DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

WEST SIBERIAN OIL-GAS PROVINCE

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Abstract

The West Siberian oil-gas province comprises the largest flat land area in the world (3.5 million km^2, or 1.3 million mi^2). Over most of the region, elevations rarely exceed 100 m (330 ft). The basin is bounded on the west by the Uralian and Novaya Zemlya uplifts, on the east by the Siberian craton and Taymyr uplift, on the south by the Kazakh and Altay-Sayan uplifts, and on the north by the North Siberian sill. Structurally, the basin is a broad, relatively gentle downwarp filled with 3-10 km (10-33,000 ft) of post-Paleozoic marine, nearshore marine, and continental clastic sedimentary rocks. The basement is composed of Precambrian and Paleozoic fold systems with large areas of partly metamorphosed Paleozoic carbonate and clastic rocks and numerous areas of Paleozoic or older granitic and mafic igneous bodies. In the central part of the basin, the basement is cut by an extensive, northerly-oriented Triassic rift system.

Paleostructural and stratigraphic trapping are important aspects of West Siberian petroleum geology. Oil source rocks are mainly marine Jurassic and Lower Cretaceous bituminous shales. Gas source rocks are mainly Upper Cretaceous humic and coaly shales. Petroleum production in the basin occurs in four major areas: 1) Middle Ob - Primarily oil from Lower Cretaceous deltaic-marine clastic reservoirs on broad regional uplifts; the Samotlor and other supergiant fields are located in this area; 2) Near Ural - primarily oil in the south and gas in the north from Upper Jurassic and Lower Cretaceous clastic reservoirs in paleostructural-stratigraphic traps; 3) Southern Basin - oil and oil-gas from Jurassic clastic reservoirs, mainly on anticlines or arches inherited from basement highs; 4) Northern Basin - gas primarily from Upper Cretaceous (Cenomanian) and gas-condensate from Lower Cretaceous and Jurassic clastic reservoirs on large anticlinal traps sealed by Cretaceous shales or permafrost; Urengoy, the world's largest gas field, and several other supergiant gas fields are located in this area. Large parts of the basin are relatively unexplored, particularly the northern offshore segments. The interrelated paleostructural and depositional character of this enormous basin provides excellent prospects for stratigraphic trap accumulations. An estimated 70 BBO (billion barrels oil) and 1,000 TCF (trillion cubic ft) gas have been found in the basin. USGS estimates (1987) of undiscovered conventionally recoverable petroleum resources are 30 BBO and 350 TCF gas.

WEST SIBERIAN OIL-GAS PROVINCE

James A. Peterson and James W. Clarke

Introduction

The Soviet Union now produces more than 20 percent of the world's oil, and the West Siberian oil-gas province accounts for more than half of this production. Soviet planning calls for maintaining this high rate of production through 1990 and beyond; therefore, the importance of West Siberian oil in the world economy is very significant.

Study of the petroleum geology of the West Siberian basin also contributes much to our understanding of the geologic processes by which these huge quantities of oil and gas were generated and then trapped in giant and supergiant fields. Present in the basin are all the geologic circumstances favorable for petroleum: high-quality source beds, excellent reservoirs, extensive seals, just the right temperatures for maturation, and absence of later significant faulting or erosion to adversely disturb earlier accumulations of oil and gas.

The West Siberian oil-gas province has an area of 3.5 million km^2 (figure 1) and is the largest flat area on earth. More than 1000 km upstream on the Ob River, elevations are still less than 100 m above sea level. Although the winters are unrelentingly cold, it is during this time that work is best accomplished in many areas, because in the summer the upper part of the permafrost melts and the ground becomes very soggy. Further, the rivers flow north, and spring melting takes place first in the upstream parts, causing downstream flooding over vast areas. This results in mosquito populations that are at best an extreme nuisance.

There were very few roads in West Siberia before the oil development. Transportation was along the rivers. Roads and rail lines now are being built, and air transport is used extensively. In addition, off-road vehicular traffic is common in the winter when the ground is frozen.

In spite of the weather and logistical difficulties associated with the sheer size of the operation, the Soviets manage to produce seven million barrels of oil a day in West Siberia and move it to European Russia. In order to maintain this level of production and at the same time prevent a drop in the production ratio, they must discover more than four billion barrels of new oil each year.

We hope that the material in this report will help the reader understand the geology of this region which has and will have a profound influence on the world's oil and gas supply. The material used in its preparation is available in the U.S. Geological Survey Library, Reston, Virginia, as well as in many large geological libraries of the country.

