CHEMISTRY OF CONGLOMERATES ANALYZED BY THE CURIOSITY ROVER. N. Mangold[1], L. M. Thompson[2], O. Forni[3], C. Fabre[4], L. Le Deit[1] , R. C. Wiens[5] , A. J. Williams[6] , R. Williams[7] , R. B. Anderson[8] , D. L. Blaney[9] , F. Calef[9] , A. Cousin[3] , S. M. Clegg[5], G. Dromart[10], W. E. Dietrich[11], K. S. Edgett[12], M. R. Fisk[13], O. Gasnault[3], R. Gellert[14], J. P. Grotzinger[15], L. Kah[16], S. Le Mouélic[1], S. M. McLennan[17], S. Maurice[3], P.-Y. Meslin[3], H. E. Newsom[18], M. C. Palucis[10], W. Rapin[3], V. Sautter[19], K. L. Siebach[13], K. Stack[8], D. Sumner[20], A. Yingst[7].
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Introduction: Among sedimentary rocks, conglomerates are those which are the least altered and the least sorted and therefore provide the most direct knowledge of the source of sediments. Preserved clasts enable a direct look to the texture and composition of the source rock. This study aims to analyze the chemistry of conglomerates in order to understand the variability in composition of the source rocks and their relevance for understanding the martian crust. Conglomerates are also a fundamental link between the source rocks and the finer-grained sediments. We provide an analysis of conglomerates as the source of finer-grained fluvial sediments (i.e., sandstones and mudstones analyzed at our field sites Yellowknife Bay, Kimberley and Pahrump Hills)[1].

Observations: This study is focused on observations taken between landing and the arrival at Mt. Sharp (sol<800). The first conglomerate outcrops encountered by Curiosity were isolated, well-indurated blocks that had pebbles up to 4 cm in diameter [2]. These conglomerates were observed on Bradbury Rise in the immediate vicinity (<200 m) of the landing site before reaching Yellowknife Bay. Progressing out of Yellowknife Bay (sols 330-390), the conglomerates of the hummocky plains appeared more often as limited exposures and as outcrops with well-exposed sections at the Darwin field site (Figure 1, sols 390-400). After Darwin, conglomerate outcrops were analyzed less frequently due to the decreased occurrence of outcrops and an increasingly rugged traverse on a different surface from the hummocky plains. A few outcrops were analyzed around the Kimberley field site (sols 550-650) and before arriving to the Pahrump field site (<sol 750). Overall, the presence of conglomerates is consistent with an interpretation of fluvial sedimentation, as interpreted at the Bradbury landing site [2], but the detailed depositional style may have varied from fluvial to denser flows with less sorting and rounding.

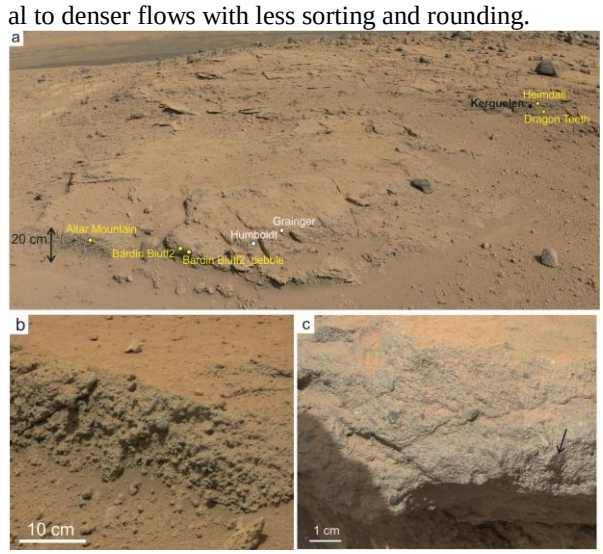

Figure 1: Images of the conglomerates of Darwin outcrop (sol 390). (a) Mosaic of MastCam images. White dots indicate ChemCam only targets. Black dot indicates APXS only targets. Yellow dots indicate common APXS and ChemCam targets. (b) Close-up of the Altar Mountain target (MastCam image); (c) Close-up on the Bardin Bluff target (mosaic of MAHLI images). The arrow to the right of the image indicates the pebble over which APXS was centered.

Chemistry: ChemCam data were acquired on 40 targets spread along the rover traverse from which 6 targets have also been analyzed by APXS. Chemistry of the 40 ChemCam targets recognizes two main groups: samples exposed across the hummocky plains map unit and at Darwin, and a smaller group of conglomerates analyzed in the Kimberley area, located at a higher elevation. Further targets acquired after Kimberley, exposed at even higher elevations, suggest a chem-

ical mixing relationships between these two end-members. Local measurements on the *Darwin type conglomerates* show the predominance of plagioclase mineralogy, with presence of alkali feldspars, in agreement with the high Na_2O/K_2O ratio of 5 to 10. The ChemCam analysis suggests the absence of feldspathoids such as nepheline or leucite. The *Kimberley type conglomerates* are distinct from the Darwin type conglomerates because they show a much higher potassium and iron content and a much lower Na_2O/K_2O ratio (<2). Individual analyses point towards the presence of alkali feldspars, including anorthoclase and sanidine. An explanation of the K-rich component being present as leucite is not supported by the data due to the low Al/Si ratio (<0.5) at these locations.

