THE IGNEOUS/UNALTERED ROCKS AT GALE CRATER AS INVESTIGATED BY APXS. M. A. McCraig¹, M. E. Schmidt², L. M. Thompson³, R. Geller¹, J. A. Berger¹, C. D. O’Connell-Cooper³, S. J. VanBormel⁴, N. Boyd¹, ¹University of Guelph, Department of Physics, 50 Stone Rd E, Guelph, Ontario, Canada, N1G 2W1 (mmccraig@uoguelph.ca), ²Brock University, Department of Earth Sciences, St. Catharines, Ontario, Canada, ³University of New Brunswick, Planetary and Space Science Centre, Fredericton, New Brunswick, Canada, ⁴Washington University in St. Louis, Department of Earth and Planetary Sciences, St. Louis, Missouri, USA.

Introduction: The Alpha Particle X-ray Spectrometer (APXS) [1] aboard the Mars Science Lab (MSL) [2] Curiosity rover has been on Mars for six and a half years and in that time has investigated approximately 750 samples of rock, soil, sand and dust. The first rock to be characterized after landing, Jake Matijevic (Jake M) was unique among the rocks previously characterized on Mars [3], including prior igneous rocks characterized by the Mars Exploration Rovers (MER) APXS instruments [3,4,5]. Jake M is a “float” rock, sitting atop the surface, apparently disconnected from the underlying bedrock, and has been classified as a mugaearite/phonotephrite [5,6]. Following Jake M on sol 46, the APXS instrument has investigated a further 15 float rocks that we would characterize as unaltered/very minimally altered/iso-chemically altered igneous rocks, that share remarkably consistent Jake M-like igneous geochemistry and appear to be relatively recently deposited volcanic rocks, largely derived from the uppermost portions of a mugaearitic flow (i.e., vesicular, plagioclase-phyric) which are collectively unaltered representatives of the elevated Na₂O, SiO₂, Al₂O₃ and K₂O reservoir of the two migmatic source reservoirs for the Gale float-[-bed- and sedimentary-rocks suggested by [7].

Methods: The APXS is an arm-mounted, contact instrument which employs six ²⁴⁴Cm sources to irradiate a spot ~ 1.5 cm in diameter (at an ideal stand-off distance). The APXS aboard MSL is an evolution of the MER predecessors and can collect X-ray spectra of sufficient statistics in 10 to 20 minutes per integration, at modest temperatures (FWHM), to allow for robust quantitative determination of major, minor and several trace element abundances [1,8]. The wt% oxide and µg/g (ppm) elemental ratio plots presented herein were produced from APXS reduced data records (RDR) available via the PDS. The images presented were acquired by the Mars Hand Lens Imager (MAHLI), a 2-megapixel focusable macro lens colour camera arm-mounted camera [9].

Results and Discussion: APXS data for the 16 unaltered igneous float rocks: Jake M, Matthew, Ruker, Nedrow, Morehouse, Oneida, Lowerre, Larabee, Clinton, Kodak, Oscar, Reedy, Monkey Yard, Nova, Tyndrum and Arrochar are presented in figures 1 and 2, and select samples are shown in images 1 thru 3. For the suite, all but two, Tyndrum and Arrochar, were encountered in the first ~ 700 sols. Those encountered earliest, atop the distal portions of the Peace Vallis alluvial fan were likely emplaced via mast wasting and fluvial activity late in the formation of the fan and their most likely source region is the Peace Vallis catchment (though emplacement via other means, e.g., volcanic processes or impact cannot be ruled out). Those found between Cooperstown and Dingo Gap were found in locales with uninvestigated breccia/conglomerates in the nearby surroundings and the emplacement mechanism(s) for the igneous rocks investigated in this region and those in their surroundings are likely related. Tyndrum and Arrochar were found in the unique and diverse Bressay deposit of float rocks found atop Vera Rubin ridge and we would not want to speculate about the emplacement mechanism for the Bressay.

These igneous floats share similar morphological features, they are all grey, most contain numerous vesicles and several have what appear to be small phenocrysts, e.g., they are plagioclase-phyric, and to more or less a degree, the majority show the hallmarks of ventifacts, i.e., pitting and scalloping by aeolian erosion, some to such an extent, that for example, Jake M is a nearly textbook example of a dreikanter. They share appearance, and they also share remarkably similar geochemistry (see figures 1 and 2), with elevated Na₂O, SiO₂, Al₂O₃ and K₂O, low MgO and Cr₂O₃, and Fe/Mn ratios of ~ 50 consistent with all the likely to be igneous rocks of Gusev and Meridiani [4].

None of the 16 were brushed or drilled so we should expect varying amounts of surficial dust, as well as soil and sand, as is apparent in the MAHLI imagery, and said coatings do play a subtle role in APXS analyses and interpretation [6], as evidenced in the variation in S, Cl and Br values shown in the ratio plots. It should be noted however, said coatings, while varying visibly from rock to rock have little to no effect on the sodium values (lowest Z, shallowest depth of origination for X-rays, ~ 2 µm), which are consistent amongst the set at ~ 2 times that of dust.

Conclusion: The macroscopic nature of the APXS data collection is robustly representative of bulk geochemistry and the varying dust/soil/sand cover seen in the imagery of these igneous rocks does not meaningfully hamper geochemical analyses. These 16 rocks
share remarkable geochemical and visual similarity which allows us discern the igneous origin of these rocks with a high degree of confidence.

**Figure 1:** Logarithmic ratio plot of major, minor and trace elements provided by the APXS in weight-percent oxides and µg/g (ppm) (Ni, Zn, Br) of float rocks Jake M, Oneida and Tyndrum (Images 1, 2 and 3, respectively) ratioed to Martian average soil, represented by Portage (sol 89). Error bars representative of 2σ statistical error.

**Image 1:** 2.5 cm stand-off MAHLI close up image (0046MH000110010100153) of Jake M, with a 25 cm stand-off MAHLI image inset (0046MH000090010100121).

**Figure 2:** Logarithmic ratios of major, minor and trace elements provided by the APXS in weight-percent oxides and µg/g (ppm) (Ni, Zn, Br) of the 16 unaltered igneous float rocks ratioed to Martian average soil. Error bars removed for clarity.

**Image 2:** 5 cm stand-off MAHLI stereo image (0506MH00022400102006) of Oneida.

**Image 3:** 5 cm stand-off MAHLI stereo image (2018MH0006990010800848C00) of Tyndrum.


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