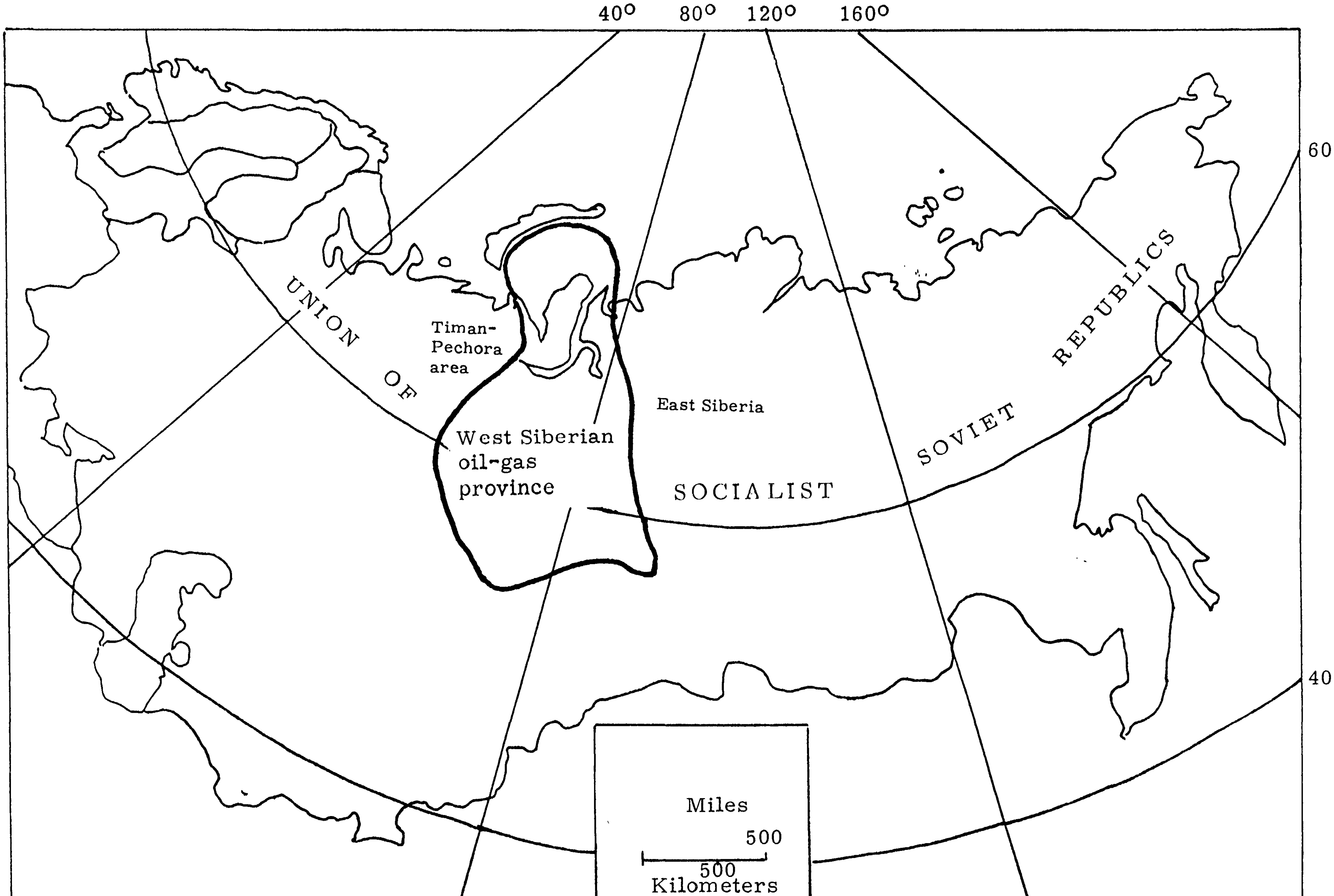


Figure 1. Location of West Siberian oil-gas province

STRUCTURE

Introduction

The West Siberian oil-gas province coincides with the West Siberian sedimentary basin. This basin, along with the Ural Mountains on the west, the Yenisey and Taymyr ranges on the east, and the Altay-Sayan and Kazakhstan shields on the south, form the north part of the Ural-Siberian or Ural-Mongolian craton. The basement of this craton is composed of Precambrian and Paleozoic fold systems, which are at the surface along the west, south, and east sides of the basin. The basin itself is a broad downwarp within this craton filled with post-Paleozoic sedimentary rocks (Surkov and Zhero, 1981, p. 4). Its northern part can be regarded as a segment of the Arctic geo-depression along with the Timan-Pechora and Barents Sea, Laptev Sea, East Siberian Sea, and the North America Alaskan North Slope, Mackenzie, and Sverdrup basins (Gramberg and others, 1984, p. 7).

