AMBs ranged from 5 to 90 cm in diameter and were spherical to ovoid with alternating internal layers of clay and limestone clasts (lithologically identical to stream gravels). AMBs were most commonly found lodged in the upper 1-3 cm of the mudflow; a few lay in the stream bed adjacent to or downslope from the flow. The majority of AMBs were concentrated near the toe of the mudflow. AMBs appeared to have been produced by a combination of rolling along the stream channel and "rafting" by the mudflow.

Observation of the mudflow and AMBs after 10 hr of steady rainfall revealed the mudflow to be intact, but all except the largest AMBs were reduced to piles of limestone clasts lying on top of the mudflow.

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Hydrodynamic Systems of Orthoconic Nautiloid Cephalopods: Independent Check on Phylogeny

Seldom is it possible to use direct evidence of the physiology of extinct marine organisms as a means of investigating the phylogenetic relationships at any taxonomic level. Hydrodynamic mechanisms of orthoconic cephalopods are an exception because the form and structure of aragonite deposits used as hydrodynamic devices reflect the genetically controlled physiology of the animal. Data on cameral and siphuncular deposits (hydrodynamic devices) of Pennsylvanian (Desmoinesian/Westphalian C) orthocones from the Boggy Formation (= Buckhorn asphalt) of southern Oklahoma provide a test of existing phylogenetic relationships established by standard paleontological methods. The analysis reveals that early growth stages of many taxa considered to be related at the family level have similar to identical morphologies of cameral deposits, while some do not. In all cases, the form of the cameral deposits changes among taxa during later growth stages. In one case, congeneric taxa are shown to belong to different genera on the basis of gross differences in deposits designed to function hydrodynamically.

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Depositional Facies, Diagenesis, and Reservoir Quality of Ivishak Sandstone (Sadlerochit Group), Prudhoe Bay Field

The Sadlerochit Group is a large fan-delta system comparable in size to the modern Kosi River wet alluvial fan of Nepal and India. Braided-stream processes distributed chert gravel and quartz and chert sand in radial fashion to construct the subaerial part of the fan delta. Fluvial energy, slope of the fan surface, and grain size decrease in a north to south basinward direction. There is also a decrease in scale of sedimentation units from source area seaward. Facies of the subaerial fan delta can be broadly categorized as midfan delta (alternating conglomerate and sandstone), distal fan-delta (chiefly sandstone), and abandoned channel-fill, overbank, and pond facies (mudstone, siltstone, fine-grained sandstone). Seaward of the subaerial fan delta are the delta-front and prodelta facies. Subaerial fan-delta and delta-front facies compose the Ivishak sandstone, which grades basinward into the Kavik shale, a prodelta facies. Diagenetic effects were gradually superimposed on the sediments deposited in the Sadlerochit fan-delta system. The sedimentary facies, and in particular their textural characteristics, seem to control the side and degree of diagenesis, including enhancement of porosity and permeability. Comparison of permeability trends among the facies of the Ivishak sandstone with permeability patterns displayed by unconsolidated sands with analogous grain size and texture, indicates that the general trends that existed in the Ivishak sediments are still recognizable in spite of the diagenetic overprint.

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Continental Slope Morphology in Northern Gulf of Mexico Mapped with Long-Range (GLORIA) Side-Scan Data

GLORIA II long-range side-scan data provide a mosaic of the continental slope in the northern Gulf of Mexico, seaward of the Texas-Louisiana coast. A swath as wide as 30 km and a 10% overlap of the data between parallel track lines provide a continuous picture of the complex slope morphology, which is largely controlled by salt deformation. Morphologic features range from piercement structures approximately 2 km in diameter to basins as much as 30 km across. The GLORIA data delineate the East Breaks submarine slide, where surface lineations are suggestive of deformation features. High-resolution 10 kHz seismic-reflection profiles indicate that the very irregular surface on the slide has a relief of 10 m. The 3 types of intraslope basins (blocked canyon, interdomal, and collapse) described by A. H. Bouma can be identified on the GLORIA data. The walls of Gyre basin, an example of a blocked canyon, have what are interpreted to be gullies, which are commonly associated with submarine canyons. Another basin downslope has similar gully-like features on the walls, which suggest that it may have been part of the original canyon system. Although many canyonlike features direct the movement of sediment downslope, the present data show that all conduits end in closed basins. No system of basins can be shown to transport sediment across the entire slope between the Mississippi Canyon and the East Breaks slide. Small-scale slumps, which can be identified on the flanks of some of the diapiric structures, also contribute sediments to basins such as Gyre basin.

