Thermal Moonquake Location Algorithm and Analysis

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Thermal Moonquakes

- What: Thermal moonquakes are small amplitude events that are produced by diurnal temperature changes.
- Why: Finding the locations of thermal moonquakes will lead to information about lunar surface processes.
- Where: Apollo 17 Lunar Seismic Profiling Experiment (LSPE) is able to locate thermal moonquake unlike Apollo 12-16.
- The primary science goal was an active source experiment to study the detailed structure of the lunar crust using 8 explosive packages (EPs).
- The secondary science goal was to passively listen for lunar seismic activity.

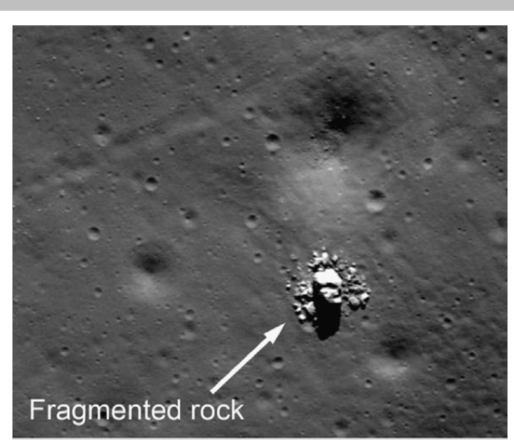

Figure 1: Partially fragmented 20 m boulder near central peak complex of Schiller crater (Basilevsky et. al., 2013).

