An analysis of ostreoliths ("oyster balls") from the Carmel Formation (Jurassic), southwestern Utah

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INTRODUCTION

The Carmel Formation contains 2-3 laterally-extensive horizons of ostreoliths, or "oyster balls" (Wilson et al., 1998; Nielson, 1990). Ostreoliths are assemblages of concentrically encrusted oyster shells (*Liostrea strigilecula*) surrounding a nucleus. They form when oysters encrust the exposed (upper) surface of a bivalve shell before being flipped over by a current; oysters encrust the newly exposed surface before the assemblage is flipped again, allowing oysters to encrust over the old oyster valves (Wilson et al., 1998). The purpose of this project is to determine whether or not the ostreoliths of one horizon (the youngest) formed in place and to add new data to the debate between Nielson (1990) and Wilson et al. (1998) on where the ostreoliths formed. The focus of the analysis is on examining the matrix composition of the horizon and comparing it with the composition of sediments trapped in the ostreoliths. Ostreolith characteristics describing size and shape are used to analyze ostreoliths as sedimentary particles, to add more to the picture of ostreolith transport and deposition.

Nielson (1990) first mentions ostreoliths, calling them "oyster boundstones". He hypothesizes that the ostreoliths grew by radial encrustation on a soft, muddy substrate, and were buried when they grew too large and heavy and sank into the mud. Wilson et al. (1998) studied the origin and paleoecology of the ostreoliths. They dispute Nielson's hypothesis, claiming that the ostreoliths rotated frequently as they grew on a soft ooid shoal substrate, and were washed into a muddy sediment by a storm current.

METHODS

Ostreoliths were examined at seven study sections spanning approximately two kilometers of the exposure (see Figure 1). Samples of ostreoliths and horizon matrix were gathered from each section.

Thin sections of ostreolith internal structure and sedimentary matrix were prepared for each field section. Point-count analysis for each thin section provided data for composition analysis, comparing the matrix and trapped sediments across the 7 sections.

Ostreolith size was analyzed as spherical volume ($V= 1/6*\pi*(D_1*D_2*D_3)$, and the diameter of a sphere of equal volume was calculated and plotted versus Hjulstrom's Diagram. Ostreolith shape was analyzed according to Zingg's Classification of Particle Shape, the ratios of three mutually-perpendicular diameters of a particle, D_S, D_I, and D_L (1935; as cited by Davis, 1992).

RESULTS

Matrix Composition

An example of the horizon matrix can be seen in Figure 2, and the composition variations across the sections can be seen in Figure 3. A trend shown in Figure 3 is the relative consistency between Sections 1-4, and the high variability in Sections 5-7. Sections 1-4 show similar percentages of micrite and ooids. Quartz and calcite are not quite as consistent. Sections 5-7, however, are very different, primarily in the relationships between the components. Sections 1-4 (except for the second sample from Section 4, labeled on chart as Section 4.5) are dominated primarily by micrite and secondarily by ooids. Sections 5 and 7 are dominated primarily by ooids. Section 5 even has more quartz silt than micrite. Sections 3, 4.5, and 6 have relatively higher calcite composition than the other sections.

Trapped Sediments

Sediments are easily trapped in the ostreoliths, either between valves or in borings, when other oysters encrust over the surface (See Figure 4). The variation in trapped sediments across sections is visible in Figure 5.

The trend across sections varies between the trapped sediments and the matrix compositions. The ooid and quartz composition does not change very much across all of the sections, although they switch positions between which one has a higher composition. The micrite composition also is very similar between Sections 1-5, but it jumps at Sections 6 and 7. The calcite composition plummets at Sections 6 and 7 as well. The two are most likely factors of each other.

Analysis of Ostreoliths as Particles

Sections 1-3 and 5 had similar population densities, which were much higher than those from the more northwest sections (4, 6-7). The Zingg's Diagrams for ostreoliths at each section show most ostreoliths clustering near the spherical/oblate border. There is a slight trend from equant to oblate/bladed from the southeast to the northwest (from Section 1 towards Section 7).

Many of the characteristics of ostreoliths that would seem to have an influence on transport and deposition did not yield significant results that indicated differences between sections. Sources of error as well as insufficient methods of data collection are to blame.

DISCUSSION

Sedimentary Matrix

The horizon matrix represents the substrate environment of deposition of the ostreoliths. The trends found in the matrix compositions compared across sections show a great deal of variability between Sections 5, 6, and 7 and the other sections (1-4). From this I hypothesize that the ostreoliths were deposited in different environments. The environments of Sections 1-4 may have been similar, but the environments of Sections 5, 6, and 7 were all different. Except for Section 6, there is a trend showing an increase in ooid content beginning at Section 3, and increasing towards Section 7.

