VELOCITY STRUCTURE OF THE SHALLOW CRUST OF THE MOON; A. Nur, N. Fujii, and E. S. Sprunt, Dept. of Geophysics, Stanford University, Stanford, Ca. 94305

The top 25 km of the lunar crust are characterized by a very large increase of velocity with depth, followed by almost constant velocity below 25 km, presumably due to lack of cracks. Because of extensive meteoritic impacts we expect extensive fracturing of the lunar crust to depths comparable to the dimension of impact craters, some of which are hundreds of kilometers in diameter. The increase with depth of v_p near the lunar surface is too great for gravitational self-compaction of fractured rock, as shown by Warren et al. (1972) and Talwani et al. (1973). It is also extremely unlikely that the velocity gradient is controlled in this region by mineralogy. Instread, it must be controlled by the systematic decrease with depth of the average crack density. Alternatively, it is possible that the large change is confined to the first 1-2 km, (Kovach et al., 1973) and the velocity at greater depth is almost 'normal' for self-compacting fractured rocks. In any case, laboratory data combined with in situ travel time data must be used to provide some constraints on the mechanical state of the shallow crust.

We have made a detailed study of velocities as a function of pressure and temperature history although without vacuum, in simulated lunar material - a fine grained volcanic ash. The results yield relations between compressional velocity and density vs. the temperature and pressure histories. The duration of pressure and temperature cycles lasted on the order of days to weeks, and the results are assumed to represent equilibrium values for durations of that order. In general, rapid changes occur in the initially loose sample to transform it into a more and more competent rock-like solid. In particular, moderate temperature causes very rapid permanent compaction. Both temperature and pressure act to compact the rock powder, but the rate of compaction with heating to a given temperature is greater at low pressure. Thus the velocity of ash at constant P = 50 bars and room temperature, has increased from 2.3 km/sec to 3.0 km/sec, 3.3 km/sec, and 3.5 km/sec after heating cycles to 130°C, 180°C and 22°C respectively. At constant P = 2.5 kbr, velocity increases from 3.8 km/sec to 4.4 km/sec after heating to 220°C. The measured velocity density relations for permanently compacted ash show that the effect of heating is to increase velocity much more than density, indicating that fast processes occur at grain boundaries to solidify the powdered rock.

The permanent increase of velocity is, to a first approximation, simply related to the maximum temperature, and not the temperature history which preceeded the maximum. In other words, the physical state of the sample is determined only by the highest pressure and temperature which it experienced, provided it achieved, under these conditions, equilibrium.

In summary we have found taht rock powders which remain unchanged following long periods of cold compaction, rapidly undergo permanent increases of their elastic stiffness even at moderate temperatures.

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The crucial question now is the time required to reach equilibrium under dry lunar conditions. Is some moisture essential for this compaction process, or can time and temperature accomplish the same in totally dry rock powder? By using results from slow solid-solid diffusion studies, combined with our fast diffusion processes we hope to constrain the possible lunar processes to eventually understand the velocity and Q structure of the lunar crust.

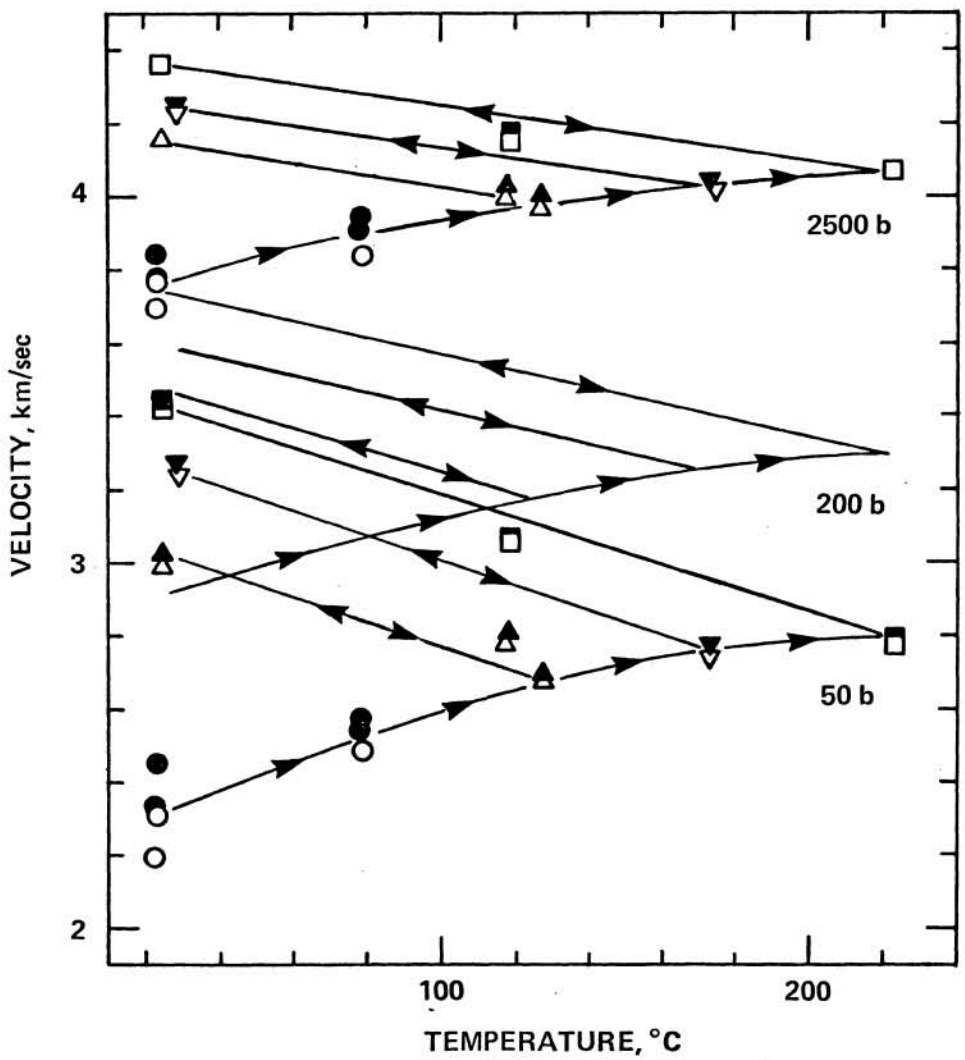

Figure 1. Compressional velocity in volcanic ash as a function of temperature history for various confining pressures. Arrows indicate the time sequence of the temperature.

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