

LABILE TRACE ELEMENTS IN APOLLO 17 SAMPLES* S. Jovanovic
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The halogens, Li, Te, U, Ru, Os and Hg are being measured in Apollo 17 samples by activation analysis. In the case of the halogens, Li, Te and U the samples are subjected to a 10 minute hot water leach, and in case of Hg to stepwise heating. The results obtained to date are given in Table 1.

Fluorine concentrations of ~30-60 ppm are about the same as for samples from other sites. Chlorine concentrations cluster between 15 and 35 ppm for soils and breccias, and are lower for some igneous rocks; a significant fraction of the Cl is hot water leachable. Bromine concentrations of ~0.17-0.4 ppm are in the range found for Apollo 11, 12 and 14 samples, but lower than those in Apollo 15 and 16 samples; it is also water leachable. Iodine, detected only in leach solutions, is in the ppb range. Unusually low U concentrations of 0.1-0.2 ppm are observed for a number of soils. A number of Li contents fall between 7 and 10 ppm; similar to Apollo 16 soils but lower than most concentrations found at other sites. Ru, Os and Hg concentrations in the ppb range are similar to those at other sites.

Apollo 17 samples that appear to be unusual from among all the lunar samples are the orange soil 74220, the black soil 74001 from the core taken through the orange soil, the troctolitic granulite 76535, and the almost pure basaltic soil at the IM site. 1. The orange 74220 and associated gray 74241 soils have appreciably higher concentrations of all the halogens. Two samples of the orange soil, 74220,34 and 74220,111, have significantly different, albeit among the highest, halogen contents. In addition the very high Te of 10^4 ppb found in 74220,34 (Jovanovic et al., 1973) is not duplicated in 74220,111. This soil appears not to be homogeneous. While the labile elements tend to vary, the more refractory elements, Li and U for instance, do not. Thermal and vapor pressure variations are inferred at the site from which the sample was derived. At the same time thorough homogenization or a well mixed source is necessary to account for the uniformity of the major and refractory trace elements. The higher Cl, Br and Te could have been derived from an impacting object, but since a comparable addition of Pt-metals did not occur the known types of meteorites appear to be excluded. 2. The black soil 74001 collected at the orange soil site represents a significantly thick layer. Its major element composition is similar to that of the orange soil (McKay and Heiken, 1973) but the fractionated trace elements are very different. In most lunar soils Cl_r and F tend to vary sympathetically. The black soil is an exception. It has 11 ppm Cl_r but a very low, <2 ppm, F. Ru is also very low in the black soil in spite of a fairly typical Os content. On the basis of these results the black and orange soils probably are of different origin. 3. Sample 76535 is described by Gooley et al. as a troctolitic granulite originating deep in the lunar crust. Relative to other lunar rocks 76535 appears to be highly depleted in Cl but not in F. It also has a very low U content. This parallels, perhaps, the terrestrial trend of ultrabasic rocks, presumably of deep-seated origin, having high F/Cl ratios and

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lower U than less basic rocks from shallower depths. 4. Soils from the plains are of interest because they appear to be primarily basaltic and hence related to the local rock. If soils 70181 or 75080 are compared with basalts from stations 4 and 5 our data indicate that an exotic component must be present in the soils to account for the enhanced Cl, Br and U. The orange soil could supply the Cl_r and possibly the F but not the U. If we assume a P₂O₅ content for 75075 equal to the 0.7 wt % reported (Apollo 17 PET, 1973) for 75055 and thus equal to the P₂O₅ in 70181 and 75080, then the Cl_r/P₂O₅ ratio of ~0.02 for these soils indicates that a KREEP-type component is not present to supply the halogens (see below).

The Apollo 17 site can be partially characterized by the samples analyzed to date. On the basis of the F-Cl_r-P₂O₅ systematics, established for samples from other sites (Jovanovic & Reed, 1973), two groupings are evident: 1. Front samples 72701, 73141, 72275 and 76315 with Cl_r/P₂O₅ = 0.008 ± 0.001, and 2. Plains samples 70181, 74241, 75080 and 75075 and Sculptured Hills sample 78501 with Cl_r/P₂O₅ = 0.022 ± 0.005. Orange soil 74220 does not belong to either group; its Cl_r/P₂O₅ ratio (>0.4) is the largest observed. Most Apollo 11, 12, 14 and 15 soil samples have Cl_r/P₂O₅ ratios of about 0.008 due to an admixture of a KREEP component. Apollo 17 front and light mantle samples are therefore KREEP-like on this basis, in agreement with the PET characterization. Breccia 76315, included in the first group, has a lower Cl_r/P₂O₅ ratio, 0.0057; this is intermediate between the 0.003 ratio for mare basalts and 0.008 for KREEP. As noted previously samples with a Cl_r/P₂O₅ ratio of ~0.022 must have most of their P₂O₅ as apatite. Apollo 17 basalts and basalt derived soils along with Sculptured Hill soil 78501 fall in this class. The 0.022 ratio sets Apollo 17 basaltic samples off from mare related basalts (Cl_r/P₂O₅ ~0.003) and soils in spite of the remarkable major and minor element similarity of, for instance, 74240 and 70181 to 10084 (PET, 1973). An interesting observation, consistent with that at other sites, is that the Cl_{total}/P₂O₅ ratio is also approximately constant within each group. It is worth noting that in the high ratio group up to 3/4 of the total Cl is leachable. Relatively little of the Cl in the low ratio group of samples is leachable.

