OVERVIEW OF GALE CRATER STRATIGRAPHY AND SEDIMENTOLOGY FROM 6 YEARS OF ROVING WITH MARS SCIENCE LABORATORY.

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Regional Context: Gale crater is a ~3.7 Ga complex 154-km diameter crater that sits on the dichotomy boundary between Mars' southern highlands and northern lowlands. Gale's northern floor is the lowest elevation feature for thousands of km in every direction. Gale's central peak is ~5 km tall and is surrounded by a crescent-shaped mound of layered sediments called Mount Sharp (formally Aeolis Mons), which is interpreted to be at least partially an erosional remnant of more extensive crater-filling deposits [1]. Since landing on the floor of Gale crater on August 6, 2012, the Mars Science Laboratory (MSL) rover *Curiosity* has traversed >20 km (10 km on Mount Sharp), gained >375 m in elevation (>315 m on Mount Sharp), and collected 19 drilled samples (16 on Mount Sharp).

Stratigraphy Overview: A composite "stratigraphic column" depicting the sedimentary facies encountered by *Curiosity* along its traverse from the crater floor up the first ~315 m of Mount Sharp is shown in Figure 1. Strata are divided by elevation because the layers are approximately flat-lying. The observed strata have been divided into 3 groups: the Bradbury group — exposed along the crater floor and interfingering with the Mount Sharp gp deposits— consists of fluvio-deltaic mudstones to conglomerates; the Murray fm, the lowermost exposed strata in the Mount Sharp gp, consists of laminated mudstones with occasional cross-stratified sandstones and has been divided into 7 members; and the unconformably overlying Stimson fm is in the Siccar Point gp, and is a much younger deposit of basaltic eolian sandstones.

Sedimentology and Geochemistry:

Bradbury gp. The Bradbury gp fluvio-deltaic deposits include a range of grain sizes deposited in river systems that transported sediment from the north rim of Gale crater south towards Mount Sharp. The provenance is dominated by high-Al basalts with at least one additional high alkali source [2]. Evidence for chemical weathering is negligible, indicating a cold climate and minimal water-rock interaction. Significant mineral sorting was observed, segregating plagioclase phenocrysts from finer basaltic minerals [3].

Murray fm (overview). The Murray fm is at least 315 m thick and dominated by lacustrine laminated mudstones with interbedded sandstones showing low-angle cross-stratification. Compositionally, the unit is uniform relative to the Bradbury sandstones, with an average composition reflecting minor weathering and a geochemically distinct source compared to average Mars crust; average Murray has slightly enriched K (likely from an alkali source), depleted Ca, Na, and Mg (interpreted as chemical weathering prior to sediment deposition), and enriched trace metals Ni and Zn relative to Mars crust. Distinctive features related to diagenetic fluids are observed throughout the Murray.

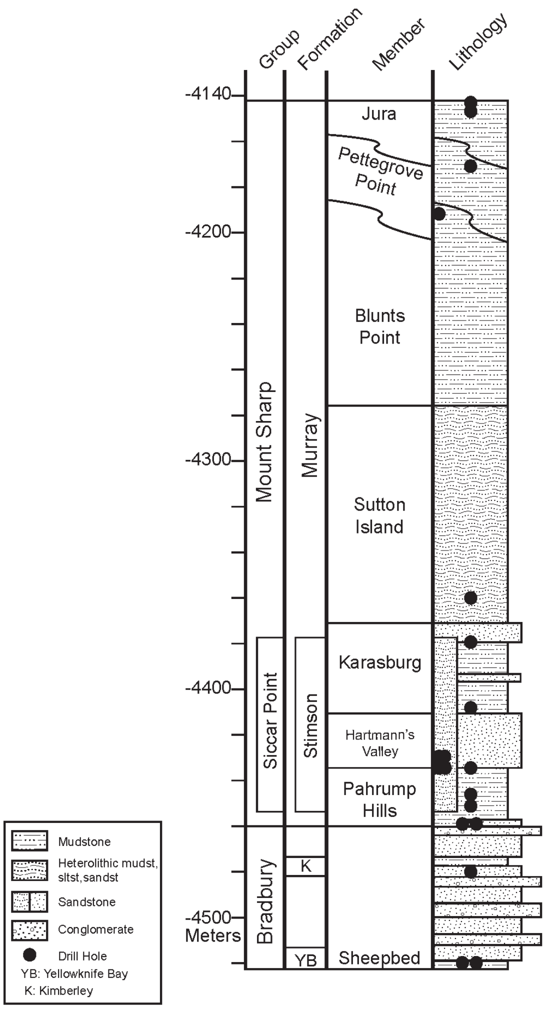

Figure 1. *Composite stratigraphic column showing facies observed by Curiosity by elevation and member divisions.*