Structurally, the West Siberian basin is a platform, the largest platform on the planet, having an area of about 3.5 million km^2 (1.3 million mi^2. Its closest analog is the Great Artesian basin of Australia (Khain, 1979, p. 55). Within the West Siberian basin, a thick Mesozoic-Cenozoic section of platformal sediments rests on a folded and metamorphosed basement. Several small terranes within the basement consist of unmetamorphosed Middle and Upper Paleozoic carbonate and clastic sediments and Triassic clastic sediments and volcanic rocks. These unmetamorphosed Paleozoic and Triassic rocks are called the intermediate complex.

The West Siberian platform consists of an inner region surrounded by an outer belt. The boundary between the two is a belt of steeper dip of the basement surface, along which Jurassic sediments pinch out toward the basin borders. The outer belt is monoclinal, and, in addition to a thinner section, it is characterized by the absence of major structure. In contrast, the inner basin includes mega-anticlines and mega-synclines, related to movements of basement blocks along faults (Surkov and Zhero, 1981).

Magnetic surveys have been conducted over the entire West Siberian platform. Since the rocks of the Mesozoic-Cenozoic sedimentary cover have low magnetic susceptibilities, magnetic anomalies reflect the magnetic properties of the pre-Jurassic rocks. These data are used by the Soviets in compiling tectonic maps of the basement and intermediate complex (Krylov and others, 1981).

Reflection seismic surveys accurately delineate structure within the Mesozoic-Cenozoic sedimentary cover because the Bazhenov Formation of Late Jurassic age is an excellent reflector. Refraction surveying has been effective in identifying the pre-Jurassic unconformity. Neither reflection nor refraction methods have been satisfactory within the underlying intermediate complex and basement. Deep seismic sounding has been the principal source of information for this deeper part of the subsurface.

The geophysical surveys show that the Earth's crust of the West Siberian platform is block faulted. Crustal thickness ranges from 45 km (28 mi) near the margins of the platform to 29-35 km (18-22 mi) in the central and northern parts.

Basement

The basement beneath the West Siberian basin consists of several fold systems as well as platformal blocks that may be microplates caught up between the fold systems (fig. 2). Some of the fold systems appear to be geosynclinal piles that are folded and metamorphosed, whereas others involve both geosynclinal sediments and older terranes that were re-worked by the later orogeny (Surkov and Zhero, 1981, p. 62-75).

Yenisey fold system. This is the oldest fold belt in the basement of the West Siberian basin; a geosynclinal prism was folded toward the end of the Precambrian during the Baykalian orogeny. The system extends along the eastern margin of the basin in a belt some 200 to 300 km (125 to 185 mi) wide and more than 2,000 km (1,250 mi) long (fig. 2). Granite plutons are present only in the south. Gravity data suggest that the system northward continues into the Yenisey-Khatanga downwarp along the northeast margin of the Siberian craton. The Yenisey fold system is bounded on both east and west by deep faults, but no ultramafic rocks have been mapped along these faults.

Associated with the Yenisey foldbelt are two Karelide blocks that were re-worked by the Baykalian orogeny. On the southwest is the Verkhneket block, and on the northwest is the Nyadoyakh block (fig. 2). The Nyadoyakh block appears to be a node of intersection of the north-south structural trends of the main part of the West Siberian basin and the east-west trends of the Yenisey-Khatanga downwarp.

Salair-Kuznetsko-Alatau fold system. This terrane in the southeast part of the West Siberian basin was consolidated in the Salair stage (Cambrian) of tectogenesis, which ended the Baykalian orogeny. A block-faulted structural style is superimposed on the fold system. Horsts are separated by intervening depressions, which are filled by unmetamorphosed Middle and Upper Paleozoic sedimentary and volcanic rocks.

The Salair-Kuznetskoalatau-Alatau system is bounded on both east and west sides by deep faults. Several ultramafic bodies are present along a segment of the western deep fault, adjacent to a Hercynian terrane (fig. 2).

