sequences. By activating and deactivating elements at various stages in the computation process, the sequential deposition and erosion during evolution of a sedimentary basin can be modeled. Simulated results indicate that excess fluid pressure occurs when a basin is progressively loaded by overlying sediments. An excess pressure gradient will cause pore fluid to flow vertically and horizontally, depending upon the regional stratigraphy and structure, toward the sediment surface. In sandstone-shale sequences, pore fluid in shales tends to flow toward adjacent sandstones, increasing the effectiveness of petroleum accumulation. The downward flow from overlying shales to sandstones, plays an important role in providing resistence to the upward migration of petroleum. The concentrated fluid flux in sandstones tends to flow parallel to the bedding plane toward highest positions of permeable strata, such as crests of anticlines, pinch-outs, or outcrops. Although the orogenic deformation further compresses sediments initially, the subsequent erosion rapidly reduces excess pressure and causes the invasion of meteoric water.

This study suggests that numerical modeling is an effective technique in evaluating histories of subsurface flow, sediment compaction, and petroleum accumulation.

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Analysis of Amplitude Versus Offset to Detect Gas/Oil Contacts in Arabian Gulf

The theoretical behavior of P-wave reflection amplitude as a function of incidence angle (offset) indicates that diagnostic changes should be spatially observable when crossing boundaries between different formation fluids. In particular, when free gas is present in porous sand, Poisson's ratios are known to be abnormally low (usually <0.1-0.2), whereas for oil and water the ratios are usually much greater than 0.3. If the overlying layer has an impedance and Poisson's ratio greater than the target layer, the reflection amplitudes will increase with offset, thereby producing bright spots in stacks.

The problems in analyzing seismic amplitudes are well known. The distortions produced in the recorded amplitudes owing to the effects of sources and receivers, instrumentation, processing, attenuation and absorption, layer tuning, multiple interference, and noise can render the measurements meaningless unless corrected for, which would be difficult. However, by using relative instead of absolute amplitudes and by applying suitable analysis techniques, most of these effects can be virtually eliminated. The resulting amplitude behavior can then be properly interpreted in terms of changes in formation properties.

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Bore-Hole Seismic Profiles in Ekofisk Field

In October 1983, a major bore-hole seismic survey was carried out in the Ekofisk oil field in the Norwegian sector of the North Sea on behalf of the Phillips Petroleum License 018 group of companies. A conventional deviated well VSP and 3 multilevel walkaway seismic profiles were acquired in an area showing poor surface seismic returns owing to gas charging in the overlying sediments.

Processing the data through to a series of conventional common-midpoint sections permitted detailed interpretation of the top of the Ekofisk formation and the top of the Tor formation away from well control. Both formations are producers separated by a tight zone. The Tor formation is the primary zone to waterflood, and information about its lateral continuity is important in the location of proposed water-flow injector wells.

A probably fault-controlled lineation subparallel to the bore hole was detected by the surveys. Reflections from below the reservoir formations are evident, and a by-product from the survey is strong evidence for the existence of apparent anisotropy in velocity or lateral velocity gradients.

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Siliciclastic Incursion in Southern Florida and Development of Florida Reefs During Late Cenozoic

Only one major interruption has occurred in the long history of shallow-water carbonate deposition that has prevailed in southern Florida since the Jurassic. This break resulted from a substantial incursion of the finer siliciclastic sands interbedded or mixed with surprisingly coarse quartz sands during the late Cenozoic. Along the southeastern margin, this influx was succeeded by the development of reefs during the Quaternary.

The siliciclastics occur in the subsurface beneath a section of Pliocene to Holocene shallow-water carbonates. Recent study of well samples shows that these sediments are thickest (120-200 m) along a north-south trend that extends from the central part of southern Florida to the upper Florida Keys. These sediments are largely composed of quartzose grains ranging in size from very fine sand to granule (0.06-4 mm), with minor proportions of calcareous clays, phosphatic grains, and marine faunal fragments. The medium sand to granule-sized sediments are composed of well-rounded quartzose grains and occur either interbedded or mixed with finer fractions.

The sudden influx of siliciclastics in southern Florida beginning in the Miocene is quite unexpected considering the remoteness of the Appalachians, the postulated source. This southward transport may have been accomplished by rivers and/or longshore currents. The siliciclastic section extends southward slightly beyond the curving arc of Quaternary reef deposits. The coincidence of the southeastern edge of siliciclastics with the arc of Quaternary reefs suggests that reef development may have been localized on the siliciclastic margin.

