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Arctic Reconstruction from an Alaskan Viewpoint

Field, seismic, structural, and stratigraphic data were used to reconstruct the geologic history of the Arctic in 10-m.y. time slices from the present to mid-Jurassic—the initial opening of the Arctic Ocean. A basic assumption is that Lomonosov Ridge, Alpha Ridge, Mendeleyev Ridge, and Chukchi Plateau are all foundered continental plates.

Opening of the Arctic occurs in two stages: Late Jurassic-Cretaceous for the Canada basin and Neogene for the Eurasian basin. Opening is facilitated by two subparallel transform shears—the Arctic (Kaltag-Porcupine) on the east and the Chukchi on the west. Deformation is essentially tensional on the Barents side of the Arctic and shear-compressional on the Alaska side.

The development of Chutkoya, North Slope, Brooks Range, northwest Canada, Seward Peninsula, and central Alaska can be sequentially related to Arctic opening, modified by impingement on the northern terrane of allochthonous terranes arriving from the south—the Pacific plates of Tintina, Denali, Orca (Prince William-Chugach-Yakutat), Anadyr, Khatyrka, Kolyman, and other minor terranes.

The North Slope of Alaska, a passive, rifted, subsided margin, is restored to line up with a similar margin on Alpha Ridge. Northeastern Alaska (the Romanzof Mountain area) lines up opposite the north end of the Sverdrup Rim, near Prince Patrick and Borden Islands.

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Cretaceous Olistostrome Model, Brooks Range, Alaska

The foothills area of the Brooks Range thrust belt in the area between the Itkillik River and the Etivluk River is composed dominantly of shallow, thrusted olistostrome sheets. Three olistostrome units can be recognized based on the dominant lithology of contained olistoliths and age of the matrix shales. The lower unit is Tithonian to mid-Valanginian in age and is characterized by abundant graywacke and turbidite, mafic rocks, black cherts, olistoliths of Norian-Rhaetic shales, Nuka sands, and glide sheets of Upper Devonian to Lower Mississippian rocks. Olistolights were derived from the Misheguk, Ipnavik, and Nuka Ridge allochthonous sequences.

The middle unit is of late Valanginian age and has olistoliths of Norian shales; more abundant Upper Triassic chert; Otuk Formation; variegated, radiolarian, black and white cherts; Siksikpuk facies red, green and black shales; Upper Jurassic graywacke; and minor occurrences of mafic rocks. The unit is characterized by glide sheets of Triassic white and multicolor cherts. Olistoliths are derived from Nuka Ridge and Brooks Range sequences.

The upper unit is Hauterivian in age and olistoliths include reworked material from all older units. Olistoliths are few and widely scattered. Isolated outcrops of white chert and conglomerate boulders are characteristic.

The oldest unit was originally deposited in a now-destroyed "southern" basin, south of the Brooks Range. The middle unit was originally deposited in a basin near the present mountain front and the upper unit in the Colville trough. Each unit developed in front of and was sourced from advancing thrust sheets.

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Structural Style—Brooks Range Mountain Front, Alaska

The Brooks Range mountain front between the Sagavanirktok River and Kurupa Lake is characterized by thrust sheets of Lisburne rocks, which dominantly have stratigraphic tops to the north and either dip northward or are overturned to the south.

The early (Jurassic-Neocomian) thrust belt strikes obliquely (N70°W) into the mountain front and can be traced on seismic sections into the foothills. Individual thrust structures die out westward into overturned folds and ultimately into plunging noses as the thrust belt plunges to the west and successively higher structural levels are exposed. The total thrust displacement remains essentially constant because of transfer of motion to higher thrusts. Most of the west plunge occurs along narrow zones of "instant plunge" with essentially zero plunge occurring along trend.

The present east-west mountain front is oblique to the original thrust vergence (N20°E) of Jurassic-Neocomian age and is due to later (Albian and younger) Brooks Range core uplift, folding, and comparatively minor thrusting.

The Lisburne folds at the mountain front respond almost plastically to the late core uplift and gravitationally slide downward on rotated north-dipping thrust faults to form cascading folds with easiest relief upward and northward.

Core uplift has rotated original thrust sheets 90° in some instances so that geologic map patterns are plunge-projection cross sections of thrust plates. The pattern at Eskimo Creek (Table Mountain quadrangle, eastern Brooks Range) illustrates how a plunge view can reveal the true structure of the thrust belt.

Examples of mountain-front structures are given at Killik River, Kurupa Lake, Kaikshak Hill, Akmagolik Creek, Atigun River, and Ivishak River.

