LUNAR SAMPLE ANALYSIS
Annual Report No. 1
As of 31 January 1975

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# Annual Report of Lunar Sample Analysis

## LUNAR SAMPLE ANALYSIS

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## Authors

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## Report Summary

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 in terrestrial analogs of lunar basalt. Recently room temperature $Q$ values as high as 2000 have been achieved by thorough outgassing procedures in $10^{-8}$ torr. Here new results are presented on $Q$ measurements for lunar rock 70215,85, along with some data on the effect on $Q$ of a variety of gases. This work shows that substantially greater...
increases in $Q$ are obtainable in a lunar rock sample than in the terrestrial analog samples studied, and that in addition to $H_2O$ other gases also can make non-negligible contributions to the internal friction.
INTERNAL FRICTION QUALITY FACTOR \( \geq 3100 \) ACHIEVED IN LUNAR ROCK 70215,85

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 in terrestrial analogs of lunar basalt \(^1,2,3\). Recently \(^3\) room temperature Q values as high as 2000 have been achieved by thorough outgassing procedures in \(10^{-8}\) torr. Here new results are presented on Q measurements for lunar rock 70215,85, along with some data on the effect on Q of a variety of gases. This work shows that substantially greater increases in Q are obtainable in a lunar rock sample than in the terrestrial analog samples studied, and that in addition to \(H_2O\) other gases also can make non-negligible contributions to the internal friction.

1. **Q-measurements in lunar rock 70215,85**

Lunar sample 70215,85 (0.4 x 0.6 x 8.5 cm\(^3\)) is a fine-grained sub-volcanic basalt with microphenocrysts of ilmenite, olivine, and clinopyroxene \(^4\). As shown in Table I, when received the sample gave a Q \(\approx 60\) in laboratory air. This value was increased to Q \(\approx 340\) by pumping down to \(10^{-3}\) torr with a molecular sieve sorption pump, and to 800 following a series of thermal heat treatments starting with a slow heat-cool run and finishing with a rapid cool-down. This procedure was followed by a Vac-Ion pump down and another extended heat treatment, which gave a Q value of 2420. Finally after an extended period (1 week) of Vac-Ion pumping, a room-temperature Q \(\approx 3130\) was achieved at \(2 \times 10^{-7}\) torr. This value of Q is substantially greater than that achieved in thoroughly outgassed terrestrial analogs and falls in the range of lunar seismic Q values reported \(^5\). Why the hard-vacuum-Q of the lunar sample is so much higher has not yet been established. However, the probable presence of combined water (hydroxyl group) within the structure and of liquid and gas inclusions in microscopic closed cavities must be held accountable for some of the loss in Q in the terrestrial rock. These sources of \(H_2O\), completely absent on the lunar rock, are not removed by the heat treatments \((\sim 300°C)\) given the rocks in the present experiments.

2. **Nature of Volatiles**

In order to find out which volatiles are playing a role in the damping mechanism, carefully controlled experiments were undertaken with the few gases most likely to have been present in the lunar environment. The effect of \(CO_2\), \(CO\), \(H_2\), and \(H\) on Q was measured for an analog of a lunar basalt as shown in Table II. The sample was first outgassed at 300\(°C\) and \(10^{-8}\) torr to Q \(\approx 500\), then suddenly exposed to one atmosphere of the gas, with the decrease in Q monitored with time. An inert gas, He, was used as reference gas for calibration purposes. The He gas was seen to have little or no effect, while \(CO_2\), \(CO\), \(H_2\), and \(H\) definitely reduced the Q. The experiment with \(H\) was carried out by heating the sample to 170\(°C\) to cause dissociation.
of the molecular hydrogen. By comparison with the effect of \( \text{H}_2\text{O} \) (changes by factors of 10\(^2\)), the decrease in Q is small for these gases. This experiment was more sensitive than our previous test of the influence of various volatiles (2), largely because the sample was much more thoroughly outgassed initially. Residual gas analysis carried out at 10\(^{-8}\) torr after bake-out revealed the presence of equal amounts by volume of \( \text{H}_2\text{O} \) and CO in the test chamber. This result shows that \( \text{H}_2\text{O} \) is still probably the most serious factor preventing the achievement of higher Q-values.

Table I

Values for Q and Resonance Frequency for Lunar Rock 70215,85

<table>
<thead>
<tr>
<th>( Q(\text{kHz}) )</th>
<th>( \nu_{\text{RES}} )</th>
<th>Outgassing Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>19.969</td>
<td>As received in laboratory air.</td>
</tr>
<tr>
<td>340</td>
<td>20.335</td>
<td>At 10(^{-3}) torr and room temperature.</td>
</tr>
<tr>
<td>400</td>
<td>20.353</td>
<td>After first heating run at 10(^{-3}) torr followed by slow cooling.</td>
</tr>
<tr>
<td>800</td>
<td>20.253</td>
<td>After second and third heating runs at 10(^{-3}) torr followed by rapid cooling.</td>
</tr>
<tr>
<td>2420</td>
<td>20.138</td>
<td>After fourth heating run followed by rapid cooling at 10(^{-6}) torr.</td>
</tr>
<tr>
<td>3130</td>
<td>20.661</td>
<td>After continued pumping at room temperature and at 10(^{-7}) torr.</td>
</tr>
</tbody>
</table>
Table II

Effect of gases on Q in terrestrial analog of lunar basalt

<table>
<thead>
<tr>
<th>Gas at 1 atm. and room temp.</th>
<th>Reduction in Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>He</td>
<td>3%</td>
</tr>
<tr>
<td>CO₂</td>
<td>8%</td>
</tr>
<tr>
<td>H₂</td>
<td>25%</td>
</tr>
<tr>
<td>H</td>
<td>40%</td>
</tr>
<tr>
<td>CO</td>
<td>45%</td>
</tr>
</tbody>
</table>

References


(4) Lunar Sample Information Catalog, Apollo 17 (1973), MSC 03211, p. 135.