CRYSTALS, CRACKS AND DUST: FROM THE PLAYA TO MARS

Jenny Verniero

Motivation

- Dust:

-mineral transport to ocean, effects marine geochemical cycle

-Global climate change

-Mars

- Cracks:

-increase roughness, produces dust

-form when surfaces erode

-cycles of wetting and drying

How do we study cracks and dust?

- Infrared Camera

-uses infra-red energy as opposed to visible light to form an image
-detects black-body radiation as a function of temperature

- Zygo Proflometer

-uses Scanning White Light Interferometry (SWLI) to capture a 3D image at a nm scale

- Numerical Modeling

-computer programming can predict patterns of drying

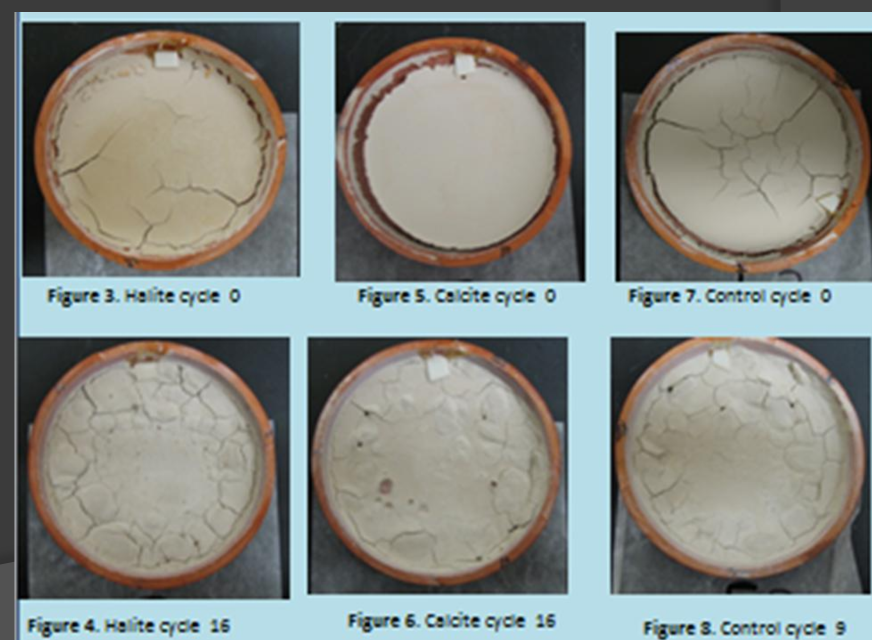
Materials

- Surfaces: clay and silica

