GERMANIUM ENRICHMENTS IN THE CLAY-SULFATE TRANSITION AND THE MARKER BED AT GALE CRATER, MARS

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Introduction: On Mars, germanium is usually a trace element with a few ppm abundance [1]. Already the MER APXS [2] found many strong enrichments in Gusev Cater and Meridiani Planum, which typically coincided with other elemental or mineralogical indicators for fluid interactions [3]. In Gale Crater, elevated germanium was first detected shortly after landing at levels of ~100ppm [4]. The same, very consistent enrichment was found throughout the Mt. Sharp group, most likely a lake deposit, uphill to the current position of the Curiosity rover some 600 meters higher in elevation [5]. Soils, intersecting aeolian sandstones and likely igneous floats show levels at or below the approximate detection limit of 30ppm for long APXS integrations.

Here we report on recent Ge levels in the Clay-Sulfate transition zone (CST) and the MarkerBed (MB). Beside indicating possible relations between different stratigraphic layers and the level of alteration, we also use germanium to discuss the bulk composition trends in the recent drill attempts at Amapari in the MarkerBedValley (MBV).

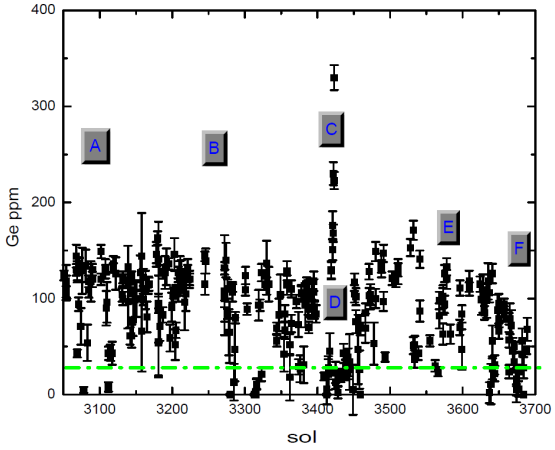


Figure 1: Ge abundance along the traverse

Results: Fig.1 shows the Ge abundance beginning at the Nontron drill target in the clay bearing unit (CBU) throughout the CST up to the current position at the MB. Prominent geographic points along the traverse are:

A: upper CBU

B: Zechstein drill target with less clay

C: Potassic Greenheugh Pediment (GHP), elevated Ge

D: Soil-like rocks of the GHP

E: MBV, Canaima drill target with $MgSO_4$, no clay

F: MarkerBed

As seen in the graph, germanium has a constant abundance of ~100ppm, beginning from YellowKnifeBay through Pahrump, Vera Rubin Ridge, the CBU up to the recent drill sample Canaima that contains crystalline Mg-sulfates [6] and likely more in an amorphous phase based on correlated Mg and S in APXS data [7].

A short diversion uphill led the Rover back onto the GHP, where earlier (~sol 2700) in the north low Ge was in the drill sample Edinburgh.

The few rocks that have elevated Ge on the pediment bear striking similarity with potassic rocks, also with elevated Ge, found at Bradbury landing and The Kimberley, as seen in Fig. 2, where the standard 16 APXS elements are ratioed to the soil Portage as aliquot for average Martian composition.

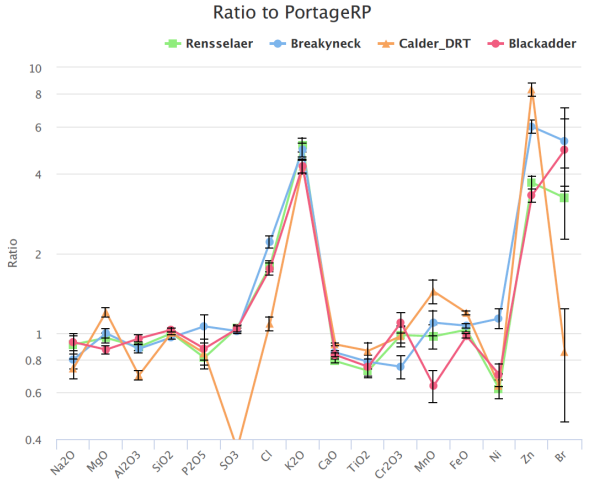


Figure 2 Pediment rocks

However, a second population on the pediment, indicated by **D** in Fig. 1 shows no elevated Ge, but still has a lesser enrichment in potassium [8]. This seems to indicate that the processes that enriched Ge over the high Ge baseline was not large scale. On the other hand, the highest Ge abundances were found in obviously altered locations, like in the GardenCity vein system.

MarkerBed: The first measurements of the MB around sol 3650 showed ~35% FeO, 1.5% Zn and MnO, 2.5% Cl and 0.4% Br in several samples [9]. Fig. 3, the log ratio to soils, shows these elements are added to an average basaltic component. Note that Zn and Br are through the roof of this log plot with ~100 times enrichment over soil. Also note, that the lower Na might be impacted by the L-line of the extraordinary high Zn.

