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# Decameter-scale pedestal craters in the tropics of Mars: Evidence for the recent presence of very young regional ice deposits in Tharsis

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ABSTRACT

Global climate models predict that ice will be deposited in tropical regions during obliquity excursions from the current mean obliquity of ~25° to ~35°, but no geological evidence for such deposits has been reported. We document the presence of very small (decameter scale) pedestal craters in the tropics of Mars (the Daedalia Planum–Tharsis region) that are superposed on an impact crater dated to ~12.5 Ma ago. The characteristics, abundance, and distribution of these small pedestal craters provide geological evidence that meters-thick ice accumulations existed in the tropical Tharsis region of Mars in the last few million years when mean obliquity was ~35° (~5–15 Ma) before it transitioned to a mean of ~25° (~0–3 Ma). A reconnaissance survey reveals similar small pedestal crater examples superposed on the older Amazonian Arsia Mons tropical mountain glacier deposit, suggesting that ice can accumulate in these tropical regions without initiating large-scale glacial conditions. These results support the predictions of general circulation models that ice can migrate to the equatorial regions during periods of moderate obliquity and then serve as a source for mid-latitude deposits.



## 1. Introduction

Currently, Mars is a hyperarid, hypothermal desert and the largest reservoir of surficial water ice on Mars resides at the poles. It is known, however, that variations in spin-axis/orbital parameters (obliquity, eccentricity, and precession) (Laskar et al., 2004) can cause mobilization of water ice, transport in the atmosphere, and redeposition at lower latitudes. Evidence has been presented that a recent, meters-thick, ice-rich mantle was emplaced from the poles down to about 30° N and S latitude in the last several million years during an "ice age," and that it has been undergoing modification in the 30°–50° latitude region in the last few hundred thousand years, as Mars' obliquity amplitude decreased and ice returned to the poles (Head et al., 2003). During earlier periods of higher obliquity (mean obliquity of ~35°) in the Late Amazonian, ice was deposited in the mid-latitudes, and formed widespread valley and plateau glacial land systems (Head et al., 2010; Madeleine et al., 2009). Somewhat earlier in the Amazonian, during periods when the mean obliquity was thought to have been ~45°, vast tropical mountain glaciers formed on the flanks of the major Tharsis volcanoes (Head and Marchant, 2003; Kadish et al., 2008a; Milkovich et al., 2006; Shean et al., 2005, 2007).

Unknown, however, has been the exact pathway and residence time of volatiles during transitions from one regime to another. Geological evidence, for example, has suggested that the higher amplitude obliquity of the past few million years caused ice stability conditions to migrate equatorward, and resulted in the deposition of a dust–ice mixture as a broad circum-polar high latitude mantle during periods of high obliquity (Head et al., 2003; Kreslavsky and Head, 2000; Mustard et al., 2001). In contrast, atmospheric general circulation models suggest that during periods of higher obliquity (mean obliquity ~25° and high amplitude variation) ice migrates directly to equatorial regions and then works its way back to the mid to high latitudes to be deposited in a more stable environment (Levrard et al., 2004). In a similar manner, mid-latitude glaciation is best explained in Mars general circulation models if mean obliquity is ~35° and the source of ice is at the equator, not at the poles (Madeleine et al., 2009). However, direct evidence of the presence of large quantities of ice that could serve as equatorial sources in the recent geologic past has not yet been documented. Finally, at mean obliquity of ~45°, ice is predicted to be deposited directly in the equatorial regions and to remain there as long as these conditions prevail (Forget et al., 2006), accumulating sufficient ice to produce the observed tropical mountain glaciers (e.g., Head and Marchant, 2003).

How can the differences between the equatorial ice predicted to occur by the models, and the lack of geological observations for the presence of such deposits, be reconciled? One difficulty recognized by both geologists and climate modelers is that ice mantles and glacial deposits are destined to be cold-based in the hypothermal, hyperarid Mars environment (Marchant and Head, 2007). Cold-based ice deposited at high polar latitudes on Earth and over much of Mars does not erode its substrate in any substantial manner (Marchant and Head, 2007) and

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