UNIQUE CHARACTERIZATION OF LUNAR SAMPLES BY PHYSICAL PROPERTIES. T. Todd, H. Wang, D. Richter, and G. Simmons, Dept. of Earth and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, Mass. 02139.

Basic differences exist between the values of physical properties of lunar rocks and those of terrestrial rocks of similar composition. For instance, room pressure values for compressional velocity of lunar rocks are typically much lower than those of terrestrial rocks. These differences have been attributed to intense microfracturing in lunar rocks caused by such processes as large temperature fluctuation on the lunar surface or shock metamorphism. To better understand how thermal cycling and shock processes influence the values of physical properties of lunar rocks, we have measured compressional velocity, shear velocity, static compressibility, and thermal expansion for several thermally cycled terrestrial rocks and for shocked samples recovered from the Ries impact crater in Germany.

Variations in values of physical properties are caused by thermal cycling. We have thermally cycled two granites (Barre, Vt. and Westerly, R.I.) and two diabases (Fairfax, Va. and Frederick, Md.) to maximum temperatures between 100 and 1000°C. The heating and cooling was gradual over a 24 hour period (implying low thermal gradients) with maximum temperatures held constant for 12 hours. Then compressional velocity, shear velocity, and static compressibility were measured to 5 kb <u>at room temperature</u>. Any simultaneous decrease in compressional and shear velocity, accompanied by an increase in compressibility, was interpreted as due to new crack formation. In an independent experiment, thermal expansions for the Barre granite and the Frederick diabase were measured from 25 to 600°C. Thermal expansions for the Westerly granite and the Fairfax diabase were measured from -100 to +300°C. Any permanent length change noted after a complete cycle was again interpreted as due to new crack formation.

For rocks containing quartz (Barre granite, Westerly granite, and Fairfax diabase), we found that thermal stresses produced by temperatures near 400°C were sufficient to initiate cracking in samples. However, no noticeable cracking occurred at temperatures below 300°C. For the Frederick diabase which contains no quartz, no microfracturing occurred until 600°C. Similarly, for any rocks cycled down to -100°C no cracking was observed. Our data therefore indicate that thermal stresses produced by anisotropic expansion or large volume expansion of one or more phases within the rock are insufficient to cause cracking at temperatures between -100 and +300°C. We conclude that it is improbable that thermal cycling between temperatures of lunar day and lunar night has any substantial effect on cracking rocks on the lunar surface. However, thermal cracking could be important on the surface of Venus where temperatures near 500°C have been recorded.

Variations in values of physical properties induced by shock metamorphism depend on the severity of the shock event. Stöffler (1971) classifies shocked rocks as coming from six zones of increasing shock metamorphism. Zone 0 rocks are shocked to peak shock pressures sufficient to cause intense microfracturing but no phase changes. Zone 1 rocks are shocked to pressures within the two-phase region of the Hugoniot. These rocks generally contain diaplectic (stress disordered) areas within crystals of the constituent minerals, as well as other shock deformational features. For zone 2 rocks, peak shock pressures reach the high pressure phase region of the Hugoniot so that a nearly amorphous disorder (diaplectic glass) is produced. Zone 3 is characterized by selective melting of some component minerals, and zone 4 by melting of all component minerals. Zone 5 rocks include all materials condensed from rocks vaporized by the shock event.

Our samples from the Ries impact crater include a granitic igneous rock from zone 0 or 1, a dioritic igneous rock from zone 1, and two basic igneous rocks from zone 3 composed primarily of glass but containing fragments of crystals, vesicles, and some flow structure (schlieren). Lunar basalts and gabbroic-anorthosites are generally zone 0 or 1 rocks and glassy lunar breccias are generally zone 3 rocks.

We have measured the values of compressional velocity, shear velocity, and static compressibility under pressure to 5 kb, in addition to thermal expansion at room pressure, for several lunar basalts, gabbroic-anorthosites, and breccias, as well as the rocks from the Ries crater. Because samples from zone 0 are intensely cracked, but not sufficiently shocked to produce glass, these rocks can be used to study the effect of shock induced microfractures. We have found that terrestrial shocked rocks from zone 0 exhibit velocity and compressibility pressure profiles similar to those of lunar basalts and gabbroic-anorthosites. The distribution function for crack aspect ratios and crack porosity ($\sim$1.5%) from Walsh's (1965) theory are similar for both terrestrial and lunar zone 0 rocks. The values for thermal expansions are approximately 30% less than intrinsic values, again similar to lunar rocks. Our data therefore imply that, in terms of crack parameters, values for physical properties of lunar rocks are the same as those of terrestrial shocked rocks.

Samples from zone 3 contain large amounts of glass. The presence of glass in rocks lowers high pressure (i.e. intrinsic) values of velocity. For this reason, high pressure velocity values for glassy lunar breccias and terrestrial breccias are 10 to 30% lower than the values expected for crystalline aggregates of the same composition. In terms of velocity and compressibility pressure profiles, relative expansion temperature profiles, crack aspect ratios, and crack porosities (3 to 4%), the terrestrial and lunar breccias are also similar.

We conclude then, that the mechanism of shock metamorphism is the primary cause for the change in physical properties of the lunar rocks from their intrinsic values. The seismic velocity versus depth curve over the first 25 km of the moon indicate decreasing shock metamorphism with depth. The 25 km depth probably represents either the maximum depth of shock metamorphism or the depth at which shock-produced microfractures are closed or annealed. More intense cracking (i.e. lower velocities) should occur under large impact craters. Large scale thermal metamorphism and thermal cycling between temperatures equivalent to lunar day and lunar night probably are not important mechanisms in changing the values of physical properties of lunar rocks.

REFERENCES

Stöffler, D., Progressive metamorphism and classification of shocked and brecciated crystalline rocks at impact craters, J. Geophys. Res., 76, 5541-5551, 1971.

Walsh, J.B., The effects of cracks on the compressibility of rocks, J. Geophys. Res., 70, 399-411, 1965.