

RARE GASES IN APOLLO 17 SOILS WITH EMPHASIS ON ANALYSIS OF SIZE AND MINERAL FRACTIONS OF SOIL 74241. W. Hübner, T. Kirsten, J. Kiko, Max-Planck-Institut für Kernphysik, Heidelberg/Germany.

The rare gas contents of eight Apollo 17 soils covering all major regolith types of this landing site have been analyzed. The results of the duplicate analyses are given in Table 1. The major implications from these data were recently discussed (1) and will be elaborated in the forthcoming Proceedings of the 5th Lunar Science Conference. In this report we restrict ourselves to the discussion of soil 74241 ("control soil"), adjacent to "orange soil" 74220 (Rim of Shorty Crater). Our previous analyses of 74240 indicated that this soil is unusual in various respects (2) and deserves further studies. Consequently we have performed a detailed analysis of 74241.

1) Grain Size Analysis: 7 grain size separates between 12 and 272 μ define a similar surface correlation for all major implanted rare gas isotopes. If n is defined by $C \sim d^{-n}$ ($C = \text{ccSTP/g}$; $d = \text{grain diameter}$), we obtain $n \sim 0.6$ for ^4He , ^{20}Ne , ^{36}Ar , ^{84}Kr and ^{132}Xe . This value is typical for mare soils (3) and implies considerable migration times after implantation (slow gardening) rather than fast burial. We cannot confirm the appreciably higher n -values reported by Hintenberger and Weber (4). By special efforts we were able to prepare an extremely fine size fraction of $\leq 2.5 \mu$ diameter. Even with the help of SEM-observation, the mean effective diameter of this fraction could only be estimated. Within this uncertainty implanted gas concentrations in μ -particles still follow the $n = 0.6$ -line for all rare gases (e.g. $0.73 \text{ ccSTP}^4\text{He/g}$). From this it follows that the quantities of implanted solar flare ions in lunar soils are negligible compared to solar wind ions.

The composition of the SUCOR-component was determined from the grain size fractions. The inferred ratios $(^{22}\text{Ne}/^{21}\text{Ne})_T = 32.2$; $(^{36}\text{Ar}/^{38}\text{Ar})_T = 5.35$ are almost identical with the ratios directly measured in the $\leq 2.5 \mu$ -fraction. A ^{21}Ne -cosmic ray exposure age of $170 \pm 30 \text{ m.y.}$ was calculated making the usual assumptions. The ^{38}Ar -exposure age is higher but inaccurate because of the large amount of trapped Ar.

2) Mineral Separates: Particularly, ilmenite separates of lunar soils have often been analyzed, but so far there has been no comprehensive attempt to analyze all major constituents of any lunar soil for rare gases, except for single grains (5). We undertook this task aiming at 1) the explanation of particularities of soil 74241, 2) the understanding of composite soil patterns in general.

Parentless ^{40}Ar and K-Ar Retention Age. One unique feature of 74241 is its exceptionally high $^{40}\text{Ar}/^{36}\text{Ar}$ ratio of 7.65. The $(^{40}\text{Ar}/^{36}\text{Ar})_{\text{SUCOR}}$ -ratio varies both with composition and with grain size! (Agglutinates 6.1; bulk 7.65; $\leq 2.5 \mu$: 9.46; $2.5\text{--}12 \mu$: 8.24; $12\text{--}24 \mu$: 7.21; $24\text{--}60 \mu$: 6.87). These large variations cannot be explained simply by radiogenic ^{40}Ar . The variability prevents the calculation of K-Ar retention ages from grain size fractions, since the usual ^{40}Ar vs ^{36}Ar -plot is invalid. Our data, as well as those of Hintenberger and Weber (4) are, in spite of their calculations, consistent with any K-Ar age between 0 and 4 b.y. Work on etched samples is in progress. Our observation together with the high concentrations of volatiles observed by Jovanovic and Reed (6) support a very early solar wind irradiation but they add also

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a new aspect to the K-coating hypothesis (7). Note that the depression of $^{40}\text{Ar}/^{36}\text{Ar}$ ratios in agglutinates, if caused by regolith dynamics (see 8) must have occurred in ancient times as nearby orange soil strata were well preserved since Shorty Crater excavation.

