PERIGLACIAL HILLSLOPE ANALOGS FOR MARTIAN GULLY FORMATION.

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Introduction: The search for terrestrial analogs for gully forms observed on Mars is an on-going endeavor. Many different models have been presented including dry flows [1], brine-rich flows [2], aquifer breakouts [3], carbon dioxide outbursts [4], volatile accumulation and melting, as well as a variety of debris flows involving the melting of water or carbon dioxide –rich snow and/or ice [5]. Preference has overwhelmingly been toward processes that do not involve liquid water due to the widely held belief that environmental conditions on Mars are unfavorable for the accumulation and flowage of liquid water on the plant's surface. Recent studies of MOLA data [6] as well as experimental investigations [7] suggest that in fact water can exist for periods of time on the surface of Mars under current environmental conditions and are also likely to have existed in the past [8]. The likelihood of the existence and persistence of water on the surface of Mars is enhanced when consideration is given to the possibility that waters may be brine rich [9]. There is widespread agreement that Mars is a cold, dry planet with annual temperatures that are on average below freezing year round. Yet there are locations and times of the year when temperatures are above freezing and evaporation rates low enough that water would be capable of flowing over limited time and across limited space. Similar environments exist on Earth. Such environments are the periglacial environments of the high latitudes and altitudes of Earth. In these environments hillslope processes are dominated by debris flows and slushflows,. Accompanying both of these process/forms are landforms that strongly resemble "gullies" on Mars. The objective of this paper is to asses the appropriateness of these processes as Mars gully analogs.

Discussion: Debris flows are a complex group of gravity induced rapid mass movements consisting of a mixture of grain sizes and varying amounts of water (Fig 1). They are characterized by a distinct failure scar, an eroded track terminating in a tongue or lobe. They are initiated and mobilized in numerous ways including 1: an abundant source of moisture 2. An abundant supply of fine-grained sediment, and a relatively steep slope. Initiation is by mobilization as a slurry that erodes its own channel and thus increases its sediment concentration or as a shallow slide that provides a high concentration of unconsolidated debris that mobilizes as a flow when runoff is mixed with debris [10]. The abundant moisture on earth is typically provided by intense rainfall or rapid snowmelt or by snow and ice melt during volcanism.

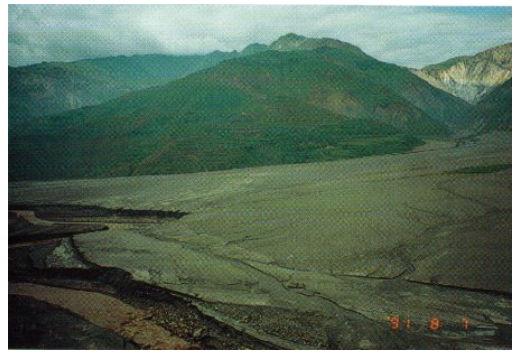

Figure 1: Extensive debris flow in terrestrial upland setting.

Slushflows are a specific type of snow avalanche in which water saturated snow masses are mobilized when rainfall, snowmelt, or a combination of both increases the water content of the snow (Fig. 2). When instability is reached the snow mass fails. Slush avalanches display several characteristic features including striations and grooves in the regolith associated with the removal and dragging of rocks and boulders. In addition, avalanche debris tails develop on the downslope side of large boulders. The boulder tongues (aprons) of slush avalanches are generally longer and flatter than those associated with other types of snow avalanches. They display a frontal horseshoe

shaped fringe of perched boulders on low slopes [11].

Figure 2: Slush avalanche path, Karkevagge Swedish Lapland.

Debris flows are typically triggered by extreme precipitation events and as such tend to have long recurrence intervals. On the other hand slush avalanches derive their moisture principally from annual melting of the snowpack and so generally have higher recurrence intervals.

Martian gullies display many of the characteristic forms associated with both debris flows and slush avalanches and as such both process forms represent viable analogs from the terrestrial periglacial realm. In evaluating the most appropriate analog it is essential to realize that different processes may have produced gullies at different times in the history of the planet and that different processes may be responsible for gully formation at different locations under prevailing environmental conditions. It is probable that debris flows were more likely responsible for gully formation at the time of abundant water on the Martian surface, while young gullies are the result of slush avalanching associated with the seasonal melting of water/carbon dioxide snow.

On those parts of the planet where seasonal snow is present in small quantities, slush avalanching may be initiated by seasonal melting of permafrost. Slope failures associated with the active layer are common in areas underlain by perennially frozen ground and ice-rich unconsolidated sediments. Such failures are generally confined to upper and middle slopes of the landscape and possess failure planes well within the slope. Our experimental studies have clearly demonstrated that both the application of liquid water and ice-water slush are able to produce forms associated with both types of hillslope form [12].

Conclusion: From a consideration of the forms of dominant hillslope movements in periglacial environments in the terrestrial context, we believe that debris flows and slush avalanches represent the most appropriate analogs for Martian gully development. Their occurrence has undoubtedly varied over space and time on Mars and their relative impotance as formative agents is undoubtedly tied to the overall geologic history of the planet. Additionally, the initiation mechanism for flow undoubtedly varies spatially depending on the local prevailing conditions. It is essential that variations in space and time be taken into account when identifying appropriate analogs for Martian gully forms.

References:

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