a brief two- to three-week breakup period in late May and early June. Streamflow virtually ceases in all streams, including the largest rivers, during the long, cold winters.

At a few locations, ground-water supplies have been obtained from shallow thawed zones adjacent to or underlying streams. Most ground water beneath the permafrost is brackish at best. Large perennial springs such as Shublik and Sadlerochit discharge from carbonate rocks in the central and eastern Brooks Range and foothills and within the southwestern Brooks Range, but are remote from areas of present development.

The most successful water-supply developments combine the use and removal of gravel with simultaneous creation of deep surface reservoirs to store abundant summer streamflow.

SMITH, D. G., BP Research Centre, Middlesex, England

Late Paleozoic to Cenozoic Reconstruction of the Arctic

The plate tectonic evolution of the Arctic is reassessed in the context of the known histories of the North Atlantic and North Pacific Oceans, and of the tectono-stratigraphic development of the lands around the Arctic Ocean. Computer map-drawing facilities were used to provide geometrical constraints on the reconstructions, which are presented in the form of eight palinspastic maps.

Stratigraphic similarities among presently dispersed continental areas identify fragments of a former "Barents plate." Collision of this plate with the Euramerican plate was the cause of the Late Devonian Ellesmerian orogeny. In later Paleozoic time, the Siberian continent also joined Pangea by collision with the combined Barents and Euramerican plates along the Urals-Taymyr suture. The Mesozoic-Cenozoic history of the Arctic is concerned with the fragmentation and dispersal of the former Barents plate, as well as the accretion of new continental fragments from the Pacific.

Of the major basins of the present-day Arctic Ocean, the Eurasia basin formed contemporaneously with the North Atlantic Ocean and is still spreading, while the earlier opening of the Canada basin was largely connected with events in the Pacific. The Canada basin formed by the separation of northern Alaska from the area now occupied by the Alpha Ridge. Initial rifting in the Late Jurassic was contemporaneous with the earliest major accretionary events in eastern Siberia and the northwestern Cordillera of North America. An Early to mid-Cretaceous age for the main phase of spreading is confirmed by the age-depth relationship for the floor of the Canada basin. After this time, the Canada basin formed part of the North Atlantic plate, and subsequent movements related to the opening of the North Atlantic and Eurasia basins were taken up within Siberia and the Bering Sea area. The history of the latter is not yet clear for times earlier than the late Eocene—the earliest time for which it is possible to make a geometrically realistic reconstruction of that area.

Earliest stages of spreading in the northern North Atlantic caused the initial separation of Greenland from North America. The Eurekan orogeny in the eastern Canadian Arctic is a local result of this spreading. Palinspastic restoration of the eastern Canadian Arctic Islands is required to fill the gap otherwise left in reconstruction of that area. The Eurasia basin opened contemporaneously with the Norwegian Sea and thus entirely postdates the Canada basin. Geometrical constraints suggest that the Makarov basin, between the Alpha and Lomonosov Ridges, formed during the Eocene.

SMITH, D. T., *Univ. Alaska, Fairbanks, AK*

Gravity Data from the Wiseman Quadrangle, South-Central Brooks Range

Bouger gravity in the Wiseman quadrangle is dominated by a steep north-dipping regional gradient. Within the regional gradient are several residual anomalies that correspond spatially to mapped geologic units. These residual anomalies have a persistent east-west trend, attesting to the continuity of the east-striking geology. The northern end of the gravity gradient is a broad gravity low of down to −100 Mgal and is believed to be due to a low-density root near the core of the Brooks Range. The southern termination of this gradient is a relative gravity maximum located near the "suture" of the Arctic Alaska terrane with the Angayuchum terrane. This relative high is typical of sutures found throughout the world where continental and oceanic plates once converged. In this case, the anomalies appear to be due to the juxtaposition of denser, mafic oceanic rocks to the south (Angayuchum terrane) with less dense, metamorphic continental rocks of the Arctic Alaska terrane to the north. By accounting for the relative densities of the rock units through gravity modeling, it is evident that the low-density root extends south to underlie the schist belt and possibly the mafics of the Angayuchum terrane.

SPICER, R. A., Goldsmith's College, London, England

Plant Megafossil Biostratigraphy and the Late Cretaceous Environment of the North Slope, Alaska

The Early Cretaceous evolution and subsequent geographic spread of flowering plants resulted in major global floristic changes. Studies of recently collected angiosperm fossil leaf-forms using analyses of comparative leaf architecture, facies associations, migrations, and community structure have resulted in a biostratigraphic tool for Alaskan Cretaceous nonmarine deposits, and a greater understanding of the Late Cretaceous terrestrial environment of the North Slope when substantial coal resources were being laid down.

Angiosperms first arrived in northern Alaska, from the south, in latest Albian time. The Brooks Range apparently acted as a filter for some taxa and may have locally modified the climate. There is no evidence for major plant radiations at high paleolatitudes at this time.

