APXS OF FIRST ROCKS ENCOUNTERED BY CURIOSITY IN GALE CRATER: GEOCHEMICAL DIVERSITY AND VOLATILE ELEMENT (K AND ZN) ENRICHMENT. M.E. Schmidt[1], P.L. King[2], R. Gellert[3], B. Elliott[4], L. Thompson[4], J.A. Berger[5], J. Bridges[6], J.L. Campbell[3], B. Ehlmann[7], J. Grotzinger[7], J. Hurowitz[7], L. Leshin[8], K.W. Lewis[9], S.M. McLennan[10], D.W. Ming[11], G. Perrett[3], I. Pradler[3], E.M. Stolper[7], S.W. Squyres[12], A.H. Treiman[13] and the MSL Science Team. [1]Earth Sci, Brock Univ, St Catharines, ON L2S3A1 Canada, mschmidt2@brocku.ca, [2]Res Schl Earth Sci, Aust Nat Uni, Canberra ACT 0200 Australia [3]Univ Guelph, ON N1G2M7 Canada [4]Univ New Brunswick, Fredericton, NB E3B5A3 Canada [5]Univ New Mexico, Albuquerque, NM 87131, [6]U Leicester, LE1 7RH, UK [7]Calif Inst Tech, Pasadena, CA 91125, [8]Rensselaer Polytech Inst, Troy, NY 121808, [9]Princeton Univ, NJ 08540, [10]Geosciences, SUNY Stony Brook, NY 11794, [111]NASA JSC, Houston, TX 77058 [12]Cornell, Ithaca, NY 14850 [13]Lunar Planet Inst., Houston, TX 77058.

Introduction: The Alpha Particle X-ray spectrometer (APXS) on the Curiosity rover in Gale Crater [1] is the 4th such instrument to have landed on Mars [2]. Along the rover's traverse down-section toward Glenelg (through sol 102), the APXS has examined four rocks and one soil [3]. Gale rocks are geochemically diverse and expand the range of Martian rock compositions to include high volatile and alkali contents (up to 3.0 wt% K_2O) with high Fe and Mn (up to 29.2% FeO*).

Methods: The MSL APXS uses ^{244}Cm sources for X-ray spectroscopy to determine abundances of major, minor, and some trace (Cr, Ni, Zn, Br, Ge) elements [1, 4]. A calibration standard [5, 6] and Peltier cooler allows for quality daytime spectra with integrations as short as 10 min. A contact sensor allows reproducible detector stand-off distance for rocks. Penetration depths to the region where 90% of the observed X-rays originate range from 2 to 80 µm for Na to Fe as a function of Z. Cross-calibration with the Guelph lab APXS unit [4] is ongoing [6]. The data presented here are preliminary [1] and do not account for background P, K, Ti, and Ni from APXS components or for stand-off >1cm; refinement will affect accuracy, not precision.

Table 1. APXS observation parameters and SO_3 concentrations

	Sol	Standoff	Dur (min)	wt% SO_3
Jake_Matijevic (JM)	46, 47	Contact	30, 12, 30	2.5-3.0
Bathurst_Inlet (BI)	54	Contact	20, 20	3.1-3.3
Et_Then (ET)	91	~4 cm	120	3.9
Rocknest_3 (R3)	102	Contact	20	4.0
Portage (soil)	89	1 cm	190	5.2

Rock Descriptions: *Jake_Matijevic (JM)* is a dark, fine to med.-grained, vuggy (possibly vesicular), 40-cm tall pyramidal rock. It is float of likely volcanic origin.

Bathurst_Inlet (BI) is a gray, fine-grained rock with cm-scale laminations and a smooth, dusty surface. Morphological similarities link *BI* to the surrounding bedrock.

Rocknest_3 (R3) is a dark, fine-grained, blocky rock with vertical fractures and planar laminations. It appears to be part of the local bedrock.

Et_Then (ET) is a dark, shiny (likely coated) rock with an irregular, vuggy surface. It is float and morphologically similar to nearby rocks of Rocknest, but it is compositionally distinct from *R3*.

