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Precambrian of Finland

Geologic maps, airborne geophysical surveys, and radiometric age determinations of Precambrian strata in Finland have been made. As a result, new information is available on the geologic evolution and the Precambrian rocks in Finland and neighboring countries.

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Middle and Upper Cambrian of Northern Part of Central Siberia

Within the central part of the Soviet Arctic a set of sections exposing successive strata from the Lower Cambrian to the Ordovician has been studied in detail. On the basis of rock composition and fossils, detailed lithostratigraphic and biostratigraphic subdivisions have been established.

From the Yenesey River on the west to the right bank of the Lena on the east, lateral and vertical heterogeneity of facies is found in Cambrian deposits. However, regularities in the evolution of trilobites and distinctive changes in their assemblages with time permit subdivisions of the Cambrian into stages, zones, and horizons.

Middle Cambrian strata are underlain conformably by rocks of the Lenian Stage containing three faunal zones in the Siberian north. The boundary between the series is determined by the disappearance of the Protolenidae and the appearance of numerous Oryctocephalidae and Agnostidae. The Middle Cambrian, according to the accepted stratigraphic code of the USSR, is divided into the Amganian and Maiyanian Stages. The Amganian deposits, in spite of their facies complexity, are characterized by similar trilobite assemblages and may be subdivided into 3 zones.

The boundary between the Amganian and Maiyanian Stages is distinguished by the disappearance of characteristic Amganian species and the appearance of representatives of Anomocarioides, *Metanonocare, Anopolenus,* and *Dorypyge.* The Maiyanian beds are lithologically uniform and richly fossiliferous; this stage also includes 3 zones.

Throughout the area there was continuous sedimentation across the Middle-Upper Cambrian boundary. This boundary is based on the disappearance of *Lejopyge, Anomocarina,* and *Bonneterrina* and the appearance of species of *Homagnostus, Agnostus, Damesella, Buttsia, Proceratopyge,* and other genera.

Upper Cambrian deposits in the central Siberian north contain several facies each with different trilobite assemblages but, due to the presence of many common species, their contemporaneity may be established easily. Upper Cambrian trilobites are grouped into 3 large assemblages, the duration of each corresponding to a stage. Within each assemblage, fossils are grouped by species and genera into a total of 6 zones.

It is difficult to determine the Upper Cambrian boundary in continuous sections because of monotonous rocks and the undifferentiated nature of the faunas.

Middle and Upper Cambrian deposits of the Siberian north are well correlated with contemporaneous formations both within the USSR and beyond its boundaries. The mutual occurrence of forms typical of different paleozoogeographical provinces within these deposits suggests that these correlations are valid.

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New Bathymetric Chart of Arctic Ocean

(No abstract submitted)

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Foraminiferal Biostratigraphy and Carboniferous Microfacies, Northern Alaska and Yukon

Eight major carbonate types are widespread in the Lisburne Group of northern Alaska and Yukon: (1) bryozoan-crinoidal recrystallized packstone; (2) bryozoan-crinoidal mudstone and wackestone; (3) crinoid-pelletoid recrystallized packstone and grainstone; (4) pseudo-oolitic grainstone; (5) oolitic grainstone; (6) bryozoan grainstone; (7) spiculite packstone; and (8) dolomitic limestone and dolomite. These facies are present in the Wachsmuth, Alapah, and Wahoo Limestones, and the Kogruk and Nasserak Formations.

The most favorable facies for foraminifers is the pseudo-oolitic grainstone which abounds in the Wahoo Limestone. Crinoid-pelletoid recrystallized packstones and grainstones also yield a good archaediscid fauna. Endothyrid assemblages are present in the bryozoan-crinoidal wackestones of the Wachsmuth Limestone. Spiculites are usually devoid of foraminifers; hence zonation of the Lisburne Group in the western part of Alaska must be based mostly on macrofaunal evidence.

Twelve consistent foraminiferal assemblages can be recognized in the northern part of the American Cordillera: (1) a late Tournaisian (Zones 8 and 9) tournayellid assemblage (*Septatournayella-Tournayella*); (2) an early Viséan (Zones 10–11) *Earlandia* facies (first appearance of *Globoendothyra*); (3) an early middle Viséan (Zone 12) *Eoendothyranopsis spiroides* microfauna; (4) a late middle Viséan (Zone 13) *Eoendothyranopsis pressa-rara* assemblage; (5) an early late Viséan (Zones 14–15) *Brunsia* facies; (6) a Meramec-Chester boundary assemblage (Zone 16_{i}), characterized by the elimination of many "Meramecian" elements such as *Eoforschia, Eoendothyranopsis, etc.;* (7) a latest Viséan (Zone 16_{s}) *Neoarchaediscus-Planospirodiscus* assemblage; (8) an earliest Namurian (Zone 17) *Asteroarchaediscus* fauna; (9) an early Namurian (Zone 18) *Biseriella* assemblage; (10) a middle Namurian (Zone 19) *Quasiarchaediscus?-Eosigmoilina?* assemblage; (11) a late Namurian (Zone 20) *Lipinella-Millerella-Globivalvulina* assemblage; and (12) Zone 21, the youngest assemblage recognized in the Lisburne Group, characterized by the outburst of numerous fusulines including *Eoschubertella* and *Pseudostaffella.*

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Geologic Structure of Baffin Bay and Davis Strait Determined by Various Geophysical Techniques

Between 1963 and 1966, approximately 10,000 mi of sea-magnetometer and bathymetry data was collected in the Baffin Bay, Davis Strait, and Labrador Sea areas. The analysis of these data has shown no clear northward continuation of the linear magnetic anomalies which are associated with the Mid-Labrador Sea

Ridge. Previous geologic investigations of the terrestrial Tertiary basalts of the Davis Strait area have shown however, that the lavas are similar enough in chemical composition to be petrogenetically related.