Central Kazakhstan fold system. The north segment of this fold system forms the southwest part of the basement of the West Siberian basin. Although this is a Caledonian terrane, it contains a large number of blocks of folded Archean and Proterozoic fold systems. In the

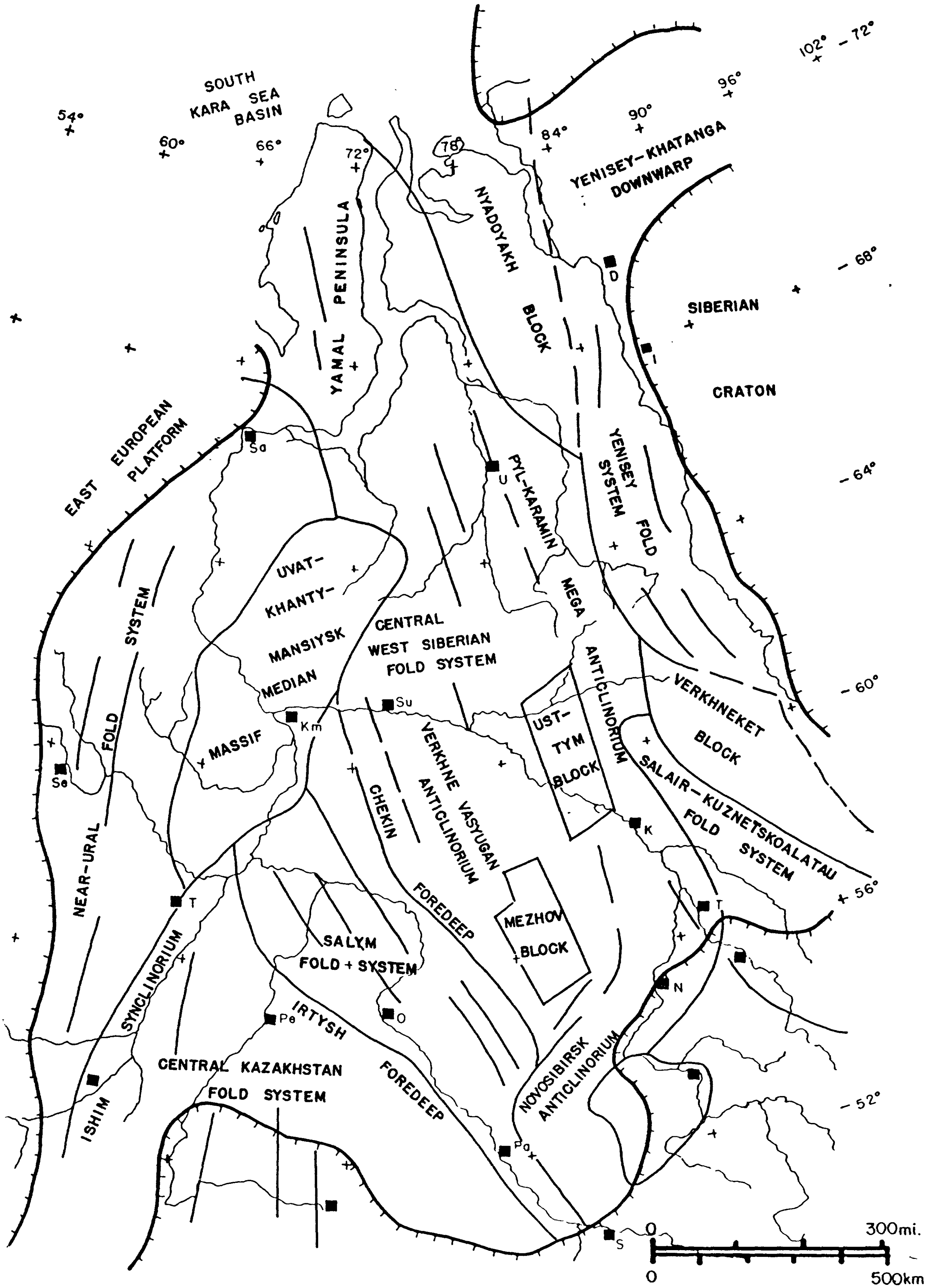


Figure 2. Structure of pre-Jurassic basement of West Siberian oil-gas province. See page 5a for towns for this and following maps.

northwest part of this terrane is the Ishim synclinorium where Ordovician sedimentary and volcanic rocks are strongly folded and metamorphosed. An anticlinorium on the east of this synclinorium is the site of large granite intrusions. No ultramafic rocks have been mapped along the borders of this fold system.

