COMPONENT ABUNDANCE AND EVOLUTION OF REGOLITHS AND BRECCIAS: INTERPRETATION BY MIXING MODELS. Ernest Schonfeld, NASA-JSC, Houston, TX 77508.

Mixing models can be used to understand the evolution of regoliths and breccias. The composition of soils and breccias depends on the availability of the rock types at a certain time, location, and the intensity of the planetesimal bombardment. The possibility that VHA basalt (1) and Low K Fra Mauro basalt (2) (LK-FM) are mixtures was investigated using the published chemical composition of these rocks and a weighted least-squares mixing model technique (3,4). There are difficulties in generating these rocks by differentiation. As shown in figure 1, VHA and LK-FM have very similar relative concentrations patterns for U, Ba, Ce, Sm and Yb that are almost identical to the pattern found in KREEP. It is difficult to generate this pattern by different degrees of partial melting from the same source (5). Also the majority of these samples have considerable amounts of meteoritic contamination (6). One simple way to generate these rocks would be to mix KREEP with other rock types that have relatively low concentrations of U, Ba, Ce, Sm and Yb. The results of the mixing model calculations using the published analysis of up to 27 elements show that it is not possible to generate these rock types by using only mare basalts, "anorthosites", KREEP, meteoritic component (met), and granite (gr). Another possible rock type is dunite and has been found only in small amounts (7,8,9). If dunite is included as another component, then the mixing model calculations (figure 2) show that it is possible to generate VHA, LK-FM and other rock types by mixing dunite, "anorthosite", and KREEP. There is an approximate trend line between KREEP and (spinel) troctolite (10). (Spinel) troctolite can be a mixture between "anorthosite" and dunite, but the trend line suggests that (spinel) troctolite is a rock type and not a mixture. The deviations from the trend line could be caused by sampling errors and/or the variable composition of the (spinel) troctolites. In conclusion it appears that it is possible that the highlands are "contaminated" with KREEP, and that dunite and/or (spinel) troctolite are significant rock types.

Apollo 15 regolith and breccia. The most abundant component in the Apennine front is the brown-glass matrix breccia (11,12). The chemical composition of this breccia is very similar to the composition of soil 15101 and has slightly higher concentrations of Ti, Fe, and K than LK-FM 15 (2). As shown in figure 2 LK-FM can be modeled as a mixture of about 18% KREEP+17% Dunite+62% "Anorth"+ 0.8%gr. Preliminary mixing model calculations on soil 15101 and other Apollo 15 breccias, suggest that the brown glass-matrix breccia=LK-FM 15+$\sim$15% Mare+ $\sim$10% green glass+(variable)KREEP. This may be an example of breccia and regolith evolution where we start with a rather "old breccia" (LK-FM) and other components are added progressively.

Apollo 16 samples. Mixing model calculations were performed on 9 Apollo 16 samples using the published chemical analysis of about 26 elements (Table I). After the "Anorth" component, the most significant component appears to be KREEPy 16 (average of 65015, 60315 and 62235). KREEPy 16 as shown in figure 2 can be modeled as a mixture of about 51% KREEP+34% "Anorth"+15% Dunite+0.9%gr. The lowest amount of KREEPy 16 was from the soils from North Ray crater(67601, 67461) and rock 68415. Sample 68415 contains meteoritic contamination (6) and gives a very good fit as a possible mixture. Simple mixtures of VHA+"Anorth"+

