New perspectives of ancient Mars: Mineral diversity and crystal chemistry at Gale crater, Mars from the CheMin X-ray diffractometer

E. B. Rampe*, T. F. Bristow, D. F. Blake, D. T. Vaniman, S. M. Morrison, D. W. Ming, R. V. Morris, C. N. Achilles, S. J. Chipera, R. T. Downs, R. M. Hazen, A. H. Treiman, A. S. Yen, V. M. Tu, N. Castle, J. P. Grotzinger, T. S. Peretyazhko, M. T. Thorpe, P. I. Craig, G. W. Downs

*elizabeth.b.rampe@nasa.gov, NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX.

The Mars Science Laboratory *Curiosity* rover arrived at Mars in August 2012 with a primary goal of characterizing the habitability of ancient and modern environments. *Curiosity* landed in Gale crater to study a sequence of ~3.5 Ga old sedimentary rocks that, based on orbital visible/near-infrared reflectance spectra, contain secondary minerals that suggest deposition and/or alteration in liquid water. The sedimentary sequence that comprises the lower slopes of Mount Sharp within Gale crater may preserve a dramatic shift on early Mars from a relatively warm and wet climate to a cold and dry climate based on a transition from smectite-bearing strata to sulfate-bearing strata. The rover is equipped with cameras and geochemical and mineralogical instruments to examine the sedimentology and identify compositional changes within the stratigraphy. These observations provide information about variations in depositional and diagenetic environments over time. The Chemistry and Mineralogy (CheMin) instrument is one of two internal laboratories on *Curiosity* and includes a transmission X-ray diffractometer (XRD) and X-ray fluorescence (XRF) spectrometer with a Co-Kα source. CheMin measures loose sediment samples scooped from the surface and drilled rock powders. The XRD provides quantitative mineralogy of scooped and drilled samples to a detection limit of ~1 wt.%. *Curiosity* has traversed >20 km since landing and has primarily been exploring the site of a predominantly ancient lake environment fed by groundwater and streams emanating from the crater rim. Results from CheMin demonstrate an incredible diversity in the mineralogy of fluvio-lacustrine rocks that signify variations in source rock composition, sediment transport mechanisms, and depositional and diagenetic fluid chemistry. Abundant trioctahedral smectite and magnetite at the base of the section may have formed from low-salinity pore waters with a circumneutral pH within lake sediments. A transition to dioctahedral smectite, hematite, and Ca-sulfate going up section suggests a change to more saline and oxidative aqueous conditions within the lake waters themselves and/or within diagenetic fluids. The primary minerals detected in fluvio-lacustrine samples by CheMin also suggest diversity in the igneous source regions for the sediments, where abundant pyroxene and plagioclase in most samples suggest a basaltic protolith, but sanidine and pyroxene in one sample may have been sourced from a potassic trachyte, and tridymite and sanidine in another sample may have been transported from a rhyolitic source. Crystal chemistry of major phases in each sample have been calculated from refined unit-cell parameters, providing further constraints on aqueous alteration processes and igneous protoliths for the sediments. Perhaps one of the biggest mysteries revealed by the CheMin instrument is the high abundance of X-ray amorphous materials (15 to 73 wt.%) in all samples measured to date. X-ray amorphous materials were detected by CheMin based on the observation of broad humps in XRD patterns. How these materials formed, their composition, and why they persist near the martian surface remain a topic of debate. The sedimentology and composition of the rocks analyzed by *Curiosity* demonstrate that habitable

environments persisted intermittently on the surface or in the subsurface of Gale crater for perhaps more than a billion years.