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Geology and oil and gas content of Arctic and Subarctic regions of the world.

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(NOM EN LANGUE ÉTRANGÈRE, TRANSCRIRE EN CARACTÈRES ROMAINS)

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TRANSLATOR'S NOTE

- a) All the hollows are referred to in this paper by two general terms: depression and downwarp, even though some of them are probably known in English as trenches, troughs, basins, etc.
- b) The word bay is also used in reference to gulfs, inlets, etc.
- c) The word strait is also used in reference to sounds, etc.
- d) Geographic names appear in the text in Russian, without any particular system: in some instances the authors attempted to render the pronunciation of these names (the way they think these words ought to be pronounced), in others transliterated them (with many mis-spellings, reversals of syllables, etc.).

S e r i e s : Oil and gas geology and geophysics.

VNIIOENG,* Moscow, 1970.

Problems of geology and oil-gas content of the North American Arctic regions are examined in this review. Productive and potential oil- and gas-bearing basins on this territory and in the shallow-water area of the Arctic Ocean adjacent to this territory, are here defined and described. Modern views on tectonic peculiarities and on the history of geological evolution of the northern part of the Canadian Platform, southern periphery of the Hyperboreal platform and geosynclinal region of the Canadian and Alaskan Cordilleras are here outlined. Potential oil and gas resources in all these basins are evaluated, and the territory is divided into zones with respect to their potential oil and gas content. The state of the oil and gas industry in these regions is here characterized, and possibilities of its further development are examined. Brief data on oil and gas resources of the Soviet Arctic regions, as well as a general outline of potential oil and gas reserves in Arctic and Subarctic regions are presented here.

This work is designed for broad circles of the specialists involved in prospecting for oil and gas, as well

*All-Union Research Institute for the organization, administration and economy of petroleum and gas industry.

as for teachers of petroleum institutes and technical colleges.

Authors: M. Sh. Modelevskii, N.S. Tolstoi.

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INTRODUCTION

The problem of oil and gas resources of the Arctic regions attracted particular attention after the discovery in 1968, of the immense oil field in the basin of the northern slope of Alaska (the Prudhoe Bay). Prior to that, one single economic oil producer was known in Alaska. This was the basin of Cook Bay, where some 10 million tons of oil were recovered in 1969.

In 1969, the presence of economic oil and gas reserves in the American Arctic has been further corroborated by the discovery of new oil fields in the region of Prudhoe, a gas field on Melville Island, as well as of the ~~gasiferous~~ oil seepage on the coast of the Beaufort Sea. The resources - (both producing and potential) of the known fields alone are close, with regard to the category, to the A + B + C₁ + C₂ sum and exceed at the present time 1 milliard tons of oil and 800 milliard cu. m. of gas. There is no doubt that Arctic regions of the USA and Canada may become in the near future one of the largest centres of oil and gas recovery in the world.

The authors attempted to estimate the predicted oil and gas resources, and to establish the main patterns of

their distribution in the Arctic and Subarctic regions of America. The most important data obtained by the middle of 1970, are presented in this work.

Trans-Arctic regions of both the USA and Canada have been so far little studied from the geological viewpoint, even though a series of geophysical and borehole investigations has been carried out in these regions. Many problems related to the geological structure and oil-gas content of this territory and of the Arctic Ocean offshore areas adjacent to it, remain unsolved or controversial. The views expressed by the authors in this work, are based on an analysis of the materials published in the foreign and Soviet press during the last decade. The chapters entitled "Geological outline", "Producing and potential oil- and gas-bearing basins," "Possibilities of oil and gas recovery and transport" were written by N.S. Tolstoi, while M. Sh. Modelevskii is the author of the chapters "Potential oil and gas resources," and "Certain data on the presence of oil and gas in the Soviet Arctic."

Geological Outline

The principal tectonic constituents of the region examined are the northern Precambrian part of the Canadian Platform and the southern periphery of the Precambrian

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Hyperboreal platform, which are separated by the geosynclinal

Franklin belt and Brooks anticlinorium, as well as the northwestern Mesozoic Cordilleras of Alaska and Canada, which enclose the Anadyr'-Seward median mass, and the north-eastern Pacific zone (Fig. 1).

The pericratonnal border of the Canadian platform, located between the Canadian Cordilleras and surface outcrops of the Archean shield, consists mainly of Paleozoic rocks overlain in the periphery by Mesozoic formations. In the east of this territory sedimentary beds have a thickness of 1000-2000 m. in the west, i.e., in the region corresponding to the Mackenzie river basin (Mackenzie downwarp), they measure up to 5000 m. in thickness /54/. Within the boundaries of this downwarp, Mesozoic rocks are represented mainly by clay shales and sandstones overlying with a marked angular unconformity schistose-arenaceous Middle Devonian beds, which enclose occasional reef-building bioherms and occur upon carbonaceous Silurian deposits. The latter occur with a marked unconformity upon Ordovician and Cambrian deposits, which are in contact with the Archean foundation. The recent intermontane Eagle Plain depression appears to be the northwestern extension of the Mackenzie downwarp and is separated from the latter by Richardson dislocations, while the Liard plateau, separated from the Mackenzie downwarp by Franklin dislocations, represents its southern extension. The northwestern part of the pericratonnal border of the Canadian platform, located between the geosynclinal Franklin

belt in the north and Canadian Cordilleras in the west, is referred to by B. Kh. Egizarov /14/ as the Mackenzie projection.

The northern periphery of the Canadian platform, superposed by Paleozoic sediments, bears the name of the North Canadian platform. It is divided in two parts. Its southern half is enclosed between the surface outcrops of the Canadian shield and the regional sublatitudinal fracture. This part corresponds to the northern pericratonial border of the platform. The portion of the platform that is located to the north of the regional fracture and is adjacent to the folded Franklin belt, appears to correspond to the foredeep formed as a result of the development of this belt. The early Paleozoic and Middle Paleozoic rocks, which fill the negative structural elements of the pericratonial extremity, do not exceed 2-3 thousand meters in thickness, while in the foredeep these formations exceed 4000 m. in thickness. The depths at which the foundation of the Canadian Platform occurs /13, 54/ indicate the presence in the northern periphery of the platform of several

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depressions and synclises that are separated by horst-like and arched uplifts of the foundation.

The foundation of the precambrian Canadian Platform is raised and crops out at the surface on the horst-like Boothia elevation east of the Baffin land, as well as in the

arch of the Minto elevation (Fig. 1)*. Two large synclises having a submeridional trend, are located between the elevations mentioned above. These are the Jones-Lancaster synclise (in the east) and the Melville-Victoria-Streis** synclise (located centrally). The latter assumes a sublatitudinal trend in the region of the Melville Strait. The Foxe depression is located in the east of the North Canadian platform and has a northeastern trend. The Wollaston depression is found in the west of the platform and has a latitudinal trend. It has been estimated that the thickness of sedimentary beds in the Foxe depression varies from 300 to 1000 m, and that the profile is here represented by Cambrian, Ordovician and Silurian deposits. It is probable that rocks of the same age and lithological composition, but of a smaller volume also fill the Wollaston depression. The overall thickness of deposits in the most markedly sagging portions of the synclises is over 3000 m, and it increases further in the direction of the foredeep.

Cross-sections of the Jones-Lancaster and Melville-Victoria-Streis synclises characterize most thoroughly sedimentary beds of the northern periphery of the Canadian Platform.

*All the illustrations are presented in the appendix.

**Transliteration. (Translator)

Cambrian, Silurian, Ordovician and Devonian deposits are here represented by limestones with interlayers of argillaceous conglomerates, Cambrian and Ordovician silicon concretions, Silurian dolomites, Upper Silurian and Devonian marlstones and aleurites. Psephytic terrigenous rocks represented by conglomerates and sandstones, occur alongside the carbonaceous formations only in the lower strata of the Cambrian cross-section and in the bottom layers of the Ordovician. Evaporitic varieties are virtually absent from the cross-sections of these depressions. A relatively thick gypsiferous bed is known only from Middle Ordovician deposits.

Jones-Lancaster and Melville-Victoria-Streis synclises are separated by the Boothia horst-like elevation. Large fractures demarcate the zones, where the depth of occurrence of the crystalline foundation changes drastically. These fractures have been established with the help of geo-physical data on the boundary of this elevation with the eastern slope of the Melville-Victoria-Streis synclise. So far no linear dislocations have been detected along the fractures, but the presence of fault disturbances and the pattern of variations in the thickness of the deposit

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indicate that such dislocations may be found on the flanks of the synclises. Linear displacements may have formed along the faults, along which the most intensive release of the

tensions, produced during the early Paleozoic, then Cenozoic stages of tectonic activization, took place.

The Franklin geosynclinal belt (with the exception of its northeastern extremity) represents in the present-day structural plan a system of complexly built folded regions of the general miogeosynclinal type of development. These regions are composed essentially of Lower and Middle Paleozoic carbonaceous formations. The geosynclinal zone underwent in the course of its development two particularly intensive stages of tectonic activization. The most ancient (i.e. the early Paleozoic-Caledonian) stage occurred on the boundary between the Silurian and Devonian. The Cornwallis folded zone, having a submeridional trend, is located on the islands of Cornwallis and Bathurst (eastern shore), on the Grinnell peninsula and in the offshore areas surrounding these islands, and it formed as a result of this activization. The miogeosynclinal Brooks belt in Alaska, located within the boundaries of the modern Brooks range, is the other folded zone, which formed during the early Paleozoic. At that time it had a submeridional orientation, which persisted until the Middle Mesozoic /10/, whereupon the Brooks belt assumed a sublatitudinal trend.

The Lower Variscian (Hercynian), which occurred between the Late Devonian and Middle Pennsylvanian, was the next stage in the formation of the major portion of the Franklin geosynclinal belt. Sublatitudinally elongate zones

(such as Parry and Ellesmere) formed at that time. The extreme northeastern part of the Ellesmere zone (the north of Ellesmere) consists of formations reflecting the eugeosynclinal type of development. In the geological literature it is referred to as the "Northern Ellesmere geosynclinal region." Thick beds of greywackes, polymictic sandstones, conglomerates and clay shales, as well as volcanic lavas and tuffs are found here. The degree of metamorphization of the entire cross-section of deposits is here considerably higher than in other parts of the Franklin geosynclinal belt. Certain Soviet and American geologists are inclined to believe that the Northern Ellesmere eugeosynclinal region, or at least its northwestern part in the Axel-Heiberg region,

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represents a Caledonian folded system and is a continuation of the caledonides of Greenland /56/ or of the caledonides of the Cornwallis folded zone /1/, which can be traced farther north under younger deposits of the Sverdrup downwarp, beyond the boundaries of the Lomonosov range.

In the eastern half of the Ellesmere Island the trend of the Central Ellesmere folded belt is submeridional. To the south of it and farther on to the Devon Island sublatitudinal trends predominate. This drastic change in the folding trend of the Franklin belt suggests that the belt is draped upon a rigid buried foundation block, which consolidated at an earlier date and above which the Sverdrup

downwarp is situated in the present-day structural plan.

The data of R. Thorsteinsson and E.T. Tozer /38/ on the presence of large disjunctive dislocations, which cut through the sedimentary beds and penetrate as far as the Paleogene-Neogene deposits, also merit attention. These dislocations are extensively developed along the boundary line of the folded belt with the Sverdrup downwarp. Intrusions of magmatic rocks have been frequently recorded along these dislocations; moreover, the disturbances are often responsible for the rectilinear character of the shore lines. The above authors associate their formation mainly with Cenozoic movements. It is possible, however, that similar dislocations along the northern boundary of the Parry, Cornwallis and Ellesmere folded structures reflect ancient fractures, which separate them from the Sverdrup depression. West of the Cornwallis Island the Franklin geosynclinal belt extends along the southern extremity of the Parry archipelago. The Cornwallis folded zone originated earlier than the Parry and Central Ellesmere geosynclines; it has a submeridional trend and structural elements of a different character.

The southwestern division of the Franklin geosyncline has been established by American, Canadian and certain Soviet geologists on a tentative basis, since so far there is no direct geological evidence of its existence. It has been visualized as a natural extension of the Parry folded

province, which turns sharply south in the southern extremity of the Prince Patrick Island, then changes its trend to sub-latitudinal, while passing through the west of the Banks Island, and extends thereupon through the Liverpool Bay in the region of the northern spurs of the Richardson and British Mountains; then it links with the Brooks range*. At the present time the Banks Island reveals no sign of Upper Paleozoic (Hercynian) folding. However, the Upper Paleozoic (Hercynian) Parry folded zone occurs northeast of the island

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and structures, which L.J. Martin /25/ assigns to the Upper Paleozoic folded zone because of their similarity to the Parry zone formations, have been detected southwest (northern part of Richardson Mountains) and east of the Mackenzie River delta. It may therefore be assumed that the Franklin geosynclinal belt does not discontinue around the Banks Island, but is buried here under a thin mantle of boreal Neogene-Paleogene deposits. This is also the case on the shores of the Liverpool Bay, in the region of the Eskimo Island and Mackenzie River valley, where geosynclinal formations of this zone are superimposed by a thicker, essentially Mesozoic sedimentary complex.

*The portion of the Franklin geosyncline which extends between the Parry zone and the Brooks range is referred to as the Mackenzie-Banks folded zone.

Narrow folds having a sublatitudinal trend, develop in the Parry zone. These folds are composed of Lower and Middle Paleozoic carbonaceous rocks. The intensity of folding decreases towards the Canadian Platform. Narrow anticlines give way to slopingly arched structures, where certain superjacent strata have a nearly flat pitch. A similar situation has been observed in the Ellesmere zone, where Paleozoic deposits form extensive folds that are often complicated by upthrow faults and thrusts. Here, too, the folding dies out in the direction of the Canadian Platform.

The Cornwallis zone is formed of submeridionally elongate folds, which are often complicated by disturbances. Narrow anticlines with steep walls are here extensively developed. The anticlines are separated by broad synclines. This zone reveals a number of specific features. In the west and in the east it is distinctly delimited by fractures, which represent the northern extension of the sutural boundaries of the horst-like Boothia elevation. Regional angular unconformities have been recorded in Middle and Upper (?) Silurian and in Middle Devonian deposits. The presence of reef complexes in the Middle and Upper Silurian deposits is of considerable interest, since no such complexes have been observed so far in any other marginal areas of the Franklin geosyncline. The occurrence of Silurian reefs in the Cornwallis zone shows that this zone had attained a considerable degree of stabilization by the Silurian, i.e. at

the time when thick carbonaceous geosynclinal formations were still in the process of development in other folded regions.

The character of the structures and, what is more important, their submeridional trend persist even farther north, beyond the boundaries of the Sverdrup depression. This circumstance led I.I. Atlasov et al /1/ to extend the Cornwallis miogeosynclinal zone into the Northern Ellesmere eugeosyncline and farther north, inside the boundaries of the Lomonosov ridge. The time of formation of the Cornwallis folded zone should be regarded as Early Paleozoic,

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and its development should be related to the formation of the horst-like Boothia elevation. Vertical movements also occurred in this zone during the Cenozoic, a circumstance reflected in the trend of the structural forms found in the central area of the Sverdrup depression (Fig. 1).

While examining the sublatitudinal Paleozoic Franklin geosyncline, extending along the northern border of the Canadian Platform over a distance of more than 3000 km, we must note its interrelation with the folded system of the Brooks range. The latter has a sublatitudinal trend and changes in the north to the foredeep of Northern Alaska. It borders in the south on the eugeosynclinal zone of Central Alaska. N.A. Bogdanov (1963) regards the Brooks range as the western extension of the Franklin geosynclinal belt.

The two do have a number of features in common, but they also reveal certain differences. During the Lower Paleozoic this territory, as well as the Franklin geosyncline, were intensively warped. Thick terrigenous beds formed here. Thereupon, during the Late Silurian-Early Devonian, the Caledonian folding occurred here, as it did in the Cornwallis folded zone. However, on the territory of the Franklin geosyncline there was virtually no sedimentation during the period subsequent to the Upper Devonian-Middle Pennsylvanian folding, whereas in the region occupied now by the Brooks range, Hercynian folding did not occur, and intensive descending movements accompanied by the accumulation of thick terrigenous beds reoccurred in this region during the Devonian. Ascending movements began to predominate on this territory again only during the Late Carboniferous-Early Permian. The Paleozoic ended in Alaska without orogeny, and the Cordilleran geosyncline continued its existence (according to Geist* and Greek*) even during the Early Mesozoic, up until the Triassic inclusively. Geosynclinal development was completed within the boundaries of the Brooks range by the Early Jurassic, and the Franklin geosyncline formed during the Upper Devonian-Middle Pennsylvanian. The new phase of the tectonic activation, which began in the

*Partly transliteration, partly guesswork. In another place the first name is spelled as Geits. I think that it should probably be Gates. (Translator)

Brooks range during the interval between the Middle Jurassic and Lower Cretaceous, was the same as the synchronous activation of the western Cordilleras, and it corresponded to the Nevadan stage of activation. Certain American researchers believe that the region of the Western Cordilleras failed to complete the full cycle of geosynclinal development.

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The Franklin belt is thus a structurally complex region of geosynclinal development, a region consisting of elements which differ in age and which represented during definite periods individual and separate geosynclinal regions. These regions became amalgamated during the final stage of development of the entire geosynclinal zone. V.E. Khain /41/ mentions Thetis and the Pacific zones as examples of such polycyclic belts situated between two older platforms or between a continent and an oceanic platform. These zones took an entire megacycle to develop.

The Franklin geosyncline forms a fairly extensive junction with the northern portion of the Western Cordilleras (the Brooks range anticlinorium) in the north of the Yukon territory in Canada. The Franklin geosyncline and the Brooks range anticlinorium should probably be regarded as one single geosynclinal belt separating the Canadian and the Hyperboreal Platforms. However, it must be kept in mind that the geological history of these two geosynclines is different. Therefore, the Brooks range anticlinorium is not

a direct continuation of the Franklin geosyncline, but represents the northern extension of the Canadian Cordilleras on the territory of Alaska. This may be seen from the differences in the time and extent of the tectonic activity on the territories of these two geosynclines, as well as from the formation^{and} composition of the cross-section in these geotectonic regions and in the territories surrounding them.

Formation compositions of the Lower and Middle Paleozoic deposits are fairly similar in the Canadian Platform and in the Franklin folded belt, which demarcates this platform (Figs. 2, 3, 4). Essentially carbonaceous complexes with subordinate quantities of terrigenous rocks and with scarcely any volcanic rocks are found here everywhere. Moreover, the carbonaceous complexes differ markedly in thickness. In the Jones-Lancaster and Melville-Victoria-Streis synclines these deposits commonly do not exceed 3-4 thousand meters in thickness, whereas in the folded zones their thickness increases markedly (up to 5800 m. in Cornwallis, 6400 m. in Parry, over 6000 m. in Ellesmere).

Thus, during the Lower-Middle Paleozoic the northern extremity of the Canadian Platform was involved in the downwarping, the amplitude of which increased drastically towards the north and attained its peak in the miogeosynclinal region of the Franklin belt. The first intensive uplift of the foundation blocks, demarcated by the submeridional fractures, occurred in the Silurian. It resulted in

the separation of the horst-like Boothia elevation and of

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the Cornwallis zone. The effect of these movements also spread farther to the north, into the territory of the Sverdrup downwarp. The transverse submeridional barrier, which divides the Franklin folded belt in two parts (Parry and Ellesmere), and the Sverdrup depression into the western and eastern zones of downwarping, began thus forming during the Early Paleozoic. At the end of the Devonian the thick complex of carbonaceous deposits in the Franklin folded belt became intensively dislocated.

Deposition of thick beds of fragmental rocks predominated on the islands of Melville, Bathurst and in the southeast of the Ellesmere Island from the Middle Devonian, and, beginning with the Upper Devonian, continental formations measuring up to 3500 m. in thickness were deposited on this territory /38/. The area of distribution of these deposits extends in a continuous band from east to southeast, from the southern extremity of the Ellesmere Island to the Banks Island. R. Thorsteinsson and E.T. Tozer believe that the formation of psephytic rocks during the Upper Paleozoic is related to the intensification of the tectonic activity, which resulted eventually in orogeny in this belt. It may be assumed that the foredeep between the Franklin belt and the Canadian Platform formed precisely at this time, during the final orogenic stage of development of the geosynclinal

Franklin belt.

This hypothesis cannot be corroborated at this time by direct geological evidence. We can merely assume that the appearance on the southern slopes of the folded belt of psephytic beds represented by conglomerates, sandstones, sands, arenaceous-argillaceous deposits with coal interlayers in the upper strata of the cross-section /36,48,63/, marks the initial phase of the molasse filling of the foredeep.

The geological structure and development of the extreme northern regions of America have been examined in the works of many researchers.

History of the geological evolution of Arctic territories and history of the formation of the Arctic Ocean attracted particularly close attention of researchers at the beginning of the XX century. Still in 1910, Taylor examined the theory of the continental drift with regard to the Arctic Ocean basin. This researcher believed that the drift proceeded from the North Pole towards the Equator, and assumed that Eurasia and North America existed initially in the form of one single continent situated in the region of the North Pole. In Taylor's opinion, the separation of these continents resulted in the formation of the Arctic basin.

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Koppen and Wegener /57/ believed that a rather small ocean existed in the Arctic territory even prior to the separation of the continents, and that this ocean kept

increasing in size as North America drifted westwards, away from Europe, while rotating around a point located in the Northern Arctic region. During the subsequent years both Soviet and foreign geologists developed this theory further.

In 1937, Du Toit /47/ suggested a hypothesis on the origin of the Arctic and northern Atlantic basins, which is based on the theory of the continental drift. This researcher believed that the individual blocks bounding the Arctic basin, rotated independently from one another and differed in size.

Carey /47/ proceeded from Du Toit's hypotheses and concluded that the Arctic basin had formed as a result of a scissor-like drift of continents, the rotation centre of which was located in the south of the Central Alaska. The triangular southern portion of the territory enclosed between these radii, coincided with the Canadian deep-water basin. The third side--the base of the triangle--is the "megaskol"/* or the shift extending from Spitzbergen to Severnaya Zemlya. Carey refers to such a rift expansion as the sphenochasm. He believes that the recurvature of the orogenic belts of the Alaskan Cordilleras is the result of the rotation of the blocks, the movement of which created the Arctic sphenochasm. In his opinion, the Lomonosov range represents a more markedly viscous section of the crust

*Transliteration. (Translator)

stretched across the Arctic sphenochasm. The Alpha-Mendeleev range is probably similar to it in nature.

Irving Taillor /62/ proposed a hypothesis on the origin and evolution of the Arctic territory enclosed between the Brooks range in the west and the Franklin geosynclinal belt (Parry-Ellesmere) in the east. Prior to the Devonian, this territory (referred to by the author as the Canadian basin) formed part of the Canadian Platform. Later on it was separated from this platform by the Paleozoic geosynclinal folded zone, which divides on the territory of Yukon (Northern Canada) to form two branches with a submeridional trend. The western branch is the miogeosynclinal belt of the Brooks range, the eastern branch is the miogeosynclinal Parry-Ellesmere belt.

The splitting up of the continent surrounded by these folded belts, occurred, in Taillor's opinion, in several stages. It began during the Early Jurassic, when the territory of the Arctic Alaska detached itself from the

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Canadian Arctic Archipelago, a process accompanied by an active intrusion of mafic rocks in the northeastern, central and southern parts of this continent. The absolute age of these rocks is 190 million years. The next stage was characterized by the intrusion in the south of Alaska of mafic and ultramafic masses that are 150-160 million years old. The Early Cretaceous stage was marked by an active

sedimentation within the boundaries of the foredeeps, by the formation of large thrusts in the region of the Brooks range, and by the appearance of plutonism. The breaking up of the continents attained its peak at the end of the Early Cretaceous and terminated in orogeny. At that time the Canadian Arctic Archipelago and Alaska began to assume a position similar to their present position.

Apparently, continental and shelf-underwater regions of the marginal Arctic Ocean seas are confined within the boundaries of the North American continent to the remnants of an ancient, probably Precambrian platform, which is known among Soviet geologists as the Hyperboreal platform. These remnants are found north of the geosynclinal Franklin belt and Brooks range, and demarcate the deep-water Canadian basin in the south. Various researchers view the origin of this basin in different ways.

At the present time most researchers believe that depressions in the ocean floor were not there originally, but arose at a certain stage of the geological history /3,4, 41,60/. This conclusion is equally valid with regard to the depressions in the internal and marginal seas, where the crust has a two-layer structure and consists of a "basaltic" and a sedimentary (often fairly thick) layer /20,58/. V.E. Khain /42/ finds evidence of the "secondary" nature of oceanic and suboceanic depressions in the correlation of their contours (i.e. contours of the areas devoid of the

"granitic layer") with the trend of the folded zones of various ages that are demarcated by these contours. It has been observed that the inconsistency is the greater, the more ancient are the zones forming the slopes of the depression. Thus, reciprocally perpendicular correlations have been recorded between the trends of the Archean beds and of the lower strata of the Proterozoic on the northern shore of the Gulf of Guinea and on the southern shore of Western Australia on the one hand, and corresponding boundaries of the Atlantic and Indian Oceans on the other. In younger folded zones, particularly (as V.E. Khain pointed out) beginning with the Balkalian^{*} zones, the contours of the oceanic and suboceanic depressions become progressively more consistent with the trend of the folded zones. In Khain's opinion, this circumstance shows that, beginning with the

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Proterozoic, the formation of oceanic and suboceanic depressions was a lengthy and gradual (multi-stage) process.

Further evidence of the "secondary" origin of the depressions with an oceanic or similar crust may be found in the paleogeographic (particularly paleobiogeographic) data, in the presence in the oceans of sections with a continental crust, in the fact that the modern continental slope

*The word Ba_kal (Balkalian) appears to refer to the geological age. (Translator)

is by nature a fault (a circumstance established in a number of regions, for example, along the edge of the North American basin of the Atlantic Ocean), as well as in the fact that continental structures extend beneath the ocean waters.

V.E. Khain /42/ believes that at the present time there are two opposite views on the evolution of the oceanic crust at the expense of the continental crust (the so-called process of oceanization). One of them (the mechanical theory) is based on the principles of the tectonic mobilism: the oceans formed when large continental masses (Laurasia, Gondvana Land) broke up, as a result of the horizontal displacement ("spreading") of their fragments, exposure of the subcrustal substrate and neogenesis of the oceanic crust in the places of such "hiates."

The other trend in the interpretation of the process of oceanization is based on the principles of the tectonic fixism: the oceans formed as a result of the collapse of the continental crust and its subsequent or synchronous transformation into the oceanic crust. This process has been given the name of basification and it probably characterizes only the physico-chemical aspect of the process of oceanization. There are two main versions of this process. Metasomatoses is the first such version, however, it raises certain geochemical problems, since it is not clear what happens to the excess silica and alkalis. The second

version postulates the assimilation of the "granitic layer" of the crust by the basaltic melt rising from the mantle /4/. This version embodies certain geophysical contradictions. In particular, it violates the principles of isostasy: granite should sink in the basalt, but in reality it does not sink. The oceanic scale of the suggested processes is also rather improbable; and so is their purely mobilistic interpretation. A number of facts does, however, support the theory of oceanization: such are the presence of "microcontinents" within oceanic depressions /17/, the extension of continental structures at considerable distances under the waters of the oceans.

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The existence of the Hyperboreal Platform has been postulated in 1936, by N.S. Shatskii /43/, who believed that this platform extends under the waters of the Arctic Ocean into the Beaufort Sea, East Siberian and Chukchi Seas, and is bounded in the south by the Franklin geosynclinal belt. It has been later established that the Hyperboreal Platform is separated in the east by the Lomonosov range. N.S. Shatskii related the formation of this platform to the subsidence of a large section of the earth crust along abyssal faults in the foundation.

The broad shelves and relatively small dimensions of the basin, the surface topography of the Canadian, Greenland, Baltic and Anabar Precambrian shields, as well as the

development and trends of the Paleozoic orogenic belts, which extend beyond the boundaries of the Atlantic Ocean through the Urals, Novaya Zemlya, Norway, Spitzbergen, Eastern Greenland, Canadian Arctic Archipelago, Severnaya Zemlya and Novo-Sibirskie Islands, led A.J. Irdley* /17/ to suggest that the Hyperboreal Platform was a mainland in the pre-Paleozoic times. Results of analyses of the conditions under which the Paleozoic geosynclines formed in Alaska, also appear to corroborate this hypothesis. It may be assumed from these data that the removal source for the accumulation of certain beds was located to the north of the present mainland at the place, where the deep-water Canadian basin is found today. The fact that North America and Europe have a common Paleozoic marine fauna is another important argument in favour of this hypothesis.

The seismic investigations carried out by Oliver, Ewing and Press /59/ in 1952, in the southern Arctic basin, appear to suggest that the parameters of the wave lengths recorded by these researchers, are characteristic only of continental structures and do not apply to the areas with the oceanic type of crust. Later on they stated, however, **

*Guesswork. Irdli in the text. (Translator)

**A portion of the sentence seems to be missing. Translated literally, the beginning of the sentence goes as follows: "Having nevertheless emphasized later on . . .". (Translator)

that the floor of the Arctic basin bears an oceanic crust and, therefore, cannot be regarded as a submerged portion of mainland. This conclusion disagrees with the theories postulated by a number of Soviet geologists in 1930-1950.

One possible way of solving this problem would be to study the southern, mainly offshore and shelf areas of the Hyperboreal Platform, and to carry out composite geophysical

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investigations of the Hyperboreal Platform and of the parts of the Canadian Platform adjacent to it. It is, indeed, possible that the continental type of crust exists at the present time only in marginal areas of the Hyperboreal Platform, and that in the deep-water Canadian basin the crust is oceanic in appearance due to the submergence and basification of the continental crust, or because various sections of the platform floated apart as a result of the continental drift /62/.

Gravimetric investigations in the south of the Arctic basin, in the Beaufort Sea and on the shelf of the Canadian Archipelago and Northern Alaska established distinctly defined gravity stages with a gradient of more than 100 g* (Fig. 1). They may reflect the abyssal faults, along which the Hyperboreal Platform subsided. Positive closed gravity anomalies have been recorded at some of the stages. These

*gals.

anomalies may reflect the magmatic intrusions, which had wedged in along the faults.

Large depressions (Sverdrup, Beaufort, and the downwarp of the Arctic slope of Alaska) are located in the southern peripheries of the Hyperboreal Platform. Geological structure and peculiarities of development of these elements are related genetically to the evolution of the Hyperboreal Platform as a whole.

The Sverdrup downwarp is an epigeosyncline developed within the boundaries of the Paleozoic Franklin folded belt. The data available at the present time merely allow us to state that this downwarp began to fill in the middle of the Carboniferous and that this process continued until and during the Cenozoic. This is corroborated by the distinctly defined angular unconformity between the non-dislocated post-Pennsylvanian beds, forming part of the infilling, and the presumed pre-Pennsylvanian folded foundation. It is important to note that this break has been detected only in the periphery of the depression, in the north of the Ellesmere Island, on Axel-Heiberg islands, as well as on the boundary between the Sverdrup depression on the one hand, Parry, Cornwallis and Ellesmere folded zones on the other.

The Sverdrup downwarp is composed of Mesozoic and (to a lesser extent) Cenozoic arenaceous-argillaceous sedimentary rocks, as well as of argillaceous and evaporitic Permo-Pennsylvanian formations. The overall thickness of

the infilling in the trough is 9-12 km. Numerous breaks have been detected in the marginal portions of the Sverdrup downwarp, particularly in the lower strata of the Permo-Pennsylvanian cross-section. No significant breaks in the sedimentation have been recorded during the post-Permo-

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Pennsylvanian period and up until the Paleogene deposits, which occur transgressively upon older sediments. The presence of diapiric structures in the central portion of this depression is its characteristic feature. The diapiric structures consist of anhydrites, gypsum and, possibly, Permo-Pennsylvanian salt. The most intensive manifestations of diapirism are associated with the tectonic activization of the development of the downwarp during the Cenozoic.

Diapirism was so active in the Sverdrup depression that Canadian and American geologists synchronize it, as a rule, with the Gulf-Costa halotectogenesis. Rock salt has not be found here thus far, although it probably does occur at a greater depth. Evaporite beds contain fragmental volcanic rocks and limestones enclosing a Paleozoic fauna. A characteristic feature of the diapirism is that it is distinctly defined in the central portions of the depression, but peters out gradually towards its folded marginal border. This pattern has been established on the Axel-Heiberg islands, as well as on the territory located north of the Mokka Fiord. Stratified evaporites have also been found in a number of

places in the folded zone adjacent to the downwarp. These evaporites form, as a rule, complex structural relationship with the enclosing beds of rocks. R. Thornsteinsson and E.T. Tozer /38/ attribute the most marked plastic deformations of evaporites to the effect of the tectonic activation during the Cenozoic. The demarcation line of the range of the Paleogene-Neogene boreal-transgressive structures of the Beaufort formation bounds the Sverdrup depression in the north-northwest. It has a distinctly linear outline and appears to coincide with the scarps, as well as with the faults which are associated with these scarps and along which the territory of the Hyperboreal Platform, adjacent from the north, had subsided.

The Sverdrup hollow is thus a large depression filled with subplatform formations. These formations are now dated as Pennsylvanian to Paleogene-Neogene inclusively. The contact of these deposits with the subjacent geosynclinal formations has been established only in the marginal areas bordering on the folded belt. So far the folded foundation has not been exposed within the Sverdrup depression. It is known that the boundary line between the downwarp and the Franklin belt is rather distinctly defined and that it passes through large, extensive abyssal fractures. The boundary has been traced on Ellesmere, Melville, Prince Patrick and on other islands of the Canadian Arctic

Archipelago. It is important to note that the trend of the Franklin geosynclinal belt varies rather markedly. Within the boundaries of the Ellesmere Island the trend of the folded belt changes from sublatitudinal to submeridional at an angle of 60° , while on the territory of the Devon Island it changes from the submeridional to sublatitudinal at an angle of 90° . The fact that the Sverdrup depression is surrounded by the geosynclinal belt suggests that the depression developed above a deeply submerged foundation block and represents an exogonal foredeep characteristic of endogonal angles of a platform. V.S. Zhuravlev (1969) studied the nature of similar depressions and noted that they are characteristic of the marginal areas of the ancient Precambrian platforms, where intensive downwarping, intensive sedimentation associated with the downwarping, and active salt tectogenesis occur.

Two depression areas separated by the transverse Ellef-Ringnes elevation (which is probably the northern extension of the Boothia horst-like uplift of the foundation) can be established on the territory of the Sverdrup downwarp. In the Eastern Sverdrup depression the foundation occurs at the depth of 11-12 km. (according to certain data--14 to 18 km), in the Western Sverdrup depression it is at the depth of 7 to 9 km. The Ellef-Ringnes elevation is superposed by a sedimentary mantle measuring approximately 3000 m. in thickness. The Sverdrup hollow probably cannot be

regarded as a superposed epigeosynclinal depression. Only its northeastern extremity may be classified (though tentatively) as such. This extremity is enclosed between the Otto and Tanquary fiords (Ellesmere Island), is bounded by disjunctive dislocations in the east of the Axel-Heiberg islands and probably formed in the place of the abyssal fracture, which separates the eugeosynclinal and the miogeosynclinal regions on the Ellesmere Island. This relatively narrow triangular territory is the most markedly elevated portion of the Eastern Sverdrup depression. It is filled with Permian and Carboniferous formations having a thickness of 1000-3000 m. No distinct boundary has been detected between these two territories. The transition between them is probably gradual.

The Beaufort depression is located in the southern periphery of the Hyperboreal Platform. It occupies the northern part of the Mackenzie delta and the coastal areas of the Beaufort Sea shelf. The southern boundary of the depression passes along the abyssal fracture at the junction

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of the Northwestern projection of the Canadian Platform with the western extension of the Franklin miogeosynclinal belt (i.e. the Mackenzie-Banks zone). The depression is bounded in the north by the Beaufort elevation located under the waters of the Arctic Ocean. Its western boundary passes along the slopes of the Martin elevation and Brooks range.

Tectonic data on the Beaufort depression are extremely scant. It is now known that this hollow is heterogeneous in structure. Its southern border occurs above the Paleozoic geosynclinal Mackenzie-Banks zone, whereas its remaining portion overlies a deeply submerged block of the Hyperboreal Platform. The deepest drill-hole was made here in the southern extremity of the Richards Island. It exposed only Paleogene-Neogene, Cretaceous and, possibly, partly Jurassic sub-platform deposits to the depth of 3800 m. It has been established that the most markedly submerged portion of the downwarp was located during the Cenozoic 65 km, east of this drill-hole and was situated not within the boundaries of the present-day delta of Mackenzie (as it was previously believed) but 160 km, farther east, at the place of the pre-Pleistocene paleodelta. American and Canadian geologists and geophysicists have also noted that the thickness of the sedimentary filling this depression increases northeast of the Tuktoyaktuk peninsula, towards and under the waters of the Beaufort Sea, where their thickness in the most markedly submerged area exceeds 10,500 m.

/50/.

The western and southwestern pericratonnal border of the Hyperboreal Platform is situated within the boundaries of northern Alaska, as well as in the Arctic Ocean and Chukchi Sea shelf areas. The pericratonnal border is bounded in the north and northeast by abyssal faults, along

which the Canadian basin may have subsided. The Brooks range and its extension beneath the waters of the Chukchi Sea (in the direction of the Wrangell Island and farther north) form its southern and eastern boundaries, while the underwater Mendeleev range acts as its northern boundary.

The region of the pericratonnal subsidence of the Arctic slope of Alaska and the Chukchi platform projection, on which the northern and southern Chukchi elevations are located, can be established within the pericratonnal border of the Hyperboreal Platform. I.P. Atlasov et al /1/ refer to this projection as the Hyperboreal Block. It formed during the Archean-Proterozoic and Epiproterozoic. A considerable portion of the Hyperboreal Block consists of plateau-basalts. B. Kh. Egiazarov /14/ regards this territory as the Hyperboreal table, which underwent descending movements during the Mesozoic and Cenozoic. A large portion

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of the table is occupied by a field of extensively developed effusives which have a basic composition and date back to the Upper Cretaceous and Paleogene.

The pericratonnal depression of the Arctic slope is bounded in the south by the Brooks range. It includes the submontane Colville downwarp, Umiat depression in the east and Chukchi depression in the west. The two depressions are separated by the transverse Meade-Barrow elevation.

During the Jurassic the anticlinorium of the Brooks

range underwent an intensive bulging and the submontane Colville downwarp began forming along its northern boundary. Sedimentation continued in the latter until the Upper Senonian /25/. The hollow is filled mainly with Triassic and Cretaceous formations having an overall thickness of more than 7 km. The Colville depression is bounded in the west by the Tigara elevation, in the east--by the horst-like Romanzof elevation, which originated during the Paleogene-Neogene. It should be noted that during the Jurassic the Romanzof elevation represented an extension of the Colville depression. Carboniferous and Devonian, possibly also Precambrian deposits crop out in the main within the boundaries of this elevation. Mesozoic deposits have been preserved here and are exposed in structural basins.

The Tigara block elevation is represented by complexly dislocated and faulted Devonian, Carboniferous and Lower Mesozoic rocks. In the opinion of Miller et al /25/, this elevation formed during the Paleogene-Neogene. The most intensive orogenic movements occurred on the territory of the Colville hollow during the Late Paleocene and post-Paleocene. The deformation of the deposits is most intensive in the southern part of the depression, is moderate in its central part, and is weak in its northern portion. During the major part of the Paleogene-Neogene, the Colville depression represented a large elevation, which was eventually degraded by weathering to a low plain; during the

Quaternary epoch this territory became uplifted anew.

The remaining continental portion of Alaska, located north of the Colville trough, is known in the American geological literature under the name of the Arctic coastal plain. Geological and geophysical investigations have shown that sedimentary mantle rocks represented mainly by carbonaceous Paleozoic and terrigenous Mesozoic deposits and having a nearly flat pitch, occur here upon the rocks of the

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Precambrian foundation. The thickness of these deposits does not exceed 5000 m. in the low-level sections, and varies from 1000 to 3000 m. in the uplifted areas. The Hyperboreal Platform (which includes this territory) began subsiding during the Early Mesozoic, giving rise to the Arctic Ocean. The Barrow arch appears to represent a portion of the continental massif, which had been preserved as a positive structural element throughout the entire Mesozoic. Its southern extension, traced in the form of the arched Meade uplift, has been established on the basis of geophysical data. The Meade dome originated during the Upper Cenomanian or Turonian. The bedrock exposed in the dome has been dated as Cenomanian or Albian.