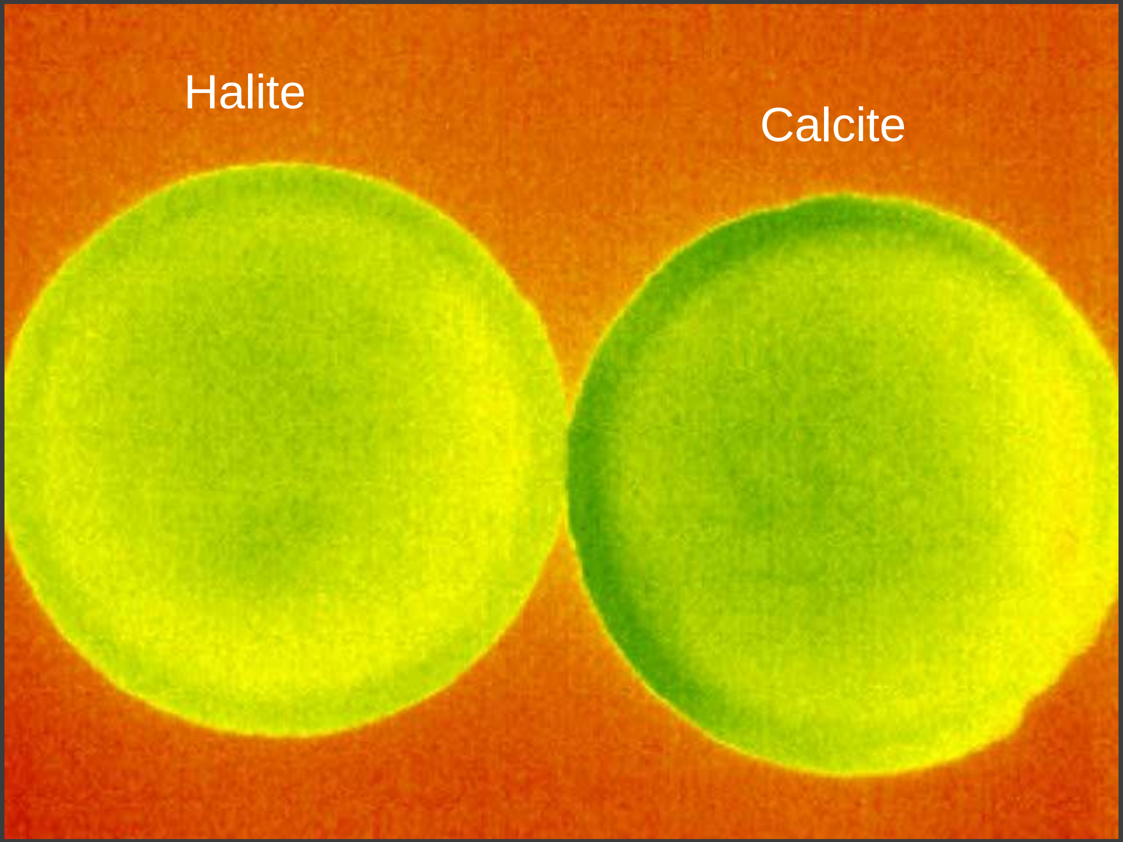
-added minerals Halite and Calcite

-these evaporites are found in the Black Rock Desert playa, major source of dust

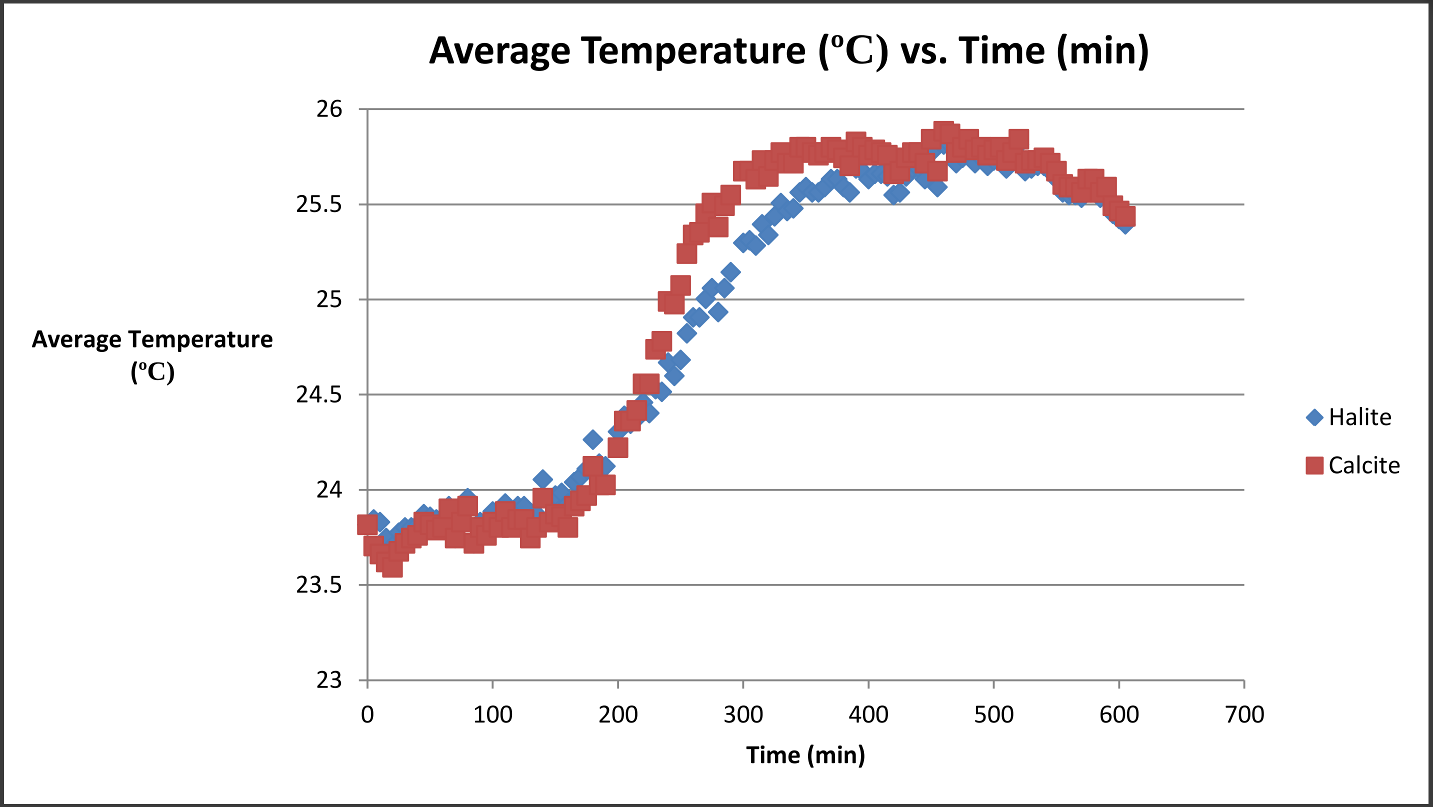
- Heated box for drying



Observations



Series of IR images every 5 minutes for 10 hours of a clay-silica surface drying.



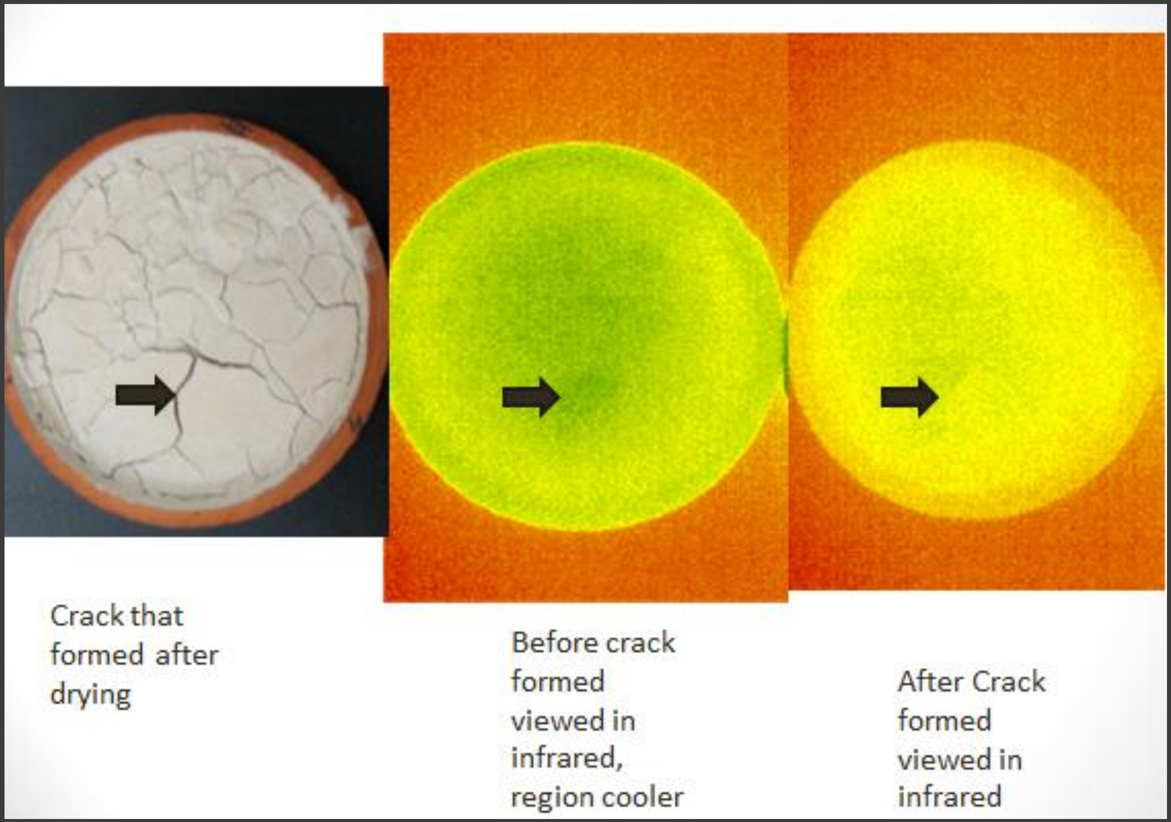
Calcite Dried Faster:

