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MELT ROCK COMPONENTS IN KREEPY BRECCIA 15205 – PETROGRAPHY AND MINERAL CHEMISTRY OF KREEP BASALTS AND QUARTZ-NORMATIVE MARE BASALTS.

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Many current models for the origin of lunar highland rocks feature as an essential component the assimilation of KREEPy material by primitive magmas parental to the Mg-rich suite and alkali suite plutonic rocks (e.g., [1]). Similar models have also been proposed for the origin of various mare basalt suites [2,3,4,5]. However, any model which considers assimilation of KREEP an important petrologic process must sooner-or-later deal with the question: what is KREEP? Because pristine KREEP basalts are rare, and most known samples are small (e.g., 15382/15386), the geochemical variability of KREEP basalts is poorly known. Other KREEP compositions which are commonly used in these models include the hypothetical "high-K KREEP" component of Warren and Wasson [6], which is derived from Apollo 14 soil data, and the "superKREEP" quartz-monzodiorite 15405 [7].

Lunar breccia 15205 is a polymict regolith breccia that consists of approximately 20% KREEP basalt clasts and 20% quartz-normative basalt clasts in a KREEP-rich matrix [8]. Bulk rock mixing calculations show that this sample comprises about 84% KREEP [9]. The clasts range up to 1 cm in size, but most are considerably smaller. The primary aim of this study is to characterize pristine KREEP basalts petrographically, to establish the range in chemical compositions of KREEP basalts, and to test models that have been proposed for their origin. In addition, we may be able to extend the compositional range recognized in the quartz-normative basalt suite and cast some light on its origin as well. Preliminary whole rock geochemical data on the KREEP basalts are presented in a companion paper by M.M. Lindstrom and co-workers [10]. We concentrate here on the petrography and mineral chemistry of these clasts, and the implications these data have for the origin of the different melt rock suites.

METHODS: Twenty-three rock fragments were extracted from the remaining large subsamples of 15205 in the Pristine Sample Lab at JSC. Six of these represent sample pairs from the same clast, so only twenty unique clasts are represented. Because of their small size (commonly ≤ 5 mm Ø), only sixteen were large enough for whole rock analysis; these data are reported by Lindstrom et al [10]. Twelve fragments representing ten clasts were prepared as polished probe mounts for petrographic examination and mineral analysis. Mineral analyses were carried out on a Cameca SX-50 Electron Microprobe at the University of South Carolina using natural and synthetic mineral standards.

PETROGRAPHY AND MINERAL CHEMISTRY

KREEP BASALTS: Seven of the ten clasts studied here are KREEP basalts characterized petrographically by modes that are rich in plagioclase (~45-50 vol%) compared to typical mare basalts. Dymek et al [8] recognized 5 textural varieties of KREEP basalt in their detailed petrographic study of serial thin sections from 15205, but all the KREEP basalt clasts extracted for this study are (with one exception) medium to coarse-grained basalts with textures that grade from ophitic or subophitic to intersertal within the same rock. The finer-grained varieties consist of slender plagioclase laths up to 0.4 x 0.08 mm in size, intergrown with somewhat larger, blocky pyroxene grains. Coarser-grained varieties have blockier plagioclase (0.8 x 0.3 mm) that is only partly included in pyroxene and may grade into an intergranular texture. Regardless of grain size, almost all of the ophitic/subophitic KREEP basalts contain an irregularly distributed mesostasis consisting of K-rich glass, K-feldspar, silica, Ca-phosphate, and ilmenite. Ilmenite, the only ferromagnesian oxide found in the KREEP basalts, also occurs as discrete slender grains between the coarser silicate phases. Pyroxene in the KREEP basalts ranges from pale tan magnesian pigeonite cores (En76 Wo4 to En67 Wo5) to rims of greenish ferroan pigeonite or augite (En42 Wo15 - En33 Wo39)(figure 1). As noted by Dymek et al. [8], some pyroxenes in the coarse-grained KREEP basalts also zoned inward to fill hollow cores (En58 Wo8). Plagioclase ranges in composition from An 78 to An 88 – more sodic than the plagioclase in mare basalt.

One KREEP basalt clast is texturally distinct from the others. This pale-grey colored clast (B1) consists of a fine-grained, variolitic intergrowth of slender quench pyroxene (En69 Wo5 - En49 Wo25) and plagioclase (An79-An85) with an opaque black glass and ilmenite between the varioles. Despite its textural similarity to rapidly-cooled mare basalts, it can be distinguished as a KREEP basalt by the occurrence of K-feldspar in the groundmass, the lack of spinel-phase oxides, and its KREEPy trace element composition [10].

