ABUNDANCES OF C, N, H, He, AND S IN APOLLO 17 SOILS FROM STATIONS 3 AND 4: IMPLICATIONS FOR SOLAR WIND EXPOSURE AGES AND REGOLITH EVOLUTION. S. Chang and K. Lennon, NASA-Ames Research Center, Moffett Field CA 94035 and E. K. Gibson, Jr., NASA-Johnson Space Center, Houston, Texas 77058

Abundances of C, N, S, H, He, and metallic Fe have been measured in two suites of Apollo 17 fines. One suite of samples is a trench sequence from the rim of Ballet Crater at station 3. These include: 73221,7, a skim sample of the thin 0.5 cm layer of medium gray soil; 73241,5, a light gray soil from the upper 5 cm of the trench which overlies a marbled zone; and 73261,8 and 73281,6, which represent the medium gray and light gray portions of the marbled zone, respectively. The second suite of samples includes 74220,84, the orange soil, and its companion gray soils 74240,16 and 74260,7. The methods of gas extraction by acid hydrolysis and stepwise vacuum pyrolysis followed by combustion are described elsewhere (Sakai et al.)[1].

Consistent intra-sample abundance patterns for solar wind derived C, N, and H species show up clearly in the data in Tables 1 and 2. These patterns define the following decreasing order of solar wind exposure experience by the samples: 73261,8 $\geq$ 73221,7 > 73281,6 > 73241,5 $\approx$ 74240,16 $\approx$ 74260,7 $\gg$ 74220,84. This sequence is also reflected in the He contents of the station 3 soils; however, the gray soils from station 4 appear to have anomalously high He abundances relative to C, N, and H. This probably reflects the greater amounts of ilmenite in the valley soils. Because of the chemical reactivity of solar wind C, N, and H ions, their retention in soils is expected to be relatively independent of soil mineralogy.

At all localities observed on the light mantle, a layer of light gray subsurface material occurs 5 to 10 cm below the medium gray surface soil (Schmitt)[2]. At station 3 accumulation of surface material was apparently interrupted by formation of Ballet Crater (Schmitt)[2]. Significantly, the solar wind exposure experienced by the light gray subsurface layer (73241,5) is about half that of the light gray portion of the marbled zone (73281,6). If these two samples have a common origin as has been suggested (Schmitt)[2], the reason for the difference in exposure times is not clear. One explanation may be that the accumulation rate of this material was not constant, but, rather, slowed with time leading to a gradient decreasing with depth of solar wind exposure for soil grains. Alternatively, deposition of the light gray layer may have been accompanied by some grain size sorting which enriched the bottom layers in coarse particles and the upper ones in fine particles and led to apparently higher bulk concentrations of solar wind species in the upper layers. In either case, the impact event would have caused (a) inversion of strata, placing the layers of light gray soil least enriched in solar wind species at the very surface, and (b) marbling, the latter involving the soil layers more enriched in solar wind material which originally interfaced with the medium gray surface soil. Deposition of medium gray surface soil then resumed. This hypothesis for regolith evolution at station 3 can be tested when results from other analyses of the soils are reported and samples from drive tubes 73002 and 73001 become available for study. The similarity in solar wind exposure of 73221,7 and 73261,8 suggests that the gray surface soil may be accumulating at essentially the same rate as it did prior to the

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marbling event. Determination of the age of Ballet Crater should permit est-
imation of the accumulation rate of light mantle regolith.

The sulfur data in Table 2 conform with the simple mixing model proposed
by Gibson and Moore:[3] soils from station 3 derived predominantly from sulfur-
poor massif material are low in S (< 700 ug/g), and soils from station 4
which contain a large sulfur-rich mare basalt component are high in S (> 1000
ug/g). Despite its mare basalt chemistry, the S content of orange soil is
anomalously low and calls for a unique high temperature history. One very
interesting result is that sample 73221,7 is very depleted in S relative to
its companion soils. This observation suggests that either recent lateral
mixing of soil on the light mantle with sulfur-rich foreign components is
slow compared to regolith accumulation or the upper 0.5 cm of light mantle
is derived in part from different source rocks than the underlying layers of
soil. However, grain compositions (Apollo 17 LSIC)[4] do not reveal gross
mineralogic differences in these soils.

Simulation studies of solar wind related processes will also be reported.
These include determination of implantation efficiencies of simulated solar
wind C and N ions into bulk lunar fines and ilmenite targets. In Figure 1 is
shown part of the gas release profile of 15013,3 fines which had been irradi-
ated with $^{13}CO^+$ ions under conditions which approximate reimplantation of
lunar atmospheric species. Evidently, the ^{13}C of the implanted species is
evolved as ^{13}CO from 600-1150°C during vacuum pyrolysis. The release of ^{13}CO
from unirradiated fines was indistinguishable from background levels, and
release of $^{13}CO_2$ from the irradiated sample was not detectable above back-
ground. Although the ion energy is an order of magnitude too high, it is
expected that CO derived from CO^+ implanted at lower energies would not
exhibit a significantly different release pattern because of the reactivity
of the carbon atoms formed upon impact. The coincidence in the release
pattern of CO obtained from implanted CO^+ and C^+ (Chang et al.)[5] suggests that
a reimplanted atmospheric carbon component derived from the CO molecule ions
cannot be distinguished by a characteristic pyrolysis temperature from C^+
which is either directly implanted by solar wind or formed by photodissocia-
tion of atmospheric CO and, then, reimplanted.

