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Determining initiation conditions for glass ramps: case study at the leading edge of the great Permian spiculite belt

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Narrative Report 2018

*Overview of Findings*

This report concludes the second year of our research funded by the American Chemical Society's Petroleum Research Fund. In the first year, we explored, mapped, and assessed the stratigraphy of spiculitic chert rocks across North-Western Utah. These rocks represent the southernmost extent of a sponge regime that wrapped around the northern coast of Pangea in the Mid-to-Late Permian. This year, we focused more closely on specific field sites that show dominance of sponges in microfacies: Lemay Island, Pigeon Mountain, and the mountains around Lucin, Utah. We finally identified, for the first time in these locations, large body fossils of sponges. More importantly, the body fossils express a unique morphological and depositional setting. The sponges appear as nested vases, like stacks of pint glasses; they form meter-thick beds that extend for at least tens (likely hundreds) of meters, and do not reveal detectable reef-like or bioherm-like edges, hummocks, or reef mounds. We could not identify any macroscopic contemporaneous fossils within these sponge meadows, and have not yet found metazoan fossils in the thin sections of these large standing meadows. I interpret this as support for the central hypothesis work, as stated in the accepted proposal: "The key hypothesis is that siliceous sponges and their detrital bioclasts formed increasingly cohesive, exclusive fabrics, limiting carbonate bioclastic production and deposition to isolated patches." Recognizing the sponges in their meadow formations also allowed us to more clearly recognize them in a variety of facies: sponges that have fallen down, sponges that were rare, sponges that were amalgamated into compressed spiculitic debris. These observations are critical pre-requisites to any kind of future sequence-stratigraphic interpretations of the regional depositional facies, as well as basin-scale interpretations of the biotic and abiotic controls on the depositional features.

Careful analysis of these outcrops in the field, along with observations of hand samples and microfacies in the lab, reveal a dynamic relationship between the demosponges and previously-observed brachiopod build-ups: we isolated specific outcrops and stratigraphic successions where sponge meadows are overlain by brachiopod-and-bryozoan banks, and where sponges and brachiopods appear – very rarely – to both encrust the same substrate at the meter-scale. Identifying these outcrops will allow us, this coming final project year, to test very specific ecological hypotheses, including those in the submitted proposal, and new interpretations based on field observations. A central hypothesis that we can now test is whether ecological hysteresis was present as a criterion for the alternation of stable states. In this framework, the general biotic and environmental conditions do not act as independent predictors of the community structure, nor does the combination of a specific set of biotic and environmental features – say, a sheltered bay with rare live sponge cover – guarantee the success of a particular biomineralization regime. Instead, we posit that hysteresis was present, such that the relative success in establishment of a brachiopod bank or a sponge meadow depends much more on what habitat and community was present in the recent past. We have more specific hypotheses about the relative balance of biomineralized components in the sediment, which we can now test on outcrops and successions identified this past project year.

We also expanded the work both spatially and in terms of research community. We welcomed an undergraduate student of Carleton College, Benton Franklin, to spend the entire summer conducting his senior thesis project in the field. For this, we settled on a transect from the mountains of the Western Great Salt Lake Desert, to the Wasatch and Uinta ranges in the East. We also extended our field explorations to rocks in Eastern Nevada, Southern Utah, and Northern Arizona. To the north, we are preparing proposals with faculty at institutions in other universities to extend the range of our collective comparative field observations into Idaho and Wyoming. We can now spend the final project year testing more specific hypotheses about ecological hysteresis in the transitional phases between these strata, and better testing our first-order observed trends in ecological character across this transect.

*Impact of the Work*

These findings are vital to our paleoecological reconstructions of ancient life in the Permian Phosphoria sea. More broadly, our findings reveal the critical importance of siliceous sponges to primary sedimentation in rocks that have long been neglected due to their cherty – and supposedly chiefly-diagenetic – nature. The rise of glass ramps is a first-order Earth-life interaction in terms of sedimentation, ecological engineering, and global geochemical cycling. Our work discovers how sponges constructed these regimes and should allow us to examine, in startlingly accurate representation, the alternations of two mututally-exclusive biomineralization factories. Hysteresis is difficult to observe or to test in the rock record, and these rocks present an unusual case of very different lithologies and community structures – both in terms of taxa and of sedimentary regime.

