equivalent depths in most of the Palo Duro basin are only marginally mature.

Although thermal maturity seems to be mirrored by the present geothermal gradient, and source rock quality appears related to depositional setting (depth of water), successful exploration outside currently productive areas will require a detailed analysis of organic geochemistry and depositional facies.

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Pore Size Distributions by Analysis of Back-Scattered Electron and Fluorescence Images

Computerized image analysis provides direct, rapid, and highly accurate measurement of pore size in thin or plane sections. The method can be applied to a wide range of rock types and requires only conventional sample-preparation techniques. Back-scattered electron or fluorescence microscopy images of impregnated samples are scanned, converted to digital form, and stored and processed on a microcomputer. Individual picture points from a matrix of up to 600,000 elements per scan are classified as rock or pore based on gray level. Pore size is obtained by area measurements of individuals pores and by Feret's diameter, the maximum spacing between parallel tangents to a pore in up to 56 directions. The measurements are readily summarized as pore size distributions.

Cumulative porosity vs. pore diameter crossplots indicate how porosity is distributed and can be used to aid reservoir evaluation and production assessment. The crossplots can also be used to determine the amount of porosity contributed by different pore types. Individual pores, or groups of pores classified by size or shape, can be interactively identified on the image analyzer monitor, enabling the user to make a visual association of pore type with size. Rocks having a wide range of pore size can be analyzed at more than one level of magnification, and the data can be merged to form a composite pore size distribution for the sample.

Pore size distributions of carbonate rocks containing complex pore systems show changes in slope that are indicative of pore type. Other carbonates, including fine crystalline dolomites and microcrystalline limestones, show relatively uniform pore size distributions, which reflect a single pore type.

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Paleozoic Producing Sequences in Ghadames Basin of Libya, Tunisia, and Algeria: New Stratigraphic Concepts for Hydrocarbon Exploration

The Ghadames basin covers an area of more than 3 million km^2 in Libya, Tunisia, and Algeria. Although the basin has been productive since the mid-1950s, recent construction of a pipeline in western Libya has spurred additional exploration. The results of this increased drilling activity and the incorporation of earlier work have provided new data that indicate the following. (1) The clastic sequence underlying the Tanezzuft shales has porous and permeable fairways that may be related to the Hogar glaciation to the south. (2) The clastic sequence overlying the Tanezzuft shales was deposited as a northerly sourced fluvial-deltaic clastic wedge, which thins and becomes less porous to the south. Only in the area of the Gargaf arch does this sequence become cleaner and more porous; there, a shoreline-sand depositional sequence dominates. An easterly source of the clastics is indicated.

With the lack of large structures in the basin, the facies model presented here for the depositional history provides indications of more productive porous and permeable fairways.

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Marine Diagenesis on Enewetak Atoll

Marine waters currently circulate through Eocene and Miocene limestones deposited in slope, fore-reef, and reef-related environments on Enewetak Atoll. Subsurface core samples (375-1,400 m deep) demonstrate that marine waters have extensively altered the original carbonate sediments. Evidence supporting alteration by marine water includes: (1) calcite cements with isotopic compositions characteristic of a marine origin ($\delta^{13}C$ = 1.3 to 2.5 ‰; $\delta^{18}O$ = −1.8 to 0.4 ‰ PDB), (2) dolomites with average isotopic compositions that are in equilibrium with cold normal-marine waters ($\delta^{13}C$ = 2.3 ‰; $\delta^{18}O$ = 2.5 ‰ PDB), (3) consistent magnesium concentrations in fossil coralline algae, and (4) a lack of diagnostic evidence for meteoric diagenesis. Products of marine diagenesis on Enewetak Atoll are dependent on the $CaCO_3$ saturation state of the diagenetic waters. Above the aragonite saturation depth (350 m), marine diagenesis is dominated by aragonite and high-magnesian-calcite cementation. Between aragonite and calcite saturation depths, marine waters apparently have dissolved aragonite and precipitated low-magnesian, radiaxial calcite cements. Below the calcite saturation depth (1,000 m), deep marine waters have apparently dissolved some calcite and have precipitated dolomite. Effective marine diagenesis requires limestones with good permeability and a hydraulic drive, such as tidal pumping or thermal convection, to move large volumes of marine water through the rock.

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Computer Mapping of Silurian Pinnacle Reefs in Northern Michigan

Current availability of high-quality well completion records accessed via computer data bases in Michigan has allowed further exploitation of the northern Michigan reef trend. Integration of these data with computer mapping enables investigation of large regions in terms of structural and stratigraphic relationships. Inferiority of subsea structure maps is clearly demonstrated because of contamination by irrecoverable surface elevation errors. Use of thickness maps of reef units and Middle Silurian salt deposits has resulted in delineation of new regional reef patterns and an increased resolution of local reef development. Case studies from the Michigan reef trend demonstrate the use of "play maps," where computer-generated maps are constructed in yearly intervals to test exploration strategies for less developed regions.

