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Polyphase mid-latitude glaciation on Mars evidenced by dating of superimposed lobate debris aprons

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Mid-latitude glaciation on Mars is a leading hypothesis that has fertilised recent research into climate evolution, volatile cycling and cryospheric processes. However, much remains to be determined, including the timing of glaciation, as well as its detailed sequence and spatiotemporal expression. Landform evidence from a subset of viscous flow features called 'superimposed lobate debris aprons' (SLDAs) has been used to suggest multiple distinct phases of glaciation. This plurality is inferred mainly from the sharp contacts observed between SLDAs and other viscous flow features onto/into which they flow. SLDAs are thus interpreted to have formed during a lower-magnitude glacial event following emplacement of the underlying units. Here, in order to provide dating control to the sequence, we derive absolute surface ages for 140 SLDAs identified globally. CTX and HiRISE imagery was used to quantify the crater density on SLDAs and underlying units. SLDAs (mean age 9.0 Ma) are significantly younger than the underlying viscous flow features (mean age 59 Ma), supporting the polyphase glaciation concept. SLDA ages are tightly clustered within the last several Ma, although some SLDAs formed as early as 70 Ma. In contrast, ages of the viscous flow features span 3-144 Ma, with no clear clustering. These findings evidence two contiguous glaciation phases with contrasting characteristics, rather than two entirely separate glaciations. The SLDA age distributions in each hemisphere are not statistically different, indicating the latter phase that formed SLDAs was broadly synchronous across hemispheres. The latitude-elevation relationship for SLDAs does not show anticipated climatic and altitudinal controls, raising questions for the mass exchange processes governing their formation and preservation. Future work should date glacier-like forms at a much higher spatial resolution to unravel their history.