cate a strong similarity to the fossil assemblage of the Tachilni Formation and the upper Bear Lake Formation, both assigned to the late Miocene Graysian Molluscan stage, approximately 12 Ma to 3 Ma.

Teeth of the desmostylian (sea cow) *Desmostylus* sp. cf. *D. hesperus* have been collected from the Cape Aliaksin beds. *D. hesperus* is known from North Pacific rocks assigned to the late early to early late Miocene, approximately 18 Ma to 10 Ma.

The Unga Conglomerate is in part typified by the middle Miocene pelecypod *Mytilus gratacapi* and an associated fauna unlike that of the Cape Aliaksin beds. It is suggested that the Cape Aliaksin beds are younger than the Unga Conglomerate, and are correlative to the upper Bear Lake Formation and Tachilni Formation rocks of early late Miocene age.

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Do Oil and Gold Mix in Alaska?

Excellent potential for sea-floor-placer heavy mineral deposits exists locally along the coast of Alaska within lands owned by the state. Aspen Exploration first applied for precious metal offshore prospecting permits (OPPs) from the state in 1980 for certain lands in Cook Inlet, including lands that are prospective for oil and gas production. Exploration to date has included geologic mapping, beach sampling at many locations, and a 6,400-mi low-level aeromagnetic survey. More than 20,000 ft of sediments underlie areas that appear most prospective for placer gold deposits, thereby facilitating geophysical interpretation of sea-floor magnetic anomalies. Work to date, now suspended, suggests large, linear, offshore heavy mineral concentrations, which likely include gold.

Obtaining permits in Alaska is difficult, frustrating, and expensive. After 5 years of effort, no permits have been issued to Aspen. Primary opposition has come from the Alaska Department of Fish and Game, which has taken the position that insufficient biological resource information is available in the prospect areas. These same offshore areas, however, are held under oil and gas leases from the state by various companies.

The difficulties encountered by smaller oil companies in attempting to carry out exploration in Alaska, which have forced virtually all of them to abandon their efforts in this state, are compared with difficulties hard-mineral companies are encountering. It is important to recognize that income to the state of Alaska from oil royalties and taxes is of such magnitude that needed support for hard-mineral exploration and mining is being suppressed by a hostile bureaucracy and by preservationists.

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Sag River Formation, Prudhoe Bay, Alaska: Depositional Environment and Diagenesis

The Sag River Formation is a minor hydrocarbon reservoir in the Prudhoe Bay field, Alaska. It comprises bioturbated, glauconitic, argillaceous, quartzose fine to very fine-grained sandstone and siltstone and varies from 55 ft (17 m) to 20 ft (6 m) in thickness in the field. The formation is the upper part of a very fine-grained, upward coarsening, terrigenous, clastic-dominated sequence deposited in Late Triassic time. This sequence includes the upper part of the subjacent Shublik Formation. Lithofacies variation within the Sag River is minimal with stratigraphic thinning from the north-northeast to a south-southwest shaleout. The formation was deposited in a low-energy, offshore, marine-shelf environment basinward of a low-relief source area. Upward coarsening, as well as slightly older Sag River facies in more proximal areas, suggests regionally significant marine regression during deposition.

In the Prudhoe Bay field, diagenesis along with abundant primary detrital matrix significantly diminishes reservoir quality. Ductile grain deformation, authigenic clay-grain coatings, quartz overgrowths, and carbonate cementation have resulted in microporosity and associated low permeability, which is the primary shortcoming of the Sag River reservoir. Larger, interconnected secondary pores (and associated improved reservoir quality) were produced by the dissolution of carbonate cement and possibly other mineral phases.

Reservoir quality in the Sag River Formation is strongly influenced by proximity to its subcrop with the overlying Lower Cretaceous "Highly Radioactive Zone." Mineral leaching probably resulted from aggressive fluid incursion at that truncation surface. The source of those fluids is not presently known.

