

PS Antecedent Topography as a Control on Facies Heterogeneity in a Shallow Heterozoan Carbonate System*

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Webmaster note: Pages 4 and 5 may require extra time to open.

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Abstract

Pliocene heterozoan carbonates in the Agua Amarga basin, SE Spain, reveal facies heterogeneity resulting from depositional processes interacting with substrate topography. The surface upon which Pliocene strata were deposited consists of two low-relief terraces separated by ~10m of vertical relief, likely resulting from episodes of transgressive marine erosion. Oldest deposits crop out on the uppermost terrace and are packstones with mollusks and rhodoliths. A Pliocene relative sea-level fall resulted in erosion of these and underlying deposits and created a local surface with morphology resembling a paleovalley. Pliocene carbonate facies deposited during or after subsequent reflooding consist of abraded, very fine to medium sand sized carbonate packstones with variable amounts of rhodoliths, oysters, and rounded micrite pebble intraclasts. On terraces, heterogeneity correlates with proximity to the edge of the terrace. Near breaks in slope on terrace margins, deposits are massive and coarse (30-55% rhodoliths, oysters, micrite intraclasts). Oysters are more common on the upper terrace. In contrast, relatively flat terrace interiors are dominated by abraded sand-sized packstone; strata are massive, normally graded, or trough crossbedded with alternating sharp-based coarser (10-50% coarse) and finer (0-10% coarse) layers. We interpret these alternations to reflect the following: (1) sporadic storms deliver coarse material derived from margin areas; (2) periods of wave and tidal energy abrade and produce crossbeds; and (3) periods of lower energy produce massive beds through bioturbation. On areas of steeper slope between terraces, facies are similar to terrace interiors, with alternation of finer and coarser packstone layers. Increased numbers of alternations on slope areas suggest intermittent transport from terraces upslope, and amalgamation on terrace interiors. Overall facies distribution indicates terrace margins as locations of preferred carbonate productivity, due to higher energy and increased nutrient input at breaks in slope. These results indicate that prediction of heterogeneity in heterozoan carbonate systems should combine an understanding of the controls on production (e.g., nutrient availability and currents) and physical processes controlling where carbonate sediments ultimately accumulate. Antecedent topography is an important control for both production and heterogeneity of heterozoan carbonate facies.

References

Dillett, P.M., 2004, (ed.) Paleotopographic and sea-level controls on the sequence stratigraphic character of a Heterozoan carbonate succession: Pliocene, Carboneras basin, southeast Spain.

Dvoretzky, Rachel A., 2009, Stratigraphy and reservoir-analog modeling of upper Miocene shallow-water and deep-water carbonate deposits: Agua Amarga basin, southeast Spain: M.S. Thesis, University of Kansas, 148 p.

Franseen, E.K., Byrnes, A.P., Xia, J., and Miller, R.D., 2007, Improving resolution and understanding controls on GPR response in carbonate strata: Implications for attribute analysis: *The Leading Edge*, v. 26, p.984-993.

James, N.P., 1997, The cool-water carbonate depositional realm, *in* Cool-Water Carbonates, N.P. James and J.A.D. Clarke, (eds.): SEPM Special Publications, v. 56, p. 1-22.

Purpose

- 1) Improve understanding of heterozoan* carbonate facies distribution and response to sea-level changes in accommodation-limited areas.
- 2) Develop heterozoan facies models, in relation to paleotopography and in a sequence stratigraphic context, to determine:

- the importance of water depth and current controls
- if marine planation occurs during sea-level rises, falls, or stillstands
- if deposition occurs during sea-level rises, falls, or stillstands
- the effects of a heterozoan association on sequence stratigraphic process-response models

*The Heterozoan Association, defined by James (1997), contains benthic carbonate particles produced by light-independent organisms and/or red algae.

Implications

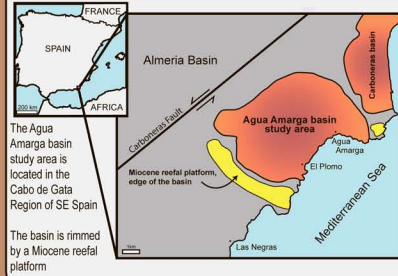
In accommodation-limited, cool-water areas the presence of a terraced paleotopography may be a control on facies distribution.

Late transgressive to early highstand deposits might be hypothesized to aggradational to progradational stacking in a photozoan system. In contrast, the heterozoan deposits observed in this study are stacked retrogradationally.

