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Ordovician Receptaculitid Reef Mounds: Distribution, Sedimentology, and Ecology

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Reefs are complex physical, chemical, and biological systems that are ecologically fragile, yet are among the most enduring and hearty of Earth's ecosystems. For over 600 million years, reef ecosystems have undergone dramatic compositional changes and harbored widely diverse communities. Reef systems are also important sedimentologically, producing massive volumes of carbonate rock and acting as reservoir rocks. Reefs are restricted to tropical and subtropical settings primarily on eastern trunks of continents or western parts of oceans, and today range between 20º and 30º north and south of the equator (Stanley, 2001). Throughout their history, reefs have been distinctly characterized by high biotic diversity, and have been suggested to be an important source of evolutionary innovation for life (Jablonski, 1993).

The Early and Middle Ordovician is a particularly interesting time in reef history. The collapse of the Early Cambrian archaeocyathid-microbial reefs was followed by the longest lasting eclipse in the history of reef ecosystems, spanning most of the remaining Cambrian plus Early Ordovician time interval (Stanley, 2001). The early Middle Ordovician reef structures that developed following this hiatus preceded the widespread stromatoporoid reefs, and although they were rarely more than mounds, they were the first analog to modern reef communities in terms of structure and diversity (Johns, 1995). These mound structures were dominated by sponges and receptaculitids. There is extensive literature available on Ordovician sponges and there is little debate on their basic anatomy and phylogeny. In contrast, receptaculitids are part of a poorly understood fossil taxon that has fueled a phylogenetic debate (between sponges and calcified algae) among paleontologists for well over a century (Nitecki, 1999). This mysterious group of fossils originated abruptly during the early Ordovician and diversified quickly, becoming important rock-building elements and a major component of massive organic buildups in limestones and dolomites.

Receptaculitids are globose, calcareous marine fossils that have a relatively primitive gross morphology but a mineralogically complex skeleton, characterized by complex helicoid arrangements of hundreds of individual skeletal elements, termed meroms, in whorls that conform to the Fibonacci sequence (Nitecki, 1999). Because meroms are unknown in any other organism and relatively little is known of their internal structures, receptaculitids have presented a sizable challenge to paleontologists attempting to categorize them phylogenetically. Indeed, receptaculitids have been classified among a wide variety of many high-level taxa; they were once even proposed to be primitive pine cones, mollusks, corals, or sea cucumbers. They are most commonly assumed to be sponges or calcareous algae, but further studies have determined these assignments to be unsubstantiated. The latest, but probably not the last, consensus is that receptaculitids are neither sponges nor calcareous algae, but an extinct clade of organisms that is not related to any other taxa, extinct or extant (Nitecki, 2004). This disassociation from any known group makes it difficult to speculate as to the nature of receptaculitids, such as feeding, respiration, and reproduction processes, as well as the effect of this group on sedimentary structures.

Receptaculitids were abundant with sponges in the reef mounds, which are interpreted to have been along the edge of carbonate platforms globally in the Middle and Late Ordovician. These mounds typically ranged in height from less than .5 m to 5 m and are 1 to 7 m in diameter, although some do reach larger sizes (Johns, 1995), and they presumably had a large effect on the sedimentology and dynamics of the platform. Receptaculitid-sponge mounds are characterized by mudstone or skeletal wackestone cores that are typically flanked by echinoderm grainstones. Most of the mounds display some degree of community succession, in which colonization, diversification, and domination stages followed some initial stabilization phase of the underlying sediment. What might have been the role of receptaculitids in the baffling and stabilizing of these mounds? The initial stabilization phase was what allowed the mounds to serve as new habitats for the ongoing development of Paleozoic fauna that began quickly radiating in diversity during the Middle Ordovician. In this way, the poorly understood receptaculitids may have had a significant role in helping set the stage and encourage the Ordovician radiation that followed.

Morphological plasticity is a fundamental characteristic of modular organisms (such as sponges) as well as calcified algae, which typically display highly variable body shapes that are determined mainly by environmental influences (Allaby, 2006). Receptaculitids have been compared to such groups for decades, but ironically, the degree of morphological plasticity in the receptaculitid group has not been addressed. This is further surprising since gross morphology is actually used to a certain extent to distinguish receptaculitid families and genera from one another (Fisher & Nitecki, 1982). The great majority of studies published to date have focused on the structural morphology of small sample groups, often within one species at a single location with particularly well-preserved specimens. Constraining the variability of the gross morphology of receptaculitids will provide critical insight into the group's biology and ecology, as well as valuable insight into their phylogeny and taxonomy.

