THE GALE IMPACT STRUCTURE, MARS: ORIGINAL SHAPE AND FORMATION AGE John G. Spray, Beverley E. Elliott and Lucy M. Thompson, Planetary and Space Science Centre, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada. Email: jgs@unb.ca

Introduction: The original form of the 154 km rim-diameter Gale impact structure, the landing site for the MSL mission's Curiosity rover, is reconstructed using theory and equations from explosion cratering data and energy considerations [e.g., 1-3]. The estimated original morphology is then juxtaposed with the present-day form of Gale with the goal of understanding how the crater shape has been obscured and/or modified since its formation. This may aid in distinguishing impact-generated features from subsequent modifications due to the various erosional and sedimentary processes that have influenced the crater since formation. We also review Gale's formation age in the context of crater size-frequency data for a 700 x 700 km evaluation area.

Original shape: On the assumption that at least part of Gale's rim crest has not been significantly reduced in height since formation, we use the 154 km diameter as the target size for the original crater (i.e., gravity-collapsed from a ~100 km-diameter transient crater). Given this approximation, Gale would have most probably been generated as a peak ring basin, with a peak ring diameter of ~77 km, a crater floor diameter of 100 km, and a terrace zone of ~27 km width (Fig. 1). The rim height would have been ~2 km and the depth from the rim crest to floor ~4.5 km. Peak ring height is difficult to assess, but would have been $\leq$3 km above the crater floor [4]. Figure 1 shows this profile with a x2.5 vertical exaggeration to emphasize the shape, and with no inference concerning fallback (ejecta) or impact melt sheet thicknesses (i.e., the section is purely morphological). Formation time would have been 60-80 seconds. The location of Gale, straddling the dichotomy, appears to have had an influence on the overall north-south slope of the structure, during formation (i.e., impact into a slope?) and/or subsequently (due to erosion); this is not considered in the simple cross-section presented here. Moreover, it is possible that Gale is a protobasin [4], such that it possesses a central peak as well as a peak ring. (In comparison to lunar basins, it is in the right diameter range, but this is difficult to test in the presence of the central mound.)

Present shape: HiRISE DEM data reveal the striking morphology of Gale with its distinctive central mound that rises more than 5 km above the crater annulus. Figure 1 superimposes the present-day form (using an approximate south to north section and also with x2.5 vertical exaggeration) with the proposed original impact structure shape. The average surface elevation beyond Gale is used as the datum to link both profiles. The superimposition indicates that the original crater has been buried and subsequently partly exhumed, with the highest (southern) rim crest undergoing limited erosion. If the original top of the mound represented a previous surface, then the entire crater was buried and hence protected from significant erosion (i.e., burial was probably rapid after impact). The current margins of the mound approximately coincide with the peak ring, and this may have acted as a confining wall to contain and protect the subsequent fill, which was otherwise more extensively eroded from the annulus. Interestingly, the implication is that peak ring material may be exposed, or at least lying near-surface, especially in the northern sector, where Curiosity may eventually traverse on its ascent up the central mound. If so, this would provide important insight into basement target lithologies and some of the oldest (>3.8 Ga) materials. The northern border of the crater may also intersect and expose part of the terrace zone. Otherwise, it appears that the crater fill is obscuring the original crater floor, including fallback and melt sheet.

Age constraints: Previous investigations have indicated a Noachian formation age for Gale (i.e., >3.7 Ga, depending on the boundary chronology used). Regional-scale crater-count appraisal of 500,000 km^2 of terrain centred on Gale indicates an age >3.74 Ga, but probably younger than 3.81 Ga [5]. On this basis we suggest a formation age of ~3.8 Ga, coinciding with the late Noachian and the end of the Late Heavy Bombardment. Crater counting of all material inside Gale, and extending east, yields an age of 3.77 Ga, with a common regional unit reworking/deposition event at 3.57 Ga. This would correlate with late Noachian deposition of the lower mound layers followed, in the Early to Late Hesperian transition, by reworking (erosion) and deposition of the upper mound layers, interior channel and onlapping valley network deposits [6]. The 3.77 Ga and subsequent 3.57 Ga periods of deposition thus correlate with earlier, wetter phyllosilicate-dominated conditions versus later sulfate-dominated conditions, respectively [7].

Discussion: A preliminary comparison between an estimated original morphology for Gale and its current shape suggests that: (1) Gale underwent complete burial soon after formation; probably such that the crater shape was essentially preserved (at least in the southern rim area); (2) subsequent erosion preferentially

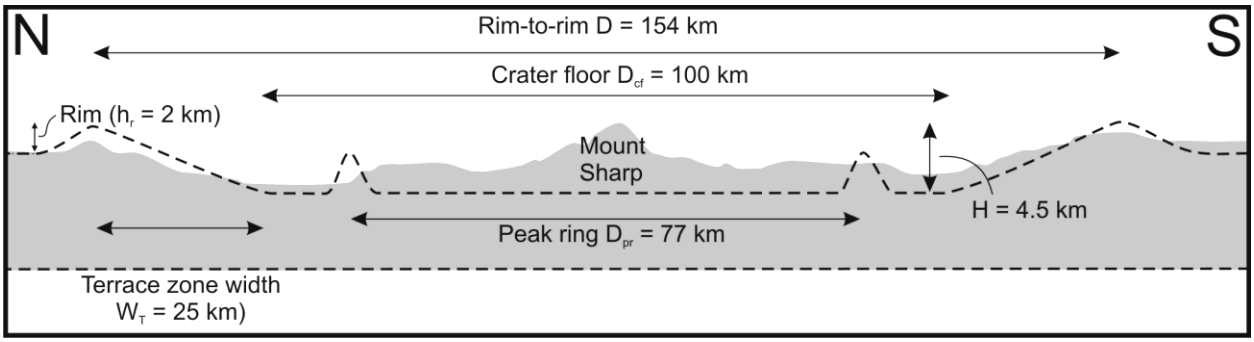

Figure 1. Reconstruction of the Gale impact structure as a peak ring basin (dashed line), with present day morphology superimposed. Vertical exaggeration is x2.5 for both profiles.

removed material from the annulus, probably due to the peak ring protecting the central fill. Deepest removal was in the northern annulus (where Curiosity landed), but this does not appear to have penetrated the original floor of the crater; (3) possible outcrops of original crater target material may be exposed in the northern terrace zone and in remnants of the peak ring around the margins of the central mound; (4) crater-count mapping suggests that the fill includes distinct groupings of ~3.77 Ga (i.e., late Noachian) and ~3.57 Ga (Hesperian) materials; (5) a formation age of ~3.8 Ga is suggested for Gale based on crater-count statistics.

References:

[1] Holsapple, K.A. and Schmidt, R.M. (1982) *J. Geophys. Res., 87,* 1849-1870. [2] Holsapple, K.A. (1987) *Intl. J. Impact Engr., 5,* 343-355. [3] Holsapple, K. A. (1993) *Ann. Rev. Earth. Planet. Sci., 21, 333-373.* [4] D. M. H. Baker et al. (2012) *J. Geophys. Res. (Planets),* 117, doi:10.1029/2011JE004021. [5] A. L. Bustard et al. (2012) *43rd Lunar Planet. Sci. Conf.* A2297.pdf [6] B. J. Thomson et al. (2011) *Icarus*, 214, 413-432. [7] J.-P. Bibring et al. (2006) *Science*, 312, 400-404.