of carbonate-rock horizons at reasonable depths there.

Despite this selective use of BHT data, the geothermal gradient contours do not necessarily represent areal variations in heat flow. Since all the horizons charted are petroleum reservoirs (and in their updip reaches, some are also aquifers), hydrodynamics also must be involved. High gradient anomalies may thus be due to upwelling of basinal waters; low anomalies may be a result of recharge. Hydrodynamic influences also provide a local means for delimiting structures, with uplifts commonly being the loci of upwelling and thus registering relatively high geothermal gradients. High anomalies are even more consistently correlated with fault zones, as seen along the Luling-Mexia trend in south-central Texas where there is an overlap of gradient highs among the three horizons contoured.

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40 Ain't Over the Hill

Some exploration philosophies dictate "If it's not new—it's not good" when referring to seismic exploration data. Costs for new data acquisition have skyrocketed. With oil demand down, less money is available for exploration. Prudent exploration management judgment must now consider and use a variety of data sources. Existing seismic data (conventional or 100%) is a viable alternative. Ninety-five percent of exploration is for shallow, small structures. Conventional data is very effective at depths less than 15,000 ft (4,600 m), and its tight data grid allows for detailed exploration. Systems are in operation to enhance the 100% conventional data using modern computer technology. Data recorded in the early 1940s when enhanced by today's state-of-the-art technology, is comparable in many cases to recently acquired data costing as much as 100 times more; in some cases, the results are better. Considerable time, effort, and expense have gone into the acquisition of this mass of valid exploration data. It cannot replace modern CDP data in some areas, but it can complement many exploration activities while stretching exploration dollars.

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Cyclic Sedimentation Within Point Lookout Formation (Upper Cretaceous)—A Model for Strandline Progradation and Sandstone Distribution

The regressive marine Point Lookout Sandstone in the southeastern San Juan basin, New Mexico, was deposited under conditions of relatively low wave energy, moderate tidal strength, and locally moderate fluvial input. Two idealized coarsening-upward vertical profiles characterize the preserved lithologic record. The first profile, documenting strike-aligned sandstones dominated by wave processes, is composed of the upward progression: offshore mudstone—offshore transition mudstone to sandstone—lower shoreface sandstone—upper shoreface sandstone—estuarine sandstone. The second vertical profile, reflecting local fluvial input and dip-aligned sandstone bodies, is typified by the upward progression: offshore mudstone—offshore transition (prodelta) mudstone to sandstone—delta-front sandstone—estuarine and tidal distributary sandstone. In both profiles, subaerial beachface and shallowest marine lithofacies are rarely preserved due to erosion and replacement by estuarine sandstones during seaward strandline migration.

Basinwide regression of the Point Lookout formation consists of numerous small-scale asymmetric transgressive-regressive cycles. Mappable erosive and/or non-depositional surfaces characterize transgressive events which separate genetically equivalent progradational sandstones. Duration of these small-order cycles is broadly estimated in the range of 10^4 years, probably at less than 50,000 years each. Cycle geometry is dependent upon the interplay of sedimentation rate and submergence, such that sedimentation rate controls the down-dip progradational sandstone width, and submergence influences the total cycle thickness. Because differences in thickness within the overall Point Lookout formation result from variability in cycle overlap (stacking), an understanding of cycle geometry allows prediction of local stratigraphic pinchouts which may serve as stratigraphic traps for hydrocarbons.

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Relative Depth Position of Fusulinids and Ammonoids in Late Pennsylvanian Regressive Sequences in North Texas

Fusulinid foraminifers and ammonoid cephalopods occur in mutually exclusive positions in the regressive portions of Late Pennsylvanian cycles exposed on the eastern shelf of the Midland basin in north Texas. Ammonoids occur consistently in deeper water parts of the cycles than fusulinids do, and are common in phosphate nodule-bearing dark shales that occur immediately over transgressive limestones. Their abundance rapidly decreases upward in the overlying gray shales of the regressive sequence. Fusulinids are absent from ammonoid-rich dark shales, and first appear in overlying gray shales where ammonoids are rare and of small size. Fusulinids found in these strata are small juveniles, and not transported. Full-size fusulinids occur in overlying gray shales containing high diversity biotas. Concentrations of unabraded fusulinids occur in shales located at the margins of limestones and sand sheets in the mid portions of the regressive sequences, and are formed by current winnowing of mud or accumulation in areas of reduced sedimentation. Fusulinids are rare in unequivocal shoal-water deposits, occurring mostly as transported, worn, and fragmented individuals in sandstones capping regressive sequences. These occurrences suggest that fusulinids are indicators of moderate depth, mid-shelf environments in Late Pennsylvanian north Texas sequences, while ammonoids are indicators of deeper water environments. The lack of mature fusulinids in deeper water deposits containing small juveniles lends support to the conclusion that fusulinids contained symbiotic microalgae, and were restricted in life occurrence to the photic zone.

