PARAGLACIAL GEOMORPHOLOGY ON MARS: APPLICATION TO POST-GLACIAL FEATURES IN MARTIAN IMPACT CRATERS. E. R. Jawin[1], J. W. Head[1], and D. R. Marchant[2], [1]Department of Geological Sciences, Brown University, Providence, RI 02912 USA, [2]Department of Earth & Environment, Boston University, Boston, MA 02215 USA (Erica_Jawin@brown.edu).

Introduction: Previous studies have identified a transitional phase in glaciated regions characterized by the exposure of large sediment stores postdating glacial retreat [1-2]. This *paraglacial period* occurs due to the instability or metastability of the system related to both the ice loss and erosion of sediment stores. This sediment is susceptible to rapid modification by a number of processes. The paraglacial period ends when the exposed sediment stores have been exhausted and a non-glacial "equilibrium" state, including sediment erosion and transport rates, has been reached [2, 3].

Variations in spin-axis/orbital parameters of Mars have led to significant variations in glacial surface conditions throughout its history, with mobilization of polar ice to the mid-latitudes and equatorial regions [4-5]. In addition, many craters, including many of those in mid-latitudes, bear morphologies which have been credited to the accumulation and flow of snow/ice such as concentric crater fill (CCF), and are similar in morphology to lineated valley fill (LVF) and lobate debris aprons (LDA) [6-7]. Additionally, many of these craters bear evidence for ice loss in the form of spatulate depressions [8] and sublimation pits, as well as stratigraphically younger features such as gullies, washboard terrain, and sediment fans (e.g. Fig. 1) [9-10].

The formation of these stratigraphically young units and landforms appears to be associated with the waning of ice accumulation [8]. The temporal relationship to the loss of glacial ice, as well as the geomorphic similarities of martian crater features to terrestrial paraglacial features, suggests that the young units observed in many mid-latitude martian craters represent a martian paraglacial phase triggered by deglaciation [3].

We undertook an analysis of candidate paraglacial features and landsystems for the population of mid-latitude impact craters modified by glacial flow as mapped by [11]. Here we report our findings, focused on paraglacial features found in a 10.6 km diameter impact crater located in eastern Newton crater (Fig. 1).

Observations: Paraglacial geomorphology includes 'landsystems' which are applicable to martian conditions: rock slopes, sediment-mantled slopes, and glacial forelands [2-3]. These landsystems comprise a range of features that represent the various processes a landscape undergoes after deglaciation.

Spatulate depressions represent the waning stage of ice accumulation (Fig. 1D). These depressions form through the sublimation and loss of ice, as the terrain undergoes deglaciaion [7-8]. In terms of the paraglacial model, the loss of ice in these arcuate depressions changes the distribution of stresses throughout the system; this debuttressing of upslope material on crater walls can trigger mass-wasting of wall material resulting in talus aprons, as well as deformation resulting in uphill-facing scarps (called 'anti-scarps" on Earth [2]) or washboard terrain, named for its similarity to a ridged washboard (Fig. 1F). This modification may continue after the immediate period of ice loss [2, 12]. There is evidence for creation of new washboard terrain on young sediment fans that cover old washboard elements (Fig. 1G), and are then themselves deformed, in agreement with the paraglacial model.

Gullies are arguably the most prominent product of the paraglacial period. Sediment stores exposed from ice loss are reworked by erosional processes and sediment-gravity flow [2]. Material is carried downslope from alcoves near the crater rim and form semi-parallel ridges which often terminate in sediment fans (Fig. 1C,E,G). Many channels intersect, vary in depth and width, and can be traced from the same source alcove, suggesting gully formation is repeated throughout the paraglacial period, even as sediment supplies decrease.

Additional paraglacial processes can create polygonalized terrain on crater walls through freeze-thaw of near-surface ice and ice-rich substrates [2]. In certain settings the near-surface ice can sublimate through polygonal cracks to form large pits in crater walls (Fig. 1A). As the sediment stores are continually eroded and modified, these polygons can become modified, creating linear or otherwise deformed polygons (Fig. 1B). Smaller-scale features, including solifluction and gelifluction lobes, are also visible and appear to be created during the paraglacial period.

Discussion: The vast majority of craters bearing spatulate depressions and associated paraglacial features occur in the southern hemisphere. Not all craters with evidence of ice contain spatulate depressions, and not all craters with spatulate depressions contain paraglacial features. Certain craters also contain typical paraglacial features such as alcoves, gullies, and washboard terrain, but do not contain spatulate depressions.

The alcoves where gullies originate are aligned with the location of spatulate depressions, and therefore may represent the same source locations as those for ice and snow accumulation. Therefore the alcoves themselves may not be completely paraglacial, but could be inherited in part from the original crater landform and could be modified during periods of high snow and ice accumulation.

