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.

A comparison of the present data and previous work shows that the greatest occurrence of extinctions is found at the Paleocene/Eocene boundary with a lower number o extinctions at the middle/late Eocene and Eocene/Oligocene boundaries. The lack of a major catastrophic change at the Eocene/Oligocene boundary may be a result of previous faunal events at the Paleocene/Eocene and middle/late Eocene boundary eliminating stenothermal species, leaving environmentally tolerant species in the late Eocene that were largely unaffected by the 3°C (37°F) temperature decrease at the Eocene/Oligocene boundary.

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Some Permian (Leonardian) Radiolarians from Bone Spring Limestone, Delaware Basin, West Texas

A sample of the deep basinal Bone Spring Limestone (Leonardian) has yielded a diverse and superbly preserved assemblage of spumellarian radiolarians, associated with siliceous sponge spicules, and conodonts. Radiolarians include typically Paleozoic paleoactinommids, entactiniids, and rotasphaerids; Permian albaillellids and parafollicucullids; and triradiate spongodiscids or hagiastrids. Triradiate forms, which include approximately 60% of the shells in the sample, have not previously been reported to be abundant in pre-Mesozoic rocks. Albaillellids and parafollicucullids are similar to forms reported from the Permian strata of Japan, but the Bone Spring forms do not fit in the biostratigraphic zonation proposed by Japanese workers. This may be due to gaps in the Japanese stratigraphic sections or to provincialism in radiolarian faunas.

Diversity in the Bone Spring assemblage is higher than in other Permian assemblages. Most reported Permian radiolarians have been recovered by HF extraction of cherts, while the Bone Spring specimens were extracted from limestone with acetic acid. Thus, diversity differences can be partly attributed to fortuitous preservation.

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Geology and Exploration in Takutu Basin, Guyana

The Takutu basin is an intracratonic graben 280 km (174 mi) long and 40 km (25 mi) wide in northern Brazil and adjoining Guyana, lying entirely within the center of the early Precambrian Guyana shield. Acidic metavolcanic rocks and thick Proterozoic quartzite lie to the north of the basin. Granulite, gneiss, and granite border the graben to the south and east. High mountains arise along the south-bounding fault whereas more subdued topography flanks the north side of the basin. Triassic basalt forms a wide band of outcrop along the southern and eastern margins of the rift. There are very poor and sparse outcrops of the basin fill. The graben is filled with up to 4,000 m (13,123 ft) of Cretaceous and Jurassic sedimentary rock underlain by 1,500 m (4,921 ft) of mafic volcanics of Triassic age and possibly older (i.e., Proterozoic).

The geologic history of the Takutu graben is interpreted to extend back into Precambrian time because it occupies an ancient suture zone in the Guyana shield. Renewed rifting and major subsidence occurred in Mesozoic time resulting in the deposition of thick nonmarine clastics, evaporites, and carbonates. A basal(?) Jurassic clastic-carbonate sequence overlies the eroded basalt. It is overlain by thick Cretaceous Aptian salt and interbedded shales that were deposited over most of the basin and contain good oil source rocks. The only indication of a marine environment is found within the subsurface post-salt clastics in Brazil. Lacustrine an deltaic depositional processes were dominant as indicated from well and seismic data.

Two main structural styles, namely pre-salt and post-salt, occur in the basin. The former is characterized by block faulting and horst and graben development. Non-piercement halokinetic forms swells and ridges in the post-evaporite Takutu Formation. Wrenching and salt solution are interpreted on seismic records. A large, cross-basin arch is present in Guyana where at least six undrilled prospects have been mapped.

Three widely spaced exploratory wells have been drilled down to the mafic volcanics. The wells are located on structures near the rift margin or in areas of thinner basin fill. Two of the tests were dry and abandoned while Home Karanambo #1 was classed as a noncommercial oil discovery in fractured basalt. Several clastic depocenters have been interpreted and delineated from the seismic and drilling results. They lie near the southern and eastern unexplored basin margins, distant from the wells drilled to date.

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Surface Expression of a Deep Mafic Pluton in Kentucky and Tennessee

The density and orientation of lineaments have been mapped from Landsat imagery in a 30,000 km^2 (11,583 mi^2) area in central Kentucky and central Tennessee to determine whether known lower crustal intrusion is expressed on the surface through anomalous lineament patterns. A seismic refraction line through northern Tennessee and southern Kentucky indicates an anomalous region approximately 200 km (125 mi) long and 70 km (43 mi) wide where the upper crust is less than 10 km (32,808 ft) thick. The anomaly is coincident with a magnetic high seen on aeromagnetic surveys and with a Bouguer gravity high. Satellite magnetic surveys indicate a high in the general region of the anomaly. A basement core in the southern part of the anomaly is composed of peralkaline riebeckite syenite, a rock characteristic of a rift tectonic environment.

Lineaments were mapped as alignments of morphologic features such as streams, escarpments, mountain ranges, and tonal features on 1:500,000 scale multispectral scanner images of Bank 6. Winter scenes were chosen for a lower sun angle for better lineament mapping. The location of the anomaly was not revealed until lineament mapping was completed. Density and orientation of the mapped lineaments were then analyzed.

The following conclusions were reached from these data. (1) The lower crustal structure has no apparent expression through anomalous direction of lineaments over the structure. (2) The lower crustal structure is expressed on the surface through an increase in density of lineaments over the structure. (3) Aeromagnetic and satellite magnetic highs coincident with lineament density highs suggest correlation with deep crustal intrusive structures.

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Plants of Devonian-Mississippian Black Shales, Eastern Interior, U.S.A.

Macrofossils of the New Albany shale and equivalents of Late Devonian of Early Mississippian age in the east-central United States are known from three main "floras" or assemblages. One "flora" is almost entirely composed of *Callixylon* logs, slabs,