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Thermal History of Sandstones and Shales: Oxygen Isotope and K/Ar Evidence

The combined use of oxygen isotope and K/Ar dating can yield information about the diagenetic history of clay minerals in shales and sandstones. In the Tertiary shale sequences of the United States Gulf Coast, in which the dominant detrital clay mineral is mixed-layer illite/smectite, the progressive conversion of expandable clay layers to illite layers can be monitored by the isotope systematics. Oxygen isotopes of fine-grained clay and quartz approach equilibrium with one another, raising the (as yet unrealized) possibility of an O-isotope geothermometer. Fine-grained quartz becomes isotopically zoned as detrital grains are overgrown by diagenetic quartz that forms, accompanying the smectite-to-illite transformation. The K/Ar clock of the diagenetically formed illite layers is set to zero age at the time of diagenesis (although that of existing illite layers within the crystals remains unaffected), and it is therefore possible to estimate the mean time of diagenesis in such shale sequences.

Illite is a common cement in sandstones. The time of cementation by illite can be estimated from K/Ar systematics in cases, such as that of the Permian Rotliegendes of the North Sea, where the clay-sized fraction of the original detritus was relatively free of illite or other K-bearing phases. Conditions of cementation can be inferred from oxygen isotope measurements, augmented by knowledge of the geologic/tectonic history of the sandstone. In the case of the Rotliegendes, the timing and conditions of illite cementation were relatively uniform within fault blocks but varied from block to block. Oxygen isotope measurements indicate that meteoric water components were important in illite formation at times when nearby sections of the Rotliegendes were exposed to the surface by uplift and erosion.

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Crust Type and Structure, Northern Gulf of Mexico: an Ocean Bottom Seismograph–Air Gun Seismic Transect

In November to December 1983, the University of Texas and the U.S. Geological Survey conducted a seismic experiment that attempted to measure crustal and upper mantle depths and velocities along a transect of the Gulf of Mexico south of Galveston, Texas. The transect is composed of 5 along-strike lines spaced to span the continental shelf and slope and reaching the deep basin. Two 2,000-in.^{3}, 2,000-psi air guns were fired simultaneously at 30-sec intervals at 5 knots for a shot spacing of 77 m. The signals were recorded by digital ocean-bottom seismographs with vertical geophones. Four seismographs were placed along each 90-km line. The seismic sections obtained are densely sampled and fully reversed, about half showing seismic arrivals at the full range of the line.

We find that the deep Gulf of Mexico is, as expected, underlain by oceanic crust. On the outer slope, we see deeply penetrating arrivals from below thick salt, and we find that this crust is thicker than the oceanic crust. North of the thick salt, we see the crust thinning to nearly the thickness of oceanic crust. Although this crust may be seismically indistinguishable from oceanic crust, we believe it to be highly extended continental crust. We interpret the two northern lines to show northward thickening, extended continental crust.

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Micropaleontology, Textural and Isotopic Characteristics of Turbidites on Continental Slope and Rise off Newfoundland

Graded turbidite deposits observed in x-radiographs of gravity and piston cores collected from the lower slope and rise (2,300-3,210 m) occur below a well-documented 9,300 y.B.P. ash zone. The largest turbidite observed on the upper rise is 35-cm thick. C^{14} dates of foraminifera tests from intervals above and below this deposit average about 13,000 y.B.P. suggesting deposition during late glacial time. The base of this deposit is marked by a textural change to comparatively coarse sediments. It is also marked by an anomalous concentration of foraminiferal species (up to 50%) belonging to the miliolid family, that constitutes 2-4% of modern assemblages. A pronounced increase in the percentage of *Valvulinaria artica* in the turbidite suggests a middle-slope source. The thinner gravity flows (10-15 cm thick) that occur in the deeper sections of the upper-rise cores have extrapolated C^{14} ages of less than 22,000 y.B.P. Their foraminiferal assemblages suggest outer-shelf to upper-slope sediment sources.

A comparatively thick (150 cm), graded turbidite sequence of unknown source occurs on the lower slope, just above ash zone 2 (approximate age is 64,000 y.B.P.). The related turbidity-current event apparently took place during the latter part of isotope stage 4. Texturally, this sequence is similar to the 35-cm thick upper-rise turbidite, but it lacks the anomalous concentrations of foraminiferal species in its basal interval. Oxygen isotope values (sinistral *N. pachyderma*) are relatively homogeneous throughout the sequence at a value of +3.75 ppt compared to +2.75 ppt for the upper Holocene section of the core.