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Significant Trends in the Downstream Sector

The characteristics of the downstream sector of the petroleum industry have changed significantly over the past decade. This paper describes the reduction in supplies of overseas equity crude available to integrated companies, decline in consumption of fuel products, changing configuration of United States refineries to use heavy and sour crude, disappearance of subsidies for small refiners in the United States, changing structure of the crude oil market and crude pricing mechanisms, and the growing importance of petroleum futures markets. The paper also discusses effects of these changes, particularly as they relate to demand for and pricing of domestic crude oil, and draws conclusions regarding the future paths these trends may take, resulting changes that may occur in this sector of the industry, and possible effects on the exploration and production sectors of the industry.

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Cyclic Sedimentation in Middle and Upper Holder (Upper Pennsylvanian) Formation, New Mexico

The Middle and Upper Holder Formation (Upper Pennsylvanian), Sacramento Mountains, New Mexico, comprises terrigenous and carbonate facies that accumulated on a narrow open-marine to restricted-marine shelf. Differential subsidence of the shelf combined with eustatic sea level changes caused cyclic deposition.

Deposition began with a varying supply of terrigenous sediments from shifting delta lobes. Several carbonate facies, lateral equivalents of the terrigenous strata, are distinguished on the basis of their allochemical constituents. Bioclastic wackestones to grainstones with cortoids and oncoids characterize open-marine intervals. Laminoid-fenestral mudstones and wackestones with oncoids were common in restricted-marine intervals. Fusulinids and algal and peloidal grainstones are common marginal-marine facies. Restricted-marine sediments were deposited after clastic influxes and during marine transgressions.

The division between the Middle and Upper Holder members can be placed beneath a channel conglomerate an unconformity that developed on a restricted platform. Deposition of predominantly restricted-marine sediments with erosional clastic influxes characterize the Upper Holder. The upward increase both in reworked and encrusted allochems might

reflect regional changes in paleogeography that caused progressive exposure of the platform. Rates of sea level rise were high and punctuated by periods of decreased rates or near stillstand as indicated by restricted-marine and clastic deposition with unconformities. The duration of these stable periods of relative sea level increased through time.

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Future Petroleum Exploration Trends in Arabian Gulf Area

The Arabian Gulf Province has more than half the world's discovered oil. The undiscovered potential is perhaps equal to the oil already discovered, and includes enormous quantities of gas. This mature basin is not thoroughly evaluated; it will be carefully reappraised for its full potential. Future exploration and drilling should concentrate on the following: (1) deep unexplored Paleozoic rocks (prolific gas play in Permian Khuff and Cambro-Ordovician rocks on known structures); (2) extension of present pay zones to adjacent areas, and exploration for non-giant structures associated with the giant fields; (3) exploration for stratigraphic and other subtle traps by analysis of geologic data and special seismic processing and interpretation; (4) enhanced recovery from producing fields and of shallow heavy oil and low-grade deposits; (5) development of Oligocene-Miocene reservoirs in northern Gulf and Zagros areas for the discovery of new giant fields; (6) development of new geologic-sedimentologic concepts to evaluate source rocks, migration mechanism, reservoirs, and traps; (7) exchange of geologic, geophysical, and geochemical data among Arab countries, and regional petroleum exploration; (8) exploration in the vast areas of the Arabian basin that are not sufficiently tested (Rub al Khali and southern Iraq); (9) better production schemes, based on reservoir and simulation studies and advanced well logs and their evaluation; (10) evaluation of all horizons in presently producing structures; (11) exploration for new oil and gas reserves offshore in the Arabian Gulf; (12) production from fields with high potential that are sealed for economic and market reasons (i.e., the reserves are not commercial by area standards); and (13) exploration in the offshore area of the Arabian Peninsula on the Indian Ocean, which has barely been explored.

Future exploration will necessarily involve extensive drilling programs, and the risk of drilling dry holes will be relatively higher.

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Improved Recognition of Sedimentary Fabrics using Fluorescence Microscopy—Implications for Interpreting Carbonate Facies and Diagenetic History

Blue-light fluorescence microscopy applied to carbonate petrography can result in more accurate recognition of depositional facies, diagenetic history, and porosity evolution in some pervasively dolomitized or recrystallized limestones previously uninterpretable using existing petrographic techniques. Fluorescence microscopy also has other useful applications for the study of less diagenetically altered carbonates.

