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.

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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.

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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.

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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.

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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.

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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 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.

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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.

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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.

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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.

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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.

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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.