Cosmic Ray Exposure Ages. The more reliable ^{38}Ar exposure ages for ilmenite, pyroxene and feldspars range from 285 to 350 m.y. in agreement with the bulk age of Huneke et al. (9). The ^{21}Ne exposure ages are significantly lower. In particular, the plagioclase age is only 60 m.y. If this is interpreted in terms of fractional losses, and we have no better alternative, then we note a surprising similarity between Ne-Ar fractionation patterns of implanted gases and of spallogenic gases in the various minerals. It seems that the extent of possible $^{21}\text{Ne}_\text{C}$ - and even $^{38}\text{Ar}_\text{C}$ -losses has previously been underestimated.

Trapped Gases.

- The diffusion properties of the major constituents of lunar soil are such that at lunar surface temperatures, severe and selective elemental fractionations occur between He, Ne, and Ar, but not between Ar, Kr, and Xe. Consequently, Ar or even Xe rather than He or Ne should be used to characterize the total amount of gas implanted into a soil.

- The absolute gas concentration (^{36}Ar) of a soil is governed by its agglutinate content more than by anything else. Note that ilmenite has the lowest Ar, Kr, and Xe-concentrations next to orange glass (less outward diffusion, less inward migration).

- The fractionation pattern of a bulk soil is determined by its modal composition. Only the analysis of mineral separates can lead to the detection of intrinsic solar wind abundance variations.

- Ilmenite has the least elemental fractionation. The diffusion properties of pyroxene are very remarkable. It is heavily depleted in He but very little in Ne (next to ilmenite). It indicates that the lunar surface temperature is intermediate between the critical temperatures for the onset of He and Ne diffusion in pyroxene. The He-Ne-Ar pattern of pyroxenes may become a sensitive thermometer.

- The etching of scoriaceous (ropy) glass reveals that gases included in cavities and microbubbles are better preserved than those in the surface layers of the glass. Devitrification of glass also increases the retentivity.

$^4\text{He}/^3\text{He}$ Ratio. One is tempted to link the exceptionally high $(^4\text{He}/^3\text{He})_\text{T}$ -ratio of 3100 and the high $(^{40}\text{Ar}/^{36}\text{Ar})_\text{SUCOR}$ ratio of 74241 to a very early solar wind irradiation. However, the data obtained from the mineral separates call for a cautious interpretation. They provide evidence for isotopic fractionation due to solid state diffusion. Ignoring those cases for which $^4\text{He}_\text{R}$, $^4\text{He}_\text{reimplanted}$, and $^3\text{He}_\text{C}$ -corrections create ambiguities, we may safely state that the $(^4\text{He}/^3\text{He})_\text{T}$ ratio in scoriaceous glass is 30% higher than in ilmenite. The most likely explanation is isotopic fractionation after implantation. Space limitation forces us to postpone the discussion of many more features implicit in the data until the publication of the forthcoming Proceedings.

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TABLE 1: Rare Gases in Apollo 17 Soils (10^{-8} ccSTP/g) and ^{21}Ne -Exposure Ages

Sample	^3He	^4He	^{20}Ne	^{21}Ne	^{22}Ne	^{36}Ar	^{38}Ar	^{40}Ar	^{84}Kr	^{132}Xe	$T_{21}(\text{m.y.})$
70011,18	8330	21940000	275500	703	21350	33600	6330	30950	22.3	2.43	285
71501,23	8500	23200000	246000	613	19000	28600	5390	20800	18.8	2.33	165
74241,11	6520	19500000	176000	466	14250	16650	3150	127000	8.3	1.14	165
75061,23	5820	16200000	179500	465	13900	22400	4215	20900	14.9	1.80	240
72501,27	3460	9720000	220000	555	17000	39400	7240	41000	25.2	2.67	195
72701,27	3200	8850000	191000	485	14900	36600	6700	37700	23.4	2.48	160
76501,44	4880	13150000	209000	524	15500	35150	6610	31100	23.8	2.91	305
78501,26	3680	9690000	166000	467	13200	27650	5120	38600	16.2	2.24	405

