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REVIEW OF THE GEOLOGY OF WRANGEL ISLAND, CHUKCHI AND EAST SIBERIAN SEAS, FAR NORTHEASTERN SOVIET UNION

Report on results of a visit to Wrangel Island as part of the Canada-Soviet exchange between the Geological Survey of Canada (Calgary), and the All-Union Research Institute of the Geology and Mineral Resources of the World's Oceans (VNII Okeanogeologia, Leningrad) July 18 - August 1, 1986.

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ABSTRACT

Wrangel Island, 140 km north of the Chukotka Peninsula, East Siberian and Chukchi seas, represents a rare exposure of the Precambrian(?) to Triassic geology on the 700 km wide Arctic continental shelf, northeastern Soviet Union. The island is divided into a northern parautochthonous zone and a southern fold and thrust belt. Among the parautochthonous zone and individual thrusts there are major variations in facies and in erosional truncation of units.

The oldest stratigraphic unit consists of a more than 2800 m thick, Upper Precambrian(?) to Middle Cambrian(?), complex of metavolcaniclastics, meta- intermediate to acidic volcanics, with minor meta-mafic volcanic rocks, and quartzites. Gromov rocks are the only units on Wrangel intruded by granite. The Gromov Complex, was deformed during Late Precambrian and/or Early Paleozoic time. Gromov strata are unconformably overlain by up to 800 m of syn- or post-orogenic immature clastic rocks of the Lower Cambrian - Middle Silurian(?) Nashok Formation. The Nashok Formation is overlain by 400 m of fossiliferous clastics of the Upper Silurian to Lower Devonian Drem-Khed Formation which is only known in the northwestern part of the parautochthonous zone. In the thrust belt the Nashok Formation is unconformably overlain by more than 150 m of Middle(?) Devonian to Lower Carboniferous clastic rocks, with gypsum. All units are unconformably overlain, above a major erosional surface, by a thick succession of Carboniferous limestone, biohermal limestone, shale and conglomerate. At the base of this succession is up to 300 m of laterally discontinuous, immature, conglomerate, which is likely associated with extensional tectonism. The Carboniferous unit is overlain by a 50 - 100 m succession of Upper Carboniferous(?) -

Permian slate and sandstone followed by 100-200 m of Upper Permian to Lower Triassic(?) black slate. The youngest rock unit on Wrangel Island is an 800-1500+ m succession of Lower(?) to Upper Triassic turbiditic sandstones and slates. Gentle tilting resulted in west to east erosional truncation into the level of the lower Carboniferous unit prior to deposition of these turbidites.

All rocks on Wrangel Island have been extensively deformed and metamorphosed to greenschist facies by a post-Late Triassic orogenic event featuring a pervasive south-dipping cleavage and north-verging folds and thrusts.

Wrangel Island lies inshore of the geographic center of a huge continental shelf. Any restoration of this continental shelf with the Canadian Arctic Islands would place Wrangel Island at a considerable distance from the Canadian Arctic. Because of this, all circum-Canada Basin comparisons must emphasize major stratigraphic and tectonic events that are unique in terms of distribution in space and in time. There are many similarities between Wrangel Island and the northern Brooks Range of Alaska. There are generally more differences from, than similarities to the Canadian Arctic Islands, with the exception of Pearya Terrane, where the data are equivocal.

ACKNOWLEDGEMENTS

This exchange visit was made possible by the enthusiasm and leadership of the late Dr. W.W. Hutchison, former Assistant Deputy Minister, Science and Technology, Energy Mines and Resources, Ottawa, and by Dr. I.S. Gramberg, Director General of the PGO "Sevmorgeologia" Nauchno-issledovatel'skii Institut Geologii i Mineral'nykh Resursov Mirovogo Okeana (VNIIOkeangelogiya), Leningrad, USSR.

We thank Dr. Gramberg for the efficient and courteous manner in which we were hosted during our visit by his staff and personnel from other geological institutes and organizations.

Thanks are also extended to L.F. Stashkevich, Administrative Director of Wrangel Island, for allowing us access to many remote and environmentally sensitive areas.

Special recognition is due to Dr. B.G. Lopatin who accompanied us for the duration of the trip. Dr. Lopatin kept us immersed in Soviet culture and geology during our whole trip and made extra efforts to ensure that we were comfortable and well looked after. We are deeply indebted to him for his consideration, courtesy, and friendship. We are also very thankful to Dr. M.K. Kos'ko, party leader on Wrangel Island, for interrupting his field work for two weeks to ensure we had an excellent review of the island's geology, for his hospitality and for his unflagging interest in solving both local and regional geological problems.

On Wrangel Island our understanding of the geology was greatly enhanced by lively and informative discussions with Dr. V.G. Ganelin, and Dr. N.V. Khandozhko. Geological assistance was provided by A.V. Matveev and O.N. Vinogradova. O.N. Vinogradova was also responsible for introducing us to exceptional Soviet Arctic cooking.

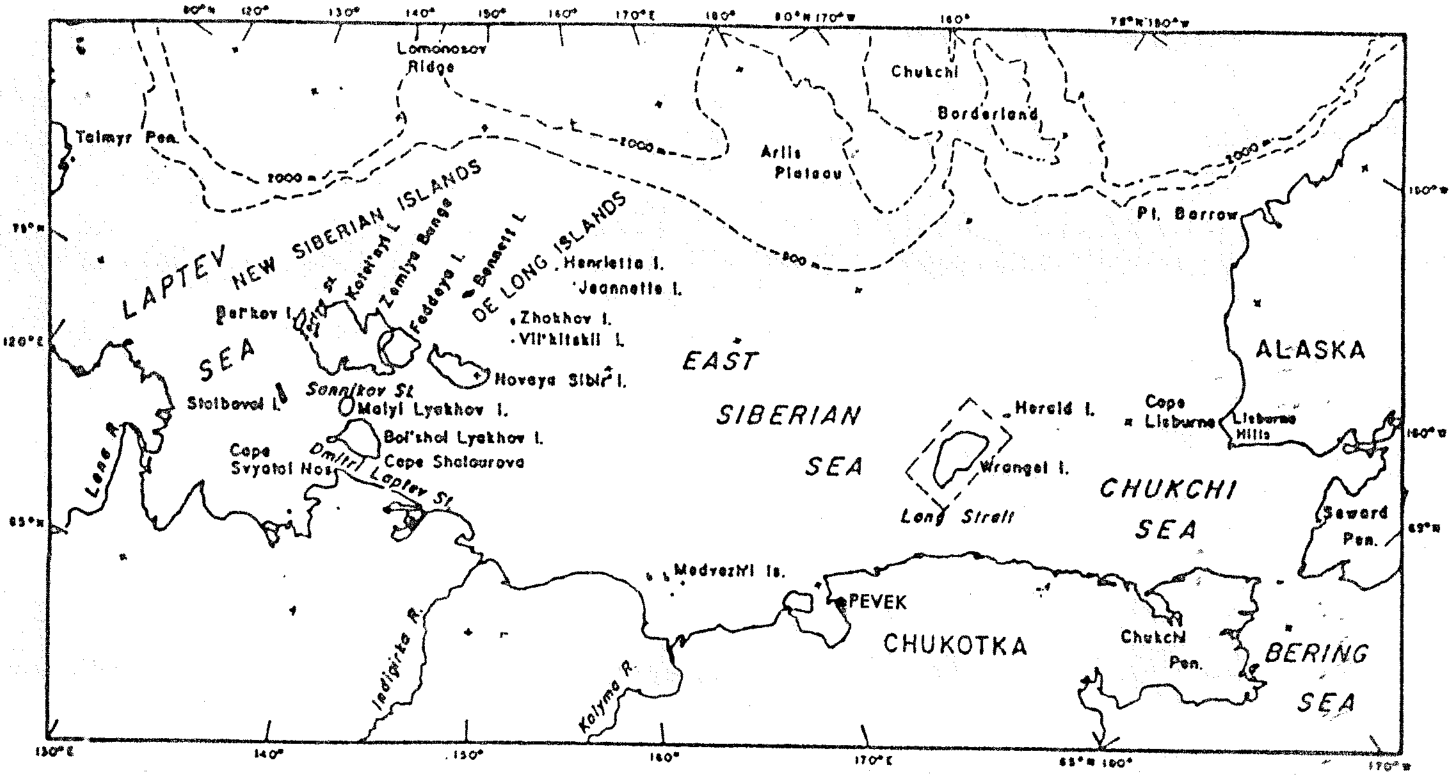
Finally we would like to offer special thanks to Y.S. Larianov, a geological pioneer of some 35 years on the Chukotka Peninsula, and to L.N. Sutugin, Director of the Pevek Expedition, who made our stay in Pevek extremely pleasant on our way to and from Wrangel Island.

LOCATION AND SETTING

Wrangel Island has an area of 7,600 km^2, centres on 179°W longitute and 71°15 N latitute, and is 140 km northeast of the nearest mainland, Cape Billings, Chukotka Peninsula, U.S.S.R. It is 700 km northwest of the Bering Strait, and 350 km northeast of the city of Pevek (Fig. 1). Pevek is the nearest settlement accessible by transcontinental airline from Moscow, Magadan, and other cities of the Soviet Union. The nearest adjacent lands on the Arctic Continental Shelf are the New Siberian Islands, located 1200 km to the west across the East Siberian Sea. Other regional geographical names appearing in this report are shown on Fig. 1. These include the Chukchi Sea which extends east of Wrangel Island as far as Point Barrow, Alaska, and the Long Strait, which separates Wrangel Island from mainland Chukotka Peninsula. The continental shelf is approximately 700 km wide in the vicinity of Wrangel Island.

Access to the island is made possible by twice daily Aeroflot jet service from Moscow, via Nor'ilsk, to Pevek; a Au/Sn mining city of approximately 15 000 people located on the Arctic Ocean. From Pevek, Aeroflot operates a charter helicopter service to various small centres including the village of Ushakovsky on southeastern Wrangel Island. Ushakovsky is an administrative centre of about 200 people. Also on the island is the village of Somnitel'nay (shown as Zvezdnay on maps), which has only a handful of residents and which was used as the base of operation by the Soviet field party. Fly camps and research sites were reached from the base by four-wheel-drive truck.

Geographically, Wrangel Island consists of a southern narrow (up to 15 km) coastal plain, a broad set of central, low relief mountains (Plate 1), and a very broad northern coastal plain (up to 25 km). The



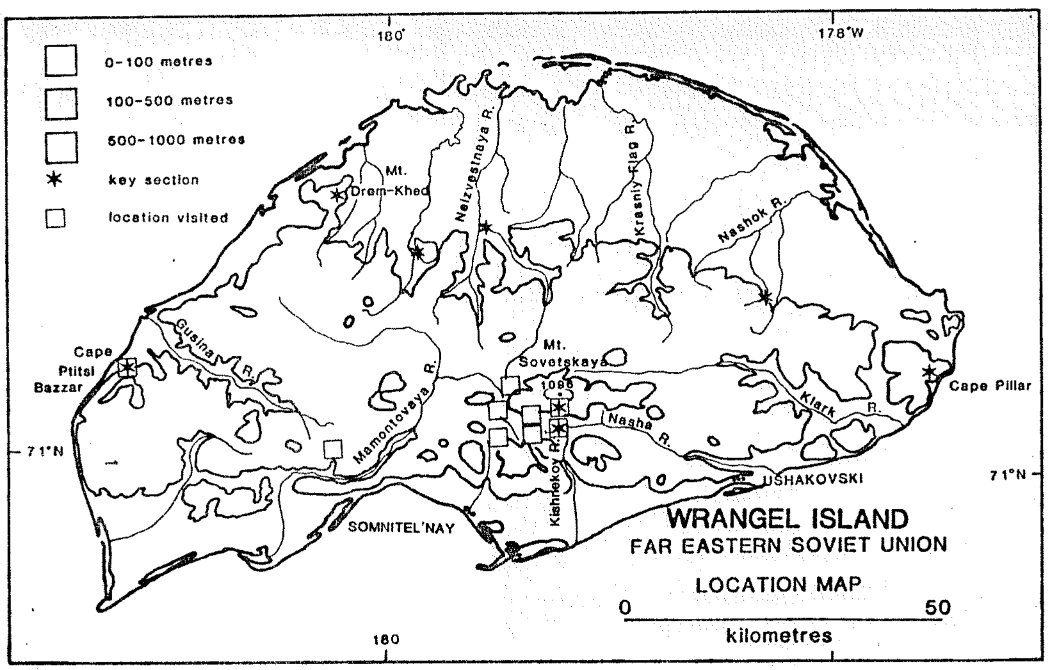


Figure 1. Geographic names used in this report.

The island is classified as a natural reserve and access is restricted to administrative and scientific personnel. It is an important Polar Bear denning site, nesting area for some forty species of birds, and habitat for more than 360 species of vascular plants, fifteen of which are endemic (B. Yurtsev, pers. comm. 1986). Muskox were introduced to the island from herds that originated in the Canadian Arctic. At the present time they form a healthy and growing herd that is expected to reach 60 by 1987 (M. Stishov, pers. comm. 1986). Caribou were also introduced to the island and the herd is farmed and kept at a maximum population of about 1000. The most frequently seen wildlife are Arctic foxes and snowy owls. Coastal sea cliffs at Cape Ptitsi Bazzar ("Bird Market") and Cape Pillar are the sites of large bird rookeries. Seals and walrus were often seen just offshore.

PREVIOUS WORK

Wrangel Island has been the object of increasing interest by scientists concerned with understanding the geological history of the Arctic continental shelf and the origin(s) of the Arctic Ocean Basin. Interest has also been generated by increasing exploration for hydrocarbons in Arctic Canada, Alaska, and the Soviet Union.

Although geological research has been periodically active on Wrangel Island since the 1930's, there are still many problems to be resolved. Specifically, they include: (1) the age of some rock successions; (2) the scale and age(s) of metamorphism and magmatic activity; (3) the style and age of pre-Late Triassic tectonic activity; and (4) the correlation of some stratigraphic units, and detailed comparisons of the geological history of Wrangel Island with adjacent areas in the Brooks Range of Alaska, the subsurface Alaskan north slope and continental shelf, the northern Yukon, the Beaufort shelf, and the Canadian Arctic Islands.

Geological work on Wrangel Island dates from the 1930's with field studies by L.V. Gromov in 1935 and 1936. In this study, Gromov assigned Triassic and Paleozoic ages to much of the sedimentary succession and postulated an Early Paleozoic age for the older more metamorphosed core complex in the center of the island. Additional studies of Paleozoic stratigraphy were made by Gromov and Kurushina (1947) and by members of the "Arctic Prospector" expedition of the early 1950's (Lobanov, 1957). Workers on this expedition recognized Cambro-Silurian, Devonian and Lower Permian rocks in the Paleozoic part of the succession (Bogdanov and Tilman, 1964). In 1960 Gorodinsky made important observations on the age of the stratigraphic succession, theorizing that the central complex was Precambrian, and noted that fossiliferous Lower Carboniferous strata rested unconformably on the Precambrian. Gorodinsky also recognized that the Carboniferous strata were unconformably overlain by Upper Triassic sandstones and shales with Carnian and Norian faunas (see review by Bogdanov and Tilman, 1964).

Additional studies by Bogdanov and Tilman (1964), Gnibidenko (1968), Tilman (1970) and Ivanov (1973) produced no significant new paleontological discoveries. However, much discussion was generated in the assignment of strata to various Devonian through Permian ages. Based on field work in 1972 Kameneva (1975), Kameneva and Il'chenko (1976), Kameneva and Chernyak (1975) and Chernyak and Kameneva (1976) recognized Precambrian, Precambrian-Cambrian, Silurian to Devonian, and Upper Permian successions on Wrangel Island. They also divided Carboniferous strata into members and recognized two different Carboniferous facies belts. K.S. Ageev believes that a much more substantial Middle Cambrian through Upper Devonian succession is also represented on the island (M. Kos'ko, pers. comm., 1986).

Both Bogdanov and Tilman (1964), and Kameneva (1977) noted the similarity between Wrangel Island and Alaska particularly with respect to Carboniferous stratigraphy.

In addition to geological studies, extensive geophysical surveys of the surrounding continental shelf have been completed by Soviet scientists, including regional gravity and magnetic surveys, and some seismic reflection and refraction work. These data have been succinctly summarized by Kos'ko (1984) for the East Siberian Sea (north and west of Wrangel Island as far as the New Siberian Islands), and by Pol'kin (1984) and Grantz et al. (1975) for the Chukchi Sea (around and east of Wrangel Island to the Bering Strait). A review of the geology and geophysics of the continental margin north of Chukotka has been recently completed by Fujita and Cook (in press). The neotectonics of Chukotka Peninsula and the East Siberian-Chukchi shelf are discussed by Fujita, et al (in press).

1986 FIELD EXCURSION

In the latter half of July, 1986, we spent two weeks traversing in the central mountains and west central coastal areas of Wrangel Island with our Soviet colleagues. The purpose of our traverses was to see as much of the general geology as feasible, with an emphasis on stratigraphy and structural style(s). Contacts between various units were examined with the view to understanding Paleozoic and older tectonic events. In addition we sampled sedimentary rocks for micro- and macro-paleontological analysis, and igneous rocks for U/Pb radiometric dating, often co-operatively paralleling collections made by our Soviet colleagues.

Our visit brings us up to date with the new data being acquired by the Soviet team working on the island, and our hands-on experience has greatly facilitated our understanding, and our ability to make inferences from geological reports of earlier workers on the island.

Paleontological and radiometric material are now being processed, but results will not be available for some time, thus this report is intended to present a description of geological sequences and their lateral variations in facies, and to develop hypotheses concerning the geological history of the area.

REGIONAL GEOLOGICAL SETTING

Interest in the northeastern Soviet Union by geoscientists working in Arctic Canada and Alaska arises in part from evidence suggesting that prior to Late Jurassic to Early Cretaceous the Canada Basin may have been much smaller or non-existent. The circum - polar regions of Arctic North America and Chukotka, which are now widely separated across the basin, may have then been spatially and genetically linked.

In one plate tectonic model, opening is achieved by rotation of the Soviet and Alaskan continental fragments away from Arctic Canada around a pivot point located in the northern Yukon (Carey, 1955; Hamilton, 1970; Tailleur, 1973). In another, separation is achieved by southward transport of Alaska and Chukotka along a left-lateral megashear parallel to the edge of the Canadian Arctic Islands shelf (Christie, 1979; Kerr, 1982).

The limits of terranes which are tectonically linked to the Canada Basin in the Chukotka - Alaska area are defined by a discontinuously exposed belt of obducted Upper Jurassic ophiolites that outcrop in the eastern Brooks Range of Alaska (Boak, et al, 1985), and by the South Anyui Suture zone of the western Chukotka Peninsula (Fig. 2; Seslavinskiy, 1979). North of these two zones there is evidence of continuity of structure and stratigraphy between the Brooks Range, the subsurface of the Alaskan North Slope, and the land and shelf areas of the East Siberian Sea as far west as the New Siberian Islands (Grantz et al., 1981).

The Soviet Arctic continental shelf beneath the Chukchi and East Siberian seas, including Wrangel Island and the New Siberian Islands, and all of the Chukotka Peninsula, lie within the North American

Plate (Fujita et al, in press; Fig. 6). The North American - Eurasian plate boundary is defined by the Nansen - Gakkel Ridge within the Arctic Ocean Basin. Spreading rates on this ridge decrease progressively from 0.6 cm/yr near Greenland to 0.2 cm/yr near the shelf edge of the USSR in the Laptev Sea (Grantz, et al, 1982). Shallow earthquake foci indicate that the plate margin underlies the shelf of the Laptev Sea and that it emerges on land near the delta of the Lena River. It then crosses the Chukotka Peninsula, where the North American - Eurasian plate boundary is probably contractional as indicated by analyses of earthquake focal mechanisms obtained from this area (Cook and Fujita, ibid.). The rotation pole for the North American and Eurasian plates lies nearly on the plate boundary near there at 71° 24′ N, and 132° 05′ E (Cook and Fujita, 1986). Southeast of Chukotka Peninsula, the North American Plate boundary follows the Aleutian and Kurile-Kamchatka trench systems where it is in contact with the northwestern edge of the Pacific Plate.

