Mars. Analysis of gullies in the Mars-like Antarctic Dry Valleys (ADV) (Marchant and Head, 2007) has shown that snowmelt from seasonal and perennial snow deposits can serve as a source for seasonal gully activity in a terrestrial hyper-arid polar desert setting (Dickson et al., 2007b; Head et al., 2007; Levy et al., 2007; Morgan et al., 2008). Recent modeling by Mischna et al. (2003) and Madeleine et al. (2009) has shown that snowfall on Mars is possible during periods of higher obliquity in the regions where gullies are located. Conditions favorable for the accumulation and preservation of snow and ice must be maintained long enough, prior to the onset of melting, in order for liquid water on Mars to carve the gullies (Hecht, 2002). The fluvial characteristics of martian gullies (McEwen et al., 2007), their distinctive latitude dependence (Malin and Edgett, 2000a), their close association with recent ice-rich mantles (Milliken et al., 2003; Head et al., 2003; Christensen, 2003) and lobate glacial-like lobes (Head et al., 2008), and evidence for snow and ice accumulation in current gully alcoves and channels (Head et al., 2008), all point to the potential role of top-down melting of accumulations of snow and ice as the source of water forming the gullies.

Recent Mars studies where gullies are found on slopes of all orientations have noted aspect-dependent variations in morphology related to slope orientation (Reiss et al., 2009). We test the viability of the top-down snowmelt model as an explanation for gully activity on Mars by investigating whether variations in insolation conditions favorable for the annual accumulation and subsequent melting of snow can account for aspect-dependant morphological differences observed in gullies. We apply the Costard et al. (2002) one-dimensional version of the LMD GCM (used to explain the global spatial distribution of gullies) to model the surface temperatures of a study area in Noachis Terra. We use site-specific topographic orientation and slope parameters as inputs for the model to assess the current distribution of surface temperatures. This was extended back in time through the application of the Laskar et al. (2004) simulations of the spin-axis/orbital history for Mars over the last 20 million years. We then assessed whether predicted variations in insolation-related surface temperatures could account for observed differences in gully morphology and the apparent ages of gully activity.

2. Terrestrial analog of gully formation: Antarctic Dry Valleys

In response to the evidence outlined above supporting the top-down melting of accumulations of snow and ice as the source of water that formed the martian gullies, this section discusses field observations of snowmelt as the source of gully activity in the hyper-arid polar deserts of the Antarctic Dry Valleys (Marchant and Head, 2007). Field research was conducted on gully systems within upper Wright Valley in the elevated extremes of the "inland mixed zone" (Marchant and Head, 2007). Gully systems ~0.5 to >1 km in length are carved into the southern slopes of the Asgard range and are comprised of the three morphological units used to define gullies on Mars (Alcove, channel and fan, see Fig. 1). The gradients of the Asgard slopes are ~35° which is consistent with martian gullies that are found on slopes in excess of 21° (Dickson et al., 2007a). Gully channels are ~2–6 m wide and up to 2 m deep.

In the Dry Valleys, precipitation occurs only as snow, and so the region provides an environment in which to study gully activity in the absence of erosion associated with rainfall. Annual precipitation consists of only a few centimeters (Bromley, 1985). Nevertheless, the wind redistributes and concentrates snow during the winter into seasonal and perennial snowpacks >30 cm thick within topographic hollows that include the gully alcoves and channels (Figs. 1 and 2) (Morgan et al., 2008; Dickson et al., 2007b; Head et al., 2007; Levy et al., 2007). Gully activity is initiated by the melting of these snowpacks in the spring by direct solar insolation, forming localized surface runoff and limited fluvial activity

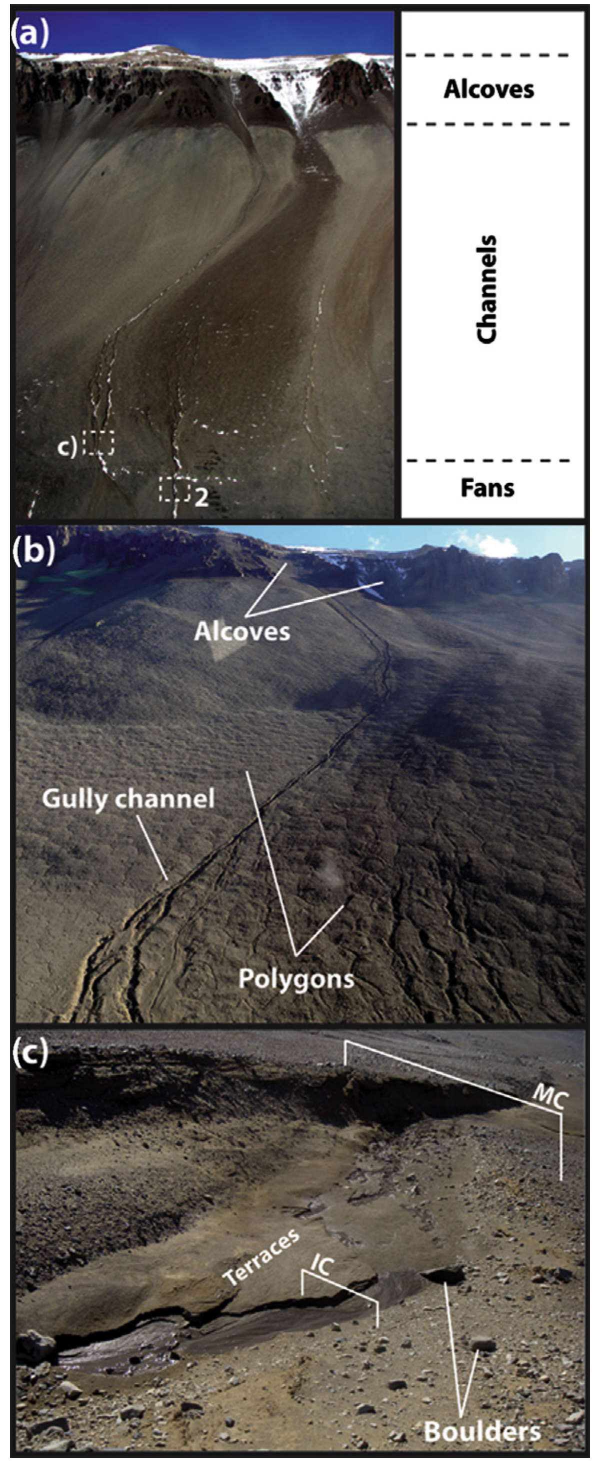

Fig. 1. Gully systems along the southern slopes of the Asgard range within upper Wright Valley of the Antarctic Dry Valleys. (a) Gully systems are comprised of the three morphological elements that define martian gullies: Alcoves, channels and fans. The difference in elevation between the alcoves and base of the fan is ~1 km. Wind blown snow can be seen within the channels of the gullies. The two boxes refer to images in (c) and Fig. 2. (b) Close-up view of the main channel and alcoves of the longest gully system in (a). Note the presence of thermal contraction crack polygons on the slopes that the gullies are carved into. (c) View of gully activity within the main channel (MC). Surface runoff due to snowmelt occurs during periods of peak insolation and carves smaller (~0.5 m) inner channels (IC) and terraces within the main gully channel. Images (a) and (b) where photographed from a helicopter, (c) was taken from the ground.