FELDSPAR BEARING IGNEOUS ROCKS AT GALE : A CHEMCAM CAMPAIGN (Sol 326-512). *V. Sautter*[1] [violaine.sautter@mnhn.fr], *M. Toplis*[2], *C. Fabre*[3], *F. Thuillier*[1], *A. Cousin*[4] ,*O. Forni*[2], *O.Gasnault*[2], *A. Ollila*[5], *W. Rapin*[2], *M. Fisk*[6], *J.G. Blank*[7] , *P.-Y. Meslin*[2], *N. Mangold*[8], *R. Wiens*[4], *S. Maurice*[2], *N. Bridges*[9], *H. Newson*[5], *N. Lanza*[4], *and ChemCam Team* [1]MNHN-UMR7590, Paris, France, [2]IRAP, Toulouse, France, [3]G2E, Nancy, France, [4]LANL, Los Alamos, USA, [5]UNM, Albuquerque, USA, [6]OSU Corvalis USA, [7]BMSIS/NASA ARC, Moffett Field USA, [8]LPGN, Nantes, France, [9]JHU Baltimore USA

Introduction: Mafic (Mara, Coronation, Jake-Matijevic) and light-toned igneous rocks (Stark and Thor Lake) were initially observed by the Curiosity rover close to the Bradbury landing site from sol 1 to 55 in the Humocky plain unit [1,2]. Since leaving the fluvio lacustrine deposit of Yellow Knife Bay (sol 326), the rover is back to hummocky unit and an increasing number of light-toned rocks dominated by feldspars have been observed along the traverse from sol 326 to sol 511. Textural and chemical analyses using ChemCam Remote Micro Imager (RMI) and Laser Induced Breakdown Spectroscopy (LIBS) with a ~300-500 μm laser spot allow the recognition of a total of 23 igneous targets (out of 122 locations totaling 680 series of laser shots) ranging from mafic targets where feldspars form at least 50% of the rock to felsic samples where feldspar is the dominant mineral.

Methodology: ChemCam offers the first opportunity to assess mineralogical diversity at grain-size scales and, from this, lithological diversity. Key element ratios (Al/Si, (Fe+Mg)/Si) and oxide concentrations are quantified from the spectral characteristics of the target using univariate analysis which uses the peak height of well-chosen LIBS lines and calibration curves derived from on-board ChemCam calibration targets (CCCTs including 3 basaltic glasses and 1 felsic macusanite glass and 4 ceramics [3,4] .

Rock morphology and texture: Rocks are mainly floats but some light toned material are partly buried. Floats are faceted due to wind erosion. Some targets form clasts in conglomerate (Fig.1a). Rocks grade in color from dark grey to light-toned felsic rock. From morphology, color, grain size, and patina, 5 different groups of supposed igneous rocks have been identified (Fig.1) : (1) porphyritic type with light-toned, bladed and polygonal crystals 1-50mm in length set in a dark gray mesostasis (*Harrison type*, 11 targets, Fig. 1a,b); (2) coarse-grained type with visible (mm size) dark and light toned grains (*La Reine type*, 5 targets, Fig.1c); (3) coarse grained light-toned often chunky strongly weathered rocks (*Bird river type*, Fig.1e, f); (4) light-toned granular rocks (*Clinton type*, 6 targets, Fig.1d,g); (5) light-toned rocks with no visible grains sometimes vesiculated or forming flat targets (*Becraft type*, 4 targets, Fig.1h). Porphyritic targets of type 1 including some altered rocks of type 3 have textures indicative of extrusive lavas, whilst type 2 and type 4 exhibit granoblastic texture corresponding to intrusive rocks. Vesiculated rocks of type 5 could be either pumice or melted rocks resulting from impact.

