The Viola Limestone (Middle and Upper Ordovician) of the southwest Arbuckle Mountains was deposited on a carbonate ramp within the southern Oklahoma Aulacogen. Depositional environments include (1) anaerobic, deep-ramp setting represented by microfacies RL, CH, CGL, and A, (2) dysaerobic, mid-ramp setting represented by microfacies B, and (3) aerobic, shallow-ramp setting represented by microfacies C and D.

Deposition in the deep- and mid-ramp environments was dominated by bottom-hugging currents produced by off-platform flow of denser waters. These currents moved down a broad slope that was locally incised by gullies. Deposits of the broad slope, microfacies A and B, originated from a line-source and are found throughout much of southern Oklahoma. Primary sedimentary structures include millimeter-size laminations, starved ripples, and concave-up and inclined erosional surfaces. Shelly benthic fauna are rare in A and B; trace fossils are common only in B. Deposits associated with the line-source gully, microfacies RL, CH, and CGL, are laterally confined; they have been observed only in the southwest Arbuckle Mountains. Primary sedimentary structures present in RL include wavy and ripple-cross laminae. Microfacies CH, contained within RL and interpreted as a submarine channel deposit, is present only at one locality. Primary sedimentary structures present in CH include an erosional base and several internal erosional surfaces, lateral accretionary sets, and imbricated, locally derived intraclasts.

Deposition in the aerobic, shallow-ramp setting (microfacies C and D) was dominated by storm processes and intervening periods of bioturbation. An increase in both size and abundance of pelmatazoan fragments is the characteristic feature of these microfacies.

High total organic carbon (TOC) values have been reported for the lower Viola. TOC values of 1% have been reported from microfacies A, and TOC values of 5% have been reported from microfacies RL. These high values suggest that A and RL may act as hydrocarbon source rocks. Recognition of these microfacies in the subsurface will contribute to our knowledge of the Viola Limestone as an exploration target.

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Tectonics, Stratigraphy, and Petroleum Potential of Tripura-Mizoram Folded Belt, Northeast India

The folded belt of the northeast Indian states of Tripura and Mizoram and the adjoining parts of Assam (Cachar district) and Manipur constitute a part of the Assam-Arakan geosynclinal basin and lie between the present-day foredeep of Bangladesh and the hinterland of Burma. This region, with its characteristic succession of synorogenic ridges and valleys, can be subdivided into a frontal subbelt of Tripura and south Cachar comprising narrow, boxlike, and cuspate anticlines separated by wide, flat synclines, and an inner mobile subbelt of Mizoram and west Manipur consisting of tight, linear, commonly isoclinal anticlines and synclines, festooned into salients and reentrants. Passing from east to west, deformation in this belt becomes progressively younger and less intense. The anticlines are commonly bounded on one or both flanks by longitudinal listric reverse faults. The individual structures are internally segmented by cross faults and oblique faults of multiple alignments, some of which have strike-slip components and have offset anticlinal axes and flank faults. These multidirectional trends combine at places to form doglegs and trap doors, disrupting a more general north-south relay pattern, and indicate polyphase deformation with structural styles grading from those associated with basement-involved compressive block-faulting to detached thrust-fold assemblages and further modified by shale flowage. Such compressional tectonic styles are characteristics of areas close to convergent plate boundaries.

The Tripura-Mizoram region exposes mainly Neogene-age clastics of molassic facies, comprising about 6 km (20,000 ft) thick, poorly fossiliferous succession of alternating shales, mudstones, siltstones, and sandstones in varying proportions, which have been lithostratigraphically subdivided from the bottom upward into Surma (Miocene-Pliocene), Tipam (upper Pliocene), and Dupi Tila (Pleistocene) Groups, with conditions of deposition ranging from shallow marine/deltaic at the bottom to fluviatile/lacustrine at the top.

