Linking decay of microbial mats and dolomite formation in the sabkhas of Qatar

ZACH A. DILORETO[1], TOMASO R.R. BONTOGNALI[23], HAMAD AL SAAD AL KUWARI[4], JUDITH A. MCKENZIE[5], MARIA DITTRICH[1]

[1]UNIVERSITY OF TORONTO, PHYSICAL AND ENVIRONMENTAL SCIENCES

[2]SPACE EXPLORATION INSTITUTE (SPACE-X), NEUCHATEL, SWITZERLAND

[3]UNIVERSITY OF BASEL, DEPARTMENT OF ENVIRONMENTAL SCIENCES

[4]QATAR UNIVERSITY, DEPARTMENT OF ENVIRONMENTAL SCIENCES

[5]ETH ZURICH, DEPARTMENT OF ENVIRONMENTAL SCIENCES

“The Dolomite Problem”

-Low-Temperature dolomite is abundant in ancient geologic sequences but inexplicably decreases with time and is quite rare in modern times

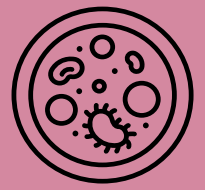
-Microbes and the exopolymeric substances (EPS) they produce facilitate dolomite precipitation through interaction of Mg water complexes with carboxylic functional groups.