During the post-Cretaceous the territory of the Colville depression was somewhat uplifted and deformed, as a result of which structural elements, such as the Chukchi and Umiat depressions, the transverse Barrow-Meade elevation,

the Martin, Northern and Southern Chukchi elevations became better defined. Structural peculiarities of these depressions, the time of their formation, their history of development and the composition of the deposits filling these depressions are probably fairly similar. Theories on the structure of the depressions are based essentially on the data of geo-physical investigations and on the drilling done on the Barrow-Meade elevation and in the coastal area of the Umiat depression. The depth of occurrence of the foundation is over 5-6 km. in both depressions. The sedimentary mantle was stripped most thoroughly by drill-holes in the Umiat depression during the drilling operations in the region of Prudhoe Bay (Fig. 5). However, so far even the deepest drill-holes failed to penetrate beyond the Carboniferous deposits.

The conjugated Canadian and Hyperboreal Platforms reveal both similarities and differences in their tectonic features and in the history of their evolution. The Canadian Platform is raised in its present-day structural plan and is devoid of sedimentary mantle in its major portion (the Canadian Shield). The Hyperboreal Platform is ~~submerged~~ (in comparison to the Canadian Platform) to the depth of 3500 m. within the boundaries of the Canadian basin, and is covered by waters of the Arctic Ocean; however, it is probably also devoid of sedimentary mantle over most of its extension.

Intensive downwarping and sedimentation occurred

initially at the boundary separating these two platforms, then spread gradually over their peripheries. Descending

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movements of the maximum amplitude occurred in the sublatitudinally elongate zone, coinciding in the modern structural plan with the Franklin geosyncline.

The time and tectonic results of the downwarping, as well as the age of the deposits accumulated here, vary.

Peripheral portions of the Canadian platform periodically underwent downwarping and were filled with sediments mainly during the Lower and Middle Paleozoic. The North Canadian platform and the foredeep conjugated with it, formed as a result of this warping. The descending movements ended in the north of the Canadian Platform and in the geosynclinal belt during the Devonian-Early Carboniferous, and culminated in the Paleozoic folding responsible for the formation of the Franklin folded belt.

Peripheries of the Hyperboreal Platform probably underwent the most intensive downwarping later, at the end of the Paleozoic, during the Mesozoic, in certain places even during the Cenozoic. This is corroborated by the presence of a sedimentary sub-platform mantle under the waters of the Beaufort Sea and in the northern delta of the river Mackenzie, as well as in the North Alaskan foredeep. The maximum downwarping compensated by intensive sedimentation, concentrated here in the peripheries of the Hyporboreal

Platform, in the Sverdrup depression and, to a lesser degree, in other regions.

It should be noted that many ancient Precambrian platforms reveal features in the development of their peripheries, which are common for all of them. V.S. Zhuravlev's (1969) works on the Russian Platform show that its characteristic peculiarity resides in the formation of deeply downwarped marginal areas marked by intensive manifestations of salt tectogenesis, i.e. the areas referred to by the author as the exogonal depressions. A similar phenomenon may be observed in the North African platform, where several large foredeeps, united in the modern plan into the Algerian-Libyan syneclyse /34/, became detached one after the other during the Paleozoic, Mesozoic and even Cenozoic. The formation of the Sverdrup depression and of the syneclyses of the North Canadian Platform should probably be also regarded as a manifestation of this process, a process characteristic of Precambrian platforms.

The folded Cordilleran belt constitutes the southwestern boundary of the Hyperboreal Platform and the western boundary of the Canadian Platform. This transcontinental structural element represents a multiple complex of mountain ranges, massifs, plateaus and ridges. The Alaskan range,

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St. Elias mountains, Coast Range, Cassiar and Mackenzie mountains are situated on the territory examined. This

territory is bounded in the south by the Canadian Rocky Mountains. This Mesozoic folded belt consists of two parallel branches which differ in geotectonic development. The eastern division is miogeosynclinal with regard to its development, the western division is eugeosynclinal. In spite of the considerable extension of this belt and despite the specific geological structure of its individual elements, it forms at the present time one single geotectonic unit. Its development consisted of several different stages and was characterized by a repeated reconstruction of the tectonic plan, by alternation of the geosynclinal cycles, and by the magmatism accompanying these cycles. At the time of the Nevadan orogeny (during the Middle Mesozoic) the eugeosynclinal portion of the belt became deformed, partly metamorphosed, and was invaded by a multitude of typhons. The miogeosynclinal area underwent repeated deformations as a result of several phases of folding during the Late Mesozoic; the Laramide orogeny (Late Cretaceous-Paleocene) was the most important one of these phases. Cordilleran structures are, however, superimposed in certain places upon folded zones which had become consolidated at an earlier date. For example, a portion of the Cordilleran folded zone on the territory of British Columbia underwent folding in the Middle Paleozoic (the Cariboo) orogeny, as well as in the Late Paleozoic, during the Cassiar orogeny.

The development of Cordilleras in the Paleogene-Neogene

was fairly complex, since during this period depressions were filled, orogenic movements reoccurred in certain places, intensive volcanic activity and block shifting began as a result of the development of parallel and transverse faults. Transverse faults or fracture zones varying in depth, in extension and length of development, are one of the major structural features of the Cordilleran folded belt. F. King /53/ believes that the presence of transverse faults is responsible for the differences in the geological structure of individual segments of the Cordilleran belt.

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B. Kh. Egiazarov /14/ established on this territory the inner and the outer zone of the mobile Pacific belt. The outer zone includes the Mesozoic North Alaskan folded system, the eastern part of the Novosibirsk-Chukchi folded zone and the Anadyr-Seward median mass of the Precambrian-Early Paleozoic stabilization. The inner zone comprises the South Alaskan and Koryakski-Kamchatka Cenozoic folded systems.

The eastern part of the Cordilleras in Canada, northeastern Alaska and Chukchi peninsula is represented by a region of the miogeosynclinal type of development. It is composed essentially of carbonaceous Paleozoic and terrigenous Mesozoic deposits, which underwent intensive deformations during the Late Cretaceous and Paleogene. The deformations resulted in the development of elongate linear folds and dislocations with a break in continuity, which

bound these folds and which formed mainly during the Laramide folding phase. Sloping thrusts develop in certain places along the eastern boundary of this region. The region at the junction of the Brooks and Mackenzie anticlinoria is the most complex sector of this province. The folds are here squeezed and form a broad, sudden bend because of the presence of a block elevation similar to that of the Richardson mountains /14/. This complex tectonic junction encloses a Middle and Late Paleozoic folding, which (in F. King's opinion) is comparable in character to the folding of the Franklin belt. F. King believes that the constriction of the Canadian Cordilleras is caused by the junction of the Mesozoic and Cenozoic Cordilleran structures with formations of the Franklin belt. The region, where Brooks range structures are linked with the structures of the Mackenzie mountains, represents a zone of conjugation of mesozoids and paleozoids of the Chukchi-Brooks branch with the Cordilleran mesozoids. It is probable /4/ that mesozoids and paleozoids of the Chukchi peninsula and Brooks range are both very similar and structurally related to the folded formations of the Arctic Canada, i.e., to the Franklin geosynclinal belt, rather than to the Cordilleran belt. The North Alaskan folded system of the Brooks range anticlinorium is represented by a complex of essentially linear structures. The position in space and the morphology of these structures are determined by the trend of the geosynclinal zones, as

well as by the presence of the Hyperboreal Platform in the north and Anadyr'-Seward median mass in the west. Structures of the Brooks range form two branches in the eastern

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part: the northeastern and the southeastern branches, which circumscribe the northwestern projection of the Canadian Platform known under the name of the Mackenzie projection.

The former branch probably extends farther to join the Mackenzie-Banks belt (the Franklin geosynclinal belt), while the latter branch passes through the Ogilvie mountain region (the Mackenzie anticlinorium) and links with the Canadian Cordilleran structures. The eastern part of the Novosibirsk-Chukchi peninsula folded zone represents the western extension of the Brooks range anticlinorium on the territory of the Verkhoyansk-Chukchi province. The Mackenzie anticlinorium forms the southern portion of this belt. It also includes contemporaneous mountain formations, such as the Ogilvie and Mackenzie mountains. Judging from the cross-sections described by L.J. Martin /24/, Archean foundation rocks, late Precambrian and Cambrian deposits, Ordovician and Carboniferous rocks ranging in age from Silurian to Middle Devonian, inclusively, participate in the formation of these structures in the central region. Upper Devonian ^{c/} shists and sandstones with carbonaceous reef lenticles have been detected in the Mackenzie depression, while Cretaceous ^{c/} shists and sandstones are found in the

cross-section at a higher level. Late Precambrian rocks occur upon Archean granites and metamorphic rocks in the southern part of this region; these rocks underlie Cambrian to Middle Devonian carbonates that are superimposed by Upper Devonian schists, and give way farther up the profile to sandstones, schists and sandstones, schists and carbonaceous rocks ranging from Mississippian to Permian in age; Mesozoic schists and sandstones occur at a still higher level in the cross-section. Geological structures of this region are represented in the main by simple anticlinoria that are complicated in certain places by faults and rather insignificant dislocations of strata.

L.J. Martin /24/ believes that the above deposits strike both eastwards and westwards. The northern sector of this territory is located in the northern part of the Richardson mountains, i.e. in the zone, where the junction of the Franklin folded belt with the Brooks range anticlinorium and Richardson dislocations is presumed to be. This is the most complex sector with respect to structure. We would probably encounter here Precambrian and Cambrian rocks (that may be represented by the series varying in age from Ordovician to Middle Devonian), as well as Mississippian, Pennsylvanian and Permian rocks superimposed by Mesozoic and

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Cenozoic formations. This territory underwent three, perhaps even four orogenic phases. The most ancient Late Cambrian

orogeny took place only in the central part of the Mackenzie mountains. A regional uplift of the southern part of this territory occurred between the Precambrian and Cambrian. No corresponding stratigraphical break has been found, however, thus far in the cross-section of the northern part of this region.

The geotectonic history of the Canadian Northern Cordilleras has been insufficiently elucidated for the period between the Cambrian and Middle Devonian. Certain data allow us to assume that a general uplift occurred on this territory in the Early Ordovician and around the Late Silurian. The oldest orogeny in the north of this territory is the tectonic activation, which took place on the boundary of the Middle and Late Devonian. The Silurian and even older schists, hornfels and carbonaceous rocks known from this region, are markedly dislocated and faulted, whereas the Mississippian deposits that are found in the border of the mountainous formations and are represented by carbonaceous rocks, are, as a rule, displaced to a negligible degree. L.J. Martin concluded that the orogenic movements which were accompanied by rock deformation and faulting, occurred prior to the deposition of the carbonaceous Mississippian rocks. This hypothesis is corroborated by the changes in the distribution of facies which took place on the boundary between the Middle and Late Devonian. While Middle Devonian deposits on the territory of the northwestern Canada consist of

carbonaceous rocks with interlayers of schists, Upper Devonian deposits are represented here by sandstones and ferruginous schists, whereas the sediments south of the spurs of the Brooks anticlinorium (Barn and British mountains) consist essentially of conglomerates.

A break in sedimentation occurs on the boundary of the Upper and Middle Devonian, a circumstance indicating that the territory became uplifted at that time. Regional unconformity between the rocks of different facies deposited during these periods, indicates local movements of the earth crust. The unconformity has been recorded in Central and Western Alberta, in the south of the Northwestern Territories, in the north of the Franklin mountains and in the

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southern part of the Richardson region. The activation was approximately synchronous with the break between the Middle and Upper Devonian and probably coincided with the orogeny in the northern part of Cordilleras and in the southwest of the Brooks range anticlinorium. The age of the quartzitic intrusion of the mountain Fitton (the northwestern slope of the Barn mountains) is 353 million years. Baads-gaard et al /44/ believe that the intrusion of granites corresponds to the Early-Middle Devonian. The next orogenic cycle recorded in the north of the Yukon territory, probably took place during the Early Pennsylvanian. Pennsylvanian deposits in the northern regions of the Richardson mountains

and in the areas bordering on these regions occur with a considerable angular unconformity upon older beds.

Near the eastern periphery of the Richardson mountains, Pennsylvanian rocks underlie deposits, which vary in age from Cambrian to Upper Cambrian. In L.J. Martin's /24/ opinion, it is therefore obvious that horst-forming processes took place during the Late Paleozoic. Baadsgaard et al /44/ established with the help of radioactive dating that granites of the Old Crow range (eastern extension of the Brooks anticlinorium) are 220 million years old, a circumstance further corroborating L.J. Martin's hypothesis.

The absence of Lower and Middle Triassic rocks, as well as the relatively small thickness and areal extent of Permian, Upper Triassic, Jurassic deposits and of the bottommost Cretaceous horizons show that a large portion of the area located on the boundary of the Mackenzie platform projection and within this projection, was somewhat raised during the interval between the Paleozoic and Cenozoic, perhaps even later. Angular unconformity between the Lower Permian and Upper Jurassic beds was, however, detected (tentatively) by J.A. Jeletsky only on the eastern slope of the Richardson mountains. It is therefore, impossible to maintain that a significant geotectonic activation took place during this period.

The Lower Cretaceous period was the next stage of the geotectonic activation in this region. The age of the

granites dated by Baadsgaard et al /44/ in the British mountains (Eastern part of the Brooks range) is 95 million years. At the end of the Lower Cretaceous (Albian) the Brooks range was uplifted. Rejuvenation of the British

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mountains took place. J.A. Jeletsky /65/ recorded two unconformities and corresponding breaks in sedimentation, which occurred during the Early Cretaceous. One of them occurred at the beginning of the Lower Cretaceous, the other one--on the boundary of Aptian and Albian. This researcher notes further that washout and unconformity have also been recorded at the beginning of the Upper Cretaceous in the northern part of the Richardson mountains and west of these mountains.

As is well known, rocks of the lower Upper Cretaceous horizons overlie more ancient formations east of the Richardson mountains and in the northern part of the Franklin mountains. L.J. Martin /24/ does not think, however, that these data suffice to determine the scale of orogenic movements during this period.

Formations of the middle part of the Upper Cretaceous are the youngest dislocated rocks found in the northern part of the Canadian Cordilleras. Deformation (folding) of these rocks may have occurred at the end of the Late Cretaceous. The fact that continental Paleogene deposits are not dislocated in the mountain regions and in

the regions adjacent to them may serve as supporting evidence for this hypothesis.

According to Hume's /51/ data, these deposits in the northern part of the Franklin mountains are of Lower Eocene age. It would appear that the orogenic movements terminated on this territory not later than in the Early Eocene, i.e. before the orogeny, which took place in the Canadian Rocky mountains.

The Brooks range consists of Paleozoic rocks. Its northern portion is represented by slightly metamorphosed Devonian and Carboniferous deposits forming squeezed folds of a latitudinal trend. The folds are often faulted and are overthrust in the northward direction. The southern portion of the Brooks range consists of metamorphosed rocks and of Lower Paleozoic limestones.

The Silurian, Devonian and Carboniferous deposits accumulated in the Paleozoic geosyncline of the modern Brooks range, are up to 4500 m. in thickness. D. Miller et al /25/ believe that the major source of removal for the accumulation of these deposits was the Paleozoic shield located to the north of the present-day mainland, i.e. the

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southern periphery of the Hyperboreal Platform. A portion of this platform (situated in the area occupied at the present time by the Brooks range) began subsiding at the end of the Paleozoic. The conformable occurrence of

Triassic rocks upon the Carboniferous deposits shows that no significant orogenic movements occurred on this territory at that time. Tectonic movements, which resulted in the formation of the Brooks range, probably began during the Jurassic. This is evident from the wedging of mafic and ultramafic intrusions, which began during the Late Jurassic. During this period a geanticline formed here. This geanticline was subjected to extremely intensive ascending movements, and represented in the Early Jurassic the principal source of removal for the premontane Colville depression.

D. Miller et al maintain that the Early Cretaceous orogenic movements led to the deformation and metamorphosis of the rocks occurring in the Brooks range province, and resulted in the formation of structures having a latitudinal trend. The bulging of this territory, which began in the Albian, continued throughout the Cretaceous, whereas volcanic activity was here at its peak only during the Late Cretaceous. Further deformation of rocks and formation of structures having a latitudinal trend, took place in the Paleogene.

An eugeosynclinal region is located south and west of the miogeosynclinal zone of the Alaskan and Canadian Cordilleras. This region is enclosed between the two Great Alaska-Cordillera fracture zones, i.e., Denali (in the west) and Tintina (in the east). Volcanic rocks represented mainly by basalts and andesites, as well as by greywackes,

clay shales, conglomerates and hornfels, are extensively developed within the boundaries of this region.

The cross-section of the Paleozoic rocks in the eugeosynclinal region differs markedly from that of the rocks which form the miogeosynclinal portion of Alaska. This territory is characterized by the presence of marine sediments, lack of thick volcanogenic deposits, sustained thickness and lithology of the rocks, graded rock debris, predominance of finely fragmental and carbonaceous rocks in the cross-section. The latter rocks accumulated during the Late Devonian, Mississippian and Permian. In the territory of Alaska the eugeosynclinal region is divided in two parts:

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the Central zone which extends from the Brooks range in the north to the Alaska and Aleutian ranges in the south, and the Southern zone which includes the arch-shaped Alaska and Aleutian ranges, Mentasta and Nutzotin mountains, as well as the coastal ranges and valleys of the gulf of Alaska, which are located farther south.

Rocks of every geological epoch, beginning with the Precambrian, have been found in the Central Alaska. Rocks of the belt* series, and in some regions still older, markedly metamorphosed Birch Creek crystalline schists are here equivalent to Precambrian deposits. This region

*Transliteration. (Translator)

underwent several orogenic phases, some of which were accompanied by the formation of intrusions. Marine Cambrian, Ordovician and Silurian sediments became deposited mainly in the region located between the Alaska range and Yukon River. The Lower Paleozoic attains here a thickness of 6100 m. The Cambrian system is represented by limestones with subordinate interlayers of black clay shales. Ordovician deposits here are widely distributed; they are represented by schists ranging from grey to black*, by argillites, siliceous rocks, greywackes, quartzites, limestones. Silurian formations are composed of limestones and dolomites. In a number of sectors these rocks had been deformed, but D. Miller et al /25/ believe that the deformation was not accompanied by intrusive activity.

The Devonian to Permian complex of deposits occurs with an angular unconformity upon Silurian and even older formations. Marine Mississippian and Devonian deposits are widely distributed in Central Alaska and attain, in certain areas, a thickness of over 600 m. These deposits consist of limestones, black clays and schists, very thick siliceous rocks, quartzites, sandstones, and are represented in a number of places by volcanic rocks of the greenstone type.

*Punctuation has been omitted in this sentence, as a result of which it is not clear whether the phrase "ranging from grey to black" refers to the schists, or to the argillites. (Translator)

(Review of Foreign Literature).

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Geologiya i neftegazovost' arkticheskikh i subarkticheskikh raspolozhenii / Geology and oil and gas content of eskich regions mira / Geology and oil and gas content of subarctic and subarctic regions of the world.

PETROLEUM INDUSTRY.

MINISTRY OF EDUCATION / MINISTERSTVO NEFTYANOJ PROMSYLLENOSTI

The world. UNIVERSITY TRANSLATION FOR THE STUDENTS AND
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Geology and oil and gas content of Arctic and Subarctic regions of the world.

LITERATURE

OBZORY ZARUBEZHNOI LITERATURY / REVIEWS OF FOREIGN

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S e r i e s : Oil and gas geology and geophysics.

VNIIOENG,* Moscow, 1970.

Problems of geology and oil-gas content of the North American Arctic regions are examined in this review. Productive and potential oil- and gas-bearing basins on this territory and in the shallow-water area of the Arctic Ocean adjacent to this territory, are here defined and described. Modern views on tectonic peculiarities and on the history of geological evolution of the northern part of the Canadian Platform, southern periphery of the Hyperboreal platform and geosynclinal region of the Canadian and Alaskan Cordilleras are here outlined. Potential oil and gas resources in all these basins are evaluated, and the territory is divided into zones with respect to their potential oil and gas content. The state of the oil and gas industry in these regions is here characterized, and possibilities of its further development are examined. Brief data on oil and gas resources of the Soviet Arctic regions, as well as a general outline of potential oil and gas reserves in Arctic and Subarctic regions are presented here.

This work is designed for broad circles of the specialists involved in prospecting for oil and gas, as well

*All-Union Research Institute for the organization, administration and economy of petroleum and gas industry.

Hypereborreal platform, which are separated by the geosynclinal

p. 4

Platform and the southern periphery of the Precambrian examined are the northern Precambrian part of the Canadian The principal tectonic constituents of the region

Geological outline

gas in the Soviet Arctic."

"gas resources," and "Certain data on the presence of oil and Modelovskii is the author of the chapters "Potential oil and transport" were written by N.S. Tolstoi, while M. Sh.

"bearing basins," "Possibilities of oil and gas recovery and "Geological outline", "Producing and potential oil and gas - Soviet press during the last decade. The chapters entitled

analyses of the materials published in the foreign and expressed by the authors in this work, are based on an cent to it, remain unsolved or controversial. The views

this territory and of the Arctic Ocean offshore areas adja-

related to the geological structure and oil-gas content of tions has been carried out in these regions. Many problems even though a series of geological borehole investigations

been so far little studied from the geological viewpoint,

Trans-Arctic regions of both the USA and Canada have

1970, are presented in this work.

America. The most important data obtained by the middle of their distribution in the Arctic and Subarctic regions of

belt in the north and Canadian Cordilleras in the west, is referred to by B. Kh. Egizarov /14/ as the Mackenzie projection.

The northern periphery of the Canadian platform, superposed by Paleozoic sediments, bears the name of the North Canadian platform. It is divided in two parts. Its southern half is enclosed between the surface outcrops of the Canadian shield and the regional sublatitudinal fracture. This part corresponds to the northern pericratonial border of the platform. The portion of the platform that is located to the north of the regional fracture and is adjacent to the folded Franklin belt, appears to correspond to the foredeep formed as a result of the development of this belt. The early Paleozoic and Middle Paleozoic rocks, which fill the negative structural elements of the pericratonial extremity, do not exceed 2-3 thousand meters in thickness, while in the foredeep these formations exceed 4000 m. in thickness. The depths at which the foundation of the Canadian Platform occurs /13, 54/ indicate the presence in the northern periphery of the platform of several

p.5

depressions and synclises that are separated by horst-like and arched uplifts of the foundation.

The foundation of the precambrian Canadian Platform is raised and crops out at the surface on the horst-like Boothia elevation east of the Baffin land, as well as in the

the faults, along which the most intensive folding took place. The syneclyses. Linear displacements may have been due to the indicate that such dislocations may be found on the surface. Fig. 6

Pattern of variations in the thickness of the clay shales, sandstones, but the presence of fault disturbance has not been detected above the Melville-Victoria series. So far no linear dislocations have been established above the eastern slope of the Melville-Victoria series syneclyses. Physical data on the boundary of this elevation will show that these fractures have been established with the help of glacial scouring. Large fractures demarcate the zones, where the depth of clines are separated by the Bootleg horizon-like elevation. Jones-Lancaster and Melville-Victoria-syneclyses syneclyses occurrence of the crystalline foundation changes diachronically.

Large fractures demarcate the zones, where the depth of

deposits.

thick gypsumous bed is known only from Middle Ordovician cross-sections of these depressions. A relatively Cambrian cross-section and in the bottom layers of the carbonaceous formations only in the lower strata of the represented by conglomerates and sandstones, occur alongside marlstones and aleurites. Psathyritic ferruginous rocks concrete, Silurian dolomites, Upper Silurian and Devonian lenticular conglomerates, Cambrian and Ordovician silicification are here represented by limestone with interlayers of argillite, Cambrian, Silurian, Ordovician and Devonian deposits

(such as Parry and Ellesmere) formed at that time. The extreme northeastern part of the Ellesmere zone (the north of Ellesmere) consists of formations reflecting the eugeosynclinal type of development. In the geological literature it is referred to as the "Northern Ellesmere geosynclinal region." Thick beds of greywackes, polymictic sandstones, conglomerates and clay shales, as well as volcanic lavas and tuffs are found here. The degree of metamorphization of the entire cross-section of deposits is here considerably higher than in other parts of the Franklin geosynclinal belt. Certain Soviet and American geologists are inclined to believe that the Northern Ellesmere eugeosynclinal region, or at least its northwestern part in the Axel-Heiberg region,

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represents a Caledonian folded system and is a continuation of the caledonides of Greenland /56/ or of the caledonides of the Cornwallis folded zone /1/, which can be traced farther north under younger deposits of the Sverdrup downwarp, beyond the boundaries of the Lomonosov range.

In the eastern half of the Ellesmere Island the trend of the Central Ellesmere folded belt is submeridional. To the south of it and farther on to the Devon Island sublatitudinal trends predominate. This drastic change in the folding trend of the Franklin belt suggests that the belt is draped upon a rigid buried foundation block, which consolidated at an earlier date and above which the Sverdrup

referred to as the Mackenzie-Banks folded zone.
extends between the Parry zone and the Brooks range is
*The position of the Franklin geosyncline which

Mesozoic sedimentary complex.

tions of this zone are superimposed by a thicker, essentially
Island and Mackenzie River valley, where geosynclinal forma-
shores of the Liverpool Bay, in the region of the Eskimo
Neogene-Paleogene deposits. This is also the case on the
Banks Island, but is buried here under a thin mantle of boreal
Franklin geosynclinal belt does not discontinue around the
Mackenzie River delta. It may therefore be assumed that the
(northern part of Richardson Mountains) and east of the
the Parry zone formations, have been detected southwest
Upper Paleozoic folded zone because of their similarity to
and structures, which L.J. Martin /25/ assigns to the

p. 8

(Hercynian) Parry folded zone occurs northeast of the Island
Paleozoic (Hercynian) folding. However, the Upper Paleozoic
the present time the Banks Island reveals no sign of Upper
British Mountains; then it links with the Brooks range*. At
the region of the northern spurs of the Richardson and
Island, and extends thenceupon through the Liverpool Bay in
latitudinal, while passing through the west of the Banks
of the Prince Patrick Island, then changes its trend to sub-
providence, which turns sharply south in the southern extremity

the time when thick carbonaceous geosynclinal formations were still in the process of development in other folded regions.

The character of the structures and, what is more important, their submeridional trend persist even farther north, beyond the boundaries of the Sverdrup depression. This circumstance led I.I. Atlasov et al /1/ to extend the Cornwallis miogeosynclinal zone into the Northern Ellesmere eugeosyncline and farther north, inside the boundaries of the Lomonosov ridge. The time of formation of the Cornwallis folded zone should be regarded as Early Paleozoic,

p.8

and its development should be related to the formation of the horst-like Boothia elevation. Vertical movements also occurred in this zone during the Cenozoic, a circumstance reflected in the trend of the structural forms found in the central area of the Sverdrup depression (Fig. 1).

While examining the sublatitudinal Paleozoic Franklin geosyncline, extending along the northern border of the Canadian Platform over a distance of more than 3000 km, we must note its interrelation with the folded system of the Brooks range. The latter has a sublatitudinal trend and changes in the north to the foredeep of Northern Alaska. It borders in the south on the eugeosynclinal zone of Central Alaska. N.A. Bogdanov (1963) regards the Brooks range as the western extension of the Franklin geosynclinal belt.

different. Therefore, the Brooks range anticlinal is not

that the geological history of these two geosynclines is

Hyperboreal Platforms. However, it must be kept in mind

single geosynclinal belt separating the Canadian and the

range anticlinal should probably be regarded as one

territory in Canada. The Franklin geosyncline and the Brooks

(the Brooks range anticlinal) in the north of the Yukon

junction with the northern portion of the Western Cordilleras

The Franklin geosyncline forms a fairly extensive

zones took an entire megacycle to develop.

forms or between a continent and an oceanic platform. These

of such polyyclic belts situated between two older plat-

ksian /41/ mentions these and the Pacific zones as examples

stage of development of the entire geosynclinal zone. V.E.

regions. These regions became amalgamated during the final

definitive periods individual and separate geosynclinal

elements which differ in age and which represented during

a region of geosynclinal development, a region consisting of

The Franklin belt is thus a structurally complex

p.10

complete the full cycle of geosynclinal development.

believe that the region of the Western Cordilleras failed to

Nevadan stage of activation. Certain American researchers

zation of the Western Cordilleras, and it corresponded to the

and Lower Cretaceous, was the same as the synchronous. activi-

Brooks range during the interval between the Middle Jurassic

the separation of the horst-like Boothia elevation and of

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the Cornwallis zone. The effect of these movements also spread farther to the north, into the territory of the Sverdrup downwarp. The transverse submeridional barrier, which divides the Franklin folded belt in two parts (Parry and Ellesmere), and the Sverdrup depression into the western and eastern zones of downwarping, began thus forming during the Early Paleozoic. At the end of the Devonian the thick complex of carbonaceous deposits in the Franklin folded belt became intensively dislocated.

Deposition of thick beds of fragmental rocks predominated on the islands of Melville, Bathurst and in the southeast of the Ellesmere Island from the Middle Devonian, and, beginning with the Upper Devonian, continental formations measuring up to 3500 m. in thickness were deposited on this territory /38/. The area of distribution of these deposits extends in a continuous band from east to southeast, from the southern extremity of the Ellesmere Island to the Banks Island. R. Thorsteinsson and E.T. Tozer believe that the formation of psephytic rocks during the Upper Paleozoic is related to the intensification of the tectonic activity, which resulted eventually in orogeny in this belt. It may be assumed that the foredeep between the Franklin belt and the Canadian Platform formed precisely at this time, during the final orogenic stage of development of the geosynclinal

increasing in size as North America drifted westwards, away from Europe, while rotating around a point located in the Northern Arctic region. During the subsequent years both Soviet and foreign geologists developed this theory further. In 1937, Du Toit (47) suggested a hypothesis on the origin of the Arctic and northern Atlantic basins, which is based on the theory of continental drift. This research believed that the individual blocks bounding the Arctic basin, rotated independently from one another and differed.

sedimentation within the boundaries of the foredeeps, by the formation of large thrusts in the region of the Brooks range, and by the appearance of plutonism. The breaking up of the continents attained its peak at the end of the Early Cretaceous and terminated in orogeny. At that time the Canadian Arctic Archipelago and Alaska began to assume a position similar to their present position.

Apparently, continental and shelf-underwater regions of the marginal Arctic Ocean seas are confined within the boundaries of the North American continent to the remnants of an ancient, probably Precambrian platform, which is known among Soviet geologists as the Hyperboreal platform. These remnants are found north of the geosynclinal Franklin belt and Brooks range, and demarcate the deep-water Canadian basin in the south. Various researchers view the origin of this basin in different ways.

At the present time most researchers believe that depressions in the ocean floor were not there originally, but arose at a certain stage of the geological history /3,4, 41,60/. This conclusion is equally valid with regard to the depressions in the internal and marginal seas, where the crust has a two-layer structure and consists of a "basaltic" and a sedimentary (often fairly thick) layer /20,58/. V.E. Khain /42/ finds evidence of the "secondary" nature of oceanic and suboceanic depressions in the correlation of their contours (i.e. contours of the areas devoid of the

is by nature a fault (a circumstance established in a number of regions, for example, along the edge of the North American basin of the Atlantic Ocean), as well as in the fact that continental structures extend beneath the ocean floor certain geological problems, since it is not clear what metasomatism is the first such version, however, it raises oceanization. There are two main versions of this process. It is only the physico-chemical aspect of the process of terraces between given the name of basification and it probably characterizes transformation into the oceanic crust. This process has the continental crust and its subsequent or synchronous fixism: the oceans formed as a result of the collapse of oceanization is based on the principles of the tectonic theory) is based on the principles of the tectonic mobility: The other trend in the interpretation of the process the places of such "hates".

The oceans formed when large continental masses (Laurasia, Gondwana Land) broke up, as a result of the horizontal displacement ("spreading") of their fragments, exposure of the subcrustal substrate and neogenesis of the oceanic crust in the oceans (so-called "hiatuses"). One of them (the mechanical process of oceanization). There are two opposite views on the evolution of the oceanic crust at the expense of the continental crust (the so-called Gondwanaland) broke up, as a result of the horizontal displacement ("spreading") of their fragments, exposure of the subcrustal substrate and neogenesis of the oceanic crust in the oceans (so-called "hiatuses").

V.E. Khaian /42/ believes that at the present time waters. Fact that continental structures extend beneath the ocean floor certain geological problems, for example, along the edge of the North American basin of the Atlantic Ocean), as well as in the fact that continental structures extend beneath the ocean floor certain geological problems, for example, along the edge of the North American basin of the Atlantic Ocean), as well as in the

development and trends of the Paleozoic orogenic belts, which extend beyond the boundaries of the Atlantic Ocean through the Urals, Novaya Zemlya, Norway, Spitzbergen, Eastern Greenland, Canadian Arctic Archipelago, Severnaya Zemlya and Novo-Sibirskie Islands, led A.J. Irdley* /17/ to suggest that the Hyperboreal Platform was a mainland in the pre-Paleozoic times. Results of analyses of the conditions under which the Paleozoic geosynclines formed in Alaska, also appear to corroborate this hypothesis. It may be assumed from these data that the removal source for the accumulation of certain beds was located to the north of the present mainland at the place, where the deep-water Canadian basin is found today. The fact that North America and Europe have a common Paleozoic marine fauna is another important argument in favour of this hypothesis.

The seismic investigations carried out by Oliver, Ewing and Press /59/ in 1952, in the southern Arctic basin, appear to suggest that the parameters of the wave lengths recorded by these researchers, are characteristic only of continental structures and do not apply to the areas with the oceanic type of crust. Later on they stated, however, **

*Guesswork. Irdli in the text. (Translator)

**A portion of the sentence seems to be missing. Translated literally, the beginning of the sentence goes as follows: "Having nevertheless emphasized later on . . .". (Translator)

anomalies may reflect the magmatic intrusions, which had wedged in along the faults.

Large depressions (Sverdrup, Beaufort, and the down-warps of the Arctic slope of Alaska) are located in the southern peripheries of the Hyperboreal Platform. Geological, structural and peculiarities of development of these local structures are related genetically to the evolution of the elements within the boundaries of the Paleozoic Franklin folded belt. The data available at the present time merely allow us to state that this downwarp began to fill in the middle of the Carboniferous and that this process continued until and during the Cenozoic. This is corroborated by the distinctity defined angular unconformity between the non-dislocated post-Pennsylvanian beds, forming part of the infilling, and the presumed pre-Pennsylvanian folded foundation. It is important to note that this break has been detected only in the periphery of the depression in the Ellesmere Islands, as well as on the boundary Island, on Axel-Heiberg Islands, as well as on the hand, Parry, between the Sverdrup depression on the one hand, Parry, Cornwallis and Ellesmere folded zones on the other.

The Sverdrup downwarp is composed of Mesozoic and (to a lesser extent) Cenozoic arenaceous-argillaceous sediments, as well as of argillaceous and evaporitic arenary rocks, as well as of argillaceous and overall thickness of Pennsylvanian formations. The overall thickness of

places in the folded zone adjacent to the downwarp. These evaporites form, as a rule, complex structural relationship with the enclosing beds of rocks. R. Thornsteinsson and E.T. Tozer /38/ attribute the most marked plastic deformations of evaporites to the effect of the tectonic activation during the Cenozoic. The demarcation line of the range of the Paleogene-Neogene boreal-transgressive structures of the Beaufort formation bounds the Sverdrup depression in the north-northwest. It has a distinctly linear outline and appears to coincide with the scarps, as well as with the faults which are associated with these scarps and along which the territory of the Hyperboreal Platform, adjacent from the north, had subsided.

The Sverdrup hollow is thus a large depression filled with subplatform formations. These formations are now dated as Pennsylvanian to Paleogene-Neogene inclusively. The contact of these deposits with the subjacent geosynclinal formations has been established only in the marginal areas bordering on the folded belt. So far the folded foundation has not been exposed within the Sverdrup depression. It is known that the boundary line between the downwarp and the Franklin belt is rather distinctly defined and that it passes through large, extensive abyssal fractures. The boundary has been traced on Ellesmere, Melville, Prince Patrick and on other islands of the Canadian Arctic

along the slopes of the Martin elevation and Brooks range. Waters of the Arctic Ocean. Its western boundary passes in the north by the Beaufort elevation located under the (i.e., the Mackenzie-Banks zone). The depression is bounded the western extension of the Franklin marginal belt of the Northwest project of the Canadian Platform with p. 19

depression passes along the abyssal fracture at the junction of the Beaufort Sea shelf. The southern boundary of the northern part of the Mackenzie delta and the coastal areas periphery of the Hyperboreal Platform. It occupies the The Beaufort depression is located in the southern is probably gradual.

between these two territories. The transition between them of 1000-3000 m. No distinct boundary has been detected with Permian and Carboniferous formations having a thickness portion of the Eastern Sverdrup depression. It is filled narrow triangular territory is the most markedly elevated synclinal regions on the Ellesmere Island. This relative fracture, which separates the eugeosynclinal and the marginal islands and probably formed in the place of the abyssal disjunctive dissociations in the east of the Axel-Heiberg Otto and Tanguay fjords (Ellesmere Island), is bounded by its northeasterly extremity may be classified (though tentatively) as such. This extremity is enclosed between the regarded as a superposed eugeosynclinal depression. Only

which the Canadian basin may have subsided. The Brooks range and its extension beneath the waters of the Chukchi Sea (in the direction of the Wrangell Island and farther north) form its southern and eastern boundaries, while the underwater Mendeleev range acts as its northern boundary.

The region of the pericratonnal subsidence of the Arctic slope of Alaska and the Chukchi platform projection, on which the northern and southern Chukchi elevations are located, can be established within the pericratonnal border of the Hyperboreal Platform. I.P. Atlasov et al /1/ refer to this projection as the Hyperboreal Block. It formed during the Archean-Proterozoic and Epiproterozoic. A considerable portion of the Hyperboreal Block consists of plateau-basalts. B. Kh. Egiazarov /14/ regards this territory as the Hyperboreal table, which underwent descending movements during the Mesozoic and Cenozoic. A large portion

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of the table is occupied by a field of extensively developed effusives which have a basic composition and date back to the Upper Cretaceous and Paleogene.

The pericratonnal depression of the Arctic slope is bounded in the south by the Brooks range. It includes the submontane Colville downwarp, Umiat depression in the east and Chukchi depression in the west. The two depressions are separated by the transverse Meade-Barrow elevation.

During the Jurassic the anticlinorium of the Brooks

Quaternary epoch this territory became uplifted anew. The remaining continental portion of Alaska, located north of the Colville through, is known in the American geological literature under the name of the Arctic coastal plain. Geological and geophysical investigations have shown that sedimentary mantle rocks represented mainly by carbonaceous Paleozoic and terrigenous Mesozoic deposits and aqueous Paleozoic and terrigenous Mesozoic deposits and platforms (which includes this territory) began subsiding from 1000 to 3000 m. in the uplifted areas. The hypoboreal does not exceed 5000 m. in the low-lying sections, and varies precambrian foundation. The thickness of these deposits during the Early Mesozoic, giving rise to the Arctic Ocean. The Barrow arch appears to represent a portion of the continental massive, which had been preserved as a positive structural element throughout the entire Mesozoic. Its southern extension, traced in the form of the arched Meade uplift, has been established on the basis of geological data. The Meade dome originated during the Upper Cenomanian or Turonian. The bedrock exposed in the dome has been dated as Cenomanian or Albian.

During the post-Cretaceous the territory of the Chukchi and Colville depression was somewhat uplifted and deformed, as a result of which structural elements, such as the Chukchi and Umiat depressions, the transverse Barrow-Meade elevation, result of which structural elements, such as the Chukchi and Colville depression was somewhat uplifted and deformed, as a result of which structural elements, such as the Chukchi and Umiat depressions, the transverse Barrow-Meade elevation,

initially at the boundary separating these two platforms, then spread gradually over their peripheries. Descending

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movements of the maximum amplitude occurred in the sublatitudinally elongate zone, coinciding in the modern structural plan with the Franklin geosyncline.

The time and tectonic results of the downwarping, as well as the age of the deposits accumulated here, vary.

