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 during the latest Tertiary overlie and are controlled by fans (deltas). Slump scars, gullies, zones of nondeposition due to currents, debris flows, and levees are identified. The Skralinge, Christian, Pining canyons, and other significant features are mapped in greater detail. Paleo-shelves and slopes of the continental margin are defined in seismic profiles. Differential erosion by the canyons reveals lithologic differences which further delineate the older structures. Implications for structural traps and resource deposits are encouraging if technology becomes available for the challenge.

ELIUK, LESLIE S., Shell Canada Resources Ltd., Calgary, Alberta, Canada

Nova Scotia Shelf Mesozoic Carbonates—Summary of Canadian Data Useful for Analogy to the South

Except for a few wells such as the Cost No. G-2 on Georges Bank, Mesozoic carbonates along the United States Atlantic seaboard are known only from seismic interpretation or from shallow or outcropping data collected by research vessels. Other sources of information are analogy from Florida–Gulf of Mexico wells, from European-West African Tethyan facies, or from wells on the Nova Scotia Shelf. Nova Scotia data that may be useful for comparison to offshore U.S.A. follows.

(1) Carbonate and deltaic sedimentation are synchronous during much of the Late Jurassic and earliest Cretaceous. (2) Smaller scale cycles and younger large scale vertical facies changes indicate repeated relative sea-level changes. (3) Shelf-edge profiles vary from rimmed/platform to prograding ramp near the Sable Island Delta where slope carbonate-shale deposits have been drilled. (4) Shelf-edge platform profiles also vary from reef-rimmed to channel to possible open sediment-bypass margins with ooid sands. Some faulted margins occur. (5) From Early to Late Jurassic, there is a reduction in evaporitic sediments, an increase in biotic diversity, and an increase in coals indicating an increasingly humid climate. (6) Depositional facies zones are easily distinguished and may be of shallow or deeper water aspect at a particular location. In the upper Abenaki, the skeletal-rich shelf margin has invariably been preserved. (7) True reefs occur. (8) Along the upper Abenaki shelf edge, carbonate facies also vary to include reef complexes, mud mounds, islands, oolite shoals, skeletal and oncolitic sands. (9) Termination of Abenaki carbonate sedimentation is either diachronous burial by deltaic sands or widespread synchronous Valanginian drowning possibly immediately preceded by brief subaerial exposure. (10) Abenaki diagenesis is dominated by porosity reduction due to burial, but dolomitization and early intraformational leaching occur at the shelf edge. (11) Later subaerial (or submarine) erosion at the top of the Abenaki occurs in a few widely separated areas. (12) Hydrocarbon shows are rare but do occur in the carbonates on some salt domes or in geopressured zones.

EMME, JAMES J., Anadarko Production Co., Denver, CO, and ROBERT J. WEIMER, Colorado School Mines, Golden, CO

Tectonic Influence on Sedimentation of Lower Cretaceous Strata, East-Central Powder River Basin, Wyoming

Recurrent movement of basement fault blocks in the east-central Powder River basin has controlled the distribution of porous and permeable reservoir facies within Lower Cretaceous strata. Subsurface isopach data for Lower Cretaceous time-stratigraphic intervals show repetitive thickness variations for both marine (Skull Creek and Mowry shales) and nonmarine (Inyan Kara and Newcastle/Muddy sandstones) units. Thickness patterns seem to be controlled by recurrent Early Cretaceous structural movement. Paleostructures ranging in width from 2 to 10 mi (3.3 to 16.6 km) and in length from 10 to 30 mi (16.6 to 50 km) trend northeast, northwest and north, and include segments of the Black Hills and Fanny Peak monoclines, which bound the west flank of the Black Hills uplift.

Early Cretaceous paleostructures seem to control the distribution of Newcastle valleys which are incised into the underlying Skull Creek Shale and drain southwest and northwest (corresponding to the Clareton, Hilight, Osage, Fiddler Creek, and Rozet fields). Alluvial plain valley-fill deposits in Newcastle Formation outcrop show abrupt facies and thickness changes which coincide with evidence of structural control (e.g., drape folds, faults, sandstone dikes, geomorphic lineaments, and increased igneous activity). A depositional model, incorporating tectonic and sea-level adjustments, illustrates that Newcastle channel incisement and valley fill are generally restricted to topographic and structural low (graben) areas. This model has been confirmed by detailed analysis of seismic data.

A model for tectonic influence on sedimentation aids in petroleum exploration by helping to predict facies distribution and fluid flow.

ENOS, PAUL, State Univ. New York, Binghamton, NY

Basin to Platform Transition, Middle Cretaceous, Mexico

Discontinuous outcrops west of Xilitla, San Luis Potosi, Mexico, preserve a sequence of middle Cretaceous (Albian-Cenomanian) carbonate rocks more than 1,500 m thick consisting of the following. (1) (Base) Well-bedded, cherty lime mudstones and wackestones with calcispheres and globular foraminifera. (2) Fine-grained, partly silicified peloidal and bioclastic lime wackestones and thin intraclast layers. (3) Massive graded beds of peloidal-bioclastic lime packstone with abundant echinoid fragments and spines, coral and mollusk fragments, but no rudists. (4) Lime breccias in massive beds with a variety of bioclasts including stromatoporoids and rudistids that are increasingly common upward. Breccias are interbedded with finely laminated, ripple-laminated, or micrograded beds alternating with burrowed mudstones. Dolomitized intervals are present at the base of unit 3 and within unit 4. (5) Massive beds of coarse rudist-fragment lime packstone. (6) (Top) Massive beds of rudist boundstone. Unit 1 is typical of basinal limestones of the upper Tamaulipas Formation. Units 2-4 represent basin-margin facies, the Tamabra Formation. Units 5 and 6 are characteristic of the reefal platform-margin Taminul facies of the El Abra Limestone.

This succession from pelagic basinal limestone to true reefs represents progradation of the eastern margin of the large (200 by 300 km) Valles-San Luis Potosi platform. Such progradational sequences are rare in the middle Cretaceous of east-central Mexico because the platform margins were steep (to 45°, locally near vertical) and relief was great (to 1,000 m). Although some faults may be present, the apparent thickness of the section (>1,500 m) is comparable to the total thickness of platform sections elsewhere.

Porosity is nil in the transitional sequence except for vugs and intercrystalline pores in the dolomite and small vugs in some of the debris beds. Clasts and particles within the basin-margin debris indicate diagenetic stages in the source area ranging from unconsolidated through lightly cemented (both submarine and subaerial) to leached and secondarily cemented.

ERKMEN, UGUR, Home Oil Co. Ltd., Calgary, Alberta,