Geochemical Studies of the Moon and Planets

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An outgrowth of the space-based Treaty Verification and Proliferation Detection Programs at Los Alamos was the fielding of experiments to determine the elemental composition of the moon and Mars. Our instruments, which included neutron, gamma-ray, and alpha-particle spectrometers, flew aboard Lunar Prospector and Mars Odyssey missions sponsored by NASA and were tailored into a small package to meet the scientific objectives of these missions. All four Los Alamos experiments aboard the Lunar Prospector mission were extremely successful. Measurements from the neutron and gamma-ray spectrometers enabled the first global mapping of the seven most abundant rock-forming elements (oxygen, magnesium, aluminum, silicon, calcium, titanium, and iron); the trace radioactive elements thorium (refer to Figure A for thorium's spatial distribution on the moon), uranium, and potassium; and the minor elements hydrogen, gadolinium, and samarium. This combined package of instrumentation marked the first application of neutron spectroscopy to planetary exploration. Several highlights emerged from our data collecting. We learned that a unique, thorium-rich geochemical province exists on the earth-facing side of the moon. Heat from the decay of radioactive elements is no doubt responsible for the iron-rich basalt flows that give the moon its black-splotched appearance. In another landmark success of these experiments, we discovered water-ice deposits that reside within the permanently shadowed craters near both lunar poles. Asteroids, comets, and interplanetary dust grains striking the surface were most likely responsible for delivering the water to the moon. In addition, using the alpha-particle spectrometer, we detected radon and its daughters that escape from vents in the lunar crust. Our experimental results help unravel the origin and evolution of the moon and show the existence and locations of lunar resources that could be used to support the manned exploration of the moon.First returns from the Los Alamos neutron spectrometer aboard Mars Odyssey have proved the power of neutron spectroscopy to map the volatile inventory of nearly airless planetary bodies. We have discovered that a vast region of Mars south of –60° latitude is rich in buried water ice. Figure B shows lower-bound estimates of water on Mars. Although water ice has been predicted to be stable at these cold Martian latitudes, we were surprised by the extent and richness of this deposit (up to 50 percent water ice by mass). Initial data were taken during the southern late summer and early fall, when the southern cap is smallest; our analysis clearly shows that the residual south polar cap of Mars is permanently covered by dry ice—or frozen carbon dioxide (CO_2). A much more extensive dry-ice cap covers the northern region, poleward of about 55°, which was in the grip of late winter and early spring. As time went on and the sun returned to the north, the northern cap shrank and the southern cap grew, as CO_2 evaporated and precipitated, respectively. This exchange of CO_2 between the Martian poles is a major driving force for Mars' atmospheric circulation, and a factor in the long-term climate variability on Mars (which is also driven by the changing obliquity, eccentricity, and perihelion of the Martian orbit). The shrinking north polar dry-ice cap reveals a basement as

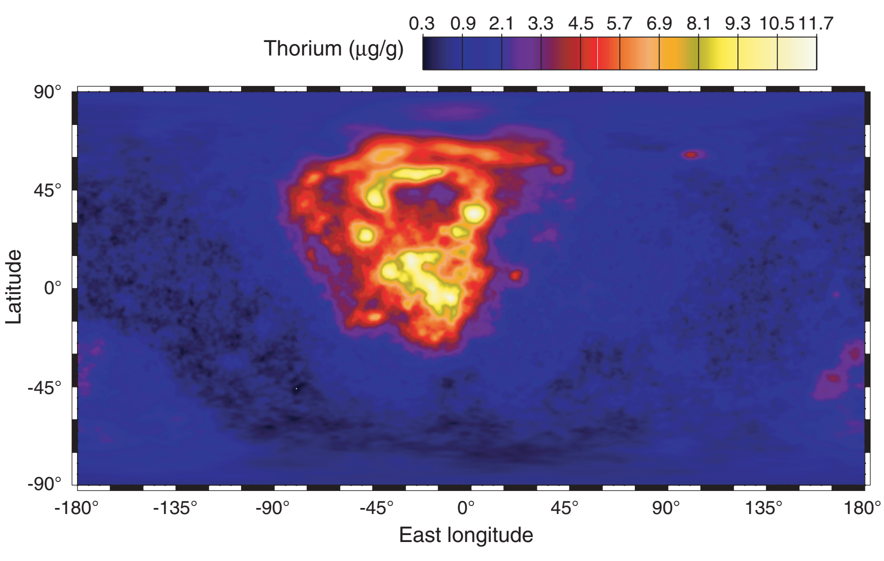


Figure A. Global Map of Thorium Abundance on the Moon

The spatial distribution of thorium looks asymmetric, being strongly concentrated in a single province on the earth-facing side of the moon. This province witnessed much of the volcanism that has distributed large quantities of basalt filling many of the large-impact basins, which are also concentrated on the earth-facing side of the Moon.