Peripheral portions of the Canadian platform periodically underwent downwarping and were filled with sediments mainly during the Lower and Middle Paleozoic. The North Canadian platform and the foredeep conjugated with it, formed as a result of this warping. The descending movements ended in the north of the Canadian Platform and in the geosynclinal belt during the Devonian-Early Carboniferous, and culminated in the Paleozoic folding responsible for the formation of the Franklin folded belt.

Peripheries of the Hyperboreal Platform probably underwent the most intensive downwarping later, at the end of the Paleozoic, during the Mesozoic, in certain places even during the Cenozoic. This is corroborated by the presence of a sedimentary sub-platform mantle under the waters of the Beaufort Sea and in the northern delta of the river Mackenzie, as well as in the North Alaskan foredeep. The maximum downwarping compensated by intensive sedimentation, concentrated here in the peripheries of the Hyporboreal

territory is bounded to the south by the Canadian Rocky Mountains. This Mesozoic folded belt consists of two parallel branches which differ in geological development, the eastern division is miogeosynclinal with regard to its eastern division is miogeosynclinal with regard to its development, the western division is eugeosynclinal. In spite of the considerable extension of this belt and despite the specific geological structure of its individual elements, the development of the eugeosynclinal cycles, and by the plan, by alternation of the geosynclinal cycles, and by the magmatism accompanying these cycles. At the time of the Nevadan orogeny (during the Middle Mesozoic) the eugeosynclinal portion of the belt became deformed, partly metaclinial portion of the belt became deformed, partly metamorphosed, and was invaded by a multitude of typhons. The most important one of these phases, Cordilleran structures were, however, superimposed in certain places upon folded zones which had become consolidated at an earlier date. For example, a portion of the Cordilleran folded zone on the territory of British Columbia underwent folding in the middle Paleozoic (the Cambrian orogeny), as well as in the late Paleozoic, during the Cimmerian orogeny.

The development of cordilleras in the Paleogene-Neogene

bound these folds and which formed mainly during the Laramide folding phase. Sloping thrusts develop in certain places along the eastern boundary of this region. The region at the junction of the Brooks and Mackenzie anticlinoria is the most complex sector of this province. The folds are here squeezed and form a broad, sudden bend because of the presence of a block elevation similar to that of the Richardson mountains /14/. This complex tectonic junction encloses a Middle and Late Paleozoic folding, which (in F. King's opinion) is comparable in character to the folding of the Franklin belt. F. King believes that the constriction of the Canadian Cordilleras is caused by the junction of the Mesozoic and Cenozoic Cordilleran structures with formations of the Franklin belt. The region, where Brooks range structures are linked with the structures of the Mackenzie mountains, represents a zone of conjugation of mesozoids and paleozoids of the Chukchi-Brooks branch with the Cordilleran mesozoids. It is probable /4/ that mesozoids and paleozoids of the Chukchi peninsula and Brooks range are both very similar and structurally related to the folded formations of the Arctic Canada, i.e., to the Franklin geosynclinal belt, rather than to the Cordilleran belt. The North Alaskan folded system of the Brooks range anticlinorium is represented by a complex of essentially linear structures. The position in space and the morphology of these structures are determined by the trend of the geosynclinal zones, as

even four orogenic phases. The most ancient Late Cambrian
Cenozoic formations. This territory underwent three, perhaps

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Pennsylvanian and Permian rocks superimposed by Mesozoic and

Victorian to Middle Devonian), as well as Mississippian,

may be represented by the series varying in age from Ordovician probably encounter here Precambrian and Cambrian rocks (that the most complex sector with respect to structure. We would find and Richardson dislocations is presumed to be. This is of the Franklin folded belt with Brooks range anticline- Richardson mountains, i.e. in the zone, where the junction

this territory is located in the northern part of the strike both eastwards and westwards. The northern sector of L.J. Martin /24/ believes that the above deposits

frequent dislocations of strata.

complicated in certain places by faults and rather insignifi- represented in the main by simple anticlinalia that are cross-section. Geological structures of this region are schists and sandstones occur at a still higher level in the rocks ranging from Mississippian to Permian in age; Mesozoic sandstones, schists and sandstones, schists and carbonaceous Devonian schists, and give way farther up the profile to Middle Devonian carbonates that are superimposed by upper southern part of this region; these rocks underlie Cambrian occurs upon Archean granites and metamorphic rocks in the cross-section at a higher level. Late Precambrian rocks

carbonaceous rocks with interlayers of schists, Upper Devonian deposits are represented here by sandstones and ferruginous schists, whereas the sediments south of the spurs of the Brooks anticlinorium (Barn and British mountains) consist essentially of conglomerates.

A break in sedimentation occurs on the boundary of the Upper and Middle Devonian, a circumstance indicating that the territory became uplifted at that time. Regional unconformity between the rocks of different facies deposited during these periods, indicates local movements of the earth crust. The unconformity has been recorded in Central and Western Alberta, in the south of the Northwestern Territories, in the north of the Franklin mountains and in the

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southern part of the Richardson region. The activation was approximately synchronous with the break between the Middle and Upper Devonian and probably coincided with the orogeny in the northern part of Cordilleras and in the southwest of the Brooks range anticlinorium. The age of the quartzitic intrusion of the mountain Fitton (the northwestern slope of the Barn mountains) is 353 million years. Baads-gaard et al /44/ believe that the intrusion of granites corresponds to the Early-Middle Devonian. The next orogenic cycle recorded in the north of the Yukon territory, probably took place during the Early Pennsylvanian. Pennsylvanian deposits in the northern regions of the Richardson mountains

deposits are not dislocated in the mountain regions and in Late Cretaceous. The fact that continental Paleogene (folding) of these rocks may have occurred at the end of the northern part of the Canadian Cordilleras. Deformation ceous are the youngest dislocated rocks found in the formations of the middle part of the Upper Cretaceous during this period.

These data suffice to determine the scale of orogenic movements during this period.

Richardson mountains and in the northern part of the Franklin mountains. L.J. Martin /24/ does not think, however, that Richarson mountains and in the northern part of the Franklin mountains overlap more ancient formations east of the

As is well known, rocks of the Lower Upper Cretaceous mountains.

northern part of the Richardson mountains and west of these recorded at the beginning of the Upper Cretaceous in the notes further that washout and unconformability have also been one--on the boundary of Aptian and Albian. This researcher occurred at the beginning of the Lower Cretaceous, the other which occurred during the Early Cretaceous. One of them unconformities and corresponding breaks in sedimentation, mountains took place. J.A. Jelletsky /65/ recorded two

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Brooks range was uplifted. Revivation of the British years. At the end of the Lower Cretaceous (Albian) the mountains (Eastern part of the Brooks range) is 95 million granites dated by Baadsgaard et al /44/ in the British

Triassic rocks upon the Carboniferous deposits shows that no significant orogenic movements occurred on this territory at that time. Tectonic movements, which resulted in the formation of the Brooks range, probably began during the Jurassic. This is evident from the wedging of mafic and ultramafic intrusions, which began during the Late Jurassic. During this period a geanticline formed here. This geanticline was subjected to extremely intensive ascending movements, and represented in the Early Jurassic the principal source of removal for the premontane Colville depression.

D. Miller et al maintain that the Early Cretaceous orogenic movements led to the deformation and metamorphosis of the rocks occurring in the Brooks range province, and resulted in the formation of structures having a latitudinal trend. The bulging of this territory, which began in the Albian, continued throughout the Cretaceous, whereas volcanic activity was here at its peak only during the Late Cretaceous. Further deformation of rocks and formation of structures having a latitudinal trend, took place in the Paleogene.

An eugeosynclinal region is located south and west of the miogeosynclinal zone of the Alaskan and Canadian Cordilleras. This region is enclosed between the two Great Alaska-Cordillera fracture zones, i.e., Denali (in the west) and Tintina (in the east). Volcanic rocks represented mainly by basalts and andesites, as well as by greywackes,

*Punctuation has been omitted in this sentence, as a result of which it is not clear whether the phrase "ranging from grey to black" refers to the schists, or to the argillites. (Translator)

number of places by volcanic rocks of the greenstone type. Rocks, quartzites, sandstones, and are represented in a limestone, black clays and schists, very thick siliceous areas, a thickness of over 600 m. These deposits consist of widely distributed in central Alaska and attaian, in certain formations. Marine Mississippian and Devonian deposits are with an angular unconformity upon Silurian and even older Cambrian to Permian complex of deposits occurs slave activity.

believe that the deformation was not accompanied by intrusions these rocks had been deformed, but D. Miller et al /25/ composed of limestones and dolomites. In a number of sections greywackes, quartzites, limestones. Silurian formations are ranging from grey to black*, by argillites, siliceous rocks, here are widely distributed; they are represented by schists nate interlayers of black clay shales. Ordovician deposits Cambrian system is represented by limestones with subordinate Lower Palaeozoic attaian here a thickness of 600 m. The region located between the Alaska range and Yukon River. Ordovician and Silurian sediments became deposited mainly in parallel by the formation of intrusions. Marine Cambrian, underwent several orogenic phases, some of which were accom-

Middle and Upper Jurassic organic remains are enclosed in
tainty in the region of the Goodnews dome where Lower,
Jurassic deposits have been established with cer-
tain age enclose beds of bituminous shales.
which measure several tens of meters in thickness. Rocks of
are represented by dark-colored marine clays and limestones
mouth of the river Nation and in the Trout Creek, where they
deposits have also been found on the Yukon River, in the
limestones, siliceous and igneous rocks. Upper Triassic
Goodnews dome and are represented by argillites, compact
formations. These deposits crop out in the region of the
rocks occur here without angular unconformity upon Paleozoic
have been detected in Central Alaska, Upper Triassic deposits
Even though no Lower or Middle Triassic deposits

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in Central Alaska.
ates and igneous rocks have been found in a number of places
thickness of 1500 m. Marine Permian limestones, conglomerate
erates, and enclose coal beds. These rocks attain a
contingent argillaceous formations, sandstones and conglomerate
is up to 3000 m. Pennsylvania rocks are represented by
schists exposed in the northern foothill of the Alaska range
section. The thickness of the Mississippian crystalline
stable for the absence of Early Devonian rocks in the cross-
deposits has been recorded on this territory and is respons-
Marked unconformity between the Devonian and Mississippian

by marine formations in the north. These deposits are of continental rocks, which become gradually interstratified the Nanushuk group have been dated as Cenomanian and consist to the Shaktolik (Shaktolik) group. The upper strata of and it encloses certain Albian ammonite species analogous deposited in the Northern Alaska under marine conditions, bottom strata of the Albian-Cenomanian Nanushuk group became note its resemblance to the conglomerates of Ungalik. The is composed of thick conglomerates. D. Miller et al /25/ located in the southern extremity of the Colville depression, The Aptian-Albian Fortresses Mountain formation, downwarped.

similar in certain respects to the rocks of the Colville sections. They are represented here by rocks, which are known essentially from the Yukon-Koyukuk and Kobuk depressions, Cenomanian marine and continental formations are probably, and clay shales of the Kandik formation. Albian and, represented by sandstones, quartzites, conglomerates, clays rocks. In the region of the river Kandik these deposits are wackes, quartzites, thin beds of limestones and igneous arach and are represented here by marine argillites, grey-formations. Rocks of this age also crop out in the Goodnews arkose sands, limestones and igneous rocks of the Koyukuk Hogatza arch. These sediments are represented by schists, Neocononian marine sediments develop in the region of the greywackes and argillites, in siliceous and igneous rocks.

Paleocene continental rocks occur upon Cretaceous
igneous rocks. These beds are over 6100 m. in thickness.
Strata of the cross-section of argillites, graywackes and
are represented by marine sediments composed in the upper
northern border of the Alaska range. Formations of this age
Central Alaska only in the Kuskokwim depressions and in the
between the Coniacian and Campanian have been found in
detected here. Upper Cretaceous deposits from the interval
North Alaskan Colville group (Turonian-Campanian) have been
the Late Cretaceous period, since no rocks equivalent to the
appear that the sea did not return to this territory during
markedly continental portion of the cross-section. It would
begin, was accompanied by the deposition of the upper, more
advances of sea. The new intensive retreat, which then
section accumulated in the course of these retreats and
and continental rocks of the middle portion of the cross-
a number of fairly negligible retreats and advances. Marine
both provinces by a retreat, which, in its turn, gave way to
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phery of the depression. The advance of sea was followed in
graywacke and clay beds with conglomerates along the peri-
section accumulated. These bottom horizons consist of thick
in the course of which the lower portion of the cross-
tation began on both territories with the advance of sea,
Central Alaska. American geologists believe that sedimen-
probably equivalent to the Katmai continental formation of

deposits without visible unconformability at a higher level of the profile in both Northern and Southern Alaska. So far no Paleocene deposits have been found in Central Alaska. D. Miller et al. /25/ maintain, however, that the Eocene deposits examined in this region, may be classified upon closer inspection as Eocene, are found mainly in the form of rocks dated as Eocene, within the boundaries of the Alaska range erosional relief within the bounded areas of the Alaska range and in the small topographic Colith, Rampart and Eagle depressions, where these rocks are represented by argillites, sandstones, conglomerates and lignites. In certain regions they attain a thickness of 1500 m. Sedimentation may have occurred in certain areas of Central Alaska during the post-Eocene, and the sediments deposited were of the continental type, and marine facies. The age of these formations varies from Paleogene-Neogene to recent; moreover, Neogene and Pleistocene rocks are found here particularly often. The stratigraphic breaks, which have been recorded, indicate an uplift occurring during the Pennsylvanian. The most significant of Alaska during the Pennsylvanian. The most significant of the Devonian and was accompanied by orogeny. This is evident from the absence of Early Devonian rocks in Alaska, as well as from the marked unconformability with which Late Paleozoic formations occur upon the Early Paleozoic.

The second fairly large oxygenic cycle took place during the Lower Cretaceous, probably in the Aptian. It was accompanied by an intensive wedging of batholiths, by

Alaska.

Similar oxygenic movements may have also occurred in Central intrusivite activity, took place on these territories. When several phases of tectonic movements, accompanied by the Southern and Northern Alaska during the Jurassic period, the first such cycle was particularly intensive in

of three large oxygenic cycles. These beds have been invaded and metamorphosed as a result of Paleocene incisively, have been deformed; in some regions the deposits, ranging in age from Devonian to

have survived along general lines up to our days. was laid for the formation of new tectonic elements, which and that during the early stages of the Jurassic, foundation, Cordilleran terminated their development during the Triassic,

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Triassic. J. Greist* and J. Greek believe that the Alaskan Cordilleran geosynclinal continued existing throughout the Alaska, where lava beds attain 1800 m. in thickness. The volcanicicity. This is particularly true of the Southern final stages of the Paleozoic are characterized by intensive

Paleozoic, continued developing in the Early Mesozoic. The

metamorphosés and mineralization of the sediments. Of the Cretaceous—beginning of the Paleogene, and was accompanied by intrusive activity. The system of abyssal fracturing formed (in the opinion of D. Miller et al./25/) as a result of the third orogenic cycle, which corresponds to the Nevadan folding, which resulted in the formation of the elongate Alaskan structure. At that time the entire eugeo-synclinal complex was intensively dislocated, metamorphosed and invaded by essentially granitic magmatic rocks /14/. Two trends of abyssal fracturing have been established on the territory enclosed between the Brooks range and Alaska range. The older fracturing has a latitudinal trend and is characterized by essentially granitic magmatic rocks /14/. The younger fracture system probably formed as a result of northwestern trend and are parallel to the Brooks range or northwestern trend and are parallel to the Brooks range. The older fractures have a latitudinal trend and Alaska range. The older fracturing has a latitudinal trend and is characterized by essentially granitic magmatic rocks /14/. The younger fracture system probably formed as a result of northwestern trend and are parallel to the Brooks range or northwestern trend and are parallel to the Brooks range.

The next orogenic cycle began in the Neogene and Miocene. The Larval orogeny occurred during the Oligocene and Lower Tertiary, accompanied by faults and broad folds, which are parallel to the arch-shaped Alaskan structure. The final stage of the

These tectonic movements led to intensive dislocations with continued during the Quaternary period. In Central Alaska

posed formations of Central Alaska (mainly in the represented by intensively dislocated and deeply metamor-

The Proterozoic-Early Paleozoic structural stage is

principally developed during phases of this territory.

established seven structural stages, which correspond to the bases of the data from this research, B. Kh. Egiazarov

Corridors, i.e. in Northern and Central Alaska. On the unconformity mainly within the boundaries of the Alaskan regional gaps in sedimentation, and detected angular

B. Kh. Egiazarov studied fossiliferous complexes of

regions of the American Arctic.

Alaska and Aleutian Islands, but it also touches upon other mainly the problems of stratigraphy and tectonic activity in

V. Kh. Egiazarov's (14) monograph. This work examines our opinion, the most important Soviet work in this field is D. Miller, I.P. Atlassov and others. The most recent and, in and gas content, have been carried out by T. Payne, V. King, territorial with regard to its geology, tectonic activity, oil

American geologists. The most thorough surveys of this

Corridors has been studied for many years by Soviet and Canadian and Alaskan

The Mesozoic folded belt of the Canadian and Alaskan mountain chains and uplands.

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rogenic cycle resulted in the formation of the modern folds, and in some areas--of large elevations. The final

a break in continuity, as well as to the formation of gentle

*Nazina in the text. (Translator)

*Translation. (Translator)

The Lower substage is separated from the older Lower Carboniferous, inclusively.

Includes the structures ranging from Middle Devonian to Cambrian-Upper Silurian structures, the upper substage divided in two substages. The Lower substage includes the Lower-Middle Paleozoic structural stage is the part of rigid consolidated structures.

Subjected to disjunctive dislocations, in which they played a role in subsequent epochs, but were merely restucturing during the subsequent epochs.

Paleozoic structures of Alaska underwent no substantial changes with the enclosing rocks, while others are younger than cordillerans, vary in composition. Some of them are synchroneous with the enclosing rocks, while others are younger than accretionary formations of Canadian and Alaskan.

Western Canada. Intrusive rocks occurring in the most structural stage of this age on the adjoining territories of Klondike, Yukon and Katsina have been classified with the Cambrian, occur on this territory. The rocks from Nazina*, stromes and schists, some of which may be assigned to the morphic and crystalline schists, greenstone basalts and Creek schists, rocks of the Tindix group represented by metabasites, as well as by virtually unaltered dolomites, limestone, Yukon-Tanana regions). Proterozoic Pellic* gneiss and Birkch

*Transliteration. (Translator).

*Tontzota in the text. (Translator)

turning point in the geological history of Alaska. Alaskan Caledonides and of graniteid intrusions. This was a and Devonian. This folding resulted in the formation of this territory on the boundary between the Upper Silurian formations. The Late Caledonian folding occurred throughout argillites, greywackes, siliceous rocks and igneous-clastic stonies, clay shales with subordinate quantities of mites of the Tontzona group, Tolovana and Skagit Lime-are represented by carbonaceous rocks-limestone and dolomitic limestone. Lower Paleozoic deposits of Central Alaska zone reveals certain features that are characteristic of presence of these igneous rocks the southern part of this terrigenous-carbonaceous and greywacke beds. Due to the local concentrations in the Yukon-Tanana region alongside Victorian did igneous rocks of the Fossil Creek series form in the Miogeogenic zone. Only during the Middle Ordovician structures were formed in Northern and Central Alaska actually at the Upper Cambrian. Throughout the Early Paleozoic the Lower Paleozoic cross-section begins here.

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omitted from the profile nearly everywhere. unconformity. Lower and Middle Cambrian deposits are folded formations by a stratigraphic hiatus and by angular

The upper structural substage (Middle Devonian-Lower Middle-Lower Paleozoic) represents a new period in the evolutionary history of Alaskan Cordillerans. In the Yukon-Tanana and other regions the Middle Paleozoic (or the undifferentiated angular unconformity and with conglomerates mainly on Silurian and still older Lower Paleozoic formations.

In Central Alaska, due to the displacement of the volcanic belt to the south, the miogeosynclinal conditions changed in the Devonian (probably Middle Devonian) to an eugeosynclinal regime, which persisted to the end of the Lower Carboniferous. Near the northern foothill of the Kuskokwim region, there accumulated carbonaceous, aspidic, terrigenous, igneous-siliceous formations (the Takotna group, Salmontrout Limestones, Woodchopper Igneous rocks and others). Magmatic activity proceeded in Central Alaska in at least four stages. The first stage occurred during the Middle Devonian, the next three stages--in the Carboniferous.

Miogeosynclinal conditions of sedimentation per-

sisted in Northern Alaska throughout the Devonian-

Carboniferous. A complex of terrigenous and carbonaceous rocks (sandstones, clay shales, conglomerates and limestones) occurs in the northern part of the Brooks range. This complex appears to have developed on account of the material supplied from the platform region that was situated farther

The Upper Paleozoic structural stage (Upper Carboniferous-Permian) has been established on the basis of stratigraphic unconformity, because of the omission from the cross-section of Middle Carboniferous deposits, as well as because of the distinct changes observed in the conditions of sedimentation. In the east of Central Alaska this stage includes Permian and, possibly, Late Carboniferous carbonaceous-terrigenous deposits--the Takakandit limestone and equivalent beds. In the South-western Alaska (Nulato, Ruby, Kuskokwim and other regions) Takakandit limestone and equivalents are included into this structural stage. The Permian terrigenous deposits invaded by basalts and ultrabasites, can be genous Sikskapak deposits and Saglekchit sandstones can be assigned to this stage in Northern Alaska.

As a result of the energetic folding movements, which occurred at the end of the Paleozoic--beginning of the Mesozoic (the final stage of the Hercynian and the early stage of the ancient Cimmerian folding), the Paleozoic region of sedimentation experienced a general uplift. The tectonic period was the beginning of a new epoch in the geological history of Alaska. From that time on different tectonic zones of the territory into individual isolated zones of

north, (i.e. in the modern structural plan--under the waters of the Arctic Ocean).

regulations, Triassic-Lower Cretaceous (pre-Albian) deposits are

L8.d

Carboniferous) structural stage of the southern Cordilleras in Alaska formed mainly in eugeosynclinal conditions. Triassic-Jurassic deposits are here represented by siliceous igneous rocks, carbonaceous and terrigenous rocks. Lower Cretaceous deposits (Kandik, Koyukuk and other formations) consist of limestone, arkose sandstone and graywacke beds. Folding movements can be established from the angular unconformity, which arose as a result of tectonic movements in the middle of the Jurassic. These movements were particularly energetic during the pre-Albian, and were accompanied by intrusion of granites and of basic rock masses. Jurassic intrusions have been detected here. In contrast to the central (?) , Jurassic-Cretaceous and Early Cretaceous intrusive

The Lower-Middle Mesozoic (Triassic-Lower

Alaska.

Triassic deposits have been recorded to occur upon Permian or Pennsylvanian and Triassic-Lower Cretaceous (pre-Albian) rocks in the Brooks range province, along its northern border. A complete cross-section of Triassic deposits has been recorded in certain regions of Northern Alaska. Karnian and Ladinian-Karnian sediments alone have been found in the region of the Yukon river, whereas Triassic and Triassic-Lower Cretaceous (pre-Albian) deposits have been recorded to occur upon Permian or Pennsylvanian rocks in the Brooks range province, along its northern border. A complete cross-section of Triassic deposits has been recorded in certain regions of Northern Alaska.

xepresented in Northern Alaska by a terrigenous complex, where siliceous and carbonaceous deposits play a subordinate role. Geological movements occurred here prior to, then during the Jurassic, as well as later on, during the pre-Early Cretaceous and pre-Albian. The Upper Mesozoic structural stage, which is of Albian-Campanian, in places continued from the marine facies. It has a great importance in Central Alaska. In this stage important structural elements in Alaska. It has a great extent. In Central Alaska formations of this stage are composed mainly of terrigenous deposits that are concentrated in a series of folds of a sublithoidal and southern type.

The final consolidation of the structures of the Alaskan Cordilleras is related to the intensive Laramide tectogeny. Moreover, the folding was here a lengthy process and continued from the end of the Cretaceous to the Eocene. The intrusive volcanic activity is related to these geological movements. No significant accumulation of marine tonic movements. No significant accumulation of marine sediments took place during the post-Cretaceous.

The Lower Cenozoic (Eocene-Pliocene), in certain places Paleocene) structural stage corresponds in time to the formation of structures in the intermontane hollows and in the hollows superposed upon the folded Mesozoic foundations. Terrigenous, occasional coal-bearing beds, as well as volcanic pyroclastic formations were deposited here during this time. The Lower Cenozoic (Eocene-Pliocene), in certain places Paleocene) structural stage corresponds in time to the formation of structures in the intermontane hollows and in the hollows superposed upon the folded Mesozoic foundations. Terrigenous, occasional coal-bearing beds, as well as volcanic pyroclastic formations were deposited here during this time.

cordilleras are represented by the eastern marginally.
The principal structures of Canadian and Alaskan
large rivers and to Arctic coastal plains.
Certain young depressions are confined to the valleys of
within the boundaries of Paleogene-Neogene depressions.
depressions reveal inherited characteristics and are located
Early Quaternary and Quaternary depressions. Some of these
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Paleocene) consists of unconsolidated deposits, which fill
Upper Cenozoic structural stage (Quaternary, here and there
the uppermost (the most recent one chronologically)
more ancient deposits and have a flat pitch.
and Northern Alaska. These formations overlap considerably
tentatively to the Lower Cenozoic structural stage of Central
dated as Paleogene-Early Quaternary, have been assigned
The undifferentiated effusive-pyroclastic formations
stocks associated with extrusive rocks.
activity resulted in intrusion of small granitic masses and
tectonic blocks along the faults thus formed. Magmatic
faulting with a break in continuity and by displacement of
dislocations were caused less by folding processes, than by
in the marginal areas of the depressions. However, these
often have a flat pitch and are gathered in steep folds only
The Paleogene-Neogene deposits are slightly tilted,
well as in the Neogene and during the pre-Quaternary period.
recorded on the boundary of the Oligocene and Miocene, as

The eastern branch of the miogeosynclinal belt of the Cordilleran is represented in the Canadian and Alaskan Cordilleras in the modern structural plan by the Brooks and Mackenzie anticlinoria and has been described earlier. The western branch of the miogeosynclinal belt consists of the Ruby, Tanaana and Coast Range anticlinoria. Precambrian and Paleozoic metamorphic rocks, as well as large intrusive bodies crop out on the territory of the Ruby geanticline. Precambrian and Lower Paleozoic (pre-Middle Ordovician) metamorphic rocks are exposed in the eastern zone of the Ruby, Tanaana and Ordovician, Silurian, Devonian and still older rocks occur in the southwestern zone. These rocks have been intensely deformed, metamorphosed and enclose large intrusions.

Jurassic and Cretaceous batholiths predominate in the geanticline of the Coast ranges. Stratified rocks are confined almost exclusively to a narrow zone along the southwesterly extension of the geanticline. This zone is composed of markedly metamorphosed igneous and clastic rocks with a certain amount of limestone. The limestone is seen with a thin layer of Paleozoic age.

The Anadyr-Seward mass stabilized during the final stage of Paleozoic age.

The eastern - Early Paleozoic. It is enclosed between the two branches of the miogeosynclinal belt. The Anadyr-Seward mass is composed of markedly metamorphosed igneous and clastic rocks with a certain amount of limestone. The limestone is seen with a thin layer of Paleozoic age.

Mitogosynglinal - older branches of the Alaskan and Iattier. This mass is located between the Mitogosynglinal and Seward median mass, but is considerably smaller than the median mass is the southeastern analog of the Anadyr - throughout the Middle Paleozoic - Late Neogene. The Yukon median mass is the distribution of depressions, and folded structures throughout the Middle Paleozoic - Late Neogene. The Yukon was broken up by large abyssal fractures into separate blocks and relic masses. Stable formations (median masses) affected Anadyr - Seward mass initially formed an integral whole and Seward peninsulae. B. Kh. Egiazarov believes that the have been encountered in denudations of the Chukchi and Pre-Paleozoic and Early Paleozoic (?) formations.

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dislocated Mesozoic and Cenozoic rocks / 14 /. Filled with looseQuaternary rocks which overlie slightly Norton and Bethel depressions). These depressions are Yukon-Koyukuk depression, probably the Anadyr depression, in the depressions located on its territory (such as the under the Mesozoic and Cenozoic formations, which developed depression. The Anadyr - Seward mass is now largely buried Bering Sea shelf. It closes in the region of the Anadyr, Yukon valley in Central Alaska and the northern part of the eastern part of the Chukchi peninsula, Seward Peninsula, position. It is triangular in shape and it embraces the folded Mesozoic Cordilleran belt and occupies a special

Canadian Cordilleran belt, within the boundaries of the coast ranges, and it is separated in the south west from the St. Elias mountains by the Shakwak trench. Precambrian gneiss, crystalline and metamorphic schist formations occur within the boundaries of this mass, which is separated similarly to the Yukon mass) by the Tintina fracture from the structure of Canadian Cordilleras of the Proterozoic Mesozoic deposits, measuring up to 6 km, in thickness in the Yukon-Porcupine depression, occur at the present time upon these smaller fragments. The Quaternary, possibly late Upper Cenozoic (?), essentially Quaternary deposits occur directly upon the Precambrian foundation, are the youngest, rather small depressions with regard to the volume of their fragments are confined to the zone of junction of the eugeosynclinal and miogeosynclinal branches of the Mesozoic folded zone of the Canadian and Alaskan Cordilleras. The Brooks and Alaska ranges (Nushagak, Holitna, Minchumina, Central Tanana, Yukon-Porcupine depressions), as well as the the Brooks and Alaska ranges (Nushagak, Holitna, Minchumina, Central Tanana, Yukon-Porcupine depressions), as well as the the Brooks and Alaska ranges (Nushagak, Holitna, Minchumina, Central Tanana, Yukon-Porcupine depressions) which complicate the Andayr-Seward mass (Kobuk,

It must be noted that both large and small platform sediments are concentrated to the zone of junction of the eugeo-synclinal and miogeosynclinal, branches of the Mesozoic folded zone of the Canadian and Alaskan Cordilleras. The largest hollos are here those located between the Brooks and Alaska ranges (Nushagak, Holitna, Minchumina, Central Tanana, Yukon-Porcupine depressions), as well as the the Brooks and Alaska ranges (Nushagak, Holitna, Minchumina, Central Tanana, Yukon-Porcupine depressions) which complicate the Andayr-Seward mass (Kobuk,

in the form of hills and are overlapped by alluvial deposits. These outcrops are confined to the projections, which rise schists, have been detected in the centre of this depression. Crosses of the Precambrian foundation, composed of crystalline rocks series is the Middle Tanana depression. Several out-these series is the Middle Tanana depression. Part of Central Alaska, within the boundaries of the Tanana extends in the form of an arch and occurs in the southern anticlinorium. The most thoroughly studied depression of structural type (Holtina, McNichumina, Central Tanana, etc.)

A series of superposed depressions of the same thickness terrigenous Eocene deposits, which measure 3 km, in thickness terrigenous rocks, as well as by beds of volcanic and marine 6000 m, in thickness, by continental-marine Upper Cretaceous rocks, by argillaceous-arenaceous juraassic deposits close to have been intensively dislocated and invaded by magmatic by schistous-arenaceous-argillaceous Triassic beds, which this depression. The sedimentary infilling is represented

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of the Paleozoic foundation exceeds 9 km, in the centre of area under the waters of Bristol Bay. The cover thickness anticlinorium. In the west it extends over a considerable the Talkeetna anticlinorium, in the north--by the Tanana The Nushagak* depression is bounded in the south by Selawik, Yukon-Koyukuk, Norton, Bethel).

The data obtained from the drill-holes made while prospecting out near the city of Fairbanks, as well as the subsidence of Quaternary, as a result of which fluvial deposits are found here below the sea level. It is highly important to find out whether the subsidence of this depression and the sediments accompanying it, took place during the Paleogene or whether these deposits have been preserved. The Yukon-Porcupine depression is situated between the Ruby and Tanana anticlinalia in the south, Brooks and somewhat uplifted northern area (the Yukon plains), and the southern, more markedly sagging area known in the American literature under the name of Kandik. It has been established that this depression is filled with a complex of recent alluvial rocks. Ordovician and Silurian formations deposited ranging from Early Paleozoic volcanic formations to Devonian, which consists of basaltic lava flows of the diabasic deposits are represented by the volcanic Woodchopper form are here represented by limestone. Middle Devonian

Hogatza elevation, which consists of Mesozoic rocks,
pre-Mesozoic rocks of the Brooks range, in the south--by the
Kobuk depression is bordered in the north by
underlie Eocene continental rocks.
Middle Cretaceous greywackes, argillaceous rocks and coal
quartzites and conglomerates. Continental and marine (?)
formation is 730 m, in thickness and consists of sandstones,
bituminous shales. Lower Cretaceous (Neocomian) Kandik
organic limestones and clay shales, which enclose beds of
tional measure 160 m, in thickness and are represented by
coal seam. Marine Permian deposits of the Takakandit forma-
conglomerates and argillaceous rocks enclosing a bituminous
1130-1830 m, in thickness and are composed of sandstones,
continental deposits of the Nation River formation measure
the limestones and shales are bituminized. Pennsylvanian
rocks with a certain amount of schists; moreover, most of
and consist of interstratified limestones and argillaceous
shells of the Calico Bluff formation measure 390 m, in thickness
argillites and siliceous rocks. Upper Mississippian depo-
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These flows are interstratified with tufts, breccias,
represented by basaltic lava flows of the diabasic type.
Mississippian deposits of the Circle formation are also
massive limestones, clays, schists and siliceous rocks.
flows. The pyroclastic rocks are interstratified with
type and of the pyroclastic rocks associated with these lava

Volcanic formations and granitic intrusions. Schreider (1904) assigned the Cretaceous rocks of the Kobuk depression to deposits of the Bergmen^{*} series. Coal-bearing rocks of this age are widely distributed in outcrops along the southern edge of the Brooks range. The cross-section of cretaceous deposits consists here of three parts: the lower marine horizons, the middle-marine and littoral-marine zones and the upper-essentially continental horizons. The cross-section measures several hundred meters in thickness. Rocks of the Bergmen series are energetically deformed and folded, and have a steep dip. The strata are often over-

The Selawik depression represents the western extension of the Kobuk depression and is bounded in the north by the Seward-Hogatza elevation. Its eastern zone is located in the basin of the river Selawik and is bounded in the north by the Werring[†] mountains, while the Yukon-Koyukuk opens in the west in the direction of the Kotzebue bay and Quaternary alluvial formations, which overlie Cenozoic coastal plains. The depression of the Kobuk may also perhaps even older rocks.

The Yukon-Koyukuk depression is bounded in the north by the Ruby anticlinorium, in the north-by the

*Kusko-kwam in the text, but it is probably a misprint. This work is very carelessly written and poorly edited, and it contains many grammatical mistakes and typings errors. (Translator)

In the south and Hogatza elevation in the north. Cretaceous in the centre of the depression, between the Kou mountains ceous rocks as the rest of the depression. It is situated downwarped Galena territory is filled with the same Cretaceous foundation occurs at a depth of approximately 3 km. The markedly downwarped portion of the Yukon-Koyukuk depression of andesites, clay shales and sandstones. In the most greywackes, aleurites and sandstones; Senonian formations-- stones and schists. Cenomanian deposits are composed of rocks are represented by conglomerates, greywackes, sand-clay shales, conglomerates and limestones. Aptian-Albian territory. Lower Cretaceous (Valanginian) rocks consist of sandstones, have been established on the adjoining Kusko-kwam volcanic rocks and limestones, as well as by clay shales and deposits represented by beds of greywackes, aleurites, are metamorphosed. Upper Jurassic and Lower Cretaceous gists believe that these rocks have a complex structure and elevations, which border the depression. American geolo-

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rocks are now known from the outcrop occurring in the into the younger Norton and Betheil depressions. Palaeozoic elevation and Hogatza arch, and in the west it goes over

of this system, occupy the southern regions of Alaska, the South Alaskan folding system). Structures forming part forms part of the Cenozoic folding (according to Egiazarov, the inner zone of the mobile Pacific belt, and therefore the southern Alaska. This territory is the eastern part of range, is commonly referred to in the American literature as The territory of Alaska situated south of the Alaska of the Yukon-Koyukuk synclinal zone.

rocks, which appear to occur upon folded Cretaceous deposits coastal plain. The depression is composed of Cenozoic areas of the Norton bay and gulf, as well as the adjoining the Yukon-Koyukuk depression. It includes the underwater The Norton depression is the western extension of sands.

are represented here mainly by arenitic and fine-grained were moved to or through the Bethel basin. Surface deposits during the Cenozoic from the central regions of Alaska and since large quantities of detrital products were removed zoic deposits. The latter are very thick in certain places, consists of Cretaceous rocks which are overlapped by Cenozoic mountains, in the north--by the river Yukon. The depression is bounded in the southeast by the Kuskokwim and Kilkuck of the two largest Alaskan rivers, Yukon and Kuskokwim, and The Bethel depression is located in the delta zones their turn, underlie Quaternary alluvial deposits.

deposits are here overlain by Cenozoic sediments, which, in

The most ancient sedimentary rocks found in Southeastern Alaska are of Ordovician age. These rocks occur unconformably upon Precambrian crystalline schists of the Birch Creek area in Kukiu, Prince of Wales, in the region of the El Captain strait and in the western part of the Alaska range, are represented in the bottom strata of the cross-section by marine graywackes, slates and clay shales measuring 900 m. in thickness. The upper portion of the cross-section is composed of limestone and clay shales, which are over 600 m. in thickness. The upper portion of the cross-section is made of limestone beds and clay shales, which are over 600 m. Middle Ordovician rocks. Even though oxygen affected in thickness, oxygen succeeded here the deposition of middle Ordovician rocks. It was not accompanied by extrusions. After the break in the sedimentation, deposition of thick silurian limestone is represented in the Southeastern Alaska by limestone with incursions of conglomrates. The thick silurian cross-section is represented in the Lower portion of the (5000 m) Silurian beds began. The Lower portion of the mass of this cross-section is represented by marine graywackes, the middle portion by limestone with incursions of conglomrates.

From the Cordilleran mesozoic by the abyssal region of the Kadiak Island. In the north this zone is separated on the coastal mountainous formations in the Gulf of Alaska and the Aleutian range, Chugach and St. Elias mountains, as well as including the Alaska range, Mentasta and Nutzotin mountains, Denali fracture.

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Aleutian range, Chugach and St. Elias mountains, as well as including the Alaska range, Mentasta and Nutzotin mountains, the coastal mountainous formations in the Gulf of Alaska and the Aleutian range, Chugach and St. Elias mountains, as well as

on this territory during this period. Upper Triassic

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Triassic deposits show that ascending movements took place vanian rocks and the total omission of Lower and Middle Silurian), the absence from the cross-section of many Pennsylvania (from the Middle Devonian to the Middle Triassic, include Southern Alaska during the Late Paleozoic and Early Mesozoic though there is no evidence of major orogenic movements in Island, where they are represented by limestone. Even rocks of Pennsylvanian age have been found on one single stones, cherts, conglomerates, sandstones and clay shales. are composed of volcanic rocks interstratified with lime-quartzites, sandstones and conglomerates. Permian deposits Southeastern Alaska are represented by limestone, cherts, without visible unconformity. Mississippian rocks of the bearing deposits occur in the cross-section at a higher level essentially of limestone and marbles. Mississippian coal-devonian rocks, measuring up to 1500 m. in thickness, consist by limestone, slates and cherts; moreover, the Middle measure up to 3000 m. in thickness and are represented in the Upper Devonian beds began after the break. These beds Southeastern Alaska by products of the underwater extrusion, measure up to 3000 m. in thickness and are represented in the Late Silurian - Early Devonian. Deposition of the Middle shoves, which terminated in a new orogenic phase during the these continental beds marks the beginning of tectonic cross-section is composed of redbed rocks. Deposition of Upper Devonian beds began after the break. These beds

The Lower Jurassic deposits of Southern Alaska consist mainly of volcanic rocks which formed from super-facial and underwater lava flows and measure up to 1000 m. in thickness. These rocks are interstratified with clay shales, sandstones and limestone and crop out in a wide band in the region of Cook Bay, Matanuska and Nenana Valley. The early stages of the Middle Jurassic are marked here by the completion of new tectonic elements, which exist even now. During the Jurassic the foundation of Alaska was downwarped and a large portion of its territory was differentiated into elevations and depressions zones, extending in the form of arches. Beds of detrital rocks measuring 4500-6000 m. in thickness, accumulated in the Matanuska synclinal during the Middle and Late Jurassic. A multitude of oil and gas shows have been detected in the cross-sections of these beds. Marine conditions prevailed during the Middle Jurassic in the synclinal of the Alaska range, and a bed of rocks the synclinal of the Middle Jurassic in the Matanuska synclinal during thicknes

Deposits, measuring several hundred meters in thickness, have been detected here. These deposits are represented by products of underwater extrusions, by relatively thick beds of limestone, clay shales and flinty slates. The trilobitic limestone recorded in denudations of the Alaska Peninsula,

the orogeny, which is responsible for the bulging of the region of the Prince of Wales Bay, is probably a result of the conglomerates and greywackes, which overlie them, in the unconformity recorded between the greenstone rocks and the deformation occurred in the Matanuska synclinorium. The

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Similarly, A similar, though considerably less extensive accumulation in the synclinoria of the Alaska range and deforrmation, then erosion of the rocks, which had previously intensive mineralization of the rocks; it induced first panted by the formation of batholithic intrusions and by an the Early Cretaceous (Upper Neocomian, Aptian), was accom- accumulated in the synclinoria of the Alaska range and by an orium. The powerful orogeny phase, which occurred during rocks, particularly in the region of the Takkeetna anticlin- batholithic intrusions and to a marked mineralization of by an intensive intrusive activity. The latter led to the have continued during the Lower Cretaceous, was accompanied by orogeny, which began in the Jurasic and may surround the Gulf of Alaska.

