

EXTRACTION OF VOLATILES FROM LUNAR CORE AND DRIVE TUBE SECTIONS. S. Jovanovic and G. W. Reed, Jr., Chemistry Division, Argonne National Laboratory, Argonne, Illinois 60439, J. L. Winkler, Jr., and J. Warren, NASA Johnson Space Center, Houston, Texas 77058.

Too little attention has been paid to the question of low temperature volatiles endogenous to the moon. The present apparent dry and gas-free conditions at the lunar surface have been the reason for this lack of interest. In addition, measurement of volatiles in samples is complicated by their low abundances and by problems of possible terrestrial contamination. However, during its evolution, the moon undoubtedly experienced periods of copious evolution of volatiles. The very vesiculation found not only in mare basalts (1) but in highland melt rocks, the presence of glass beads and shards which might be pyroclastic, the possibility that early magma differentiated under wet conditions (2) and the possibility that vapors have become trapped in permanently shadowed sites at the lunar poles (3) are reasons for investigating the question of lunar volatiles, past and present. If primitive undifferentiated matter remains at depth in the moon, it could be a source of volatiles. Even if melting and differentiation occurred throughout the moon, juvenile volatiles may still be present and are slowly being released to the surface.

The purpose of the Abstract is to describe the experiment being conducted in the experimental laboratory of the new Lunar Sample Curatorial Facility in which the object is to collect and measure the volatiles released at room temperature from large quantities (drive tubes and cores) of lunar soil.

It is hoped that other investigators might take advantage of the present experiment since there will not be another opportunity to obtain chemical data on such large quantities of material.

The experiments have the following objectives:

1. Determine the amounts, if present, of Hg and halogens that are mobile in the lunar regolith at subsurface temperatures of $\sim 27^\circ\text{C}$ at 3 cm depth to -23°C at greater than 10-15 cm depth. The large samples greatly increase the detection limits. Volatiles extractable at room temperature will also be mobile at the lower temperatures. Since volatiles entering the lunar atmosphere due to subsolar heating may be lost from the moon, the very existence of low-temperature mobile fractions raises the question of a reservoir to maintain the supply (4). In the present experiment core sections containing material from below the range of the diurnal pulse can be measured and the presence of low temperature volatiles might be indicative of an internal reservoir. Measurement of volatiles released at higher temperatures ($>100^\circ\text{C}$) from dissected core samples may not be appropriate for such considerations. For example, in DDC 60007 in the interval from 0-13 cm depth an average of 2.3 ppb Br is released at 130°C and 10.8 ppb at 13.5-22 cm. The question is whether the latter reflects a previous near-surface exposure or an addition from an interior source.

EXTRACTION OF VOLATILES

S. Jovanovic, et al.

2. At $\sim 100^\circ\text{C}$ enough Hg and Br are released to permit measurements on 50-100 mg samples. The kinetics of migration of such volatiles at maximum subsolar temperatures can thus be measured. Whether these kinetics can be extrapolated to volatile mobilization at much lower temperatures is not known. A modification of the present experiment which would permit collection of several fractions (at room temperature) will allow lower temperature kinetics to be determined. These should be more directly applicable to processes occurring in the regolith.

3. Dissected core sample studies provided profiles of various depth-sensitive parameters, in our case volatile element contents. Measurements of whole core sections provide site-specific information on the low temperature mobile fractions in a single measurement. Significant variations in the mean volatile element concentration in cores from various sites have been observed (5), for example, in Br collected at 130°C , Table 1. As noted, these 130°C data may reflect present or past near surface volatile response. Low temperature volatiles in whole core sections may provide a different type of information about the site - for instance, volatile migration from the interior, the amount (if present) and the rate of which could be dependent not only on an available reservoir but also on the permeability and thermal conditions at the site. Higher temperatures in a region could facilitate volatile migration. The 14211 Br data in the table may thus not only be related to near-surface exposure but also to an increased supply of volatile Br from depth. A similar interpretation does not seem appropriate for Hg in 14211. Different mechanisms for mobilizing and different sources of these volatiles may be inferred. A better understanding of low temperature volatile contents and behavior in the lunar regolith is needed.

The experimental procedure has been described (6) and involves slow pumping of the core tube in a stainless steel vacuum system. The volatile Hg is collected on an in-line gold mesh; the halogens and other volatiles and gases are trapped in a LN_2 cold trap which is later isolated from the pump and core tube chamber, permitted to warm up and the volatiles are transferred to a LN_2 chilled cold finger containing silica gel. The system is prebaked under vacuum at 100°C , the Au and silica gel traps at $400\text{-}500\text{ C}$.

Halogen and Hg data were obtained on DDC sections 70002 and 70006 (6) in a satellite experiment to one whose object was to measure the thermal diffusivity of lunar soil (7). Concentrations of Cl, Br and I in the 0.04-7 ppb range were found, Blank corrections were of the order of 10-20%. The source(s) of the halogens and especially contamination problems could be addressed from interhalogen ratios. The concentration of Hg collected, $\sim 5 \times 10^{-12}$ gm/gm of core, can be compared with the $\sim 3 \times 10^{-11}$ gm/gm of soil and rock in the Ap. 16 and 17 Apollo lunar sample return containers - the only other large sample volatile extraction experiments (8).

In the present experiment volatiles from Apl2 single drive tube 12027, 17.4 cm long and containing 95 gms of soil, have been extracted and halogen and Hg data should be available at the LPS conference.

EXTRACTION OF VOLATILES

S. Jovanovic, et al.

Ultimately, concentration data along with low temperature kinetic measurements will be used to address some of the questions raised above.

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Table 1. Mean concentrations of Br released at 130°C from cores.*

Core	Length cm	Br Mean ppb
14211	0-7	16
15006	0-7.7	1.8
74002	0-8.5	8.3
60007	0-13	2.3
60007	13.5-22	11

* Data from (5).