-more cracks→ larger surface area → faster rate of evaporation

-Halite more soluble, harder to break bonds between water and surface

-Calcite precipitates easier, higher vapor pressure

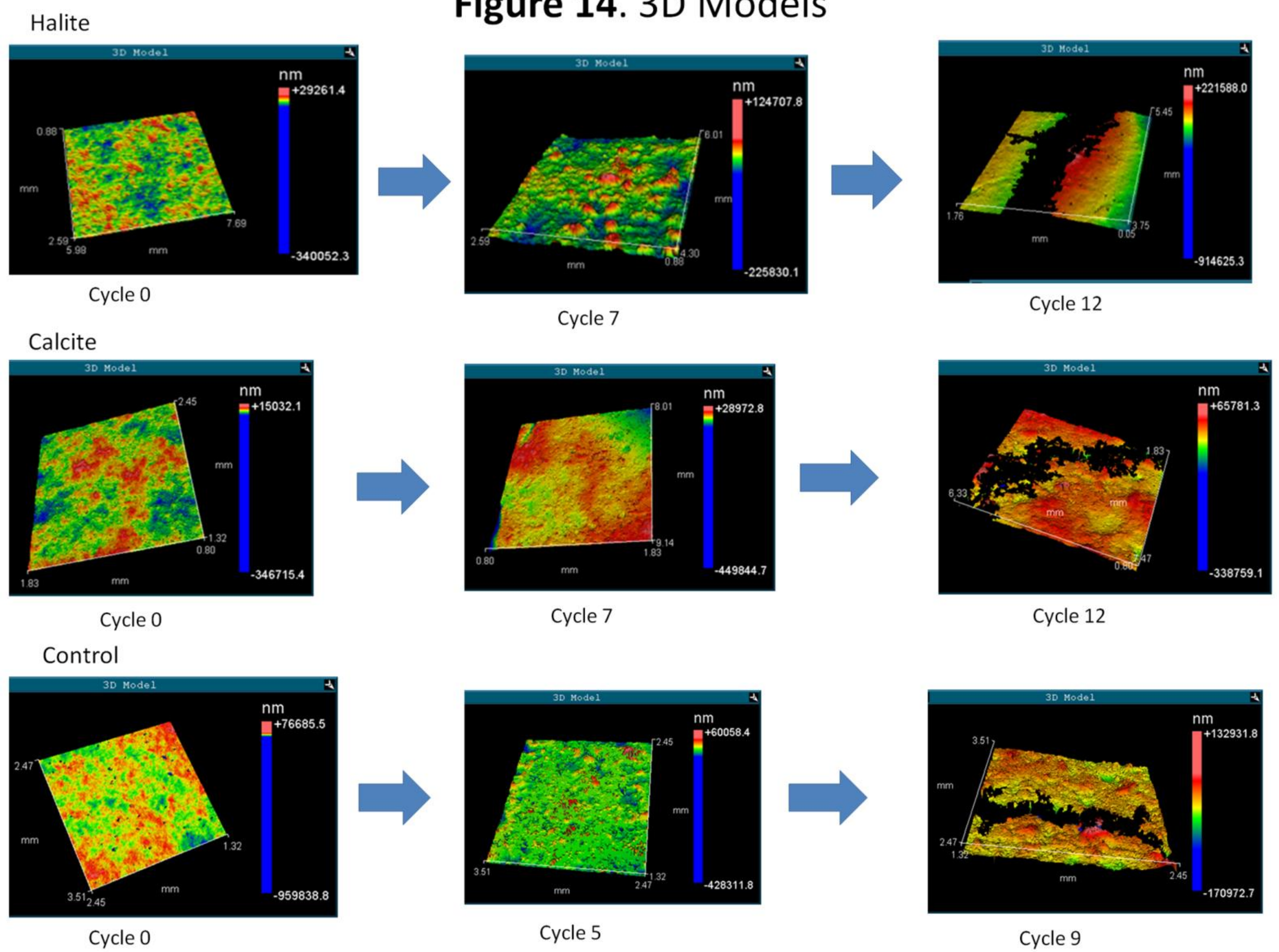
Cracks found to be initially cooler

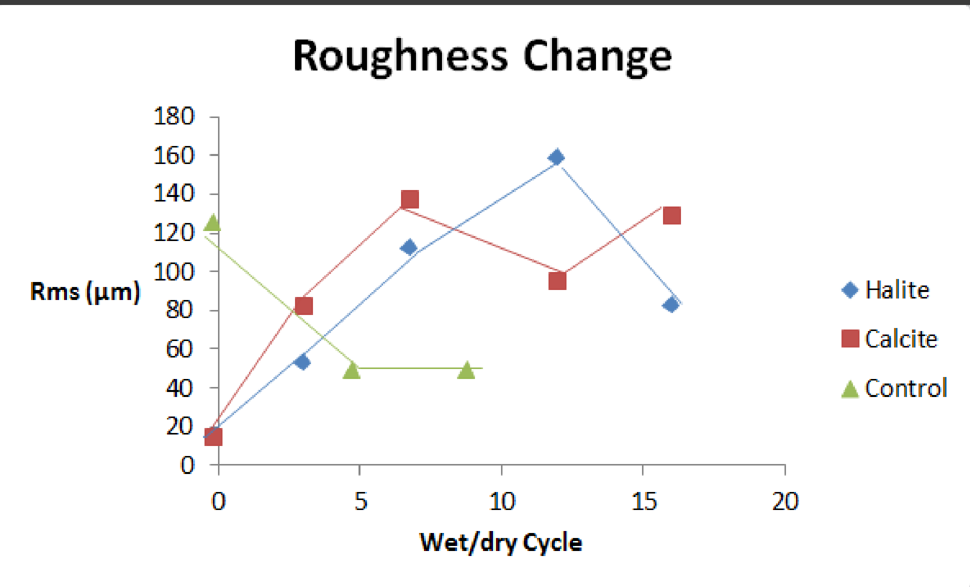


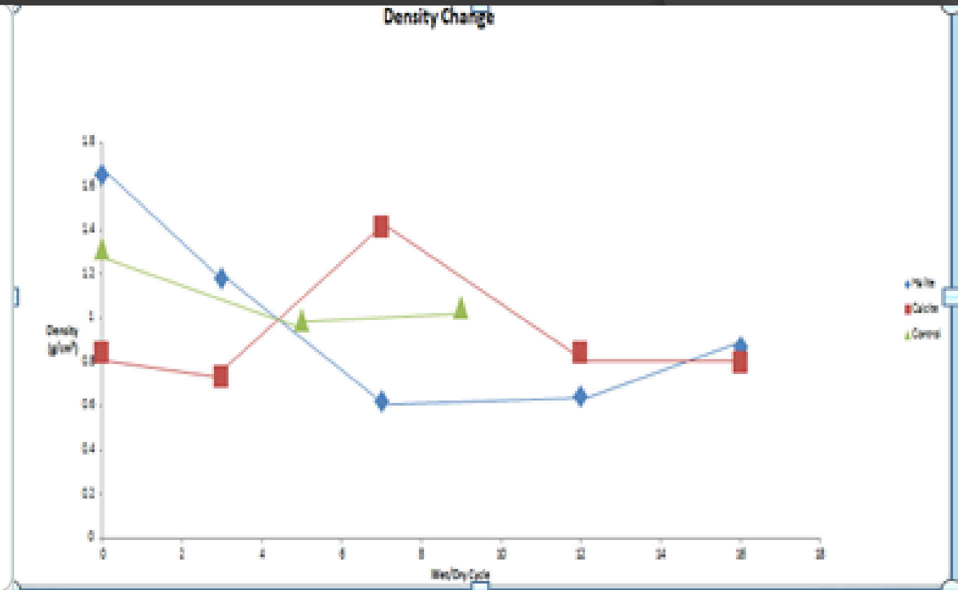
- Heat tends to go from cold to hot, so the transfer of moisture creates stress and thus forms a crack