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Reservoir Description of Endicott Field, Prudhoe Bay, Alaska

Located about 2 mi offshore and several miles east of Prudhoe Bay, the Endicott field contains about 1.4 billion reservoir bbl of oil and 0.5 billion reservoir bbl of gas.

Hydrocarbons occur within Mississippian fluvial sandstones of the Kekiktuk formation, which unconformably overlies the Neruokpuk Formation and grades upward into the Kayak and Itkilyariak formations. Stratigraphy is subdivided into three lithofacies that, from the base upward, reflect deposition in a swamp/lacustrine/flood plain environment (zone 1), a braided stream system (zone 2), and a meandering stream system (zone 3). Sediment dispersal was from a northerly source.

Endicott field structure defines a southwesterly plunging antiform that is bounded to the north, northeast, and southwest by major normal faults and is truncated to the northeast by the Lower Cretaceous Unconformity (LCU). Shales overlying the LCU and shales of the Kayak and Itkilyariak formations form the reservoir cap.

Reservoir properties within the hydrocarbon column vary by zone with zones 3 and 2 typified by an average net/gross-porosity-water saturation-permeability of 37%-18%-22%-500 md and 88%-22%-13%-1,100 md, respectively. In contrast, zone 1 quality is very poor. Reservoir sands are compositionally very mature and exhibit an enhanced pore network. Diagenetic minerals include quartz along with lesser kaolinite and carbonate.

Gas is present from about 9,500 ft (2,850 m) to 9,855 ft (2,958 m), oil is down to 10,180-10,200 ft (3,054-3,060 m), and tar accumulations are down to 10,400 ft (3,120 m) subsea. Average oil gravity is 23° API. Geochemical data indicate that the tar accumulations originated through a physical deasphalting process. Cenozoic imbibition resulted in water overriding tar.

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North Slope Oil and Gas: The Barrow Arch Paradox

In the 40-year history of hydrocarbon exploration on the Alaskan North Slope, about 21 accumulations with a total in-place volume of more than 60 billion bbl of oil and 35 trillion ft^3 of gas have been discovered. Although the density of exploratory drilling in this region is not uniform, enough drilling has been done to show a distinct concentration of oil and gas in the Prudhoe Bay area between the Colville and Canning Rivers. This concentration is also evident when the Prudhoe area resources are compared with the USGS estimates of undiscovered in-place oil and gas resources of the adjacent areas, the National Petroleum Reserve in Alaska and the Arctic National Wildlife Refuge. Most oil and gas in the Prudhoe area accumulated near the present coastline in reservoirs that overlie a southeasterly plunging basement ridge, the Barrow arch. The location of these accumulations, in low-relief structural-stratigraphic traps midway along the arch and downdip from its apex at Point Barrow, is the paradox.

An answer to this paradox is provided by analysis of two cross sections, one along the Barrow arch and one perpendicular, showing their original structural positions for the beginning, middle, and end of Cretaceous time. In the Early Cretaceous (mid-Neocomian), the crest of the Barrow arch was near sea level along its entire length. Because of northeasterly sediment progradation during later Cretaceous time, the Barrow area became more deeply buried than the Prudhoe area, thus making the Prudhoe area the focal point for migrating oil and gas. Beginning in the early(?) Tertiary, the Barrow area was slowly uplifted while the Prudhoe area subsided, thus beginning the process that resulted in the reversal of their relative elevations and the focus for migrating oil and gas. Studies show that the Prudhoe Bay field was tilted during the Tertiary, and some oil and gas escaped, migrated toward Barrow, and was trapped in the Kuparuk, West Sak, and Ugnu fields. This analysis suggests that most North Slope oil and gas were generated during the Cretaceous.

