NOT HEADED DOWNHILL YET: CELEBRATING 10 YEARS OF CURIOSITY AT GALE CRATER. A. R. Vasavada[1], A. A. Fraeman[1], R. McCauley Rench[2], and the MSL Science Team, [1]Jet Propulsion Laboratory, California Institute of Technology, [2]NASA Headquarters.

Introduction: NASA's Mars Science Laboratory mission, with its Curiosity rover, has been exploring Gale crater since 2012 with the goal of assessing Mars' potential to support past or present life. The rover's field area, Aeolis Palus and Aeolis Mons (informally Mount Sharp), was chosen to allow exploration of an extended stratigraphic record of multiple ancient aqueous environments and environmental transitions inferred from orbital imaging and spectroscopy [1]. The mission's science team has studied nearly 700 vertical meters of stratigraphy over the rover's 30-km journey to date, acquiring and analyzing 42 samples of drilled or scooped surface materials in onboard laboratories, and observing thousands of additional targets with remote and contact science instruments. Curiosity has revealed that habitable surface environments likely persisted in Gale crater for millions of years and potentially longer in the subsurface. Concurrent investigation of the modern environment has advanced the understanding of sand transport, the space radiation environment at Mars' surface, meteorology, and atmospheric composition [2].

Geology and Habitability Overview: Exploration of Mount Sharp and the surrounding plain has revealed a succession of stream, delta, and lake depositional environments representing millions, perhaps tens of millions, of years [3]. Subsurface fluids interacted with the sediments over multiple episodes after deposition, overprinting the rocks texturally and compositionally. The plains and lower mound consist dominantly of clastic sedimentary rock composed of basaltic igneous minerals, secondary phases including hydrated phases, and X-ray amorphous materials [4]. Chemical and mineralogical compositions are consistent with surface and subsurface environments that remained within the ranges of temperature, pH, and salinity that could have supported life over much of the time that fluids were present [2]. A diversity of organic molecules was found (<300 ppb; detections up to C12, evidence of higher molecular weight species) in clay-bearing mudstones and sandstones, despite the rocks' age and radiation exposure [5, 6]. Igneous clasts and the mineralogy of some sediments argue for unexpectedly high magmatic diversity around Gale [7, 8].

Highlights of Extended Mission 3 (2019-2022): The primary focus was Glen Torridon [9], a broad trough that spans the area where smectite clay minerals had been inferred from orbital spectroscopy. Nine drilled samples allowed the team to characterize the chemistry and mineralogy. On three samples, the team conducted wet chemistry experiments designed to extract refractory organic molecules via derivatization or thermochemolysis [10]**.** The team also investigated the Greenheugh pediment, a sloping surface capped by rocks interpreted to be the remnants of an extensive dune field that formed after Mount Sharp was eroded to its present shape [11]. The latter half of EM3 focused on the stratigraphic interval between the orbital clay-bearing and Mg sulfate-bearing units, seeking to understand the changing environmental conditions that correlate with a higher diversity of depositional environments (e.g., increasing aeolian and fluvial facies relative to lacustrine) [12], and rover measurements of decreasing clay mineral abundance and enrichment in sulfates and other salts [this session].

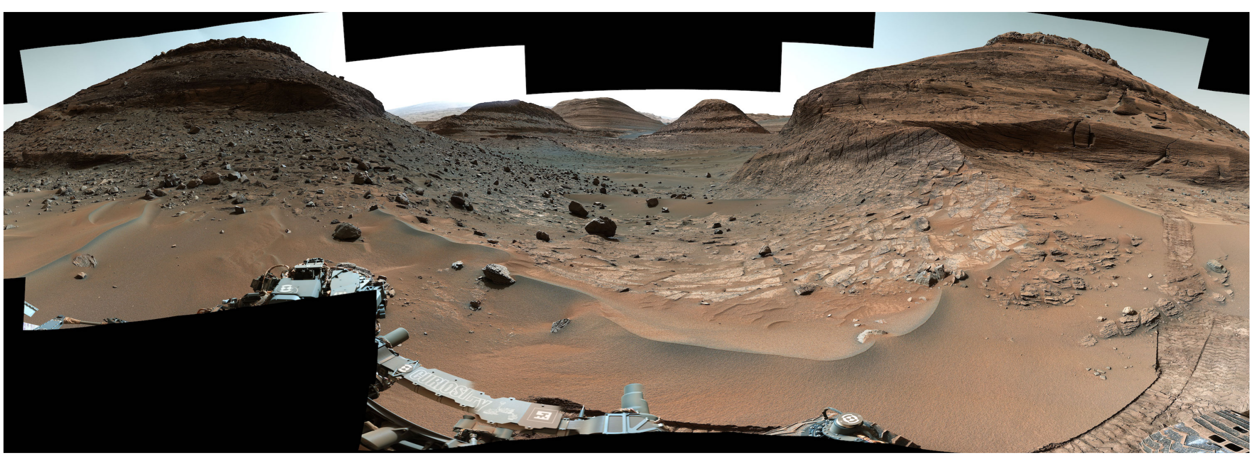

Figure 1. Panorama of Paraitepuy Pass with the buttes of the Mg sulfate-bearing unit in the distance. Mastcam mosaic ML02555 acquired on Sol 3563 (August 14, 2022). Credits: NASA/JPL-Caltech/MSSS.

