Lunar and Planetary Science Conference, March 16th, 2014

COMMUNITY USER WORKSHOP ON PLANETARY LIBS (CHEMCAM) DATA

Past and Current ChemCam Results

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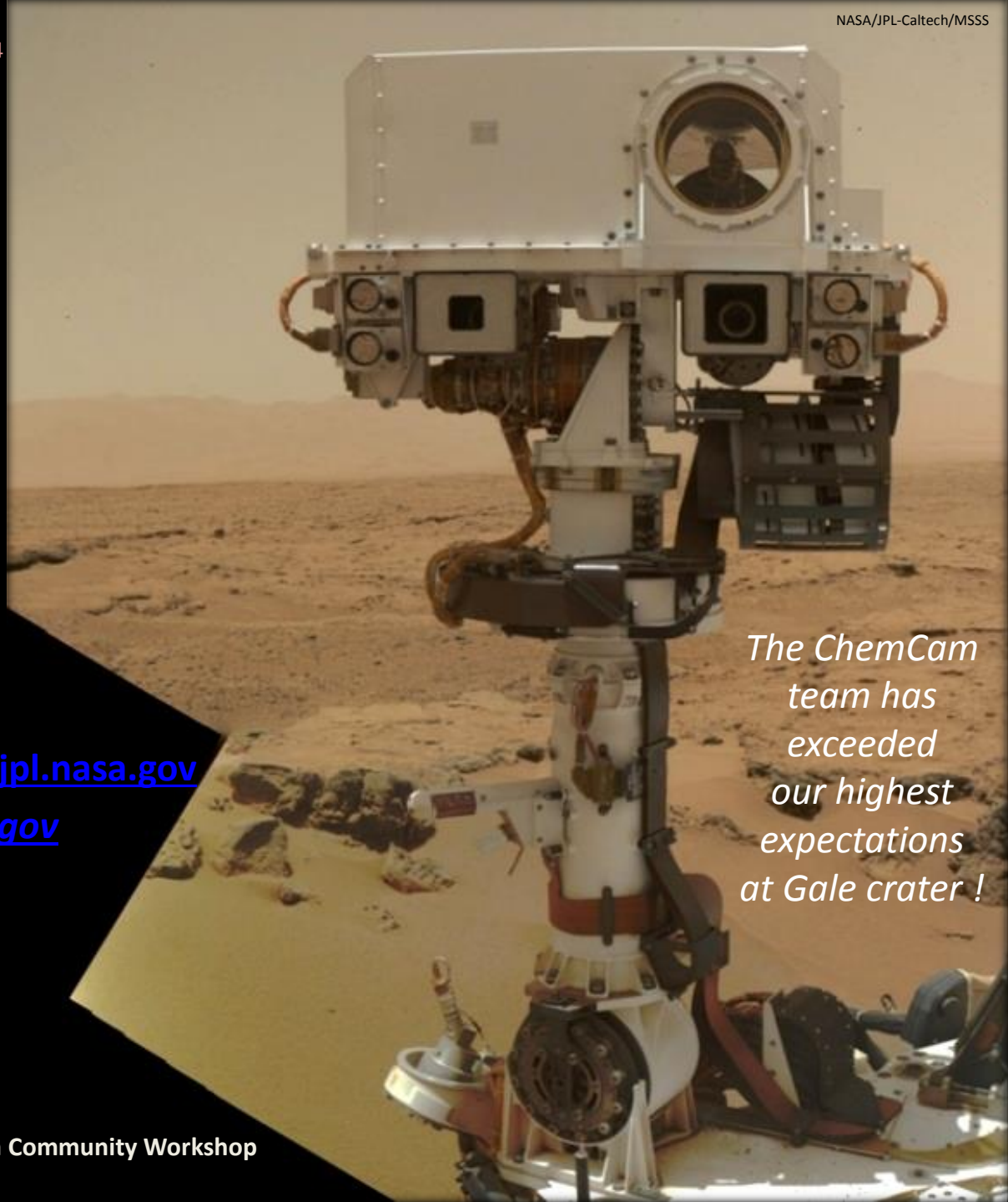
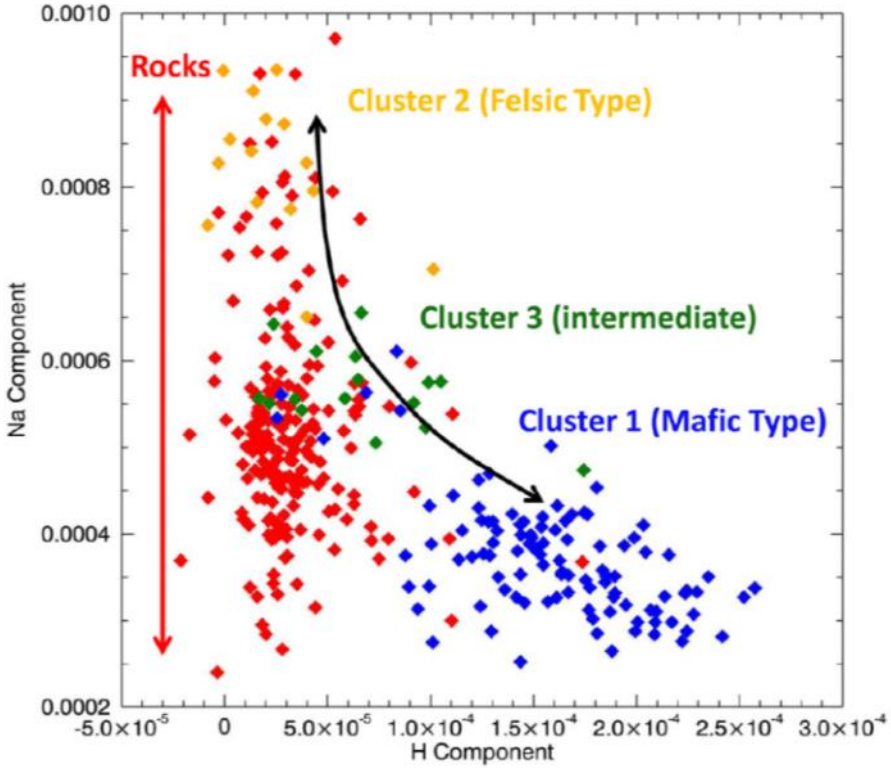
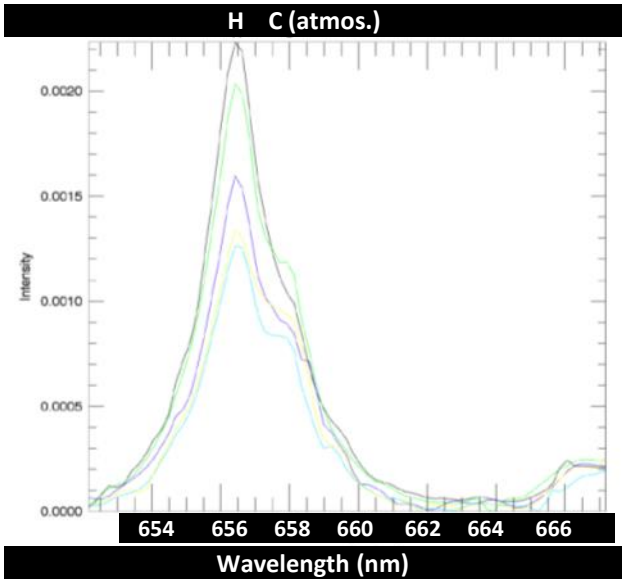
and the entire ChemCam Team



Hydrated soil and dust

With the very first laser shot on Mars we discovered that the soil and even the wind-blown dust is hydrated. The SAM instrument quantified the amounts, but ChemCam has shown the ubiquity of water in the soils and has helped constrain the mineral component in the soil containing the water.



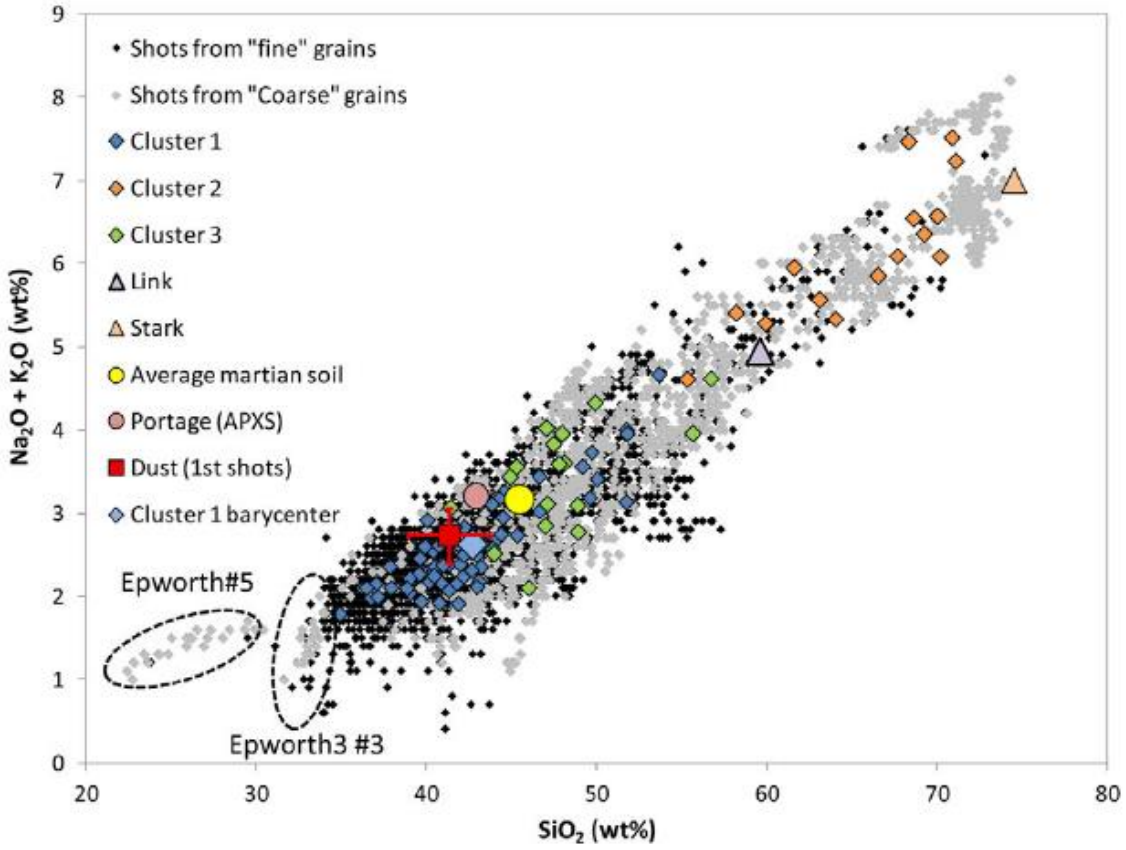


- Schroeder S.et al. (2014) First analysis of the hydrogen signal in ChemCam LIBS spectra. Icarus, submitted.

- Meslin P.-Y. et al. (2013) Soil diversity and hydration as observed by ChemCam at Gale crater, Mars. Science 341, DOI: 10.1126/science.1238670.

Multiple components in soils

ChemCam provides the first microbeam analysis of soils, showing for the first time that all soils we have analyzed so far consist of multiple components including contributions from the local rock types. We can correlate these components with characteristic grain sizes.



