Mapping 72275,136: Spatial Relationships within a Breccia Containing KREEP Basalts of Distinctive Compositions.

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Introduction: Apollo 17 KREEP basalts are found as clasts within a single polymict breccia 72275. The breccia is made up of angular lithic (largely basaltic) fragments that are poorly sintered together [1]. Clasts within 72275 are diverse and include microbreccias, anorthosite, granites, and pigeonite basalts [1]. KREEP basalt clasts are composed of equal parts pigeonite and plagioclase with minor olivine [1,2], with a matrix of ilmenite, iron metal, a silica mineral, plagioclase, K-feldspar, augite, troilite, and phosphate [1]. Rare-earth-element (REE) profiles of the Apollo 17 KREEP basalts and the breccia are very similar to each other having a La/Yb ratio of 2.16 to 2.48 and La/Sm ratios of ~2.0-2.5 but are distinct from Apollo 14 & 15 KREEP basalts (**Fig. 1**).

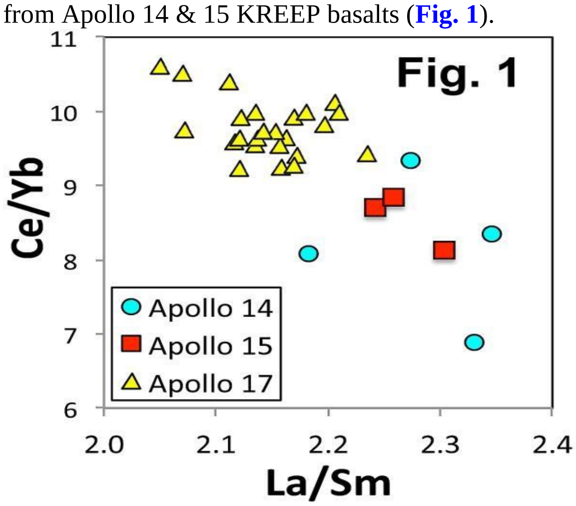

Fig 1: Distinction of Apollo 17 72275 KREEP basalts from those returned by Apollo 14 and 15 based upon whole rock data..

KREEP is a chemical component found in a wide range of lunar materials [4]. Originating as the last ~0.5% of the Lunar Magma Ocean, pure "urKREEP" is not found within the lunar sample collection, but KREEP basalts contain the evolved trace element signature, but relatively primitive major element compositions. KREEP basalts are thought to have formed either by impact melting of lunar surface lithologies or as endogenous melts of the lunar interior. Traditionally, identification of impact melts is made by quantifying the abundances of Highly Sidirophile Elements (HSEs), as they are typically enriched in these elements while endogenous samples are not [5]. Evaluating HSE is not possible on all samples as it requires the destructive analysis of a large quantity of material. Therefore, such analyses are not possible and/or prudent to conduct on low-mass/rare samples. Petrographic methods, both qualitative and quantitative have been used to discriminate impact and endogenous basalts [1,3,6]. KREEP basalts at Apollo 14 are thought to have formed through impact melting [7], whereas those from Apollo 15 and 17 are considered to be endogenous pristine melts of the lunar interior [8,9].

72275,136 is a thin section of a basaltic micro breccia containing several basalt clasts (1-3 mm). The pyroxene, plagioclase, ilmenite, olivine, and mesostasis fragments [1] make up the breccia. Pyroxene (mainly pigeonite) and plagioclase along with minor ilmenite, and rare olivine make up the KREEP basalt clasts (cf. [1,2]). Plagioclase is intergrown with pyroxene in a subophitic texture. Basalt clasts in 72275 are often grouped near each other, and at times, are found as a part of a distinct large brecciated clast (**Fig. 2**) within 72275,136.

Previous work [10] found that the KREEP basalt clasts within 72275,136 are endogenous melts of the lunar interior, and that the pyroxenes are similar in major element composition to 14310,25 and 15434,181. However, only a few pyroxenes were analyzed when compared to the size and number of clasts in 72275,136. In this study high spatial resolution element maps are used to evaluate, qualitatively at first, the major element compositions of 72275,136 and plan future Electron Probe Micro Analysis (EPMA) and in situ trace element analysis to be carried out at the University of Notre Dame by LA-ICP-MS at the Midwest Isotope and Trace Element Research Analytical Center (MITERAC).

Methods: Element maps were made using a Cameca SX-50 at the University of Notre Dame. A 1μm beam at 10kv & 25nA was used. EDS spectra were collected using a scanning electron beam. The EDS spectra & BSE image were recorded as TIFF files using *Hi-view*. TIFF files were imported to *ImageJ* [11] and then made in to multi-element maps.

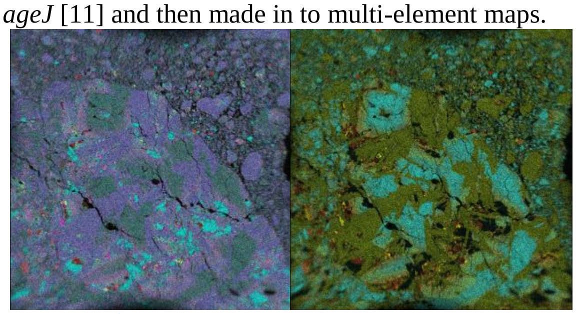

Figure 2: Left RCMY Fe Si Al K. Right RCY Fe Mg Ca.

Results: Two different styles of maps were made. The first Red Cyan Magenta and Yellow (RCMY) was used to identify zoning in feldspars and locate areas of high Si. Red Cyan and Yellow (RCY) identifies shifts in pyroxene compositions.

