KREEP BASALT 15382: NOT AS PRISTINE AS ORIGINALLY THOUGHT.

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Introduction: KREEP (potassium [K], rare-earth elements [REE], phosphorus [P], and other incompatible trace elements [ITE]), is a chemical component, that has been identified at each sample return site from the Moon. It is thought to be derived from the last dregs of the lunar magma ocean, or urKREEP [1]. KREEP basalts returned from the Moon represent the purest form of KREEP currently available for study. They identified from the Apollo 14, 15 and 17 samples.

KREEP basalts are distinct from mare basalts as they possess a lower Ca/Al ratio reflecting a paucity of high-Ca pyroxene [2]. They are the result of endogenous melting of the lunar interior (e.g. [3]) or by the mixture of KREEP and surrounding lithologies by impact melting (e.g. [4]). Traditionally, highly siderophile element (HSE) abundances were used to differentiate between these two hypotheses (e.g. [5]) but this has not been without issue [6]. Recently, quantitative petrographic methods have been used to determine between the endogenous or impact origins for KREEP basalts and other lunar samples [7,8].

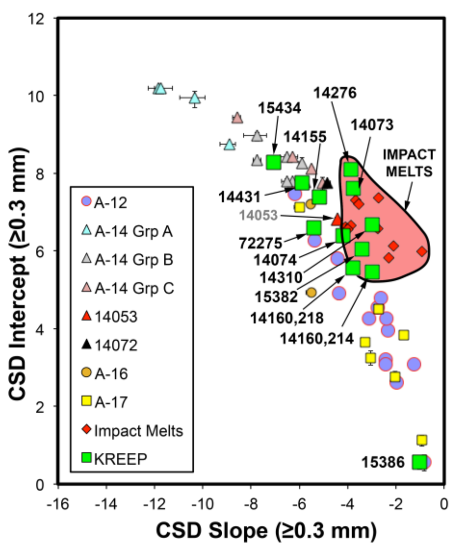

Figure 1: CSD intercept vs. slope of plagioclase for size bins larger than 0.3 mm following the method of [7]

KREEP basalt 15382 stands out as an oddity. When using CSDs to determine between endogenous and impact melts 15382 is consistent with the impact melt field (**Fig. 1**). However, HSE abundances suggest it is a pristine endogenous melt of the lunar interior as it possesses significantly lower abundances of Ir and Au, than that of the pristine KREEP basalt 15386 (**Fig. 2**) [41]. This issue is not without some precedent as 14053 was identified by [7], as being on the border of /within \ the impact melt field (**Fig. 1**), and yet being endogenous according to the HSEs (**Fig. 2**). [7] hypothesized that this was caused by 14053,18 undergoing Oswald ripening (textural coarsening), due to reheating as evidenced by the work of [9]. 15382 is also thought to have been partially re-melted as previous work by [10] found evidence of melting and regrowth on the rims of plagioclase.

Here we will use quantitative petrography, in situ major and trace element analysis, and equilibrium liquids to further evaluate the origin of KREEP basalt 15382.

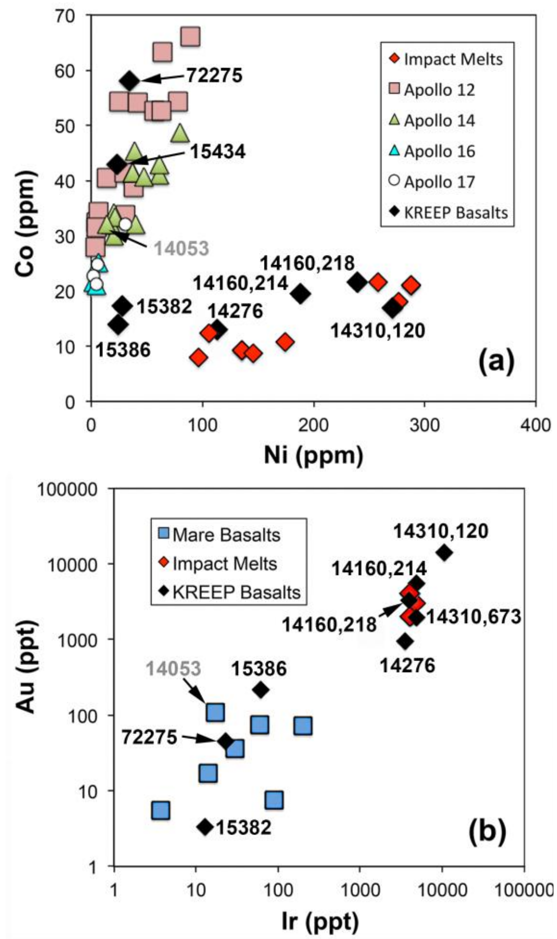

Figure 2: a. Co vs Ni and **b.** Au vs Ir (both HSEs) plot of endogenous and impact generated lunar samples form Apollo 12, 14, 16 and 17. KREEP basalts are labeled, note how 15382 possesses low abundances of both. Data from [11-46]

Methods: Electron Probe Micro Analysis (EPMA) on the samples were conducted using a Cameca SX-50 Microprobe at Notre Dame's Materials Characterization Facility. 70 pyroxene, and 57 plagioclase analyses were conducted.