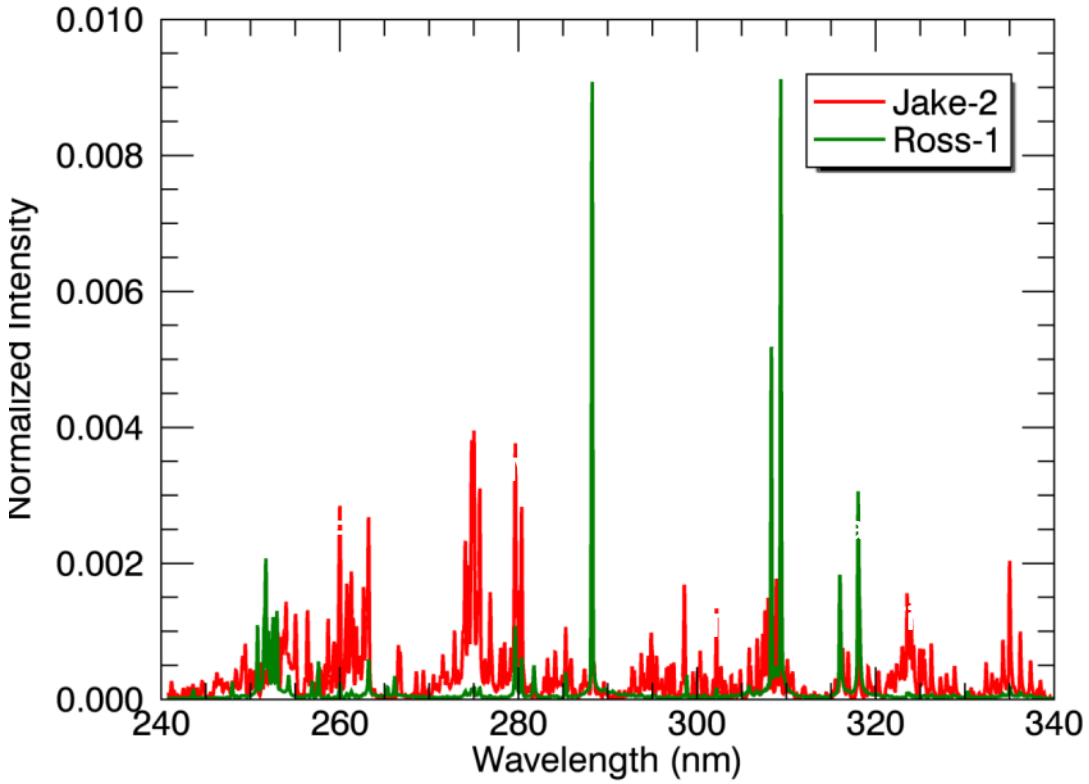
- Meslin P.-Y. et al. (2013) Soil diversity and hydration as observed by ChemCam at Gale crater, Mars. Science 341, DOI: 10.1126/science.1238670.
- Cousin A. et al. (2013) Compositions of sub-millimeter-size clasts and fine particles in the Martian soils at Gale: A window in tot the production of soils. Icarus, in press.

Felsic rock and pebble compositions

- Meslin P.-Y. et al. (2013) Soil diversity and hydration as observed by ChemCam at Gale crater, Mars. Science 341, DOI: 10.1126/science.1238670.
- Williams R. et al. (2013) Martian fluvial conglomerates at Gale Crater. Science 340, 1068-1072, DOI: 10.1126/science.1237317.
- Sautter V.et al. (2013) Igneous mineralogy at Bradbury rise: The first ChemCam campaign. J. Geophys. Res., accepted.

In the very first week ChemCam yielded the first high-silicon rock compositions. These compositions have been found not only in float rocks, but in the pebbles comprising the first conglomerates, and in the coarse soil grains. These were reported in the first Science papers and have been discussed in several papers since. The implication is that the igneous volcanism of Mars is much more varied, including much more evolved magmas, than previously thought.

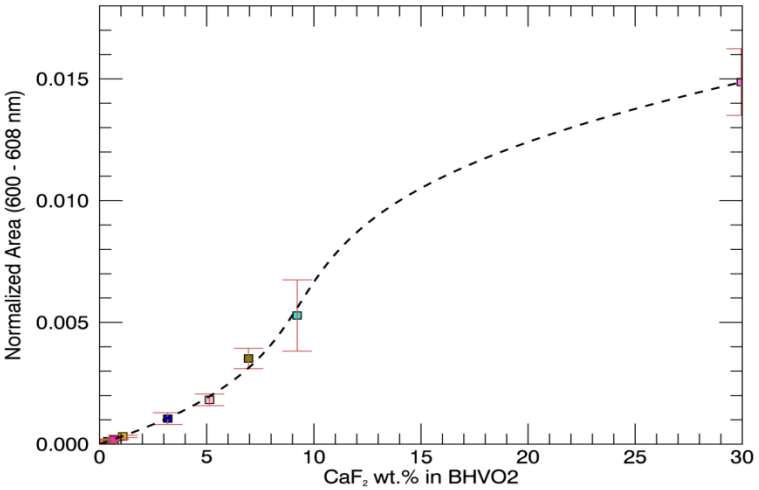
Ross-1 = felsic composition



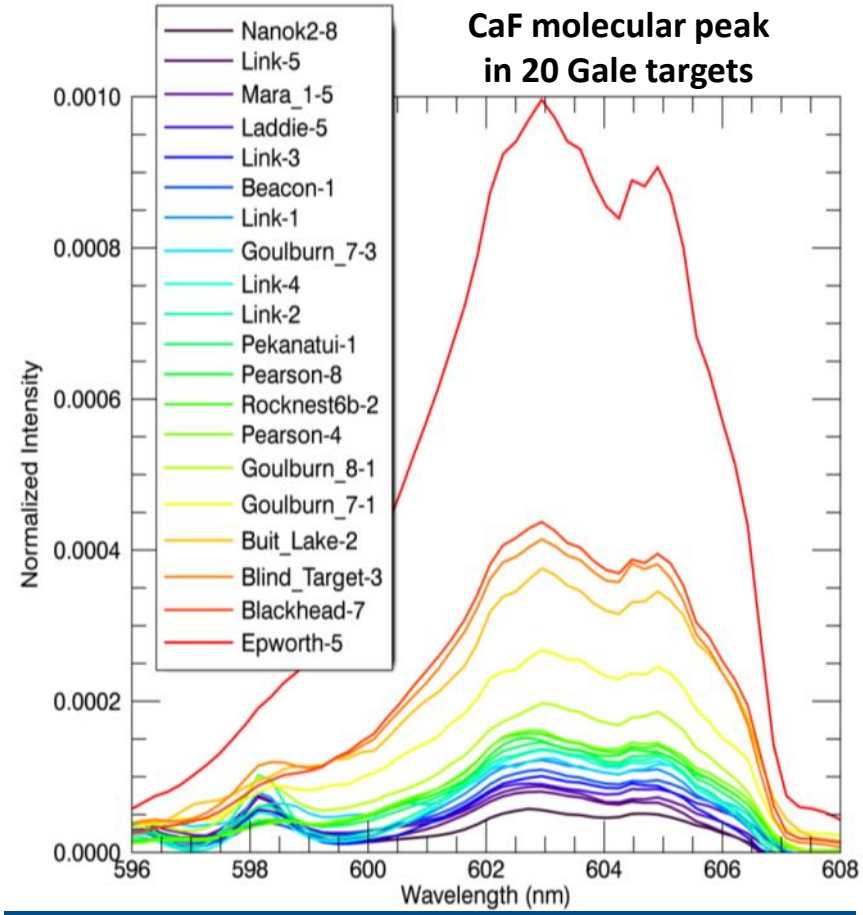
First Mars fluorine chemistry

Fluorine could not be previously analyzed on Mars, as XRF-type instruments cannot observe elements with atomic masses lighter than sodium. ChemCam has now made multiple observations of fluorine, which is relatively abundant in SNC meteorites. Its presence implies lower magma melting temperatures, and it is often present as an element within alteration minerals.

Quantitative analysis



CaF molecular peak in 20 Gale targets

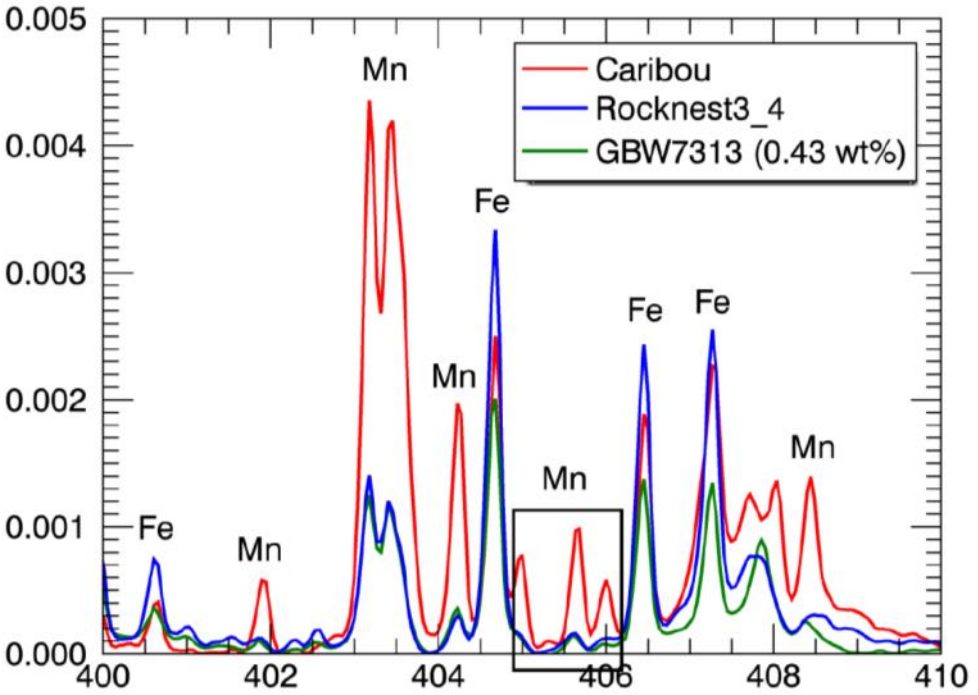


- Forni O. et al., First detection of fluorine on Mars: implications for Gale crater's geochemistry LPSC Friday Room 4 11:15 AM.

First manganese-rich minerals

The production of manganese-rich minerals requires a highly oxidizing environment, which currently does not exist on Mars. The discovery by ChemCam of a number of Mn-rich minerals has powerful implications for the paleo-atmosphere of Mars.

