tary mouth bar and distal bar lithofacies and Lewis marine central bar lithofacies constitute the primary Mississippian reservoirs in the basin. Primary interparticulate porosity has been reduced through the development of quartz overgrowths and/or calcite cementation. Secondary porosity involves leaching of carbonate allochems, calcite cement, and/or matrix. The Carter prodelta and interdistributary bay shales and Lewis marine shales make excellent petroleum source rocks. These shales contain amorphous and herbaceous kerogen. The state of alteration of the kerogen indicates that the thermal history of the basin has been favorable for the generation and preservation of hydrocarbons, principally gas. The petroleum-trapping capabilities of these strata have been enhanced because of their association with normal faults.

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Bellerophontaceans from Hancock, Maryland—Gastropod (Torted) or Monoplacophoran (Untorted)?

Mollusk specimens from the Briery Gap Sandstone Member of the Foreknobs Formation in Hancock, Maryland, were previously assigned to the gastropod genus *Bellerophon*. In recent years, the controversy of whether *Bellerophon* belongs to the molluscan class of torted gastropod or that of untorted monoplacophoran has resurfaced. Because of the need for better understanding of molluscan evolutionary history, resolving this controversy is very important for an interpretation of fossil phylogenies as a whole, thus increasing the effectiveness of fossils as biostratigraphic tools.

In determining whether or not these animals were torted or untorted, past emphasis on muscle scar patterns has been proven inadequate due to the lack of specimens exhibiting suitable scars. The emphasis is presently being directed toward other aspects of shell morphology, such as apertural slits and secondary shell layers known as "inductura." The position of the inductura relative to the slit is significant and implies that the animal is oriented in a particular fashion within its shell. This position, in turn, helps to determine whether the animal was torted or not and hence whether it is a gastropod or a monoplacophoran.

Because original shell material was absent, recreating the shell was necessary in evaluating the morphology. This was achieved by replicating the shell using liquid latex. The pouring, hardening, and extraction of latex from external molds yielded replicas exhibiting detailed shell features. Observed was the location of the lateral inductural deposits opposite the apertural slit, implying that the animal's coiled shell was carried over its extended foot as a result of torsion, and therefore the animal belongs to the class Gastropoda.

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Thermal Maturity of Carboniferous Strata, Ouachita Thrust Fault Belt

The Ouachita thrust fault belt, a large, relatively untested hydrocarbon province, contains more than 30,000 ft (9,100 m) of Carboniferous flysch rich in potential source and reservoir rocks. To estimate the thermal maturity of these strata, vitrinite reflectance (in oil) was measured from more than 90 bulk samples of the Carboniferous-age Stanley, Jackfork, Johns Valley, and Atoka Formations. Inasmuch as no subsurface samples were available, the freshest possible outcrop samples were used for the analysis, despite the possible deleterious effects of oxidation on the accuracy of measured reflectance values.

Iso-reflectance contours generally trend parallel to structural grain in the western two-thirds of the Ouachitas. The "core" areas where pre-Carboniferous strata are exposed, as well as areas immediately adjacent to the core, are well defined by reflectance values greater than 2.0%. Outward from the core areas toward the north and south, reflectance values tend to decrease, although some minor variations owing to complex structure are present. In Arkansas, samples from the thrust-fault belts both north and south of the Benton uplift yield reflectance values between 1.0 and 2.0%. In Oklahoma, samples from the area north of the Broken Bow uplift yield reflectance values between 0.5 and 1.0%.

In the eastern third of the Ouachitas, iso-reflectance contours obliquely cut structural grain, and reflectance values are significantly higher. Samples from the Benton uplift give reflectance values higher than 3.0%, and measured values approach 5.0% from samples in and near the core. Although there is a general decrease outward from the core area to both the north and south, reflectance values greater than 2.0% characterize the entire width of the Ouachitas in this eastern area.