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Provenance of Conglomerate Clasts from Upper Cretaceous Kuskokwim Group, Southwest Alaska

The predominantly Upper Cretaceous (Albian to Coniacian) Kuskokwim Group consists of marine turbidites and subordinate fluvial and shallow marine strata, deposited in an elongate southwest-trending basin covering over 70,000 km^2 in southwestern Alaska. In the Sparrevohn and Cairn Mountain areas of the Lime Hills A-7 and A-8 quadrangles, fluvial, inner fan, middle fan, and outer fan facies are stacked with distal facies over proximal facies by northwest vergent thrust faults. Inner fan pebble-to-cobble conglomerate and pebbly sandstone were deposited as submarine grain flows up to 10 m thick containing reversely graded bases and normally graded tops. Clasts from these conglomeratic deposits are predominantly sedimentary rock fragments—particularly sandstone, siltstone, and argillite—originally thought to have been derived from the nearby Jurassic and Lower Cretaceous flysch (Kihiltna terrane). Detailed examination of these clasts, however, indicate that they contain as minor constituents Paleozoic coral, oolitic limestone, algal boundstone, radiolarian chert, and mafic, intermediate, and felsic volcanic rocks, most likely derived from the adjacent Nixon Fork, Dillinger, and Mystic terranes. Sandstone clasts are arkosic (Q25-F37-L38, n = 7) and contain subequal amounts of K-feldspar and plagioclase. Sand grains within these clasts are moderately sorted, subrounded, and have pre-solved contacts. Similar arkosic rocks have been described from the Dillinger terrane of the McGrath quadrangle and are the most likely source for the pebbles and cobbles within the Kuskokwim Group.

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Cretaceous Basin-to-Shelf Transition in Northern Alaska: Deposition of the Fortress Mountain Formation

The Fortress Mountain Formation (Albian) is a sequence of shale, sandstone, and conglomerate exposed as isolated synclinal outcrops in the southern foothills province of the Brooks Range. The formation overlies a variety of severely deformed older rocks, particularly the Okpikruak Formation of Neocomian age. The unit records a significant change in the depositional architecture of the North Slope Cretaceous and is closely tied to the evolution of the Brooks Range orogenic belt.

Detailed stratigraphic and sedimentologic studies of the Fortress Mountain Formation within the type region and at easternmost exposures have demonstrated a systematic change in lithology and bedding style. The lower 40% of the Fortress Mountain is transitional with the Torok Formation and is composed of thick (up to 2,000-m) intervals of gray to black shale with thin, rhythmically interbedded, fine-grained sandstone beds. This succession is interrupted periodically by allochthonous blocks of conglomerate and conglomeratic sandstone. The sequences record a transition from basin plain to slope sedimentation. The middle 30-40% of the formation is composed of thick conglomerate and conglomeratic sandstone lenses that thin toward the north and are arranged in multiple upward-coarsening sequences and megasequences.

Regional dispersal patterns indicate these beds accumulated within the midfan environment of a northward-prograding submarine fan complex. The upper 20-30% of the Fortress Mountain rests above a conspicuous angular discordance and is composed of upward-fining channel sequences of conglomerate, sandstone, and shale. This phase of deposition records progradation of fan-delta and fluvial environments. The regional depositional architecture of the Fortress Mountain records the buildup and sedimentologic evolution of the Cretaceous shelf, which ultimately allowed progradation of overlying deltaic and interdeltaic complexes of the Nanushuk Group and related strata.

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Crude Oil Chemistry and Classification, North Slope, Alaska

Detailed chemical analyses of crude oil from the North Slope of Alaska began with United States Bureau of Mines efforts about 35 years ago. The discovery of major commercial accumulations within the past 15 years has resulted in routine application of modern analytical techniques, with the resulting classification of North Slope oils into two chemically distinct, and presumably separately sourced, families. This report will review published analytical results obtained for North Slope oils to date, in light of data for nine specific North Slope oils analyzed by Union Oil.

The nine oils analyzed are from the National Petroleum Reserve in Alaska and Prudhoe Bay field, and include a condensate and at least four biodegraded oils. Gravity and sulfur content variations are 65-54.1° API and 0.01-1.85%, respectively. Carbon isotope ratios of total (untopped) oils vary between −29.4 and −25.3 ‰, and are a discriminating parameter for grouping these oils into two chemical families. Other distinguishing chemical attributes include vanadium, nickel, and sulfur concentrations, V/(V + Ni) ratios, carbon number distribution of the major $5(\alpha)$, $14(\alpha)$, $17(\alpha)$, 20R-steranes, and i-C_{19}/i-C_{20} isoprenoid ratios. Using these distinctions, the oils are successfully grouped into two types. Type A oils, typified by the Prudhoe crude, are relatively high in vanadium, nickel, and sulfur content, isotopically light, and high in tricycle terpane content. Type B oils, typified by the Umiat and Simpson crudes, are low in sulfur and metals and contain relatively high concentrations of $5(\alpha)$, $14(\alpha)$, $17(\alpha)$, 20R-ethylcholestane. Although little definitive published work on potential source rocks of maturities less than peak generation is available, the oil typing demonstrated here and elsewhere strongly suggests at least two distinct source sequences. Based on the biological marker geochemistry of the oil types, the nature of these sequences may be predictable.