Caribou Sandstone with High-Mn Mineral

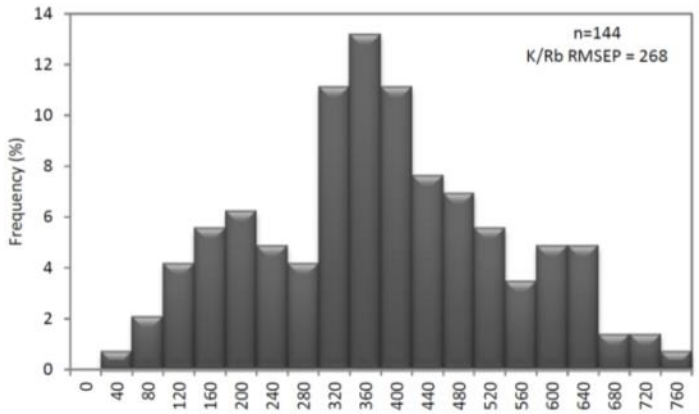


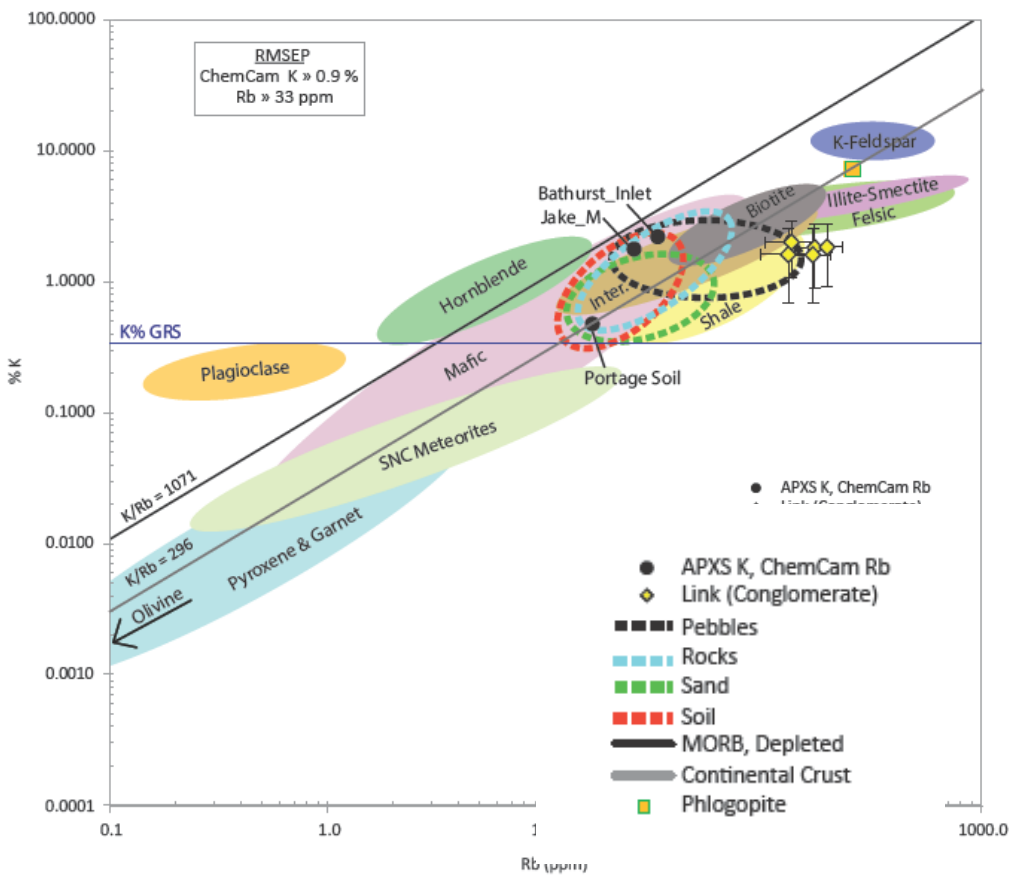
- Lanza N. et al. (2014) Understanding the signature of rock coatings in laser-induced breakdown spectroscopy data. Icarus, submit.
- Lanza N. et al., Manganese trends with depth on rock surfaces in Gale crater, LPSC Wed. Room 4, 9:45 AM.

First Li, Rb, Sr, and Ba on Mars

LIBS is highly sensitive to the alkali and alkaline-earth elements, so much so that our detection limit for lithium is ~5 ppm. These elements have generally never been seen on Mars before and they each have implications for Mars geochemistry. Lithium is a strong indicator of alteration; Rb, Sr, and Ba each tend to be sequestered in different minerals: Rb in anorthoclase, Sr in albite and more so in anorthite, etc. The global Rb/K ratio has important implications for planetary origins.

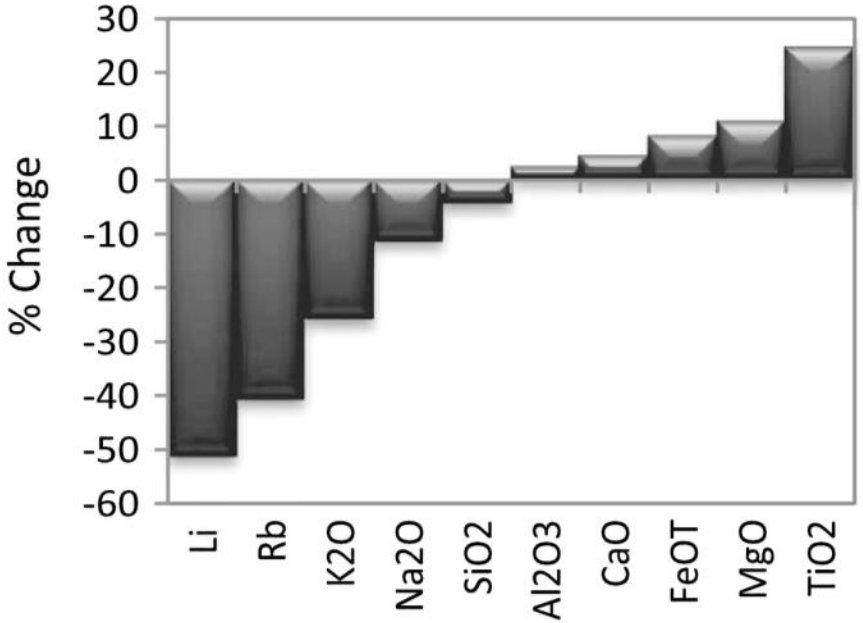
- Ollila A.M. et al. (2013) Trace element geochemistry (Li, Ba, Sr, and Rb) using Curiosity's ChemCam: Early results for Gale crater from Bradbury Landing Site to Rocknest. J. Geophys. Res., in press.

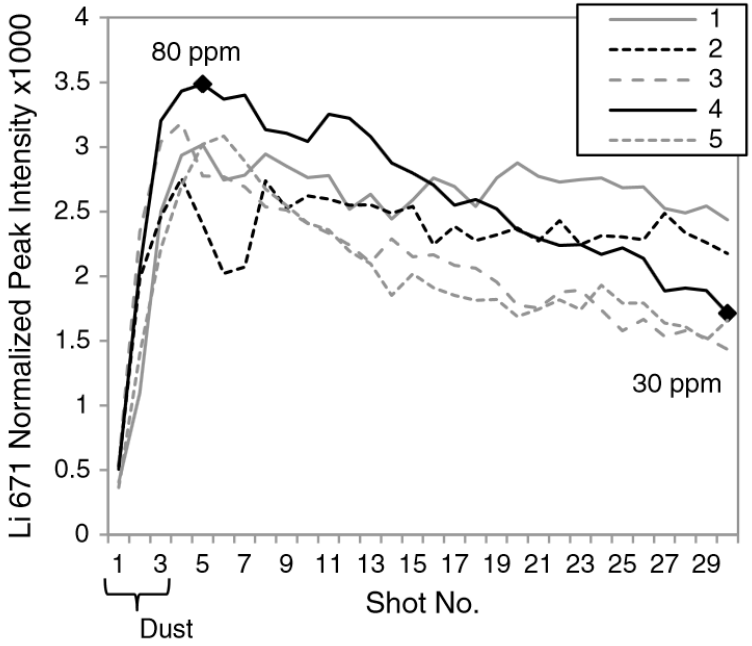




Rock surface alteration of mobile elements

On the Bathurst_Inlet sample all five ChemCam observations showed surface depletions in mobile elements, grading from the most mobile element (Li) to the less mobile elements (e.g., Si, Ti). The gradient was consistent among all observed elements, definitively showing relatively recent rock surface alteration.

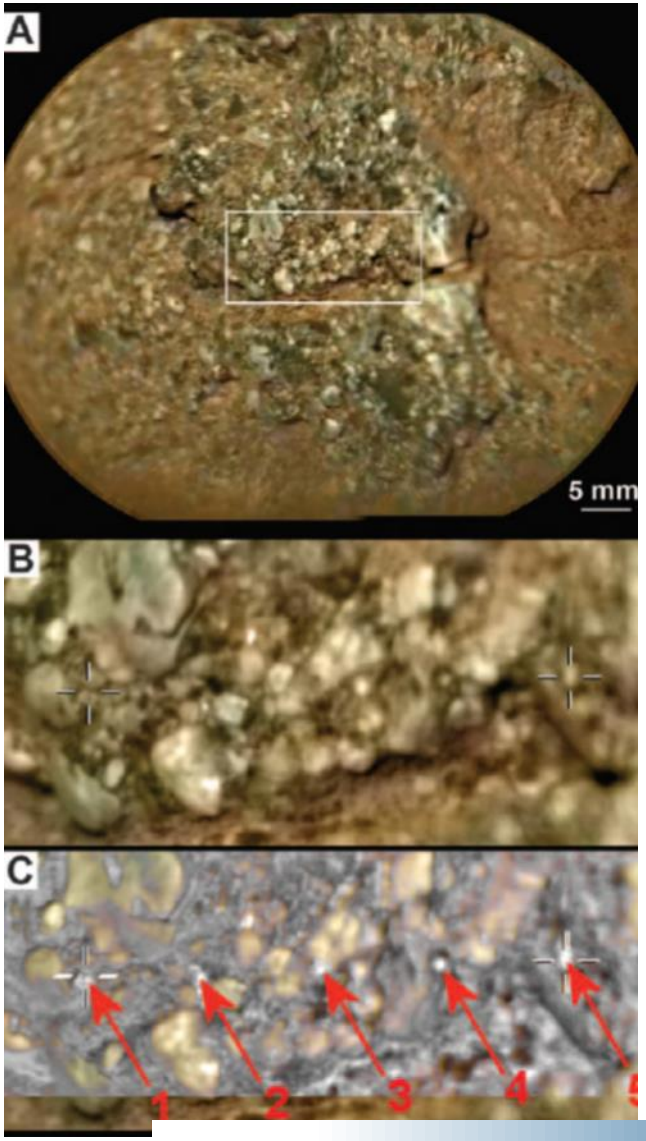




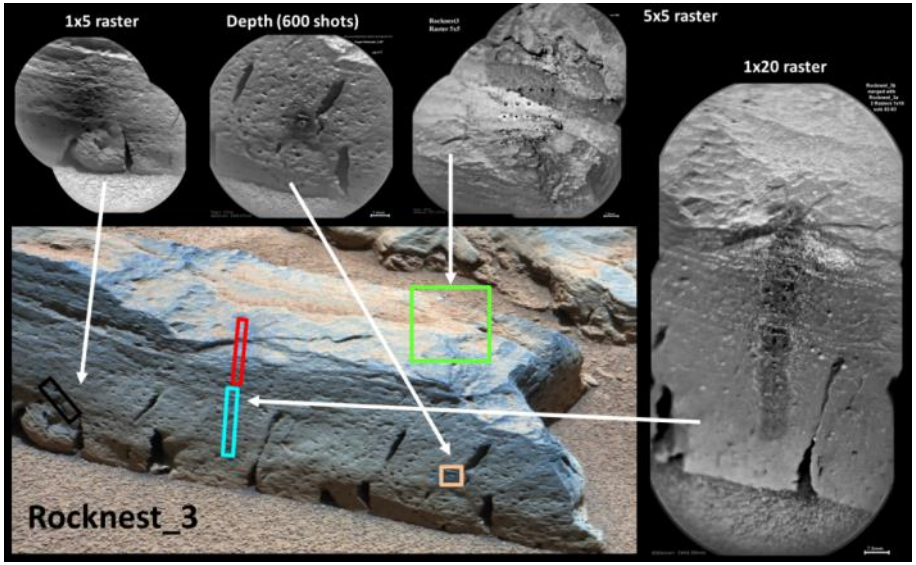
- Ollila A.M. et al. (2013) Trace element geochemistry (Li, Ba, Sr, and Rb) using Curiosity's ChemCam: Early results for Gale crater from Bradbury Landing Site to Rocknest. J. Geophys. Res., in press.

