MAJOR-ELEMENT COMPOSITIONS SEEN BY CHEMCAM ALONG THE CURIOSITY ROVER TRAVERSE: THE FIRST 8,000 OBSERVATIONS

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Overview: The ChemCam instrument suite on the *Curiosity* rover uses laser-induced breakdown spectroscopy (LIBS) to obtain elemental compositions of target points at distances to 7 m [1,2]. Located on the rover's mast, it is designed for rapid analyses of targets in the vicinity of the rover, with an observational footprint of 350-550 µm. This footprint allows analysis of individual mineral grains in coarse-grained igneous clasts while giving whole-rock compositions for fine-grained mudstones. We will report on some 8,000 Mars chemical observations and ~7,000 high-resolution images which together provide a comprehensive view of the changing chemistry along the rover's 12 km traverse so far.

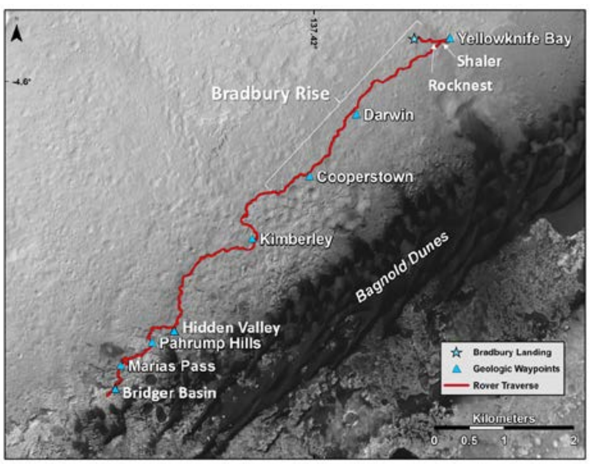

Fig. 1. HiRISE image of Gale crater region traversed by Curiosity. Areas mentioned in the text and in Figs. 2-4 are labeled. The Darwin and Cooperstown waypoints are part of the Bradbury Rise. (NASA/JPL/University of Arizona)

Data and Field Area: Fig. 1 shows the *Curiosity* rover traverse in Gale crater, with the different regions and areas labeled. Figs. 2-4 show abundances of Al, Si, Fe, Mg, Na, and K from different regions along the traverse. A re-calibration of the major-element compositions in 2015 [3] provides improved accuracies, particularly for compositions that are relatively different from the average Mars crust.

Bradbury Rise (Sols 0-53, 326-520): Curiosity landed on the distal end of an alluvial fan containing conglomerates and igneous clasts transported from the rim of the crater. The average composition of conglomerate clasts [4] is significantly enriched in Al_2O_3 and SiO_2 (Fig. 2) and alkalis (mean Na_2O+K_2O = 5.0 wt %) compared to the canonical Mars crustal composition [5] and to SNC meteorites, while soils in Gale still cluster near the average crustal composition (Fig. 2). Sautter et al. [6] suggest that a Southern Highlands dominated by this composition would fit crustal density data from orbiting spacecraft [7]. This putative Mars 'continental crust' enrichment in feldspars was largely missed by orbiting spacecraft due to the difficulty of identifying feldspars with infrared spectroscopy. Studies of individual feldspar grains observed by ChemCam are in progress [8]. Interestingly, the Noachian crust around Gale seems to be devoid of quartz [6].

Rocknest, Bathurst, Yellowknife Bay, and Shaler: Targets in Yellowknife Bay, dominated by the fine-grained fluvio-lacustrine Sheepbed mudstone [9, 10], are very homogeneous and close to the average Mars composition. The first Ca-sulfate veins (Fig. 2) were observed at Sheepbed (first drill location; sols 126-300) [11]. Mg-rich diagenetic ridges were also present in Sheepbed [20] (Fig. 3). Rocknest, an outcrop of rough-textured rocks encountered prior to arriving at Yellowknife Bay, are very rich in Fe (up to 35 wt. % FeO_T) but poor in Mg (Fig. 3) [12], while nearby Bathurst outcrop and associated float rocks showed the first enrichments of potassium [10]. The Shaler outcrop (sols 306-325) [13] represented the first foreset beds [14] observed on Mars. These fluvial sandstones with alternating recessive and resistant beds showed greater het-

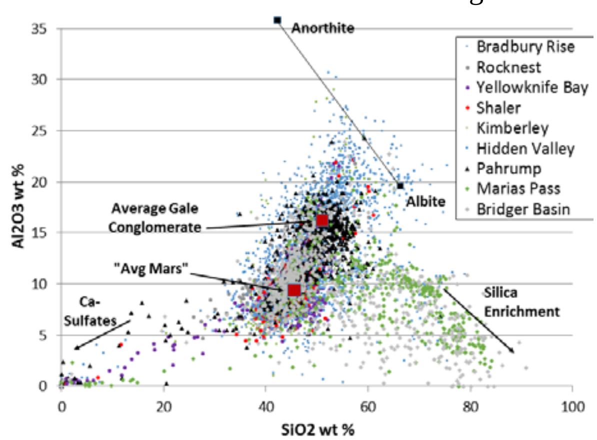

Fig. 2. Al_2O_3 vs SiO_2 for all ChemCam Mars targets. Soils, Yellowknife Bay, and some portions of Bridger Basin composition are relatively similar to the average Mars crust [5], while Bradbury Rise shows significant enrichment in Al due to abundant feldspars. Diagenetic effects are seen in targets from a number of regions.

erogeneity than any of the other nearby strata (Fig. 4).

Kimberley: *Curiosity* stopped in this region dominated by foreset beds for its second drilling campaign *(~ sol 612)*. As seen in Fig. 4, the Kimberley is characterized by uniquely elevated potassium abundances and high K/Na ratios [15], consistent with CheMin's observation of high levels of sanidine [16]. This is believed to be detrital, although the source region of this unique material is unknown.

