Rocknest, Bradbury Plateau, and Kimberly: Iron Cemented Sediments Observed in Gale Crater with ChemCam. D. L. Blaney[1], R.C Wiens[2], S. Maurice[3], S.M. Clegg[2], R.B. Anderson[4], L.C. Kah[5] , S. Le Mouélic[6], A. Ollila[7], N. Bridges[8], , G. Berger[3], J.C. Bridges[10], A. Cousin[2], B. Clark[11], M.D. Dyar[12], P.L. King[13], N. Lanza[2], N. Mangold[6], P.-Y. Meslin[3], H. Newsom[7], S. Schröder[3], S. Rowland[14], J. Johnson[8], L. Edgar[15], O. Forni[3], M. Schmidt[16] , W. Goetz[17], K. Stack[18], D. Sumner[19], M. Fisk[20], M.B. Maden[21], R. Tokar[9] and the MSL Science Team. [1]Diana.L.Blaney@jpl.nasa.gov, JPL/Caltech, 4800 Oak Grove Drive, MS 264-527, Pasadena, Caltech, [2]Los LANL[3] U. Paul Sabatier; UPS-OMP; IRAP; CNRS; IRAP;.[4]USGS, Flagstaff,[5]U. Tennessee, [6]U. Nantes, [7]U. New Mexico,[8]APL Johns Hopkins U., [9]PSI, [10]U. of Leicester,[12]Mount Holyoke College,[13]Australia National U., [14]U. of Hawaii,[15]U. Arizona, [16]Brock U.,[17]Max-Planck-Institut für Sonnensystemforschung,[18]Caltech,[1] U. C. Davis,.[20]Oregon State U.,[21]U. Copenhagen.

Introduction: The Curiosity Rover has been exploring the sedimentary deposits in the informally named region of the Bradbury Rise, Gale crater, since August 2012. Previous locations with iron-rich rocks (Link and Rocknest) have been identified via ChemCam and APXS data sets [1,2,3,4]. Williams et al. [1] found that a ChemCam observation in the Link conglomerate had a surface-correlated elevated Fe abundance, potentially resulting from Fe-rich cement. APXS data found elevated iron in the rock Et Then (located at the Rocknest sand shadow) and suggested the presence of an iron coating or cement [2,3].

We used the ChemCam data set to investigate the prevalence of iron-rich cements in the Bradbury rise region and explore the implications for their abundance and distribution. While direct evidence for potential iron-oxide cemented sediments on the bulk of Bradbury rise is rare, recent observation (sol 576-581) at the Square Top portion of the Kimberly outcrop show similar trends in iron to Rocknest, indicating that these outcrops too may have iron cements present.

Data: ChemCam is a Laser Induced Breakdown Spectrometer (LIBS) with an integrated Remote Microscopic Imager (RMI) to provide context of where each LIBS spectra is collected. ChemCam LIBS works by firing a laser focused to a 350-550 μm diameter spot that produces plasma from the rock. Spectra of elemental emission lines are recorded from 240-850 nm and used to determine the elemental composition of the rock [5,6, for more details on ChemCam and data analysis]. Chemical compositions were generated from individual spectra using the ChemCam team standard Partial Least Squares-1 analysis to produce an elemental oxide abundance for SiO_2 Fe_2O_3, CaO, MgO, Al_2O_3, TiO_2, Na_2O, and K_2O [e.g. 7,8, 9].

Rocknest Review: The Rocknest site consists of a local topographic high that marks the northern edge of a broad, aeolian sand shadow which was the first sampling site for Curiosity. The rocks at Rocknest, which is part of the Glenelg facies, are situated stratigraphically below the Bathurst Inlet outcrop and above the other facies (Gillespie Lake and Sheepbed) exposed within Yellowknife Bay [10].

Detailed examination of RMI images suggest that Rocknest samples consist of fine-grained sedimentary rocks. Rock surface textures range from rough to smooth, can be pitted or grooved, and show various degrees of wind erosion. Some rocks display poorly defined layering while others seem to show possible vertical flow features. Narrow vertical voids are present in Rocknest-3, one of the rocks showing the strongest layering (Figure 1) indicating a sedimentary origin. Possible diagenetic features in these rocks include the distinctive pitting, tapered cracks in the laminated rocks, and the fractures in the massive rocks. Sulfates [4] and CaF phases are also present in the rocks [4,11].

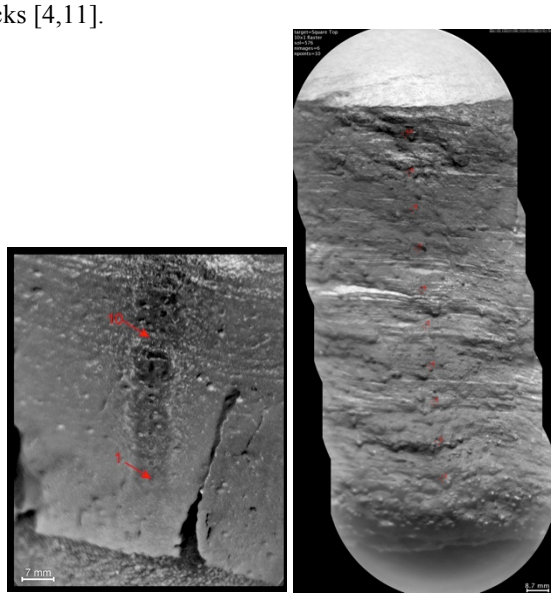

Figure 1. Post-LIBS RMI images of Rocknest 3 (left, Seqid: ccam01082) showing laminations, vertical voids, pits indicative of sedimentary origin and of diagenesis; and of Square Top (right, SeqID ccam01576) with laminations supporting sedimentary origin and nodules.