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Tectonic Evolution and Hydrocarbon Prospects of Tunisia-Sicily Shelf

The stratigraphic evolution, structural styles, and principal hydrocarbon prospects of the Tunisia-Sicily shelf are all linked to the crustal "template" created during the middle Mesozoic rifting of the Tethyan margin of North Africa. Transtensional stretching and fragmentation of the Tunisia-Sicily shelf during the Late Triassic to Jurassic at the junction of the south Sahara and Gilbraltar fracture zones created a complex array of ridges and furrows and localized pull-apart basins. This block-faulted shelf region was buried during the Cretaceous and early Cenozoic beneath a cover stratigraphy that ranged widely from a thin pelagic limestone succession devoid of terrigenous components in Sicily to a considerably thicker neritic Tunisian succession containing terrigenous and carbonate rocks. Differences in stratigraphic character across the shelf relate to the relative position of Sicily and Tunisia between the unstable and subsident Tethyan margin and the stable and emergent Saharan platform. As the North African continental margin subducted northward beneath the accretionary Kabyle-Calabrian belt in the late Cenozoic, the thin carbonate successions of Sicily responded by detaching in a series of southward-migrating thrust sheets. Along strike in Tunisia, the thrust sheets die out and stress was taken up by folding the thick marly succession weakened by numerous Late Triassic evaporite diapirs. Despite differences in structural style, the orientations of the structures in both Tunisia and Sicily have been guided by the crustal template created by middle Mesozoic rifting.

Hydrocarbons on the Tunisian-Sicily shelf are related to (1) Mesozoic or younger structures that deform the early Paleozoic black shale–orthoquartzite succession of the Saharan platform, (2) synrift anoxic basin facies, (3) the Cretaceous–early Cenozoic shelf margin in the Tunisian section, and (4) late Cenozoic synorogenic clastic facies.

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Structural Style, Stratigraphic Variability, and Hydrocarbon Traps in Gulf of Suez

Hydrocarbon traps in the Gulf of Suez, whether of a structural or a stratigraphic type, fundamentally are all products of the highly complex late Cenozoic fault-block mosaic. Understanding the geometry and the evolution of this tilt-block mosaic is the key to further successful exploration in the Gulf.

The major faults forming the Gulf of Suez basin are listric normal faults broken along strike by synchronous cross faults that serve as transform or "transfer" structural elements. The cross faults are a consequence of the inability to form uniform and laterally continuous listric fault surfaces within the mechanically anisotropic and inhomogeneous crystalline basement terrane of the Gulf. The combination of contemporaneous Gulf-parallel listric faults and cross-strike "transfer" faults gives rise to the complex mosaic of polygonal tilt blocks. Vertical variations in the structural behavior result from a synrift stratigraphy dominated by thick marls and evaporites. The ductile synrift rocks exhibit shallow secondary detachments, drape folds, and compaction and/or diapiric structures that are decoupled from, but appear controlled by, the brittle underlying basement-rooted tilt-block mosaic.

Lateral stratigraphic variability observed in the Gulf is the consequence of sea level rising and falling relative to the higher structural elements in the tilt-block mosaic. This has resulted in deeply eroded basement highs, clastic apron and perched reef reservoirs associated with the highs, and thick organic-rich marl accumulations in the intervening lows that serve as "kitchen" areas.

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Remote Detection of Anomalous Mineralogy Associated with Hydrocarbon Production, Lisbon Valley, Utah

Diagenetic mineral assemblages within the Wingate formation are closely associated with hydrocarbon production at Lisbon Valley, Utah. The Wingate formation, exposed along the southwestern flank of the anticline, has a relatively uniform composition and appearance over the entire Colorado Plateau, except at isolated localities such as Lisbon Valley, where it is locally bleached. Previous workers have suggested that hydrocarbon microseepage may account for bleaching of the Wingate Sandstone and the presence of uranium mineralization in outcrops overlying the reservoir at Lisbon Valley. Using broad-band, Landsat Multispectral Scanner (MSS) and airborne Thematic Mapper Simulator (TMS) data, the bleached facies was mapped on the basis of brightness and lack of ferric iron. Examination of the TMS data provided further discrimination of bleached facies because relative abundances of clay minerals are detectable with this sensor.

Analysis of high-resolution airborne spectroradiometric data, thin sections, and x-ray diffraction suggests that the bleached rocks overlying the reservoir at Lisbon Valley contain abundant kaolinite and minor amounts of feldspar. Unbleached exposures contain substantially less clay and abundant feldspar.

This study shows a correlation between the abundance of clay minerals, particularly kaolinite, and hydrocarbon production at Lisbon Valley. Because one of the principal differences between the bleached and