thrown block may contain shale barriers to vertical fluid flow if the threshold subsidence rate was exceeded.

EGGERS, MARGARET R., and ROBERT EHRLICH, Univ. South Carolina, Columbia, SC

Distinction of Glacial and Interglacial Cycles in Feni and Gardar Drifts, North Atlantic

The Feni and Gardar drifts of the North Atlantic are thought to represent large accumulations of current-deposited material and should record changes through time in direction and intensity of overflows in the Norwegian Sea and Iceland–Faereo Ridge, respectively. Both drifts were drilled by DSDP Leg 94. Initial shipboard examination revealed no visual differences between these sediments and typical pelagic North Atlantic sediments. Fourier shape analysis on quartz silts, augmented by SEM, showed that each sample consists of a mixture of 3 grain populations. One grain type is covered with surface fractures unmodified by subsequent abrasion. Lack of such abrasion and the fact that the abundance of these grains varies independently of other shape types suggest a glacial-ice rafted origin. A second shape family is covered with irregular, platy silica overgrowths, typical of diagenesis in a poorly sorted, clay-rich environment and is likely the product of erosion of submarine lutites. A third grain type, plastered with fine-grained silica, is characterized by protuberences and indentations typical of primary continental source terranes. These last 2 grain types vary inversely with one another, implying that at glacial maxima, bottom currents deposited first-generation continental material, but at glacial minima, they eroded material from the sea bottom and redeposited it as drift sediments.

EHRLICH, ROBERT, Univ. South Carolina, Columbia, SC, and HADDOU JABOUR, ONAREPT, Rabat, Morocco

Exploration Potential of Paleozoic Rocks of Morocco

Paleozoic rocks of Morocco have some similarities with the producing Paleozoic sequences in Algeria. In Morocco, there is a basic division between the cratonal sequences of the Tidouf basin and continguous areas and the Paleozoic megabasin to the north and possibly to the west under the present continental shelf areas. The Paleozoic of the northern megabasin has the following positive exploration elements. (1) Both wrench and normal extensional tectonics have produced significant structures that may have been reactivated during 2 later orogenic events. (2) Reservoir quality, although poor in outcrop, can be significantly improved in the subsurface. Wells from the Bojad region of the Tadla basin encountered porosities up to 30% in Devonian clastic sequences. (3) No area can be condemned on the basis of present published geochemical evidence. Burial depths are sufficient for mature hydrocarbons, and rocks with organic material are present in sediments ranging in age from Cambrian to Carboniferous. Paleozoic oil shows have been encountered and may actually serve as the source of hydrocarbon in the Essouira basin in a downfaulted Triassic red-bed sequence. (4) Quality of seismic data is good, even where Paleozoic rocks are onlapped by Mesozoic and Cenozoic sediments.

Drilling for Paleozoic targets has been sparse, hence, few data are available to test both source and reservoir potential. Paleozoic rocks still need to be tested by industry and must be considered a frontier area.

EISENBERG, LEONARD I., Chevron Overseas Petroleum, San Francisco, CA, and PATRICK L. ABBOTT*, San Diego State Univ., San Diego, CA

Eocene Tidal Deposits, Northern San Diego County, California

A transgressive-regressive sedimentation sequence is recorded in a band of middle Eocene strata a few miles wide. An abundance of primary sedimentary structures, along with interfingering relationships and paleontology, define 12 lithofacies representing depositional environments including nearshore shelf, outer and inner barrier island, tidal flats and channels, lagoon and lagoonal delta. Tide-influenced sedimentary features are well defined and include meandering and abandoned tidal channels, oppositely inclined superimposed cross-strata, interlaminated mud and sand along the basal and lateral accretion surfaces of migrating tidal channels, flaser and wavy bedding, and storm-deposited strata.

The first sedimentary half cycle was transgressive and documents the compression of dominantly tidal-flat and lagoonal environments against a steep, hilly coastline by the overall rising sea level of early and medial middle Eocene time. The inboard tidal-flat and lagoonal mudstones (Delmar and Friars Formations) and outboard tidal flat, channel and bar sandstones (Torrey Sandstone and Scripps Formation) interfinger in a landward-climbing, 3-dimensional sedimentary mass that parallels and meets the basement with a pronounced unconformity.

The second half cycle was regressive and occurred in the medial and late middle Eocene. It formed due to the influx of coarser, more angular sediment from the adjacent basement into the narrowed paralic zone. This westward (seaward) progradation of lagoonal delta and inner tidal-flat sandy sediments occurred despite the still-rising sea level.