Salym fold system. This system consists of two mega-anticlinoria separated by a mega-synclinorium, all trending parallel to one another in a N.30'W. direction. The system is about 300 km (185 mi) wide and more than 1,000 km (625 mi) long. It is separated from the Central Kazakhstan fold system by the Irtysh foredeep and from the Central West Siberian fold system by the Chekin foredeep. This latter boundary appears to be a major suture along which ultramafic bodies are present. The geosynclinal stage developed in the Early Paleozoic, and the system was folded in the Devonian during Early Hercynian orogenesis. Carboniferous and Permian sediments are platformal and are part of the intermediate structural stage; they consist largely of intermediate and basic volcanic rocks, but numerous granite plutons are present along both the mega-anticlinoria and the mega-synclinorium.

Central West Siberian fold system. This fold system was first recognized in 1967. It extends north-south through the entire West Siberian basin. Information on its nature is spotty because it is exposed at the surface only on the south, and few drill holes have reached it.

The system had its inception in Silurian or Early Devonian time on continental crust. Geosynclinal downwarping was intensive and deep, and the fill is largely clastic rocks. In the final phase of Hercynian orogenesis these rocks were folded, granitized, and uplifted.

The west boundary of this Late Hercynide belt is a deep fault or suture separating it from the Ural foldbelt, the Uvat-Khanty-Mansiysk block, and the Salym foldbelt. The east boundary is also marked by deep faults.

The structure of this fold system trends south-southeast through its entire area to the vicinity of Novosibirsk where it swings at almost a right angle into the transverse Novosibirsk anticlinorium (figs. 1,2).

Along the east side of the Central West Siberian foldbelt is the Pyl-Karamin mega-anticlinorium, where phyllites have been drilled in many places along its hundreds of kilometers length. This feature is reflected as highs in the platform cover. To the west of the Pyl-Karamin mega-anticlinorium is a succession of parallel synclinoria and anticlinoria extending to the western border. The westernmost of these is the Verkhne-Vasyugan anticlinorium, which consists of schists and meta-igneous rocks.

In the north on the Yamal and Gyda Peninsulas the Central West Siberian fold system passes into a Karelian-Baykalian craton, within which are aulacogens filled by sedimentary and volcanic rocks of probable Early and Middle Paleozoic age (Rudkevich and others, 1988). Elsewhere within the Central West Siberian fold system are other blocks ("median massifs") of Baykalide and Karelide terranes that became involved in the late Hercynide folding. One such feature is the Mezhov block, a Baykalide terrane, and another is the Ust-Tym block, a Salairide terrane (fig. 2). Many of these blocks carry granitic plutons. Other granite plutons lie within the metamorphosed Paleozoic geosynclinal sediments. Ultramafic bodies are disposed along the west boundary suture with the Salym fold system and another fault parallel to it about 50 km (30 mi) to the east.

Near-Ural fold system. In the western part of the West Siberian basin, the basement is the subsided eastern part of the Ural geosynclinal trough, which was deformed during late Hercynian tectogenesis at the end of the Paleozoic to form the Ural fold system. In contrast to the Hercynides of the Central West Siberian fold system, the Ural geosynclinal trough began in Riphean time and continued development throughout the Paleozoic. Volcani-clastic sedimentary deposits are characteristic of the fills of the downwarps of this sytem. Numerous basic and ultramafic intrusions are closely associated with the Early and Middle Paleozoic volcanism here. The geosynclinal rocks of the Central West Siberian fold system were deposited on granitic crust, whereas beneath the Ural geosynclinal system the granitic crust is thin or absent altogether.

The near-Ural fold system is juxtaposed against the Central Kazakhstan fold system along a deep fault or suture. A foredeep developed above this fault at the end of the Paleozoic. This Ural foredeep extended from the Aral Sea on the south to near Khanty-Mansiysk on the north (fig. 2).

Within the near-Ural fold system is a series of anticlinoria and syn-clinoria, which extend north-south parallel to one another. These are commonly separated by deep faults along which basic and ultramafic rocks have been protruded. The cores of some of the anticlinoria are Baykalide folded complexes and contain granitic intrusives. Other granitic intrusives are disposed within the metamorphosed volcano-sedimentary geosynclinal fill and are Late Paleozoic in age.

Uvat-Khanty-Mansiysk median massif or microplate. This massif lies between the near-Ural and Central West Siberian late Hercynian fold systems (fig. 2). In the south part of the massif the gravity anomalies have an east-west trend, whereas on the north they strike northwest as if a continuation of the trends from the northeast part of the Russian (East European) platform. The massif was folded during Baykalian tectogenesis and restructured during the Hercynian.

