APOLLO 15 KREEP BASALTS AND EMPLACEMENT OF THE APENNINE BENCH FORMATION.

G. Jeffrey Taylor[1], Linda M. V. Martel[1], and Paul D. Spudis[2], [1]Hawaii Inst. of Geophysics and Planetology, SOEST, Univ. of Hawaii, 1680 East-West Rd., Honolulu, HI 96822 (gjtaylor@higp.hawaii.edu), [2]Lunar and Planetary Institute, Houston, TX.

Introduction: The mare basalt lava flows at the Apollo 15 site are underlain by a sequence of KREEP basalts, the Imbrian-age Apennine Bench Formation [1–5]. This stratigraphy is demonstrated particularly by breccias 15205, a fragmental breccia rich in KREEP basalts and containing green volcanic glass and pyroxene-phyric mare basalts, but no olivine basalts [6], which has been shown to be a sample of a paleoregolith beneath the mare basalts at the Apollo 15 site [5]. We report here the preliminary results of a new study of KREEP basalts collected at the Apollo 15 site. Our goal is to determine the range in magma compositions represented by the samples and on the emplacement of the large flow field represented by the Apennine Bench Formation.

Regional context: The Apennine Bench Formation (Fig. 1) is a prominent feature to the west and northwest of the Apollo 15 landing site and crops out near the base of the massifs near the site [7]. It is likely to be the source of the KREEP basalts at the site [4,8,9]. Thus, understanding the petrologic history of the Apollo 15 KREEP basalts sheds light on the petrologic history of the Apennine Bench Formation.
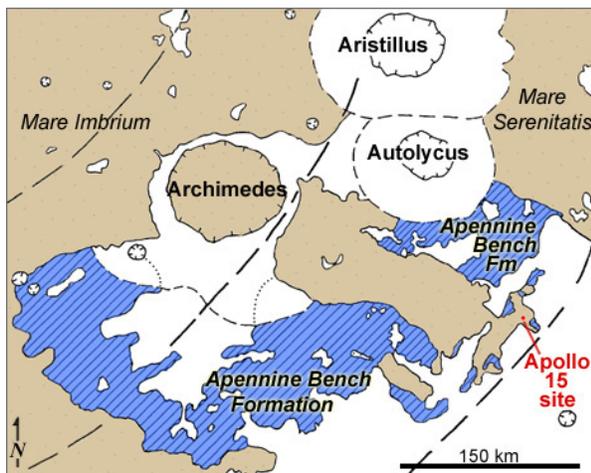

Fig. 1. Apennine Bench Formation in relation to Apollo 15 landing site and to maria. Map based on [2,10].

Petrology: Apollo 15 basalts have been studied previously [e.g., 6, 8–9, 11–12]. All are found as lithic clasts in breccias or rock fragments in the regolith. They range in texture from intersertal, somewhat glass-rich and fine-grained to subophitic medium- to coarse-grained textures; subophitic textures dominate. We have extended these studies to determine the range

in parent magma compositions and emplacement mechanisms of the Apennine Bench basalts represented by the Apollo 15 KREEP basalt suite. We are studying two major groups of rocks: (1) Those derived close to the Apollo 15 site, such as the suite in breccia 15205 and others collected from the regolith. (2) KREEP basalts from more distant locales found in impact melt breccia 15405, which has been interpreted to be thrown to the Apollo 15 site from either Aristillus or Autolycus, large craters 150-300 km from the site [13].

To assess the range in lava flow compositions represented by the Apollo 15 KREEP basalt suite, we determined the compositions of pyroxene and plagioclase in 12 clasts in 15205, 7 clasts in 15405, and 15434,188, with emphasis on analyzing the most magnesian (hence first formed) pyroxene cores. We accomplished this by using back-scattered electron images to identify those with the lowest Fe/Mg. (We analyzed the entire range of compositions in each clast, but report only the most magnesian here). The results for pyroxene are shown in Fig. 2. (Plagioclase will be reported elsewhere.)

The earliest pyroxenes in the KREEP basalt clasts studied range in both Fe/(Fe+Mg) and Ti, Cr, and Al concentrations. This must reflect some variation in parent magma compositions, but minor and trace element concentrations can be affected by crystal growth rates [14] and by crystallization order. Nevertheless, some general trends are discernible in Fig. 2. First, the clast population shows a range in Fe/(Fe+Mg), suggesting a role for fractional crystalllization in producing the suite. The set of data from 15405 shows a particularly pronounced fractionation trend, consistent with previous interpretations of whole-rock data [8–9]. Second, the relatively large range in TiO_2, Cr_2O_3, and Al_2O_3 concentrations among the clasts may indicate variation in initial concentrations of these elements in the parent magmas. We also observe variations in the FeO concentrations among the most calcic plagioclase in the clast population.