*Impact on Student Trajectories*
The first MS student to work on this project, Seana Hood, is now finished with all field work and lab work, and will submit a first-authored manuscript to Palaios this semester. This project provided Seana with challenging opportunities to complete independent field research, stratigraphic reconstructions, and paleoecological hypothesis testing. Seana discovered the sponge meadow outcrops on which much of our future work will be based.

Zackary Wistort is now working on the project for a PhD, and he did his MS on these same outcrops, creating identification criteria for burrows in cherty carbonates. In the past project year, Zack completed the MS and submitted the manuscript to Palaios; it is now in revision, and will credit the PRF, which is now supporting both writing and additional field and lab revisions. Zack's new work addresses the sponges specifically, including testing hysteresis hypotheses and more complex models of spiculite establishment and resilience. Zack's PhD project will also involve many comparisons of this field-derived data with observations from the Paleobiology Database. This engages the challenge of valorizing field observations and overcoming the sharp contrasts in data type, resolution, and certainty that dominate and devide many paleoecological research endeavors over the past century. Zack also mentored our undergraduate summer student, Benton. This helped Zack develop leadership skills in the field and Lab. First Seana, and now Zack, are our top experts on the advanced microscopic imaging software we use in the Marine Paleoecological Lab.

Benton Franklin completed all the field work and microfacies collection necessary for his senior thesis, which he will write this academic year at Carleton College. Benton is returning to our Marine Paleoecology Lab at the University of Utah in December 2018 to complete the microfacies analysis, and is likely to produce enough material for one first-author and one supporting author publication. Benton's stipend is entirely supported by Carleton College.

Seana and Zack presented talks about this work at the GSA meeting in Seattle in October, 2017. Zack, Benton, and PI Ritterbush (with Seana as a co-author) will present these results in oral (2) and poster (1) form at GSA in Indianapolis this November, 2018.

*Significance for PI*
This research and the support provided by PRF have been invaluable to starting PI Ritterbush's lab at the University of Utah. The funds arrived the the PI's second year, and funded the PI's first two students. This work is the dominant focus of the field and lab work in the Marine Paleoecology research group. It makes the PI's research visible to her department, and internationally in geobiology and sedimentology communities. This work has generated invitations to conferences and universities across North America (the first international Geobiology Conference in Banff, CAN, 2017, and talks at the Utah Geological Association and the Geology Department at the University of Wisconsin in Madison (2017-2018). The funds entirely support the students' stipends, as well as all field, conference, and microscopy and lab expenses. The research has been an intellectually engaging puzzle and a bold start to the PI's career at the University of Utah.

At the Geological Society of American Annual Meeting this fall in Indianapolis, IN, the PI's lab will show eight research presentations, including two talks and one poster explicitly on the Permian work supported by this proposal. In the same years as this project has been active, the PI published a review of previously-published spiculite materials from glass ramps worldwide across the Phanerozoic, including a comparison of the economically valuable rocks from each interval. The PI has re-established work on her previous Triassic-Jurassic transition spiculite microfacies. Taken together, these spiculite projects engage a key challenge in paleoecology today: the combination and comparison of observations that are easily fit into a database at high resolution (taxa, strata, abundance, location, etc.) with those that defy such discrete classification (community engineering and framework structure – or lack thereof; the predominance of materials from compressed sponges, which cannot be easily named or counted. etc). Bridging these two worlds, and maximizing the information we can glean from past work and collections with new field observations is one of the PI's major ongoing research objectives. At a higher level, the project allows unique ways to explore the interactions of life and the Earth system, and to distinguish the habits and history of organisms that shape the development, retention, and availability of critical petroleum resources.