Paleozoic sedimentary rocks of the intermediate structural stage occur on part of this massif, reaching a maximum thickness of 3 km (10,000 ft) in downwarped sectors. These sediments are probably age equivalents of the geosynclinal rocks of the near-Ural and Salym fold systems. The massif has been broken into blocks by the tectonic

Triassic Rifts

In the central part of the West Siberian platform where the basement has a late Hercynian age are long, narrow Triassic rift systems, which cut across the Hercynide trend (fig. 3) and are reflected by strong positive gravity and magnetic anomalies. On the surface of the basement, the rifts are deep grabens filled largely by basic intrusive rocks. In only the upper part of the graben fill are volcanic and sedimentary rocks present. Vertical displacement along the graben margins is 3 to 5 km (1.85 to 3 mi) (Surkov and Zhero, 1981).

The Triassic rifts are clearly expressed in the geothermal field. At a depth of 1 km (0.625 mi) the temperature in the Mesozoic-Cenozoic sedimentary cover above the grabens is 3-4^{o}C above background.

The largest of the Triassic rifts is the Koltogor-Urengoy graben, or mega-trough, which extends north-south for 1,800 km (1,100 mi) from Omsk on the south to the Kara Sea on the north (fig. 3). The northern continuation in the Arctic Ocean is the Saint Ann Trough, which in turn opens into the deep-water Nansen Trench. The width of this graben increases from a few kilometers in the south to 80 km (50 mi) in the north and about 200 km (125 mi) in the Saint Ann Trough. The complexity of this graben is shown diagramatically in figure 4.

The Triassic rifting as an event of partial spreading of the lithosphere was short-lived. The northern part of the Koltogor-Urengoy graben was a spreading center in latest Permian and Early Triassic time for 17 million years. Symmetrical bands of alternating magnetic polarity indicate seven stages of alternating normal and reversed magnetization during this spreading activity (Aplonov, 1986). The process was accompanied by intrusion of large volumes of basaltic magma not only in West Siberia but also on the Siberian craton to the east.

The increase in transverse dimensions and depth of the Koltogor-Urengoy graben to the north as well as the presence there of this and other large grabens, such as the Khuduttey and Khudosey, indicates that extension in the lithosphere was substantial. As the Triassic rifting proceeded further, the entire region began to subside, forming the West Siberian basin; and indeed the most intensive subsidence was in the north where the Triassic rifting was greatest.