Ooids form in high-carbonate, shallow water that is subject to regular current action (J. Wilson, 1975). Well-developed ooids form on shelf margins instead of behind a well-developed barrier reef or in well-protected lagoons where the water currents are too restricted (J. Wilson, 1975). The ostreoliths with ooids as trapped sediments couldn't have formed in a muddy lagoon like Nielson claimed.

The high percentage of ooids and the presence of well-formed ooids indicates that the depositional environment around Section 7 (and possibly also Section 6) was that of an ooid shoal (see Figure 7). At the shoal, there would be more ooids than at other sections, but less ostreoliths deposited because they are more likely be rolled downslope into deeper parts of the lagoon (per Wilson et al., 1998). The horizon sediments may have been carried in with the ostreoliths. If this is the case, then the higher percentages of ooids should be closer to the sediment source.

There are differences in the trends between the matrix and the trapped sediment compositions. The similarity of the trapped sediments, especially across Sections 1-5, support the hypothesis that the ostreoliths formed in a similar environment, if not in the same location. Despite the differences in micrite and calcite compositions at Sections 6 and 7, the ooid and quartz compositions are still very similar to those from the other sections. The differences between the micrite and calcite compositions are probably insignificant. The micrite and calcite compositions affect each other, but they do not significantly affect ooid and quartz content.

After assuming that the environments of formation are similar while the environments of deposition vary, the question is whether or not there any similarities between the environments of formation and deposition. From the graphs, the ooid and quartz compositions are a lot lower, and also more consistent among the trapped sediments than the matrix samples.

The oyster boundstone horizons are interbedded with restricted lagoonal deposits (mudstone and siltstone; See Figure 6a) (Nielson, 1990). The underlying bed is a thin bedded limestone, beneath which is a mudstone (Nielson, 1990). The ostreolith-bearing horizon is overlain by another mudstone (Nielson, 1990).The oyster boundstone can be seen as an increase in grain size, as well as an increase in grain size distribution, that often characterizes a storm deposit.

However, Nielson (1990) finds that the oyster boundstone makes a gradational contact with the underlying layer, which is not indicative of a storm deposit. Storm deposits frequently have erosional bases, making a sharp contact with the underlying bed (Seilacher & Aigner, 1991). Perhaps the underlying limestone is part of the storm deposit, because it also marks an increase in grain size from the mudstone, and it makes a sharp contact with its underlying mudstone (Nielson, 1990). The oyster boundstone and the underlying limestone together look similar to the stratigraphy of a debrite (See Figure 6b), the sequence of a debris flow that contains a wide range of grain sizes and is usually coarsening upwards (Davis, 1992).

Analysis of Ostreoliths as Particles

The high density of ostreoliths in the southeast sections (1-3, 5) show that this is where a large drop in current velocity occurred (Davis, 1992). Grain shape effects both transport and deposition of particles. Less spherical grains are both dislodged from the bed less frequently and transported less efficiently (Pye, 1994), so the more spherical ostreoliths should theoretically have traveled farther than less spherical ones. This implies that Sections 1-3 were down-current from the other sections.

CONCLUSIONS

My research agrees with the analysis of M. Wilson et al. (1998) in that the ostreoliths did not form in a restricted lagoonal environment (as claimed by Nielson, 1990), but were transported there by currents. This is shown by:

1) The trapped sediments do not match with the matrix sediments.
2) The trapped sediments do not represent restricted lagoon sediments.
3) The horizon matrix varies across the horizon, while Nielson claimed only one environment of formation.

The analysis of matrix sediments combined with the population density distribution along the horizon seem to place the most southeast sections (Sections 1-2) landward, in the deeper parts of the lagoon, and the northwest sections (6 and 7) on the seaward side of the lagoon, at or near ooid shoals.

More research, especially of the horizon matrix, ostreolith orientation within the matrix, and other characteristics of ostreoliths as sedimentary particles, would clarify analysis of ostreolith transport and deposition.

REFERENCES

Davis, R.A., 1992, Depositional Systems: An Introduction to Sedimentology and Stratigraphy: Prentice Hall, Englewood Cliffs, NJ.

