (Table 1), namely plagioclase REE profiles that display a *negative* Eu (-Eu) anomaly (Fig 1). Sample 60635,2 is the focus of this study because of the large amount of plagioclases with a -Eu (Table 1, Fig 1).

Parent	Thin Sec #	Neg Eu	Pos Eu
60235	5	1	16
60335	13	1	19
60618	3	4	15
	4	7	17
60635	2	34	28
64817	3	1	15

Table 1. Samples containing anomalous plagioclase compositions and the total number of analyses with negative and positive Eu anomalies.

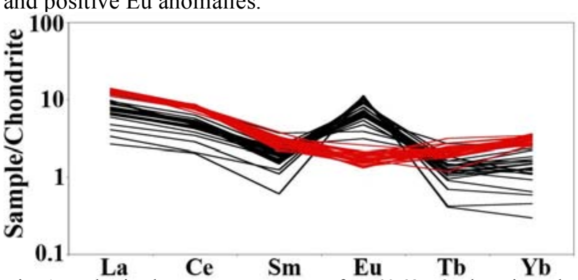

Fig 1. Plagioclase REE patterns for 60635,2 showing the prevalence of analyses displaying a negative Eu anomaly.

Sample 60635 is a coarse-grained, subophitic impact melt with anorthite laths and interstitial pyroxene [1]. Olivine is absent, but traces of ulvospinel, troilite, and K-feldspar have been identified [3]. Previous studies have classified 60635 as a slow-cooling Anorthositic Noritic Melt Rock (ANMR, [1-2]) with a KREEP-free precursor [4]. Among a larger set of A16 impact melts, 60635 is part of compositional Group 3, which has lower absolute incompatible trace element abundances than Groups 1 & 2 [2].

Methods: *Mineral Analyses:* Major element mineral analyses were conducted using a JEOL JXA-8200 electron microprobe (EMP) at Washington University in St. Louis, MO with a 5 µm spot size and a 30s on-peak counting time. Calcium abundances obtained by EMP were used as the internal standard for laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) analyses to determine trace element abundances in both plagioclase and pyroxene crystals; NIST SRM 612 glass was used as the extermal standard for both phases. LA-ICP-MS analyses were conducted at the University of Notre Dame using a New Wave UP-213 laser ablation system and a ThermoFinnigan Element2 ICP-MS, with a repetition rate of 5 Hz and a corresponding fluence of ~17-18 J/cm^2. All pyroxene crystals were ablated using a 40 µm spot size, while spot sizes for plagioclase crystals ranged 40-65 µm depending on crystal size. Elemental abundances were determined using *GLITTER* © software.

Whole Rock Analysis: Previous studies [1-2] have conducted whole rock analyses on 60635 using Instrumental Neutron Activation Analysis (INAA) that defined a slight negative Eu anomaly in the REE profile. Given the dominance of plagioclase in the sample, it is rather surprising that the whole rock analyses do not show a strong *positive* Eu (+Eu) anomaly. Major element data are being determined via solution using ICP-Optical Emission Spectrometry at the University of Notre Dame's Center for Environmental Science and Technology and trace elements via solution mode ICP-MS using the methods in [5].

Results: *Mineral Phase Analyses:* The average Anorthite content of the plagioclase crystals is 97.2% with a minimum of 94.4% and a maximum of 97.8%. Although some crystals display differences amongst each other with regards to their trace element compositions, the major elements appear basically indistinguishable indicating crystallization from a relatively homogeneous melt and/or cooling was slow enough to allow major element equilibration across crystals. Some plagioclase crystals contain only +Eu REE patterns, some only –Eu REE patterns, and some contain + ***and*** –Eu anomalies (Fig 2) from different locations in the crystal.

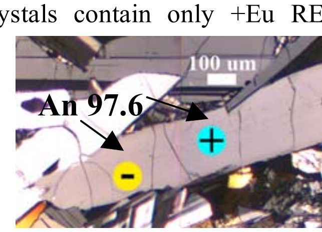

Fig 2. XPL image of 60635,2 plagioclase with - & + Eu anomalies, but with identical An content.

For major elements, 60635,2 plagioclase analyses, including those with –Eu anomalies, are not distinct from the rest of the A16 impact melt population (Fig 3). Similarly, atypical plagioclase crystals from the other anomalous samples (Table 1) are also indistinguishable from the rest of the A16 plagioclase population in major elements. Although lunar plagioclase REE profiles typically display a positive Eu anomaly, approximately half of the crystals from 60635 display a negative Eu anomaly for at least one datapoint and show an enrichment in the light- and heavy-REE in comparison to more typical profiles (Fig 1).

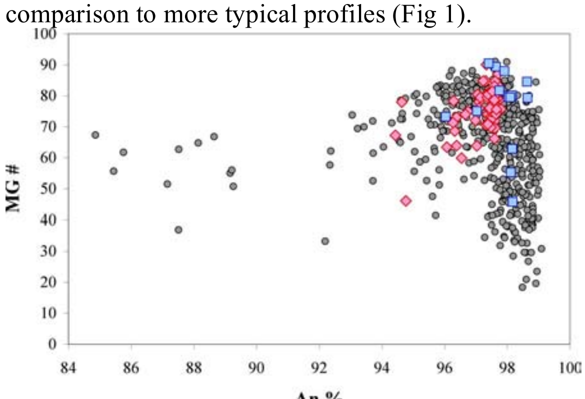

Fig 3. Plagioclases with -Eu from 60635 (red diamonds) and other A16 samples from Table 1 (blue squares) are indistinguishable from the rest of the A16 impact melt population (black circles).

