# CHEMICAL AND TEXTURAL OBSERVATIONS BY CHEMCAM OF CONGLOMERATES IN GALE CRATER

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**Overview and Localization:** Observations of conglomerates along the Curiosity rover traverse provide important clues to the sedimentary history of Gale crater [1]. Differences in clast sizes, and context, including imbrication, may indicate flow velocities. Clast shapes including rounding, and compositions may signal different source regions and episodes of fluvial activity. The extent of the conglomerate bedding helps define the stratigraphic relationships and the time-ordered history of the distal portion of Peace Vallis fan and the lowest topographic portions of Gale crater [2]. Compositions of the cementing material provide insights into the fluid chemistry during deposition [1].

The ChemCam instrument suite provides elemental compositions and remote imaging to 40 µrad resolution [3,4]. Over the first 360 sols ChemCam returned >75,000 laser-induced breakdown (LIBS) spectra from 2,256 locations on the Mars surface, accompanied by > 1,000 images from the Remote Micro-Imager (RMI).

Conglomerates were observed from sol 14, at the landing site, until ~40 [1,5], and then again after sol ~326, upon leaving Yellowknife Bay (YKB). The locations of those analyzed by ChemCam are shown in Fig. 1. The coverage suggests that the dominant bedrock composition over Bradbury rise, comprising most of the rover traverse to date except for YKB, is a combination of conglomerates and sandstones.

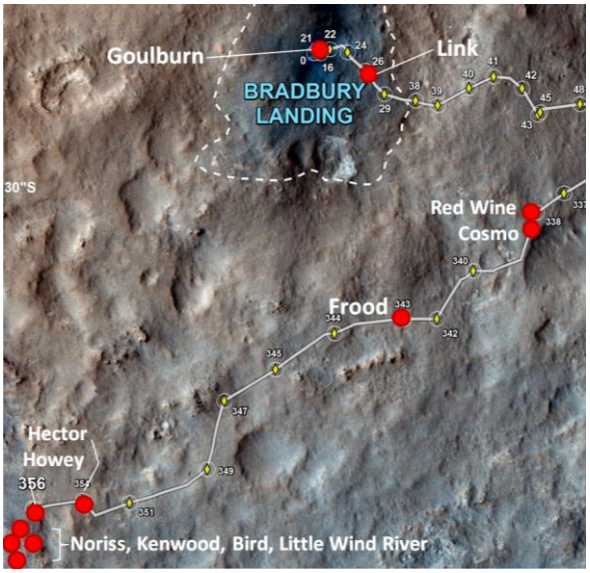


Fig. 1. Names and locations of conglomerates analyzed by ChemCam in the first 360 sols. YKB is to the right.

**Description of Observations, Classification:** The targets sampled by ChemCam have been classified first as likely igneous or sedimentary, with the igneous classified by grain size and other characteristics [6]. Sedimentary targets are classified as conglomerate bedrock, conglomerate floats or small outcrops, sandstone-like layered floats, and sandstone bedrock. The target Bathurst is the only layered float analyzed by APXS [7]; ChemCam analyzed these in various locations and found them identical in composition [8].

Conglomerate morphologies are illustrated in Fig. 2. They usually appear as cemented agglomerates of subangular to rounded pebbles with sand-size or finer-grained matrix. They usually lack obvious layering but often have a flat top due to erosion. Conglomerates often weather leaving loose pebbles on the ground whereas finer material is removed by wind. Conglomerate pebbles vary from light-toned to dark-toned, suggesting variety in the source material. Whereas many conglomerates are similar to the previously-studied clast-supported Link and Hottah targets [1], several have distinct morphologies such as poorly cemented breccia and matrix-supported conglomerates, suggesting origins other than fluvial are locally possible, including local impact breccia floats or cemented soil. Detailed studies of textures are ongoing. In contrast, sandstone-like material (or perhaps siltsone/mudstone, at grain sizes not accessible with RMI images) are usually relatively light-toned and display flat tops and a smooth texture suggesting they are either of sedimentary or volcaniclastic origin. Their composition is usually homogeneous and similar to Bathurst [7] (e.g. Kasegalik, sol 336) and are not discussed here.

**Conglomerate Compositions:** The conglomerates present varied compositions overall, as might be expected for a 400 µm probe. Fig. 3 shows these compositions to be much more felsic than the Sheepbed sedimentary unit, and in fact, significantly dissimilar to any of the YKB units [9]. It is perhaps instructive to compare the mean of these 61 conglomerate locations to Jake Matijevic [10], with the caveat that ChemCam's 14 points on Jake leave it underrepresented. The conglomerates are on average higher in alkalis and Al, and lower in Fe, Ti, Mg, and Ca (Fig. 3). A norm calculation suggests the conglomerates are on average higher in albite, anorthite, and k-feldspar; and substantially lower in high-Ca pyroxene.

Perhaps more instructive are comparisons among the different conglomerate regions, observed by independent component analysis (ICA).

Fig. 4 shows that conglomerates encountered near the landing site form an alkali ratio trend parallel to Jake (which was not a conglomerate [10]), while those encountered after sol 350 are richer in Na, with floats being the highest in alkalis. Link (sol 27; [1]) remains a high K/Na outlier.

