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

mosaic of fault blocks that were differentially active through geologic time. The buildups are elongate northwest, and their distribution and overall shape appear to be controlled by northwest-trending paleostructures. Some larger buildups (i.e., Ismay) show local northeast-trending thicks within an overall northwest-trending buildup.

Examination of Landsat imagery revealed an extensive network of northwest-and northeast-trending lineaments that parallel linear patterns apparent from aeromagnetic, gravity, and subsurface isopach data. Additionally, outcrops along selected lineaments contain fractures that parallel these lineaments, suggesting that the lineaments are related to fundamental (i.e., basement) fracture zones along which algal buildups may have developed. Comparison of the fracture network to the distribution of algal thickening reveals these buildups occur predominantly along northwest-trending lineaments. Local disruptions within and apparent terminations of the buildups correspond to cross-cutting northeast-trending lineaments. This relationship provides guidance to locating prospective algal buildups. Integration of these data with detailed subsurface mapping can refine some leads into prospects. Several of these features have been successfully drilled.

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Application of Landsat Imagery to Hydrocarbon Exploration in Niobrara Formation, Denver Basin

The Niobrara Formation produces commercial quantities of oil from fractures in several places in the Denver basin. The Niobrara in this basin is an oil-prone, mature source rock having as much as 3.4% TOC, and has been in the generating window since early Eocene. This implies that hydrocarbon generation from the Niobrara is partly contemporaneous with the Laramide orogeny. The Laramide was a multiple-phase orogenic event that began with compression directed to the east-northeast during the Late Cretaceous to Paleocene and ended with compression directed to the northeast during the Eocene. We believe the Eocene phase activated northeast-trending extension fractures that may have acted as loci for storage and migration of hydrocarbons, locally generated in the Niobrara. The auto-fracing pressures related to hydrocarbon generation in the Niobrara theoretically would preferentially open and fill this northeast-trending fracture system.

Examination of Landsat imagery shows that zones of northeast-trending lineaments are present throughout the basin. Numerous northeast-trending faults are present in the basin, and many overlie older zones that were reactivated during the Laramide. This suggests that these lineaments are previously unrecognized fracture zones. We have defined an exploration fairway within the basin based on subsurface isopach and resistivity mapping. We believe that mapping of northeast-trending fractures can help identify leads (within this fairway) prospective for Niobrara production. Support of this concept is the location of several apparently productive Niobrara wells along a zone of northeast-trending lineaments.

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Sedimentation and Tectonic Implications of Cambrian-Ordovician Clastics, Renville County, North Dakota

Cambrian-Ordovician clastics of the Deadwood Formation were studied in detail from Newporte field in Renville County, North Dakota. This small Cambrian-Ordovician oil pool was extensively cored, often to the Precambrian basement, allowing close examination of clastic deposition influenced by local basement tectonics.

In Renville County, the basal unit consists of a well-rounded, fine to medium-grained glauconitic quartz sandstone. Paleohighs appear to have had a pronounced effect on Deadwood sedimentation. Sands, from quiet water settings, show poor to moderate sorting, are commonly finely laminated, and/or show traces of minor small-scale cross-bedding. In places, bedding planes are highly disrupted, suggesting intervals of intense bioturbation (Skolithos). Sands associated with paleohighs are clean, well sorted, and commonly friable. Their association with basement structure is suggestive of beach–barrier-bar sequences related to irregularly upthrown basement blocks. In one example, this clean basal sand is associated with an upthrown basement block and is sharply truncated by the pre-Winnipeg (early Ordovician) unconformity.

The first unit above the basal sandstone in structurally lower wells is an anomalous conglomerate unit. Large angular basement clasts up to cobble size were viewed in core. This unit grades upward into a fine sand sequence and distally grades into a marine sand. It terminates abruptly in upthrown wells and indicates rapid fault movement and offset during middle Deadwood deposition, with development of localized fanglomerate sequences associated with fault scarps.

Immediately capping this sequence is a dark-gray marine shale that thins depositionally toward paleohighs.

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Feldspar Diagenesis in Neogene Sediments, Northern Gulf of Mexico

Alteration of feldspars in the youngest of the Gulf Coast Cenozoic sands and sandstones is dominated by dissolution and albitization. Volumetrically significant amounts of alteration are only observed below burial depths of about 4.5 km in sands of Pliocene and Miocene age. Only trivial amounts of plagioclase dissolution were observed in Pleistocene units. In general, plagioclase exhibits minor amounts of secondary dissolution at all depths, and greater amounts in the deepest samples. Potassium feldspar is subject to very little dissolution to depths of about 3.5 km; by 4.5 km K-feldspar removal is virtually complete. Albitization affects only plagioclase and appears to be operative, in these sediments, over temperatures of 110°C-140°C.

Compared to older Cenozoic units elsewhere around the Gulf of Mexico feldspar dissolution and albitization in Neogene sands have advanced to a lesser degree, at least in the sense that they affect a smaller proportion of the total section. Comparison of pre-alteration feldspar composition, temperatures of alteration, and geothermal gradients for Gulf Coast sandstones of different ages suggests that the main controls on feldspar alteration are temperature, pre-alteration plagioclase composition, and possibly the amount of fluid flow. Time per se seems to be a factor of negligible importance, at least over time spans greater than 10^6 yr. Thus, the lesser volume of Neogene sand affected by feldspar dissolution and albitization can be attributed primarily to the lower geothermal gradients of the northern Gulf.

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Reservoir Description Applied to Iatan East Howard Field, Mitchell County, Texas

A reservoir description has been completed to help improve recovery over Mobil Producing Texas and New Mexico's leases in the Iatan East Howard field in Mitchell County, Texas. The following 5 phases of study have been used: core description, log analysis, stratigraphy, mapping, and follow-up.

Two 850-ft cores were used to study depositional environment and diagenetic history. Clear Fork (Permian Leonardian) pay is characterized by thin, discontinuous porosity zones cut by vertical fractures. Porosity development is controlled by facies zonation from a tidal flat similar to that on Andros Island today. Porosity developed in carbonate-sand accumulations along tidal channels that meander and bifurcate across the flat. Thickness and continuity increase northwestward toward the basin. Six major zones of transgressive channel belt sediments separated by regressive supratidal marsh sediments were identified in the upper Clear Fork.

Digitized logs were analyzed and log analysis was accepted where porosity matched whole-core porosity measurements. Histograms of log response were used to normalize uncored wells to cored wells for equivalent results.

Stratigraphy was studied by cross sections of each zone. Facies-biased contouring was used to map reservoir parameters. Pay thickness was mapped using 2 porosity cutoffs with the higher identifying the best reservoir. Maps were digitized and used to calculate the original oil in place. The fracture orientation was recognized as N60°E from injection-water breakthrough, water sampling, and water-oil ratio mapping. Injectors will be placed along this trend perpendicular to porosity trends. Follow-up with reservoir engineering will continue with comparisons of mapped