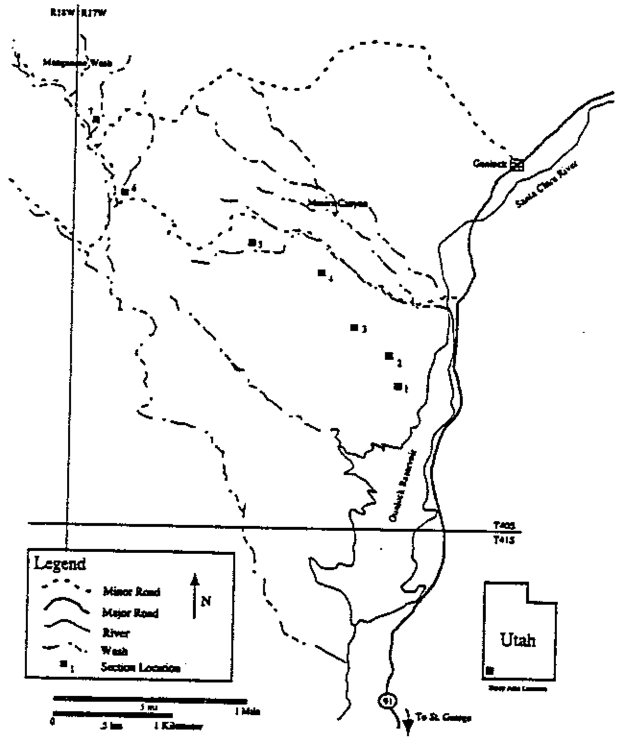
Nielson, D.R., 1990, Stratigraphy and sedimentology of the Middle Jurassic Carmel Formation in the Gunlock area, Washington County, Utah: Brigham Young University Geology Studies, V. 36, p. 153-192.

Pye, K., 1994, Properties of sediment particles, *in* Pye, K., ed., Sediment Transport and Depositional Processes: Blackwell Scientific Publication, Oxford, p. 1-24.

Seilacher, A., and Aigner, T., 1991, Storm deposition at the bed, facies, and basin scale: the geologic perspective,*in* Einsele, G., Ricken, W., and Seilacher, A., eds., Cycles and Events in Stratigraphy, Springer-Verlag Berlin Heidelberg.

Wilson, J.L., 1975, Carbonate Facies in Geologic History: Springer-Verlag, Berlin, 471 pp.

Wilson, M.A., Ozanne, C.R., and Palmer, T.J., 1998, Origin and paleoecology of free-rolling oyster accumulations (ostreoliths) in the Middle Jurassic of southwestern Utah, USA: Palaios V. 13, p. 68-76.



(From USGS Gunlock Quad; Modified after Wilson, 1997 and Nielson, 1990)

Figure 1: Map of study area, including sections.

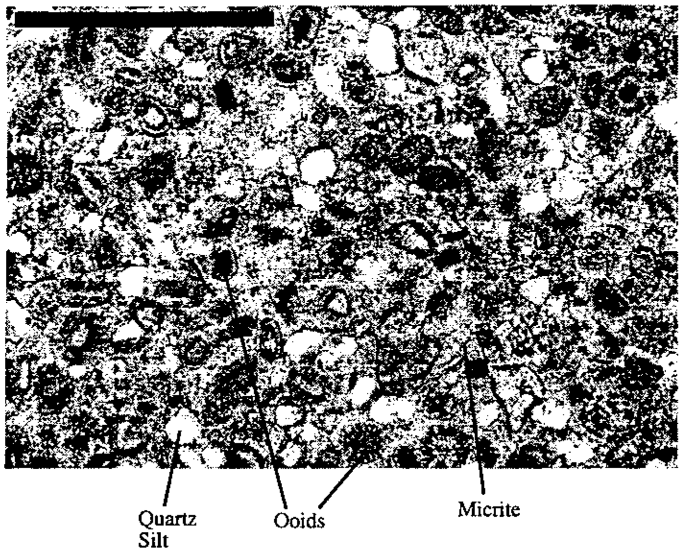


Figure 2: Photomicrograph of matrix sample (from Section 6). Scale bar is 1 cm.

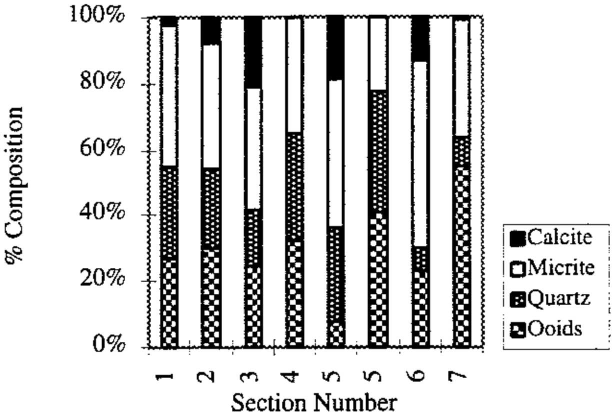


Figure 3: Matrix composition compared across sections.