Trace elements: Link also contains the highest abundances of Sr (to 1670±160 ppm) and Rb (to 190±30 ppm) in any target analyzed in the first 360 sols [1,11]. Point 4 in Kenwood_River has a similar Rb abundance to the lowest Rb in Link (~140 ppm) and this point is associated with high Si, Al, Na, and K, similar to Link. Ba is present in several locations, up to ~500 ppm and is generally associated with high Si. For comparison, the highest Ba observed in the first 360 sols is found in the light-toned rock called Chakonipau (~2000 ppm, Sol 338). Li is low in the majority of these targets. The highest Li is found in the 5th point of Kenwood_River, which has ~40 ppm. This point also has high $TiO_2$ and $FeO_T$ (1.8, 20 wt. % resp.) relative to the other 4 locations on this target. Interestingly, when the conglomerates are divided into bedrock-type (n=19 points) and float/small outcrop-type conglomerates (n=21 points), the latter generally show increased trace elements, consistent with Fig. 4. For example, the average Ba abundance is nominally higher in the float/small outcrop conglomerates, the mean Sr is 5x higher, and average Rb is 4x higher. This may be evidence for differing origins between the two types of conglomerates, and similar provenances within each group.

**Conclusions:** At more than 60 locations across Bradbury Rise, traversed prior to sol 40 and after sol 326, conglomerate analyses confirm that alkali-rich compositions first observed at conglomerate Link [1] are prevalent throughout the local area. Differences, particularly in Mg and alkalis (Li, Na, K, Rb), suggest different source regions for the clasts.

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**References:** [1] R.M.E. Williams et al. (2013) Science 340, 1068-1072, DOI: 10.1126/science.1237317. [2] J.P. Grotzinger et al. (2013) Sciencexpress, 9 December, DOI:10.1126/science.1242777 [3] S. Maurice et al. (2012) SSR 170, 95-166, DOI 10.1007/s11214-012-9912-2. [4] R.C. Wiens et al. (2012) SSR 170, 167-227, doi 10.1007/S11214-012-9902-4. [5] A. Yingst et al. (2013) JGR 118, 2361–2380, doi:10.1002/2013JE004435. [6] Sautter et al., this meeting. [7] M.E. Schmidt et al. (2013) JGR, in press. [8] N. Mangold et al. (2014) submitted. [9] S.M. McLennan et al. (2013) Sciencexpress, 9 December, DOI:10.1126/science.1244734. [10] E.M. Stolper et al. (2013) Science 341, DOI: 10.1126/science.1239463. [11] Ollila et al. (2013) JGR, in press.

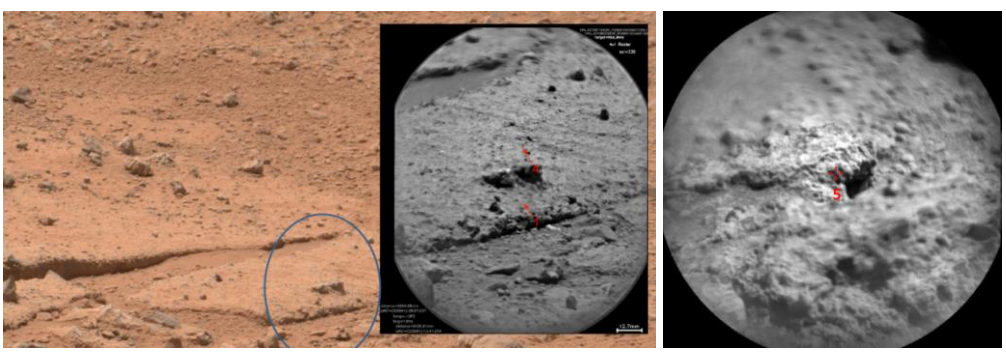

Fig. 2. Flat-lying conglomerate Red Wine, sol 339, Mastcam and ChemCam images (left); Float conglomerate Bird River, sol 359 (rt). FOV = 7.4 cm.

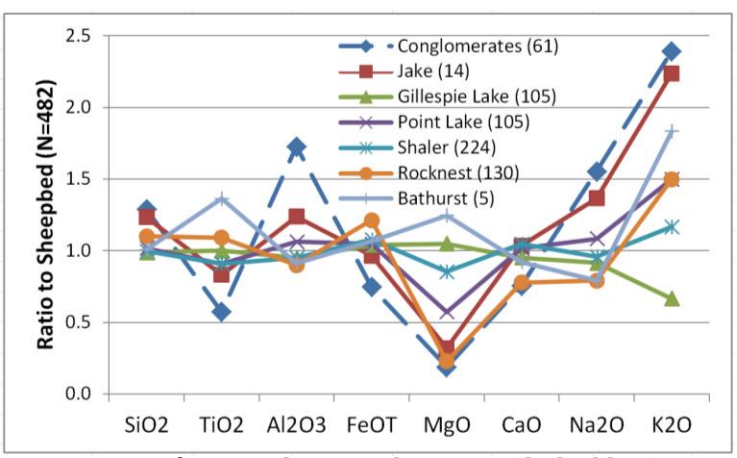


Fig. 3. Mean of 61 conglomerate locations (dashed line), ratioed to Sheepbed, show that conglomerates are, overall, more depleted in Fe, Ti, Mg and enriched in Al, Na, and K than the YKB units, and even more than Jake [10].

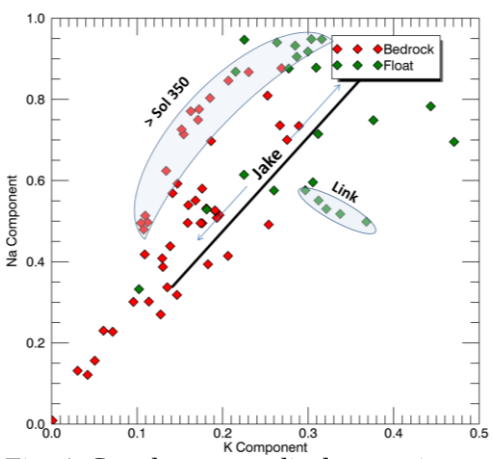


Fig. 4. Conglomerates display varying Na/K ratios corresponding to location on Fig. 1. Targets early in the mission trend with Jake [10], shown for reference.