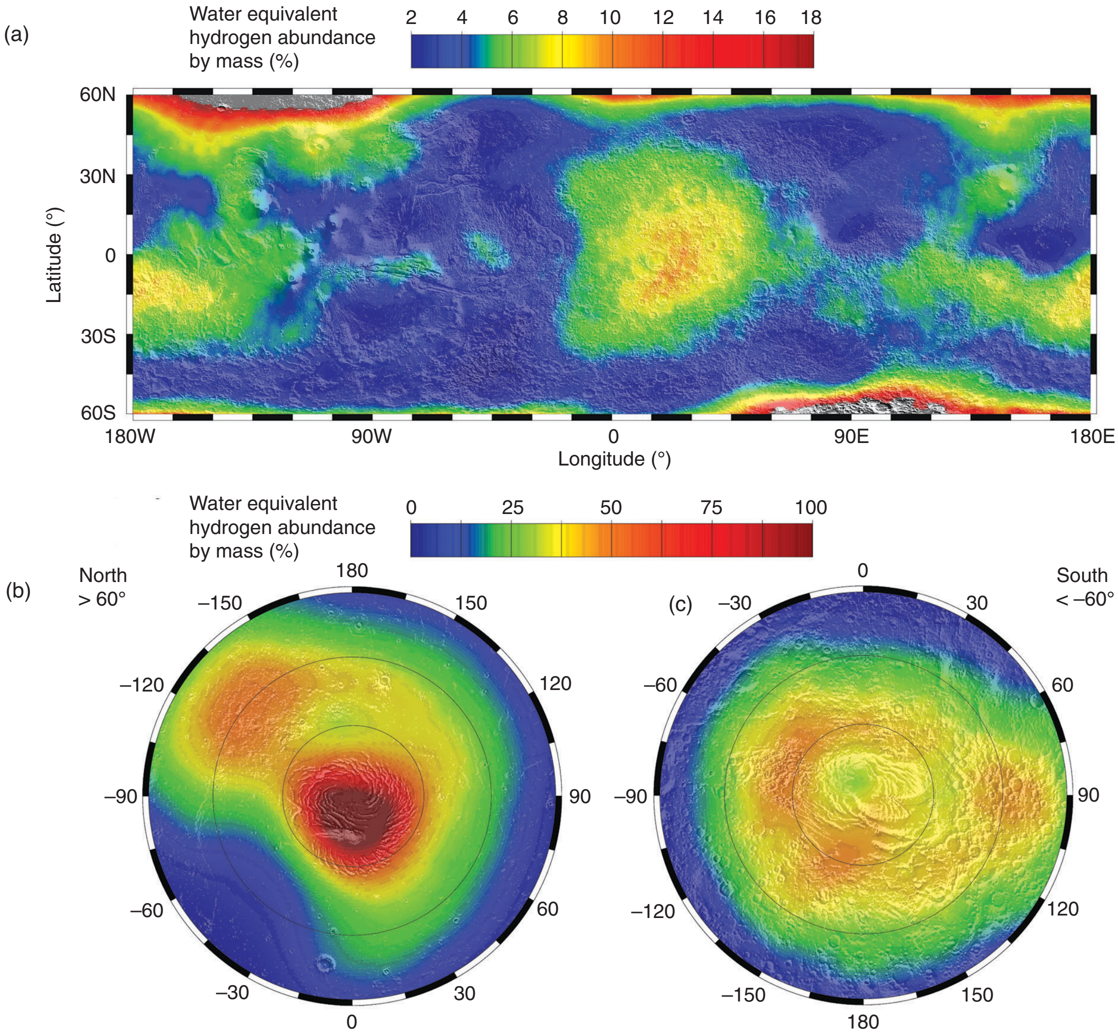
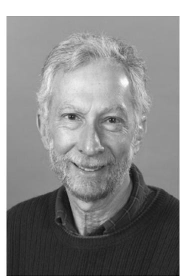


Figure B. The Distribution of Water on Mars
Data taken between February 2002 and April 2003 by the neutron spectrometer aboard the Mars Odyssey were used to determine the minimum water distribution on Mars. Measurements of the epithermal neutron flux streaming from the planet's surface allow us to determine the amount of hydrogen trapped in the upper one meter of soil. We then assume that the hydrogen is most likely in the form of water ice and uniformly distributed throughout the soil layer, and convert the data to water mass equivalent. (a) This cylindrical projection map of the midlatitudes shows the water equivalent hydrogen abundances by mass overlayed on a shaded relief map of the planet's surface. The relief map was derived from tomography data taken by the Mars Orbiter laser altimeter (MOLA), an instrument designed at the Goddard Space Flight Center. The data are presented in stereographic projection in (b) and (c), in which the latitudes poleward of +60° and –60° are shown, respectively.

rich in water ice as that in the southern cap.Future work for our group includes the development of a neutron spectrometer, to be launched to Mercury in 2004, and a combined neutron and gamma-ray spectrometer, which is scheduled for launch in 2006 for a rendezvous with the asteroids Vesta and Ceres. ■



William Feldman earned his bachelor's in physics from the Massachusetts Institute of Technology in 1961 and his Ph.D. in physics from Stanford University in 1968. A technical staff member at Los Alamos National Laboratory since 1971, he has extensive experience in the analysis and interpretation of solar wind and magnetospheric plasma data. He was responsible for a fast neutron spectrometer aboard the Air Force LACE mission that was launched into low-Earth orbit in 1990, the neutron subsystem of the Mars Observer gamma-ray spectrometer that was launched to Mars in 1992, the neutron, gamma-ray, and alpha particle spectrometers that were launched to the Moon aboard Lunar Prospector in 1998, and the neutron spectrometer component of the gamma-ray spectrometer that is presently returning data from Mars. He provided the design for the neutron spectrometer aboard Messenger, which will be launched to Mercury in 2004 and is responsible for the gamma-ray and neutron spectrometer aboard DAWN, which will be launched to Vesta and Ceres in August 2006.