APXS MEASUREMENTS ALONG THE MSL TRAVERSE AT GALE CRATER, MARS.

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Introduction: The MSL Alpha-Particle-X-ray-Spectrometer(APXS) [1] is the third generation of chemical in-situ instruments of its kind onboard a NASA Mars rover. It measured 54 samples with 83 distinct spots over the first 450 sols along the traverse from the landing site at Bradbury Rise over YellowknifeBay (YKB) towards Mount Sharp.

APXS Performance: The APXS measures typically 16 major, minor and trace elements using x-ray spectroscopy. A short spectrum of a spot at Shaler taken on sol 322, 9pm at -20C is shown in fig.1.

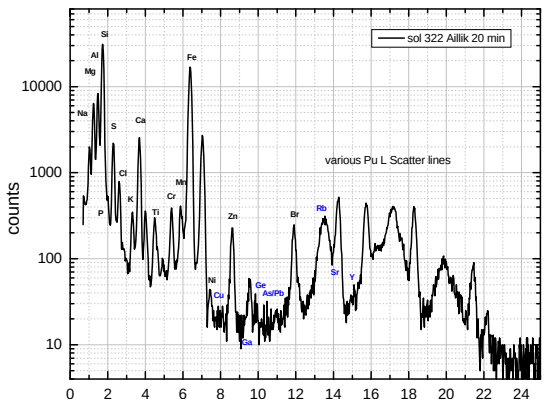

Fig 1 20 minute spectrum at -20C. K lines of standard elements are labelled in black, blue indicates elements quantifiable in longer runs and/or at elevated levels.

The sensitivity is increased ~5 times over MER, a FWHM of <150 eV is reached from fall to spring all day except ~ 1pm and 5pm, allowing pre-drive placements and evening multiple spot rasters. Like on MER the major chemistry can be used to group similar rocks, establish geologic relationship or diagenetic connection between different members. In Gale so far several distinct classes of rocks have been identified based on their APXS chemistry. A very suitable way to plot the chemical trends and distinctions is to ratio the composition to the soil Portage, fig. 2. A logarithmic scale allows to capture the large variations encountered. Dust, possibly covering the real bulk properties, will typically skew the ratio towards 1.

Distinct Rock Classes: JakeM has high Na, Al, K and low Mg, Fe and Ni and was identified being similar in composition to terrestrial Mugearites [2]. Bathurst is rich in K, Fe and Zn. Wernicke is one sample representative for the YKB outcrop, where up to 30%

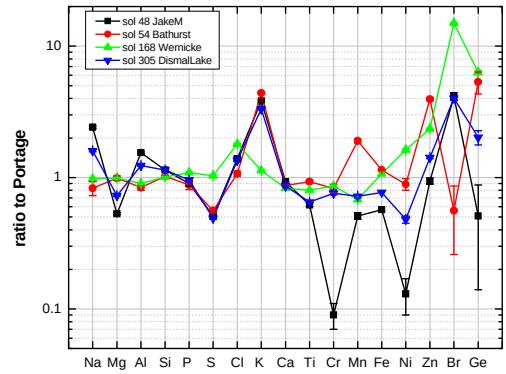

Fig 2: 4 distinct rock classes shown as ratios to soil

clays were identified by Chemin [3]. It has similar major chemistry as the soil or average Mars, with clear enrichments in Cl, Ni, Zn and Ge and a distinct higher Fe/Mn ratio than established for igneous rocks on MER or in SNCs [4]. DismalLake is one of the Shaler samples that have some JakeM like characteristics but with variable K content.

Ge is quantifiable by the APXS for values larger than ~ 30ppm within 20 minutes, e.g. 40±10ppm for the spectrum in fig 1with a visible Ge peak at 9.9 keV.

Trends during the Traverse: Plotting the elements along the traverse (sols), fig. 3, can reveal geologic relationships and boundaries and can be correlated to geological maps. After landing Curiosity traversed the so called hummocky terrain, encountered the float JakeM and several Bathurst type rocks, before it

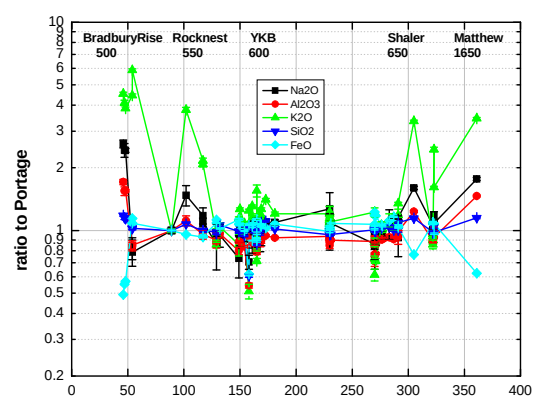

Figure 3: Major elements along traverse as ratio to soil. Terrain names and approx. distance in meters are given.

reached YKB. Curiosity spent sols ~150 to 300 exploring YKB. The compositions of ~20 in-situ spots measured there are remarkably constant, with the exemption of CaSO4 rich vein material (Mavor) and Mg, Fe and Cl enriched raised ridges (McGrath raster)[4]. Drill fines from ~5cm depth are similar in composition to rock surface. Brushed surfaces showed mainly a significant decrease in Sulfur, exposing a very low SO3 content as low as 1%. Leaving YKB a couple of spots were measured at Shaler that showed variable K. Trace elements in Shaler shown in fig 4. reveal additional clues for the rock class relationships. Ni is clearly depleted in Shaler, supporting an admixture of JakeM type material, while Ge, Zn and major elements are more like YKB.