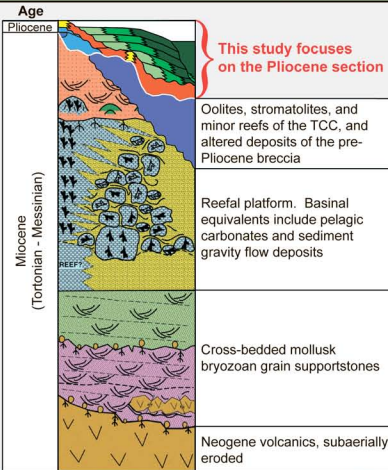
In heterozoan systems, the lack of anticipated aggradation or progradation in late transgressive-early highstand deposits might be explained by slow sediment production rates. Transgressive stacking patterns and deepening-upward trends could then develop just before highest sea level.

Sediment production rate appears to be a major factor influencing stacking patterns in accommodation-limited, heterozoan areas.

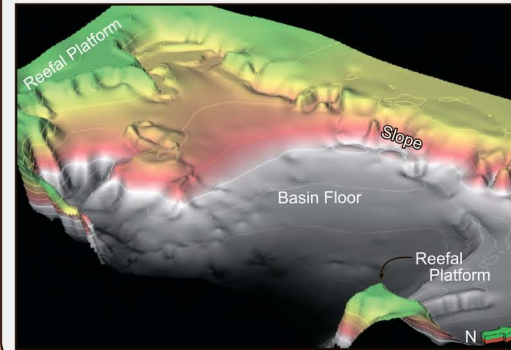
Location



Generalized Stratigraphy



Pre-Pliocene Basin Character



Photozoan* components, such as *Tarbellastrea* and *Porites* corals, thrived on the margin of the Agua Amarga basin during the Miocene.

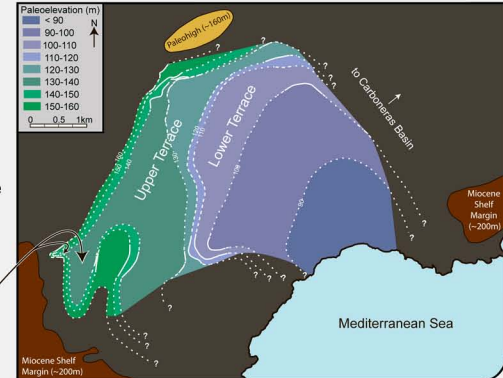
Reefal platforms developed ~230 m above the basin floor, bounding the basin to the east and southwest.

Even after Miocene deposition, much of the reefal margin-to-basin paleotopography is preserved before Pliocene marine flooding.

*The Photozoan Association, defined by James (1997), contains benthic carbonate particles produced by light-dependent organisms, non-skeletal particles, and/or heterozoan components.

Paleotopography at Base of Pliocene

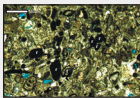
- Pliocene deposits overlie a surface with terraced paleotopography (marine planation) and valley incision (subaerial).
- The lower terrace is from ~100–110 m above sea level and slopes $\leq 0.69^\circ$ – 2.9° seaward.
- The upper terrace is from ~120–140 m above sea level and slopes $\sim 0.39^\circ$ – 3.2° seaward.
- Underlying Miocene deposits are truncated by the terraced paleotopographic surface.
- Two paleovalleys drained from the exposed Miocene reefal platform on the south-south west edge of the basin.



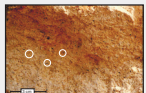
Foraminifer packstone—grainstone

Description: Foraminifera dominate, with highly abraded rhodolith and oyster fragments throughout. Mud may be present, and large oysters become less abraded, mostly articulated, and more prevalent upwards.

Interpretation: Associated oysters and their increasing prevalence upsection indicates a relatively shallow environment, proximal to shallow oyster banks. Mud in some instances suggests a sheltered environment.



Photomicrograph showing rhodolith fragments (r) and foraminifera (f)



Note mollusks (white circles)

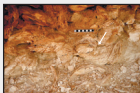


Note articulated oysters (white arrows) which increase in concentration upwards

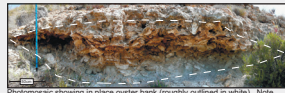
Oyster boundstone

Description: Large, articulated oysters are intergrown and slightly abraded to un-abraded. Interstitial spaces are filled with carbonate sand.

