

DEEP MOONQUAKE FOCAL MECHANISMS: RECOVERY AND IMPLICATIONS. R. C. Weber¹ and M. Knapmeyer², ¹NASA Marshall Space Flight Center (renee.c.weber@nasa.gov), ²DLR Institute of Planetary Research (martin.knapmeyer@dlr.de).

Introduction: A defining characteristic of deep moonquakes is their tendency to occur with tidal periodicity, prompting previous studies to infer that they are related to the buildup and release of tidal stress within the Moon [refs]. In studies of tidal forcing, a key constraint is the focal mechanism: the fault parameters describing the type of failure moonquakes represent.

The quality of the lunar seismic data and the limited source/receiver geometries of the Apollo seismic network prohibit the determination of deep moonquake fault parameters using first-motion polarities, as is typically done in terrestrial seismology [ref]. Without being able to resolve tidal stress onto a known failure plane, we can examine only gross qualities of the tidal stress tensor with respect to moonquake occurrence, so we cannot fully address the role of tidal stress in moonquake generation.

Approach: We will examine the extent to which shear (S) and compression (P) wave amplitude ratios can constrain moonquake fault geometry by determining whether, for a given cluster, there exists a focal mechanism that can produce a radiation pattern consistent with the amplitudes measured by the Apollo instruments (Figure 1). Amplitudes are read in the ray coordinate frame, directly from seismograms for which the P and S arrivals are clearly identifiable on all long-period channels of the four Apollo stations. We apply an empirical station correction to account for site effects and the differences between P- and S-wave attenuation [ref].

Instead of focusing on the best fitting solution only, we formulate the inverse problem using a falsification criterion: all source orientations that do not reproduce the observed S/P ratios within an error margin derived from the uncertainty of the amplitude readings are rejected. All others are accepted as possible solutions. The inversion is carried out using an exhaustive grid search on a regular grid with predefined step size, encompassing all possible combinations of strike, dip, and slip. To assess the sensitivity of the inversion to the uncertainty of the lunar interior structure, we will carry out repeated inversions with different velocity structures [refs].

Our data set consists of a total of 106 events from 25 deep moonquake clusters. The largest contribution of 37 events originates from the most active cluster, A001, while other clusters are represented by 1 to 9 events.

Results: Since the definition of a cluster implies that all events share the same source orientation, a comparison of the inversion results of all events from one cluster reduces ambiguities in the inversion. Using the method outlined above, we were able to reduce the fault plane parameter space for a given cluster on average by half, with the best constrained cluster eliminating 72% of the focal sphere (Figure 2).

Once we obtain a suite of fault parameters for a given source, we can attempt to further constrain the focal mechanism by including analyses of tidal stresses. In an earlier study [ref], we used the occurrence times of individual events from a given moonquake cluster to evaluate the tidal shear and normal stresses similarly resolved onto failure planes described by a regular grid of fault parameters. We imposed the failure criterion that a linear combination of shear and normal stress that best approximated a constant value indicated the most likely fault orientation. Combining the results of this grid search with our amplitude analysis further constrains the most likely focal mechanism for our set of clusters (Figure 3).

Future work: With the best-fit focal mechanism in hand for each cluster, we can create synthetic seismograms using a reflectivity approach [ref], for comparison with the Apollo seismograms. This will allow us to predict the times and amplitudes of reflected seismic phases from the Moon's deep layers, placing further constraints on the structure of the lunar interior.

References: Add here.