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Near-Surface Methane Anomaly over Shallow Foley Gas Field, Baldwin County, Alabama

The shallow Miocene stratigraphic gas field discovered near Foley, Alabama, in late 1979, afforded an excellent opportunity to test whether gas from an accumulation seeps upward through overlying "impermeable" beds in adequate concentrations for detection in the near surface. In mid-1980, when this survey was done, several confirmation wells had been drilled, but the field was not yet producing.

Samples were collected from the bottom of 10-ft holes drilled on a rough 0.5 mi grid and were quickly sealed in gas-tight containers for later analysis. At several sites, sampling was done from grass roots down to 15-20 ft. At sites where the deeper samples had anomalous concentrations of gas, there was virtually no gas from the surface down to 6-8 ft. Below this, where anomalous gas concentrations were encountered, they tended to increase gradually downward. This confirmed previous conclusions that sampling for near-surface surveys should generally be done at 10 ft.

Gas contents of survey samples ranged from 3 to 87 parts per million by volume, and it was virtually all methane (i.e., identical with the gas at Foley). Probability plots revealed a background population with a mean of 10 parts per million, with values above 20 ppm being anomalous. The mapped and contoured anomaly has a striking correspondence to the outline of the field determined by later drilling. These results show that near-surface hydrocarbon surveys can sometimes detect microseepage from petroleum reservoirs and that such surveys can be valuable in exploration.

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Migration and Maturation of Hydrocarbons—Evidence from Fluid Inclusions

Oil-filled fluid inclusions occur in cements in petroleum reservoirs and are evidence for the generation and migration of hydrocarbons in a basin. Generally, oil-filled inclusions occur together with aqueous inclusions in the same cement crystal. Geothermetric studies of the aqueous inclusions provide thermal and compositional data pertinent to interpreting the time of cementation and hydrocarbon migration relative to source rock maturation.

Oil-filled inclusions occur both in random locations and in alignment with crystal cleavages or fractures. Random distributions of fluid inclusions suggest oil entrapment during growth of the cement crystal into primary porosity whereas the occurrence of fluid inclusions along sealed fractures suggests migration through secondary porosity. Generally, the oil-filled inclusions consist of liquid hydrocarbon and a gas phase, but inclusions containing oil, water, and gas also occur. Those different compositions suggest differences in the migration and mechanism of petroleum.

Oil-filled inclusions are characterized by fluorescence spectra. In many cases, different episodes of hydrocarbon migration are indicated by the occurrence in the same crystal of oil-filled inclusions whose fluorescence spectra are different.

The organic chemical compositions of aqueous and oil-filled inclusions are determined by decrepitation-gas chromatography. Those compositions are compared to organic compositions of whole reservoir rock, reservoir oils, and source rock to decipher the history of oil emplacement and maturation. Oil alteration effects, possibly induced during the early stages of migration, are also detected.

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Petroleum Resources of North American Arctic Basins

Seven geological provinces considered to be highly prospective for hydrocarbon accumulation are known to exist in the North American Arctic, extending from the Wandel Sea in the east to the Chukchi Sea in the west. Each of the provinces contains thick sedimentary sections, identified source rocks, and favorable trapping configurations that have known or probable hydrocarbon accumulations. Sediments range in age from the early Paleozoic rocks of the Arctic stable platform to the late Tertiary and Holocene sediments of the Beaufort Sea.

Active exploration to date has been limited to the Alaskan Arctic Slope, Mackenzie Delta-Beaufort Sea, and Sverdrup basin where exploration activity has been largely focused around several significant discoveries. Relatively sparse drilling has tested hydrocarbons in the Arctic stable platform and Franklinian geosyncline regions, although no major accumulations have been identified. Wandel Sea and most of the Baffin Bay basin have yet to be tested by drilling.

The range of estimates of undiscovered potential must reflect a high level of uncertainty for most of these provinces until such time as exploration drilling has tested not only the current targets but also some of the completely untested plays. Because of the constraints imposed by hostile environments, remoteness of location, and costs of operations, none of the provinces has received the exploration effort commensurate with their geological prospectivity.

