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.

DOYLE, LARRY J., Univ. South Florida, St. Petersburg, FL, and U.S. Geol. Survey, Corpus Christi, TX

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.

DRAVIS, JEFFREY J., Exxon Production Research Co., Houston, TX

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.

DUTTON, SHIRLEY P., Bur. Econ. Geology, Univ. Texas at Austin, Austin, TX

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.

DYMAN, T. S., S. H. FROST, and K. I. TAKAHASHI, Washington State Univ., Pullman, WA

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

taxonomy.

More than 250 thin sections were measured for as many as 24 variables in equatorial section and 14 variables in vertical section. Equatorial and vertical sections were analyzed using univariate and bivariate statistical analyses, cluster analysis, R-mode factor analysis, analysis of variance, and discriminant function analysis. Results show that the range of morphologic variation is large.

High correlation coefficients between some variables and the grouping of variables into factors indicate redundancy in the variable set. Future studies of this type could use fewer variables without sacrificing much information.

Morphologic differences in *Lepidocyclina (L.)* sp. forms found in this sample were not great enough to allow classification of subgroups as separate species. The differences are gradational, and the intermediate forms were impossible to classify objectively. The variation in this sample, however, has limits, and these limits are considered the range of variation of *Lepidocyclina (L.) pustulosa.*

Previous classifications based on only a few variables and individuals are inadequate considering the large degree of uncorrelated morphologic variation in some samples. The most useful classification scheme should be based on a wide range of morphologic features of the test, analyzed by statistical techniques on high-speed computers.

EBANKS, W. J., JR., Cities Service Co., Tulsa, OK, and J. F. WEBER, Carmel Energy Inc., Deerfield, MO

Sedimentology and Development of Shallow Heavy Oil Deposit, Eastburn Field, Missouri

Eastburn field, Vernon County, Missouri, produces heavy, 21° API, crude oil at a depth of 110 ft (33 m) from a thin, 20 to 30 ft (6 to 9 m), sandstone stratigraphic trap in the Cherokee Group of Middle Pennsylvanian age. Sedimentary structures, grain-size trends, and geometry of the sandstone and the nature of associated sediments indicate the fluvial-deltaic origin of the reservoir.

Development drilling at very close spacing, 200 ft (60 m) between wells, provided information from which a sedimentologic model of the Eastburn field reservoir could be developed early in project life. From this model, strategies were proposed that guided further drilling and completion of wells, extension of the field, and placement of production facilities. Development drilling guided by the sedimentologic model resulted in tripling the known volume of the heavy oil resource, with a minimum number of dry development wells being drilled.

The reservoir sandstone is composed mostly of medium to very-fine sand-sized quartz, rock fragments, and mica, with abundant interstitial detrital silt and clay. Authigenic kaolinite clay, and calcite and siderite cements reduce reservoir quality and contribute to problems in production, such as low injectivity of steam and exhaust gases in the thermal recovery process. Identification of the permeability reducing minerals aided in design of well-stimulation treatments and contributed to increased productivity.

In a few places, where contouring of the sandstone thickness was doubtful, production performance of individual wells provided additional data to guide the geologic interpretation. This synergistic approach helped to minimize the cost and maximize the efficiency of the field development.

EDMAN, JANELL, D., and RONALD C. SURDAM, Univ. Wyoming, Laramie, WY

Diagenetic History of Phosphoria, Tensleep, and Madison Formations, La Barge Platform, Wyoming

Petrographic and geochemical data from cores in the Wyoming Overthrust belt are used to integrate thermal maturation of the Phosphoria with timing of cementation and porosity development in the Tensleep and Madison. Vitrinite reflectance studies from the Phosphoria indicate that it contains both bitumen and kerogen and that it has already generated some hydrocarbons and retains the potential to generate more. These hydrocarbons migrated into the Tensleep during an intermediate stage of silica cementation and into the Madison prior to the last phase of dolomitization.

The observed diagenetic sequences for the underlying Tensleep and Madison, in conjunction with depositional interpretations, demonstrate that porosity generation was critically affected by both depositional environment and early diagenetic history. The Tensleep and Madison underwent dramatically different histories of cementation and porosity development. This is reflected in the present maximum of 5% porosity in the Tensleep contrasted with 20% porosity in parts of the Madison. If porosity in the Tensleep was not destroyed by early evaporitic cements, then continuous destruction of porosity by silica and dolomite cementation occurred throughout its burial history. In contrast, preliminary isotopic studies indicate porosity in the Madison was developed at temperatures of less than 35° C. These regionally correlatable porous zones in the Madison which have persisted from shallow burial to present depths of 15,000 ft (4,572 m) emphasize the potential of the Madison as a hydrocarbon reservoir both now and in the geologic past.

EGER, CHARLES K., Univ. Maryland, College Park, MD

Comparative Petrography of Two Upper Devonian Oil Sands of Warren County, Pennsylvania

The Glade sand and Clarendon sand are Upper Devonian shoestring sands occurring at relatively shallow depth, in most places not exceeding 1,500 ft (457 m). Both are producers of Penn Grade crude oil, having been discovered before the turn of the century. Data for this study are derived from four independent sources, namely the petrographic microscope, image analysis instruments, the X-ray diffractometer, and geophysical (nuclear and electric) log data. Special emphasis is given to grain shapes, grain sizes, primary and secondary mineral compositions (including matrix constituents), rock textures, and the relationship of permeability and porosity in thin section to geophysical data. Compositionally, the Glade and the Clarendon are very-fine to medium-grained low-rank graywackes with variable amounts of muscovite, biotite, chert, plagioclase feldspar, orthoclase feldspar, and carbonates. The Clarendon, however, is predominantly more silty throughout. Porosity in thin section is measured on the basis of its ratio to the total area of the rock being examined. Permeability, however, is described in terms of the relative interconnectivity of pore space and its tortuosity. In the end, correlation of these petrographic features with geophysical data aids in interpreting the rocks' characteristics.

EGLOFF, JULIUS, Naval Ocean R&D Activity, NSTL Station, MS, GERD SOMMERHOFF, Univ. Munich, Munich, Germany, and G. LEONARD JOHNSON, Office of Naval Research, Arlington, VA

Canyons, Submarine Fans, and Older Structures of Southern Greenland Continental Margin from Seismic Surveys

Submarine fans stemming from development of canyons dur-