Management; (2) the petroleum province boundaries of the U.S. Geological Survey Resource Appraisal Group as used in the 1981 national assessments; and (3) the geologic boundaries which distinguish the sedimentary-rock provinces having petroleum potential from the crystalline-rock provinces having no petroleum potential. All of the wilderness lands are digitized for mapping purposes and for calculation of the areas for each respective wilderness tract within the boundaries of the sedimentary-rock province. A computer search and compilation of exploratory-well data from the Petroleum Information Corp.'s Well History Control System (WHCS) was conducted for all the wilderness areas and their immediate surrounding. This tabulation of known well data is a part of the geologic input to the resource-assessment procedures.

Assumptions incorporated into the resource-appraisal methods are: (1) resource potential is not uniformly distributed throughout a petroleum province; (2) the total distribution of all recoverable petroleum resources is considered, both discovered and undiscovered; (3) consideration of the geologic characteristics favorable for the accumulation of petroleum resources in all the wilderness areas; (4) probability distributions are used to calculate a range of resource values to deal with the risks of uncertainty; and (5) the use of several alternative resource-appraisal methods are critically assessed.

The petroleum-resource assessments are compiled and reported by petroleum province and for each state. A total aggregation of the estimated petroleum resources for the existing and proposed wilderness areas in the 11 western states are presented as probability distributions.

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Eocene to Oligocene Paleo-Oceanography of the Northern North Atlantic: Seismic, Isotopic, and Faunal Evidence

Seismic stratigraphic evidence from the western and northern North Atlantic indicates that a major change in abyssal circulation occurred in the latest Eocene to earliest Oligocene. In the northern North Atlantic, the widely distributed reflector R4 correlates with an unconformity that can be traced to its correlative conformity near the top of the Eocene. This horizon reflects a change from weakly (Eocene) to vigorously (early Oligocene) circulating bottom water. Sediment distribution patterns provide evidence for strong contour-following bottom water flow beginning at reflector R4 time; this suggests a northern source for this bottom water, probably from the Arctic via the Norwegian-Greenland Sea and Faeroe-Shetland Channel. Erosion and current-controlled sedimentation continued through the Oligocene; however, above reflector R3 (middle to upper Oligocene), the intensity of abyssal currents decreased. Above reflector R2 (upper lower Miocene), current-controlled sedimentation became more coherent and a major phase of sedimentary drift development began. This resulted from further reduction in speeds and stabilization of abyssal currents.

Late Paleogene paleontological and stable isotopic data support these interpretations. In the Bay of Biscay/Goban Spur regions, a major $\delta^{18}O$ increase began at ~38 Ma (late Eocene), culminating in a rapid (<0.5 m.y.) increase in $\delta^{18}O$ just above the Eocene/Oligocene boundary (~36.5 Ma). A rapid $\delta^{13}C$ increase also occurred at ~36.5 Ma in these sites. Major changes in benthic foraminiferal assemblages also occurred between the middle Eocene and the earliest Oligocene: (1) In the Labrador Sea, a predominantly agglutinated assemblage was replaced by a calcareous assemblage between the middle Eocene and early Oligocene, (2) In the abyssal (>3 km, 10,000 ft paleodepth) Bay of Biscay, an indigenous Eocene calcareous fauna including *Nuttallides truempyi, Clinapertina* spp., *Abyssammina* spp., *Aragonia* spp., and *Alabamina dissonata* became extinct between the middle Eocene and earliest Oligocene, (3) In shallower sites (<3 km, 10,000 ft paleodepth) throughout the Atlantic, a *Nuttallides truempyi*-dominated assemblage was replaced by a *Globocassidulina subglobosa-Gyroidinoides-Cibicidoides ungerianus-Oridorsalis* assemblage in the early late Eocene (~40 to 38.5 Ma). These faunal and isotopic changes represent the transition from warm, old, corrosive Eocene bottom waters to colder, younger (lower CO_2 and higher pH, hence less corrosive) early Oligocene bottom waters.

