Igneous Cumulate Samples in Gale Crater, Mars

UNIVERSITY OF LEICESTER

D. L. Bowden[1](dlb28@le.ac.uk), J. C. Bridges[1], A. Cousin[2], S. P. Schwenzer[3], R. C. Wiens[4], O. Gasnault[2], L. Thompson[5], P. Gasda[4], C. C. Bedford[6,7], S. Turner[3], R.M.E. Williams[8] and V. Sautter[9]

[1]School of Physics and Astronomy, University of Leicester, UK, [2]IRAP-OMP, CNRS-UPS, Toulouse, France [3]*AstrobiologyOU*, The Open University, UK, [4]Los Alamos National Laboratory, Los Alamos, NM, US. [5]Planetary and Space Science Centre, University of New Brunswick, Canada. [6]Lunar and Planetary Institute USRA, TX, USA. [7]Johnson Space Center, TX, USA. [8] Planetary Science Institute, Tucson, AZ, USA [7]IMPMC, Muséum National d'Histoire Naturelle, Sorbonne Université, Paris, France

- Igneous chemistry in Gale crater is more varied than any other currently explored site on Mars, with a range of basaltic-trachybasaltic compositions [1-3],
- These compositions can be generated by crystal fractionation of magma with similar composition to the Adirondack basalts found in Gusev crater [3].
- At the Bressay and Kimberly localities, the rover examined two float samples, "Askival" and "Bindi", which show characteristic texture and chemistry of feldspar cumulates.
- These cumulates offer an opportunity to examine magmatic processes in the Gale crater region. Their large feldspar grains are ideal for investigation using the ChemCam instrument, which functions as a geochemical microprobe.

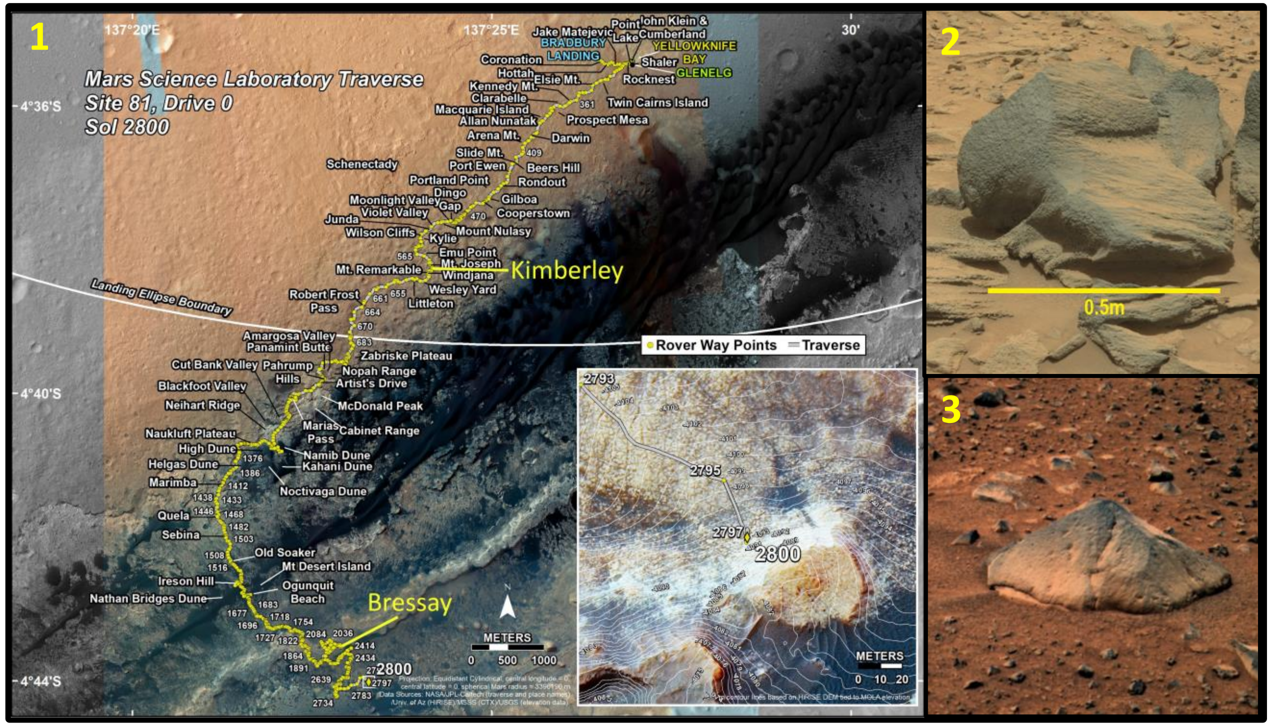


Fig. 1: Curiosity rover traverse map up to sol 2800, with Kimberley and Bressay sites highlighted.

