Construction of 3D Reservoir-Analog Model for an Oolite-Microbialite Sequence

C.J. Lipinski, Robert H. Goldstein, Evan K. Franseen

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Purpose
The project is focused on developing 3D reservoir analog models of oolite-microbialite-coralgal reef sequences from the Miocene of Spain. The goal is to evaluate the control of paleotopography on reservoir characteristics to develop quantitative models of reservoir heterogeneity suitable of use in subsurface examples.

Project Description
To make careful stratigraphic work useful to the oil and gas industry, it is essential that outcrop analogs be developed into three-dimensional quantitative models of porosity and permeability. This project develops 3D reservoir analogs for two areas of outcrop of the Miocene Terminal Carbonate Complex (TCC) of SE Spain. The TCC consists of four sequences consisting of oolite, microbialite, bioclastic sands, and coralgal reefs. In the Ricardillo area, highstand and intermediate positions are preserved and tend to onlap and drape paleotopography.

The microbialite-oolite-reef sequences of the TCC are of great interest because many highly productive reservoirs are composed of microbialites and oolites deposited in similar settings (Kerans and Tinker, 1997). Understanding the distribution of porosity within similar carbonate systems will aid in the development of preexisting and recent discoveries such as the Tupi field of the Santos Basin, which is thought to consist primarily of microbial carbonates (Nakano et al., 2009). This study will provide a better understanding of patterns of porosity distribution as they correspond to changes in sea level and paleotopography, and will provide conceptual and quantitative models for porosity distribution for more effective exploitation of analogous carbonate reservoirs.

Deliverables
Models for both areas reveal reservoir-quality values and have the potential for substantial hydrocarbon storage. All data are quantified in two models built in Petrel.

- Flow and baffle facies were distinguished based on thickness, lateral distribution, porosity and permeability.
  - Flow facies for the field areas are laterally extensive, have significant thickness, large storage quantities, and good permeability values providing good lateral connectivity. The flow facies consist of trough cross-bedded ooid grainstone, massive ooid grainstone, beach sequence lithofacies, trough cross-bedded ooid bivalve grainstone, cross-bedded oolitic gastropod grainstone, vuggy thrombolite boundstone, volcanioclastic-rich planar bedded ooid grainstone, and *Porites* boundstone. The flow facies all have reservoir-quality porosity and permeability.
Baffle facies for the field areas vary in their lateral extent, have lesser storage capacities due to less pore volume and common thin accumulations, and poor permeability values. The baffle facies consist of stromatolite, dense thrombolite boundstone, and fenestral ooid grainstone. Some of the facies have reservoir-quality porosity, however, the low permeability values would hinder exploitation.

- The baffle facies are concentrated near the sequence boundaries and would likely constrict connectivity between sequences. Stromatolites deposited above fenestral ooid grainstone would create laterally extensive baffles with significant thicknesses at the sequence boundaries.

- The trough cross-bedded ooid grainstone is volumetrically the most abundant lithofacies within both models, is laterally extensive across the entirety of sequences, and has large storage capacities with good permeability. The lithofacies would also have good connectivity with the other flow facies. This lithofacies represents the best reservoir-quality facies and would be the primary target for hydrocarbon exploitation.

- Best exploitation of hydrocarbons at the two field areas differs.
  - At La Molata, the central high would be the best place for drilling. Hydrocarbons would flow updip to the central high through the reservoir facies. Multiple perforations would be needed to extract oil from the sequences because of the baffle facies located at the sequence boundaries.
  - At La Rellana/Ricardillo (Figure 1), the best location for drilling would differ for the sequences. Sequence 1 is absent west of the Ric 11 section. If the hydrocarbons remained trapped within the sequence, this would be the best place to drill. The contact between Sequence 1 and 2 at La Rellana/Ricardillo lacks the concentration of baffle facies that occur at other sequence contacts. Sequence 1 fenestral ooid grainstone has variable laterally connectivity and Sequence 2 has no stromatolites at the base. Hydrocarbons would likely migrate from Sequence 1 to Sequence 2. The highest preservation of Sequence 2 deposition occurs at 263 m elevation. This would be the best place to drill for exploitation of hydrocarbons. The last preservation of Sequence occurs at 242 m elevation (just west of section Ric 12). Baffle facies of fenestral ooid grainstones from Sequence 2 and stromatolites from Sequence 3 would hinder connectivity between the sequences. In order to exploit the hydrocarbons stored in Sequence 3, an additional well would be needed at updip preservation limit of Sequence 3. Sequence 4 is only preserved as a partial sequence and lacks significant storage capacities.

References
Figure 1. 3D model of facies (A), porosity (B), and permeability (C) in Miocene carbonates of the TCC, Ricardillo area, Spain.