3-D Stratigraphic Modeling from High-Resolution Seismic Reflection Data: An Example from North Carolina Continental Shelf

Over 2,000 km (1,240 mi) of high-resolution seismic reflection data were "rapidly" reduced to stratigraphic line drawings with a predetermined vertical exaggeration of 100:1 using a graphics digitizing tablet and desk-top computer. These data form the basis of a three-dimensional stratigraphic model for the upper southeastern North Carolina continental margin.

Correlations between the seismic data and drill, core, quarry, and outcrop data from the adjacent emerged coastal plain, supplemented by lithostratigraphic and biostratigraphic analyses of over 200 (9 m [30 ft]) vibracores collected along the seismic lines depicts an internally-consistent chronostratigraphic framework ranging in age from middle Eocene to late Pliocene. Seismic sequence analysis delineates five mid-late Paleogene depositional sequences, each bound by basin-wide unconformities. The distribution of these sequences is regionally controlled by the mid-Carolina Platform high of the Cape Fear Arch and locally influenced by Gulf Stream erosional events.

The Neogene section is an extremely complex, highly variable lithic package consisting of at least ten depositional sequences bound by regional unconformities and associated channels. Preliminary biostratigraphic analyses (both nannoflora and planktonic foraminifera) of vibracores penetrating these sequences suggest they represent high-frequency (4th- and possibly 5th-order) sea-level cyclicity. The seismic data indicate that these short pulse sea-level episodes were primarily low amplitude (<50 m [164 ft]) events. The general distribution for each Neogene sequence, as well as the temporal and spatial relationships of lithofacies changes, seems to be a consequence of a constant interplay between high-frequency sea-level cyclicity and concomitant Gulf Stream dynamics.

The evolving depositional model for the upper southeastern North Carolina margin consists of a few low-frequency (3rd-order) high-amplitude, mid-late Paleogene sea-level events. During their maximum transgression, the western boundary current bypassed the Charleston Bump to the south and impinged on the North Carolina shelf 35 to 40 km (22 to 25 mi) southeast of Cape Fear. These Gulf Stream erosion events deeply scoured the shelf, extending the Blake Plateau to the north. Conversely, the Neogene was dominated by high-frequency, low-amplitude sea level cyclicity. Maximum transgression was relatively lower, forcing the Gulf Stream to be deflected by the Charleston Bump to the south. Consequently, the Neogene sequences comprise a major depositional episode in which the shelf prograded east to the present location of the Florida-Hatteras slope.

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Evolution of a Fluvial Clastic Wedge, Abo Formation (Wolfcampian), Sacramento Mountains, New Mexico

Outcrops of the Abo Formation (Wolfcampian) in the northern and central Sacramento Mountains of south-central New Mexico record the evolution of fluvial systems within a major clastic wedge. This wedge was derived from the Pedernal uplift and prograded westward into the Orogrande basin. Regionally, the Abo Formation thickens from 60 m (197 ft) in the central Sacramentos, to over 545 m (1,788 ft) in the northern portion of the range, a distance of approximately 29 km (18 mi). Superposed on the regional pattern are local thickness variations of up to 91 m (300 ft). These occur within distances as small as 0.4 km (0.25 mi), and represent local tectonic and paleotopographic controls on sedimentation.

Clast-supported cobble conglomerates, associated with laminated mudstones and discontinuous coarse arkosic sandstones, are present near the base of the Abo Formation. The conglomerate lenses range from 0.5 to 20 m (1.5 to 66 ft) thick, and from 15 m (49 ft) to several kilometers wide. They exhibit poor stratification, occasional clast imbrication, and near horizontal to concave-upward erosional bounding surfaces. Locally, nodular $CaCO_3$ occurs in beds or scattered throughout the associated mudstones.