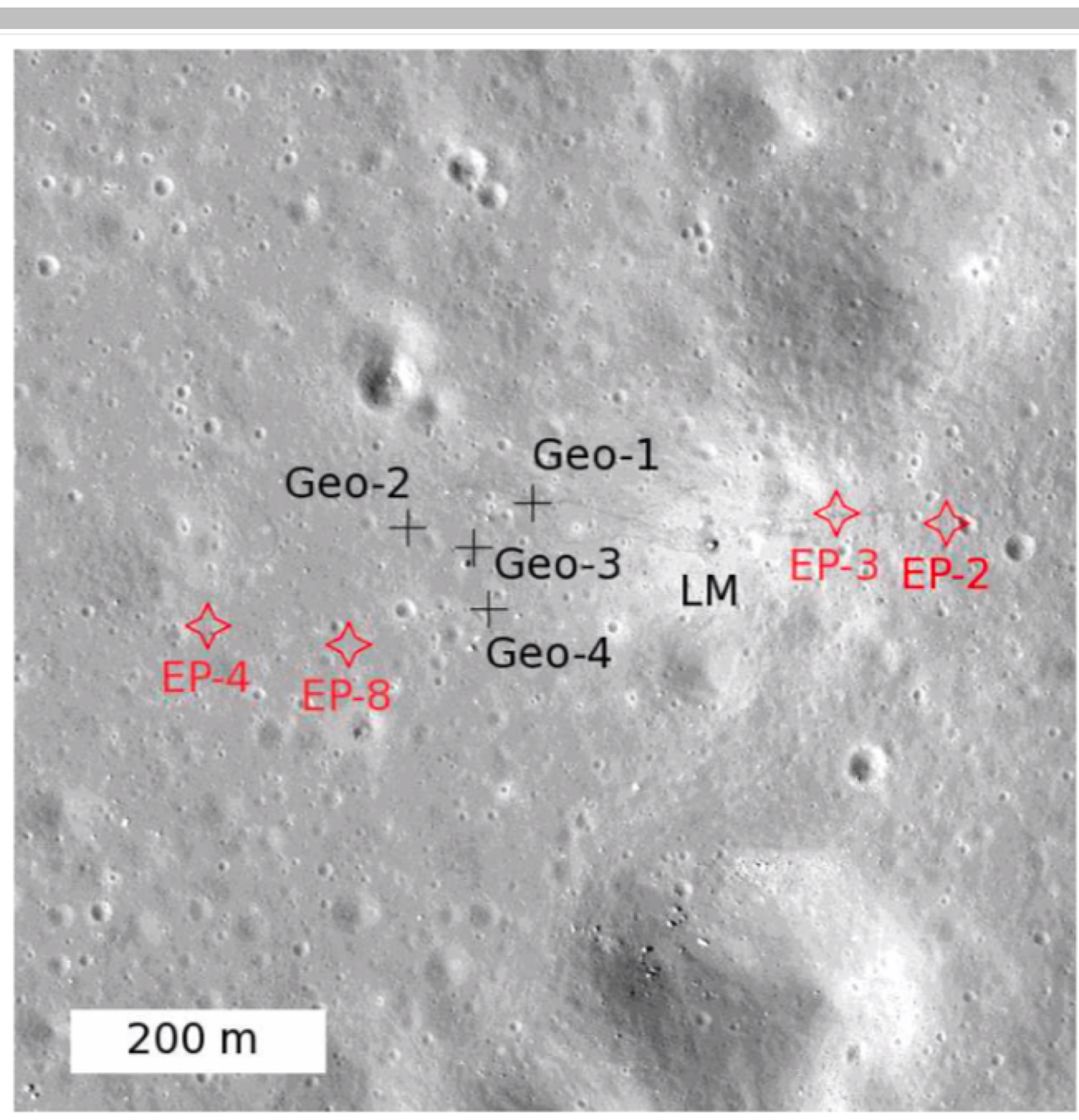

Figure 2: Apollo 17 EP2, 3, 4, and 8 (red diamonds) locations with LSPE geophones (black plus) and the lunar module (Haase et. al., 2013).

Location Algorithm

- How: We used arrival times to locate thermal moonquakes using a least squares location algorithm incorporating ray tracing with several shallow structure velocity models.