The Modern Environment: Curiosity measures the space radiation environment at Mars' surface as part of NASA's Heliophysics System Observatory. These measurements have revealed how radiation from the sun and space are modulated by solar activity and have quantified the radiation risk to future crewed missions [13], including the shielding effect of natural topography. Measurements of atmospheric methane show a persistent but diurnally and seasonally variable abundance, indicating active production [14]. The mission's meteorological record is the longest of any landed mission, providing a new understanding of how regional topography influences pressure tides, winds, and aerosols. A recent discovery is the presence of high-altitude noctilucent clouds prior to the seasonal onset of the Aphelion Cloud Belt.

Rover and Payload Status: All rover systems and science instruments remain capable of addressing key mission objectives. The rover's radioisotope power system is degrading per expectation, with less energy available for science operations as time progresses. This reduction has been offset by more efficient planning and usage but is expected to decrease productivity in coming years, particularly in southern winters. The rover no longer has a fully redundant main computer, although the second computer remains available to support basic operation in the case of a major anomaly. Drill-based sampling continues cautiously after overcoming the loss of a key motor and the redundant brakes on two arm joints. Wear of the rover's wheels is not predicted to limit the length of the rover's remaining traverse, but it does preclude certain pathological terrain types. While some key instrument measurement capabilities have degraded over time, measuring wind speed and direction is the only full functional loss.

Plans in Extended Mission 4+: Curiosity is currently assessing the *persistence* of habitability by exploring two features of Mount Sharp hypothesized to be evidence of major environmental transitions. The first is the 400-m thick hydrated Mg sulfate-bearing unit (Fig. 1) that may be associated with a planetary-scale change from wetter to drier conditions [15]. Also within that unit is a set of landforms that may represent the most recent stage of water-driven activity in Gale (Fig. 2): a possible fluvial channel within the wind-carved Gediz Vallis, and a large ridge likely deposited by debris flows [16]. By ~2025, Curiosity will reach a field of decameter-sized, cemented fractures (boxwork structures) that might present the best opportunity to assess a record of a once-habitable environment preserved in the subsurface [17].

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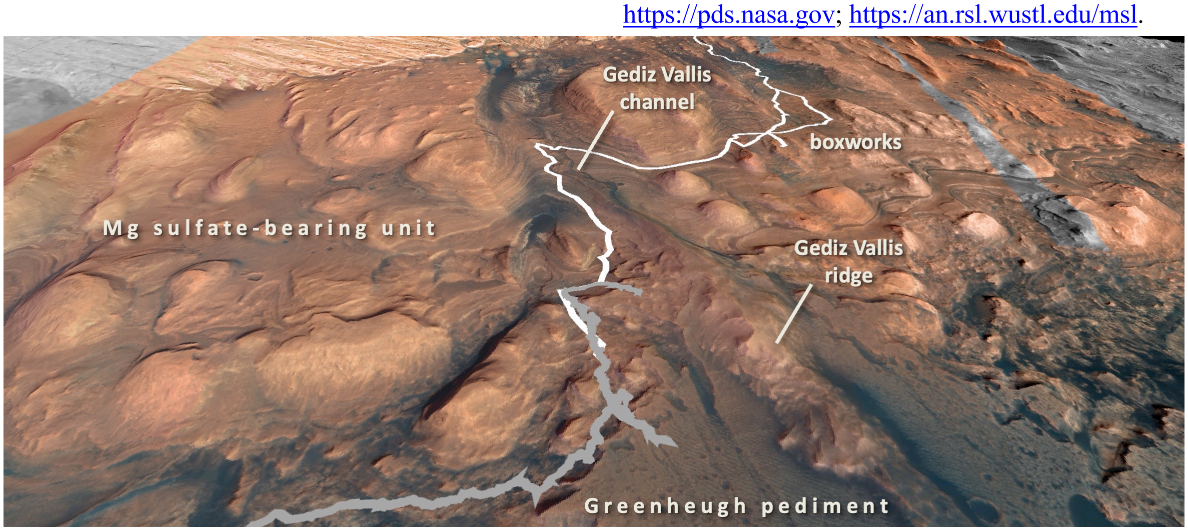

Figure 2. Perspective view of Curiosity's recent past (gray) and planned (white) traverse. Credits: NASA/JPL-Caltech/MSSS/UofA/USGS-Flagstaff.