Preliminary observations establish that fluorescence microscopy potentially can: (1) make depositional grain types and textures visible in thin sections of massively dolomitized or recrystallized limestones; (2) identify or clarify diagenetic fabrics; (3) more precisely relate porosity evolution to depositional fabric and diagenesis; (4) provide a clearer understanding of the relative timing of diagenetic events (dolomitization, pressure solution, cementation, neomorphism) and their relationship to porosity evolution; (5) aid in the differentiation of carbonate cement from neomorphic spar, both for calcite and dolomite; (6) permit more rapid evaluation of mineralogical stabilization and neomorphism in Holocene and Pleistocene carbonates; and (7) improve delineation of porosity and pore geometries.

Fluorescence microscopy is a rapid, easily-used and nondestructive technique that requires no special sample preparation. As with standard staining techniques or cathodoluminescence, this tool does not work for all samples. However, when fluorescence microscopy is successfully applied to the study of carbonates, it elicits important information from a thin section that, in many cases, other standard petrographic techniques fail to detect. Based on its potential usefulness, fluorescence microscopy should become a routine tool for the petrographic evaluation of carbonates.

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Radiometric Dating of Wolfcamp Ground Water Using ^4He and ^{40}Ar

Hydrologic investigations of the Wolfcamp aquifer, Palo Duro basin, Texas Panhandle, report slow flow rates and long travel paths, which lead to a prediction of very old ages for the ground water. Because the expected ages are about 10 million years, many methods of dating ground water are unsuitable. The U, Th→^4He and $^{40}K \rightarrow {}^{40}Ar$ clocks are suitable. All ground water samples have large amounts of radiogenic ^4He and ^{40}Ar. Using these ^4He and ^{40}Ar data and a mixture of estimated and measured values for K, U, and Th contents, water-rock ratios, and release factors, the initial age estimate for the ground water is about 100 million years at two wells, Stone and Webster 1 Sawyer in Donley County, Texas, and Stone and Webster 1 Zeeck in Swisher County, Texas. At a third well, Stone and Webster 1 Mansfield in Oldham County, Texas, the concentrations of ^4He and ^{40}Ar are much higher, and the apparent ages are about 250 million years. Other isotopic and chemical data (δD, $\delta^{18}O$, Br/Cl) for ground water from this third well indicate a different origin and/or history. The current working hypothesis is that ground water sampled in the 1 Mansfield well is a mixture of meteoric water and a deep-basin ground water.

The ^4He ages for the 1 Sawyer well and 1 Zeeck well samples appear to be valid and are presently assigned errors of about a factor of two, determined almost entirely by uncertainties in U and Th concentrations and water-rock ratios. The ^{40}Ar ages remain suspect because data are currently too few to confirm or negate the possibility that a significant fraction of the ^{40}Ar is inherited from detrital minerals.

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Gamma-Ray Spectrometry of Marine Shales in Outcrop—A Tool for Petroleum Exploration and Basin Analysis

Gamma-ray spectrometry was conducted on outcrops of marine shale and chalk deposited in the Cretaceous Western Interior seaway. Study of the Cenomanian-Turonian Greenhorn cyclothem of Colorado, New Mexico, and Utah showed that profiles of gamma-ray spectra are useful in evaluating organic carbon content, interpreting paleoenvironments, and correlating otherwise homogenous sequences of marine shale. Gamma-ray spectra provide estimates of total gamma radiation and K, U, and Th contents. Th/U and K/U ratios can be used to estimate relative abundances of detrital minerals and organic matter, whereas the Th/K ratio is an indicator of clay mineralogy. Variations in these ratios reflect both local depositional processes and widespread events that can be correlated for hundreds of kilometers across lithofacies boundaries. Profiles of total gamma radiation can be used to help map shale facies. Spectrometer surveys can be used to show directions of sediment transport, to indicate proximities of paleoshorelines, and to aid in estimation of lateral and temporal variations in paleosalinity. Outcrop profiles can be compared directly with well logs of gamma-ray spectra.

Gamma-ray spectrometry of shale outcrops is a versatile technique. Results can be interpreted in the field, the sampling program can be modified as it progresses, and the effects of event deposits such as bentonites and bone beds can be characterized. If lead shielding is used to keep sample mass and geometry constant, reproducible results can be obtained even from shales that contain below-average concentrations of K (< 2%), U (< 2 ppm), and Th (< 10 ppm).

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Dolomitization Patterns in Subtidal Bighorn Dolomite (Upper Ordovician), Southeastern Wind River Range, Wyoming

The Bighorn Dolomite, which is 38–53 m (125–174 ft) thick, lies disconformably between the Cambrian Gallatin Limestone and Mississip-