vironments was able to keep pace with rising sea level as the transgression continued. In the pinnacle-reef environment, several lithofacies developed through time. Of special importance, due to recent production, is an upper porous dolomite in which the original limestone has undergone extensive fabric-obscuring dolomitization. In the platform environment, there developed a patch-reef lithofacies and several quiet-water shallow-marine lithofacies which illustrate a vertical subtidal regressive sequence. In addition, the pinnacle-reef and platform environments grade into an uppermost intertidal and/or supratidal regressive series of dolomites and anhydrites. Carbonate production did not keep pace with rising sea level in the interreef environment resulting in topographic relief. Subaqueous laminated lithofacies were deposited throughout the basin and between the pinnacle reefs.

During the regressive phase, barrier reefs formed in northern Alberta which restricted the basin and resulted in the deposition of evaporites (Prairie) which eventually filled the basin.

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Programmed Pyrolysis of Organic Matter in Thermally Altered Cretaceous Black Shales

Organic-rich, Cretaceous black shales from DSDP Site 41-368 on the Cape Verde Rise in the eastern Atlantic were penetrated by hot diabase sills during Miocene time. Programmed pyrolysis and pyrolysis-gas chromatography were conducted on organic matter from core samples taken at various distances from a major sill. These methods show the types of hydrocarbons generated, the remaining generative potential, and the thermal maturity of the kerogen in the shales.

Systematic changes in kerogen elemental compositions are a consequence of the thermal cracking of volatile organic products from the kerogen. Loss of these products causes progressive aromatization of the residual kerogen closer to the sill. This conclusion is supported by an increase in the ratio of thermally distilled hydrocarbons to total hydrocarbons generated by pyrolysis, and an increase in the temperature required for maximum generation of hydrocarbons from the kerogen.

Although the major sill was 15 m thick, solvent extraction and pyrolysis results show that hydrocarbon generation was restricted to within about 10 m of the shale/sill contacts. At a given distance, the temperature appears to have been higher above than below the sill.

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Seismic Stratigraphic Analysis of Lower Cretaceous Rocks, Deep Southeastern Gulf of Mexico

A dense grid of multifold seismic reflection lines was combined with results of DSDP Leg 77 to subdivide the Lower Cretaceous section in the deep southeastern Gulf of Mexico into four seismic sequences (I to IV). Age and gross lithologic assignments were made by correlation with DSDP holes 535 and 540. Isochron and seismic facies maps were constructed for each sequence. These data document the complex filling of the deep southeastern Gulf of Mexico by pelagics and fine-grained carbonate debris shed from the adjacent growing Early Cretaceous margins on the east and west. This sedimentation accompanied subsidence of a rifted continental (transitional) crust formed during the early rift history (Late Triassic–Jurassic) of the Gulf basin.

The oldest unit (IV, Hauterivian-Berriasian) thins to the east, whereas unit III (Barremian-Aptian) thins to the west, suggesting a depocenter or source area shift to the east. A chaotic, hummocky, discontinuous unit (II, Aptian–mid-Albian) thinning to the south indicates deposition, in part, by northeast- or northwest-source debris flows from the flanking margins. Unit I (mid-Albian–Early Cenomanian) is a tabular parallel to subparallel sequence grading to more discontinuous facies at the base of the Florida escarpment, suggesting an eastern source. A prominent regional unconformity, characterized by erosional truncation, forms its cap. This corresponds to a 50-m thick pebbly limestone unit encountered in DSDP holes 97 and 540 that may span the entire Upper Cretaceous.

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Dipmeter Interpretation of Turbidite-Channel Reservoirs, Delaware Basin, New Mexico

Stratigraphic interpretation on high-resolution dipmeter logs can provide important information concerning the morphology and distribution of reservoir sandstones. Stratigraphic dip data were correlated with primary rock properties observed in cores and borehole-log data to define the internal morphology of turbidite-channel sandstones in the Cherry Canyon Formation at Indian Draw field, Eddy County, New Mexico. Characteristic dip patterns allowed the delineation of erosional unconformities, channel sequences, slump faulting, contorted and massive bedding, and sedimentary drape.

