TRAPPED LUNAR VOLCANIC GASES WITHIN APOLLO 15 GLASS SPHERULES.

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Introduction: The study of volcanic gases can provide information about magmatic processes that occurred at the time of crystallization of the melts. The study of gases associated with lunar volcanism has proved difficult because the moon is unable to retain all but the heaviest gass for any appreciable amount of time [1]. Based on the petrography and mineral chemistry associated with the Apollo 11 basalts, Wellman [2] calculated the theoretical partial pressure ratios for the major gases that should be present: H_2, N_2, and CO, with small amounts of CO_2 and H_2O, and possibly even CH_4 at higher pressures. Naughton et al. [3] calculated mole fractions for a large number of possible lunar volcanic gases.

Delano [4] observed that several lunar glass spheres thought to be of volcanic origin contained voids and vesicles. It is believed that Apollo 15 green glass spheres formed during volcanic "fire fountaining" about 3.1 b.y. ago [5]. Some green glass spheres contain vesicles [4] which might contain trapped samples of volcanic gases associated with the lunar magmatic event. It was hoped that spheres containing voids could be isolated, opened with a laser, and trapped gases identified with a mass spectrometer.

Experimental: Approximately 1000 sherules from lunar soil 15426,155 were separated from a 2 gm aliquot using tweezers. Separated spheres were backlighted to assist locating any voids. By microscopically focusing down through the sphere, any void became visible (Figure 1). Three spheres containing voids were identified. They were mounted in indium metal and analyzed using the Laser Microprobe/Quadrupole Mass Spectrometer technique described by Gibson and Carr [6]. Samples were "zapped" with the laser and the volatiles released were analyzed with the mass spectrometer. Spheres with no apparent voids were analyzed to determine background concentrations of volatiles.

Discussion of Results: LM/QMS analysis of the three spheres showed that two spheres contained only vacuum or gas concentrations so small that detection of any gases was not meaningful. The third sphere, named Odin (Fig. 1), contained detectable levels of trapped gases. Fig. 2 shows the spectra of the volatile species released from Odin. The background substraction for this spectra was the average spectra from the three shots which preceeded the opening of the void and the background was substracted from the data obtained during the opening of the vesicle (after Hartmetz et al.[7]). The void within the sphere could be seen to be opened after the laser shot. In addition, the spectra produced released large abundances of m/z=32 (O_2) and lesser amounts of m/z=14 (N). This was one of the very few spectra that showed any oxygen from a lunar sphere.

Table 1 contains selected gas ratios for the analysis of Odin 3a1. Also present are spectra data from the background analysis of Odin 3a2. Within Table 1 are the CO/CO_2 ratios from a typical solid sphere analyzed for background information, Wellman's CO/CO_2 ratios [2], and Naughton's ratios [3]. The Wellman ratio was calculated assuming a 1300^oK to 1400^oK solidification range, similar to that of terrestrial basalt [2]. The absence of graphite was also assumed. Naughton's ranges were calculated assuming a 1200^oK to 1600^oK solidification range, and the mole fractions of the gases presented in their data were considered equivalent to the partial pressure, according to Raoult's Law.

If the entire abundance of the m/z=28 is attributed to CO, the CO/CO_2 ratio for Odin 3a1's spectra is above both Wellman's and Naughton's ranges, while the solid sphere ratio (i.e. background data) falls within the ranges. If one assumes half of the m/z=28 abundance is taken to represent CO and the other half N_2 (note that m/z=14 was observed during the opening of the void and this assumption has merit), then the ratios for CO/CO_2 obtained from the gases released upon opening the void within the 15426 lunar sphere agree with those expected from the theoretical calculations. It should be noted, however, that the N_2/O_2 ratio, while it may not agree with Naughton's ratio, is an order of magnitude larger than that of the terrestrial atmosphere. Unfortunately, abundances of hydrogen gas within the lunar vesicle could not be determined with our study. However, because hydrogen readily diffuses through glass, any analysis of trapped hydrogen from a 3.1 b.y. old glass bead would probably be meaningless because of the loss of hydrogen over geologic time.

Conclusions: It has been demonstrated that selected lunar glass beads contain voids which may contain trapped indigeneous lunar gases associated with the lunar volcanism. We believe that the gases analyzed from the 15426 glass bead Odin are indigenous lunar gases. The CO/CO_2 ratios fall within Wellman's and Naughton's theoretical ranges. From our studies, we feel that the abundance ratios of the CO and CO_2 gases associated with the magmatic event which formed the 15426 glasses were essentially identical to those obtained from theoretical calculations based upon mineral chemistry and oxygen partial pressures at the time of formation of the magmatic materials.