EKDALE, A. A., Univ. Utah, Salt Lake City, UT, and R. G. BROMLEY, Geologisk Centralinstitut, Copenhagen, Denmark

Multiple Parallel Microstylolites and Early Diagenetic Pressure Solution in Chalk

Pressure-solution phenomena, including both early-stage microstylolites and late-stage macrostylolites, are locally common in chalk. It is now well known that Upper Cretaceous chalks of northwestern Europe exhibit a wide range of stylolitic development in association with nodular fabrics and hardgrounds, generally in *Thalassinoides*-rich facies. It is not widely recognized, however, that virtually uncemented chalk commonly exhibits extensive microstylolitization of remarkably unique character. Multiple parallel horizontal microstylolites are well-developed in homogeneously white non-nodular pure-calcitic chalks of Denmark and elsewhere. They can be seen, however, only when samples are treated with contrast-enhancing methods, such as the application of light oil, to increase the visibility of small-scale primary and secondary structures in the sediment.

The microstylolites are nearly planar and some are slightly wavy, but almost none are zigzag or sharply spiked. They occur in fairly evenly spaced sets that render a finely laminated appearance to the rock upon close inspection. Typically, each dark lamina is only about 10-50 μm thick, and they are spaced approximately 100-500 μm apart. The lamination planes obviously are diagenetic and not primary, because they are imprinted on top of a totally bioturbated ichnofabric; the tiny dissolution seams cut straight through some burrows and are diverted around others. The relationship of these planar microstylolites to healed hairline microfractures and to various trace fossils, especially *Zoophycos*, suggests that the microstylolites are very early diagenetic in origin, postdating the burrows but predating or coinciding with the microfractures.

ELAM, JACK G., Independent Geologist, Midland, TX

Initial Process of Rifting

The generally accepted model of rifting (the McKenzie model) has certain geometric and spatial constraints that seem to preclude its operation in the earliest stage of rifting. It may be a more advanced stage of the rifting process, if it is correctly described.

An aborted rift system can be studied in the subsurface of the Permian basin. The Delaware, Val Verde, and Marfa basins formed a rift-rift-rift triple junction in mid-Pennsylvanian time, but it never progressed far enough to cause permanent extension. It apparently rose thermally, and then settled back down in place during the cooling cycle. The details of earliest rifting are preserved.

Several geometric factors need to be considered in the rift model. The first is that the earth is a sphere. On a sphere, uplift causes extension, and downwarping causes compression. The dominant fracture system in the brittle crust tends to be vertical, and on a sphere, vertical planes converge at the center.

The rheology of the basement and the overlying sedimentary rocks is different. The basement can be extended areally by dilating the fracture system during uplift and extension, but the sedimentary rocks will be stretched plastically. During the cooling cycles, vertical fractures can close, but there will be sediment to spare. The rocks will be buckled, crinkled, and overturned during the cooling cycle as they are lowered from the arc toward the chord. Many interpret this as evidence of external compression.

A Permian basin model can explain many diverse and, to many geologists, unrelated structural and stratigraphic phenomena. If this model is correct, it may mean that many other aborted rift systems are not being properly described. The North Sea is a case in point.

ELLIOTT, LAURA ANN, Univ. Texas at Austin, Austin, TX

Depositional Controls on Production in San Andres Stratigraphic Traps, Southeastern New Mexico

The San Andres Formation of Permian age (late Leonardian-early Guadalupian) is the most prolific producer of hydrocarbons within the Permian basin. The Levelland-Slaughter trend, located in the northwestern shelf province, is a series of east-west-trending fields characterized by stratigraphically controlled, updip porosity pinchouts from porous dolomites to nonporous dolomites and evaporites. Equivalent facies crop out in Chaves and Lincoln Counties, New Mexico.

Outcrop study and examination of subsurface data from shallow pay zones within the Diablo, Linda, and Twin Lakes fields, indicate that a variety of high- and low-energy subtidal facies serve as reservoirs. These include (1) oolite packstones and grainstones, (2) wispy-laminated crinoid wackestones, (3) fossiliferous wackestones, and (4) ripple-laminated pellet grainstones. These facies were deposited as a mosaic in channels, lagoons, shoals, and shallow open-marine environments. Vertical and lateral facies relationships are therefore highly variable and play a major role in reservoir heterogeneity.

Secondary porosity is wholly responsible for oil production, although the depositional setting controls its type and abundance. Intercrystalline porosity is characteristic of the mud-rich facies and is crucial for economic production. Sucrosic textures associated with coarse crystalline dolomite and large intercrystalline pores provide the highest production potential. Moldic porosity is characteristic of the oolitic and fossiliferous facies, but pores are disconnected and only marginally productive unless combined with fractures.

Producing intervals are sealed by tight dolomite mudstones and a thick (5-10 ft), laterally continuous bed of nodular mosaic anhydrite. Unequivocal evidence for supratidal sabkha deposition of this lithofacies is absent. The location of the sealing anhydrite and the presence of high intercrystalline porosity in the underlying subtidal facies are the most important factors determining San Andres production.

