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John M. Ryan
University of Arkansas, Fayetteville

Doy L. Zachry
University of Arkansas, Fayetteville

DEVELOPMENT OF ORGANIC MUD MOUNDS IN A MIXED CARBONATE-SILICICLASTIC DEPOSITIONAL ENVIRONMENT

JOHN M. RYAN and DOY L. ZACHRY
Department of Geology
University of Arkansas
Fayetteville, Arkansas 72701

ABSTRACT

Organic carbonate mud mounds in the Prairie Grove Member of the Hale Formation developed on a shallow shelf swept by competent tidal currents. The mounds were stabilized by crustose red algae and fostered a sheltered setting where phylloid algae and marine invertebrates could thrive. The mounds supplied skeletal sediment locally to the intermound areas as well as regionally along the stable platform. This sediment mixed with quartz sand to form a major mixed carbonate-siliciclastic system in northwestern Arkansas.

INTRODUCTION

Carbonate bioherms in Upper Mississippian and Lower Pennsylvanian strata of northwest Arkansas occupy stratigraphic positions between the more thoroughly investigated "Waulsortian reefs" of Early Mississippian age and the phylloid algal banks of Middle and Late Pennsylvanian age. Upper Mississippian mounds, localized in the Pitkin Formation, (Fig. 1) are features in which cyanobacteria and bryozoans trapped carbonate mud and silt (Webb, 1987). The Bloyd Formation (Fig. 1) of Early Pennsylvanian age contains mounds dominated by carbonate mud trapped and bound by stromatolites (Marsh, 1988). Both types grew in depositional settings where wave and current energy were not sufficiently competent to remove carbonate mud.

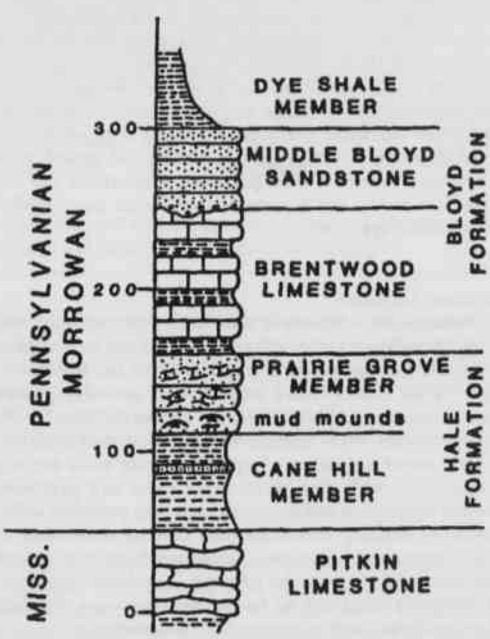

Figure 1. Stratigraphic section of lower Pennsylvanian (Morrowan) strata in central Madison County, Arkansas. Bioherms occur in the base of the Prairie Grove Member of the Hale Formation (modified from Marsh (1988)).

Carbonate bioherms, stratigraphically positioned at the base of the Prairie Grove Member of the Hale Formation (Fig. 1), are dominated by carbonate mudstone and a diverse group of marine algal and invertebrate components including abundant encrusting forms. They stabilized and developed in a depositional setting characterized by strong tidal currents and substantial sediment transport involving both skeletal grains and quartz sand. The growth of carbonate mud mounds in a high energy setting is unusual and differentiates these features from those stratigraphically below in the Pitkin Formation and above in the Bloyd Formation (Fig. 1).

LOCATION AND GEOMETRY

The carbonate bioherms in the Prairie Grove Member crop out in an elongate cut along Highway 23 approximately 11 miles south of Huntsville in Madison County, Arkansas (Fig. 2). The Highway trends north-south and the outcrop is located on the east side. Approximately 30 feet of Prairie Grove strata are continuously exposed over a distance of 780 feet. Two major and several smaller mounds and associated beds are present in this interval. Shale assigned to the underlying Cane Hill Member of the Hale Formation (Fig. 1) is exposed at highway level and the mounds stabilized and began development near the Cane Hill-Prairie Grove contact..