Putative evergreens form a large component of the pre-angiosperm floras. Throughout the Late Cretaceous, progressive loss of evergreen and thermophilic elements suggest a deteriorating climate. Paleoclimatic interpretations based on gymnosperm and angiosperm taxa are that: (1) there was no seasonal dark period on the North Slope in mid-Cretaceous times; (2) a mid-Cretaceous warm, mildly seasonal climate deteriorated to being cool temperate, with pronounced seasonality, by the Paleocene; and (3) vegetation may have been light- or cold-limited by latest Cretaceous times. The paleolatitude of greater than 70°N predicted for northern Alaska by paleogeographic reconstructions would appear to conflict with the interpretation that plants experienced no seasonal dark period. An obliquity of 15° could explain this conflict and a closer relative position to the rotational pole accounts for the apparent climatic deterioration.

A detailed study of high-latitude terrestrial-plant ecosystems provides information critical to global climate models and therefore our understanding of the biosphere as a whole.

SPICER, R. A., and B. A. THOMAS, Goldsmith's College, London, England

Mississippian Alaska-Siberian Connection: Evidence from Plant Megafossils

The protolepidodendrid genera *Tomiodendron, Ursodendron, Angarophloios*, and *Meyenodendron* have been discovered on the North Slope. These taxa, with the exception of *Tomiodendron*, are known only from Mississippian (Tournaisian-Visean) units in eastern Siberia and therefore are of uniquely Angaran affinity. The absence of these genera from extensively collected European assemblages strongly suggests that eastern Siberia and northern Alaska were joined, or in very close proximity, during Mississippian time, contrary to most paleogeographic reconstructions. A disjunct relict distribution is discounted on the basis of paleogeographic reconstructions showing even greater separations between Alaska and Siberia during the Devonian.

STICKNEY, R. B., and R. C. WARTHEN, Union Oil Co., Anchorage, AK

McArthur River Field—A Cook Inlet Giant

The eighth major discovery in Cook Inlet basin was announced on October 24, 1965, as a result of drilling the Union-operated Grayling 1-A well near the crest of a broad, low-relief anticline that had been mapped from seismic data as early as 1959. The prolific Hemlock Conglomerate was tested at rates exceeding 2,000 BOPD. As delineation wells confirmed the size of the accumulation, three separate platforms were ordered and were in place by July 1967, and within three months, production from the Hemlock had begun.

Additional oil-productive sands in the Tyonek Formation, immediately overlying the Hemlock as well as several more in the underlying West

Foreland Formation, were placed on production in September 1969. Significant gas reserves in shallower Tyonek Formation sandstone have only been used so far for platform power and gas lift. Development plans are currently being formulated for these reservoirs in response to the recent increasing demands for gas in Cook Inlet.

STONE, D. B., Univ. Alaska, Fairbanks, AK

Paleomagnetism, Paleolatitudes, and Magnetic Overprinting on the North Slope, Alaska

Several paleomagnetic studies have been made in Arctic Alaska, by industry, by the U.S. Geological Survey, and by the University of Alaska. In general, the results available to the public have been disappointing—most samples of pre-Cretaceous rocks give very steep magnetic inclinations with respect to present horizontal. This has been generally interpreted in terms of a Cretaceous overprinting event.

A study of the paleomagnetism of Cretaceous rocks from the North Slope shows that although the Cretaceous field was steeply inclined, it was not as steep as conventional paleogeographic reconstructions would indicate, and not as steep as the bulk of the apparently remagnetized older rocks. This finding leaves open the possibility that the steeper directions recorded by the older rocks are the result of regional tilt, or the result of a paleogeography that allowed an earlier, steeper remagnetizing field.

The shallower inclinations seen in the Cretaceous sediments of the Nanushuk Group (Albian-Cenomanian based on the fossil record with one K-Ar age of 100 Ma from an ash parting) give paleolatitudes of about 75°N. The predicted paleolatitude based on North American paleogeographic reconstructions is 80-85°N. Circumstantial evidence that the paleolatitude was shallower than 80-85°N comes from the enormous biogenic productivity needed to form the extensive coal deposits of the Nanushuk Group. Lower paleolatitudes also may be needed to explain the apparent existence of broad-leaved evergreens and the recently reported dinosaur tracks and skin imprints in the Nanushuk Group.

STUWE, KURT, Montanuniversitat, Leoben, Austria

Structural Features Controlling Emplacement of Gold-Bearing Quartz Veins in Port Wells Mining District, Prince William Sound, Alaska

Data collected in the Port Wells mining district confidently show that the present structural features developed in several stages. These stages were folding, intrusion, faulting, and emplacement of quartz veins. The oldest stage was folding and concomitant metamorphism of the Cretaceous Valdez Group flysch during accretion. The semilithified rocks were folded in at least two phases. An early phase (F1) resulted in a 50% shortening in a northwest-southeast direction; the second phase (F2) caused minor shortening in a northeast-southwest direction. The next stage involved the intrusion of Oligocene plutons (36 m.y.) that crosscut earlier structures. Fracturing and faulting of the plutons and flysch characterized the next stage. Initial faults and structures caused only minor right-lateral displacement. The fault and joint data show details of the time relationship between intrusion and deformation. Several generations of epigenic gold-bearing quartz veins were emplaced along these joint systems. Minor deformation continuing to the present caused some disruption of the veins.

