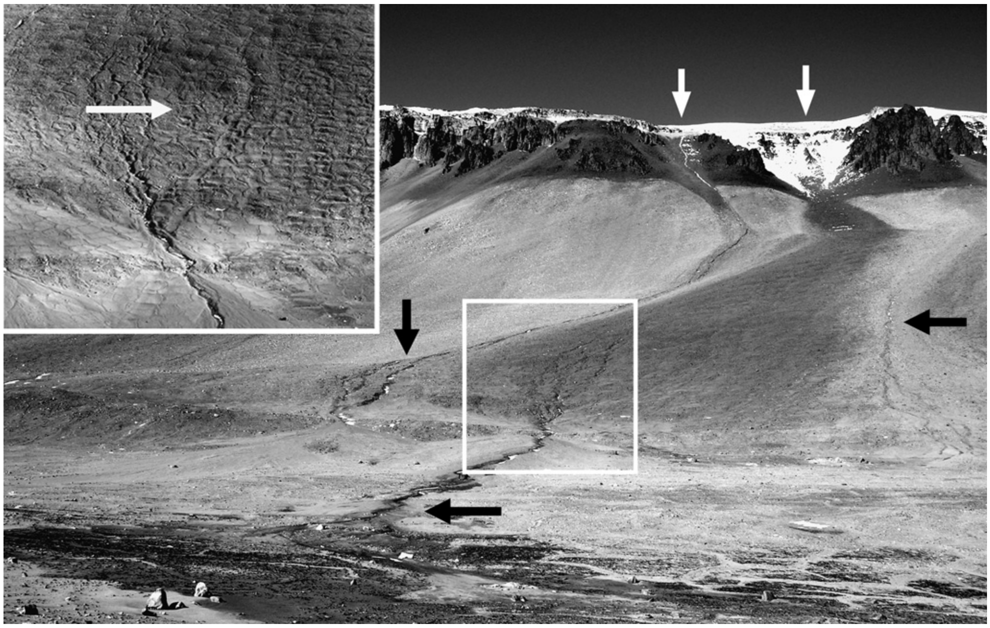

Fig. 1. Perspective view of a portion of the South Fork study area in upper Wright Valley, Antarctica. Black arrows indicate channels on the southern wall of the valley and white arrows indicate large alcoves present in the dolerite bedrock, approximately 1000 m above the valley floor. The dark, tongue-shaped lobe of dolerite boulders at center is approximately 300 m wide. Inset. Boxed region showing a small concavity present in the colluvium slope. White arrow indicates the center of the depression. Channels enter into and emanate from the concavity.

polygons is altered by proximity to developing gullies. We describe such reciprocal modification relationships as "gully–polygon systems."

We then analyze HiRISE images that document the interplay between polygonally patterned ground, ice-cemented permafrost, and gullies on Mars. If strong morphological similarities exist between gullies and polygons observed on Mars and those documented in the ADV, then this evidence would suggest that, to a first order, some martian gullies formed and were modified by processes analogous to those occurring in ADV gully–polygon systems. Such morphological comparisons can help constrain the physical and hydrological properties of gully flow. We address concerns over equifinality (similar morphologies produced by different processes) by focusing our analysis on morphological relationships that illustrate specific spatial and stratigraphic relationships.

2. The Antarctic Dry Valleys (ADV)

The Antarctic Dry Valleys are a suitable laboratory for understanding the geomorphological effects of water moving through temperature-dependent phase transitions (freezing, melting, sublimation, evaporation). On the basis of summertime air temperature, relative humidity, soil temperature, and soil moisture conditions, the ADV region is divided into three microclimate zones. The three zones include a coastal thaw zone, an inland mixed zone, and a stable upland zone (Marchant and Denton, 1996; Marchant and Head, 2007). In the inland mixed zone, melting, evaporation, and sublimation occur, whereas in the stable upland zone, sublimation is the dominant phase transition (Ragotzkie and Likens, 1964; Marchant et al., 2002; Kowalewski et al., 2006; Marchant and Head, 2007). The stable upland zone is interpreted to be closely analogous to Mars under current, average climate conditions, whereas the inland mixed zone may be a good analog for more clement martian conditions produced by orbitally-driven climate change (Marchant and Head, 2007) or for short duration peak temperature and insolation conditions. Landforms that are produced in equilibrium with microclimate conditions in each zone are termed equilibrium landforms (Marchant and Head, 2007). Gullies and polygons are the two dominant equilibrium landforms on inland-mixed zone valley walls.

2.1. Gully–polygon systems in the ADV

In the inland mixed zone of the ADV, gullies are characterized by a recessed alcove, sinuous channels with seasonally moist hyporheic zones (McKnight et al., 1999; Gooseff et al., 2002; Levy et al., 2008b), and one or more distal fans (Figs. 1 and 2). The hyporheic zone is the area marginal to and beneath a stream that exchanges water with the stream channel. Within and adjacent to most gullies, dry, ice-free sediment overlies sediment that is cemented by pore ice. The lower depth of this pore ice is unknown, but its surface, called the "ice-cement table," is fairly uniform and occurs on average at about 15–20 cm depth (Bockheim et al., 2007; Levy et al., 2007b). Typically, the ice-cement table deepens with increasing distance from isolated snow banks and gully channels.

In ADV areas with extensive pore ice, the ground commonly shows well-developed thermal contraction crack polygons (Berg and Black, 1966). All gullies save one observed in the Wright Valley study site are present on polygonally-patterned slopes (Levy et al., 2008b; Morgan et al., 2008). Across the ADV, active and recently active gullies are typically present in association with contraction-crack polygons; relict gullies in the coldest and driest portion of the ADV that have been inactive for up to 10 My (Lewis et al., 2007) typically lack polygons characteristic of the Wright Valley site. The most common polygons present in the South Fork area are composite-wedge polygons (Levy et al., 2008b). Composite-wedge polygons are those in which alternating layers of sand and ice fill thermal contraction cracks (Berg and Black, 1966). Importantly, areas in the Dry Valleys that lack pore ice within the upper ∼1 m of soils tend to lack all varieties of thermal contraction crack polygons (Marchant and Head, 2007).

2.1.1. ADV gully water sources

Soil-temperature measurements indicate that melting along the ice-cement table in the inland mixed zone is uncommon, and