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Alaska—an Explorationist's Jambalaya

Seaward growth of Alaska since Jurassic time has resulted from terrane accretion and deposition of thick clastic sequences in successor basins. Post-accretionary strike-slip faulting and rifting have fragmented both newly accreted terranes and older continental rocks. Accretion and dispersion have resulted in a jambalaya of geologic units that may be viewed in the context of terrane analysis. This offers a spectrum of opportunities and problems for exploration.

Large continental fragments (e.g., North Slope, Nixon Fork, and Tatonduk terranes) consist predominately of Paleozoic rocks with relatively continuous stratigraphy and the greatest potential for regional source and reservoir trends. Other exploration targets may include continental rocks beneath oceanic terranes (e.g., Kagvik, Angayucham, Innoko, and Tozitna terranes), which occur as extensive, relatively thin thrust sheets. An island-arc terrane, the Peninsular terrane, has acted as a source both of hydrocarbons from its organic-rich oceanic sediments, and of reservoir-quality deposits shed into the Cook Inlet successor basin. Post-accretionary rifting and strike-slip dispersion of the growing continental framework of Alaska have resulted in formation of a series of basins filled with clastic sediments, including the Bering Sea and Interior basins, which are current targets for hydrocarbon exploration.

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Thickness Trends and Structure of Berea Sandstone (Mississippian) in Washington County, Ohio

The Berea Sandstone has been a drilling target for hydrocarbon production in Ohio for over 100 yr. Although extensively produced, the Berea still rewards the driller with new commercial production. Due to its shallow depth and low cost of completion, the Berea has undergone a renaissance in interest in recent years. This paper presents the results of a study of more than 3,500 geophysical and driller's logs in Washington County in southeastern Ohio. Structure contours show major trends, such as the Burning Springs anticline and the Cambridge arch, trending almost north-south. In the western third of the county, structural trends change, however, to a more complex, less continuous pattern with a predominant northeast-southwest trend. Isopach trends delineate a system of channel sands trending roughly east-west with sandstone thicknesses ranging from 0 to greater than 25 ft (8 m). Both structures and thalwegs are relatively narrow and thickness changes rapidly, both parallel to and normal to the thalweg. Although no new interpretations of Berea structure or depositional environment is intended, this study graphically shows that even in a mature province, low-cost, closely spaced data can indicate new minor structures and delineate new areas for profitable and productive testing with the drill.

CLAYPOOL, GEORGE E., and CHARLES N. THRELKELD, U.S. Geol. Survey, Denver, CO

Methane Hydrate in Slope Sediments on West Coast of Central America

Offshore Mexico and Guatemala slope sediments are classic sites of deep-sea gas hydrate occurrence. Gassy, frozen sediment was recovered in cores from this region on Legs 66, 67, and 84 of the Deep Sea Drilling Project. In addition, a massive 3 to 4-m thick layer of nearly pure methane hydrate at a depth of 250 m was cored on Leg 84 and preserved for study. The gas from the hydrate is 99+ % methane with a few tenths percent carbon dioxide and traces (10^{-4} v/v) of ethane. Most of the sites with gas hydrate in the sediments have methane with $\delta^{13}C$ of -70 to -60 ‰, indicating origin from methane-generating bacteria. The massive gas hydrate contained methane with $\delta^{13}C$ of -40 ‰, and the surrounding sediment had bicarbonate in the pore water with $\delta^{13}C$ of $+35$ ‰. The 75 ‰ separation in $\delta^{13}C$ between coexisting methane and bicarbonate is consistent with kinetic fractionation during bacterial reduction of carbon dioxide to methane, with continuous replenishment of carbon dioxide by fermentation processes.

The areal extent of the massive gas hydrate is not known, but the single point yields a gas-in-place estimate of 5.2×10^8 m^3/km^2 or 48 bcf/mi^2.

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Applications of Geochemistry to Production, Storage, and Use of Natural Gas

Geochemistry has become a standard tool in the exploration for oil and gas. Many of the concepts and techniques developed for exploration can be used with equal effectiveness in identifying environmental problems related to the production, storage, and use of natural gas.

Contamination of shallow aquifers as a result of improperly completed gas or oil wells is a problem in some areas. Similarly, gas which has migrated from underground gas-storage reservoirs also can contaminate shallow aquifers. Many shallow aquifers contain relatively high concentrations of microbially generated methane, and therefore detection of hydrocarbons is not sufficient to determine the source of the gas. Although microbial gas can frequently be distinguished from thermogenic gases by the absence of ethane and heavier hydrocarbons, migration through hundreds or thousands of feet of porous sediments can result in changes in the chemical composition of the gas, analogous to the changes that occur as gas passes through a chromatographic column. Therefore, the absence of heavier hydrocarbons is not always an indicator of source. Carbon isotopic composition of methane, however, appears to be relatively unaffected by migrational changes and can generally be used to distinguish between microbial and thermogenic methane.

