RESULTS FROM THE APOLLO LUNAR SEISMIC EXPERIMENT*

(Research Note)

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With the successful installation of a seismic station near Hadley Rille by the Apollo 15 astronauts, and the continued operation of the two previous stations installed during missions 12 and 14, the Apollo program has for the first time achieved a network of seismic stations on the Moon; a network that is required for the locations of natural events. Seismic signals detected by the network are generated by three types of sources: moonquakes, meteoroid impacts, and man-made impacts (the third, or S-IVB, stage of the Apollo booster, and the LM ascent stage). Study of the signals detected by the lunar seismic network has recently resulted in several important discoveries about the Moon.

Moonquakes are much less frequent and are much smaller than are earthquakes. But fortunately, the Moon does not possess oceans or winds which, on Earth, produce disturbances which conceal the seismic signals from quakes. As a result, the lunar seismometers can operate at much higher sensitivity than is possible on Earth. The moonquakes are of two types: periodic moonquakes that occur every month when the Earth and the Moon come closest to one another; and sequences of many small moonquakes, called moonquake swarms.

The monthly moonquakes occur at not less than 10 different locations, and always at exactly the same locations month after month. However, one source is much more active than the rest. This source is 800 km deep: deeper than any known earthquake. Thus, unlike the Earth, the deep interior of the Moon must be rigid enough to rupture at these depths. The source of energy which causes the Moon to rupture at these great depths is unknown, but it is probably the internal heat of the Moon, or the fact that the shape of the Moon is changing as it slowly moves away from the Earth at a rate which is estimated to be about 3.2 cm/yr. The occurrence of the deep moonquakes at monthly intervals means that they are triggered by tides raised in the solid body of the Moon by the Earth.

The swarms of tiny moonquakes are detected without any apparent regularity. During a swarm, moonquakes occur as often as 1 every 2 h over periods of several days. These moonquake swarms may be generated by the delicate adjustment of blocks in the crust of the Moon, or by subsurface volcanic activity.

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The entire Moon appears to be covered by a layer of 'rubble' of thickness between 5 and 20 km. This layer was probably produced by the crushing of the lunar surface by collisions with fragments of rock in space (meteoroids) over the past 4 billion yr. Since the Moon has no atmosphere, meteoroids can come into the surface without burning up as most of them do on Earth. Such collisions are still going on and are detected by the Apollo seismic network at the rate of about 1 every 2 days.

The man-made impacts are the only sources of seismic energy whose location and time of occurrence are precisely known. From the study of these signals, it has been found that the Moon has a crust and a mantle as does the Earth. The lunar crust is approximately 50 km to 70 km thick and is composed of much lighter rock than the dark mare rock. To develop such a crust, the Moon must have been molten very soon after its formation, at least to depths of several hundred km. Whether or not the entire Moon was molten, as was the Earth, is not yet known.

Soon after the crust solidified, it appears that a large asteroid may have passed so close to the Earth, that it was broken into fragments by the pull of the Earth's gravity. These fragments struck the Moon between 3 and 4 billion yr ago in an intense bombardment. The largest fragments formed huge craters which filled with dark basaltic lava to form the lunar mare.

It appears the Moon is now quite cold and stable compared to the Earth, without movements of the crust which form mountains and great fractures as is now occurring on Earth. But neither is the Moon completely dead. Moonquakes occur. The source of energy for these quakes is an intriguing question for further study.