MOONQUAKES, METEOROIDS, AND THE STATE OF THE LUNAR INTERIOR, G. Latham*, J. Dorman*, F. Duennebier*, M. Ewing*, D. Lammlein*, and Y. Nakamura*,

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Thousands of very small moonquakes have been recorded by the four stations of the Apollo seismic network. Moonquakes are recorded at the most sensitive station, station 16, at an average rate of 3,200 per year. This compares with rates of 1,600 quakes per year at station 14 and 650 per year at stations 12 and 15. Forty-one active moonquake source zones have been identified thus far. Nine of these have been located, as shown in figure 1. They are all between 600 and 1,000 km deep. It is probable that signals too small to be analyzed in detail with the existing seismograph network originate at numerous other active zones. The dimensions of each focal zone must be small (a few km or less) and fixed in location over periods of several years. Moonquakes at each active zone occur at monthly intervals and show longer term variations closely correlated with lunar tides; hence, lunar tides must contribute significantly to the total strain energy released as moonquakes. The low total seismic energy release and the absence of large moonquakes implies that the present rate of accumulation of strain within the moon is extremely low.

Seismic data relevant to the structure and state of the deep lunar interior derive from deep moonquakes and from distant meteoroid impacts. The presence or absence of shear waves, which cannot propagate through a liquid, and the travel times and relative amplitudes of both compressional waves (P) and shear waves (S) from these events are the most direct sources of information. High frequency shear waves (0.5 hz and higher) have been detected from all moonquakes with epicenters on the near side of the moon located thus far. Thus, since these signals originate at depths approaching 1000 km, we can say immediately that widespread melting cannot occur in the outer 1000 km of the near-side portion of the moon. The locations of moonquake foci are based upon the seismic velocity model derived by extrapolation of upper mantle velocities, determined from the LM and S-IVB impacts, to great depth. For the cases in which signals are recorded at all four stations from deep moonquakes, comparison of arrival times suggests that the seismic velocities remain nearly constant to a depth of at least 900 km. A slight decrease in velocity with depth, or increase in Poisson's ratio, is suggested by the available data.

Several events (one meteoroid impact and four moonquakes) that originated on the far side of the Moon have recently been discovered. In contrast with near-side events, shear waves from these far-side events cannot be identified in the records at several of the stations. These observations can be explained by introducing a highly attenuating zone in the deep interior beginning at a depth of 1000 to 1100 km. If the attenuation results from melting or partial melting, as seems most plausible from thermal models (1), minimum temperatures of roughly 1500°C at a depth of between 1000 km and 1100 km are implied if an interior of silicate composition is assumed.

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Seismic signals detected by the Apollo seismic network from meteoroid impacts appear to be generated by objects in the mass range 100 gm to 1000 kg. The average flux estimated from data of more than one year is

$$\log N = -1.62 \quad -1.16 \log m$$

where N is the cumulative number of meteoroids of mass m (in gm) and greater, which strike the moon per year per km^2. This flux estimate is 1 to 3 orders of magnitude lower than that derived from earlier Earth-based methods. Our estimate is also lower than the average flux estimated from the distribution of crater sizes on the youngest lunar maria. This is consistent with a hypothesis that the population of small fragments in the solar system decreases with time as they are gathered up by collisions with the planets. The seismic data predict that a meteoroid of mass 7 to 10 kg can be detected by the least sensitive station (station 12) from any point on the Moon. The total data appear to contain at least two distinct meteoroid populations: The normal distribution of fragments that varies little throughout the year, and a population of relatively large objects that intersect the lunar orbit during the months of April through July each year. Since the latter are detectable from anywhere on the Moon, the Apollo seismic network affords greater exposure to these rare events than any other method of measurement.

REFERENCES

(1) TOKSOZ N., SOLOMON S., MINEAR J., and JOHNSON D. (1972) The Moon 4, no. 1/2, 190-213.

FIGURE CAPTIONS

Fig. 1. Map showing the locations of the Apollo 12, 14, 15, and 16 seismic stations and moonquake epicenters. Station numbers indicate the Apollo missions in which the stations were installed. Numbers at moonquake epicenters are arbitrary designators used by the authors to identify the various moonquake foci.

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