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Processes producing rock fragments in a hyper-arid, frigid and windy environment, the interior of Gale Crater, Mars

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Rovers on Mars have revealed in unprecedented detail rocky landscapes with decaying outcrops, rubble, stone-littered regolith and bedrock that reflect diverse processes breaking down and redistributing surface rocks in the cold and dry Martian environment. Processes include erosional undermining and gravitational collapse of cap rock, downslope displacement of bedrock fragments, mechanical breakdown of rock fragments, and shaping of rock surfaces by wind-driven sediment. Additional potential contributions of fractured rocks at the surface include a) a complex burial, diagenetic, and exhumation history, which resulted in fractures in the sedimentary bedrock that are commonly mineralized, and b) meteoritic impacts that fragment bedrock and deliver fragments ballistically to the Mars surface; they have been inferred to form thick, widespread regolith [1].

Herein, we consider data acquired by Curiosity, the Mars Science Laboratory rover currently exploring the interior of Gale Crater, Mars. The surfaces traversed by Curiosity are generally characterized as eroded bedrock mantled with very thin debris, decimetres at most. Bedrock exposures seldom show signs of local meteoritic impacts, suggesting that the importance of impact gardening of the Martian surface is not universal. Exposed bedding planes are largely undisrupted and undeformed. Although cracks pervade the bedrock, they generally define fragments that fit together as pieces of a puzzle with no “missing” ejected pieces. The common gap between fragments, and lack of preferred crack orientation and offset across cracks suggest in-situ fracturing due to layer-parallel, isotropic contraction of the fragmented layer relative to the adjacent bedrock.

Evidence from diverse sources points to the importance of thermal stresses driven by cyclic solar exposure in contributing to the mechanical weathering of exposed rock and generation of regolith in various settings on Earth [2], and especially on extra-terrestrial bodies where cyclic temperature variations are large and rapid (e.g. Mars [3], comets [4], asteroids [5]). We consider the influence of size and thermo-mechanical properties on the development of the temperature and stress fields in loose rocks on the surface of Mars, using a 3-D numerical model constrained by ground-based surface temperature measurements from the Curiosity Rover's Environmental Monitoring Station (REMS). Using Earth-analogue studies to develop insight and simple numerical experiments, we explore how the shapes and surface details of rock fragments reflect the likely importance of crack propagation due to thermal stress relative to other mechanical weathering processes on Mars.

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