high-latitude glaciation commenced more than 3 m.y. ago.

Three climatic units are distinguished.

The oldest, *Unit III*, consists of Mn- and Fe-rich Foraminifera-poor sediments. Calcareous Foraminifera, in part corroded, are thick-shelled forms. Arenaceous Foraminifera (*Glomospira gordialis, Cyclammina pusilla,* and *Alveolophragmium subglobosum*) dominate the benthic assemblages. Lower than present sedimentation rates could account for the selective solution of the less resistant calcareous tests and the impoverished character of the fauna.

Unit II, deposited between 3 and 0.7 m.y. ago, is poor in Fe and Mn oxides, and Foraminifera. It contains one Foraminifera-rich layer; the predominant foraminifer in this layer is temperate-subarctic, euryhaline *Globigerina quinqueloba* ($O^{18/16}$ determinations). This species occurs with sinistral *Globigerina pachyderma* throughout Unit II. Fragile calcareous benthonic Foraminifera (*Stetsonia horvathi, Sphaerodina bulloides* and *Bolivina* sp. A n. sp.) periodically abound, constituting up to 88% of the fauna. Concentration of thin-walled benthonic Foraminifera suggests that the near absence of planktonic forms was due to adverse environmental conditions rather than to dissolution of the less resistant tests.

It is assumed that the Arctic was free of permanent pack-ice during the deposition of Units II and III.

Unit I was deposited within the last 0.1 m.y., a time of conspicuous climatic fluctuations as indicated by the temporal variations in fauna and in mineral/fauna ratio. Beds rich in Foraminifera and in Mn and Fe oxides alternate with layers poor in both Foraminifera and Mn and Fe oxides. The former represent conditions similar to present (permanent pack-ice cover) and contain sinistral *G. pachyderma* almost exclusively. *G. quinqueloba* attains high frequencies at the beginning and end of some of these cold periods. In the Foraminifera-poor beds, deposited during pack-ice-free intervals, sinistral *G. pachyderma* is accompanied by *G. quinqueloba;* other low-latitude Foraminifera are present in a few places. Pteropods (*Limacina helicina*) are preserved principally in core tops.

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STRATIGRAPHY OF BEAUFORT FORMATION ALONG WESTERN MARGIN OF CANADIAN ARCTIC ISLANDS

The Beaufort Formation of Late Tertiary (probably late Miocene-early Pliocene) age occupies the western parts of the Arctic Islands bordering the Beaufort Sea. It extends from southern Banks Island on the south to Meighen Island on the north.

The best exposures of the Beaufort Formation, which are on northwestern Banks Island, can be lithologically subdivided into 2 or possibly 3 units separated by erosional unconformities. The lowest unit consists of a basal medium-fine cross-stratified sandstone followed by clay, woody peat, and a second clay zone. Each of these subunits is successively truncated by erosion on the east. The middle unit is characteristically light-colored gravel and coarse sand with minor amounts of uncompressed wood. This unit is overlain (in erosional contact) by darker, coarser gravels with abundant wood lenses. The two upper units correspond to the Beaufort Formation as defined on Prince Patrick Island, whereas the lower unit represents strata not known from that island. Elsewhere the strata can be assigned to either the upper or lower unit.

Mineralogically, the lowest unit is composed of about 70% quartz, 25% chert, and 5% others (shale chips predominantly). The middle unit consists of 60% quartz, 30–35% chert, and 5–10% others (predominantly shale). The upper unit consists of about 50% quartz, 35–40% chert, and 10–15% others (predominantly shale). The quartz is polycyclic whereas the chert and the shale are monocyclic. Paleocurrent data indicate that the straits between the islands developed in post-Beaufort time.

Megafossils belonging to *Picea, Pinus, Larix,* Alnus, 14 species of Bryophytes (identified by M. Kuc), and about 30 pollen and spore species have been identified. These indicate that at the time of deposition of the Beaufort, the climate was very similar to that of the Great Lake region today.

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BERING SEA BASALTS: THEIR SEQUENCE AND ORIGIN

Late Cenozoic volcanic rocks in the Bering Sea region include both slightly undersaturated tholeiitic basalts and highly undersaturated nepheline basalts. The two kinds of basalt are interspersed in time and space. On Nunivak Island volcanism was episodic, and most of the volcanic episodes included both highly alkalic and tholeiitic eruptions. At 3 places on Nunivak Island and at numerous other places in the Bering Sea volcanic province, nepheline basalt cones and flows underlie tholeiitic flows and indicate that highly alkalic volcanism commonly preceded tholeiitic volcanism.

Study of the vents and flows shows the nepheline basalts erupted more violently and consequently were much richer in gases than the tholeiite basalts. This fact and the volcanic sequence suggest that the nepheline basalts represent early formed products of partial melting which would normally contain a relatively large proportion of the gaseous elements.

The occurrence of lherzolite inclusions (generally considered to be fragments of mantle material) in most of the nepheline basalts and in tholeiite at Nanwaksjiak Crater, together with the close association of the 2 types of basalt, suggests a common mantle origin.

