analytical sophistication of organic geochemistry and the application of organic geochemistry to better evaluating risks when making exploration decisions. Unfortunately, the applications available from present technology have not been fully exploited. Thus, a major frontier exists in the increased exploitation of presently available technology. This frontier can best be exploited by placing an experienced exploration geologist, with an interest in organic geochemistry and basin analysis, between the chemist in the lab and the exploration manager.

Meanwhile, technology improves and new opportunities appear, although we will probably be dealing with incremental improvements, not the conceptual breakthroughs of the past 20 years. Anticipated developments include the following. (1) Finer tuning of the "generation window" for different types of organic matter, generation products, and rock matrices. (2) Better generation, migration, and accumulation models. Many numbers are multiplied together in these models, thereby leading to large uncertainties in the final prediction. Geochemistry will help better define such models in several ways; however, its major contribution will probably be in the increased accuracy and numbers of measurements of the actual distribution of hydrocarbons and other organic compounds in the subsurface. More such data are sorely needed to increase our ability to quantitatively evaluate migration mechanisms. Most of the oil and gas remains in the potential source rock. Better understanding of when, how, and why some of it does move is clearly an important frontier. (3) Improved prediction of source rock distribution, type, thickness, and maturity. This will be accomplished by integrating organic geochemistry with modern and paleo-oceanography, paleoclimatology, and plate tectonics. By better understanding why source rocks are where they are, we will better predict where others might exist, and conversely, where they are not to be expected. (4) Increased efforts to apply "biomarker" geochemistry to exploration problems. (5) More sophisticated, non-"biomarker," methods for characterizing oils. These will lead to better oil-oil and oil-source correlations for use in exploration, but will also be increasingly applied to a variety of development and production problems. (6) Increased studies of interactions between organic matter, rocks, and fluids. In the past, the prime interest was in the effects of different rock matrices on organic maturation rates. Results have been disappointing, perhaps because the major effects are in the other direction. Organic matter and its decomposition products can have a major effect on rock diagenesis and sedimentary ore deposits. (7) The geochemistry of deep, hot, gas accumulations.

This list is not exhaustive. Opportunities abound for the application of geochemistry to exploration problems. The technology exist, or soon will. The frontier is how well the resourcefulness of our profession will be used to apply the available technology to our problems.

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A Discussion of Crude Oil Production Potential in Alaska and California

Nearly half of the proved oil reserves in the United States are located in Alaska and California. In 1980, production from this 14 billion bbl reserve base averaged nearly 2.6 million BOPD or roughly 30% of total United States production. Although there is little doubt that Alaska's and California's future contributed to total United States production will increase, a great deal of uncertainty exists concerning the magnitude of this contribution.

A range of forecasted production values is presented for Alaska and California. The forecast reveals that there is a 67% spread between the high and low boundaries of California's production potential during the mid 1990s; this range is even greater (167%) in the case of Alaska.

The forecast is accompanied by a comprehensive discussion of factors that will determine actual production. These factors are organized into three groups: exploration success, market conditions, and regulatory environment. The first, exploration success, is described in terms of geologic prospects, lease sale timing, technology performance in harsh frontier environments, and economic risk in comparison to other regions. The second group comprises factors affecting petroleum company perception of future West Coast market conditions. Forecasts of refined product demand, crude supply potential, and refinery configuration are presented to help define this perception. The third group, future state and federal regulatory environments, is discussed from the perspective of conflicts between state and federal outer continental shelf operational jurisdiction, potential governmental responses to serious accidents, and policies concerning taxes, royalties, and crude exports.

This information will help petroleum companies formulate crude exploration, development, production and processing plans based on personal perceptions of the future.