Alaska, including the greenstone greywacke-schistous belt may also be found in a number of places in the Southeastern Southeastern Alaska. Middle and Upper Jurasic formations Admiralty Island, Kupreanof, Gravina Islands and in the acious and schistous rocks encountered in the region of the Upper Jurasic deposits are composed of the argill- conglomerates, slates and several layers of limestones.

Lacking in the Matanuska synclinorium, a circumstance of the Alaska range. Cenomanian and Turonian deposits are occurrence of continental deposits in the synclinorium of the Cenomanian, are responsible for the unconf ormable of the orogenetic movements, which occurred at the end from the Matanuska synclinorium.

Chitina* and Psephytic Albian-Cenomanian rocks are known conglomerates have been recorded in the valley of the river river valley and in the region of the Arkose range. Marine deposits of this age have been detected in the Matanuska measure several hundred meters in thickness. Continental sandstones, conglomerates and argillaceous rocks and deposited here after the break. These formations consist Alaska. Aptian-Cenomanian continental formations were ness. So far no Aptian rocks have been found in Southern mountains these deposits consist mainly of limestones, sandstones, and argillaceous rocks measuring 240-360 m. in thickness. In the southern slope of Talkeetna 250 m. in thickness they are composed of arenaceous limestones up to clinoform they are little in the region of the Herendeen Bay and Matanuska synwackes, which measure several hundred meters in thickness, region of Nutzotin mountains by marine clay shales and gray deposits are represented in the Alaska range and in the anticlinal zone located along the Gulf of Alaska. Neocomian

movements at that time is further corroborated by the loss predominated at that time. The occurrence of ascending movements along the abyssal faults bounding these follows, Alaska during the Upper Cretaceous, were slight. Ascending p. 46

Milner et al (25) in the downwarped areas of Southern The dislocations, which occurred (according to D. Albian-Cenomanian continental deposits. beds consist of tufts and other fragmental rocks overlying beds occur in the synclinalum of the Alaska range. These clay shales and graywackes, while corresponding continental river Chugach Upper Cretaceous deposits include marine in thickness overlie these deposits. In the synclinalum of several tens of meters and 750 m. Marine clays up to 2500 m, thickness of these deposits varies in this region between which consist mainly of sandstones and conglomerates. The horizons of the cross-section by beds of marine deposits, Upper Cretaceous deposits are represented in the bottom Chitina* and the eastern zone of the Matanuska river basin Matanuska synclinalum. In the region between the river Upper Cretaceous rocks are widely distributed in the rocks, is another argument in support of this hypothesis. contact with Lower Cretaceous, Jurassic and even Triassic that period. The fact that Coniacian deposits are here in indicating that ascending movements occurred here during

of Maestrichtian and Danian deposits from the cross-section; weathering, or were never deposited on these territories. The first phase of the Laramide orogeny took place at the end of the Cretaceous—at the beginning of the Tertiary. The thick beds filling the depressions were uplifted and folded. This process was accompanied by an intensive intrusive activity. The folds, which formed at that time, are parallel to the trend of the principal up-lifts. The modern ranges of Alaska also formed at that time. The infilling rocks of the Chugach synclinorium became less intensive at the end of the Cretaceous—at the beginning of the Tertiary. The Chu-gach synclinorium was considered less intensive in the southeastern part of the Matanuska synclinorium; tectonic movements resulted here mainly in the general uplift of the territory and in the activation of the volcanic activity.

The Cenozoic period in the development of Alaska was characterized by the general bulging and weathering. Never-

theless, local deformations led to the development of elongated downwarped areas, where Cenozoic sediments accumulated along the coastlines, where Cenozoic sediments accumulated, were deposited, which formed during the Mesozoic. During this action remained accurate, similarly to that of the tectonic considerations, which formed during the Mesozoic. During this period advances of sea affected only the southern border of Alaska and were particularly intensive in the Yakutian and

mainly in the general uplift of the territory and in the formation and formed the Chugach mountains. The deformation was considered less intensive in the southeastern part of the Matanuska synclinorium; tectonic movements resulted here mainly in the general uplift of the territory and in the activation of the volcanic activity.

The Chu-gach synclinorium was considered less intensive in the southeastern part of the Matanuska synclinorium, where Cenozoic sediments accumulated, were deposited, which formed during the Mesozoic. During this period advances of sea affected only the southern border of Alaska and were particularly intensive in the Yakutian and

these formations were either destroyed by subsequent weathering, or were never deposited on these territories. The first phase of the Laramide orogeny took place at the end of the Cretaceous—at the beginning of the Tertiary. The thick beds filling the depressions were uplifted and folded. This process was accompanied by an intensive intrusive activity. The folds, which formed at that time, are parallel to the trend of the principal up-lifts. The modern ranges of Alaska also formed at that time. The infilling rocks of the Chugach synclinorium became less intensive at the end of the Cretaceous—at the beginning of the Tertiary. The Chu-gach synclinorium was considered less intensive in the southeastern part of the Matanuska synclinorium; tectonic movements resulted here mainly in the general uplift of the territory and in the activation of the volcanic activity.

The Chu-gach synclinorium was considered less intensive in the southeastern part of the Matanuska synclinorium, where Cenozoic sediments accumulated, were deposited, which formed during the Mesozoic. During this period advances of sea affected only the southern border of Alaska and were particularly intensive in the Yakutian and

The total thickness of marine and continental Eocene rocks and of marine sedimentary Oligocene rocks is here up to 7500 m. These formations have also been detected in the Yakataga downwarp, where they occur upon faintly metamorphosed Late Mesozoic (perhaps even older) sedimentary and volcanic rocks. Eocene deposits in the region of the Sheliakin downwarp became deformed during the Oligocene and of downwarp became folded a large portion of Miocene. The Lamaride folding affected a large portion of

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Sheikhof depressions. Lower Paleozoic deposits (presumably of Paleogene age) are (in the opinion of D. Miller et al. /25/) more closely related with regard to their structure to Mesozoic than to Cenozoic rocks. Continental deposits representing a thickness of about 2000 m, occur in the Matanuska River valley upon upper Cretaceous rocks, without visible unconformity. These deposits characterize the final stage of the sedimentation, which took place in the Matanuska synclinorium, since continental coal-bearing deposits, perhaps partly also marine deposits, measuring up to 3000 m in thickness, are extensively developed in the Cook Bay and Becharof depression. In the south of the Matanuska synclinorium lava beds, tufts and tuft breccias alternate with clinothrust rocks. This is a result of the early phase of sedimentary rocks. In the south of the Matanuska synclinorium, which has been going on intermittently volcanic activity, which has been going on intermittently

which occurred at that time. B. Kh. Egiazarov /14/ establishes within the boundary areas of the South Alaskan folded system six structural stages, which reflect the principal phases in the geological development of this region. The most ancient stage is the Lower Paleozoic (Cambrian /?/- Upper Silurian, possibly Late Cambrian) structural stage. In contrast to the Cordilleran belt, the south Alaskan folded zone is characterized in the Lower Paleozoic by eugeosynclinal conditions terraced in the Lower Paleozoic by eugeosynclinal conditions of sedimentation. Formations of slates, greywackes, cherts volcanic-pyroclastic and carbonaceous rocks accumulated during the Ordovician in the region of Kuitu and Prince of Wales Islands, on the islands of the Southeastern Alaska archipelago part of the Alaska range. Silurian deposits in the western part of the Alaska range. Silurian deposits separated from Ordovician formations by an angular unconformity, are represented by the formations listed above, as well as by carbonaceous and terrigenous formations. More over, the upper portion of the Silurian cross-section is composed of continental redbed formations.

The Southern Alaska and resulted in various degrees of deformation of the entire Alaskan territory. The closing stages of the Cenozoic were accompanied by orogeny, which continued well into the Quaternary. This led to the crumpling of the rocks, which were deposited during the Tertiary, into minor and modern folds. The modern mountain system of Alaska formed as a result of the intensive uplifts

enogenouslich. Thick beds of greenstone volcanic-pyroclastic
formity. The conditions of sedimentation remained here
are separated from the lower sub-stage by an angular uncon-
certain places) Perm-Triassic. These structural formations
of the undifferentiated Perm-Carbonaceous, Permian and (in
the upper structural sub-stage includes structures
stones, marbles, greywackes and greenstone slates.
and in the eastern part of the Range mountains by lime-
deposits are represented in the Alaska and Aleutian ranges
erates and greywackes formed at that time. Middle Devonian
alterations. Slates and cherts, to a lesser degree conglom-
the products of which were subjected later on to "greenstone"
marked by energetic manifestations of underwater volcanicity,
tation remained here enogenouslich. Furthermore, it is
formed, is characterized by that the conditions of sediment-
The period, during which the lower sub-stage was

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undifferentiated Perm-Triassic formations.
Permian substage. The latter includes in certain places
lower carbonaceous substage and the upper Carbonaceous-
consists of two sub-stages: the lower Middle Devonian -
terrigenous of the territory of Alaska. This structural stage
the cross-section of the Lower Devonian, a feature charac-
marked angular unconformity accompanied by the omission from
Paleozoic, is separated from the underlying stage by a
The next structural stage, i.e. the Middle-upper

clay shales, sandstones and limestones. At that time slates, altermations. The volcanic formations include cherts and which formed as a result of underwater, partly surface characterised by the occurrence of volcanic greenstone rocks, similarly to the Middle and Late Paleozoic, this period is the sedimentation proceeded under eugeosynclinal conditions. stages, i.e. during the Late Triassic and Early Jurassic, lying stage by a marked angular unconformity. At the early the Neocomian, inclusively. It is separated from the under after that, and it embraces the period from the Triassic to the Lower-Middle Mesozoic structural stage formed in the South Alaskan folded zone with the Upper Triassic. The cross-section of the Early Mesozoic begins clime. The orogeny continued during the Lower-Middle Mesozoic folded foundation of the Mesozoic-Cenozoic geosynclinal type, which have acted from then on as the pre-for the formation of the Paleozoic linear structures of the Paleozoic and Mesozoic. These movements are responsible orogenetic movements occurred on the boundary of the occur in the Southeastern Alaska.

In the Chintana river valley and in other regions. Silicic, carbonaceous, terrigenous and volcanic formations occurs, carbonaceous, terrigenous and volcanic formations rocks, accumulated at that time in the Wrangell mountains, formations alternating with carbonaceous and terrigenous

The intrusive activity, which accompanied these tectonic cross-sections of Hanterivian, Barremian and Aptian deposits. Circumstance evidenced by the omission from the Early Cretaceous, and later on, during the pre-Albian, a between the Late Jurassic (the Upper Cretaceous age) and the end of the Early Jurassic, as well as on the boundary stage was being formed. They were particularly energetic at intrusive activity occurred repeatedly while this structural Tectonic movements accompanied by an intensive angular unconformity.

wackes, which occur upon Upper Jurassic rocks with an represented mainly by thin beds of clay shales and grey Lower Cretaceous (Neocomian) deposits are here rocks with subordinate quantities of slates and greywackes. result of which there developed terrigenous and carbonaceous clinal conditions gave way to a lithology called regime, as a Jurassic folding terminated on this territory, the eugeosynclinal beginning with the Middle Jurassic, after the pre-Middle

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regions surrounding the Gulf of Alaska. Thereupon, schistous Nikolai formation accumulated, mainly in the During the Triassic the greenstone greywacke- Island and in the region of the Prince of Wales Bay. valleys of Matanuska and Nenana rivers, on the Kodiak along the boundaries of the Cook Bay depressions, in the greywackes and diabases were in the process of accumulating.

The Upper Mesozoic (Albian-Campanian, partly Maastrichtian) structural stage is represented by the structures consisting of marine deposits enclosing occasional coal seams. Minor genous deposits occurred in the Late Cretaceous - pre-Eocene. It folded zone during the Late Cretaceous - Upper Mesozoic structures and resulted in the formation of Upper Mesozoic structures and granitic intrusions, as well as in the migration of the sediments towards the Pacific Ocean. The geosynclinal downwarp towards the Pacific Coast, where thick terrigenous beds accumulated during the Eocene-Pliocene. The next, i.e. the Lower Cenozoic structural stage represents a new phase in the evolution of the territory including the Eocene-Pliocene formations. This stage examined. Intersratified continental and shallow-water marline deposits undergirding reciprocally facies - sandstones, which alternate here and erates, aleurites and argillites, which accumulate here and subsistutes, , accumulated here. Sandstones, conglom-

batholiths perforate the arch-shaped folded belt of Southern Late Jurassic and Early Cretaceous. A multitude of granitic movements, was particularly intensive in the Middle Jurassic, Alaska.

Geotectonic movements of this period have been recorded on the boundary between the Middle and Late Miocene, at the end of the Pliocene and in the Pleistocene. Block uplifts predominated here. The regions where Paleogene-Neogene deposits occur, are characterized by fairly gentle folds, whereas in the zones of intensive diastrophism the character of the folds changes drastically and they scarcely differ from the linear folds of the geosynclinal type.

The volcanic-pyroclastic formations dated tentatively as ranging from Paleocene to Pliocene in age possibly belong to the Early Quaternary, incisively, also belonging to the Lower Cenozoic structural stage. Deposits of this age overlie unconformably more ancient formations, have a gentle dip and a flat pitch.

The cross-section ends with the Upper Cenozoic formations generated in the Young downwarp of the Cook Bay, (Neogene-Quaternary) structural stage, which amalgamates the Gulf of Alaska and Shelikof Straits regions. This stage formats generally of unconsolidated Quaternary sediments consists mainly of unconsolidated Quaternary sediments

the southern part of the Shelikof downwarp. And tuff breccias with blocks of sedimentary rocks occur in cross-section of this structural stage. Lava beds, tufts

deposits are represented by limestones, sandstones and other

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of all the stages, with the exception of the Cambrian. These extension of the Talkeetna anticlinorium. It includes rocks The Prince of Wales anticlinorium is the southernmost volcanic products.

encountered in outcrops, which contain large quantities of

norium. Mississippian and Permian deposits have been

extensively developed within the boundaries of the anticlinal-

igenous rocks, as well as volcanic Cenozoic rocks are

Mesozoic and Cenozoic rocks. Jurassic and Cretaceous

Alaska range synclinorium, is composed of Paleozoic,

The Talkeetna anticlinorium located south of the

perfected here and there by intrusive bodies.

greywackes, occasionally calcareous sandstones, that are

Mesozoic terrigenous rocks, such as sandstones, schists,

with heavily metamorphosed and displaced Paleozoic and

The Seymour and Alaska range synclinoria are filled

Alaska.

orogenic arch forms the boundary between Central and Southern

Alaska. The Coast Range-Seymour-Prince of Wales-Talkeetna

greenstone zone (Fig. 1), have been established in Southern

the Coast range, Prince of Wales, Talkeetna, Seldovia,

Matanuska, Chugach, Yakataga) separated by anticlinoria of

large synclinoria (Seymour-Alaska range, Sheldtka-

filling the Copper, Susitna and other depressions.

and other American researchers believe that the Cook Bay which overlie dislocated Paleozoic rocks. T.E. Kelly /19/ montane hollow filled with Cenozoic and Mesozoic rocks, The Cook Bay depression is a narrow elongated inter-

are situated within the boundaries of this synclinorium. norium. Depressions of Cook Bay, Susitna, Alaska peninsula tectonic elements as one single Matanuska-Sheleiko synclinal /25/. It therefore appears expedient to examine these ties of composition, as those of the Matanuska synclinorium deposits reveal the same lithological and facies pecularities western extension of the Matanuska synclinorium, and its Sheleiko downward is essentially the south- occur in the southwest extremity of the Alaska peninsula. Shelikof downward, while marine Eocene and Neogene deposits and volcanic Eocene rocks, are widely distributed in the examined. Paleogene-Neogene outcrops composed of continental here, since it is located to the south of the territory Alexander Archipelago. This depression is not described regarding to oil and gas, is the intermediate depression in the Wales anticlinorium known to hold a certain promise with volcanic rocks. So far the only region of the Prince of with the exception of the Pensylvanian formations, contain is markedly deformed and metamorphosed. All these deposits, rocks of marine origin. A large portion of the cross-section

beginning of the Middle Jurassic, and that prior to that it formed part of a large depression, which occupied most of the territory of the modern Southern Alaska. Rocks ranging from Upper Triassic to Middle Tertiary in age are now exposed in the Cook Bay depression (Fig. 7). Volcanic Mississippian deposits consisting of argillites, limestones, siliceous rocks and conglomerates, also participate in the formation of the depression on the upper course of Susitna River. F. Smith /61/ concluded on the basis of paleontological data that the Mississippian and Permian deposits are separated by a hiatus. B. Kh. Egiazarov /14/ believes that the absence of Pennsylvania and Permian formations corroborates the existence of such a break.

Permian formations are represented by basalts, tufts, tuff breccias, argillites, siliceous rocks, limestones and conglomerates. The overall thickness of the sedimentary mass is in the Cook Bay depression up to 8-9 km.

Lower Triassic deposits occur commonly in this depression upon Permian rocks and are represented mainly by greenstone rocks of the Nikolai formation, while upper Triassic formations are here represented by hornfels, schists, sandstones, tufts and limestones. The total thickness of the Triassic

The Jurassic cross-section begins following the deposits is over 600 m./19/.

*Transliteration. (Translator)

*Chinita in the text. (Translator)

measuring over 600 m, in thickness, has been traced in the horizon of the Arkose Ridge arkose sandstones, . A horizon of the Arkose Ridge arkose sandstones, by marine schists and sandstones with isolated interlayers of conglomerates. This formation is over 1200 m, in thickness. These deposits include the Matsunaka formation represented by massive schists and sandstones which measure 61 m. in thickness. Deposits occur unconformably upon the Lower Cretaceous rocks. The Nechohina formation 100 meters thick. Upper Cretaceous rocks and arkose beds of massive fine-grained limestone of conglomerates and arkose sands, which measure 61 m. in thickness. Formations. Lower Cretaceous rocks are represented by tuff Cretaceous deposits occur unconformably upon Jurassid between 610 and 1525 m.

sent by schists and sandstones. Their thickness varies (probably with a break) upon this formation, and are represented by the Naknek* formation, which occurs unconformably thick. Rocks of the Nechohina* formation occur unconformably red and dark red marine argillaceous shales 1000 meters sent by the Chinita* formation, which consists of beds of arkose sands having a maximum thickness of 2440 m. Upper jurassic deposits occur at a higher level and are represented by the Arkose has a thickness of 900 m. The middle jurassic tuckeadi formation consists of sandstones, schists, conglomerates and which has a thickness of 900 m. The middle jurassic tuckeadi upper Triassic break with the volcanic Takkeetna formation,

and lignite beds. According to the data of T.E. Kelly /19/,
conglomerates and schists interstratified with mineral coal
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are represented here by Lenticular sandstones, argillites,
analogues of the Paleogene-Meogene deposits. These rocks
rocks of the Kenai formation on Kenai Island are
unconformably has been recorded between these two formations.
section of the Eska formation. A distinctly defined local
have been established by Barnes and Payne /45/ in the cross-
thickness of 1000 m. Two formations (Tsadaka and Wischbone)
arenaceous rocks of the Eska formation. The latter attain a
by gravel, sand and conglomerates with sparse horizons of
in the profile these deposits are unconformably overlapped
thickness of this formation is close to 1500 m. Higher up
argillaceous rocks with a multitude of coal beds. The total
represented in the Matanuska valley mainly by arenaceous
Paleogene deposits of the Chikaluk^{*} formation are
formations.

formation occur unconformably upon the Upper Jurassic
the eastern part of the Alaska Peninsula. Deposits of this
Kochuyak formation, have been detected at certain points in
Cretaceous sandstones and argillites referred to as the
strata of this horizon may be of Cenozoic age. Upper
upper portion of the Cretaceous cross-section. The top

The thicknesses of these deposits in their deepest portion is 5490 m. Deposits of this formation are subdivided by American geologists in electrical coring/logging/diagrams into five zones, which are distinctly defined from the geological viewpoint in the region of Cook Bay. The upper zone (measuring 1525 m. in thickness) consists mainly of thick beds of medium- and coarse-grained sands with relatively thin intercalations of grey schists and Lenticular lignite. The zone of sand overlies beds 610 meters thick, which are composed of interstratified schists and argillites with fine interlayers of sandstones and lignites. The third zone consists of schists and measures 915-1525 m, in thickness. The schists overlie the fourth Hemlock sand zone, which is represented by sand lenses markedly varying in thickness even over small distances. The fifth zone extends from the foot of the Hemlock zone of sands to the root of the Mesozoic deposits; it consists of alternating beds of fine-grained sandstones and dark schists. The thickness of the zone varies from 10 to 100 m.

The relatively small limestone Susitna depression separated from the Cook Bay depression by a fracture, which extends along the slope of the Castle mountains, is located to the north of the Cook Bay depression, on the territory of the Matanuska synclinorium. T.E. Kelly concluded that this depression, though linked in the south with the Cook Bay

The intermediate depression of the Alaska peninsula
600 m, south of this outcrop, near its northwestern boundary.
together with the lateritic volcanic formations may attain
the Paleogene formations, which crop out on the surface,
younger formation of the Paleogene system. The thickness of
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has been tentatively dated as Oligocene or as a somewhat
coarse-grained gravel measuring 150-330 m. in thickness. It
wakes. It appears to be conformatly overlapped by a bed of
formity upon markedly discordant Mesozoic schists and grey-
presumed to be of Eocene age and occurs with angular uncon-
gritstones and clays containing lignite. The block is
block consists of loose and weakly cemented sandstones,
northwestern boundary of the Cook Bay depression. This
having a maximum thickness of 270 m, crops out near the
continental coal-bearing Eocene deposits). A block of rocks
partly, by Paleogene-Mesogene stratified rocks (mainly by
essentially with unconformable Quaternary deposits and,
the Susitna mountains. The Susitna depression is filled
granite massif of the Talkeetna mountains and intrusions of
It is possible that this ridge forms a link between the
faults from Clark Lake to the Castle mountains, incisively.
does, indeed, exist. The hills extend along the system of
with the Susitna depression, indicate that the buried ridge
granite ridge. Granite hills resting on the southern border
two depressions are probably separated by a partially buried

located to the south of the Sel'dov'ia anticlinorium. Rocks

The anticlinorium of the Chugach mountains is

intrusions.

deformed, metamorphosed and invaded by large and small outcrops of the anticlinorium these rocks are, as a rule, markedly cherty, clay shales and graywackes. Within the boudaries and sedimentary marine rocks, which consist of limestone, and sandstone, crop out in the eastern part of this anticlinorium. Outcrops of Triassic and Permian rocks have also been found here. These outcrops are represented by alternating volcanic incrustations of volcanic products and recrystallized lime-sheikholes-Matankaska synclinorium. Mississippian deposits composed of slates and crystalline schists with negligible thickness of shale-Matankaska synclinorium. The southeastern part of the Sel'dov'ia anticlinorium is situated south of the Sheleikof-Matankaska synclinorium.

The Mesozoic deposits appears to be 5-8 km. downwarped part of the depression. The overall thickness of bearing continental Pliocene deposits in the most markedly Cretaceous age. These deposits may be overlapped by coal-unaltered, mainly marine deposits of Triassic, Jurassic and in its continental portion the depression is filled with even farther, under the waters of the Pacific Ocean (Fig. 1). Located under the waters of the Sheleikof Bay and extends slope of the Aleutian range, while its southern part is portion of this depression embraces the southwestern coastal the Matankaska-Sheleikof synclinorium. The northwestern is located southwest of the Cook Bay, on the territory of

data and neither oil manifesterations, nor gas shows have been received. However, further investigations failed to corroborate these indications of the presence of oil and gas in these beds.

and gas-bearing region because of certain information and gas-bearing initiation rated by American geologists as a potential oil.

its unfavourable general character, this territory was of rocks encloses a multitude of quartz veins. In spite of territorial of the anticlinorium, and the sedimentary complex bodies are fairly small, but extensively developed on the

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number of places argillaceous rocks are schists. Intrusive mafic deposits have been intensively disseminated. In a zone of dip of the rocks on the territory of this anticlinorium show that the sediments of displacement and the high angle of Upper Coniacian - Lower Santonian. The presence of the zones These deposits have therefore been tentatively dated as have been found here only at three widely separated locations. though these deposits are of marine origin, organic remains from several hundred thousand meters. Even thicknesses varies according to the data of D. Miller et al with compact, poorly differentiated sandstones. Their total sented by beds of argillites and schists interstratified central part of the Kadiak Island. These rocks are represented across the Chugach and Kenai mountains, as well as in the the territory of this anticlinorium, in the zone extending of a clearly defined lithological composition crop out on

The Chugach mountains synclinalum is bounded in the south by an anticlinalum composed of greenstone rocks of the Mesozoic belt. This belt surrounds the Gulf of Alaska and is located between the Kadiak Island in the west and Baranof Island in the southeast. D. Miller et al /25/ believe that the greenstone belt anticlinalum resembles the Seladovia anticlinalum in its lithological composition, mode of occurrence of its rocks, their sedimentation, as well as in the time of its formation. Schists, gleywackes and same deposits crop out on the surface within the boundaries of which the greenstone belt anticlinalum is formed. These products of underwater lava flows are the type of deposits in the Seladovia anticlinalum in its lithological composition, mode of occurrence of its rocks, their sedimentation, as well as cross-sections of its rocks may underlie Upper Cretaceous schists and gleywackes of this zone. Many researchers believe that these deposits may underlie Upper Cretaceous rocks in the synclinalum of the Chugach mountains. As a result of the decomposition of vegetation remains formed as a result of the decomposition of contemporaneous marshes and lakes. Between Seward and Kenai Lake, is a typical marsh gas, which detected in Cordova and along the Alaskan railway line found here. It has now been established that the gas at the bottom of contemporaneous marshes and lakes.

between Seward and Kenai Lake, is a typical marsh gas, which detected in Cordova and along the Alaskan railway line found here. It has now been established that the gas between Seward and Kenai Lake, is a typical marsh gas, which detected in Cordova and along the Alaskan railway line found here. It has now been established that the gas

guided by the assumption that the complexes established
In differentiating these beds, the researchers were
stratigraphic complexes.

and faunal characteristics into three lithological
Paleogene-Neogene rocks on the basis of their lithological
area of the Gulf of Alaska. D. Miller et al subdivided the
and extend farther south, into the offshore and inner
the Quaternary sediments, which crop out in the coastal zone
Paleogene-Neogene formations also occur under the mantle of
western shore of the Yakutat Bay. It is quite probable that
widely distributed between the Katalla region and the

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stages, from the Eocene to the Pliocene inclusively, and are
The Paleogene-Neogene rocks are represented by all the
unconformity upon volcanic and sedimentary Mesozoic rocks.
group is 7600 m. These deposits occur with an angular
maximum thickness of the sedimentary rocks of the Cenozoic
are overlain by unconformably deposited rocks of Quaternary age. The
are the predominant rocks exposed here. These formations
which probably formed during the Paleogene-Neogene period,
south of the greenstone belt. Marine deposits, most of
The Yakataga (St. Elias) synclinorium is located
hold no promise of oil and gas.

phism active in this zone, the rocks of the belt examined
action of the rocks caused by the thermo- and dynamometamor-
result of an intensive deformation and because of the alter-

*Transliteration. Is spelled Kalite in another place. (Translator)

complex are completely omitted from the Malaspina which crop out in the Vituya region. Deposits of this part of the cross-section of the Paleogene-Neogene rocks Paul Creek formation in the Yakataga region and the bottom Katalla formation in the region of Katalla, as well as the complex includes the lower and middle portions of the Yakataga regions are associated with this complex. The organic matter. The principal oil shows of the Katalla and this area. Rocks of this contain an abundance of tufts and agglomrates is a sign of volcanic activity in the cross-section of alternating interlayers of marine slates of compact argillites and aleurolites. The presence of Middle Miocene - Middle Oligocene complex regions, and does not occur at all in the Vituya* region. The Kugitag*, Stilwatter and Tokun formations in the Katalla the Kugitag*, Stilwatter and Tokun formations in the Katalla menets of salinized basins. This complex of deposits includes well as by shallow-water and marine formations and by sediments of salted carboniferous deposits, as interstratified continental and carboniferous deposits, as perhaps also Lower Miocene in age, and it is represented by the Yakataga synclinorium. The oldest complex is Eocene, tions of sedimentation, which took place on the territory of reflect in their composition the main changes in the condi-

coastal zone is characterized by broad synclines and by greater areal extent and are less markedly sinuous. The are, generally smaller, but more markedly elongate, have a more easterly orientation. Farther south, in the intermediate zone, the folds the many steep upthrusts sloping down in the northern direction. Minor folds, are often overturned, and are displaced along Palaeogene-Neogene deposits are intensively crumpled into Chugach mountains towards the St. Elias mountains, where zone borders on the regional disturbance extending along the boundaries of the Yakataga synclinorium. The foothill three tectonic zones have been established within

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islands in the Gulf of Alaska.

by the rocks cropping out on the surface of the Middleton which occurs in the Yituya region. Lastly, it is represented now been classified as an independent stratigraphic unit and as well as of the upper part of the cross-section, which has Yakataga formation in the region of Yakataga and Malaspina, the Katalia formation in the region of Katalia, of the argillites. This complex is composed of the upper part of argillites. Intermediate shaly-water sandstones and aleuropelites interstratified with conglomrates and arenaceous represented by marine shaly-water sandstones and aleuropelites between the Middle or Upper Miocene and Upper Pliocene, is between the Lower and Upper Quaternary rocks.

The youngest complex, which formed during the period cross-section, where unconformability has been established

instance. (Translator)

*Transliteration. Spelled Koltit in another

and gas shows from these basins have been known for a long structures in the south and in the west (Table I). Many oil above, as well as to the Cordilleran belt bordering these Canadian and Hyperborean platforms, which have been described basins are confined to the large negative structures of the subarctic regions of the North American continent. These bearing basins has been established in the Arctic and a total of 21 producing and potential oil - and gas-

American Arctic and Subarctic regions.

Producing and potential oil - and gas-bearing basins of the

at ion upon the Paleogene or pre-Paleogene rocks. Formable occurrence of the upper part of the Yakataga formation and Yakataga deposits, as well as in the unconformably and Yakataga in the form of lithified breaks between the observed in the deformations and uplifts. These two stages can now be during the Paleogene-Neogene there occurred here two stages folds are particularly extensively developed in this region. Cenozoic orogeny, block movements along the faults occurred essentially above the folding, as a result of which broad In the region of Malaspina, during the upper ances.

narrow, squeezed folds broken up by longitudinal disturbance

virtually demarcated. Its recoverable reserves have been
of the discovery well. By the end of 1969, this field was
the second well drilled in this structure, 11.51 m. south east
bearing Ivishak sandstones of Triassic age were stripped in
with a flow of 159 tons/day was tapped in that well. Oil-
limestones, which occur at the depth of 2851-2947 m, oil
2597-2601 m. While testing the Mississippian Lissabone
flow of approximately 334 tons/day from the interval of
2475 m, then oil, having a density of 0.84 g/cu. cm. and a
from the Triassic sandstones occurring at the depth of 2463-
of all a gas spot with a flow of 1.1 million cu. m./day
fold measuring 56 x 5 km. The discovery well yielded first
The Prudhoe oil field is confined to an anticlinal
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deposition.

covered early in 1968, in the coastal zone of the Umiat
basin. The largest, i.e. the Prudhoe oil pool was dis-
Mead elevation, within the boundaries of the Arctic slope
1950's on the territory of the uplifted part of the Barrow-
small oil and gas fields were detected in the Late
Bay (Cook Inlet) and St. Elias (Yakataga).
of Alaska, Beaufort, Sverdrup, Mackenzie, Eagle Plain, Cook
found only in the following seven basins: the Arctic slope
time, but economic deposits of oil and gas have so far been

having a density of 0.84 g/cu.cm. and yielding a flow of 55
discovered on the slopes of the Colville depression. Oil
A number of small oil and gas fields has also been
1.4 tons a day.

stones occurring at the depth of 914 m. Its flow is up to
density of 0.97 g/cu.cm. was obtained from Cretaceous sand-
milliard cu. m. In the Fish Creek field, oil having a
depth of 770-1080 m. Its reserves amount to at least 0.5
field is confined to jurassic sandstones occurring at the
as equal to 1.7 milliard tons. The gas pool of the Barrow
to Cretaceous sandstones. Its reserves have been estimated
Barrow dome. The oil pool of the Simpson field is confined
Three oil pools were discovered in 1948-1950, in the
and measuring up to 100 m, in thickness, contain oil.
horizons occurring here at the depth of approximately 3000 m.
covered that the arenaceous and carbonaceous Triassic
region. These are Ugnus, Eileen and Delta. It was dis-
In 1969, three more fields were detected in this
speculation by various oil companies.

intensive prospecting operations, as well as to risk
the adjacent mainland and offshore regions are subject of
the present time this entire oil-bearing region, as well as
in some of the estimates as high as 2-4 milliard tons. At
estimated as equal to 0.7-1.35 milliard tons, and are rated

argillaceous sedimentary rocks of Mesozoic, to a lesser

The Sverdrup basin is filled with arenaceous-

3800 m.

possibly, Jurassic deposits having an overall thickness of

Richards Island, exposed Tertiary, Cretaceous and,

A well bored on the southern extremity of the

from the depth of 964 m.

Furthermore, an oil gusher was obtained in the same well

not been determined as yet (Paleogene-Neogene-Cretaceous?).

is represented by sands and sandstones, the age of which has

depth of 1738 m. It is assumed that the productive horizon

on the Tuktoyaktuk peninsula, stripped an oil horizon at the

ratory N-25 Atkinson well, located in the delta of Mackenzie

present in the Beaufort basin. In January 1970, the explo-

Cenozoic and Upper Mesozoic deposits are known at

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a day; these fields have no economic significance.

fields the flow of gas did not exceed a few thousand cu.m.

gas reserves are here 8.5 billion/cu.m. In the remaining

of productive horizons varies between 270 and 1130 m. The

clinal fold measuring 20 x 4 km. The depth of occurrence

million tons. The Gubik gas pool is confined to an anti-

reserves of the two fields amount to approximately 9.5

later date, is located east of the Umiat field. Oil

the Umiat field. The East Umiat field, discovered at a

tons/day, is obtained from Lower Cretaceous sandstones in

exten^t Cenozoic age, as well as with argillaceous and evaporative bituminous sands of the Lower Triassic Björn formation, which crops out throughout the periphery of the basin, have been detected on the Melville Island in 1962. G.R. Tretiakov and L.V. Khil's (Hilts?) (1964) have estimated that the bitumen reserves are up to 0.7-1.35 million tons and that 0.4 million tons of oil having a density of 1.03 g/cm³. can be extracted from these reserves. These researchers believe that the bitumen formed here between the Pennylvanian and Jurassic, and that a portion of the oil produced migrated to the Middle Jurassic and still younger formations.

Mesozoic reservoir beds which measure up to 10,000 m, in thickness, are now the principal object of prospecting. Cenozoic deposits commonly crop out on the surface and have little economic value, even though in certain places they have a thickness close to 3000 m. Those deposits are represented in the main by coal-bearing formations with inter-

In June of 1969, when the Drake Point well was drilled on the Melville Island, a gas burst occurred when layers of conglomerates and boulders.

In June of 1969, when the Drake Point well was drilled on the Melville Island, a gas burst occurred when

gas pools are here confined to the upper part of the Keokuk confined to the Paleogene-Neogene deposits. Moreover, most

The main oil reserves of the Cook Bay basin are

been explored further.

from Pennsylvania sandstones. So far this field has not produced oil and gas issue from a depth of 1275 m, of 6-7 tons. The oil and gas issue from a large meridional fold, yielded a productive flow of gas and low-density oil with a discharge bored on the dome of a large meridional fold. In 1960, the exploratory well intermediate depression. In 1960, the exploratory well

The Eagle Plain basin is confined to the Eagle Plain

OrdoVICIAN age may also hold a certain promise.

basalitic sandstones and bioluminal formations of Silurian and been estimated as equal to 7 million tons. Cretaceous imately 300 m. The recoverable reserves of this field have of Middle Devonian age, which occur at the depth of approx enzite basin in 1920. It is confined to bioluminal limestones The Norman wells field was discovered in the Mack-

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of 1403-1445 m.

well, an unproductive oil flow was recorded in the interval small bursts occurred from the same interval. In another occurring in the 1098-1159 m. interval. In May 1969, two from the 27.5 meter thick stratum of Jurassic sandstones released. Certain specialists believe that the gas issues however, no precise data on the depth from which the gas was the core was lifted from the depth of 2569 m. There are,

Inaskin Peninsula was generated in the same formation, in it is now believed that the Jurassid oil of the recorded at the depths of 1920-2930 m. oil and gas, as well as of their distillates have been ranging from several meters to 2800 m. Small seepages of traces of oil and gas have been encountered at the depths are the Mesozoic oil reservoirs in the region of Cook Bay. Middle Jurassic sandstones of the Tuxedni formation interlayers.

occurs in thick sandy clay beds and in slender lignite depth of 900-1500 m. In producing horizons methane gas also is located in the first zone of the Kenaï formation, at the main bulk of the sands containing productive gas, up to 30-60 cu.m./ton.

sandstones at the depth of 3000-4600 m. The gas factor is 0.83 g/cu.cm. are confined to moderately compact Lenticular mudrocks. Reservoirs of oil having a density of 0.88- this region are associated with the sands of the Hemlock zone having a porosity of 18-24% and a permeability of 1000 of the Kenaï formation (Fig. 8). The main oil horizons of region. These fields are confined to the arenaceous deposits fields and nine gas fields are now known in the Cook Bay situated with the Hemlock zone of the same formation. Six oil formations (the first zone), while oil pools are here associ-

gulfically because of the proximity of the removal sources, and Palaeogene-Neogene rocks. The latter became deposited very phosered and deformed prior to the accumulation of the Neogene oil reservoirs, since these rocks had been metamorphosed not have served as source rocks for the Palaeogene could not have collected in Tertiary reservoirs, appears to be less the oil collected in Tertiary reservoirs, appears to be less these same Neogene-Palaeogene rocks. The Jurassic source of formations may have formed in Cretaceous deposits, or in formed in these same rocks. Oil of the Palaeogene-Neogene found in the Jurassic deposits, probably poor conductors.

stones, which occur above the volcanic beds, are equally the tuffogenic oozes interstratified with the cherty limestone middle Jurassic reservoirs. It must be further noted that the hydrocarbons would have to pass on their way to the fragmental volcanic rocks 1000 meters thick, through which middle Jurassic reservoirs, since they underlie beds of ever, that these beds could scarcely generate oil into among the source rocks of oil. T.E. Kelly maintains, how-

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that many American researchers also range Triassic limestones migrates from there into sandy reservoirs. It must be noted by T.E. Kelly /19/ as the source rocks of the oil, which the basaltic horizons of the Tuexdant formation, are regarded which it is found today. Dark amphibolites, which abound in

River Field (Fig. 8). The oil-bearing sands of the Kenai
the Kenai Peninsula from the well, which found the Swanson
In the Cook Bay basin oil was obtained in 1957, on

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oils of California.

explored fields) is similar in base to the Paleogene-Mesocene
River Field, (i.e., one of the largest and most thoroughly
American geologists believe that petroleum from the Swanson
both continental and offshore marine sedimentary formations.
the Paleogene-Mesocene basaltic sand beds, which consist of
Most researchers believe that petroleum formed in

Cretaceous and in still older deposits.

should have affected the distribution of the oil formed in
Cretaceous and Paleogene-Mesocene deposits. This unconformity
unconformity (though it is fairly negotiable) between the
the Hemlock horizon. We must take here into account the
bottom strata of the porous and readily previous sands of
upper Cretaceous source rocks, have accumulated in the
would appear that the hydrocarbons, which migrated from the
the basis of the data available at the present time. It
cul to trace the paths of migration of the hydrocarbons on
of the oil found in these rocks, but it is extremely diffi-
formation. Cretaceous deposits are probably another source
of the oil accumulated in the sandy reservoirs of the Kenai
rocks of Paleogene and Mesocene age were probably the source
never became either metamorphosed, or dissolved. Basaltic

suíte referred to as the Hemlock horizon, were stripped at the depth of 3400 m, amidst coal-bearing deposits of Eocene age. The thickness of this horizon fluctuates between 2.5 and 90 m. While testing the well, a 125 tons/day flow of oil with a density of 0.876 g/cu.cm. was obtained. In 1969, a gas pool with a flow of gas equal to 227 thousand cu.m./day was detected in this field at the depth of 2325-2332 m. In the course of 12 years (1957-1968) of exploitation, a total of 11.6 million tons of oil and 330 million cu.m. of gas was produced from this field. The original recoverable petroleum reserves were estimated as equal to 27.5 million barrels produced from this field. The next stage was the discovery in 1959, of the large Kenai gas field, which is the main gas producer even now. This field is located 40 km. southeast of the Swanson River field, and is confined to an elevation, which measures 3.5 x 2.5 km, and extends partly under the waters of the Cook Bay. The gas-bearing horizon is confined to the sandstones of the Kenai suite, which has a thickness of 11-40 m. and occurs at a depth of 1067-1673 m. In 1967, a gas-bearing horizon was found in this field, in the middle of the Kenai suite, at the depth of 2745-2916 m. The initial flow of gas was 524 thousand cu.m. a day. At the present time the gas flow fluctuates between 140 and 350 thousand cu.m. a day. The original gas reserves in this field exceeded apparently 100 million cu.m. During the period of time the gas flow fluctuates between 140 and 350 thousand cu.m. a day. The original gas reserves in this field exceeded apparently 100 million cu.m.