Reflectance values obtained from samples collected from both sides of major thrust faults in the western Ouachitas reveal that older, upthrown strata are more thermally mature than younger, downthrown strata. In contrast, samples collected from analogous structural positions in the eastern Ouachitas display identical thermal maturities on both upthrown and downthrown sides of thrust faults.

In the western two-thirds of the Ouachitas, stratigraphic depth of burial appears to have been the primary factor that controlled thermal maturity. The Carboniferous strata at the surface in this area are well within the window of oil and gas generation and preservation. The anomalously high thermal maturity of Carboniferous strata in the eastern third of the Ouachitas is probably the result of heat dissipated from Mesozoic rifting and intrusive events. This thermal overprint places the maturity of these strata beyond the limits of oil preservation and locally beyond the limits of wet gas preservation.

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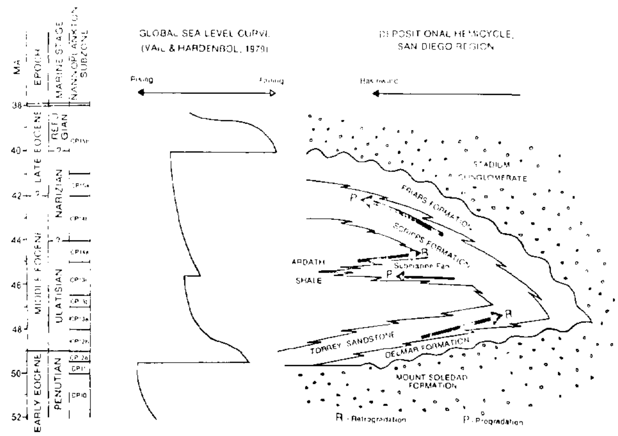
Eustatic Control of Synchronous Stratigraphic Development: A Case for Facies Prediction in Basin Modeling

Field studies document an apparent eustatic control on facies patterns in isolated basins along a tectonically active margin. In the San Diego embayment and along northern Baja California, progradational-retrogradational shoreline sequences characterize Late Cretaceous and Eocene fore-arc basin-margin stratigraphy. Extensive paleontologic control helps establish the age and distribution of facies changes along these depositionally compact, steep-gradient margins. The observed depositional sequences may be stratigraphically arranged into three scales and patterns of sedimentary cycles. Timing of the two largest cycles provides relative sea level curves that correlate exceptionally well with worldwide sea level curves of Vail and others.

The major depositional cycle is asymmetric—a "hemicycle" hundreds of meters thick, characterized by a thin, basal retrogradational sequence overlain by a thick progradational sequence—and corresponds to eustatic supercycles. Depositional hemicycles are composed of smaller scale rhythmic successions controlled by sea level cycles and paracycles. Depositional pulses produced by local conditions, in turn, overprint these two larger scales of sedimentation. Coeval hemicycles and depositional rhythms in coastal basins from Oregon to Baja California further indicate a primary eustatic control on sedimentation.



Field-based facies analysis, having resolution far greater than that provided by seismic stratigraphy, thus supports using the "Vail curve" as a predictive tool in exploration. Deposition, distribution, and geometries of reservoir rocks can be modeled prior to drilling. Initiation and duration of sedimentary cycles defined by this study may be estimated ahead of the bit. Variations in expected facies patterns yield improved structural and stratigraphic interpretations for basin analysis. Worldwide comparison of stratal patterns in coeval basins from various tectonic settings ultimately will provide a data base for developing basin models.

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Influence of Basin History on Reservoir Quality of Sandstones: Upper Cretaceous of Northern Mexico

Upper Cretaceous sandstones of northern Mexico for a distance of 200 km (125 mi) south of the Rio Grande have similar mineral composition but differ markedly in reservoir quality in the north versus the south depending on the post-depositional history of the basins in which the sandstones were deposited. The sandstones are composed largely of detritus from volcanic and intrusive igneous rocks and were deposited in paralic and fluvial environments.

