**Constraints on the ages of the martian polar deposits**

Introduction (Fishbaugh, Forget)

* Why the age of the polar deposits is so important to our understanding of Mars’ climate history
* Evolution of ideas about dating methods and estimates of the ages
* Purpose of this paper: to review the various constraints on the ages of the polar deposits, to provide recent updates to these constraints, and to suggest further measurements

Crater Counting

* Techniques and updates for the PLD (Herkenhoff)

Counting craters and evaluating their surface density has long been used to estimate the relative age of terrains on Mars. Because the provenance of the martian meteorites is unknown, the evolution of the rate of crater formation on Mars cannot be accurately determined. Therefore, early estimates of the cratering history of Mars relied on the better-known lunar cratering history and simple scaling of the lunar cratering rate. Observations of the current distribution of comets and asteroids have been used to constrain the recent cratering rate on Mars (Shoemaker and Shoemaker, 1990). The current cratering rate has been estimated based on the discovery of new craters in the dusty regions of Mars (Malin et al., 2006). While uncertain to a factor of about 2, these cratering rates can be used to constrain the age and resurfacing rate of exposures of polar layered deposits by counting the number of craters preserved on the surface.

Recognition of craters is inevitably limited by the resolution of available imagery and the degradation state of the craters. Previous studies have shown that pits as small as 3 pixels across can be recognized in images of the Martian polar regions (Herkenhoff and Plaut, 2000), and that rim crests can be recognized on fresh craters that are at least 5 pixel across (Kahn et al., 1986). Degraded craters must be larger to be recognized, especially if they are highly degraded. These constraints limited the number of craters that could be recognized in Mariner 9 and Viking Orbiter images of the polar regions (Plaut et al., 1988; Herkenhoff and Plaut, 2000); in fact, no craters larger than 300 m diameter could be found on the north polar layered deposits and residual cap. As higher resolution imagery became available from the Mars Global Surveyor and Mars Odyssey missions, more craters were recognized and estimates of surface age and modification rate were refined (Koutnik et al., 2002; Tanaka, 2005). Most recently, images from the Mars Reconnaissance Orbiter are being used to improve the polar crater size-frequency statistics further (Banks et al., 2009).

* Residual caps (Byrne)

Stratigraphic Constraints

* Overview of major geologic units and estimated ages (Tanaka)

Layer dating techniques

* NPLD layer stratigraphy and implications for dating layers (Fishbaugh)
* Spectral analysis (Winstrup, Milkovich, Hvidberg, Svensson)

Radar results

* Lack of craters within the PLD (Putzig, Holt, Plaut)

Trough formation

* Conditions required and when it could have happened (Hvidberg)

Flow modeling

* What does evidence of or lack of evidence of flow mean for the age? (Hvidberg, Koutnik)

Climate modeling

* How do obliquity, water sources, etc. constrain the age? (Forget, Montmessin)

Do the age constraints agree? (All)

Age differences between the north and south

* Is there a difference in age? (Herkenhoff, Koutnik)

The paradoxical difference in crater density between the north and south polar layered deposits was evident in Viking Orbiter images (Cutts et al., 1976; Plaut et al., 1988; Herkenhoff and Plaut, 2000). As described above, new image data has allowed the recognition of many more craters in both polar regions, but estimates of the average surface ages have not changed significantly: The exposed south polar layered deposits are 107 to 108 years old (Koutnik et al., 2002), while the north polar residual cap (which covers most of the NPLD) is only about 104 years old (Tanaka, 2005; Banks et al., 2009). Clearly the recent geologic history of the polar regions has been very different, with most of the exposed south polar layered deposits having been stable for many cycles of orbital/axial variations while resurfacing of the NPLD may be currently active. However, this major hemispherical difference may not have extended back in time to the origin of the oldest polar deposits. Craters on some of the basal north polar materials indicate that they may date to the Early to Middle Amazonian periods (Tanaka et al., 2008)

* Were there contemporaneous episodes of deposition/erosion? (Tanaka)
* What are the implications of these differences?
  + In a climatalogical sense (e.g., climate history and water sources)? (Forget, Montmessin)
  + In a geologic history sense (Tanaka, Fishbaugh, Herkenhoff, Milkovich)
  + For formation of CO2 residual caps (Byrne, Herkenhoff, Forget)

Astrobiology implications

* Do the results from these age constraints have implications for the habitability of the polar deposits? (Fishbaugh)

Future missions

* What *in situ* data is required, e.g. from a drilling mission? (Milkovich)
* What more can we do with existing remote sensing data? (All)
* What other types of remote sensing data would help? (All)

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