- Cold water molecules are left behind in the crack and takes longer to evaporate

Zygo Profilometer Images

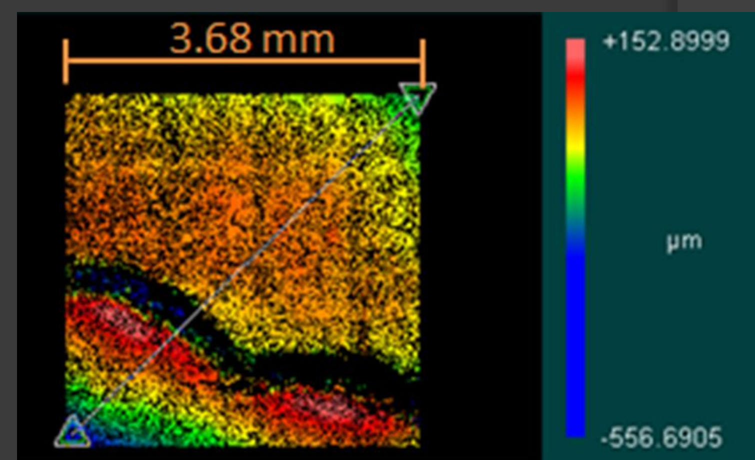
Figure 14. 3D Models







- The presence of halite and calcite increases surface roughness over series of wet/dry cycles.
- The presence of halite resulted in the roughest surfaces and soil density decrease.
- Halite is more soluble than calcite and could have dissolved and precipitated more rapidly.