The paraglacial phase on Earth is of short duration, and the morphology is often rapidly erased by subsequent pluvial and fluvial processes. On Mars, however, these features are readily visible and appear to have lasted for hundreds of thousands to millions of years. We interpret this to mean that the paraglacial phase on Mars is longer in duration than in terrestrial settings, owing to lower erosion rates and potentially larger sediment supplies exposed by ice loss in crater interiors.

Conclusions: We find that the application of the paraglacial model to martian impact craters that have recently undergone glaciation and deglaciation is an appropriate model for postglacial modification. Paraglacially-derived features are present in a wide range of craters across the martian surface, although the association of features from ice, ice loss, and paraglaciation are not ubiquitous through all craters. More paraglacial craters are present in the southern than the northern hemisphere. Paraglacial features are still present on Mars associated with glaciation that ended tens of millions of years ago, suggesting that very low erosion rates and slow processes perpetuate the periglacial phase for a much longer time than on Earth.

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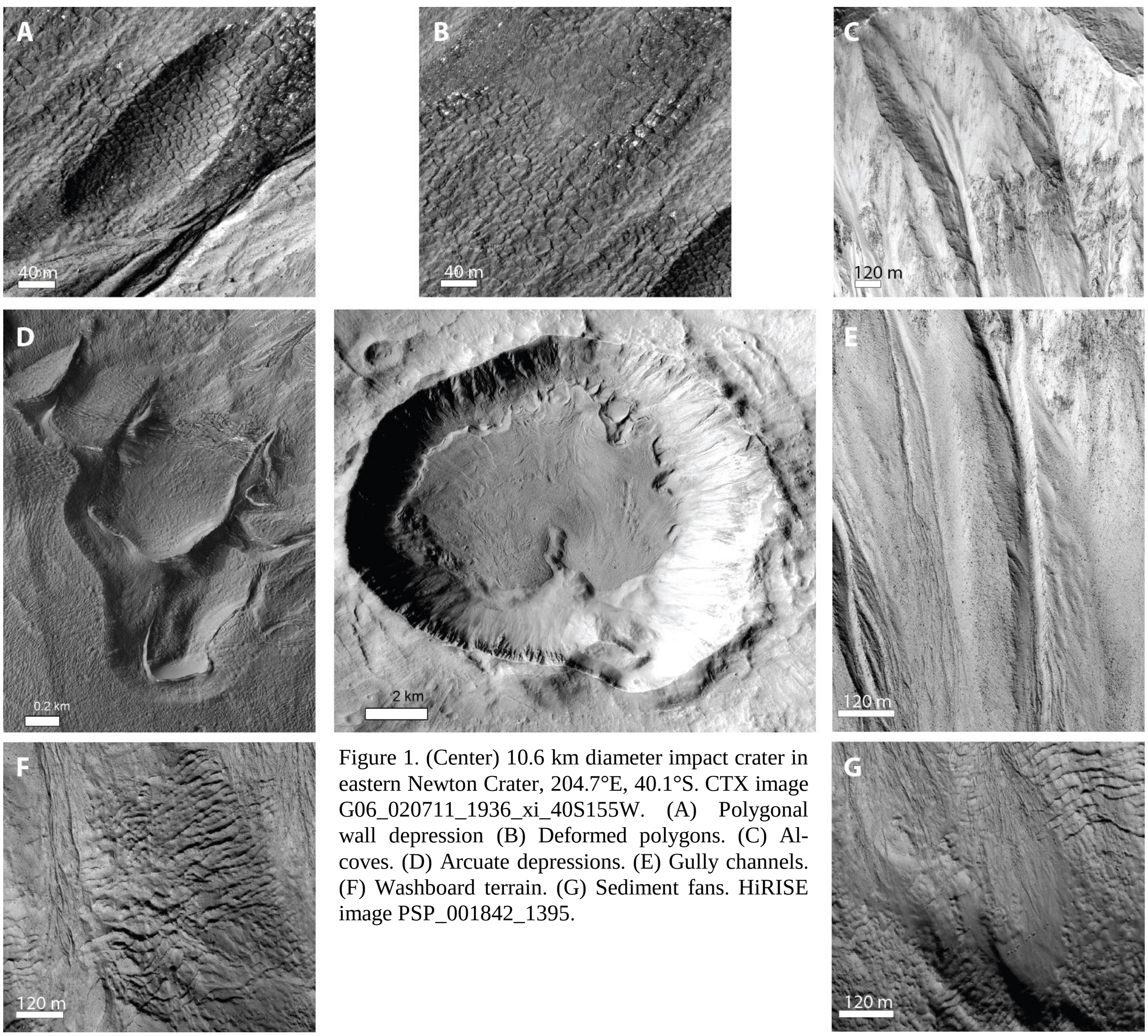

Figure 1. (Center) 10.6 km diameter impact crater in eastern Newton Crater, 204.7°E, 40.1°S. CTX image G06_020711_1936_xi_40S155W. (A) Polygonal wall depression (B) Deformed polygons. (C) Alcoves. (D) Arcuate depressions. (E) Gully channels. (F) Washboard terrain. (G) Sediment fans. HiRISE image PSP_001842_1395.