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Brines, Clay Minerals, and Equilibria: Predicting Diagenetic History and Reservoir Quality in Oligocene Frio Formation of Texas

Sandstone reservoirs of good quality, displaying abundant deep secondary porosity, exist on the upper Texas coast, whereas secondary porosity and permeability in sandstones of the lower coast are occluded by authigenic ferroan calcite and chlorite. This difference in regional reservoir quality is controlled by bulk mineralogy, temperature, pressure, and pore-fluid chemistry. Concentrations and activities of major species show depth dependent trends that correspond to pore pressure gradients and associated thermal gradients. Salinities decrease near the base of hydropressure, but increase at intermediate pressure gradients between 0.465 and 0.7 psi/ft (10.5 and 15.8 kPa/m). At higher pressure gradients salinities decrease with depth. The Ca/Na ratio is lowest at top of geopressure. Predictions from solution-mineral equilibria using approximately 130 analyses of Frio brines add new insight on relative mineral stabilities and in-situ pH, and are consistent with the diagenetic sequence developed from petrographic data. Kaolinite is stable in geopressured waters relative to Ca-montmorillonite and plagioclase; it is abundant on the upper coast as a late stage cement. Lower temperature and in-situ pH (high P_{CO_2}) explain the general absence of chlorite on the upper coast; its formation on the lower coast is promoted by higher temperature, a mineralogy rich in volcanic and carbonate detritus, and inferred higher pH. The key to predicting reservoir quality at depth is the deep hydropressured waters. Activity indices are indicators of reservoir quality. Waters of the lower coast plot more deeply into the stability field of chlorite than do those of the upper coast.

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Egyptian Exploration: Background, Models, and Future Potential

Egypt has proven to be an area with excellent exploration potential. Recent discoveries in the Western Desert tilted fault blocks are leading to a reevaluation of new play concepts based on an east-west Tethyan rift structure model. Facies favorable to hydrocarbon accumulation are associated with shallow-water marine depositional environments. Production has not been great on a per-well basis, but fields have consistently outproduced the original recoverable reserve estimates.

The Gulf of Suez lies within the rift between North Africa and Arabia-Sinai. It remains a major producing area with production from sandstones which range in age from Carboniferous to Cretaceous. The Upper Cretaceous and Lower Tertiary carbonates are potentially attractive zones, as are the Miocene clastics and carbonates. Miocene marls and Upper Cretaceous shales are source rocks, and thermal maturation can be directly related to continental rifting with the oil window most attractive in the southern third of the Gulf of Suez. Structural style is strongly rift-influenced with tilted and locally eroded hosts prevalent. The central gulf has a general eastern dip, whereas the northern and southern areas have a regional westward dip. This has had a direct influence in isolating some major oil fields and has adversely affected reflection seismic surveys.

Exploration has been difficult because of excessive Miocene and younger salt thicknesses. With increasingly refined technology, attractive targets now are being delineated in the hitherto unexplored lows between horsts within the gulf.

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Depositional Environments of Schuler Formation (Cotton Valley Sands), Upshur County, Texas

Exploration for "tight" gas (F.E.R.C. Section 107) production from the Schuler Formation (Cotton Valley sands) has provided recent data for the recognition of the lower Schuler (Shongaloo member) shoreface facies and delineation of the upper Schuler (Dorcheat member) delta plain complex in Upshur Country.

Shoreface facies within the lower Schuler have a typical funnel-shaped log pattern (coarsening-upward clastic), with individual sequences ranging from 90 to 100 ft (27 to 30 m) thick. In core, the corresponding coarsening-upward sequence grades from offshore to upper shoreface facies. Upper offshore sediments are dominated by a heavily bioturbated and intercalated sandstone/shale sequence with numerous trace fossils, escape traces, and shell debris. Intensity and diversity of this bioturbation decrease toward the upper shoreface. The lower shoreface is a very fine-grained quartz sandstone with horizontal to slightly inclined stratification. Climbing vertically in the sequence, the upper shoreface is interbedded fine-grained quartz sandstone and biomodal, pebbly carbonate cemented quartz sandstone exhibiting a steep inclined stratification with low-angle truncations.

