INORGANIC GAS RELEASE INVESTIGATIONS AND TOTAL SULFUR ABUNDANCES IN LUNAR SAMPLES. Everett K. Gibson, Jr., NASA Manned Spacecraft Center, Houston TX 77058 and Gary W. Moore, Lockheed Electronics Co., Houston, TX 77058.

PART I

Gas release studies of two Apollo 16 soil samples have been carried out. Additional gas release studies for Apollo 16 samples have been reported previously[1,2]. Procedures employed for the analyses have been described previously[3,4]. Samples were heated at 6°C/minute to 1400°C under a vacuum of 10^{-6} torr, and the released gaseous species, abundances, temperature ranges, and sequence of release determined (Figs 1 and 2). Gases measured included H_2, He, H_2O, CO, N_2, O_2, HCN, H_2S, CO_2, SO_2, and CS_2.

Apollo 16 soil 69961,33 which was taken from beneath a 0.5 meter boulder and soil 69941,36 taken beside the same boulder, are discussed here. The gas release profiles for the samples (Figs 1 and 2) are identical for all gaseous species examined except for the abundance of H_2O released below 400°C. The released H_2O is not adsorbed terrestrial water because adsorbed H_2O is usually released below 200°C. Sample 69941,36 contains more adsorbed water than sample 69961,33 as noted by the sharp water release peak between 100° and 200°C. Additional traces of H_2O previously identified as being derived from solar wind proton irradiation of the silicates are released between 300° to 800°C[4,5].

The soil sample taken from beneath the boulder contains an unusual amount of H_2O whose release behavior between 200 and 400°C is identical with the decomposition of a hydrated mineral phase such as goethite. Sample 69941,36 (taken beside the boulder) contains only trace amounts of this component as determined by the small H_2O release shoulder between 200 and 400°C. Goethite has been previously reported in numerous Apollo 16 samples[6] and could account for the small amount of H_2O released in the temperature ranges observed in our studies. The thermal stability and origin of goethite in the lunar environment has recently been examined by Williams and Gibson[7]. In addition to the possible goethite in the soil beneath the boulder, other volatile elements (i.e., Hg, Cl) may also be enriched in the "semi-permanently" shadowed sample site. Reed and Jovanovic[8] noted enrichments in Hg abundances from soils taken beneath similar sized boulders at the Apollo 15 site. The "shadowed" region beneath the boulder apparently functions as a cold trap for volatiles.

PART II

Total sulfur abundances have been measured on four Apollo 14 samples, seven Apollo 15 soils, and nine Apollo 16 soils. The analytical technique used in the total sulfur measurements was combustion in O_2 at 1600°C followed by detection of the SO_2 produced using an infrared Luft cell. Sample sizes were between 20 and 40 mg. The analyzer was calibrated using N.B.S. steel 55e.

The total sulfur abundances for the samples analyzed ranged from 474 to 867 μgS/g (Table 1). The analytical values are similar to previously reported sulfur contents for lunar soils[9,10]. The only differences noted with the sulfur abundances are for soils taken at the large boulder at Station 13 from Apollo 16 and a trench sample (61221,11) from the same landing site.

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The permanently shadowed soil 63320,10 contained 488 ppm S while the soils 63340,10 and 63500,6 taken near the boulder had 502 and 474 ppm S respectively. The lower S concentrations for soils taken near the large boulder as compared to other surface soils may indicate either a lack of mixing with other soils[10] or a lower meteoritic contribution to the sheltered soil near the boulder.

Total sulfur measurements have been made on soils subjected to thermal volatilization studies. The analytical results are given in Table 2. Samples were heated at 750°, 950°, and 1100°C for 24 hours under a vacuum of 10^{-6} torr and $p_{O_2} < 10^{-10}$ atms. At temperatures as low as 750°C between 12 and 30 percent of the total sulfur in the sample was lost during heating. These volatilication results (Table 2) indicate that there appears to be an easily volatilized fraction of sulfur present in the sample. The low temperature sulfur fraction may be grain size or surface correlated and represents the meteoritic component contributing to the total sulfur content of the soils.

