with planar to cross-laminated quartz-carbonate metasandstone and phyllite.

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Metamorphic Facies Map of Alaska

A metamorphic-facies map of Alaska has been compiled, following the facies-determination scheme of the Working Group for the Cartography of the Metamorphic Belts of the World. Regionally metamorphosed rocks are divided into facies series where P/T gradients are known and into facies groups where only T is known. Metamorphic rock units also are defined by known or bracketed age(s) of metamorphism. Five regional maps have been prepared at a scale of 1:1,000,000; these maps will provide the basis for a final colored version of the map at a scale of 1:2,500,000. The maps are being prepared by the U.S. Geological Survey in cooperation with the Alaska Division of Geological and Geophysical Surveys.

Precambrian metamorphism has been documented on the Seward Peninsula, in the Baird Mountains and the northeastern Kuskokwim Mountains, and in southwestern Alaska. Pre-Ordovician metamorphism affected the rocks in central Alaska and on southern Prince of Wales Island. Mid-Paleozoic metamorphism probably affected the rocks in east-central Alaska. Most of the metamorphic belts in Alaska developed during Mesozoic or early Tertiary time in conjunction with accretion of many terranes. Examples are Jurassic metamorphism in east-central Alaska, Early Cretaceous metamorphism in the southern Brooks Range and along the rim of the Yukon-Koyukuk basin, and Late Cretaceous to early Tertiary metamorphism in the central Alaska Range. Regional thermal metamorphism was associated with multiple episodes of Cretaceous plutonism in southeastern Alaska and with early Tertiary plutonism in the Chugach Mountains. Where possible, metamorphism is related to tectonism. Meeting participants are encouraged to comment on the present version of the metamorphic facies map.

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Revised Megafossil Biostratigraphic Zonation for Carboniferous of Northern Alaska

Carboniferous megafossils are widely distributed in the Kayak Shale and Lisburne Group throughout the northern Brooks Range. Diverse assemblages of brachiopods, corals, and mollusks, with subordinate echinoderms and bryozoans, were collected from 40 measured sections. The combined stratigraphic ranges and abundances of more than 300 species were assessed to construct a biostratigraphic zonation that can be applied regionally for correlation. Preliminary zonations, used for more than a quarter century, were revised to account for the rapidly accumulating data. The 18 assemblage zones, from youngest to oldest, are: *Umboanctus?* sp., *Corwenia jagoensis, Choristites?* sp., *Delepinoceras* sp., *Siphonodendron ignekensis, Gigantoproductus striatosulcatus-Stelechophyllum?* aff. *S.? mclareni, Goniatites americanus-Siphonodendron lisburnensis, Sciophyllum lambarti, Eumetria costata, Stelechophyllum? mclareni, Naticopsis suturicompta-Lithostrotion reiseri, Skelidorygma subcardiiformis, Spirifer tenuicostatus-Siphonodendron dutroi, Sychnoelasma konincki* s.l.-*Actinocrinites* sp., *Brachythyris choteauensis, Cryptoblastus-Pentremites, Leptagonia analoga,* and *Scalarituba-Lepidodendropsis.*

In the central and western Brooks Range, the deeper water Kuna formation contains a low-diversity fauna of mollusks and brachiopods. Goniatites are found at several levels but never more than two zones in any partial section. Regionally, these goniatite zones, from youngest to oldest, are: *Delepinoceras* (late Chesterian), *Goniatites americanus* (late Meramecian–early Chesterian), *Beyrichoceras* (early to middle Meramecian), *Ammonellipsites* (Osagean) and *Muensteroceras-Protocanites* (late Kinderhookian?).

Correlations of megafossil zones with the foraminiferal zones of Mamet are discussed. The 15 Mississippian zones have an average age-resolution of about 2 m.y. By themselves, the goniatite zones give an age-resolution of about 6 m.y. zone.

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Coal Resources of Northwest Alaska

Rural areas in Alaska depend almost entirely on expensive imported fuel oil for heat and power generation. Following the drastic price increase in petroleum a few years ago, local governments and state agencies have shown considerable interest in determining the potential for northwest Alaska as an alternative energy source. A compilation of earlier work by the U.S. Geological Survey, Bureau of Mines, and industry located over 50 separate coal occurrences within the 50,000 mi^2 Cape Beaufort, Kobuk Valley, Seward Peninsula, and Norton Sound areas. The most promising localities were examined in the field by DGGS and BLM geologists, and six of these were selected for drilling and geophysical surveys by contractors.

Two of the areas drilled were found to have coal of sufficient quantities and quality to justify additional drilling and feasibility studies. The Cape Beaufort–Kukpowruk River area contains Cretaceous-age coal beds up to 20 ft thick and extends from the coast to about 20 mi inland. Drilling under the DGGS-USGS/MMS/BLM–administrated program indicated approximately 20 million tons in the Deadfall syncline alone, where four moderately dipping beds have a 1 to 5 stripping ratio. One 320-acre tract may contain eight million tons of bituminous coal having a 13,000 to over 14,000 Btu value as received.