Li trends with depth for 5 points on Bathurst_Inlet

Fe-rich cements in sediments



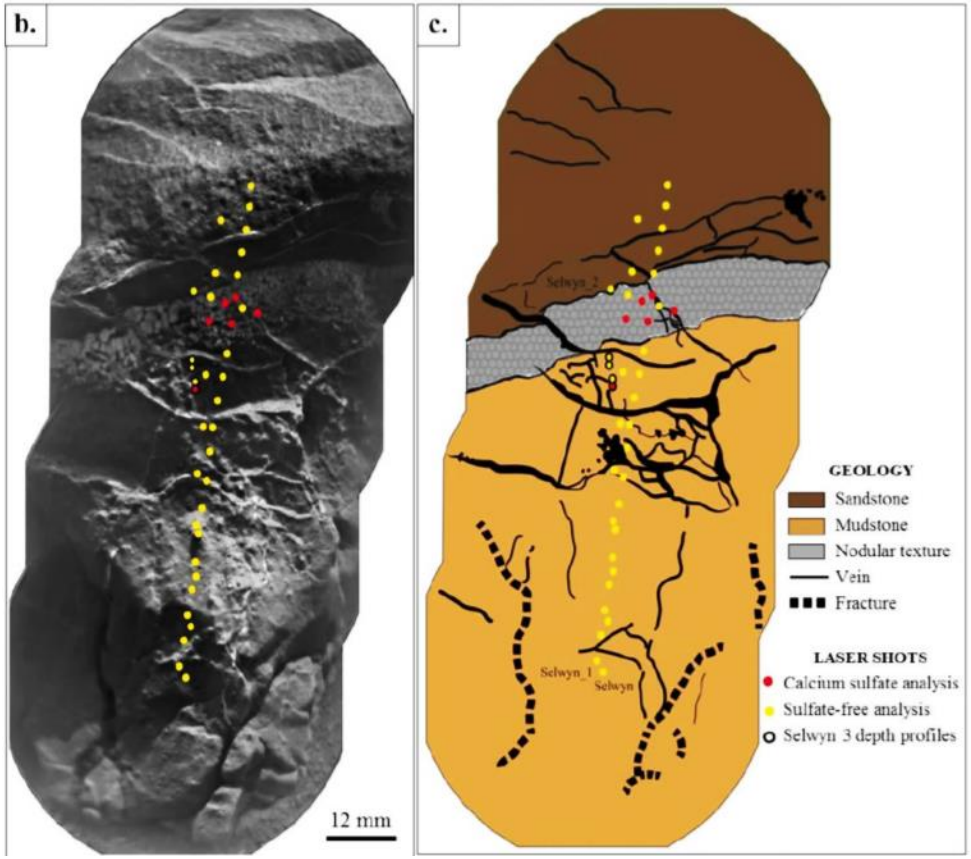
The micro-beam LIBS technique allows us to probe small areas, looking for interstitial material. In the first Science paper on conglomerates we reported that one observation point showed the beam profiling through a Fe-rich hydrated phase which we interpret to be an iron-rich cement binding the conglomerate clasts. We have evidence for this cement in the Rocknest rocks as well .

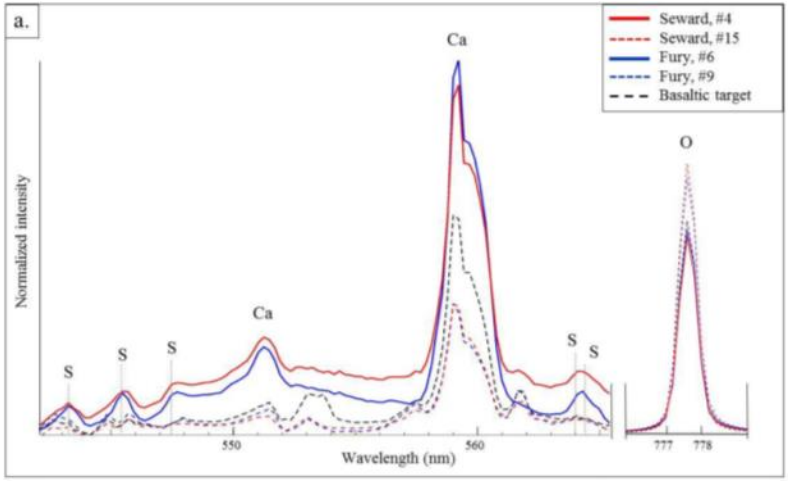


- Williams R. et al. (2013) Martian fluvial conglomerates at Gale Crater. Science 340, 1068-1072, DOI: 10.1126/science.1237317.
- Blaney D. et al. (2013) Chemistry and texture of the rocks at “Rocknest”, Gale crater: Evidence for iron-rich cements. J. Geophys. Res., submitted.

Ca-sulfate veins, variable hydration

ChemCam was the first to observe and confirm the composition of the calcium sulfate veins in the Yellowknife Bay units. We were also able to show that the veins were variably hydrated, confirmed by the Mastcam 1 micron band.



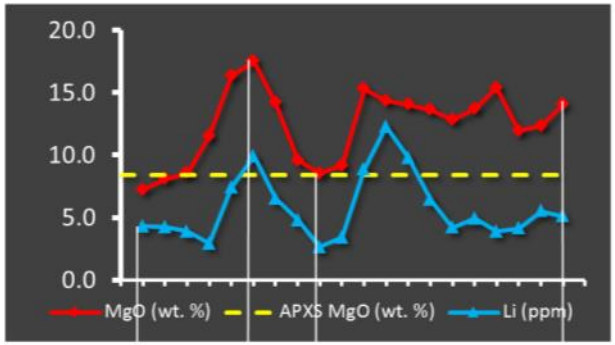


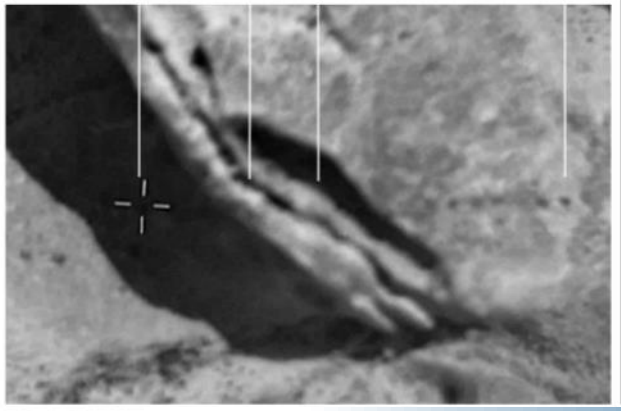
Chemostratigraphy with ChemCam laser

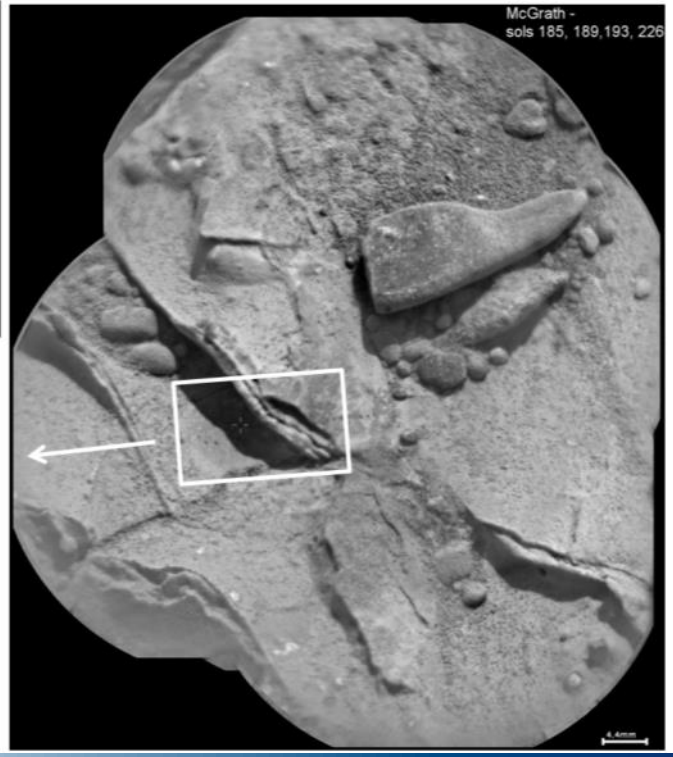
- Nachon M. et al. (2013) Calcium sulfate veins characterized by the ChemCam instrument at Gale crater, Mars. J. Geophys. Res., submitted.

Mg ridge transect

ChemCam is providing fine-scale geochemical constraints within the Yellowknife Bay formation: Mg and Li variations are correlated at the site of the raised ridge. Elevated Mg (but not Li) likely represents the outer layer of the cement, exposed on the dipping surface. ChemCam analyses of isopachous cements within early diagenetic raised ridges indicate the presence of a Mg-Fe-Cl rich phase (or assemblage).



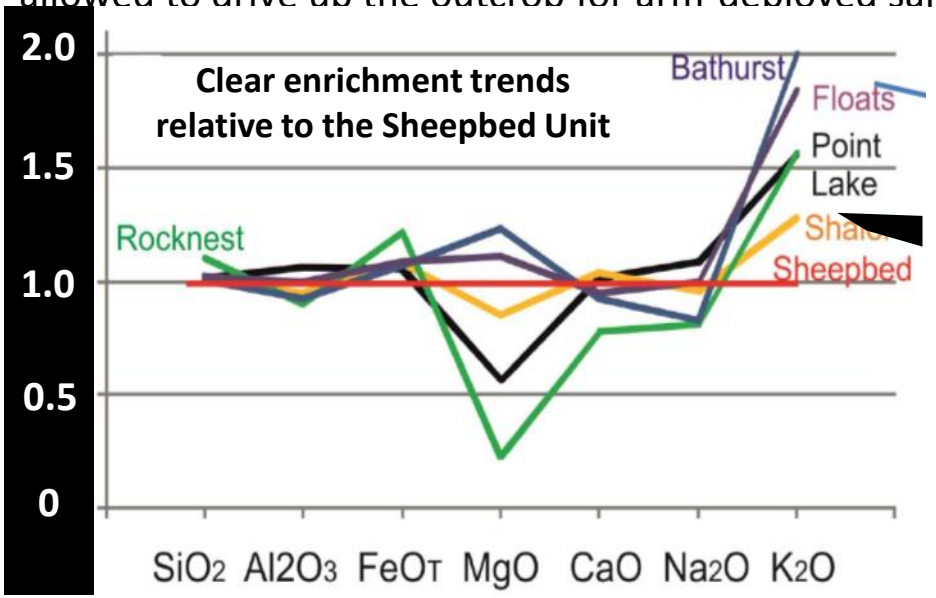




- McLennan S.M. et al. (2013) Elemental geochemistry of sedimentary rocks in Yellowknife Bay, Gale Crater, Mars. Sciencexpress, 9 December, DOI:10.1126/science.124473.
- Leveille R.J. et al. (2014) Chemistry of fracture-filling raised ridges in Yellowknife Bay, Gale crater: Windows in to past aqueous activity and habitability on Mars. Submitted to Icarus.

