demonstrated that due to the expected dust content of snow on Mars, the initial effects of sublimation would lead to the generation of a surface lag and thus reduce the albedo sufficiently (0.13, albedo of dust layer; Williams et al., 2008) to permit melting to occur (Fig. 8). In addition to this, localized dust storms generated by the high thermal gradient between the receding CO_2 frost cover and the exposed ground could deposit a thin layer of dust over exposed snowpacks. Fig. 9 shows the evolution of the daily maximum temperature profile at ~1 cm depth using the assumed thermal properties for a martian windblown snowbank during obliquity of 34.9°. As is the case with the surface (Fig. 8), temperatures do rise above the melting point at this depth. Williams et al. (2009) has shown that the melting of small dusty snowpacks ~1 cm thick

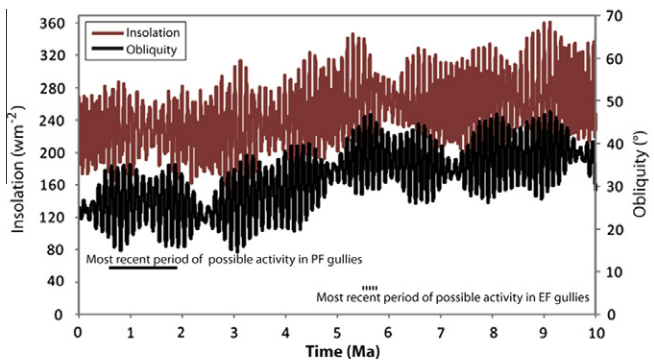

Fig. 10. Obliquity and insolation values for 46°S simulated by Laskar et al. (2004). The potential periods of the most recent gully activity for PF and EF slopes are plotted based on the results of the model and the morphologic investigation.

can generate 1 mm of runoff/m^2. This volume of snowcover over an average PF alcove (~2 km^2) could generate a maximum 2000 m^3 of runoff, enough to fill a 200 m long section of inner channel (10 m × 1 m; Fig. 5c) to bankfull conditions (assuming no losses to infiltration, evaporation and freezing). This level of activity would require repeated cycles of accumulation and melting to generate the ~2 km channels and is consistent with geomorphic evidence for multiple episodes of activity (such as abandoned channels, see Fig. 5).

4.2. Equator-facing gullies

The model results for the equator-facing slopes (Fig. 8) are significantly different than the pole-facing slope results. On EF slopes, gully activity is only likely to have taken place during periods when obliquities are ~45°, despite conditions favorable for melting during all obliquities. For obliquities below 45° the winter (L_s 90–180°) surface temperatures do not become sufficiently cold for CO_2 frost to be deposited (Fig. 8). The absence of CO_2 ice prevents any trapping of wind-blown water snow. In addition to this the surface temperatures warm gradually to the melting point of H_2O during the spring and thus are unfavorable for the formation of meltwater (Hecht, 2002; Costard et al., 2002). At obliquities ~45° the annual surface and subsurface (at ~1 cm depth with the snowpack) temperature regime is similar to the PF slopes (Figs. 8 and 9), and CO_2 condensation can occur. However, the potential accumulation period (L_s 70–190°) is close to half the length that is experienced during the same period on the PF slopes (L_s 20–250°), and as a consequence the gullies may have had less time to accumulate snow (and thus have a lower potential supply of meltwater).

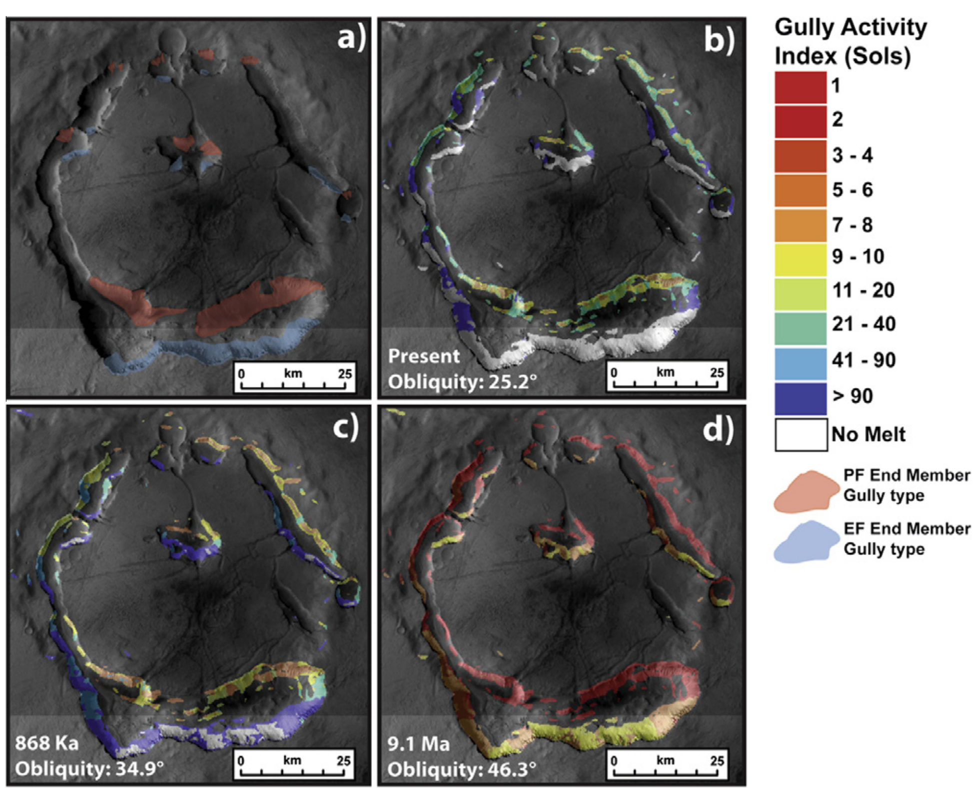

Fig. 11. (a) The location of the two morphologic gully end member types. Pole-facing gullies (PF) are highlighted in red and equator-facing gullies (EF) are in blue. Panels b–d show the spatial representation of the model results based on the aspect and slope values for the study site derived from a 200 m/pixel HRSC DTM. The value represented on the maps is the length of time (in sols) taken for the spring maximum surface temperatures to rise from 150 K (frost point of CO_2) to the melting point of water. No activity corresponds to conditions where either the temperature never becomes cold enough for CO_2 frost to form or the melt point is never achieved. Hence, the lower the number the larger the potential for gully activity to occur in the year from a combination of snow deposits being stable long enough to accumulate sufficient volumes and then being able to melt rapidly. (b) The present. (c) 868 ka (obliquity 34.9°). (d) 9.1 Ma (obliquity 46.3°). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)