A ^{18}O enrichment noted previously in the Southern and Indian Oceans is synchronous with the enrichment in the North Atlantic. The enrichment probably cannot be attributed only to initial entry of Arctic/Norwegian-Greenland Sea sources of cold bottom water. There is evidence that initial formation of cold, vigorously circulating bottom water from both northern sources (as denoted by reflector R4 and Horizon A^u) and southern sources (as denoted by erosion of widespread unconformities and other changes previously described from the Southern and Pacific Oceans) began near the end of the Eocene. These events also were reflected by a major ^{18}O enrichment. High-salinity water provided by North Atlantic deep water is important in the formation of Antarctic bottom water today. Such linkages or "teleconnections" might be invoked to explain the formation of southern bottom-water sources following the tectonically-controlled entry of northern sources of bottom water into the North Atlantic.

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Paleogene Bathymetry and Oceanography of Deep-Sea Benthic Foraminifera from the Atlantic Ocean

Paleodepth estimates obtained from empirical age-versus-subsidence curves of oceanic crust allow an independent determination of the paleobathymetric distributions of deep-sea benthic foraminifera. Such "backtracking" of DSDP sites together with studies of planktonic biostratigraphy, seismic stratigraphy, lithostratigraphy, and isotopic studies allows the placement of benthic foraminifera into a chronologic, paleobathymetric, and paleoceanographic framework. This approach has proven to be successful in recognizing several bathymetrically distinct deep-sea foraminiferal biofacies from the Paleogene of the Atlantic Ocean. Paleocene species have broad bathymetric ranges, but Eocene and Oligocene species tend to be bathymetrically more restricted.

Paleocene deep-water benthic foraminifera are predominantly relict Cretaceous taxa. Comparison of Paleocene deep-water benthic foraminiferal faunas with Cretaceous benthic faunas shows that, unlike planktonic organisms, there was no crisis in benthic foraminifera at the end of the Cretaceous. Most of the faunal variation in the Paleocene is attributable to the gradual bathymetric restriction of the shallower *Gavelinella beccariiformis* assemblage and the bathymetric expansion of the deeper *Nuttallides truempyi* assemblage. Such depth migrations, both expansions and restrictions, are prominent among the faunal changes noted in deep-sea benthic foraminifera studied to date. A major benthic faunal crisis occurred in the latest Paleocene (Zone P6a) with rapid massive extinctions at the generic and specific levels. Most of the extinctions occurred in the shallower *G. beccariiformis* assemblage containing predominantly Cretaceous relict species; the *N. truempyi* assemblage was characterized more by appearances than extinctions.

Various lines of evidence (seismic, lithostratigraphic, isotopic) indicate that a major, rapid change in abyssal circulation occurred near the end of the Eocene. As modern benthic foraminifera distributions often correlate with modern water-mass distributions, benthic foraminifera may be expected to have responded to the circulation changes. However, the Eocene/Oligocene boundary was not catastrophic for deep-sea benthic foraminifera, and the late Eocene-Oligocene deep-sea fauna evolved in a series of events over several million years. The major faunal abundance change at all depths greater than ~0.5 km (1,600 ft) was the apparently synchronous decrease in abundance of *Nuttallides truempyi* just above the middle/late Eocene boundary (~38.5 to 40 Ma); this pre-dates by 2 m.y. the major ^{18}O enrichment and the change in abyssal circulation regime inferred from seismic stratigraphic studies. The record in deep abyssal locations (paleodepths >3 km, 10,000 ft) shows the greatest changes, for here *N. truempyi* is associated with many endemic deep-water taxa (*Abyssammina, Clinapertina, Aragonia, Alabamina dissonata*, among others) that decrease in abundance and become extinct prior to the Oligocene. In shallower abyssal depths (2 to 3 km, 6,500 to 10,000 ft), a series of first and last appearances occurred in the late Eocene to earliest Oligocene. In lower bathyal depths (~0.5 to 1.5 km, 1,600 to 5,000 ft), a great number of first appearances occurred in the late Eocene through Oligocene.

Oligocene abyssal faunas mark a change from Paleocene (Cretaceous relict) and Eocene taxa (e.g. *N. truempyi, Alabamina dissonata, Aragonia* spp.) to abyssal assemblages that have many taxa in common with modern assemblages. The Oligocene abyssal fauna is dominated by stratigraphically long-ranging and bathymetrically wide-ranging taxa that survived the extinctions of the Eocene. During the middle Oligocene, *Nuttallides umbonifera* became important in deep abyssal locations in the North Atlantic and shallow and deep abyssal locations in the South Atlantic. Shallow abyssal Oligocene faunas throughout the Atlantic differ from Eocene faunas primarily by the absence of *N. truempyi*. Oligocene bathyal (0.5 to 1.5 km, 1,600 to 5,000 ft) assemblages are similar to the Eocene bathyal *Lenticulina-Bulimina-Osangularia* assemblage, although many new taxa appeared in the late Eocene through Oligocene.