The porosity varies from 12 to 22% (i.e. on an average is 15.111 idarites and it is equal on an average to 100 million idarites. and coal. The previous sandstones has been estimated as 1 to 500 coarsely differentiated sandstones with an admixture of clays markedly in thickness. Reservoirs are represented by

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in the northern part of the structure. The horizons vary confined to the middle of the Kenai suite and are situated and contains heavy oil. The main productive horizons are this structure. The first one is at the depth of 1590 m, south. Several productive beds have been established in The structure measures 1.5 x 1.6 km. and extends north to in 1963, in the central part of the Cook Bay water area. The large Middle Ground Shoal oil field was detected for the time being.

The Sterling, Beluga River and North Cook Inlet fields were being exploited. The remaining, smaller fields are frozen the Middle Creek (1967), Beaver Creek (1967). By 1970, only Nikolai Creek (1966), Middle Ground Shoal North (1966), Ivan River (1962), North Fork (1966), Birch Hill (1962), Beluga River (1962), North Fork (1961), West Frelan and False Creek (1961), North Cook Inlet (1961), Sterling (1961) are as follows: West Fork (1960), Sterling (1961), Island) are the gas fields discovered between 1960 and 1967, in the region of the Cook Bay (including the coast of the Kenai field.

1959-1968, 475 million cu. m. of gas were obtained from this

The Granite Point field is situated in the north-western part of the Cook Bay. A petroleum flow of 380 tons/day was obtained from the sands of the middle horizons of the Kewai suite, from a depth of 2340-2490 m. The flows obtained from the other wells fluctuate between 347 and 764 tons/day at the diameter of the drill bit equal to 15.8 mm, and at the operating pressure of 30.5 atmospheres. The gas factor is here 750 cu.m./cu.m. Since the beginning of exploitation in 1969, 4.1 million tons of oil having a density of 0.816 g/cu.cm. have been recovered from 22 wells. The MacArthur River field is located west of the Middle Ground Shallow fields. An oil gusher having a flow of

In 1965, three other large fields were discovered in
the Cook Bay. These are Granite Point, MacArthur River and
Wells.

16%). The content of gas in the petroleum fractions within the limits of 83-115 cu.m./cu.m. The virgin rock pressure is 280 atmospheres at the depth of 2550 m, in the middle of the structure; in other parts of the structure the pressure changes at the depth of 2784 m from 189 to 406 atmospheres. Oil flows in producing wells are of the order of 700 tons/day. The initial recoverable oil reserves of this field amounted to 20 million tons. Since the beginning of the exploitation in 1969, 2.8 million tons of oil having a density of 0.849 g/cu.m., have been recovered from 33 producing

1967-1968, led to the discovery of another oil pool farther here. The survey and prospecting operations carried out in cu.m./day of gas and a 47 tons/day flow of oil were obtained

suit, at the depth of 1806 m. A flow of 132 thousand tapped a new gas-bearing horizon in the middle of the Kenaï

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at the depth of 2400 m. Another well drilled in 1966, at the bit of 12.7 mm) from the Hemlock sandstones occurring spout with a flow of 76 tons/day (at the diameter of the MacArthur River Fjeld. The discovery well yielded an oil

The Trading Bay oil field is located north of the

area forms part of the MacArthur River Fjeld.

the depth of 3257 m. It was discovered later on that this mm) was obtained from the Hemlock sandstones occurring at 185 tons/day (at the diameter of the drill bit equal to 19 the territory of Dolly-Werden*, an oil spout with a flow of

In 1966, 6 km, south of the MacArthur River Fjeld, on

g/cu.cm. have been recovered from 6 wells.

1.05 million tons of oil having a density of 0.84-0.85 at a depth of 3340 m. Since the exploitation began in 1969, tons/day from the same horizon, which occurs here, however, oil in another well drilled 3 km, farther southeast, was 256.2 horizon occurring at the depths of 2896-2905 m. The flow of 190 tons/day, was obtained from the sands of the Hemlock

the Katalla oil field) have been detected in the Paleogene-Neogene deposits of the St. Elias basin. In the course of the 32 years of exploitation (i.e. from 1902 until 1933), 20 thousand tons of paraffin-base petroleum with a density of 0.802-0.820 g/cm. have been recovered in this field. Jointly sandstones and aleurolites, occurring at the depth of 110-534 m, serve here as reservoir rocks. On the slope of the mountain Raggled, west of the Katalla region, liquid oil was found in solid aleurolites and sandstones (possibly of Paleogene age), as well as in Cenozoic metamorphosed rocks, which occur in contact zones with Paleogene rocks. Oil shows confined to the diasturbance which extends along the coast of Alaska, have also been discovered here. Oil and gas manifestations were discovered on this territory in the well drilled in 1954-1955. A large number of oil shows has been detected near the northern edge of the Malaspina

The latter is confined to deposits of the Hemlock horizon north (Trading Bay North) and of another productive horizon and occurs at the depth of 2947-3035 m. Since the beginning of the exploitation in 1969, 0.3 million tons of oil having a density of 0.85 g/cu.cm., have been recovered from 12 wells. The oil-and-gas-bearing Cook Bay basin is now actively exploited, even though in 1968, it ceded its leading position to the Arctic regions of Alaska.

example, in the southern part of the basin, in the reef biotopes of Devonian age, a situation discovered, for platform part of the basin they may also be associated with tonic screened oil pools in the foredeep. In the remaining anticlinal folds, having a meridional trend, and with ductive beds taper out, as well as with the zones of the pools may be associated with the zones, where the main productive northern Subarctic part of the basin the oil and gas

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part of the basin by terrigenous Mesozoic formations. In basin is composed in the main of pre-Devonian and Devonian carbonaceous deposits, which are overlain in the foothill east to west, towards the Cordilleran folded belt. The territory of this basin increases to 5 thousand meters from basin). The thickness of the sedimentary mantle on the northern extension of the West Canadian gas-and oil-bearing belt of the Canadian Platform (representing essentially the downwarped and the northern part of the western homoclinal Victoria, Jones-Lancaster depressions, Pirri-Eillesmere Canadian Platform are the Wollaston, Foxe, Melville other potential oil-and gas-bearing basins of the continental deposits of Upper Cretaceous age.

Kalite* formation, which consists of alternating marine and glaciator. The oil is here enclosed in the rocks of the

central Tanana, Nushagak, Copper and Susitna depresions, as

The Yukon-Koyuk, Yukon-Flats-Kandik, Selawik,

be regarded as a potential oil - and gas-bearing basin.

Folded belt in Northern Greenland. This depression can also

occurred at the time of the formation of the Caledonian

probably formed originally in ancient fractures, which

Baykalian, Caledonian and Hercynian age. The depression

place of intersection of various folded systems of

within the boundaries of a complex geological junction, at the

carboniferous and Permian systems. The depression formed

superimposed Wandel's depression filled with deposits of the

and littoral parts of the Wandel's Sea, there occurs a small

In the extreme north of Greenland, in the coastal

and gas-bearing basin.

Local structures indicates that it may be a potential oil-

area, the thickness of its infilling and the presence of

in thickness. The favourable structural position of this

with Ordovician and Silurian deposits measuring 1000-3000 m,

platiform joins the folded Franklin belt. It is filled mainly

land coast, and it extends into the zone, where the Canadian

coast of the Ellesmere Island and on the northwestern Green-

located within the boundaries of the southern and eastern

The pericratonal Piriki-Ellesmere downwarp is

Rainbow-Zama* region.

Letters of "oil". Bituminous limestone and shales have also Creek Valley, showed that 1 ton of the rocks contains 106 clay shale sample taken from Triassic rocks of the Trout amidst the Upper Triassic deposits. Analyses of a bituminous formation. Fairly thick combustible shale beds occur overlie Triassic rocks containing bituminous-argillaceous where they are not in contact with durassic deposits, they blocks measuring 600-900 m. in thickness. In the events lower Cretaceous (Neocomian) deposits include sandstone and carboniferous formations hold here a certain promise. Geological surveys and geological investigations, Devonian No drilling has been done so far on the territory of the Yukon-Flats-Kandik depression. According to the data of p. 68

Sea shelves and probably includes the Anadyr' depression found. The basin extends beyond the boundaries of the鄂毕 river the Colville downwarp, where oil and gas pools have been and previous and resemble the Aptian-Albian formations in oil. Its thick beds of Aptian-Albian rocks are both porous territory of Central Alaska with regard to prospecting for The Yukon-Koyukuk depression is the most favorable basins of the Mesozoic and Cenozoic folded belts in Alaska. Peninsula basin) may also be potential oil - and gas-bearing offshore regions (referred to by the authors as the Alaska north on Alaska peninsula and its southern coastal and well as the southern part of the Shelikof-Matanuska syncli-

In 1950, while drilling for water on the territory been recorded in the cross-section of Mississippian rocks. Of the Selawik depression, a gas spout was released from the depth of 72.5 m. Three natural oil seepages are known here. All this allows us to classify this depression as a potential oil-and-gas-bearing basin. The Middle Tanana depression and the Minchumina tial oil-and-gas-bearing basin. The Miocene rocks having a thickness of at least 1500 m, occur the central part of this basin, while continuous Paleogene the central part of the Pre cambrian foundation are found in basin. Outcrops of the Pre cambrian foundation are treated by the authors as one single Tanana depression. Miocene rocks having a thickness of at least 1500 m, occur throughout the rest of its territory. Coal-bearing Eocene formations overlapped by gravel, occur in the bottom part of the cross-section. The thickness of these formations varies the cross-section. Numerous natural shows of oil have been from 300 to 600 m. Numerous natural shows of oil also information on oil shows in the Miocene detected on the territory of this basin.

There is also information on oil shows in the Mioceneocene deposits of the Nushagak Bay and on the Lower course of 1083 m. In this potential oil-and-gas-bearing Sustina The Rosetta-1 well was drilled in 1956, to the depth of the Nushagak river.

The Rosetta-1 well it encountered gas-bearing sands of a coal-bearing Paleogene formation. In the course basin. In the 177-229 m interval it encountered gas-bearing sands at the same year, the Rosetta-2 well which was made at a distance of 30 km. from the Rosetta-1, encountered gas-bearing sands at the depth of 244 m. In 1951-1952, in the wells

drilled in the vicinity of Houston, a seepage of gas was recorded at the depth of 169-236 m, from coal-bearing Paleogene-Neogene formations. The gas detected in 1955, by the reconnaissance borehole, which was drilled to the depth of 1175 m, near the western shore of the Knik Arm Bay,

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probably originated in the same Paleogene-Neogene coal-bearing deposits. In this territory there is no evidence of oil shows associated with Eocene and still younger Paleogene formations, however, the rocks filling the intermontane depression, may have served as sources of gas production.

In the Kopner* depression, a borehole was drilled in 1955-1956, to the depth of 1468 m. Small gas and oil seepages were recorded during the drilling. Gas manifestations from deposits of Cretaceous age have also been observed in one of the structural drillholes. Aeromagnetic and gravimetric works, as well as geological survey have been carried out on the territory of the basin, as a result of which a number of structures have been discovered. Reconnaissance drilling carried out in these structures yielded, however, no significant results so far.

Upper Triassic bituminous carboniferous deposits are known in the basin of the Alaska peninsula. Oil shows have been detected in denudations of Middle and Upper Jurassic

*Transliteration. Copper? (Translator)

rocks, which also enclose arenaceous bands. The lenticular occurrence and the marked lithological lateral variation of the sandstones show that they formed under coastal conditions. Upper Cretaceous deposits include bituminous sandstones. Paleogene-Neogene deposits have on the whole a continental appearance, hold little promise and could have scarcely been source rocks of petroleum. However, they might have served as reliable reservoirs for the accumulations of the oil and gas, which migrated from the underlying marine Mesozoic deposits.

All this allows us to regard rocks of this age as potential oil- and gas-bearing beds, and to take them into account alongside the rocks of the Mesozoic beds when estimating the predicted reserves of this basin. The largest of the reliably established areas of oil and gas concentration in the Alaska peninsula basin are the areas confined to the central part of this basin. Oil and gas shows from Upper and Middle Jurassic deposits have been detected; bitumen has been encountered in Upper Triassic formations; and Lower Jurassic rocks contain bituminous sands.

Potential oil and gas resources

The data on lithology, thickness, range and depth of occurrence of the most promising complexes of deposits

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presented above in conjunction with the information

available on the geological history of the basins and of the oil and gas shows known to us (from both denudations and wells), were used to estimate the potential oil and gas resources of all the basins located on the territory of the Arctic and Subarctic regions of America. The estimates were made to the depth of the sedimentary mantle of 5 km. In the areas examined in the adjacent off-shore regions the evaluation was done to the depth of 300 m. or less. The overall areal extent of the regions of promise is 2800 thousand sq. km., of which approximately 1500 thousand sq. km. (i.e. 53%) represent shallow-water areas.

The saturation-balance method developed by the NIL-Zarubezhgeologii* /27,30/, was used in estimating the potential oil and gas resources. This method is based on the direct correlation between the rate of accumulation of oil and gas and the capacity of natural reservoirs (hydrodynamic systems) of the oil- and gas-bearing basins. This method is particularly convenient for the evaluation of oil and gas resources in relatively unexplored regions, on which there are no data required for the objective calculation of predicted reserves by other methods (according to the averaged structure or hectareage).

The estimates were made separately for each large stratigraphic complex of deposits. These complexes were

*Research Institute of Geology in Foreign Countries

tentatively regarded for this purpose as lithologic-stratigraphic valuation complexes /32/. Valuation sections were established within the range of potentially promising deposits of each complex. These valuation sections usually correspond to large geostructural elements of the basin (foredeeps, platform depressions, median elevations), less often to various portions of the basin differing in hypsometric position (rims and central parts of depressions), or to relatively small structures (ancient downwarps, young superimposed basins, etc.).

The capacity of the natural reservoir of one or another complex was determined within each given valuation section as the product of the surface area of this section and the value of the productive arenaceousness or carbonaceousness of the complex (the ratio of the permeable portion of the complex enclosed between the regional structures impervious to water, oil and gas, to the overall thickness of the complex). The total capacity of the natural reservoirs of all the sections represents the capacity of the natural reservoirs of the given complex, and the sum of these latter capacities represents the total capacity of natural reservoirs of the given basin.

The ratio of the volumes of oil and gas in productive horizon to the capacity of the natural reservoir (i.e. of a section, complex, basin) is known as the oil or gas

concentration coefficient (of a section, complex, basin).

The highest values of this coefficient are naturally characteristic of local sections, i.e. of oil or gas pools and traps. As the capacity of the natural reservoir increases (i.e. as we move towards the progressively increasing surface area of a complex), the values of the coefficient decrease, since the oil and gas volumes increase at a considerably slower rate than does the capacity of natural reservoirs: the former are limited by the value of the proven and potential petroleum reserves, whereas the latter are relatively unlimited. An analysis of the actual correlations between the geological oil-gas reserves and the capacities of natural reservoirs of the sections enclosing these reserves, was carried out in various oil- and gas-bearing basins of the USSR and abroad. This analysis has shown that the dependence of the oil or gas concentration coefficient on the capacity of the natural reservoir appears in the form of a descending, gradually flattening out curve, (known as the "Napol'skii's curve" in honour of the researcher, who discovered this dependence). The maximum value of the concentration coefficient, towards which the curve rises asymptotically, while the capacity of the natural reservoir increases to infinity, corresponds to the threshold concentration of hydrocarbons in the basin, to the threshold retaining capacity of the hydrodynamic system of this basin, i.e. to the maximum amount of oil or gas capable of

accumulating in the form of productive concentrations. The threshold value of the concentration coefficient can therefore be referred to as the index of the retaining capacity of a basin. The value of the index proved to be independent both of the type of the oil- and gas-bearing basin, and of the age and thickness of the sedimentary formations comprising the basin. It varied within the limits of 0.00012-0.00018 for oil and 0.0013-0.0023 for gas, and was equal on an average to 0.00015 and 0.00185, respectively. Deviations from the mean values do not exceed 20-25% in different individual basins. The precision of calculations is approximately equal to this figure, since the reliability of the values characterizing the geological oil and gas reserves of the A + B category, on the basis of which the concentration coefficients were calculated, is also scarcely higher than \pm 25%. We can therefore formulate the hypothesis that the total value of potential oil and gas resources in a given basin is determined to a great extent by the capacity of the natural reservoirs of this basin and of its hydrodynamic system. It should correspond to approximately 0.00015 of this capacity for oil, 0.00185--for free gas.

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In calculating potential oil and gas resources, the threshold value of the concentration coefficient should be used only in the events, where the capacities of natural reservoirs of the valuation sections are very large and

correspond to the asymptotic part of the Napol'skii's curve. If the capacities of natural reservoirs are relatively small, i.e. correspond to the flattening out portion of the curve, the values of the concentration coefficient obtained at the corresponding point of the curve would be higher (occasionally several times higher) than those of the retaining capacity index of the basin. M. Sh. Modelevskii (1970) demonstrated that threshold values of the capacity of natural reservoirs, i.e. values that can be exceeded only by using the minimum values of the gas and oil concentration coefficient, are different for different types of basins: 8000 cu. km. for 10,000 cu. km. for platform basins, 1000-1500 cu. km. for premontane basins, 200-300 cu. km. for intermontane basins. When potential oil and gas resources of the Arctic and Subarctic regions of the USA and Canada were estimated, all valuation sections used proved to be very large, since it was impossible to carry out a detailed zoning in the regions that have been so little explored from the geological viewpoint. The capacities of natural reservoirs within the boundaries of the valuation sections also proved to be very large, considerably larger than the threshold values indicated for these types of basins. The minimum values of oil or gas concentration coefficient, the values corresponding to the indices of the retaining capacity of the basins, were therefore used in the calculation for all basins. Capacities of natural reservoirs have been

proceeding from the predominant lithological features of the given complex, since there are no factual data on the distribution of permeable zones in the cross-section. The data available (Figs. 2, 4, 7) show, however, that the cross-sections of the sedimentary mantle of the American Arctic and Subarctic regions reveal certain lithological and stratigraphic features similar to those of the cross-sections of certain thoroughly explored Soviet oil- and gas-bearing basins. For example, basins of the Hyperboreal Platform resemble those of the eastern periphery of the Russian Platform (Timan-Pechora and Volga-Urals); basins of the northern part of the Canadian Platform are similar to those of the northwestern periphery of the Russian Platform; basins of the intermontane depression in the Cordilleras resemble certain Central Asian basins (Afghan-Tadzhik,

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Fergana basins). This circumstance enabled us to use in the calculations the mean values of the coefficients of the productive arenaceousness and carbonaceousness that were obtained for the American Arctic basins from the values known for the aforementioned basins of the USSR (with corrections for the specific geological conditions). For example, if readily permeable terrigenous deposits predominate significantly in the cross-section of a complex (within the boundaries of a valuation section), the content of natural reservoirs in this cross-section drops from 20-25%

(thick, essentially arenaceous Eocene beds of the Cook Bay basin) to 10-15% (the argillaceous-arenaceous cross-section of the Mesozoic deposits in the Sverdrup basin). In carbonaceous deposits, the average content of natural reservoirs in the lithological-stratigraphic complex was estimated as equal to 10% by analogy with that of most carboniferous cross-sections in the USSR. It decreased to 3-5% in the event of heavily clayey limestones, and it increased occasionally (for example, when reef-building limestones predominated in the cross-section) to 20-30% (western part of the Mackenzie basin). In the presence of terrigenous-carbonaceous deposits, intermediate values of the coefficient of productive capacity of the lithological-stratigraphic complex were used; the choice of the values depended on whether terrigenous or carbonaceous rocks predominated in the cross-section.

The predominant physical state of hydrocarbon concentrations (oil, gas, gas-oil, gas condensate pools) was determined for each valuation section. In doing so, the geological history of this section and the probable average conditions within the productive horizons were taken into account /28/. The regions, in the geological development of which the tendency to steady downwarping predominated and the pressure in productive horizons never dropped below the valuation of the saturation pressure (i.e. where conditions were unfavorable for the liberation of dissolved gas into

the free phase), were regarded on the basis of these horizons as essentially oil-bearing regions. The regions, which lagged behind in the general subsidence and which were uplifted during different periods of their geological development, i.e. the regions, where the pressures in productive horizons have been consistently lower than the saturation pressures of the oils of the same age, should contain dry free gas in their most markedly elevated sections, gas-oil pools (to a lesser degree oil pools) in their relatively low areas. The mobile zones, where the descending vertical

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movements repeatedly gave way to ascending movements, enclose an intricate combination of different types of pools. Pools of gas condensates, gas condensates-oil and oil should predominate in their deep-seated horizons. The upper horizons, where pressures in the productive strata may be either lower than or comparable to the saturation pressures of oils, should enclose in principle oil, gas-oil and gas pools. The quantitative ratios of the liquid and gaseous phases in the interior of the earth are characterized in each valuation section by the mean value of the G index of the ratio of phases. This index is calculated from the value of the ratio of the mean oil saturation pressure in the given complex to the mean pressure within productive horizons in the given section of this complex /26/.

Potential oil and gas resources are calculated

according to the formulae, which take into account the capacity of the natural reservoir, the value of the oil and gas concentration coefficient and the value of the phase correlations coefficient. These formulae are modifications of the formulae proposed by M. S. Napol'skii /30/, and of those developed by M. Sh. Modelevskii and E.I. Parnov /27/.

Predominantly oil-bearing sections.

$$Q_{NP} = V_R \cdot \psi_H \cdot dN \quad \text{million tons;} \quad (1)$$

$$G_{r*GP} = \frac{Q_{NP} \cdot G}{(1 - G)} \quad \text{milliard cu. m.} \quad (2)$$

Predominantly gas-bearing sections.

$$G_{SGP} = V_R \cdot \psi_G \cdot F \cdot 10^{-3} \quad \text{milliard cu. m.} \quad (3)$$

Sections in which gas-oil pools predominate.

$$G_{SGP} = \frac{V_R \cdot \psi_H \cdot P \cdot F \cdot 10^{-3}}{1 - G} \quad \text{milliard cu. m.}; \quad (4)$$

$$Q_{NP} = \frac{G_{SGP} (1-G) \cdot dN}{(1.6 G - 0.6) F \cdot 10^{-3}} \quad \text{million tons;} \quad (5)$$

*The characters used in these formulae, are a mixture of Cyrillic and Latin. To avoid confusion with the V_R symbol, I shall use a small r to denote this particular index. (Translator)

$$G_{rGP} = \frac{0.6 Q_{NP}}{dN \cdot v} \quad (6)$$

Sections in which gas condensate and oil pools predominate.

First of all, resources of free gas are estimated according to the formula (4); thereupon oil resources are calculated according to the formula (5). These total oil resources include both liquid oil and the condensate, which, when found in the rocks of the productive horizon, is dissolved in the gaseous phase. In order to differentiate these reserves, the possible maximum reserves of the condensate must be calculated according to the formula

$$Q_{GK \cdot Pr} = \frac{G_{SGP} \cdot d_{GK}}{F \cdot 10^{-3}} \quad \text{million tons;} \quad (7)$$

liquid oil reserves Q_{NP}^1 are then calculated according to the formula

$$Q_{NP} = Q_{NP} - Q_{GK \cdot Pr} \quad \text{million tons.} \quad (8)$$

Should the $Q_{GK \cdot Pr}$ value, determined according to the formula (7), prove to be greater than the Q_{NP} value, determined according to the formula (5), it would mean that under these particular conditions of occurrence the entire oil is represented by the gaseous phase (condensate).

Symbols used in the formulae (1) - (8):

V_R - volume of natural reservoirs, cu. km.;

- ψ_H - oil concentration coefficient, % (thousandth fractions);
- ψ_G - gas concentration coefficient, %;
- G - index of phase correlations, fractions;
- r - index of the content of petroleum fringes in the total volume of the gas-oil or gas condensate-oil pools (determined from the known G value), fractions;
- v - volume coefficient of dissolved gas, cu.m./cu.m.
• 10^{-3} ;
- F - volume coefficient of free gas, cu.m./cu.m.;
- d_N - density of oil, g/cu.cm.;
- d_{GK} - density of condensate, g/cu.cm.;

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- Q_{NP} - potential oil resources, millions of tons;
- G_{rGP} - potential resources of dissolved gas, milliards of cu. m.;
- G_{CGP} - potential resources of free gas, milliards of cu. m.

Results of the calculations are shown in Tables 2-5 and in the schematic map of potential hydrocarbon resources of producing and potential oil- and gas-bearing basins of northern Canada, Alaska and of the off-shore areas adjacent to these regions (Fig. 9). The values of potential resources correspond to the sum of the subgroups D_1 and D_2 to the

500 m. depth of the sedimentary mantle and to the 300 m. isobath of the ocean floor.

In the Arctic slope basin the Umiat and Chukchi depressions, the Barrow-Meade elevation separating these depressions, as well as the Southern Chukchi elevation and the premontane Colville downwarp were chosen as valuation sections. The total surface area of the Umiat depression is 75 thousand sq. km., some 30 thousand sq. km. of which are covered by the Arctic Ocean. The Chukchi depression occupies an area of 210 thousand sq. km., of which 140 thousand sq. km. are in submarine regions. The mean thickness of Paleozoic and Mesozoic terrigenous-carbonaceous complexes of deposits in these depressions are 3000 and 2500 m, respectively, while the average depth of their occurrence is 5000-2000 m. The capacities of natural reservoirs in the Paleozoic and Mesozoic complexes come to approximately 30 thousand cu. m. in each of these complexes in the Umiat depression, to about 50 thousand cu. km. in the Chukchi depression. The mean values of the saturation pressure of oils in the Paleozoic complex were chosen by analogy with the Timan-Pechora basin of the Russian platform and were regarded as equal to 120 atmospheres; those of the Mesozoic deposits were selected by analogy with the West Siberian basin, and were estimated as equal to 100 atmospheres. The steady tendency of these depressions to subside throughout the major part of their geological history, allows us to

rate them as essentially oil-bearing (mainly if the conditions correspond to those, where the rocks occur at a mean depth of 2-5 km). This does not mean, of course, that pools of free gas cannot be found in these regions, particularly in the subsurface horizons. But on the whole such pools would represent a negligible fraction of the total potential hydrocarbon resources. In this instance the value of the index of the ratio of phases was determined as equal to 0.02-0.03 for the Chukchi depression and to 0.02-0.10 for the Umiat depression (for the Paleozoic and Mesozoic deposits, respectively). Potential resources of oil and

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dissolved gas were estimated according to the formulae (1) and (2) as equal to 19.5 milliard tons and 240 milliard cu. m. for the Chukchi depression, as 6.9 milliard tons and 220 milliard cu. m. for the Umiat depression. About 70% of the potential oil and 40% of the potential dissolved gas resources of these two depressions belong to their submarine areas. These estimates of potential resources have been corroborated by the discovery in 1968-1969, of several oil fields with immense reserves in the Umiat depression, on the coast of the Arctic Ocean. The mean density of the potential resources in both depressions comes to 100 thousand conventional tons/sq.km.

The Barrow-Meade elevation occupies an area of 41 thousand sq. km., of which 25 thousand sq. km. are located

within the boundaries of the shelf. The thickness of the productive complexes of deposits and their depths of occurrence are here considerably smaller than in the adjacent depressions. For the purpose of estimates the thickness of Paleozoic and Mesozoic terrigenous-carbonaceous complexes was regarded as equal to 2000 and 1000 m, respectively, while their average depths of occurrence were estimated as equal to 800 and 600 m. The capacities of natural reservoirs were calculated as equal to 11 and 6 thousand cu./km. The specific tectonic conditions of this region, are responsible for the fact that it remained hypsometrically uplifted over lengthy geological periods of time. These conditions and the low present-day pressures in productive horizons (considerably lower than saturation pressures of oils) allow us to classify the Barrow-Meade elevation as a region bearing mainly gas and gas-oil. As is well known, several small gas and gas-oil pools have been detected here in Jurassic deposits on the mainland. The value of the index of the phase ratio varies from 0.85 in the Paleozoic to 0.94 in the Mesozoic deposits. Potential resources of oil and of free and dissolved gas were estimated in the Barrow-Meade elevation according to the formulae (4) - (6) as equal to 400 million tons, and 300 and 100 milliard cu. m. Over 60% of these resources belong to the shelf portion of this elevation. The mean density of the potential resources is 20 thousand conventional tons/sq.km.

The Colville downwarp covers an area of 180 thousand sq. km., 120 thousand sq. km. of which are located under the waters of the Arctic Ocean. The mean thickness of the terrigenous-carboniferous Paleozoic deposits and of the essentially terrigenous Mesozoic sediments are 3 and 3.5 km, respectively. Natural reservoirs of these complexes have a capacity of 32 and 43 cu. km. The mean depths of occurrence used in the estimates are 5000 and 2000 m. Because of the highly active tectonic conditions of the foredeep, repeated reversals in the sign of vertical tectonic movements, and considerable amplitude of these movements, the Colville downwarp is regarded as a region where gas condensate and,

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to a lesser degree, oil pools predominate (at the mean depths indicated above). Gas-oil and oil pools may occur mainly in the upper horizons of Mesozoic age, which occur at relatively small depths. As was mentioned in the preceding chapter, several small gas and oil pools have been discovered here in Cretaceous deposits at the depths of 200-560 m. Potential oil and free gas resources of the Colville downwarp have been estimated according to the formulae (7) and (8) as equal to 550 million tons and 5300 milliard cu. m. The mean density of the potential resources was calculated as equal to 30 thousand conventional tons/sq. km. The shelf portion of the downwarp accounts for 75% of its total oil and gas resources.

On the whole, potential resources of oil and gas amount in the Arctic slope basin to 27,300 million tons and 6200 milliard cu. m. Condensate accounts for some 600 million tons of the total petroleum resources, and 560 milliard cu. m. of the gas represent the gas associated with oil pools.

In the Sverdrup basin, the territories (mainland and offshore) situated within the boundaries of the Eastern and Western Sverdrup depressions, as well as the Ellef-Ringnes elevation, separating these depressions, were chosen as valuation sections. Furthermore, the low-level central areas and the relatively uplifted marginal portions of the depressions were also selected as such.

The surface areas of the East Sverdrup and West Sverdrup depressions are 140 and 100 thousand sq. km., respectively; of these areas 60 and 45 thousand sq. km., respectively, are situated in the shelf zone as far as the 300 m.isobath. The mean thickness of the Mesozoic and Cenozoic terrigenous deposits used in the estimates are 9000 and 500 m, while their mean depths of occurrence are 4000 and 1000 m, respectively. Both depressions are treated as regions of a lengthy steady downwarping, therefore as regions, where oil pools predominate in Mesozoic deposits. Pressures in productive horizons of these deposits are probably considerably higher than saturation pressures of oil by dissolved gas. Only the uppermost horizons of the

Jurassic-Cretaceous deposits, which occur at a depth of less than 1000-1200 m., may enclose gas-oil and gas pools alongside oil. This is corroborated by the seepages of oil from Jurassic deposits at the depth of 1400 m, and of gas from the depth of 1100 m, which were recorded in 1969, on the island of Melville. The Cenozoic deposits are essentially gas-bearing, since they are relatively thin and are

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represented to a considerable extent by continental sediments (including carboniferous rocks) occurring at small depths.

Potential oil and gas resources of the Eastern and Western Sverdrup depressions, have been estimated as 7000 million tons and 500 milliard cu. m., respectively, in the former, as 11,000 million tons and 900 milliard cu. m. in the latter. Somewhat less than 50% of these resources occur in the offshore region of the Arctic Ocean. The mean density of the potential resources is 116 and 119 thousand conventional tons/sq.km.

The Ellef-Ringnes elevation covers an area of 45 thousand sq. km., two-thirds of which are located under the ocean waters. The terrigenous Mesozoic deposits having a total thickness of up to 3000 m. and occurring at an average depth of 2000 m, are the only sediments of promise on the territory of this hypsometrically elevated structural element. It is presumed that these deposits enclose mainly

gas condensate and oil pools. The capacity of natural reservoirs is 27 thousand cu. km. The potential oil and free gas resources are here 200 million tons and 800 milliard cu. m., respectively. The mean density of the potential resources is 22 thousand conventional tons/sq.km.

The total potential hydrocarbon resources of the Sverdrup basin are as follows: 26,200 million tons of oil, including 200 million tons of condensate, 400 milliard cu. m. of dissolved gas, 2600 milliard cu. m. of free gas.

Potential resources of the Beaufort basin were estimated in the same manner. The low-lying central area, which is completely covered by the Beaufort Sea, and the outer border located on the mainland, were treated here separately. The overall surface area of the basin is 100 thousand sq. km., including 70 thousand sq. km. which are located below the sea. The potential hydrocarbon resources of the Paleozoic and Mesozoic deposits occurring at the average depths of 5 and 2 km. in the central region, and at 1500 and 800 m. on the outer border, are as follows: 6900 million tons of oil, 900 milliard cu. m. of gas. The mean density of the potential resources is 100 thousand conventional tons/sq.km. within the boundaries of the water area, and 55 thousand conventional tons/sq.km. on the mainland.

The Jones-Lancaster basin occupies a surface area of approximately 230 thousand sq. km., 35% of which is covered

by coastal waters. Lower and Middle Paleozoic terrigenous-carboniferous and carboniferous deposits are here sediments of promise. These deposits have an average thickness of 1-2 km. The areas chosen here as valuation sections are the

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central downwarped zone and the raised border, the platform part of the basin and the premontane downwarp. The promising complexes occur in the former at the depth of 2000-3000 m, in the latter--at the depth of about 1000 m. (Upper Paleozoic only), in the downwarp--3500-2500 m. The low-lying platform portion of the basin has been rated as essentially oil-bearing, the raised border area--as gas-bearing. The premontane trough is believed to be an area enclosing mainly gas condensate and oil pools. Potential resources of oil and of the gas accompanying the oil, have been estimated as equal to 2700 million tons and 100 milliard cu. m. in the low-lying platform part of the basin, as 3000 million tons and 900 milliard cu. m. in its border area. Moreover, resources of free gas were estimated as equal in the latter to a volume of 1300 milliard cu. m. Potential resources of the premontane downward have been estimated as equal to 100 million tons of oil, 600 milliard cu. m. of free gas. The mean density of potential resources in these parts of the basin is equal to 32, 46 and 17 thousand conventional tons/sq.km. The total hydrocarbon resources of the Lancaster basin amount to 5800 million tons of oil and 2900 milliard

cu. m. of gas.

In the Melville-Victoria basin, which covers an area of 400 thousand sq. km. and more than half of which is situated under the ocean, the valuation sections selected included the low-level central areas and the raised marginal platform zones, as well as the premontane downwarp. Potential oil and gas resources of these sections were estimated by analogy with similar sections of the Lancaster basin, by applying to these sections the appropriate mean densities of potential resources calculated for analogous sections of the latter basin. Paleozoic deposits of the Melville-Victoria basin enclose 10,400 million tons of oil and 6300 milliard cu. m. of gas.

In the Wollaston and Foxe basins Paleozoic deposits offer a certain interest only in the central, most markedly downwarped portions of the basins, where the mean depth of occurrence of these deposits is approximately 600 m. These basins are believed to hold little promise, and are essentially gas-bearing. Potential resources of free gas are estimated as equal to 200 milliard cu. m. in the former basin, as 500 milliard cu. m. in the latter. The mean density of potential resources is here equal to 4-6 thousand conventional tons/sq.km.

The northern part of the West Canadian basin includes within the boundaries of the region examined the

Anderson elevation, Hyland Plateau and Peel Plateau. The total surface area of this territory is approximately equal to 210 thousand sq. km. Carboniferous, often reef-building Paleozoic deposits measuring 250-700 m.in thickness, are here sediments of promise. These deposits occur at the depth of 800-1000 m.in the Anderson elevation and Peel Plateau, at 3000 m.in the Hyland Plateau. In the most

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markedly uplifted sections these deposits appear to bear mainly gas-oil, but in the relatively low-level sections they are believed to be essentially oil-bearing sediments.

Potential oil and gas resources of this region have been estimated as 200 million tons and 360 milliard cu. m. Mean densities of the potential resources are rather low: 2-3 thousand conventional tons/sq.km. in the Anderson elevation and Hyland Plateau, and up to 6 thousand conventional tons/sq.km. in the Peel Plateau.

- The Mackenzie basin is situated on the upper course of the Mackenzie River and covers an area of some 30 thousand sq. km. Sediments of promise are here carbonaceous, to a considerable extent reef-building deposits of Paleozoic (mainly Devonian, Silurian and Ordovician) age, having a mean thickness of about 500 m, and the mean depth of occurrence of 1000 m. The latter circumstance leads us to regard this basin as an area enclosing mainly gas-oil and oil pools, with concentrations of gas in a subordinate position. One

single oil field (Norman Wells) is known here so far. The productive horizon (Middle Devonian) occurs in this field at the depth of 300 m. Potential oil resources of this basin have been estimated as equal to 100 million tons, potential gas resources--as equal to 140 milliard cu. m. The mean density of the potential resources is 6 thousand conventional tons/sq.km.

The Cook Bay (Cook Inlet) basin covers an area of 20 thousand sq. km. Half of this territory is located under the waters of the bay. Terrigenous deposits of Mesozoic and Paleogene-Neogene age are here sediments of promise. The Mesozoic deposits, having a thickness of 1000-1200 m, were evaluated as a single unit, whereas the Cenozoic deposits were subdivided into three lithological-stratigraphic valuation complexes (in the ascending order): basaltic strata, the Hemlock formation and the upper horizons of the Kenai formation. Their thickness is 200-1200 m. The marginal and central portions of the basin were chosen as valuation sections. The mean depths of occurrence of Cenozoic deposits on the territory of the former were calculated for the estimates as equal to 2500-3000 m, of Mesozoic deposits--as equal to 4000-4500 m. In the latter the respective depths were calculated as equal to 4000-5000 and 5000-6000 m.

