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Reconstruction of Deformed North Pyrenean Basin

The North Pyrenean basin in southern France was initiated in middle Cretaceous time along the North Pyrenean fault zone. An understanding of the middle Cretaceous is critical because it corresponds in time to opening in the Bay of Biscay, to postulated strike-slip along the North Pyrenean fault, to a controversially dated episode of metamorphism, and to emplacement of lherzolite. A field study of the Albian and Cenomanian fill of the North Pyrenean basin has been undertaken in order to provide constraints on postulated regional relationships during this time.

Two steps are required for the study. The first is to reconstruct the structure of the basin that was deformed during the Late Cretaceous to Oligocene Pyrenean orogeny. The orogeny is here summarized as a north-south shortening that reactivated the North Pyrenean fault zone as a north-vergent reverse fault. Dominantly south-directed thrusting followed, and detachment along incompetent Triassic shale and evaporite layers was important in both phases. The second step is a sedimentologic analysis. The basin fill is dominantly marine, clastic mud, up to 4 km thick. Abrupt lateral thickness and facies variations demonstrate that the basin was bounded by active faults. Excepting the absence of high organic productivity, reconstruction suggests that the North Pyrenean basin is a partial analog in terms of geometry, facies arrangement, and regional setting to Cenozoic marine basins in California, particularly to those in which Monterey Formation lithologies were deposited.

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Carbonate to Siliciclastic Transitional Facies in Tectonic Delta Complex—Basal Upper Devonian of East-Central New York State

In an early stage of building of the Devonian Catskill delta complex of New York state, a submarine topographic high developed 100 km offshore. On the landward side of the high, in an intermittently subsiding trough, sediment from an eastern source terrane accumulated as a landward-thickening and coarsening lithosome (Gilboa Formation) of interlensing gray siltstone and shale and very fine-grained sandstone with subordinate coquinite lenses. Locally abundant in the lithosome are ball-and-pillow structures, thin conglomerates, trace fossils, fossil seed ferns, sole markings, shallow cross-bedding, laminations, and ripple marks. The high was a barrier to clastic influx. On its seaward side, a carbonate lithosome (Tully Formation) formed. This formation has been subdivided into facies including: abraded calcarenite, chamoside oolite, skeletal calcilutite, barren shaly calcilutite, mound calcilutite, back-mound calcilutite, and encrinite. The effect of combined intermittent subsidence in the basin-margin trough and variation in rate of terrigenous influx is well expressed in the seaward part of the siliciclastic lithosome. Rapid subsidence and low terrigenous influx finally resulted in a short-lived carbonate transgression across the barrier prior to overwhelming of the shelf by terrigenous influx.

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Age of Douglas Creek Arch, Colorado and Utah

Isopach mapping and stratigraphic studies in the Douglas Creek arch area, a north-south–trending structure that separates the Uinta basin of Utah from the Piceance Creek basin of Colorado, indicate that the arch was formed largely during the Laramide orogeny (Late Cretaceous, late Campanian through Eocene). Formation was contemporaneous with the formation of the Uinta and Piceance Creek basins, but may have been present as a very broad, low-amplitude structure earlier during the Sevier orogeny. Recent paleogeographic reconstructions by other workers, however, suggest that the Douglas Creek arch was largely pre-Laramide.

The Dakota to Castlegate Sandstone interval, which predates the Larmide orogeny, thickens toward the northwest on the west flank of the arch and toward the northeast on the east flank. This thickening roughly outlines the arch, but is much broader, and more closely parallels the Uncompahgre uplift south of the arch. The thickness of the Castlegate to Cretaceous-Tertiary unconformity interval, which brackets the early stages of the Laramide orogeny, is nearly uniform west of the arch, but thickens abruptly east of the crest of the arch. This interval has been modified by an unknown amount of erosion during the following hiatus. Upper Paleocene rocks above the unconformity lap out toward the arch from both directions, indicating that the arch was rising during the hiatus. The intervals from the Cretaceous-Tertiary unconformity to the lower Eocene Long Point bed and from the Long Point bed to the middle Eocene Mahogany bed thicken away from the arch, indicating that the arch was active during early to middle Eocene. A structure contour map of the top of the Mahogany bed indicates considerable post-Mahogany movement as well. The arch was therefore largely if not totally a Larmide structure.

