deposits that might provide stratigraphic traps, such as pinchouts, barrier islands, and channels. Drapes over basement highs might trap petroleum. The seaward part of the Blake Plateau Basin contains a thick (14 km), landward-dipping section, probably composed mainly of carbonate platform deposits. Carbonate banks and an Albian-Aptian rudist reef might provide traps, although the seaward part of the platform has been breached by erosion.

In the Carolina trough, flow of Jurassic(?) salt has formed diapirs, and withdrawal of salt has caused a large growth fault complex to form along the landward side of the trough. Because the block of sedimentary rock (12 km thick) above the salt is subsiding almost vertically, structures at the fault may include compressional features. The diapirs and faults may provide traps. A large shelf-edge anticline exists more than 150 km long and with a closure of as much as 500 m. Other possible traps might result from stratigraphic features of the onlapping sedimentary wedge landward of the Carolina trough and the eroded and buried paleoslope on the seaward side of the trough.

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North Sea Petroleum Province: A Failed Rift Basin

The North Sea oil and gas province is primarily a Mesozoic failed rift basin developed in response to the break-up of the Pangean supercontinent. The associated tectonism controlled deposition of reservoirs, source, and seals and development of structures and thus was the important factor in the generation, migration, and trapping of hydrocarbons.

The tectonic history of the basin can be divided into three major phases: (1) initiation of subsidence as a broad intracontinental downwarping during Permian, (2) tension induced normal faulting and half graben development from Triassic to Early Cretaceous, and (3) a return to broad basinwide subsidence from Late Cretaceous to the present.

The primary reservoirs include Lower Permian eolian sands, Upper Triassic to Middle Jurassic shallow to marginal marine sands, Upper Jurassic and Paleocene deep marine sands, and Danian and Maestrichtian chalks. Primary source rocks are Middle to Upper Jurassic marine shales and Carboniferous coals. The main structures include buried rotated fault blocks and halokinetic features.

Of the approximate 1,400 exploration wells, 490 have been oil and gas discoveries representing a 1:3.5 success rate. Total proved recoverable reserves are over 32 billion bbl oil equivalent with total potential recoverable reserves estimated at 46 to 70 billion bbl oil equivalent. Nine fields contain more than one billion bbl oil equivalent.

More than 53 billion dollars have been invested in the North Sea since 1965. Average cost to find and totally develop fields is approximately 2 billion dollars. At present, at least 100 million bbl recoverable reserves are usually needed for a field to be economic.

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Facies and Porosity Distribution, Swan Hills Reef Complex, Snipe Lake Oil Field, Alberta, Canada

All of the 11,700 ft (3,566 m) of core in this 130-well limestone reef oil pool was logged for a proposed miscible flood enhanced recovery scheme. The textures, fauna, porosity types, cements, and exposure surfaces are well preserved. Selected examples of each are presented by colored slides.

Nine sedimentary facies and eight porosity types are noted. The porosity is facies selective, but is modified by solution and cementation. Submarine, blocky calcite cement is common. Vadose pendular cement is developed beneath some exposure surfaces.

Twelve lithofacies, based on texture, fauna, color, porosity, and stratigraphic position are recognized. In the lagoons, poorly connected thin beds of porosity are present, whereas the reef flank porosity is relatively thick and contiguous.

Three major depositional cycles, each about 40 ft (12 m) thick, are interpreted. The first terminated with subaerial exposure and local erosional truncation. A few inches of green shale formed in the lagoon. The second cycle began with a major transgression characterized by dense dark brown laminar strom bindstone containing brachiopods, corals, and crinoids. A shallowing-upward gradation to porous massive and branching strom framestone followed. A second exposure surface, capped by discontinuous green shale, marks the termination of this cycle. The third cycle is predominantly biostromal, thickening gradually to the southwest into thin-bedded lagoonal sediments. Local well-washed rudstones suggest beach environments.

Stylolites are common in the lagoonal areas, and less numerous toward the reef front. Fractures are poorly developed and have only sparse porosity. Examples of porous stylolites and fractures from the nearby Goose River reef complex are shown.

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Episodic Sedimentation—How Normal is Average? How Rare is Rare? Does it Matter?

Do sedimentary rocks record mainly average, continuous, day-to-day processes or relatively rare, large-magnitude ones separated by long nondepositional intervals? Subtle legacies from Lyellian uniformitarianism may still impose a subconscious abhorrence of unique events, discontinuities, and large deviations from "average" magnitudes. Where repeated sharp changes of sedimentation are inescapable, periodic cycles are commonly invoked to preserve uniform, orderly variations from some supposed norm. The sedimentary record rarely reflects such uniformity, however, as sedimentologists have gradually realized.

Magnitude versus frequency of processes has long been debated in geomorphology, but has received less attention in sedimentology. *Recurrence interval, recovery time,* and *preservation potential* are critical factors for evaluating significance for the sedimentary record. Large-magnitude processes, which represent positive deviations from the norm and are rare on the human time scale, must be significant over geologic time. But how significant? Could not everyday processes have obliterated much of the evidence? Flood deposits have relatively low preservation potential because they lie above base level. Marine gravel layers dispersed by abnormal waves have greater preservation potential because most ordinary processes are not competent to modify them. Sandy or shelly deposits formed by large waves and displaying either hummocky cross-stratification or graded bedding have a moderate preservation potential, especially if too thick for burrowing animals to homogenize them. Turbidites, which provide exceptional records of episodicity, have excellent preservation potential because they lie well below base level. Many bedding planes are important records of episodicity, too; some are surfaces of erosion, others of nondeposition. These represent negative deviations from average process magnitudes.