Trace elements were analyzed using a Thermo Scientific Element 2 high-resolution magnetic sector ICP-MS and a New Wave UP213 laser system at Notre Dame's Midwest Isotope and Trace Element Research Analytical Facility (MITERAC). The NIST 612 glass [47] and Calcium (determined by EPMA) were used as the external and internal standards respectively. Six pyroxenes, and five plagioclase analyses were carried out by LA-ICP-MS.

Equilibrium liquid compositions were calculated using major and trace element data for pyroxene [48,49] and plagioclase [50,51]. Temperature information is necessary for these models to work, following previous work [52] we calculated pyroxene crystallization temperatures using the methods of

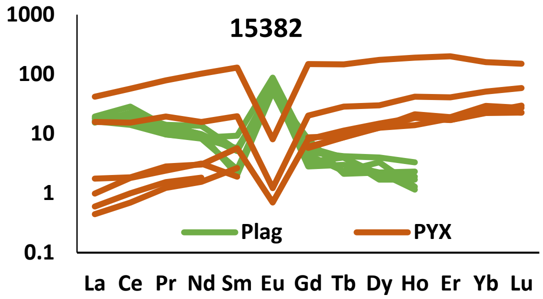

Figure 3: Plagioclase (green) and Pyroxene (brown) chondrite normalized REE data.

[53]. Crystal size distributions (CSD) were produced using the method of [7].

Results: Plagioclase within 15382 is An_{77-88} with an average of An_{84}. Pyroxene varied with regard to Mg# from 41 to 85 with a median value of 75. Chondrite normalized REE profiles are in **Figure 3**.

Discussion: 15382 appears to have undergone limited re-melting as evidenced by its plagioclase as they began to melt and then reform along their edges [10]. Such reheating caused the coarsening of 15382, which would decrease the gradient of the CSD profile [54].

Like the other KREEP basalts 15382's plagioclase equilibrium liquids are uniformly high-K KREEP-like. Pyroxene equilibrium liquids are distinct. There is a single extremely LREE enriched über-KREEPy liquid (Pyx-2 $[Ce/Yb]_N>20$) similar to those found in impact melts (see **Fig. 4**). It is derived from the only rim analysis. Pyx-1 represent a core analysis from the same crystal as Pyx-2. If the equilibrium liquid of Pyx-1 undergoes 80% fractional crystallization (crystallizing 50% plagioclase, 49.8% pyroxene and 0.2% zircon) a similar composition to the rim is produced (**Fig. 5**). 15382 is unique

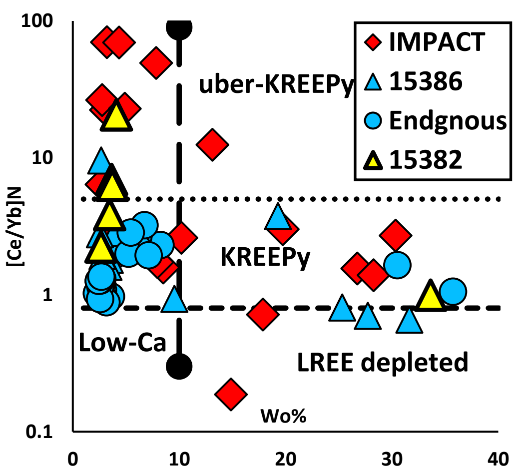

Figure 4: Wo of pyroxenes vs $[Ce/Yb]_N$ of the corresponding equilibrium liquid equilibrium liquid.

in that its über-KREEPy pyroxene equilibrium liquids likely were produced by in situ crystallization of the KREEP basalt flow as it cooled magma, rather than being present at that start of crystallization (unlike those of KREEP basalts formed by impact processes; e.g., [52]).

Conclusion: KREEP basalt 15382,6 is a pristine endogenous melt of the lunar interior before being partially re-melted as revealed by plagioclase textures[10] and the CSD. And is also noted for possessing a uber-KREEPy rim analysis that formed by in situ crystallization.

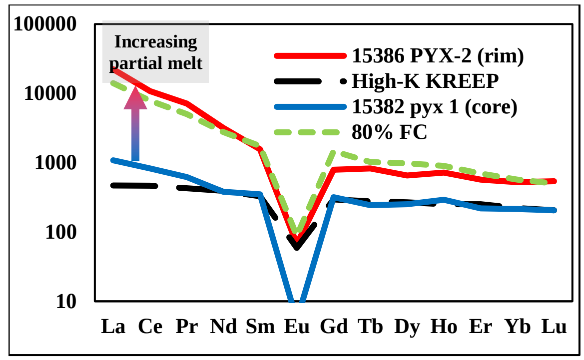

Figure 5: 80% fractional crystallization of 50% plagioclase 49.8% pyroxene and 0.2% zircon of Core composition pyx 1 can reproduce the rim composition pyx 2. High-K KREEP from [55].

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