Lower Portion of Mt. Sharp: The *Curiosity* rover encountered a transition from material dominated by sediments and clasts from the crater rim or channel catchment areas to a surface region associated with Mt. Sharp when it arrived at the Pahrump Hills (sols 753-919). This area is characterized by significantly higher aluminum in fine-grained materials (Fig. 2), suggesting more chemical alteration [17] than was seen in the previous regions. Upon arriving at Marias Pass, ChemCam detected a sharp rise in SiO_2 to > 80 wt % (starting sol 992) [18] (Fig. 2). The high Si values were observed associated with finely laminated targets in the Marias Pass area and also with diagenetic halos surrounding fractures in the Bridger Basin (Fig. 1). Tridymite, a high-temperature silica polymorph, likely of detrital origin, was observed by CheMin at the Buckskin drill hole, while significant amounts of opal were observed there and at another drill hole [19]. The silica enrichment process(es) are still being studied, but strongly suggests that, as the Stimson aeolian unit in Bridger Basin drapes over other units, its diagenesis indicates significant water activity much later in Mars history than expected [18].

Summary: Gale crater has turned out to be extremely diverse in the chemistry studied so far, with many different regions displaying unique chemistry representing different sedimentary inputs to the crater basin as well as diagenetic fingerprints. ChemCam has been able to clearly track each of these different chemical signatures. The traverse ahead includes features that are far more distinct from orbit than the preceding terrain, suggesting that chemical diversity will continue for the duration of the mission.

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References: [1] R.C. Wiens et al. (2012) Spa. Sci. Rev. 170, 167; [2] S. Maurice et al. (2012) Spa. Sci. Rev. 170, 95; [3] S.M. Clegg et al. (2016) in preparation; [4] N. Mangold et al. (2016) JGR, in revision; [5] S.R. Taylor & S.M. McLennan (2009) *Planetary Crusts*, Cambridge; [6] V. Sautter et al. (2015) Nat. Geosci. 8, 605; [7] V. Belleguic, et al. (2005) JGR 110, E11005; [8] P. Gasda et al. (2016) this meeting; [9] S.M. McLennan et al. (2014) Science 343; [10] N. Mangold et al. (2015) JGR 120, 452; [11] M. Nachon et al. (2014) JGR 119, 1991; [12] D.L. Blaney et al. (2014) JGR 119, 2109. [13] R.B. Anderson (2014) Icarus 249, 2; [14] J.P. Grotzinger et al. (2015) Science, 350; [15] L. LeDeit et al. (2016) this meeting; [16] A. Treiman et al. (2016) JGR, in revision; [17] J. Hurowitz et al. (2016) this meeting; [18] J. Frydenvang et al., H. Newsom et al., P. Gasda et al. (2016) this meeting; [19] R.V. Morris et al. (2016) this meeting. [20] R. Leveille et al. (2014) JGR 119, 2398.

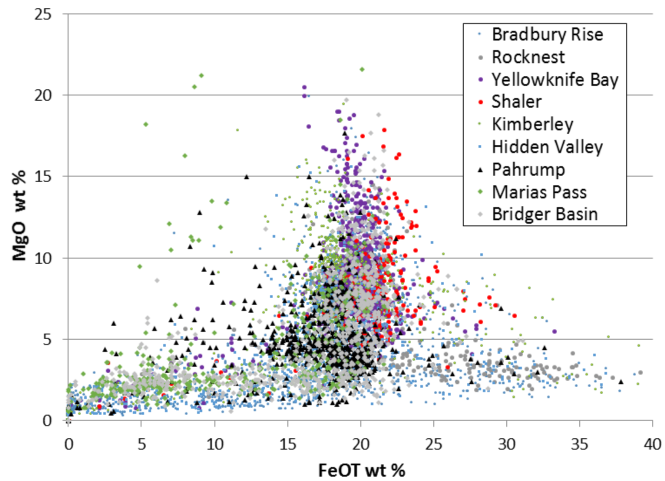

Fig. 3. FeO_T vs. MgO abundances. Yellowknife Bay shows some of the highest MgO due to enrichments along ridges that are likely diagenetic features [20]. Rocknest targets show the highest Fe values along with low Mg [12]. Some Pahrump targets enriched in Mg but low in Fe are diagenetic sulfate features.

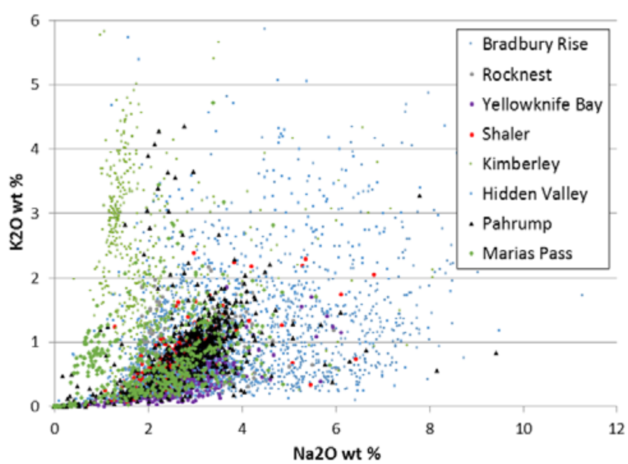

Fig. 4. Na_2O vs K_2O abundances. Bradbury Rise points spread to high alkali values reflecting significant feldspar inputs. Kimberley shows distinctively high K, while some Marias Pass points have the same K/Na ratio. Bridger Basin data (not shown) has some of the lowest K/Na ratios.