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K-Ar Ages of Allochthonous Mafic and Ultramafic Complexes and Their Metamorphic Aureoles, Western Brooks Range, Alaska

New K-Ar ages from allochthonous mafic and ultramafic complexes of the western Brooks Range (Brooks Range "ophiolite") show that igneous rocks yield ages nearly identical to those of underlying metamorphic aureole rocks. Dated rocks of the Misheguk igneous sequence from Tumit Creek consist of (1) hornblende gabbro with minor greenschist and lower grade alteration, hornblende age 147.2 ± 4.4 Ma; and (2) hornblende-bearing diorite, also slightly altered, age 155.8 ± 4.7 Ma. Both samples come from presumed higher levels of the Misheguk sequence. Dated samples of metamorphic aureole rocks come from outcrops near Kismilot Creek and lie structurally beneath the Iyikrok Mountain peridotite body. The rocks consist of amphibolite and garnet-bearing biotite-hornblende gneiss considered to be metamorphosed Copter igneous sequence and related sedimentary rocks. Hornblende ages are 154.2 ± 4.6 Ma and 153.2 ± 4.6 Ma. Metamorphism is clearly related to the structurally overlying peridotite, as the degree of alteration decreases downward.

We suggest that the K-Ar ages of these rocks represent the effects of thermal metamorphism post-dating igneous crystallization and are related to tectonic emplacement of the complex. Earlier K-Ar data on igneous rocks give similar ages and have been interpreted as reflecting tectonothermal events. The age of igneous crystallization of the mafic and ultramafic rocks of the Misheguk igneous sequence remains uncertain.

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Age and Correlation of the Otuk Formation, North-Central Brooks Range, Alaska

Allochthonous Triassic rocks of the north-central Brooks Range thrust belt were originally mapped as part of the Middle to Upper Triassic Shublik Formation. Recently, these strata were named the Otuk formation. Detailed paleontologic studies of 11 measured sections more precisely document the age of the Otuk and show that its base is older than the base of the Shublik and that its top is younger than the top of the Shublik. Megafossils (pelecypods and ammonites) and microfossils (radiolaria, conodonts, and foraminifers) indicate an age range of Early Triassic (Dienerian-Smithian or older) to Middle Jurassic (Bajocian). The lithology consists of 120 m (390 ft) of interbedded, very fine-grained rocks (shale, limestone, and chert) representative of very slow deposition, below wave base in an open marine environment. The Otuk formation does not contain suitable reservoir rocks, but organic geochemical data indicate that the shales are possible oil source rocks. The Otuk formation is disconformable with both the underlying Permian (Wolfcampian-Guadalupian) Siksikpuk Formation and overlying Lower Cretaceous (Valanginian) coquinoid limestone and shale. These unconformities are correlative with similar unconformities in the northeastern Brooks Range and subsurface of the North Slope. Thus, the Otuk formation is a condensed, deeper water, more distal equivalent of the Ivishak and Shublik Formations, Karen Creek Sandstone, and lower Kingak Shale of the northeastern Brooks Range and equivalent subsurface units of the North Slope.

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Early Cretaceous Evolution of Yukon-Koyukuk Basin and Its Bearing on Development of Brookian Orogenic Belt, Alaska

The Brookian orogenic belt (Seward Peninsula, Brooks Range, Ruby geanticline) forms three sides of the Cretaceous Yukon-Koyukuk basin of west-central Alaska. Low Sr_i values from igneous rocks within the basin suggest that it is not underlain by older continental crust. The basin encloses a south-facing horseshoe-shaped trend of Lower Cretaceous andesitic volcanic rocks. Major-element chemistry of these rocks indicates that they are calc-alkaline and of island-arc affinity.

Berriasian to Valanginian volcanic rocks in the basin are predominantly clastic and were deposited in shallow marine to subaerial environments. Marked subsidence began during Hauterivian time, accompanied by a change to highly potassic (shoshonitic) pyroclastic volcanism. During the Barremian (Aptian?), these tuffs were interbedded with Brookian-derived turbidites, deposited in a trough between the subsided volcanic platform and the uplifted Brookian metamorphic belt. Paleoflow was clockwise around the basin from west to east. By the Albian, significant volcanism had ceased, and the intervening trough filled with Brookian sediment. The Brookian orogeny apparently resulted from attempted subduction of the North American margin beneath the intraoceanic Koyukuk arc. The relatively long timespan (approximately 30 Ma) between initial continental underthrusting (Tithonian?) in the Brooks Range and the shutoff of arc volcanism (Aptian?) suggests a very slow convergence rate (1-2 cm/year).