Chemostratigraphy of Yellowknife Bay sediments

ChemCam used > 30,000 shots and > 100 of super-high resolution images to characterize the Yellowknife Bay sediments far more comprehensively than with any other instrument. Using large aggregates of observations provides high confidence in the relative differences in these units. In the Shaler outcrop alone, only ChemCam was able to cover the whole area, as the rover was not allowed to drive up the outcrop for arm-deployed sampling.



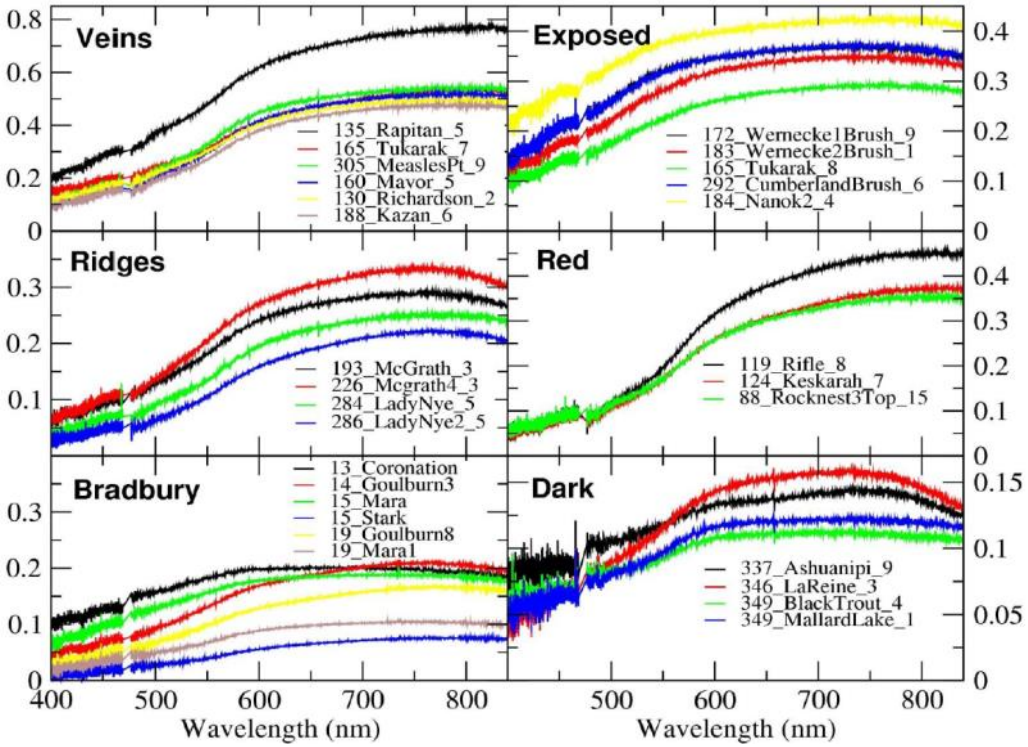
RMI LIBS

Stratigraphy	Texture	Chemistry	Interpretation
Glenelg member Bathurst	Faint layering, mm thick lamination. Sandstone to siltstone.	High alkali, distinct strong K/Na ratio. Similar to floats found in hummocky plains.	Eolian or volcaniclastic. Unknown cementation. May not be part of YKB sediments.
Glenelg member Rocknest	Layered sandstone or massive texture with flow features.	High Fe and alkali. Mg depleted. Similar composition of both textures.	Unknown depositional origin. Cement with Fe-oxides. Disturbance by late event may explain the massive textures.
Glenelg member Shaler	Laminated sandstone with cross-bedding, locally siltstone. Lateral variations with pitted texture.	Close to Sheepbed and Gillespie Lake composition except higher K. Locally low Mg in pitted texture.	Fluvial sediments. Local alteration during diagenesis forming pitted texture.
Glenelg member Point Lake	Pitted texture locally large vugs with glassy texture. Layering not obvious. Many cracks.	High alkali. Low Mg. Glassy texture contains points with high K, Na (feldspar-like)	Diagenetically modified sediments with enhanced alkali content and dissolution features.
Gillespie Lake member	Fine-grained to pebbly sandstone. Strong induration, poor layering. Many cracks and filled veins.	Similar to Sheepbed. Unidentified hydrated phases.	Fluvial sediments. Cementation by aqueous fluids.
Sheepbed member	Local layering visible. Mudstone to siltstone. Many filled veins and open cracks	Homogeneous mafic composition except diagenetic features.	Lacustrine sediments. Early in situ diagenetic alteration. Late diagenetic episode with calcium sulfate veins.

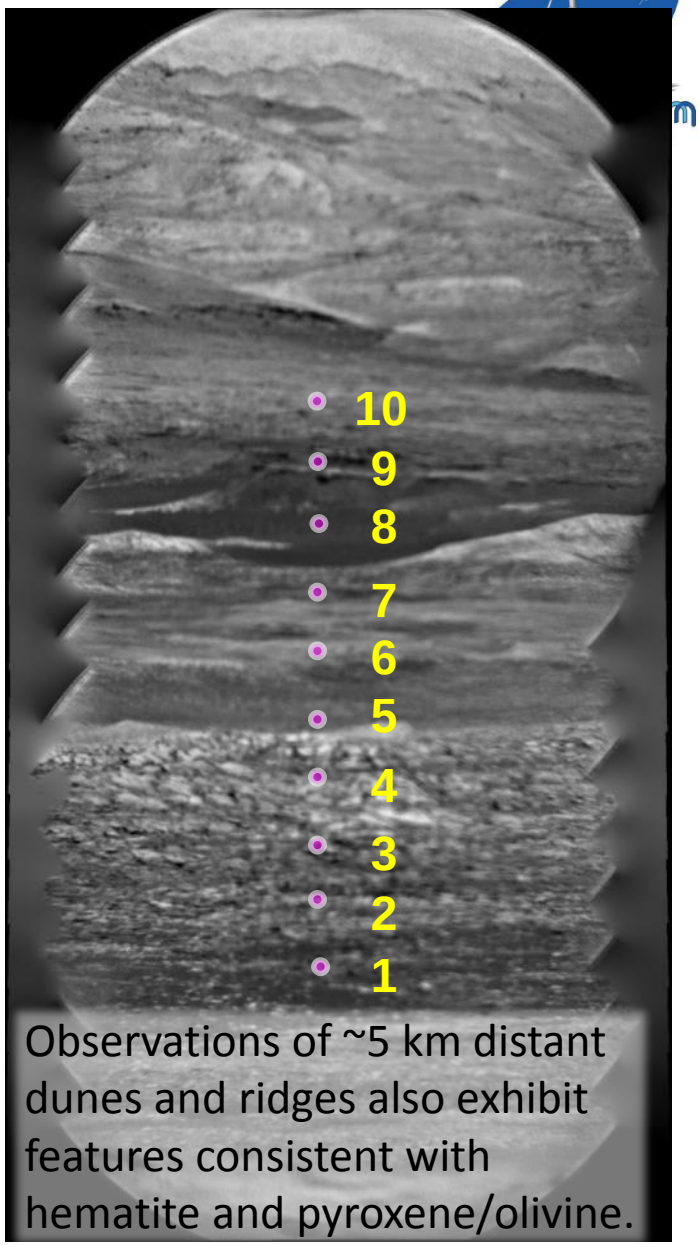
- Mangold N. et al. (2014) Chemical variations in Yellowknife Bay Formation sediments analyzed by the Curiosity rover on Mars. Submitted to J. Geophys. Res.
- Anderson R.B. et al. (2014) ChemCam Results from the Shaler Outcrop in Gale Crater, Mars. Submitted to Icarus.

High-resolution reflectance spectroscopy

While the spectral range only covers the 0.4-0.9 micron range, spectral features consistent with hematite, pyroxenes/olivine, and calcium sulfate have been observed.



- Johnson, J.R. et al. (2014), ChemCam Passive Reflectance Spectroscopy of Surface Materials at the Curiosity Landing Site, Mars, Icarus, in press.

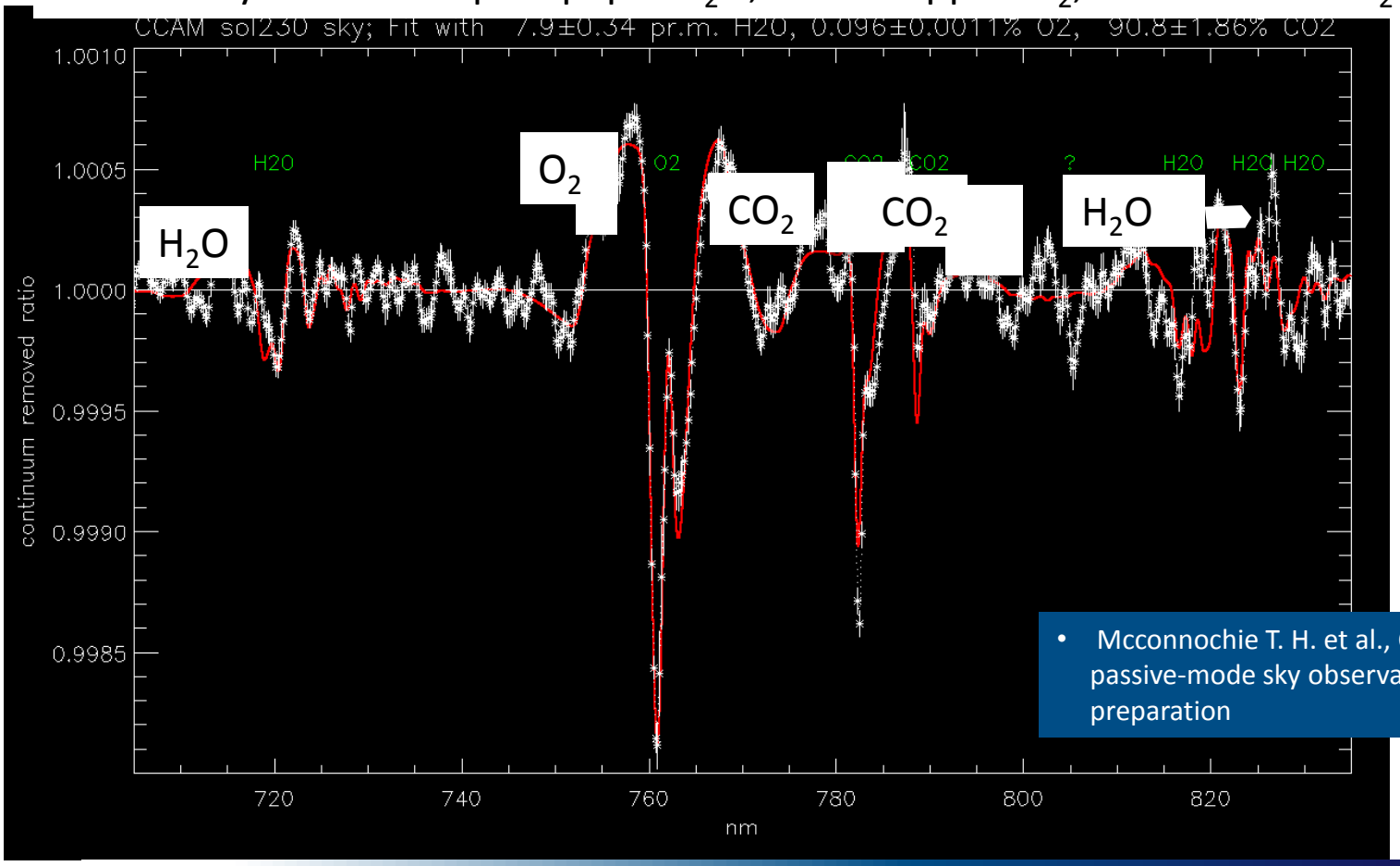


Observations of ~5 km distant dunes and ridges also exhibit features consistent with hematite and pyroxene/olivine.

