ORIGIN AND DISTRIBUTION OF KREEP IN APOLLO 15 SOILS. Paul D. Spudis, Dept. of Geology and Center for Meteorite Studies, Arizona State University, Tempe, AZ 85281

One of the more interesting and perplexing problems in the interpretation of Apollo site geology is the origin and distribution of KREEP in the soils of the Apollo 15 landing site. Numerous recent studies of KREEP fragments from this site have confirmed that they are probably of volcanic origin (1, 2, 3, 4). These fragments vary widely in abundance at given sampling stations around the site (2) and attempts to explain their distribution pattern have been generally inadequate. A companion paper (5) shows that these KREEP fragments are probably derived from the Apennine Bench Fm., a post-Imbrium basin, pre-mare light plains unit that crops out near the site and closely resembles Apollo 15 KREEP in bulk chemistry. The purpose of this paper is to present a geologic model for the origin and distribution of KREEP in Apollo 15 soils based on the interpretation of the Apennine Bench Fm. as post-basin volcanic KREEP basalt flows. The proposed model unifies many previously unconnected observations and also permits prediction of *relative* KREEP contents of sample stations unvisited during the Apollo 15 mission.

Geology and Distribution of KREEP at the Apollo 15 Landing Site. The regional and local site geology of the Apollo 15 landing site is summarized in the post-mission science report (6). Mare basalts embay terra of the Imbrium basin at the site and these units were of high sampling priority during the Apollo 15 mission. The Apennine Bench Fm. crops out west of the site; pre-mission geologic mapping suggested this material probably underlies the mare basalts in the landing site region (7). Two large Copernican age craters, Aristillus and Autolycus, lie about 200 km north of the site and many secondaries and rays from these craters are superposed on the mare units in this region.

Figure 1 shows the *relative* concentration of KREEP at the various sampling stations of the Apollo 15 landing site, based on both petrographic inventory of coarse fines (2) and mixing model studies of lunar soils (8, 9, 10). It is seen that the highest concentrations of KREEP occur near the LM, Station 9, and at stations situated along the Apennine front. Lowest concentrations occur at southern mare sites (Stations 1, 4) and sites near the lip of Hadley Rille (Stations 2, 9A). It has been commonly assumed (8, 9, 10) that much of the KREEP component in Apollo 15 soils is derived from "ray material" from Aristillus and/or Autolycus. Several lines of reasoning suggest this is not the case. Rays of large craters consist primarily of locally derived material excavated by high energy secondary cratering (11) and contain little primary crater ejecta. Secondly, Dune crater and the South Cluster are interpreted as secondary craters from Aristillus/Autolycus (6, 7, 12). As such, they should show high KREEP concentrations if that component is derived from Aristillus/Autolycus; KREEP is effectively absent at the South Cluster (2, 10). Finally, the ray model does not explain the high concentration of KREEP at the Apennine front in relation to low concentrations of KREEP at the nearby South Cluster.

A previous study favored a local origin for the Apollo 15 KREEP basalt component (3) but did not advance a satisfactory mechanism for its admixture to the regolith. Since the Apennine Bench Fm. underlies mare basalts at the site and these light plains compositionally match Apollo 15 KREEP (5), a local origin for the KREEP component is highly probable. Figure 2 is a schematic geologic cross section of the Apollo 15 site presenting a possible model to explain the distribution of KREEP throughout the site. The North Complex is a group of low hills that have albedo comparable to the mare basalts and probably represents terra material draped by mare lava when the mare basalts stood at a higher topographic level in the vicinity of the site (13). Pluton crater is deep enough (approximately 80 m) to have excavated material beneath the relatively thin mare cover in this region and probably was responsible for the addition of significant quantities of Apennine Bench Fm. materials to the local regolith. Extensive vertically reworked deposits of Pluton ejecta are probably responsible for the high KREEP contents of Stations 8 and 9. The very low concentration of KREEP at Station 9A is probably due to its position inside the lip of Hadley Rille, where

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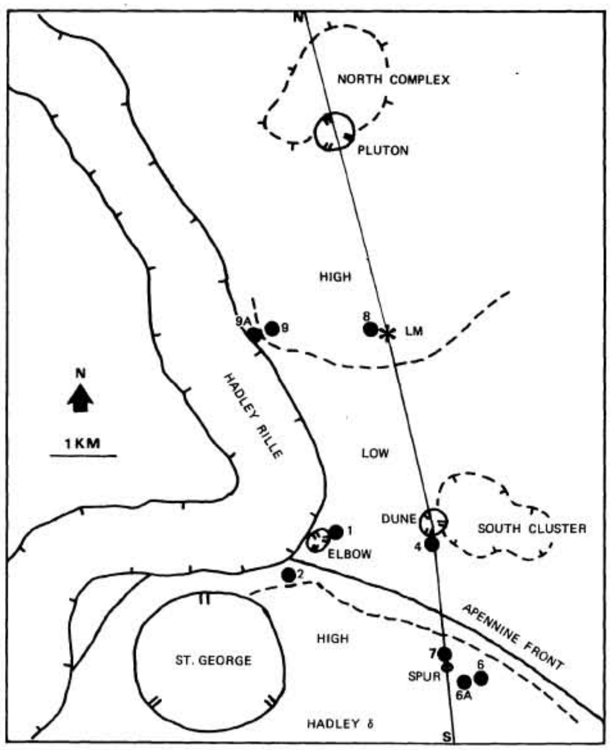