Numerous surface and subsurface manifestations of oil and natural gas in Tripura, Cachar, and Mizoram areas, occurrence of gas fields in the neighboring areas of Bangladesh, and a favorable geologic history indicate the existence of conditions conducive to petroleum generation in this region. On the basis of geochemical studies, it has been concluded that there are good prospects of striking gas in the relatively shallower zones and both oil and gas in the deeper zones in several structures of Tripura and Cachar. The expected hydrocarbon traps include discrete culminations and trap doors in individual anticlines, cross-faulted noses, subsidiary flexures in synclinal areas, subthrust warps against block-bounding faults, and various associated stratigraphic traps, as well as combination traps resulting from clay diapirism. However, on account of logistic constraints, unfavorable subsurface conditions (including steep dips and high pressures), inherent stratigraphic and structural complexities, and a paucity of seismic data, exploratory operations conducted in this region have had limited success. An accelerated exploration program with the help of improved techniques and additional resources is being initiated.

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Lower Eocene Carbonate Facies of Egypt—Paleogeographic and Tectonic Implications

The northern Arabo-Nubian craton witnessed a major Late Cretaceous-early Tertiary marine transgression that culminated in the deposition of widespread shelf-sea carbonates during Early Eocene (Ypresian) time. In Egypt, these Early Eocene strata (the Thebes Limestone and its equivalents) crop out over more than 100,000 km^2 (38,610 mi^2), and reveal a mosaic of carbonate facies consistent with the general model of "epeiric clear water sedimentation" proposed by Irwin in 1965.

"Outer shelf" facies characterize exposures in central Egypt (Assiut, Luxor, Kharga), and are composed primarily of rhythmically interbedded chalk and micritic limestone with minor intercalated marine hardgrounds. To the south (Kurkur-Dungul), these fine-grained lithologies give way to "inner shelf" foraminiferal wackestones and grainstones, typical Tethyan "Nummulitic" facies. Missing in southern Egypt is the restricted dolomitic evaporitic facies predicted by the Irwin model and observed in the lower Eocene of the Sirte basin to the west and the Arabian Platform to the east. The absence of this marginal marine evaporite belt in Egypt is presumably the result of post-Ypresian uplift and removal.

Comparing the areal distribution of these lower Eocene carbonates to coeval facies developed across the remainder of northern Africa and Arabia reveals the presence of a broad marine embayment which extended through central and eastern Egypt into northern Sudan during Ypresian time. The widespread subsidence that resulted in the development of this feature may have been an effect of regional crustal attenuation preceding the rifting of the Red Sea.

Concomitant with this regional subsidence were localized uplift and extensional block faulting in the vicinity of the incipient Red Sea rift (the Safaga-Quseir coastal plain). Here, lower Eocene carbonate facies are indicative of shallow water platforms developed on horst blocks, and deeper water, turbidite-fed basins in intervening grabens.

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Hydrocarbon Accumulations in Turbidite and Contourite Sands of Upper Cretaceous Forbes Formation, Bounde Creek Gas Field, California

Upper Cretaceous marine strata of the Forbes Formation in the northern Sacramento Valley are composed of terrigenous clastic detritus deposited in westward-prograding shelf to basinal sedimentary environments that existed in a south-trending fore-arc basin. Subsurface stratigraphic investigations in the Bounde Creek gas field indicate that upper, middle, and lower informal divisions of the Forbes Formation are composed of submarine fan and slope sediments deposited in the northern extension of the fore-arc basin.

The upper Forbes contains deposits of inner slope sub-association. Predominantly very fine to fine-grained contourite and feeder channel sands are present within this upper section. These inner slope deposits are underlain by, and are interpreted to pass westwardly into, outer slope and inner fan deposits that comprise the middle part of the Forbes. Sands within this middle part are generally coarser (very fine to coarse-grained), thicker bedded, and have greater stratigraphic irregularity than vertically adjacent deposits within the formation. The lower Forbes consists of middle and outer submarine fan deposits. Sand bodies in this interval were deposited in channels and as suprafan lobes. Ongoing analysis indicates that channel configurations were, in some places, influenced by syndepositional faulting that created steep channel margins and abrupt route alterations and/or abandonments. Sand lobe deposits exhibit areal continuity and lateral lithologic gradations.