Atmospheric H_2O, O_2 abundances

Water and O2 adsorption bands will provide the highest precision local ground-based measurements.

Preliminary fit: 7.9±0.7 precip. µm H_2O; 960±22 ppm O_2; 90.8±3.76% CO_2



Continuum-removed ratio

- Mcconnochie T. H. et al., ChemCam passive-mode sky observations, in preparation

Other ChemCam related publications (submitted or in press)

1. - 14. Cited in presentation

15. Le Mouelic S. et al. (2013) The ChemCam Remote Micro-Imager at Gale crater: Review of the first year on Mars. Submitted to Icarus.
16. Fabre C. et al. (2013) In situ prediction of Martian rock and soil compositions using univariate analyses based on the onboard ChemCam calibration targets. Submitted to Spectrochim. Acta.
17. Melikechi N. et al. (2014) Correcting for variable-target distances of ChemCam LIBS measurements using emission lines of martian dust spectra. Submitted to Spectrochim. Acta B.
18. Bridges J. et al. (2013) Fluid composition and low temperature alteration at Yellowknife Bay, Mars. Submitted to JGR Planets.
19. Bridges N. et al. (2013) The rock abrasion record at Gale Crater: Results from the first 100 sols of MSL. J. Geophys. Res., submitted.
20. Goetz W. et al. (2014) Internal structure and evidence for diagenesis of the Rocknest aeolian deposit, Gale crater, Mars. Submitted to J. Geophys. Res.
21. Newsom H.E. et al. (2014) Gale crater and impact processes: Observations during Curiosity's first 360 sols on Mars. Submitted to Icarus.
22. Arvidson et al. (2014) Terrain physical properties derived from orbital data and the first 360 sols of Mars Science Laboratory Curiosity rover observations in Gale crater. Submitted to J. Geophys. Res. Planets.

For More Information

- ChemCam papers, abstracts, and posters can be accessed at: http://www.msl-chemcam.com
  - Go to the ChemCam tab and select Publications

- Today's presentations can be found at:
  - http://pds-geosciences.wustl.edu/workshops/ChemCam_Workshop_Mar14.htm

ChemCam at LPSC

- Many ChemCam team members have posters at LPSC report on the current studies under way.
  - Feel free to stop by and talk to the authors if you want more information.

CHEMCAM @ LPSC 2014					
TOPIC	AUTHOR	#	DAY	ROOM	TIME
Impact processes	Newsom	2103	MON	4	3:00
Fluid modeling	Bridges-J	1944	TUE	4	2:15
Shaler outcrop	Anderson	2380	TUE	POSTER	
Fe-rich cements	Blaney	2122	TUE	POSTER	
Calibration database	Clegg	2378	TUE	POSTER	
Blind targets	Cousin	1278	TUE	POSTER	
Si-Fe-rich components	Fisk	1674	TUE	POSTER	
Remote reconnaissance	Le Mouelic	1361	TUE	POSTER	
Classification of spectra	Lewin	2817	TUE	POSTER	
LIBS distance correction	Mezzacappa	1517	TUE	POSTER	
Ca-sulfates	Nachon	2006	TUE	POSTER	
Sr, Ba, Rb, Li analyses	Ollila	2490	TUE	POSTER	
H2O in soils	Rapin	1982	TUE	POSTER	
Igneous rocks	Sautter	1369	TUE	POSTER	
H peak backgrounds	Schroeder	1928	TUE	POSTER	
Auto ID unusual targets	Wagstaff	1575	TUE	POSTER	
Conglomerates	Wiens	1171	TUE	POSTER	
Shaler grain sizes	Williams-A	2342	TUE	POSTER	
1st Mn-rich minerals	Lanza	2599	WED	4	9:45
1st reflectance spectrosc.	Johnson	1306	WED	4	10:00
Dune monitoring	Bridges-N	1849	THU	4	3:15
Pinpoint software	Altinok	2871	THU	POSTER	
Mars analogs, e-probe	Gallegos	2305	THU	POSTER	
1st fluorine on Mars	Forni	1328	FRI	4	11:15
Aeolian dust composition	Lasue	1224	FRI	4	11:30
Mineralogy, cation ratios	Dyar	1788	PRINT ONLY		

ChemCam capabilities and instrument status

Instrument Status

ChemCam is doing great!

As of SOL : 517

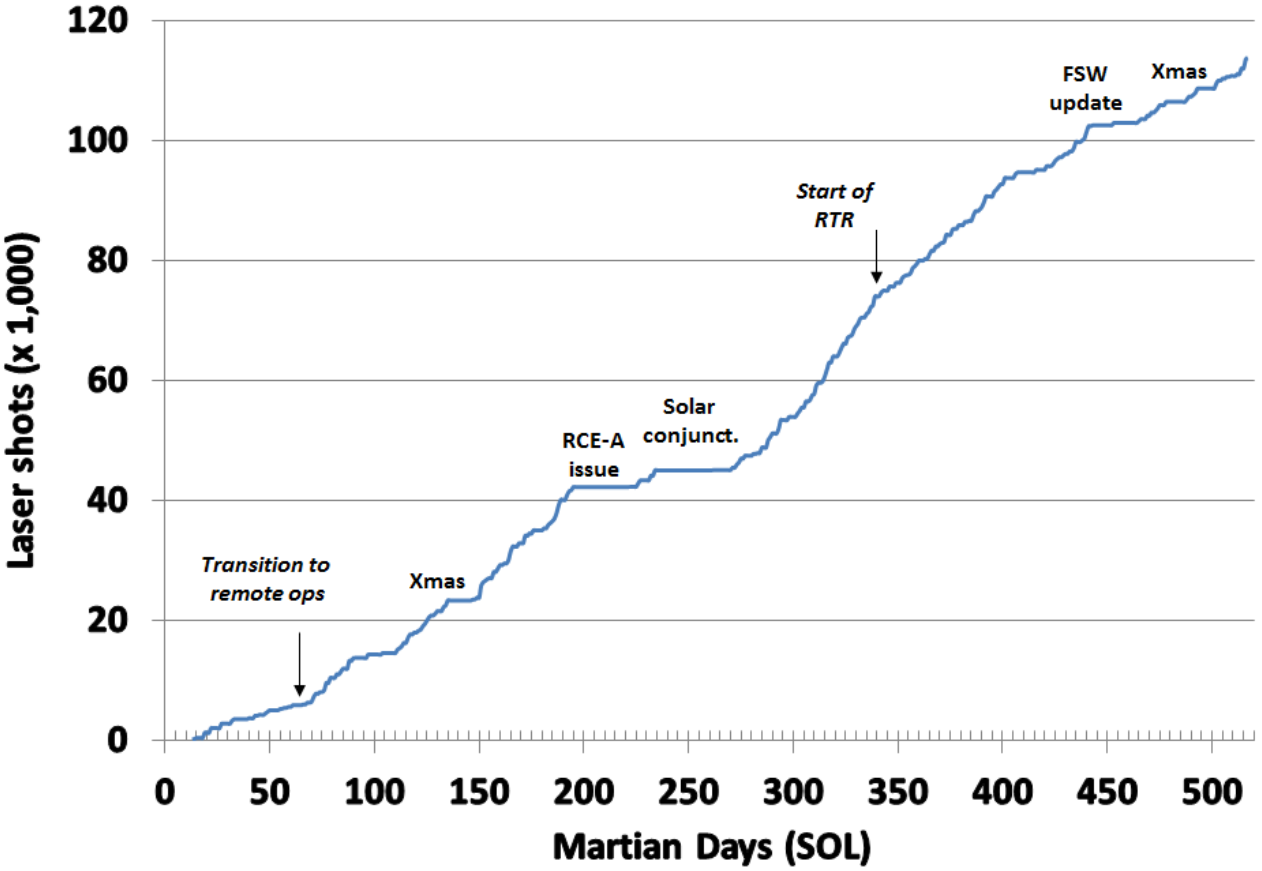
sequences : 666

working SOLs : 252

Mars targets : 452

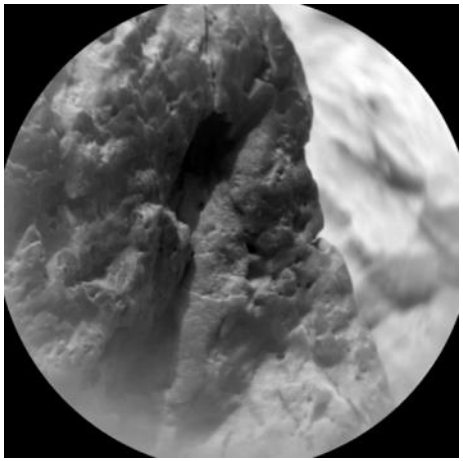
LIBS points : 3162

Images : 1585

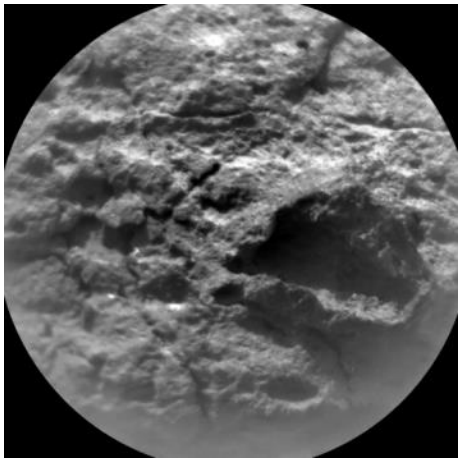


Variety of fine scale textures

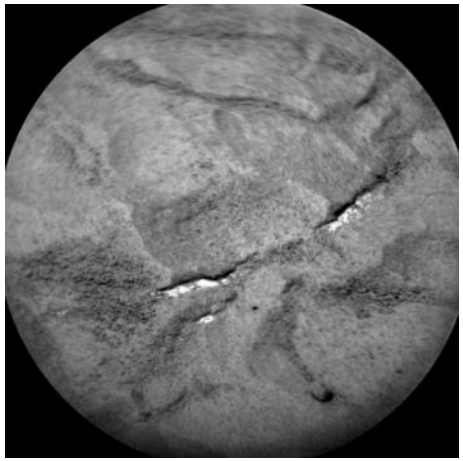
Pointing_test (sol 100)



