GEOCHEMICAL CLASSIFICATION OF ROCKS IN GALE CRATER WITH APXS TO SOL 360: SEDIMENT PROVENANCE, MIXING, AND DIAGENETIC PROCESSES. M.E. Schmidt,1, J.A. Berger,2 D. Blaney,3 R. Gellert,4 J.P. Grotzinger,5 O. Forni,6 P.L. King,7 N. Mangold,8 1Brook Univ, St. Catharines, ON L2S3A1 Canada, mschmidt2@brocku.ca, 2Western U., London, ON N6A3K7 Canada, 3JPL, Pasadena, CA 91109, 4Univ Guelph, ON N1G2M7 Canada, 5Caltech, Pasadena, CA 91125, 6Aust Nat Univ, Canberra ACT 0200 Australia, 7U. Paul Sabatier, UPS-OMP Toulouse, France, 8U. Nantes, 44322 France.

Introduction: The MSL Curiosity rover landed in a lithologically diverse region of Mars [1, 2]. As exploration of Gale Crater is ongoing, the amount of geochemical data collected continues to multiply. Working with diverse, and growing datasets requires correlation of rocks of similar composition for the development a common language and models for geologic and geochemical processes.

Classification Scheme: We here build from a simple rock classification scheme for MER data from Gusev Crater [3], whereby rocks were classified based on elemental compositions measured by the Alpha Particle X-ray Spectrometer (APXS). The MSL APXS measures abundances of major, minor, and some trace elements (Cr, Ni, Zn, Br, Ge) of ~1.7 cm spots on surfaces of rocks and soils [4]. Geochemical classes are named for a prominent rock or outcrop. In some instances, related, yet distinct subclasses are also defined. Rock target surfaces were examined by the APXS as is, excepting 3 brushed targets in Yellowknife Bay, and so all analyses are variably contaminated by dust. To account for the S- and Cl-rich dust, all analyses are renormalized S- and Cl-free.

One way the MSL payload differs from MER, however is there are two instruments capable of determining rock chemistry – the APXS [4] and ChemCam, which utilizes Laser Induced Breakdown Spectroscopy (LIBS) to determine compositions of 300-400 μm spots [5]. Integration of the two datasets by the MSL science team is ongoing.

Another distinction from Gusev is that extensive geologic and geomorphic mapping of the Gale landing ellipse, a largely sedimentary setting with HiRISE imaging has been conducted [6]. Geochemically distinct classes that share certain traits (e.g., high or low K2O) were found to generally correlate with geomorphic unit and with stratigraphic position in the Yellowknife Bay Formation [1]. We define such geological and geochemical groupings of rock classes as assemblages [2].

Rock classes: Up to sol 360, the MSL APXS has examined two assemblages (Bradbury and Lower) that encompass seven rock classes, and one subclass. Rocks are broadly interpreted as igneous or sedimentary, and sedimentary rocks largely preserve the composition of their igneous protoliths with little modification little by chemical weathering [1, 2]. A total alkali versus silica diagram (Fig. 1) for igneous classification indicates rock compositions range from basaltic to trachybasaltic to mugearitic/phonotephritic (Fig. 1).

Fig 1. Total alkali vs. silica diagram for APXS analyses of Gale rock classes to sol 360, SNC meteorites, and select landed mission datasets (modified from [2]). RU and RB are unbrushed and brushed analyses.

Bradbury assemblage. The Bradbury assemblage includes the first four rocks examined by APXS during the initial traverse [2], as well as others examined later during the traverse of the Hummocky Plains (HP) unit on the Rapid Transit Route (RTR) to Mt. Sharp. Classes comprised by this assemblage share high K2O (>~1 wt%) abundances (Fig 2A).

The Jake Matijevic (Jake M) class consists of two float rock targets of the HP unit (Jake M and RTR rock Matthew; sols 46 and 360) that are rich in Na, K, and Al (up to 7.1 wt% Na2O). Rock surfaces are pitted and possibly vesicular. A volcanic origin and mugearite classification is based on likeness to terrestrial ocean island alkaline suites [7]. The multiple Jake M class APXS (and ChemCam) analyses of HP floats suggests this class is a significant component of the HP unit.

