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Gale crater and impact processes – Curiosity's first 364 Sols on Mars

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ABSTRACT

Impact processes at all scales have been involved in the formation and subsequent evolution of Gale crater. Small impact craters in the vicinity of the Curiosity MSL landing site and rover traverse during the 364 Sols after landing have been studied both from orbit and the surface. Evidence for the effect of impacts on basement outcrops may include loose blocks of sandstone and conglomerate, and disrupted (fractured) sedimentary layers, which are not obviously displaced by erosion. Impact ejecta blankets are likely to be present, but in the absence of distinct glass or impact melt phases are difficult to distinguish from sedimentary/volcaniclastic breccia and conglomerate deposits. The occurrence of individual blocks with diverse petrological characteristics, including igneous textures, have been identified across the surface of Bradbury Rise, and some of these blocks may represent distal ejecta from larger craters in the vicinity of Gale. Distal ejecta may also occur in the form of impact spherules identified in the sediments and drift material. Possible examples of impactites in the form of shatter cones, shocked rocks, and ropy textured fragments of materials that may have been molten have been observed, but cannot be uniquely confirmed. Modification by aeolian processes of craters smaller than 40 m in diameter observed in this study, are indicated by erosion of crater rims, and infill of craters with aeolian and airfall dust deposits. Estimates for resurfacing suggest that craters less than 15 m in diameter may represent steady state between production and destruction. The smallest candidate impact crater observed is ~0.6 m in diameter. The observed crater record and other data are consistent with a resurfacing rate of the order of 10 mm/Myr; considerably greater than the rate from impact cratering alone, but remarkably lower than terrestrial erosion rates.

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1. Introduction

The surface of Mars has been affected by impact cratering processes throughout its history. Gale crater is an example of an impact crater (155 km diameter) that formed in the late Noachian to early Hesperian (Anderson and Bell, 2010; Thomson et al., 2011), most likely as complex crater (Pike, 1980; Schwenzer et al., 2012). Gale crater and vicinity comprise a rich and diverse geologic history, including volcanic activity (Stolper et al., 2013; Schmidt et al., 2013), mineralogical evidence for aqueous alteration (Milliken et al., 2010; Fraeman et al., 2013; Ehlmann and Buz, 2014), and the presence of fluvial and lacustrine sedimentary environments (Williams et al., 2013; Grotzinger et al., 2013; Palucis et al., 2014). The early results from the MSL mission provide evidence for a habitable environment with abundant near-neutral pH water (Grotzinger et al., 2013). Understanding the effects of impact cratering on surficial materials provides insight into how later, smaller impacts and subsequent aeolian processes may complicate the interpretation of the preserved stratigraphic record, as well as provide constraints on resurfacing rates.

Gale crater is superimposed on the martian dichotomy boundary and, more specifically, formed on Noachian and Hesperian-aged units on its eastern, southern and western margins. Gale is bounded by Noachian to Amazonian aged transitional materials on its northern margins according to the new *Geologic Map of Mars* (Tanaka et al., 2014a,b). A schematic map (Fig. 1B) provides the context for this study, as well as highlighting Gale crater ejecta that were not well identified in past studies. The mapping was done at a regional scale using the THEMIS daytime and nighttime mosaic. Thermal imagery is especially powerful to differentiate patterns related to the crater's ejecta, which behave differently than surrounding bedrock. HRSC, CTX and HiRISE images were used to locally check the mapping, but coverage was partial and was not used for the full scale mapping.

Orbital images show thick ejecta outside of Gale's rim, particularly around the southern rim, indicating that it is one of the younger large craters in the region. Superimposed on the Gale deposits are five craters mapped with fresh ejecta blankets (Fig. 1B). Distal ejecta from these nearby, similarly aged or younger craters are likely to have diverse compositions reflecting the varied lithology of martian crust north and south of the dichotomy. Variations in the regional chemistry have been noted, for example, in Odyssey Gamma Ray data (Newsom et al., 2013a,b). There is a strong potential for some of the ejecta from these more recent craters to have formed secondary craters and be present as loose blocks within Gale crater.

