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Lithological and Geochemical Facies of Shublik Formation (Triassic), North Slope, Alaska

The Shublik Formation is a heterogeneous unit consisting of several distinct facies, including: (1) fossiliferous sandstone or siltstone; (2) glauconitic sandstone or siltstone; (3) siltstone, calcareous mudstone, or limestone with phosphate nodules; and (4) black, calcareous mudstone or black limestone, usually fossiliferous. This sequence of lithologies is interpreted as having been deposited along an onshore-offshore (north to south) gradient. Bioturbation of the sediments is variable but generally decreases offshore. Organic carbon increases offshore, and phosphate increases from the paleoshoreline and decreases again farthest offshore.

The distribution of glauconite, phosphate, and organic-carbon–rich rock is consistent with the facies expected in an upwelling zone that has a well-developed oxygen minimum. Glauconite is consistent with dysoxic conditions, and well-laminated, organic-carbon–rich rock in the offshore facies is consistent with anoxic conditions. High biologic productivity coupled with normal oceanic circulation may have caused the basin's low-oxygen conditions, as indicated by the presence of phosphate nodules and the extreme abundance of bivalves that have been interpreted to be pelagic. Phosphate indicates a high rate of supply of organic matter to the sediment-water interface, where it was mobilized from the organic matter within the anoxic zone and reprecipitated at the zone's edges. Pelagic bivalves (*Monotis* and *Halobia*) are present in such large numbers as to suggest unusually abundant food supply; in addition, their distribution is consistent with mass kills, which are common among fish in upwelling zones.

Although an open-ocean divergence was predicted previously for the North Slope region in the Triassic, the distribution of the facies of the Shublik Formation relative to the paleoshoreline and the rapidity of the facies change onshore to offshore are more consistent with a coastal upwelling zone.

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Diagenetic Variations in Permo-Triassic Ivishak Sandstone in Prudhoe Bay Field and Central-Northeastern National Petroleum Reserve in Alaska (NPRA)

Porosity in the Ivishak sandstone on the North Slope is frequently cited as an example par excellence of secondary, or leached, porosity. In an attempt to corroborate and expand this contention, 100 thin sections were examined from representative wells in the Prudhoe Bay field and in NPRA. Monocrystalline quartz and biogenic chert are dominant framework grains in the two areas. Minor amounts of polycrystalline quartz, and sedimentary and metamorphic rock fragments are also present. Most of the chert in NPRA is nonporous, whereas Prudhoe Bay chert contains microscopic pores where siliceous biogenic debris, chalcedony, or dolomite formerly existed.

The diagenetic sequence of the NPRA samples includes: (1) initial porosity loss by either compaction or siderite, chlorite, or pedogenic calcite cementation; (2) minor carbonate dissolution; (3) localized chert dissolution; and (4) quartz overgrowth formation. The diagenetic sequence of the Prudhoe Bay samples includes: (1) chert dissolution; (2) quartz overgrowth, kaolin, pyrite, and siderite formation; and (3) siderite dissolution.

Some workers have suggested that an early carbonate cement maintained the large intergranular pore volumes in the Ivishak at Prudoe Bay. A more likely possibility is that a long, initial period of shallow burial maintained a loose packing density without early cementation. Later chert and siderite dissolution increased porosity. By contrast, the Ivishak in NPRA was subjected to deeper burial early in its history. This caused porosity reduction by relatively early compaction. The later diagenetic events, which ultimately control porosity and permeability variations between the two areas, are, in part, also controlled by the different burial regimes.

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Nuclear Well Logging in Permafrost

A Mount Sopris portable well logger was calibrated for gamma-gamma density and neutron porosity in dry geophysical-type boreholes in unfrozen materials. Since the hydrogen index of ice is less than that for water, the response of the neutron porosity for 100% ice reads as approximately 72% porosity. Thus, by cross plotting gamma-gamma density vs. neutron porosity, we can determine if the soils are frozen and estimate the unfrozen water contact.

Using this crossplotting technique, we believed that the hydrogen indices of natural gas hydrates, detected in oil wells on the North Slope of Alaska, provide a sufficient contrast with those of water and/or ice to provide a method of quantitative evaluation of hydrates in situ.

Logs of a hole drilled through a buried, artificial-ground ice mass showed that the natural gamma-log count rate decreases significantly in the vicinity of the ice, indicating that the natural gamma log could prove useful for detecting and delineating massive ice.

Calibrated logs were also used to estimate potential thaw consolidation and to follow seasonal variations in moisture content and bulk density.

