PDART 2015: Apollo Passive Seismic Experiment Expanded Event Catalog

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This document contains information to explain the contents of the archive, which consists of an integrated catalog of lunar seismic events (11 CSV files).

Moonquake Catalog CSV Files

These files are based on the original moonquake catalog published and curated by Yosio Nakamura at the University of Texas, Austin, which can be found here:
http://www-udc.ig.utexas.edu/external/yosio/PSE/catsrepts/

The original catalog contains information on seismic events originally detected manually (by eye), as well as detections later added after application of automated event detection algorithms (Bulow et al., 2005 & 2007). As part of our PDART award, my group developed an expanded version of the catalog, and compiled information from the literature for subsets of events, or in the case of deep moonquakes, clusters of events, that have been located using a variety of models and methods. There are 11 CSV files, described below:

1. "levent.1008weber" is my edited version of the original moonquake catalog, from which the "levent" nomenclature originates. Columns A-U contain the original information from the catalog published by Yosio Nakamura. The only difference is that I have copied information (event class) from columns R&S into columns T&U if the latter were blank, meaning their classification had not changed between Yosio's pre- and post-2004 versions of the catalog. Additionally, I added "grade" information (everything in column V and beyond) which is a proxy for event quality, as described in Bulow et al., (2005).
2. Nakamura_2005_DM_locations are deep moonquake locations from Nakamura (2005).
3. Nakamura_2005_DM_arrivals are deep moonquake arrivals from the same paper.
4. Nakamura_1979_SM_locations are shallow moonquake locations from Nakamura (1979). The descriptions for columns C through G further cite information in Nakamura et al. (1976).
5. Nakamura_1983_SM_arrivals are shallow moonquake arrivals from Nakamura (1983).
6. Nakamura_1983_M_arrivals are meteorite impact arrivals from the same paper
7. Nakamura_1983_AI_locations are artificial impact locations from the same paper
8. Nakamura_1983_AI_arrivals are artificial impact arrivals from the same paper
9. Gagnepian_2006_Catalog is the event catalog used in Gagnepain-Beyneix et al. (2006). (note: in this paper, the cluster A24 refers to cluster A10)
10. Lognonne_2003_Catalog: is the event catalog used in Lognonné et al. (2003). (note: this paper was written before A10 and A24 were found to be the same cluster. Yosio kept A10 and reclassified all A24 events as A10).
11. Weber_2011_DMQ_S_picks: S wave arrival picks from selected deep moonquake stacks used in Weber et al. (2011).

Note: in many cases, published moonquake location errors may be underestimated. See e.g. Hempel et al., 2012 and Garcia et al., 2019.

Note: Event times are preserved as published. For those files with times, the format is as follows:

gagnepian_2006_catalog	YYMMDDHHmm
levent.1008weber	YY JJJ HHmm
lognonne_2003_catalog	YYMMDDHHmm
nakamura_1979_sm_locations	YYYY JJJ HH mm
nakamura_1983_ai_locations	YY JJJ HH mm
nakamura_1983_m_arrivals	YYYY JJJ HHmm
nakamura_1983_sm_arrivals	YYYY JJJ HHmm

Y = year
M = month
D = day
J = Julian day
H = hour
M = minute

A space in the time format indicates a separate column in the csv file.

Moonquake GIS files

Our team also integrated moonquake locations from the catalog into the GIS platform so the moonquake data can be easily compared and cross-referenced with other available lunar data (see e.g. Figure 1). These data are available for download from the Lunar and Planetary Institute website: https://repository.hou.usra.edu/handle/20.500.11753/1719