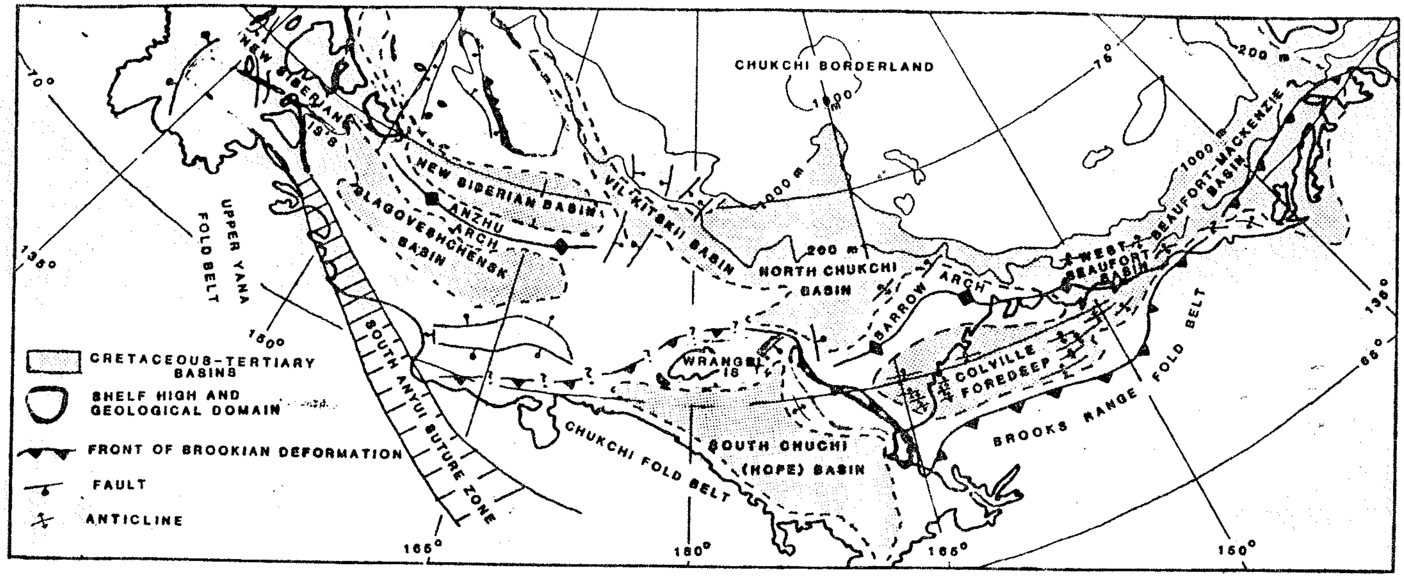


Figure 2. Structural elements of the Eastern Siberian Sea Continental Shelf (compiled from Fujita and Cook, in press; Kos'ko (1984); Dixon et al. (1985) and Grantz et al (1979).

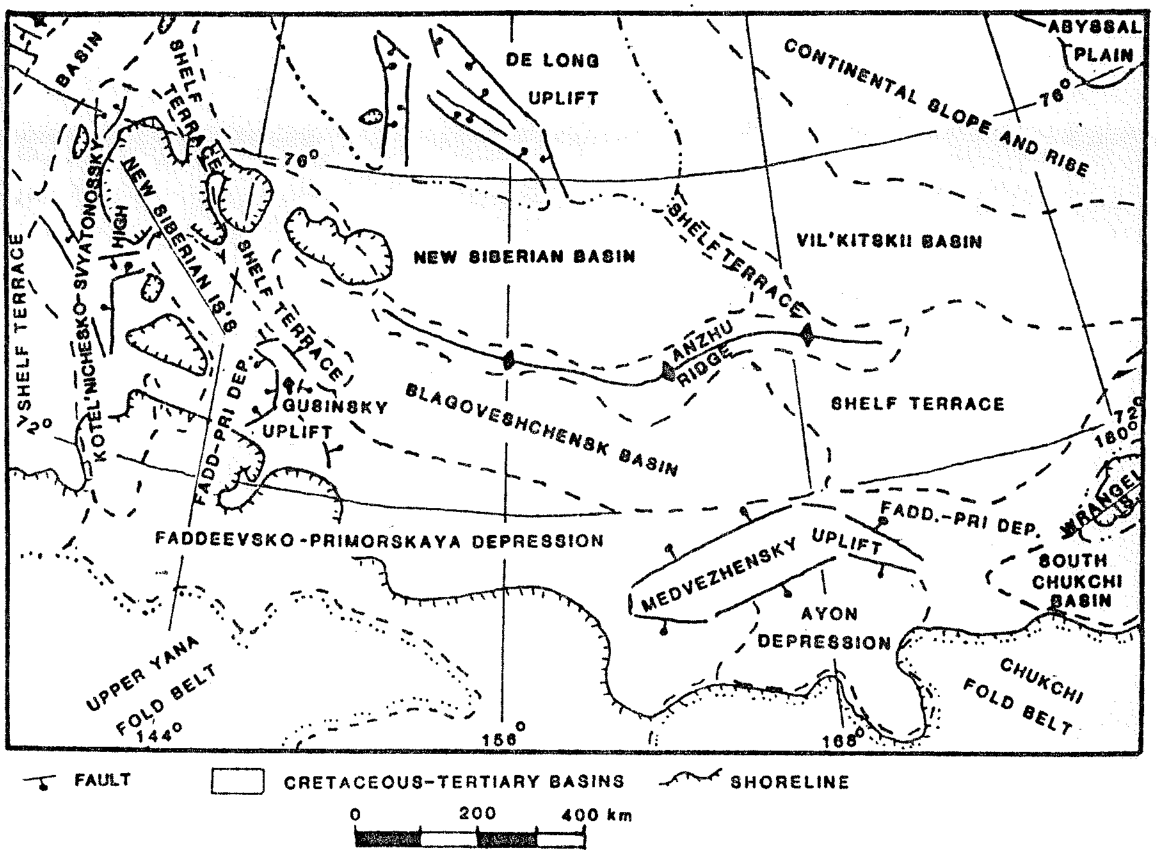


Figure 3. Structural elements on the continental shelf of the Chukchi Sea. (from Pol'kin, 1984, translated by O. Rodkin, 1986).

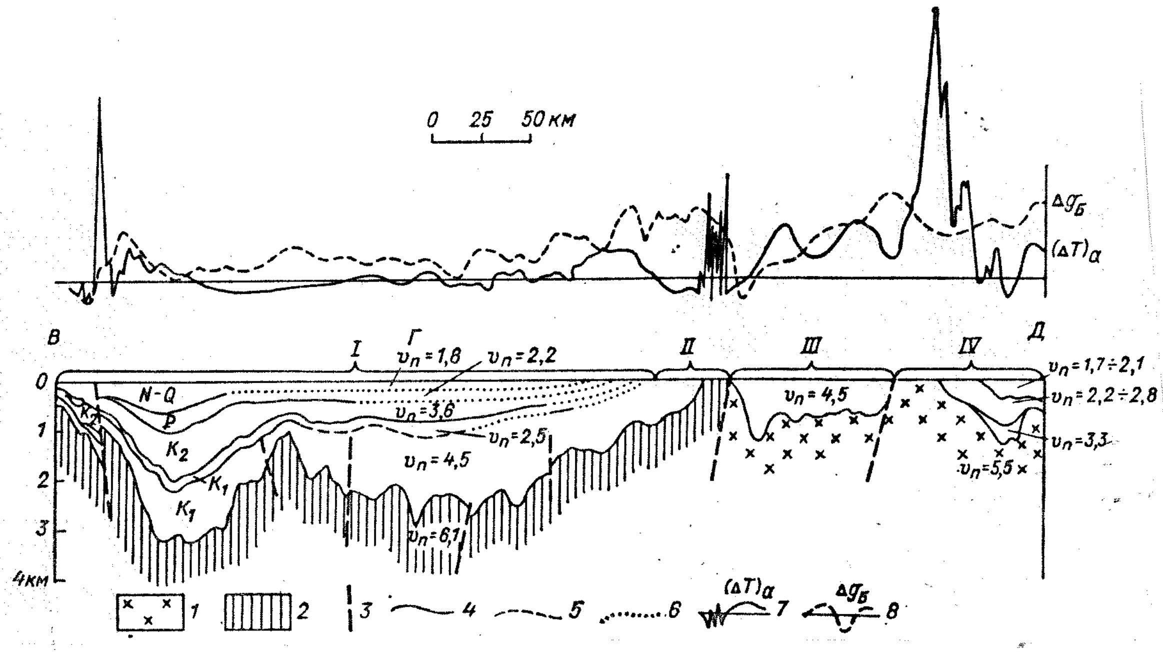


Figure 4. Geophysical and interpreted geological profiles across (I) South Chukchi basin, (II) Wrangel Herald Arch, (III) Eastern Herald basin, and (IV) Herald Uplift (see Fig. 5 for location). Legend - 1. Basement complex of Baikalian and/or Caledonian age; 2. Basement complex of Kimmeridgian age; 3. Faults; 4,5,6, Seismic reflectors - 4 defined, 5 approximate, and 6 assumed; 7. Magnetic profile; 8. Gravity profile. (from Pol'kin, 1984; translated by O. Rodkin, 1986).

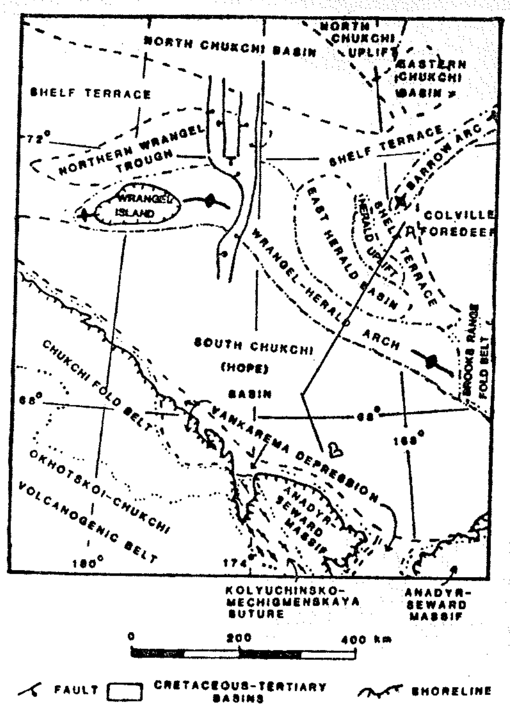


Figure 5. Structural elements of the continental shelf of the Eastern Siberian Sea. (from Kos'ko, 1984, translated by O. Rodkin, 1986).

Wrangel Island is situated at the western end of the Wrangel-Herald Arch (Figs. 2,3,5). This arch is believed to represent the northern limit of Late Jurassic to Cretaceous (Brookian) deformation. The Wrangel-Herald Arch trends southeast from Wrangel Island and may link up with north-trending contractional structures of the same age exposed on the Lisburne Peninsula, Alaska. Refraction studies (Fig. 4) indicate an average sonic velocity of 6.1 km/sec. for highly deformed pre-Upper Jurassic rocks believed to underlie much of this area. Similar Jura-Cretaceous foreland uplifts on trend to the west include the submerged Medvezhenskiy uplift in the offshore north of the Kolyma River area , and the Gusinsky and Kotelnichesko-Svyatonosskiy uplifts in the New Siberian Islands (Fig. 5; Kos'ko, 1984).

The Wrangel-Herald Arch is separated from the Barrow Arch, and Colville Foredeep of northern Alaska by the small NNW trending Herald Uplift and Eastern Herald Basin (Fig. 3), which are believed to lie beyond the limits of pervasive Brookian (Jura-Cretaceous) deformation. The succession in the Eastern Herald Basin, and possibly in the similar Northern Wrangel Trough north of Wrangel Island, includes Cretaceous (?) strata with a sonic velocity of 4.5 km/sec lying on a deformed basement complex with a velocity of 5.5. km/sec (Pol'kin, 1984).

The Wrangel-Herald Arch is also separated geologically from the northwest-trending Jura-Cretaceous Chukchi foldbelt of the Chukchi Peninsula by a thick succession of low velocity strata within the South Chukchi (Hope) Basin (Fig. 4). Pol'kin (1984) distinguishes five seismic stratigraphic units in this basin ranging from a velocity of 4.5 to 1.8 km/sec and ranging from Albian to Quaternary in postulated age. The South Chukchi Basin underlies much of the coastal shelf of the De Long Strait south of Wrangel Island, and it may locally contain up to 4.5 km of strata which were deformed during Brookian Orogenesis. Seismic basement beneath and adjacent to the trough has a sonic velocity of 6.1 km/sec north of the Chukchi Peninsula and 5.2 km/sec north of Bering Strait. The oldest sequence of Pol'kin has a velocity similar to intervals found in the Eastern Herald Depression which have been assigned an Albian to Cenomanian age, above which are Cenomanian-Turonian strata (2.5 km/sec), Turonian-Campanian strata (3.1-3.6 km/sec), Paleogene strata (2.1 - 2.3 km/sec) and Neogene to Quaternary strata (1.8-1.9 km/sec).

Widespread evidence exists for extensional tectonism during the Jurassic and Cretaceous. In the Canadian Arctic Islands, evidence for shelf-parallel extension is represented by emplacement of a Lower to Upper Cretaceous dyke swarm of continental tholeiitic affinity, extrusion of Lower Cretaceous to Upper Cretaceous tholeiitic basalts, and the opening of shelf-parallel basins such as the Eglinton "Graben" (Balkwill and Fox, 1982) and Banks Basin (Miall, 1979) beginning in the Middle Jurassic. On the East Siberian Shelf, alkali basalts interlayered with, and overlying Lower Cretaceous strata are exposed on Bennett Island. Neogene alkali basalts and nepheline basalts also underlie Zhokova and Vil'kitskogo Islands (Fujita and Cook, in press). In addition, over 2000 metres of spilites are known to be interstratified with Albian marine clastic rocks in the Okhotsko - Chukchi volcanogenic belt (see Fig. 5; Pol'kin, 1984). Linear, large amplitude, shelf - parallel aeromagnetic anomalies east of the New Siberian Islands and northwest of Wrangel Island are also believed to be caused by intrusion of gabbro-dykes. The age of these dykes remains uncertain but may be either Late Triassic or Early Cretaceous, or both (Pol'kin, 1984). These anomalies also parallel some of the larger basins on the shelf that have been delineated by various regional geophysical surveys. Basins containing low velocity Lower Cretaceous and younger strata include the North Chukchi and Vil'kitsky basins on the outer shelf (Grantz, et al, 1975; Kos'ko, 1984), the New Siberian and Blagoveshchensk basins trending east from the New Siberian Islands (Kos'ko, 1984) and the South Chukchi Basin (Pol'kin, 1984; Hope Basin of Grantz, 1975) between Wrangel Island and Chukotka Peninsula (Figs. 2,3,5). The latter may in fact be either an intermontane or foredeep/ basin because it is assumed to have received detritus from, and to have been partly uplifted by northward propagating Cretaceous Chukchi Fold and Thrust Belt structures.

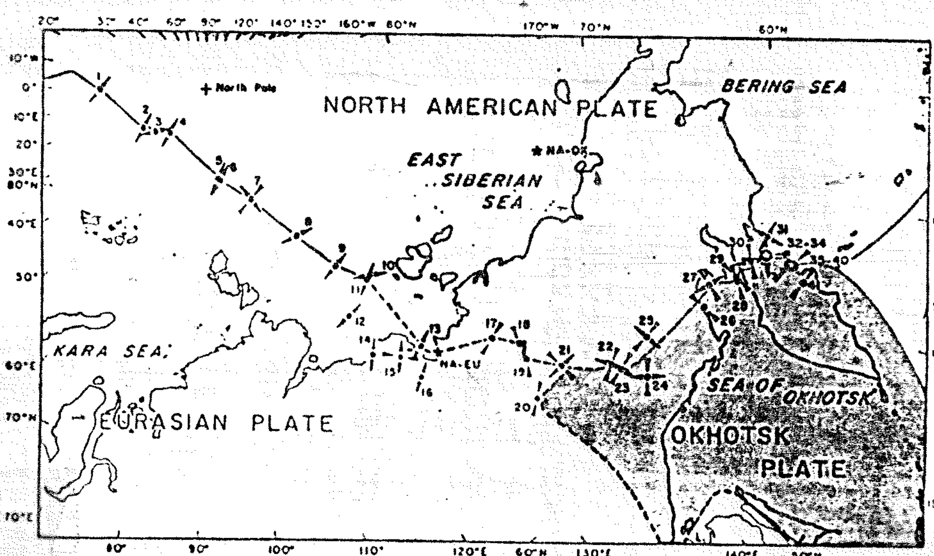


Figure 6. Modern plate boundaries and earthquake foci in the northeastern Soviet Union (from Fujita, et al, in press).

GENERAL GEOLOGY OF WRANGEL ISLAND

Details of the geology of the Wrangel-Herald Arch are known almost exclusively from bedrock exposures on Wrangel Island and on Herald Island to the east. Herald Island is underlain by granites postulated to be Jurassic in age (Grantz et al, 1981) and by a suite of older metamorphic rocks including sandstone, slate, schist and mylonite; possibly correlative with the older volcanic-plutonic complex on Wrangel Island (Fujita and Cook, in press).

Wrangel Island is much larger than Herald Island and is geologically more complex. It comprises two structural provinces; a northern parautochthonous region and a southern thrust belt (Fig. 7).

The northern parautochthonous region includes flat to gently-dipping strata of Late Silurian to Late Permian age exposed in a large, open synclinorium the axis of which trends east-west close to the geographic centre of the island. Silurian and Devonian strata are exposed on the north limb of the synclinclinorium, Lower and Upper Carboniferous strata are prominent and extensively exposed on both limbs, and Permian rocks are known only in the axial zone. Small anticlines developed across the synclinorium expose elliptical areas of Gromov Complex [Precambrian(?) - Cambrian(?) and Nashok Fm. (Cambrian(?) - Silurian(?); M.K. Kos'ko pers. comm. 1986].

The northern limit of the thrust belt is defined by a north-vergent thrust, which we will refer to as the "northern thrust". This thrust places Precambrian(?) and Cambrian(?) rocks over Upper Paleozoic strata exposed on the south margin of the northern parautochthonous region.

