

EVAPORATION AND DELIQUESCENTE RATES OF MARS ANALOG SEDIMENT-BRINE MIXTURES.

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Introduction: Studies suggest that liquid brines may have a connection to recurring slope lineae on Mars by altering the freezing point and evaporation rate of water [1]. While previous research has investigated the deliquescence of salts such as magnesium and calcium perchlorates [2], mineral-brine interactions may affect deliquescence and evaporation rates due to surface tension [3] and interlayer charge effects [4].

Here we investigate the potential effects of sediment-brine interactions on evaporation and deliquescence rates to better understand the behavior of brines at the surface of Mars. We focus on magnesium chloride and sodium chloride brines, as these salts have been previously observed on Mars [5], and fine-grained basalt sand, kaolinite, montmorillonite, and JSC-Mars 1 soil simulant [6], representing a range of potential Mars-analog solid compositions.

Methods: We obtained montmorillonite and kaolinite from the Clay Mineral Society, micronized McKinney basalt from the University of Oklahoma's research collection, and JSC-Mars 1 simulant soil from NASA. We conducted evaporation and deliquescence experiments within a sealed vinyl reaction chamber in the laboratory at 298K to control as many variables as possible. Samples of sediment, salt, and/or brine were massed and placed in aluminum weigh boats that were then housed in the sealed container to minimize humidity variations. Temperature and humidity were recorded using a RH83 Digital Psychrometer.

Evaporation Experiments: In the first set of experiments, we mixed 0.75 grams of each sediment and 1.00 mL of solution (15 wt% $MgCl_2$, 10 wt% NaCl or ultra-pure water) in individual 70mm diameter aluminum weigh boats, along with a control sample that contained only solution. The mixed samples were weighed and then placed in the sealed chamber with a beaker of near-saturated $MgCl_2$ brine to buffer the humidity. Each weigh boat was measured at least twice in the first two days and once a day for another three days until the mass did not fluctuate significantly.

Deliquescence Experiments: In the deliquescence experiments, 0.75 grams of sediment and 0.75 grams of anhydrous $MgCl_2$ or NaCl salt were mixed in individual weigh boats, along with weigh boats containing only sediment or salt as controls. These were weighed and then placed in the sealed container with three 250mL beakers containing ultra-pure water to increase humidity and create an environment for deliquescence. The mass of each weigh boat was measured in the

morning and evening for the first two days then every morning thereafter for an additional five days.

Results: Evaporation Rates: Evaporation rates of all sediments follow an almost identical path through the first ~4 hours (Figure 1).

Following this evaporation period, all three solution mixtures with the JSC-Mars 1 soil simulant consistently showed more mass loss than the other samples. The basalt had a slightly slower evaporation rate in the brine solutions. In the UPW experiments, the UPW control has an initially slower, but more linear evaporation rate compared to the UPW-sediment mixture.

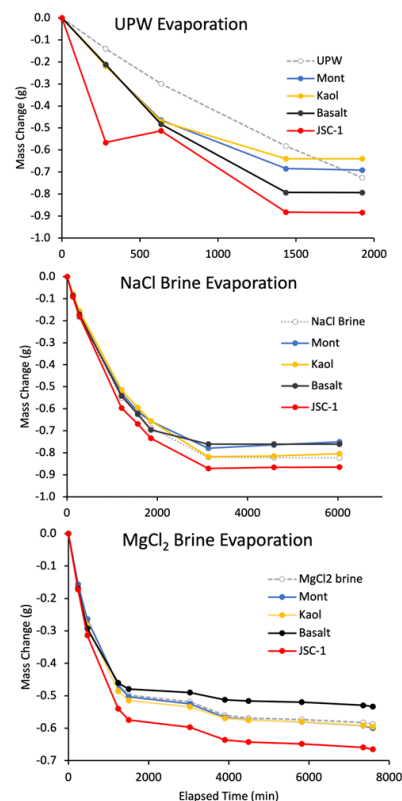


Figure 1: Evaporation rates in UPW, NaCl brine and $MgCl_2$ brine mixtures.

