DETERMINATION OF NATURAL AND COSMIC RAY INDUCED RADIONUCLIDES IN APOLLO 17 LUNAR SAMPLES. J.E. Keith, R.S. Clark and L.J. Bennett, NASA Johnson Space Center, Houston, TX 77058.

The natural and cosmic ray induced radionuclides have been determined in 15 rocks and 7 soils from the Apollo 17 mission by non-destructive gamma ray spectrometry. The gamma ray spectrometer and the data reduction techniques used at the Radiation Counting Laboratory have been discussed previously (1). The Preliminary Examination Team has divided the rock samples from Apollo 17 into 8 groups (2), 7 of which are represented in our sample set (see Table 1).

The rock sample analyses in Table 1 and in the data provided by PET (2) are divided into two groups by their K, U and Th contents. All breccias in this set of 43 samples with the exception of 70175 have K, U and Th contents in the ranges $1750 \leqslant [K] \leqslant 3000$, $1.2 \leqslant [U] \leqslant 2$, and $4 \leqslant [Th] \leqslant 8$ ppm, and all the basalts and gabbros have K, U and Th contents in the ranges $270 \leqslant [K] \leqslant 590$, $.1 \leqslant [U] \leqslant .23$ and $.26 \leqslant [Th] \leqslant .83$ ppm, with the basalts strongly clustered about (500, .1, .4) and the gabbros in the higher part of the gabbro-basalt range. As in the case of the Apollo 16 samples, the dependence of Th on U can be represented by a straight line [whose coefficients are found by the weighted least-squares method of York (3) where both variables have significant errors] having an insignificant constant term:

for rocks: $[Th] = -.052 \pm .023 + (3.85 \pm .11)\,[U]$, ($\chi^2_\nu = 1.23$) and

for soils: $[Th] = +.052 \pm .041 + (3.64 \pm .11)\,[U]$, ($\chi^2_\nu = .71$).

However, the same method will not represent the dependence of K on U well for rocks even after the exceptional point due to the bedded polymict breccia, 76255, (2) is ommitted. Moreover, the constant terms are no longer insignificant:

for rocks: $[K] = 250 \pm 30 + (1570 \pm 110)\,[U]$, ($\chi^2_\nu = 8.23$) and

for soils: $[K] = 426 \pm 29 + (1130 \pm 64)\,[U]$, ($\chi^2_\nu = 2.11$).

The lowest K, U and Th contents are exhibited by the dunite clast 72415.

The cosmic ray and solar proton induced radionuclides showed great increases in activities over previous missions due to the group of extremely large and energetic proton-accelerating solar flares which occurred on August 2-6, 1972. Well over half the solar proton induced ^{22}Na activity in Apollo 17 samples was due to these flares. The high Fe and Ti contents of the basalts combined with the high proton fluxes from the flares produced large amounts of ^{56}Co and ^{54}Mn (mainly from the Fe) and ^{46}Sc and ^{48}V (mainly from the Ti).

The activities of the cosmic ray and solar proton induced radionuclides in the soil samples (see Table 2) are consistent with their sampling. The permanently shadowed soil 76240 showed evidence of nearly complete shadowing, and the boulder fillets 72221 and 72241 showed evidence of partial shadowing. The ^{26}Al activities of all three of these soils are somewhat higher than might be expected and may be the result of movement of either the soils or the boulders in the last million years. The suggestion that 70175 (4) might have been buried is not consistent with its large ^{56}Co activity, which indicates less than 50% burial. However, 76215 and 72255 appear to have been partially shielded from flare protons by their parent boulders. Two rock samples, 78135 and 70255, appear to be unsaturated in ^{26}Al. Using the chemical analyses of

Table 1. Gammary ray analysis of Apollo 17 rocks.