The original morphometry of Gale has also been extensively modified by accumulation of deposits preserved within the central mound, Aeolis Mons (informally named Mt. Sharp), which can include sedimentary and/or volcaniclastic and distal ejecta deposits. In addition, the crater contains alluvial and fluvial deposits originating at the crater rim, and younger (i.e., active) sedimentary dunes and dust deposits (Silvestro et al., 2012). Crater count studies by Grant et al. (2014) show that the bulk of the alluvial deposits of Gale were deposited in the Hesperian, in particular the Peace Vallis Fan, including the distal Bright Fractured terrain, that includes Yellowknife Bay studied by Curiosity, date to 3.2–3.3 Ga. The thick succession of strata preserved within Mt. Sharp could represent an erosional remnant of a much more extensive crater fill (Cabrol et al., 1999; Malin and Edgett, 2000), or reflect its original shape resulting from atmospheric effects during mound growth (Kite et al., 2013). Much of the rest of the crater floor, including the

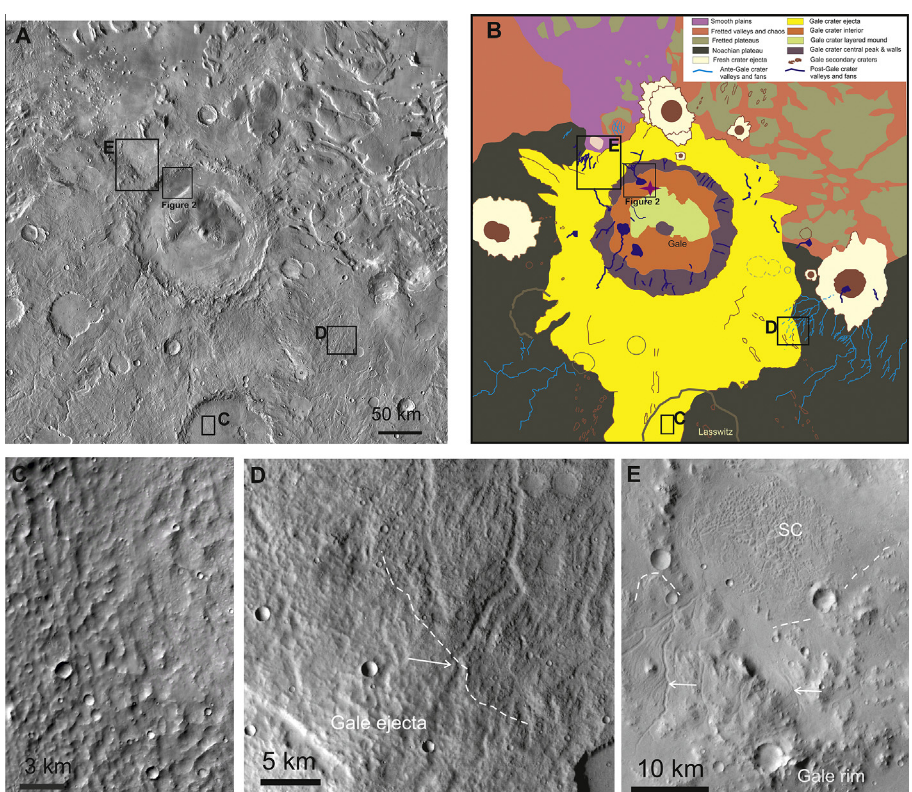

Fig. 1. (A) THEMIS mosaic of Gale crater and surroundings (http://www.mars.asu.edu/data/thm_dir/). (B) Geological sketch map of the same area. The star in the box labeled "Fig. 2" denotes the landing site of Curiosity. (C) Hummocky terrain typical of thick ejecta deposits. Portion of CTX image B21_017720_1703. (D) The dashed white line separates approximately hummocky material interpreted as ejecta to the left from non-buried highlands to the right. The white arrow points to a fluvial valley apparently buried beneath ejecta. Portion of HRSC image from orbit 5273. (E) Examples of fluvial valleys incising ejecta are indicated by white arrows. SC indicates small chaotic terrains on the floor of Gale. Portion of HRSC image, orbit 4191.