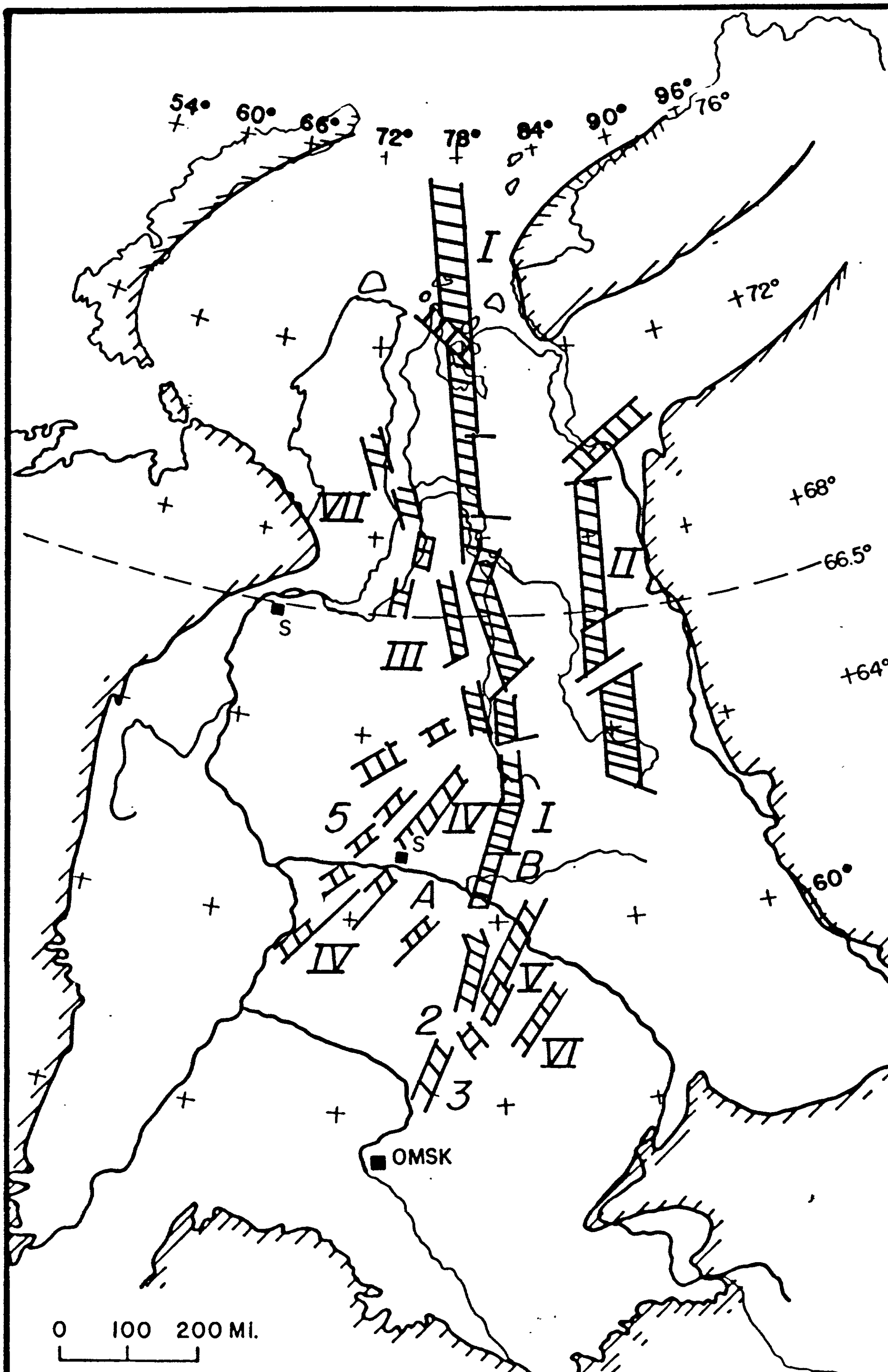


Figure 3. Rift systems of basement of West Siberia

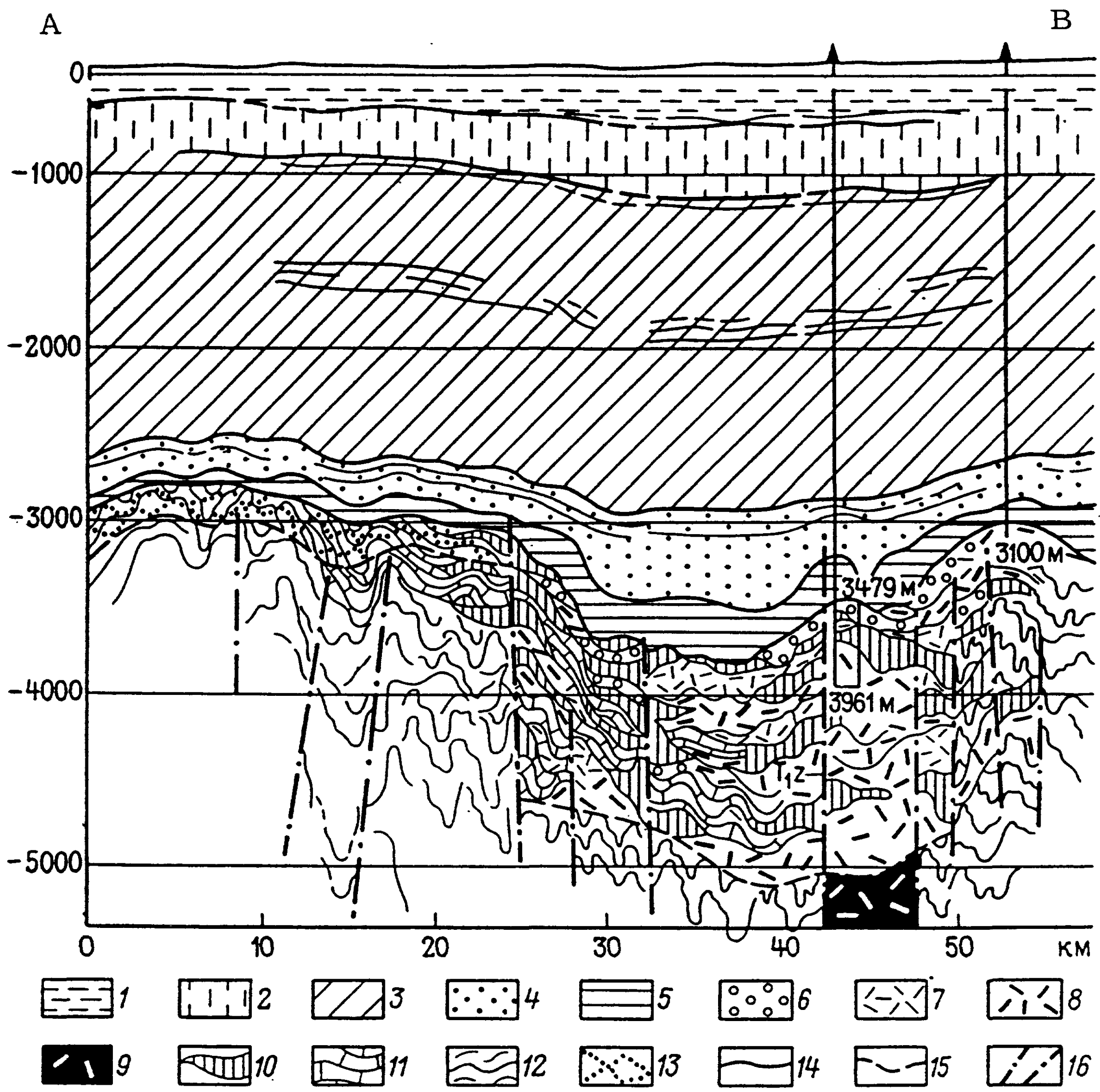


Fig. 4. Geological-geophysical profile of the Koltogor-Urengoy graben along line A-B of fig. 3.

Sediments: 1-Paleogene-Quaternary; 2-Upper Cretaceous; 3-Upper Jurassic-Lower Cretaceous; 4-Upper Jurassic; 5-Lower-Middle Jurassic; 6-amgydaloidal porphyry lavas; 7-tuffs; 8-basalt and dolerite; 9-olivine basalt; 10-rocks altered hydrothermally; 11-limestone; 12-metamorphic rocks; 13-weathered rocks; 14-reflecting interfaces; 15-refracting interfaces; 16-faults.

Mesozoic-Cenozoic Sedimentary Cover

The structure of the sedimentary cover of the West Siberian platform developed in response to vertical movements along basement faults as well as to uneven distribution of the clay-rich and sand-rich sediments of the basin and their subsequent differential compaction.

The longer the time interval between an orogenic event and the deposition of platform sediments on the deformed terrane, the less likely is the structure of the sedimentary cover to reflect the structure of its basement. Since most of the basement of the West Siberian platform was affected by late Hercynian orogeny, structural trends on the top of the Jurassic System (100 m.y. younger) generally correspond to those of the basement (fig. 5). On the west the regional strike as well as that of individual highs and lows are parallel to the Uralide trend of the underlying basement. In the central part of the platform the trends are northwest as is the buried late Hercynide structure, or they are north-south or northeast in response to the Triassic rifts.