Interpretation: *In situ* oyster buildup. Interstitial carbonate sands filtered in from overlying deposits.



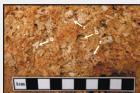
Note oysters growing on older generations of oysters (white arrow)



Carbonate sandstone with bryozoans

Description: Flattened stick bryozoans (>10%) and slightly-moderately abraded sand-sized unidentifiable carbonate grains. Highly abraded rhodolith fragments, highly abraded mollusks, and moderately abraded barnacles locally present.

Interpretation: Relatively shallow environment, more proximal than foraminifer packstone—grainstone. Tend to form near landward edges of terraces.



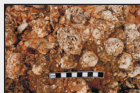
Note articulated oysters (white arrows) which increase in concentration upwards

Lithofacies

Coarse, slightly abraded rhodolith grainstone

Description: Large, slightly abraded rhodoliths (≤8 cm) and slightly-highly abraded oysters in a carbonate sand matrix. Oysters are aligned horizontally in concentrated layers. Deposits are finer and more abraded upwards.

Interpretation: *In situ* rhodolith buildup in ~5 m water depth. Interstitial carbonate sands washed in by waves, tides, or storms. Growth into shallower, higher energy environment results in fining and increasing abrasion upwards.



Large rhodoliths provide the support mechanism for these deposits



Large rhodoliths (r) with matrix dominated by abraded rhodolith and mollusk matter

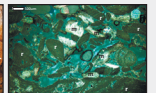
Coarse rhodolith oyster grainstone

Description: Slightly abraded rhodoliths and concave-down oysters in a moderately-highly abraded rhodolith and oyster matrix. Deposits may be massive, bedded, have scoured bases, or contain trough cross-bedding.

Interpretation: Rhodolith material redistributed and abraded by wave, tidal, and storm processes. Most deposited in ~0–15 m water depth.



Sharp, erosional base to a coarse rhodolith grainstone bed



Photomicrograph showing highly abraded rhodolith (r) and oyster (m) matrix

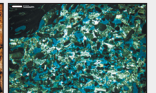
Fine, cross-bedded rhodolith oyster grainstone

Description: Mixed abrasion sand-granule sized unidentifiable carbonates with highly abraded rhodolith fragments. Deposits may be normal or reverse graded, massive, bedded, or multidirectional or unidirectional cross-bedded.

Interpretation: Rhodolith material redistributed and abraded by wave, tidal, and storm processes. Most deposited in > ~15 m water depth.



Inversely graded bed



Photomicrograph showing highly abraded rhodolith fragments and the edge of a rhodolith

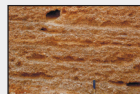
Metamorphic rock fragment conglomerate

Description: Poorly sorted metamorphic clast conglomerate with rounded metamorphic granules—pebbles and barnacles in a fine lithic sandstone matrix. Deposits are low angle cross-stratified and elongate grains tend to align with cross-stratification.

Interpretation: Shoreface deposits ~0 m water depth.



Note metamorphic clasts



Note low angle cross-stratification



Metamorphic pebble with encrusting barnacles

Metamorphic rock fragment sandstone to conglomerate

Description: Fine-grained lithic sandstone with metamorphic granules—pebbles, highly abraded barnacle fragments, and un-abraded—highly abraded mollusks. Deposits are horizontally bedded 2–20 cm or unidirectional or trough cross-bedded.

Interpretation: Foreshore deposits, transitional between coarser, shallower deposits and finer, deeper deposits, ~2–12 m water depth.



Note metamorphic clasts



Trough cross-bedding downlapping onto surface indicated by white arrow

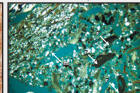
Metamorphic rock fragment sandstone

Description: Very fine-fine-grained lithic sandstone with abraded sand-granule sized unidentifiable carbonate grains. Deposits are massive, horizontally bedded 10–15 cm, or unidirectionally or multidirectionally trough cross-stratified.

Interpretation: Foreshore to offshore deposits distal to coarser but similar deposits, > ~12 m water depth.

