of corrosion after subaerial exposure for at least 3 m.y. Their preservation is attributed to encasement by subsequent gypsum cements. Although these botryoidal, banded aragonite cements are strontium-rich (7,000 ppm) and resemble modern marine examples, they were precipitated in secondarily enlarged pores that formed during erosional episodes. Multiple cycles of enrichment in oxygen and carbon stable isotopes are recorded in the aragonite cement layers. The $\delta^{18}O$ values of these cycles range from -0.9 to +6.8‰, whereas the $\delta^{13}C$ values range from +0.6 to +3.8‰ (PDB). These cyclic variations, indicated by isotopic data together with the petrology of the cements, are believed to record major changes in salinity, temperature, and organic productivity of the Mediterranean waters during the Miocene-Pliocene transition. These Messinian reefs were subaerially exposed and later onlapped by the upper evaporite unit with multiple cycles of marine hypersaline carbonate and evaporite deposition separated by periods of erosion. Aragonite cements formed in the enlarged cavities of the lower Messinian reefs during time of deposition of the upper evaporite and recorded the changes in Mediterranean water chemistry. This cementation is believed to have continued into the early Pliocene when colder Atlantic waters invaded the Mediterranean, ending reef growth and evaporite deposition.

EVANS, DIANE L., and LESLIE R. SCHENCK, California Inst. Technology Jet Propulsion Lab., Pasadena, CA

Applications of Digital Terrain Data to Multisensor Image Analysis

Some of the key factors for detection of facies changes in sedimentary environments, such as changes in surface composition and texture, are parameters that can be detected using the remote sensing techniques presently available. For example, multipolarization aircraft synthetic aperture radar (SAR), Landsat 4 Thematic Mapper (TM), and airborne Thermal Infrared Multispectral Scanner (TIMS) images were acquired over the Deadman Butte area of the Wind River basin, Wyoming. The SAR images were acquired at L-band (wavelength = 24.6 cm) simultaneously in 4 polarization states (HH, HV, VV, VH). The 6 visible and near infrared TM bands range in wavelength from 0.45 to 2.35 μm, and the 6 TIMS bandpasses range from 8 to 12 μm. Thus, reflected and emitted radiation, and radar backscatter from geologic targets can be simultaneously analyzed using a coregistered image data set. In this way, lithologic variations can be mapped based on compositional information derived from the TM and TIMS data and detailed surface scattering information derived from the multipolarization SAR data. In addition, coregistration of the image data set to digital terrain data results in the ability to generate a stratigraphic column based on the remote sensing data, and to perform detailed structural analyses.

FAILS, THOMAS G., Independent, Denver, CO

Intimate Relationships: Growth Faulting and Diapirism in South Louisiana

Data published during the recent past have improved understanding of initiation of salt and shale diapirism and of growth faulting on the central Gulf continental slope. Growth faults appear on diapir flanks during initial development, as well as along upper-slope depocenter flanks and the continental shelf edge. Rapid deposition, differential loading and subsidence on the upper slope and outer shelf enhances segmentation of salt ridge or massifs into individual diapiric spines, causing additional diapir-related growth faulting. Most growth faults originating on the slope remain active and, projected upward 5,000-20,000 ft, provide the structural framework within which south Louisiana petroleum exploration takes place.

Study of 31 piercement and 19 semipiercement salt domes plus 117 nonpiercement domes formed by salt and/or shale diapirs reveals important growth fault variations genetically related to diapiric structure type. Fault patterns associated with piercement and semipiercement salt domes are different and more complex than those on nonpiercement features. Counter-regional faults, commonly in compensating or crossing patterns, are far more common; fault splitting and crestal grabens are particularly common on semipiercement structures. Local growth faults related to differing flank subsidence rates around high-relief diapirs play a major role on these structures. In contrast, fault patterns are less complex on nonpiercement diapiric structures. Counter-regional faults, compensating and crossing systems and splitting are less common; most major faults appear to be regional growth faults only indirectly related to diapir development. Implications for additional deep exploration diapiric structures exist.

FERGUSON, JERRY D., Triad Energy Corp., Houston, TX

Jurassic Salt Tectonism Within Mt. Enterprise Fault System, Rusk County, Texas

A synthesis of seismic, bore-hole, and gravity data in southeastern Rusk County, Texas, indicates that faulting within the Mt. Enterprise fault system was the result of Jurassic salt tectonism. Faults were developed in response to salt movement and subsequent collapse of the overlying section into areas of salt withdrawal, resulting in the formation of a graben containing no Louann Salt. An abnormally thick Bossier Formation within the graben indicates a Late Jurassic age for significant structural deformation within the fault zone.

The potential exists for numerous untested traps within the Jurassic section associated with salt-generated structures along the Mt. Enterprise fault system.