The central portion of the sequence is characterized by abundant conglomeratic medium to very coarse-grained arkosic sandstone lenses interbedded with laminated mudstones. These lenses range from 0.25 to 10 m (0.8 to 33 ft) in thickness, and 10 to 110 m (33 to 361 ft) in width. Commonly, several lenses will coalesce, forming laterally extensive belts. Both erosional and depositional (lateral accretion) bounding surfaces are well developed within individual lenses. Low-angle, large-scale trough cross-bedding is the dominant stratification type within these units, however, small to large-scale tabular foresets occur, as do planar, ripple, and small-scale trough stratification. Occasionally, individual units fine upward in grain size and/or scale of structures. This sandstone-rich horizon varies laterally in thickness, and grades upward into a mudstone-rich horizon at the top of the Abo Formation.

The upper interval of the Abo sequence contains infrequent fine to coarse-grained arkose lenses enclosed in laterally extensive red mudstones. Paleosols and caliche horizons are present, but not common, in the mudstones.

The basal conglomeratic horizon of the clastic wedge represents braided stream deposition at the distal end of arid alluvial fans associated with the tectonically active Pedernal uplift. Caliche and paleosols developed in the overbank mud drapes and levees of these deposits. The conglomerates grade into arkosic sandstones, reflecting the intense weathering and erosion of the granitic core of the uplift. The multilateral sandstone lenses characteristic of the mid portion of the Abo Formation were deposited in low-sinuousity, coarse-grained (bed-load) meander belts; however, higher sinuousity, mixed-load channel and crevasse splay deposits also occur locally. Finally, as the Pedernal source area was buried by its own debris, thick, broad flood-plain deposition predominated. Sandstones associated with the red mudstones were deposited in shallow ephemeral channels and crevasse splays.

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Effects of Lower Cambrian Archaeocyathid Patch Reefs on Distribution of Interreef Faunas

In general, reefs create a physical obstruction to existing circulation patterns as they develop and grow vertically; thus the growth of a reef can promote changes in the local physical-sedimentological conditions. As a reef grows, it develops a distinctive biological zonation that appears to be correlated with changes in the associated sedimentological regime of the reef. Thus some change should also be produced in the interreef organism-sediment associations. These changes should be more pronounced near the reef, where the perturbation in the circulation pattern is higher, and diminish gradually away from the reef. Such physical changes may be small and yet have a significant effect on the local biological habitat.

Archaeocyathid patch reefs of the lower Forteau Formation, southern Labrador, developed in the relatively quiet water environment of the Lower Cambrian epeiric sea. Even though the patch reefs only stood 1 to 3 m (3 to 10 ft) above the sea floor, it is obvious from the external morphology of individual Archaeocyathids and the number of overturned and restored colonies that the patch reefs encountered higher energy conditions as they grew. Thus, these Archaeocyathid patch reefs apparently created many small, discontinuous obstructions to currents and waves.

Two distinctly different faunas associated with the environments around these reef complexes show a similar change in dominance diversity (d). The faunal assemblages on the flanks of each complex illustrate a general decrease in the abundance of the dominant species or a more equitable distribution of individuals per species with distance from the complex. However, the composition of each faunal association remains consistent with distance from the complex. The gradual lowering of dominance diversity with distance from the complex could be related to a subtle but gradual change in the marine environment.

In each assemblage, the high degree of dominance close to the reef appears to approach a geometric distribution of the individuals per species. Faunal assemblages in which the distribution of the individuals per species approaches a geometric distribution are indicative of physically disturbed habitats. The decrease in dominance farther from the complex suggests that these areas could have been under less physical stress.

Currents diverted by a small patch reef would flow over and around this obstruction, thereby creating a zone of higher physical energy around the reef. In each of the lower Forteau reefs examined, the interreef faunal distribution could be related to a zone of higher physical disturbance directly around the reef. Thus, changes in the local physical-sedimentological environment produced by the reefs appear to have affected the ecological structure of the interreef faunas.

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Vertically Accreted Foreshore to Shoreface Deposits of Sego Sandstone (Campanian), Northwest Colorado

Exposures of the Sego Sandstone, on the northern flank of Rangely dome, Colorado, represent a thick (50 m [165 ft]) sequence of shoreline sandstone. The Sego Sandstone generally represents a progradational sequence. However, the interplay between sediment supply and subsidence resulted in stabilization of shoreline position. Deltaic distributaries were not observed, suggesting interdeltaic deposition.