Fig. 2: MastCam image of "Johnnie" igneous float rock, Gale crater

Fig. 3: PanCam image of "Adirondack" float rock, Gusev crater [4]

1. Schmidt, M.E., et al., *Geochemical diversity in first rocks examined by the Curiosity Rover in Gale Crater: Evidence for and significance of an alkali and volatile-rich igneous source.* Journal of Geophysical Research: Planets, 2013. **119**(1): p. 64-81. **2.** Cousin, A., et al., *Classification of igneous rocks analyzed by ChemCam at Gale crater, Mars.* Icarus, 2017. **288**: p. 265-283. **3.** Edwards, P.H., et al., *Basalt-trachybasalt samples in Gale Crater, Mars.* Meteoritics & Planetary Science, 2017. [4] Image courtesy of NASA/JPL & M. Lyle

Methodology

UNIVERSITY OF LEICESTER

Instruments

Geochemistry

Geochemical data was taken from two instruments:

- The ChemCam instrument [5,6] is a laser-induced breakdown spectroscopy (LIBS) instrument, which uses a 1067nm laser to induce atomic emission from a target, at typical ranges up to 3m.
- The Alpha Particle X-Ray Spectrometer (APXS), which uses an alpha particle source to induce x-ray emission in contacted targets.

Imagery

Images were taken using a combination of the MastCam stereo camera, the Mars Hand Lens Imager (MAHLI) and ChemCam Remote Micro-Imager (RMI), allowing for a range of spatial resolutions and fields of view covering the targets.

Software

MELTS

In order to simulate magmatic activity in Gale crater, we use the MELTS software package [7], using the Rhyolite-MELTS algorithm [8] and graphical interface as well as the alphaMELTS command frontend.

- MELTS provides a wide range of crustal temperatures and pressures, calibrated using experimental data.
- Numerous previous works have used MELTS to investigate compositions from Martian meteorites and in situ samples, and accuracy has shown to be equivalent when compared to terrestrial modelling.
- Low temperature modelling of phases such as amphibole is also not recommended with MELTS, and modelling of these phases using alternative software is ongoing.

5. Maurice, S., et al., *The ChemCam Instrument Suite on the Mars Science Laboratory (MSL) Rover: Science Objectives and Mast Unit Description.* Space Science Reviews, 2012. **170**(1-4): p. 95-166. **6.** Wiens, R.C., et al., *The ChemCam Instrument Suite on the Mars Science Laboratory (MSL) Rover: Body Unit and Combined System Tests.* Space Science Reviews, 2012. **170**(1): p. 167-227. **7.** Ghiorso, M.S., M.M. Hirschmann, and R.O. Sack, *New software models thermodynamics of magmatic systems.* Eos, Transactions American Geophysical Union, 1994. **75**(49): p. 571-576. **8.** Gualda, G.A.R., et al., *Rhyolite-MELTS: a Modified Calibration of MELTS Optimized for Silica-rich, Fluid-bearing Magmatic Systems.* Journal of Petrology, 2012. **53**(5): p. 875-890.

