merian 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

Windy River placer deposit at Red Mountain and inferred reserves at the Halibut Bay complex on Kodiak Island. Seventy less-accessible deposits in the remote western Brooks Range contain between 0.6 and 1.4 million tons of high-chromium chromite. The Rampart, Yukon-Koyukuk, and Alaska Range trends and the southeast Alaska region contain deposits with minor production potential.

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Neogene Drape Folding Over Pre-Neogene Flexural-Slip Movements in Western Transverse Ranges, California

In several locations in the western Transverse Ranges of California are folded Neogene sedimentary sequences that unconformably overlie homoclinal sequences of pre-Neogene rocks. To accomplish the folding of the rocks above the unconformity without apparent deformation of those below the unconformity, a mechanism other than simple crustal shortening is required. It is proposed that differential flexural slip along bedding planes in the limbs of large-amplitude pre-Neogene folds produced drape folds of small amplitude in the unconformably overlying Neogene rocks. This drape mechanism implies that the Neogene rocks were folded while they were still in the soft-sediment stage and that they were lengthened parallel to bedding during the process. Procedures that use the length of folded beds to determine the amount of crustal shortening, therefore, may indicate a greater amount of crustal shortening than actually occurred.

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Seastacks Buried Beneath Newly Reported Lower Miocene Sandstone, Northern Santa Barbara County, California

Three large, isolated exposures of a light-gray, coarse-grained, thick-bedded sandstone unit occur in the northern San Rafael Mountains of Santa Barbara County, California. These rocks are moderately fossiliferous and contain *Vertipecten bowersi, Amussiopecten vanvlecki, Aequipecten andersoni, Otrea howelli,* shark teeth, whale bones, and regular echinoid spines. The fossils indicate that the sandstone unit, although previously reported as upper(?) Miocene, correlates best with the lower Miocene Vaqueros Formation.

This unit was deposited in angular unconformity on a Cretaceous, greenish-gray turbidite sequence of interbedded sandstone and shale, and onlaps the unconformity erosion surface from west to east, the unit being thicker in the west and older at its base. The underlying Cretaceous sandstone beds are well indurated, and during the eastward transgression of the early Miocene sea, they resisted wave erosion and stood as seastacks offshore of the advancing coastline, thus creating a very irregular topographic surface upon which the Vaqueros Formation was deposited. Some seastacks were as much as 4 m tall, as indicated by inliers of Cretaceous rock surrounded by 4-m thick sections of the Vaqueros Formation.

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Smectite Diagenesis in Bentonites of Shale Wall Member of Seabee Formation, North Slope, Alaska

The Upper Cretaceous Colville Group is present over much of the north-central North Slope and includes the Seabee Formation, a part of a progradational clastic wedge derived from the ancestral Brooks Range. The lower member of the Seabee Formation, the Shale Wall Member, contains thin to moderately thick bentonite beds. Biotite separated from bentonite from the Shale Wall Member in the northwestern subcrop area yielded K/Ar ages of about 92 Ma, dating the origin of these pyroclastic deposits as early Turonian. In the northern part of the National Petroleum Reserve in Alaska (NPRA) and in the vicinity of Prudhoe Bay field, the less than 2-millimicron fraction of Shale Wall bentonites consists predominantly of smectite with trace to minor amounts of kaolinite. Eastward along the Barrow arch, the depth of burial of the Shale Wall Member increases from less than 300 m in the NPRA to at least 3,855 m in the vicinity of Mikkelsen Bay as a result of downwarping of the Barrow arch and thick Tertiary deposition. At a depth of burial of about 3,600 m, the smectite-rich bentonites are replaced by rectorite, an ordered mixed-layer illite/smectite (I/S). With increasing depth of burial, the percentage of expandable layers in the ordered I/S decreases from about 45% to 20%. K/Ar dating of the ordered I/S phase places the time of formation in the mid-Miocene, in close agreement with predicted timing of clay diagenesis based on burial history/thermal gradient considerations.

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Effect of Geothermal Pore-Pressure Conditions and Natural Gas Composition on In Situ Natural Gas Hydrate Occurrences, North Slope, Alaska

The factors controlling the distribution of natural gas hydrates (solid compounds composed of natural gas and water) in the earth include mean annual ground temperatures, geothermal gradients, subsurface pressure conditions, gas composition, and pore-fluid salinity. A thorough analysis of the effect of these parameters on thickness and depth of hydrate stability zones has been conducted. A thermodynamic model has been used to compute depth and thickness of zones of stability of gas hydrates in 34 representative wells on the North Slope. Several well logs in these depth ranges have been analyzed to determine hydrate zone thickness, porosity, and hydrate saturation. In well log analysis, the hydrate presence has been indicated by the following evidence: increase in acoustic velocity, strong resistivity deflection, small spontaneous potential deflection, gas shown on mud log, oversized caliper increase in the neutron porosity, separation of long normal from short normal, and decrease in drilling rate. In several of these wells, multiple zones of hydrates have been detected.

In the Prudhoe Bay and Kuparuk fields, hydrates are expected to occur primarily in six stratigraphic horizons, mostly in an unconsolidated unit characterized by a poorly sorted sandstone and conglomeratic lithology. Detailed examination of the neutron porosity and sonic velocity responses within one hydrate horizon in six wells in Kuparuk field indicates an average porosity of 44% and hydrate saturation of 93%. Such information is extremely relevant to quantification of gas hydrate deposits.

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Genesis of Gold Deposits in Chugach Terrane of South-Central Alaska—Evidence from Fluid Inclusions

Gold-bearing quartz veins occur in shear zones, faults, and joints within the Upper Cretaceous Valdez Group flysch in the Kenai and Chugach Mountains of south-central Alaska. The veins are regionally restricted to areas of medium greenschist-grade metamorphic rocks and are notably absent in lower and higher grade metamorphic rocks.

Fluid inclusion studies were conducted on samples of gold-bearing quartz from the Moose Pass, Hope-Sunrise, Port Wells, and Port Valdez districts. Ice and clathrate melting temperatures indicate that the ore-forming fluids had low salinities, ranging from 0 to 5-equivalent wt.% NaCl. These fluids contain appreciable amounts of dissolved gases, as shown by the nearly ubiquitous formation of clathrates during inclusion freezing and by the common presence of three-phase inclusions consisting of aqueous fluid, liquid CO_2, and vapor. Total gas content varies from essentially nondetectable to as much as 10 vol.%. Freezing measurements on the inclusion fluids show the gas composition to vary from nearly pure CO_2 to mixtures dominated by CH_4 and N_2. Inclusion data indicate minimum trapping pressures of 1.5 kbar and corrected homogenization temperatures ranging from 260°C to 330°C.

We believe that the gold-bearing veins represent pathways for the escape of metamorphic fluids during rapid uplift of the Chugach and Kenai Mountains. The veins are believed to have formed along hydraulic fractures or along dilated preexisting fractures, created when fluid pressure exceeded load pressure.

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Relative Motions between Eurasia and North America in Bering Sea Region