porosity.

Exploration in the deep south Texas Smackover Formation cannot depend upon finding reservoirs consisting of preserved, early types of porosity, but must depend upon defining areas where late subsurface-derived oomoldic porosity formed reservoirs.

LOWENSTEIN, TIM K., Johns Hopkins Univ., Baltimore, MD

Petrographic Approach for Study of Ancient Potash Evaporites, Salado Formation (Permian), New Mexico

Petrographic analysis of a potash evaporite, the Salado Formation (Permian) of New Mexico and Texas, has allowed distinction of primary sedimentary features, from metamorphic alteration "overprints." Primary sedimentary textures in laminated anhydrite, thin-bedded halite, and muddy halite include vertical growth structures (gypsum "swallowtails" and "chevron" halite), incorporative and displacive intrasediment growth of gypsum, halite, and glauberite, carbonate-gypsum and gypsum-halite couplets, and gypsum wave ripples. The Salado primary chemical and depositional environment, interpreted by comparison with similar features from modern evaporite environments, is a salt pan up to halite saturation alternating with a perennial brine body stage at gypsum and sometimes halite saturation.

A complex diagenetic-metamorphic history has imparted a secondary alteration overprint on the Salado salts. Halite has recrystallized; gypsum has dehydrated to anhydrite, reacted with brine to form polyhalite, or dissolved, leaving a void now occupied by halite or sylvite. Formation of new minerals, the most important being sylvite, carnallite, langbeinite, and kieserite, has occurred as displacive or incorporative intrasediment growth (langbeinite), or as void filling cement (sylvite, carnallite). Further alteration is recorded as reaction of brine with langbeinite to form kieserite, kainite, leonite, and bloedite. From their observed distribution, texture, and mineralogy, and by comparison with experimental data, secondary features in the Salado are interpreted to have resulted from the subsurface migration of alien, nonseawater composition brines at elevated temperatures.

LU, KEZHENG, Stanford Univ., Stanford, CA

Tectonic Setting and Eastward Migration of Mesozoic-Cenozoic Sedimentary Basins, Eastern China

Basins of eastern China are characterized by thin crust and alternately arranged NE or NNE-trending regions of subsidence and uplift. During the Indosinian (Late Triassic), the western part of eastern China was depressed relative to eastern areas. Upper Triassic and Jurassic formations comprise the major basin fill of the Sichuan and Eerduos basins, while only minor Upper Triassic-Jurassic rifts and related basins are superimposed on earlier swells in eastern regions. In the Early Cretaceous, the depocenters of the Sichuan and Eerduos (Ordos) basins shifted westward or southward, and soon afterward were uplifted as a whole. In contrast, the most extensive and intensive subsidence in the Songliao basin occurred during the Quantou-Nenjiang stage (middle Cretaceous). To the south, the Huabei basin had a multicyclic, rifted history, but the most intensive subsidence occurred during the Eocene-Oligocene. Still farther east, the present-day marginal seas formed mainly during the Late Cretaceous-early Neogene. Thus, the history of these basins clearly shows the eastwardly migratory nature of the timing of basin formation in eastern China. The development of these basins was influenced not only by subduction of the Pacific plate in the formation of initial stage shearo-compressional swells and depressions, but also by the motion of Tethys-Indian plate northeastward. The latter movements resulted in an eastward component which led to the progressive elevation of the west. Back-arc spreading also played an important role in this process.

Basins of eastern China can be classified into two groups, one formed in compressive or shearo-compressive settings, the other in tensile or shearo-tensile settings. Basins of the former type formed as structural depressions or flexures due to lithosphere deformation. These display foreland fold-thrust belts on their western borders. The tensile group of basins includes: (1) complex rift-depression types (monocyclic or polycyclic); (2) simple rift valleys or minor block-fault depressions; (3) coastal delta-shelf basins on the rifted continental margin; and (4) back-arc spreading basins.