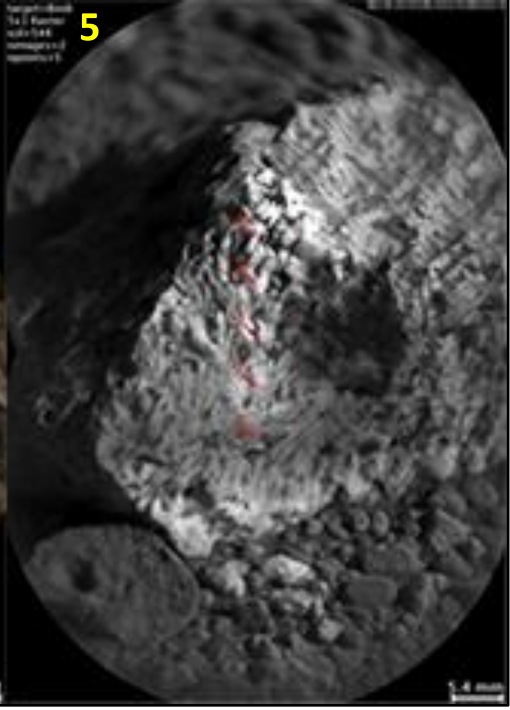
Results

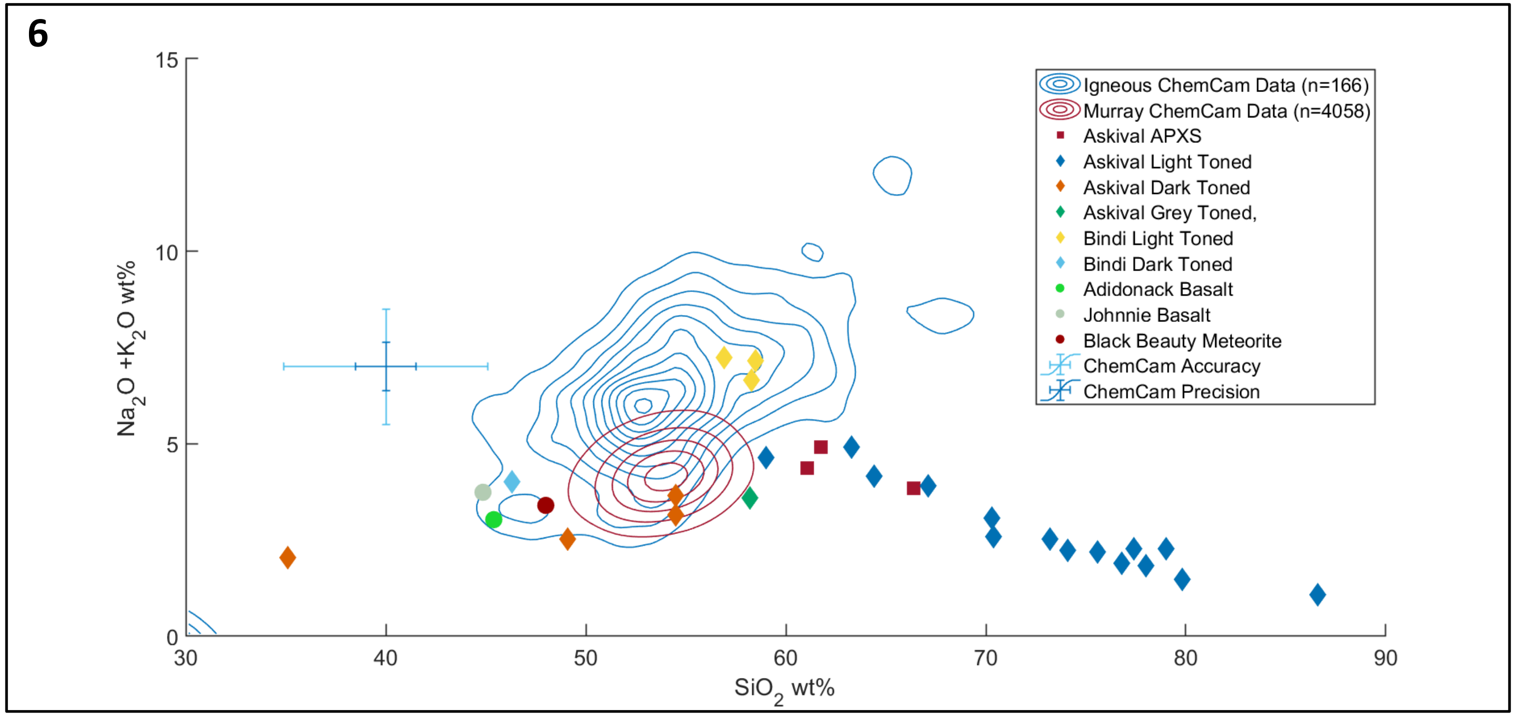
Figs 4 & 5: RMI Images of Askival (4) and Bindi (5). Red markers indicate the locations of LIBS target points. Both samples consist primarily of a light toned phase with large (>1cm) grained crystals, with an interstitial dark phase which occasionally also occupies larger spaces.

Fig 6: Total Alkali vs Silica diagram showing the geochemistry of Askival and Bindi. Points are divided into phase groupings based on RMI targeting images. Additionally, bulk ChemCam data from both igneous and sedimentary targets is displayed as contours.

The light phase in both targets is chemically identifiable as feldspar. However, as shown here, Askival's light phase has a wide range of silica content, which suppresses other chemical oxide abundances as it increases. We interpret this as the result of some fluid-driven alteration of the cumulate post-formation. Prior to this alteration, Askival and Bindi's feldspar chemistry was similar.