In spite of the textural variation in the rocks, chemically the rocks are similar. In general the ChemCam data show that the rocks are basaltic in composition with high and variable iron compared to most Martian basalts. Analysis of the major elements indicates that detrital source material was a mixture of felsic and basaltic rock. Sulfur and soluble calcium phases are also present. Rocknest rocks, however, are depleted in magnesium compared to surrounding rocks and soils, suggesting that if the sediments were made from locally derived igneous material, magnesium loss must have occurred—potentially during digenesis [4].

While iron is elevated in Rocknest (averaging around 20 wt% FeOT with values as high as 26 wt%), iron is not well correlated with other elements such as Ti, MgO. Comparison with SiO_2 shows the highest abundances of FeO_T correlating with moderate SiO_2 abundances. We interpret these geochemical trends to indicate that the excess iron is present as non-silicate cement.

Bradbury Rise: In general the rocks on Bradbury Rise are dominated by felsic conglomerates [12]. Iron content is generally low. However additional observations have been identified that show clear evidence for excess iron, likely as cement. Watterson (ccam01329) a float rock with iron ranging 21-25 wt% (with low MgO) and the conglomerate Gowganda (ccam01370) with a high (24 wt%) FeO content.

Square Top Outcrop (Kimberly): Upon reaching the first location in the investigation of the Kimberly region (Square Top, outcrop), ChemCam again encountered high and variable iron content. Iron content of the outcrop averaged 20 wt%, ranging to > 25 wt%. At the Square Top outcrop the Mg is anti-correlated with iron (Figure 2). At Square Top as at Rocknest other major elements such as silica, titanium, and potassium showed no correlation with iron content. This supports that the iron is present as an iron cement and not as mafic minerals.

Unlike Rocknest, the magnesium values were not depleted at Square Top, resulting in a compositions almost identical to Bathurst. APXS classification includes Square Top in the Bathhurts Inlet rock class [13,14].

Texturally, the rocks are fine grained and exhibit lamination supporting a sedimentary origin. However, unlike Rocknest, the rocks do not have the distinctive pitting—instead nodules are present at some locations. A hypothesis for this difference is that the rocks formed in a similar manner, but had different diagenetic histories. At Rocknest, void formation was interpreted as due to diagenesis and Mg loss [4]. The abundance of Mg and the lack of voids may indicate that this process did not occur at Square Top.

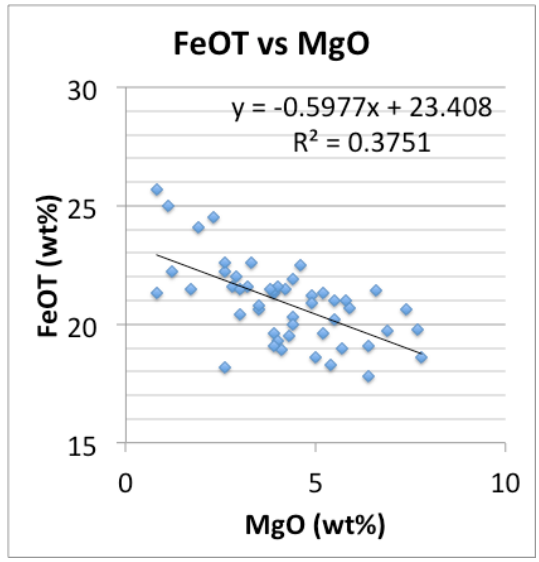

Figure 2. Iron and Magnesium trends for the observations at the Square Top Outcrop, Kimberly. (Seqids: ccam01576, ccam03578,ccam04578, ccam01581, ccam02581, and ccam04581)

Conclusion: The identification of multiple locations where iron-rich cements are likely present indicates that iron-rich waters may have been regionally important in the geochemical cycle at Gale crater. Iron rich waters may have been involved in the formation of the conglomerates as well as outcrops such as Rocknest and Square Top, Kimberly. Rocks additionally seem to have a rather complex history after formation at Gale. Variations in the diagnetic processes involving magnesium, and other soluble minerals such as sulfates and calcium floride are observed.

References: [1] Williams et al. 2013, Science 340, 1068-1072. [2] Schmidt et al. 2013, in press JGR-Planets. [3] McLennan et al. 2013, *Science*, doi:10.1126/science.1244734. [4] Blaney et al. 2013, submitted JGR-Planets [5]Wiens et al. 2013 . Spa. Sci. Rev. 170, 167-227. [6]Maurice et al. *Space Science Reviews*, 170:95-166, doi:10.1007/s11214-012-9912-2. [7] Wiens 2013 Spectrochimica Acta Part B: Atomic Spectroscopy 82, 1-27. [8] Clegg et al., 2009 Spectrochim. Acta Part B 64, 79–88. [9] Anderson 2012 Spa. Sci. Rev. 170, 57-75. [10] Grotzinger 2013, *Science*, doi:10.1126/science.1242777. [11] Forni et al, 2014, this volume, [12] Mangold et al 2014, this volume. [13] Gellert et al. 2014 this volume. [14] Thompson et al. 2014 this volume,

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