References: [1] Fielder G. and Wilson J. (1975) Volcanoes of Earth, Moon and Mars, Ch. 5, Elek Science., [2] Wellman T.R. (1970) Nature 225, 711-712., [3] Naughton J.J. et al. (1972) Proc. 3rd LPSC 2015-2024., [4] Delano J.W. (1986) Proc. 16th LPSC D201-D213., [5] Taylor S.R. (1975) Lunar Science: A Post Apollo View, pp. 144-145, Pergamon Press., [6] Gibson E.K.Jr. and Carr R. (1989) New Frontiers in Stable Isotope Research: Laser Probes, Ion Probes, and Small Sample Analysis, U.S.G.S. Bull 1890, 35-49. [7] Hartmetz C.P. et al. (1990) Proc. 20th LPSC 343-355.

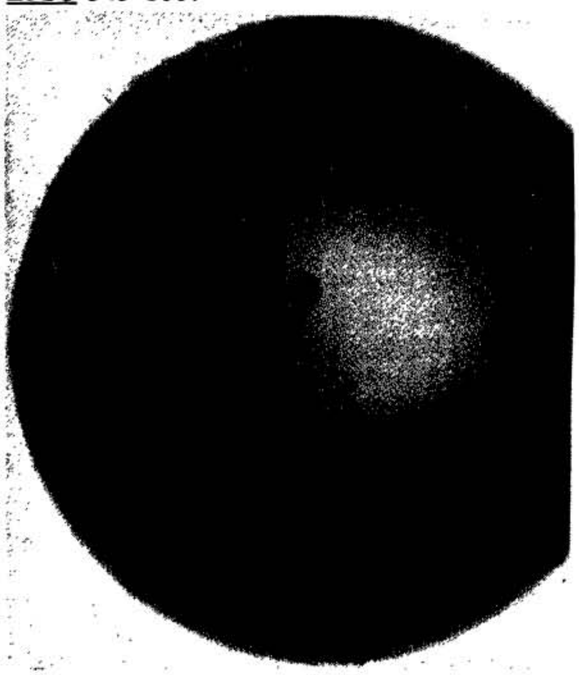

Fig. 1. Photomicrograph of 15426,155 glass sphere identified as Odin 3a1. Sphere is 425 microns in diameter. Interior void is 25 microns in size.

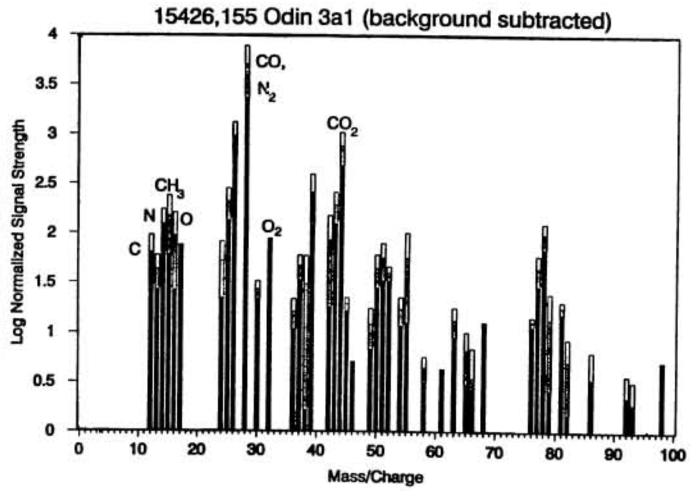

Fig. 2. Mass spectrum of gases released from interior of lunar sphere 15426,155 during laser microprobe opening of void.

Table 1. Gas Ratios

Sample	CO/CO_2	CO^*/CO_2	N_2/O_2	N_2^*/O_2	CO_2/CH_4	CO_2/O_2
Odin 3a1	9.0	4.5	56.0	28.0	3.6	6.0
Odin 3a2	10.0	5.0	79.0	40.0	3.1	8.0
Solid	5.0	---	---	---	---	---
Wellman	1.6-6.7	---	---	---	---	$\sim10^{15}$
Naughton	2.95-6.92	---	$\sim10^{14}$-10^{10}	---	---	$\sim10^{15}$-10^{10}

* Denotes that equal amounts of CO and N_2 contribute to the abundance of m/z=28 (i.e., half the total abundance of m/z=28 is used to calculate the ratios for CO/CO_2 and N_2/O_2).