COMPARING GALE CRATER AND GUSEV CRATER ENRICHMENTS OF FLUID-MOBILE ELEMENTS MEASURED BY ALPHA-PARTICLE X-RAY SPECTROMETERS ON MARS.

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Introduction: The exploration of Gale Crater by *Curiosity* over sols 0-360 has revealed clear enrichments in fluid-mobile elements by alpha-particle X-ray spectrometry (APXS) [1-2]. This is mirrored at locations investigated elsewhere by APXS on Mars [e.g., 1-3]. Knowing the occurrence and distribution of elements mobilized by fluids is useful for interpreting aqueous processes on Mars. Here, we present APXS data for sols 0-359 in Gale Crater and compare it with select samples from the Mars Exploration Rover mission in Guesv Crater (MER-A).

Approach: The fluid-mobile element abundances – Cl, Br, Na, K, Zn, and Ge – for all rocks investigated by APXS on *Curiosity* sols 0-359 are presented (Figs. 1-2). These comprise the classes [4] 1) Jake_M, a mugearite float rock; 2) Bathurst_Inlet, a fine-grained sandstone/siltstone; 3) Rocknest3, likely derived from Jake_M and Bathurst_Inlet material; 4) Et_Then, a high-FeO* (~26 wt%) float rock (high error from high standoff); 5) Bell Island clastic sedimentary rocks; and 6) John Klein sedimentary rocks (JK) at Yellowknife Bay (YKB) [5-7]. We excluded targets containing S-rich veins and nodules as well as analyses with higher FWHM (>215 eV, Fe) due to higher temperatures.

We compare the Gale Crater results to select MER-A APXS results for rocks with enrichments of Cl, Br, K, Zn, and Ge in Gusev Crater. These occur at Home Plate (HP), an 80 m outcrop of altered basaltic tephra, and the Low Ridge outcrop (LR) ~20 m south and underlying HP [8]. MER-A targets include HP rocks Barnhill and Pesapallo, LR rocks Montalva and Grahamland, and FuzzySmith, a SiO_2-rich (68 wt%) float rock on top of HP [3]. Irvine, a proposed protolith for the rocks in this region, contrasts the enrichments [3]. Unabraded rocks are compared because *Curiosity* does not abrade surfaces.

Enrichment/depletion of elements was determined relative to local soil composition by element ratios (Fig. 1) using the Rocknest sand shadow target Portage (sol 89) for Gale soil and average undisturbed soils for Gusev, excluding sulfate- and silica-rich soils. Soil is similar at different Mars exploration sites and may approximate the average surface basaltic protolith with an input of global dust [9].

Gale Crater: Halogen elements in Gale range to highest levels of enrichment at the Shaler outcrop (Bell Island class) and in JK rocks (Fig. 1). Dust does not necessarily increase Cl concentrations; Cl is 1.6-2.8 times greater than the soil (Portage ~0.6 wt%) and does not decrease with brushing. Drill fines at the Cumberland site (sols 283-287) are also enriched in Cl (~1.4 wt%), however, JK drill fines ~2.5 m away

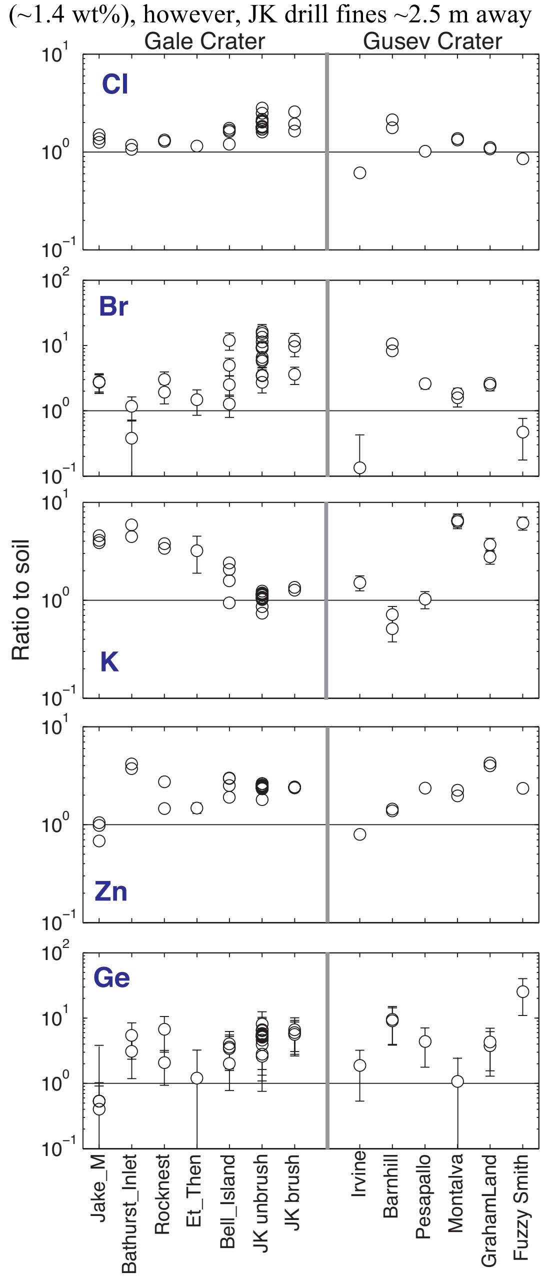

Fig. 1: *Element ratios (rock:soil, see text) of fluid-mobile elements in rocks in Gale Crater sols 0-359 and selected rocks from Gusev Crater sols ~200-1200.*

(sol 230) have lower Cl (~0.6 wt%) than the unbrushed and brushed surface (1.1-1.8 wt%). Further heterogeneity in the subsurface is seen in Cl enrichment in raised veins (McGrath; sol 270). This distribution of Cl indicates subsurface fluid flow. Br concentrations in the JK rocks are also variable (93-578 ppm), and span a greater range than Cl (Br ~3-15 x soil). Br does not follow trends with drilling or brushing, so the Br depth distribution is unclear. Heterogeneity in Br is consistent with observations by MER, and is attributed to multiple processes [9]. Excluding the highly variable JK rocks, Cl and Br have a positive correlation that is broadly consistent with mobile halogen salts.