Met and LK-FM+"Anorth"+Met gave in all cases poor fits for Mg. Therefore, there appear to be no significant amounts of VHA and/or LK-FM in the Apollo 16 soils, whereas KREEPy 16 appears to be the main contributor of LIL elements. Apollo 17 regoliths. A preliminary mixing model analysis was performed on the chemical composition of 16 Apollo 17 soils (7). Two sets of components were tested. In the first case KREEP, dunite, "anorth", mare basalt 17, orange glass, granite, and met. components were used. In the second case KREEPy 17 (noritic breccia) and anorthositic gabbro from 17 were used instead of KREEP and "anorth". In both cases the fit was similar and quite good, with the exception of soil 76501 that required a component with more Mg, such as 76055, or a 5% excess dunite. Also, instead of KREEPy 17 other components were tested such as VHA and LK-FM. In most cases KREEPy 17 gave a better fit. Therefore, it appears that KREEPy 17 (that could be a mixture as shown in figure 2) and anorthositic gabbro 17 are significant components in the Apollo 17 regoliths. The elements used in the mixing model are those published (7) with the exception of Zn. In a few cases other elements were included such as Li, Ce, Sm, Eu, Yb, U and Th with similar results. The results are shown in figure 3. The amounts of orange glass have an uncertainty of about 35%. The meteoritic contamination is based mainly on Ni and is "equivalent" to about 1 to 2% CC-1, and granites in all cases are less than 0.3%. In figure 3 the distance between stations is approximately proportional to the actual distance between stations. The Apollo 17 site has similarities with the Apollo 15 site in the sense that in both places the abundance of mare basalts is inversely proportional to the abundance of "anorthositic" material. The ratio of KREEPy 17 to anorthositic gabbro 17 is different in the North and South Massif regoliths. In the case of sulphur it was assumed that the meteoritic component is negligible (13). The good sulphur material balance suggests that there is no bulk volatilization of S in these regoliths.

Table I. Results of mixing model for Apollo 16 samples.

	Solution I (a,b,c)		Solution II (a,c)	
	KREEPY 16	"ANORTH"	KREEP	"ANORTH"
60601	17.9 ± 3	71 ± 6	13 ± 1	85 ± 3
61221	12 ± 2	80 ± 4	6.7 ± 1	92 ± 5
61801	15 ± 3	75 ± 4	10 ± 1	86 ± 2
63501	10.7 ± 3	82 ± 6	6.9 ± 1	93 ± 3
64421	22 ± 3	65 ± 5	11.6 ± 1.5	87 ± 2
68501	18.5 ± 2	70 ± 4	11.7 ± 1	86 ± 2
67601	8 ± 3	88 ± 3	4.7 ± 1	95 ± 2
67461	5 ± 2	92 ± 3	2.5 ± .5	96 ± 2
68415	8 ± 1	87 ± 3	4.7 ± .5	94 ± 2

(a) All samples had a meteoritic component. (b) VHA was included as a component and approximately correlated with KREEPy 16(VHA $\gtrsim$ 0.4 KREEPy 16). (c) "ANORTH" $\sim$ 60% Gab. Anorth + 20% Anorthosite + 20% An. Gabbro. (d) Solution I gave slightly better overall fit than Solution II, but much better fit for Mg. (e) Mare basalt is present about 1-2% and granite is less than 0.3%. (Exception: 68415 has no mare basalt).

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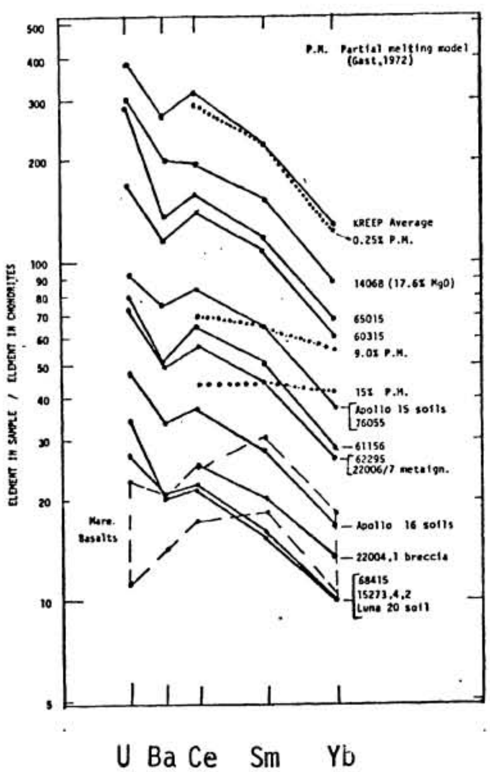