Comparison with Mars crustal average: The entire dataset of 40 conglomerates display a significant difference relative to the bulk martian crust, especially higher alkali and aluminium, both with ChemCam and APXS (Figure 2). Apart from the Gale rocks, only those of the Columbia Hills at Gusev, presumed to be Noachian in age, display higher alkali content than the average crust, but with relatively low SiO_2 content [e.g., 3]. All post-Noachian data consist of basaltic rocks of which those from the Gusev plains are typical Hesperian-aged examples. Typical Hesperian and younger rocks plot at lower SiO_2 and total alkalis relative to the average crust (Figure 2), whereas conglomerates plot at higher values. Conglomerates provide a possible representative composition for a Noachian component of the crust at Gale crater. Float rocks observed during the rover traverse have diverse compositions, including felsic compositions corresponding to lighter-toned rocks with frequent coarse or porphyritic textures [4]. Many float rocks have compositions consistent with pebbles weathered out from conglomerate outcrops, but a minor part may have been transported ballistically by impacts and may sign other sections of the Noachian crust.

Comparison with finer-grained sediments analyzed by Curiosity at Gale crater: The composition of fine-grained sediments at Pahrump Hills (Murray formation) is consistent with a source similar to a mixing of the two types of conglomerates defined in our study with only small modifications, such as a slight enrichment in MgO observed by ChemCam. Mg-rich diagenetic features have been observed at Pahrump Hills [5] and may have contributed to this overall enrichment. For the Yellowknife Bay formation, the strong differences between the composition of both conglomerates and that of finer-grained sediments cannot be explained by a single process. If these sediments are derived from conglomerates only, both physical sorting and Mg-enrichment from circulating fluids (and/or Mg cements) may explain the systematic shift towards higher Mg compositions. At Kimberley, the specific high-K proportion of Kimberley type conglomerates is consistent with a similar source for conglomerates and finer-grained sediments [6]. Authigenic K-feldspars in fine-grained sandstones is unnecessary given their presence in conglomerates.

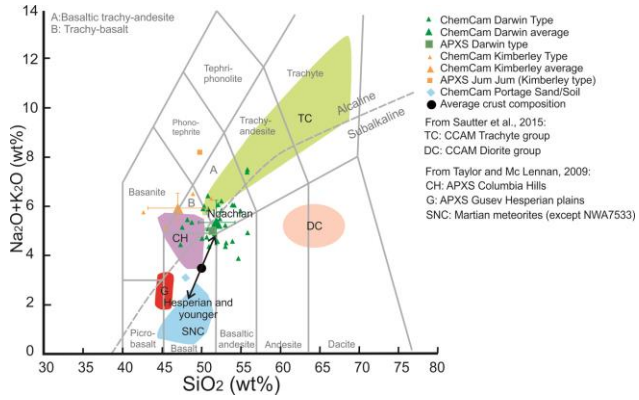

Figure 2: TAS diagram of all conglomerate data (green and yellow plots) compared to some previously published data for the martian crust.

Conclusions: We report the results of 6 conglomerate targets analyzed by APXS and 40 analyzed by ChemCam. The bulk chemistry of both instruments suggests two distinct end-members for the conglomerate compositions. The first group (Darwin type) is typical of conglomerates analyzed before sol 540; it has a felsic alkali-rich composition, with a $Na_2O/K_2O>5$. The second group (Kimberley type) is typical of conglomerates analyzed between sol 540 and 670 in the vicinity of the Kimberley waypoint; it has an alkali-rich potassic composition with $Na_2O/K_2O<2$. The average composition of conglomerates can be taken as a proxy of the igneous crust composition at Gale crater. Differences between the composition of conglomerates and that of finer-grained detrital sediments analyzed by the rover suggest modifications by a combination of physical sorting, diagenetic fluids and mixing with finer-grained material of distinct origin.

References: [1] Grotzinger, J. P., 2015, Science, 350 DOI: 10.1126/*science*.aac7575. [2] Williams R. M. E. et al., 2013, Science, 340, 1068-1072. [3] Mc Sween, 2006, *J. Geophys. Res.-Planets*, 111, E09S91. [4] Sautter, V., 2015, Nat. Geo., doi:10.1038/ngeo2474. [5] Nachon M. et al., submitted to Icarus. [6] Le Deit et al., LPSC, this issue

Additional Information: Imaging and chemical data presented here are available in the NASA Planetary Data System http://pds-geosciences.wustl.edu/missions/msl.