Surface with added Halite shows density decrease around crack

Conclusion:

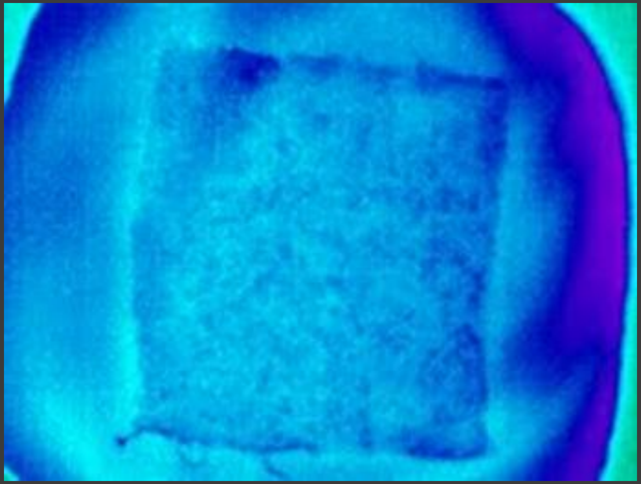
- Soils containing halite are more prone to dust emissions as opposed to soils containing calcite.
- This is because in a recent model,

$$F = \alpha \frac{\rho_a}{g} u_*^{3} \sum_i \left(1 + \frac{u_{*tr_i}}{u_*}\right)\left(1 - \frac{u_{*^2 tr_i}}{u_*^{2}}\right) s_i \quad ,$$

where F is the dust emission flux and u_* is the surface friction velocity, which is directly proportional to roughness.

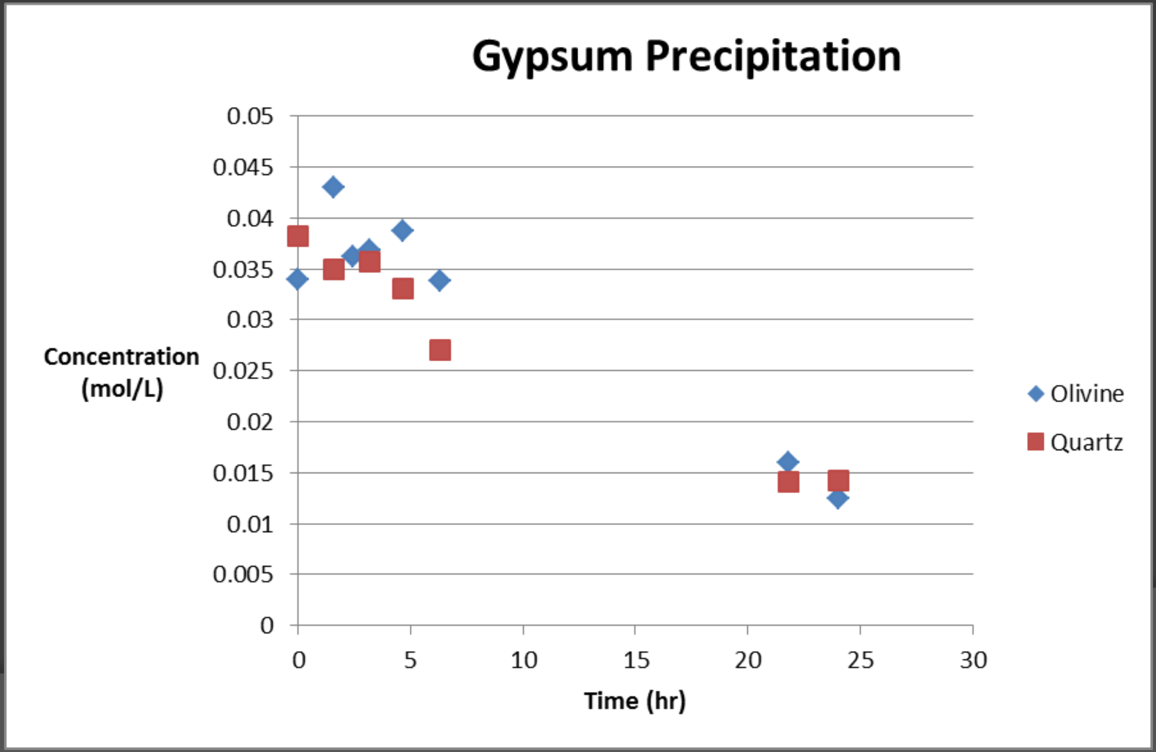
Programming

- Learned Python and Matlab
- Modeled drying of a washcloth
- Tested with IR camera



Gypsum Precipitation

- Grew $CaSO_42H_20$ crystals on different surfaces and compared rates
- Learned titration techniques



Gypsum precipitated at a rate of 26.5 micromols/hr on Olivine sand and 22.1 micromol/hr on quartz.