Dust coverage. Rocks analyzed by the APXS exhibit varying amounts of dust coverage. This partially and variably masks the underlying rock composition as reflected by SO_3 contents (Table 1): i.e., dust contains S, but the rock itself is expected to be relatively S-poor. *JM* has the cleanest surface in MAHLI images and lowest SO_3. SO_3 contents suggest *R3* and *ET* are similarly dusty and that *BI* has dust cover between that of *JM* and *ET*. We do not correct for dust or volatiles [cf. 7, 8]. Image inspection combined with SO_3 contents are consistent with 5-20% dust contamination.

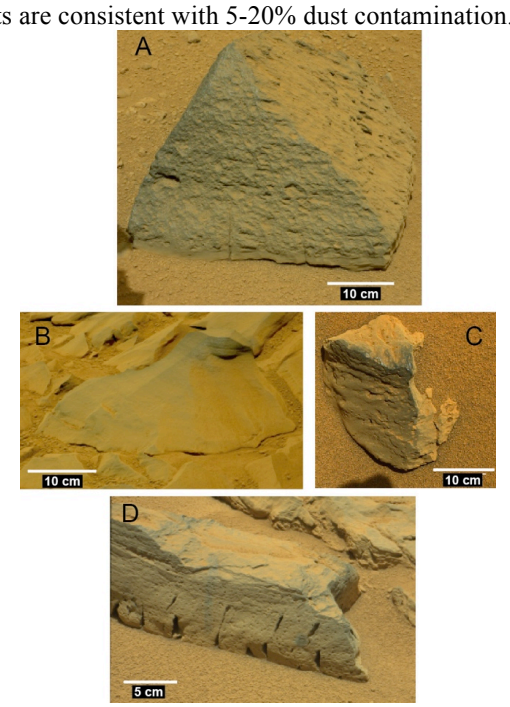

Fig 1. APXS rock targets (A) JM by Mastcam, (B) BI by Mastcam, (C) ET by MAHLI at 80 cm, (D) R3 by Mastcam.

Results: Gale Crater was chosen in part because it is lithologically diverse [9]; this is borne out by the first four APXS analyses (Fig 2). As a group, the Gale rocks span nearly the entire range in FeO* and MnO for the Martian dataset (Fig 2B). In addition, they are particularly enriched in volatile elements (K, Zn, and

~50 ppm Ge in *BI* and *R3*; Fig 2C), distinguishing them from other Martian rocks. *JM* is also notably alkaline and evolved. If its surface contains significant dust the corrected composition has even higher K_2O+Na_2O (Fig 2A). Corrected *JM* analyses suggest it is a nepheline-normative mugearite [7]. The other three rocks plot in the basanite field in a TAS diagram (Fig 2A), with high K_2O (3.0% in *BI*) and low SiO_2 concentrations (43.6-46.0%). These three rocks are SNC-like with high Fe and low Al abundances.

Discussion: With only four rocks analyzed so far in Gale Crater and ambiguity as to their geologic context (e.g. outcrop vs. float; *BI*: sedimentary, volcanic, impact, vs. hydrothermal origin), additional analyses are needed to fully understand the region. Nonetheless, the unusual compositions of these rocks allow some general statements regarding their origin.

JM is the most convincingly volcanic and its alkaline nature suggests high pressure, low degree partial melting of the mantle, followed by extensive plagioclase-free fractional crystallization [7]. Alternately, the parent melt of *JM* may have formed by partial melting of primary or metasomatized mantle or old crust [10].

The three basanitic rocks are notable for high FeO* and Zn abundances, and variable MnO. These elements do not correlate with halogens or S, indicating they are not associated with salts as they are at the Mars Exploration Rover (MER) landing sites [e.g., 11, 12]. Rocks similarly enriched in K, Zn, and Ge were identified aound Home Plate (Gusev), but they are localized occurrences with very high Fe^{3+}/FeO_T [11]. Even so, hydrothermal models for their enrichment [e.g., 13] may apply here. Another comparable Gusev rock is Mazatzal (Fig 2C), which has a K, Zn, and Cl-rich, oxidized rind [14]. Curiosity has no means to assess Fe^{3+}/FeO_T, although *ET* appears to have a dark coating in MAHLI images (Fig 1C). Fe-rich cements formed during diagenesis of basaltic sediments may also contribute to the unique compositions of these rocks.

