Controls on the Distribution and Geometries of Sandstone Bodies in Platform Carbonate Systems: Examples from the Middle Permian (Guadalupian), Permian Basin, Texas*

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Abstract

Although mixed shallow-water platform systems containing both carbonate and siliciclastic facies are common in the geological record, the processes that lead to this admixture and the geometries of the resulting facies are not well understood. Detailed, core-based study of two producing oil fields in the Permian Basin (Permian Grayburg Formation) has shed important light on these questions.

We examined more than 16,000 ft of core from 54 wells in two fields along the eastern side of the Central Basin Platform. Cores were used to define facies, stacking patterns and cyclicity and pore types. Core data were also used to calibrate wireline logs as a basis for defining field-wide correlations and sequence architecture.

Both fields display similar assemblages of carbonate and siliciclastic facies and record a similar accommodation history. By contrast, the abundance, distribution, and reservoir quality of siliciclastic facies (sandstone, siltstone, and siliciclastic-rich carbonate) in the two reservoirs vary widely. In South Cowden reservoir, siliciclastics are limited to a few intervals associated with cycle-scale flooding surfaces and transgressions and are non-porous. In North Cowden field, 20 mi (32 km) to the north, siliciclastics are locally thicker, are found in both transgressive (TST) and highstand (HST) systems tracts, and contain significant porosity and permeability.

Essentially all of these siliciclastics can be tied to low-accommodation sedimentation associated with early TST or late HST. This association is consistent with enhanced flux of siliciclastics onto carbonate platforms during sealevel fall and lowstand and is supported by both outcrop and subsurface studies of other Permian successions.

Data from North Cowden field suggest two distinctly different patterns of siliciclastic bed geometries. Siliciclastics associated with major flooding events (e.g., composite or third-order sequences) display greater continuity (along both strike and dip), although they are commonly thinner and of lower reservoir quality. Siliciclastics associated with high-frequency sequence (HFS) flooding events, by contrast, display
limited dip continuity but are thicker and of higher reservoir quality. In many cases they are developed as thick strike-elongate successions immediately distal to backstepping tidal-flat complexes. These geometries may be the result of more pronounced topographic relief produced by high rates of aggradation during HFS sedimentation.

**Selected Bibliography**


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Summary

A key objective of this study was to develop a comprehensive model of sandstone body distribution and architecture in Middle Permian (Guadalupian) platform carbonates of the Permian Basin. This was accomplished through a multidisciplinary approach that combined high-resolution sedimentology, sequence stratigraphy, and 3D reservoir modeling. The Middle Permian (Guadalupian) of the Permian Basin provides a unique opportunity to study the development of sandstone bodies within a carbonate platform setting due to a combination of factors: (1) significant variation in sandstone abundance across the basin; (2) high-quality core and outcrop data; and (3) well-developed sequence stratigraphic architecture.

Data

Cores and outcrop data from multiple fields were analyzed to define facies, stacking patterns, and their distribution across the Permian Basin. The study area includes the Borden, Crosby, and Glorieta/Holt Series, which are part of the Middle Permian (Guadalupian) sequence. The primary focus was on understanding the controls on sandstone body distribution and geometry, including the influence of facies, lateral facies zonation, and sequence boundaries.

Highstand Model

Carbonate banks and shelf that also acted as source areas for siliciclastics. During lowstand, siliciclastics were deposited in areas that had been previously emergent. The above model depicts paleoenvironmental setting at lowstand. During lowstand, siliciclastics abundance and distribution are a function of both eustasy and sediment supply. In areas of moderate subsidence, siliciclastics were deposited in areas that had been previously emergent. The above model depicts paleoenvironmental setting at lowstand.

Lowstand Model

Siliciclastics were deposited in areas that had been previously emergent. The above model depicts paleoenvironmental setting during highstand. During highstand, siliciclastics abundance and distribution are a function of both eustasy and sediment supply. In areas of moderate subsidence, siliciclastics were deposited in areas that had been previously emergent. The above model depicts paleoenvironmental setting at highstand.