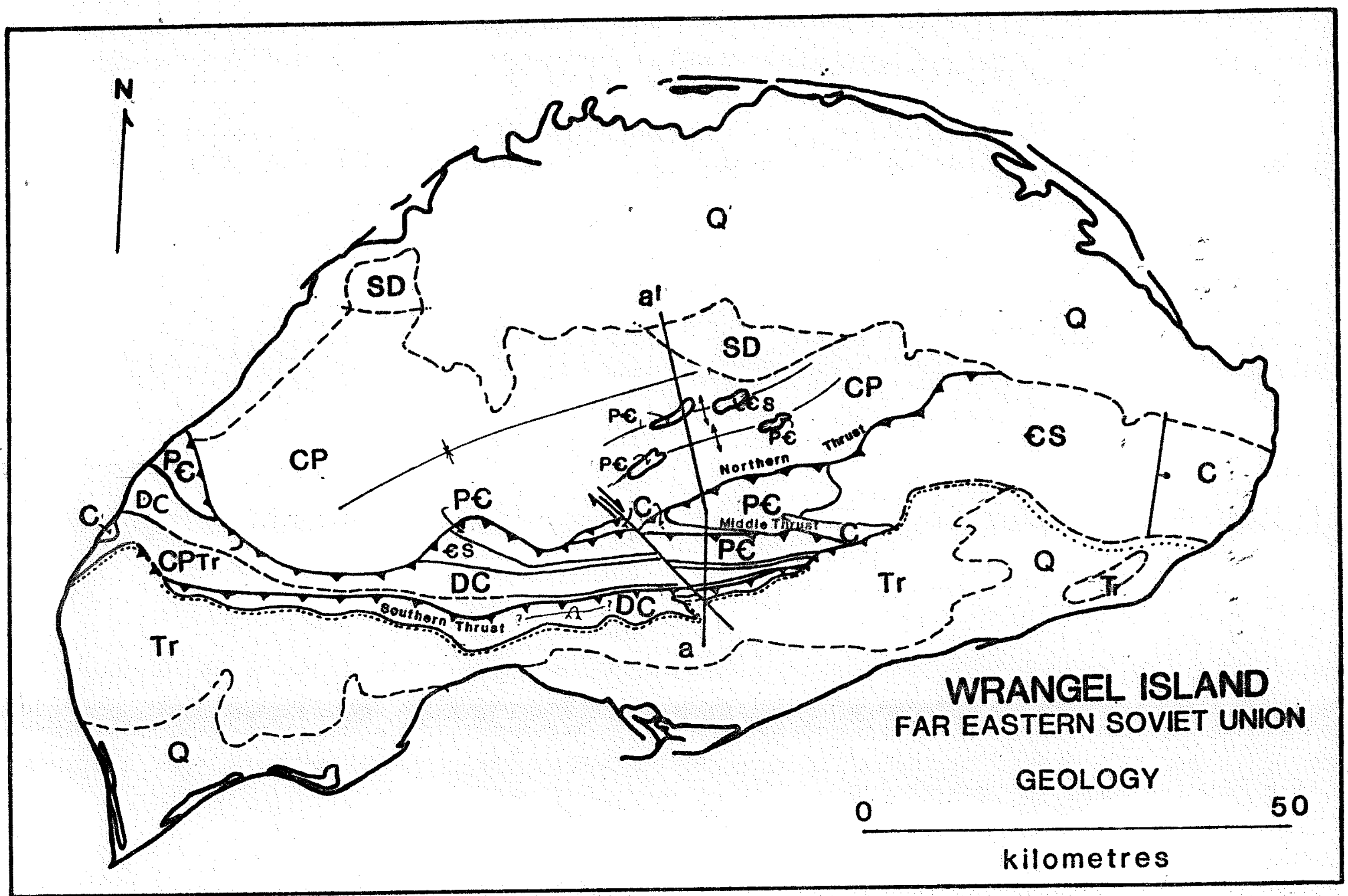


Figure 7. Simplified geology of Wrangel Island from compilation of Kameneva and Chernyak (1974), new data of M.K. Kos'ko, N.V. Handozko, V.G. Ganelin, and B.G. Lopatin - pers. comm. 1986.

LEGEND

P€ - Precambrian(?)-Middle Cambrian(?) Gromov complex; €S - Cambrian(?)-Silurian(?) Nashok Fm.; SD - Upper Silurian and Lower Devonian Drem-Khed Fm.; DC - Devonian and Carboniferous undivided in the overthrust belt; CP - Carboniferous and Permian undivided in the parautochthonous belt; CPTr - Permian Triassic black slate; Tr - Triassic greywacke and slate; Q - quaternary gravels and colluvium.

LEGEND STRATIGRAPHIC UNITS FIG. 8

PЄg - Gromov suite: ЄSns Cambrian to Silurian(?) Nashok Fm.; S_2D_1 - Upper Silurian and Lower Devonian Drem-Khed Fm.; DC - Middle(?) Upper Devonian and Lower Carboniferous; C - Carboniferous undivided; C_1 Tournasian(?) and Visean; C_2 - upper Visean to early Namurian; C_3 middle Namurian to Bashkirian (or Moscovian); CP - Upper Carboniferous to Lower Permian (Sakmarian to Artinskian); PTr - Upper Permian(?) to Middle Triassic(?); Tr - Lower Triassic(?) to Upper Triassic.

LEGEND LITHOLOGIC SYMBOLS

metavolcanics, orthogneiss; volcaniclastic rocks, chloritic slate; felsic and mafic meta-intrusive rocks, orthogneiss;

conglomerate; sandstone; slaty siltstone;

silty slate; black slate; calcareous slate;

limestone, dolomitic limestone; argillaceous limestone

dolostone; bedded gypsum, silty slate;

macrofauna; microfauna; load structures;

cross-bedding; desiccation cracks; current indicators;

flute marks; graded beds; thrust contact.

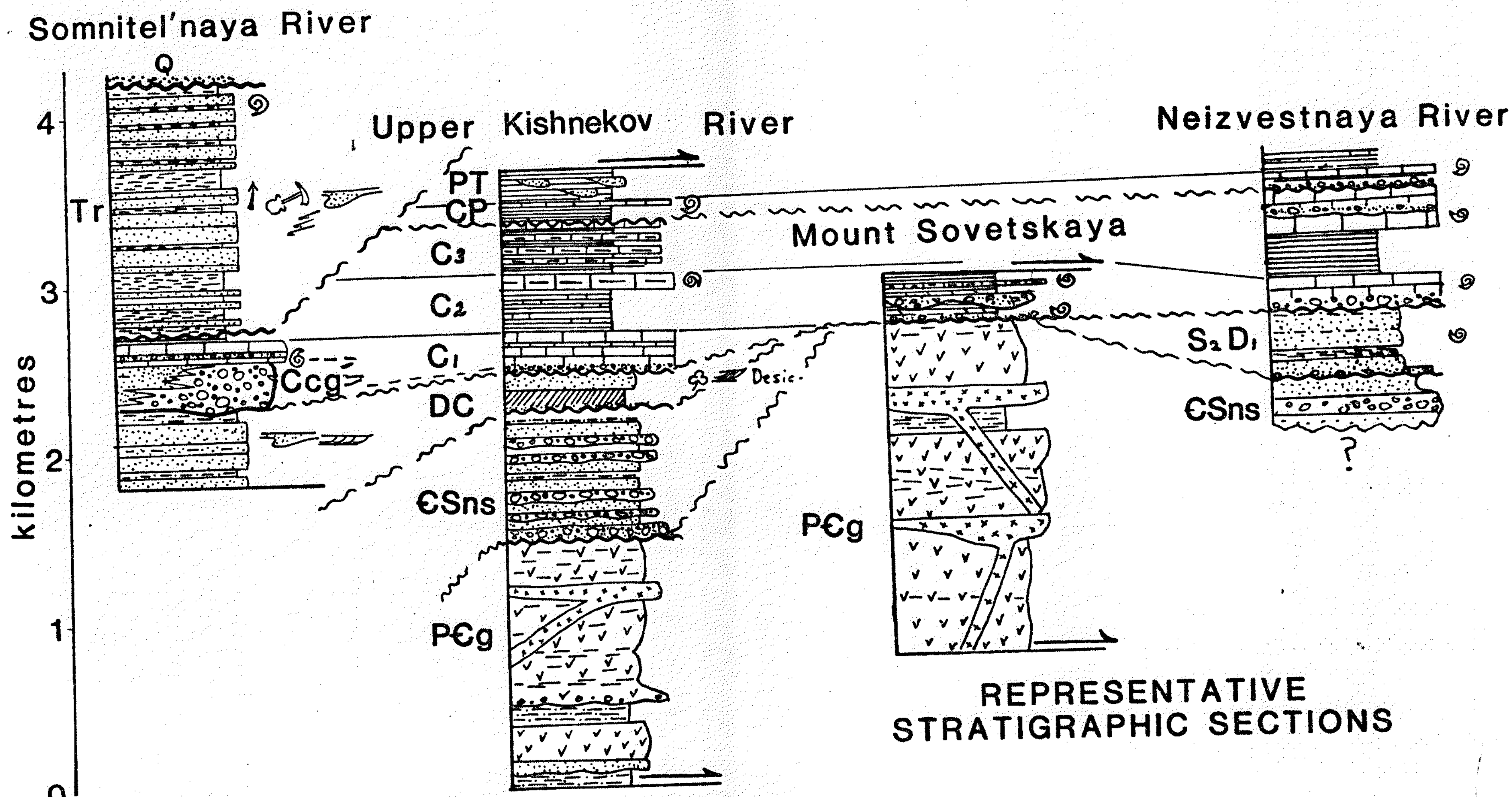


Figure 8. Schematic stratigraphic sections across Wrangel Island.

TABLE OF FORMATIONS

System	Series (Stage)	Sequence	Lithology
Quaternary		Q	alluvium, colluvium, Recent stream and beach gravels.
Triassic	Lower(?) to Upper Triassic (Norian, Carnian)	Tr	black to dark grey argillaceous quartz sandstone with minor feldpar and lithic fragments, black slate; minor siltstone (total thickness - 800 - 1500 m).
Permian(?)- Triassic(?)	Upper Permian(?) - Middle Triassic(?)	PTr	black slate; minor lensoidal bodies of buff-weathering quartz sandstone, siltstone and quartz-pebble conglomerate in the south; minor thin limestone in the north (total thickness - 100-200 m)
Carboniferous(?) Permian	Upper Carboniferous(?) - Lower Permian (Sakmarian, Artinskian)	CP	dark grey-green slate, slaty argillite with beds of arenaceous to argillaceous dark brown foetid limestone, and in the west arenaceous crinoidal wackestone and packstone in the upper part of the unit; contains pyrite crystals and black to brown weathering pyrite nodules (total thickness - 50 - 100 m).
Carboniferous	Lower Carboniferous and Upper Carboniferous (Namurian to Moscovian)	C3	interbedded brown argillaceous limestone, crinoidal wackestone, packstone, black slate and calcareous slate; includes thick-bedded fossiliferous limestone in the north. (total thickness - up to 300 m).
	Lower Carboniferous (Visean and Namurian)	C2	dark grey to grey fossiliferous thin and thick-bedded limestone and argillaceous limestone, crinoidal wackestone, packstone (south and center); massive, thick bedded biohermal limestone, fossiliferous limestone, dolomitic limestone; minor basal? conglomerate (total thickness - up to 300 m).
	Lower Carboniferous (Visean)	C1	discontinuous unit of polymictic (dominantly slate/argillite and sandstone clasts) conglomerate; minor quartz sandstone, units of buff fossiliferous dolomitic limestone, dolostone, grey crinoidal wackestone, grey slate, (total thickness - 0 to 300 m).
Devonian - Carboniferous	Middle(?), Upper Devonian - Lower Carboniferous	DC	buff to grey-green slate, quartz sandstone, siltstone; minor unit of white gypsum (a few meters) in the hanging wall of the northern thrust; minor fossiliferous limestone, dolostone, pebble conglomerate, cobble conglomerate, (total thickness - > 150 m).
Silurian and Devonian	Upper Silurian and Lower Devonian	SD	DREM-KHED FORMATION: fossiliferous sandstone, siltstone, slate; minor basal conglomerate (total thickness - 400 m).
Cambrian - Silurian(?)	Cambrian - Middle Silurian(?)	ЄSns	NASHOK FORMATION: maroon and green slate, abundant intraformational conglomerate, pebbly arkosic sandstone, sandstone; cobble-sized basal conglomerate, (total thickness - up to 800 m).
Proterozoic(?)- Cambrian(?)	Late Proterozoic(?) - Middle Cambrian(?)	PЄg	GROMOV COMPLEX: metavolcaniclastics, meta- intermediate to acidic volcanic hypabyssal intrusive rocks; minor mafic metavolcanics (chlorite schists with actinolite), quartzite, units of grey and black slate, garnet-diopside calcsilicate rock, marmorized limestone; intruded by small dykes and sills of tectonized quartz-feldspar porphyry, granite and leucogranite (total thickness - up to and in excess of 2800 m).

This thrust has a sinuous trace, and like all structures on the island it strikes roughly east and west. Two other prominent thrusts are exposed in this belt on Wrangel Island and we will refer to them as the middle and southern thrusts.

Comparison of stratigraphic successions between thrust sheets reveals considerable variation, which is summarized in a series of four representative stratigraphic sections shown in Fig. 8. The hanging wall of the northern thrust has Precambrian(?) - Cambrian(?) strata overlain unconformably by Carboniferous strata; the hanging wall of the middle thrust contains the most complete section found in the thrust belt. Represented here are strata of Precambrian(?), Cambrian(?), Devono-Mississippian, Carboniferous, Permian and possibly Triassic age (Plate 2). The hanging wall of the southern thrust contains strata of Devonian to Late Triassic age; however in the center of the island up to 700 m of Carboniferous and Permian strata are missing beneath Triassic shales and sandstones in this hanging wall succession.

All rocks on Wrangel Island, Precambrian(?) to Upper Triassic, have a pervasive south dipping slaty cleavage, have been metamorphosed to or close to lower greenschist facies, and were deformed by a post-Triassic orogenic event. Most folds and thrusts are north-vergent.

STRATIGRAPHY

GROMOV COMPLEX ($P\epsilon_G$)

Definition: The Gromov Complex consists of more than 2,800 m of felsic to intermediate metavolcanic rocks, metavolcaniclastics, sericitic and chloritic slate/schist with minor grey and black slate, mafic metavolcanics, quartzite, and conglomerate (Plates 3, 4,a,b, 5, 6). Kameneva and Il'chenko (1976) also report the presence of lenses and beds of "garnet-epidote-diopside marble and marmorized limestone" in this complex. The reference section (Kameneva and Il'chenko, 1976) for this unit is in the "Lagernyy Creek" valley which we believe is the central headwaters tributary of the Kishnekov River. Gromov metasedimentary and metavolcanic rocks are intruded by a suite of quartz-feldspar porphyry, metagabbro, metadiabase, and aplitic felsic dykes and sills and small granitic and aplitic intrusive bodies. All intrusives have been tectonized to some degree.

Kameneva (1975) and Kameneva and Il'chenko (1976) divided the older "metamorphic complex" of central Wrangel Island into two formations (Gromov and Inkalin) on the basis of acritarchs, microphylites and algae. Recent observations by our Soviet colleagues however, indicate that both formations are lithologically similar and that the inferred contact between the two is difficult to recognize and is at best gradational, making unequivocal separation and mapping of these units difficult. Thus in this report we use the term Gromov Complex to describe strata of the combined Gromov and Inkalin formations, and their associated intrusive rocks.

Contacts: The basal contact of the Gromov Complex is everywhere tectonic. The oldest Gromov rocks are probably encountered in the hanging wall of the northern and middle thrusts. We did not observe the lower hanging wall fault contacts of these thrusts. Bogdanov and Tilman (1964) describe the northern thrust area as a zone of mylonite tens of metres in width. The Gromov Complex is unconformably overlain by Carboniferous strata in the hanging wall of the northern thrust and unconformably overlain by Cambrian (?) - Silurian (?) strata (Nashok Fm.) in the hanging wall of the middle thrust.

Age The age of the Gromov Complex rocks is also problematic. Based on the identification of acritarchs, microphytoliths and algae similar to ones found in the southern Urals and Baikal region, Kameneva and Ilchenko (1976) assigned a middle to late Riphean (Hadrynian) age to the upper Gromov Complex, and a Vendian (Eocambrian) age to the Inkalin Complex. The accuracy of age determinations using these faunal assemblages is considered debatable, (M.K. Kos'ko pers. comm., 1986). K-Ar ages summarized by Ivanov (1973) display a wide scatter between 115 and 575 Ma. The oldest ages obtained are from a granite porphyry with values of 513 and 575 Ma (Early and Middle Cambrian); however these ages should probably be considered a minimum since all igneous rocks in the Gromov Complex are metamorphosed and more or less deformed. The younger K/Ar ages, which cluster between 420 amd 457 Ma (Middle Ordovician to Early Silurian), and between 115 and 224 Ma (Late Triassic to Early Cretaceous; Ivanov, 1973) probably represent various metamorphic and/or uplift ages, because there are no known igneous rocks cutting strata younger than the Gromov Complex on the island.

Distribution: In the thrust belt the Gromov Complex is found in the central mountains of Wrangel Island at the base of the northern and middle thrust hanging wall successions, and in the hanging wall of the merged northern and middle thrusts on the central west coast of the island (Fig. 7). In the northern parautochthonous zone Gromov Complex rocks are exposed in a small number of anticlines in the south central part of this area. One important regional characteristic of Gromov relationships is that in both the hanging wall of the northern thrust, and in the parautochthonous zone north of this thrust, Carboniferous strata rest unconformably on Gromov rocks. This distribution is an important constraint on the amount of displacement that can be inferred for the northern thrust (see section on Structure).

In addition to difficulties in assigning unequivocal ages to Gromov Complex strata other aspects of the Gromov remain problematical or unresolved. These include: (1) the level of deformation and the number of phases of deformation; and (2) the degree and character of metamorphism.

Deformation A variety of outcrops of the Gromov Complex in the hanging wall of the northern thrust reveal the problem of the level of deformation. Some intermediate metavolcanic rocks contain numerous phenocrysts of quartz and idiomorphic feldspar of apparently primary magmatic origin (Plate 3). Foliation in these rocks may be in part caused by extrusive flow during crystallization or compaction of pumice fragments in a hot ash flow deposit (fiamme). In contrast, there are also a variety of less competent phyllitic slates that have long since lost all evidence of their primary depositional character, except perhaps a relict compositional lamination. Other rocks are essentially augen gneisses (Plate 4 a,b). It is unclear in these rocks whether the feldspar augen are: deformed primary phenocrysts which were already oriented due to fluid flow during emplacement of their host magma; sheared and rotated phenocrysts associated with lenses of subvolcanic porphyry; or large metasomatic feldspars which were later deformed. In one stream bank exposure several hundred metres above the middle thrust, it is possible to observe aplite dykes cross-cutting layering in the adjacent intermediate metavolcanic rocks. These dykes are in turn deformed into a series of ductile folds and, in one case, have also been boudinaged. Bogdanov and Tilman (1964) also describe metagabbro-metadiase sills that have been folded along with the enclosing rocks, lending support to the theory that these rocks have in some areas undergone elevated levels of strain.

The elevated level of ductile flow deformation in most Gromov rocks also makes internal subdivision of the unit difficult. Although volcaniclastic rocks appear to structurally overlie various metavolcanic and hypabyssal meta-intrusive rocks in sections south of the middle thrust, this apparent stratigraphic order is nowhere confirmed by tops indicators. Where volcaniclastic rocks and slates structurally underlie metavolcanic rocks, such as in the allochthonous package above the northern thrust, it is not known whether these rocks occur in their correct stratigraphic position on an overturned fold limb, or whether they are part of a thrust repetition of the apparent stratigraphic sequence observed south of the middle thrust. In spite of difficulties in assessing strain there appears to be a real difference in the level of strain of Gromov Complex rocks in comparison to younger successions.

In the hanging wall of the northern thrust a conglomerate was found in a single outcrop within Gromov Complex argillite and volcaniclastic sandstone near the base of the Carboniferous strata. The conglomerate in this outcrop contained mainly slightly foliated leucrocratic granites with some quartzite and minor slate clasts. The foliations in these leucogranite clasts, unlike clasts found in nearby basal Carboniferous(?) strata, showed only minor variation of contained clasts from a cleavage parallel orientation. This is considered evidence for a pre-Carboniferous deformation of the Gromov Complex (see later discussion "Sedimentary Evidence for Pre-Jurassic Tectonism").

Metamorphism: The level of metamorphism in the Gromov Complex is also problematic. Typical mineral assemblages reported by Kameneva (1975;,1977) and Kameneva and Il'chenko (1976) include: amphibole-epidote-chlorite (including actinolite); amphibole-biotite-chlorite; and quartz-albite-muscovite-chlorite. These assemblages indicate a grade of metamorphism that is not higher than lower amphibolite facies.

