MATERIALS IN THE APENNINE FRONT, APOLLO 15. Graham Ryder, Lunar and Planetary Institute, 3303 NASA Rd.1, Houston, TX 77058; and Paul D. Spudis, U.S. Geological Survey, 2255 N.Gemini Dr., Flagstaff, AZ 86001.

A primary highlands objective of the Apollo 15 mission was to sample the material constituting the Apennine Front. The Front is part of the Montes Apenninus chain, which marks the southeastern topographic rim of the Imbrium basin. Its materials were expected to be a combination of uplifted materials older than Imbrium (especially Serenitatis ejecta) and Imbrium ejecta (1). The site is on the 4th ring of Imbrium and between the 3rd and 4th rings of Serenitatis (2), so has a roughly similar radial relationship to each basin, but the Imbrium event is superposed on the Serenitatis event. Differences between Serenitatis and Imbrium ejecta would be significant in understanding the regional variations of materials on the Moon at 3.9 b.y. ago, in turn placing constraints on the earliest evolution and crustal production. Unfortunately there is a paucity of non-mare materials among the rock samples collected even from the Front sites.

Spudis (3) drew the schematic cross section in Figure 1, illustrating the inferred relationships between rock types and geology at the Apollo 15 site. Several early studies had led to the inference that the Apennine Front consisted of materials of low-K Fra Mauro basalt composition. This inference was first made from the compositions of glass in the regolith, which included a disperse cluster of LKFM composition, and glasses of this composition increased in abundance towards the Front (4,5). Chemical mixing models can match soil compositions well if LKFM is used as an end member, and they also indicate an increase in LKFM towards the Front (5,6,7,8). Remote geochemical data indicate that LKFM compositions are widespread in (at least) the northern Apennines (9). Finally, a few impact melt samples are an LKFM composition, for instance the melt of the "black and white" rocks (10). Spudis (3) postulated that the LKFM glass composition was derived from Serenitatis ejecta, as it was chemically similar to the Apollo 17 melts but different from the melt of the "black and white" rocks, which had earlier been concluded to be Imbrium melt (11), almost solely on account of its dissimilarity from the Apollo 17 melts. Spudis also suggested that rake sample melt 15359 was similar to Apollo 17 melts and hence might be a product of the Serenitatis event. In general however, the definition of the Front as LKFM has been a loose one, with little attempt at chemical or petrological definition. Most studies have assumed some kind of average "LKFM breccia", and different LKFMs have been used in different studies.

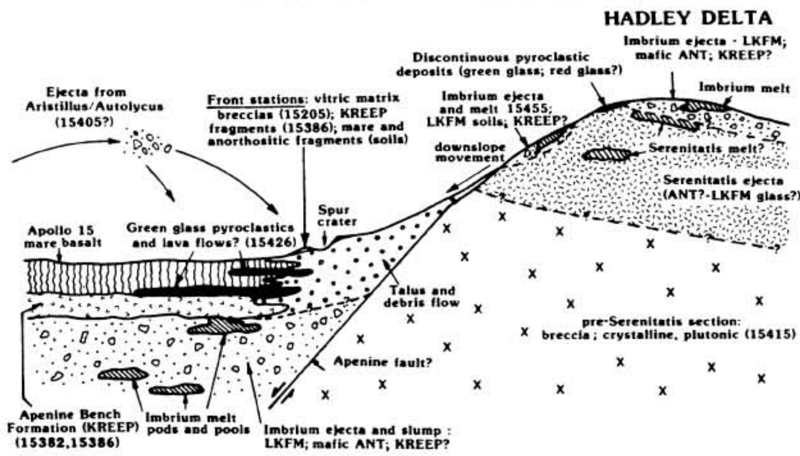

Figure 1. Cross section showing inferred relationships between rock types and geology at the Apollo 15 landing site (3).

There are severe limitations to deriving an understanding of the Apennine Front LKFM from either glass compositions or from mixing models. The LKFM glass clusters are disperse, not tightly constrained as are volcanic glass clusters, hence do not represent any unique composition. Neither is the composition entirely dissimilar from the compositions of A15 soils themselves (differing mainly only in the higher FeO of the soils) hence it is not readily apparent which glasses should be used when producing an average, and which should be omitted. Nonetheless, that these glasses form a cluster at all, and that they are not local soil compositions, is evidence that they are from a locally available, extensive, non-mare source i.e. the Front. But their derivative, mixed nature makes them suitable only for the essential inference that the Front composition approximates an LKFM composition with about 10% FeO and 11% MgO. This composition is indeed similar to Apollo 17 impact melts (except for the slightly lower TiO_2 of the glasses), and indicates that the source may be dominated by Serenitatis ejecta or that Imbrium and Serenitatis ejecta are very similar. These LKFM glasses exist even at the LM site and the Rille, and their source then is presumably as likely to be high on the Front (Imbrium) as low (Serenitatis, pre-Serenitatis).