The other site where work continues is the old Chicago Creek coal mine near Candle on the Seward Peninsula. The coal bed here has been traced by drilling and geophysics for 3,500 ft along strike and found to average 35 ft in thickness. While the deposit is up to 80 ft thick in one drill hole, the coal is lignite and typical of the Tertiary coals in this region, being erratic in character and averaging about 6,900 Btu/lb. Three and one-half million tons of lignite are indicated and another million tons inferred.

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Geological Setting of North Slope Oil Fields, Alaska

The North Slope is a prolific hydrocarbon province in which discoveries to date amount to some 60 billion bbl of oil in place and 50 tcf of gas in place.

Reservoirs and prolific source rocks occur throughout the stratigraphic column, which consists of a lower (or Ellesmerian) megasequence of Carboniferous to Jurassic age and an upper (or Brookian) megasequence of Early Cretaceous to Recent age. Discovered oil is almost equally divided between Ellesmerian and Brookian reservoirs.

Patterns of hydrocarbon generation and migration have been controlled by deposition of clastic sedimentary wedges derived from the Brooks Range orogen. In the Late Jurassic to Early Cretaceous, the main oil kitchen was located in the Western Colville trough. Clastic depocenters and associated kitchen areas migrated progressively eastward with time and are now located in the East Beaufort offshore. Important source rocks include the Jurassic Kingak and Late Triassic Shublik Formations of the Ellesmerian megasequence, and the Aptian-Cenomanian "HRZ" and Turonian-Paleocene Shale Wall formations of the Brookian megasequence.

In the Ellesmerian megasequence, productive reservoirs are known at several stratigraphic levels, with best reservoir properties associated with secondary porosity development in subcrop beneath a mid-Hauterivian unconformity.

The Kekiktuk Formation (Mississippian), oil- and gas-bearing in the Endicott field (ca. 1 billion STBOIP), is a fluvially dominated unit, locally deposited in fault-controlled basins. The Lisburne Group (Mississippian to Early Permian) contains oil in the Lisburne pool of the Prudhoe area (?2-3 billion STBOIP). The reservoir is primarily early diagenetic dolomites within a thick platform carbonate sequence.

The major reservoir on the North Slope is the Early Triassic Ivishak Formation, reservoir to the Prudhoe field (22 STBOIP), the Seal Island discovery (?1 billion STBOIP), and target in the recent Mukluk well. Sands and conglomerates were deposited by a series of alluvial fan deltas shed from a nearby northern landmass.

Arctic Ocean rift events culminated in mid-Hauterivian continental breakup, which generated the subcrop unconformity of the rift margin uplift. Post-unconformity sands associated with local erosion of Ellesmerian and basement strata occur in widespread sheets. These sands can be important reservoirs, such as the Kuparuk and Point Thomson formations, of late Hauterivian–Barremian age (?ca. 11 STBOIP total).

Finally, within the Brookian megasequence, large volumes (?ca. 20 billion STBOIP) of relatively heavy oils are trapped in the Late Cretaceous to early Tertiary West Sak and Ugnu formations. These sands are of marine-shelf to fluvial/deltaic depositional environments, topset strata of a Laramide prograding clastic wedge.

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Petrology, Diagenesis, and Reservoir Quality of Lower Cretaceous Kuparuk River Formation Sandstone, Kuparuk River Field, North Slope, Alaska

The Kuparuk River formation consists of upper and lower members separated by an intraformational unconformity. Marine sandstone in each is distinct in terms of depositional environments, sand-body geometry, texture, composition, diagenesis, and reservoir quality.

Sandstone in the upper member is very fine to very coarse-grained sublitharenite to lithic arenite with an average quartz-feldspar-lithic (QFL) of 75-1-24. Glauconite constitutes 10-50% of framework grains. Chert, muscovite, heavy minerals and mudstone, limestone, siderite, and metasedimentary rock fragments are less abundant. The diagenetic sequence is: aragonite or high-Mg calcite-collophane-pyrite-siderite-ankerite-calcite-(dissolution of carbonate cements and glauconite)-quartz-kaolinite-illite/smectite-pyrite.

Sandstone in the lower member is very fine to fine-grained quartz arenite to subarkose with an average Q-F-L of 92-5-3. Mudstone fragments, chert, muscovite, heavy minerals, and glauconite are less abundant. The diagenetic sequence is: pyrite-siderite-ankerite-calcite-(dissolution of ankerite and feldspar)-quartz-kaolinite-illite/smectite-pyrite.

Early diagenesis in upper and lower member sandstones is different, whereas burial diagenesis is similar. Early siderite cemented sandstones in the upper member but did not significantly affect sandstones in the lower member. Subsequent changes in pore fluid chemistry during burial resulted in precipitation of the cement sequence siderite-ankerite-calcite in both upper and lower member sandstones. Stable isotope trends in carbonate cements parallel those of cement texture and composition.

Upper member porosity (mostly secondary) and permeability average 23% and 130 md, with upper limits of 28-33% and 500-1,500 md, respectively. Reservoir quality is heterogeneous and controlled by grain size, distribution of primary and secondary porosity, and fractures. Both horizontal and vertical permeability are similar except where fractures enhance horizontal permeability.

