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

Key and Missouri Key. The top of the crust has been dated at approximately 400 years B.P., indicating very recent cementation in the littoral zone of these areas.

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Morphology, Sedimentology, and Genesis of Three Large Submarine Canyons Adjacent to Navarin Basin, Bering Sea

Three large submarine canyons cut deeply into the Bering Sea margin adjacent to the Navarin basin, a prospective petroleum province scheduled for leasing in 1984. These canyons, Navarinsky, Pervenets, and Zhemchug, head in water shallower than 150 m, extend seaward as far as 230 km, and debouch onto extensive deep-sea fans at depths of 3,200 m. The three canyons are incised as deeply as 2,400 m into Neogene and older more lithified Paleogene rocks that make up much of Navarin basin. These canyons are apparently controlled by structures dating back to the Paleogene. Major cutting of the canyons probably occurred when lowered sea levels exposed the Bering shelf and allowed such large rivers as the Yukon to carry large amounts of sediment to the outer shelf. Slumping and the resulting turbidity currents are the most likely canyon-cutting processes. Seismic-reflection profiles across and down the canyons indicate that numerous slumps and well-developed cut-and-fill structures are present throughout the canyon systems. The large width of the modern Bering Sea shelf may have resulted in low rates of sediment accumulation on the outer shelf during present highstands of sea level. However, the presence of a few graded sand layers in 2 to 5-m cores recovered from the canyons and their fans suggest at least some occasional ongoing turbidity-current activity in these canyons. Extensive fields of sand waves have recently been discovered at the heads of all three canyons. Preliminary interpretations of geophysical data indicate that these sand waves are relict features that formed at times of lower sea level during glacial episodes.

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Sidescan Sonar Depiction of Slump Features Associated with Diapirism on Continental Slope Off Southeastern United States

A newly developed mid-range sidescan sonar system having a range of 2.5 km/side was used in conjunction with long-range, GLORIA II, sonographs (maximum range 22 km/side) and high-resolution seismic profiles to map parts of the continental slope and upper continental rise between Cape Hatteras and the Blake Spur, off southeastern United States. A 60-m-high scarp that traverses the slope to encircle a near-surface diapir complex was identified from seismic-reflection records and traced laterally for approximately 30 km by using GLORIA II data. More detailed mid-range sidescan sonographs of the area show detached-block slide paths cut into the sea floor, which have scarps 15 to 20 m high and areal extents of at least 3 to 5 sq km. These slide blocks appear to originate at the scarp face and extend downslope to lobate deposits of apparent sediment debris, or to areas beyond our data coverage. Such features as overlapping slide paths and minor sediment failures on the scarp face revealed in the images indicate the relative chronology of events. The position of the scarp relative to the near-surface diapir complex, and its presence on an otherwise featureless and gently sloping segment of the continental slope, suggests that the scarp was created during the formation of the diapir complex, when withdrawal of salt at depth led to local oversteepening of the slope surface and consequent failure by slumping and surficial slides.

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Ubarana Oil Field, Offshore Brazil: Case History

Ubarana is the first commercial oil field on the northern continental shelf of Brazil. Discovery well 1-RNS-3, drilled in 1973, was located on a seismic structural high in the offshore extension of the Potiguar basin, about 13 km from the coast and 160 km northwest of Natal. The well penetrated oil-bearing, fluvio-deltaic sandstones of the Cretaceous Acu Formtion. Five outpost wells, also located on the mapping of seismic horizons adjacent to the producing interval, helped to extend the limits of the accumulation. A total of 1.4 million cu m of oil has been produced between 1976 and October 1980.

The surface area of Ubarana field is about 35 sq km with oil-bearing reservoirs at an average depth of about 2,400 m. Permeability and porosity of the sandstones are generally poor. Pressure is normal and the main production mechanism is solution gas-drive. The volume of oil in place is about 37 million cu m; estimated recovery factor is 29%. There are presently four platforms in the Ubarana field active in drilling and production with 32 producing wells, and 14 locations to be drilled. Ubarana is not yet fully delimited because a recently drilled well, 3-UB-25, has shown that the field extends southward. This has resulted in selection of four additional production platforms which will allow drilling another 48 wells for production.

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Petrofacies and Depositional Environments of Upper Jurassic Naknek Formation, Lower Cook Inlet, Alaska

More than 3,000 m of conglomerate, sandstone, and siltstone were deposited in fluvial, shelf, slope, and basin-floor environments in an Upper Jurassic fore-arc basin on the Alaska Peninsula. Distance from uplands to basin floor was short and sediment supply locally concentrated, resulting in narrow facies belts and abrupt facies changes. Three successively younger depositional packages are exposed from north to south: (1) deep-water proximal turbidites from the Iniskin-Tuxedni area to Contact Point; (2) nonmarine sandstones northwest of Akumwarvik Bay; and (3) shallow-shelf sandstones east of Akumwarvik Bay.

Three distinctive and successively younger sandstone petrofacies are recognized from north to south, but these petrofacies do not correlate exactly with the three depositional packages. (1) Naknek sandstones in the Iniskin-Tuxedni area contain abundant plagioclase (typically replaced by zeolites), volcanic rock fragments, reddish hornblende, with a notable lack of quartz and K-feldspar. (2) Naknek sandstones south of Iniskin Peninsula and north of Akumwarvik Bay contain quartz, K-feldspar, and metamorphic rock fragments, with a decrease in volcanic rock fragments. (3) Naknek sandstones east of Akumwarvik Bay have more quartz, K-feldspar, and metamorphic rock fragments than older Naknek sandstones