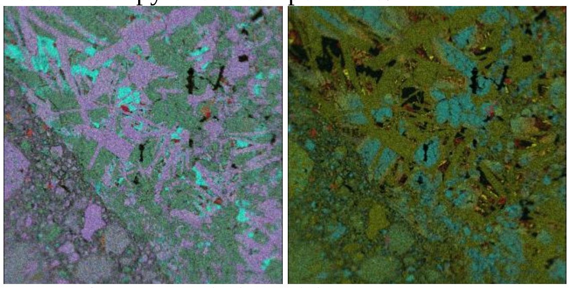

Fig. 3: Left RCMY Fe Si Al Na. Right RCY Fe Mg Ca.

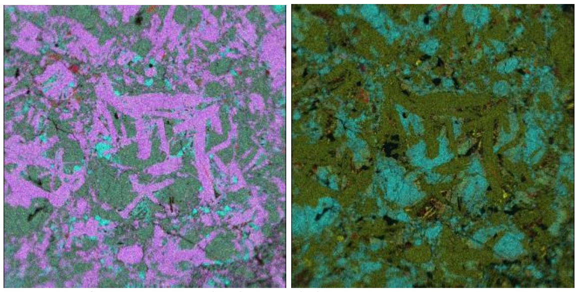

Fig. 4: Left RCMY Fe Si Al Na. Right RCY Fe Mg Ca.

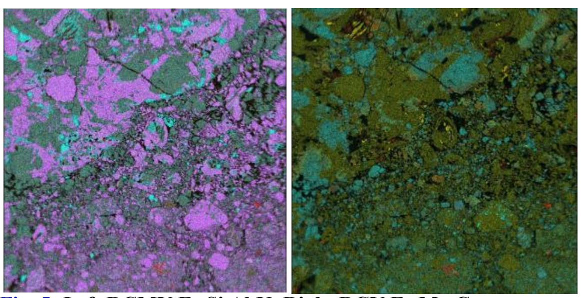

Fig. 5: Left RCMY Fe Si Al K. Right RCY Fe Mg Ca

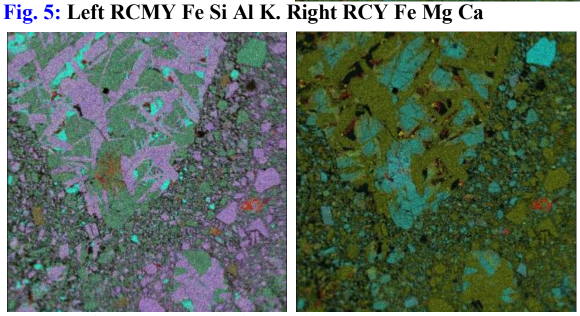

Fig. 6: Left RCMY Fe Si Al K. Right RCY Fe Mg Ca

Using the element maps, qualitative information on mineral compositions can be gathered. Pyroxenes are predominantly Mg-rich with increasing Ca content towards the rim. Pyroxene rims with higher Fe content are less common but are found near iron rich hot spots (**Fig. 2** right). Olivine (where present) is relatively high in Mg, and over grown by Mg-rich pyroxene (**Fig. 6**). Si-rich areas are found in the basalt clasts and within the breccia filling in space between pyroxene and plagioclase. (**Fig 3-6** left). Plagioclase is predominantly An-rich, with little to no Na or K enrichment towards the rims. No significant change in composition is apparent between the basalt clasts and the surrounding breccia

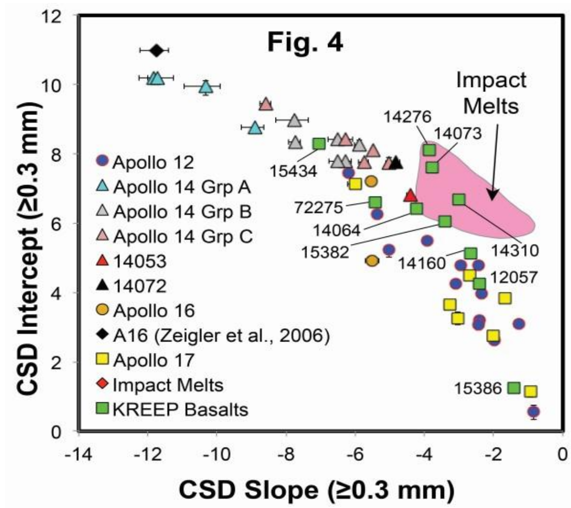

Fig. 7: Plagioclase CSD plot taken from [10] used to differentiate pristine endogenous basalts from impact melts. Green squares = KREEP basalts.

Interpretation: Observations of the basalt clasts and breccias agree with those of [1], the breccia is and basalt clasts are made of the same material. Texturally 72275,136 shares some similarities to 15434,181, both have plagioclase and pyroxene intergrowths, and pyroxene compositions are predominantly Mg-pigeonite with augitic rims. Plagioclase CSD analyses indicate that 72275,136 and 15434,181 are endogenous melts of the lunar interior [9].

References: [1] Salpas P. et al. (1987) PLPSC 17, E340-E348. [2] Ryder et al., 1977 EPSL, 35, 1-13 [3] Ryder G. (1987) PLPSC 17, E331 [4] Warren P.H. & Wasson J.T. (1979) Rev. Geophys. Space Phys. 17, 73-88. [5] Warren P.H. (1985) AREPS 13, 201. [6] Neal C.R. et al. (2015) GCA 148, 62-80. [7] McKay G. et al. (1979) PLPSC 10, 181-205. [8] Cronberger K. & Neal C.R. (2013) LPSC XLIV, abstract 2878 [9] Ryder G. (1976) PLSC 7, 1925-1948. [10] Cronberger K. & Neal C.R. (2015) LPSC XLV, abstract 1298. [11] Rasband WS. *ImageJ*, U.S. NIH, Bethesda, Maryland, USA, imagej.nih.gov/ij/, 1997—2012