Origin, Chemistry, and Geomicrobiology of Terraced, Crystalline Mirabilite Mounds on the Southeastern Shore of Great Salt Lake, Utah

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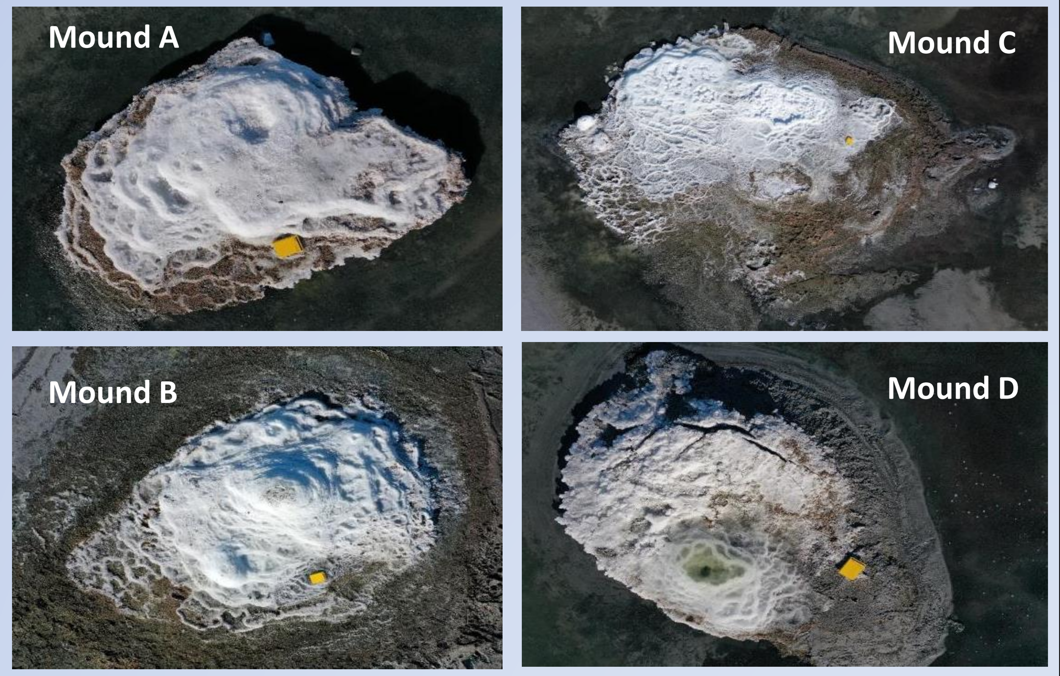
Introduction

During the late fall of 2019, four crystalline mirabilite mounds formed on the southeastern shore of Great Salt Lake (GSL) in northern Utah, near Great Salt Lake State Park. Soon after, several more mound complexes were discovered on nearby Antelope Island. Recent historic low lake levels permitted sulfate-saturated spring waters to emerge on the exposed shoreline during cold temperatures.



- *Four mound complexes grew at different times/rates*
- *Mound size varied from 5 to 20 ft wide and up to 3 ft tall*
- *Lateral changes in hydraulic head created flowing and abandoned discharge zones*

What is Mirabilite?

- Mirabilite is a hydrous sodium sulfate evaporite ($Na_2SO_4 \cdot 10H_2O$) - vitreous, colorless to white and monoclinic
- It forms from sulfate-rich brines at cold temperatures (winter) (e.g., polar regions)
- Mirabilite dehydrates in dry air to thenardite (Na_2SO_4) at temperatures > 40-50 ˚F (5-10 ˚C)

https://upload.wikimedia.org/wikipedia/commons/8/8f/Mangxiao.jpg

Observed Chemical Sedimentary and Physical Processes

micro-terracettes composed of clear bladed and prismatic crystals (1-10 cm in length; 1-5 cm in width)

Flowing phase: micro-terracettes (rimstone-dams and pools) form from cascading water and crystal precipitation at the air-water interface

Dehydration phase: decrease in hydraulic head and seeps are plugged by crystallization. Crystals turn white and powdery due to dry climate and warm air temperatures

Thin tabular crystals precipitate from remaining brine pools

Lake level rise and storm events destroyed and dissolved mounds; creating mushroom tops, fractures and caverns, and coated by sediment

Field and Laboratory Measurements

Measurement	Spring Water	Lake Waters
Temperature (°C)	10 – 15	0 – 3
Density (g/cm^3)	1.1031 – 1.117	1.0872
pH	7	7
ORP (mV)	-250	12
$\delta^{34}S$	20‰	
Sulfide (µM)	6200	

Lake and Spring Water Chemistry

Sample ID	Na^+ (g/l)	Mg^{2+} (g/l)	K^+ (g/l)	Ca^{2+} (g/l)	Cl^- (g/l)	SO_4^{2-} (g/l)	HCO_3^- (g/l)
South Arm Brine	38.10	4.54	2.58	0.193	70.14	9.55	0.475
South Arm Brine	37.90	4.50	2.56	0.192	70.56	9.53	0.479
Mirabilite Spring B1	31.28	2.33	1.72	**0.460**	49.031	**20.80**	0.603
Mirabilite Spring B2	39.93	2.16	1.61	**0.415**	44.608	**42.62**	
Mirabilite Spring B3	32.64	2.29	1.67	**0.443**	47.65	**25.47**	0.598
Mirabilite Spring C	42.35	2.44	1.78	**0.408**	50.77	**21.08**	0.499
Mirabilite Spring D	41.91	2.58	1.87	**0.395**	54.31	**37.87**	