-Most information about the precipitation mechanism has been obtained through controlled laboratory studies making it difficult to interpret the phenomenon in modern and ancient environmental conditions

-Attempts at delineating this phenomenon are incomplete despite over a century of study

Knowledge Gaps

-Complex environmental variations (e.g. salinity) and their influence on dolomite precipitation are inadequately addressed

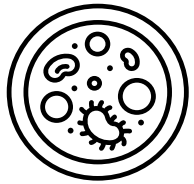


- The role of microbial community dynamics *in-situ* and their effect on EPS composition remain unknown

-A mechanism that can be interpolated between low-t dolomite formation in modern and ancient environments is still missing

Hypotheses

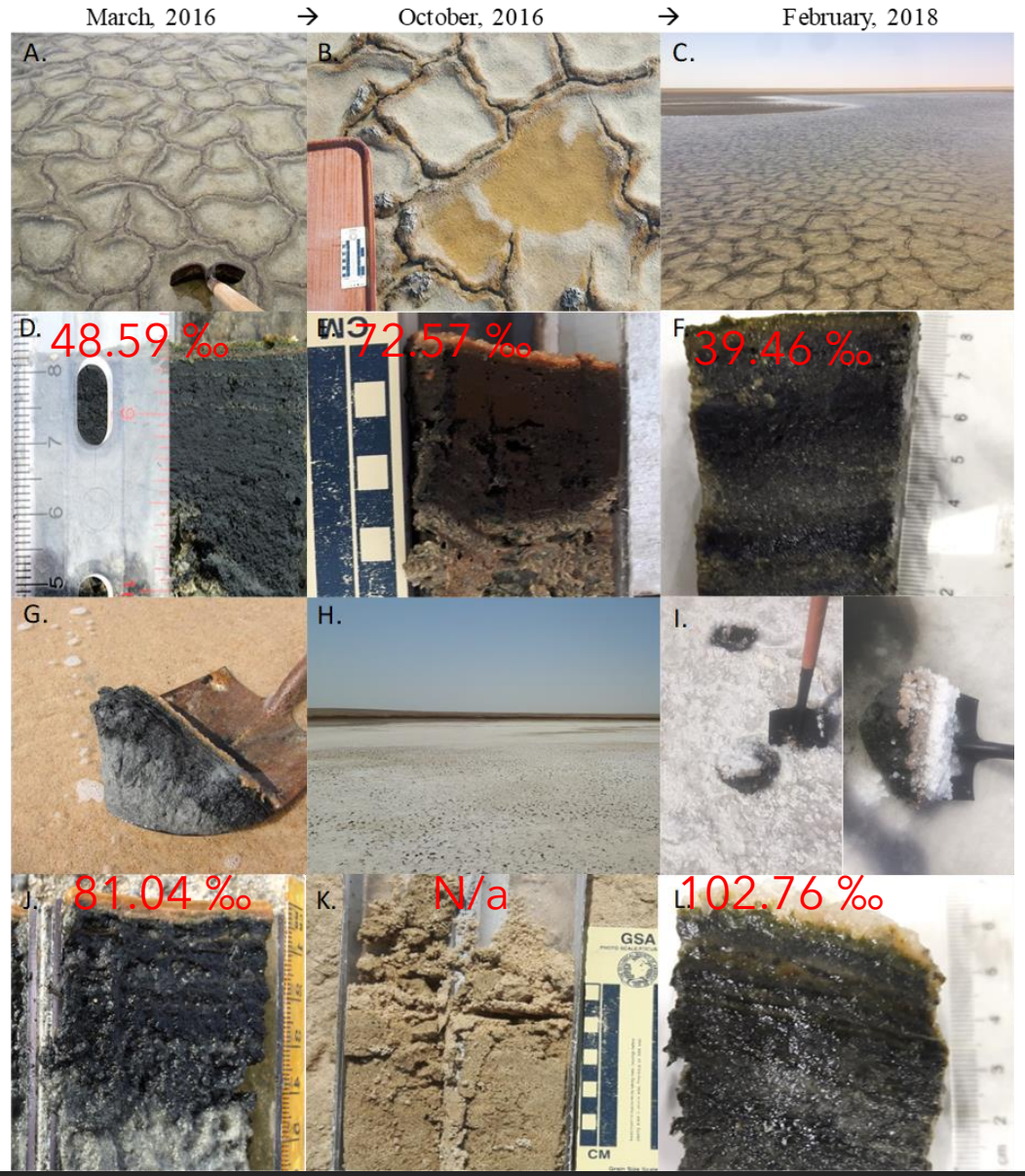
We propose that dynamic environmental variation (e.g., salinity) are the key to understanding modern and ancient dolomite forming processes. These factors are the major drivers of biomineralization and operate over long-time scales.