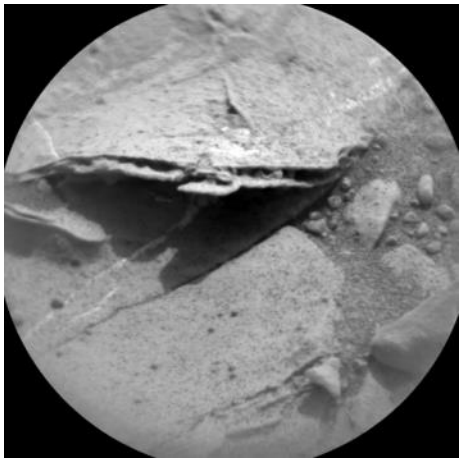
Athole_point (sol 302)



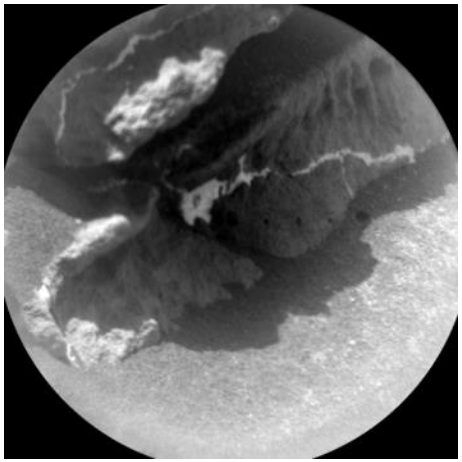
Beachrock (sol 126)



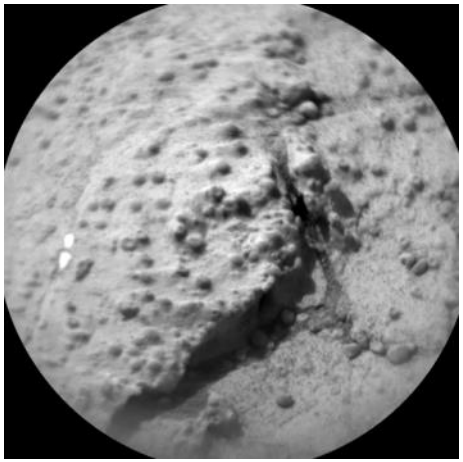
John_Klein_RP3 (sol 165)



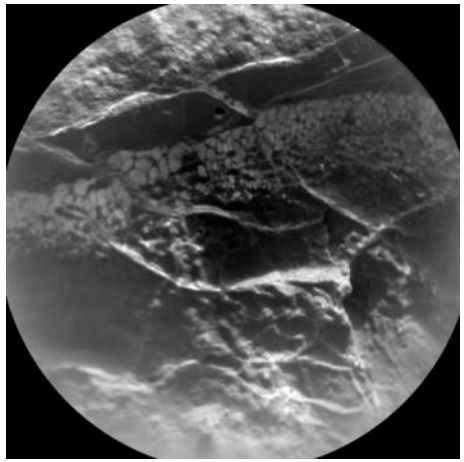
Denham (sol 326)



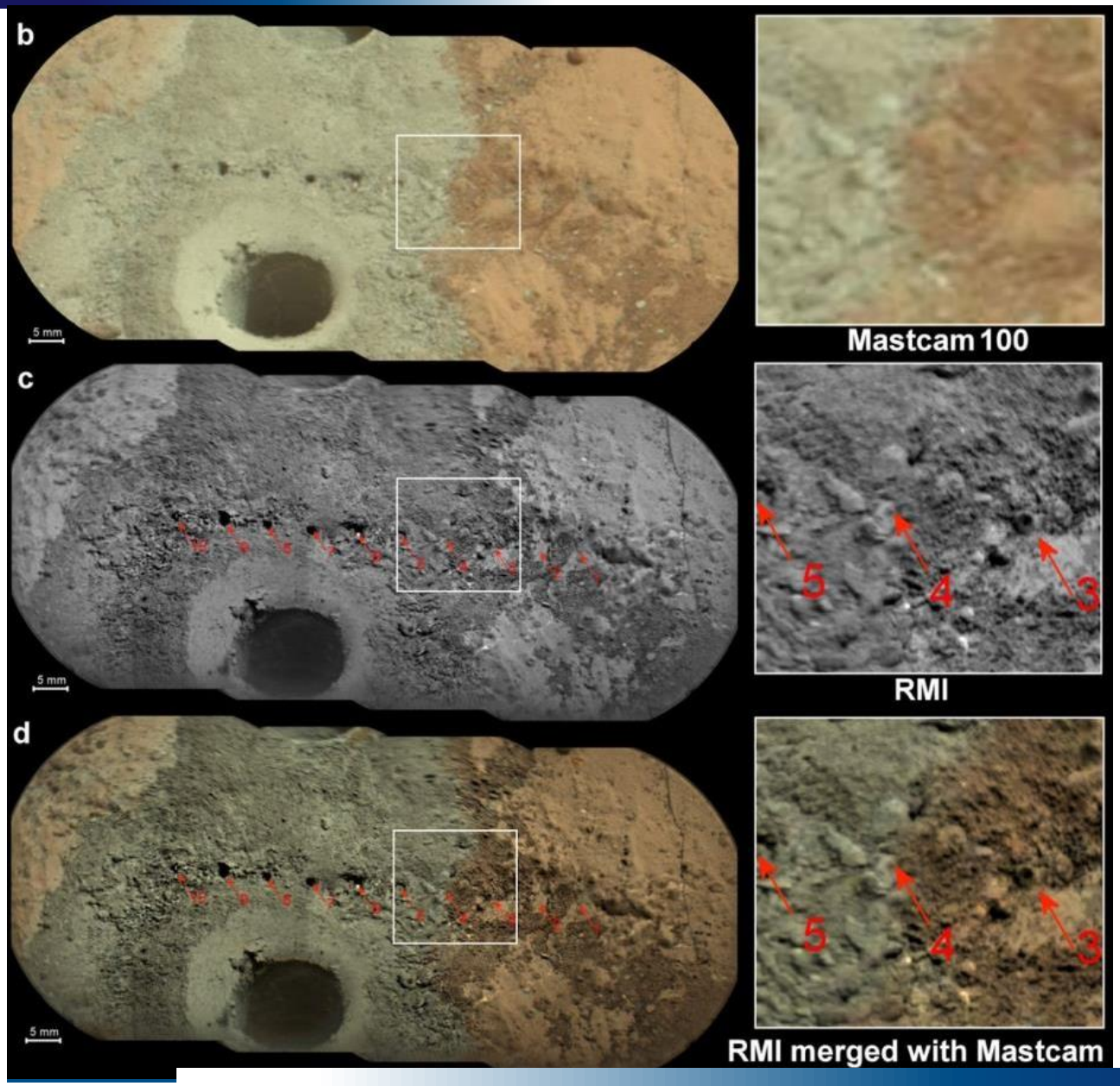
Fabricius_Cliffs (sol 322)



Cumberland (sol 187)



Selwyn (sol 157)

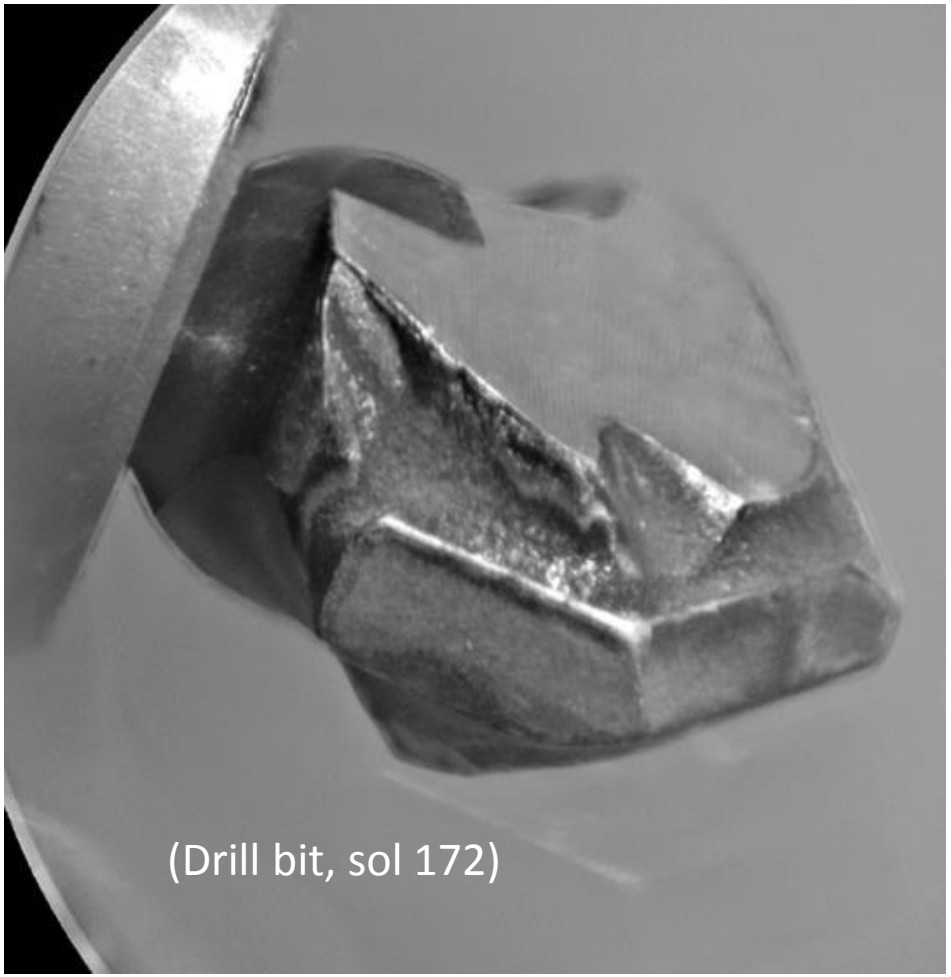


High res. Color images

Drill Tailings sol 183

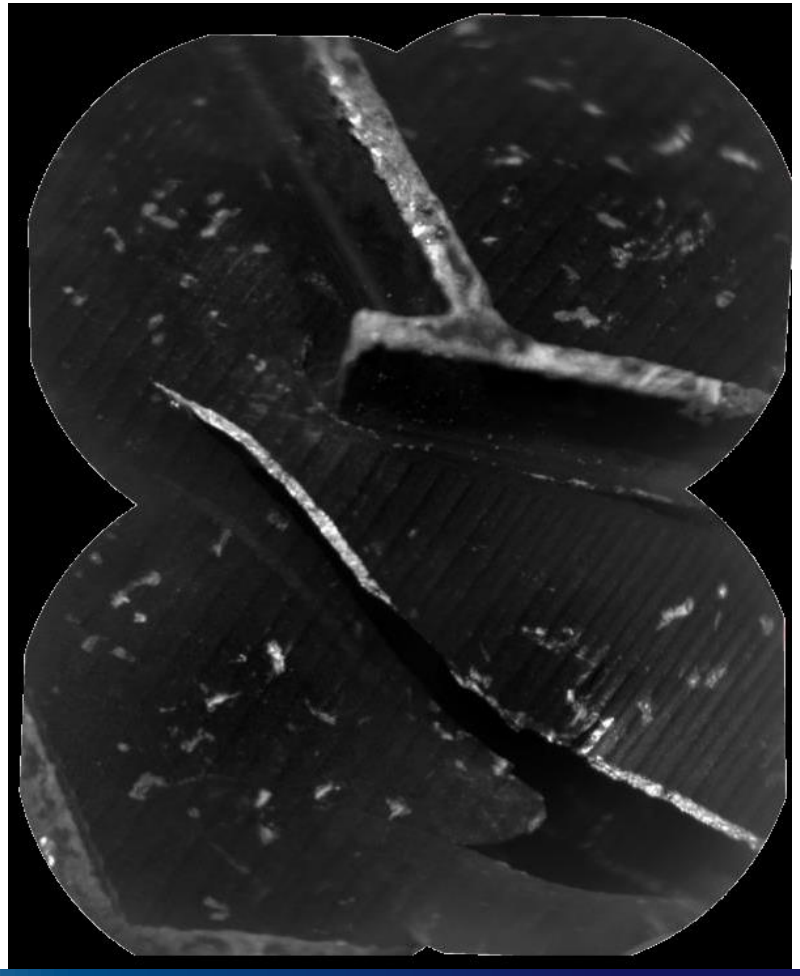
- Le Mouelic S. et al. (2013) The ChemCam Remote Micro-Imager at Gale crater: Review of the first year on Mars. Submitted to Icarus.