K enrichment in Gale clastic sedimentary rocks (0.7-5.9 x soil) is attributable to igneous alkali feldspar (Fig. 2a) [7]. The high alkalis in Jake_M, interpreted to result from partial melting of metasomatized mantle [5-6], point to Jake_M-like material as a protolith for K-rich rocks [7]. However, a change in provenance is evident in the underlying, lower-K JK rocks [7]. More high-K rocks have been encountered in sols 360-450, and its distribution may further constrain K mobility.

Zn and Ge levels in Gale Crater are higher than soil (Zn ~1.5-4.2, Ge ~1.2-8.1 x soil) in all rocks except Jake_M (Fig. 1). Zn does not vary predictably with K_2O (Fig. 2b). Zn and Ge have a positive correlation indicative of aqueous mobilization, however, Ge is concentrated in JK rocks with no change in Zn (Fig. 2c). Unlike typical Earth hydrothermal systems [10], no correlation is apparent between the halogens and Zn or Ge. However, Ge does not change predictably with SiO_2, as expected with Ge-Si substitution in silicates, therefore Ge may have been mobilized in fluid.

Excepting vein- and nodule-containing rocks, S is depleted (0.2-1.4 x soil). The lowest values are seen in brushed JK targets (Werneke sol 169, SO_3 ~0.9 wt%). S-rich dust and S correlation with dust coverage are evidence that measured S is dust-influenced [11-12].

Synthesis- Gusev and Gale Craters: The interpreted basaltic protolith for HP, Irvine, is depleted in halogens and Zn, and has low Ge (Fig. 1) [10]. Irvine-like material was likely altered in a hydrothermal system at or near HP, causing the localized concentration of Cl, Br, K Zn, and Ge in HP and LR rocks (Figs. 1-2) [10]. This is supported by evidence of sulfate fumarolic deposits, highly altered rocks, and high-silica rocks and soils (≤ 90 wt% SiO_2) [3, 8].

While enrichments of fluid-mobile elements call for a comparison of aqueous processes in Gale and Gusev Craters, the evidence of hydrothermal activity seen in Gusev has not been found in Gale. Limited low temperature alteration has been interpreted for Gale, particularly in JK rocks [e.g., 7, 13], and these processes may have increased the concentration of fluid-mobile elements. However, hydrothermal and/or volcanic exhalative activity in, or adjacent to, Gale is plausible. These could be caused by impact or volcanic processes. To determine if fluid-mobile element enrichment is caused by secondary alteration (possibly hydrothermal), or if it reflects the igneous protolith composition, we will need to investigate the distribution and occurrence of these elements along the traverse of the crater floor and up Mt. Sharp.

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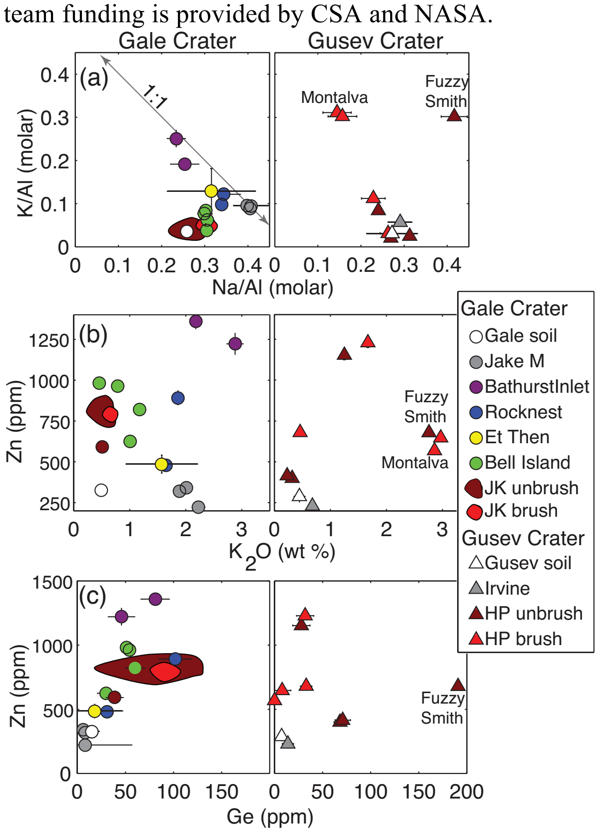

Fig. 2: *Concentrations of (a) K/Al versus Na/Al, (b) Zn versus K_2O, and (c) Zn versus Ge for Gale (circles, polygons) and Gusev (triangles) Craters. The line in (a) indicates 1:1 stoichiometric mixing of phases containing alkalis coupled with Al (e.g., alkali feldspar).*