Sequence Model

Sequence stratigraphy is a key tool in understanding the depositional history of carbonate platforms. This study used sequence stratigraphic analysis to define the architecture of carbonate successions. This approach allowed for a better understanding of the relationship between sequence boundaries and sandstone body distribution.

DEPOSITIONAL FACIES

Carbonate-Dominated Facies

Siliciclastic-Dominated Facies

Carbonate Facies Model

Siliciclastic Facies Model

Depositional Setting

Geologic Setting

Sequence Stratigraphy

Paleogeographic map of the Permian Basin showing the locations of studied fields.
**DEPOSITIONAL FACIES**

**Carbonate-Dominated Facies**
- Algal-Laminated Mudstone-Wackestone
- Pisolithic Peloidal Wackestone-Packstone
- Mudstone
- Calcium Sulfate in Tidal Flats

**Siliciclastic-Dominated Facies**
- Low Accommodation, Peritidal Siliciclastic Facies
  - Quartzose Mudstone-Wackestone
  - Quartz Sandstone-Siltstone
- Higher Accommodation, Subtidal Siliciclastic Facies
  - Cross-bedded Sandstone-Siltstone

**DIAGENETIC FABRICS**

**Karst/Dissolution Fabrics**
- Sulfate Diagenesis
- Burrow-related Dolomite Diagenesis
- Anhydrite Dissolution Fabrics
- Grain-Rich Dolopackstones
- Breccia clasts
- Contorted algal layers
- Nodular anhydrite
- Palmate structure
- Calcium Sulfate in Tidal Flats
- Anhydrite cement
- Stylolites
- Carbonate Facies Model

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CONCLUSIONS

Queen 937

HFS 1
Slope-basin
Unocal Moss Unit # 6-16
5000 ft

GR
N

Unocal Moss Unit # 8-12

Correlations of carbonate facies and cycles are problematic, however. Facies contrasts are greatest. At South Cowden field, this is largely limited to ramp crest areas.

Sandstone-sandstone Facies-Stacking Patterns

proximal, low accommodation are widespread and continuous siliciclastics. These siliciclastics provide robust insights into the sequence-scale architecture of the Grayburg at both fields.

High Accommodation, Distal Siliciclastics

High Accommodation, Distal Siliciclastics

Low accommodation siliciclastics accumulated on the inner ramp and are invariably associated with tidal flat mudstone-wackestone. These rocks are typically more poorly sorted and clay-rich due to the low clay content. Consequently, these rocks are poorly consolidated and exhibit secondary porosity.

Low accommodation proximal siliciclastics are more abundant at high energy, inner ramp settings and are associated with tidal flat mudstone-wackestone. These rocks are typically well-sorted and have high clay content. Consequently, these rocks are well-consolidated and exhibit low secondary porosity.

Siliciclastic reservoirs are not abundant at high energy, inner ramp settings because these rocks are typically poorly consolidated and exhibit low secondary porosity.

High frequency sequence-scale boundaries. (e.g., climate, tectonics, eustasy), both types of siliciclastic deposits are typically high continuity, they are commonly mud-rich and exhibit poor reservoir quality.

3.

Low accommodation siliciclastics accumulated on the inner ramp and are invariably associated with tidal flat mudstone-wackestone. These rocks are typically more poorly sorted and clay-rich due to the low clay content. Consequently, these rocks are poorly consolidated and exhibit secondary porosity.

4.

High accommodation proximal siliciclastics are more abundant at high energy, inner ramp settings because these rocks are typically well-sorted and have high clay content. Consequently, these rocks are well-consolidated and exhibit low secondary porosity.

Siliciclastic reservoirs are not abundant at high energy, inner ramp settings because these rocks are typically poorly consolidated and exhibit low secondary porosity.

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REFERENCES


PUBLICATIONS