Assisting rover operations

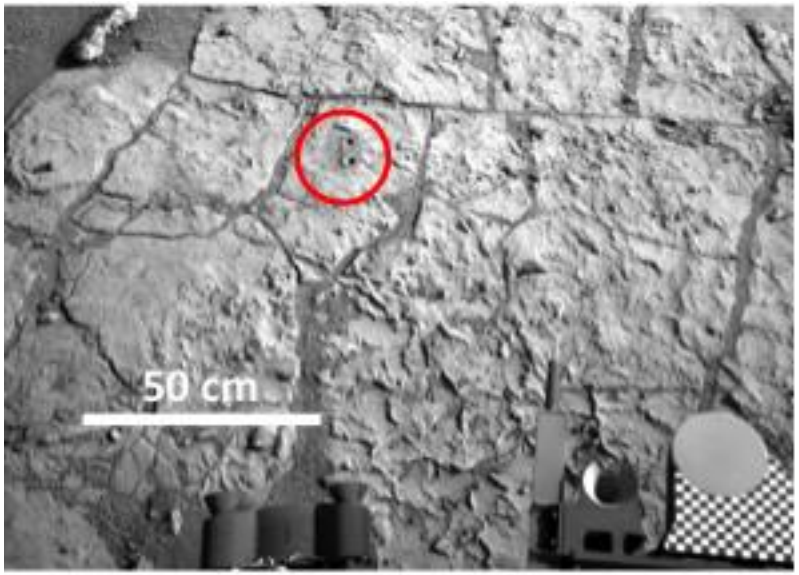


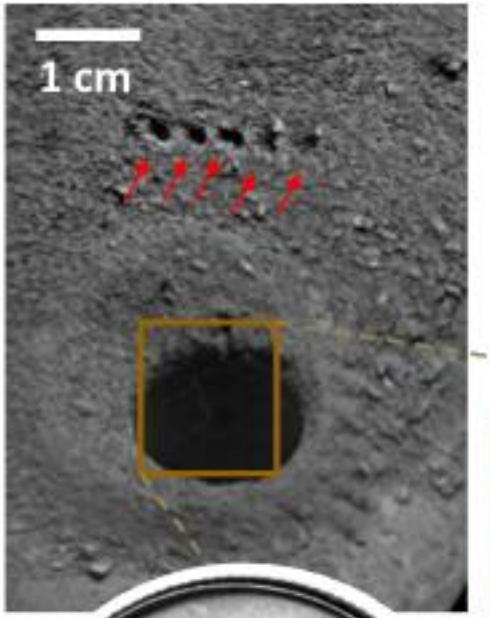
(Drill bit, sol 172)

(Wheel inspection, sol 520)

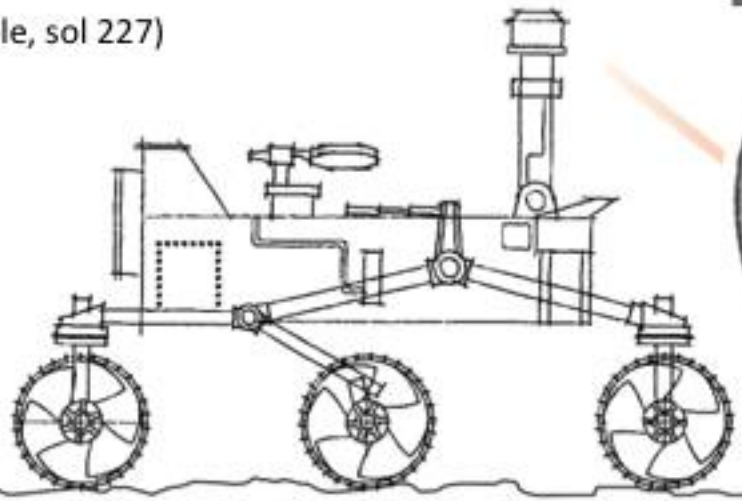


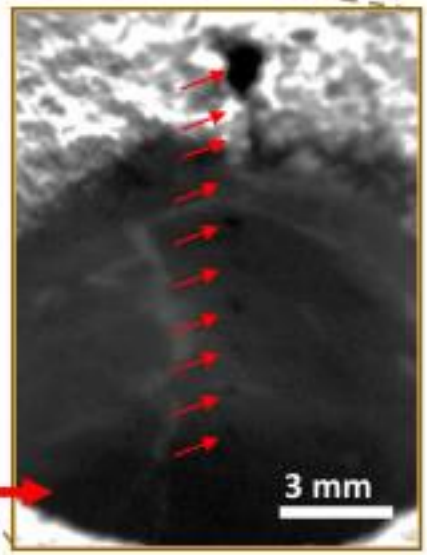
Fine pointing





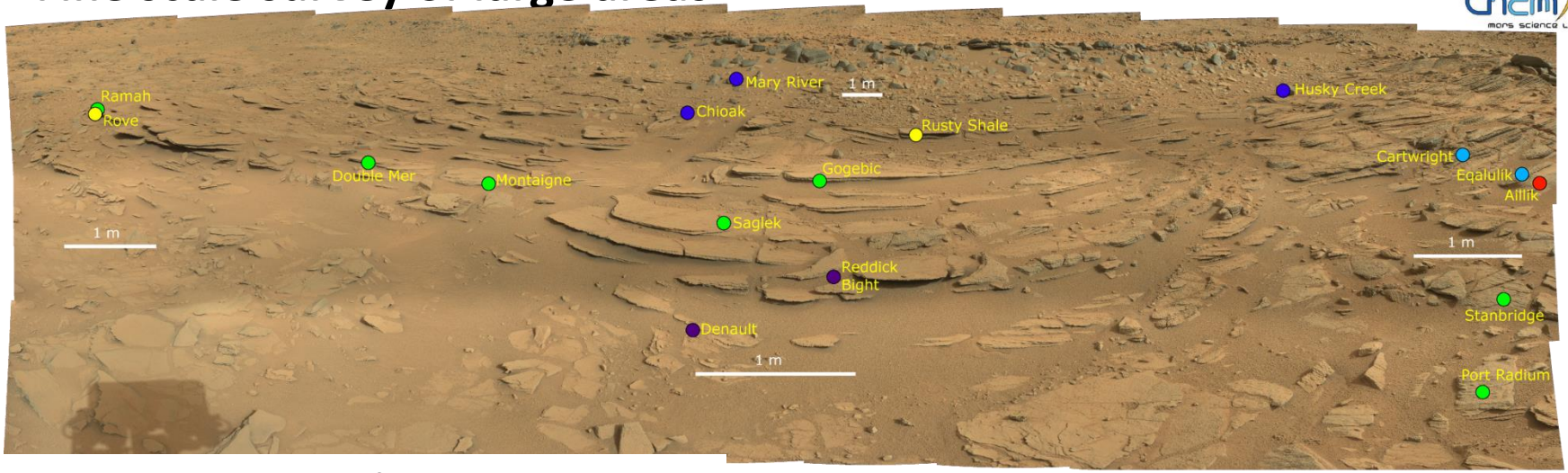
(Drillhole, sol 227)



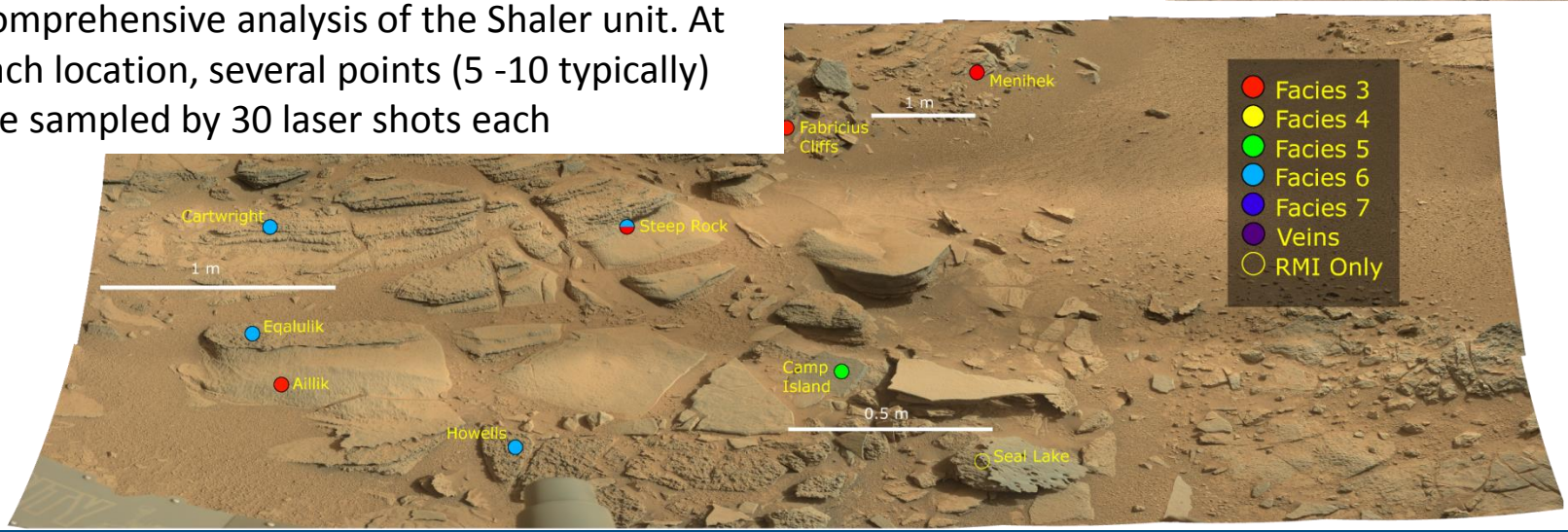


To Scale

Fine scale survey of large areas



Comprehensive analysis of the Shaler unit. At each location, several points (5 -10 typically) are sampled by 30 laser shots each



- Anderson R.B. et al. (2014) ChemCam Results from the Shaler Outcrop in Gale Crater, Mars. Submitted to Icarus.