Type*	Basalts					Breccia			Breccia	Brecciated or shocked anorthosites to gabbros			Miscellaneous		
Subtype	Fine		Medium		Coarse	Dr. Matrix	Agglutinate	Grn-grey Matrix	Lt.-grey banded matrix	Norite	Coarse norite		Poikilitic clasts		Brecciated Dunite
Sample	70255	71155	70275	78135	78505	70175	70019	76215	72255	76535	78235	78255,1	72315,17	72355	72415
Weight (g)	224.9	25.80	171.4	133.93	499.6	338.8	128.0	642.8	402.57	145.57	128.8	31.01	84.02	367.4	29.79
Comments		Boulder chip			With soil sample	Friable	from crater floor	boulder spall	boulder chip	rake sample	boulder chip	boulder chip	boulder clast	boulder chip	boulder clast
Th (ppm)	.31 ± .03	.31 ± .06	.43 ± .04	.26 ± .05	.39 ± .05	.40 ± .04	1.03 ± .10	4.6 ± 2	4.4 ± .4	.19 ± .02	.59 ± .08	.83 ± .06	4.80 ± .5	5.3 ± .3	<.15
U (ppm)	.107 ± .008	.118 ± .017	.120 ± .013	.107 ± .012	.135 ± .006	.105 ± .007	.23 ± .02	1.27 ± .06	1.20 ± .15	.054 ± .01	.196 ± .016	.227 ± .016	1.53 ± .15	1.39 ± .15	<.06
K (%)	.048 ± .004	.040 ± .003	.043 ± .006	.0525 ± .0018	.0508 ± .008	.055 ± .002	.0692 ± .0012	.215 ± .014	.184 ± .008	.0235 ± .0008	.0490 ± .0016	.059 ± .003	.284 ± .015	.284 ± .016	.007 ± .002
^{26}Al (dpm/kg)	49 ± 6	105 ± 8	91 ± 5	42 ± 4	72 ± 10	42 ± 5	45 ± 3	56 ± 3	78 ± 6	94 ± 5	77 ± 7	65 ± 6	62 ± 8	62 ± 8	77 ± 6
^{22}Na (dpm/kg)	72 ± 7	119 ± 11	84 ± 5	74 ± 5	67 ± 8	76 ± 18	110 ± 8	60 ± 4	61 ± 5	119 ± 13	111 ± 8	50 ± 5	73 ± 5	73 ± 5	290 ± 30
^{54}Mn (dpm/kg)	137 ± 15	160 ± 20	180 ± 30	180 ± 20	100 ± 6	156 ± 9	166 ± 12	22 ± 17	41 ± 6	24 ± 6	55 ± 8	10 ± 5	90 ± 9	90 ± 9	77 ± 16
^{56}Co (dpm/kg)	211 ± 19	310 ± 50	220 ± 20	240 ± 20	59 ± 13	300 ± 70	240 ± 30	45 ± 6	35 ± 15	8 ± 5	52 ± 9	30 ± 20			150 ± 30
^{46}Sc (dpm/kg)	63 ± 6	81 ± 7	83 ± 20	76 ± 5	45 ± 4	39 ± 5	59 ± 5	5 ± 3	6 ± 6	<1.5	1.4 ± .9	<15			8 ± 3
^{48}V (dpm/kg)	<30		32 ± 15	18 ± 5		17 ± 5					<12				
Th/U	2.9	2.6	3.6	2.4	2.9	3.8	4.5	3.6	3.7	3.5	3.0	3.7	3.1	3.1	
K/U	4500	3400	3600	4900	3800	5200	3000	1690	1500	4400	2500	2600	1900	1900	>1170
Group composition+	70215				75055	79135		77135	77135	76235	78155				72415
SiO_2 (%)	37.19				41.27	42.29		46.13	47.54	44.52	45.75				39.93
TiO_2 (%)	13.14				10.17	5.15		1.54	.91	.20	.27				.03
Al_2O_3 (%)	8.76				9.75	15.08		18.01	17.01	27.01	25.94				1.53
FeO (%)	19.62				18.24	14.01		9.11	11.58	5.14	5.82				11.34
MgO (%)	8.52				6.84	10.42		12.63	9.35	7.63	6.33				43.61
CaO (%)	10.43				12.30	11.44		11.03	11.71	15.17	15.18				1.14

* As classified by LSPET (1973).
+ Taken from rocks in the same group (LSPET, 1973).
Shortlived activities are corrected to time of lunar liftoff.

other samples of the same rock types and a method of calculating the saturated ^{26}Al activity discussed by the authors in another abstract (5), it is possible to estimate the surface exposure ages of these two samples as about 3/4 million years. Two other samples, 70175 and 70019, also appear to be unsaturated in ^{26}Al, probably because of their great friability.

REFERENCES:

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5) Keith, J.E. and R.S. Clark (1974) The saturated activity of ^{26}Al in lunar samples as a function of chemical composition and the exposure ages of some lunar samples. In "Lunar Science V", The Lunar Science Institute, Houston, TX.

Table 2. Gamma-ray analysis of Apollo 17 fines.

Sample*	72221,0	72241,0	72441,0	74220,92	75061,5	76240,2	76261,1
Desc.	boulder overhang fillet	boulder fillet	under boulder	orange soil	boulder top skim	shadowed soil	skim reference
Approx. depth (cm.)	0-3	0-5	70**	5-8	0-1	0-5	0-2
Th (ppm)	3.6 ± .4	3.6 ± .5	3.5 ± .4	.65 ± .09	.91 ± .13	2.5 ± .3	2.1 ± .3
U (ppm)	.89 ± .03	.94 ± .03	.83 ± .03	.164 ± .010	.248 ± .015	.618 ± .018	.49 ± .02
K (%)	.142 ± .004	.144 ± .004	.141 ± .004	.068 ± .002	.066 ± .002	.118 ± .004	.102 ± .003
^{26}Al (dpm/kg)	132 ± 12	187 ± 17	65 ± 6	45 ± 4	180 ± 16	156 ± 14	182 ± 17
^{22}Na (dpm/kg)	63 ± 4	143 ± 8	47 ± 3	51 ± 3	187 ± 10	41 ± 3	148 ± 8
^{54}Mn (dpm/kg)	48 ± 11	78 ± 13	38 ± 11	50 ± 3	200 ± 14	28 ± 6	93 ± 7
^{56}Co (dpm/kg)	<200	130 ± 90	<300	31 ± 6	490 ± 30	28 ± 17	240 ± 20
^{46}Sc (dpm/kg)	5 ± 2	11 ± 3	6 ± 2	19.1 ± 1.6	86 ± 5	7.2 ± .8	23 ± 2
^{48}V (dpm/kg)				13 ± 14	47 ± 12	7.0 ± 1.4	18 ± 12
Th/U	4.0	3.8	4.2	4.0	3.7	4.0	4.3
K/U	1600	1500	1700	4100	2700	1900	2100

* All Sample weights were approximately 100 gm.
**Approximate thickness of the boulder.