The initial progradational phase within this sandstone complex is represented by three facies. (1) Basal facies composed of bioturbated shale with occasional silt stringers. (2) Medial facies, averaging 5 m (16 ft) in thickness, grading upward from the underlying shales, and composed entirely of ripple-stratified fine sandstone. Starved ripples at the base of this sequence grade vertically into flaser and amalgamated ripples. Channels filled with clay and ripple-stratified sand oriented south-easterly are present. (3) Upper facies is composed of fine-grained sandstone exhibiting basal hummocky cross-bedding that grades vertically into small-scale troughs and planer stratification. This facies is capped by a thin (35 cm [14 in.]) coal. Maximum observed thickness for this facies is 7 m (23 ft), with thinning toward the northwest.

Facies 1 represents the marine shale deposits of the Buck Tongue. Facies 2 is an ebb delta system believed to have functioned concurrently with the prograding shoreface (facies 3).

Stabilized shoreline conditions are characterized by four facies. (1) The basal unit is composed of fine to medium-grained sandstone. Trough and tabular cross-bedding is abundant, as is ripple stratification. Individual beds are 10 to 50 cm (4 to 20 in.) thick and the unit thickness is 10 to 20 m (33 to 66 ft). No apparent vertical trends with respect to either grain size or sequence of sedimentary structures were observed. (2) The second facies is fine grained, predominantly ripple stratified with some tabular and low angle bimodal cross-beds. Sand-filled channels with *Ophiomorpha* are present. This facies is 9 m (29.5 ft) thick and onlaps with a portion of facies 1. (3) The third unit is fine to medium grained, and as with facies 1, contains abundant trough and tabular cross-bedding as well as abundant ripple stratification. Paleocurrent data suggests a northwesterly transport direction for facies 3 as opposed to a southwesterly direction for facies 1. Bedding is between 10 to 50 cm (4 to 20 in.) thick with unit thickness of from 0 to 12 m (0 to 39 ft). This unit thins northwestward. (4) The upper unit thickens northwestward and is composed of bioturbated shales, humates, and very fine-grained sandstone.

Facies 2 represents a sand tidal flat situated behind the coastal barrier (facies 1). The lack of well-developed trends either in grain size or sedimentary structures within facies 1 indicates that the bar formed from the amalgamation of diverse environments. Overlying both the bar and tidal flat facies is the spit (facies 3) and lagoonal muds and washovers (facies 4). This shoreline sequence is overlain by fluvial deposits of the Mesaverde Group.

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Detailed Reservoir Analysis using EPT-Cyberlook and Dipmeter Computations

In recent years, a tremendous amount of work by oil companies has been done to evaluate tertiary flood programs in heavy oil reservoirs. One of the keys to understanding how a flood will behave, and therefore an input to the modeling, is a basic knowledge of the depositional environment and reservoir geometry. This often requires the analysis of a large amount of information. The core analysis alone on a multiple well project can be extremely time consuming if it is to be done with any significant detail.

This paper outlines the basis for a technique which allows a fairly detailed analysis of the reservoir potential and depositional environment. Using field generated Cyberlook logs and the dipmeter programs of Cluster and Geodip, a fairly rapid interpretation can be made which will confirm the depositional environment, the reservoir potential, and the orientation of any permeability barriers within the reservoir.

Several examples are presented where the Electromagnetic Propagation log is used in the Cyberlook to identify the mobile oil potential of the reservoir. This computation is then compared to Cluster and Geodip plots and, where anomalies occur, either changes in Rw or oil viscosity are implied. Reservoir geometry is then estimated from knowledge of the depositional environment and the dipmeter computations.

With these tools at hand, it is now possible to predict not only which hydrocarbons will move, but the general direction of movement during initial production or flooding of the reservoir.

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Plate Tectonics and Offshore Boundary Delimitation: Tunisia-Libya Case at the International Court of Justice

Advances in the technology for exploiting resources of the oceans, particularly recovery of hydrocarbons and minerals in deep water, is benefiting a growing number of nations. At the