HIGH-FREQUENCY LUNAR TELESEISMIC EVENTS

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A small number of lunar seismic signals of distinctive properties lead us to believe that either there are some regions of more competent geologic structure than the normal, regolith-covered surface structure, or some impacting objects effect unusually deep penetration, or shallow tectonic moonquakes occur. A total of eleven such events, listed in Table 1, have been identified to date, representing only about 0.2% of the events detected by long period seismographs.

Major characteristics of these events are: (1) Signals detected by the short period instruments (peak response at 8 Hz) are several times greater in amplitude than those on the long period instrument (peak response at 0.45 Hz). (2) Both P- and S- wave arrivals are distinctly observable, with greater amplitude for the latter and P-to-S intervals ranging from 2 to 5 minutes. (3) The signal rise time of each phase is very short, indicating negligible scattering of seismic waves at the source region. (4) With the exception of the smallest event, the signals are detected by all stations. (5) The observed amplitudes range from a few digital units to nearly full scale (1023 digital units) at the highest seismometer gain. The amplitude of the largest event is thus nearly two orders of magnitude greater than that of the largest signal previously identified as a moonquake and is one of the largest seismic events observed to date. (6) Source locations, as given in Table 1, are widely distributed and no two events occurred at the same location.

Figure 1 shows the SPZ/LPY amplitude ratio vs. P-S interval of these events at Station 14 in comparison with other representative seismic events of relatively large P-S intervals. In this plot, the high frequency teleseismic events are clearly separated from other types of events without any transitional cases between the two sets.

Table 1. List of High-Frequency Teleseismic Events with Estimated Origin Times and Source Locations (nearest 5^o; surface source assumed)

Year	Day (Date)	Estimated Origin Time (h m s)	Estimated Source Location
1971	107 (Apr. 17)	07:00:20	50^oN, 35^oE
1971	140 (May 20)	17:26:20	40^oN, 20^oW
1971	192 (July 11)	13:24:40	35^oN, 50^oW or 35^oS, 60^oW
1972	002 (Jan. 2)	22:28:40	2300 km NE of station 15
1972	261 (Sept. 17)	14:34:10	15^oN, 60^oE
1972	341 (Dec. 6)	23:07:50	45^oN, 50^oE
1972	344 (Dec. 9)	03:50:30	1500 km SW of station 14
1973	039 (Feb. 8)	22:52:00	1000 km NE of station 15
1973	072 (Mar. 13)	07:56:10	80^oS, 150^oW
1973	171 (June 20)	20:21:50	0^o, 65^oW
1973	274 (Oct. 1)	03:57:30	30^oS, 30^oW

H-F LUNAR TELESEISMIC EVENTS

Nakamura, Y.

The most important data that would determine whether these events are of external (meteoroid impacts) or of internal (moonquakes) origin, namely, the precise depths of focus of these events, are lacking because of the poor accuracy of hypocenter determinations. However, the shear wave observed at station 15 from the March 13, 1973, event at an estimated distance of greater than 120 degrees, would have intersected the attenuation zone below the 1000 km depth if the depth of this event had been greater than 300 km. Because of the apparent lack of evidence against either one, we accept two working hypothesis: one of external origin and another of internal origin.

If these high-frequency teleseismic events are from meteoroid impacts, they must occur in a way grossly different from ordinary meteoroids impacting upon the typical lunar surface. The gradual rise and decay of signal strength of all artificial impacts and a large number of natural events are attributed to intense scattering of seismic energy in the highly heterogeneous surface zone that supposedly blanket the entire moon. In contrast, the high-frequency teleseismic events have nearly impulsive beginnings similar to those of moonquake signals, indicating that scattering of seismic energy near the source region is negligible. Therefore, if these events are in fact meteoroid impacts,one possible explanation for the unusual characteristics would be that the meteoroid impacted upon material of exceptionally high competency. This suggests either that the impact sites were relatively free of pulverized overburden, or that the penetration through the regolith was greater than normal.