LUNDIN, ROBERT F., Arizona State Univ., Tempe, AZ, and LEE E. PETERSEN, Anadarko Production Co., Denver, CO

Succession of "Nonpaleocope" Ostracods Related to Graptolite Biozones, Type Wenlock Series

Analysis of the stratigraphic occurrences of 23 species of podocope, metacope, and platycope ostracods in Wenlockian strata of the type Wenlock area of the Welsh Borderland demonstrates the following. (1) Five species are restricted to the lower Wenlockian; four of these range from the *centrifugus* Biozone through the *rigidus* Biozone, and one ranges from the *centrifugus* Biozone through the *ellesae* Biozone. (2) Five species range throughout or nearly throughout the Wenlockian sequence. (3) Thirteen species are restricted to the upper Wenlockian; eleven of these range from the *lundgreni* Biozone through the *lundensis* Biozone, one ranges from the *nassa* Biozone through the *lundensis* Biozone, and one ranges from the *lundgreni* Biozone through the *nassa* Biozone.

These observations, which are based on the identification of more than 11,000 ostracods, indicate a significant change in the ostracod fauna in the middle of the Coalbrookdale Formation, i.e., in the middle of the type Wenlock Series or near the Sheinwoodian-Homerian boundary. A similar change occurs in the brachiopod succession in the same interval. Because the change in the ostracod fauna is relatively abrupt (i.e., within two graptolite biozones), we believe that it was induced by an environmental change which did not significantly affect the lithology of the stratigraphic interval involved. We conclude that the interval near the Sheinwoodian-Homerian boundary in the type Wenlock area represents the time of maximum Wenlockian transgression, after which regression and shallowing occurred.

LYNCH, VANCE M., Union Oil Co. of California, Los Angeles, CA

Erawan Field, Gulf of Thailand: A History of Applying Evolving Geophysical Technology to a Complex Geologic Structure

The Erawan gas field, with estimated recoverable reserves of 1.5 tcf of natural gas, was discovered in 1972. The drilling locations have all been selected on the basis of complicated reflection seismograph results. The productive section is a Tertiary sand-shale sequence of fluvial to shallow-marine origin, and individual sand units rarely exceed 50 ft (15 m) in thickness. The Erawan structure is a complexly faulted graben, with fault block rotation producing an anticlinal attitude. High fault density (200 to 500 m separation) and thin productive beds result in many separate hydrocarbon traps. Commercially productive sands occur at depths between 5,000 and 9,000 ft (1,525 to 2,740 m) subsea.

Union Oil Co. of California acquired the acreage in 1968 and shot the first seismic survey the same year. These data were adequate to confirm a thick sedimentary section, and they contained sufficient structural indications to select the initial drill site. By 1974, four different seismic surveys had been conducted. More and more faulting became apparent with improving data quality. To resolve the structural pattern, a high-resolution seismic survey was conducted in 1976. These data first demonstrated the very complicated fault patterns now known to exist. Additionally, processing of this survey proved that migration is essential for fault definition, although dips are relatively shallow. Paradoxically, it was observed that the best seismic correlations across the many faults were predominantly low frequency. Consequently, a "low-frequency" seismic survey was initiated in 1979. Interpretation of this survey made it possible to correlate gross sedimentary units over large areas of the structure. These correlations were consistent with well control. In 1979, development plans were completed and a 3-D seismic survey was conducted prior to installation of permanent production facilities. This survey comprised 5,000 line-km of data with subsurface coverage of 25 m in the dip direction and 75 m along strike. Nonstandard processing techniques are being tested, both for Erawan field data and other structures in the Gulf of Thailand. Wavelet processing, utilizing a recorded far-field signature, has shown significant improvement in some cases. Migration before stack has significantly enhanced the data by better fault definition and improved correlations across the faults. Development plan for Erawan field consists of five platforms with 12 well slots per platform. Gas will be transported by pipeline to Bangkok and condensate will be separated and offloaded via a single point mooring system. Gas production of 250,000 mcf is planned with first production in the fall of 1981. The development program will continue to be heavily dependent upon detailed analysis of 3-D and other seismic reflection data for optimum positioning of boreholes in both horizontal and vertical dimensions.

