the summer of 1979 a 3-D seismic survey covering 190 km^2 was shot. Interpretation and drilling were simultaneous. Before drilling, probable recoverable reserves were calculated to be 1,600 million bbl. After drilling the estimate was revised to 1,200 million bbl. The field has now been declared commercial and a successful exploration period has been terminated. This discovery has opened new possibilities in an area under active exploration.

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Study of Subtle Traps Using Horizontal Seismic Sections

A three-dimensional seismic survey, after proper design, data collection, and data processing, yields a three-dimensionally migrated data volume. Horizontal, or Seiscrop™, sections sliced from this data volume provide a direct horizontal view of the subsurface from which structural interpretation can be straightforward.

In the absence of structure, Seiscrop sections display stratigraphic or paleogeomorphic features directly. However, structural deformation can be removed from the data by flattening. Horizon Seiscrop sections, sliced from the flattened volume, permit stratigraphic and other depositional features to be recognized and studied in detail without the confusion of structure.

Using horizontal seismic sections primarily from the Gulf of Thailand, a variety of small and subtle traps have been identified. These include small fault traps, sand channels, and sandbars. The acoustic nature of these features has been further studied using seismic logs, derived by wave equation inversion. Reservoirs thicker than 30 ft (9 m) have proved mappable.

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Surface Detection of Free Hydrocarbon Microseepage from Subsurface Petroleum Accumulation: Case Study

In January 1979, PEMEX began a 2-year test project designed to evaluate the surface detection of free hydrocarbon microseepage as an integrated exploration tool. The tests were performed by analyzing samples collected over fields selected to represent various hydrocarbon entrapment conditions (differing hydrocarbon type, differing trap mechanisms, varying depths, etc). All analyses were performed in the field, and the sample types, sample depths, and collection procedures were varied to determine the best procedures for detecting microseepage anomalies.

In addition to summarizing the various sample collection and analytical procedures utilized in the field operation, results are presented from one of the successful tests conducted over a known producing structure. The analytical field procedures used were C_1-C_7 gas chromatography and $C_{10}+$ spectrum fluorescence analysis of cuttings and core samples collected at varying depths between 2 and 30 m. The structure selected is a lenticular anticline that produces oil from an Austin equivalent at 2,500 m and dry gas from the Jurassic at approximately 3,500 m.

The 350 surface samples definitely indicate that methane is seeping into the near-surface sediments and forming a distinct anomaly directly above the two superimposed reservoirs. Apparently, only the methane is able to migrate through the stratigraphic section, and the heavier components, if they were able to escape from the Cretaceous reservoir, have been stripped and retained by the sediments.

The surface anomaly appears to contain elements of both a circular halo and a centralized anomaly that overlies the apex of the producing structure. The intensity of the anomaly was of a sufficient degree that its detection should have been possible using blind reconnaissance sampling.

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Structural Deformation in Northern Gulf of Alaska: Transition from Transform to Convergent Plate Motion

Multichannel seismic reflection data reveal the late Cenozoic structure along the continental margin in the northern Gulf of Alaska, where transform motion along the Queen Charlotte-Fairweather fault system gives way to convergent motion along the Aleutian Trench. The active trace of the Fairweather fault system lies generally near the outer shelf and upper slope but, south of Sitka, broad folds and associated faults in late Cenozoic strata seaward of the active trace may indicate additional fault splays beneath the continental slope. The intensity of deformation in these strata decreases to the north, and slope deposits seaward of the Fairweather fault are undeformed between Sitka and Cross Sound. Between Cross Sound and Icy Bay (the Yakutat segment), Eocene and younger shelf strata are relatively undeformed along the continental slope. Late Cenozoic abyssal strata, which partly onlap the continental slope, are relatively undeformed except for local recent deformation seaward of Fairweather Ground. The observed structure along the Yakutat segment of the continental margin is more readily explained by strike-slip motion between the Yakutat segment and the Pacific plate than by oblique subduction of the Pacific plate as deduced from plate tectonic models. Between Icy Bay and Kayak Island (the Yakataga segment), northeast-trending faults and folds that deform Cenozoic strata beneath the shelf and slope suggest relatively continuous late Cenozoic convergence between the Yakataga and Yakutat segments of the continental margin. Thus, the Yakutat segment may have been coupled to the Pacific plate during much of the late Cenozoic.

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Results of DSDP Leg 77 in Deep Southeastern Gulf of Mexico—How Good Was our Seismic Stratigraphic Interpretation Ahead of the Drill?

A detailed seismic stratigraphic interpretation of an extensive grid of multifold seismic reflection data provides the basis for a model of the pre-middle Cretaceous sedimentary history of the southeastern Gulf of Mexico. The study area is located in the deep-water part of the western Straits of Florida between the Campeche and Florida Banks north of Cuba. The model predicts that: (1) block-faulted basement topography represents the top of a rifted and attenuated continental (transitional) crust; (2) a syn-rift sedimentary sequence possibly consisting of volcanic and nonmarine rocks of Triassic to Middle Jurassic fills in rift basins and covers the rift topography; (3) a post-rift sedimentary sequence representing a transition upward from shallow- to deep-marine rocks of Late Jurassic

to middle Cretaceous (150 to 97 m.y.) was deposited on transitional crust and syn-rift strata as the crust cooled and subsided. This model was tested by four DSDP holes drilled on Leg 77 of the RV *Glomar Challenger* during December-January, 1980-81. Two holes were drilled to sample the thick pre-middle Cretaceous sedimentary sequences, and two holes were drilled to sample basement. Results of this drilling are presented and are compared with the model predicted by the seismic stratigraphic analysis. Data concerning the geologic history of this area, developed from the drilling and the seismic stratigraphic analysis, have important implications for future hydrocarbon exploration in adjacent shallow-water provinces such as the South Florida Bank, the Campeche Bank, and Cuba.