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TECTONIC DEVELOPMENT OF BERINGIA, LATE MESOZOIC TO HOLOCENE

Beringia—northeastern Siberia, western Alaska, and the separating shallow Bering Sea—is dominated by an M-shaped structure comprising the Alaskan and Chukotkan oroclines, and a broader intervening flexure that is submerged on the continental shelf. The Beringian flexures were evidently initiated during the Jurassic Period, possibly in conjunction with early rifting in the Atlantic. In Beringia curvilinear basins developed and filled with terrigenous and volcanic sediment. Near the end of the Cretaceous new stresses crumpled and uplifted these basins. The great transcurrent faults of Alaska and Beringia were initiated at this time. We also speculate that the Aleutian-Komandorsky Ridge (and adjacent trench?) formed at this time, signifying a southward shift (from continental margin to ridge) in the site of ocean-continental crust interaction.

Beringia stood high during the Paleogene; sediment accumulated only in subsiding parts of the Bering continental margin and in rather restricted basins at the apices of the Alaskan and Chukotkan oroclines.

In the early Tertiary, possibly in response to the extension of Atlantic rifting into the Arctic basin, a new stress field developed that produced subsidence and basin formation. Neogene subsidence allowed the sea to invade progressively linked subshelf basins, creating the first sinuous shallow water connection between the Pacific and Arctic Oceans late in Miocene time. This seaway was severed about 5 m.y. ago, probably in response to uplift of the Bering Strait horst. Subsidence resumed, and the Bering and Chukchi Seas assumed their present form about 3.5 m.y. ago during the late Pliocene Beringian transgression.

Local basin formation combined with general subsidence of the Bering shelf continues to the present. However, movement along the western submerged extensions of the major transcurrent faults of Alaska appears to be slow or absent.

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Permafrost in Prudhoe Bay Field: Geology and Physical Characteristics

In the recently discovered Prudhoe Bay field on the North Slope of Alaska the upper part of the production wells penetrates a massive permafrost zone. The base of this zone gets deeper as the distance from the existing seashore increases, the greatest depth so far found being about 2,000 ft. The extent of the permafrost zones may be seen quite clearly on logs run in the hole prior to casing, provided the hole diameter is not too large. The best definition can be obtained from the sonic, resistivity, and caliper logs. In addition, temperature surveys run in the completed wells several months after completion show clearly the base of the permafrost, and the different thermal conductivity of the frozen and unfrozen material.

Soils and geologic data have been obtained from a continuous core of the permafrost zone in the Prudhoe Bay area in the interval from 500 to 1,850 ft, and from several cores taken in parts of the upper 500 ft. A wide range of measurements has been made including densities and relative densities, porosities, ice saturations, and soil and ice classifications. From the results of these and other studies some comments and speculation on the deposition of the permafrost and the general geology of the surface deposits can be made.

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Logistics' Costs Associated with Oil and Gas Exploration and Exploitation in Far North of Canada

Realization of the oil and gas wealth in Canada's North has been, and will continue to be limited by difficult logistic problems and attendant costs.

During the past decade, however, there has been a continuous improvement in the northern infrastructure, including community development, communications and, most notably, in transportation, which have served to reduce greatly the cost of logistic requirements. Roads suitable for year-round use are complemented by roads suitable in the winter. Barge transportation on the Mackenzie River has greatly expanded, as has commercial sea-lift to the Arctic Islands in the summer months. Cargo aircraft, both fixed and rotating wing, carry bulky and heavy loads and land and take off on water, or on improvised airstrips on land and ice on river or sea, adding a surprising degree of flexibility in transportation. Large diameter pipelines may be built on the permafrost of the Arctic region for cheap transport of crude oil and gas to Canada's Arctic or Pacific seacoast, or to southern interior markets.

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Jurassic Paleogeography of Alaska

During the Jurassic, marginal seas occupied considerable areas in southern and northern Alaska and in the western part of the Kuskokwim region of southwestern Alaska. They appear to have been less extensive during Bathonian and Tithonian times and absent during late Callovian time. They appear to have been absent from large areas in the interior of Alaska. Connection of the northern with the southern seas may have occurred through Siberia, through Yukon territory or, possibly, through westernmost or central Alaska.

The ammonite succession in Alaska is similar in general to that in central and northern Europe; in the Lower Jurassic, it is essentially identical. In Bajocian and in Callovian to Kimeridgian beds, the ammonite succession in Alaska differs mainly by the presence of some genera that have been found only in areas bordering the Pacific Ocean. In contrast, the Bathonian rocks of Alaska contain ammonites, such as *Arcticoceras, Arctocephalites,* and *Cranocephalites* that are widespread in the Arctic region but are unknown in central Europe. Comparisons with the Tithonian of Europe are not possible because ammonites of that age are not yet known from Alaska. The presence of Tithonian strata, however, is shown by the occurrences of *Buchia piochii* (Gabb) at a few places.

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Arctic Oil and the World—One Perspective

The Arctic is the latest accretion to the prospective petroliferous areas of the world which historically has grown in steps as new areas have come within reach through technical and economic breakthroughs.

The production of Arctic oil will depend on the effort expended. Historically, though total world oil supply and demand have increased smoothly and exponentially, individual country productions and demand have moved in steps as the effort expended has varied with the presence or absence of restrictions, self or externally imposed.

Resulting world oil supply patterns over the past 30 years have also shown some marked changes, some short, some longer lived.

North American Arctic oil, on presently indicated reserves, will be used in the United States. But what would the world supply pattern be in 1985 if the North American Arctic had proved to be equal to the Middle East in size of reserves?

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Importance of Foraminifera for Zoogeographical Division of Arctic Seas in Late Jurassic and Early Cretaceous Times

The discovery of abundant and varied benthonic Foraminifera in marine deposits of the Pechora basin and in western and middle Siberia has made it possi-