Data to-date suggest that models of oxidation and acidic alteration developed for the MER landing sites [e.g., 12] may not apply to Gale. The identification of clay minerals at Mt. Sharp from orbit [15] suggests some rocks among the diverse Gale suite may have experienced less acidic conditions. We may need new models for volcanism and aqueous alteration to explain the chemistry of rocks at Gale Crater.

References: [1] Gellert, R et al (2013) this conf. [2] Gellert, R et al (2006) *JGR 111*, E02S05. [3] Yen et al (2013) this conf. [4] Campbell, JL et al. (2012) *Space Sci Rev,* 170, 319-340. [5] Thompson, L et al (2013) this conf. [6] Campbell, JL et al (2013) this conf. [7] Stolper, EM (2013) this conf. [8] McSween, HY et al. (2009) *Science 324*, 736-739. [9] Grotzinger, JP et al (2012) *Space Sci Rev 170*, 5-56. [10] Schmidt, ME & McCoy, TJ (2010) *EPSL 296*, 67-77. [11] Squyres, SW et al (2004) *Science 306,* 1709-1714. [12] Morris RV et al (2008) *JGR 113,* E12S42. [13] Schmidt, ME et al (2009) *EPSL* 281, 258-266. [14] Haskin, LA et al (2005) *Nature 436,* 66-69. [15] Milliken et al (2010) *GRL* 37, L04201. [16] Brückner, J et al (2003) *JGR 108*, E12 8094.

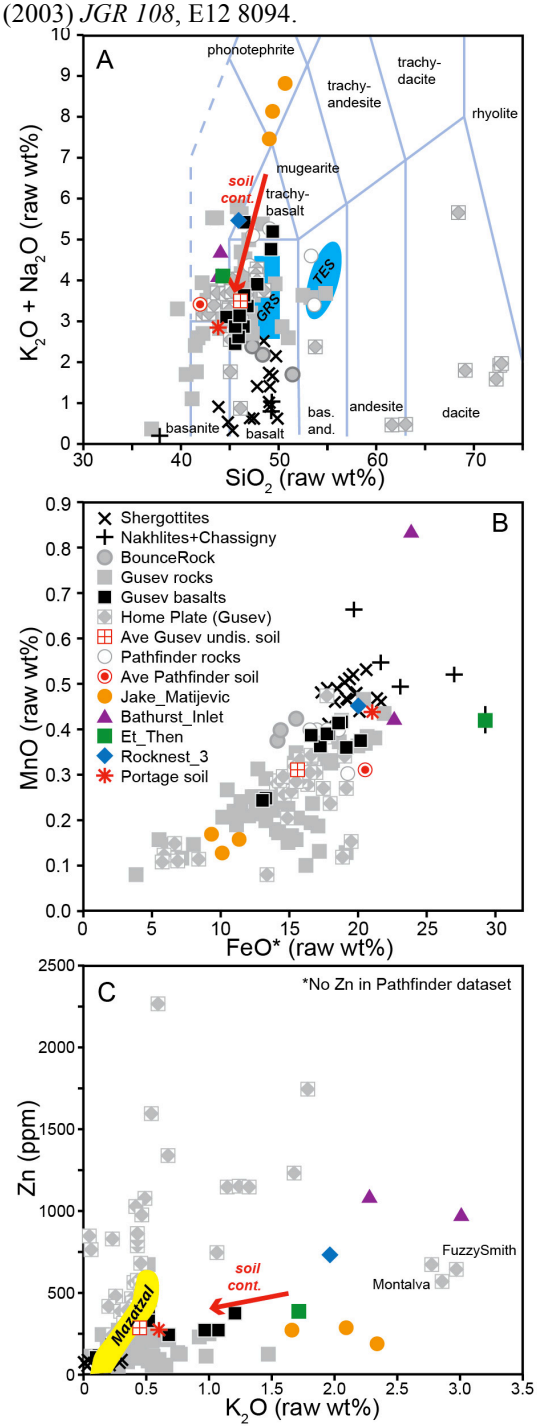

Fig 2. A. Total alkalis vs. SiO_2 after [8]. B. MnO vs FeO. C. Zn vs K_2O. Martian data are from compilation in [8] and [16].*