FERRELL, RAY E., JR., and ALLISON H. DREW, Louisiana State Univ., Baton Rouge, LA

Hydrocarbon Migration and Diagenesis in Miocene Marine-Shelf Deposits

Miocene marine-shelf deposits typically found in the Gulf Coast basin are composed of thin (0.1-10.0 cm), horizontally bedded or cross-stratified quartzarenites to subarkoses, laminated silty clays up to 50 cm thick, and bioturbated admixtures of these 2 end members. Some of the coarser grained sand units may contain appreciable quantities (up to 50%) of shell fragments. These lithotypes exert a significant control on the diagenetic mineral products and amount of secondary porosity observed in specimens that have been subjected to temperatures in excess of 120°C. Low-magnesian calcite, maximum microcline, high albite, and a kaolin mineral (possibly dickite) are the major diagenetic products in the sandstones. A regular mixed-layered illite/smectite (rectorite) is dominant in the clay-rich materials. Secondary porosity is most common in those rocks that originally contained numerous shell fragments. Quartz overgrowths are ubiquitous. The diagenetic differences are striking when the closeness of the sand and clay association is considered. The thin clay seams may have obtained small quantities of potassium from some of the associated sands. The sands illustrate considerable reaction with connate fluids, during the albitization process. Kaolinitic minerals are most abundant in the sand with the highest original porosity. The original composition and diagenetic products define the optimum conditions for hydrocarbon migration.

FETT, THOMAS H., Schlumberger Well Services, Corpus Christi, TX

Practical Guide to Dipmeter Applications in Gulf Coast

The dipmeter is truly a jambalaya of geologic information. Consider the many situations where knowledge of inclination and direction would be useful. Determination of structural dip and identification of faults and unconformities caused by abrupt changes in that dip are well-known uses. Furthermore, bending of beds resulting from drag of postdepositional faults and roll of contemporaneous faults allows determination of the exact depth, strike, and downthrown direction of the beds. Dip and direction define drape over bars and within channels, foresetting of fans, and compaction under sands. This can identify the type, trend, and pinch-out direction of these sand bodies. The knowledge of paleocurrent direction and strength, available from very short-interval dipmeter computations, combined with an understanding of the relationship to the drapes provides a powerful tool for defining stratigraphic traps.

The dipmeter's extremely fine vertical resolution and multidirectional sensors allow precise determination of bed thickness, laminations, vertical grain-size profiles, bore-hole geometry, and fractures. The recently introduced Dual Dipmeter service, with 8 sensors and 0.1-in. sampling rate, adds an order of magnitude increase in this type of information.

Dipmeter data can provide a link between large-scale seismic and small-scale core information that is being used to identify structural and stratigraphic traps of the mature, highly faulted Gulf Coast area. This information is available on the first well drilled and can help unravel complexities inevitably uncovered in field development.

FIELD, MICHAEL E., and KEITH A. KVENVOLDEN, U.S. Geol. Survey, Menlo Park, CA

Gas Hydrates Beneath Continental Slope off Northern California

The continental slope and plateau off northern California are underlain by a well-defined and extensive acoustic reflector that crosses other reflectors and mimics the surface of the sea floor. This bottom-simulating reflector (BSR) lies at an average subsurface depth of 250 m and is laterally continuous beneath the Klamath Plateau (water depths of 800-1,200 m) off northernmost California. Limited data show that it extends northward into offshore Oregon and seaward at least to the base of the slope (3,000 m water depth). The BSR has been mapped along the continental margin for a distance of over 130 km and underlies an area of at least 3,000 km^2.

The water depths and sediment depths of the BSR, as well as its pervasiveness, all suggest that it represents the base of a natural-gas hydrate. Using standard phase-boundary diagrams for hydrate stability, we estimate that the geothermal gradient in this area is about 50°/km. Such a gradient is higher than found along most subduction margins, possibly because the subducting oceanic crust in this region is young. This acoustically inferred gas hydrate is the first mapped along the western United States conterminous continental margin.

FIGUEIREDO, A. M. F., M. J. PEREIRA, W. U. MOHRIAK, P. C. GAGLIANONE, and L. A. F. TRINIDADE, PETROBRÁS, Rio de Janeiro, Brazil

Salt Tectonics and Oil Accumulation in Campos Basin, Offshore Brazil

Salt tectonics were responsible for the development of optimum conditions for accumulation of large hydrocarbon reserves in Campos basin.

The salt movements, triggered by basin tilting and differential loading, initially formed low-relief salt pillows that controlled the porous facies of the shallow-water Macaé limestones. The continuous evolution of halokinetic processes produced growth faults, rollover crests, and faulted anticlines. Upper Cretaceous turbidite sandstones were channelized in the downthrown blocks of growth faults. Salt-collapse, residual, and relief-inversion features were formed in areas where the salt was sufficiently thick.

The oil, generated in the Neocomian shales of Lagoa Feia Formation, migrated to upper formations through normal faults associated with the rift phase, stratigraphic conduits such as porous rocks and regional unconformities, and gaps created by salt flowage in the Aptian evaporite section. Oil migration to the post-salt rocks was favored by active growth faults and by the presence of a regional unconformity developed at the Cretaceous-Tertiary boundary and covered by turbidite sheet sands.

