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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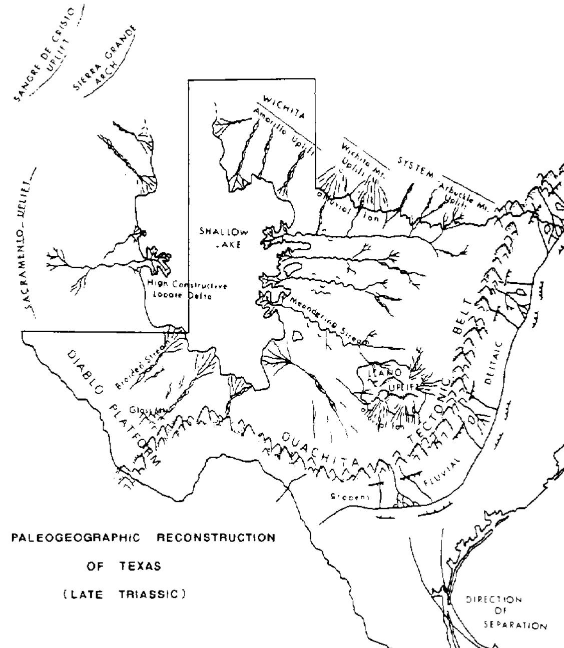
Exploration Implications of Neotectonic Fault Pattern, Gulf of Suez

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 set consists of NW-trending, gulf-parallel faults which define major horst and basin systems. Breaking these are roughly NE-trending cross-faults. Paralleling the coast is a NW-SE trending horst segmented by cross-faults. Relative dissection and weathering of the relict gravel surfaces indicate the most recent uplift of the area occurred sequentially from northwest to southeast in three major segments. As uplift shifted along structure, motion on intervening cross-faults reversed.

Bed-rock facies changes indicate gulf-parallel faulting has continued from the Miocene along preexisting trends to the present day. Miocene and Pliocene reefal concentrations at the crest of the horst give way to thinly laminated limestone down structure and deeper water marls, evaporites, or clastics off structure. Local fault-associated arching also influenced deposition, resulting in thickening Pliocene clastic fill off the crest of the uplift. In the adjacent basins, ongoing sedimentation encouraged growth faulting. In general, the NE-SE cross-faults did not influence sedimentation to the same extent as the gulf-parallel fault system.

Detailed mapping of the neotectonic fault system indicates a continuation of past structural movement through the Quaternary. These fault patterns and their effects on local sedimentation provide a model for subsurface projection of Neogene facies variations. As oil concentrations are intimately related to local structures in the Gulf of Suez, detailed knowledge of Quaternary fault movements combined with seismic interpretation, can significantly aid in understanding the sedimentology and structural features of potential oil reservoirs.



PALEOGEOGRAPHIC RECONSTRUCTION OF TEXAS (LATE TRIASSIC)

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Stratigraphy and Environmental Significance of Continental Triassic Rock of Texas

The continental Triassic rocks of Texas are represented by four distinct but similar rock groups that exist both in outcrop and in the subsurface and include the Eagle Mills Formation (south-central and northeast Texas), Sycamore Formation (central Texas), Dockum Group (west Texas), and Bissett Formation (southwest Texas). They are clearly terrigenous in nature derived principally from older Paleozoic sedimentary rocks. The rock groups are composed in part or entirely of mudstone, siltstone, medium to coarse-grained sandstone, and pebble to boulder conglomerate (intrabasinal and extrabasinal). The sediments were deposited in alluvial fans, braided and meandering streams, lobate deltas, fan deltas, and lakes. The coarse sandstone and conglomerate are the products of high-energy, short-duration depositional events. Sedimentation was greatly affected by alternating climatic conditions that produced changes in base level, water depth, and lake area as well as the type of streams that flowed into the depositional basins. The character of the rock groups strongly suggests semi-arid to arid deposition typical of the low latitude desert regions of today. Thus, the rocks comprising the Eagle Mills, Sycamore, Dockum, and Bissett Formations appear to be products of continental clastic deposition during a major semi-arid to arid climatic episode, such as that of late Triassic time.

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Structural Style of Foothills of Andean Overthrust Belt, Northern Neuquen Basin, Argentina

Basement plays an important role in Andean deformation in central western Argentina. Shortening is controlled by moderate-angle basement-rooted thrusts, primarily eastwardly directed. Four glide horizons in the sedimentary cover locally modify the style of deformation. A variety of structures result, including broad open folds, overturned folds, imbricate thrusting, and décollement-type faults.

Two fault zones, active chiefly during a Miocene compressional event, exert primary control on the structure. The westernmost is a zone of east-verging imbricate thrusts, closely paralleling the hinge line between thick Jurassic sediments to the west and thinner deposits to the east. This zone probably represents reactivation of basin-opening normal faults, which were active during back-arc extension in the late Triassic and early Jurassic. Balanced cross sections indicate marked basement shortening along this belt. The eastern fault zone lifts basement upward and eastward with a throw of 2 to 7 km (1.25 to 4.3 mi). Where these fault zones are widely separated, they divide the foothills into three structural belts: a realm west of both faults consisting of broad basement-cored folds with minor thrusting, a central zone with a variety of structures deriving from both fault zones, an an eastern region with basically minor structures obscured by Quaternary alluvium. Where these two fault zones closely approach each other or merge, the marginal belts remain virtually unchanged. However, the central zone, which is updip from the thickest basinal sediments and encompasses a region of complex stratigraphy, is more intensely deformed and becomes a structurally elevated band, paralleling the faults.

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Secondary Detachment Above Basement Faults in North Sea: Clyde Field Growth Fault

The Clyde field in the southern North Sea is a Jurassic (Fulmar Sand) reservoir developed on a fault-bounded terrace on the margin of the Central graben. The structural style of this region was formerly thought to comprise simple tilted fault terraces that were active through the Jurassic. Seismic mapping of the Clyde reservoir and deeper Zechstein, Rotliegendes, and Devonian events shows that Jurassic and Triassic rocks form a characteristic thick structural high, lensoid both in plan and cross section, (see figure) above deeper events dipping toward the basin.