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Late-Stage High-Angle Faulting, Eastern Doonerak Window, Central Brooks Range, Alaska

Three deformation phases are recognized in the eastern Doonerak window. From oldest to youngest, they are (1) an isoclinal folding event characterized by pervasive axial-planar slaty cleavage, (2) formation of kink bands and chevron-style folds of the slaty cleavage, and (3) development of gentle flexures with associated crenulation cleavage or close-spaced joint planes. First- and second-phase structures are related to thrust faulting. High-angle faulting may be related to third-phase deformation.

Most of these high-angle faults strike west to northwest, are subvertical, and exhibit slickenside striations that plunge gently west. Another set of high-angle faults strikes northeasterly and contains two generations of slickenside striations, a younger subhorizontal set and an older subvertical set. These perpendicular slip directions support the existence of two separate stress regimes: (1) a north-trending principal compressive stress axis, σ_1, and (2) a west-trending σ_1.

Structural analysis of several west-northwest–trending high-angle faults and associated extensional fractures demonstrates a stress regime with σ_1 plunging gently west-northwest. This regime is incompatible with north-directed thrusting and supports a separate late-stage deformational event. Two possible interpretations are that the high-angle faulting is (1) related to west-northwest thrusting or (2) is a separate phase of deformation involving significant east-west compression.

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Reconnaissance Oxygen Isotope Study of Gold-Bearing Quartz Veins Within Metasedimentary Rocks of Valdez Group, Alaska

A reconnaissance oxygen-isotope study of gold-bearing quartz veins within the metasedimentary rocks of the Valdez Group from around Prince William Sound was conducted to examine the variations and similarities within and between the different gold districts, and to investigate the origin of the ore-forming solutions. Analyses were made of mineralized samples from mines and prospects in the Port Valdez, Port Wells, Girdwood, Hope-Sunrise, and Moose Pass gold districts.

In the Hope-Sunrise district the $\delta^{18}O$ values of the gold-bearing veins are relatively constant, ranging from +16.0 to +16.7 ‰, whereas in the Port Valdez district, the vein values are more variable (+13.9 to +17.0 ‰), implying variations in temperature or fluid compositions. Within individual mines, the $\delta^{18}O$ values are constant to within 0.1 ‰ along strike in continuous veins, and vary by a maximum of 0.2 ‰ between bands of quartz in ribbon vein samples.

Petrographic and fluid inclusion data suggest a temperature of approximately 325°C for formation of the mineralized quartz veins. Calculated $\delta^{18}O$ values for fluids in equilibrium with the veins range from +8 to +12 ‰. A quartz separate from an altered quartz diorite intrusion at the Rough Tough mine in the Port Valdez district has a $\delta^{18}O$ value of +14.0 ‰; fluid in equilibrium with the intrusive at a reasonable temperature for its emplacement would have had a $\delta^{18}O$ value of approximately +12 o/oo. These data suggest that the mineralized quartz veins formed from fluids derived from the Valdez Group during metamorphic dewatering.

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Paleomagnetic Results from the Sadlerochit and Shublik Mountains, Arctic National Wildlife Range (ANWR), and Other North Slope Sites, Alaska

Carboniferous through Triassic sedimentary units exposed in the Shublik and Sadlerochit Mountains were sampled in an attempt to obtain reliable primary magnetic components. Reliable pre-Cretaceous paleomagnetic poles from this area would greatly advance the understanding of the rotation and latitudinal displacement history of the North Slope.

Carbonate rocks of the Carboniferous Lisburne Group were drilled in south-dipping units of Katakturuk Canyon, Sadlerochit Mountains, and in the north-dipping Fire Creek section, Shublik Mountains. Magnetic cleaning involved stepwise thermal demagnetization to 550°C. Principal component analysis of the demagnetization results defines two major components of magnetization. The secondary component is steep and down (inc = 87°), but the characteristic component (325°C-500°C) is reversed. The secondary magnetization postdates Cretaceous and younger folding, whereas the characteristic component was acquired before folding. The components may have recorded two phases of overprinting: a Late Cretaceous into Cenozoic normal overprint and a predeformation remagnetization episode during a time of reverse polarity. However, the reverse component more likely is primary remanence. If so, it would suggest little latitudinal displacement but 40° of clockwise rotation with respect to North America.

The Devonian Nanook Limestone, sampled in the Shublik Mountains, also reveals two major components of magnetization; however, the characteristic component is isolated at blocking temperatures greater than 500°C and is shallower in inclination than expected from the Devonian reference pole for North America.

The recovery of the reversed characteristic component in this study is a significant result by itself. It is good evidence that at least part of the northeast Brooks Range has escaped the thorough Cretaceous normal-polarity overprinting that has been observed in the north-central Brooks Range. We hope that analyses of additional samples from the Katakturuk Dolomite, Nanook Limestone, Lisburne Group, Sadlerochit Group, and Shublik Formation in ANWR and from the Triassic and Jurassic Otuk Formation in the east-central foothills will also discriminate pre-Cretaceous magnetizations and will provide constraints on the time they were set.

