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Apollo 17 Lunar Surface Gravimeter: A New Moonquake Catalog and Implications of Expanding the Passive Seismic Array

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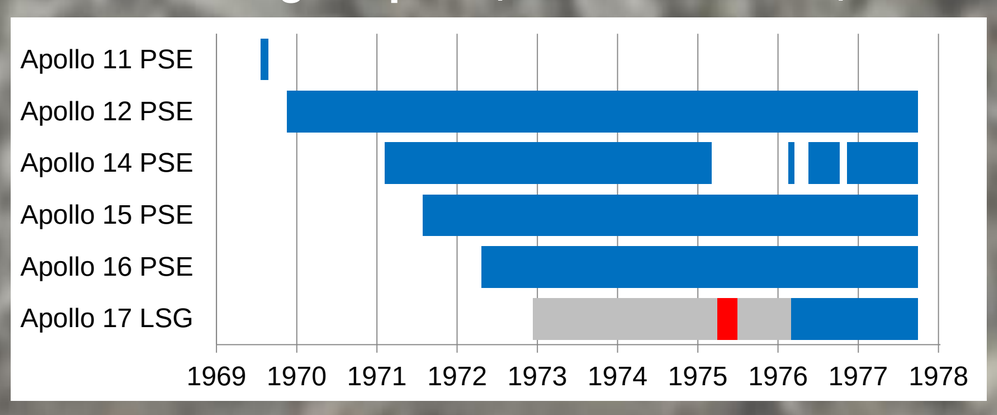
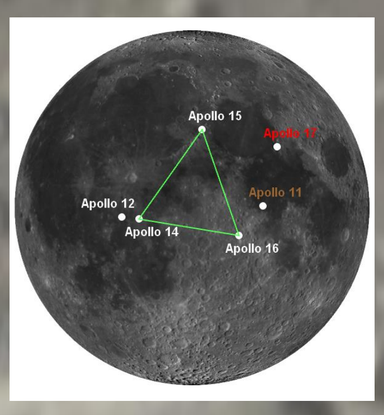
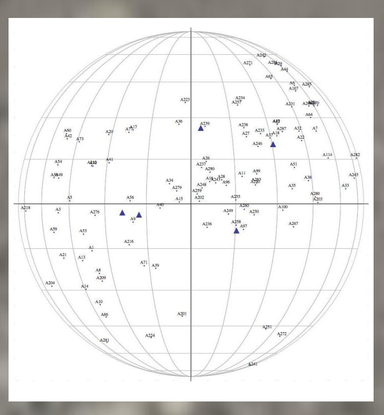
Introduction and Goals

- **Goals:**
  - **Verify deep moonquake detections in Apollo 17 Lunar Surface Gravimeter (LSG) data**
  - **Identify detections of deep moonquakes in Apollo 17 LSG data that correlate with Apollo 12–16 Passive Seismic Experiment (PSE) data to decrease the uncertainty of deep moonquake cluster locations and learn more about the interior of the Moon.**
- **Motivation: LSG partially malfunctioned when deployed on the Moon and data was never thoroughly analyzed. Kawamura et al. (2015) demonstrate potential for LSG data to provide additional deep moonquake detections.**
- **Date Range: April 2, 1975 – June 30, 1975**







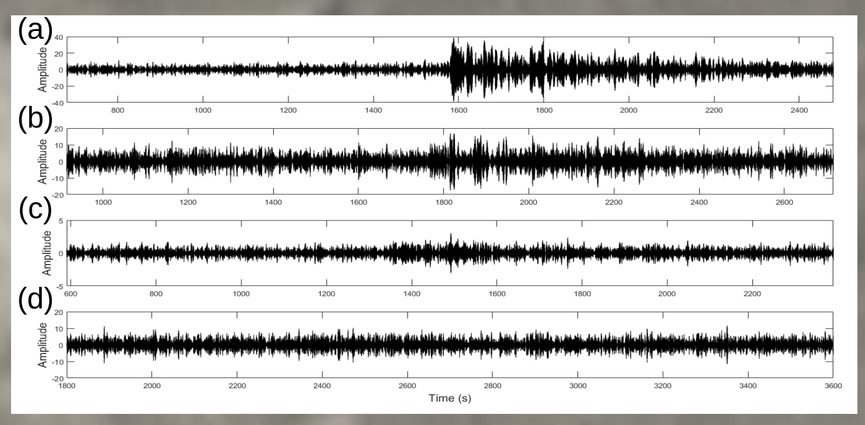
Left: Period of observation for each Apollo station from 1969 to 1977. Gray indicates the instrument was functioning, but no data has been found. Red is the observation period. Blue is data that has been analyzed. Middle: Apollo 11, 12, 14, 15, 16, 17 landing sites. Apollo 17 is red because it is not currently in the seismic network. Apollo 11 is brown because it does not contribute to seismic network. (Adapted from Kawamura et al., 2015) Right: Deep moonquake cluster locations.

