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Centimeter to decimeter hollow concretions and voids in Gale Crater sediments, Mars

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ABSTRACT

Voids and hollow spheroids between ~1 and 23 cm in diameter occur at several locations along the traverse of the Curiosity rover in Gale crater, Mars. These hollow spherical features are significantly different from anything observed in previous landed missions. The voids appear in dark-toned, rough-textured outcrops, most notably at Point Lake (sols 302–305) and Twin Cairns Island (sol 343). Point Lake displays both voids and cemented spheroids in close proximity; other locations show one or the other form. The spheroids have 1–4 mm thick walls and appear relatively dark-toned in all cases, some with a reddish hue. Only one hollow spheroid (Winnipesaukee, sol 653) was analyzed for composition, appearing mafic (Fe-rich), in contrast to the relatively felsic host rock. The interior surface of the spheroid appears to have a similar composition to the exterior with the possible exceptions of being more hydrated and slightly depleted in Fe and K. Origins of the spheroids as Martian tektites or volcanic bombs appear unlikely due to their hollow and relatively fragile nature and the absence of in-place clearly igneous rocks. A more likely explanation to both the voids and the hollow spheroids is reaction of reduced iron with oxidizing

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groundwater followed by some re-precipitation as cemented rind concretions at a chemical reaction front. Although some terrestrial concretion analogs are produced from a precursor siderite or pyrite, diagenetic minerals could also be direct precipitates for other terrestrial concretions. The Gale sediments differ from terrestrial sandstones in their high initial iron content, perhaps facilitating a higher occurrence of such diagenetic reactions.

1. Introduction

The Mars Science Laboratory (MSL) rover, *Curiosity*, is the first to traverse across and explore substantial sedimentary deposits in a depression that was once a large, habitable lake (Grotzinger et al., 2015). The first nine kilometers of the traverse (Fig. 1) covered terrain characterized by conglomerates (e.g., Williams et al., 2013), sandstones (e.g., Anderson et al., 2015), and mudstones (e.g., Grotzinger et al., 2014; McLennan et al., 2014). Evidence from the morphology (Grotzinger et al., 2014) as well as the chemistry and mineralogy (e.g., Vaniman et al., 2014) point towards deposition of much of the material in either flowing water or in a significant body of standing water. Further, the rover team's observation of dipping beds interpreted as foresets occurring over a significant fraction of this traverse suggests that a large sediment load was deposited over an elevation of at least 200 m (Grotzinger et al., 2015). The amount of sediments suggests that the lake, or succession of lakes, was long-lived, likely existing a minimum of 10,000 to as much as 10 million years or more, as a large standing body of water (Grotzinger et al., 2015; Palucis et al., 2016).

Observation of the surface texture at Yellowknife Bay revealed areas covered with millimeter-scale nodules concentrated most strongly over and around the Cumberland drill site but also near the John Klein drill hole. A total of 1729 solid nodules and 513 hollow nodules were measured in 20 Mars Hand Lens Imager (MAHLI) images of the surface in this area (Stack et al., 2014). The nodules were suggested to have originated as concretions, possibly surrounding gas bubbles (Grotzinger et al., 2014; Kah et al., 2014). No compositional differences were detected by ChemCam in the nodules compared to the average Sheepbed unit composition, except when filled by calcium sulfate, which is interpreted as a late stage filling of a pre-existing cavity (Nachon et al., 2014).

In this work we study larger post-depositional features, specifically hollow spheroids up to ~23 cm in diameter, interpreted as concretions, and spheroidal voids in the ~1–10 cm range in nearby bedded material. Collectively these features may provide further clues to diagenetic processes in the Gale crater sediments.

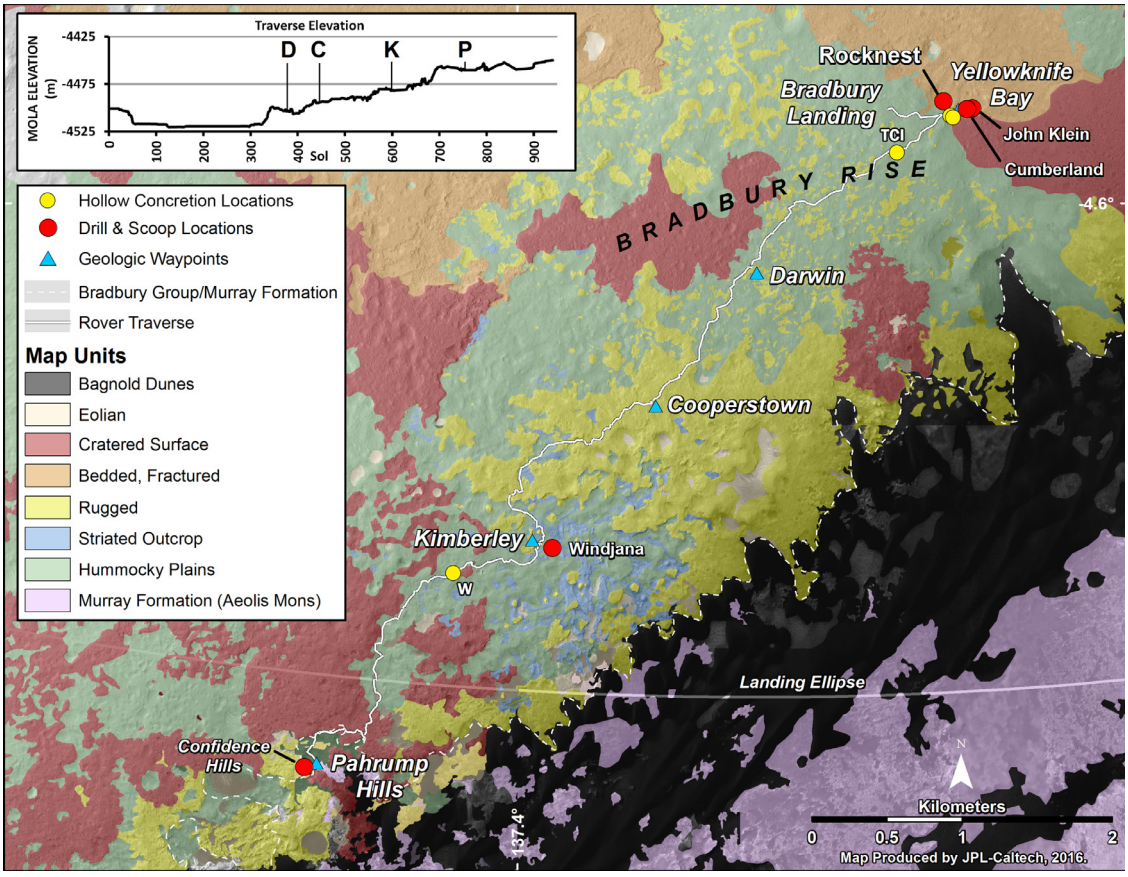

Fig. 1. Rover traverse map in Gale crater up to sol 800. An inset shows the elevations of the waypoints indicated on the map. Yellow circles indicate the locations of the features discussed in this work. Twin Cairns Island ("TCI") is just southwest of Yellowknife Bay on Bradbury Rise. The target Winnipesaukee ("W") is just west of the Kimberley outcrop, still well within the landing ellipse, and approximately 6 km from the Yellowknife Bay area. Tochatwi and Point Lake, indicated by unmarked yellow circles, are shown in greater detail in Fig. 2. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)