The Bathurst Inlet class includes the fine-grained bedrock target Bathurst Inlet (sol 54) [2], as well as two more (Pine_Plains and Renssleear; sols 441-442). Bathurst_Inlet has high MgO (8.6-8.9 wt%) and low SiO2 (43.8 wt%) and is most notable for its elevated K2O (up to 3.0 wt%) and Zn (1210-1332 ppm; Fig 2). These rocks are interpreted to be a fine-grained basaltic sandstones/siltstones with compositions largely reflective of its igneous precursor materials.
The **Rocknest3 class** includes one near in place target (Rocknest3, sol 102) next to the Rocknest sand shadow and one bedrock target (Dismal Lakes, sol 304) of the Point Lake outcrop [6]. These rocks have high K\textsubscript{2}O (1.7-1.9 wt%), are intermediate in composition to Jake M and Bathurst class rocks, and are interpreted to be the product of mixing between Jake M-like and Bathurst-like materials, likely by sedimentary processes [2].

The **Et Then class** is named for a float rock target (sol 91) next to the Rocknest sand shadow. The vuggy-textured rock contains a very high abundance of FeO* (total Fe as FeO) of 26.3 wt% and low MgO (4.2 wt%), Al\textsubscript{2}O\textsubscript{3} (8.4 wt%), and Cr\textsubscript{2}O\textsubscript{3} (0.1 wt%). High Fe is thought to result from a Fe-oxide cement or coating [2], possibly added to a Rocknest3 class rock [8].

**Bell Island class.** The Bell Island class includes the dusty Bell Island bedrock target (sol 117), three bedrock targets examined at the Shaler cross-bedded sandstone outcrop (sols 322-323), and the Snake River target (sol 149) interpreted to be a sedimentary dike cross-cutting the underlying units. Compositions are basaltic and range from moderate to low K\textsubscript{2}O (0.42-1.1 wt%), which suggests these rocks are transitional to the Bradbury and Lower assemblages. These rocks stand out for ranging to relatively high Cr\textsubscript{2}O\textsubscript{3} (up to 0.8 wt%) with moderate Ni (Fig. 2).

**Lower assemblage.** The two classes and one subclass of the Lower assemblage were examined at Yellowknife Bay, where a drill campaign was done [6, 7].

The **John Klein class** includes 3 brushed and 18 unbrushed Sheepbed mudstone bedrock targets and a Gillespie sandstone bedrock target [1] (sols 129-287). These rocks are relatively uniform, Fe-rich, and alkali-poor (18.6-22.6 wt% FeO*, 0.3-0.8 wt% K\textsubscript{2}O). Ni is elevated and variable (446-921 ppm; Fig 2). High FeO*/MnO suggests redox reactions involved in its diagenesis.

The **Mavor subclass** of the John Klein class includes 5 Sheepbed mudstone bedrock targets (sols 154-165) with abundant white, cross-cutting veins and high Ca and S content (up to 28.0 wt% SO\textsubscript{3}). CheMin analysis of the John Klein sample suggests these veins are a hydrated CaSO\textsubscript{4}, likely bassanite [9]. The Mavor subclass is not plotted in Figs 1 and 2 because the S- and Cl-free renormalization of the data to account for the dust produces unrealistic compositions.

The **Yukon class** is named for a target with lots of small, rounded pebbles (sol 161) and another target Maya examined along the RTR (sol 373). Yukon has higher Al\textsubscript{2}O\textsubscript{3} and lower Cr\textsubscript{2}O\textsubscript{3} than John Klein, and may be a mixture of Jake M-like and John Klein-like materials.

**Discussion:** Geochemical variations of diverse lithologies suggest mixing between at least three sediment components ±Fe-oxide cement, ±sulfate veins (Jake M, Bathurst, and John Klein; Fig. 2). Identification of the endmember and intermediate rock classes allows the construction of sediment mixing models. The best method for distinguishing the Gale rock classes is by minor and trace elements detectable by APXS, including K, Cr, Ni, Zn, which are more variable than the major elements, particularly for the more mafic classes (Fig. 2). One minor element, K, is a useful stratigraphic marker and likely reflects a greater input of alkaline and feldspar-rich materials in the Bradbury assemblage rocks [2].

---

**References:**


[4] Gellert et al. (this meeting).


[8] Blaney et al. (this meeting).