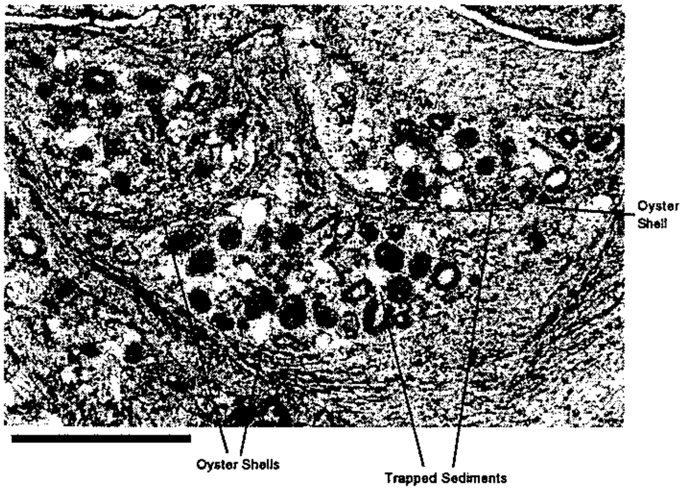


Figure 4: Photomicrograph of sediments trapped between oyster valves, as 2 oysters encrust over older valve. Scale bar is 1 cm.

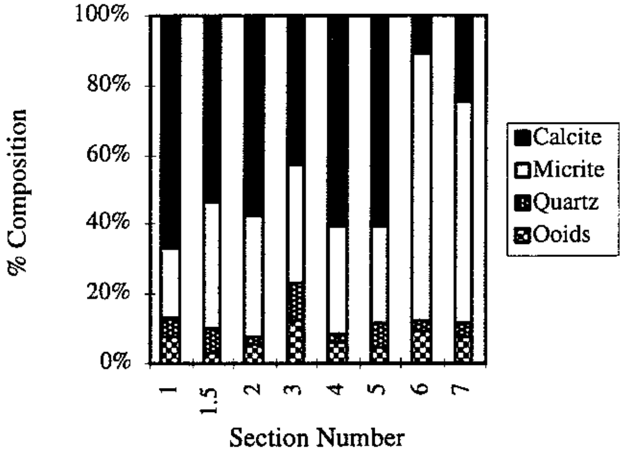


Figure 5: Trapped sediment compositions across sections. Section 1.5 is another data set from Section 1.

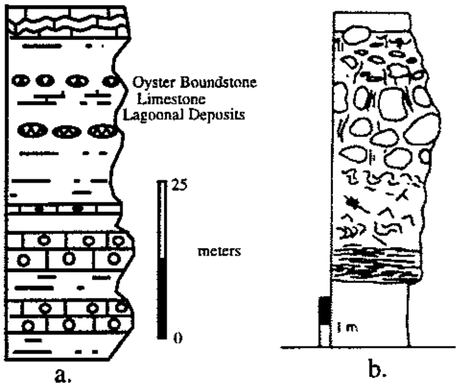


Figure 6: a.) Strat column of section of Carmel containing oyster boundstone horizon. Upper horizon is the one studied in this paper (From Nielson, 1990).
b.)Idealized stratigraphy of a debrite. (Davis, 1992)

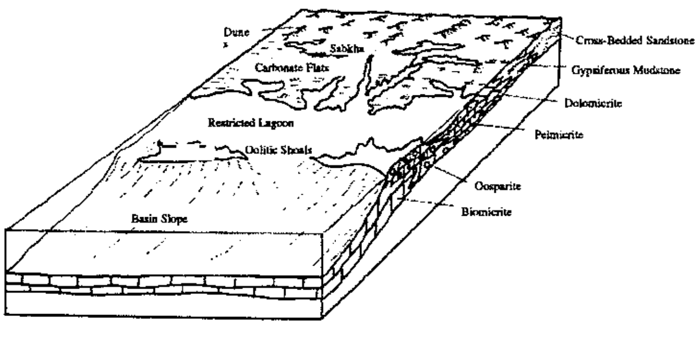


Figure 7: Idealized facies model of a carbonate lagoon system. (Wilson, 1975)