sylvania, and New York is price-driven and tax shelter related. With the designation of almost all of the Clinton reservoir sands as "tight sands" for gas pricing, payout can be expected in many, but not all Clinton wells despite the nearly 90% or higher drilling success ratio.

New regional studies show the upward, deltaic progradation to the west as previously documented, but they also demonstrate new stratigraphic relationships between the upper Cabot Head shales, the sandstone reservoirs of the Clinton, and the overlying Packer Shell Limestone. The upper Cabot Head lies only landward of the progradational edge and the transition westward is from reservoir sands into calcareous sands and carbonate rocks. Within this deltaic system, one which covered much of eastern Ohio, Clinton wells have produced oil and gas from these fluvial, fluvial delta-margin and delta-margin bars, and beach sands for over 50 years.

Both regional and local patterns indicate better areas of Clinton development drilling at various depths. In the fluvial sequences, total sand maps, clean sand maps, porosity maps, and water, oil, and gas saturation maps point to locations of higher oil and gas deliverability. In the delta margin system, sand mapping, cross sections, and porosity maps show multiple bar systems at the edges of deltaic plains and tidal flats where there is higher gas and oil production from the Clinton reservoirs.

Local structural highs and faults affect production in this mainly stratigraphic trap. Locally, structure segregates oil and gas in the same reservoir body, but separate, though laterally equivalent, reservoir sands act differently on the same structure in adjacent wells.

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Precision Measurements of Interval Velocity Differences from Seismic Data

A new seismic technique, the DIVA (Differential Interformational Velocity Analysis) (trademark, Copyright Zenith Exploration Co., patents pending), which makes use of ultra refined seismic velocity analysis has been developed to identify and localize low velocity anomalies in the subsurface. Reservoir quality porous rock formations will always be distinguished by reduced seismic velocities whether or not hydrocarbons are present. In favorable settings, however, low velocities correlate well with hydrocarbon reservoirs. Where gas is present, the velocity reductions can be spectacular making the DIVA display an indicator with as much visual impact as the "bright spot" offshore. Color acoustic impedance sections further corroborate the reality of DIVA detection anomalies and assist in localizing them in reflection time. In addition, the color display, which in fact represents the essential information content of the seismic amplitudes, though very imprecise, is a vital monitor of the detailed changes in lithology. Fourteen wells to date have tested the concept ranging in depths from 7,00 to 15,000 ft (2,133 to 4,572 m) and targeting both carbonate and sandstone reservoirs. Several of these results are reviewed to illustrate the power of the approach. The technology has not only been proven by the drill but has also initiated new and exciting exploration plays which can not even be detected with usual seismic approaches. An east Texas reef bank sequence illustrates such a circumstance.

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Sedimentology of Some Allochthonous Deep-Water Carbonate Reservoirs, Lower Permian, West Texas: Carbonate Debris Sheets, Aprons, or Submarine Fans?

During the Wolfcampian, sediment gravity flows were common events at some shelf margins in the Permian basin. These mass flows transported large volumes of shoal-water bank and reef carbonates downslope into the Midland and Delaware basins, forming a wide variety of redeposited lithofacies. For example, along a segment of the Eastern shelf margin at least 40 km (25 mi) long, redeposited carbonates extend into the Midland basin 25 km (16 mi) or more. Within this basin margin setting, several petroleum pay zones occur in mass-transported debris.

In designing exploration strategies for these types of frontier deep-water reservoirs, whether within the Permian basin or elsewhere, one must develop appropriate depositional models. Some questions come to mind. Do these deposits represent episodic, widespread, single-pulse debris sheets, debris aprons dominated by numerous but rather random pulses of areally extensive sheet-flow calcarenites, or more systematically developed submarine fan facies having both channelized deposits in inner and mid-fan settings as well as sheet-flow calcarenites deposited as outer-fan lobes?