Amapari_DRT was the usual triage for the drill campaign in the MB. Two drill attempts failed, nevertheless

allowed access to the deeper layers of this intriguing rock, likely representative for a large scale formation from orbital mapping [10].

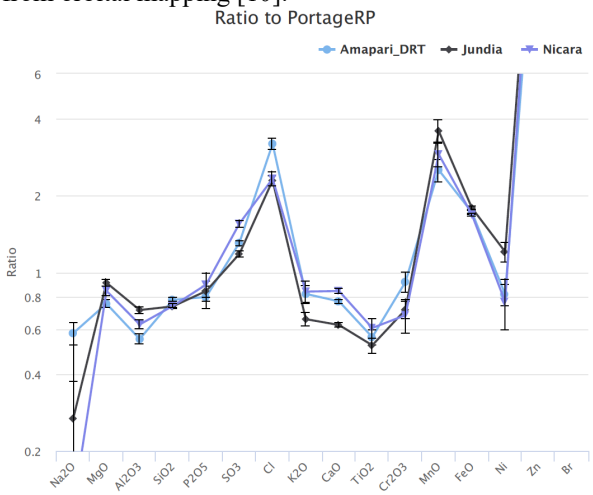
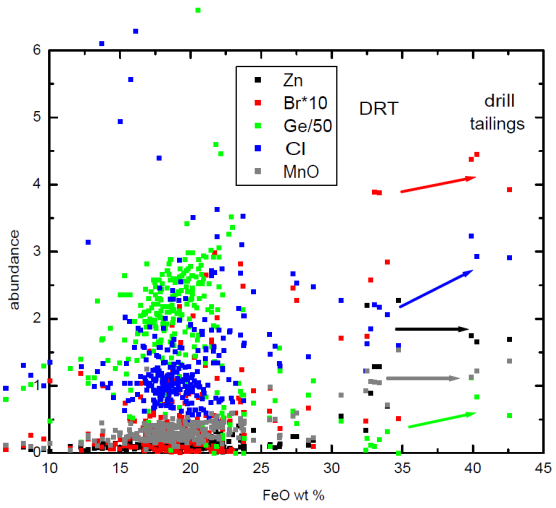


Figure 3 Amapari and other MB rocks

Fig. 4 shows the four highly enriched elements against FeO, which actually goes up from 35 to ~40% in the ~1cm shallow drill holes, partly covered by tailings. These measurements represent a significantly deeper look inside the rock. The high Z elements above Fe have a typical information depth of at least 50 µm for their characteristic X-rays, usually enough to still detect the bulk composition even through dust and possible alteration rinds.

For all MSL drill holes, the APXS results of tailings and dumped drill powders are regularly compared to the DRT surface to check if any significant differences within the first ~5cm is visible. For most elements the results agree well. However, in several occasions, Cl and Br went significantly down in the drill sample and tailings, indicating a thin halogen salt-enriched layer at the surface.

While the drill attempts only penetrated ~1cm, Fig. 4 indicates that all highly enriched elements stay constant or even increase with depth. Curiously, germanium, which was around the detection limit in the DRT and other MB samples, increases to ~50ppm. This indicates that the elemental signature of this MB rock is not a surficial alteration rind, which is consistent with the hardness that prevented a full drill. Germanium seems depleted in the top ~100 µm. Interestingly, this could indicate that Ge was removed during the processes that enriched the surface with Cl and Br in many rocks in Gale Crater and emphasizes the importance of drill samples accessing deeper layers.



Discussion: Germanium, about 30-fold enriched over the average Martian meteorite content, is found throughout the 600 m elevation gain in the Mt. Sharp group. It maintains its constant value, regardless of changes in secondary alteration minerals from clays to hematite to sulfates so far, together with the overall bulk chemistry. Aeolian sandstones, soils, likely igneous rocks, the Silica rich halos and the all-present late stage Calcium-sulfate veins show low Ge abundances.

The highest values of Ge are found in locations with clear indication of localized alteration, like the large scale vein system GardenCity. The information depth of the 10keV Ge X-rays is usually large enough to sample the bulk, not impacted by dust or thin rinds, even in short 20 minute measurements without brushing. Data from the MB drill attempts show that Ge is likely present at APXS detectable levels in the MB with lower Ge abundances at the surface.

This might indicate that the process that formed the MB either had the germanium in it or a process mobilized Ge between the MB and the Murray formation.

References: [1] Lodders, Fengley, 1998, [2] Rieder et al (2003) JGR, [3] Mittlefehldt et al, (2020), JGR, 305, [4] Gellert, Clark, (2015) Elements,11(1), [5] Berger, J. A., et al. (2017), JGR, 122, [6] Rampe et al, this conference, [7] Berger et al, this conference [8] Thompson et al, EPSC, 2023, [9] Thompson et al, this conference [10] Weitz et al, this conference

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