This study seeks to examine the morphology and ecology of receptaculitids, their role in carbonate buildups and reef mounds, and their distribution on Ordovician carbonate platforms, as well as the effect of that distribution on the depositional environments and sedimentary packaging represented in these strata. Specifically, the goals of this study are to:

1.) Document the sedimentology and stratigraphy of the reef mounds and their surrounding sediment. Do the mounds occur at the same place in the sequence stratigraphy framework? This will help to identify where the mounds are occurring on the carbonate platform and their effect on the surrounding sediment.

2.) Evaluate Ordovician receptaculitids in their environmental context. There have yet to be studies conducted on the specific environmental conditions where receptaculitids are found in their greatest abundance, although it is evident that they had environmental preferences because they are not present throughout the carbonate platform.

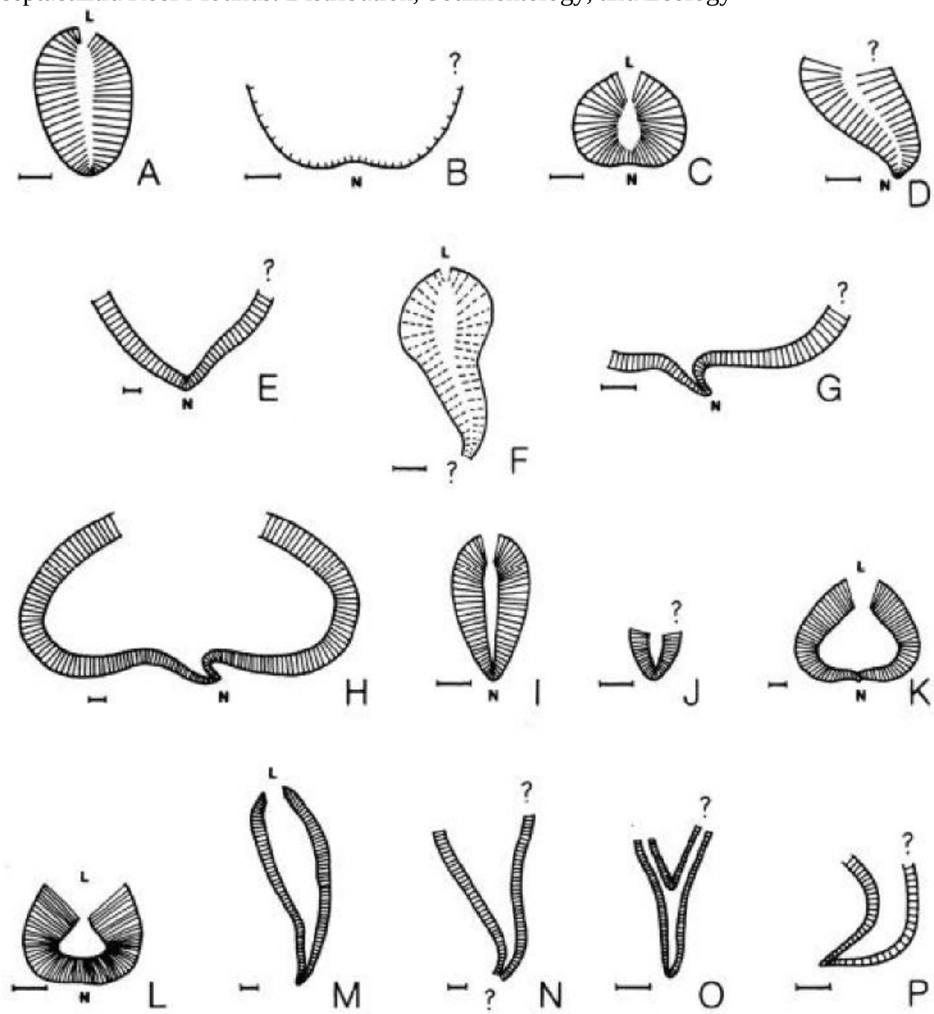
3.) Examine the variation of receptaculitid gross morphology across different environments, as I suspect that there is a degree of morphological plasticity that is directly related to environmental conditions. This may be considered analogous to today's scleractinian corals, which indisputably display environmentally-induced morphological plasticity (Todd, 2008).