Lower member porosity (mostly primary) and permeability average 23% and 100 md, with upper limits of 28-30% and 400-500 md, respectively. Reservoir quality is homogeneous. Ankerite locally eliminates porosity, and shale beds and laminations reduce vertical permeability.

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Refined Names for Brookian Elements in Northern Alaska

The major negative element of the North Slope has been called the Colville geosyncline, the Colville trough, the Colville foredeep, or the Colville basin, whereas the positive element coupled to the north has been universally called the Barrow arch. The name "Colville basin" is most consistent with the apparently compound nature of this foreland successor element. We also recommend that "Barrow inflection" be substituted for "Barrow arch" as the name for the positive element or structural hinge that formed between middle Cretaceous deposits in the basin and those along the continental margin. The term "inflection" aptly describes the weak reversals in regional dip that mark this feature, and constrains the sense of either active uplift or a preexisting high, which has evolved with current usage of "arch".

The markedly asymmetric Colville basin consists of: deformed and thickened middle Cretaceous flyschoid deposits lying on earlier Cretaceous allochthons of the ancestral Brooks Range; a greater than 10-km thick belt of deposits that is incoherent on seismic records but is floored by poor reflectors, presumably of earliest Cretaceous and older age; and a foreland flank that slopes gently from within a kilometer of the surface at Point Barrow, about 200 km to the north. Seismic profiles show this flank to have been an abyssallike plain after Barrovia, the northern provenance of Ellesmerian deposition, had been replaced by the Arctic Ocean early in Cretaceous time. The flank was more than 1 km deep and stretched broadly southward from the new continental edge that now seems to be nearly 30 km north-northeast of Barrow. The plain was progressively loaded and depressed, first by the downlapped distal edge of the flysch prism in the south and then by the shelf of molassoid deposits that prograded from the Brookian orogen during the middle Cretaceous.

The Barrow inflection denotes reversals in regional dips from less than 2° to the south to approximately 1° to the north. The axes of reversals subparallel the present coastline between Barrow and the Arctic National Wildlife Refuge and plunge eastward at a rate of approximately 1 km/100 km. Inflections on successive stratigraphic horizons do not stack vertically as in parallel folds; dip reversals in the lowest Brookian strata, for example, occur several kilometers south of the inflection on the basement surface. The structure appears to have formed as the prograding middle Cretaceous deposits (Nanushuk Group) made the foundation for the present continental terrace; subsidence of the continental margin beneath that load reversed dips along the former north edge of the Colville basin. Minor and relatively passive upward bowing likely occurred along this hinge between the negative (depressed) elements. The Barrow positive feature clearly is an arch neither in the sense of a broad anticlinal fold nor in the sense of a high such as the Cincinnati arch. It had no north flank before the Late Cretaceous, and it could not have been an element of pre-Brookian (Ellesmerian) geology.

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Seismotectonics and Structure of Brooks Range, Alaska

Data collected by seismic networks operated by the Geophysical Institute of the University of Alaska–Fairbanks are used to study the seismicity and tectonics of northern Alaska. Microearthquake activity (less than 4.7 M_L) is seen as a diffuse band trending north-northeast from Fairbanks to Barter Island and as an easterly trend roughly parallel to, but south of, the crest of the Brooks Range. Depths of the events range from 10 to 25 km. Some clustering occurs, with the most clearly defined feature being a line of epicenters at 157° 30′ that trends north between 66° and 67°N.

A crustal velocity structure of the eastern Brooks Range is constrained using refracted phases from earthquakes local to the Barter Island, Fort Yukon, and Fairbank networks, respectively. Focal mechanism solutions from the Brooks Range show normal, thrust, and strike-slip faulting. Common to all of them, however, is an east-striking nodal plane that parallels the regional structural grain, suggesting that the fault planes are on reactivated faults. This is in contrast to the earthquakes in interior Alaska, which show mainly strike-slip focal mechanisms. The orientation of the pressure axes in both areas is consistent with the convergence of the Pacific and North American plates.

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Critical and Strategic Minerals Investigations in Alaska: Chromium

The Bureau of Mines investigated chromite deposits and occurrences in Alaska between 1979 and 1984 as part of the Bureau's critical and strategic minerals program. Beneficiation and mineralogical characterization tests were performed on 68 samples.

Chromite-bearing ultramafic rocks occur in eight regions in Alaska. One hundred sixty-one subeconomic podiform-type deposits and one placer deposit are estimated to contain 3.4-4.7 million tons of chromic oxide (Cr_2O_3) in high-chromium and high-iron chromite. In most cases, mine-site beneficiation would be required to produce shipping-grade concentrates.

In the Chugach trend, an inferred reserve base comprises 2.8 million tons of Cr_2O_3 in 42 deposits that are all within 10 mi of tidewater or existing transportation routes. Most of these are indicated reserves (1.8 million tons) contained in the newly discovered Turner stringer zone and