INTERNAL FRICTION AND SEISMIC ACOUSTIC VELOCITY IN LUNAR ROCK 70215,85 AND TERRESTRIAL ANALOG: TEMPERATURE AND VACUUM DEPENDENCE;

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Previous studies have shown that very small amounts of absorbed volatiles - only removed by outgassing in high vacuum and elevated temperatures - drastically increase the internal friction Q^{-1} in terrestrial analogs of lunar basalt (1,2,3). Recently (3,4) room temperature Q^{-1} values of the $2x10^{-5}$ - $3x10^{-5}$ range have been achieved with lunar rock 70215,85 by thorough outgassing procedures in ultra high vacuum. Here results are presented on the temperature dependence of Q^{-1} as measured in the range 25°C to 600°C along with some data on the change in Q^{-1} with pressure in ultra-high vacuum. The temperature dependence shows the existence of an internal friction peak at around 200°C followed at high temperatures by an extensive region with flat Q^{-1} ($\sim 1x10^{-3}$); the work at ultra-high vacuum shows decreases in the internal friction with decreases in ambient pressure even in the range 10^{-8} to 10^{-10} torr.

1. Temperature dependence. The low-frequency apparatus (3,5) was used to measure the internal friction Q^{-1} and velocity in the flexure mode on a terrestrial analog of a lunar basalt at 50 Hz in the range from 25°C to 600°C. The data was collected in a series of experiments with two separate samples with runs for increasing and decreasing temperature, in vacuum at 10^{-7} torr, and in laboratory air. The measurements performed in air gave a more or less flat temperature dependence with Q^{-1} values in the range of $1.8x10^{-3}$ to $2.2x10^{-3}$ with the low Q^{-1} values occurring at high temperatures in approximate agreement with previous work on basalts (6). In contrast, the measurements in vacuum revealed a much lower Q^{-1} at all temperatures with a peak between about 120°C and 250°C as shown in Fig. 1 which displays one of the runs for decreasing temperature after long-term exposure (days) to 600°C. On the high temperature side the internal friction achieves and maintains rather low values over a wide range of temperatures. These features are in good agreement with those obtained on other runs on the same sample and on another sample cut from the same mother rock. The source of mechanism of the internal friction peak is not understood at this time. The existence of a low Q^{-1} regime at such high temperature may help explain why the low lunar seismic Q^{-1} persists to some depth (7,8). The 6% decrease in frequency - and therefore velocity - with decreasing temperature seen in Fig. 1 is tentatively thought to be associated with a partial opening of microcracks and resultant decrease in compliance. The cooling, from the high temperature is thought to open up old (and/or new) crack tips as a consequence of the various constituent minerals relaxing with different thermal expansion coefficients.

2. Vacuum dependence. The ultra-high vacuum apparatus (3) was used at 20 kHz to measure the changes with ambient pressure of the Q^{-1} and velocity (in the compressional mode) on lunar rock 70215,85. The measurements were

performed with the sample at room temperature and without having been subjected to the exacting and critical procedures of mounting and heat treating required for the extremely low Q^{-1} so that the Q^{-1} values were in the range of only about 3×10^{-4} to 5×10^{-4}. Table I shows that even in the range of ambient pressures as low as 10^{-8} - 10^{-10} torr noticeable decreases with pressure are observed for the Q^{-1}, while the resonant frequency is seen to increase. This small increase in frequency is possibly associated with a partial closing of microcrack tips and resultant increase in compliance caused by the removal of volatiles such as H_2O.

References

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Table I. Effect of ultra-high vacuum on resonance of lunar rock 70215,85.