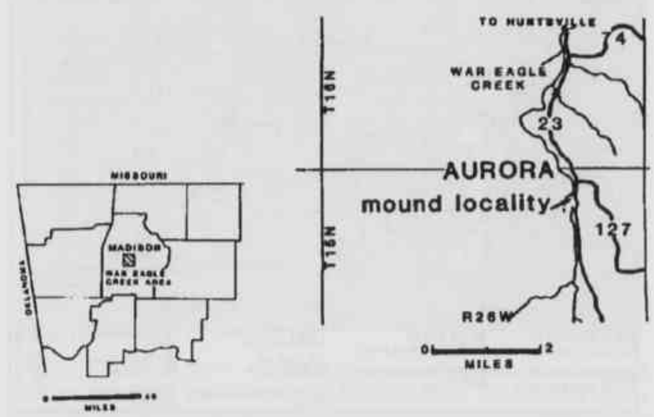

Figure 2. Northwest Arkansas and central Madison County delineating the War Eagle Creek study area along Arkansas State Highway 23.

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Major mounds in the interval range from 07 to 10 feet in thickness and 12 to 27 feet in breadth. Smaller satellite mounds are as small as two feet thick. The mounds are generally symmetrical (Fig. 3). They have well defined crestal areas and the flanks are inclined from 20 to 34 degrees away from the crests (Fig. 3). The mounds, within a solitary complex, are linked by tabular beds of mound lithology that extend from the base of a single mound to adjacent ones. Strata, laterally adjacent to the mounds, are characterized by current laminations and herringbone cross stratification. The mounds are massive and display little stratification. The boundaries between the mounds and the laminated flanking beds are both gradational and abrupt. The abrupt boundaries indicate that at the time they developed, the mounds had some synoptic relief and were clearly above the adjacent, current-swept sea floor. Transitional boundaries suggest that, at the time they developed, little relief was present and mound sediment mixed with sediment from the adjacent sea floor.

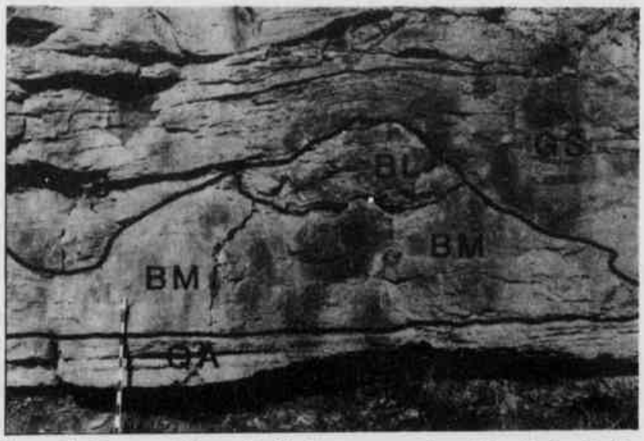


Figure 3. Outcrop of lower Prairie Grove strata along War Eagle Creek. Various facies and subfacies associated with the mounds are illustrated by (QA) calcareous quartzarenite, the mound facies which includes (BL) algal biolithite subfacies and (BM) skeletal biomicrite subfacies while (GS) represents the intermound grainstone facies. Cane Hill shale (CH) underlies the sequence.

LITHOFACIES

The mounds and the strata in which they are enveloped are lithically complex. The rocks involved have been assigned to the 1) calcareous quartzarenite, 2) skeletal grainstone, and 3) mound facies (Fig. 4). The mound facies contains two subfacies. Each facies and subfacies is believed to reflect a depositional environment extant when the mounds developed.

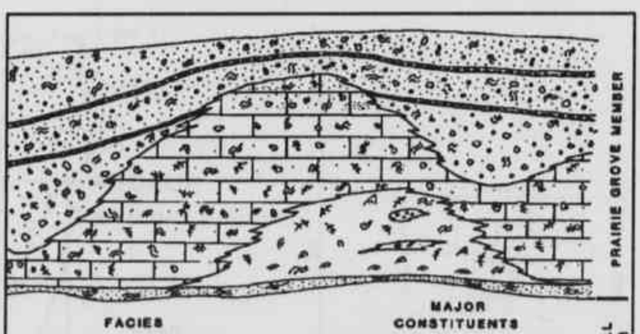


Figure 4. Facies cross section of a typical carbonate mound. Facies distribution is modified after the mound in Figure 3.