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Table 1

Total Sulfur Abundances in Lunar Samples

Sample No.	Sample Description	Sulfur Content (μgS/g)
14003,71	Fines	706
14163,178	Fines	773
14259,111	Fines	778
14321,242	Breccia	844
15201,21	Fines	607
15210,2	Fines	549
15261,26	Fines, Trench Bottom	712
15271,25	Fines, Trench Top	669
15301,25	Fines	517
15471,12	Fines	572
15601,61	Fines	652
61221,11	Fines, Trench Bottom	496
62240,6	Fines	775
63320,10	Fines, Permanently Shadowed	488
63340,10	Fines	502
63500,6	Fines	474
64801,30	Fines	645
66041,12	Fines	766
69941,36	Fines, beside 0.5 meter Boulder	765
69961,33	Fines, beneath 0.5 meter Boulder	794

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Table 2
Residual Sulfur Abundances (μgS/g) from Volatilization Experiments

Sample Temperature	15021,21	15210,2	15301,25	64801,30
Initial	607	549	516	645
750°C	488	386	455	458
950°C	244	212	257	188
1100°C	88	53	43	40

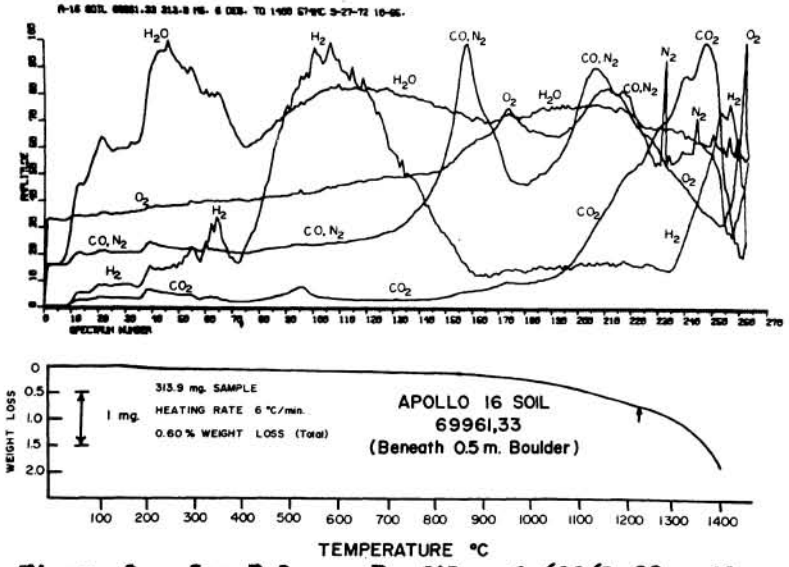

Figure 1. Gas Release Profile of 69961,33 soil taken from beneath a 0.5 meter boulder.

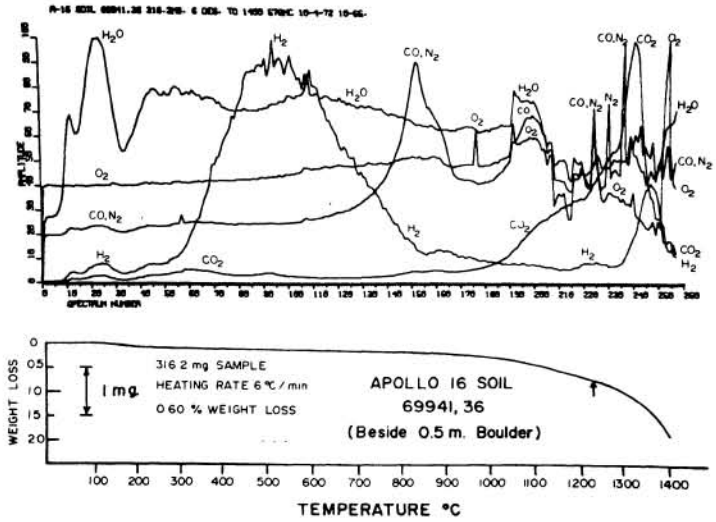

Figure 2. Gas Release Profile of 69941,36 soil taken beside a 0.5 meter boulder.

Note: The gas release patterns vs temperature have been plotted so that each of the gases has been normalized to 100% amplitude in their region of greatest abundance. The arrow on the weight loss curve of each figure represents the initial melting of the sample.

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