URANIUM-THORIUM-LEAD ISOTOPE RELATIONS IN THE REMARKABLE DEBRIS BLANKET AT HADLEY-APENNINE, Leon T. Silver, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California. Contrib. No. 2305.

Six samples of regolith fines (four front, two mare) and four breccias (two front, two mare) from the Apennine-Hadley region have been analyzed for total uranium, thorium and lead chemically and isotopically by mass spectrometry and isotope dilution (Table 1). Volatile lead characterization of ten soils and a breccia have been established by sequential step-heating experiments. Components of two breccias have been analyzed separately and compared with the total systems. These data combined with results reported earlier on four other mare surface soils and eight regolith segments from the deep drill core[1] provide a comprehensive survey of the regolith visited on the Apollo 15 mission. A remarkable homogeneity of U-Th-Pb isotopic systematics in all of the regolith data compels the conclusion that the visited surfaces of the mare and the front at the Apollo 15 site are veneered to a depth of at least several meters with a recently acquired uranium- and thorium-rich glassy debris layer from an as yet undefined source.

The four soils from front stations 2, 6, and 7 have uranium concentrations similar in average value (1.18 ppm) and range (0.84 - 1.69) to values previously noted in other mare floor soils (0.62 - 1.75 ppm). The two new mare soils from stations 1 and 9a, close to the rille edge, extend the lower limit of this range. Thorium concentrations vary consistently with the uranium and the Th/U ratio for all six soils averages about 3.72 compared with 3.77 for 12 previous mare samples reported. The range in concentrations observed in the mare soils can be attributed, from bulk chemical and trace element studies[2], to mixing between basalt debris from the mare flows and a high uranium-thorium aluminous rock component with greater than 1.3 ppm uranium. The local basalts, which generally contain less than 0.2 ppm U and 0.8 ppm Th, dilute the more radioactive component, particularly at points close to the rille edge and on the rims of large craters such as Elbow (sta. 1) and Dune (sta. 4).

Samples of three large glass-coated vitric breccia blocks from station 6 on the front, and from station 9 and the LM have uranium and thorium (1.18; 4.34 ppm) averages and Th/U ratios (3.67 ± 0.04) similar to the soils. Concentration and analysis of the glassy surface of one of these breccias (15505,8 G) and comparison with an internal matrix breccia fraction (15505,8 M) showed no difference in concentration levels indicating the glass was internally derived and representative of the bulk sample. A fourth breccia sample which has been intensively studied is one of the so-called black and white breccias (15455) from Spur crater. It has markedly lower uranium and thorium values as can be seen for two components listed in Table 1. It is a rare type of breccia in the Apollo 15 suite.

The lead concentrations are somewhat more variable than the uranium and thorium among the soils and breccias. However, with two noteworthy exceptions, all of the leads have similar isotopic compositions. They are quite radiogenic reflecting $^{238}U/^{204}Pb$ ratios of 100 - 300 and great apparent ages. Based on $^{207}Pb/^{206}Pb$ corrected with primordial initial lead, ten of these samples have 207/206 of 0.57 - 0.61, and model ages

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between 4500 and 4600 million years, coincident with 15 other soils from the mare surface [1,3]. Only two samples 15455 and 15301 differ. The "black-and-white" breccia surprisingly shows younger model ages distinct from any other breccias reported from the Apollo 15 site. The soil 15301 shows a distinctly older apparent age which can be traced directly to an anomalous lead contributed by approximately 25% of green glass spheres (cf. with 15425) which it contains. Although no other soil reported here contains so much green glass probably much of the slight variation in the other soils can be traced to minor quantities of this green glass component. Another contribution to the isotopic variation in the soil lead comes from a low-temperature volatile lead component. Eight of ten soils studied at this site have from 3 - 10 percent of their lead readily volatilized in vacuum at 500 - 600°C. Seven of the soils yield $^{207}Pb/^{206}Pb$ values of 0.83 ± 0.02 including soils from the mare, the rille edge, the front and the deep drill core. Only 15301 shows a somewhat higher value. The radiogenic daughter-parent relations in the uranium systems are shown in figure 1. In addition to new analyses reported here, data from [1] has been plotted to show the remarkable groupings. The patterned region representing Apollo 15 basalts represents unpublished data now being extended. Tatsumoto et al. [3] have reported several additional basalt analyses which occupy the same region.

Breccia 15455 fractions and soil 15301 show distinctive locations in Figure 1 reflecting their atypical lead compositions. All other samples (more than 20) define a limited belt distinguishable from soils from any other Apollo site [4]. A variety of fine detail may be read within this distribution, but the homogeneity and distinctive position of the suite, regardless of local sample site, indicates that a single radiogenic isotopic system dominates all other contributions to the Pb-U-Th characteristics of the Apollo 15 regolith. This system clearly is not contained in the local basalts. The vitric breccias appear to be the largest fragments of debris containing the system which are undiluted by the local basalts. Their high fragmental glass content suggests the breccias may have been derived from a regolith layer at some other site. Among their possible sources may be considered Aristillus-Autolycus rays, the Apennine front, Hadley rille (!?) and the crater Pluton and the North Complex (?!!). Available geological and chemical data provide no compelling preferences at this time. However, several isotopic and geological arguments suggest that the addition of an exotic blanket of material to the regional surface (ranging from $<$ 1mm fines to breccia boulders) occurred abruptly, considerably less than 10^9, perhaps less than 10^8 years ago.