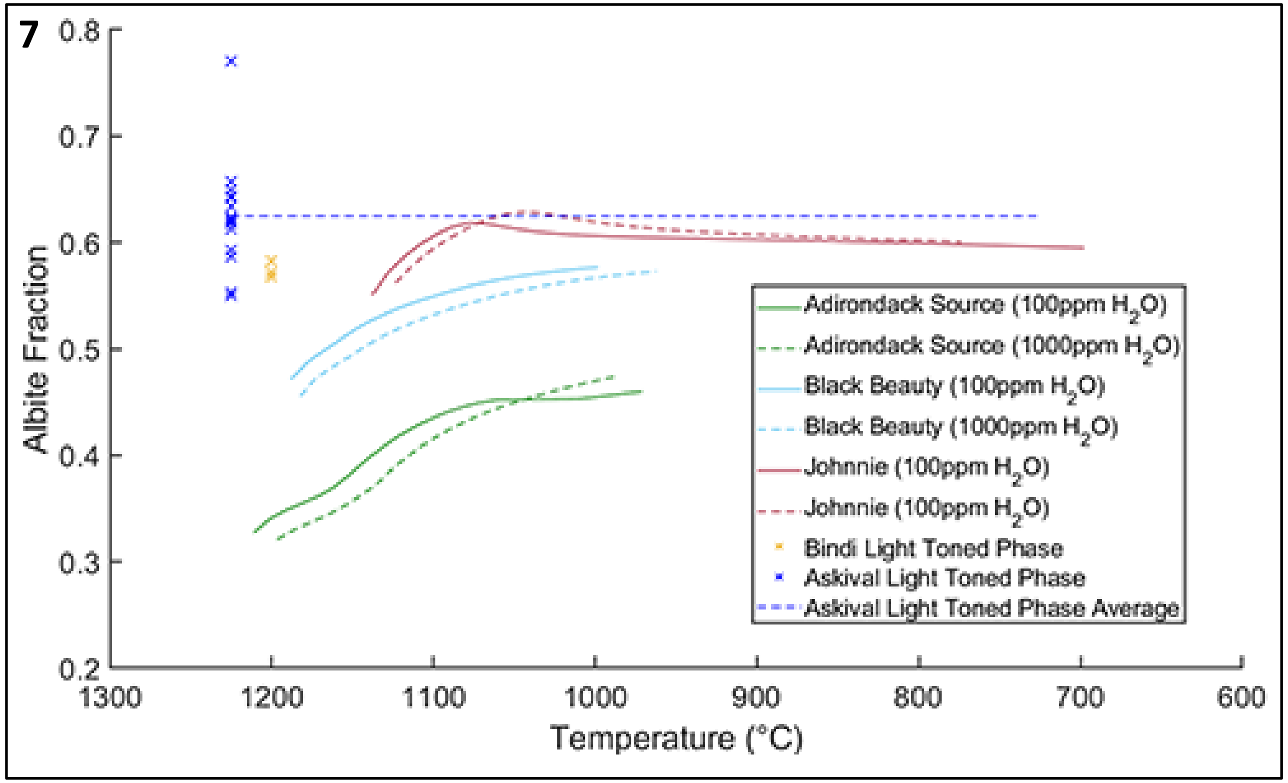
The dark phase in both rocks has a mafic composition, with Askival's dark phase again having a range of silica content; however, other elemental abundances also vary in these measurements, so this variation may be intrinsic to the minerals formed rather than the result of alteration. The target point with lowest SiO_2 has chemistry reminiscent of amphibole.





Discussion

- Using MELTS, we simulated the fractionation of solid phases from a set of basaltic Martian compositions: the Adirondack basalt from Gusev crater [9], the Johnnie basalt from Gale crater [2] and basaltic clasts of the Martian meteorite NWA7034 ("Black Beauty") [10].
- Simulations were performed using a pressure of 5kbar and a variety of water contents – 100ppm and 1000ppm H_2O results are shown opposite.
- We see that feldspar of the same phase proportion as the Askival and Bindi targets was most likely formed from a magma with similar composition to the Johnnie sample under these conditions.
- Gale crater basaltic compositions are understood to be derived from compositions similar to Adirondack. Our results show that this step is necessary before cumulates with the chemistry measured here can form.
- Our work is ongoing, with expansion of the simulated parameters and investigation of the mafic dark phase.



2. Cousin, A., et al., *Classification of igneous rocks analyzed by ChemCam at Gale crater, Mars.* Icarus, 2017. **288**: p. 265-283. **9.** McSween, H.Y., et al., Characterization and petrologic interpretation of olivine-rich basalts at Gusev Crater, Mars. Journal of Geophysical Research: Planets, 2006. 111(E2). **10.** Santos, A.R., et al., Petrology of igneous clasts in Northwest Africa 7034: Implications for the petrologic diversity of the martian crust. Geochimica et Cosmochimica Acta, 2015. 157: p. 56-85.