RELATIVE MAGNITUDES OF WATER SOURCES TO THE LUNAR POLES.

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Introduction: The lunar south pole is enjoying intense scrutiny recently in part because of the many lines of evidence for the presence of water ice that may support human activity. The main recognized sources for polar water are the impacts of comets and water-bearing asteroids [1], the solar wind [2], and the newly recognized importance of volcanism as a water source [3]. Balancing these sources are loss mechanisms including sublimation, sputtering, Lyman alpha radiation, and meteorite impact[4].

We estimate the contributions from impact, solar wind and volcanism over the Copernican, Eratosthenian and Upper Imbrian (post-Orientale) when the polar cold traps may have been in operation, and compare these to the steady loss to micrometeorites.

We begin with the Copernican where more solid estimates are available and summarized in Table 1. Ong et al. 2010 [5] made detailed estimates of the mass of water from comets and asteroids retained after impact over 1 Ga: roughly 10^{17} and 10^{18} g respectively. We assign a transport loss of a factor of 10 [6], leaving 10^{16} and 10^{17} g to be deposited at the poles. These values are consistent with a simple estimate of water mass from large Copernican crater impactors assuming an average density of 2.5 g/cc, an impactor to crater size ratio of 1/10, and an average water fraction of 1/10 and a vapor fraction retained of 1/10 also yielding 10^{17} g, and 10^{16} g deposited at the poles. For smaller impactors we integrate [7] from 10^{-3} to 10^{3} m and find 10^{15} retained and 10^{14} deposited. Finally, from Grun et al. [8] we find for < 1mm impactors 10^{16} g water retained, and 10^{15} g deposited over the Copernican at the poles.

Contrast this with an estimate of water derived from solar wind. Hurley et al. [9] give about 30 g/s of protons striking the Moon on average for a total mass of protons of 10^{18}g over 1 Ga. If we assume 1 part per thousand eventually is converted to water, and 10% of that reaches a cold trap, a total of 10^{14} g of water is supplied to the poles by the solar wind over the Copernican. To assess the relative contribution of volcanism, we scale the impact sources to earlier epochs. For the Eratosthenian we assume a 5 times higher impact flux, and a somewhat longer duration to apply a factor of 10. For the post-Orientale Imbrian, we scale the Copernican rate by 100x. The most salient comparisons are the thicknesses of ice deposits. We use the estimated mass fluxes and assume a total area of cold trap of $3x10^4$ km^2 [10]. In the Eratosthenian we estimate 3 m of ice based on the masses given by Needham et al. but a more generous transport efficiency of 0.1 to be consistent with the impact sources. The Upper Imbrian shows 30 m of potential ice thickness from volcanism.

Table 1. Order of Magnitude Masses and Deposit Thicknesses from Major Sources

	Retained (g)	Deposited at Poles in Copernican (g)	Deposit Average Thickness		
			Copernican	Eratosthenian	Post-Orientale Imbrian
Comets[5]	10^{17}	10^{16}	2 m	20 m	200 m
Asteroids[5]	10^{18}	10^{17}	20 m	200 m	2000 m
Large Copernican crater impactors [14]	10^{17}	10^{16}	2 m	20 m	200 m
Impactors 10^{-3} to 10^{3} m [7]	10^{15}	10^{14}	2 cm	20 cm	2 m
Impactors < 1 mm[8]	10^{16}	10^{15}	20 cm	2 m	20 m
Solar wind[9]		10^{14}	30 cm	30 cm	30 cm
Volcanism[3]		-	-	3 m	30 m
Micrometeorite loss[4]		-	30 cm	3 m	30 m

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