In earlier accounts of the geology of Wrangel Island, much significance was placed on the observation that the greenschists of the central mountains were significantly higher in metamorphic grade than the fossiliferous strata typical of the Paleozoic rocks. Gorodinsky (as reported by Bogdanov and Tilman, 1964) went so far as to assign a Proterozoic age to these greenschists based solely on their apparently higher grade. Kameneva (1975) also believes that there is a clear distinction in metamorphic facies between the slates and schists of the central mountains and the "shales", limestones, sandstones, etc. of the Phanerozoic. Chloritic and sericitic slate units are found in all Devonian, Carboniferous, Permian, and Triassic strata. Based on field observations and data of Kameneva (1975) and Kameneva and Il'chenko (1976) it appears that the grade of metamorphism in the Gromov Complex is greenschist to lower amphibolite facies, and the metamorphic grade in the younger overlying strata is greenschist facies. Without the benefit of detailed sampling and petrography to assist in complete evaluation of the metamorphic history of all rocks on Wrangel Island (including for instance, the possibility of retrograde metamorphism, or of superimposed metamorphic events) there is at present essentially only one discernible metamorphic event which ranges from greenschist facies in the youngest rocks to lower amphibolite facies in some of the older strata. Thus we do not concur with Kameneva (1975) and others that there is a significant break in the level of metamorphism between the Gromov Complex and younger strata.

NASHOK FORMATION (6Sns)

Definition: Kameneva and Il'chenko (1976) and Kameneva (1975) assigned 800 m of slates, quartzites and quartzitic sandstones which overlie the Gromov Complex to the Nashok Group (Plate 7). Because this "Group" is not divided into formations we will refer to this unit as the Nashok Formation. Kameneva and Il'chenko (ibid.) describe a reference section for the lower Nashok Formation along Lagernyy Creek (central headwaters tributary to the Kishnekov River?), a reference section for the middle Nashok formation along a headwaters tributary to the Klark River, and a reference section for the upper Nashok Formation near Drem-Khed Mountain. The exact location of the Drem-khed Mountain Nashok Formation exposures is not reported and no exposures of the Nashok Formation are shown on existing maps in that area (see Figs. 1, 7).

We examined the Nashok Fm. at two localities one within the hanging wall of the northern thrust and the other in the hanging wall section of the middle thrust, central mountains. The first locality visited was along the central headwaters tributary to the Kishnekov River (Lagernyy Creek?), where the lower Nashok Formation is well exposed. The second locality was a less well exposed section at the headwaters of the Neizvestnaya River.

Within the hanging wall of the middle thrust, the Nashok Fm. is a mappable unit (Plate 2) that can be divided into two members of roughly equal thickness. The lower member includes a basal conglomerate, approximately 250 m of green weathering slate, pebbly arkosic quartz sandstone, quartz sandstone and intraformational conglomerate. Clasts in the intraformational conglomerate are dominated by angular maroon and green slate and some quartz sandstone, all of which are lithologically similar to Nashok strata. The lower member of the Nashok is gradationally overlain by maroon-weathering slaty phyllite, intraformational conglomerate, and pebbly, arkosic quartz sandstone of the upper member.

Contacts: The Nashok Formation unconformably overlies the Gromov Complex. The basal conglomerate exposed along the central headwaters tributary of the Kishnekov River, consists of several metres of polymictic conglomerate dominated by rounded clasts of crystalline quartzite and foliated sucrosic granite (up to 10 centimetres) both of which are similar to rocks found in the underlying Gromov Complex (Plate 8). The granite clasts show a slight gneissic foliation from which we were not able to ascertain whether foliation was aquired before or after the deposition of the conglomerate. The upper contact with overlying Devonian-Carboniferous (DC) units is not exposed in the hanging wall of the northern thrust. At Drem-Khed Mountain the upper Nashok Formation is overlain by the Drem-Khed Formation (Kameneva and Il'chenko, 1976). In the hanging wall of the middle thrust the upper part of the Nashok is truncated beneath the overlying Middle(?) Devonian to Lower Carboniferous strata.

Age: The age of the Nashok has been determined by Kameneva and Il'chenko (1976) as Early Cambrian on the basis of assemblages of acritarchs, microphytoliths, and algae. The accuracy of age determinations using these faunal assemblages is considered debatable, (M.K. Kos'ko, pers. comm., 1986). Based strictly on radiometric data it is possible that the Nashok is as young as Late Cambrian to Middle Silurian because it unconformably overlies the Gromov Complex which contains subvolcanic intrusives with maximum K-Ar age of 513 and 575 Ma. The Nashok is older than the Upper Silurian to Lower Devonian Drem-Khed Formation which contains distinctive macrofaunal assemblages (Kameneva, 1975). Thus the possible range in age for the Nashok Formation is Early Cambrian to Middle Silurian.

Distribution: Extensive exposures of the Nashok Formation are found in the vicinity of the Nashok River from which the formation name is derived. The Nashok is well exposed in an east-west trending outcrop belt within the hanging wall of the middle thrust, between the Mamontovaya and the Nasha rivers. The Nashok also outcrops in the hanging wall of the northern thrust east and southeast of Tri Druga Mountain and in low hills north of the Klark River, but it is missing in the same thrust panel in the central mountains where Carboniferous rocks rest directly on the Gromov Complex. The Nashok Formation is also found in an anticline in the south central part of the parautochonous zone and near Mt. Drem-Khed in the northwestern part of this structural zone. Strata previously assigned to the Nashok Fm. (along the west coast and south of the Gusina River) are green weathering slates of Carboniferous(?) - Permian age.

DREM-KHED FORMATION (SD)

Kameneva (1975, 1977) assigned 400m of argillite, siltstone and quartz sandstone exposed in isolated hills on northern Wrangel Island (parautochthonous zone) to the Drem-Khed Formation. This unit underlies Drem-Khed Mountain and two other areas between the Krasniy Flag and Neizvestnaya rivers. A Late Silurian and Early Devonian age was determined on the basis of an abundant and diverse assemblage of brachiopods, bryozoans, ostracods, corals and pelecypods. Kameneva (1975) reports a "quartzitic" pebble conglomerate at the base of the Drem-Khed succession. Kameneva (ibid.) does not specifically indicate that this is the base of the formation, nor that older units are present. However, Kameneva and Il'chenko (1976) note that the best exposures of the upper Nashok Formation are found near Drem-Khed Mountain. It seems logical, therefore, that they observed one directly overlying the other, or in outcrops in close proximity to one another. We did not have the opportunity of visiting the type area or any other exposures of the Drem-Khed.

MIDDLE DEVONIAN - LOWER CARBONIFEROUS STRATA (DC)

Definition: Kameneva (1975) recognized an unnamed succession of 150+ m of sandstone, slate and gypsum found between the Nashok Formation and Carboniferous strata in the headwaters area of the Kishnekov and Somnitel'naya rivers (Plate 9) as a distinct unit. Although this unit is in the same stratigraphic position as the Drem-Khed it yielded Late Devonian palynomorphs (see below), younger than fauna collected from the Drem-Khed. We will refer to this succession as the DC (Devonian - Carboniferous) unit.

Contacts: The DC unit rests unconformably on the Nashok Formation and is unconformably overlain by Carboniferous strata.

Distribution: The DC unit is recognized in the hanging wall of the middle and southern thrusts from the Mamontovaya River area to the headwaters area of the Nasha River. A similar unit is also recognized at Cape Pillar on the east coast by Ivanov (1973). Other small outcrops have been identified in the middle and upper reaches of the Gusina River. No occurrences of the DC unit are known from the parauthochtonous zone, although with better biostratigraphic control it is possible that a partial correlation may yet be established between the DC and Drem-Khed Formation.

In the overthrust belt, we studied Devonian strata lying unconformably on the Nashok Formation in the hanging wall of the middle thrust (Fig. 7; Plates 2, 10-13), and also in the hanging wall of the southern thrust where it represents the oldest strata exposed within a major northerly-verging anticline. The most complete exposures are in the hanging wall of the middle thrust between the Kishnekov and Somnitel'naya rivers. In all of these areas bedrock exposures are limited and felsenmeer and talus are dominant.

Devonian strata in the hanging wall of the middle thrust, near the Kishnekov River consist of two locally mappable members which are both highly recessive and repeated by internally detached folds. The lower member consists of an approximately 60 - 80 m thick succession of tan, grey and green weathering slate, buff siltstone, boudinaged, white, thinly-bedded gypsum and minor quartz sandstone (Plate 10,11). The sandstone beds in many of the exposures are mature and well sorted. On strike to the west, on the Mamontovaya River, the lower member is thicker (150 m +) and contains coarser, more proximal, clastic strata including trough cross-stratified (Plate 12), coarse-

The upper member of the Devonian- Mississippian section (Plate 13) includes buff-weathering, thin bedded calcareous medium-grained quartz sandstone and minor intercalated grey slate. Primary depositional structures include ripple cross-laminae and dessication cracks. The dessication features are found in thin, grey or buff, slaty partings where cleavage is parallel to compositional laminae. Sand from the overlying sandstone beds fills the desiccation cracks indicating sub-aerial exposure. This upper member has a minimum thickness of 60 - 80 m. Solitary rugose corals are common in some sandstone beds.

The thickest development of the DC succession occurs in the hanging wall of the southern thrust. Strata here are thought to be overturned to the north in a single north verging anticline. Dolostone and conglomerate which lie immediately above the thrust on the overturned limb of the anticline, are thought to be Visean. Likewise the buff-weathering sandstones, siltstone and slates containing scattered crinoidal limestone units, and which occur immedately below the Triassic, high in the hanging wall succession, are also believed to be Visean. Intervening strata in the core of the fold are tentatively assigned to the DC unit and are estimated to exceed 450 m in thickness. This succession consists of grey slate, grey to black, and buff siltstone and black, grey, and buff, thin- to medium-bedded, fine-grained quartz sandstone. Primary sedimentary structures include loads, ball and pillow structures, flat and ripple cross-laminae.

Primary sedimentary features of the DC unit in both the middle and southern thrusts are typical of clastic rocks deposited in fluvial, shelf and strand environments.

In the south, the assumed DC unit clastic rocks are the oldest strata known above the southern thrust. In the panel above the middle thrust, the DC unit lies either on the upper or lower member of the Nashok Fm. Locally it is also thrust over Carboniferous strata. DC unit strata are absent in the panel above the northern thrust, and are apparently absent in cores of small anticlines in the northern parautochthonous belt and may also be absent beneath the Carboniferous near the mouth of the Gusina River at the west end of the island.

Age: DC unit strata contain unspecified Frasnian palynomorphs (Kameneva, 1975; N.V. Khandozhko, pers. comm. 1986). A similar clastic section at Cape Pillar has been assigned an Early Carboniferous age by Ivanov (1973). K.S. Ageev would place much of the 1400 m of section found south of the central mountains into the Middle and Late Devonian (M.K. Kos'ko, pers. comm. 1986). Thus this unit is considered to be Middle(?) Devonian to Early Carboniferous in age and appears to be entirely younger than the Drem-Khed Fm.

CARBONIFEROUS STRATA (C_1 - C_3)

Definition: Kameneva (1975), Kameneva and Chernyak (1975), and Chernyak and Kameneva (1976) recognized two belts of Carboniferous rocks on Wrangel Island which differ in facies and age at the base of the respective successions. The most complete sections were found in the southern part of the island (hanging wall, middle thrust), where the Carboniferous unit consists of more than 800 m of Lower to lower Upper Carboniferous (Visean to Moscovian) argillaceous limestone and black slate with a lensoidal basal conglomerate. In the north (parautochthonous zone) the Carboniferous unit consists of 650 m of upper Lower and lower Middle Carboniferous (early to latest Namurian) biohermal limestone and slate.

In the south (hanging wall, middle thrust) Kameneva (ibid.) recognizes three divisions of the carbonate unit in the area of the Kishnekov River. In ascending order they are: a basal conglomerate; a 200 m succession of Lower Carboniferous (Visean) fossiliferous, argillaceous limestone; and an upper member consisting of a 300 m thick succession of limestone and slate. The upper two divisions are essentially our C_2 and C_3 units (Fig. 8). The northern succession (parautochthonous zone), as described by Kameneva (ibid.) in the area of the Neizvestnaya River and Klark River basins, includes two successions. The lower succession consists of 25 to 50 m of coarse-pebble conglomerate overlain by 100 - 150 m of limestone and the upper succession consists of 250 m of unfossiliferous slate and above that, 250 m of limestone containing a 10 - 15 m thick conglomerate horizon in mid-section.

contact of the Carboniferous unit is a sub-Quaternary or present day erosional surface over much of the northern parautochthonous zone and in the area of the northern thrust.

Locally, occurrences of Carboniferous(?) to Triassic(?) strata conformably(?) overlying the Carboniferous unit have been reported (Kameneva 1975). In the hanging wall of the middle thrust, Carboniferous unit strata are conformably(?) overlain by Carboniferous(?) to Triassic(?) argillite and slate. In the hanging wall of the southern thrust a substantial part of the Carboniferous unit is missing below a sub-Triassic unit unconformity.

Distribution Carboniferous rocks outcrop over a large part of Wrangel Island, they are distinctive and can be reliably dated (Fig.7,8). Exposures are found throughout the northern parautochthonous belt from the Krasniy Flag River and Cape Pillar, on the east, to Cape Ptitsi Bazzar, on the west. In the overthrust belt Carboniferous strata are represented in each of the three major thrust panels with excellent exposures throughout the central mountains and at Cape Ptitsi Bazaar on the west end of the island. At Cape Pillar, Ivanov (1973) has collected Early Carboniferous corals (Serpukhovian) from a 1400 m thick section of sandstones, siltstones, and minor conglomerates. This section is lithologically similar to, and may be partly equivalent to, the DC unit in the hanging wall of the southern thrust.

Observations on Distribution, Thickness and Facies: We observed the Carboniferous in all three thrust sheets in the central mountains between the Kishnekov and Somnitel'naya rivers, and as well, at a single locality near the headwaters of the Gusina River, and at Cape Ptitsi Bazaar on the west coast. In addition to the conglomerate units there are additional variations in thickness and facies, particularly in the lower part of the Carboniferous unit successions, from one thrust panel to the next and in an east to west direction.

In strata above the northern thrust we examined the Carboniferous unit at two locations at the top of the hanging wall succession. At the easternmost location less than 100 m of Carboniferous strata are preserved, and believed to be of latest Visean or early Namurian age on the basis of direct physical correlation and lithological comparisons with the $C_{1,2}$ succession examined in the same structural panel to the west. This thin and variable succession consists of dark grey to black slate, and thin bedded, dark grey limestone and argillaceous limestone which rests unconformably on the Gromov Complex. The limestone beds are locally replaced by chert parallel to layering and are also dolomitized. Crinoidal floatstone and wackestone occur sparingly throughout the section (Plate 14). Minor constituents of the unit are lenticular bodies of quartzite cobble conglomerate with a chloritic matrix, quartz pebble and quartz granule chloritic sandstone and rare crinoidal packstone containing angular clasts of slate derived from the Gromov Complex. On strike to the west (headwaters of a tributary to the Mamontovaya river), the same succession consists of a basal conglomerate, inferred from large creek bottom boulder (see following discussion on "Signficance of Conglomerates") overlain by quartzite that grades upwards into crinoidal limestones and sparsely fossiliferous (brachiopods) orange weathering dolostone with units of black slate.

dark grey to black, calcareous slate interstratified with lesser units of thin- to medium bedded grey to dark grey crinoidal floatstone and crinoidal packstone. This unit also contains scattered crystalline dolostone olistoliths up to several metres in size (Plate 16). This second sequence shallows upwards and is capped by resistant dark brown-weathering, dark grey limestones 30 - 50 m thick (Plates 2, 17). The third succession (C_3) begins with a basal 15 - 20 metres of unfossiliferous black slate which is overlain by interstratified black slate, dark brown weathering crinoidal packstones and laminated carbonate mudstones (Plates 2, 18). The slates and limestones in this upper unit are arranged in couplets 2 - 5 metres thick, locally as much as 8 m thick. Limestone beds frequently show soft sediment deformation structures. Total thickness of this succession was estimated at 300 m by Kameneva (1975). The top of the Carboniferous succession is placed beneath dark grey-green slates of Late Carboniferous(?) to Permian age (CP unit).

In the hanging wall of the southern thrust steeply dipping to overturned unfossiliferous buff-weathering dolostone, which outcrops immediately above the thrust, is tentatively correlated, on the basis of lithology, with upper Visean to Namurian strata of the $C_{1,2}$ succession. This dolostone is tectonically brecciated and quartz-veined; breccia fragments have been selectively silicified. A thin, quartz pebble conglomerate horizon (10-20 cm thick) found at several localities structurally overlying this overturned dolostone is thought to be equivalent to the basal conglomerate to Carboniferous strata found in the hanging wall of the middle thrust.

Also in the hanging wall of the southern thrust, Carboniferous unit strata (equiv. to $C_{1,2}$?) are prominently exposed beneath the sub-Triassic unconformity (Plate 18) south of DC unit rocks. In the Kishnekov River area, these strata consist of crinoidal limestone with units of slate and siltstone in direct contact with the DC unit. At the head of the Somnitel'naya River, however, Carboniferous unit strata consists of a thick succession of immature conglomerate (C_1), the upper part of which is interstratified with units of coralline limestone over a 20 m interval. The conglomerate is overlain by 80-100 m of fossiliferous buff weathering limestone and dolomitic limestone (also C_1?). Above this are ten to fifteen metres of black slate interbedded with thin-bedded limestone which are assumed to be the erosional remnants of the thick C_2 succession preserved beneath the Triassic at this locality. The rest of the C_2 succession and overlying Carboniferous and Permian units (a total of 700 m) are missing in this part of the southern thrust, hanging-wall succession.

At Cape Ptitsi Bazaar (Plate 18), south of the Gusina River on the west end of Wrangel Island, Carboniferous(?) to Triassic(?) strata overlie very thick-bedded massive limestones the lower part of which is tentatively assigned a Namurian age, and the upper part of which may be as young as Permian. The subhorizontal limestones are exposed in a sea-cliff face close to 100 m high. The base of the Carboniferous section here is in the subsurface. Although it was not possible to closely observe the entire exposed section, the light grey to medium grey, thick- to massive-bedded carbonates (Plate 19) consist of interbedded micritic limestone (lime mudstone), and lesser algal framestone containing pisolitic textures, stromatactic voids, and calcite lined vugs. Some beds contain diverse faunal assemblages including solitary and small colonial corals, algal mats, brachiopods, and fenestellid bryozoans. At the north end of these carbonate exposures there is a substantial development of forereef carbonates including crinoidal wackestone and packstones. Nevertheless, most of the carbonates appear to be of reefal or biohermal association and are probably similar to Namurian-Bashkirian strata described by Kameneva (1975) from the northern facies zones of Wrangel Island. This would suggest that the mid-Carboniferous shallow marine to deep marine (sub-wave base) facies transition has an orientation that trends WSW or SW across the island.

Significance of Conglomerates: Variations in the thickness of C_1 basal conglomerates are abrupt, possibly indicative of growth faulting during their deposition. Near the headwaters of the Gusina River this conglomerate overlies Middle Devonian to Lower Carboniferous sandstones. Here it is 2 to 10 m thick and consists of grey, maroon and green slate fragments in a sparse chloritic matrix. It is gradationally overlain by a least 100 m of buff-weathering dolomitic limestone which contains scattered silicified rugose corals. On strike and 24 km to the east, at the head of the Somnitel'naya River, (hanging wall of the southern thrust), the same basal conglomerate is in excess of 300 m thick (Plate 18). Like the thinner Gusina section it is composed of clasts of green and maroon slate, and as well contains clasts of green siltstone, fine-grained sandstone, black slate, minor quartzite, vein quartz, and red calcite. Although tectonically strained the conglomerate appears to be clast supported with a chloritic matrix of about 10%. The most likely sources of clasts are the Nashok Fm., and DC unit clastic rocks.

Whereas the conglomerates described above are dominated by clastic sedimentary rock clasts, conglomerates in areas where the Carboniferous unit rests directly on the Gromov complex contain granitic and volcanic clasts as well as clasts of sedimentary rocks and quartz.