The Great Basin provides an excellent laboratory for this study, as thousands of Ordovician-age receptaculitids can be collected in a variety of depositional environments over a wide geographic range in a well-constrained stratigraphic framework. Preserved and well-exposed throughout Nevada are the remnants of an extensive Ordovician carbonate platform. The edge of the carbonate platform in central Nevada had a westward facing carbonate slope and ramp, which opened to a deep basin in western Nevada (Droser & Sheehan, 1995). By the Ordovician, this region was a passive margin that formed after the breakup of the supercontinent Vendia. During the Ordovician, the carbonate platform was repeatedly flooded and drained. Deposition was dominated by muddy carbonates in the Early and Middle Ordovician, followed by widespread quartz sand deposition in the Middle Ordovician and clean carbonates in the Late Ordovician. Paleogeographically, the Great Basin drifted from a few degrees north of the equator at the beginning of the Ordovician to about 10º south of the equator by the end of the Ordovician (Droser & Sheehan, 1995).

Major sponge-receptaculitid buildups of this age with abundant, well-preserved receptaculitids occur in the Antelope Valley Limestone (AVL) of central Nevada and the correlated Pogonip Group of southern Nevada. Outcrops are accessible at multiple field locations in several different ranges. This study will be examining receptaculitids from 6 field sites: Lone Mountain, Whiterock Canyon, and Martin Ridge in the Monitor Range, Shingle Pass in the Egan Range, the west side of the Pahranagat Range, and the northwest Arrow Canyon Range. At each of these field areas, the sedimentology, stratigraphy, facies analysis, and sequence stratigraphy have already been thoroughly studied and firmly established. Ross (1964) conducted a comprehensive study of the Ordovician over much of Nevada and California, and correlated other units to the AVL. He also established three biozones within the unit that maintain consistent time throughout the Great Basin. Kaya produced a PhD dissertation in 1993, hammering down the depositional environments, diagenesis, and burial history of the AVL, followed by a 1997 paper documenting the sedimentation and facies analysis of the AVL and associated lithofacies. Siewers (1995) refined the ages for parts of the middle Ordovician group using mid-continent and North Atlantic conodont zones, and designated the receptaculitid-bearing member of the Pogonip Group (member Opf) as middle to upper Whiterockian (the lowermost stage of the Middle Ordovician) in age.

This extensive wealth of research and analysis of the stratigraphy of the Antelope Valley Limestone provides an excellent framework and environmental context from which to address the main questions of this study. Beyond the great contributions of Ross, Siewers, and Kaya, many others have addressed questions of sedimentology, stratigraphy, and facies analysis of the AVL (Kay, 1962; Merriam, 1963; Lowell, 1965; Stricker and Carozzi, 1973; Ross, 1977 and 1989). Field locations have been selected on the basis of receptaculitid abundance and variation in size and shape. Furthermore, formations chosen for this study record mounds that were largely dominated by receptaculitids in the absence of sponges, allowing closer examination of the singular role of receptaculitids in reef mound environments.

I will spend 7 to 8 weeks this summer collecting receptaculitid specimens from 3 of the 6 field locations listed above. Field work at Lone Mountain and Martin Ridge was completed last summer, while field work at Arrow Canyon is currently being conducted. This summer, I will return to central Nevada to conduct field work at Whiterock Canyon, Shingle Pass, and the Pahranagat Range. Detailed sections will be measured at each location. Reef mounds will be measured and mapped with consideration of horizons – do the mounds tend to occur on single horizons, as preliminary field work would suggest? Additionally, how much morphological variation is exhibited within these mound settings versus other settings in which they might occur? Fisher and Nitecki (1982) provided a standardization of anatomical orientation of receptaculitids that described ten of the most common types of receptaculitid body forms as seen in cross section (see figure below). Using this as a guideline, I will compare gross morphology as it relates to merom structure, both within and across environments to address these questions. Specimens will be measured and their morphological characteristics compared; external merom arrangement and body shape will be examined. Thin sections will be produced to examine structural morphology of meroms.



Diagrammatic cross section of common receptaculitid body forms.
From Fisher and Nitecki, 1982.

This study seeks to examine the morphology and ecology of receptaculitids, their role in carbonate buildups and reef mounds, their distribution on Ordovician carbonate platforms, and the effect of that distribution on the depositional environments and sedimentary packaging represented in these strata. Receptaculitids may have been critical agents in the stabilization of Ordovician reef mounds that then served as a launch pad for the Ordovician Radiation. If this is the case, receptaculitids had a much larger role in the establishment of the first analog to modern reef communities than previously recognized. Additionally, this study will assist in constraining the variability of the gross morphology of this group, which could provide new insight into the biology, ecology, phylogeny, and taxonomy of this most enigmatic fossil taxon, the receptaculitids.

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