1. H. Sakai, I. R. Kaplan, C. Petrowski and J. W. Smith (1974) Analyses of
C, N, S, He, H and metallic Fe in lunar samples by pyrolysis and hydrolysis.
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2. H. H. Schmitt (1973) Apollo 17 report on the valley of Taurus-Littrow,
Science, 182, pp. 681-690.
3. E. K. Gibson, Jr. and G. W. Moore (1974) total sulfur abundances and
distributions in the valley of Taurus-Littrow: evidence of mixing. In
"Lunar Science V", The Lunar Science Institute, Houston.
4. Apollo 17 Lunar Sample Information Catalog (1973).
5. S. Chang, R. Mack and E. K. Gibson, Jr. (1973) Simulated solar wind implan-
tation of carbon and nitrogen ions into terrestrial basalt and lunar fines.
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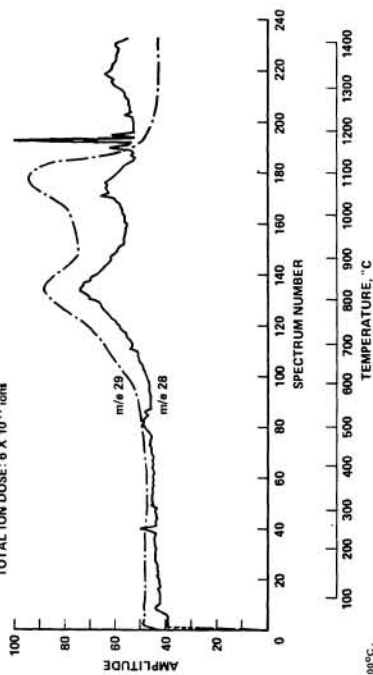*Table 1. Abundances of Stable Light Elements Released by Vacuum pyrolysis-combustion

Sample (wt,g) / Gases Released / T(°C)	71221,7 (0.184)			71241,5 (1.040)			74261,8 (0.951)			73281,6 (0.969)			74220,84 (1.265)			74240,16 (1.488)			74260,7 (1.266)		
	600°	1200°	1200°+O2	600°	1200°	1200°+O2	600°	1200°	1200°+O2	600°	1200°	1200°+O2	600°	1200°	1200°+O2	600°	1200°	1200°+O2	600°	1200°	1200°+O2
CH4 (µgC/g)	.	1	1	-	-	-	-	0.2	0.6	-	0.4	-	-	0	1.2	-	0	1.9	-	0.4	-
CO2 "	16	7	1	9.8	3.2	0.7	11.3	11.6	0.6	11.9	21.4	-	6.5	0.9	-	16	6	1.9	11.3	7.4	1.8
CO "	3	51	-	1.7	26	-	1.6	61.4	-	1.8	44.3	-	0.4	2.4	-	3.5	21.6	-	2.1	19.6	-
Total Carbon	81 µg/g			42 µg/g			88 µg/g			81 µg/g			11 µg/g			50 µg/g			42 µg/g		
N2 (µg/g)	-	44	0	-	21.9	1.5	-	51.2	3.4	-	39.8	0	-	7.3	0	-	16.4	1.9	-	13.1	5.0
He "	-	8	0	-	3.8	0	-	9.2	0	-	NM	NM	-	2	0.3	-	19.4	0	-	24	0
H2 "	20	5.2	-	5.2	-	-	22	-	-	14.8	-	-	0.6	-	-	5.5	-	-	7.8	-	-

**Table 2. Abundances of stable light elements released by acid hydrolysis in 6N H2SO4 at 120°C for >150 hr.

Sample / wt(g) / Gases Released	71221,7 0.111	71241,5 0.958	71241,8 0.951	73281,6 0.992	74220,84 1.142	74240,16 0.957	74260,7 0.931
bCH4 (µgC/g)	7	3.5	7.1	3.4	0	1.3	1.3
CO2 "	28	15.8	16.2	10.8	5.8	15.8	16.5
CO "	6	1.2	2.0	5.8	0	1.9	1.8
H2S (µgS/g)	110	606	677	578	564	1199	1015
He (µg/g)	8	1.7	7.0	6.0	1.5	22	21
cH2 (µg/g)	211	124	184	191	13.3	58	41
dFe (wt %)	0.51	0.41	0.41	0.49	0.035	0.15	0.18

a) Detection limits are as follows: CH4, CO2, CO, 0.2 µgC; N2, 0.1 µgC; He, 0.06µg; H2S, 0.5µgS; H2, 0.1). System blanks for gases are as follows: CH4, <0.5µgC; CO2, <0.2µgC; CO, <0.2µgC; CO2 from direct combustion, <0.2µgC; He, <0.06; N2, <0.4µg; H2, <0.06µg; H2S, <0.1µgS. Prior to analysis all samples were outgassed under vacuum (<10^-4 torr) at 150°C for up to 1 hr.

b) CH4 represents indigenous methane derived from hydrolysis of carbide-like carbon.

c) H2 represents sum of solar wind hydrogen plus methane derived by dissolution of metallic iron.

d) Metallic Fe is calculated from H2, after correction for solar wind hydrogen from Table 1.

e) Stepwise measurement not performed at indicated temperature. In the cases of CH4, He and N2, gases evolved at 600° pyrolysis were stored until after the 1200°C pyrolysis for measurement. For solar wind H2, evolution is essentially complete at 600°C.

Figure 1.

IRRADIATED LUNAR FINES 15013,3

IMPLANTED ION: $^{13}CO^+$
ION ENERGY: 29 KeV
ION FLUX: 2.7×10^{16} ion/hr
TOTAL ION DOSE: 8×10^{17} ions

m/e 29
m/e 28

AMPLITUDE

SPECTRUM NUMBER

TEMPERATURE, °C