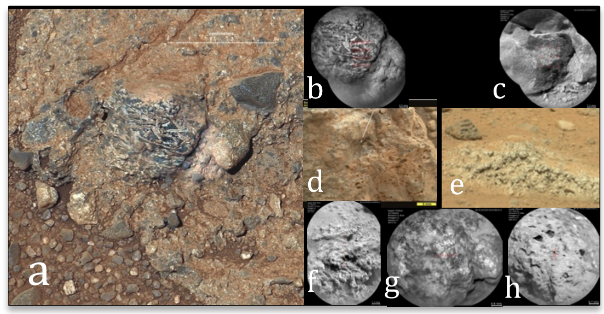

Figure 1 : MastCam, MAHLI and RMI images depicting different rock textures: a) porphyritic clast Harrison in conglomerate (MastCam); b) porphyritic Harrison (RMI);c) coarse-grained La Reine (RMI); d) coarse-grained, intrusive Clinton (MAHLI) ; e) chunky, weathered Little Wind River (MAHLI); f) chunky weathered Bird River (RMI); g) coarse intrusive Clinton (RMI); h) vesiculated Becraft (RMI).

Chemical composition and mineral inference: Quantification of the 23 anhydrous targets have been plotted in Al/Si vs. (Fe+Mg) / Si (mole %) diagrams (Fig 2 and 3) where felsic minerals (quartz, plagioclase solid-solution, nepheline) plot on the Y-axis whilst mafic ones (HCP, LCP, olivine, oxides) plot on the X-axis. Porphyritic type and coarse grained type (Robin Hood, Horlick, green symbols in Fig. 2) plot on the same mixing line between oligoclase (Al/Si 0.38-0.44; An 10-28) and mafic composition. The porphyritic type has mafic points gathered on the central part of the line indicative of very fine grained (with respect to LIBS beam size) or glassy mesostasis with basaltic composition. On the countrary, coarse grained rocks (La Reine, Ashuamipi, Black Trout, Beacon) have a mafic component consistent with augite mineral phase.

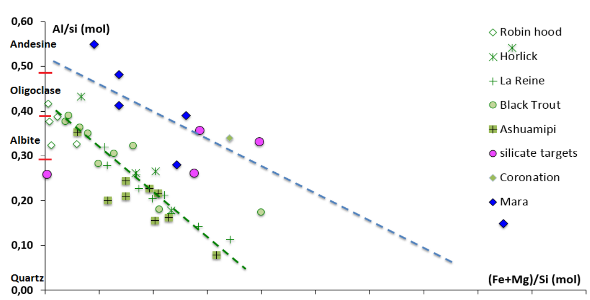

Figure 2: Porphyritic (type1) and coarse grained (type 2) rocks plotted in Al/Si vs. Fe + Mg/Si (mole%) diagram. Blue

symbols represent Bradbury targets whilst green one correspond to post sol 326 targets. Purple symbols represent the calibration targets CCCTs.

Felsic rocks (Fig.3) plot on (or close to) the Y-axis. Light-toned rocks such as Clinton (type 4: red symbols) plot on a mixing line between oligoclase-albite (Al/Si: 0.48-0.33 ; An30-0) and a silica-rich component. Chunky weathered rocks (yellow symboles) are not aligned but show some scaterring that may be due to alteration. Vesiculated light-toned rock such such as Becraft (type 5: mustard symbols) have compositions close to the macusanite CCCT, a rhyolitc glass (Al/Si < 0.33), indicative of silica satured rocks mixed with an alkali-feldspar component.

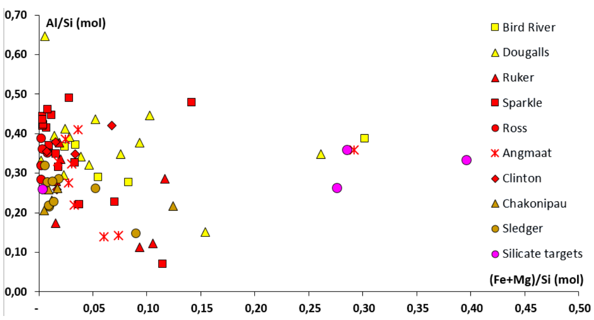

Figure 3 : Chunky weathered (type 3 in yellow), light-toned granular (type 4 in red), light-toned with no visible grain (type 5 in mustard) plotted in the same diagram as figure 2

Barium in type 5 spectra reaches concentrations of more than 1000 ppm whilst the other targets contain less than 700 ppm. Major and trace elements (Ba and Rb) clearly point to the existence of K-rich feldspars in light toned samples although no grains are visible.

