where the belt crosses the shelf. These offshore prolific areas represent only 25% of the total shelf area. The reported offshore ultimate recoverable oil is 4.8 billion bbl or 25.4% of the Nigerian total. In general, the proportion of natural gas to oil in Nigeria is relatively high and increases basinward. Reserves in the order of 40 to 50 tcf have been reported. However, due to the lack of marketing opportunities, this gas has been found incidentally to oil exploration. It is, therefore, possible that in the least prolific offshore areas, considerable reserves of gas could be established if the proper economic incentives existed.

PAYNE, JOHN B., and ALAN J. SCOTT, Univ. Texas at Austin, Austin, TX

Late Cretaceous Anastomosing Fluvial Systems, Northwestern Colorado

Basal Mesaverde deposits exposed near Rangely Dome in northwestern Colorado indicate a progradation of deltaic sandstones over the marine Mancos Shale. Overlying these deposits is a thick nonmarine sequence containing four major facies: (1) extensive organic-rich siltstones with laterally discontinuous coals, (2) elongate lenticular cross-bedded sandstones, (3) thin (0.3 to 2.5 m) ripple-stratified, sheetlike fine sandstones, and (4) thick (maximum 11 m) fine-grained sandstones with large-scale foresets and syndepositional slumping.

Two fluvial facies models were developed on the basis of study of over 80 measured sections. Variations in the models are seen in the types of cross-bedded sandstones. Type 1 forms belts 80 to 130 m wide and up to 21 m thick. Major erosion surfaces delineate nearly symmetrical units 3 to 8 m thick. In contrast, type 2 lenticular sandstones belts are broader (600 m) and thinner (3 to 7 m). The component lenses are fewer in number, have a greater width to depth ratio, and commonly show evidence of lateral accretion. Individual units in type 1 belts show little vertical variation in grain size or scale of structures. Type 2 units commonly fine upward in both respects. The fine-grained sandstones flank the major belts and have paleocurrent indicators at high angles to the transport direction of the coarser lenses.

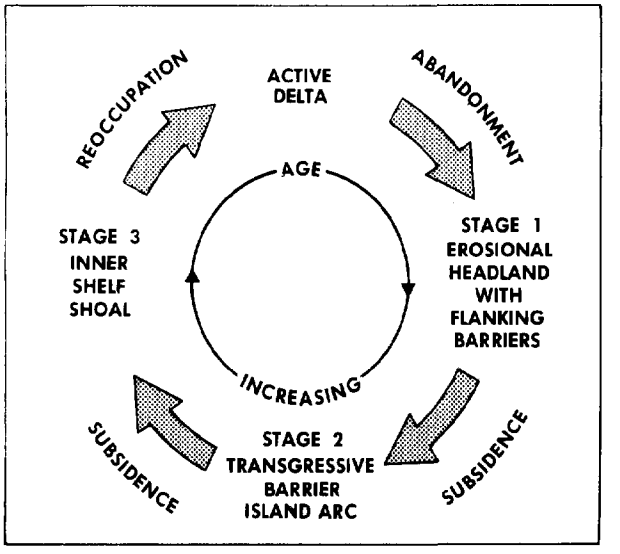
The coarse-grained sandstones were major channels and the fine-grained sandstones were crevasse splays. The thin splays were deposited along levees or in shallow flood basins. The thick splays with foresets are associated only with type 1 belts. They were Gilbert deltas which prograded into interfluvial lakes. The type 1 belts, major interfluvial lakes, and Gilbert splays were associated with greater subsidence rates. This model is comparable to recently described anastomosing fluvial systems. Our other model is similar to a low-sinuosity fluvial system.

PENLAND, SHEA, Louisiana State Univ., Baton Rouge, LA, and RON BOYD, Louisiana Geol. Survey, Baton Rouge, LA

Evolution of Transgressive Deltaic Environments on Louisiana Coast

Mississippi River sedimentation is dominated by the process of delta switching. Upstream distributary diversion during the Holocene Epoch periodically shifted the depocenter of Mississippi River sedimentation, producing a sequence of four abandoned shallow-water delta complexes on the Louisiana coast. Abandonment and the cessation of active distributary sedimentation result in subsidence, creating a rapid coastal transgression in each abandoned delta complex.

In its destructional phase, the delta evolves through a sequence of three stages, each associated with distinct transgressive sedimentary environments. This evolutionary sequence begins with an *erosional deltaic headland and flanking barrier stage,* backed by restricted interdistributary bays. In the following *transgressive barrier island arc stage,* the barrier island encloses an open intra-deltaic lagoon. Long-term sea-level transgression eventually causes the destruction of the subaerial barrier and the development of an *inner-shelf sand sheet and shoal.*



Coarse-grained sediment dispersal following delta abandonment is characterized by reworking of distributary sand bodies into transgressive coastal barrier systems. Barrier orientation to the dominant wave approach controls the pattern of longshore sediment dispersal. Sediment transported offshore during frontal and tropical cyclone passage forms the inner-shelf sheet sand. Fine-grained sediments accumulate in a variety of subsiding back-barrier environments and on the continental shelf.

If the validity of the model proposed for Louisiana holds true for older shallow-water Mississippi-type deltas, an idealized stratigraphic record for this category of transgressive deltaic environments should contain the following vertical sequence: a thin bay facies overlain by tidal inlet and/or recurved barrier sands that grade updip into a thickening lagoonal facies overlain by extensive washover sands. The uppermost unit would consist of shallow marine sands with an overlying cap of continental-shelf muds.

PERRIN, NANCY A., Univ. North Dakota, Grand Forks, ND

Environment of Deposition of Winnipegosis Formation (Middle Devonian), Williston Basin, North Dakota

The Winnipegosis Formation (Middle Devonian) is the major carbonate unit of the first transgressive-regressive pulse of the Kaskaskia sequence. The sea invaded the narrow, elongated Elk Point basin which extended from northern Alberta southeastward to North Dakota. The southeastern end of this basin corresponds to the present-day Williston basin.

In North Dakota, reworking of red beds and deposition of restricted argillaceous carbonates occurred (Ashern). Winnipegosis deposition began after a brief hiatus. Initially, there was a widespread establishment of a clear quiet shallow-marine environment. Subsequently, the basin differentiated into three distinct environments of deposition: (1) scattered pinnacle reefs, (2) a deeper interreef basin, and (3) an encompassing carbonate platform.

Carbonate production in the pinnacle-reef and platform en-

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.

PETERS, KENNETH E., Chevron Oil Field Research Co., La Habra, CA, and JEAN K. WHELAN and JOHN M. HUNT, Woods Hole Oceanographic Inst., Woods Hole, MA

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.

PHAIR, RONALD L., and RICHARD T. BUFFLER, Univ. Texas Inst. Geophysics, Galveston, TX

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.

PHILLIPS, SANDRA, Texas A&M Univ., College Station, TX (present address: Cornell Univ., Ithaca, NY)

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.

PHILLIPS, STEPHEN T., Chevron U.S.A., Inc., Denver, CO

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.