Figure 1

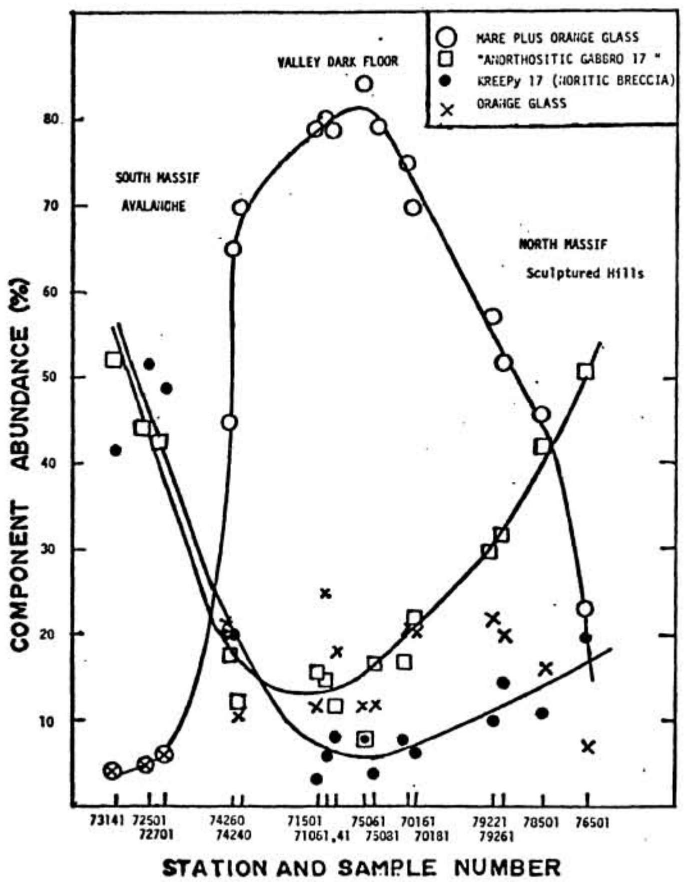

Figure 3

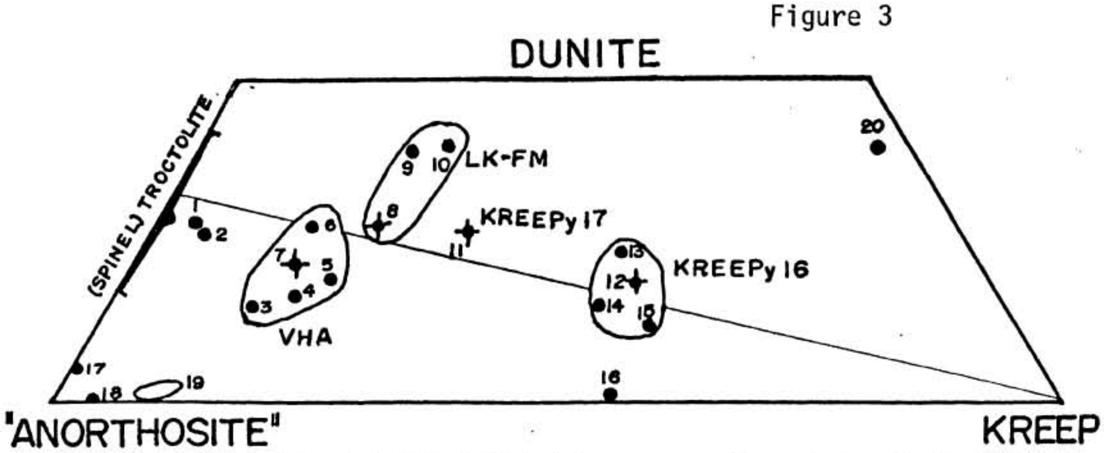

Figure 2. Results of mixing model. Points labeled 1,2,3 .... correspond to samples Luna 20 soil, 15273,4,2 , 61016, 61156,2 , 15273,4,3 , 62295, average VHA, average low K Fra Mauro Basalt, 15455 dark, 76055, average KREEPy 17, average KREEPy 16, 60315, 65015, 62235, 14310, 67955, 68415, Apollo 16 soils, and 14068. "Anorthosite" is a mixture of anorthosite, gabbroic anorthosite and anorthositic gabbro. KREEPy 16 is the average of 60315, 65015, and 62235. Average VHA is the average of 61016,61156,and 62295. Average KREEPy 17 is the average of 72435, 72275, 76315, 77135, and 76055.