The first group of samples has been collected at the valley floor, the second at mountain slopes. The data are averages of duplicate analyses and are corrected for procedural blanks and mass discrimination. Absolute errors at most $\pm 8\%$, for isotopic ratios $\pm 3\%$; however in most cases errors are much smaller. Typical sample weights 1.5mg. T_{21} calculated with a production rate of $0.145 \cdot 10^{-8}$ ccSTP $^{21}\text{Ne}/\text{g} \cdot \text{m.y.}$

TABLE 2, cont'd: Elemental and Isotopic Ratios and Exposure Ages

Sample	$\frac{^4\text{He}}{^{20}\text{Ne}}$	$\frac{^{36}\text{Ar}}{^{36}\text{Ar}}$	$\frac{^{84}\text{Kr}}{^{132}\text{Xe}}$	$\frac{^{40}\text{Ar}}{^{36}\text{Ar}}$	$\frac{^4\text{He}}{^{36}\text{Ar}}$	$\frac{^4\text{He}}{^{36}\text{Ar}} \cdot \frac{1}{T_{21}}$	$T_{21}(\text{m.y.})$	$T_{38}(\text{m.y.})$
agglutinates	63.4	8.02	18.00	6.99	6.10	3020	3250	-
glass, scoria- ceous	104.0	6.36	1880	7.03	6.88	3400	3750	-
dto, etched ⁺	153.0	10.20	1750	6.74	6.89	3580	4070	-
glass devitri- fied	117.0	9.96	1814	7.03	7.65	2720	3380	190
ilmenite	378.5	27.90	2440	6.08	8.17	2710	2795	-
pyroxene	40.3	18.00	2350	6.50	8.03	1440	3200	175
plagioclase ⁺	75.3	3.37	1470	5.50	11.40	2450	-	55
>95% pure								295
plagioclase, >80% pure	65.3	5.00	1775	6.00	10.00	2500	-	65
orange glass	82.0	9.04	1400	6.81	6.79	2250	2910	50
bulk 109-272 μ	103.5	8.88	2060	7.10	7.76	2730	3125	-
bulk aliquot	111.0	10.60	2000	7.38	7.65	2985	3070	170 \pm 30 ²⁾

1) assuming $^3\text{He}_c = 6.7 \times 10^{-8} \text{ccSTP/g}$

2) from grain size analysis

TABLE 2: Rare Gases in Mineral Separates of Soil 74241,11. Bulk data are included for reference. Unit 10^{-8} ccSTP/g.

Sample	^3He	^4He	^{20}Ne	^{21}Ne	^{22}Ne	^{36}Ar	^{38}Ar	^{40}Ar	^{84}Kr	^{132}Xe
agglutinates	2900	8745000	105000	297.5	8625	13100	2515	79800	7.11	1.02
glass, scoria- ceous	1250	4250000	40850	124.5	3465	6420	1240	44200	3.41	0.485
dto, etched ⁺	944	3385300	22150	75.9	1920	2170	428	14950	1.24	0.184
glass, devitri- fied	1020	2770000	23650	90.5	1995	2375	484	18150	1.31	0.185
ilmenite	2830	7665000	20250	64.3	1660	726	153	5930	0.298	0.049
pyroxene	383	553000	13700	67.0	1180	763	172	6130	0.325	0.050
plagioclase, >95% pure ⁺	110	268000	3560	18.8	323	1055	234	12000	0.72	0.13
plagioclase, >80% pure	209	522500	3000	31.4	670	1595	338	16000	0.90	0.15
orange glass	216	486000	5950	22.4	494	658	132	4470	0.47	0.069
bulk 109-272 μ	1150	3130000	30300	99.4	2510	3410	660	26450	1.66	0.233
bulk, aliquot	6520	19500000	176000	466	14250	16650	3150	127000	8.30	1.14

⁺Single measurement, all others are averages of replicate analyses. Data corrected for procedural blank and mass discrimination. Absolute error $\pm 8\%$.