Redeposited Wolfcampian carbonates are subdivided into three major lithofacies. (1) Limestone and dolomite conglomerate debris flows and turbidites with dark interstitial micrite. Individual beds are as much as 8 m (26 ft) thick, normal to massively graded, and some beds are arranged by thinning-upward sequences. These carbonates form on of the reservoir facies with intercrystalline, solution interparticle, fracture, and vuggy porosity. (2) Wackestone to packstone calcarenite turbidites consisting largely of biotic grains. This lithofacies forms the most abundant type of redeposited sediment. The calcarenites occur in beds a few cm to 2.5 m (8 ft) thick that exhibit a variety of Bouma turbidite divisions and in some localities are arranged in thickening-upward units. Calcarenite turbidite locally form petroleum reservoirs with solution interparticle, intrabiotic, biomoldic, and fracture porosity. (3) Wackestone to packstone calcisiltite and calcarenite turbidites that occur in less than 2 cm (1 in.) thick beds. This facies does not exhibit vertical cycles of bed thickness nor good reservoir qualities.

Analyses of cores from 12 wells both within and outside the petroleum fields suggest that these redeposited carbonates may represent a combination of debris sheet and submarine fan depositional processes. The conglomerates could be genetically unrelated to the calcarenites and represent episodic debris sheet pulses; or alternatively, these conglomerates may be channelized deposits in inner fan to mid-fan positions near the basin margin. Some of the thick-bedded calcarenites possibly represent mid-fan channelized deposits whereas the more basinward thickening-upward calcarenites resemble unchannelized outer-fan calcarenite lobes. Thin-bedded calcisiltite turbidites appear to occupy basin plain, outer-fan fringe, and interchannel settings. If these reservoirs are developed within one or more fan facies, the size and spatial arrangement of the individual fans still remain to be determined. A better knowledge of appropriate depositional models should enhance future exploration efficiency.

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Upper Jurassic Carbonate Deposition, Smackover and Buckner Formations, East Texas

Examination of cores from the upper Smackover Formation from 30 wells in east Texas confirms the presence of a belt of blanket high-energy ooid sandstone throughout much of the area. Pockets of lower energy deposits within this ooid grainstone belt are characterized by pellet-*Favreina* packstones and grainstones and ooid-rhodolite packstones and grainstones. In the easternmost part of the study area, ooid grainstones grade updip into lower energy lagoonal facies including pellet and *Favreina* wackestones and packstones. These lagoonal deposits are not as widespread to the west. Lower in the Smackover, low-energy skeletal, pellet and oncolite wackestones and packstones dominate. Two cores contain coralgal fragments suggesting nearby reef development.

The overlying lower Buckner Formation is composed dominantly of red beds and evaporites deposited in a sabkha setting. The presence of thick red beds in cores from the western part of the study area suggests a strong continental influence. Anhydrite is the major evaporite mineral in the lower Buckner. It is present as displacive mosaic and nodular mosaic masses in red beds and dolomitic mudstones. Partial preservation of some original gypsum crystal outlines provides evidence for lesser amounts of primary evaporite precipitation. Small amounts of halite are present in some lower Buckner red beds and associated with anhydrite to the west. Environments and depocenters within the Buckner are thought to have ben partly controlled by movement of the underlying Louann Salt and by rejuvenation of basement structures.

Major structural influences on Smackover and Buckner deposition or present distribution include the Mexia-Talco fault system, the Sabine uplift, and Louann salt structures. Movement along the Mexia-Talco fault system began in Late Jurassic time and may have affected Smackover and Buckner deposition to an as yet undetermined extent. The extent of the influence of the incipient Sabine uplift on deposition in east Texas has not been determined, although studies to date suggest that it had a significant effect on facies development and on the configuration of the Smackover-Buckner carbonate shelf and associated basin.

The major influence of Louann Salt movement on Smackover and Buckner deposition is confined to the western half of the study area. Salt movement began after the close of Smackover time. Withdrawal of Louann Salt into ridges formed a series of strike-trending linear troughs in the western part of the study area. The Buckner Formation thickens dramatically within the linear troughs, suggesting possible salt movement during Buckner time.

A second linear zone of thickened Buckner section, apparently unrelated to Louann Salt movement, lies to the northeast of the area of salt structures. This strike-oriented Buckner depocenter is well developed in the east and pinches out to the west. Salt is present within the Buckner in the western part of the depocenter.