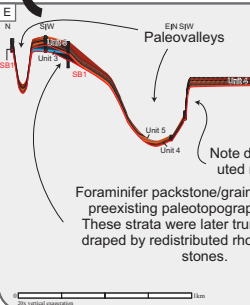
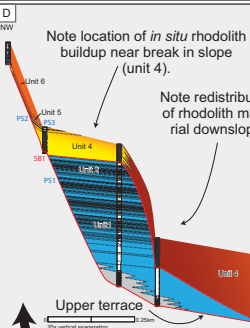
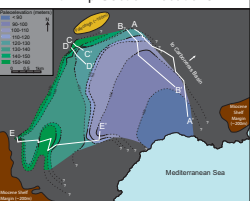


Lithic sandstone with mollusk shells

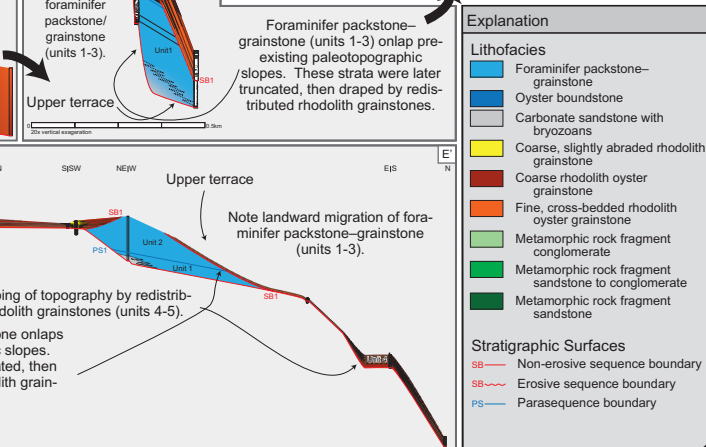
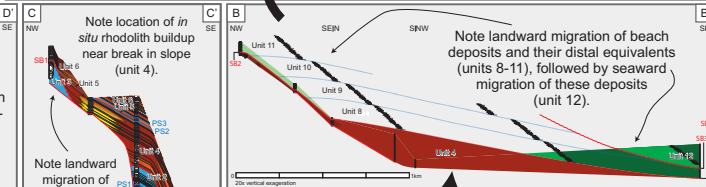
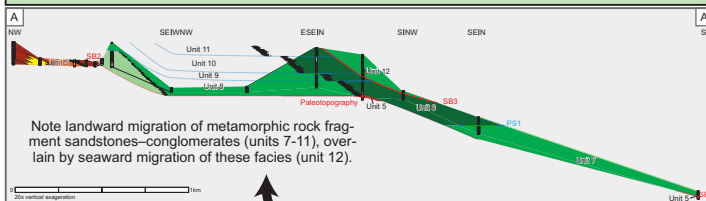


Photomicrograph showing metamorphic pebble (m) and abraded rhodolith fragments (r)

Paleotopography at Base of Pliocene with Dip Section Locations



Stratigraphy and Paleotopography



Explanation

Lithofacies

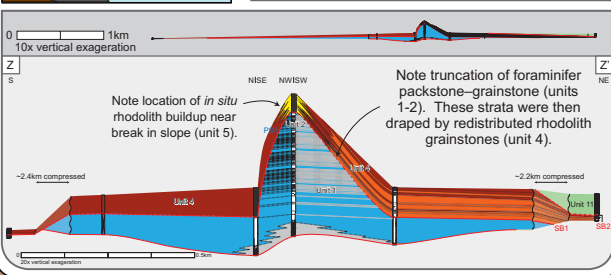
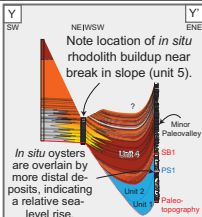
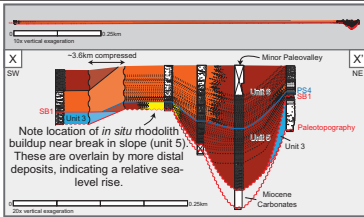
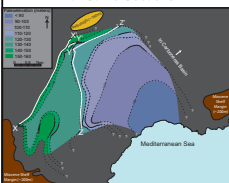
- Foraminifer packstone—grainstone
- Oyster boundstone
- Carbonate sandstone with bryozoans
- Coarse, slightly abraded rhodolith grainstone
- Coarse rhodolith oyster grainstone
- Fine, cross-bedded rhodolith oyster grainstone
- Metamorphic rock fragment conglomerate
- Metamorphic rock fragment sandstone to conglomerate
- Metamorphic rock fragment sandstone