We propose that there are previously unconsidered seasonal biogeochemical interactions which are linked closely to the expression of microbial community and influence EPS at the molecular scale.

We suggest that observations from the sabkha can be used to gain insight into ancient dolomite forming environments.

Impact of Environmental Conditions



-KAAS-1 shifts from green to orange and back to green based on salinity fluctuations

-KAAS-2 follows a similar pattern although desiccates completely during times of higher temperature

-KAAS-1 resembles KAAS-2 when salinities are comparable

-Variations based on season and location within the intertidal zone

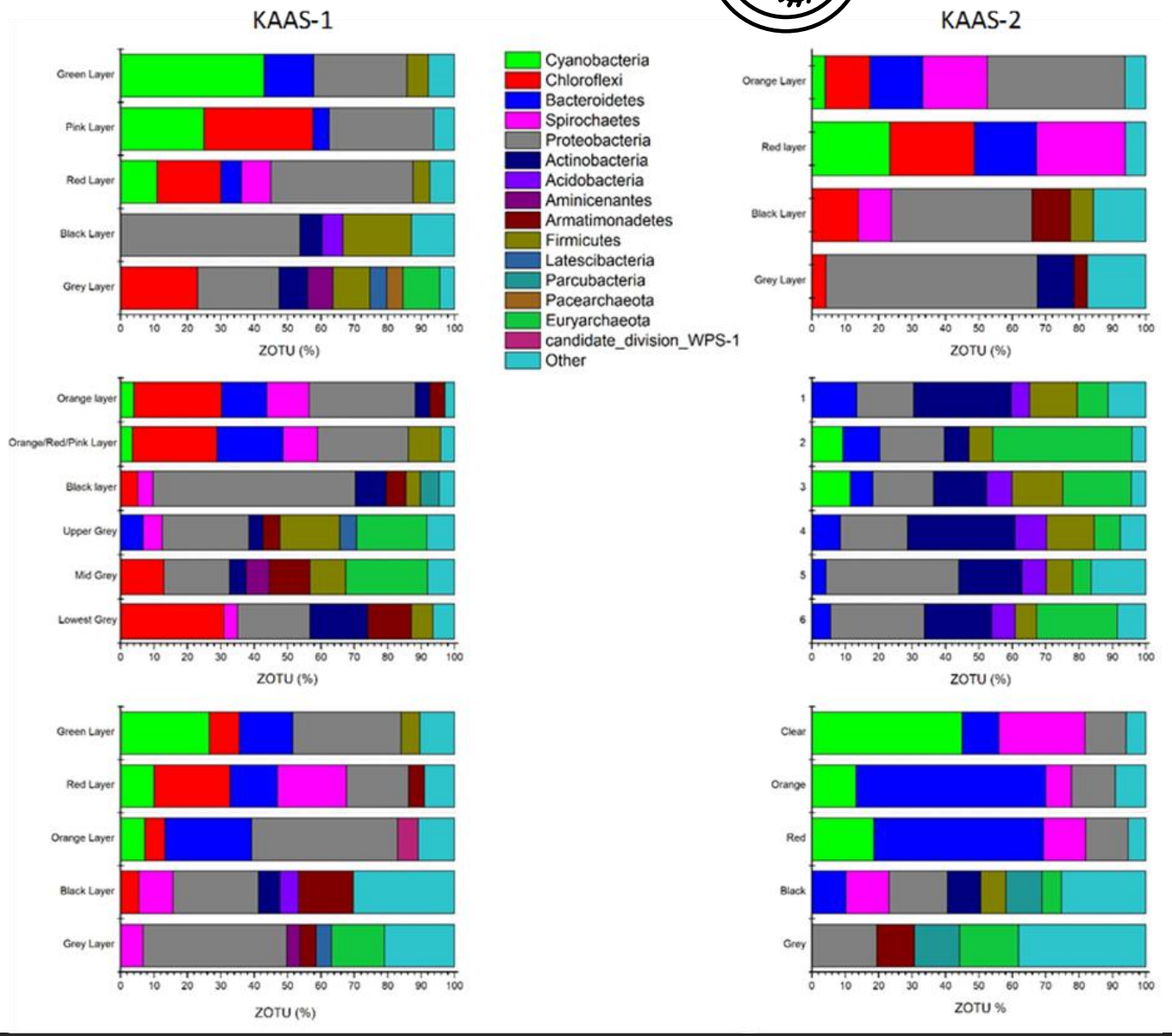
Role of Microbes on EPS Composition

		KAAS-1 March 2016	KAAS-2 March 2016	KAAS-1 October 2016	KAAS-1 February 2018	KAAS-2 February 2018
Functional Group	pKa Range	Average L_T (umol/g EPS)	Average L_T (umol/g EPS)	Average L_T (umol/g EPS)	Average L_T (umol/g EPS)	Average L_T (umol/g EPS)
Carboxyl	3-5.8	0.113 ± 0.08	0.173 ± 0.04	0.461 ± 0.23	0.075 ± 0.03	0.091 ± 0.05
Phosphoryl	6-8	0.149 ± 0.01	0.103 ± 0.04	0.260 ± 0.32	0.044 ± 0.02	0.020 ± 0.01
Amine	8-9	0.845 ± 0.25	0.224 ± 0.03	0.721 ± 0.48	0.545 ± 0.01	0.223 ± 0.02
Amine (hydroxyl)	9-10					