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Late Tectonic History of Beaufort Sea-North Pacific Area

The Kaltag fault (and its northern associated splay, the Rapid fault array) is the sheared suture between the Eurasian-Alaskan plate and the North American plate in the area between the Mackenzie Delta and the Alaskan Border. This condition has been maintained throughout considerable additional phases of faulting and folding from mid-Cretaceous to the present. Previously, the Alaskan plate had been the northwestern nose of the North American plate. The interplate suture was deflected to the north as the Canadian Shield was approached. The Kaltag fault continued northeastward 2,000 km seaward of the Sverdrup rim, northwest of the Canadian Arctic Islands, and north of Greenland. The driving force was directed from the southwest by the Eurasian plate after its collision in Early Cretaceous (Hauterivian) with the North American plate and the docking of north-moving exotic terranes from the Pacific.

During the early Tertiary, perhaps in concert with the accretion of the Okhotsk block to the Asian plate north of Japan, the northern Pacific subduction zone jumped southward to the Aleutian Arc where it has persisted until today.

A distance of 800 km separates the stable shelf of the Canadian craton, at the Alberta Foothills thrust belt, from the subduction zone off Vancouver Island. The foreland thrust belt and the accretion of exotic terranes in Mesozoic and Tertiary times extended the continental crust of the North American plate westward to the present active transform margin with the Pacific plate along the Queen Charlotte fault zone.

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Regional Paleogeography and Habitat of Hydrocarbons in Ouachita Foredeep Basins

Nine present-day structural basins occur along the leading edge of the Ouachita thrust belt, a 1,400 mi (2,250 km) Paleozoic overthrust trend that extends from the Appalachians to Mexico. These basins, now separated by either subtle arches or pronounced basement uplifts, are components of a widespread late Paleozoic foredeep that formed in front of the Ouachita orogenic belt as a result of tectonic loading. This elongate depression filled during Pennsylvanian and Permian times with up to 15,000 ft (4,590 m) of sediment ranging in origin from alluvial to deep marine.

An estimated 10 tcf of commercially recoverable natural gas has been discovered to date in the clastics of this foredeep basin trend. Four basins contain the bulk of these known reserves.

The major conclusions of a study of late Paleozoic paleogeography, the structural style, and the habitat of hydrocarbons in this foredeep trend are:

1. The clastics were derived from cratonic or Appalachian sources, not from the rising Ouachita orogene. There appear to be a least 4 major entry points along the northern margin of the foredeep.

2. The facies range from coal-bearing deposits to deep-water turbidities. Fluvial and shallow-marine facies are found in the more stable areas; several turbidite depocenters occur in the areas of rapid, early subsidence.

3. The vast majority of the discovered hydrocarbons (gas) occurs in gas-saturated deep-basin traps. These very large fields occur in turbidites (Val Verde and Arkoma basins) and fluvial to shallow-marine deposits (Fort Worth basin).

4. Large undeveloped reserves can be documented in several basins in low-permeability reservoirs. In addition, there has been only rank wildcat exploration in 3 of the basins—Desha, Kerr, and Marfa.

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Quantitative Shape Analysis of Carbonate Sands by Use of Contour Registration and Template Matching

Carbonate sands are composed of relatively few particle types (e.g., *Halimeda*, coralline algae, corals, mollusks, and foraminifera). The shape of a particular sand grain is highly dependent on the particle type of which it is composed. Previous, studies of modern carbonate environments show that the composition of sand substrates from different subenvironments are dependent on the organisms that inhabit them. These depositional environments can thus be distinguished from each other according to their constituent particle compositions and, therefore, also by analysis of particle shapes.

Template (shape) matching can be accomplished only after the digitized shapes have been normalized to a unit-sized circle and registered. Registration involves the simple computation of shape-specific points within, on, or near the 2-dimensional contour of the sand grain. Shapes are subsequently rotated so that all of the shapes are in a similar position relative to their shape-specific points, allowing more meaningful comparisons between particles. After registration, 36 equi-angular radial lengths are calculated for grain from the center of mass to the boundary outline. A template-matching algorithm was devised in order to determine the relative percentages of several reference shape types, representing the constituents contained within 35 samples from 4 carbonate beaches and associated subtidal environments from the Florida Keys. Reference shapes may be chosen arbitrarily or obtained by computing average shapes of the various constituents. The precision of the shape classifications may be enhanced by adding supplemental reference shapes to the algorithm.

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Application of Structures Mapped from Landsat Imagery to Exploration for Stratigraphic Traps in Paradox Basin

Significant quantities of petroleum occur in algal buildups of Pennsylvanian age in the Paradox basin. Isopach and lithofacies mapping by others suggest that low-relief paleostructures appear to have controlled Pennsylvanian sea-floor topography and thus the distribution of the buildups. Several workers have reported that these paleostructures trend northwest and northeast. Therefore, the basin can be visualized as a