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Controls of Deformation Mechanisms and Fracturing on Local and Regional Hydrocarbon Potential in the Central Appalachian Overthrust Belt

In highly deformed fold and thrust belts, strain associated with different deformation mechanisms can significantly alter the porosity and permeability of potential reservoir rocks. In general, mechanisms such as pressure solution, intragranular deformation, and cataclasis reduce porosity, whereas extension fracturing increases porosity, and more importantly, permeability. Since these mechanisms are dependent on parameters such as temperature, pressure, deviatoric stress, lithology, and grain size, they can produce significant regional and local variations in reservoir potential. Thus studies of these mechanisms are important for defining regional limits for exploration and, more locally, for evaluating individual prospects.

In the central Appalachians, exploration is presently confined to the Plateau and Valley and Ridge provinces. However, the regional limits of hydrocarbon potential need to be defined, particularly in light of the recent hypothesis by Harris et al in 1981 of subthrust potential underlying the Blue Ridge in the southern Appalachians. This can be done by combining data on strain and deformation mechanisms with conodont CAI data and estimates of displacements on major faults. Penetrative strain axial ratios (R) range between 1.1 and 8.0 in Great Valley carbonates and between 1.6 and 6.9 in Blue Ridge clastics. In the Valley and Ridge, R is usually less than 1.2. For most reservoir rocks, porosity is completely eliminated for $R = 1.5$, so that little porosity is expected east of the Valley and Ridge. Conodont CAI data of Epstein et al in 1977 show values approaching 5.0 for the Cambro-Ordovician carbonates and 4.5 for the Silurian-Devonian carbonates along the eastern edge of the Valley and Ridge. These values are at the upper limit for commercial gas production. The North Mountain and Blue Ridge faults, the two major thrusts east of the Valley and Ridge, both have maximum estimated displacements less than 20 km (12 mi), so that subthrust Valley and Ridge-type Silurian-Devonian rocks underlying the Great Valley rocks are fairly limited. Subthrust Cambro-Ordovician carbonates may be more widespread under the North Mountain ramp, but their potential is low because of high CAI and R values. The eastern limit of potential is therefore marked by the North Mountain fault, except for limited areas of subthrust Silurian-Devonian rocks.

The local effects of deformation mechanisms are related to interactions between pressure solution and fracturing, defined by relative timing, lithological characteristics, and structural position. Longitudinal fractures formed early or during the main phase of deformation are often healed or sealed by pressure solution, while transverse fractures, particularly those formed late tend to remain open. Lithological types susceptible to pressure solution, such as impure limestones, are less likely to retain matrix or fracture porosity than pure orthoquartzites. Structural positions with dilational strain, such as fold hinges in competent units, retain more porosity than those undergoing plane strain, such as thinned forelimbs of folds. Brittle deformation zones along splay faults are typically sealed through cataclasis. Consideration of these factors can significantly improve the evaluation of prospects in overthrust belts.

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The Interaction of Natural Organic Matter with Grain Surfaces: Implications for Calcium Carbonate Precipitation

Seawater is a complex solution of inorganic ions and organic molecules in contact with solid phases. Because of its reactivity and sorptive properties, some of the organic matter (OM) will directly affect the kinetics (and possibly the equilibria) of inorganic reactions by modifying the rates and types of reactions occurring between the inorganic ions and the solids. The interaction of natural OM with $CaCO_3$ systems occurs in two ways: (1) adsorption of the OM to $CaCO_3$ surfaces, and (2) complexation or chelation of free cations by dissolved or adsorbed OM. Both processes involve polar functional groups on the organic molecules, with the carboxylate anion ($-COO^-$) being the most likely interacting species, although other functional groups may also be important.

OM associated with a variety of skeletal and nonskeletal $CaCO_3$, including skeletal organic matrix, OM within ooids, and OM extracted from carbonate grain surfaces, was studied for chemical characterization, adsorption phenomena, and cation-binding ability. Skeletal OM is largely protein, whereas ooid and adsorbed OM are humic substances with proteinaceous components comprising about one-third of the composition. Aspartic acid is the most abundant amino acid in both skeletal protein and the humic substances. Conversely, OM associated with noncar-