Pyroxene crystals from 60635 are augite and pigeonite (MG#: 57.0-80.6, avg 69.4), but are also indistinguishable from pyroxenes from the rest of the A16 impact melt population (Fig 4a). Similarly, pyroxenes from 60335,13 and 64817,3 are indistinguishable from the bulk population; other anomalous samples do not contain pyroxenes. Pyroxene REE profiles span a wide range and the sub-parallel profiles (Fig 4b) are suggestive of crystal fractionation.

Mixing Models: Lunar plagioclase containing negative Eu anomalies must have crystallized from melts with a strongly negative Eu anomaly. This is consistent with a KREEP influence, but such an influence is not seen in Sr isotopes. We have conducted various liquid (liquids calculated via method in [6], although Yb could not be modeled) mixing models to account for the presence of REE patterns with –Eu anomalies. We suggest that by incorporating a contaminant of quartz-monzogabbro (QMG [7]) or a whitlockite-rich-QMG (W-QMG [7]), which are forms of KREEP, the solidification of plagioclase crystals with –Eu anomalies is possible. Here we show the two most likely scenarios to date of 70% Anorthosite +30% QMG or 90% Anorthosite +10% W-QMG (Fig 5). Modeling that incorporate other trace elements are ongoing as is modeling of the whole-rock Sr isotope composition.

Conclusions: The –Eu phenomenon shown by A16 impact melt plagioclases can be produced by incorporating a low-melting point KREEP contaminant such as (W-)QMG, assimilated when the impact melt was crystallizing. It also demonstrates the potential for an intricate evolution of impact melts after their formation, which is only seen at the crystal scale.

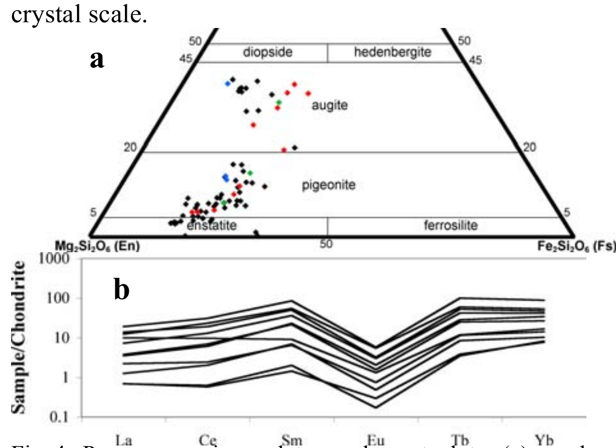

Fig 4. Pyroxene major and trace element plots: (a) quad plot for 60635 (red); 60335,13 (blue); 64817,3 (green); and all other A16 impact melts in this study (black); (b) subparallel REE patterns from 60635.

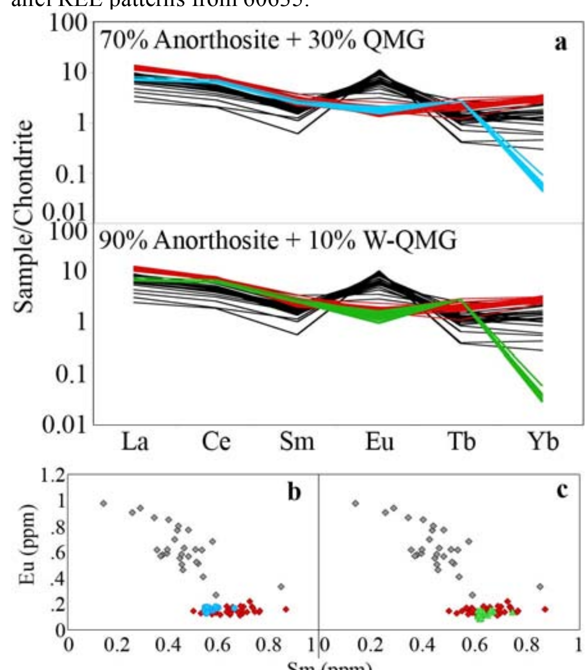

Fig 5. Model results for plagioclase crystallization (a) REE patterns of modeled crystals (blue and green); (b) crystals (blue) modeled with 70:30 Anorthosite:QMG and (c) crystals modeled with 90:10 Anorthosite:W-QMG. Actual analyses are also shown.

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References: [1] A. Deutsch & D. Stoffler (1987) *GCA, 51*, 1951-1964. [2] R.L. Korotev (1994) *GCA, 58,* 3931-3969. [3] E. Dowty et al. (1974) *PLPSC, GCA Supp. 5,* 431-445. [4] D. Stoffler. et al. (1985) *PLPSC 15th*, C449-505. [5] A.L. Fagan & C.R. Neal (2012) *LPSC this volume.* [6] I.N. Bindeman et al. (1983) *EPSL, 64*, 175-185. [7] B.L. Jolliff (1991) *PLPSC, 21,* 101-118.