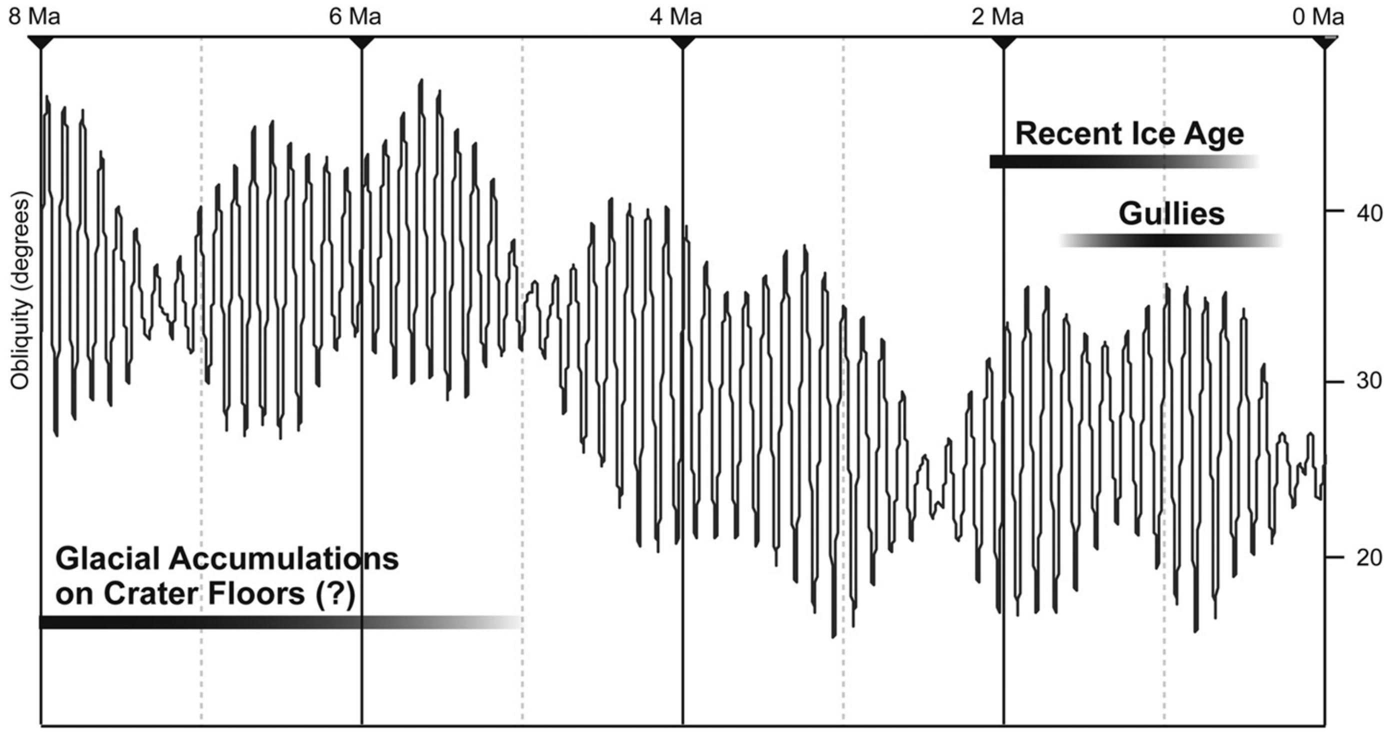

Fig. 18. Timeline of obliquity modulated (Laskar et al., 2004) latitude-dependent mantle deposition and modification during the Latest Amazonian period of Mars history. Mantling deposits are interpreted to have been emplaced in a latitude-dependent manner during an ice age coincident with the most recent period of enhanced obliquity (Head et al., 2003). Mid-latitude gullies, formed by the melting of ice-rich mantling deposits are coincident with the waning of this period (Head et al., 2008; Dickson and Head, 2009; Schon et al., 2009b). During the past 5 Myr obliquity has averaged ~25°, but prior to approximately 5 Ma mean obliquity was ~35°. Glacial accumulations on crater floors (e.g., Head et al., 2008; Dickson et al., 2011) are suggested to date from this period (Arfstrom and Hartmann, 2005; Berman et al., 2005; Berman et al., 2009). High latitude mantle terrain (e.g., Fig. 2; Fig. 3) with crater retention ages < 1 Ma correspond to the waning of the most recent ice age. Older more equatorial dissected latitude-dependent mantle terrain (e.g., Fig. 12) could correspond to the beginning of the most recent ice age, or alternatively to the transition to lower mean obliquity that occurred ~5 Ma. The chronological constraints (Fig. 19) support an equatorial ice source for deposition of the mantle (Levrard et al., 2004). Since high obliquity conditions were common in Mars' history, our observations of the current latitude-dependent mantle may represent only the most recent manifestation of a longer-term cyclic process that reconfigures surface ice reservoirs.