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Geotectonics of the Bering Sea Area, Alaska

Plate tectonic interactions in the Bering Sea area have played a major role in its structural and geological history since Paleozoic time. The geotectonic style of different areas is similar due to the widespread influence of plate motions. Three major structural and depositional belts have been identified linking the Siberian area to Alaska across the Bering Sea. The northern belt, the Verkhoyansk-Chukotsk-Seward-Brooks, consists of early Mesozoic miogeosynclinal sediments. The middle belt, the Okhotsk-Chukotsk-Yukon-Koyukuk, consists of a Mesozoic magmatic arc and numerous accreted allochthonous terranes. These features were formed as a result of convergence/subduction of a southern oceanic plate. The southern belt, the Koryak-Anadyr-Peninsular, consists of terranes accreted during Cretaceous time and forms the southern limit of Mesozoic subduction.

During Late Cretaceous to early Tertiary time, rifting in the Atlantic caused these belts to be oroclinally bent southward and resulted in a shift of the Mesozoic subduction zone to a more southerly location. During formation of the oroclinal fold, subduction along the Bering Shelf margin changed from direct to oblique subduction, then to transform motion. Major movement along this margin ceased as the current Aleutian Island arc system began to form.

Late Cretaceous to early Tertiary structures within the Koryak-Anadyr-Peninsular area are potentially important for petroleum exploration because they could have formed concurrently with source and reservoir facies.

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The Paleogene Sequence on the Alaska Peninsula

Paleogene strata are exposed nearly the entire length of the Alaska Peninsula. They include continental and marine volcaniclastic rocks and a thick volcanic sequence. The strata are divided into the Tolstoi, Stepovak, Meshik, and Belkofski (in part) Formations in the southern part of the peninsula, and into the nonmarine clastic West Foreland Formation and the Hemlock Conglomerate in the northern part.

The Tolstoi Formation (Paleocene and Eocene), 670-1,380 m thick, consists mainly of continental quartz- and chert-rich sandstone and conglomerate, siltstone, and coal. Volcanic clasts and tuffaceous detritus increase in abundance upward. Neritic strata are present as interbeds in the type area. The formation overlies, with a major unconformity, strata ranging in age from Late Jurassic to Late Cretaceous. Partly coeval strata at the north end of the peninsula (West Foreland Formation) are mainly volcanic sandstone and conglomerate.

The Stepovak Formation, 1,800-2,000 m thick, represents two contrasting depositional environments—a lower dark siltstone and sandstone turbidite, about 975 m thick, and a shallow neritic sandstone and siltstone, rich in volcanic material, about 1,000 m thick. Locally, the upper part is deltaic sandstone, siltstone, and coal. An abundant megafauna of Eocene and Oligocene age is found in the neritic deposits. A thick coeval volcanic unit, the Meshik Formation, is present in the central part of the peninsula. Andesitic to basaltic lava, breccia, tuff, and lahars, as much as 1,500 m thick, have been K-Ar dated at 27-38 m.y. Similar rocks with interbedded sediment at the end of the peninsula are included with the Belkofski Formation.

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Lower Paleozoic and Proterozoic Rocks of Southern Brooks Range, Alaska

Lower Paleozoic or Proterozoic basement rocks occur in windows and thrust plates in several areas of the Brooks Range. Uranium-lead radiometric analyses of highly metamorphosed rocks from the Baird Mountains and Ernie Lake area have yielded Proterozoic ages. Structural, stratigraphic, petrologic, and isotopic evidence exists for Proterozoic(?) rocks in the schist belt; around the Chandalar, Arrigetch, and Igikpak plutons; and in the Cosmos Hills window. Fossiliferous, lower Paleozoic, low-grade metasedimentary rocks occur in the Romanzof Mountains, Doonerak window, and Baird Mountains, and may also surround the Chandalar plutons. Locally, the Lower Paleozoic rocks are unconformably overlain by Devonian to Mississippian metasediments and may stratigraphically overlie older, higher grade metamorphic rocks. Similarities in the stratigraphic settings and lithologies and in fossil ages and affinities allow correlation of the lower Paleozoic rocks in the southern Brooks Range.

Correlation of lower Paleozoic rocks exposed beneath the Endicott allochthon at the Doonerak fenster with coeval rocks in an overlying thrust plate to the south at Snowden Mountain is especially significant. A west-trending thrust fault, which is rooted in lower Paleozoic basement, along the north side of Snowden Mountain is postulated to account for these relationships. Apparently, the Endicott allochthon roots beneath the Snowden Mountain thrust fault. Evidence from conodont samples currently being studied by A. Harris may bear on the extent of the lower Paleozoic rocks in the upper plate of the Snowden Mountain thrust and in the Chandalar area.

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Llama-Supported Geologic Fieldwork in Brooks Range, Alaska

For the first time since their camelid ancestors migrated from Asia, across the Bering Sea land bridge, into the Brooks Range, and eventually south to the Andes during the Late Pleistocene, domestic llamas trekked through Arctic Alaska mountains. During August 1981, six llamas carrying 520 lb of gear supported a field party of eight people that traveled 80 mi over 11 days. The route followed left the Dietrich Trans-Alaska Pipe-