Questions also frequently arise as to the source of gas from gas and oil wells around the margins of gas-storage reservoirs. Although chemical analysis can sometimes be useful in distinguishing between storage gas and native gas, these gases are sometimes chemically quite similar. In the event that the gases cannot be distinguished chemically, determination of the carbon and/or the hydrogen isotopic composition of the methane may still provide positive identification.

Gases generated in sanitary landfills or marshy areas sometimes can be interpreted as being the result of leakage from pipelines. In addition to the techniques already mentioned, radiocarbon dating of methane can be used to identify gases from these sources.

COLEMAN, JAMES L., JR., Amoco Production Co., New Orleans, LA

Stratigraphic Evolution of Paleozoic Erathem, Northern Florida

Unmetamorphosed Paleozoic sedimentary and volcanic rocks have been drilled in numerous wells throughout northern Florida and southern Georgia, in what is today a gently folded and block-faulted relict continental fragment of northwest Africa and northeast South America. Stratigraphic and lithologic equivalents of these North American Paleozoic units are prolific hydrocarbon producers in North Africa.

The northern Florida Paleozoic sediments were deposited on Pan-African and Cadoman basement. Widespread continental glaciation from late Precambrian to Early Cambrian introduced a thick sequence of fine-grained marine sandstones ("glacial flour"), which overlie medium to coarse-grained glaciofluvial sandstones. Basinward of the sand shelf, the accretion of a volcanic island arc complex began during the Ordovician. A fluctuating transgression, accompanying a major glacial minimum, brought open-marine, graptolitic, black shales onto the sand shelf, producing an interbedded shoreface-shelf sand and black shale section during the Middle and Late Ordovician. At the Ordovician-Silurian boundary, renewed continental glaciation lowered sea level, producing a widespread unconformity. A Late Silurian major marine transgression returned black, graptolitic, highly organic shales onto the sand shelf. Devonian deltaic sands from Avalonia(?) to the north and the craton to the south closed the Paleozoic sedimentary record of northern Florida.

COLLETT, TIMOTHY S., U.S. Geol. Survey, Menlo Park, CA

Evaluation of Local Geothermal Gradients on North Slope of Alaska

The U.S. Geological Survey is conducting a detailed assessment of worldwide natural-gas hydrate occurrences. Thermodynamic conditions controlling hydrate occurrences of northern Alaska have been examined. Pressure and temperature conditions on the North Slope indicate that hydrates would be potentially stable both above and below the permafrost base. Geothermal gradients needed to predict the thickness of the hydrate stability zone are not easily obtained. A survey of preliminary data suggested wide variations in averaged regional geothermal gradients across the North Slope.

To evaluate regional variations of geothermal gradients, 2 techniques were employed to calculate local gradients. The first method used bottom-hole temperatures recorded during successive wireline logging runs and corrected by Horner crossplots to determine undisturbed formation temperatures. The Horner crossplot method requires a series of recorded bottom-hole temperatures. However, in most of the North Slope production wells, only 2-3 log runs are conducted per well, thus limiting the number of bottom-hole temperatures. To overcome this limiting factor, a second method has been developed to evaluate local geothermal gradients. This new technique uses permafrost depths delineated from well-log data to project geothermal gradients. Gradients within the permafrost zone have been projected from the base of permafrost, which is in equilibrium at $-1°C$. A series of mean ground temperatures has been used to project the upper extent of each gradient. Geothermal gradients change abruptly at the base of the permafrost. In order to calculate the gradient below the permafrost base, a constant generated from subsurface temperature data was used to correct for this change in geothermal gradient. Data from 398 wells were examined by each method to develop a series of geothermal gradient maps. The gradient maps generated by the 2 methods compare favorably; trend-surface comparisons indicate a high degree of similarity.

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Post-Laramide Uplift and Erosional History of Northern Wind River Basin, Wyoming

Landsat Thematic Mapper (TM) multispectral scanner images together with aerial photographs have been used to infer Laramide to Holocene tectonic events along the northern fringe of Wind River basin near Wind River Canyon, Wyoming.

TM images reveal the presence of a large system of alluvial fans, terraces, and residual tongue-shaped debris deposits covering an area of 90 mi^2 at the base of Copper Mountain. The debris system contains predominantly dark metasedimentary clasts. Both Eocene (Wind River and Wagon Bed Formations) and Quaternary deposits are present, and some Eocene gravel has been reworked into the later units. These deposits contrast sharply in brightness and color with rocks in adjacent areas.

Detailed topographic analysis of the terraces and fan remnants disclosed an episodic history of post-Wagon Bed (upper to middle Eocene)