MAJID, A. HAMID, and JAN VEIZER, Univ. Ottawa, Ottawa, Ontario, Canada

Depositional History and Dolomitization, Kirkuk Oil Field Host Rocks, Iraq

The modified lithostratigraphic framework of the Kirkuk (northern Iraq) carbonates shows that the Paleocene shoal/shelf facies graded northward into the nearshore dolostones and southward into the offshore (basinal) limestones. During Eocene time the shoal deposition covered the whole shelf area, with basinal equivalents present in the southwest. In contrast, the two major cycles of Oligocene sedimentation were controlled by shelf-edge bioherms (in-situ mechanical pilings of skeletal grains). In the Baba-Tarjil area, the bioherms grade laterally into mud flat (NW to NE) and basinal (SE to SW) facies.

Subaerial exposure caused cementation, dolomitization, and dissolution; moldic porosity being the dominant factor controlling the porosity development in the Kirkuk oil reservoir. The associated fine-grained dolostones of the Paleocene time show petrographic, chemical, and isotopic characteristics of the hypersaline (sabkha) type, whereas their coarse-grained Eocene and Oligocene counterparts resemble the diagenetic (Dorag) type dolostones.

MAJOROWICZ, JACEK, Geological Inst., Warsaw, Poland, and ALAN M. JESSOP, Energy, Mines & Resources, Ottawa, Ontario, Canada

Present Thermal State of Western Canada Sedimentary Basin

The regional geothermal pattern of Western Canada sedimentary basin was studied using available temperature data from shut-in wells. Average heat conductivity was estimated with net-rock data from Canadian Stratigraphic Services. These data allow heat-flow estimations.

The geothermal gradient and heat-flow values for the basin are exceptionally high in comparison with the other Precambrian platform areas, especially in the northwestern part of the Prairies basin in Alberta, British Columbia, and most of southern Saskatchewan. Low-gradient areas are found close to the eastern limit of the Disturbed belt of Alberta and British Columbia. Neither the analysis of regional conductivity nor heat generation of the basement rocks based on U, Th, and K data after Burwash (1979) explains the heat-flow patterns. Certain hydrogeological phenomena do suggest the significant influence of fluid flow on geothermal features. Low geothermal gradient areas coincide with water recharge and high hydraulic head regions.

The phenomenon of upward water movement in the deep strata and downward fluid flow through much of the Cenozoic and Mesozoic strata seems to be the main influence on heat distribution in the basin. Analyses of coal metamorphism in the upper and middle Mesozoic formations of the Foothills belt and in the central Prairies basin suggest that pre-Laramide heat-flow distribution was different from the present. It is probable that the Foothills belt had a higher geothermal gradient than the central part of the Prairies basin, opposite to the present relationship.

MALTBY, SARAH H., Duke Univ., Durham, NC

Hydrodynamic and Geologic Significance of Upper Jurassic Smackover Marine Oncolites—Evidence for Penecontemporaneous Lithification

Smackover oncolites from the Chalybeat Springs field, Columbia County, Arkansas, exhibit evidence for penecontemporaneous cementation. "Flower spar" cement, previously reported only in caliche and vadose pisoliths, has been found as thin ribbons within the oncolites. Bivalve and polychaete borings penetrate both the concentric algal laminations and the bioclastic nuclei of the nodules. Boreholes are found around the entire periphery of the nodules indicating that the oncolites were mobile at the time boring occurred. Some borings have their openings capped by subsequent layers of algally bound material, implying that the oncolites were periodically lithifying while still accreting. Foraminifera, serpulids, and bryozoans are seen to encrust the oncolites suggesting that the nodules were indurated at the time of encrustation.

Smackover oncolites are characterized by micritic and pelletal laminations and contain blue-green algal filaments attributed to *Girvanella*. Thus, they closely resemble modern marine oncolites with the exception that modern forms are unlithified. Recent lithifying blue-green algae are known only from freshwater and hypersaline environments.

The density of these large (5 to 35 mm), hard, cemented grains would be considerably higher than that of modern marine oncolites. If the cemented oncolites are assumed to have the same specific gravity as recent freshwater oncolites, current velocities exceeding 100 cm/sec would be required to initiate movement.

A survey of ancient oncolites suggests that virtually all Mesozoic oncolites show evidence of penecontemporaneous cementation.

MANCINI, ERNEST A., and RICHARD P. WILKERSON, Univ. Alabama, University, AL, and JANYTH S. TOLSON, Geol. Survey of Alabama, University, AL