At least one Carboniferous(?) conglomerate preserves a pre-Carboniferous unit tectonic foliation. In the hanging wall of the northern thrust, stream bed boulders of conglomerate are found in the contact zone between the Carboniferous unit and the Gromov Complex. This conglomerate consists of clast-supported cobbles and boulders and is believed to be to be derived from nearby outcrops of basal Carboniferous strata. Angular clast compositions here include variably fine- grained and medium- grained leucocratic and mesotypic gneiss, feldspar-augen gneiss, pink granite, and dark green slate. These conglomerate clasts show little or no post-depositional flattening or rotation: orientation of clasts and foliations in clasts is entirely random (Plate 15). One clast is cut by a quartz vein (nearly orthogonal to foliation) which in turn fails to cut the matrix. Clast types are very similar to rocks types encountered in the underlying Gromov Complex.

Age: Carboniferous unit fauna on Wrangel Island, particularly in the northern parautochthonous zone consist of a diverse assemblage of brachiopods, bryozoans, corals, goniatite ammonites, gastropods, crinoids, nautiloids, trilobites, and bivalves.

In the southern belt, within the hanging wall of the middle thrust, C_1 member is assigned a late Visean age on the basis of brachiopod and coral fauna found within it (V.G. Ganelin, pers. comm. 1986). In the C_2 division Kameneva (1975) and Kameneva and Chernyak

(1976) report on a variety of brachiopods, fenestellid bryozoans, corals and crinoids that have a Tournaisian to Visean range in age. Because the underlying C_1 unit contains Visean fauna, this unit is also assumed to be Visean. Foraminifera identified previously from this unit (Kameneva and Chernyak, 1975) include Pseudoendothyra aff. ovalis, Archaediscus itinerarus, A. krestovnikovi koktjubensis, and Planoarchaediscus spirillinoides, believed to correlate with foraminiferal zones 16, 17 of Armstrong et al (1970) - approximately latest Visean to early Namurian. Limestone beds in the C_3 unit above the middle thrust are reported by Kameneva and Chernyak (1975) to have yielded abundant forminiferal assemblages including Eostaffella aff. pseudostruvei, Endothyranella aff. donbassica, Millerella elegantula, Archaediscus aff. magnus, Neoarchaediscus aff. collatus, Tetrataxis aff. digna, and Planoarchaedisus stilus. Solovieva (1975) places these fauna within the Planoarchaediscus stilus - Eostafella pseudostruvei foraminiferal zone which correlates with zones 18 - 20 of Armstrong et al. (1970) - middle to late Namurian of Alaska and the northern Yukon.

Carboniferous strata in this northern belt transgressively onlap older units and range from early to latest Namurian in age. The lower limestone succession of the Carboniferous unit in the area of the Neizvestnaya and Klark rivers basin, yielded a variety of foraminifera including Ammodiscus compactus, Endothyra prisca, E. bradi, Pseudoendothyra sp., Archaediscus krestovnikovi, and Eosigmoilina explicata which Solovieva (1975) places within the foraminiferal zone Eosigmoilina explicata- Eostaffellina paraprotvae (or zones 18 - 19 of Armstrong, 1970: middle and late Namurian). Chernyak and Kameneva also report a variety of corals and brachiopods from the lower limestone which they assign an early Namurian age. In the same area, the upper part of the Carboniferous unit yielded a foraminiferal assemblage assigned to the *Ozawainella - Pseudostaffella* zone of Solovieva (1975) (or zones 20 - 21 of Mamet and Mason (1975) - latest Namurian). Chernyak and Kameneva (1976) report finding many late Bashkirinan to early Moscovian foraminifera from the top of the northern Carboniferous unit, including *Endothyra* cf *bradyi*, *Eostaffella* cf *pseudostuvei chomatifera*, *Novella pulchra*, *Peudostaffela* ex gr. *subquadrata*, *Ozawainella eoangulata*, *Profusulinella* sp., *Schubertella* sp., and *Globivalvulina granulosa*.

CARBONIFEROUS (?) - PERMIAN - TRIASSIC(?) STRATA - CP, PTr UNITS

Definition: Permian strata on Wrangel Island were recognized by Kameneva (1975) on the lower reaches of the Neizvestnaya River, at Nashaya Hill, on the middle reaches of the Mamontovaya River, and on Kit and Tundrovaya Mountains. The most completely described and the most fossiliferous section is located in the Neizvestnaya River exposures. The Permian there consists of two units which in total are about 150 m thick. The lower member is 56 m thick and includes 15 m of basal conglomerate containing clasts of limestone and phyllitic slate. These basal beds are overlain by grey to black argillite with some limestone interbeds.

Although we did not visit any of Kameneva's Permian localities, we observed correlative strata in a series of exposures preserved in the hanging wall of the middle thrust; and exposures in the hanging wall of the southern thrust preserved in the area of Cape Ptitsi Bazaar, near the mouth of the Gusina River, on the west coast.

Observations on distribution, thickness and facies: Two units can be identified in the hanging wall of the middle thrust and they can be traced for at least 18 km from the headwaters of the Nasha River to the middle reaches of the Mamontovaya River. They are a lower succession of green cleaved slaty argillite with minor limestone units, which we refer to as the CP unit, and an upper succession of black slate with minor quartzite lenses, which we refer to as the PTr unit.

The lower sequence (CP) is recessive and exposed only in small discontinuous outcrops. Near the Kishnekov River, it consists of approximately 50 - 100 m of green to dark green thin to medium bedded slaty argillite with prominent nodules of pyritized mudstone (Plate

20). The nodules weather dark brown to black. Internally this unit is laminated with green and light green layers. Upwards this unit is slightly better indurated and exhibits blocky weathering. The uppermost beds include 1-2 m of dark brown arenaceous foetid limestone interstratified with green slaty argillite.

The upper succession (PTr) consists of 100 to 200 m of black slate (Plate 2, 21) that locally, in the east, includes lenses of buff weathering quartzite. Most outcrops are entirely black slate but in some localities lenses of quartz sandstone are several tens of metres wide and several metres thick.

In the hanging wall of the middle thrust the CP unit is apparently conformable with underlying Carboniferous unit strata, and with overlying PTr unit slates. The upper contact of the PTr unit is invariably truncated by the fault plane of the southern thrust (Plate 21).

At Cape Ptitsi Bazaar, Permian to Triassic strata are repeated in a series of north-vergent folds. The Carboniferous to Triassic section here is also divisible into a lower succession of green slaty argillite (Plate 22) with limestone (CP unit) and an upper succession of black slate (PTr unit). The lower succession consists of 30+ m of medium to dark green and rarely black weathering slaty argillite, siltstone and minor fine-grained sandstone. Near the middle of the unit there are several limestone beds interstratified with the argillite and one discontinuous thin bed of buff weathering quartz pebble conglomerate. The limestones consist of brown to buff weathering, medium to thick beds of arenaceous crinoidal wackestone and arenite (Plate 23). North of Ptitsi Bazaar the limestones occur within only a couple of metres of section, however south of Ptitsi Bazaar these limestones are found over a few tens of metres of section with very little associated argillite. The green argillite also has beds of centimetre-scale nodules composed of disseminated to nearly pure pyrite in argillite, and large (up to 5 cm) euhedral crystals of pyrite.

By projection the CP unit must overlie, and may in part be laterally equivalent to, limestones of the Cape Ptitsi Bazzar rookery, but the upper surface of the rookery is eroded and lateral contacts with other units were not directly observed. The CP unit is gradational over a few meters into the overlying PTr unit. The PTr unit is also apparently conformable with black shales of the Triassic unit at this locality. However, in the hanging wall of the southern thrust near the Somnitel'naya and Kishnekov rivers, all the Permian to Triassic, as well as some Carboniferous units, are missing beneath the overlying Triassic greywackes and slates.

In the central mountains and in the coastal area north of Cape Ptitsi Bazaar the limestone beds of the lower CP unit are found within a 1 - 2 m thick section, whereas to the north, in the Neizvestnaya River area, and in the area south of Cape Ptitsi Bazaar limestones in equivalent strata occur throughout a 15 m section (Chernyak and Kameneva, 1976).

Age: In the area of the Neivestnaya River the lower member of Chernyak and Kameneva (1976) and Kameneva (1975) contains a variety of foraminifera including Nodosaria sp., Protonodosaria cf. proceraformis, Nodosaria sp., Protonodosaria cf. praecursor, Frondficularia prima, and Tolypammina cf. confusa: which are considered to be similar to fauna found in the Munugudzhak and

Dzhigdalin Fms. of the Upper Yana Basin (A.A. Gerke, in Chernyak and Kameneva 1976). Limestone beds in the middle and upper parts of the Neizvestnaya River section contain fragments of Kolymia which led Chernyak and Kameneva (1976) amd Kameneva and Chernyak (1975) to conclude that these are likely analogs of the Dzhigdalin Fm. and thus are of Early Permian (late Sakmarian - early Artinskian) age. Kolymia is a relative common fossil in Permian rocks in localities throughout the northeastern Soviet Union (Gerke, A.A., in Kameneva and Chernyak, 1975; V.G. Ganelin, pers. comm., 1986).

At several localities in the hanging wall of the middle thrust near the Kishnekov River, we observed the limestone unit in the upper CP succession to contain beds with large and abundant fragments of the pelecypod Kolymia, which as reported above indicates an Early Permian age. Other than crinoid ossicles, these were the only fossils that we found within the CP and PTr units. Thus their assigned age ranges of Late Carboniferous(?) - Early Permian (CP unit) and Late Permian(?) - Middle(?) Triassic (PTr unit) are based on the Kolymia beds and their apparently conformable stratigraphic relationship with underlying lower Upper Carboniferous strata and their position below Upper Triassic strata, near Cape Ptitsi Bazaar.

TRIASSIC (Tr)

Definition: Triassic unit strata on Wrangel Island consist of a very thick monotonous succession of interstratified units of black rhythmic, turbiditic sandstone-slate. Although the succession is sandstone dominated, depositional units vary from sandstone with slate to slate alone.

Near Cape Pillar, the basal strata have been described by Tilman (1970) as consisting of 15 to 20 m of cross-laminated and ripple cross-laminated sandstone and very fine pebble conglomerate containing clasts of quartz, black schist, and feldspar in sub-equal proportions. The bulk of the remainder of the Triassic unit in this area consists of fine-grained arkosic sandstone, shale, and minor siltstone. Sandstones in this part of the section consist of medium to coarse sand grains comprising equal amounts of plagioclase and quartz, minor chert and with a muscovitic matrix making up 35% of the rock (Tilman, ibid.).

It is possible that part of the Cape Pillar section (Fig. 7) includes strata assigned to the Carboniferous by Ivanov (1973), and to the Devonian by Ageev (M.S. Kos'ko, pers. comm., 1986).

Contacts: We briefly examined basal Triassic strata near the Kishnekov River and at the headwaters of the Somnitel'naya River (Plate 18). In these localities medium to thick beds of dark grey to black, fine grained turbiditic sandstone and some interbedded black slate directly rest on Devonian (?) quartz sandstones, and on Carboniferous limestones and coarse clastic rocks. The contact is sharp and apparently free of any sort of basal conglomerate or pebble lag. Although it is not completely exposed, it can be traced in three dimensions as a sharp, southward dipping contact unassociated with structural complications, such as gouge, riedel shears, quartz veins, high strain indicators, minor folds or faults. In the headwaters area of the Somnitel'naya River the Triassic unit rests unconformably on Carboniferous unit limestone ($C_{1,2}$). This contact is well exposed for several kilometers along strike and at least 3 kilometers down dip. Everywhere in these exposures the Triassic unit rests on about the same thickness of Carboniferous limestone. Therefore any angular relationships between the older strata and the Triassic must have values of less than 5^{o}. Tilman (1970) examined the same area and reports that the contact between the Triassic unit and Upper Paleozoic units is a 15- 20^{o} angular unconformity. In basal Triassic unit exposures just east of the Kishnekov River, central mountains, we observed truncation of a thin Carboniferous limestone, from west to east, over a distance of about 4 kilometers. This truncation also requires an angular relationship of less than 5^{o}. We also oberved the basal Triassic unit contact near Cape Ptitsi Bazzar where it appears to conformably overlie the PTr unit. The Triassic unit is the youngest rock unit on Wrangel Island and its upper limits are the present day or sub-Quaternary unconformities.

Distribution: Triassic strata on Wrangel Island are exposed in a south dipping homocline up to 20 km wide and traceable from Cape Ptitsi Bazaar in the west to Cape Pillar in the east. Triassic beds, originally documented north of the central mountains by earlier geologists (e.g. Tilman, 1970) have not been confirmed by the work of Kameneva (1975) and Kameneva and Chernyak (1974; Fig. 8).

In the south, the most complete exposures are found south of Cape Ptitsi Bazaar on the southwestern coast, and near Cape Pillar in the east. In the central mountains, there are scattered small outcrops and abundant talus or felsenmeer along the Kishnekov River and its tributaries. Triassic strata preserved after post-Triassic erosion, range from a minimum estimate of 800 m (Til'man, 1970) to 1500 m (Kameneva, 1975).

Observations on Thickness, Lithology and Facies: South of Cape Ptitsi Bazaar the lower contact with underlying black slates assigned to the PTr unit is covered. Black slates of less than 200 m thickness comprise the base of the Triassic succession (Plate 24). These fine grained clastic rocks grade upwards into a transitional interval of thinly interbedded black slate and thin-bedded, fine grained, dark grey to black sandstone and siltstone. Sandstone beds (Plates 25,26) display some of the classic elements of a very thick bedded turbidite assemblage, including normally-graded bedding, load stucture, rip-up clasts, flutes, large scale scours and other prominent current indicators. Many sandstone beds are massive at their base, and become laminated and convoluted upwards. There is also a tendency to darken upwards indicating a decrease in grain size and/or an increase in mud content. The thickest sandstone beds are 1.5 m thick. This is unusally thick for turbidites indicating either a very proximal source or deposition near the outlet of a submarine channel.

At 300 to 400 m above the base of the Triassic section south of Cape Ptitsi Bazaar, intraformationally detached tectonic folds are common. Medium scale folds and thrusts are observed or inferred throughout the Triassic succession. With such complex intraformational structure it is impossible to measure or estimate the true thickness of the succession or the extent of internal thrust repetition. The uppermost Triassic beds are peneplained and covered with Quaternary alluvium.

Samples examined from the Kishnekov River area and Cape Ptitsi Bazaar consist of fine- to medium-grained sandstone of dominantly quartz and fine grained sedimentary rock clasts, and 10- 15% plagioclase in a matrix of less than 10% muscovite and low birefringent minerals. The majority of lithic clasts are flattened and could easily be mis-identified as matrix. Semi-quantitative x-ray analysis shows a sample of Triassic sandstone from near the base of the Triassic unit section, Cape Ptitsi Bazaar as consisting of 37% quartz, 29% albite, 21% chlorite, 8% dolomite and 5% muscovite. Thus the low-birefrigent matrix is likely a mixture of silica, chlorite and albite. Samples of Triassic unit slate from the middle part of the succession on the Kishnekov River were determined by semi-quantitative x-ray analysis to have 10-20% quartz, 35-40% chlorite, 25-25% muscovite, 20-15% albite and minor alkali feldspar.

Age: Norian Stage pelecypods _Halobia_ ex gr. _superba_, _Monotis scutiformis_ var. _typica_, _M. pinensis_ and _M. setacanensis_ have been reported from argillaceous sandstones on the southeast part of the island near Bolsevik Point (between the outlet of the Klark River and Cape Pillar, Fig. 1; Tilman, 1970). The pelecypods _Monotis jakutica_, _M. ochotica_ var. _densistriata_ and _M._ aff. _subcircularis_ have been identified from argillaceous siderite nodules believed to have been transported downstream from upland exposures of Triassic sandy-slates on the southeast coast. These fossils were reported by Tilman (1970) as Carnian but Tozer (1970) assigns this group of fossils to the Norian. The nodules were found at the outlet of a small tributory feeding into the Klark River.

sinuous is the northern thrust which can be traced from Cape Florens on the west coast to east of the Krasniy Flag River.

The middle thrust is only known within the central mountains. It emerges from beneath flat-lying, or gently south-dipping Triassic strata east of the Nasha River and strikes westward as far as the Mamontovaya River where it merges with the northern thrust.

The southern thrust also emerges from beneath the Triassic near the Nasha river then strikes westward across the central mountains as far as the middle reaches of the Gusina River. The abundance of intraformationally detached folds and thrusts in Carboniferous to Triassic strata near Cape Ptitsi Bazaar indicates that the southern thrust may have merged into an upper detachment level in this Carboniferous-Permian section.

Minor thrust planes displaying up to a few tens of metres of shortening are well exposed within Carboniferous-Permian strata in the sea cliffs south of Cape Ptitsi Bazaar. Here thrust planes and thrust slickensides are parallel to the pervasive south-dipping cleavage and in several cases are also associated with hanging-wall anticlines. These outcrops reveal the common genetic association of south-dipping cleavage, north-vergent folds and north-vergent thrusts that are mappable regionally across Wrangel Island.

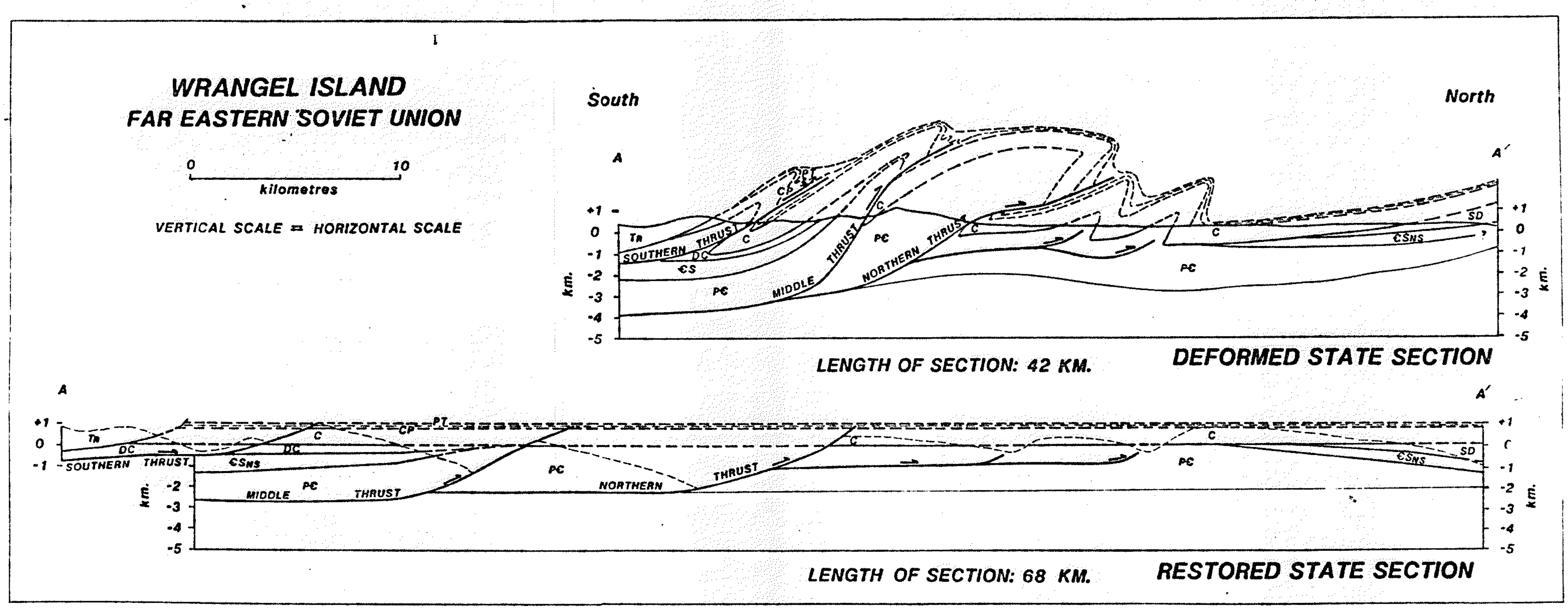


Figure 9. Cross section and restored section, central Wrangel Island (see Fig. 8 for Legend and Fig. 7 for section location).

