Water, Water, Everywhere: But How to Find and Use It on the Moon!

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The last few years has seen the Moon go from "bone-dry" all the way to almost hosting the "Winter Olympics". The paradigm from 1973 for the production of nanophase metallic iron (np-Fe) in the lunar soil was the reduction of FeO in the micrometeorite melts by solar-wind hydrogen. This should produce water as a product from the combination of the hydrogen and the oxygen from the FeO. Yet, Larry Taylor in 1995 could find nil by FTIR examination of agglutinitic glass.

Fast forward to the persistent search for OH in apatite by electron microprobe analysis, led by Francis McCubbin that spurred on several other endeavors. In 2008, Alberta Saal's team determined minor, but real, hydrogen in pyroclastic beads. This was followed in 2010 by teams led by Jim Greenwood, Yang Liu (and later by Jeremy Boyce), and Francis McCubbin, aided by Eric Hauri, culminating in pubs by these teams in 2011-2012. The annual Lunar and Planetary Science Conference continues to be the exciting venue for such discoveries. Onward to Hauri's 'water' in lunar olivine melt inclusions. accompanied by Yang Liu's proof of the presence of OH by FTIR. Next, back to the agglutinates

More recently in 2012, Yang's team demonstrated a "hidden reservoir" of H, OH, and HOH in lunar soil agglutinitic glasses, up to >500 ppm. These impact-produced glasses consist of upwards of 80 % of the fine soil. Thus, the agglutinates are a very real reservoir for lunar water, from several sources. But the remote sensing community has been active with lunar orbiters.

Enter Carle Pieters's Moon Mineralogy Mapper team, who first observed OH in reflectance spectra of the Moon, to be subsequently verified by Roger Clark with re-examined Cassini data and Jessica Sunshine, with the EPOXY flyby data, which also hinted at a "dew" like quality for this OH. They all reported together in 9/2009. Then came the LCROSS impactor, with its trailing spectrometers sensing water, water-ice, and many volatile components indicative of cometary water. This was proof for the presence of water-ice in the permanently shadowed craters at the poles, following strong hints by various neutron-spectrometer signals on Pathfinder and LEND/LRO.

Let us take count of the possible sources of OH, HOH, water, and water-ice as seen In and On the Moon: 1) indigenous water from the lunar magmas; 2) water in agglutinates from Solar-wind hydrogen reduction; 3) meteorite and micro-meteorite contamination, accounting for up to 2 wt% (e.g., carbonaceous chondrites); 4) cometary water, particularly collected at the poles; 5) solar-wind proton-induced OH-HOH. All this water, BUT how much?

Paul Spudis and his Mini-SAR team came up with a modest estimate of only 600 million tonnes of water-ice, and only surveying the North Pole. The MMM team came up with something like a liter of water. LCROSS found lots more. But, the major unknown for lunar OH-HOH around the Moon is in the agglutinates, which in general comprise ~50 wt% of lunar regolith.

Any settlement to the Moon will require In-Situ Resource Utilization (ISRU) of lunar materials. And water for human and plant consumption is required, with the use of hydrogen and oxygen for rocket fuels as a major and substantial need. Where the landing is located will require different sources of water, even with the possible need for oxygen production from lunar soil directly as reviewed by Taylor and Carrier (1973) (e.g., hydrogen reduction of soil). The nature of lunar water, its quantities, its capture, and needs form the basis for this presentation.