- Spring waters have a higher density and high concentrations of SO_4^{2-}
- Spring waters have a strong sulfur odor, very low oxidation reduction potential (ORP), high sulfide concentration and positive
- $\delta^{34}S$, implying a sulfate-reducing bacteria may play a major role on spring chemistry

Biological Components and Antelope Island Spring Mounds

GSL State Park

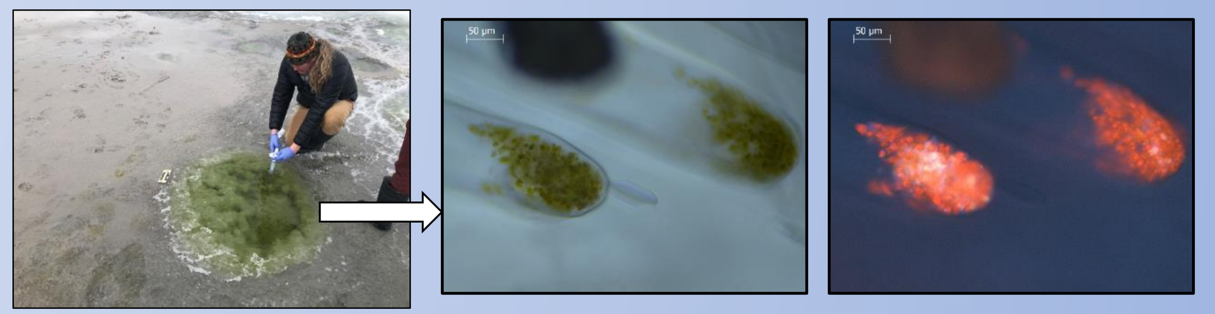
Groundwater flowed upon coring

Core hole penetrated bottom at 5 ft

Bottom core showing Green cyanobacteria or algae at core base

Antelope Island

Filamentous sulfur oxidizing bacteria



Polarized light *Fluorescent light*

Thin-section photomicrographs of green algae trapped within fluid inclusions; likely Dunaliella salina

Conclusions and Interpretation

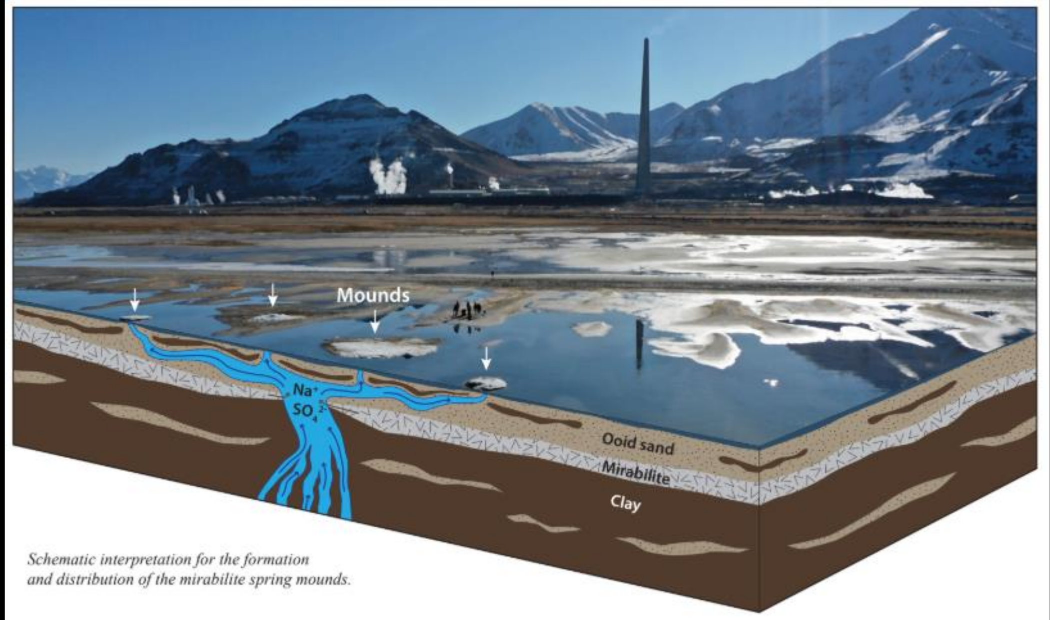
- Bureau of Mines (1957) identified a 6 ft thick layer of mirabilite NW of the GSL State Park (SE shoreline of GSL)
- Mirabilite was saturated in the south arm lake pre-causeway and was washed onto leeward shores by storms
- The mirabilite dissolved and accumulated in the subsurface in porous oolitic sediments

Similar North Arm Observations

- The north arm brine is at mirabilite saturation during the winter
- Mirabilite forms as a hydrated slush that washes onto shorelines

Groundwater sediment collapse seeps

Mirabilite-filled seep hole



Spring Mound Hypothesis
Increased hydraulic head during low lake level allows groundwater to mix with subsurface mirabilite layer and flow Na^+-SO_4^{2-}-rich brines to the surface. Microbial communities may drive spring chemistry