INTERNAL FRICTION IN ROCKS AND ITS RELATIONSHIP TO VOLATILES ON THE MOON. B. R. Tittmann, R. M. Housley, and E. H. Cirlin, Science Center, Rockwell International, Thousand Oaks, CA 91360.

Our recent work (1,2) showed that very small amounts of absorbed volatiles - only removed by outgassing in high vacuum and elevated temperatures - drastically increase the internal friction in terrestrial analogs of lunar basalt. Here new results are presented on the frequency dependence of the effect of outgassing in the analogs of lunar basalt along with some new data on other materials. This work shows that the effect of strong outgassing is qualitatively independent of the composition of the matrix and the shape and size of the pores. The frequency dependence data suggest that the effect will still be important at seismic frequencies. Therefore also presented are the results of a preliminary effort to use our data in placing constraints on the lunar outgassing history.

Representative results are displayed in Table I, and the key results are discussed below.

1. Outgassing of various materials. As shown in Table I, a sample of commercial grade PZT (lead zirconate titanate) was found to undergo large increases in Q with outgassing similar to the terrestrial basalt. This ceramic has a moderate porosity but no fractures and is nearly homogeneous in composition. Similar to PZT in having no fractures and a uniform composition but being characterized by very small pores (~40Å diameter) is Corning Vycor 7930, a glass composed of 90% SiO_2 and filled with an interconnected system of pores (porosity 28%). The Vycor also showed a similar increase in Q with outgassing so that we conclude that the effect arises from the adsorption of volatiles in porous materials qualitatively independent of the shape and size of the pores. As an alternative to outgassing by heat treatment in vacuum, a rock sample was subjected to a field of intense microwave radiation in order to remove the water with negligible heating of the rock itself. This experiment was performed with another terrestrial analog of lunar basalt with somewhat lower porosity than W-8. At a vacuum of 10^{-6} torr with an exposure time of only 12 min., the Q improved by a factor of 10 confirming that increases in Q are due to strong outgassing independent of the procedure followed.

2. Frequency dependence of Q in Outgassed Samples and its Relationship to Lunar Outgassing History. Table I shows data obtained on the frequency dependence of Q in outgassed samples. These limited results suggest that the effect of volatiles should be strong at seismic frequencies. The difficulty in removing the absorbed volatiles during outgassing treatments seems to imply that a monolayer or less is all that is required to increase internal friction. This conclusion combined with the estimate of 0.01 m^2/gm for the upper limit to the internal surface area of lunar basalts made by Cadenhead et al. (3), one can obtain an estimate for the upper limit on the amount of H_2O which could have outgassed from the interior of the moon during or after formation of the maria. The amount of H_2O so calculated corresponds to a layer on the surface only a few cm thick in contrast to

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TABLE I.

INTERNAL FRICTION QUALITY FACTOR Q AND RESONANCE FREQUENCY ν_{RES}

Terrestrial Analog of Lunar Basalt (W-8)			Outgassing Conditions
15kHz	47 kHz	80 kHz	
688 (15,531 Hz)		683 (79,755 Hz)	at 2×10^{-8} torr and room temperature after long exposure to air.
1478 (15,335 Hz)		999 (78,388 Hz)	at 2×10^{-8} torr and room temperature after one heat treatment to 200°C and re-exposure to N_2 enriched air for about 2 hours.
1890 (15,294 Hz)	960 (47,159 Hz)		at 10^{-8} torr and room temperature 2 hours after second heat treatment at 200°C in vacuum.
2010 (15,294 Hz)	1025 (47,160 Hz)		at 10^{-8} torr and room temperature 5.5 hours after second heat treatment.
Lead Zirconate Titanate			
	1070 (12,795 Hz)		at room temperature in air at one atmosphere after sawing with wet diamond saw, cleaning in acetone bath and drying.
	1425 (12,809 Hz)		at 10^{-4} torr and room temperature after soaking in hydrogen peroxide and drying at temperature not exceeding 40°C.
	1730 (12,804 Hz)		at 10^{-8} torr and room temperature after long term (6 days) outgassing with one thermal treatment to 50°C.

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Vycor 7930			Outgassing Conditions
11 kHz	33 kHz	56 kHz	
200 (11,123 Hz)	200 (33,368 Hz)		As received at STP
810 (11,312 Hz)	770 (33,915 Hz)	556 (56,382 Hz)	At 10^{-8} torr and room temperature.

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the hundreds of m which would be expected if the moon had an internal constitution similar to that of the earth.

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