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Correlation of Monterey Shale to Paleo-Oceanographic and Paleoclimatic Events

Three distinct oxygen isotope events, which appear to record successive stages in the growth of the east Antarctic ice sheet, have been identified and dated paleomagnetically in middle and upper Miocene sediments from the Pacific Ocean. These stages are as follows: (1) late Magnetic Epoch 15 to early Magnetic Epoch 12 (c. 15 to 12 m.y.B.P.); (2) early Magnetic Epoch 11 (c. 11 m.y.B.P.); and (3) early Magnetic Epoch 6 (c. 6.7 m.y.B.P.). An additional slight cooling is recorded in Magnetic Epoch 10 at c. 10 m.y.B.P. These events can be tied to changes in paleo-oceanography, paleobiogeography, and opal accumulation in the Pacific Ocean, and, in turn, can be identified in the Monterey. The initiation of the east Antarctic ice sheet at c. 14 to 12 m.y.B.P., and its attendant changes in surface circulation and paleoproductivity, is correlated to the beginning of the Monterey Shale. In addition to the beginning of massive opal accumulation along the California coast, increased silica accumulation in the equatorial Pacific is noted. This is accompanied by changes in diatom communities marking the beginning of present-day circulation patterns. The role of the Southern Ocean as an arbiter in the Miocene and Pliocene silica budget is noted and discussed.

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Late Cenozoic Paleoclimatic and Paleotectonic Setting for Hydrocarbon Formation in Southern California

The Miocene formation of hydrocarbons in southern California is synchronous with high phytoplankton accumulation and subduction of the Farallon-Pacific spreading ridge. In North Pacific piston and DSDP cores, there is an increase in the amount of biogenic opal (largely phytoplankton) in middle to upper Miocene deep-sea sediments. A similar increase in phytoplankton accumulation is recorded in sediments from neritic environments in California, Japan, and Java. This increased accumulation is related to growth of the east Antarctic ice sheet, as inferred from the oxygen isotope climatic curve and specific biotic indicators of cooling water in deep-sea cores. The relation of hydrocarbon formation to phytoplankton accumulation and subduction of a spreading ridge is demonstrated by comparing time-slice maps showing variations in the pattern of phytoplankton accumulation with maps of paleotectonics and paleogeography of California. Moreover, this comparison demonstrates a close correlation of middle and late Miocene climatic events to sea level changes. Using southern California as a model, it is proposed that Miocene subduction of the Farallon-Pacific ridge played a role in producing the heat for formation of hydrocarbons from phytoplankton in marginal basins.

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Sedimentation on North Shelf of Puerto Rico

Regional sediment analyses along 100 km of the north shelf of Puerto Rico show the area to be a site of modern sedimentation. Sediments delivered to the steep, narrow, high-wave-energy north shelf by the Rio de la Plata, the Rio Grande de Manati, and the Rio Grande de Arecibo are in or approaching textural and compositional equilibrium with shelf processes. Modern sediments are being deposited over relict shelf sediments which are not in textural or compositional equilibrium. Relict and recent sands are easily distinguished by their contrasting color, composition, and texture.

The river sands are predominantly dark colored and can contain a large percentage of mud. Upon entering the nearshore, they are entrained in the dominant westward littoral and shelf currents produced by persistent northeast trade winds. Minor eastward transport occurs partly as a result of an easterly component of tidal currents. Where terrigenous deposits are continuous between rivers, sediment sources have been delineated using X-ray diffraction of the heavy mineral suites.

The relict calcareous shelf sands are predominantly light colored and of biogenic origin. They are occasionally isolated in nearshore shadow zones behind promontories or exposed in mid-shelf windows. Some mixing of relict and recent sands occurs immediately off the river mouths. The high wave-energy winnows the nearshore sands clean. Mid-shelf to basin transport of mud occurs in a series of storm-generated resuspensions.

A low level of terrigenous contamination of carbonates indicates limited overlap between shelf sediment facies. Indeed, boundaries between sediment types are very sharp, often less than 200 m wide. This suggests localized controls on depositional processes.

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Recent, Supracrustal, Carbonate Cementation, Florida Keys

Algal stromatolites, the crust of which ranges in age from 5,680 years B.P. at the bottom to 400 years B.P. at the top, overlie Pleistocene bedrock in the Florida Keys. Recent beachrock has been reported at Dry Tortugas, and recent cay rock was discovered at Bahia Honda.

Two examples of supracrustal carbonate cementation were found in the intertidal zone of the Florida Keys. On the Florida Bay side of Grassy Key, small gastropod shells of the genera *Cerithium* and *Batillaria* are cemented to the top surface of the laminated crust that overlies the Pleistocene Key Largo Limestone. On the Atlantic side of Missouri Key, isolated blocks of rubble are cemented to the top of the crust. Preliminary observations of thin sections suggest that the low-magnesium calcite cement includes alteration products of the underlying crust as well as supracrustal clasts at both Grassy