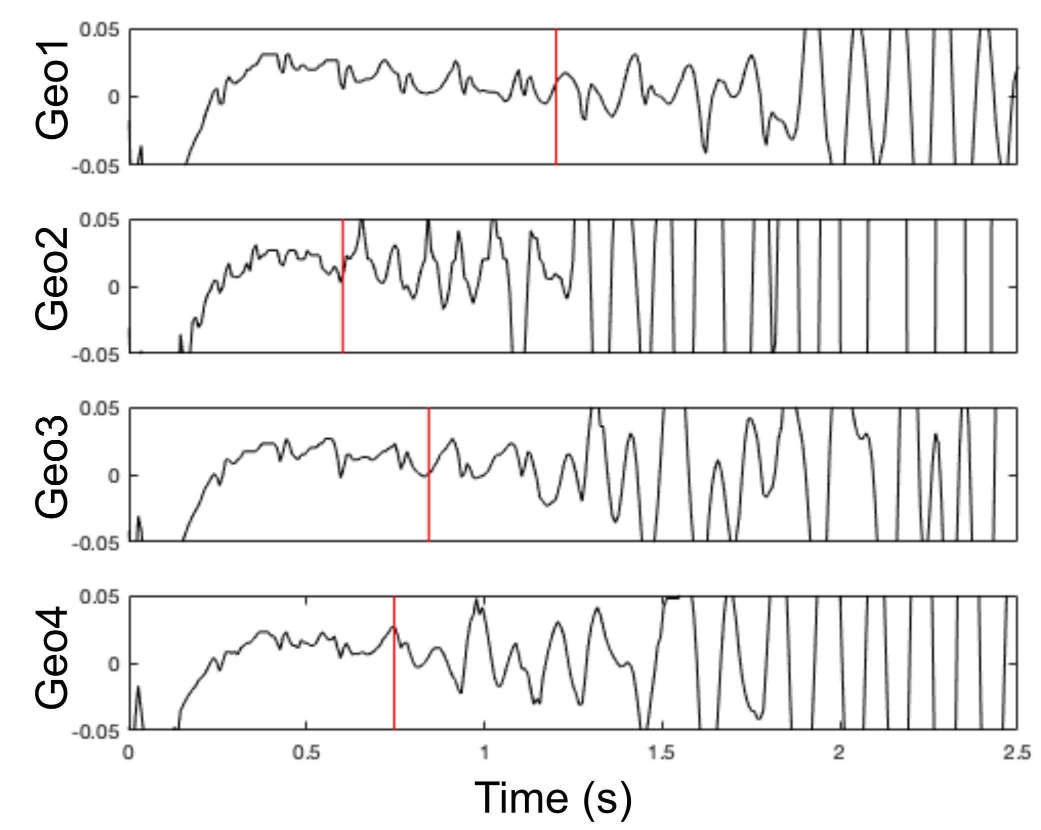

Figure 3: Apollo 17 EP4 waveform data from Geo1, Geo2, Geo3, and Geo4. The red line is the chosen arrival time.

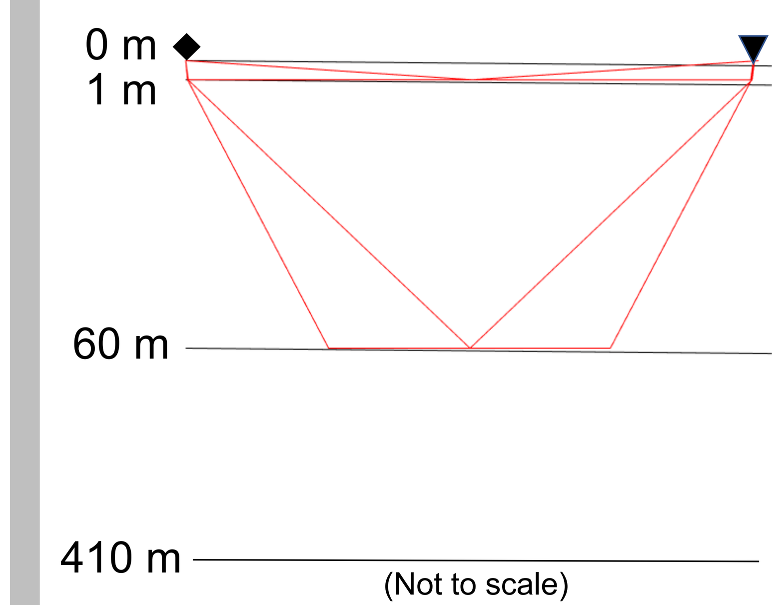

Figure 4: Ray tracing using Sollberger velocity model including EP4 as the source (black diamond), Geo2 as the receiver (black triangle), and the depth of the resulting path.

<table>
<tr><th></th><th>Cooper</th><th>Heffels</th><th>Sollberger</th><th>Heffels Modified</th></tr>
<tr><td>0-4 m</td><td>100 m/s</td><td rowspan="4">285 m/s</td><td>100 m/s</td><td>100 m/s</td></tr>
<tr><td>4-32 m</td><td>327 m/s</td><td rowspan="2">370 m/s</td><td rowspan="3">285 m/s</td></tr>
<tr><td>32-60 m</td><td rowspan="3">495 m/s</td></tr>
<tr><td>60-96 m</td><td rowspan="3">500 m/s</td></tr>
<tr><td>96-390 m</td><td rowspan="3">580 m/s</td><td rowspan="3">580 m/s</td></tr>
<tr><td>390-410 m</td><td rowspan="4">960 m/s</td></tr>
<tr><td>410-773 m</td><td rowspan="2">1100 m/s</td></tr>
<tr><td>773 m-1 km</td><td rowspan="3">1825 m/s</td><td rowspan="3">1825 m/s</td></tr>
<tr><td>1-1.385 km</td><td rowspan="3">4.90 km/s</td></tr>
<tr><td>1.385-2 km</td><td rowspan="2">4.90 km/s</td></tr>
<tr><td>2-15 km</td><td>4.90 km/s</td><td>4.90 km/s</td></tr>
</table>