On the other hand, events of internal origin would require regions where shallow moonquakes occur. All the moonquakes located previously occurred at depths greater than 700 km. Though the high-frequency teleseismic events have signal envelopes similar to those of known moonquakes, the former differ from the latter in four important characteristics: (1) frequency content is much higher; (2) some of them are stronger than the largest known moonquakes by several orders of magnitude; (3) they do not occur periodically as the moonquakes do; and (4) no matching signals have been found. The difference in physical properties of material in the source regions may account for these differences.

In summary, the small number of teleseismic events with unusual characteristics suggest that either (1) there are some regions of restricted extent where rock of exceptional competency with structural homogeneity is found near the surface, or (2) a class of rare impacting objects exist that can penetrate to unusually great depth, or (3) a small number of moonquakes occur at shallow depth. The correct hypothesis may be determined from refined lunar models, where depth of focus may be determined with better accuracy than at present. Sites at which these unusual events originate should be considered as prime candidates for landing sites in any future lunar exploration program.

H-F LUNAR TELESEISMIC EVENTS

Nakamura, Y.

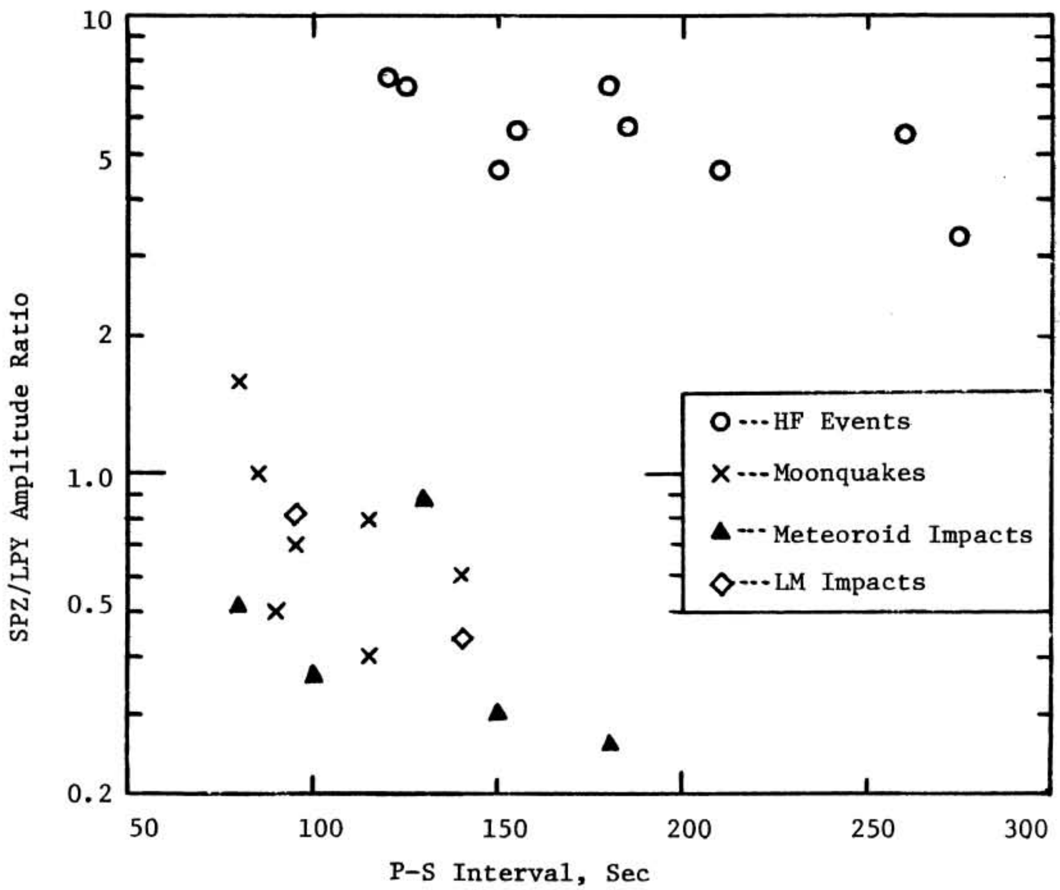

Fig. 1. SPZ/LPY amplitude ratio vs. P-to-S intervals of high-frequency (HF) teleseismic events and selected other events at station 14.