The central part of this basin underwent steady downwarping during the Mesozoic and Cenozoic. It is regarded as essentially oil-bearing in all of its valuation

complexes. The marginal, tectonically more active part of the basin has been rated on the basis of its Mesozoic deposits and upper Cenozoic horizons as a region which

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encloses both oil and gas condensate pools. Gas and gas-oil pools may also be encountered in most markedly uplifted structures, in the upper horizons of the Paleogene-Neogene deposits found in the marginal part of the basin. These deposits occur at the depth of 1000-1500 m, where pressures in productive horizons are probably comparable with saturation pressures. This pattern of oil and gas distribution in the Cook Bay basin agrees perfectly with the information available on the fields that have already been discovered. As is well known, oil pools have been detected here in Cenozoic rocks at the depths ranging from 1600 to nearly 5000 m, and gas pools have been recorded at the depths of 900-1100 m.

Potential oil resources of this basin have been estimated as equal to 1350 million tons, of which close to 550 million tons occur in the central portion of the basin covered by the waters of the bay. Gas resources have been estimated here as equal to 180 milliard cu. m. The submarine territory of the Cook Bay accounts for 700 million tons of oil and for 40 milliard cu. m. of gas of the total resources of this basin. The mean density of the potential resources in this basin as a whole is 66 thousand conventional

tons/sq.km.; the marginal area has a somewhat higher density (76 thousand conventional tons/sq.km.) than the central zone (where the density is 55 thousand conventional tons/sq.km.).

Potential oil resources of the Nushagak and Yukon-Flats-Kandik basins were estimated in a similar manner. The raised marginal zones, where the promising Cenozoic and Mesozoic deposits have a small thickness and a small depth of occurrence, and the relatively low-level central areas, where the depth of occurrence and the thickness of these complexes are approximately twice those of the marginal zones, were chosen in both these basins as valuation sections. Potential oil and gas resources of the other intermontane depressions in Alaska were also estimated with the help of the mean densities of analogous complexes of deposits from the basins, where these resources were calculated by means of more reliable methods.

The total potential geological resources of oil and natural gas of the Arctic and Subarctic basins of America were estimated on the basis of the factual data available in early 1970, as equal to 92.6 milliard tons and 24.5 trillion cu. m., respectively (Table 2). Free gas accounts for 19.2 trillion cu. m. of the total gas resources. The remaining amount represents the gas associated with oil pools. At the probable mean coefficient of the oil yield equal to 30%, the recoverable portion of the potential oil resources amounts to 27.7 milliard tons; at the coefficient of the oil yield

equal to 50%, it is equal to 46 milliard tons, etc. The recoverable portion of the potential resources of dissolved gas is 2.6 trillion cu. m. at the coefficient of recovery of the gas equal to 50%, that of free gas at the 80% coefficient of recovery is 15.2 trillion cu. m. (Table 3). Over 60% of potential oil and gas resources occur in the underwater shelf areas. Some 45% of potential oil and gas resources are concentrated in the basins located on the USA territory and in American submarine regions, about 55% occur on the territory and in the submarine regions of Canada.

The largest resources of oil and free gas are concentrated in the basins of the southern periphery of the Hyperboreal Platform, and on the territory of the latter--in the Arctic slope and Sverdrup basins.

Basins of the northern part of the Canadian Platform range second with regard to their oil and gas resources among the Arctic and Subarctic regions of America. Basins of the intermontane depressions in Canadian and Alaskan Cordilleras occupy the third place (Table 4).

Recoverable potential oil resources of the Arctic slope basins have been estimated as equal to 8-13 milliard tons.

In the course of over a hundred years of the history of petroleum industry in the USA, close to 16-17 milliard tons of recoverable oil reserves (according to the sum of the categories A + B + C₁ + C₂) have been surveyed. Over 11

milliard tons of these reserves have already been extracted. Potential recoverable oil resources of the USA (excluding the Arctic regions) were estimated in 1966, by the Mining Bureau of the USA as equal to 138 milliard tons. Potential recoverable gas resources were estimated around that date by the Institute of Gas Technology of the USA as equal to 49.5 trillion cu. m., and are equal to 52.5 trillion cu. m. according to our estimates, made at the beginning of 1969 (Modelevskii, 1970). Recoverable resources of gas in the Arctic slope basin amount to 4.8 trillion cu. m. This basin thus contains about 10% of all the potential oil and gas resources of the USA.

In the basins of Sverdrup and Beaufort, potential recoverable resources of oil amount to 10-16 milliard tons, of gas--to approximately 3 trillion cu. m. The Jones-Lancaster, Melville-Victoria, Wollaston and Foxe basins, situated behind the Arctic Circle, contain 5-8 milliard tons of oil and over 7 trillion cu. m. of gas. We can therefore expect to find 15-24 milliard tons of oil and over 10 trillion cu. m. of gas in the high Arctic of Canada.

According to the estimates of the Geological Resources Committee of the Canadian Petroleum Association, potential recoverable oil resources in the rest of the country amount to 16 milliard tons, gas resources--to 20.5 trillion cu. m. We may thus see that as a result of the intensification of prospecting in the Arctic regions,

potential oil resources have virtually doubled in Canada, those of gas--increased one and a half times.

Basins of the intermontane depressions in Central and Southern Alaska also play an important part in the overall potential oil and gas resources of American Arctic and Subarctic regions. It is interesting to note that the only basin of this region, where successful economic oil extraction has been going on for several years, is the Cook Bay basin, which does not contain the largest potential oil resources. This basin is at par with the St. Elias*, Alaska peninsula, Yukon-Flats-Kandik basins, and encloses considerably lower potential resources of petroleum than either the Nushagak, or the Bethel-Yukon-Koyukuk basin.

Stratigraphic distribution of potential oil and gas resources is highly interesting (Table 5). The oil and gas resources are divided nearly equally (in terms of the conventional equivalent) between the Mesozoic and Cenozoic deposits. These resources constitute approximately 90% of the total resources of the basins examined. If we keep in mind that at the depths exceeding 5 km, to which some 60% of the cross-section of the Hyperboreal Platform basins is confined and which we did not take into account, productive horizons are probably represented mainly by Paleozoic deposits, it becomes obvious that the part played by these

*St. Edias in the text. (Translator)

deposits in the total oil and gas resources of the Arctic regions of America is even greater. In the meantime, nearly all the surveyed oil and gas reserves of these regions are associated with Cenozoic and Mesozoic rocks, a circumstance indicating that immense new fields will be eventually discovered in the northern regions of the USA and Canada.

It is also interesting to note that the oil fraction decreases in more ancient rocks, while the gas fraction increases. This means that we may find mainly gas pools in the deep-seated Paleozoic deposits of the Hyperboreal Platform basins.

Our estimates of potential oil and gas resources of the American Arctic and Subarctic regions can be checked only against similar estimates found in the foreign literature. And it is very difficult to make such a comparison. The valuations published abroad are often contradictory and

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speculative. The figures presented in these estimates commonly refer to some geographic regions (for example, the coastal plains and the shelf of the Arctic slope of Alaska, the region of the Mackenzie River, Arctic Archipelago, etc.) without strict geographic allocation or geological substantiation and analysis of these figures. Lastly, in the foreign literature potential resources commonly mean recoverable resources, yet the conventional recovery coefficients used are never indicated. Furthermore, none of the

valuations published gives the thickness and depth of the sedimentary mantle and ocean floor, for which these estimates are valid. Comparison of the results obtained by the authors of this review with the data available in the foreign press is therefore highly tentative and can serve merely as a rough verification of our results.

The figures of potential (recoverable) oil and gas resources of the high Arctic regions of North American (it is not clear whether the South Alaskan basins, located south of the Arctic Circle, are included into this territory) that are quoted most frequently in the foreign literature, are 21-22 milliard tons of oil and 25-26 trillion cu. m. of gas. According to our estimates, these resources amount to about 28 milliard tons of oil (23 milliard tons, if we exclude the South Alaskan basins) and about 18 trillion cu. m. of gas (15 trillion cu. m. without the South Alaskan basins). Potential oil resources of the regions situated within the boundaries of the Mackenzie and Yukon river basins, Arctic Archipelago and the adjacent underwater shelf, are estimated in Canadian journals as approximately equal to 14.5 milliard tons. The recoverable potential oil resources of the Beaufort, Sverdrup basins and of the northern part of the Canadian Platform, which is analogous to these regions, amount, according to our estimates, to approximately 15 milliard tons.

Keeping in mind what we said earlier about the

nature of the comparisons made between our estimates and those published in the foreign press, we can conclude that the data obtained by the authors of this review represent fairly objectively the true amounts of the oil and gas resources of the Arctic and Subarctic regions of America. These data provide an objective picture of the main patterns of distribution of these resources over the territory and in the cross-section, as well as of the relative importance of individual basins and various stratigraphic subdivisions of their sedimentary infilling in the total bulk of potential oil and gas resources.

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Possibilities of recovery and transport of oil and gas.

In spite of the fact that the Arctic regions are virtually unexplored, in spite of the difficulties associated with the drilling, exploitation of the wells and transport of oil in the high Arctic conditions, in spite of the high production and exploitation costs, the development and exploitation of new fields on the shores of the Prudhoe Bay is a matter of the near future. All the oil fields discovered in the American and Canadian Arctic regions will be rapidly developed, provided they contain significant reserves. The enormous sums paid by American, Canadian, British and French companies for exploration rights in the Arctic regions at the most recent auction in 1969, corroborate this assertion. The income from this auction amounted

to approximately \$1 milliard at the average price of \$2- to \$28 thousand an acre, whereas the price of lease sections during the preceding year did not exceed \$17.00 an acre, and while the total income from the previous 22 sales of exploration rights amounted to mere \$90 million. The biggest bidders at the 1969 auction were large companies, such as the Mobil, Phillips, Standard Oil of California, Getty, Hunt, British Petroleum, which have extensive experience in northern mining and are naturally disinclined to waste large sums of money. Intensification of the prospecting for and production of oil in the Arctic regions is regarded as a major means of reducing the dependence of the oil industry of various capitalist countries upon the unreliable import of oil from the Middle East and Africa.

The first region in line for exploitation is the Prudhoe Bay, where three new fields (apparently quite large ones) were discovered in 1969. Production of oil in this region could rise to 50 million tons by 1975. By that time, recovery of oil in the Cook Bay basin may be as high as 11-12 million tons. The overall level of oil extraction in the American and Canadian Arctic regions in 1980, may be estimated as 120-130 million tons a year, if we take into account the probable discovery of new fields. About 100 million tons of this total production would be recovered in Alaska, 20-30 million tons in Canada.

Prospecting for oil fields and exploitation of these

fields in the Arctic regions involve extremely large investments. Drill rig and workers can often be transported only

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by air, since transportation by land is virtually impossible. The possibility of using hovercraft as the main means of transport is therefore now seriously debated. The foreign press emphasizes at the same time that in the long run it is more profitable to use in the Arctic regions airborne transport rather than by land routes. Thus, the use of a freight aircraft in the northwestern Alberta to transport some 3.6 thousand tons of equipment at a distance of 300 km, cost \$274 thousand. To transport this freight by trucks would cost at least \$490 thousand, if we take into account the construction and repair cost of the roads. Transportation of a ton of freight by plane from Fairbanks to Prudhoe costs \$160.00, i.e. the same as the transportation of this freight by a tractor train, which would take 28 days.

The possibility of using submarines for exploratory purposes also attracted a great deal of attention. The Council for the Development of marine mineral resources of Canada concluded an agreement with Sweden for the purchase of three "Neptune" submarine boats having a tonnage of approximately 1000 tons and a length of 61 m. These boats will be used for seismic survey of the Arctic waters, and they can operate below the ice cover all the year around by

using the ISZ* system of navigation. The boats would emerge on the surface through natural or artificial clearings in the ice, which can be made with the help of a special equipment mounted on these boats. The cost of a submerged kilometer of seismic profile would amount to \$750.00 or even \$1000.00, if the survey includes various special investigations, beside the prospecting for oil. The main submarine base will be built in 1970-1971, on the island of Ellef-Ringnes.

In the course of the many years of the survey and prospecting carried out prior to 1969, a total of 602 reconnaissance and exploratory wells had been drilled in Alaska. Oil was tapped by 231 of these wells, gas by 57 wells, while the remaining 314 wells proved to be dry. The overall effectiveness of the prospecting and exploratory drilling operations during the period of 1944 to 1968, was fairly high and amounted to 48% /2/. The scale on which the drilling is conducted has been increasing at a particularly high rate during the last few years. In 1966, 50 wells had been completed (154 thousand meters). This number includes 38 prospecting wells (121 thousand meters) and 12 exploratory wells (33 thousand meters). In 1968, 104 boreholes were completed (332 thousand meters), including 18 prospecting boreholes (52 thousand meters) and 86 exploratory

*Transliteration. (Translator)

wells (280 thousand meters). The effectiveness of the drilling operations has also improved. In 1966, 40% of the wells proved to be productive, in 1968 the number of productive wells increased to 80%.

The high degree of effectiveness was obtained due to a drastic increase in the scale of exploratory drilling at a simultaneous reduction (to a half) of the prospecting drilling, because it became necessary to develop the large oil fields of the Cook Bay explored in 1965-1968. The

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number of wells drilled on the mainland and in the ocean in 1966, was 32 (98 thousand meters) and 18 (56 thousand meters), respectively, while in 1968, 17 wells (41 thousand meters) were drilled on the mainland and 87 (291 thousand meters) were made in the sea, i.e. the scale, on which the offshore drilling was conducted (mainly in the Cook Bay water area), increased during these years more than 5 times. However, after 1968, the number of the offshore drill rigs dropped by more than 30% (from 18 in 1967, to 12 in 1969), while on the mainland their number increased more than 5 times. This is due to the fact that in 1969, 15 drill rigs were moved to the Prudhoe Bay, 6 of which came from the Cook Bay (in addition to the two used for the prospecting-exploratory drilling in 1968). While the major drilling operations were centered in 1966-1967, in Alaska, in the Cook Bay region, where 90% of prospecting drill-holes and

100% of exploratory wells were made during this period, in 1968-1969, the centre of prospecting and exploratory works moved to the Arctic slope. By the end of 1969, 25 prospecting boreholes were drilled in the region of the Prudhoe Bay; 80% of these wells proved productive at the time, when 17 others were still being drilled.

During the period of 1959-1968, a total of 226 reconnaissance boreholes and test wells were drilled in Alaska; 186 of them were reconnaissance boreholes, 40--extension wells. Fifty-two of these wells proved to be productive. The overall effectiveness of the reconnaissance and exploratory drilling in the course of the 10 years thus amounted to 23%, of which 15.6% refer to the reconnaissance boreholes, 57.5%--to extension wells. The increase of reserves per meter of the reconnaissance and exploratory drilling in Alaska during this period is twice that recorded in Canada, and more than 5 that of the USA indices. If we take into account the proven oil reserves of the Prudhoe field (which were not included into the statistical data of 1968), then the 1968 increment in the reserves per meter of reconnaissance and exploratory drilling was 14.4 thousand tons (in the petroleum equivalent), i.e. nearly 200 times the average increment recorded in the USA during this period, and 100 times that reported in Canada for the same 10 years (Badovskii et al, 1970).

If we recalculate the 1968 increment in the reserves

(in the units of the petroleum equivalent) in Alaska (including Prudhoe) per reconnaissance-exploratory borehole, it amounts to 41.5 million tons versus the mean values of 112 thousand tons in the USA and 205 thousand tons in Canada recorded for the previous 10 years.

The high geological effectiveness of the prospecting and exploratory operations in Alaska is accompanied by high

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technological and economic indices of the drilling efficiency (Table 6).

The extremely difficult conditions, under which drilling is organized and conducted in the Arctic slope, raise the cost of these operations. The mean wages of drill team members in Alaska are \$62.40 an hour as compared to \$30.60 an hour in Texas. The cost per well and per meter of drilling is here also considerably higher (Table 7).

But the biggest problem associated at the present time with the development of the Arctic oil resources is not the difficulty or the cost of drilling, but the transport of

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the Arctic oil, since there are virtually no consumers in the Arctic regions proper. In 1968, 17% of the oil extracted in Alaska, was used for the local needs, while the remaining oil was exported to the West Coast of the USA and to Japan.

Transportation of the Arctic oil is one of the most difficult technological problem which the oil industry has

ever encountered. It still has not been decided whether the preference should be given to tankers, or to oil pipelines. Each of these means of transportation has advantages and disadvantages.

The only decision adopted so far is to build a 960-kilometer long oil pipeline, measuring 1220 mm. in diameter, between the Prudhoe Bay and the ice-free Valdez harbour on the southern shore of Alaska. 320 kilometers of the pipeline length will be laid across the marshy tundra, 480 km--

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in the permafrost regions, where the temperatures fluctuate between 62 below zero and +32°C. The cost of the pipeline construction has been estimated as \$900 million. The construction is supposed to be completed by 1972. The oil moved along this pipeline, will then be shipped by sea to the West Coast of the USA and to Japan.

However, at least half of the oil, which will be recovered on the Arctic coast of Alaska, is destined for the central and eastern regions of the USA. It has therefore been proposed to build a 2600 kilometer-long pipeline with a diameter of 1219 mm, from the Prudhoe Bay, across the Mackenzie River valley and western Canada to Edmonton (province of Alberta), where this line would be linked with the already existing Edmonton-Chicago pipeline. The transportation of oil along this pipeline would cost \$10.00-\$11.00 a ton.

The ice-breaker "Manhattan", a tanker with a tonnage of 115 thousand, completed a trial voyage in the middle of 1969. It covered 16 thousand miles from Philadelphia to the Prudhoe Bay by way of the "Northwest passage". The cost of the voyage was \$40 thousand. Should it be found expedient to ship the Arctic oil in this manner, it would be necessary to build a port and loading-unloading installations at a distance of 12-48 km. from the shore. The cost of this construction has been estimated as equal to \$150-\$500 million. Moreover, tankers having a total tonnage of 12 million tons, would have to be built by 1980, an operation requiring additional \$2.4 milliard of capital investment. The cost of the transportation of oil by tankers from the Prudhoe Bay to the East Coast of the USA has been estimated as \$6.60-\$7.40 a ton.

It is entirely possible that nuclear submarine tankers, having a cargo-carrying capacity of the order of 170 thousand tons, will seriously compete with the ordinary tankers. Such nuclear tankers may be introduced in 4-5 years. It has been estimated that the cost of the transportation of oil by such tankers would be much lower than the use of pipelines. The American company "General Dynamics" proposed a project for construction of 6 submarine tankers measuring 274.5 m. in length, 42.7 m. in width and 25.9 m. in height. The boats (having a tonnage of up to 170 thousand) would be able to transport some 160 thousand

tons of oil under the Arctic ice, where the temperature is stable (minus 2°C), where there is no wave disturbance, etc. The oil can be shipped in this manner from the Arctic regions to the Atlantic and Pacific coast of the USA, as well as to Japan and Western Europe. The distance from Alaska to Tokyo and from the mouth of the Mackenzie River to

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Rotterdam is 7500 km, whereas the distance from the Persian Gulf to Japan and Western Europe is now 15,000 and 20,500 km, respectively.

Gas production increased considerably in Alaska during the last 10 years, alongside the production of oil. While in 1959, the two productive wells of the Cook Bay yielded 0.91 million cu. m. of gas, by 1968, the number of productive wells increased here to 22 and the total production of gas amounted to 2.8 milliard cu. m. During the period of 10 years (1959-1969), 6.68 milliard cu. m. of gas had been produced, 66% of which was represented by free gas, 34%--by the gas associated with oil pools.

The major bulk of the recovered gas is used to maintain the pressure in the productive horizons of the oil fields located nearby. Thus, 3.3 million cu.m./day of gas from the Kenai field are used for this purpose in the Swanson River field. Due to the use of secondary recovery methods, about 13 million supplementary tons of oil were extracted in the Swanson River field. A small portion of the gas (up to

4%) produced is burnt in torches on the site. This is mainly the gas associated with oil pools.

The new discoveries in the Arctic make the problem of the utilization of natural gas particularly urgent.

In the Prudhoe field, the recoverable reserves of the oil pool gas alone (not counting the gas pools proper, which occur in the upper intervals of the cross-section) appear to be in excess of 50-100 milliard cubic meters.

Once the Prudhoe region is developed, exploitation of the small proven gas pools of this region will also become economically expedient. After the 1969 discovery of oil fields in this region and of gas fields on Melville and in the Cook Bay, it would not be an exaggeration to estimate the overall explored (proven and potential) reserves of gas in the American Arctic for 1970, as equal to 300-320 milliard cubic meters. The reserves of natural gas in this region will undoubtedly increase further in the near future.

A project for the construction of a gas pipeline from the Prudhoe Bay to the Canadian and USA border across the Northwestern Territories and British Columbia, has been developed. The length of the gas pipeline would be 3300 km, its diameter 2000-1200 mm. The construction of the gas pipeline should be completed by 1978. Its carrying capacity would be as high as 220 milliard cu.m./year. California is expected to become the principal consumer of this gas. Projects of special pipelines for transportation of the

Arctic gas in a rarified state to industrial regions of the USA and Canada are also under consideration.

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The large chemicals and gas industrial compound located 120 km. southwest of the city of Anchorage, will be an important consumer of this gas. Two plants, which produce ammonia and carbamide and have a capacity of 530 and 350 thousand tons/year, respectively, were built here in 1968. The plant producing ammonia will be consuming 1.7 million cu.m./day of gas from the Kenai field.

Japan will be one of the major consumers of the Alaskan gas. It will be exporting about 1.5 milliard cu. m. of rarified gas yearly in the course of 15 years. For this purpose, a gas rarifying plant with a capacity of 3.8 million cu.m./day, was built in Nikiski in 1968. The gas will be shipped by tankers.

Brief data on the oil and gas resources of the Soviet Arctic.

The aforegone shows that an immense new oil- and gas-bearing region has now been discovered in the northern periphery of the American mainland and in the shelf areas adjacent to it. With regard to its potential resources (about 117 milliard tons in conventional petroleum equivalent), this region is at part with the Western Siberia, Ural-Volga region and Northern Africa.

A large portion of the oil and gas resources of the

American Arctic is confined to the basins situated along the southern periphery of the Precambrian Hyperboreal Platform. The structure of these basins, as well as the thickness, age, lithological and facies composition of the infilling deposits are similar in many respects to the structure and sedimentary infilling of the oil- and gas-bearing basins situated in the eastern periphery of the Russian Platform (Volga-Ural, Timan-Pechora basins). Basins of both these groups are boundary basins (according to the classification suggested by I.V. Vysotskii and V.B. Olenin, 1969), with distinctly defined broad platform regions and relatively narrow premontane downwarps. The main potentially promising deposits in these basins with respect to oil and gas are Middle-Upper Paleozoic and Lower Mesozoic terrigenous and carboniferous sediments. The similarities established between these basins, show that the values obtained by us and by certain foreign researchers, when estimating the potential oil and gas resources of the USA and Canadian Arctic Basins, are not exaggerated.

This also shows that potential oil and gas resources of the Soviet Arctic (both on the mainland and in the offshore areas) should be re-evaluated, and that the data from the prospecting in North America should be taken into account in these estimates. More than half the total shelf area of

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the Arctic Ocean is located in the territorial waters of the

USSR. The large Timan-Pechora oil- and gas-bearing basin opens into the Barents Sea, the West Siberian basin opens into the Kara Sea. Another large basin may be discovered within the boundaries of the East Siberian Sea.

The Arctic portion of a number of proven and potential oil- and gas-bearing basins, situated in the northern regions of the Soviet Union and in the shallow-water areas of marginal seas adjacent to these regions, are characterized here in brief. The description is based on the data from published materials of the investigations carried out by the NIIGA, VNIIMORGEO, geological organizations of the North, Siberia and Far East of the USSR, as well as from the most recent monographs dealing with the oil- and gas-bearing offshore regions /18,21/.

European USSR. In the Arctic sector of the European USSR the oil and gas industry is concentrated in the large section of the northeastern periphery of the Russian Platform, which is located between the eastern slopes of Timan, western slopes of the Northern and Arctic Urals, and Pai-Khoya. This section is known in the literature under the name of the Timan-Pechora oil- and gas-bearing basin. Its northern part extends under the waters of the Pechora and Barents Sea. Oil and gas shows have been repeatedly recorded in the north of the Barents Sea shelf, on the Spitzbergen and Franz Josef Land archipelagos. R. M. Demenitskaya and L.E. Levin /16/ believe that the entire

Barents Sea hollow can be regarded as one single perioceanic Barents Sea - Norwegian megabasin. The territory of the Timan-Ural syneclyse may be a constituent of this megabasin /22/. At the present level of information about this problem, it is probably more correct to talk of two separate basins (i.e. the Timan-Pechora and the Barents Sea basins), even though they may not be divided by a distinct hydrogeological barrier.

The ancient European Platform, the Barents-Kara tableland and the Ural-Pai Khoi foredeep of the Novaya Zemlya folded system of hercynids are the tectonic constituents of the region examined. The most reliable data available on the conditions of occurrence, stratigraphic volume and lithological composition of the potentially gas- and oil-bearing sedimentary beds found within the three aforementioned structural elements, are presented below.

The Barents-Kara tableland is accessible to direct surveying in the east of the Spitsbergen archipelago, on the Franz Josef, and in the west of the Severnaya Zemlya archipelago, beyond the boundaries of the region examined. The geological and geophysical data available so far, are insufficient to subdivide the shelf portion of this tableland into tectonic zones.

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Sedimentary beds are divided here in two structural stages: the Upper Paleozoic and the Mesozoic-Cenozoic. The

Upper Paleozoic stage is represented in the Spitsbergen by thick beds of Permo-Carboniferous age, occurring with a marked angular unconformity upon slightly dislocated Devonian deposits. This upper stage is subdivided in its turn in two sub-stages: the Lower Mesozoic (Triassic-Jurassic) and the Upper Mesozoic-Cenozoic (Cretaceous-Neogene). The Lower Mesozoic sub-stage of the Franz Josef Land includes the coastal-continental and marine deposits of the Upper Triassic, as well as of all the divisions of the Jurassic system. These deposits have a thickness of up to 1500 m. Deposits of the Upper Mesozoic-Cenozoic sub-stage occur unconformably upon horizons ranging in age from Volga to Norian-Rhaetian, inclusively, even upon the Middle Carboniferous rocks (in the southern extremity of the George Land). The Mesozoic sedimentary and effusive rocks are intruded by a multitude of cross-cutting and parallel bodies of dolerites and gabbro-dolerites. A thin, virtually undeformed complex of Upper Pleistocene and Holocene marine, less often glacial rocks occurs at a still higher level.

The European Platform is represented on the territory of the shelf by the submarine extensions of the Timan-Pechora zone and Bol'shaya Zemlya syneclyse. The sedimentary mantle is subdivided in three structural stages: the pre-Devonian, the Upper Paleozoic and the Mesozoic-Cenozoic. The foundation descends in a scalariform manner from the Timan ridge to the Urals along longitudinal faults having a

northwestern trend. Transverse fractures dissect it in the northeastern direction. The combination of the transverse and longitudinal fractures in the foundation accounts for the formation of large separate foundation blocks in the Timan, Pechora ridge and Pechora depression. In the latter the depth of occurrence of the foundation on the uplifted blocks is 2-2.5 km, in the low-lying sections--3 to 4 km. Linear dislocations of the sedimentary mantle formed along the zones of junction of these blocks. The angles of tilt of the flanks of local structures vary from a few fractions to several degrees; their amplitudes are up to 250-300 m. Dislocations of the Pechora ridge have an echelon-like arrangement, and the angles of dip increase on the sides of flexures to 40-50°. Flexures of the sedimentary mantle change in the foundation to faults with an amplitude of 1000-1500 m.

The geophysical and geological surveys carried out in the Barents Sea by the LGI, OMGR and NIIGA, established a tectonic relationship between the marine extensions of the Timan-Pechora zone and the continental part of this zone, which are defined by a system of transverse faults having a

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northeastern trend. These faults are responsible for the echelon-like junction of the structural elements, as well as for the fact that northwest of the Kanin island the regional northeastern tilt of the foundation surface changes from

northeastern to southwestern. The character of the junction between the Timan-Pechora zone and the Baltic shield is determined by the presence of a deep downwarp along its southwestern periphery. This downwarp encloses a sedimentary mantle measuring several kilometers in thickness. The downwarp was detected mainly on the basis of the data from marine geophysical investigations.

The structure of the sedimentary mantle of the Bol'shaya Zemlya synclise is controlled by the reciprocally perpendicular systems of faults of southeastern and southwestern trends. The former occur mainly on the mainland, the latter--on the territory of the sea. Movements of foundation blocks along the faults resulted in the formation of a number of elevations and depressions. On the mainland they can be readily detected with the help of gravimetric and seismic data (the Kolva and Upper Kolva ramparts) or on the basis of the data from geological surveys (the Chernyshev ridge). On the shelf negative structural elements are demarcated on the basis of the filling of depressions by the youngest Paleogene-Neogene deposits. Furthermore, submarine extensions of elevated zones of the mainland have been mapped in the Pechora Sea by means of seismic investigations.

The Novaya Zemlya - Pai Khoi foredeep is situated in the eastern periphery of the Barents Sea shelf, along the folded system of hercynids bearing this name. This system consists of two structural elements: a geosyncline

(Paleozoic) and a post-geosyncline (Mesozoic-Cenozoic). The former is subdivided in its turn, in three sub-stages: Lower Paleozoic, Lower-Upper Paleozoic and Upper Paleozoic /6/. The lower sub-stage formed during the Cambrian. In the region of junction of the recent Ural and Pai Khoi structure, as well as in the entire Yugorskii peninsula, the Cambrian structures have a northwestern trend inherited from a past period. In the south of Novaya Zemlya the axes of the folds make a wide turn assuming eventually a latitudinal trend. This reversal of the trend affects the trend of the structures occurring in the underwater extension of the Bol'shaya Zemlya syneclyse. The Lower-Upper Paleozoic sub-stage reflects the interval in the geological history ranging from the Ordovician to the Lower Carboniferous in the northwest of Novaya Zemlya, to the Upper Carboniferous in the more southerly regions of the archipelago. The Upper Paleozoic sub-stage embraces the intervals between the Lower-Upper Carboniferous and the Late Permian. In certain places it also includes the Triassic.

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Formations of the Mesozoic-Cenozoic stage fill in three superimposed depressions of the shelf: the Mezdusharskii, Admiralteistvo and Russkaya Gavan'. There are virtually no data on the abyssal structure of these depressions. It may be assumed that transverse dislocations, determined by the trend of the folds of more ancient structural stages,

occur within the boundaries of these depressions.

The territory of the Timan-Medvezhinskii zone and Bol'shaya Zemlya syneclyse, together with the superimposed depressions of the pre-Ural and pre-Pai Khoi foredeeps, is classified by I.O. Brod^{/7/} as the southeastern part of one single (Timan-Pechora) basin opening into the Barents Sea. It is entirely possible that the elevations located on the Spitsbergen and Franz Josef archipelagos will prove to represent the northern boundaries of this basin.

The extreme southeastern part of this basin contains several milliard tons of proven and predicted oil and gas reserves in the sub-Domanik beds of Devonian age. However, over a considerable portion of the Barents Sea shelf these deposits are either lacking or are of continental origin^{/8/}. The southeastern part of the sub-Domanik deposits on the shelf, i.e. the submarine extension of the large anticlinal elevations of the Bol'shaya Zemlya syneclyse (Kolva, Upper Kolva, Sorokin, etc. ramparts), are the most promising sub-Domanik sediments. Middle and Lower Devonian horizons occur here (according to the data from marine seismic surveys and from the drilling in the Usa region) at the depths of 4-5 km. These horizons are probably composed of essentially terrigenous rocks having a thickness of up to 300-500 m, and enclose mainly concentrations of low-density oil.

Upper Devonian and Permian-Carboniferous carbonaceous and terrigenous rocks form on the mainland the second

stage of productive oil and gas reserves. Apparently these deposits are extensively developed on the territory of the Barents Sea shelf. Large oil fields have been detected in this complex, in the Bol'shaya Zemlya syneclyse (the Kolva rampart) and in the Pechora depression, while gas fields have been discovered in the Upper Pechora depression of the pre-Ural downwarp and in the Denisov downwarp. The main potentially promising oil- and gas-bearing deposits of this shelf are associated with the underwater extensions of the uplifted zones of the Bol'shaya Zemlya syneclyse. It must be kept in mind that the formation of the traps in Lower Permian deposits may have been determined on the territory of the modern Barents Sea shelf by the salt-dome tectonic.

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This type of tectonic is very characteristic of the regions marked by descending pericratonial movements of the European Platform. Permian-Carboniferous deposits of the superimposed Novaya Zemlya - Pai Khoi depressions and of the pre-Ural downwarps (Korotaikhinskii, Mezhdusharskii and others) also held considerable promise with regard to the prospecting for oil and gas.

Oil and gas shows have been recorded in the Mesozoic and Cenozoic deposits in the process of structural core drilling of wells in a number of sections of the Bol'shaya Zemlya syneclyse. In 1969, the Shapkinskii gas field, associated with deposits of Triassic age, was discovered in

the northern part of the Denisov downwarp. Horizons of bituminous rocks have been detected in these deposits on the Spitsbergen and Franz Josef Land. In the marginal portions of the shelf the thickness of the Post-Paleozoic beds does not exceed 2-2.5 km, but in the central part of the present Barents Sea basin it may measure up to 5-6 km. It must be kept in mind that the fairly intensive manifestations of the Mesozoic volcanicity in the northern part of the shelf may have had an adverse effect on the conditions of preservation of hydrocarbon deposits, while in the southeast, near the Timan-Pechora basin, no such phenomena took place.

Thus, judging from a conjunction of proven and presumed factors, central and southeastern regions of the Barents Sea shelf hold a considerably greater promise of oil and gas than its northwestern peripheries. These factors are as follows: the presence of the sub-Domanik Devonian deposits, the persistent predominance of subsidence over ascending movements, a predominance compensated by the accumulation of a thick sedimentary mantle during the Paleozoic and Mesozoic, the absence of magmatic activity at the platform stage of development.

Asian USSR. Northern parts of the West Siberian, Tunguska and Verkhoyansk-Vilyui (Lena-Vilyui) oil and gas basins, as well as the Enissei-Khatanga, Kolyma and North Yakutian (Indigirka-Khroma) basins are located in the Arctic sector of the Asian USSR. Depressions of the East Siberian

Sea, eastern part of the Laptev Sea and northeastern zone of the Kara Sea appear to represent independent possible oil- and gas-bearing basins of the Arctic Ocean water area.

The foundation of the West Siberian basin consists of folded complexes, which consolidated during the Baykalian, Salairian, Caledonian and Hercynian epochs. The depth of occurrence of the foundation surface attains 6-7.5 km, and the principal tectonic zones have essentially a submeridional orientation /33,40/. The West Siberian tableland

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is shaped in the form of a calicular depression and has an overall surface area of 3.4 sq. km. The Arctic portion of the basin occupies approximately a quarter of this territory. Two structural stages (the Paleozoic - Lower Mesozoic and the Mesozoic-Cenozoic stage) have been established in the cross-section of the sedimentary mantle. The overall thickness of the sedimentary infilling in the pre-axial zones of internal depressions of the Subarctic basin (northern part of the Purskii trough) has been established by M. Ya. Rudkevich as equal to 6.5-7.5 km. This researcher also postulates that the Subarctic part of the West Siberian lowland underwent an active uplift at the close of the Oligocene and during the Neogene, and that this uplift resulted in the displacement of the northern border of the depression to the south, towards the Ob' gulf, and in the general tapering out up the cross-section of both the depression

itself, and the large structures, which complicated this depression. It has been noted that the large internal elevations of the northern and pre-polar parts of the lowland are characterized by a lengthy consedimentary growth, which continued at a fairly intensive rate until the end of the Mesozoic.

Seven oil- and gas-bearing horizons have been established in the Jurassic-Cretaceous deposits: the Lower-Middle Jurassic, the Upper Jurassic, the Lower-Middle Valanginian, the Upper Bavly, the Hauterivian-Barremian, the Aptian-Albian-Cenomanian and the Upper Cretaceous horizon. By the beginning of 1970, over 120 oil and gas fields had been discovered in this basin. Some of these fields are unique with regard to their reserves (the Urengois'kii, Samotlorskii, Zapolyarnyi fields). The proven reserves of this basin exceed 8 trillion cu. m., and its predicted reserves amount to several tens of trillions cu. m.

The report summarizing the valuation of potential oil and gas resources in the West Siberian lowland /31/ mentions that thick argillaceous-arenaceous Jurassic and Cretaceous beds occur in the northern areas of this lowland (the so-called Northern oil- and gas-bearing province) and that a number of oil and gas fields have been discovered here (Novoportovskii, Tazovskii and others). These fields are confined to large positive structural elements (domes and megaramparts). The Nydovskii, Nurmiskii, Ma'lo-Khetskii

and Messoyakhskii fields are the most promising ones among them.

The authors evaluate the potential of the Kara Sea offshore area. It is assumed that the thickness of the sedimentary platform mantle is here 2-3 km, and that gas pools, confined to Jurassic and Lower Cretaceous deposits, predominate in this region. V. G. Vasil'ev et al /9/ believe that oil and gas-oil fields are also extensively developed

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in these deposits. R.M. Demenitskaya and D.E. Levin /16/ suggest that the most promising objects for prospecting for oil and gas are confined to the submarine extension of the Koltogorskii-Urengoiszkii downwarp, which is filled in this region with Mesozoic-Cenozoic deposits over 4 km. in thickness. However, the water area of the West Siberian basin is generally less promising with regard to oil and gas than is the adjoining mainland.

In the opinion of R.M. Demenitskaya and L.E. Levin, the northeastern part of the Kara Sea holds no promise of oil or gas. The downwarp near the northwestern shores of Severnaya Zemlya constitutes here an exception. The spatial relations of this downwarp with the Barents Sea basin are not clear. I.S. Gramberg /12/ believes that deposits of the Devonian system may prove to be potentially promising in this downwarp. It is possible that the North Kara Sea and Barents Sea basins are separated by a bend. In this event

the North Kara depression should be regarded as an independent possible oil- and gas-bearing basin.

The Enisei-Khatanga oil- and gas-bearing basin is confined to a downwarp which bears the same name, but is referred to occasionally as the pre-Taimyr downwarp. It is situated in the zone of junction of the East Siberian and West Siberian Platforms with the Taimyr folded region. The basin borders in the east on the West Siberian basin, in the south and southeast on the Tunguska and Lena-Vilyui basins; it is bounded in the north by the Taimyr upland (Byranga mountains), in the northeast--by the submarine extension of mesozoids of the Yana-Kolyma folded zone.

In D.B. Tal'virskii's opinion /35/, this downwarp represents a superimposed syncline of the East Siberian Platform. Its crystalline foundation consists of Archean and Lower-Middle Proterozoic rocks. The platform mantle ranges from Riphean to Cenozoic, inclusively, in age. The sedimentary mantle is subdivided in three structural stages: the Upper Proterozoic -Lower and Middle Paleozoic, the Upper Paleozoic - Lower Mesozoic, and the Mesozoic-Cenozoic stage.

The bottom stage is composed essentially of carbonaceous, to a lesser degree arenaceous-argillaceous deposits ranging in age from Riphean to Devonian, inclusively. The Riphean deposits are represented by uniform, rhythmically built beds having a terrigenous-carbonaceous composition.

The Devonian rocks often consist of evaporite formations, which compose the cores of salt domes and the gypsum cap-rocks overlapping these domes. These formations have an overall thickness of several hundred meters, and underlie argillaceous-dolomitic deposits. The total thickness of the Lower-Middle Paleozoic rocks in the Turukhansk-Noril'sk

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region is approximately 6000m.

Rocks of the middle structural stage are represented by terrigenous-carboniferous formations of Carboniferous and Permian age. These deposits are overlain by thick beds of volcanic rocks (traps). These rocks occur with a marked unconformity upon essentially carbonaceous deposits of the lower structural stage. The overall thickness of these beds exceeds 6000 m.

The Mesozoic-Cenozoic deposits are represented by marine, lagoon and continental terrigenous formations of Triassic, Jurassic-Cretaceous and Pliocene-Quaternary age, which have a total thickness of 7-8 km or more. This complex resembles along general lines the platform mantle of the West Siberian lowland.