What I learned

- Challenges:

-manipulating surfaces to fit under lens of profilometer

-acquiring meaningful data

-picking out coral in the olivine sand

- Astrofest:

-Astronomy outreach for kids

- Graduate School preview

Thanks

- DC and Pennsylvania Space Grant Consortium

A quantification of surface roughness and density change of playa samples over a series of wet/dry cycles

Jenny Verniero

Introduction

- The Black Rock Desert, located in northwest Nevada, contains 2600 km^2 of playa which was once the lake bed of Lake Lahontan and is a source of dust.
- The surface of the playa undergoes transformations during cycles of flooding and dryness. When flooding occurs, the surface is less erodible and when the surface is dry, it is more erodible and less dense.
- Evaporites halite and calcite are found here, which might affect disruption of surface.
- The goal of this research is to quantify the effect of several wet/dry cycles on the playa using parameters such as soil density change, surface roughness, and crack formation
- These parameters are important to understand dust emissions of the playa.
- Dust emissions are responsible for transportation of minerals to the ocean, so understanding the source is vital for studying marine geochemical cycles.
- Dust also affects climate change such as temperature and atmospheric conditions.
- Understanding dust transport on Earth can contribute to understanding aeolian processes on other planets such as Mars.

Figure 1. Black Rock Desert Dust

Figure 2. Black Rock Desert Playa

Method

3 playa samples were replicated in small saucers of about 6.5 cm in diameter using:

1. Silica, Clay and Halite
2. Silica, Clay and Calcite
3. Silica and Clay (control)

- Each sample went through 16 wetting and drying cycles, where the samples were sprayed with about three grams of water and placed in a heated box of about 38° C.
- After about every 4 cycles, each sample was analyzed with the Zygo Optical Profilometer NewView 7300 which uses Scanning White Light Interferometry (SWLI) to capture a 3D image of the surface at a nm scale.
- Such small-scale technology is rarely used on these relatively larger-scale and non-reflective samples.

Figure 3. Halite cycle 0

Figure 5. Calcite cycle 0

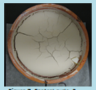


Figure 7. Control cycle 0

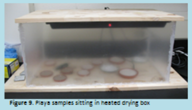


Figure 9. Playa samples sitting in heated drying box

Figure 4. Halite cycle 16

Figure 6. Calcite cycle 16

Figure 8. Control cycle 9

Figure 10. Zygo Optical Profilometer NewView 7300

Data

Rms value: a quantification of roughness

The Metropro software that accompanies the Zygo Profilometer gives each image a root mean square value (rms) which quantifies roughness by using equation (1), where x represents each height value in micrometers.

(1) $x_{rms} = \sqrt{\frac{1}{n}(x_1{}^2 + x_2{}^2 + \cdots + x_n{}^2)}$

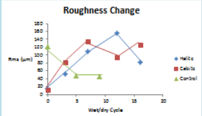


Figure 11. This graph represents the rms value (roughness) of each sample over a series of wet/dry cycles

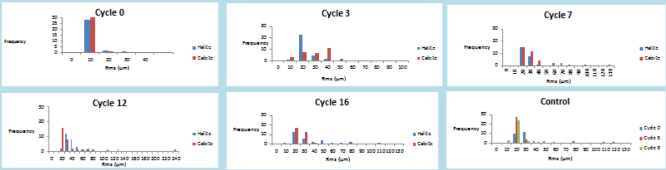


Figure 12. In each image, 30 subsets were analyzed to give 30 variations of rms values which are plotted on these histograms.

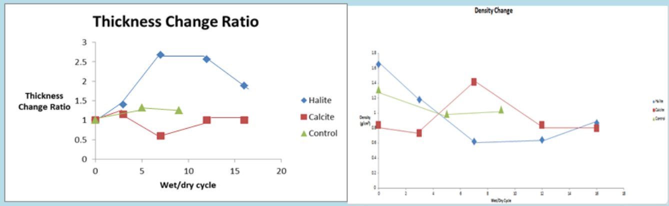


Figure 13. The left graph represents the thickness change over a series of wet/dry cycles. The values were created by calculating a ratio of initial and final thickness. The right graph represents the change in soil density of each sample over a series of wet/dry cycles.