In the Bounde Creek gas field, distinct hydrocarbon accumulations occur in sand packages that are interpreted to represent: (1) feeder channels and contourites of slope associations; (2) channel lag or mouth bars of middle to inner fan sub-associations; and (3) suprafan lobes of middle to outer submarine fan sub-associations. Paleogeographic reconstructions of depositional horizons within the Forbes reveal a scenario of development and progradation of these inner slope to outer fan associations, and allow geometric projections of hydrocarbon-bearing sand bodies within the system.

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Significance of Gamma-Ray Spectroscopy for Evaluating Shallow Gas Reservoirs from Bowdoin Dome, Montana

Natural gas is currently being produced from shallow gas reservoirs of Late Cretaceous age in the Bowdoin dome area, north-central Montana. Clay-rich rocks of the Mosby Sandstone Member of the Belle Fourche Shale, the Greenhorn Formation, and the Carlile Shale are the principal reservoirs. Laterally equivalent rocks are major producers of gas in southeastern Alberta. The Mosby consists of composite bedsets of lenticular to wavy-bedded sandstone and dark-gray shale. The Greenhorn, which unconformably overlies the Mosby, is as much as 40 ft (12 m) thick and consists of black, organic carbon-rich (as much as 9% organic carbon) shales, bentonites, and calcarenties consisting mainly of inoceramid prisms. Lateral equivalents of the Greenhorn are probably the principal source beds for oil occurrences farther west in the Montana disturbed belt. The Carlile Shale overlies the Greenhorn with apparent conformity and is lithologically similar to the Mosby. However, the Carlile mudstones contain more smectitic mixed-layer clays than those of the Mosby.

Exploration and production of hydrocarbons from these clay-rich rocks present significant problems in log interpretation and in well completion and treatment procedures. In an effort to address these problems, a detailed geochemical, petrologic, mineralogical, and stratigraphic study was undertaken to characterize the gas-productive formations at Bowdoin dome and to evaluate the usefulness of natural gamma-ray spectroscopy for interpreting geology and reservoir quality. The gamma-ray spectral log resolves the total gamma-ray spectrum into the three most common components of radiation—gamma rays from ^{40}K, U-series decay, and Th-series decay. In principle, the log can be used to determine clay content, clay composition, source-bed richness, and lithology. Results of this investigation suggest that the log successfully estimated organic-carbon content, identified bentonites, and located the unconformity at the base of the Greenhorn. In addition, subtle differences in clay composition between the Belle Fourche and Carlile Shales were apparent. These differences in clay mineralogy have important implications for interpreting the irreducible water saturation and water sensitivity of the formations and thus for the choice of drilling and completion techniques.

Detailed analyses of individual core samples provide much more accurate information about single point samples than did interpretations of single points from the spectral log. However, analyses of individual core samples only distinguish mineralogical or geochemical deviations with frequencies greater than two times the sampling interval. In contrast, the log provided a running average capable of resolving relatively small-scale fluctuations and displayed considerable precision and accuracy when calibrated to laboratory analyses. In conclusion, gamma-ray spectroscopy provides a potentially important tool for the investigation of unconventional gas reservoirs and source beds in clay-rich and organic carbon-rich rocks.

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Exploration Implications of Neotectonic Fault Pattern, Gulf of Suez

Detailed topographic mapping of the Ras Issaran area along the west bank of the Gulf of Suez reveals Quaternary faulting along preexisting trends, cross-fault reversals, and tectonically controlled sedimentation. The neotectonic fault systems of the region were identified and mapped by altimetry of selected bed-rock units and Quaternary gravel surfaces. The relict gravel surfaces are tilted gulfward, bowed near faults, displaced across faults, and show fault-induced drainage changes, evidenced by truncation and rerouting of wadis. Although the current major fault scarps on the high Quaternary surface have migrated back from the original bed-rock faults, the configuration and magnitude of the Quaternary faults are clearly visible. This has important implications for the interpretation of subsurface data. In particular, ability to detect subsurface structures, reversed faults, and significant fault trends is enhanced by knowledge of the modern fault patterns.

Tectonic activity in the Ras Issaran area is dominated by movement occurring on two major sets of normal faults. The primary