Impact

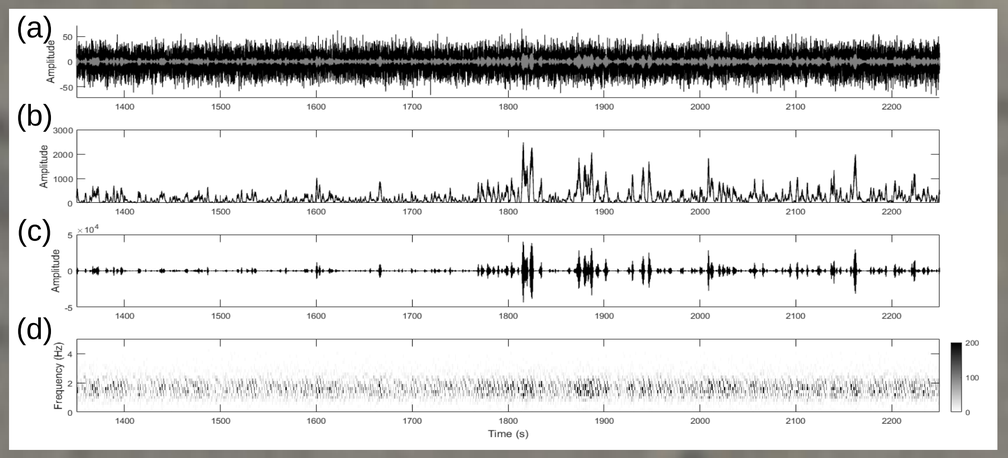
- **Immediate Impacts: Detections of deep moonquakes lead to reduced deep moonquake cluster location uncertainty**
- **Broader Impacts: Understanding further aspects of the interior of the Moon and application of analysis techniques for future planetary seismology missions to Mars (e.g. InSight)**

Selected Results

Type of Event	Catalog Events	A Events	B Events	C Events	D Events	F Events	No Data
Deep Moonquakes	137	1	5	12	33	69	17
Shallow Moonquakes	2	0	0	0	0	2	0
Meteorite Impacts	105	7	3	7	16	61	11
Thermal Events	1	0	0	0	0	1	0
Unclassified Events	16	0	1	1	0	10	4
Total	261	8	9	20	49	143	32



Arrival Time Uncertainty (sec)	A Events	B Events	C Events	D Events	Total
≤ 10 sec	1	3	11	7	22
> 10 sec	0	1	3	4	8
TBD	0	0	1	14	15



- **Visual grading of the events to identify events with higher signal to noise ratio and coherence**
- **Event quality is designated from A to F, where A is the best event quality, and F signifies no LSG event for the catalogued event seen at Apollo 12-16**
- **Choosing an arrival time for localization parameters and assigning an arrival time confidence region based on the uncertainty in arrival time**

Top Left: Types of seismic events and event quality within the passive seismic catalog. For some events, Apollo 17 LSG stopped recording indicated in the No Data column. Top Middle: Event grades with a) an A-Event, b) a B-Event, c) a C-Event, and d) a D-Event. Each window is 3 minutes. Top Right: Arrival Time Uncertainty for Deep Moonquakes. Bottom Left: Choosing arrival times. a) black is the raw file, while gray indicates filtered file, b) magnitude of the data, c) polarization filter, and d) spectrogram of the filtered file showing the power of the frequency content.

Future Work

- **Localization of deep moonquakes using chosen arrival times and including meteorite impact times**
- **Probe structure of the Moon using improved moonquake characterization**

References

Kawamura, T., Kobayashi, N., Tanaka, S., & Lognonné, P., (2015), Lunar Surface Gravimeter as a lunar seismometer: Investigation of a new source of seismic information on the Moon, *J. Geophys. Res. Planets*, **120**:343–358.

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