Water in pyroclastic deposits and cold traps on the Moon: Possible resources for future exploration

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Two possible water (OH/H_2O) reservoirs on the lunar surface were identified using the Moon Mineralogy Mapper (M^3) data that can be exploited in future exploration of the Moon. Significant amount of water (OH/H_2O) has been detected in the lunar pyroclastic deposits at the equatorial region corresponding to a surface abundance of 0.01 - 0.05 wt. % in volcanic glass beads. The thickness of these relatively OH/H_2O rich pyroclastic deposits is 4-7 m based the sizes of craters identified in the NAC data that penetrated the deposits. Assuming that the water abundance observed on the surface can represent the entire layer of pyroclastic deposits, we estimated 10^5 – 10^7 tons of water at individual deposits depending on their sizes, which is equivalent to 100 – 1000 tons of water per square kilometer. Water and other resources of pyroclastic deposits in the equatorial region are much easier to be accessed than those in the polar regions. However, the low water abundance at pyroclastic deposits means that mining such low abundance of water from lunar regolith is challenging, especially when most of the water could be in the form of strongly chemically bounded OH.

Alternatively, the possible ice deposits in the lunar polar region recently verified using M^3 may have much higher abundances of water. Our modeling results suggest that the water ice abundance could reach over 50% by area at the surface. However, we cannot tell the thickness of the ice deposits using the reflectance data. Our detected ice deposits could be very thin (i.e. ~mm) or the ice particle is very small (deposits could be thick). The Mini-RF circular polarization ratio (CPR) data did not suggest large blocks of ice. In addition, the possible ice deposits are located at relatively small individual discrete cold traps, which is not like the pyroclastic deposits expanding thousands of square kilometers. The patchy distribution of ice deposits is a challenge for exploitation owing to the extreme thermal environment.

In summary, exploiting water (possibly in the form of OH) in the large pyroclastic deposits at the equatorial region and water ice in the cold traps near the poles both have exploration potential. Exploring water in the pyroclastic deposits is challenged by its low abundance, while it shows advantages in easy access, concentrated distribution of water bearing materials, and availability of solar energy for rovers. On the other hand, the local abundance of water in the ice deposits in the polar region is much higher than in pyroclastic deposits. However, the volume of water ice in the polar region is still unknown. Mining water from the polar region is challenged by the patchy distribution of ice deposits and the extreme temperature environment.

Exploiting water in the large pyroclastic deposits at the equatorial region and water ice in the cold traps near the poles both has scientific significance. The former is critical for understanding the magmatic activities in the early history of the Moon, the volcanic process, and the process of water retention, while the latter is important for revealing the formation and deposition processes of water ice in the polar region.