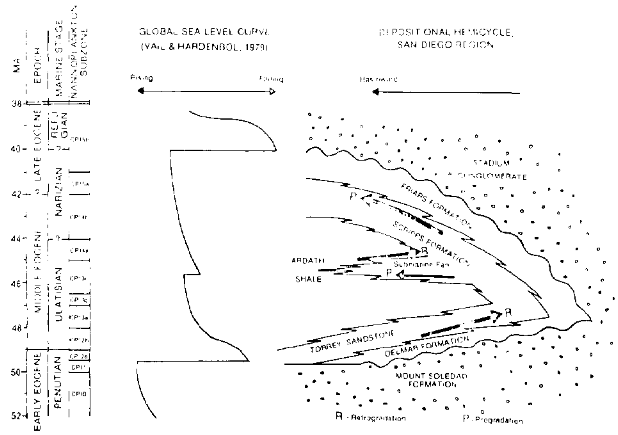
mentation. Coeval hemicycles and depositional rhythms in coastal basins from Oregon to Baja California further indicate a primary eustatic control on sedimentation.



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 significantly than the compressional transit time—a fact which is consistent with the observations. We thus conclude that shear-to-compressional transit time ratio measurements provide a method for estimating variations in the sand-shale ratio of a formation.

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Depositional Environment of Eocene Queen City Formation in East Texas

Lithostratigraphic correlation of the Eocene Queen City Formation in Anderson, Cherokee, and Upshur Counties reveals three distinct facies indicative of a clastic shoreline environment: (1) flood-tidal delta, (2) lower shoreface and shelf, and (3) coastal barrier-island complex. These facies were identified on the basis of diagnostic physical structures.

The Eocene flood-tidal delta in Cherokee County is dominated by landward-dipping (northwest) foreset beds. This delta probably formed at the mouth of a microtidal estuary and was affected by storm processes and tidal currents. Lower Queen City shoreface and shelf structures are found in northern Cherokee County revealing the enigmatic feature of hummocky cross-stratification. These undulating sets of low-angle cross-beds are commonly affected by storm-wave processes and indicate a fairly shallow fairweather wave base during their Eocene deposition. Exposures of the Eocene coastal barrier-island complex in Upshur County reveal a regressive sequence with a back-barrier coastal marsh at the base. Successively overlying the coastal marsh are lagoon, coastal mud flat, tidal channel, and bayhead-delta facies. Preservation of the vertical succession of these facies beneath the transgressive Weches formation implies continued subsidence and sedimentation.

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Tectonic History and Influence on Sedimentation of Rhomb Horsts and Grabens Associated with Amarillo Uplift, Texas Panhandle

The Amarillo uplift consists of an en echelon series of fault blocks separating the Anadarko basin from the Palo Duro basin. The uplift is part of a northwest-southeast zone of basement weakness that extends from the Wichita Mountains in Oklahoma to southeastern Colorado.

Initial faulting, related to the opening of the southern Oklahoma aulacogen, took place from late Precambrian through Middle Cambrian time. Renewed movement in the Late Mississippian or Early Pennsylvanian, probably of a left-lateral transcurrent nature, broke the Amarillo uplift into a series of rhomb grabens and rhomb horsts. The Lefors basin, for example, in Gray County is a small rhomb graben 4 mi (6.4 km) by 8 mi (12.8 km) that contains in excess of 4,000 ft (1,200 m) of Pennsylvanian and Wolfcampian arkose ("granite wash"). The Amarillo uplift continued to subtly affect depositional patterns following its burial in Wolfcampian time.

Salt beds in the Clear Fork Formation (Leonardian) are purer and thicker in grabens where salt deposition proceeded at a faster rate relative to horsts. Recurrent motion on the Potter County fault in northern Potter and northeastern Oldham County produced cumulative displacements of 1,600 ft (488 m) on top of the Pennsylvanian, 800 ft (244 m) on Wolfcampian strata, 600 ft (183 m) on top of the Clear Fork Formation, and 450 ft (137 m) on the Dockum Group (Triassic). Post-Permian displacements are the result of both salt dissolution and minor structural movement. There is no direct evidence for Quaternary faulting, although the uplift is seismically active.

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Structural Evolution of the Guadalupe Mountains, South-Central New Mexico and West Texas

The Guadalupe Mountains of south-central New Mexico and west Texas occupy a unique physiographic and structural position. Physiographically, the mountains lie on the boundary between the block-faulted Basin and Range province to the west and the stable Great Plains province to the east. Structurally, the mountains form the northwestern margin of the Delaware basin, a prolific petroleum-producing region.

A combination of field observation, subsurface correlation, and map and photo interpretation has revealed four important phases in the complex structural evolution of the Guadalupe Mountains and adjacent Delaware basin.

Pennsylvanian to Early Permian (Wolfcampian) faulting and folding created the Huapache monocline and initially defined the limits of the Delaware basin.

Permian flexing and differential subsidence accentuated the shelf-to-basin transition and resulted in deposition of the prograding carbonate shelf sediments now exposed in the Guadalupe Mountains.

Late Cretaceous to early Tertiary (Laramide) deformation created the Carlsbad and Guadalupe Ridge folds, a series of anticlines and synclines in the eastern mountains.

Late Tertiary (post-Ogallala) to Pleistocene uplift and tilting brought the mountains to essentially their present configuration. The western border of the uplift is defined by Basin and Range-type normal faulting, whereas the eastern margin is both faulted and monoclinally folded. Minor faulting has been active into Holocene time.

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Fault Analysis in Wichita Mountains

Analysis of a large population, but small displacement, fault array in the Wichita Mountains of southern Oklahoma strongly supports the hypothesis of left-lateral wrench faulting as a major tectonic control for the region. Middle Cambrian granites make up most of the exposed core of the Wichita uplift. Because these granites were implaced prior to the development of the Anadarko basin structures, they should reflect Anadarko tectonics. In addition, the granites would have behaved in a brittle manner so that abundant faulting is practically the only mechanism of deformation within them; this permits uncomplicated structural analysis. Offset and trend measurements were made both in the field and from aerial photographs, and the collective data show statistically significant groupings with respect to trend and sense of shear. The fault fabric is consistent with a left-lateral wrench system that trends N70°-80°W, but also contains strong elements of the entire Riedel system (R, R′, and P shears). In addition to the wrench motions indicated by the analysis of small displacement faults, there is also a large component of vertical displacement in the region. A fault system known as the Wichita front, separates the Wichita uplift from the Anadarko basin and has 9 km (5.5 mi) of differential vertical relief across a zone 10 to 20 km (6 to 12 mi) wide. The relationship between the lateral and vertical motion is essential in understanding the types and distribution