Long-lasting Science Returns from the Apollo Heat Flow Experiments

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The Apollo astronauts deployed geothermal heat flow instruments at landing sites 15 and 17 as part of the Apollo Lunar Surface Experiments Packages (ALSEP) in July 1971 and December 1972, respectively. These instruments continuously transmitted data to the Earth until September 1977. Four decades later, the data from the two Apollo sites remain the only set of in-situ heat flow measurements obtained on an extra-terrestrial body. Researchers continue to extract additional knowledge from this dataset by utilizing new analytical techniques and by synthesizing it with data from more recent lunar orbital missions such as the Lunar Reconnaissance Orbiter. In addition, lessons learned from the Apollo experiments help contemporary researchers in designing heat flow instruments for future missions to the Moon and other planetary bodies. For example, the data from both Apollo sites showed gradual warming trends in the subsurface from 1971 to 1977. The cause of this warming has been debated in recent years. It may have resulted from fluctuation in insolation associated with the 18.6-year-cycle precession of the Moon, or sudden changes in surface thermal environment/properties resulting from the installation of the instruments and the astronauts' activities. These types of re-analyses of the Apollo data have lead a panel of scientists to recommend that a heat flow probe carried on a future lunar mission reach 3 m into the subsurface, ~0.6 m deeper than the depths reached by the Apollo 17 experiment. This presentation describes the authors' current efforts for (1) restoring a part of the Apollo heat flow data that were left unprocessed by the original investigators and (2) designing a compact heat flow instrument for future robotic missions to the Moon. First, at the conclusion of the ALSEP program in 1977, heat flow data obtained at the two Apollo sites after December 1974 were left unprocessed and not properly archived through NASA. In the following decades, heat flow data from January 1975 through February 1976, as well as the metadata necessary for processing the data (the data reduction algorithm, instrument calibration data, etc.), were somehow lost. In 2010, we located 450 original master archival tapes of unprocessed data from all the ALSEP instruments for a period of April through June 1975 at the Washington National Records Center. We are currently extracting the heat flow data packets from these tapes and processing them. Second, on future lunar missions, heat flow probes will likely be deployed by a network of small robotic landers, as recommended by the latest Decadal Survey of the National Academy of Science. In such a scenario, the heat flow probe must be a compact system, and that precludes use of heavy excavation equipment such as a rotary drill for reaching the 3-m target depth. The new heat flow system under development uses a pneumatically driven penetrator. It utilizes a stem that winds out of a reel and pushes its conical tip into the regolith. Simultaneously, gas jets, emitted from the cone tip, loosen and blow away the soil. Lab experiments have demonstrated its effectiveness in lunar vacuum.