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Southeastern Alaska Tectonostratigraphic Terranes Revisited

The presence of only three major tectonostratigraphic terranes (TSTs) in southeastern Alaska and northwestern British Columbia (Chugach, Wrangell, and Alexander) is indicated by critical analysis of available age, stratigraphic, and structural data. A possible fourth TST (Stikine) is probably an equivalent of part or all of the Alexander. The Yakutat "block" belongs to the Chugach TST, and both are closely linked to the Wrangell and Alexander(-Stikine) TSTs; the Gravina "TST" is an overlap assemblage. The Alexander(-Stikine) TST is subdivided on the basis of age and facies. The "subterranes" within it share common substrates and represent large-scale facies changes in a long-lived island-arc environment.

The "Taku TST" is the metamorphic equivalent of the upper part (Permian and Upper Triassic) of the Alexander(-Stikine) TST with some fossil evidence preserved that indicates the age of protoliths. Similarly, the "Tracy Arm TST" is the metamorphic equivalent of (1) the lower (Ordovician to Carboniferous) Alexander TST without any such fossil evidence and (2) the upper (Permian to Triassic) Alexander(-Stikine) with some newly discovered fossil evidence.

Evidence for the ages of juxtaposition of the TSTs is limited. The Chugach TST deformed against the Wrangell and Alexander TSTs in Late Cretaceous. Gravina rocks were deformed at that time and also earlier. The Wrangell TST was stitched to the Alexander(-Stikine) by middle Cretaceous plutons but may have arrived before its Late Jurassic plutons were emplaced. The Alexander(-Stikine) and Cache Creek TSTs were juxtaposed before Late Triassic.

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Structure of Shumagin Continental Margin, Western Gulf of Alaska

The Shumagin continental margin lies between Kodiak Island and Unimak Pass. The oldest rocks known to underlie the margin are highly deformed, deep-water turbidites of Late Cretaceous age (Shumagin Formation). These turbidites were intruded by Paleocene and early Eocene granodiorites. Paleogene sedimentary rocks of the Kodiak region may extend southwest to and underlie at least parts of the Shumagin margin but are not known in outcrop on shelf islands. The Cretaceous and Paleogene(?) rocks form acoustic basement on multichannel seismic reflection data, and are overlain by a basin fill of probable late Miocene and younger age. Mesozoic rocks of the Alaska Peninsula extend seaward only to the inferred location of the Border Ranges fault.

The Shumagin margin is characterized by five major structural features or trends: (1) Shumagin basin, containing about 2.5 km of late Miocene and younger strata above acoustic basement; (2) Sanak basin, containing as much as 8 km of dominantly late Cenozoic strata in two subbasins separated by a basement high; (3) Cenozoic shelf-edge and upper-slope sedimentary wedges that are 3-4 km thick and possibly as thick as 6 km; (4) a midslope structural trend, Unimak ridge, that is characterized by numerous surface and subsurface structural highs; and (5) a 30-km wide accretionary complex at the base of the slope. A thin (less than 1-2 km) sediment cover of Miocene and younger age covers the continental shelf areas outside of Shumagin and Sanak basins.

The tectonic history of the margin includes: (1) Late Cretaceous or early Tertiary removal of the seaward part of the Cretaceous Alaska Peninsula margin along the Border Ranges fault and accretion of the Shumagin Formation against the truncated margin; (2) Miocene uplift and erosion of the shelf; (3) middle or late Miocene uplift of Unimak ridge; and (4) late Miocene and younger subsidence and infilling of Sanak and Shumagin basins, and subduction-accretion along the Aleutian Trench.