Stratigraphic Surfaces

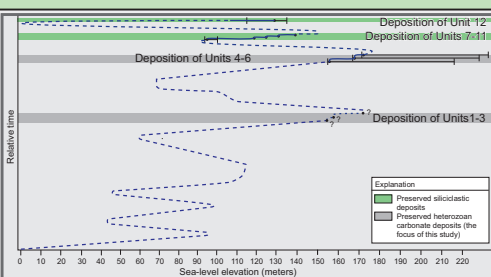
- SB Non-erosive sequence boundary
- ~ SB Erosive sequence boundary
- PS Parasequence boundary

Stratigraphy and Paleotopography

Paleotopography at Base of Pliocene with Strike Sections



Sea-level Curve



Preserved heterozoan deposits (gray areas) form late during the relative rise in sea level, just before the highstand turnaround point

Preserved siliciclastic deposits (green areas) form during relative rises in sea level

Dashed areas of curve based on Dillett (2004) sea-level curve from adjacent Carboneras basin

Origin of Terraced Paleotopography

Truncation of strata beneath the terraces, their gentle seaward slope, and the presence of overlying marine deposits indicate that terraces formed as the result of marine planation.

Marine planation surfaces form in the surf zone during stillstands or slow rises. The simplest explanation is that the Agua Amarga basin terraces formed during a stepped transgression.

Discussion

Topographic Control on Facies Distribution

In situ rhodoliths are found near breaks in slope. These are areas where current energies are focused, creating a better environment for rhodolith formation.

Rhodolith material is redistributed by wave, tide, and storm energy. Coarser deposits are found closer to *in situ* rhodolith deposits. With rhodolith formation concentrated on the seaward edge of terraces, this material is more easily distributed basinward down the steeper slope than landward across a relatively flat surface.

Sequence Stratigraphy of Heterozoan Deposits

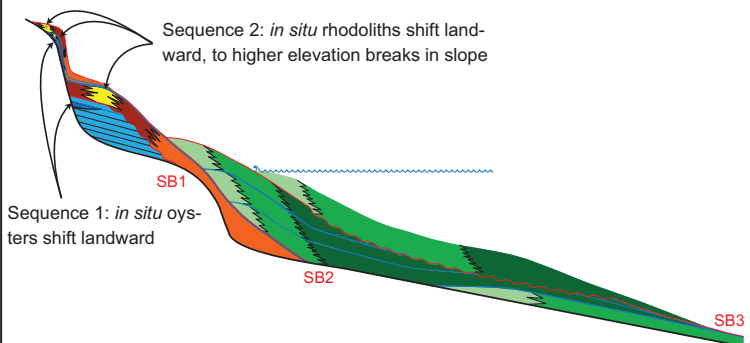
Preserved heterozoan deposits form late during the relative rise in sea level, just before the highstand turnaround point. In photozoan systems, late transgressive to early highstand deposits are hypothesized to show aggradational to progradational stacking. In contrast, the heterozoan deposits observed in this study are stacked retrogradationally.

In heterozoan systems, sediment production rates are commonly low, which explains the lack of anticipated aggradation or progradation just before the highstand turnaround point. Transgressive stacking patterns and deepening-upward trends could then develop even when rate of relative rise in sea level is slow.

Later highstand and forced regressive deposits are not preserved. They may have been removed by erosion.

Generalized Basin Stratigraphy Through Time

NW SE
Note retrogradational stacking in heterozoan deposits (sequences 1 and 2)



Conclusions

Origin of Terraced Paleotopography

Marine planation in the surf zone occurred during a stepped transgression, resulting in a terraced morphology. Each terrace records a stillstand or slow rise of sea level.

Topographic Control on Facies Distribution

In accommodation-limited areas, where heterozoan carbonates are deposited over a terraced paleotopography, rhodoliths may form near breaks in slope. These are potential areas of focused energy. Abraded rhodolith material is redistributed by wave, tide, and storm energy, and fines away from the rhodolith source area.

Sequence Stratigraphy of Heterozoan Deposits

In this heterozoan carbonate system, retrogradationally stacked strata are deposited just before the highstand turnaround. In heterozoan systems, sediment commonly accumulates slowly. There may be insufficient sediment to produce the aggradational-progradational stacking typical of photozoan systems just before the highstand turnaround. A transgressive (retrogradational) stacking pattern and deepening-upwards trends could then continue into what is normally identified as early highstand systems tracts.