Tentative whole rock compositions have been calculation where possible (e.g. raster of 16 points for coarse grained rocks or averaging different points in a given target when they show similar composition). These calculations show two trends; a quartz-normative trend including rocks from type 4 and 5 which are close to diorite, quartz diorite, and a nepheline-normative trend (type 1, 2, and 3) that plot in the basaltic trachy-andesite and trachy andesite (type 1) and monzonitic (type 2) fields of the TAS diagram.

Discussion: The trachy-basalts showing porphyritic texture as well as the monzonitic coarse-grained rocks plot along the oligoclase-HCP mixing line which differs from Bradbury rocks (Coronation, Mara) which plot along andesine-LCP trend. Interstingly the monzonitic clast from the Noachian breccia NWA7533 [5] plots on the same mixing line as type 1 and 2. Some rocks of types 1 and 2 form clasts in polymict conglomerates (Fig.1a). Therefore monzonitic as well as trachytic fragments could originate from Gale crater rim.

Felsic targets of type 5 have the same composition as Stark. Comprised of major elements Si, Al, Na and K and high in Ba [6] they are the first felsic alkali-rich volcanic rocks analyzed *in-situ* so far on Mars. From their vesiculated texture they could be ejecta although possible connection with the Medusae Fossae Formation should be tested. Finally, types 3 and 4 could be related, the former being an altered form of the later.

Conclusion: The abundance of feldspar-rich compositions is one of the most striking magmatic features encountered so far at Gale crater. In addition, coarse-grained soils that characterized the hummocky plains are also dominated by felsic-rich mineralogy [7] contrasting with fine-grained soils in the Rocknest area, similar to the average mafic soil component on Mars [8]. Major and trace element chemistry (i.e., Ba and Rb [6]) clearly points to the existence of feldspars with a significant K-rich orthoclase component as a principal mineral in magmatic rocks studied by ChemCam in the hummocky plain. Such feldspars have been recently described for the first time in two SNC meteorites, the Noachian breccias NWA 7034 and 7533 [5,9]. Finally, felsic rocks with quartz normative compositions have been analyzed for the first time in the post-Shaler unit. This result provides further evidence to support a high degree of differentiation of primary mantle-derived magma sufficient to achieve saturation in alkali feldspar. Overall, the *in situ* ChemCam data from Gale provide unprecedented insights into the diversity of igneous rocks at the surface of Mars. From these initial MSL data it appears likely that alkali feldspar-bearing rocks are present as ejecta and alluvial fan detritus in the Gale landing site, potentially representative of material from the region surrounding Gale [1]. The extent of the source region of these rocks will have to be determined from orbit. Possible connection with Medusae Fossae Formation materials remains to be tested [10] as does the possibility that large regions of feldspar dominated lithology occur in the rim [11] and the floor [12] of large craters from the southern highlands.

References:[1] Sautter et al 2014 *JGR-Planets doi :10.1002/2013JE004472,* [2] Stolper et al. 2013, *Science 341, doi :10 :1126/science.1238670,* [3], Fabre et al. 2014, *SAB*, in press, [4] Fabre et al. 2011, *SAB*,,66, 280-289, [5] Humayun et al. 2013 *Nature,*doi :10.1038/nature, [6] Ollila et al. *JGR-Planets* (2013) doi :, [7] Meslin P.-Y.. et al. (2013) *Science,341,doi,1238670*, [8] Mc Sween et al. 2009, [9] Agee et al. 2013, *Science* 339,780-78512764 [10]. Harrison et al. 2010 [11] Carter & Poulet 2013, *Nature Geoscience* 6,1008-1012, [12]. Wray et al. 2013, *Nature Geoscience, 6, 1013-1018*.