Do the results from the Lunar Prospector prove water ice at the Lunar poles?

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Abstract

The question of whether or not water ice is located at the lunar poles has been subject to much debate. The idea was first proposed by Watson, Murray,and Brown (1961), then later expanded upon by Arnold (1979). More recently, the Lunar Prospector mission which was equipped with a neutron spectrometer received results of a large hydrogen abundance at the lunar poles. But does this abundance of hydrogen take the form of water ice, or could it possibly be solar wind implanted hydrogen? This question was addressed in a recent article by Schmitt(1998) and will be examined in this report.

Background

The lunar samples brought back to earth from various Apollo missions have shown conclusively that the lunar regolith is generally exceedingly dry.(Epstein and Taylor, 1971, 1972) Yet speculation of water ice trapped at the lunar poles continues. In 1979 a comprehensive article was written by Arnold in an attempt to explore this possibility. His conclusions site a reasonable heat balance for retention of water ice at the poles. He then combined this with the geometry of the polar craters, which account for regions of up to 5% of the total lunar surface, and are permanently shadowed from the sun, keeping temperatures as low as 40-50 degrees Kelvin on the floor of the craters, and never more than 100 degrees Kelvin. These areas, according to Arnold, would be locations where water ice could become trapped for billions of years.

Neutron Spectrometer experiment and results

The most recent findings are from the Lunar Prospector Mission, launched in January 1998. This mission included an experiment, the Neutron Spectrometer, designed to detect hydrogen atoms by looking for “slow neutrons”. These slow neutrons result when there are collisions between hydrogen atoms and “fast neutrons”. The results of this experiment, announced in March 1998, show a clear abundance of hydrogen at both polar regions. The data indicated that .3 to 1 percent of the regolith is water ice. To the principal investigator of this mission, Alan Binder, this was a clear indication that the abundance of hydrogen was due to water ice being caught within the “cold traps” of the craters.

Discussion and Conclusion

In a recent article in Space News, Schmitt (1998) countered this idea with an alternative: since the neutron spectrometer has detected a hydrogen abundance at the poles, it is possible that this abundance is due to solar wind implanted hydrogen. The possibility that the Lunar Prospector could be locating solar wind implanted hydrogen is indeed real. However in order to explore this possibility, it is important distinguish the mechanism of solar hydrogen implantation.

The solar wind contains an abundance of hydrogen (in the form of alpha particles) which invade lunar material energetically typically in the range of 1 keV/nucleon (Leich, et al. 1973). The alpha particles become injected into the spaces between the molecules of the grains. These atoms can then work there way into the interstitial parts of the grains and move further down into the grain as more alpha particles hit the grain. This process proceeds until a point of saturation, which is about 1000-4000 Angstroms from the surface of the grain. The rim of the grain thus becomes altered in a very distinctive way, and one that is fairly easy to recognize by experiment.. This is how studies of lunar grains have distinguished the fact that there is solar implanted hydrogen. Studies of the moon's regolith have been done to determine if the samples brought back from the Apollo missions contained solar hydrogen (Leich, et al., 1973, DesMarais, et al., 1974, Epstein and Taylor, 1971,1972, Leich, et al. 1974, Bibring, et al., 1972) These studies have shown conclusively that the hydrogen found within the regolith of the moon was solar implanted. The hydrogen to deuterium ratio found in the lunar samples matches that of the ratio within the solar wind exactly. A detailed study of this was done by Payton (1974) in his dissertation. He showed that solar wind had indeed implanted hydrogen (as well as many other elements) into the lunar surface grains.

However the grains at the surface are not the only ones which contain solar wind implanted hydrogen rims. The grains which are anywhere from .5-2 meters can contain solar hydrogen due to the effects of "gardening". This is where the lunar surface grain become lifted off the surface, and the surface is overturned from impacts. This means that the lunar surface can contain up to 2 meters worth of solar wind implanted grains. The question then becomes, how much solar wind hydrogen can become implanted within the lunar soil? Studies of the lunar soil from the Apollo missions have shown that anywhere from 150 to 2000 PPM or 0.015 (Schmitt, 1998) to .2 percent (Leich, et al., 1973) by weight of solar implanted hydrogen is contained within the lunar soil. Notice that the percentages of solar implanted hydrogen which can be contained within the lunar soil (.015-.2 %) , and percentages of water ice claimed from the Prospector mission (.3-1 %) are within an order of magnitude to one another, and certainly comparable.

Yet in these craters there is not a consistent bombardment of solar hydrogen, since these grains are never directly in the solar wind. Why then would there be an abundance of solar hydrogen? The answer may lie in a temperature dependence of solar wind retention. Normally, (as within the regolith which is consistently bombarded by solar wind particles) the temperatures of the regolith are such that retention of the hydrogen within the grains is low. Lord (1968) performed experiments which show release profiles of implanted hydrogen in direct correlation with an increase in temperature. Even though these experiments were performed on olivine, the comparison for lunar regolith is justified, since there is a reasonable amount of olivine within the lunar regolith. Conversely then, it is possible for retention of hydrogen to be greater in regions where temperatures are lower, such as within the craters. In fact, Payton (1974) specifically accounts for the escape time of solar implanted hydrogen from the regolith thusly:

> "The escape time listed... is calculated by dividing the time per pass and multiplying by 2 since the moon is dark half the time and escape is only probable in the day."

It seems equitable then, to conclude that colder temperatures and retention of solar wind implanted hydrogen may be contemporaneous.

This does not prove conclusively that the hydrogen found by the Lunar Prospector Mission is solar implanted hydrogen, and not water ice. It does, however, offer a alternative and reasonable explanation for the hydrogen found at the poles. Further work is necessary for proof. A suggestion of research would be to experiment specifically on the lunar regolith for hydrogen retention versus temperature, for final proof of a correlation between hydrogen implantation and temperature dependence. Such an experiment may bring us closer to a final answer.