Associated facies overlying the upper shoreface are lagoonal. Thin marsh deposits are characterized by carbonaceous shales with visible root traces cutting across partings. Subaerially exposed mottled red and green siltstone and red mudstone show evidence of root penetration and are interpreted as coastal plain to tidal flat. The marsh deposits (green siltstones and red mudstones) gradationally interbed with a subtidal lagoonal facies containing dark gray, fossiliferous, argillaceous, limestone containing oysters, echinoid fragments, and annelid worm tubes.

In an effort to tie the limited core data (4 wells) to a countywide environmental interpretation, sand percent interval slice maps were constructed above and below the ubiquitous subtidal lagoonal "marker." These maps and core data in the lower Schuler delineate a strike-oriented, linear clastic shoreline (ENE-WSW). Within Upshur County, lower Schuler sediments were deposited as interdeltaic, shoreface facies. Slice maps and sample logs indicate a significant environmental discontinuity exists between the upper and lower Schuler. The upper member is characterized by a dip-oriented sandstone trend interpreted as an aggradational delta plain complex associated with the Lone Oak delta system.

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Preliminary Synthesis of Eocene-Oligocene Stable Isotope Data from Atlantic, Indian, and Pacific Ocean Sites

Generally consistent patterns of Eocene-Oligocene oxygen and carbon stable isotopic change are emerging from all ocean basins where well-preserved pelagic carbonates have been studied. The major features of benthic foraminiferal oxygen isotopic change are enrichment of close to 1‰ in ^{18}O associated with the middle-late Eocene boundary and the Eocene-Oligocene boundary at locations which differ by more than 3 km (2 mi) paleodepth. The Eocene-Oligocene enrichment occurs mostly in the earliest Oligocene and is clearly isochronous according to planktonic foraminiferal biostratigraphy. Completion of the Eocene-Oligocene event took less than one million years, with maximum earliest Oligocene $\delta^{18}O$ values giving rise to lower values later in the Oligocene. Surface-dwelling planktonic foraminifera from low latitude locations become enriched in ^{18}O by only a few tenths ‰ from the Eocene to the Oligocene, whereas at high latitude locations they show the same enrichment as benthic foraminifera (about 1‰).

Down-core oxygen isotopic trends are best interpreted as reflecting changes in the thermal or density structure of the ocean from Eocene to Oligocene time. This reasoning follows from the general lack of covariance of benthic and planktonic $\delta^{18}O$ from tropical locations, which in the Quaternary is the strongest evidence of large glacial-interglacial changes in seawater isotopic composition. Thus, high latitude locations where the planktonic $\delta^{18}O$ increased the most were probably the source of dense water to the deep ocean everywhere. A major increase in the density structure of the ocean should be evident in plots of planktonic foraminiferal $\delta^{18}O$ versus paleolatitude and benthic foraminiferal $\delta^{18}O$ versus paleodepth. Our preliminary data indicate the $\delta^{18}O$ versus latitude gradient increased from Eocene to Oligocene times, although more data from non-upwelling areas is required to establish the significance of this change. Reconstructions of vertical $\delta^{18}O$ structure in the late Eocene suffer from too little data from individual basins, although our synthesis of the early Oligocene North Atlantic reveals about a 1‰ $\delta^{18}O$ increase between 1 and 2 km (0.6 to 1.2 m) paleodepth.

Carbon isotopic results apparently do not vary systematically in time series, but display differences which probably reflect the hydrographic conditions overlying each site. For example, there are large variations in planktonic foraminiferal $\delta^{13}C$, which vary symmetrically about the equator, as does the $\delta^{13}C$ of total CO_2 today. Some of the lowest $\delta^{13}C$ values come from sites which backtrack to equatorial latitudes, perhaps reflecting upwelling. Benthic foraminiferal $\delta^{13}C$ varies by as much as 1‰ within the North Atlantic during the Oligocene, unlike today when similar variability is only seen between deep basins. This probably reflects dramatically different Paleogene circulation patterns due at least, in part, to the absence of the Panama Isthmus as a barrier between the Atlantic and Pacific.