CALCAREOUS QUARTZARENITE FACIES

A shale unit at the top of the Cane Hill Member is directly overlain by laminated beds of the calcareous quartzarenite facies (Fig. 4). The facies is tabular in shape and ranges from 0.5 to one foot in thickness. It directly underlies each of the mounds (Figs. 3 & 4) and served as the substrate colonized by the mound organisms. Large bedforms created by currents may have formed bathymetric highs that were initially colonized by encrusting organisms. The calcareous quartzarenite facies is composed of fine to medium-grained quartz sandstone pervasively cemented by calcite.

Crinozoan and bryozoan skeletal fragments compose about 20 % of the framework grains. The rock contains shale clasts derived from underlying Cane Hill strata.

MOUND FACIES

The mounds are composed of two major rock types assigned to the algal boundstone subfacies and the skeletal packstone subfacies. The boundstone subfacies contains abundant remains of encrusting organisms that stabilized carbonate mud. The associated skeletal packstone subfacies is composed of carbonate mud with abundant skeletal organisms and phylloid algae. Encrusting skeletal organisms in growth position are absent.

Algal Boundstone Subfacies

The algal boundstone subfacies is the central feature of all mounds and was the core around which the other environments developed (Fig. 4). The facies is composed of carbonate mud and contains abundant remains of crustose red algae. The encrusting coral ***Aulopora*** is also present and grows within algal laminae (Fig. 5). Rugose corals and bryozoans occur in secondary amounts. Individual algal plants had plate-like morphologies and are most frequently preserved as laminar features composed of sparry calcite. In thin section, the algae appear as successive strips of sparry calcite (Fig. 6).

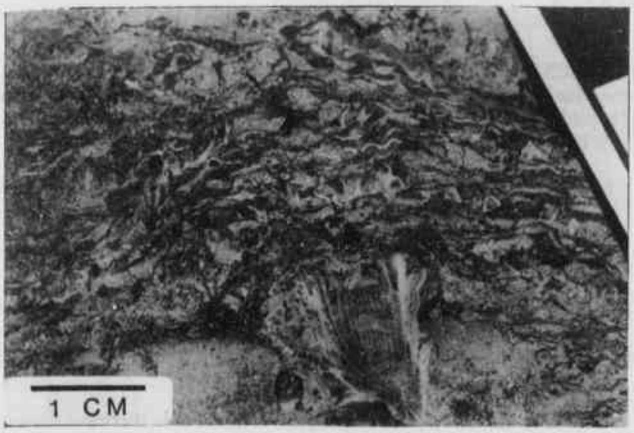
Rock of the algal boundstone subfacies is characteristically affected by minor brecciation, due to bioturbation, suggesting that the mud had a degree of rigidity soon after deposition. This compactional affect created a rigid core which supplemented the ability of the crustose organisms to continue mound accretion within the strong winnowing regime of tidal currents. The algae-encrusted the sediment-water interface and bound carbonate mud allowing vertical accretion and mound growth to occur. The algalencrusted sediment also provided a substrate for rugose, occasional tabulate corals, and bryozoans to colonize and contribute to mound development (Figs. 5 & 6).

