the trimline, or as a contact between vegetated land above the trimline and bare surface below. On Mars, in both locations where we have observed this phenomenon, the "trimline" takes the form of a generally continuous ridge along the wall parallel to the slope of the valley (Fig. 4), which we interpret to be a marginal moraine that formed from deposition of debris as ice within the valley underwent downwasting before receding to its present level.

5. Conclusions

The two-crater system described in this study provides evidence for glaciation involving a kilometer-scale thickness of ice in the northern mid-latitudes, followed by recession and more focused localized debris-covered glacial flow of ice within tributary valleys and the crater interior to produce the classic CCF texture. This sequence of events is similar to that inferred from the study of Dickson et al. (2008) along the dichotomy boundary. Each glacial system appears to have undergone a similar sequence of evolution (Fig. 8):

1) Kilometer-thick glaciers/ice-sheets fill valleys and regional lows such that flow into neighboring canyons is induced (Fig. 8A).
2) Environmental conditions change and ice stagnates and undergoes significant downwasting, leaving perched glacial deposits in the small crater (Fig. 8B).
3) During and after downwasting to present day topography, ice is still able to accumulate within local cold traps, producing alpine-like glaciers with convex up profiles and CCF deposits (Fig. 8C).
4) Mars undergoes continued climate change, desiccating the mid-latitudes and causing sublimation of these alpine-like glaciers. The most recent high-stand is recorded in the form of marginal moraines, or the martian equivalent of terrestrial "trimlines" (Fig. 4).

What are the implications of the similarity between the deposits observed along the dichotomy boundary (Dickson et al., 2008) and those observed here? If kilometer-thick ice was common at these latitudes, then we may be seeing the surface deposits of regional/hemispheric ice sheets in the Late Amazonian (Head et al., 2010-this issue). HRSC data show that nearby craters to the system described here show similar evidence for large-scale glaciation in the Late Amazonian (Fig. 9).

These examples may, however, represent more localized or regional occurrences of accumulation of wind-blown snow during transitions from high-to low-obliquity. Numerical simulations show that the present obliquity of Mars (~25°) is low compared to its predicted mean value over the last 250 million years (~34°) (Laskar et al., 2004). Therefore, the hyper-arid desert conditions observed in the mid-latitudes of Mars today may not be indicative of the surface in the relatively recent past. Precise solutions for the obliquity of Mars prior to ~20 Myr are not presently available (Laskar et al., 2004), but geologic evidence suggests that Mars may have undergone obliquity excursions in excess of 40°–45° within the last several hundred million years (Kreslavsky and Head, 2006).

What is the water cycle of Mars like under such higher obliquity conditions? Head and Marchant (2003) documented evidence for tropical mountain glaciers on Mars in the Late Amazonian, leading Forget et al. (2006) to try to reproduce the conditions under which these might have formed. They showed through general circulation models (GCMs) that at obliquity values of 45°, ice from the northern polar cap can be mobilized and redistributed within the equatorial zone, preferentially on the western flanks of the Tharsis Montes (Forget et al., 2006). As Mars transitions to lower-obliquity conditions, these ice deposits become unstable and are transported back towards high-latitudes (Levrard et al., 2004). But where are the most likely places for ice to accumulate in the northern mid-latitudes? Recent GCMs show that during this transition from high to low obliquity, ice that is sourced from the Tharsis Montes glaciers would be deposited in the northern mid-latitudes (Madeleine et al., 2007). While ice can be deposited widely across the northern mid-latitudes, Madeleine et al. (2007) found that the most likely sites for significant accumulation of ice are eastern Protonilus Mensae (near the high-stand of Dickson et al. (2008) and the deposits interpreted to be of glacial origin (Head et al., 2010-this issue)) and the Phlegra Montes (each accumulating > 12.5 mm/year of ice at ~35° obliquity).

The nature of the topography in this environment is such that the two-crater system is likely to have acted as a local trap and microclimate for wind-blown snow in the region, as well. In addition

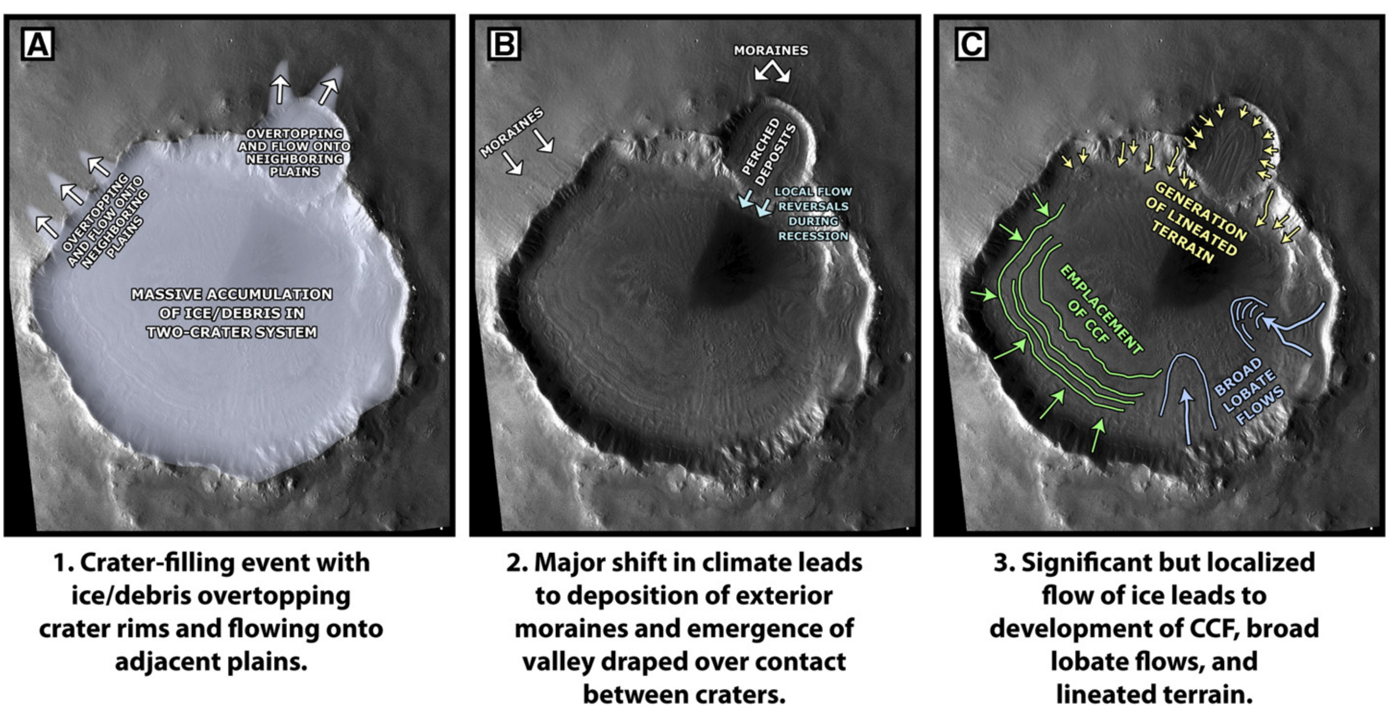

Fig. 8. Sequence of modification within and around the two-crater system. Base map is a CTX mosaic of P01_001619_2232 and P01_001619_2232.