After Shaler the rover started driving expeditiously toward Mount Sharp. APXS integrations were usually done as pre-drive short Touch and Goes or during weekends. Two waypoints (WP1 and WP2) were investigated with several dedicated contact science sols beyond sol 360 several kilometers en route.

Fig 4 shows that Ge is clearly enriched in all YKB spots with values typically from 80-120 ppm and in many Bathurst or Shaler samples. It is below detection limit in soil, in JakeM and at WP1 ~sol 395, but again present in all WP2 samples. WP2 shows a striking similarity of all major and minor elements with YKB rocks.

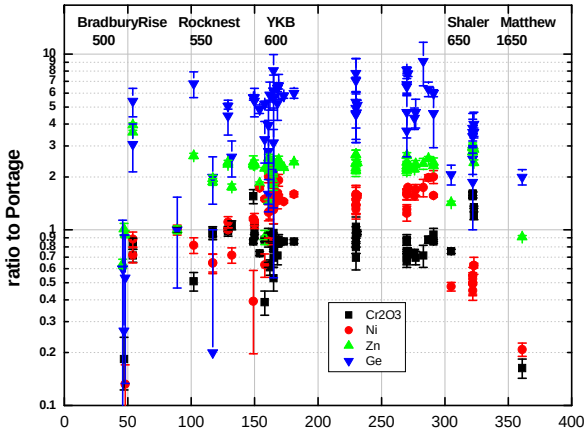

Figure 4: Minor and trace elements along the traverse

The strength of APXS sampling along the kilometer long traverse became clear, when on sol 360 the float rock Matthew was examined. As visible in fig. 5 Matthew, as well as other following samples resemble all characteristics of JakeM, albeit slightly lower Na. This confirms that the float rock JakeM is not an isolated appearance, but an important type of rock in Gale Crater, as well as possibly at different places on Mars.

K shows a peculiar behavior at Gale Crater so far. In JakeM type K is clearly elevated correlated with the higher feldspar component. In the Bathurst and Shaler type, however, it is typically decoupled from feldspar elements and sometimes highly enriched [5]. YKB outcrops typically show a K/Na similar to soil.

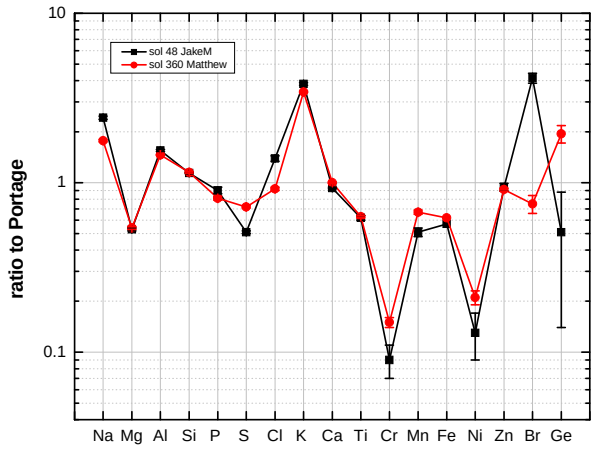

Figure 5: Comparison of JakeM and Matthew

Summary: The APXS has identified various new rock classes previously unreported on Mars during the traverse at Gale Crater. APXS data allow unique comparisons with MER and showed some striking similarities with other landing sites (Opportunity: Cape York average basaltic composition, CaSO4 veins [6], Spirit: Home Plate, Columbia Hill alkaline basalts, Martian soil) as well as with new Martian meteorites, e.g. [7]. Possibly the most remarkable result from the APXS at Gale Crater is the low SO3 content of about 1% at the brushed YKB spot. This contrasts sharply to the many high sulfate findings on MER, indicating more habitable environmental conditions at Gale crater, which will be further investigated on the way to Mount Sharp.

References: [1] Gellert et al. (2009) *LPSC*, #2364, [2] Stolper et al. (2013) *Science* , 1239463, [3] Vaniman et al. (2013) *Science*, 1243480, [4] McLennan et al. (2013) *Science*, 1244734, Schmidt et al., this conference, [6] Squyres et al (2012) *Science*, **1220476,** [7] Agee et al. 2013, *Science* **1228858**

Acknowledgements: The MSL APXS is managed and financed by the Canadian Space Agency, with MDA as prime contractor to build the instrument.
Science team funding is provided by CSA and NASA. We appreciate and acknowledge the unwavering support of dedicated engineers at JPL during operations