A number of the samples measured have Ru/Os ratios near the 0.5 value found in a number of Apollo 14 and 16 soils and in anorthositic breccia 66095. An exception to this pattern is the exterior sample 76315,69. Its low Os content relative to that of the interior sample 76315,70 is consistent with the depletion of Os from rock surfaces first noted in Apollo 12 basalts. Samples 73141 and 76315, have Os/Ni ratios similar to Apollo 14 samples; however the Ru/Os ratios do not correspond to those in Apollo 14 samples. This is perhaps further evidence for a lunar chemistry of these Pt-metals.

Another assessment of the presence of lunar atmospheric Hg has been made possible by collecting Hg from the lunar sample return containers (SRC). Through the cooperation of R. Davis, Jr. and R. W. Stoenner Hg was pumped from the rock boxes and trapped on Au mesh. Apollo 16 and 17 SRCs maintained their vacuum on return from the moon. They contained several kgs of soil gathered from a mean depth of ~3 cm. At this depth we have estimated a day time temperature of ~27°C. Our measurements indicate that the amount of Hg

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mobilized at 27°C will be $\leq 1/10$ of the surface-related Hg concentration of ~ 1 ppb released at $\sim 130^\circ\text{C}$ (Reed et al., 1971). The amount of Hg found was consistent with what might be expected for surface Hg desorbed at room temperature.

References. Apollo 17 Prel. Excep. Team (1973), Science 182, 659; Gooley, R., Brett, R., Warner, J. and Smyth, J. R., (1973), Preprint; Jovanovic, S., Jensen, K., and Reed, Jr., G. W. (1973), Trans. Am. Geophys. Union, 54, 595; Jovanovic, S., and Reed, Jr., G. W., (1973), Geochim. Cosmochim. Acta, Supple 4, Vol. 2, 1313; McKay, D. S. and Heinken, G. H. (1973), Trans. Am. Geophys. Union, 54, 599; Reed, G. W., Goleb, J.A., Jovanovic, S. (1971), Science 172, 258.

Table 1. Halogens, lithium, uranium, tellurium, mercury, ruthenium and osmium in Apollo 17 samples.*

Sample	F ppm	Cl r [†] ppm	Br r ppm	I ^{††} ppb	Li ^a ppm	U ^a ppm	Hg ppb	Ru ppb	Os ppb
Soils									
70181,17	52	14	19	840	43	1.2	7.2	0.22	26
70006,11 ^b	94	13	5	190	60	3	9.4	0.29	
70005,11 ^b	135	14	3.8	130	60	3	7.2	0.24	
70002,11 ^b	256	21	7.9	190	90	9	9.8	0.51	
72701,34	55	12	1.8	80	35	8.3	8.4	0.79	
73141,20	17	10	6.5	210	130	2	9.3	0.10	5.3
74220,34 ^{b*}	102	23	49	380	1200	14	9.7	0.17	10
74220,111 [*]	25 ^c	36 ^c	82	21	120	300	13	11	0.17
74241,64 ^b	230 [‡]	27	32	420	380	13	13	0.14	5.7±1.5
74001,12	<2	11	29	95	85	5.9	11	0.15	3
75080,8	58	12	22	140	230	5.1	7.3	0.25	3±1
76241,17 ⁺							2.2	17	0.7±0.3
76241,17 ⁺								193,12	0.8±0.2
76241,17 ⁺								12	20
76261,17								19	
76281,7 [*]								35	
78501,52	38	11	3.5	100	100	2.4	8.2	0.34	6.3
		12	3.9	180	200	2.2	5.6	0.20	18
Rocks									
72275,110 ^d		28	1.6	94	30	3.3	12	1.6	
73275,27	30	11	0.89	71	44	0.9	9.4	1.1	
74275,61	43	2.8	0.64	8±2	3±1	0.9	9	0.17	61
75075,24 ^d		12	3.1	10	42	0.8	8.7	0.13	
76315,69 ^d ext.		7.8	1.3	52	24	1.3	15	1.0	6.7
76315,70 int.	49	15	1.4	68	10	1.2	13	1.1	4.7
76535,23	9	0.22	0.77	6	43	1.1	-	0.03	6.3

* The counting statistical errors are usually 10% or less. Tellurium at greater than ppb level detected only in 74220,34 = 10^4 ppb; 74220,111 = 16 ± 6 ppb and 76281,7 = 26 ± 12 ppb.

[†]r = residue after leach. [‡] = leach solution.

^{††}I detected in leach only. a. U and Li are < 10% leachable. b. Jovanovic et al. (1973).

c. pH 5 leach. d. Exterior surface with patina. ext. = exterior. int. = interior.

⁺permanently shadowed sample.