The erosional unconformity which marks the base of the Indian Draw channel exhibits a characteristic dip pattern consisting of an abrupt change in the trend of dip magnitude and dip azimuth across the unconformity, marked by higher dips (6 to 9°) above the unconformity in the channel-fill, and lower dips (2 to 4°) in the basin-plain sediments below. Slump faults exhibit an abrupt increase in dip with depth over a small interval, and an associated progressive dip azimuth rotation approaching the fault. Contorted beds show a random dip pattern, commonly marked by poor-quality, high-magnitude dips. Massively bedded sandstones lack computed dips and sedimentary drape patterns typically consist of a decrease in dip upward within basinal deposits overlying a sandstone.

Detailed mapping of the reservoir sandstones indicates deposition as stacked, laterally discontinuous lenses within a previously eroded channel. Direction of sedimentary drape over sandstone lenses can be used to map their trends. Channel-fill lenses are 5 to 30 ft (1.5 to 9.1 m) thick, and are elongate parallel with depositional dip with a sinuous geometry. Such turbidite-channel deposits can be anticipated to form complex multilayered reservoirs, consisting of a series of isolated sandstone lenses of restricted areal extent.

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Fan-Delta Sedimentation, Waltman Member, Fort Union Formation, Wind River Basin, Wyoming

The Fort Union Formation (Paleocene) was deposited in structural and sedimentary basins which developed in the Rocky Mountain states in response to Laramide structural disturbances. Exposures of the Waltman Member in the eastern Wind River basin reveal an interaction of alluvial fan and lacustrine depositional processes. Fan deltas developed where the distal reaches of alluvial fans, which issued from the tectonically active Granite Mountains to the south, prograded into an isolated or restricted body of fresh water that occupied the rapidly subsiding basin.

Facies of the Waltman depositional system, in basinward progression, include distal alluvial-fan, proximal fan-delta, delta-front, and prodelta. This sequence of facies exhibits an increasing influence of lacustrine over fluvial processes. Depositional environment of each facies is interpreted through examination of outcrop and subsurface characteristics, and supported by analogy with other ancient and modern depositional systems.

Sedimentation was largely controlled by the tectonic behavior of the source area and receiving basin. Rapid subsidence of the basin relative to the source area resulted in three vertically stacked fan-delta lobes in the study area. Uplift of the source area relative to the basin subjected preexisting formations and facies to erosion and redeposition. Climate and basin morphology (which controlled storm activity), stream runoff, waves, currents, basin slope, water depth, and water salinity were also factors which influenced sedimentation within this depositional system.

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Integrated Exploration: Frustration, Fulfillment, or Fun?

The development of optimum integrated exploration has both technical and humanistic aspects. Experience in the borehole-geophysics field with integration of measurements shows the connotations for integration of measurement systems (e.g., seismic and borehole) on more ambitious scales. It is concluded that many of the technical tools needed for effective integration are already available. The challenges and opportunities posed by the humanistic aspects are considered. Modes of integrated exploration suggested by experiences of organizations and conclusions to be drawn from these experiences are reviewed.

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Carbonates, Evaporites, Red Beds, and Organic Shales—Global Tectonic Model for Their Chemical Cycling and Hydrocarbon Potential

The partitioning of oxidized and reduced species of exogenic carbon and sulfur, as calculated from secular Phanerozoic trends in $\delta^{34}S$ and $\delta^{13}C$, suggests a strong coupling between major reservoir transfers and global changes in sea level due to geotectonic mechanisms. The stoichiometry of the major reservoir transfers can be approximated by two tectonic-geochemical end-member scenarios.

