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The science of the lunar polar volatile deposits

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The Moon possesses an extremely small tilt of its rotation axis relative to the plane of its orbit. Near the poles impact craters and other topographic lows are permanently shaded from the Sun. While lunar polar temperatures have not yet been directly measured, thermal models show maximum surface temperatures of 40 kelvins are likely common, and 25 kelvins is possible, potentially allowing cold trapping of volatiles. There are many potential sources of lunar polar volatiles. These include solar wind hydrogen, with abundances enhanced by slow diffusion through cold lunar mineral grains, comets, wet asteroids, IDPs, interstellar molecular clouds, the Earth and the Moon itself. Emplacement mechanisms are direct impact into the poles, and ballistic random walk of molecules with trapping prior to escape. Loss mechanisms are dominated by Lyman alpha ultraviolet radiation and micrometeorite vaporization and remobilization. Preservation mechanisms are thermal diffusion into the regolith where temperatures and diffusivities permit, burial by macrometeorite impact, and chemical processing to hydrated minerals or organics. This zoo of sources and processes suggests a complex and highly interesting volatile deposit at the poles regardless of its economic merits. Landed experiments that sample the polar regolith in various ways are virtually certain to yield interesting results, and may yield insights into the volatile history of the Earth-Moon system.