A common feature of all units on Wrangel Island is a pervasive cleavage that dips south at 25^{o} to 40^{o}. Cleavage and compositional layering are parallel or semi-parallel in about 80% of the exposures we examined. Obliquity of compositional layering and cleavage were noted most frequently in less competent and recessive formations including Devonian slate-gypsum-sandstone strata (basal DC) and basal Carboniferous - Permian unit laminated grey green slaty argillite (CP). This was primarily because these units developed intraformationally detached minor folds with cleavage parallel or semi-parallel to fold axial planes. In two good fold exposures that we examined the cleavage fanned slightly around the attitude of the axial plane.

Some shallow dipping cleavage planes have an element of contractional slippage as defined by small scale offsets of compositional lamination. Cleavage in these rocks is interpreted as planes of weakness orthogonal to the principal axis of compression. This interpretation is supported by the universal association of south dipping cleavage planes and north-vergent asymmetric folds (Plates 27, 28). Such folds are observed in all units from the Gromov Complex to the Triassic unit. At one locality near the Kishnekov River we observed crenulation of the south-dipping cleavage a few meters above the southern thrust (Plate 29).

On the basis of most of these observations we conclude that most gross structures and structural fabrics are the product of a post-Late Triassic orogenic event. The exact age of this event is unknown but the third and youngest group of K/Ar ages from Gromov Complex rocks of 115 to 224 ma may represent the tectono-thermal activity associated with this event.

In addition to contractional structures, several steeply-dipping fault planes having demonstrable right-lateral separations have been observed in the central mountains (Plate 2). The largest fault strikes N40°W and displays up to 1 km of lateral offset. This fault is a young tectonic feature as it displaces the southern thrust and the sub-Triassic unconformity. Gypsum beds in the Devonian dip vertically, adjacent to the fault and also display right-lateral drag consistent with the sense of separation on offset strata. Permian slates exposed close to the covered trace of the fault contain a high concentration of sheared, lenticular, quartz veins. The orientation and sense of motion on these faults is kinematically consistent with a north-south axis of compression coeval with dextral wrench faulting along northwest striking planes of weakness. Photo-lineaments of similar orientation have been noted by previous workers; the amount of displacement on these faults is usually small.

The youngest structural feature shown on Wrangel Island is a single north-striking fault on the east central part of the island (Fig. 7).

To assess the degree of foreshortening across Wrangel Island a cross-section has been constructed through the center of the island paralleling and close to the Kishnekov River in the south and near the Neizvestnaya River in the north. Although there are numerous local detachment surfaces within the stratigraphic succession, there appear to be only two or possibly three decoupling levels of regional importance. The first and structurally lowest is a detachment within the Gromov Complex, inferred from the presence of Gromov Complex strata at the base of the northern and middle thrust hanging wall successions. The second is inferred from the presence of Devonian-Carboniferous strata as the oldest unit in the hanging wall of the southern thrust, and the presence of gypsum beds in DC unit strata, a likely detachment surface. The third major level of detachment is between the Triassic and Carboniferous strata. Using these master detachments the cross-section shown in Figure 9 was constructed.

Because the northern thrust brings up the thickest section of Gromov Complex, and has the longest surface trace, it is considered to have the largest displacement. However, both the northern thrust hanging wall and parautochthonous zone share a common Pre-Carboniferous unit paleogeographic high which limits the amount of relative displacement between the two areas.

On the north pre-Carboniferous erosion has truncated all but Gromov Complex rocks over a small, distinct and definable area in the south-central part of the parautochthonous belt; and on the south a similar area of erosion is found only in the hanging wall of the northern thrust. Cutoffs of the Nashok Formation beneath Carboniferous unit strata can be drawn in the hanging wall succession of the northern thrust and can also be drawn immediately below it in the parautochthonous zone without major offset. Sinuosity of the thrust indicates no more than 15 kilometers of shortening. Thus we assume that the thrust belt is not highly allochthonous with respect to the northern parautochthonous zone, and that the northern thrust has not travelled much more than 15 kilometers.

SEDIMENTARY EVIDENCE OF PRE-JURASSIC TECTONISM

Gross structures or fabrics specifically attributable to older tectonic events could not be unequivocally distinguished from Mesozoic events on the basis of our observations. However, the restriction of granitic intrusives to the Gromov Complex, the distribution and composition of conglomerates and sandstones, and the record of unconformities are evidence of at least one major and one or possibly two minor tectonic events prior to the Middle Triassic.

Most sub-unit unconformities have an associated basal conglomerate which contains clasts of the Gromov Complex and associated granites. Granites were only found intruding the Gromov Complex. Granite clasts are found in the basal conglomerate of the Cambrian(?) to Middle Silurian(?) Nashok Formation. The Middle Devonian to Lower Carboniferous strata on the Mamontovaya River also contain intraformational conglomerate with clasts of granite, quartzite, and minor foliated gneiss resembling the Gromov Complex. Sub- or basal Carboniferous strata in the hanging wall of the northern thrust contain a variety of clasts of igneous origin all of which resemble the underlying Gromov Complex. In the same area the random orientation of foliation in different clasts and presence of feldspar augen, in large river boulders of assumed Lower Carboniferous conglomerate indicates a major pre-Carboniferous deformation and metamorphism of the Gromov Complex. In addition, the angularity, compositional immaturity and large size of clasts (up to 70 cm) indicate an immediately adjacent source area.

There are two clusters of pre- Mesozoic ages 513 to 575 Ma (Ivanov, 1973) and 402 to 475 Ma. These ages could represent two primary igneous events, an igneous event and a post-intrusive thermal event (uplift or metamorphism), or two post-intrusive thermal events. Because no granites are found intruding rocks younger than the Gromov Complex the intrusive igneous event is very likely pre- Nashok, but metamorphism and structural fabric development in Gromov Complex strata could be either pre-Nashok and/or pre-Middle Devonian and/or pre-Early Carboniferous, but definitely no younger because of foliated granites in various orientations within an assumed pre-Lower Carboniferous conglomerate. In spite of these possibilities the restriction of granitic rocks to the Gromov Complex suggests that the first major orogenic event recorded in rocks on Wrangel Island is a pre-Nashok deformation of Precambrian to/or Cambrian age.

The immature and arkosic nature of the Nashok Fm. immediately above the Gromov Complex suggests that it is likely a syn- or post-orogenic succession marking the end of Gromov complex deformation. However, because neither the Gromov Complex nor the Nashok Formation are precisely dated there may be a large time gap between formation of Gromov rocks and deposition of the Nashok formation, and thus the Nashok could also be associated with a much younger uplift of Precambrian rocks in this area.

Although there is an unconformity between the DC unit and the Nashok Formation in the hanging wall of the middle thrust little is known about its nature and extent, and no inferences are made concernings its tectonic significance. Rapid thickness changes of the DC and Carboniferous units resemble the post-tectonic sub-Ellesmerian basins discussed by Grantz and May (1982) in Alaska. Over most of Wrangel Island Carboniferous strata rest unconformably on a variety of older units. This pre- Carboniferous unit erosion featured a paleotopographic high with exposures of Gromov complex at its centre. This high is found both in the parautochthonous zone and in the fold and thrust belt (see preceeding discussion). Associated with this erosion are local accumulations of thick immature sedimentary conglomerates (C_1) of local derivation.

The extent of this Early Carboniferous (post DC unit and C_1 or pre-C_1) unconformity, its truncation of various units, and the variable thickness of the associated conglomerate indicate Early Carboniferous extensional tectonism. The presence of thick, local successions of immature lithic conglomerate and of lateral facies change, is indirect evidence for syn-depositional faulting associated with this event.

The contact between the Triassic unit and older strata is distinct, and except for fine pebbles reported in the Cape Pillar area, it is generally free of conglomerate. There is however considerable local omission of section beneath the Triassic unit in the central part of the island. The nature of omission of section suggests pre-Triassic tilting of strata. The style of omission or non-deposition of strata beneath Triassic rocks is a widespread phenomenon in the Circum-Canada Basin area (cf. maps in Thorsteinsson, 1974).

PALEOGEOGRAPHIC SUMMARY

Following the enigmatic "Gromov Complex" orogenic event the Wrangel Island area became a topographic high with the characteristics of a cratonic platform area (miogeocline; Fig. 10). The first post-Gromov Complex deposits are a relatively thin succession of proximal, immature fluvial to marginally marine clastics of the Nashok Formation and the DC unit. These rocks are followed by successions of mainly carbonate, fossiliferous carbonate and shale. The central mountains area, now mainly underlain by Gromov Complex strata, shows both stratigraphic and structural evidence that it was a long-lived positive feature. As discussed in the preceding section there are notable omissions in strata towards this area; part of the Nashok is cut out beneath the Middle Devonian to Lower Mississippian succession, all Paleozoic rocks are eventually cut out by Carboniferous strata; there are numerous conglomerates through the Paleozoic sequence with Gromov clasts; and there are notable facies changes in post-Nashok and Pre-Triassic strata away from the central mountains (Fig. 8). The Devonian-Carboniferous succession in the hanging wall of the southern thrust, when compared to the middle thrust panel, is apparently thicker and portions of the succession consist of dark grey to black fine grained sandstone. The Paleozoic high is not expected to extend much further north than the area of the northern thrust because of the appearance of the Drehm-Khed and Nashok formations in this area suggesting that a more complete Paleozoic succession exists to the north.

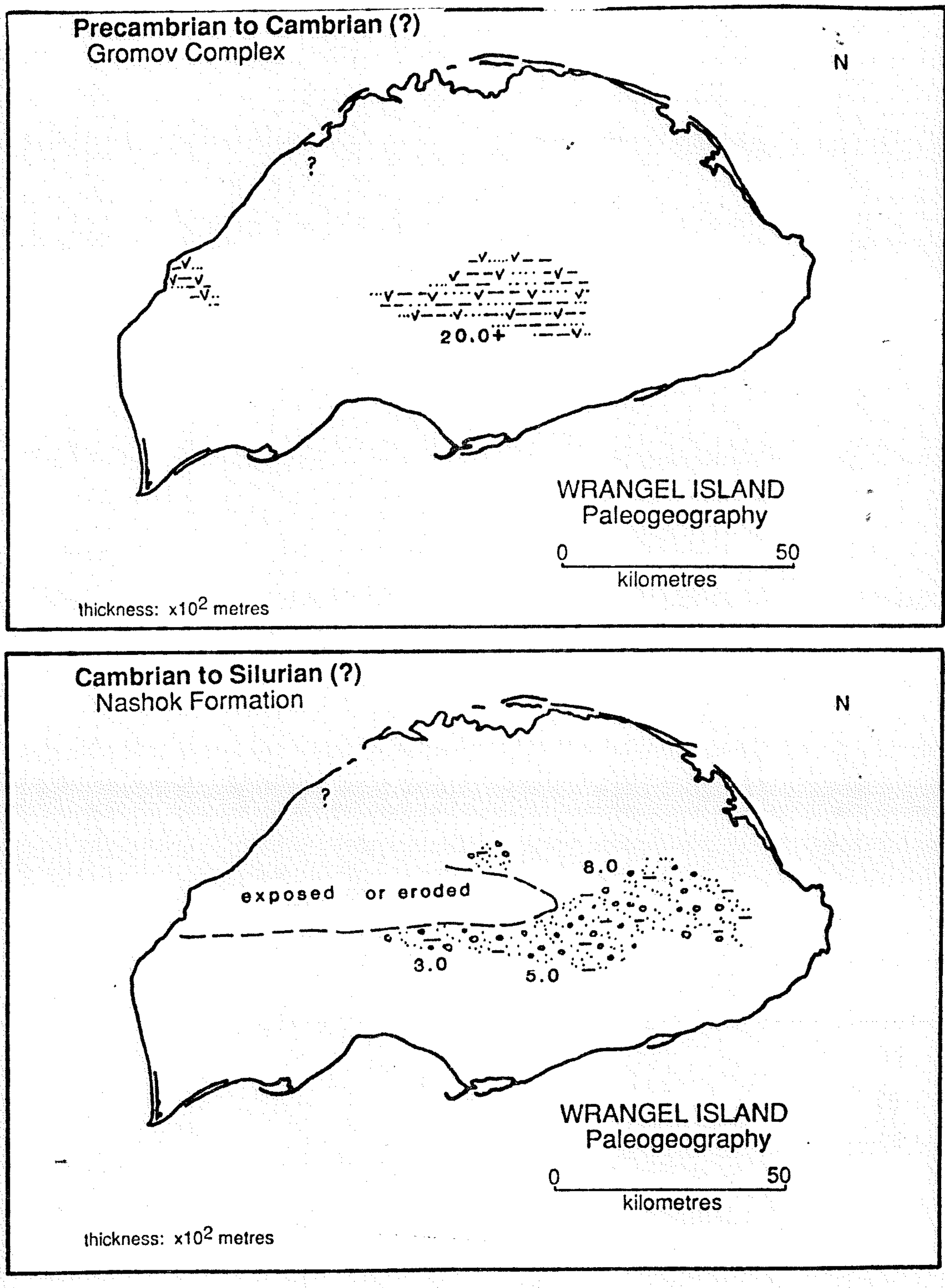
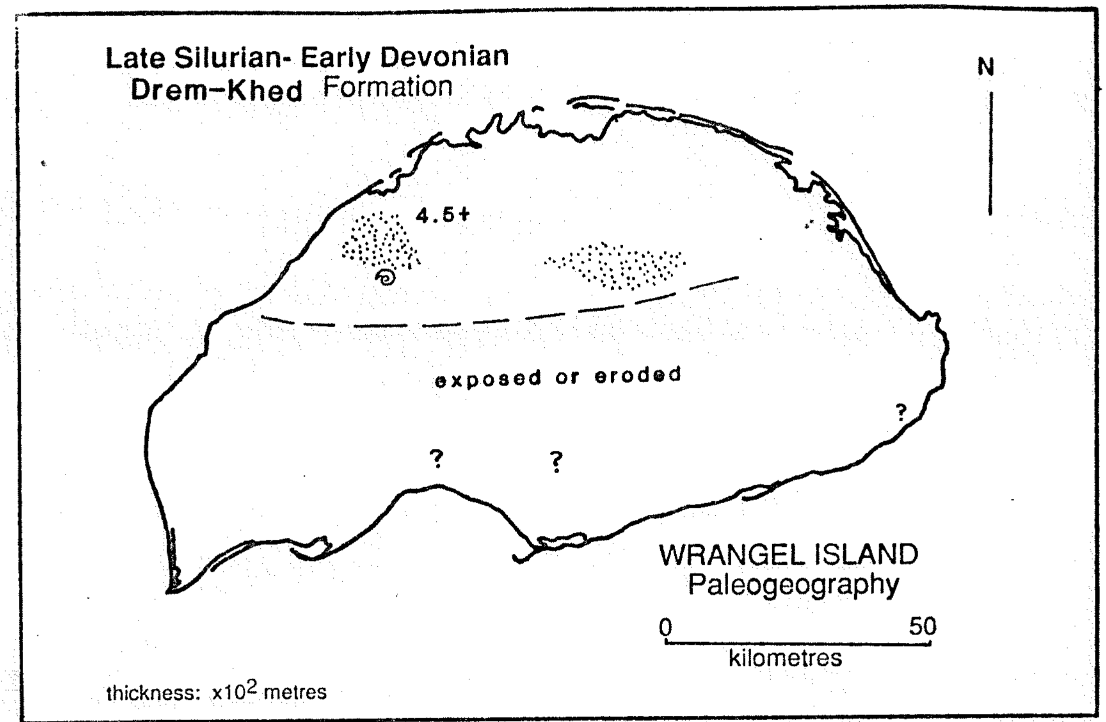
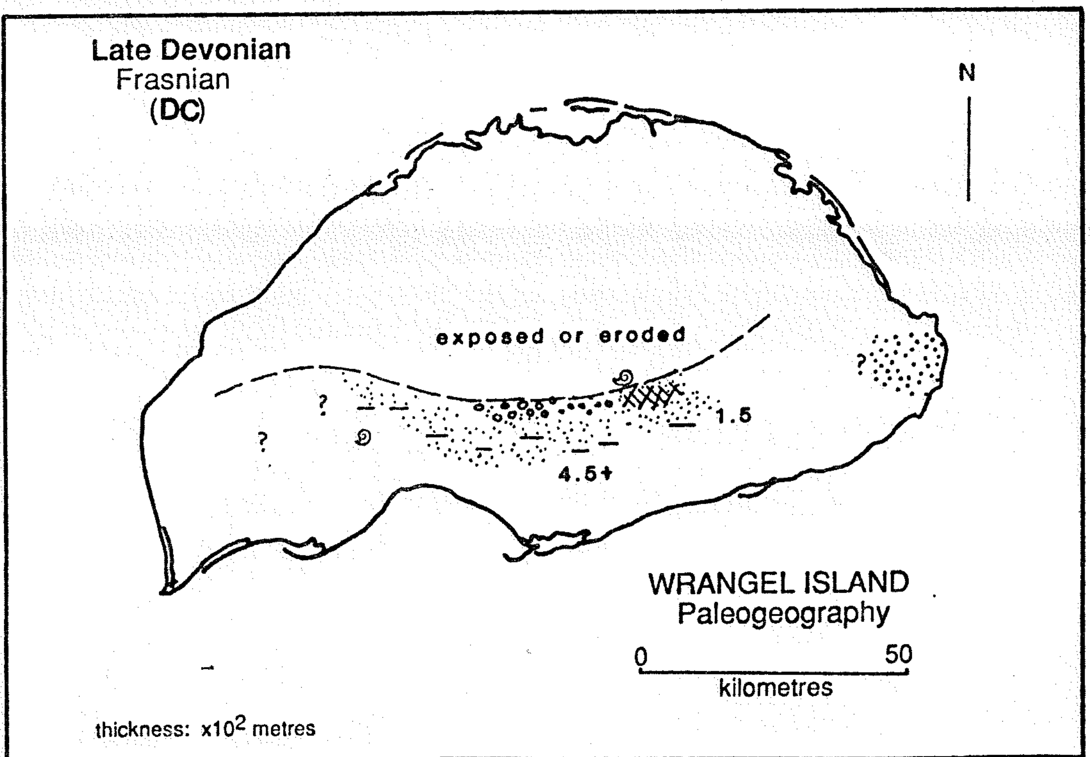


Figure 10. Unrestored paleogeographic maps of Wrangel Island (see Fig. 8 for Legend)


Late Silurian- Early Devonian
Drem-Khed Formation
N
4.5+
exposed or eroded
?
?
?
WRANGEL ISLAND
Paleogeography
0
50
kilometres
thickness: x10² metres