Pressure (torr)	Exposure Time (Hrs)	Q^{-1} (10^{-4})	Increase In Frequency
1×10^{-7}	12 hrs	5.4	0%
1×10^{-8}	12 hrs	4.2	.06%
1×10^{-10}	14 hrs	3.0	.21%

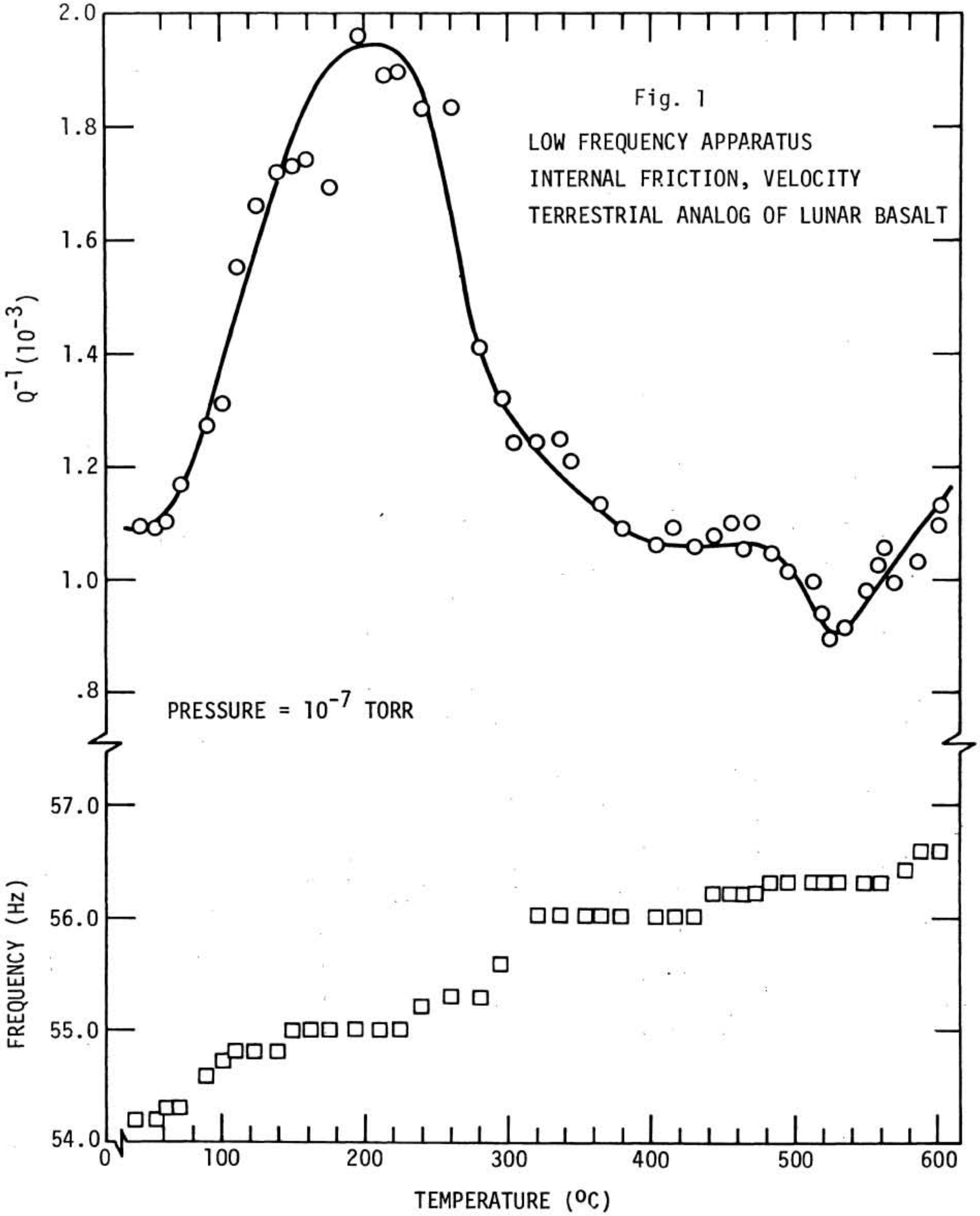

Fig. 1

LOW FREQUENCY APPARATUS
INTERNAL FRICTION, VELOCITY
TERRESTRIAL ANALOG OF LUNAR BASALT