COMPRESSIONAL WAVE VELOCITY IN COMPACTING FINE-GRAINED POWDERS UNDER HIGH VACUUM. R.M. Stesky, University of Toronto, Erindale Campus, Mississauga, Ont., Canada L5L 1C6.

Although there seems to be general agreement that the powder layer of the lunar regolith probably is thin (on the order of 10 to 20 m. thick), there is considerably more uncertainty about the nature of the transition from the upper powder layer to the deeper solid rock layer at 1 km. or so depth. Since the main information used to study this region is seismic data, there is clearly a need for more data on the seismic properties of powders, as well as powder-boulder mixtures, under the conditions present at depths of tens or hundreds of meters in the moon. Most measurements to date have been under atmospheric pressure, rather than high vacuum, and under load stresses or pressures considerably in excess of the few tens of bars maximum pressure expected in this region of the moon [e.g. 1,2]. One brief study of P-wave velocity under high vacuum and pressures below 2 bars was made by Johnson and others [3], but more is needed. In an earlier paper [4], we reported some preliminary measurements of P- and S-wave velocities in powders in air and under low vacuum to confining pressures up to 5 bars. Our measurements have now been extended to high vacuum.

The apparatus is essentially the same as described previously [4]. Briefly, the powder is confined within a brass sample cup and is compacted under uniaxial strain loading at a strain rate of about $3 \times 10^{-3}$ sec$^{-1}$. The applied force, displacement, and ultrasonic wave velocity (either P- or S-wave) are continuously monitored. The sample cup is mounted within a vacuum chamber. Vacuum pressures down to $9.8 \times 10^{-7}$ torr. have been achieved after heating and outgassing the chamber and sample. The velocity measurements were made in the pressure range of $1 - 4.5 \times 10^{-6}$ torr. Only one shear velocity run has been done under high vacuum, so only the compressional velocity results will be presented in this report. The powder is a finely crushed olivine diabase with an average grain size of 25 μm.

The compaction curves are summarized in Fig. 1. The initial density was varied by tapping the chamber. Strikingly, the final density is approximately the same for all runs ($1.921 \pm 0.029$ g/cc.), statistically independent of the initial density. In contrast, in air the final density is higher ($1.908$ to $2.036$ g/cc.) and tends to increase with increasing initial density. The density values in Fig. 1 are compatible with density models for the moon [5]. Upon unloading the density decreased only slightly from the peak value and remained at approximately the same value upon reloading to 5 bars.

Fig. 2 shows a typical series of P-wave velocity measurements during two compaction cycles of a powder sample. Note that there is considerable hysteresis and that part of the initial velocity increase is irreversible. This irreversible change is less marked for samples with higher initial density. All of the initial-loading velocity data are shown in Fig. 3. The variation in velocities between runs cannot be simply related to the variation in density between samples. The average of our measurements is shown by a dashed line. For comparison, we show the range of values found by Johnson and others [3] for lunar soils. While the variability between runs cannot be explained at present, the relation between velocity and stress can
be examined by normalizing the velocities to that at 5 bars and plotting the results as shown in Fig. 4. Most of the data can be adequately described by a relation of the form: \( V_p \propto (\text{stress})^{1/3} \). This result is in agreement with the earlier result that the uniaxial-strain elastic compliance \( \propto (\text{stress})^{-2/3} \) [2,4]. Note that for the two runs with higher initial density, the low stress velocity is higher than predicted by the power-law relationship.

References
HIGH VACUUM P-WAVE VELOCITY IN POWDERS

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**Fig. 2**

In vacuum 1.3 x 10^{-6} torr

**Fig. 3**

In vacuum

**Fig. 4**

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