SZUMIGALA, DAVID J., Univ. Alaska, Fairbanks, AK

Tin Creek Zinc, Lead, and Silver Skarn Prospects, Farewell Mineral Belt, Alaska

Several zinc, lead, silver, and copper skarn and replacement bodies occur in a 500 km^2 area near Farewell, in the McGrath quadrangle, Alaska. Detailed examination of the skarns in upper Tin Creek, one of the major mineralized areas, indicates ore and gangue zoning, which inversely follows dike density.

Host rocks for skarns are mid-Paleozoic sedimentary rocks that are contact-metamorphosed, folded, faulted, and overlain and intruded by Tertiary igneous rocks. Skarns in the Tin Creek area are small (up to 3 m wide), discontinuous bodies of exoskarn found along dike contacts and as endoskarn in the dikes. Skarn also forms mantos in marble and irregular bodies along thrust and high-angle faults. Semimassive to massive sulfide mantos are present in calc-silicate hornfels. Many dikes do not have skarn along their contacts while others have skarn along only one margin, indicating that dikes and faults are only structural conduits for later metasomatic fluids.

Sulfide distribution and deposition are intimately associated with calc-silicate metasomatism. The skarn prospects are areally zoned, with garnet- (Ad_{12-100}) and chalcopyrite-dominant skarns proximal and pyroxene- (Hd_{15-86}) and sphalerite-dominant skarns distal to the center of most intense dike swarms. Sphalerite is preferentially associated with pyroxene, while chalcopyrite is preferentially associated with garnet. Metamorphic garnet and pyroxene are devoid of sulfides and have the lowest iron compositions. Early metasomatic garnet and pyroxene are generally richer in iron and are accompanied by minor sphalerite + chalcopyrite. Late metasomatic (main-stage) garnet and pyroxene contain the highest iron contents for these minerals and are extensively replaced by sphalerite + chalcopyrite. Main-stage skarns are locally retrograded to amphibole or epidote + quartz. These calc-silicates may be replaced by sphalerite + chalcopyrite, with galena locally abundant as veins in pyroxene-dominant skarns.

Zinc, lead, and silver ore potential at Tin Creek exists at distances greater than 2 km from the dike swarm center. Zinc, lead, and silver ore is preferentially associated with pyroxene-dominant skarns formed during the main stage of metasomatism.

TAILLEUR, I. L., U.S. Geol. Survey, Menlo Park, CA

A Framework for North Slope Seminar II

This meeting focuses on a province with enormous potential for fuels and minerals. Oil reserves approach 10% of the total oil already produced in the rest of the country. Estimated coal resources could store a thousand times the 70-80 quads of energy the U.S. uses every year. Potential yields of silver, lead, and zinc range from 10 to 100% of the amounts produced domestically since the middle of the 19th century. Prospects for copper are also large.

The province is dominated by the east-trending Brooks Range, whose structures formed during the late Mesozoic Brookian orogeny and are now being shortened longitudinally. Flanking basins succeeded the uplift; the northern one is bounded by a passive continental margin. Early in the orogeny, a relatively thin early Paleozoic through Jurassic megasequence of clastic-wedge, carbonate, and siliceous sediments was telescoped into a fivefold stacking of allochthons and beneath allochthons of volcanic and mafic-ultramafic rocks. The greater than 500-km breadth of sialic crust that had underlain the allochthons disappeared. At about the same time, the Arctic Ocean basin replaced the northern provenance. A mid-Paleozoic sialic source area on the opposite margin of the megasequence disappeared by the end of the Carboniferous and near the beginning of siliceous deposition. Basement beneath the North Slope part of the megasequence was created when the Devonian Ellesmerian orogeny added to the crust the late Precambrian to early Paleozoic clastic, carbonate, and volcanic rocks of an older megasequence.

The northern successor basin accumulated large amounts of coal. Truncation and sealing of potential reservoir rocks on replacement of the northern landmass led to huge pools of hydrocarbons. Late Paleozoic rocks in the lowest allochthon host stratabound base-metal deposits. A narrow belt of reportedly Devonian shallow-seated felsic rocks contain deposits of copper.

John Maher foresaw the benefits that the first North Slope seminar has provided. That precedent and developments during the past 15 years promise similar benefits from this meeting.

THRUPP, GORDON A., and R. S. COE, Univ. California, Santa Cruz, CA

Tectonic Implications of Paleomagnetism of Paleogene Volcanic Rocks on the Alaska Peninsula

Paleontologic and paleomagnetic data demonstrate that the Alaska Peninsula lay far south of its present location relative to North America in the early Mesozoic. Paleomagnetic studies of Late Cretaceous–early Tertiary volcanic rocks inboard of the Alaska Peninsula indicate no major northward displacement. Outboard of the peninsular terrane,