The oils underwent progressive alteration along their paths to the post-salt reservoirs. Oil-oil and oil-source rock correlations suggest that the hydrocarbons trapped in many diverse plays, although affected by bacterial degradation and water washing, belong to only one oil family. The oil degradation was probably enhanced by meteoric water invasions during Tertiary low stands of sea level in areas close to the paleocoastline. These phenomena resulted in large amounts of oil becoming heavier and enriched in sulfur, resins, asphaltenes, and cycloparaffins.

FINLEY, ROBERT J., Bur. Econ. Geology, Austin, TX, and LEWIS R. LADWIG, Colorado Geol. Survey, Denver, CO

Depositional Systems of a Tight Gas-Productive Barrier-Strandplain Sequence: Corcoran and Cozzette Sandstones, Northwest Colorado

The Corcoran and Cozzette sandstones (Campanian) are members of the Price River Formation within the Mesaverde Group of the Piceance Creek basin, and consist of marginal-marine facies between the underlying Mancos Shale and the overlying continental Mesaverde. Log-interpreted facies within the Corcoran-Cozzette vary from shale with thin siltstone to sandstone interbeds (shelf to lower shoreface), through upward-coarsening sequences (upper shoreface to foreshore), to interbedded thin coal, sandstone, and shale (alluvial plain to bay or lagoon). Plateau and Shire Gulch are the largest fields that produce gas from low-permeability (0.002-0.08 md), fine-grained to very fine grained sandstone of the Corcoran and Cozzette (over 8.4 bcf produced through 1982).

Within these fields, 7 distinct northeast-trending strandplain and barrier units have been identified. Strandplain sandstones form the lower half to two-thirds of each member, and barrier sandstones form the upper depositional units. Net sandstone thickness of the strandplain units increases from less than 20 ft southeast of the fields to more than 80 ft within Plateau field. Along the southeastern Plateau field margin, upper units in each member contain 30-55 ft thick sandstones that repeat the shoreface sequence.

Most completions are in the lower (39%) and upper (33%) Corcoran, whereas the lower and upper Cozzette each account for 14% of perforated intervals. The underlying Mancos Shale and overlying coal may account for the greater gas production of the Corcoran. Gas productivity of individual depositional units cannot be defined due to commingled production from multiple intervals in most wells.

FLETCHER, CHARLES H., III, Univ. Delaware, Newark, DE

Coding, Storage, and Retrieval of Stratigraphic Data: FORTRAN Mapping Technique

A unique technique of coding, storing, and plotting descriptive stratigraphic data uses a series of FORTRAN programs. The basis for the technique is a search-and-store algorithm that may be modified to produce a time-series sequence of lithologic or environmental maps. Coded data are displayed as a 2-dimensional output array in the form of an inked, line-drawn planimetric view of the research area. User-specified intervals of the range of data are represented by symbology, color code, or literal string. The final product is a time series of computer-constructed surfaces representing the geologic evolution of a particular area. These surfaces may emphasize environments of deposition, sediment lithology, or any other stratigraphically derived information (porosity, permeability, consolidation, mineralogy, biostratigraphy, geochemistry).

Stratigraphic data are stored as an alphanumeric code. Data are presumed to have been derived from cores or some similar means of vertical sequence control. A single core occupies one line of a data file with an operating field width of 132 columns. Columns 1-9 and 122-132 contain location and identification data. The remaining locations (columns 10-121) consist of repeating 14-column groups. Each group contains codes describing a single stratigraphic unit. Thus, each line of the data file may describe a sequence of 8 stratigraphic units.

This technique was used to display the development of the Bay and Atlantic coasts of Delaware from 10,000 b.p. to present. A series of maps has been produced that details the geomorphology of the coast at regular chronologic intervals. This allows a detailed analysis of the evolution of a complex region as a response to known Holocene conditions of rising sea level.

FLEXER, A., and A. LIVNAT, Tel Aviv Univ., Tel Aviv, Israel

Evolutionary Importance and Economic Potential of Mesozoic Unconformities of Levant

Six unconformities are discerned in the Mesozoic section of Israel and adjacent countries. Four unconformities (mid-Triassic, Late Triassic, Late Jurassic, and Aptian-Albian boundary) are genetically related to global sea level drops and divergence of the Tethys. The divergent processes are associated with faulting, volcanism, and clastic accumulations along the passive margins of the Arabian craton.

The Late Cretaceous unconformity is associated both with global sea level drop and convergence of the Tethys. The late Middle Jurassic unconformity is related to a global eustatic low without any apparent tectonic activity in the region. All the unconformities are widely distributed and, except the one at the Jurassic-Cretaceous boundary, mark only short periods. Therefore, they serve as markers and correlation guides for the geologic evolution of the Middle East. Their economic importance can be summarized as follows. (1) The tectonic setting of the blocks overlying