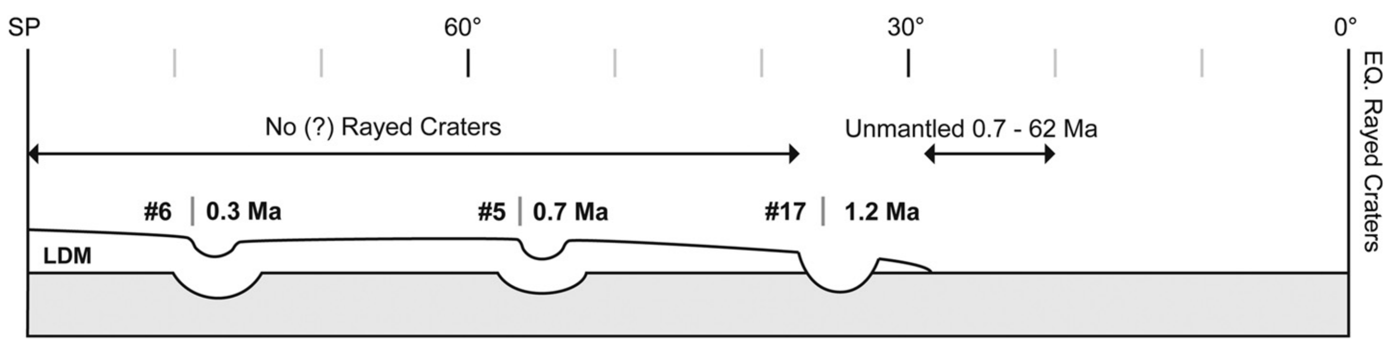

Fig. 19. This diagram shows the chronological constraints on the development of the latitude-dependent mantle derived from our observations. Two high-latitude craters (Fig. 5; Fig. 6) are draped by latitude-dependent mantling deposits. Crater counts on the polygonalized mantle surface at those locations reveal young crater retention ages. Gasa crater (Fig. 17) at 35.7°S superposes latitude-dependent mantling deposits which indicates that the mantle in this region is older than the high-latitude mantle. Unmantled craters near the boundary of the LDM indicate that dissected mantle is restricted to the ~30–60° region (Fig. 1).

expected based on regional depositional heterogeneity, weather and climate patterns, and preservation potential (e.g., Costard et al., 2001; Madeleine et al., 2009; Morgan et al., 2010). The most equatorial mantle with a crater retention age of ~7.9 Ma (Fig. 12) is at least a factor of several older than the high latitude mantle terrain (Fig. 5; Fig. 6). This suggests that the mantle observed at the surface today was not emplaced synchronously across the mid- and high-latitudes. The presence of ~1.2 Ma Gasa crater rays and secondaries on mid-latitude mantle surfaces (Schon et al., 2009b; Schon and Head, 2011b) also indicates that mid-latitude LDM is older than high latitude mantle. Although substrate is important for recognizing rays on Mars (Tornabene et al., 2006), our data show that crater rays in the equatorial region can persist for tens of millions of years. In contrast, other rayed craters similar to Gasa, are not observed superposed on the LDM, which further supports the young age of the mantle.

What was the source region of the ice for the ice-rich latitude-dependent mantle? The polar caps have been suggested as a potential source, but climate models indicate that an equatorial ice source (formed at high obliquity) is necessary to precipitate the mantling deposits (Levrard et al., 2004). With the exhaustion of an equatorial ice source, the equatorial extent of the LDM would become unstable and simulations of Levrard et al. (2004) indicate that surface ice would be re-deposited poleward. Our data and observations of older dissected mantle relative to younger high latitude LDM provide geological support for this scenario of poleward redistribution during