Late Devonian
Frasnian
(DC)
N
exposed or eroded
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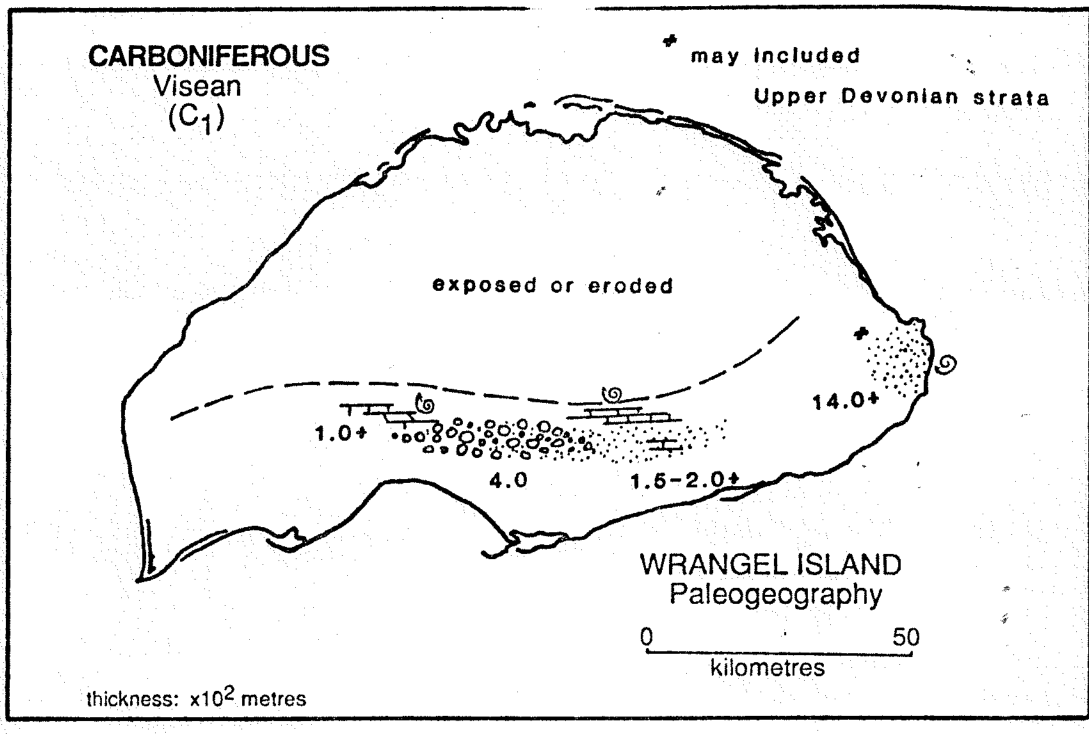
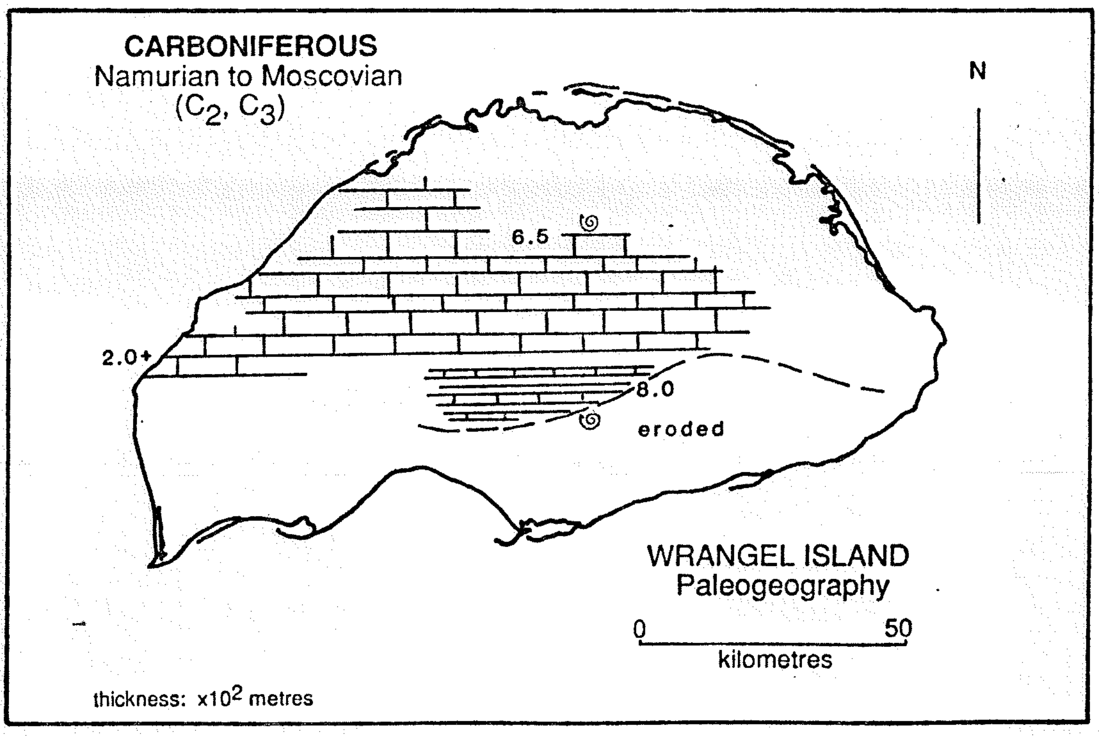
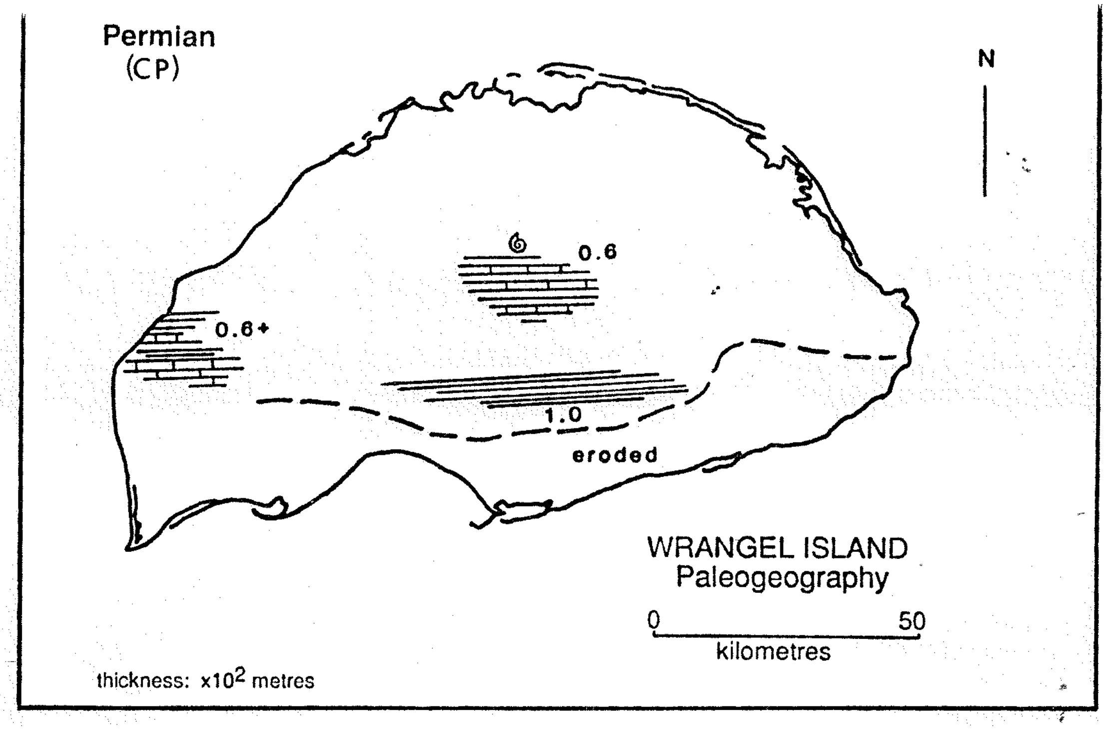
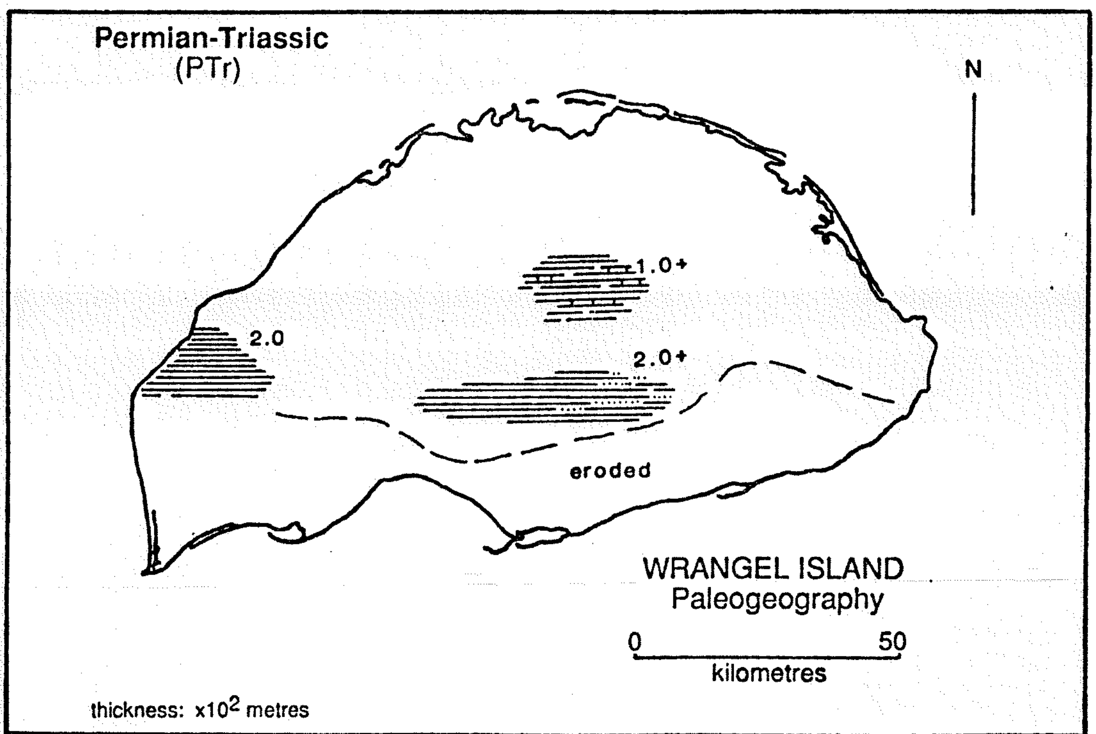
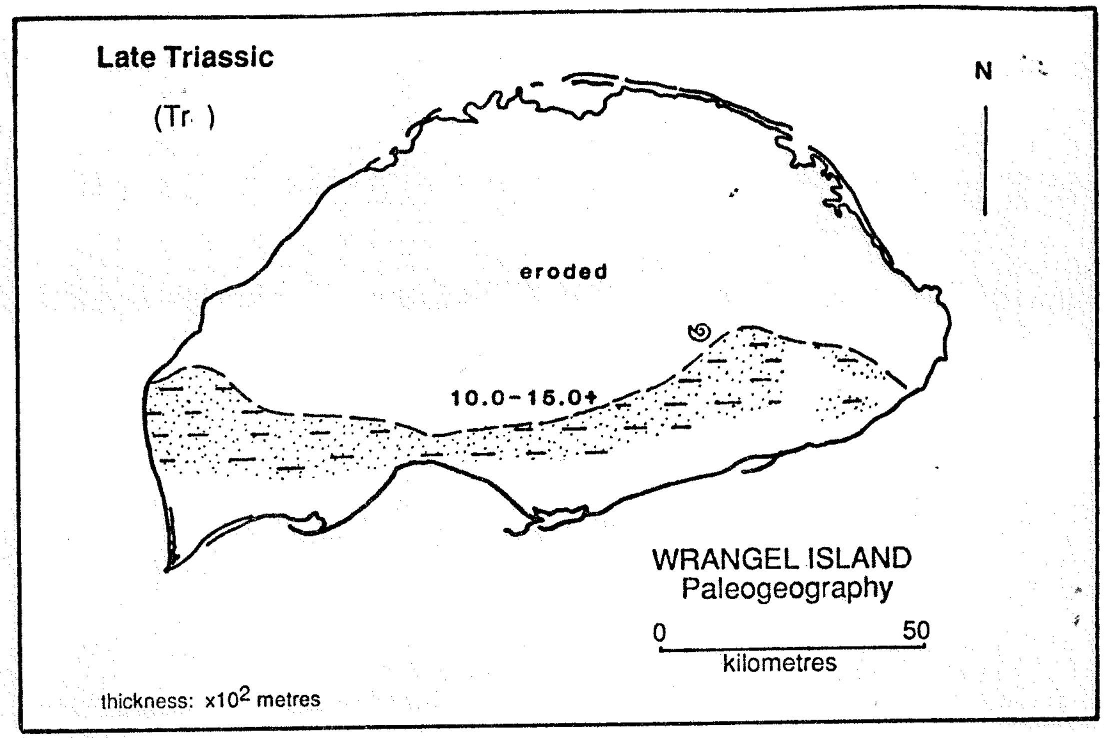
1.5
4.5+
WRANGEL ISLAND
Paleogeography
0
50
kilometres
thickness: x10² metres


CARBONIFEROUS
Visean
(C1)
* may included
Upper Devonian strata
exposed or eroded
14.0+
1.0+
4.0
1.5-2.0+
WRANGEL ISLAND
Paleogeography
0
50
kilometres
thickness: x10² metres


CARBONIFEROUS
Namurian to Moscovian
(C2, C3)
N
6.5
2.0+
8.0
eroded
WRANGEL ISLAND
Paleogeography
0
50
kilometres
thickness: x10² metres


Permian
(CP)
N
0.6
0.6+
1.0
eroded
WRANGEL ISLAND
Paleogeography
0
50
kilometres
thickness: x10² metres


Permian-Triassic
(PTr)
N
1.0+
2.0
2.0+
eroded
WRANGEL ISLAND
Paleogeography
0
50
kilometres
thickness: x10² metres



Late Triassic
(Tr)
N
eroded
10.0-15.0+
WRANGEL ISLAND
Paleogeography
0
50
kilometres
thickness: x10² metres

The entire central and northern parts of Wrangel Island were uplifted or extensively exposed in Visean time. At this time the thick, poorly sorted, sedimentary-clast conglomerate of the Carboniferous C_1 unit was deposited south of the central area, as far west as possibly Cape Ptitsi Bazzar. During much of post-Visean time there was a shallow-water platform area in the NNW and a relatively deeper water area to the SSE (Fig. 10). Also in the southwest are large reefal buildups that have been assigned a Namurian to possibly Permian age. Carboniferous/Permian strata are relatively thin and feature slate with limestone and isolated carbonate buildups in the north and southwest and slate cut by sandstone channels in the southeast.

Deposition of Triassic unit strata represents a major change in the character of Wrangel Island paleogeography. Triassic unit strata are a thick succession of thick bedded (proximal) turbiditic sandstones. The varied composition of the sandstones, quartz, lithic clasts, and plagioclase suggests derivation from uplift of older sedimentary, metamorphic and/or volcanic terranes. These deposits contrast sharply with Triassic strata found in Alaska to the east (Detterman et al, 1975) and the New Siberian Islands on the west (Fujita and Cook, in press), which are thin successions of shales and limestones. Interestingly, virtually all of the Chukotka Peninsula area overlying North American crust as shown on Figure 6 is underlain by a thick succession of Lower, Middle and Upper Triassic sandstone with shale, with the exception of a small area east of Pevek and south of Billings, where Upper Triassic carbonates and sandstones overlie Carboniferous strata (Drabkin, 1970).

The thick bedded nature of the Triassic unit sandstones, on

Wrangel Island, and the widespread occurrence of a thick succession of sandstone-dominated clastics over much of the Chukotka Peninsula, are very good sedimentary evidence of a major Triassic tectonic event within the northeastern Soviet Union.

PRELIMINARY COMPARISONS OF WRANGEL ISLAND AROUND CANADA BASIN

One of the more important scientific objectives of the Canada-Soviet exchange program is to make comparisons between the geology of major crustal blocks fringing the Canada Basin, the Canadian Arctic Islands, Alaska, and the East Siberian and Chukotka regions of the Soviet Union to better understand the origin of the Canada Basin. Wrangel Island is only a small component of the geology of this area. It is useful, however, to give a preliminary review of the implications of Wrangel Island geology for cirum-Canada Basin comparisons to illustrate the potential, and the difficulty of making such comparisons.

One of the greatest problems in comparing circum-Canada Basin geology is that the continental shelf under the Chukchi Sea and East Siberian Seas (CS-ESS) is a large area that is mainly submerged and covered by Cretaceous and younger strata. The CS-ESS continental shelf is equal in area to all of the land area and associated submerged parts of the Canadian Arctic Islands. The only exposures of rocks on the CS-ESS shelf are the New Siberian Islands, which occupy a middle shelf position, and Wrangel and Herald Islands, which occupy a south of center position. On virtually any restoration of the CS-ESS continental shelf area with Arctic Canada, Wrangel and Herald Islands and the New Siberian Islands would still be hundreds of kilometers across <u>most</u> structural trends from any part of the Canadian Arctic.

In addition, Wrangel Island itself was persistently the site of topographic highs during the Paleozoic and it likely represents only a particular aspect of the geology of the CS-ESS shelf which greatly increases the difficulty in making comparisons with other geological terranes. Because of all of these factors, circum-Canada Basin comparisons must focus on major structural and stratigraphic events, and be prepared to consider different facies of the same age as potential counterparts to one another.

Four tectonic events can be established or inferred for strata on Wrangel Island. Two of these are major orogenic events - Precambrian(?)-Cambrian(?) deformation of the Gromov Complex and deformation of all strata during a major post-Late Triassic orogenic event. The others are minor events: one of Early Carboniferous age which consists of broad regional erosional truncation, with deposition of associated conglomerate lenses in association with probable growth faulting; and the other, a broad regional truncation and tilting of Upper Paleozoic and possibly Middle and Lower Triassic strata before deposition of Upper Triassic turbidites.

The Early Carboniferous and pre-Late Triassic events are recognized in all parts of the circum-Canada Basin, and although their presence is consistent with a common tectonic/eustatic history, it is not necessary to make any changes to the present plate configurations to accommodate their occurrence in rocks on Wrangel Island. In Late Devonian - Early Carboniferous time the Arctic Islands, northern Canadian Cordillera and Alaska feature numerous areas with significant unconformities with associated growth faults and conglomerates. In the Arctic Islands - northermost Yukon and northeastern Alaska this style of tectonism is peripheral to an Ellesmerian orogenic event, while in other parts of Alaska and in the northern Canadian Cordillera erosional truncation and growth faulting are associated with transpressional tectonism (Eisbacher, 1983). Thus while the existence of Early Carboniferous erosional truncation allows for correlation around the Arctic rim, it has little value in limiting areas of potential correlations, and may have developed within terranes that were never connected to one another. Similarily, sub-Triassic erosional truncation is found over the entire Arctic region and is generally regarded as a circum-polar event (see maps in Thorsteinsson, 1974; H.P. Trettin and A.F. Embry, Pers. Comm. 1986). Thus the existence of this event again demonstrates that Wrangel Island has tectonic elements in common with other polar rim areas but a pre-existing connection of terranes is not required, and even if they were connected, this event has little value in identifying components of now separated terranes.

The major orogenic events on Wrangel Island, by comparison, are found in some but not all parts of the circum-Canada Basin area and do have the potential of establishing specific correlations or non-correlations in the region. Precambrian and Early Paleozoic orogenic events are recognized on northwestern Ellesmere Island (Trettin, 1987) and within parts of the Brooks Range of northern Alaska (Dutro et al, 1976). A post-Upper Triassic deformation is recognized throughout Alaska and northern Yukon, but is not recognized in the Canadian Arctic Islands. Thus, comparisons and non-comparisons of Wrangel Island around the Canada Basin must be based mainly on the two major orogenic events and on major stratigraphic/facies comparisons.