Observations

- The presence of halite and calcite increases surface roughness over series of wet/dry cycles.
- The presence of halite resulted in the roughest surfaces and soil density decrease.
- Halite is more soluble than calcite and could have dissolved and precipitated more rapidly.
- Surfaces that evolved in the presence of halite grew in thickness, as shown in figures 15-17.
- Surfaces that evolved in the presence of calcite behaved opposite to the surface that evolved in the presence of halite.
- Calcite rate of precipitation could have been slower than halite.
- Surface that evolved in the presence of calcite did not change significantly, as shown in figures 18-20.
- Profilometer 3D models clearly show roughness and height change over a constant subset of each sample.

Conclusions and Further Work

Conclusion:

- Soils containing halite are more prone to dust emissions as opposed to soils containing calcite.
- This is because in a recent model, $F = \alpha \frac{\rho_a}{g} u_*{}^3 \sum_i \left(1 + \frac{u_{*}tr_i}{u_*}\right)\left(1 - \frac{u_*{}^2 tr_i}{u_*{}^2}\right) s_i$,

where F is the dust emission flux and u_* is the surface friction velocity, which is directly proportional to roughness.

Future work:

- More cycles of wetting and drying could be conducted to determine if the rms values and soil density changes will oscillate. This is important to determine when the Black Rock Desert Playa will be a source of dust.
- Halite and calcite crystals themselves could be observed under SEM to investigate morphology and to confirm precipitation rate differences.
- This study confirms that the Zygo Profilometer can be utilized for samples on a centimeter scale.

References and Acknowledgements

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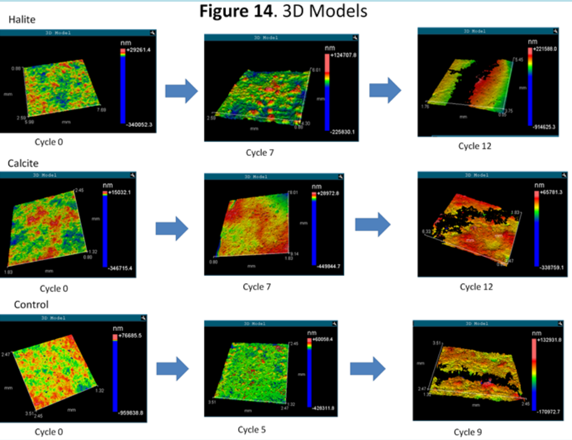
- Special thanks to Heather Tollerud, Dr. Matthew Fantle, and Josh Stapleton

Profilometer Images

Figure 14. 3D Models



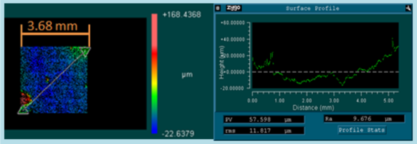


Figure 15. Halite cycle 0

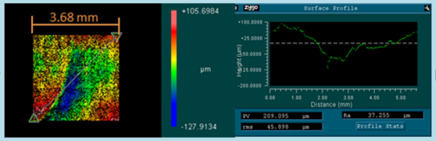


Figure 16. Halite cycle 3

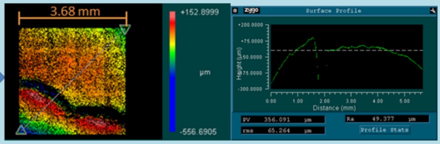


Figure 17. Halite cycle 7

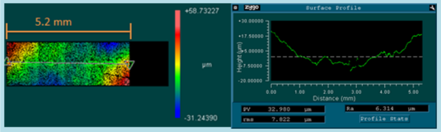


Figure 18. Calcite cycle 0

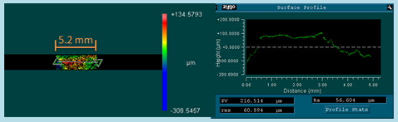


Figure 19. Calcite cycle 3

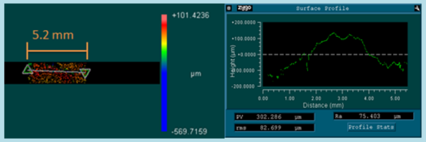


Figure 20. Calcite cycle 7