Sandstones in the north were never buried more than 1,000 m (3,300 ft) and were subjected to slow, gentle, basinward downwarping. They underwent a complex diagenetic history of cementation by chlorite, quartz, calcite, and kaolinite, and the development of modest secondary porosity; and they form hydrocarbon reservoir rocks of moderate quality (ϕ = 5 to 15%, k = 5 to 300 md). Sandstones to the south were buried rapidly by 1,000 to 4,00 m (3,300 to 13,000 ft) of younger strata and immediately thereafter underwent strong compressional folding and local thrust faulting during the Laramide orogeny. The sandstones lost from 20 to 35% porosity by compaction and the remainder of the porosity by cementation with calcite. They are tight, did not develop secondary porosity, and have no shows of hydrocarbons.

During slow subsidence of sandstone-shale sequences in the north, the shale and associated organic matter underwent normal maturation events. Shale water was expelled in stages, organic matter evolved to produce liquid and gaseous hydrocarbons, and acid formation water was generated. The associated sandstones underwent a diagenetic sequence, including the development of secondary porosity from the acid formation water, that is typical of many sedimentary basins. To the south, Laramide compressive forces caused strong compaction and premature de-watering of the Upper Cretaceous shales. Most water present in the shales was expelled prior to maturation of hydrocarbons. Thus, compaction was rapid and severe and there was no opportunity for the development of typical formation waters that might have developed secondary porosity. Close to the Sierra Madre front, rapid and early expulsion of water produced a strong fracture cleavage in shale and siltstone.

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Case Study of Stratigraphic Interpretation Using Shear and Compressional Seismic Data

Compressional and horizontal shear wave data recorded at the surface are used to detect lateral changes in the physical properties of a clastic unit. Shear and compressional wave transit times across the formation were measured from CDP-stacked sections derived from data collected along collocated shear and compressional seismic lines. At each surface position, the ratio of the shear to compressional transit times is formed from common CDP traces. It is shown how lateral changes in the transit time ratio primarily correlate with variations in the sand-shale ratio in the zone of interest.

The horizon selected for this case study was the Morrow Formation, which produces gas from sand-channel bodies in the Empire-Abo field, New Mexico. As this field has been extensively drilled, a detailed cross section of the producing horizon was mapped along a seismic line which crossed two wells. In well "A," the nonproductive Morrow cycles 1, 2, and 3 are principally shale and nonpermeable shaly sand facies. In well "B," this same interval contains as much as 160 ft (49 m) of permeable gas-productive sand which has a calculated absolute open flow of 61 MMCFGD. Shear wave and compressional wave Vibroseis surveys were conducted along this seismic profile using data acquisition parameters designed to produce comparable signal-to-noise ratios and resolution in the field data. Similar care was taken during data processing to insure that the differences and similarities observed in the final CDP sections were due to variations in geology and not simply artifacts of the particular set of processing parameters that were employed.

Along the seismic profile both compressional and shear wave interval transit times across the Morrow Formation showed a statistically significant decrease in going from the nonproductive to productive thicknesses of sand. There is, however, a proportionately greater decrease in the shear wave transit time than in the compressional transit time which results in an overall decrease in the shear-to-compressional transit time ratio. There are two changes in the physical properties of the Morrow which could account for the observed transit time ratio variations. First, the replacement of pore fluid in the sand by a small amount of gas would cause a decrease in the transit time ratio in going from well "A" to well "B." However, the compressional wave transit time should increase drastically in this case, while the shear wave transit time would decrease slightly. This behavior was not observed. A second possible explanation is that the decrease in transit time ratio was due to an increase in the sand-shale ratio between the two wells. Because of the marked differences in the shear-to-compressional transit times for pure shale (2.4) and pure sandstone (1.7), any increase in the sand-shale ratio should be accompanied by a decrease in the formation transit time ratio. Furthermore, it would be anticipated that a change in the sand-shale ratio would influence the shear wave transit time more sig-