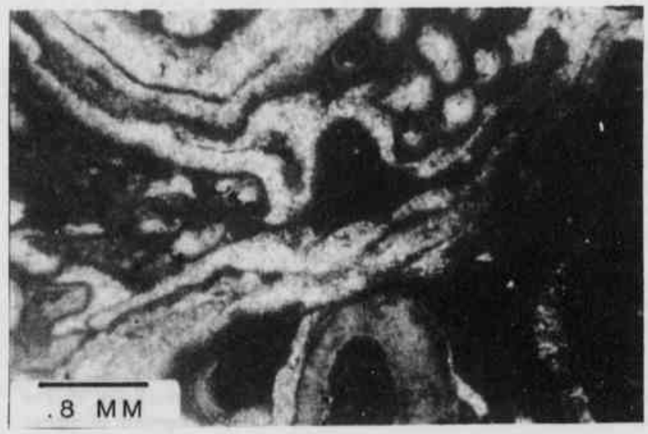
Skeletal Packstone Subfacies

The algal boundstone subfacies is bordered by mound strata assigned to the skeletal packstone facies (Fig. 4). This rock is composed of carbonate mud and skeletal grains of phylloid algae and bryozoans. The phylloid algae of the Prairie Grove mounds were probably green algae with aragonite skeletons. Modern forms characteristically inhabit environment protected from intense wave and current activity. The phylloid algae occur as plates of sparry calcite with no original microstructure preserved. The plants were erect and performed no binding function on passing sediment although they probably influenced mound growth by baffling carbonate mud thereby enhancing mound accretion. Bryozoans and occasional crinozoan fragments were transported to the environment from the adjacent boundstone lithotope. The protected setting was inhabited by fenestellid bryozoans, brachiopods, trilobites, foraminiferans, and numerous other invertebrates

SKELETAL GRAINSTONE FACIES

The skeletal grainstone facies includes strata sedimented concurrently with the mound sediment as well as that which covered the mound





Figures 5 & 6. Micro and macro photographs of mound biolithite subfacies depicting initial mud stabilization of mound by various encrusting organisms (*i.e.* Aulopora, red algae, encrusting bryozoans, and phylloid algae).

interval (Fig. 4). These rocks are composed of crinozoan, bryozoan, and brachiopod grainstone. Quartz sand composes 20% to 40% of the framework grains (Fig. 7).

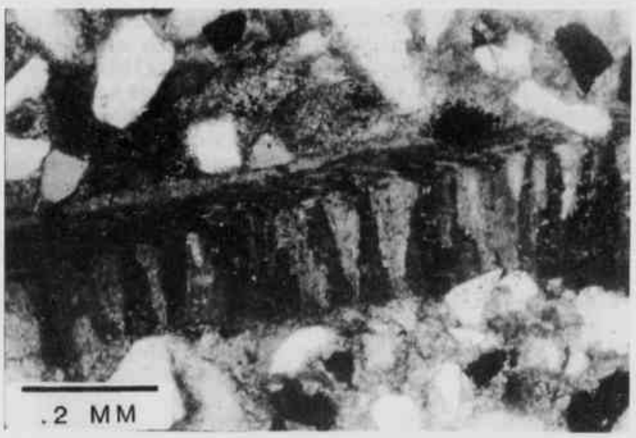


Figure 7. General skeletal grainstone photomicrograph depicting mixed quart sand and skeletal fragments (brachiopod).

The beds are prominently laminated and display small-scale cross stratification (Fig. 8). They fill depressions and channel-ways in the mound complex as well as dominating the intermound areas. Laminations of quartz sand occur in the crestal region of the mounds representing a transition from mound rock to the skeletal grainstone facies. This incursion of sand may have played a role in terminating mound growth.

DEPOSITIONAL SYNTHESIS

The Prairie Grove bioherms were established by the colonization of a firm substrate of calcareous sand (calcareous quartzarenite facies) by crustose red algae. The mounds developed as the binding activity of the algae consolidated carbonate muds and developed bathymetric relief (algal boundstone subfacies). Although erosional surfaces are present, the mounds were structurally resistant to competent tidal currents that swept the surrounding sea floor. The core of crustose red algae and mud provided a sheltered area on the leeward side of the individual mounds. Phylloid algae meadows flourished in these areas and contributed further mud accumulation (skeletal packstone facies). Fenestrate bryozoans, crinoids, brachiopods, trilobites and foraminifers also inhabited this environment and contributed to mound growth.

Skeletal and quartz sand of the skeletal grainstone facies was deposited adjacent to the mounds. These sands are frequently cross-bedded and always laminated. They are free of calcareous mud. The sedimentary structures and mud-free condition of the sand suggests that competent currents moved through the mound complex dominated by mud. This activity attests to the success of the crustose red algae in binding and retaining mud for mound construction in the face of strong currents.