MARE BASALTS: Four clasts of mare basalt were extracted from breccia 15205 for this study, but only three are available for petrographic study. Two are pyroxene-phyric basalts with fine-grained, variolitic groundmass, the third is a medium-grained ophitic/subophitic olivine-phyric basalt. Phenocrysts in the pyroxene-phyric basalts typically form large, elongate grains up to 1.5 x 0.3 cm in size, many of which contain hollow cores filled with the groundmass assemblage. The pyroxene phenocryst's have pigeonitic cores (En71 Wo4 to En66 Wo6) which zone outwards to ferroan pigeonite or subcalcic augite rims (En19 Wo15 - En37 Wo35)(figure 2). The variolitic groundmass consists dominantly of pyroxene-rich varioles with less abundant intergrown plagioclase, separated by an opaque glass and accessory oxide phases (chromian ulvospinel, ilmenite). Goundmass pyroxenes are more Fe-rich than the phenocrysts (En25 Wo10 - En5 Wo24) and many plot within the forbidden zone on the pyroxene quadrilateral (figure 2). Plagioclase occurs only in the groundmass as slender needles intergrown with the pyroxene-rich varioles. It is generally more calcic than plagioclase in the KREEP basalts, ranging from An83 to An92 in composition, and forms only 25-35 vol% of the mode.

The single ophitic-textured olivine-phyric basalt consists of blocky pyroxene grains 0.2-0.8 mm Ø (50-55 vol% of mode) which enclose somewhat smaller, randomly-oriented plagioclase laths $\leq$ 0.4 x 0.05 mm in size (25-30 vol% of mode). The small Fo50-55 olivine phenocrysts up to 0.4 mm Ø are jacketed by pigeonite, similar to other olivine-phyric members of the QNB suite (e.g., [11-13]). The larger blocky pyroxenes have pigeonite cores (En58 Wo9) that zone outwards to augite or ferroan pigeonite (En40 Wo30 - En25 Wo18); smaller interstitial pyroxenes have compositions similar to these rims (figure 2). Plagioclase in this basalt is more calcic than the other basalt samples (An89 - An92) and exhibits a more restricted range in composition. Accessory phases include Ti-rich Cr-spinel, chromian ulvospinel, ilmenite, Fe-metal, and troilite.

DISCUSSION

KREEP BASALTS: All of the KREEP basalts studied here are (with one exception) texturally and mineralogically the same, with only minor variations in grain size and mode. Grain size variations do not exceed those found within single flows of slowly cooled terrestrial basalts, consistent with the idea that all of the medium to coarse grained KREEP basalt samples studied here represent fragments derived from a single lava flow. This interpretation is supported by the limited range in mineral compositions observed, which is approximately the same for all of the medium/coarse-grained KREEP basalts. The most obvious difference between these basalts petrographically is in the proportion of mesostasis present, which ranges from almost zero up to 15 or 20 vol% of the mode. These variations are not surprising when the small size and coarse textures of these clasts is considered. As noted by Lindstrom et al [10], these modal variations in the mesostasis could easily account for the range in trace element concentrations observed in the KREEP basalt clasts studied here, according to the short-range unmixing model of [14-15]. The fine-grained KREEP basalt studied here may represent the quickly cooled outer portion of this same flow, but the the extreme textural difference seems more consistent with its origin in a separate flow. Nonetheless, its trace element composition is identical to the other KREEPy basalts.

MARE BASALTS: Two of the mare basalts studied here are pyroxene-phyric basalts with nearly identical groundmass textures and similar ranges in mineral chemistry; these clasts may represent different pieces of a single, quartz-normative basalt flow. Texturally, they resemble typical pyroxene vitrophyres of the QNB suite [11-13]. The olivine-phyric basalt is petrographically similar to olivine-phyric basalts of the QNB suite - a relationship suggested by the occurrence of pigeonite mantles on the olivine. It cannot be from the same flow as the pyroxene-phyric QNBs, however, because those rocks are no longer saturated with olivine.

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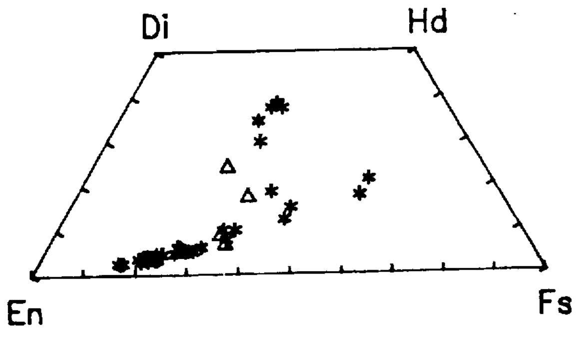

Figure 1. Pyroxene compositions in 15205 KREEP basalts. Ophitic/subophitic KREEP = *, Variolitic KREEP = triangle.

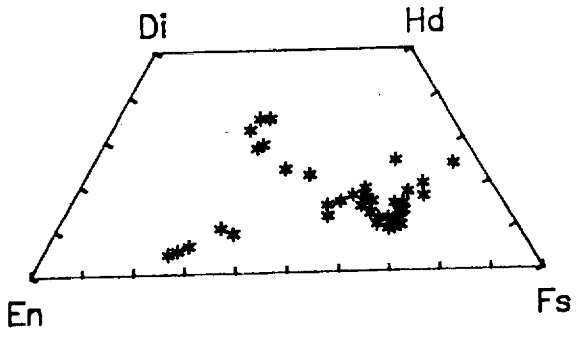

Figure 2. Pyroxene compositions in the QN mare basalts.