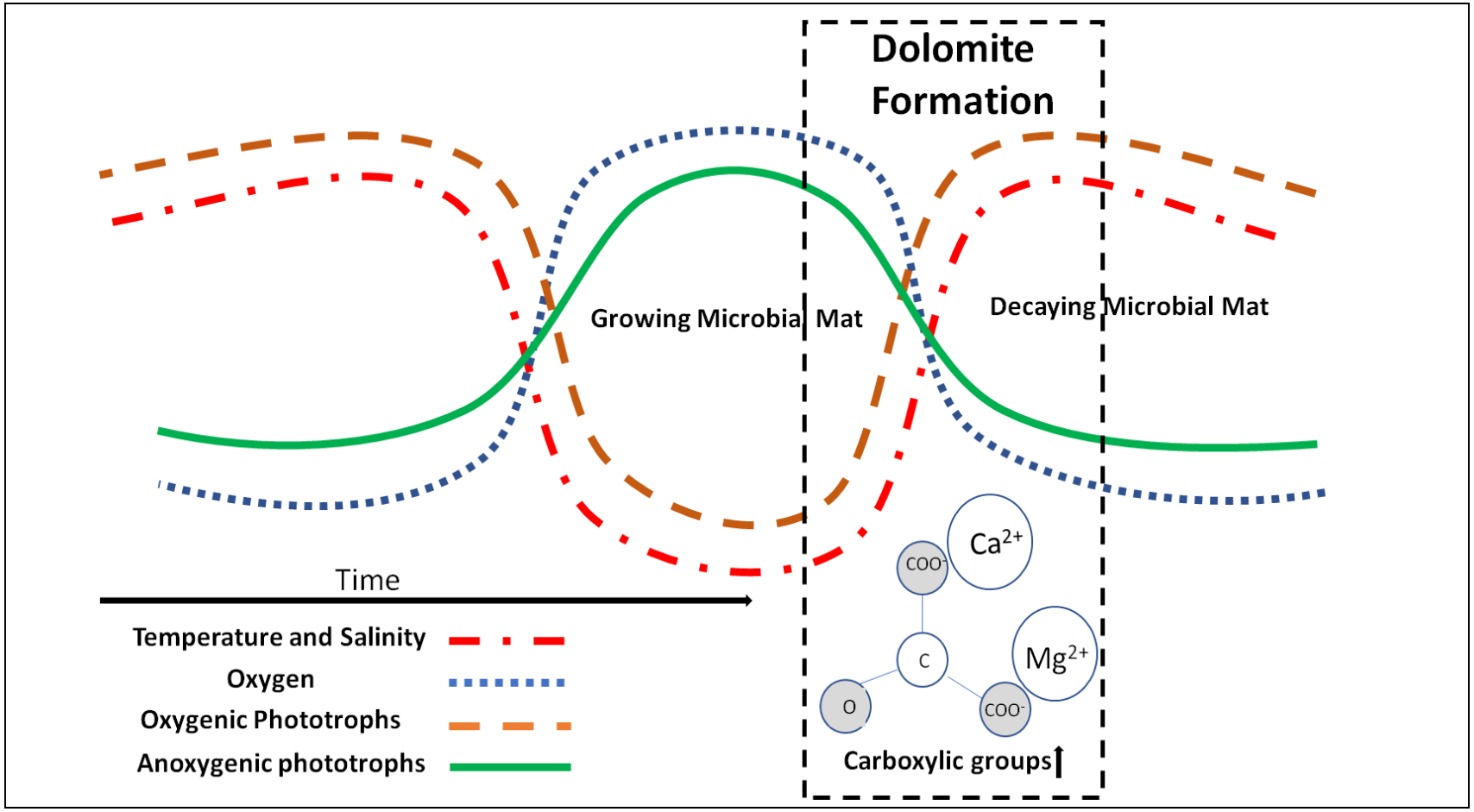
-During times of low salinity mats are dominated by cyanobacteria

-During times of high salinity mats are dominated by anoxygenic phototrophs

-This corresponds to decreased and increased carboxylic functional groups, respectively



Formation of Dolomite through Geologic Time



-We observed increased dolomite-phase crystallinity during times of high salinity and temperature

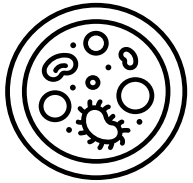
-High salinity drives cycling between oxidative phototrophs to anoxygenic phototrophs, respectively

-Increased carboxylic groups occurred in conjunction with increased salinity and anoxygenic phototrophs

-This dynamic appears to have occurred in the past and results provide new context to ancient dolomite sequences

Conclusions

Dramatic environmental fluctuations, in particular salinity, caused shifts in microbial community dynamics which favor increased carboxylic group concentration



Increased carboxylic group concertation was associated with the change from oxygenic to anoxygenic phototrophs suggesting increased environmental stress and mat degradation. Degradation of EPS by anoxygenic phototrophs appears paramount in dolomite precipitation

Comparison of other modern as well as paleoenvironmental studies corroborate our findings and suggest that salinity influxes may be a key trigger for dolomite precipitation through the degradative process. These findings also indicate that dolomite precipitation may be tied to evolution of O_2 in the Earth's atmosphere.