The contact between mound lithologies and the adjacent skeletal grainstone facies is transitional in some areas and abrupt in others. Transitional facies suggest that the mound crests were only slightly above the adjacent sediment water interface and that mound growth was extremely slow and almost ceased. This is attributed to a greater supply of quartz sand and higher sedimentation rates that buried most of the mound. Small laminae of skeletal grainstone and quartz sand within the mounds indicate low relief allowing traction currents to transport sands across the mound surface..

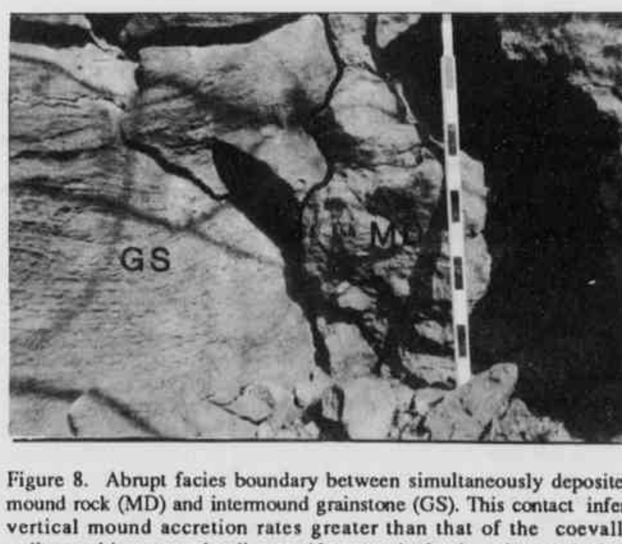


Figure 8. Abrupt facies boundary between simultaneously deposited mound rock (MD) and intermound grainstone (GS). This contact infers vertical mound accretion rates greater than that of the coevally sedimented intermound sediment. Also note the laminated cross beds of the grainstone demonstrating competent currents which are required to laminate sand sized skeletal particles.

Abrupt boundaries (Fig. 8) are far more common and indicate that mound growth exceeded accumulation rates on the adjacent sea floor and that the relief exceeded two feet. During these times the supply of quartz sand was diminished and organisms could recolonize the mound surface.

Quartz sand is far more abundant in strata that drape across the mound crests than in beds laterally adjacent to the mounds. This is reflected in the crestal areas of the mounds by alternating quartzose laminae and mound lithologies and suggests that ultimately a significant and prolonged increase in the supply of quartz sand may have buried the mounds and caused growth to cease.

The Prairie Grove Member of northwestern Arkansas is composed of quartz and skeletal sand and is characterized by horizontal laminations and cross stratification. The sediments accumulated on a high energy, shallow shelf dominated by strong tidal currents (Wiggins, 1978, Black, 1986). Quartz sand derived from the ancestral Mississippi River to the east was transported by competent north-south directed tidal currents across the shelf and impinged on the developing mounds (Fig 9). The mobile sand bottom was not suitable for widespread growth of marine invertebrates. The developing organic mounds provided the skeletal material that mixed with the quartz sand and was deposited locally around the mounds as well as transported regionally away from the mound complexes. These mounds existed as a skeletal sand factory supplying carbonate material for the Prairie Grove Member and formed a mixed carbonate/siliciclastic system in northwest Arkansas.

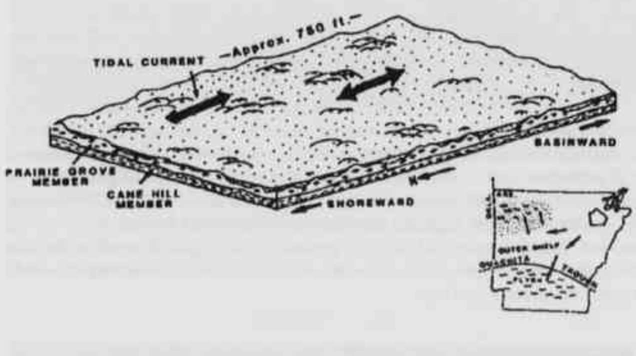


Figure 9. Early Morrowan paleogeographic map of Prairie Grove deposition with War Eagle Creek mound interval schematic depicting the development of the bioherms within the current systems which were actively transporting quartz and skeletal sand. VE = *4. (modified from Sutherland (1988) and Black (1986)).

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