Scenario I—high ridge volume, high spreading rates, high global sea level:

$$Me^{2+}CO_3 + SiO_2 + 8CaSO_4 + 2Fe_2O_3 + 15CH_2O \rightarrow Me^{2+}SiO_3 + 4FeS_2 + 8CaCO_3 + 15H_2O + 8CO_2.$$

Scenario II—low ridge volume, low spreading rates, low global sea level:

$$Me^{2+}SiO_3 + 4FeS_2 + 8CaCO_3 + 15H_2O + 8CO_2 \rightarrow Me^{2+}CO_3 + SiO_2 + 8CaSO_4 + 2Fe_2O_3 + 15CH_2O.$$

Scenario I tends to be a time of globally widespread carbonates, elevated carbon dioxide, warmer temperatures (greenhouse effect), extensive iron sulfides, light $\delta^{13}C$ and heavy $\delta^{34}S$. Conversely, scenario II represents a time of globally widespread evaporites, red beds, reduced carbon, carbon dioxide consumption, more frequent glaciation, heavy $\delta^{13}C$ and light $\delta^{34}S$.

These secular trends which track the first-order sea-level curve have important bearing on global hydrocarbon-reservoir and source-rock strategies. Owing to elevated carbon dioxide in scenario I, the widespread carbonates on the flooded shelves would tend to be composed of allochems and marine cements of metastable aragonite and/or Mg calcites greater than 8 mole % Mg. Such compositions are vulnerable to becoming excellent secondary porosity reservoirs. The carbon dioxide concentrations might also enhance the "anoxic" preservation of source-rock organic matter in areas where slow depositional rates would normally lead to oxidation of reduced carbon before burial. Scenario II, on the other hand, would yield less favorable conditions for carbonate reservoir development. This would be a result of both a decrease in areal extent (lower sea level, increased clastic input) and a general decrease in potential secondary porosity development owing to the lower carbon dioxide levels which lead to a dominance of more stable non-aragonite Mg calcitic (less than 8 mole % Mg) allochems and marine cements. However, the source-rock potential at this time would tend to be generally favorable owing to the greater global storage of reduced carbon. Furthermore, scenario II would also represent a time of widespread areas for the potential application of a variety of evaporite and red-bed play concepts.

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Residual Temperature Analysis—Tracking Subsurface Fluid Migration

Positive temperature anomalies associated with fluid-migration paths are expected effects within a compacting and dewatering sediment pile. However, temperature anomalies are also produced by lateral variations in thermal conductivity of the sediments. Using established relations between thermal conductivity and seismic velocity, an estimate of regional heat flow, and average surface temperature, it is possible to estimate the local geothermal gradient (due to solid state, one-dimensional conduction) from sonic logs or downhole velocity surveys. Subtraction of such calculated temperatures from corrected bottom-hole or log temperatures produces mappable residual temperature anomalies which can be interpreted as effects of active upward fluid migration. Mapping of such residual temperature anomalies and comparison with structural setting provide a stronger tool for interpreting routes of water (and perhaps hydrocarbon) migration, than using temperature values without removal of conductive effects. The procedure is analogous to removing a predicted regional gravity field to produce residual gravity anomaly. Interpretations are strengthened by mapping calculated fluid pressure and salinity anomalies which might also be attributable to fluid movement.

Examples from the Louisiana Gulf Coast Miocene illustrate the application and promise of the technique. Residual temperature anomalies occur close to faults, suggesting the potential importance of such structures as routes for fluid escape. The method also provides a means of interpreting correspondence of thermal highs with structural highs as products of either conductive focusing or fluid movement up structure, though two- or three-dimensional modeling is required.

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Classification of Onshore Sedimentary Basins in Brazil

The major sedimentary basins of Brazil range in age from late Proterozoic to Cenozoic. They overlie a stable Precambrian craton consolidated by several orogenic events. Two major regions can be distinguished in this basement: the relatively calm Amazonic Province and the strongly tectonized Atlantic Province, welded together 900 to 1,200 m.y. ago.

The oldest of the major superimposed basins is the Bambui (Sao Francisco) basin, whose sedimentary sequence was, especially along the margins, slightly folded and metamorphosed during