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Origin, Migration, and Accumulation of Petroleum in Thick Cenozoic Delta Systems

The distribution and percentages of oil and gas in Cenozoic delta systems have often been attributed to the variations in the distribution and amount of "oil-prone" and "gas-prone" organic matter in the presumed source rock. This genetic relationship has been greatly exaggerated. Data have become available in the past 10 yr indicating that the distribution and amount of oil versus gas in reservoirs primarily reflects the relative ease of migration of the 2 hydrocarbon phases. For example, pressure (active compaction) seals are the preferred cap for gas in the McKenzie delta, fault conduits were not available hydrocarbon migration until the primary source rock was in the gas stage of thermal maturation in the eastern portion of the ancestral Orinoco delta, mature source rocks in the Mahakam delta yield oil to the reservoirs if they are normally pressured but only gas when they are overpressured, the amount and distribution of oil and gas in the Niger delta are primarily controlled by fault displacement and leakage, and in the Mississippi delta the primary control is overall structural complexity.

Although specific source rock units have been tentatively identified in several of the Cenozoic deltas, it is possible that the more than 10,000 ft of overmature marine shales that underlie all of these delta systems contain the most important driving force for the migration of both oil and gas. Although the TOC's are usually modest, the total amount of methane generated is very large. As the methane moves upward through the section, it sequentially dissolves, moves, and precipitates the liquid hydrocarbons. Faults are very important in the focusing of the migration and the accumulation of the hydrocarbons.

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Three-Dimensional Computer Modeling for Exploration and Reservoir Analysis

Anyone who has done exploration or reservoir studies involving large numbers of logs, cores, or seismic data is aware of the great amount of manual labor required to reduce the data, to draw structure and thickness contour maps, and to make lithologic cross sections. While computers are commonly used to draw contour maps, lithologic cross sections and 3-dimensional interpretations are still made by hand. Computer programs have been developed that build and use 3-dimensional models. These programs use data from wells or shotpoints to interpolate the geologic properties in 3 dimensions between control points much as a geologist would construct cross sections (i.e., by correlating between stratigraphic horizons). Modeling may be done at any scale, from large basins to individual reservoirs, and with an appropriate amount of incorporated detail. After the model is constructed, it is available for calculations and displays. Cross sections can be constructed showing the geographic extent of the rock properties. Similarly, facies maps can be drawn to depict geology at specified depths or along geologic time surfaces. Information in the model can also be used to construct contour maps such as net pay thickness or average porosity, and to compute volumes.

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Holocene Carbonate Facies of Pulau Seribu Patch-Reef Complex, West Java Sea

The Pulau Seribu patch-reef complex, located 50 km northwest of Jakarta, is elliptical in plan view, measuring 40 km north-south and 12 km east-west. Individual reefs range in length from 50 m to over 6 km, show a strong east-west lineation due to seasonal winds and currents, and grow up into the intertidal zone.

Facies mapping (based on 250 bottom samples and Landsat image analysis) shows the extent of reef-crest, reef-flat, beach, island, reef-slope, and lagoonal facies. The reef crest is fairly narrow, flat, continuous along strike, and consists of coral-algal boundstones. The reef framework of predominately platy and branching corals is infilled with coral-skeletal packstones and wackestones and represents a small percentage of reef-related facies developed in the reef complex, being overshadowed by extensive reef flats of coral-skeletal packstones. Commonly, beach and island facies of coral-skeletal grainstones occur near the center of individual patch reefs. In front of the reef crest, an apron of reef-derived coral-skeletal packstones is deposited as reef-slope facies. This grades downdip into lagoonal facies of highly burrowed molluscan foraminiferal wackestone and packstone and coral molluscan wackestone and packstone, both with low TOC values that indicate no source rock potential.

Pulau Seribu is an important lithofacies model for better understanding Tertiary reefs in Indonesia, especially the prolific hydrocarbon reservoirs of northern Sumatra.

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Carbonate Facies and Landsat Imagery of Shelf Off Belize, Central America

A reevaluation of Holocene sediments on the Belize shelf is based on (1) a newly constructed composite of 7 Landsat images, enhanced and registered to form a regional base map, and (2) a Holocene facies map based on a rigorous treatment of compositional and textural parameters for approximately 600 bottom samples. The sediments are mapped in terms usually applied to lithified carbonate rocks, allowing direct comparisons with carbonate facies in the subsurface.

By combining Landsat imagery with this facies map, it is possible to point out the following geologic features: (1) major tectonic elements, such as the Maya Mountains, the Yucatan Plateau, several offshore ridges, and 3 large atolls, (2) major physiographic features such as the Belize barrier reef with its reef platform and crest, middle-shelf shoal deposits, middle-shelf patch reefs (including lagoon reefs or rhomboid reefs), (3) Holocene facies patterns with potential reservoir facies of foraminifera-grainstone bars, *Halimeda* grainstones, and branching-coral, encrusting red-algae boundstones, and (4) nearshore clastics and a sharp transition eastward to carbonate sediments.

