UNDERSTANDING THE EFFECTS OF TRIBOELECTRIC CHARGING ON CROSS SAMPLE CONTAMINATION IN THE MARS SCIENCE LABORATORY SAMPLE HANDLING SYSTEM.

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Introduction: Accurate scientific analysis requires that materials collected and analyzed by in-situ instruments represent the initial (chemically and mineralogically), unaltered material prior to its collection and delivery. This is not always achievable for automated robotic in-situ analysis because of the challenges faced with collecting and distributing the sample to the on-board instruments. One significant challenge facing the MSL Sample Delivery System is cross contamination between samples [1,2]. Cross sample contamination needs to be minimized or better understood so that samples analyzed by analytical instruments can be correctly correlated and put into the proper scientific context. There are three main mechanisms that can cause samples to be altered as they pass through a sample acquisition, handling and processing chain: 1) differential comminution, where one type of mineral is preferentially created 2) thermal alteration of material in the creation of fine samples (drilling, crushing), and 3) adhesion due to electrostatic build up. Here we will discuss the effects of adhesion resulting from electrostatics and the alteration of the sample that may occur.

***Background*:** Electrostatics deals with charged particles and the potential of materials to gain or lose electrons. Moving particles cause electrostatic charging, specifically triboelectric charging, which occurs when particles become charged as they are moved when they are in contact with other particles or other materials (e.g. walls of the sample tube). The presence of induced charges on particles causes individual particles to either stick together due to the attraction of opposite charges (adhesion) or repel each other due to the presence of like charges (repulsion). Under the cold, dry, dusty ambient conditions found on Mars, triboelectric induced charging of materials should readily occur and may complicate controlled particle transport in much the same way it affects particle movement in terrestrial dry environments. For the Martian environment, it is important to understand the role of electrostatics in the transport and adhesion of fine-grained particles [1,2].

There are two forms of triboelectric charging that have been observed to occur on Earth as sown in Figure 1 [1-4]. While individual particles can have different net charge, the bulk material can become charged due to grain to grain contact of different minerals constituents in the sample and/or through grain contact with the wall. This results in a very complex system of particle interaction that has yet to be fully understood and characterize. This effect can lead to a charged volume of sample adhering to a wall through attraction to a mirror charge created in a metal. No electrostatic repulsion will occur if the entire sample is all charged with the same polarity. This can cause different types of phenomena including 1) charged particles *clumping* together, not moving through a sieve, 2) charged particles *sticking* to surfaces; retention causing cross-contamination problems, 3)charged particles *clogging* up tubes and openings and ceasing to flow.

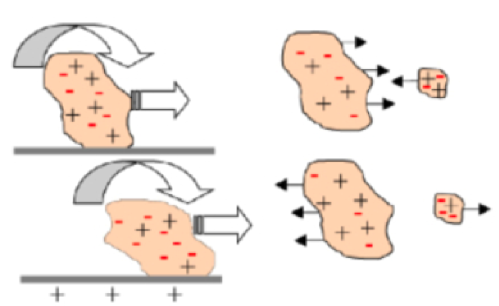

Figure 1. Two types of triboelectric charging. *Left*, when dissimilar material comes in contact charge transfer takes place. In this case electrons have transferred onto the material cause it to have a negative charge, and leaving the hardware with a net positive charge. *Right*, when the same type of particles interact the larger particle can lose an electron to the smaller one, resulting in one particle to be positively charged and one to be negatively charged.

***Adhesion*:** Figure 2 shows several clumps that were generated from loose basaltic material that was triboelectrically charged and simply poured from a titanium tube under ambient Martian pressures. Numerous clumps of basaltic materials can be identified. Understanding the formation of these materials is critical for Martian landed missions. In order for MSL to maximize scientific results, it is important to characterize how electrostatic charging may affect the transport of fine-grained samples in the Martian environment, and how this charging might bias the quality of the material that is delivered to the science instruments.

***Experimental Setup*:** In a Mars simulation chamber, 1 g of Mars Mojave Simulant (MMS) was placed inside a titanium tube, the system was pumped down to Martian ambient conditions, and the sample was transferred into a collection plate while using vibration and gravity to feed the sample through the tube. Table 1 illustrates the amount of material that was transferred for six different particle sizes. In a second test, we ran the same material and particle size numerous times to simulate the MSL sampling system. For this procedure, we place 150-125 µm material through the tube three times (Table 2). After each run the chamber was quickly brought up to atmospheric pressure, 1g more sample was added, and the chamber was pumped down again and the process was repeated. No effort was made to clean the tube, and it remained electrically isolated from traditional ground.

Fig 2. Result of transferring 1 g of Mars Mojave Simulant (MMS) in a simulated Martian environment. This material, when introduced consisted of fine particles of less than 150 µm diameter. In the process of transferring the material, clumping readily occurs (shown with red arrows.).

Table 1. Amount of material transferred versus particle size.

Size (µm)	Sample Mass (g)	Amount Passed (g)	% Passed
> 150	1.0248	0.9141	89%
150-125	0.9771	0.8776	89%
125-75	1.0552	1.0274	97%
75-63	0.9703	0.9179	94%
63-32	1.0226	0.9926	97%
<32	1.0767	1.0387	96%

Preliminary Results: Table 1 shows the effects of transferring different diameter particles through the titanium tube. As the size of the particles decrease the amount of material that passes through the tube increases. This indicates that material from each particle size fraction (below 150 µm) displays adhesion of particles to the walls of the tube (Note: with the size of the chamber and the diameter of the tube it is not possible to see within the tube). Once a layer of material has been deposited, subsequent material flowing through the tube is not affected. This is especially true for the smallest particles where the charge on the particles dominate. This is illustrated in Table 2 were the amount of material transferring through the tube increases (up to 99%) after each subsequent sample. It is conceivable that a sample introduced into the CHIMRA sample handling system on MSL may require multiple "cleaning" operations before it exists the CHIMRA system; complicating the ability to correlate mineralogy of a sample and instrument analysis. This is illustrated in Figure 3. Figure 3 is a photograph of two different materials that were transferred right after each other while no attempt was made to clean the tube. Here the MMS was transferred at mars simulated conditions after a black hematite material had previously been transferred. From the photo it is evident that there is a lot clumping and cross sample contamination.

Table 2. Amount of material remaining after multiple samples.

Amount Introduced (g)	Amount Passed (g)	Accumulated inside the tube (g)
0.9618	0.9331 (97%)	.0287
0.9701	0.9573 (98%)	.0415
1.0766	1.0761 (99%)	.0420

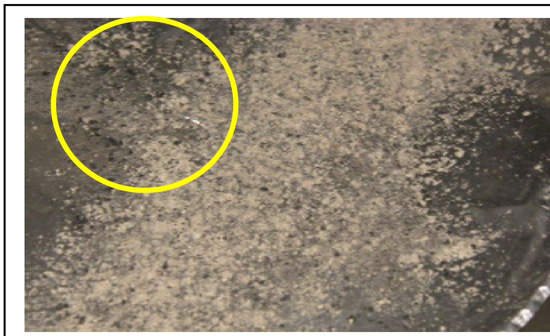

Fig 3. Result of transferring 1 g of Mars Mojave Simulant (MMS) after 1 g of black hematite had already been passed (see yellow oval).

References: [1] Anderson R.C. et al. (2009) *Icarus 204*, 545-557. [2] Beegle L.W. et al. (2009) *Icarus 204*, 687-696. [3] Stow C.D. (1969) *Weather 24*, 134-139. [4] Forward K.M. et al. (2009) *PRL 102*. 1-4.