

GAS RELEASE PATTERNS FOR 15016 AND 15065 AND THEIR SIGNIFICANCE,  
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It is now well established that, in comparison with terrestrial rocks, the lunar samples are poor in both gases and volatile elements (except for those introduced from the solar wind). Either crushing or heating can be used to release the gas from rocks for analysis. Interpretation of the composition of the gas released by crushing is complicated by adsorption of polar compounds onto the new surfaces generated by the crushing since this changes both the amount and composition of the gas. The gas released by melting rocks is also difficult to interpret because it may have come from many different sites within the rock. However, because each site has its own characteristic temperature for gas loss, a slow heating from room temperature to the melting point releases gases from the various sites at different times. This technique has been used in the present study.

A quadrupole mass spectrometer was used to monitor the evolution of gas from 15016:48(basalt), 15065:44 (gabbro), ten terrestrial basalts and four chondrites. Heating rates of  $10^{\circ}\text{C}/\text{min}$  were used and the mass spectrum scanned continuously at 137 sec/scan. Samples of approx. 20 mg were loaded into a side arm above an alumina sample tube and left under vacuum overnight. The outgassed alumina sample boat and tube were given a preliminary heating to  $1000^{\circ}\text{C}$  to remove adsorbed gas, cooled to room temperature and loaded with the sample by pushing it out of the side arm with a magnet. The lunar samples were loaded into the sample tubes in a nitrogen dry box.

All the samples studied showed three distinct episodes of gas evolution. For the terrestrial basalts the initial gas release, in the temperature range from  $50$  to  $500^{\circ}\text{C}$ , can be related to alteration, with the most highly altered samples giving the largest contribution, but even fresh samples also release gases (mainly  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ) in this range. Acid leaching reduces the amount of gas evolved and removes the carbon dioxide evolution peaks characteristic of carbonates. The lunar samples also evolve much of their gas in this low temperature range. This gas is richer in water and carbon dioxide than the gas released at higher temperatures. A  $\text{CO}_2$  peak, unrelated to the release of other gases, occurred at  $500^{\circ}\text{C}$  in both 15016 and 15065 and is thought to correspond to carbonate decomposition.

An intermediate-temperature gas release ( $700$ – $1000^{\circ}\text{C}$ ) is present in both lunar samples. By analogy with the terrestrial basalts this is tentatively attributed to the rupturing of gas vesicles. The terrestrial basalts show a correlation between the amount of gas released by crushing and the size of the intermediate peak. No crushing experiments were carried out with the lunar samples.

The final gas release occurs near the melting point. Experiments with terrestrial samples indicate that this gas comes from melt inclusions, fluid inclusions or the mineral lattice. Fluid inclusions do not appear to be important in lunar samples and the

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contribution from the mineral lattice is small for samples which crystallized within a few miles of the surface. This suggests that melt inclusions are the main source of gas released from lunar samples at high temperatures. As the minerals crystallized, they trapped small volumes of the melt together with the gas dissolved in it. Thus the gas released from melt inclusions should be the best estimate of the composition of the gases associated with the magma. Samples 15016 and 15065 differ from all terrestrial basalts analyzed in having CO as the major component, with only minor amounts of CO<sub>2</sub>, H<sub>2</sub>O, H<sub>2</sub> and other gases. The Allende chondrite is the only other sample which has evolved gas with a composition similar to that from the lunar samples. Gases react with one another very rapidly at high temperatures and it is probably misleading to quote compositions in terms of specific compounds. Figure 1 shows the gas compositions plotted on a carbon-hydrogen-oxygen ternary diagram since these three elements are by far the most abundant. This method of displaying the data is independent of chemical reactions if all the gases remain volatile. The figure shows clearly that the gases associated with the lunar magmas that produced rocks 15016 and 15065 were very similar and both were much more carbon rich than those associated with terrestrial magmas. In both the basalt and the gabbro the gas in the vesicles is much enriched in water relative to that in the original magma. This has been the normal trend observed for the terrestrial basalts studied so far.

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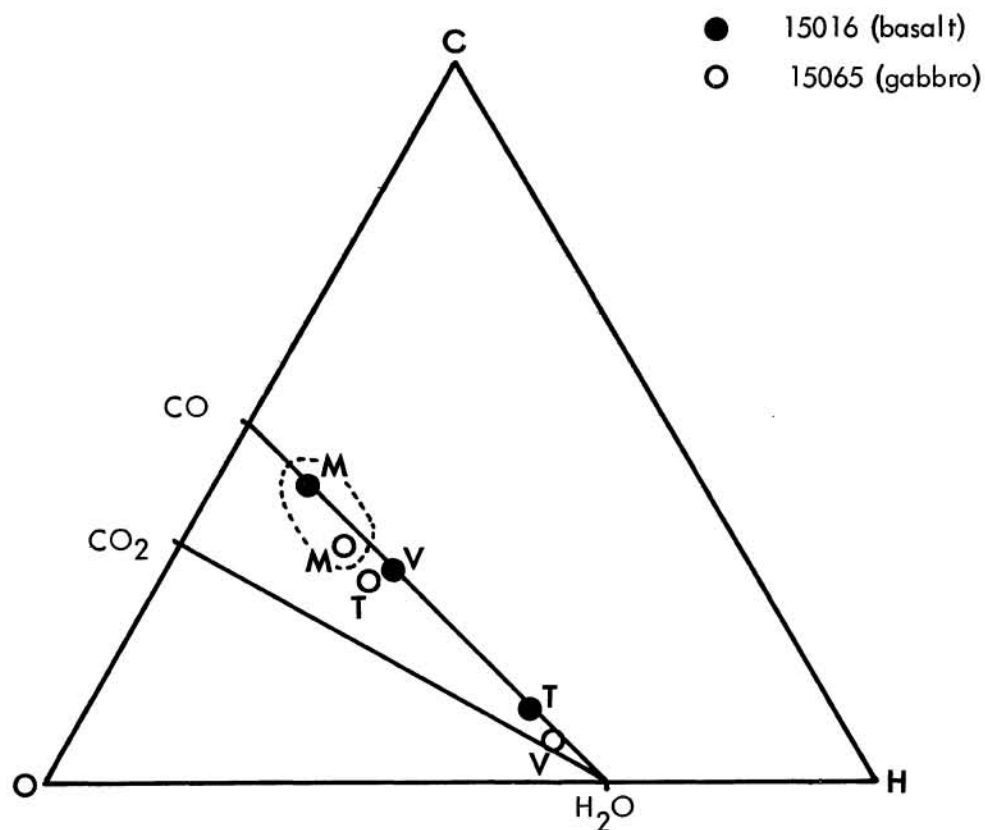


Figure 1 : Carbon-hydrogen-oxygen ternary diagram showing the composition of the gases present in samples 15016:48 and 15065:44. The area enclosed by the dotted line shows the composition of the magmatic gas phase present during the formation of rocks 15016 and 15065.

- M : Gas from melt inclusions
- V : Gas from vesicles
- T : Total gas evolved (20–1400° C)