REFERENCES: (1) Silver, L.T. (1972) Uranium-thorium-lead isotopes and the nature of mare surface debris at Hadley-Apennine. The Apollo 15 Lunar Samples, Chamberlain and Watkins ed. Lunar Science Institute, p. 388-390. (2) LSPET (1972) Preliminary examination of lunar samples, NASA SP-289, p. 6-1. (3) Tatsumoto, M., C.E. Hedge, R.J. Knight, D.M. Unruh, and B.R. Doe (1972) U-Th-Pb, Rb-Sr and K measurements on some Apollo 15 and Apollo 16 samples. The Apollo 15 Lunar Samples, Chamberlain and Watkins ed. Lunar Science Institute, p. 391-395. (4) Silver, L.T. (1973) Uranium-thorium-lead isotopic characteristics in some regolithic materials from the Descartes region. In Lunar Science IV, ed. Chamberlain and Watkins, Lunar Science Institute.

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Table 1.

Sample	Expt. No.	Sta.	Pb Isotope Composition $\frac{206}{204}$	$\frac{207}{204}$	$\frac{208}{204}$	Concentrations (ppm) Total Pb	U	Th	Th/U
Soils									
15071,6	1,2	1	121.05	77.11	132.93	1.752	0.714	2.650	3.71
15091,6	1,2	2	238.90	150.79	231.14	2.239	0.964	3.642	3.78
15260,1	1,2	6	357.18	223.74	352.54	3.052	1.688	6.343	3.76
15290,1	1,2	6	278.70	176.94	258.76	2.965	1.248	4.633	3.71
15301,39	1,3	7	159.08	108.09	166.10	2.222	0.835	3.055	3.66
15531,19	1,2	9a	108.84	67.95	113.18	1.033	0.453	1.669	3.68
Breccias									
15015,13	1,2	LM	298.85	176.79	299.32	2.837	1.357	5.049	3.72
15299,2	1,2	6	148.64	95.16	159.37	3.031	1.175	4.271	3.63
15505,8	1,2	9	219.23	132.21	226.14	2.116	1.039	3.685	3.68
15505,8	3 (M)	9	156.78	96.71	(1)	2.032	0.984	3.570	3.63
15505,8	3A (G)	9	172.20	106.38	(1)	1.998	0.975	3.565	3.66
15455,70 A	1 (W)	7	98.83	54.03	(1)	0.592	0.258	0.665	2.57
15455,183	1 (D)	7	185.26	103.98	(1)	1.857	0.770	2.855	3.71

(1) Spiked with ^{208}Pb; (M) = matrix breccia concentrate; (G) = surface glass concentrate; (W) = white leucogabbro clast; (D) = dark injection phase. Concentrations have precisions of ± 1%, but minor Pb corrections may be expected for spiked-only samples.

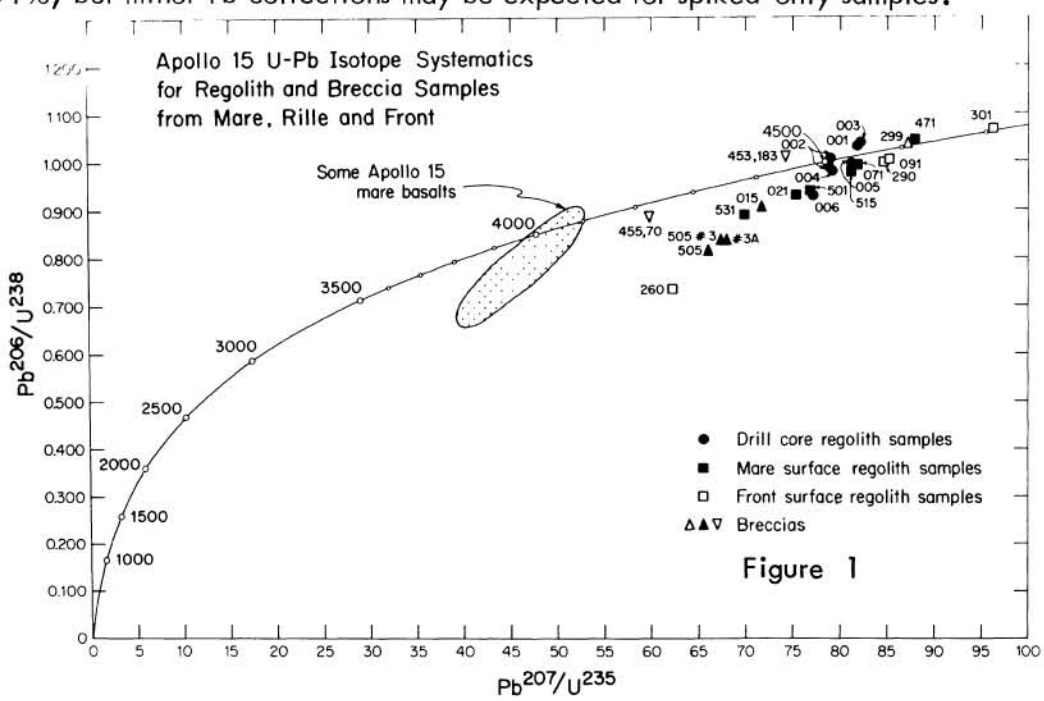

Figure 1