The sedimentological importance of rare events is difficult to assess because the record of such events may be very subtle. This is especially true if a deposit has been thoroughly bioturbated or if the record of an event is simply an erosional surface. It has now become possible to evaluate quantitatively ancient episodic sedimentation using modern-process rates as well as refined biostratigraphic and isotopic dating. I predict that such evaluation will necessitate revision of our favorite depositional models, which have become so important for exploration as well as for research.

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West Florida Continental Margin: A Major Carbonate Deposit Which is Not Dominated by Active Reefs

The West Florida continental margin is a vast accumulation of over 500,000 km of Mesozoic to Recent carbonates and evaporites. Carbonate and evaporite domination is primarily due to the fact that the region has been cut off from clastic sedimentation since the Jurassic. Surface facies are now being deposited under semitropic and temperate climates. A relict quartz-dominated sand band which makes up the beaches and innermost shelf is the product of lower stands of sea level when the Tertiary terrace deposits of the central Florida hinterland were eroded by rejuvenated streams which carry little load during highstands. The band is gradually undergoing carbonatization as it is now cut off from any clastic source and the only components being added are mollusk shells and fragments. The shelf is dominated by molluscan shell hash with few corals or coralline algae. Even the few active patch reefs like the Florida Middle Ground have sediments dominated by molluscan debris and are barely surviving.

The slope facies resembles a deep-sea foraminiferal ooze. Transition from the margin to the deep Gulf of Mexico is from shallower ooze to deeper clastic lutite. Slope sediments are accumulating at the relatively rapid rate of about 20 cm/1,000 years. Mass wasting has occurred on the slope and karstification is evident in the stratigraphy of the shelf. While the West Florida margin surface facies are different from those of the more intensively studied coral reefs and banks, they may have many significant analogs in the ancient and warrant more attention.

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Bahamian Subtidal Stromatolites (Oolitic!)

Subtidal oolitic stromatolites are forming in normal marine waters (1-5 m) in the high energy oolitic sand environment on Eleuthera Bank, Bahamas. Penecontemporaneous marine cementation transforms these stromatolites into hardgrounds, some of which may localize subsequent reef development.

Accretion of oolitic stromatolites results from trapping and binding of ooids by various algae. Direct precipitation from seawater of aragonite and/or high magnesium calcite, calcification of algal filaments by high magnesium calcite, or commonly a combination of both processes lithify these stromatolites to create hardground substrates. Degree of marine cementation increases downward from stromatolite surfaces. Stromatolites themselves are localized on other low-relief oolitic hardgrounds.

Morphologies of oolitic stromatolites are strikingly similar to some Shark Bay algal stromatolites. Bahamian stromatolites originate as small pinnacles which can evolve into mounds over a meter in height. Individual pinnacled stromatolites also coalesce laterally into continuous elongated ridges which develop preferred orientations in response to local hydrographic conditions. Internal crude algal laminations often are destroyed by macroborers.

Oolitic stromatolite growth is ephemeral, apparently controlled by the rate of burial by shifting oolitic sand. This physical stress, therefore, sufficiently excludes grazers and encrusters, permits algal binding of ooids and explains stromatolite development in normal marine waters. Buried stromatolites that become exposed are recolonized by algae and begin accreting upward. Where physical stresses are removed for longer periods of time, oolitic stromatolites become susceptible to colonization by coralgal organisms and represent an early stage of reef development.

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Facies Control of Cementation and Porosity, Pennsylvanian Fan-Delta Sandstones, Texas Panhandle

Interbedded fan-delta sandstones and limestones were deposited on a shallow carbonate shelf in the southern Anadarko basin during Missourian time. Hydrocarbon production from the fan-delta sandstones at Mobeetie field, Wheeler County, is controlled both by structure and facies-determined porosity distribution. Distal margins of some fan-delta lobes were reworked by marine processes, and carbonate fossil fragments and oolites were mixed with terrigenous clastics. Diagenetic history of the distal, marine-reworked sandstones was strikingly different from that of the more proximal, non-reworked sandstones.

The first cement to precipitate in the reworked sandstones was a thin, isopachous rim of Mg-calcite cement that probably precipitated in the submarine environment soon after deposition. Next, establishment of a freshwater, phreatic environment in the sediments resulted in extensive calcite cementation in the calcareous sandstones. Dissolution of aragonitic oolites and fossils provided the source of the calcite that occluded primary porosity. In contrast, the non-reworked sandstones were not cemented because they lacked a calcite source, and so they retained high porosity. Rims of authigenic chlorite, which reduced porosity by only a few percent, were the earliest cements to precipitate in the non-reworked facies.

With increasing burial, porosity in both the reworked and non-reworked fan-delta sandstones was reduced by precipitation of authigenic quartz, feldspar, kaolinite, Fe-calcite, and ankerite. These cements are generally minor in volume and do not influence porosity distribution. Generation of secondary porosity by dissolution of feldspars and rock fragments occurred in all sandstones but was more extensive in non-reworked facies. However, the main control of present porosity distribution is the presence or absence of early, freshwater calcite cement.

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Preliminary Statistical Analysis of Large Sample of *Lepidocyclina*, an Eocene Orbitoid Foraminifer from Isla de Margarita, Venezuela

A statistically large sample of *Lepidocyclina (Lepidocyclina)* sp. from the upper orbitoid beds of the Punta Carnero Group, at Punta Mosquito, Isla de Margarita, Venezuela, was analyzed to determine the amount and nature of morphologic variation and to provide a basis for evaluation of present lepidocyclinid