Cross sections constructed from electric logs and data from core analysis demonstrate these relationships and may help delineate potential areas for hydrocarbon exploration.

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Structural Stratigraphy of Austin Chalk

The mechanical behavior (structural stratigraphy) of the Upper Cretaceous Austin Chalk is established from the study of fracture intensity along its outcrop trend from Dallas to San Antonio and westward to Langtry, Texas, and in the subsurface from the study of core and/or fracture identification logs from 39 wells. Three mechanical-stratigraphic units are recognized as: (1) an upper, fractured massive chalk corresponding to the Bid House Chalk Member, (2) a middle, ductile chalk-marl corresponding to the Dessau Chalk and Burditt Marl Members, and (3) a lower, fractured massive chalk corresponding to the Atco Chalk Member.

Representative samples from these units were experimentally shortened dry, at 10, 17, 34, and 70-MPa confining pressure, 24°C (75°F), and at $2.5 \times 10^{-4}\ s^{-1}$ to determine if the relative mechanical behavior observed at the surface could be extrapolated into the subsurface at different simulated depths of burial. The experimentally determined ductilities do parallel those determined from outcrop and subsurface studies. Through multiple linear regression analyses of strength versus intrinsic rock properties and environmental parameters, it appears that first porosity and then smectite-content are most strongly correlated with strength. For low-porosity specimens (9 to 13.5%) smectite present in amounts as little as 1% by volume has the highest correlation with strength accounting for 83% of its variability. For example, the strength of specimens with 4% smectite is reduced by a factor of 2 compared to those with no smectite. The coefficient of internal friction at 70-MPa confining pressure decreases from 1.58 to 0.57 as the smectite content increases from 0 to 1 to 4%.

SEM photomicrographs of the experimentally deformed specimens show that smectite and other clays are distributed as small, discrete, concentrated masses throughout the chalk. They are smeared-out along the induced shear fracture surfaces where they are greatly reduced in grain-size. These observations suggest that the smectite acts mechanically as a "soft-inclusion," localizing shear failure and correspondingly weakening the material.

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Eocene-Oligocene Benthonic Foraminifera: Implications for Deep-Water Circulation History

Quantitative analysis of middle Eocene-early Oligocene bathyal deep-sea benthonic foraminifera was carried out on samples from DSDP Sites 77, 292 (Pacific Ocean), 219 and 253 (Indian Ocean), 363 (Atlantic Ocean), and Eureka 67-128 (Gulf of Mexico) and compared with benthonic foraminiferal stable isotopic data to determine the effects of deep-water circulation changes on the faunas, Faunal changes (first and last occurrences) are found throughout the sequences, and a catastrophic turnover of the benthonic foraminiferal fauna at the Eocene-Oligocene boundary does not occur. A few distinct events do occur associated with inferred coolings at the middle/late Eocene and Eocene/Oligocene boundary. For example, *Nuttallides truempyi*, an important middle Eocene species, has an isochronous last occurrence within the *Globigerinatheka semiinvoluta* zone in Sites 219, 253, 292, and 363 and coincides with a 3° deep-water cooling inferred from the O^{18} record.

During the late Eocene and early Oligocene these bathyal sites are marked by a remarkably uniform assemblage dominated by *Oridorsalis tener, Globocassidulina subglobosa*, and *Cibicidoides ungerianus*. In Sites 292 and E67-128 additional species that are important are *Bulimina alazanensis, Buliminella grata*, and *Bulimina tuxpamensis*. This relatively uniform bathyal faunal assemblage in these Atlantic, Indian, and Pacific sites is similar to an assemblage found previously in North and South Atlantic bathyal sites. This faunal pattern, as well as the isochronous last appearance of *N. truempyi*, suggests that a relatively uniform and widespread bathyal water mass extended throughout the world ocean during middle Eocene-early Oligocene time.

The faunal data show three responses to the sharp deep-water coolings at the middle/late Eocene and late Eocene/early Oligocene boundary: (1) a dominant species may have a last occurrence as a direct result of the cooling, (b) an increase in species abundance precedes the cooling followed by a sharp decrease associated with a decrease in deep-water temperatures, or (c) a species is largely unaffected by the temperature change.