The planned 1970 field work, consisting of sea magnetometer, gravity, bathymetry, seismic reflection profiling, seismic refraction measurements, and dredging, should enable the seaward extent and possible chemical evolution of the "aseismic ridge" of Davis Strait and the crustal type, structure, and sedimentary thickness of Baffin Bay to be determined. The analysis of these data may enable more substantial comment to be given on the pattern of sea-floor spreading between Greenland and Canada.

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BENTONITIC DEBRIS FLOWS NEAR UMIAT, ALASKA

Mudflows and bentonitic debris flows are found at numerous locations around the globe. Those that occur in arctic regions or at high elevations are unique in that the base material normally will remain frozen during periods of flow activity. The influence of a frozen base on flow morphology and frequency of activity was investigated for large-scale bentonitic debris flows along the Colville River near Umiat on the North Slope. These features originate in bentonitic detritus slumping from bluffs 150–200 m high. When the material becomes sufficiently hydrated it flows downslope leaving slickensided, fluted channels ranging in depth from 0.5 to 2 m and from 2 to 12 m wide. During July and August flow velocities up to 6 m/minute were observed.

Data were obtained that yielded relations among precipitation, water content, flow rate and frequency, thaw depth, and channel morphology. Flow was observed as initiating in the upper, steeper parts of the bluffs along an initial slip zone at the upper boundary of the permafrost. However, snow meltwater and thawing of the active layer were not sufficient to bring about the critical relationship between water content and slope angle required to initiate flow. As with mud- and debris-flows in warmer regions, frequency of flow was found to be closely related to the occurrence of precipitation.

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HIGH-LATITUDE EVAPORITE DEPOSITS AND GEOLOGIC HISTORY OF ARCTIC AND NORTH ATLANTIC OCEANS

High-latitude evaporites—late Proterozoic through Early Permian—are widespread in Canada, Siberia, and Europe. Their distribution patterns show that they precipitated from marine waters entering the continents from the Eurasian-Arctic basin, *not* from the Canadian-Arctic basin, which is separated from the former by the Proterozoic Lomonosov sill, and from the North Pacific by the 1,350-km-wide, Archean, Bering-Chukotsk shelf. Late Proterozoic through Devonian evaporites which precipitated from Arctic waters do not extend (except locally) west of the Rocky Mountains or east of the Chukotsk-Koryak Ranges. Marine connections between the high-latitude evaporite basins and those of the Tethys seas were minimal. After Devonian time, evaporite depocenters shifted systematically Atlanticward with the progressive formation of the Franz Josef and Faeroes-Greenland sills. High-latitude evaporite deposits are scarce after formation of the Faeroes-Greenland sill.

Thus the requisite temperature and salinity for late Proterozoic-Paleozoic evaporite deposition in high latitudes during evaporite-maximum periods can be attributed only to the existence, and persistence, of the Gulf Stream–North Atlantic Drift system since middle Proterozoic time. No proposed mechanism of continental drift or polar wandering accounts for the high-latitude evaporite-deposition pattern, or for the consistent and progressive Atlanticward shift of evaporite depocenters through time. Continental drift and polar wandering in the Arctic and North Atlantic Ocean areas, if either ever took place, are pre-late Proterozoic events.

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RUSSIAN ARCTIC PETROLEUM PROVINCES

Major hydrocarbon reserves have been discovered and developed during the last 20 years in the Russian Arctic. Productive basins include the West Siberian. Pechora, and Vilyuy. Gas discoveries in the Anadyr basin are too new to be evaluated. Untested basins include the following: (1) *onshore:* Anabar, Lena delta, Indigirka, and Kolyma; and (2) *offshore:* Barents and Pechora Seas, Kara Sea, Laptev Sea, East Siberian Sea, Bering Sea, and Sea of Okhotsk.

In the West Siberian basin, as of January 1, 1970, more than 40 oil fields and 50 gas fields had been found. Production is from Cretaceous and Jurassic paralic to nonmarine strata. At least 9 oil fields had reserves greater than 500 million bbl; 20 gas fields had reserves greater than 3.5 Tcf. Samotlor is the largest oil field with 15.1 billion bbl; Urengoy, the world's largest gas field, had 210 Tcf. Deepest production was from about 10,500 ft, but most production was shallower than 8,150 ft.

The Pechora basin contained about 62 oil and gas fields productive from Devonian through Permian marine strata. Of these, 1 oil field contained more than 500 million bbl and 2 gas fields, more than 3.5 Tcf. Deepest production was from about 11,155 ft.

The Yenesey-Khatanga trough contained several fields, but is relatively undeveloped.

The Vilyuy basin contained about 41 gas fields, of which 2 gas fields contained more than 3.5 Tcf each in Triassic and Jurassic paralic strata. Deepest production was from about 9,840 ft.

More than 200 structures remain to be tested in the 4 basins. Although deformed basement has been penetrated in several areas, particularly near basin margins, the basin centers have not been explored thoroughly. In most of the West Siberian basin, for example, 2,000–8,000 ft of section below the deepest producing zones has not been tested.

In the West Siberian basin alone, proved plus probable oil reserves exceed 35 billion bbl, and proved plus potential gas reserves exceed 400 Tcf. If the results from the West Siberian, Vilyuy, and Pechora basins are indicative of Russian Arctic potential, a bright future could be in store for the Russian petroleum industry.

Despite the high costs and enormous logistics problems involved in development of these remote permafrost areas, the Russians are well on their way in devel-