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The essential role of LKFM in chemical mixing models is to provide for the higher Mg/Fe of the soils over mixtures of the other end-members (mare, A15 volcanic KREEP, and anorthositic lithologies). It has little required contribution to any of the other chemical characteristics, including incompatible elements. Therefore it is not clear that its choice as an end-member is unique. Calculations using Mg-suite rocks have not yet been done to see if they can replace LKFM, which can itself be modelled as a mixture. The LKFM composition used is not in any way defined by the modelling, and can tell us little specific about the Front. This is demonstrated by the range of LKFM compositions which have been used and still produced good matches for the soil compositions. Further, the appropriateness of an end-member is influenced by the choice of other end-members. Only one study (8) has used a reasonable composition for the ubiquitous A15 volcanic KREEP,and that study used an LKFM composition (62295) both rare anywhere and unlike anything observed at the A15 site. Because the LKFM composition is roughly similar to the soil compositions, quite a lot of the difference can be made up by small adjustments in the percentages of other end-members,again denying any uniquely defined composition for LKFM. Finally, all mixing models have used a single LKFM composition, and provide no information on the subtleties of chemical variations among Front rock types.

Duncan et al (6) concluded from factor analysis that LKFM was a dominant regolith component because of a well-defined trend from mare materials to LKFM. Figure 2 is a two element equivalent of their plot of Factor 1 against Factor 2, but with more samples (including regolith breccias, which generally are similar to the local soils), plotted. A single trend is not particularly apparent, and suggests no unique LKFM composition. This plot also illustrates one of the problems with LKFM for mixing models which is carried over into higher dimensions: its mixed composition gives it an intermediate composition which can be replaced by a combination of other end members.

To establish the nature of the Front itself hence requires resorting to an study of actual rock fragments, scarce though they may be. Simonds et al.(12) noted clast-laden,impact melted, polymict breccias that display a range of matrix textures. These include well-known samples such as 15445, 15455, and 15405, as well as smaller fragments (rakes, some coarse fines). Except for the larger fragments numbered, there is very little data about any of these fragments such as can be plotted on Figure 2. Hence it is not possible with the data in hand to establish the presence or absence of melt clusters (such as exist at A16), although there is at least some indication of a range. These melts are mainly LKFM, roughly. Sample 15405 is not, but cannot be basin-related. because it is young. Sample 15359, suggested to be Serenitatis-produced (3), has some chemical data and might be too low in Ti for such an origin. 15308 might be similar to 15445/15455, but is apparently lower in Cr (Fig. 2). Substantial improvement in the chemical data base for these rocks is needed to establish more about the Front materials. Work on coarse fines (2-4mm, 4-10mm) is necessary to provide enough statistical data to establish the range and clustering of impact melts. Highlands fragments in the soil populations have also been ignored, and generally merely described as "feldspathic crystalline breccias"; they occur in small percentages. A detailed petrographic study of these highland particles ,including good-quality defocussed-beam analyses of fine-grained impact melts, could provide much-needed data, as could a study of similar materials in regolith breccias. Materials capable of providing information on the Apennine Front exist in the Apollo 15 collection, but so far have not been utilized for the purpose. Until they are, the higlands objective of the Apollo 15 mission will remain incomplete.

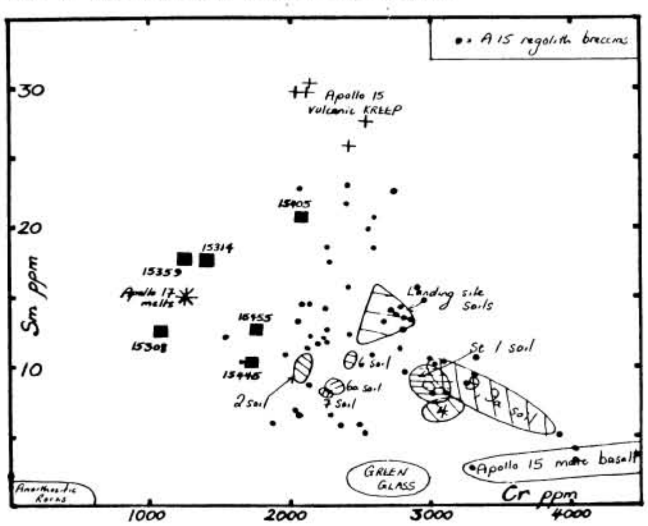

Figure 2. Sm v. Cr for Apollo 15 samples. Data from many sources.

(1) Swan,G. et al.(1972), NASA SP-289,5-1. (2) Spudis, P. (1982) Ph.D. Thesis, Arizona State University. (3) Spudis, P. (1980) Conference om Multiring Basins, LPI Contr. 414, p.83. (4) Reid A. et al. (1972) Meteoritics 7, p.395. (5) Carr M. and Meyer C. (1974) Geochim. Cosmochim. Acta 38, p.1183. (6) Duncan A. et al. (1975) Proc. Lunar Sci. Conf. 6th, p.2309. (7) Chou C.-L. et al. (1975) Proc. Lunar Sci. Conf. 6th, p.1701. (8) Walker R. and Papike J. (1981) Proc. Lunar Plan. Sci. Conf. 12th, p. 509. (9) Metzger A. et al. (1979) Proc. Lunar Plan. Sci. Conf. 10th, p. 1701. (10) Taylor S. et al. (1973) Proc. Lunar Sci. Conf. 4th, p.1445. (11) Ryder G. and Bower J. (1977) Proc. Lunar Sci. Conf. 8th, p. 1895. (12) Simonds et al. (1975) Lunar Sci. VI, p.744.