Deliquescence Rates: We did not observe any visual evidence of deliquescence, nor did we observe any mass increase in NaCl + sediment mixture or the sediment only samples throughout the experiments. However, abundant deliquescence was observed in all the experiments containing $MgCl_2$ salt (Figure 2). The observed mass changes suggest that $MgCl_2$ deliquescence occurs at a faster rate than evaporation.

Similar rates were observed in all MgCl_2 + sediment experiments as well as a sample containing only MgCl_2 salt.

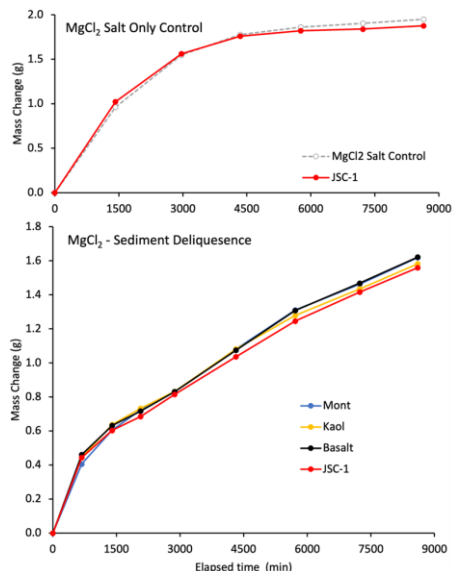


Figure 2: Deliquescence rates of MgCl_2 salt mixtures.

Discussion: The UPW experiments were the only samples that showed a significant difference in evaporation rates between the solution only control and the solution-sediment mixture. We hypothesize that surface area may play a role in the UPW experiments, with evaporation rates increasing with surface area. In this case, the UPW control has a much smaller surface area than the UPW-sediment mixtures, where the water coats individual grains. Therefore, the water only control shows a slower, linear evaporation rate, compared to the faster initial rates observed in the UPW-sediment samples that have more surface area.

In addition, the UPW control does not contain any solutes to alter the concentration of the liquid during evaporation. However, solutes may be added to the UPW in the sediment mixtures through alteration and leaching [7], decreasing the activity of water as the solution evaporates, thus slowing the evaporation rate as observed.

In addition to leaching, cation exchange reactions may also affect solute chemistry in the brine-sediment experiments, particularly in the clay experiments. Secondary minerals have been detected when clays such as montmorillonite and kaolinite are mixed with brines, suggesting cation exchange occurs quickly in these systems [8]. Isomorphic substitution is extensive in montmorillonite while negligible in kaolinite, resulting in montmorillonite having a much higher cation exchange capacity - 89meq/100g compared to 3meq/100g [9]. Therefore, slight differences in evaporation rates observed between kaolinite and

montmorillonite may be due to cation exchange reactions affecting solution chemistry. We hypothesize that short-term aqueous alteration reactions may also affect the apparent evaporation rate observed in the JSC-1 samples. JSC Mars-1 contains a significant volatile species [6], that may be released via aqueous alteration.

In contrast, deliquescence rates observed in all four sediments mixed with MgCl_2 salts were remarkably similar, as well as a control experiment comparing the deliquescence behavior of pure MgCl_2 with MgCl_2 salt mixed with JSC-1. This suggests that the mineral component does not influence deliquescence behavior.

In the Martian arctic, research has shown large diurnal variations of water vapor pressure (two-orders-of-magnitude) suggesting a strong atmospheric-regolith interchange [10] in addition possible evidence of brine formation on the Phoenix landing struts [10]. This research shows that sediment-brine interactions may alter evaporation rates due to changes in surface area and/or solution chemistry, but deliquescence rates are unaffected by sediment. This work provides insight on how sediment-brine interactions and atmospheric-brine interactions could potentially play a role on deliquescence and evaporation rates. Understanding these rates contribute to a fuller understanding of Martian geochemistry and the atmosphere.

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