In deposits of the bottommost structural stage the main rocks holding a promise of oil and gas are the jointy carbonaceous and terrigenous interlayers occurring in the subsaliferous deposits. An economically insignificant seepage of oil was recorded from these deposits in one of

the areas. The rocks of the middle stage are equally promising: oil seepages have been recorded from terrigenous Permian and Triassic deposits in the Nordvik-Khatanga region.

The principal productive complex is represented at the present time by Mesozoic deposits. Gas pools have been discovered in these deposits in six areas located at a distance of 150-225 km, from Noril'sk. The proven gas reserves made it possible to build and bring into operation the Messoyakha-Noril'sk gas pipeline.

The predicted reserves of gas in this basin have been evaluated as equal to 1.5 trillion cu. m. (Avrov et al., 1965). The western part of the basin, particularly the marginal zones of the downwarp, are the most promising objects of search for new fields.

According to V.G. Vasil'ev's data (1965), the northern part of the Verkhoyansk-Vilyui oil- and gas-bearing basin extends into the Arctic sector of the Asian USSR. This portion of the basin is bounded by the slope of the Anabar-Olenek anteclise and by the Verkhoyansk folded region. In the modern structural plan the basin is a heterogenous formation composed of the merged Verkhoyansk foredeep and Vilyui syneclide. In the map of the oil- and gas-bearing basins of the world (I.V. Vysotskii, V.G. Levinson et al., 1967), the Anabar-Olenek anteclise is amalgamated with this territory into one single Lena-Vilyui basin. The foundation

of the basin was stripped by a key well in the northern part of the Verkhoyansk downwarp, and was dated as Proterozoic /8/. On the territory of the Anabar-Olenek anteclide

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the foundation is represented by Archean formations. Sedimentary rocks are here represented by Riphean, Paleozoic, Mesozoic and (to a lesser degree) Cenozoic deposits having a total thickness of 18-22 km. in the Verkhoyansk downwarp, and 12 km. in the Vilyui synclise. In the lowest-level portion of the Vilyui synclise, Mesozoic rocks constitute at least 5-6 km. of the cross-section, whereas in the Verkhoyansk downwarp about 70% of the cross-section of the sedimentary mantle consists of Paleozoic deposits.

The stratigraphic range of the possible oil and gas content in this basin is very large (from the Sinian to the Upper Cretaceous, inclusively). Lower Cambrian, Ordovician, Silurian, possibly Upper Paleozoic and Mesozoic deposits are here the most promising rocks. A gas-bearing region of economic importance has been detected in the central part of the Verkhoyansk downwarp. Five fields with the proven total gas reserves of 252 milliard cu. m. and with some 2 trillion cu. m. of predicted gas reserves /9/, were discovered on this territory. Productive terrigenous deposits are here of Jurassic and Triassic age. Intensive oil and gas shows have been recorded in Cambrian deposits of the northern flank of the Aldan anteclide. The main region of

prospecting for new fields in Mesozoic deposits is the central part of the Vilyui synclise, in Cambrian deposits--the northern flank of the Aldan anteclide and the southern border of the Anabar-Olenek anteclide. The total predicted reserves of natural gas in this basin are estimated as equal to nearly 13 trillion cu. m. /9/.

The Tunguska possible oil- and gas-bearing basin is one of the largest (with regard to its areal extent) basins of the Soviet Asia. The Arctic sector of the USSR includes, however, only the northmost peripheral portion of this basin. The basin has been very little explored. The Tunguska synclise (i.e. the principal geostructural element of the basin) represents a large intraplatform depression composed of Riphean and Paleozoic terrigenous-carboniferous beds with a total thickness of 9-11 km. Of these deposits, 2.5-3.5 km. are represented by Paleozoic rocks. The oil and gas potential is here associated mainly with Cambrian deposits, to which numerous oil and gas shows are confined /8/.

The parageosynclinal depression /1/ of the Laptev Sea is situated on the territory of the depression bounded in the west by mesozoids of the Yana-Kolyma folded zone, in the east--by the Novosibirsk-Chukchi peninsula folded zone. This depression is filled with Upper Cretaceous-Neogene deposits. The thickness of the sedimentary mantle in this

to represent an independent basin, i.e. the Laptev Sea possible oil- and gas-bearing basin. There are, however, also somewhat different views on the subdivision of this region into oil- and gas-bearing zones. R.M. Demenitskaya and L.E. Levin /16/ assume that the Verkhoyansk downwarp closes at the latitude of the Olenek projection, which serves here as a divide between the Verkhoyansk-Vilyui and Anabar-Laptev oil-gas basins. At the present time this is an open problem. On the whole, these authors have a favourable opinion of the Laptev Sea depression with regard to its oil and gas potential.

The Kolyma oil- and gas-bearing basin is located in the northeastern part of the Kolyma platform /8/ or Kolyma massif /39/. The most promising region with regard to oil and gas is here the Moma-Zyryanskii depression situated in the direct vicinity of the Arctic Circle. The depression is composed of thick (up to 6-7 m) beds of Mesozoic deposits, in the cross-section of which coastal-marine and lacustrine argillaceous-arenaceous formations occur alongside the lacustrine-continental effusive-sedimentary carboniferous deposits.

The North Yakutian (Indir*-Khroma) basin is situated

*Probably another mistake and should be Indigirkka.
(Translator)

on the territory of the Yana-Indigirka lowland and in the adjacent coastal regions of the East Siberian Sea. A.A. Trofimuk /39/ refers to this region as the Maritime depression, and points out that it resembles from the geological viewpoint the Upper Mesozoic-Cenozoic depressions of Alaska. A.A. Trofimchuk believes that the oil and gas potential of this depression is greater than that of the Moma-Zyryanskii hollow.

R.M. Demenitskaya and L.E. Levin /16/ refer to this region as the Indigirka-Chukchi peninsula possible oil- and gas-bearing basin, and assume that this basin extends into the East Siberian and Chukchi sea basins. However, at the present level of our knowledge of the geological structure of these depressions, we cannot reject the possibility that an independent Chukchi - East Siberian oil- and gas basin may be situated on the territory of these depressions. The shelf of these sea basins is located within the boundaries of the submerged blocks of the Hyporboreal Platform, enclosed between the mountainous formations of the geosynclinal Mesozoic structures. B. Kh. Egiazarov /14/ isolated here the East Siberian parageosynclinal depression, which is filled with Upper Cretaceous and Paleogene deposits and is

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analogous to the Laptev Sea basin and to the North Alaskan depression (the depression of the Arctic slope). In the northeastern direction, the roof of the foundation subsided

to the depth of 10 and more kilometers. Other researchers assert that the sedimentary mantle of the East Siberian syneclyse is filled mainly with carbonaceous-terrigenous rocks of Paleozoic and Mesozoic age /16/. These researchers believe that the oil and gas potential of the East Siberian shelf is at par with that of the submarine mainland periphery of the Barents Sea.

A group of intermontane depressions of the southeastern Chukchi peninsula and northern Kamchatka forms several small oil- and gas-bearing basins. Among them the basins located closest to the Arctic Circle are the Penzhina, West Kamchatka, Kamchatka-Olyutorskii basins and the Soviet portion of the Anadyr'-Seward basin, which extends under the waters of the Bering Sea into the Central Alaska.

These basins are composed mainly of terrigenous and carboniferous deposits of Upper Cretaceous-Cenozoic age, and attain a thickness of several kilometers. All the basins enclose a profusion of oil and gas shows. In 1969, a productive gas seepage from arenaceous Eocene rocks was reported near the city of Anadyr'. In general these basins reveal a considerable geological resemblance to the oil- and gas-bearing basins of the Southern and Central Alaska, described here earlier.

A composite map illustrating the oil and gas potential of the Arctic and Subarctic regions, is presented in Fig. 10. The total surface area of the territory holding a

promise of oil and gas is 10.5 million sq. km. above the 60th parallel, 7.5 million sq. km. inside the Arctic Circle. Over 5 million sq. km. of the potentially promising territory represents shallow-water areas of various sea basins of the Arctic Ocean. These figures are fairly close to the data presented by M.K. Kalinko /18/, who estimated the total surface area of promising and possibly promising areas in the Arctic Ocean as equal to 4 million sq. km. Of the total promising territory in the Arctic and Subarctic regions, about 8 million sq. km. (i.e. 76%) are located on the Soviet mainland and in the territorial waters of the USSR. Highly promising sections occupy approximately one-third of this surface area. The Arctic slope basin, the Beaufort and Sverdrup basins have the highest oil and gas potential in the American Arctic. Basins of the Soviet Arctic, which are at part with these American basins, are the Timan-Pechora,

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Barents Sea basins, the northern part of the West Siberian basin and, possibly, the Chukchi - East Siberian basin. As a result of the survey and prospecting works carried out in the American and Canadian North, the predicted oil and gas resources of the Arctic USSR territories should be re-evaluated and raised accordingly, and the potential oil and gas resources in the adjacent water areas should be estimated anew.

It is thus evident that the Soviet Arctic (including

its shallow-water areas) represents one of the largest oil and gas reserves, a locale for future development of the oil and gas industry of our country, and may become one of the principal objects of prospecting for oil and gas within the next 10-20 years.

At the modern rate of development of the oil and gas production, improvement in the organization methods, drilling techniques and exploitation of wells under a variety of climatic conditions, it is difficult to predict the exact date, on which the development of the oil and gas resources in the Soviet Arctic will begin. It is, however, obvious that these resources must be taken into account in the objective long-term (i.e. to the years 2000-2050) planning of the development of national resources.

In order to gain a correct perspective for the future surveying and prospecting for oil and gas in the Soviet Arctic (both on the shelf and on the adjacent mainland territories), a large-scale marine reconnaissance of the entire shelf area should be initiated. It should include a systematic study of the natural geophysical fields (magnetic and gravity fields) in conjunction with the regional GSZ* profiles, as well as a series of regional MOV* profiles in addition to those already available. The purpose of

*These symbols probably refer to the gravity and magnetic profiles, respectively. (Translator)

these investigations is to elucidate the main features of the floor of the sedimentary horizons on the territory of the shelf, as well as of the earth crust as a whole.

Reconnaissance survey of the shallow southeastern part of the Barents Sea, in the East Siberian Sea and Laptev Sea should be continued in order to define precisely the structural pattern of the principal complexes of the sedimentary mantle not only in the water areas, but also on the mainland adjacent to these areas. It is easier to study geology, oil and gas content of coastal areas by approaching these areas from the sea, than under the conditions of the tundra, which is accessible with difficulty. In order to provide a general valuation of the oil and gas resources for a number of regions, it appears expedient to drill deep parametric boreholes and to carry out a detailed geophysical survey on the Kolguev peninsula, on one of the Novosibirskie islands and in the Spitsbergen archipelago. All this will enable us to select in future the main objects of prospecting for oil and gas more rationally and objectively.

TABLE 1

Oil and Gas Discovered in the Arctic and Subarctic Regions of America (according to the data of 1970)

TABLE 1 (cont'd)

Basin	Age of productive deposits										
	Cambrian	Ordovician	Silurian	Devonian	Carboniferous	Permian	Triassic	Jurassic	Cretaceous	Paleogene	Neogene
<u>Intermontane depressions of Cordilleras</u>											
Cook Bay	-	-	-	-	-	-	OSh GSh	OSh GSh	-	O G	-
St. Elias	-	-	-	-	-	-	-	-	-	O	-
Alaska Peninsula . .	-	-	-	-	-	-	B	OSh	B	OSh	-
Nushagak	-	-	-	-	-	-	-	-	OSh	-	-
Copper	-	-	-	-	-	-	-	-	GSh	-	-
Yukon-Flats-Kandik .	-	-	-	-	-	B	-	B	-	-	-
Bethel-Yukon-Koyukuk	-	-	-	-	-	-	-	-	-	-	GSh OSh
Tanana	-	-	-	-	-	-	-	-	-	-	GSh OSh
Selawik	-	-	-	-	-	-	-	-	-	-	GSh OSh

LEGEND: O - oil pools;
 G - gas pools;
 OSh - oil shows;
 B - bituminous sands.

*Transliteration. (Translator)

TABLE 2

Geological Potential Oil and Gas Resources of the Arctic and Subarctic Basins of America (to the depth of 5000 m. and to the isobath of 300 m.)

Basins	Promising territory in thousands of sq. km.		Potential resources			
	Total area	Under-water area	Oil, millions of tons			
			Paleo-zoic	Meso-zoic	Ceno-zoic	Total
Hyperboreal Platform	890	590	17600	42800	-	60400
Arctic slope	500	330	13900	13400	-	27300
Sverdrup	290	140	-	26200	-	26200
Beaufort	100	70	3700	3200	-	6900
Canadian Platform .	1000	360	16500	-	-	16500
Lancaster	230	80	5800	-	-	5800
Melville-Victoria .	400	210	10400	-	-	10400
Wollaston	40	10	-	-	-	-
Foxe	90	60	-	-	-	-
Mackenzie	30	-	100	-	-	100
Northern part of the West Canadian Basin	210	-	200	-	-	200
Cordilleras	930	540	1600	7200	6900	15700
Cook Bay	20	10	-	150	1200	1350
Nushagak	280	220	-	1600	2200	3800
Alaska Peninsula . .	40	30	-	200	1600	1800
St. Elias	50	40	-	-	1900	1900
Yukon-Flats-Kandik .	30	-	1300	1000	-	2300
Bethel-Yukon-Koyukuk	380	210	100	3500	-	3600
Eagle Plain	30	-	100	-	-	100
Copper	20	-	-	150	-	150
Tanana	30	-	-	-	-	-
Selawik	50	30	100	600	-	700
TOTAL	2820	1490	35700	49100	6900	92600

TABLE 2 (cont'd)

Basins	Potential resources							
	Dissolved gas, milliards cu. m.				Free gas, milliards cu. m.			
	Paleo- zoic	Meso- zoic	Ceno- zoic	Total	Paleo- zoic	Meso- zoic	Ceno- zoic	Total
Hyperboreal Platform .	300	1000	-	1300	3700	3300	1800	8800
Arctic slope	200	400	-	600	3700	1900	-	5600
Sverdrup ...	-	400	-	400	-	800	1800	2600
Beaufort ...	100	200	-	300	-	600	-	600
Canadian Platform .	3200	-	-	3200	7200	-	-	7200
Lancaster ..	1000	-	-	1000	1900	-	-	1900
Melville- Victoria .	2100	-	-	2100	4200	-	-	4200
Wollaston ..	-	-	-	-	200	-	-	200
Foxe	-	-	-	-	500	-	-	500
Mackenzie ..	40	-	-	40	100	-	-	100
Northern part of the West Canadian basin	60	-	-	60	300	-	-	300
Cordilleras	100	400	300	800	100	700	2400	3200
Cook Bay ...	-	10	20	30	-	100	50	150
Nushagak ...	-	60	140	200	-	500	100	600
Alaska Peninsula	-	10	60	70	-	100	100	200
St. Elias ..	-	-	80	80	-	-	100	100
Yukon-Flats- Kandik ...	70	60	-	130	-	-	200	200
Bethel-Yukon -Koyukuk .	10	200	-	210	-	-	1700	1700
Eagle Plain	10	-	-	10	100	-	-	100
Copper	-	10	-	10	-	-	50	50
Tanana	-	-	-	-	-	-	100	100
Selawik	10	50	-	60	-	-	100	100
TOTAL	3800	1400	100	5300	11000	4000	4200	19200

TABLE 3

Recoverable Potential Oil and Gas Resources of Arctic and
 Subarctic Basins of America (to the depth of
 5 km, and to the isobath of 300 m)

Basin	Potential resources		
	Oil, millions of tons		Dissolved gas, milliards of cubic meters
	K=0.3	K=0.5	Free gas, milliards of cubic meters
Hyperboreal Platform . . .			
Arctic slope	18200	30000	650
Sverdrup	8200	13600	300
Beaufort	7900	13000	200
	2100	3400	150
Canadian Platform			
Lancaster	4900	8250	1550
Melville-Victoria . . .	1700	2900	500
Wollaston	3100	5200	1000
Foxe	-	-	-
Mackenzie	-	-	-
West Canadian basin . .	30	50	20
	70	100	30
Cordilleras (Canadian and Alaskan)			
Cook Bay	4600	7700	400
Nushagak	400	700	20
Alaska Peninsula	1150	1900	100
St. Elias	550	900	30
Yukon-Flats-Kandik . .	550	950	40
Bethel-Yukon-Koyukuk .	700	1150	60
Eagle Plain	1000	750	100
Copper	30	50	10
Tanana	20	50	10
Selawik	-	-	-
TOTAL	27700	46000	2600
			15200

TABLE 4

Distribution of Potential Oil and Gas Resources of the Arctic and Subarctic Regions of America
in the Main Groups of Basins (to the depth of 5000 m. and to the 300 m. isobath)

Basin	Oil		Dissolved gas		Free gas		Conventional equivalent	
	millions of tons	%	milliards of cu. m.	%	milliards of cu. m.	%	millions of tons	%
Hyperboreal Platform	60400	65.0	1300	25.0	8800	46.0	70500	60.0
Arctic slope	27300	-	600	-	5600	-	33500	-
Sverdrup	26200	-	400	-	2600	-	29200	-
Beaufort	6900	-	300	-	600	-	7800	-
Canadian Platform	16500	18.0	3200	60.0	7200	37.0	26900	23.0
Lancaster	5800	-	1000	-	1900	-	8700	-
Melville-Victoria	10400	-	2100	-	4200	-	16700	-
Other basins	300	-	100	-	1100	-	1500	-
cordilleras	15700	17.0	800	15.0	3200	17.0	19700	17.0
Cook Bay	1350	-	30	-	150	-	1530	-
Nushagak	3800	-	200	-	600	-	4600	-
Alaska Peninsula	1800	-	70	-	200	-	2070	-
St. Elias	1900	-	80	-	100	-	2080	-
Yukon-Flats-Kandik	2300	-	130	-	100	-	2530	-
Bethel-Yukon-Koyukuk	3600	-	210	-	1700	-	5510	-
Other basins	950	-	80	-	350	-	1380	-
TOTAL	92600	100	5300	100	19200	100	117100	100

TABLE 5

Distribution of potential oil and gas resources in the Arctic and Subarctic basins of America by the main stratigraphic complexes of deposits (to the depth of 500 m. and to the 300 m. isobath).

Groups of Basins	Oil		Dissolved gas		Free gas		Conventional equivalent	
	millions of tons	%	milliards of cu. m.	%	milliards of cu. m.	%	millions of tons	%
perboreal Platform	60400	100	1300	100	8800	100	70500	100
Cenozoic	-	-	-	-	1800	20	1800	2
Mesozoic	42800	71	1000	77	3300	38	47100	67
Paleozoic	17600	29	300	23	3700	42	21600	31
nadian Platform	16500	100	3200	100	7200	100	26900	100
Cenozoic	-	-	-	-	-	-	-	-
Mesozoic	-	-	-	-	-	-	-	-
Paleozoic	16500	100	3200	100	7200	100	26900	100
rdilleras	15700	100	800	100	3200	100	19700	100
Zenozoic	6900	44	100	13	2400	75	9400	48
Mesozoic	7200	46	400	50	700	22	8300	42
Paleozoic	1600	10	300	37	100	3	2000	10
TAL:	92600	100	5300	100	19200	100	117100	100
Zenozoic	6900	7	100	2	4200	22	11200	10
Mesozoic	50000	54	1400	26	4000	21	55400	47
Paleozoic	35700	39	3800	72	10000	57	50500	43

TABLE 6

Technological and Economic Indices of the Drilling for Oil
and Gas in Alaska during the Period of 1959-1968

Indices	Values of Indices
Total drilling, <u>thousands of m, boreholes</u>	1291.5 428
Including:	
reconnaissance and exploratory wells	600.1 226
producing wells	691.4 202
Mean depth of the wells (of all the types) in m	3020
Mean depth of reconnaissance and exploratory wells, in m.	2650
Mean depth of producing wells, in m.	3420
Increment in proven reserves (in conventional equivalent), millions of tons	210
Total capital investment in the oil-producing industry (in millions of dollars)	1000
Including:	
the prospecting and exploratory works	93.9
Mean number of wells per drill rig	5.8
Mean drill rig sinkage (in thousands of meters)	17.5
Mean cycle speed, in m/st.* - mes.*	1455
Specific capital investments in prospecting and surveying per ton of increment in the reserves, calculated in terms of the oil equivalent, dollars/tons	0.45

*Transliteration. (Translator)

TABLE 7

Relative Cost of Drilling in Alaska and in Other Oil- and
 Gas-Producing States of the USA (according to the
 data of N.A. Badovskii, V.V. Shimanovskii,
 N.S. Tolstoi)

Alaska	21	2720	1268	473.0
Texas	12730	1462	56	40.0
mainland . . .	12696	1462	55	36.6
sea	34	2900	347	123.3
Louisiana	5395	2040	132	66.6
mainland . . .	4494	1800	85	46.6
sea	901	3230	367	116.6
California	2601	1065	59	56.6
mainland . . .	2541	1620	54	50.0
sea	60	1065	258	163.3
Oklahoma	4009	1340	53	40.0
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USA	44481	1310	56	43.3
mainland . . .	43486	1280	49	40.0
sea	225	3110	360	116.6

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*This name appears in this paper in two different forms: Geist and Geits (both are transliterations). It may be Gates, (Translator).

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APPENDIX.

Fig. 1. Schematic tectonic map of the northern periphery of the Canadian Platform, of its geosynclinal border and of the portions of the Hyperboreal Platform adjacent to the Canadian Platform(drawn by N.S.Tolstoi on the basis of the data from the works by V.F.*King,1969; T.Payne,1955; R.Thorsteinsson and E.Tocer, 1964; I.P.Atlasov' et al, 1964; B.Kh.Egiazarov, 1969).

Canadian Platform: 1-Precambrian foundation exposed on the surface; 2-Contour lines of the Pretambrian foundation; 3-Proven direction of the dip of strata; 4- Syneclyses, depressions and pericratonnal downwarps.

Hyperboreal Platform: foredeeps: 5- On the mainland; 6-In water areas; 7-Depressions in the outer corners of the platform; 8-Ramparts and large local elevations; 9-Diapiric structures.

The Proterozoic folded belt of Greenland: 10-Baykalids of the Northeastern Greenland.

The Paleozoic folded Franklin belt: 11- Region of the Early Paleozoic Cornwallis miogeosyncline and of the Northern Greenland; region of the Late Paleozoic folding; 12-The Piri^{**}, Ellesmere, Mackenzie-Banks miogeosyncline; 13-The Northern Ellesmere eugeosyncline.

The Mesozoic folded belt of Alaska and Canada: The miogeosynclinal province: 14- Anticlinoria; 15-Depressions; The eugeosynclinal province: 16-anticlinoria, elevations; 17-Depressions.

*If this is the author listed in the bibliography, the initials are Ph.B. (Translator).

**Transliteration. Should probably be Peary. (Translator).

(Fig.1, continued)

The Cenozoic folded belt of Alaska and Canada: The eugeosynclinal province: 18-anticlinoria; 19-synclinoria, depressions; contour lines along the Mesozoic marker surfaces in depressions; 20-Nushagak - the floor of the Jurassic, Cook Bay - the roof of the Middle Jurassic, Copper - the roof of the Jurassic, St.Elias - the roof of the Cretaceous.

Magmatic rocks: 23- intrusive; 24- effusive; 25- abyssal master faults; 26- disjunctive dislocations.

Gravity terraces demarcating the Hyperboreal Platform with its foredeeps and downwarpes: 27- detected; 28- presumed; 29- superimposed Quaternary depressions of the Cordilleras, Alaska and Canada.

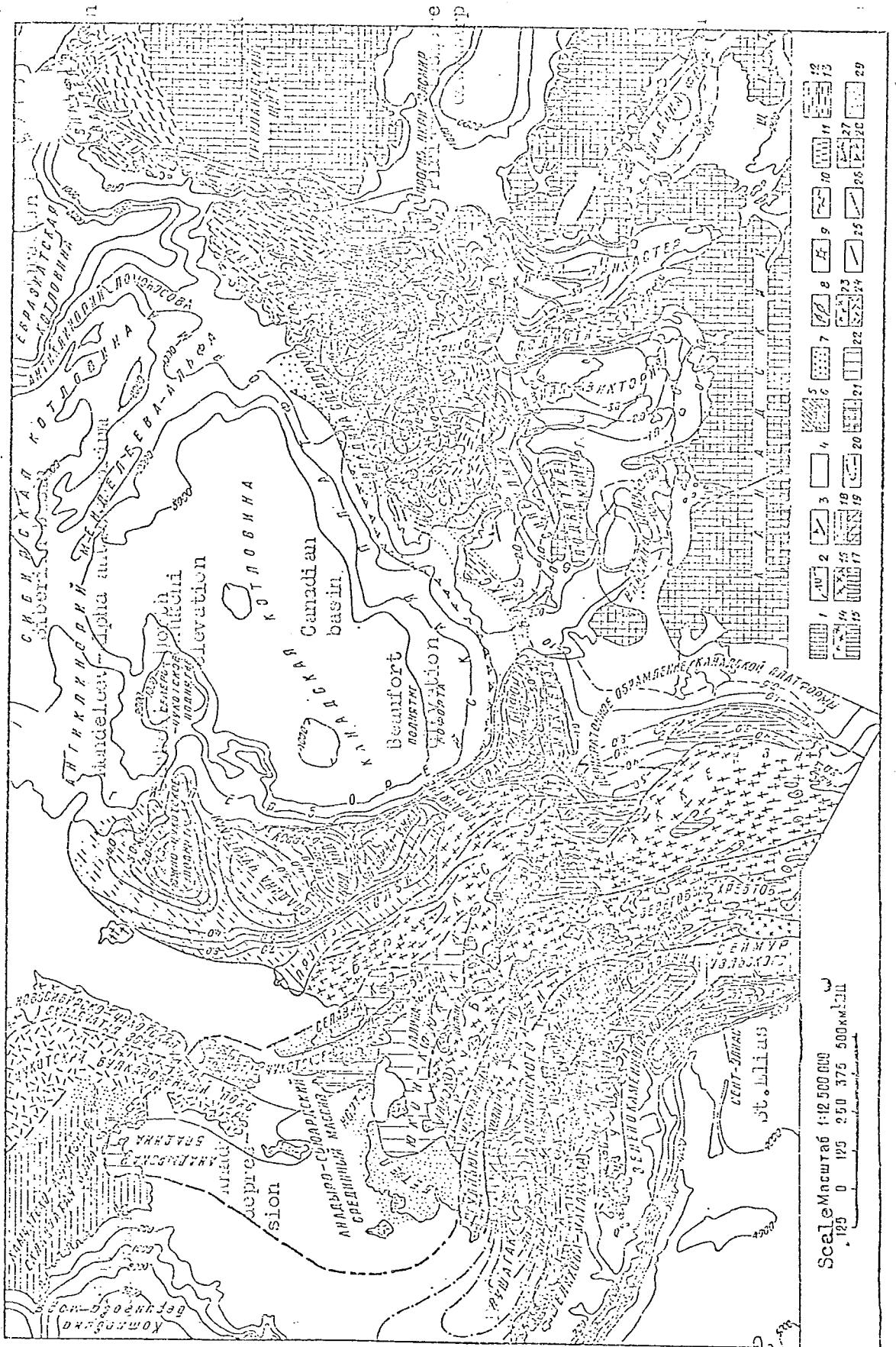
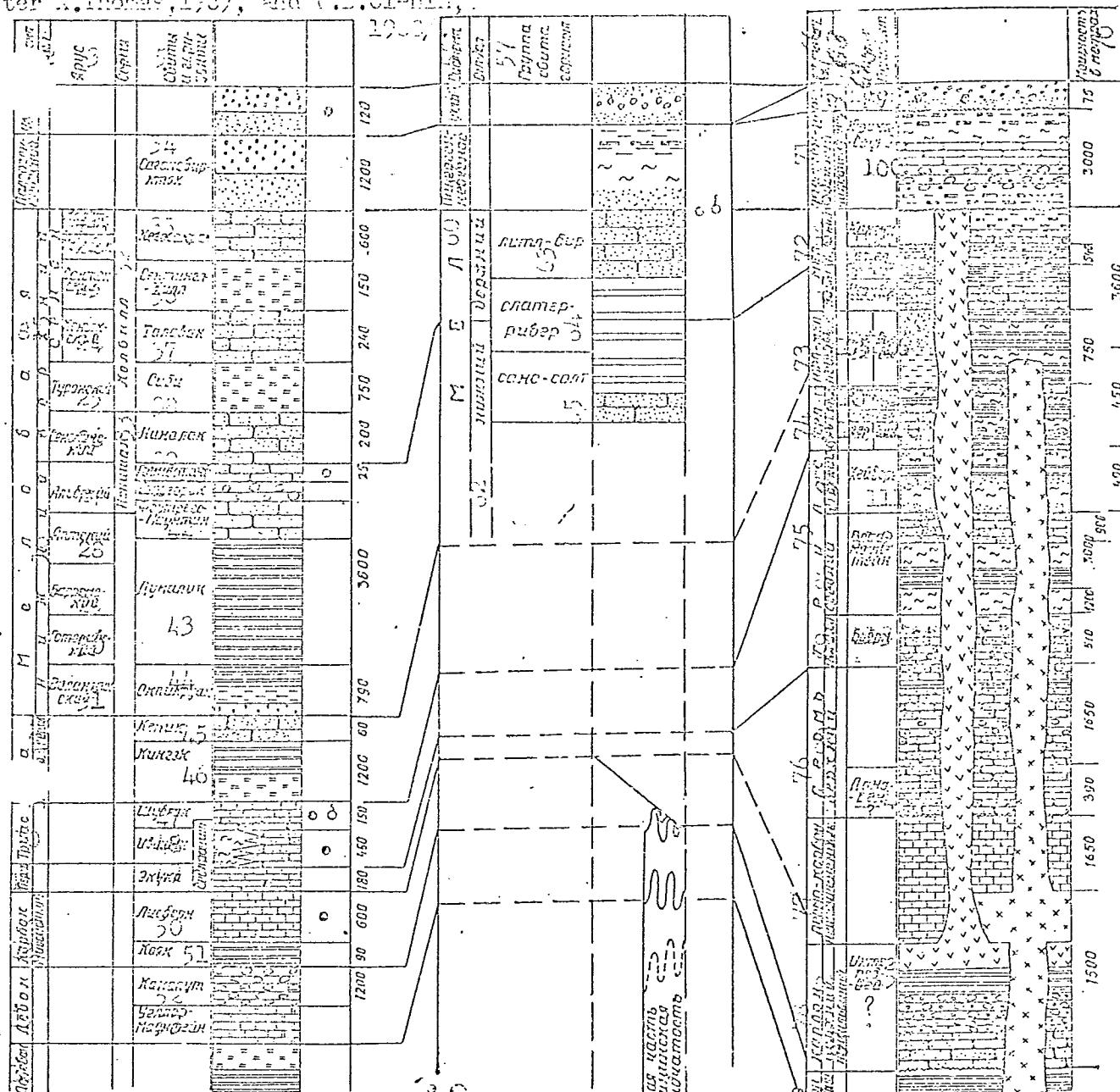


Рис. 1. Схематическая тектоническая карта северной окраины Канадской платформы, ее геосинклинального обрамления и прилегающих частей Гренландской платформы (составил Е. С. Толстой, по материалам В. Ф. Книга, 1959; Т. Пенса, 1955; Р. Торстейнсона и Е. Тозера, 1954; И. Г. Агасона и др., 1951; Б. Х. Еринаарова, 1959):

Канадская платформа: 1 — докембрийский фундамент на дневной поверхности докембрийского фундамента; 2 — изогипсы поверхности докембрийского фундамента; 3 — установочные направления на пласты; 4 — сплошные, впадины и перикратонные изогипсы, впадины и крупные ложбинные прогибы, Гренландская платформа; 5 — на суше, 6 — в сгустках; 7 — впадины винческих углов платформы; 8 — вали и крупные ложбинные прогибы, Гренландия; 9 — диапировые структуры. **Протерозойский складчатый пояс Гренландии:** 10 — байкальский Северо-Восточный складчатый пояс Гренландии, 11 — обширный раннепалеозойской многосторонней складчатости; 12 — многосторонней складчатости Пирри, Эуэлли, Нарри, Маккензи-Банкс, 13 — эпигенетическая область Северной Эскимоидной Гренландии; 14 — антиклиналь Канады и Аляски; 15 — антиклиналь Канады и Аляски; 16 — антиклиналь, поднятия, 17 — впадины. **Кайнозойский складчатый пояс Канады и Аляски:** 18 — антиклиналь Канады; 19 — антиклиналь Аляски; 20 — антиклиналь Канады; 21 — антиклиналь Аляски; 22 — антиклиналь Канады; 23 — антиклиналь Аляски; 24 — антиклиналь Канады; 25 — антиклиналь Аляски; 26 — антиклиналь Канады; 27 — антиклиналь Аляски; 28 — антиклиналь Канады; 29 — антиклиналь Аляски.

after A. Thomas, 1953, and V. B. Olenin,



Southwest part of
Territory of
Siberian Platform

Volga

Fig. 2.

Рис. 2. Схема корреляции сводных литолого-стратиграфических разрезов южной окраины Гиперборейской платформы (составил Н. С. Толстой):

1 — конгломераты; 2 — песчаники; 3 — пески; 4 — алевролиты; 5 — аргиллиты; 6 — сланцы; 7 — глины; 8 — известняки глинистые; 9 — известняки; 10 — известковистые сланцы; 11 — доломитизированные известняки; 12 — доломиты; 13 — гипс; 14 — ангидриты; 15 — интрузивные породы; 16 — эфузивные породы; 17 — ископаемый уголь; 18 — конкреции; 19 — кремень; 20 — перерывы в осадконакоплении; 21 — брекчии; 22 — брекчированные конгломераты; 23 — аркозовые песчаники; 24 — кварциты; 25 — битумы

Fig.2. Correlation scheme of the summary lithological-stratigraphic cross-sections of the southern periphery of the Hyperboreal Platform (by N.S.Tolstoi).

1- conglomerates; 2- sandstones; 3- sands; 4- aleurites; 5- argillites; 6- schists; 7- clays; 8- clayey limestones (marlstones); 9- limestones; 10- calcareous shales; 11- dolomitized limestones; 12- dolomites; 13- gypsum; 14- anhydrites; 15- intrusive rocks; 16- effusive rocks; 17- mineral (fossil) coal; 18- concretions; 19- silicon; 20- breaks in sedimentation; 21- breccias; 22- brecciated conglomerates; 23- arkose sandstones; 24- quartzites; 25- bitumens.

The figures typed in red on the drawing stand for:

1-System; 2-Division; 3- Stage; 4- Series; 5- Suites and horizons; 6-Quaternary; 7- Paleogene-Neogene; 8-Cretaceous; 9-Jurassic; 10-Triassic; 11-Permian; 12-Carboniferous; 13-Devonian; 14-Pre-Devonian; 15-Upper; 16-Lower; 17-Upper; 18-Middle; 19-Lower; 20-Mississippian; 21-Maestrichtian; 22-Campanian; 23-Santonian; 24-Coniacian; 25-Turonian; 26-Cenomanian; 27-Albian; 28-Aptian; 29-Barremian; 30-Hauterivian; 31-Valanginian; 32-Colville; 33-Nenashak*; 34-Saganavirktok**; 35-Kogosukruk; 36-Sentinel Hill; 37-Talavak; 38-Sibi*; 39-Ninalak***; 40-Grandstand; 41-Topagoruk; 42-Fortress Mountain; 43-Dumalik*; 44-Okpikruak; 45-Kamik; 46-Kingak; 47-Shublik; 48-Ivishak; 49-Ekuka****; 50-Lisburne; 51-Kayak; 52-Kanaput*; 53-Weller

*Transliteration.(Translator).

**Saganavirktok in the text. Probably another mistake.(Translator).

***Nina Lake? (Translator).

****Akook?(Translator).

Mountain; 54-Saddlerochit; 55-System; 56-Division; 57-Stage; 58-Group, suite, horizon; 59-Quaternary; 60-Paleogene-Neogene; 61-Cretaceous; 62-Upper; 63-Lower; 64-Little Bir*; 65-Slater River; 66-Sans Salt; 67-System; 68-Stage; 69-Group, suite, horizon; 70-Thickness in meters; 71-Paleogene-Neogene; 72-Cretaceous; 73-Jurassic-Cretaceous; 74-Jurassic; 75-Triassic; 76-Permian; 77-Permo-Carboniferous; 78-Carboniferous; 79-Devonian; 80-Ordovician-Silurian; 81-Lower; 82-Upper; 83-Lower; 84-Undifferentiated; 85-Lower; 86-Middle; 87-Upper; 88-Middle; 89-Lower; 90-Upper; 91-Undifferentiated; 92-Upper; 93-Upper; 94-(same as 80); 95-Eocene; 96-Paleocene?; 97-Pennsylvanian; 98-Undifferentiated; 99-Beaufort; 100-Eurica Sound; 101-Kanguk; 102-Hassel; 103-Christopher; 104-Isachsen; 105- (Illegible) Bay; 106-Deep Bay; 107-(illegible); 108-(illegible); 109-Jaeger; 110-Seivik*; 111-Kheiverg*; 112-Blaa* Mountain; 113-Björn; 114-Donovan; 115-Intrepid; 116-Allen; 117-Christopher; 118-Dzhe Ger**.

*Transliteration. Probably should be Little Bear. (Translator).
110,111,112-Transliterations. (Translator).

**Transliteration. Jaeger? (Translator).

Лю Ф. Стити 1959, Р. Дурсади Р. Гардстейнсону,
Б. Дору 1959, В. Есупову 1959, Г.В. Никанорову 1959.
Гартер. Г. Альб. 1959, Г. Тодор. 1963.

S. Tozer, 1963, —
B. M. Agiazarov, 1969, T. V.
. Lechenova, 1969/.

Рис. 3. Схема корреляции сводных литолого-стратиграфических разрезов северной окраины Канадской платформы (составил Н. С. Толстой)

Fig.3. Same legend as in Fig.2.

Correlation scheme of summary lithological-stratigraphic cross-sections of the northern periphery of the Canadian Platform (by N.S. Tolstoi).