Magmatic system: The suite of KREEP basalts in 15405 has been shown to be consistent with a single fractionating magma [9], so is useful as a guide to estimating the range of magma compositions in the rest of the clasts studied. The entire set plotted in Fig. 2 roughly follows similar trends to the 15405 suite, but the data show that there is a range of Ti, Cr, and Al concentrations for a given Fe/(Fe+Mg). A straightforward interpretation of the trends in Fig. 2 is that a se-

ries of magmas, each differing slightly in composition, experienced fractional crystallization. This might have involved episodic replenishment of a magma chamber system with more primitive magma, giving rise to a range of lava flow compositions. We cannot rule out additional fractional crystallization in individual lava flows. The location of the magma chamber(s) and the number of eruptive sites is not known.
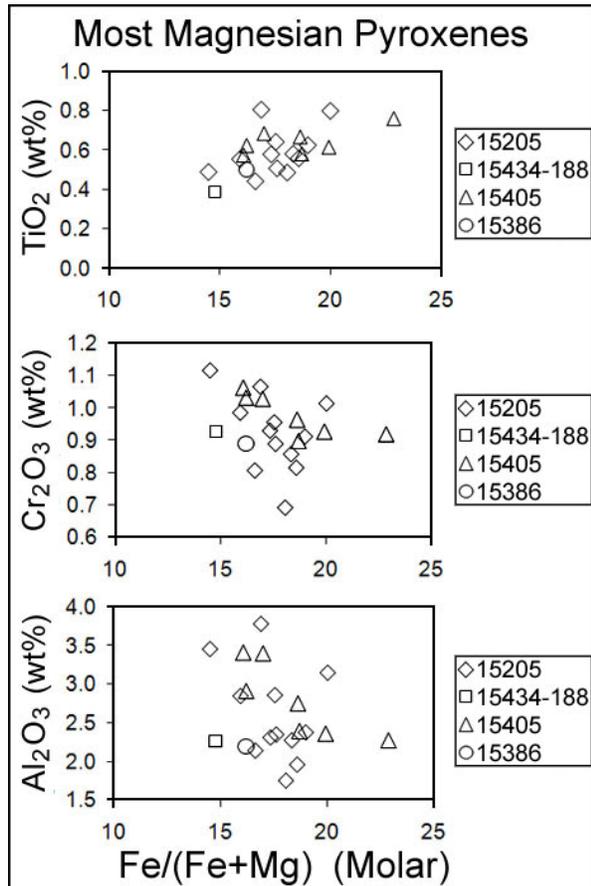

Fig. 2. Minor elements in the most magnesian [lowest Fe/(Fe+Mg)] pyroxenes in Apollo 15 KREEP basalts. All are in the range $Wo_{2.2-4.8}$.

Lava flow emplacement and eruption rates: In spite of KREEP basalts having a range of textures and grain sizes, they are all strikingly similar to the interiors (deeper than 15 cm from the top or bottom) of terrestrial pahoehoe lava flows. We show this quantitatively in Fig. 3. The vast difference in crystal density and grain size of terrestrial 'a'a and pahoehoe lava flows is caused by the emplacement mechanism, which in turn causes vastly different crystal nucleation densities [15]. Pahoehoe flows are emplaced slowly and have insulated surfaces, resulting in low nucleation rates. In contrast, 'a'a flows involve rapid flow rates and channelized, often incandescent lava, resulting in

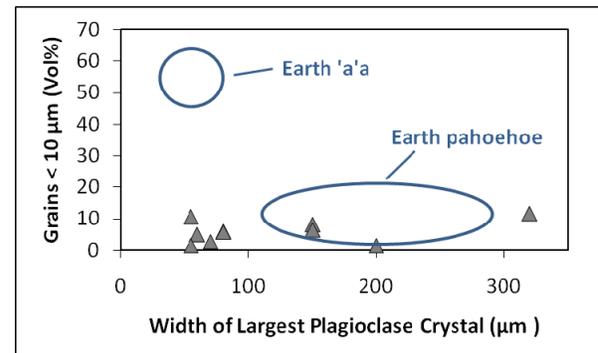large nucleation densities. These data suggest that KREEP basalts were emplaced like terrestrial pahoehoe flows.

Fig. 3. Plagioclase number density vs the abundance of crystals < 10 μm for terrestrial 'a'a and pahoehoe lava flows, compared to Apollo 15 KREEP basalts. The lunar basalts fall squarely into the pahoehoe field.

If Apollo 15 KREEP basalt flows were emplaced as pahoehoe, we can place limits on the duration of volcanism needed to produce the Apennine Bench Formation. Rowland and Walker [16] showed that terrestrial pahoehoe flows are emplaced at lava eruption rates of < 5 m^3/sec. Assuming that the Apennine Bench Formation underlies the mare basalts in the vicinity of Apollo 15 (Fig. 1) and that the formation underlies Aristillus, we estimate that it would require thousands to tens of thousands of years of eruptions to build the Apennine Bench Formation, depending on the total flow thickness.

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