EMBRY, ASHTON F., Geol. Survey Canada, Calgary, Alberta, Canada

Mesozoic Stratigraphy of Canadian Arctic Archipelago and Implications for Opening of Amerasian Basin

Mesozoic strata in the Canadian Arctic archipelago occur mainly in the Sverdrup basin where the succession is up to 9 km thick. The strata consist of alternating sandstone-dominant units and argillaceous intervals and record 25 regional transgressions and regressions. These resulted from the interplay of sedimentation, tectonics, and eustatic sea level changes. Subaerial unconformities occur on the basin margins and disappear basinward. Most of these unconformities are interpreted to be the product of eustatic sea level fall on the basis of correlation with global sea level charts. However, unconformities of latest Aalenian, late Callovian, Hauterivian, and Coniacian ages are interpreted to be related to tectonic activity and the formation of the Amerasian basin.

Normal faulting and basic dike and sill intrusion occurred in the Sverdrup basin from Middle Jurassic to early Late Cretaceous. The latest Aalenian and late Callovian unconformities probably reflect early rifting events. Hauterivian uplift was widespread and coincides with the final phase of rifting and initiation of sea-floor spreading in the Amerasian basin. Marine onlap across the breakup unconformity began in Barremian time and by Albian much of the Arctic archipelago had been transgressed.

Basalt flows are intercalated with Barremian to Turonian strata in the northeastern Sverdrup basin and represent the cratonward extension of the Alpha-Mendeleyev volcanic ridge, which was active during the opening of the Amerasian basin. Coniacian uplift coincided with the cessation of volcanism in the Sverdrup basin and of sea-floor spreading in the ocean basin to the north.

ENSLEY, ROSS ALAN, Exxon Production Research Co., Houston, TX

Evaluation of Direct Hydrocarbon Indicators Through Comparison of Compressional- and Shear-Wave Data: Case Study of Myrnam Gas Field, Alberta

A recent paper documents a new method of evaluating bright spots or other direct hydrocarbon indicators (DHIs). The technique involves the qualitative comparison of compressional (P)-wave and shear (S)-wave[1] seismic data. In practice, such a comparison offers a viable means of evaluating DHIs previously observed on P-wave data. The application of SH-wave seismic data for evaluation of DHIs was documented with a case study of P- and SH-wave data from the Putah Sink field of central California. As a second case history, this paper presents an interpretation of P- and SH-wave seismic data from the Myrnam field of Alberta.

Shear waves differ from compressional waves in both the direction of particle motion relative to the direction of wave propagation and in the rock properties that control the wave velocity. A P-wave is an elastic wave in which the particle motion is perpendicular to the direction of wave propagation. Because of this relationship between P- and S-waves, the velocities of the two are functions of different rock properties.

Consideration of the elastic properties that control the velocity of P- and S-waves in a rock indicates that P-waves are sensitive to the type of pore fluid present within a rock whereas S-waves are only affected slightly by changes in fluid type. Thus, if the presence of gas within a reservoir rock gives rise to an anomalous seismic expression on P-wave data, a DHI, there will be no comparable expression on S-wave data. However, a P-wave anomaly generated by a lithologic feature, a false DHI, will have a corresponding S-wave anomaly. One consequence of this relationship is that it is possible to evaluate the potential of P-wave DHIs through a comparison of P- and S-wave seismic data recorded over a prospect.

ESCHNER, TERENCE B., Chevron U.S.A., Denver, CO, and GARY A. KOCUREK, Univ. Texas at Austin, Austin, TX

Eolian Paleotopographic Highs as Stratigraphic Traps: Origin and Distinction

Significant hydrocarbon accumulations occur where eolian paleotopographic highs are preserved beneath transgressive marine deposits. Paleotopographic highs can represent erosional remnants of an unconformity, or partly preserved eolian dunes, or combinations of both. Paleotopography reflects the extent of modification undergone by eolian units prior to or during transgression. Modification varies between extremes of (1) destruction—where eolian deposits are deeply eroded and the former dunal profile is lost, and (2) preservation—where dunes and interdune areas are preserved nearly intact. The extent of modification that occurs during transgression is controlled primarily by (1) the energy of the transgressing sea, (2) the speed of transgression, and (3) the abundance of sand-stabilizing early cements or plants. High-energy seas destroy dunes through persistent erosion by tides and waves and by initiating dune collapse and mass flowage of dune sands. Preservation occurs where quiescent seas flood interdune areas and create shallow to periodically emergent marine environments, such as interdune sabkhas or tidal flats. Gradual filling of interdune areas with shallow marine sediments can fortify and preserve adjacent dunes. These varied processes that interact between marine and eolian environments to create different types of topography are exemplified in ancient eolian-marine sequences of the Western Interior of North America, and preserved Holocene dunes of coastal Australia. Different types of eolian highs can be recognized by analysis of bounding surfaces in outcrop or core. An understanding of eolian-marine processes and environments that create topography allows for prediction of areas of potential stratigraphic traps.

ESTEBAN, MATEU, and D. R. PREZBINDOWSKI, Amoco Production Co., Tulsa, OK

Preserved Aragonite Cements in Miocene Coral Reefs: a Record of Messinian Salinity Crises in Mediterranean

Layers of fibrous aragonite cement up to 2 cm thick, developed on aragonitic corals and micritic cements, occur in outcrops of Miocene coral reefs in western Sicily. These aragonitic fabrics show only minor amounts