An understanding of Holocene facies patterns on the Belize shelf is important to the explorationist, because these facies patterns are living examples of exploration fairways and invite comparisons with several petroleum provinces: (1) Cretaceous reefs of Texas, (2) upper Paleozoic skeletal-grainstone bars in west Texas, and (3) Devonian reefs of the Alberta basin.

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North African Geology: Exploration Matrix for Potential Major Hydrocarbon Discoveries

Based on results and models presented previously, it is possible to consider an exploration matrix that examines the 5 basic exploration parameters: source, reservoir, timing, structure, and seal. This matrix indicates that even those basins that have had marginal exploration successes, including the Paleozoic megabasin and downfaulted Triassic grabens of Morocco, the Cyrenaican platform of Libya, and the Tunisia-Sicily shelf, have untested plays. The exploration matrix also suggests these high-risk areas could change significantly, if one of the 5 basic matrix parameters is upgraded or if adjustments in political or financial risk are made.

The Sirte basin and the Gulf of Suez, 2 of the more intensely explored areas, also present attractive matrix prospects, particularly with deeper Nubian beds or with the very shallow Tertiary sections. The Ghadames basin of Libya and Tunisia shows some potential, but its evaluation responds strongly to stratigraphic and external nongeologic matrix variations based on degree of risk exposure to be assumed. Of greatest risk in the matrix are the very deep Moroccan Paleozoic clastic plays and the Jurassic of Sinai. However, recent discoveries may upgrade these untested frontier areas.

Based on the matrix generated by the data presented at a North African Petroleum Geology symposium, significant hydrocarbon accumulations are yet to be found. The remaining questions are: where in the matrix does each individual company wish to place its exploration capital and how much should be the risk exposure?

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Role of Minerals in Generation and Release of Hydrocarbons

The morphology and composition of minerals are known to be of great importance in determining the suitability of rocks as hydrocarbon reservoirs. However, their role in the generation and release of hydrocarbons from kerogen is still poorly understood. Recent studies suggest that the interaction of some clay minerals with the organic matter in source rocks results in a series of processes which can be characterized as follows: (1) catalytic increase in the rate of organic carbon decomposition, (2) control of the chemical nature of the hydrocarbon products, (3) retention of bitumens and asphaltenes that may be carried to depths where the geothermal gradient causes them to be cracked to light hydrocarbons, (4) transform nonporous carbonate rocks to porous reservoir rocks as a result of early catagenic CO_2 and organic acids' release, (5) recrystallize minerals involving release of water, mineral dissolution, and release of trapped bitumen, and (6) influence the formation of mature sweet light oil or immature sour heavy oil.

This evaluation suggests that the character of hydrocarbons produced, which is generally thought to be facies controlled, is a result of both mineral as well as kerogen type within the source rock. Recognition of the above could have important implications in the strategy of geochemical exploration for oil and gas.

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High-Resolution Seismic Data of Atlantic Margin Basement

Reflection seismic data for petroleum exploration have improved resolution of the rift structure of the United States Atlantic margin. Previously conjectural features are not clearly seen and additional features have been recognized. Our best data are from the Long Island–George's Bank area. Generally, the geologic elements visible, looking landward, are: (1) a belt of block-faulted oceanic crust that merges into a wedge of synrift sediments, (2) a basement ridge 10-15 km wide with maximum relief of 1.5 km, at a depth generally below 9 km, under the East Coast Magnetic Anomaly (ECMA), (3) a very wide zone of rising basement, structurally bland except for a major hinge near the updip edge of the ECMA, (4) an updip zone of complicated rift-stage faults with basinward-dipping listric faults, which visibly sole at ~ 14 km, and common listric counter-regional faults, and (5) a major unconformity, the base of the drift sequence, with rift-stage structures extensively peneplaned. Graben fill is 2-stage and includes earlier highly rotated beds separated by an unconformity from mildly deformed sediments. Downdip, the major unconformity at the base of the drift sequence becomes a strong, continuous reflector that downlaps the landward edge of oceanic crust.

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Sedimentary Features and Soil-Like Fabrics in Cycles of Upper Lockatong Formation, Neward Supergroup (Upper Triassic), New Jersey and Pennsylvania

The Upper Triassic Lockatong Formation is composed of cycles of fine-grained sediments interpreted as lacustrine deposits. These sedimen-