Murray fm – Pahrump Hills mbr. The lowermost exposed ~25 m of Murray fm is dominated by thinly laminated mudstone interpreted by [4] to result from hyperpycnal river-generated plumes in a freshwater lake. Some exposures contain thicker-laminated mudstone, low-angle cross-stratified mudstone, or interbedded cross-stratified sandstone, which is consistent with deposition in a lake proximal to a prograding delta system [4]. Geochemically, this section of the Murray has unusually variable Al_2O_3 and significant upward-decreasing trends in redox elements Mn, Ni, and Zn. An ~10 m portion of very finely laminated mudstone in this section has extraordinarily high SiO2 (>70 wt%) including cristobalite, tridymite and amorphous opal-A [5]. Mineralogical transitions from hematite/phyllosilicate to magnetite/silica dominated assemblages in this portion of the Murray formation have been interpreted as either evidence for a redox-stratified lake [6] or due to element mobility from acidic fluids during diagenesis [7].

Murray fm – Hartmann's Valley mbr. The subsequent ~25 m of observed Murray fm is characterized by large-scale cross-stratified deposits interpreted to represent possible eolian or fluvial reworking of fine sediment, although the grain size is not distinguishable with available imagery despite 16 µm/px resolution. Geochemically, this section is homogeneous and parallels the average composition of the entire Murray fm.

Murray fm – Karasburg mbr. The Karasburg member, ~37 m thick, is dominated by mudstones with interbedded sandstones. This member is interpreted to have a depositional environment similar to the Pahrump Hills member; lake deposits with some interbedded lake-margin facies. Geochemically, this section is also homogeneous and similar to average Murray.

Murray fm – Sutton Island mbr. The Sutton Island member includes ~98 m of stratigraphy that is largely broken up into displaced meter-scale blocks, which make facies transitions difficult to discern. The overall facies is described as a "heterolithic mudstone-sandstone"; different blocks include finely laminated mudstone, cm-scale ripple cross-stratification, and dm-scale cross-stratification. Original sedimentary features are sometimes obscured by dense concretions and diagenetic fracture fills. Cm-scale desiccation cracks were observed in one fine mud layer above sandstone [8]. Abundant distinctive sub-horizontal fractures filled with mixtures of rock and 30-100 wt% calcium-sulfate are erosion-resistant and also frequently obscure primary depositional features (although sub-horizontal sulfate-filled fractures are discordant to primary bedding where observed). A sharp increase in Zn is observed at ~-4435 m. Geochemistry and mineralogy in this section indicate increased chemical weathering, interpreted to reflect a warmer environment [9,10].

Murray fm – Blunt's Point mbr. The Blunt's Point (BP) member is comprised of finely laminated mudstones representing low-energy suspension from fallout in a lacustrine environment. Cross-cutting erosion-resistant sulfate veins sometimes obscure primary laminae, but are discordant to primary features.

Murray fm – Pettegrove Point and Jura mbrs. Strata of the Pettegrove Point (PP) and Jura members form the Vera Rubin Ridge (VRR), an erosion-resistant ridgeline that is associated with a strong hematite detection in orbital spectroscopy data [11]. Like BP, both members are dominated by finely laminated mudstones representing low-energy suspension fallout in a lacustrine environment, although the Jura member shows some large-scale inclined beds. The boundary between the BP and PP members does not follow elevation contours, and Curiosity did not observe any clear evidence for a hiatus here [12], leading to the interpretation that the morphologic differences between BP and PP members are likely due to secondary diagenetic processes. Geochemically, the VRR is the most variable of any member of the Murray, likely related to diagenetic elemental remobilization. Broadly, despite the orbital hematite signature traditionally interpreted to reflect iron enrichment, the VRR trends to higher Si and Al, and lower Fe and Ti than the rest of the Murray.

Stimson fm. The Stimson formation unconformably overlies the Murray formation and is interpreted as a much younger deposit of basaltic eolian sandstones [13]. Mapping of the cross-stratification as observed in patchy plateau-forming and mesa-capping rocks indicates that the Stimson was deposited as an extensive dry dune field with dunes ~10 m high [14]. Lithification of the Stimson and later fracturing and diagenetic fracture zone alterations indicate that despite a much drier depositional environment, groundwater and, later, deep subsurface fluids, were present [15,16].

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