Comparisons with Alaska/Northern Yukon

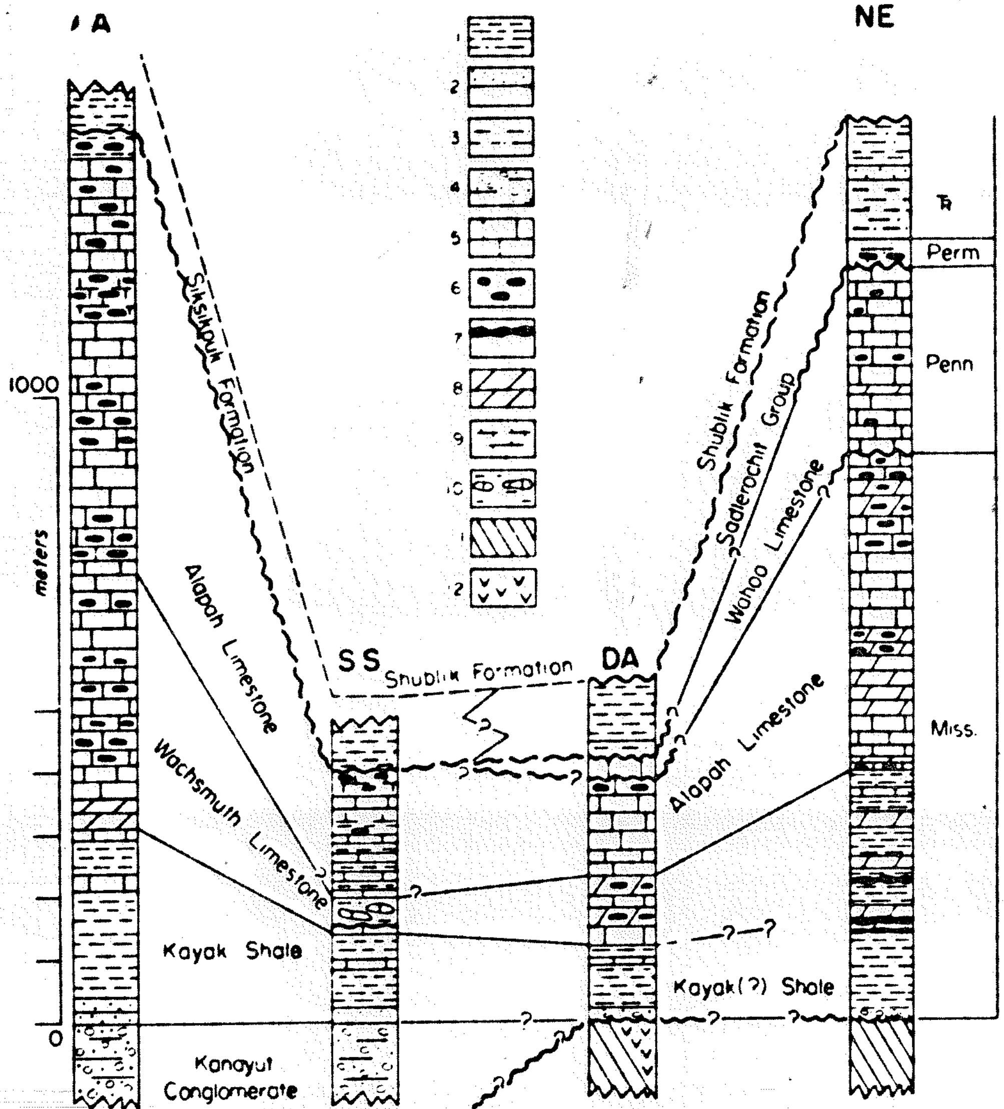
Alaska, the Chukchi Peninsula, and their continental shelves are one continuous crustal block with similar, on trend, geological terranes and fold belts. Because of this, virtually all theories concerning the opening of the Canada Basin have assumed that Alaska/northern Yukon, and the Chukotka Peninsula and adjacent Chukchi - East Siberian seas continental shelf have acted as a single entity. Comparisons between Wrangel Island and Alaska were first made during some of the early studies of Wrangel Island (Bogdanov and Tilman, 1964; Kameneva, 1977)

The geology of both areas however is quite variable and complex. To evaluate comparisons in the best way possible, we looked for the most comparable geological situation within Alaska/northern Yukon. The most comparable area to Wrangel Island is the Doonerak 'Window' in the central Brooks Range (see Figs. 11,12). Our comparisons are based mainly on the reports of Dutro et al, 1976; Oldow et al, 1984; Julian, 1986; and Mull et al, 1987).

The Doonerak 'Window' area, like Wrangel Island, features a "core complex" composed of metamorphosed clastic sediments and volcanic rocks. Both "core complexes" are similar in shape and dimension. The shape of the Wrangel "core complex" however is in part a reflection of its prolonged history as a paleotopographic high. Dutro et al (1976) also interpreted the Doonerak 'Window' as a paleotopographic feature, but subsequent studies have been unable to confirm this hypothesis (see, for instance, cross-sections of Mull et al, 1987). Both areas do however feature significant pre-Early Carboniferous erosional truncation of older Paleozoic units. Both areas are involved in post-Triassic deformation and are located close to the northern limits of orogenesis (Fujita and Cook, in press). In both areas structures associated with this Mesozoic event dominate and mask all earlier features, with most folds and thrusts verging to the north.

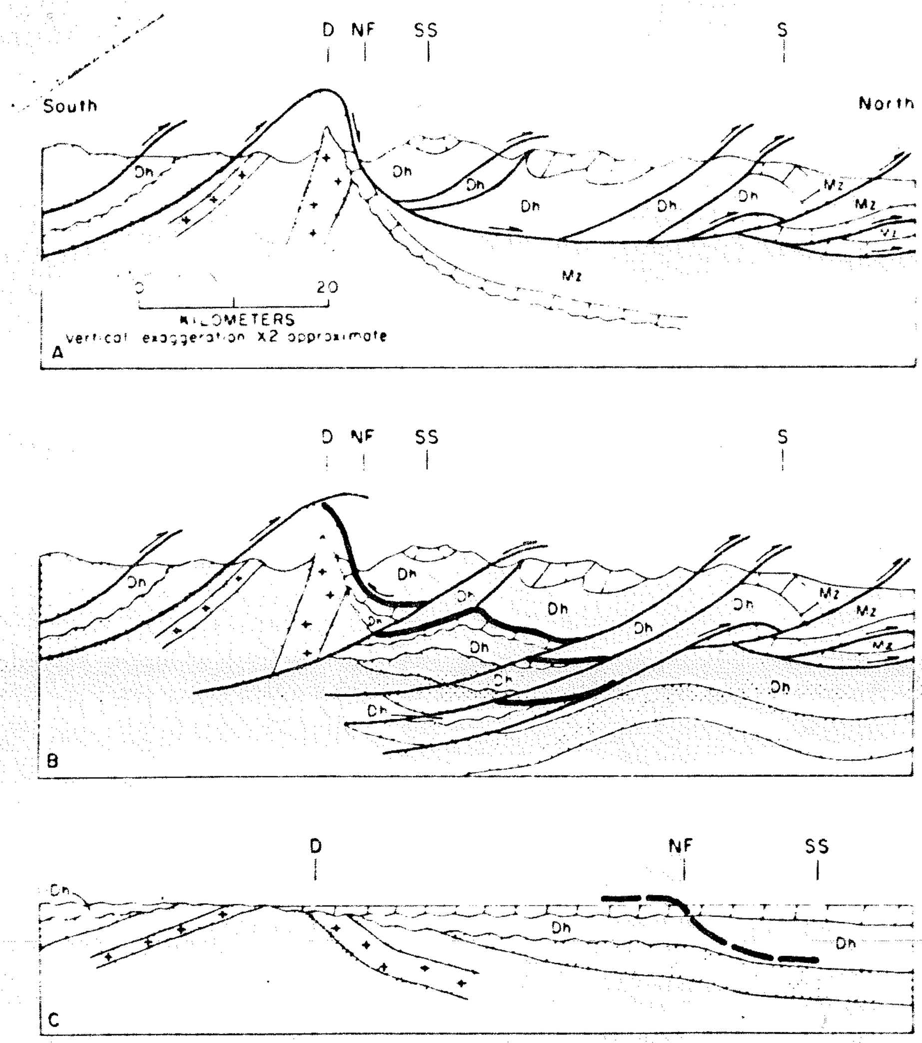
In detail the stratigraphic successions of both Wrangel Island and the Doonerak 'Window' are remarkably similar, with some minor, and two notable, exceptions (Fig. 13). The first notable exception is that the core complexes are reported to be of different ages. This in fact appears to be an artifact. The Wrangel strata have been assigned a Precambrian age on the basis of acritarchs, microphytolites and algae, which are now considered of questionable age (see earlier text - Gromov Complex), whereas the Doonerak successions have been dated on the basis of radiometric data from granites and metamorphic rocks which give a Early Paleozoic age. The range of radiometric ages from the Doonerak "core complex" is, in fact, almost identical with those reported from the Gromov Complex on Wrangel Island (cf. mafic dykes from the Doonerak "Window" have values of 465 to 520 ma; Dutro, et al, ibid.). The other notable exception, is that Triassic strata on Wrangel Island are a thick succession of turbiditic sandstones with shales. Equivalent rocks in the Brooks range are a succession of conglomerate sandstone and siltstone characterized as pro-delta in facies, of Early Triassic age, followed by a condensed succession of black marine shales with some limestone, which were deposited in the Middle and Late Triassic time (Detterman et al, 1975). Recently, however, Triassic sandstone turbidites have been discovered in the Lisburne Peninsula area (C.S. Cameron, pers. comm. 1987). Considering that the only ages from the Wrangel succession are Late Triassic, then the two successions make compatible facies variations of each other, one proximal turbidites and the other distal equivalents in another part of the same basin. In addition, there are some variations in the characteristics of some Devonian and Permian clastic rocks, and there are no rocks with Silurian ages like the Drem-khed Fm. reported from the vicinity of the Doonerak 'Window'.

Based on the stratigraphies, Wrangel Island and the Doonerak 'Window' appear to have had a very similar pre-Jurassic tectonic history. Most notably, both have a Precambrian(?)-Lower Paleozoic volcanic-sedimentary complex that underwent major deformation and intrusion of granites before deposition of younger Paleozoic units, and both have undergone similar deformation during a Mesozoic orogenic event.



—Correlated stratigraphic sequences of upper Paleozoic rocks in central and northeastern Brooks Range. *A*, Anaktuvuk Pass (after Porter, 1966); *SS*, Savioyok synclinorium (from A. K. Armstrong, written commun., 1975); *DA*, Doonerak area (from Armstrong et al, 1976); *NE*, northeastern Brooks Range (Carboniferous from Mamet and Armstrong, 1972; Permian and Triassic from Detterman, 1974). *1*, Dark shale or argillite; *2*, sandstone; *3*, siltstone; *4*, conglomeratic sandstone; *5*; limestone; *6*, nodular chert; *7*, bedded chert; *8*, dolomite; *9*, argillaceous limestone; *10*, shaly nodular limestone; *11*, phyllite and semischist; *12*, volcanic rocks.

Figure 11. Stratigraphic cross-section Doonerak Window and surrounding area (from Dutro et al, 1976).



* –Schematic cross sections of central Brooks Range illustrating, **A**, structural-window hypothesis, and **B**, two-fault hypothesis. **C**, is restored section in Mississippian time showing unconformities beneath Lisburne Group and Hunt Fork Shale and future location of North Fork fault according to two-fault hypothesis. Limestone pattern – Carboniferous, Permian, and Triassic rocks. (

Figure 12. Cross-sections through the Doonerak High (from Dutro et al, 1976).

LEGEND FOR FIG. 13

GNEISS COMPLEX	VOLCANIC-PLUTONIC COMPLEX
VOLCANIC-SEDIMENTARY COMPLEX	CONGLOMERATE
CRATON-DERIVED SANDSTONE, SHALE	SILICICLASTIC TURBIDITES
DEEP-WATER SHALE, CARBONATE	EVAPORITES
PLATFORM CARBONATES	FOREDEEP SILICICLASTICS
ANGULAR UNCONFORMITY	—?— CONTACT (? - AGE UNCERTAIN)

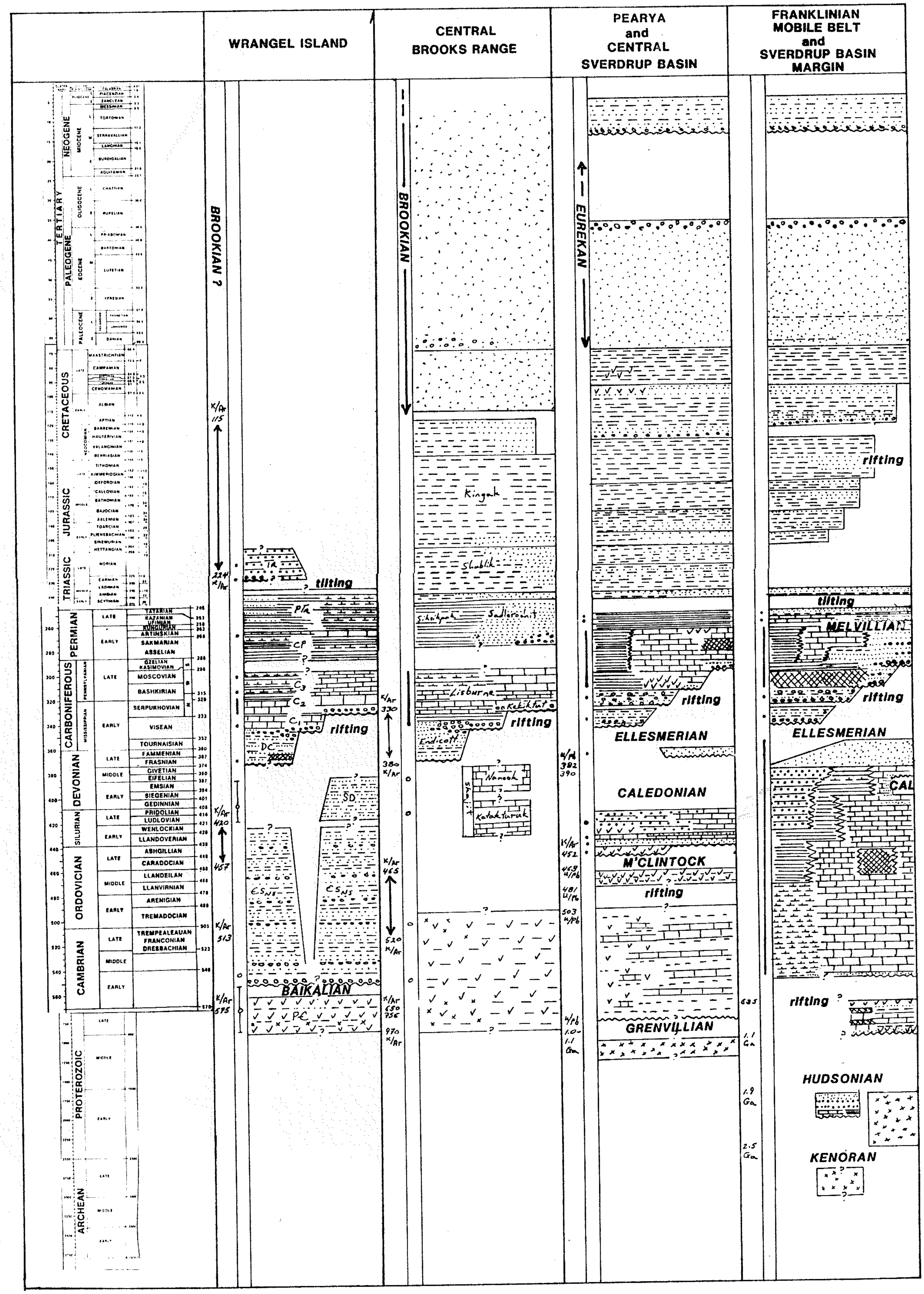
FACIES FRONT

115 K/AR RADIOMETRIC AGE (IN Ma UNLESS OTHERWISE STATED)

420 ↕ 457 RANGE OF RADIOMETRIC AGES

PALEONTOLOGICAL AGE - KNOWN, RANGE KNOWN, EPOCH KNOWN, PROBABLE RANGE

Fig. 13. Comparison of Wrangel Island geology with other circum-Canada Basin areas.


WRANGEL ISLAND
CENTRAL BROOKS RANGE
PEARYA and CENTRAL SVERDRUP BASIN
FRANKLINIAN MOBILE BELT and SVERDRUP BASIN MARGIN
TERTIARY
NEOGENE
PALEOGENE
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
PROTEROZOIC
ARCHEAN
BROOKIAN ?
BROOKIAN
EUREKAN
tilting
rifting
MELVILLIAN
ELLESMERIAN
CALEDONIAN
M'CLINTOCK
GRENVILLIAN
BAIKALIAN
HUDSONIAN
KENORAN
Kingak
Shublik
Sadlerochit
Lisburne
Kekiktuk
Endicott
Nanook
Katakturuk

Comparisons with Arctic Canada

Along the western edge of the Canadian Arctic most of the central area is underlain by uppermost Paleozoic and Mesozoic strata, and thus only a small part of the geological history of the two areas can be compared. However Triassic strata are preserved in both areas. In the Canadian Arctic Islands Lower and Upper Triassic strata consist of deltaic clastic rocks with orthoquartzites, and Middle Triassic strata of shales and carbonates (A.F. Embry, pers. Comm., 1987). On Wrangel Island and the Chukotka Peninsula the Triassic consists of a thick succession of sandstone-dominated clastics which, on Wrangel Island, are proximal turbidites containing significant quantities of lithic clasts and plagioclase. Although in a very large clastic basin these contrasting successions can be accommodated as counterparts to each other, clearly both have significantly different source areas, and no restoration of the two into a common basin is necessary to explain their occurrence. Upper Paleozoic clastic rocks and carbonates exposed through the west central Arctic Islands also are reasonable facies equivalents to time equivalent strata on Wrangel Island. The Wrangel strata are a few hundred metres of mainly argillites, and black shale with limestones, with increasing dominance of limestones laterally. Canadian Arctic Islands equivalents consist of a few to several hundred metres of siltstone, shale and limestone, laterally dominated by limestone.

Extensive exposures of Paleozoic strata are found in the southwestern Arctic. In fact, using simple rotation of the Alaska-Chukotka area around a northern Yukon pivot point would place Wrangel Island in close juxtaposition with this area. However, although there are some comparisons in terms of facies compatabilities at various times during the Paleozoic, there is basically little else in common between the two areas other than pre-Early Carboniferous and pre-Triassic regional unconformities, which as noted before are found all over the circum-Canada Basin area. The southwestern Canadian Arctic features extensive lower and middle Paleozoic successions that are transitional from platform into basinal facies. These successions are overlain by a very thick, laterally extensive succession of clastic rocks deposited in the foreland basin of the Arctic Islands Ellesmerian orogenic belt and which were subsequently mildly foreshortened by the continuing Ellesmerian orogenesis and Permian (Melvillian) tectonic events (see Tozer and Thorsteinsson, 1964). Wrangel Island preserves little Lower Paleozoic strata, has only a thin, mostly fine grained, Lower Paleozoic succession, and there is no thick and extensive foredeep sedimentary succession that can be attributed to an Ellesmerian orogenic event. The only evidence of Middle Paleozoic tectonism on Wrangel Island are local, immature conglomerates found within basal Carboniferous strata, that are likely the products of extensional tectonism.

The last area of Arctic Canada which can be compared with the Chukchi - East Siberian sea continental shelf is Pearya Terrane on northwestern Ellesmere Island. Assuming simple rotation of the Soviet continental shelf, Wrangel Island would, on reconstruction, not only be separated from Pearya Terrane by the remaining width of the continental shelf, but it would also be offset several hundred kilometers from the exposed part of the Pearya Terrane on Ellesmere Island in a southwesterly direction, parallel to the pre-Cretaceous sutured continental margins.

Pearya Terrane, however, has been recently interpreted by Trettin (1987) as a complex of allochthonous fragments, with Caledonian affinities, which arrived at their present position by sinistral transpressive convergence during the Late Silurian. Given this history, it is not unreasonable to expect that other terranes with Caledonian characteristics might be found nearly anywhere on the Chukchi-East Siberian Continental shelf, if it was juxtaposed with the Canadian Arctic in pre-Cretaceous time.

However, comparisons between Wrangel Island and this part of the Canadian Arctic are equivocal. Pearya Terrane has an old Grenvillian basement, and no rocks as old as this are exposed on Wrangel. This does not in any way preclude the possibility that Grenvillian rocks underlie the Chukchi- East Siberian continental shelf. Pearya Terrane has an extensive succession of Lower Paleozic sedimentary strata with some volcanic rocks, in fault contact with a partially time equivalent, or slightly younger succession of arc-type volcanic and sedimentary strata, all of which were deformed and metamorphosed during the early Middle Ordovician M'Clintock Orogeny (Trettin, 1987). The faulted contacts between the two Lower Paleozoic successions are all overlapped by upper Middle Ordovician strata.

The age of the Wrangel Gromov Complex is problematic, and existing radiometric data suggest that Gromov strata were intruded by granites and deformed during the Early Paleozoic. Thus, Gromov rocks could be time equivalent to the Lower Paleozoic volcanic-plutonic successions found in Pearya Terrane. In addition, the event that deformed Gromov rocks could be correlative with the M'Clintock Orogeny and the overlapping successions of the Pearya terrane may be similar to the Drem-Khed Formation of Wrangel Island.

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