FIGURE 1. Map of the Apollo 15 landing site showing the approximate zones (dashed lines) of high and low *relative* KREEP concentrations in relation to the sampling stations (numbered). Line NS is the line of cross section shown in Figure 2. Data taken from the literature (2, 8, 9, 10).

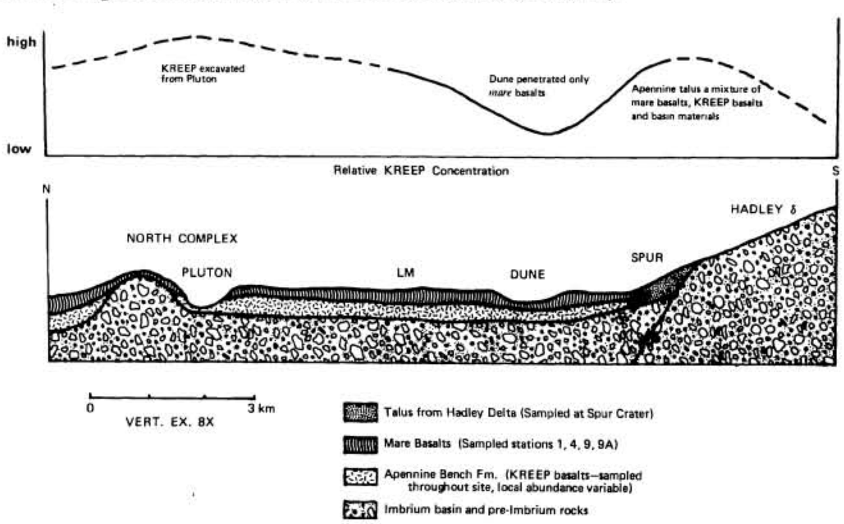

FIGURE 2. Schematic geologic cross section of the Apollo 15 landing site showing inferred relations of the major rock units. Graph at top indicates *relative* KREEP concentration as a function of position along the section line shown in Figure 1 (line NS).

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mass wasting has removed most of the local regolith and mare basalt bedrock is exposed (6). Very low concentrations of KREEP are seen at Dune and Elbow craters because in these regions, the mare cover is thick enough so that the relatively shallow sampling depths of Dune (approximately 40 m) and Elbow (approximately 30 m) did not penetrate the mare basalts to excavate underlying Apennine Bench materials. KREEP contents are relatively high at all front stations except Station 2. This is probably due to the interfingering relationships of Apennine front talus, Apennine Bench Fm. flows, and mare basalt flows (Fig. 2). All front stations sampled an extensively reworked talus deposit and the multi-component makeup of Apennine front soil breccias (such as 15205, which contains highland, KREEP, and mare basalt clasts (14)) confirm that the talus deposit is not solely derived from the Apennine mountains. KREEP is less abundant (although not absent (2)) at Station 2 (St. George) because this is an area where Hadley Rille has cut into and eroded some highland material by lava erosion (7, 13, 15). This would tend to remove most Apennine Bench materials at this station and subsequent mass wasting would produce talus consisting primarily of Apennine front derived material. The extremely low abundance of a KREEP component in soils from this station (10) suggests Apennine material is significantly depleted in medium-K KREEP but substantially enriched in low-K Fra Mauro materials. The top portion of Figure 2 is an idealized, qualitative graph of the relative proportions of KREEP basalt materials in Apollo 15 soils based on the proposed geologic model. These results suggest that volcanic KREEP fragments in Apollo 15 soils are primarily of local origin, and although occasional exotic fragments of distant crater ejecta may be present anywhere throughout the site, they are not quantitatively significant.

Summary and Conclusions. The results of this study suggest that KREEP basalt fragments in Apollo 15 soils are primarily of local derivation and that the contributions from distant craters (e.g., Aristillus) are minor and insignificant. This conclusion reaffirms the importance and dominance of vertical mixing of the lunar regolith and indicates lateral mixing is a far less efficient process (16). The distribution of KREEP at the Apollo 15 site also supports earlier conclusions (8, 17) that Apennine mountain material contains little medium-K KREEP and is composed primarily of low-K Fra Mauro materials. Post-Imbrium basin KREEP volcanism appears to have been an important process in the geologic evolution of the Apollo 15 region.

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