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Marine Magnetic Survey of Kachemak Bay, Alaska

Kachemak Bay in south-central Alaska is approximately 38 mi (60 km) long and 13 mi (20 km) wide at the mouth. Geologically, Kachemak Bay marks the boundary between the Mesozoic rocks of the Kenai Mountains and the low-lying Tertiary sediments of the northwestern part of the Kenai Peninsula. The Border Ranges fault is believed to traverse the bay, though the fault's exact location is not known. In the summer of 1981, a marine magnetic survey was carried out to locate the fault and/or other geologic boundaries. The magnetic data indicate that a fault, presumed to be the Border Ranges fault, traverses the bay between the Seldovia and Homer areas. The location of what is inferred to be the contact between the Mesozoic and Tertiary rocks can also be seen in the magnetic data. The data also suggest the existence of an ultramafic body beneath the bay.

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Satellite Transmission of Geologic Data from the Ocean Odyssey

Current satellite communications technology makes it possible and practical to transmit geological and other information from remote oil rigs, under adverse environmental conditions. Under such critical conditions, the ability to provide experts, who are at a significant distance from the rig, with the information necessary to understand what is happening and to carry out timely interpretations has an important impact on successful exploration and economic objectives.

The Ocean Odyssey, operated by Shell in Alaskan waters, provides a practical example of the benefits of satellite communications. From locations in the Bering Sea, Shell is transmitting information to its offices in both Anchorage and Houston for review and analysis. Digital information, suitable for detailed processing and analysis by a mainframe computer is also transmitted. Transmissions designed for managerial and specialist review include periodic reports and tabular printouts, as well as selective color plots of key parameters. The latter are being sent at key points in the drilling process and in response to specific office-based requests for information. Examples of useful transmission formats are provided.

A close relationship exists between the status of well-site operations and the manner in which data communications are carried out. Operational schedules are normally keyed to the work schedule on the rig. But as office-based users become accustomed to examining timely information, additional transmissions are requested. With the present satellite communications configuration the operational schedule is also constrained by the availability of the satellite link. Data communications are based upon batch transmission in which digital information, prints, plots, and reports are accumulated according to the operational schedule and then transmitted, via the Inmarsat satellite. Automatic error correction assures that the information arriving at each office is reliable. Automatic data-encryption assures that the information is properly secured against unauthorized access.

Extensive planning is necessary to allow for special problems that arise in establishing a satellite communications link from offshore rigs. These range from technical considerations in providing effective satellite coverage over a wide geographical area in which the offshore rigs may range, to equipment placement and operation, to the development of effective training programs for personnel on the rig and in the office. The elements of the plan are discussed, and examples drawn from the Ocean Odyssey are reviewed. Estimates of actual communication-time requirements are provided along with some of the cost and benefit considerations.

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Chemical and Petrographic Characterization of Drill Core from Beluga Coalfield.

Chuitna River field is part of the Beluga-Yentna field in the upper Cook Inlet basin. Coal occurs in the Tertiary rocks of entirely continental origin. In order to characterize the vertical variation of coal more completely and to understand the environments of coal deposition, a drill hole was cored to a depth of 290 ft with the help of Diamond Alaska Coal Co. The core included five coal beds: Blue (bottom 15 ft), Red 3 (13 ft), Red 2 (26 ft), Red 1 (16 ft), and Purple (5 ft). These beds were sampled foot by foot and were characterized for ash, moisture, ash fusibility, ash composition for major oxides and trace elements, vitrinite reflectance, and petrographic composition under normal incident light as well as fluorescent illumination. A palynological evaluation is in progress. Ultimate analyses were made for 5-ft intervals.

Ash composition of foot-by-foot samples varied widely. For example SiO_2 ranged from 0.58 to 65%, Fe_2O_3 from 1.97 to 57%, CaO from 2.5 to 35%, P_2O_5 from 0.07 to 17%, and Ba from 0.19 to 3.7%. Petrologic analyses showed less drastic variations within a seam. The wide variation in ash composition, particularly of iron and silica, among others, is indicative of periodic changes in pH of the swamp environment. Lack of high inertinite zones within the seams studied shows that the swamp was not subjected to drastic changes in the water table and that the subsidence kept pace with peat accumulation during the formation of each of the seams.

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Northeastern Brooks Range, Alaska: New Evidence for Complex Thin-Skinned Thrusting

Extensive fieldwork has shed new light on the style of deformation in the Franklin, Romanzof, and British Mountains of the northeastern Brooks Range. Bedding-parallel thrusting controls the structure, and two