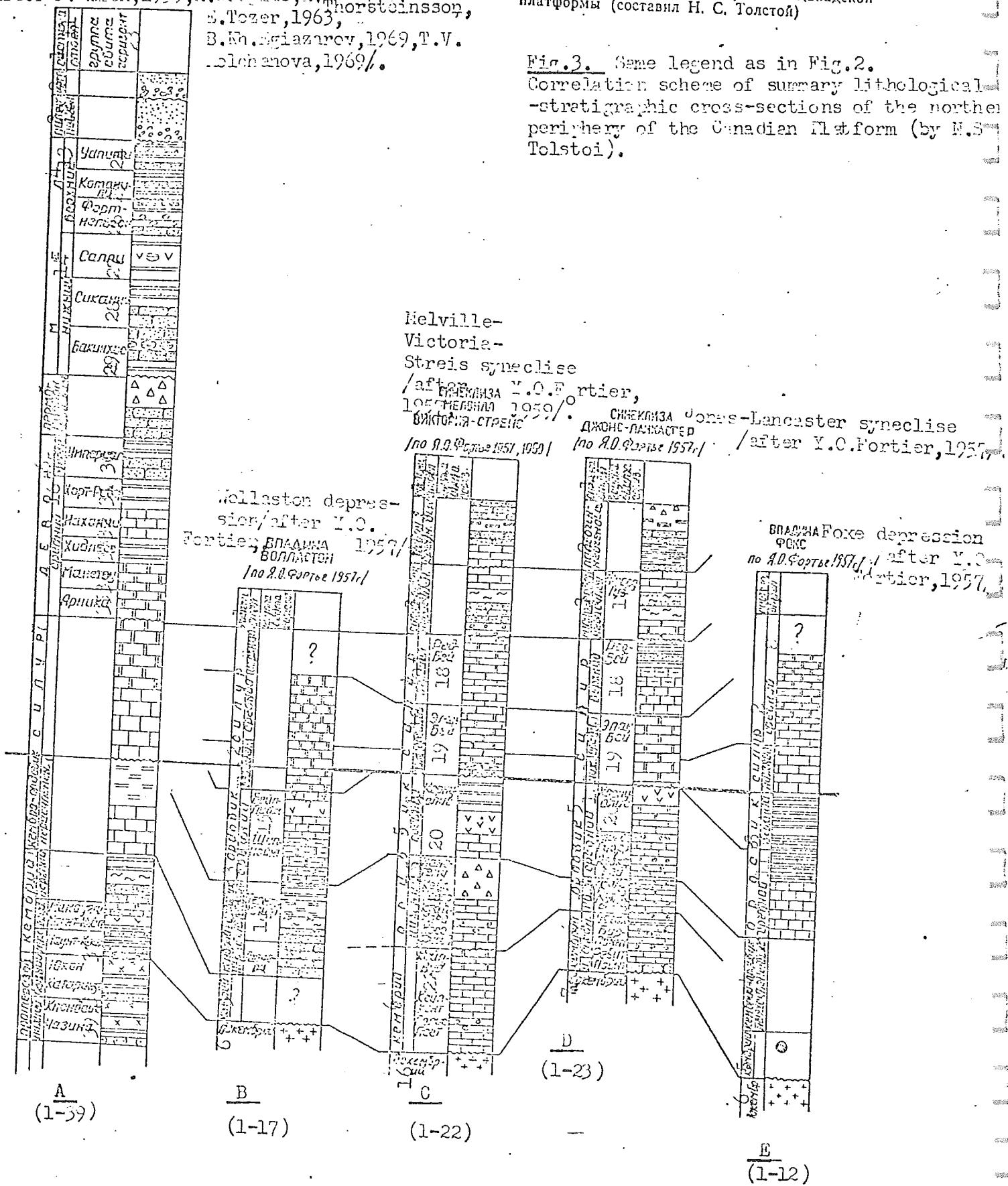


Fig.3.A

1-System; 2-Quaternary; 3-Paleogene; 4-Cretaceous; 5-Permo-Carboniferous
 (undifferentiated); 6-Devonian; 7-Silurian; 8-Cambro-Ordovician; 9-Cambrian;
 10-Proterozoic; 11-Division; 12-Neogene; 13=Upper; 14=Lower; 15=Upper;
 16-Middle; 17=Undifferentiated; 18=Upper; 19=Middle; 20=Lower; 21=Upper;
 22=Lower; 23=Group, suite, horizon; 24-Uapiti*; 25-Kotaneelee; 26-Fort Nelson;
 27-Sally; 28-Sikanni*; 29-Bakinkhos*; 30-Imperial; 31-Khort* River; 32-
 Nahannie; 33-Khidless**; 34-Manetoe; 35-Arnica; 36-McDougal; 37-Mount Cape;
 38-Yukon-Katarina*; 39-Klondike-Nazina*.

B

1-System; 2-Silurian; 3-Ordovician; 4-Cambrian-Ordovician; 5-Cambrian; 6-
 Precambrian; 7-Division; 8=Upper; 9=Middle; 10=Lower; 11=Upper; 12=Middle;
 13=Undifferentiated; 14=Group, suite, horizon; 15-Bail Lodge, Ship Point;
 16-Turner Cliff; 17-Gallery.

C

1-System; 2-Devonian; 3-Silurian-Devonian; 4-Silurian; 5-Ordovician; 6-Camb-
 rian; 7-Division; 8=Upper; 9=Middle; 10=Undifferentiated; 11=Upper; 12=Middle;
 13=Lower; 14=Middle; 15=Lower; 16-Precambrian; 17-Group, suite, horizon; 18=
 Red bay; 19-Manay Bay; 20-Cornwallis; 21-Manotumi?/Manetumi??*, Cape Weber, Cape
 Clay, Kess?/Kese?* fiord; 22-Cape Wood, Cape Kent, Police post.

D

1-System; 2-Paleogene-Neogene; 3-Silurian-Devonian; 4-Silurian; 5-Ordovician;
 6-Cambrian; 7-Precambrian; 8-Division; 9=Undifferentiated; 10=Upper; 11=Middle;
 12=Lower; 13=Middle; 14=Lower; 15=Middle; 16=Group, suite, horizon;

*Transliteration. (Translator).

**Probably Khidless. (Translator).

17-Goose Fiord; 18-Red Bay; 19-Alan Bay; 20-Cornwallis; 21-Eleanor River;
Crocker Bay; 2-Neito?/Neipo?* River, Mingo?*Minto?* River, Bear Point,
Rabbit Point.

Ea

1-System; 2-Silurian; 3-Ordovician; 4-Jambrian-Ordovician; 5-Cambrian;
6-Precambrian; 7-Division; 8-Middle- 9-Lower; 10-Upper; 11-Middle; 12-Undif-
ferentiated.

*Transliteration.(Translator).

Лист № 1
Антиклинальный хр бруска Д. М. Шигазарову, 1969г.
по Б. Елангарову

Лист № 2
Складчатый пояс Элсилий
по Б. Елангарову, 1969г.

центральная часть
северная часть
западная часть
восточная часть
южная часть
полярная часть
юго-западная часть
юго-восточная часть
юго-восточная часть
юго-западная часть

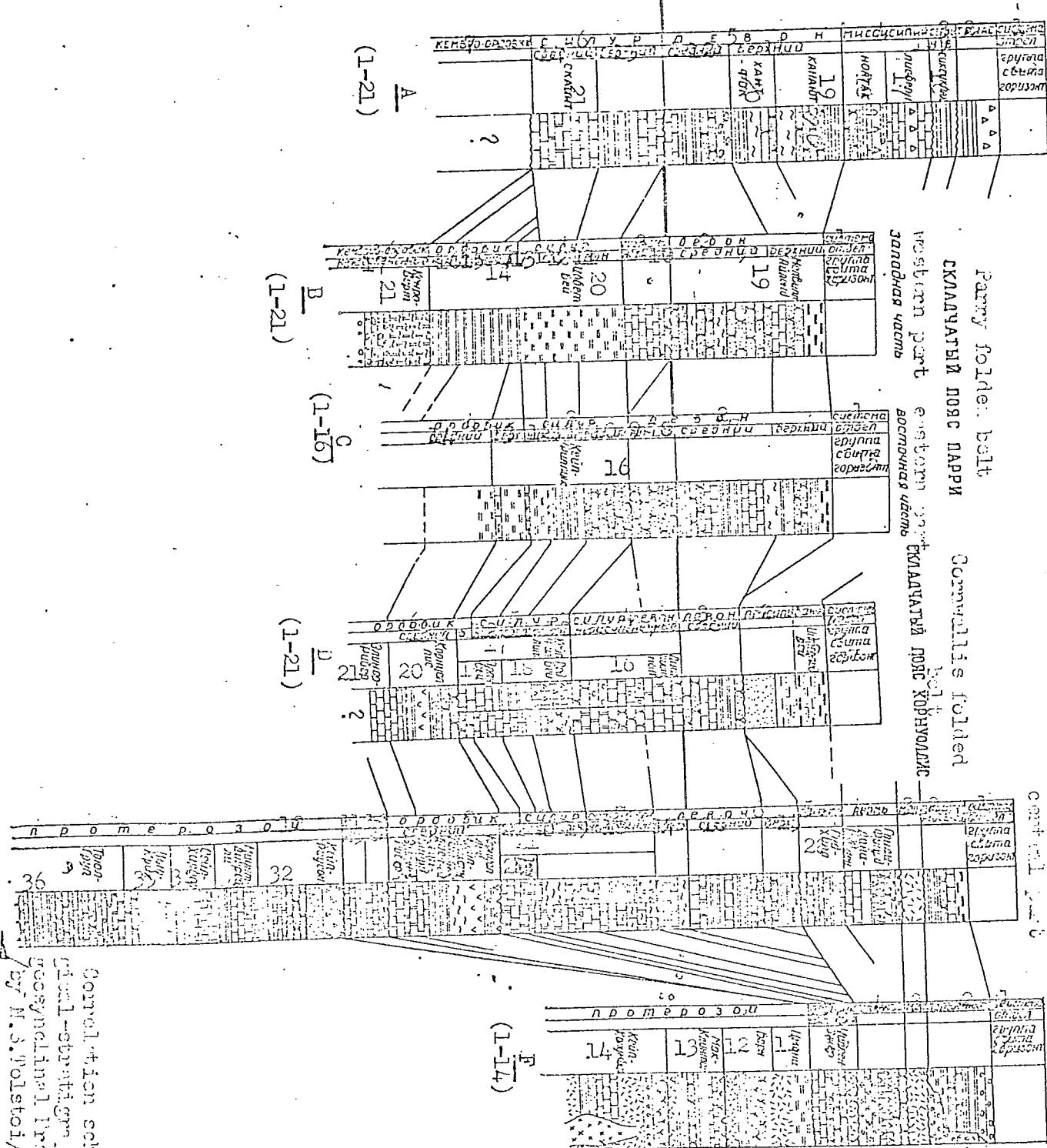


Рис. 4. Схема корреляции сплошных литолого-стратиграфических разрезов геотектонического пояса франклинов и хрестообразного бруска (составил Н. Г. Томин)

Условные обозначения те же,
что на рис. 2

Correlation scheme of the sub-area lithological-stratigraphic continuous cross-sections of the geotectonic Franklin belt and Brooks range (compiled by N. G. Tomin).

(1-36)

Fig. 4.

A

1-System; 2-Triassic; 3-Permian; 4-Mississippian; 5-Devonian; 6-Silurian;
7-Carbo-Ordovician; 8-Division; 9-Upper; 10-Lower; 11-Upper; 12-Middle;
13-Upper; 14-Middle; 15-Group,suite,horizon; 16-Siksikpak; 17-Lisburne;
18-Noatak*; 19-Kanayut; 20-Hunt-Fox/Foxe; 21-Skaiit*.

B

1-System; 2-Devonian; 3-Silurian-Devonian; 4-Silurian; 5-Ordovician; 6-
Cambrian-Ordovician; 7-Division; 8-Upper; 9-Middle; 10-Indifferentiated;
11-Upper; 12-Middle; 13-Lower; 14-Upper; 15-Middle; 16-Upper; 17-Undif-
ferentiated; 18-Group,suite, horizon; 19-Melville Island; 20-Ibbett; 21-
Kenro-Bert.

C

1-System; 2-Devonian; 3-Silurian; 4-Ordovician; 5-Division; 6-Upper; 7-
Middle; 8-Middle; 9-Lower; 10-Upper; 11-Middle; 12-Lower; 13-Upper; 14-
Middle; 15-Group,suite,horizon; 16-Cape Phillips.

D

1-System; 2-Pennsylvanian; 3-Devonian; 4-Silurian-Devonian; 5-Silurian;
6-Ordovician; 7-Division; 8-Middle; 9-Undifferentiated; 10-Upper; 11-
Middle; 12-Lower; 13-Middle; 14-Group,suite,horizon; 15-Intrepid Bay;
16-Disappointment; 17-Cape Phillips; 18-Red Bay; 19-Alan Bay; 20-Cornwal-
lis; 21-Eleanor River.

*Transliteration.(Translator).

E

1-System; 2-Paleogene; 3-Cretaceous; 4-Permian; 5-Permo-(illegible); 6-
Devonian; 7-Silurian-Devonian; 8-Silurian; 9-Ordovician; 10-(illegible);
11-Carboniferous; 12-Proterozoic; 13-Division; 14-Neogene;
15-Upper; 16-Middle; 17-Lower-Middle; 18-Undifferentiated; 19-Upper; 20-
Middle; 21-(illegible); 22-Upper; 23-Middle; 24-Undifferentiated; 25-
Middle; 26-Group,suite,horizon; 27-Greely Fiord, Donovan,(illegible); 28-
Good Hill/Goodhill; 29-Alan Bay; 30-Cornwallis, Cape Kolkhoun*, Ganiake*,
Daz* Bay(or:Ganiakedaz Bay), Cape Baird; 31-Eleanor River; 32-Cape Rawson;
33-Mount Disraeli; 34-Sail Harbour; 35-View Creek; 36-Tryul?Toyul?* Group.

F

1-System; 2-Paleogene-Neogene; 3-Cretaceous; 4-Permo-Carboniferous; 5-Or-
dovician; 6-Proterozoic; 7-Division; 8-Middle; 9-Group,suite,horizon;
10-Chaplen/Chaplain Eshet**; 11-Imina*; 12-Barn; 13-MacClintock; 14-Cape
Columbia.

*Transliteration.(Translator).

**Transliteration.. Azure?(Translator).

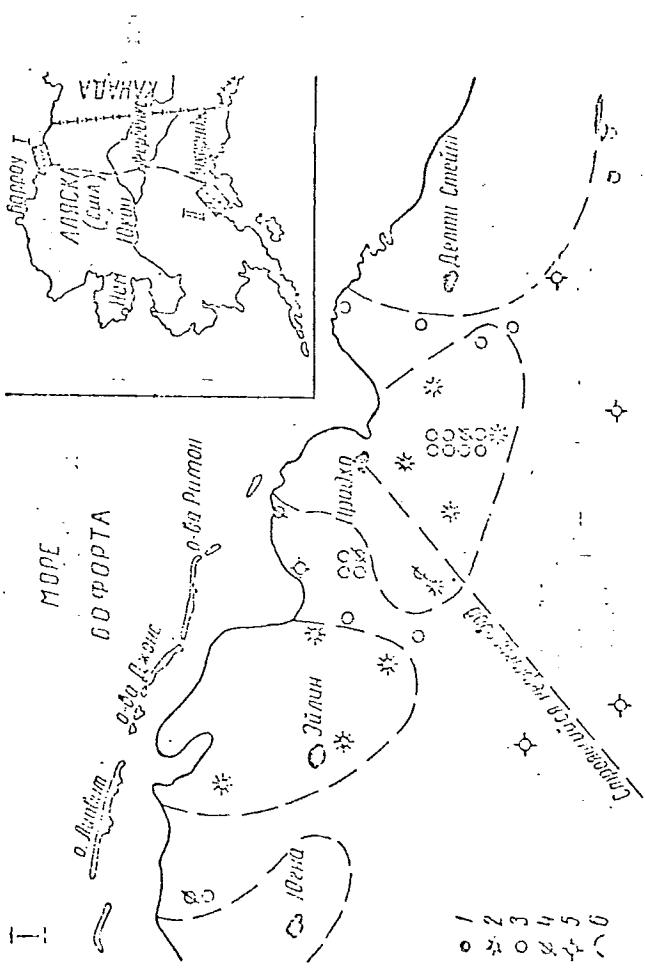


Рис. 5. Схема размещения нефтяных месторождений в районе залива Прудхоу (составлено Г. А. Байденской и Н. С. Толстой):
1 — скважина-первоначальная; 2 — другая продуктивная нефтяного пласта до 1970 г.; 3 — скважина скважинной, находящейся в бурении на начало 1970 г.; 4 — скважина, находящаяся в бурении на начало 1970 г.; 5 — скважина скважинной, или законтурной, или перекрестной на сухом. II — прорезка: I — район залива Прудхоу, II — район залива Кукы.



Рис. 7. Гидролого-стратиграфические разрезы бассейна Залива Кукы (составлены Н. С. Толстой по материалам Ф. Смита, 1939; Т. Келли, 1957). Условные обозначения те же, что на рис. 2.

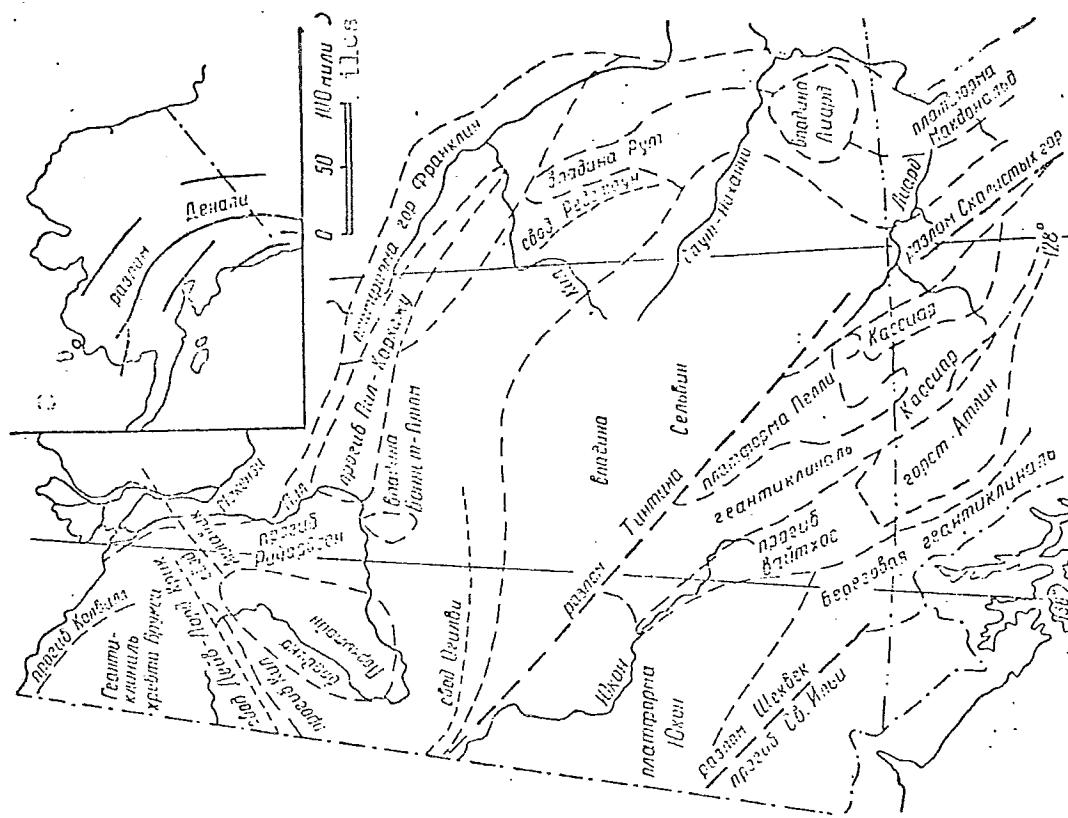


Рис. 6. Схема расположения основных тектонических элементов Северных Кордильер (по Х. Габриэлсону, 1967 г.; из книги В. Х. Еназарова, 1969 г.).

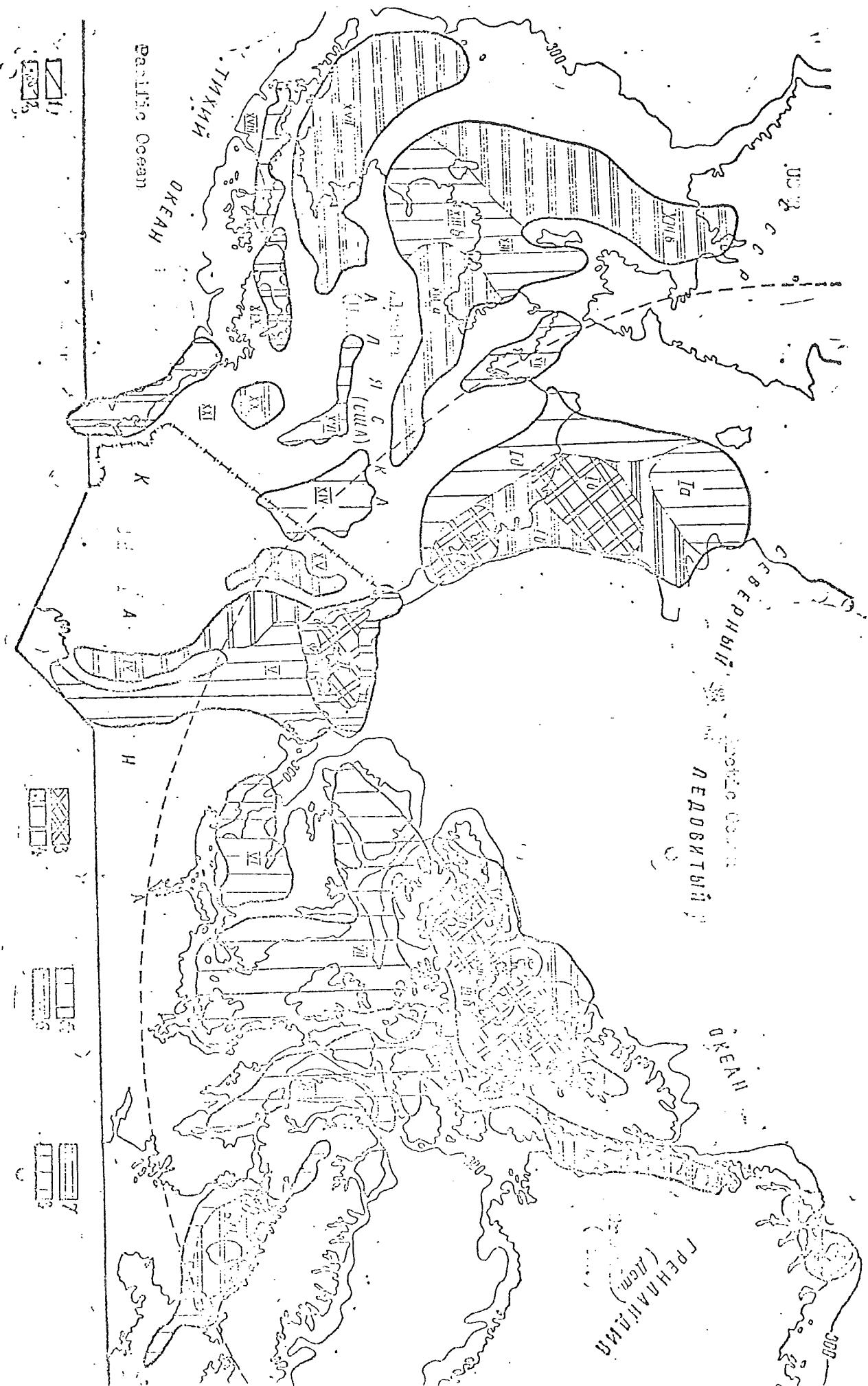
Северные Кордильеры — это система горных хребтов, расположенных вдоль побережья Северного Ледовитого океана от Берингова пролива до Берега Чукотки. Основные горные хребты Северных Кордильер — это Аляскинская горная система и Чукотская горная система. Аляскинская горная система включает в себя горы Клондайк, Горы Аляски, Горы Канадиан и Горы Сибирь. Чукотская горная система включает в себя горы Чукотка, Горы Камчатка и Горы Сибирь. Северные Кордильеры являются результатом активной тектонической деятельности, которая началась в эпоху палеогена и продолжается до настоящего времени. Основные тектонические элементы Северных Кордильер включают в себя: 1) горы Клондайк, 2) горы Аляски, 3) горы Канадиан, 4) горы Сибирь, 5) горы Чукотка, 6) горы Камчатка, 7) горы Сибирь. Северные Кордильеры являются важным источником минеральных ресурсов, в том числе нефти и газа.

Page 7.

1-System; 2-Quaternary; 3-Neogene-Paleogene; 4-Cretaceous; 5-Jurassic; 6-Triassic; 7-Permian; 8-Carboniferous; 9-Division; 10-Post-Eocene; 11-Eocene; 12-Upper; 13-Lower; 14-Upper; 15-Middle; 16-Lower; 17-Upper; 18-Lower; 19-Upper; 20-Lower; 21-Upper; 22-Lower; 23-Group,suite,horizon; 24-Eska; 25-Tsadaka; 26-Wishbone; 27-Chickaloon; 28-Arkose; 29-Natanuska; 30-Naknek*; 31-Chinitna; 32-Tuxedni; 33-Talkeetna; 34-Nikolai; 35-Lithology; 36-Glacial-alluvial deposits; 37-Gravel, sand, conglomerate; 38-Sandstones, argillites, schists, conglomerates with coal seams; 39-Schists, sandstones with inter-layers of conglomerates; 40-Dark fine-grained limestones with (illegible), tuff-conglomerates and arkoses; 41-Basal conglomerates, schists, arkoses, sandstones; 42-Schists; 43-Sandstones, schists, conglomerates, arkoses; 44-Volcanic rocks; 45-Schists, limestones; 46-Greenstone rocks (effusives and their pyroclasts); 47-Basalts, tuffs, tuff breccias, argillites, siliceous rocks, limestones; 48-Volcanic rocks, argillites, limestones, siliceous rocks, conglomerates; 49-Thickness; 50-Group,suite,horizon; 51-Kenai; 52-Hemlock; 53-Nikolai; 54-Lithology; 55-Glacial-alluvial deposits; 56-sandstones, argillites, conglomerates, schists; 57-sandstones, conglomerates, ampelites; 58-Basal Tertiary continental rocks; 59-Marine meta-sediments, mainly argillites; 60-Volcanic rocks; 61-Limestones, volcanic rocks; 62-greenstone continental rocks (effusives and their pyroclasts); 63-Thickness; Transliteration.(Translator).

64-Group,suite,horizon; 65-Kenai; 66-Hemlock; 67-Koguak*; 68-Lithology;
69-Glacial-alluvial deposits; 70-Sandstones, argillites, conglomerates,
schists; 71-Sandstones, conglomerates, ampelites; 72-Basal Tertiary con-
tinental rocks; 73-Marine and continental sandstones and argillites; 74-
Marine schists and sandstones; 75-Marine meta-sediments (argillites?);
76-Volcanic rocks; 77-Limestones, volcanic rocks; 78-Greenstone rocks (ef-
fusives and their pyroclasts); 79-Thickness; 80-Group,suite,horizon; 81-
Koyalagvik*
Naknek; 82-Chinitna; 83-Tuxedni; 84-Kamishak; 85-Lithology; 86-Glacial-
alluvial deposits; 87-Schists, arkoses, sandstones; 88-Marine argillaceous
shales; 89-Sandstones, schists, conglomerates, arkoses. Arenaceous schists,
conglomerates; 90-Volcanic rocks; 91-Hornfels, siliceous rocks, clay shales,
limestones.

*Transliteration.(Translator).



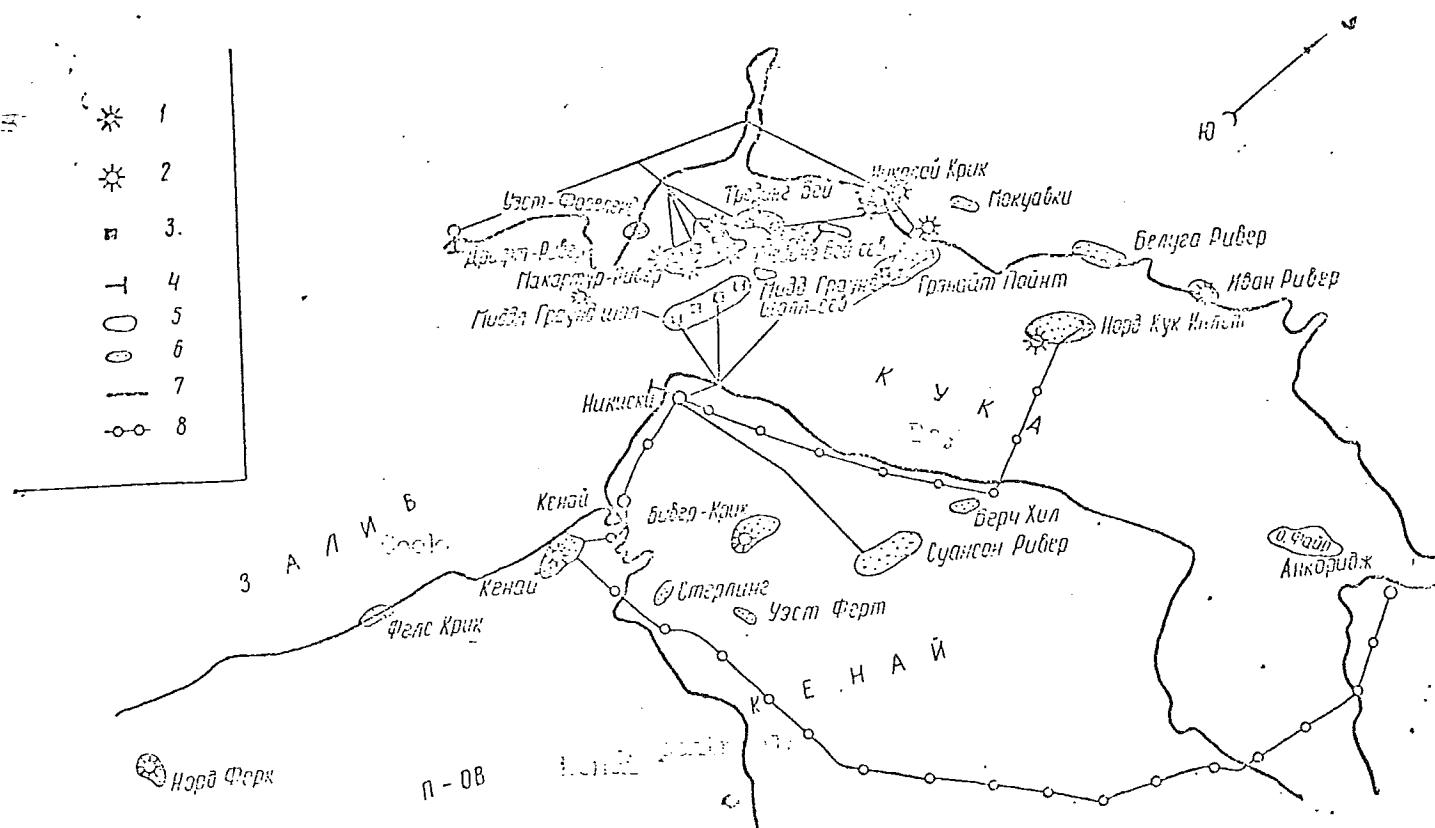


Рис. 8. Схема размещения месторождений нефти и газа в районе залива Кука (составили Н. А. Бадовский и Н. С. Толстой):

1 — поисковые скважины, давшие нефть; 2 — поисковые скважины, давшие газ; 3 — действующие стационарные буровые платформы; 4 — базы отгрузки; 5 — месторождения нефти; 6 — месторождения газа; 7 — нефтепроводы; 8 — газопроводы

Приложение 9. Схематическая карта потенциальных ресурсов углеводородов нефтегазоносных и возможно нефтегазоносных бассейнов севера Канады, Аляски и прилегающих к ним акваторий (составили М. Ш. Моделевский и Н. С. Толстой):

Schematic map of potential resources of hydrocarbons

Рис. 9. Схематическая карта потенциальных ресурсов углеводородов нефтегазоносных и возможно нефтегазоносных бассейнов севера Канады, Аляски и прилегающих к ним акваторий (составили М. Ш. Моделевский и Н. С. Толстой):

1 — границы нефтегазоносных и возможно нефтегазоносных бассейнов, 2 — изобаты 300 м. Плотность потенциальных ресурсов нефти и газа в условном нефтяном эквиваленте, тыс. т/км²: 3 — более 100, 4 — 50—100, 5 — 30—50, 6 — 10—30, 7 — 5—10, 8 — менее 5.

Бассейны: I — Арктического склона (а — Южно-Чукотское поднятие, б — Чукотская впадина, в — поднятие Барроу-Мид, г — Балтейкин; I — Арктического склона (а — Южно-Чукотское поднятие, б — Чукотская впадина, в — поднятие Барроу-Мид, г — Чукотская впадина Униат, д — прогиб Колвила); II — Баффория; III — Свердруп (а — Западно-Свердрупская впадина, б — поднятие Эл впадина Униат, д — прогиб Колвила); IV — Макконзи; V — Западно-Канадский; VI — Волластон; VII — Медведев-Рингнес, в — Восточно-Свердрупская впадина); VIII — Джонс-Линкастер; IX — Пирн-Элекмар; X — Ванделя; XI — Фокс; XII — Селавик; XIII — Аналвиль-Виктория; XIV — Юкон-Кокиук, б — впадина Бета, в — Аназдырская впадина); XV — Юкон-Флете-Кандик; XVI — Аляско-Сьюардский (а — впадина Юкон-Кокиук, б — впадина Бета, в — Аназдырская впадина); XVII — полуострова Аляска; XVIII — полуострова Аляска; XVIII — полуострова Аляска; XIX — залива Кука; XX — Коннер; XXI — Игл-Плейн; XVI — Танана; XVII — Нушагак; XVIII — полуострова Аляска; XIX — залива Кука; XX — Коннер; XXI — Сент-Элиас —

Fig.9.

1-Boundaries of the proven and possible oil- and gas-bearing basins; 2- The 300m. isobath. Density of potential oil and gas resources in the conventional oil equivalent, thousands of tons/ sq.km.; 3-over 100; 4- 50 to 100; 5- 30 to 50; 6- 10 to 30; 7- 5 to 10; 8- less than 5.

Basins: I- Arctic slope (a- South Chukchi elevation, b- Chukchi depression, c- Barrow-Meade elevation, d- Umiat depression, e-Colville downwarp); II- Beaufort; III- Sverdrup (a-West Sverdrup depression, b- Ellef-Ringnes elevation, c- East Sverdrup depression); IV-Mackenzie; V- West Canadian; VI- Wollaston; VII- Melville-Victoria; VIII- Jones-Lancaster; IX-Peary-Ellesmere; X- Wandel; XI- Foxe; XII- Selawik; XIII- Anadyr'-Seward (a-Yukon-Koyukuk depression, b-Bethel depression, c- Anadyr' depression); XIV- Yukon-Flats-Kandik; XV-Eagle Plain; XVI-Tanana; XVII-Nushagak; XVIII- Alaska peninsula; XIX- Cook Bay; XX- Copper; XXI-St.Elias.

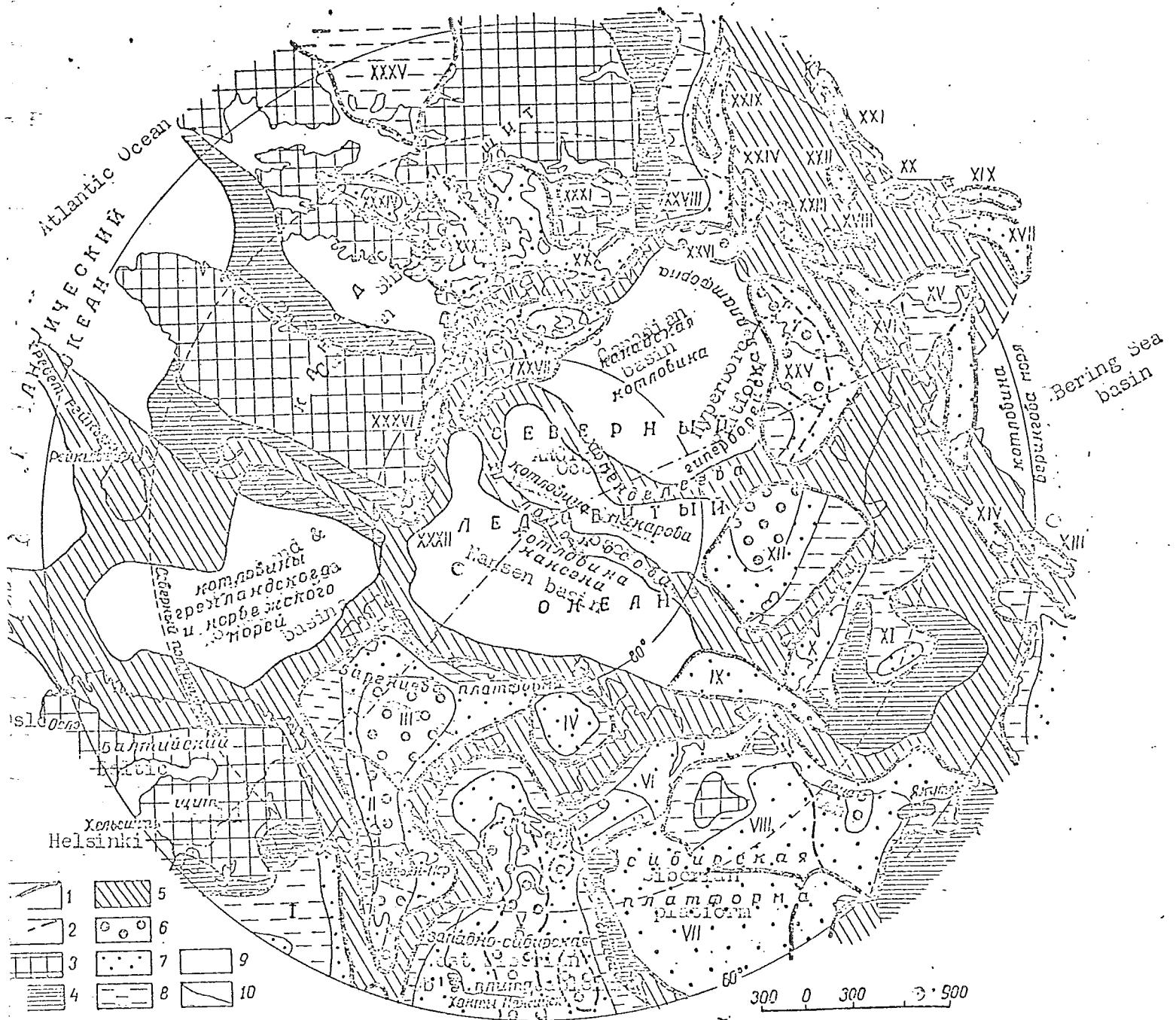


Fig. 10.
10. Схематическая карта перспектив нефтегазоносности Арктики и Субарктики составили М. Ш. Моделевский и Н. С. Толетой, 1970):

— границы нефтегазоносных и возможно нефтегазоносных бассейнов; 2 — границы крупных геоструктурных элементов внутри бассейнов; 3 — области выхода фундамента на поверхность; 4 — области распространения маломощного (менее 500 м) осадочного чехла; 5 — складчатые области.

Категории перспективности: 6 — высокоперспективные; 7 — перспективные; 8 — малоперспективные; 9 — глубоководные единицы и бесперспективные терриории и акватории; 10 — границы зон различной перспективности.

Бассейны: I — Мезенский, II — Тимано-Печорский, III — Баренцевоморской, IV — Восточно-Карский, V — Западно-Сибирский, VI — Енисей-Хатангский, VII — Тунгусский, VIII — Лено-Вилюйский, IX — Лаптевоморской, X — Северо-Якутский, XI — Колымский, XII — Чукотско-Восточно-Сибирский, XIII — Олоторский, XIV — Пенжинский, XV — Анадыро-Сынгирдский, XVI — Селавик, XVII — Нушигак, XVIII — Таанана, XIX — Полуострова Аляска, XX — Залива Кука, XXI — Сент-Элиас, XXII — Коннер, XXIII — Юкон-Флэтс-Кандик, XXIV — Игл-Плейн, XXV — Арктического склона; XXVI — Бофорта, XXVII — бердруп, XXVIII — северная часть Западно-Канадского бассейна, XXIX — Маккензи, XXX — Мельвилл-Виктория, XXXI — Волластон, XXXII — Ванделя, XXXIII — Джонс-Ланкастер, XXXIV — Фокс, XXXV — Гудзонова залива, XXXVI — Пари-Элсмир

Fig.10.

Schematic map of oil and gas prospects in the Arctic and Subarctic regions
(by M.Sh.Medelevskii and N.S.Tolstoiy, 1970).

1-Boundaries of producing and possible oil- and gas-bearing basins; 2-Boundaries of large geostructural elements of internal basins; 3-regions marked by foundation outcrops; 4-Regions of distribution of thin(less than 500m. in thickness) sedimentary mantle; 5-Folded zones.

Degrees of promise: 6-highly promising; 7-promising; 8-of little promise;
9-Deep-water depressions and territories of submarine regions, which hold no promise; 10-boundaries of the zones varying in degree of promise.

Basins: I-Mezenskii; II-Timan-Pechora; III-Barents Sea; IV-East Kara; V-West Siberian; VI-Enisei-Khatanga; VII-Tunguska; VIII-Lena-Vilyui; IX-Laptev Sea; X-North Yakutian; XI-Kolyma; XII-Chukchi-East Siberian; XIII-Olyutorski XIV-Penzhina; XV-Anadyr'-Seward; XVI-Selawik; XVII-Nushagak; XVIII-Tanana; XIX-Alaska peninsula; XX-Cook Bay; XXI-St.Elias; XXII-Copper; XXIII-Yukon-Flats-Kandik; XXIV-Eagle-Plain; XXV-Arctic slope; XXVI-Beaufort; XXVII-Sverdrup; XXVIII-Northern part of the West Canadian basin; XXIX-Mackenzie; III-Melville-Victoria; XXXI-Wollaston; XXXII-Wandels; XXXIII-Jones-Lancaster; XXXIV-Foxe; XXXV-Hudson Bay; XXXVI-Parry-Elesmere.