Location Analysis

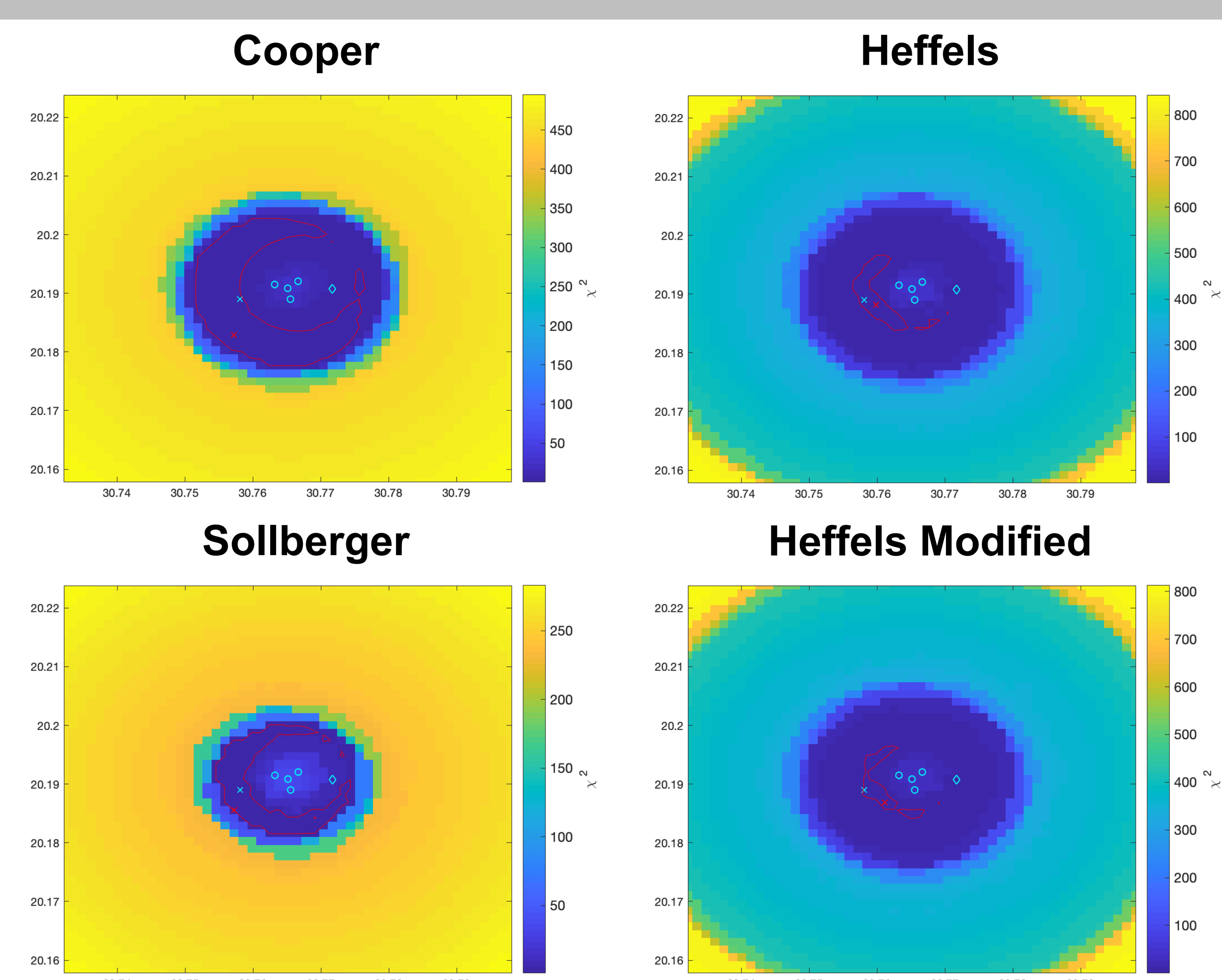

Figure 5: Theoretical EP4 location using location algorithm showing the geophones (light blue circles), lunar module (light blue diamond), and the known location of the EP (light blue x). The red x is the theoretical location using a) Cooper, b) Heffels, c) Sollberger, and d) modified Heffels velocity models with a 95% chi squared confidence region (red contour).

Future Work

- Considering the grouping of EP2, EP3, EP4, and EP8, we can possibly find a velocity model that is split on both sides of the geophone array.
- Additionally, we are exploring options to perform local noise tomography on the Moon.

References

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