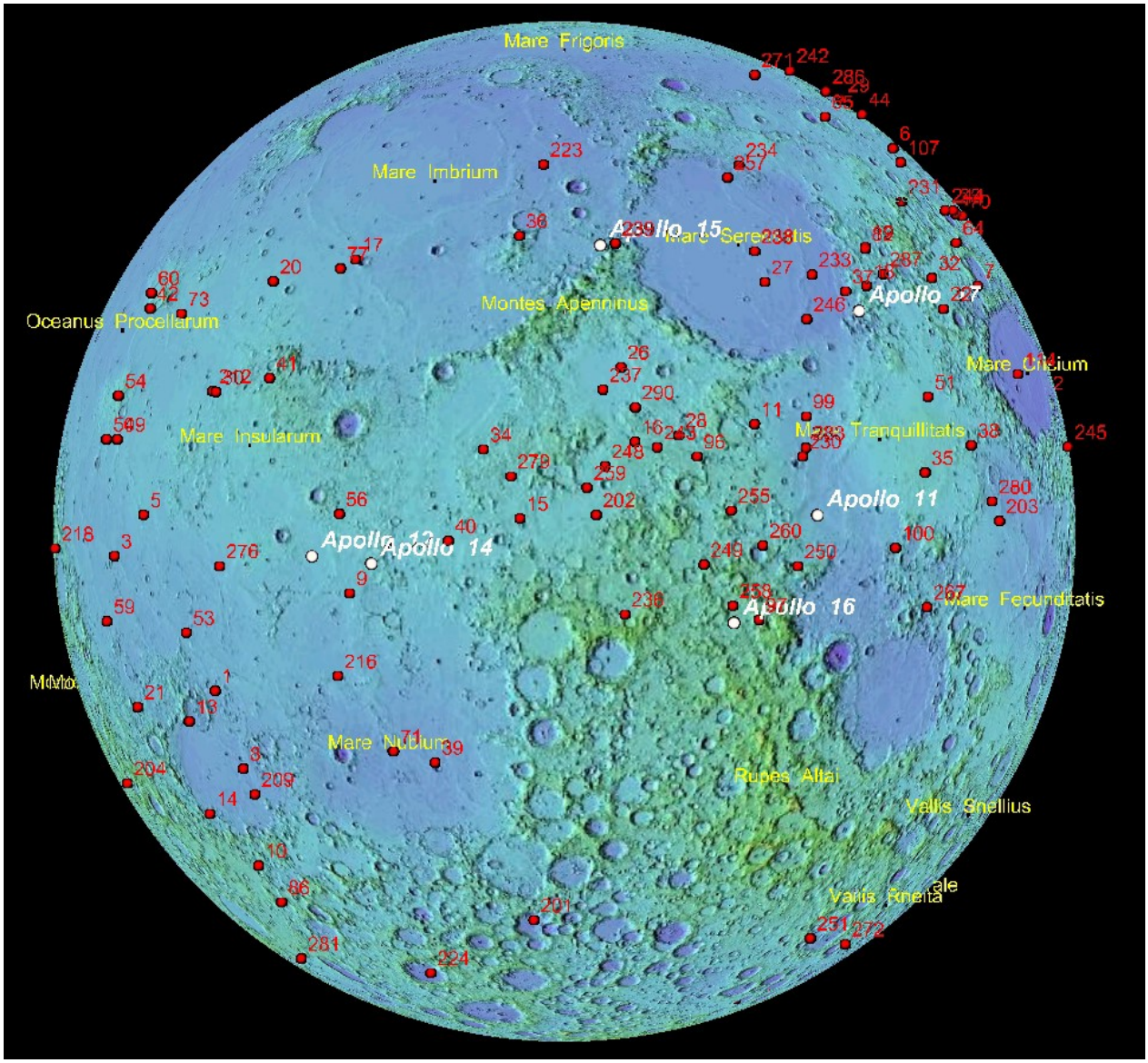

Figure 1: The near side of the Moon with the epicentral locations of moonquake clusters (Nakamura, 2005), plotted on the topographic relief map generated by USGS (data from the Lunar Orbiter Laser Altimeter onboard the Lunar Reconnaissance Orbiter). The red labels show the ID numbers assigned to the clusters. The white dots indicate the Apollo landing sites.

References

Bulow, R. C.; Johnson, C. L.; Shearer, P. M. (2005) New events discovered in the Apollo lunar seismic data. Journal of Geophysical Research: Planets, 110(E10). https://doi.org/10.1029/2005JE002414.

Bulow, R. C.; Johnson, C. L.; Bills, B. G.; Shearer, P. M. (2007) Temporal and spatial properties of some deep moonquake clusters. Journal of Geophysical Research, 112(E9). https://doi.org/10.1029/2006JE002847.

Gagnepain-Beyneix, J.; Lognonné, P.; Chenet, H.; Lombardi, D.; Spohn, T. (2006) A seismic model of the lunar mantle and constraints on temperature and mineralogy. Physics of the Earth and Planetary Interiors, 159(3), 140–166. https://doi.org/10.1016/j.pepi.2006.05.009.

Garcia, R. F.; Khan, A.; Drilleau, M.; Margerin, L.; Kawamura, T.; Sun, D.; Wieczorek, M. A.; Rivoldini, A.; Nunn. C.; Weber, R. C.; Marusiak, A. G.; Lognonné, P.; Nakamura, Y.; Zhu, P. (2019) Lunar seismology: An update on interior structure models. Space Science Reviews 215:50, https://doi.org/10.1007/s11214-019-0613-y

Hempel, S.; Knapmeyer, M.; Jonkers, A. R. T.; Oberst, J. (2012) Uncertainty of Apollo deep moonquake locations and implications for future network designs. Icarus 220, 971–980. https://doi.org/10.1016/j.icarus.2012.06.026

Lognonné, P.; Gagnepain-Beyneix, J.; Chenet, H. (2003) A new seismic model of the Moon: implications for structure, thermal evolution and formation of the Moon. Earth and Planetary Science Letters, 211(1), 27–44. https://doi.org/10.1016/S0012-821X(03)00172-9.

Nakamura, Y. (1983) Seismic velocity structure of the lunar mantle. Journal of Geophysical Research: Solid Earth, 88(B1), 677–686. https://doi.org/10.1029/JB088iB01p00677.

Nakamura, Y. (2005) Farside deep moonquakes and deep interior of the Moon. Journal of Geophysical Research, 110(E1). https://doi.org/10.1029/2004JE002332.

Nakamura, Y.; Duennebier, F. K.; Latham, G. V.; Dorman, H. J. (1976) Structure of the lunar mantle. Journal of Geophysical Research, 81(26), 4818–4824. https://doi.org/10.1029/JB081i026p04818.

Nakamura, Y.; Latham, G. V.; Dorman, H. J.; Ibrahim, A.-B. K.; Koyama, J.; Horvath, P. (1979) Shallow moonquakes - Depth, distribution and implications as to the present state of the lunar interior (Vol. 10, pp. 2299–2309). Presented at the Lunar and Planetary Science Conference Proceedings. Retrieved from http://adsabs.harvard.edu/abs/1979LPSC...10.2299N.

Weber, R. C.; Lin, P.-Y.; Garnero, E. J.; Williams, Q.; Lognonné, P. (2011) Seismic Detection of the Lunar Core. Science, 331(6015), 309–312. https://doi.org/10.1126/science.1199375.