The structural trends of the lower Aptian reflector, however, are in general north-south (fig. 6). This change in direction may be due in part to the presence of a sand-starved basin in the western part of the region bordered on the east by deltaic sands deposited along north-south-trending shore lines of the Cretaceous seas. Differences in compaction between the clays of the sand-starved basin and the sands of the deltas would produce north-south structural trends. Also, north-south and northeast-trending Triassic rifting contributed to the regional trends on this lower Aptian reflector. In any case, the trends of the underlying Hercynides are not reflected on this Aptian surface.

The largest structural elements of the Mesozoic-Cenozoic sedimentary cover of the West Siberian platform are the outer belt and the inner region (fig. 7). The boundary between these is not well defined; it coincides, however, with the zones of steepest dip of the surface of the basement along the periphery of the sedimentary basin.

The sedimentary section of the outer belt is much thinner than that of the inner region, due particularly to thinning and pinchout of units in the lower part of the section. The outer belt is generally monoclinal and is characterized by the absence or weak manifestation of movements of basement structures. Accordingly, the outer belt consists of the Ural, Kazakh, Altay-Sayan, Yenisey, and Taymyr monoclines (fig. 7). These are in turn host to smaller structures, many of which have no closure (Surkov and Zhero, 1981, p. 123).

The inner region of the West Siberian platform is subdivided by the Koltogor-Urengoy graben into western and eastern blocks. The Cretaceous system is somewhat thicker on the western block than on the eastern, whereas the Jurassic is thicker on the eastern block than on the western. Closure on structures of the western block is much less than for corresponding structures of the eastern block. These eastern-

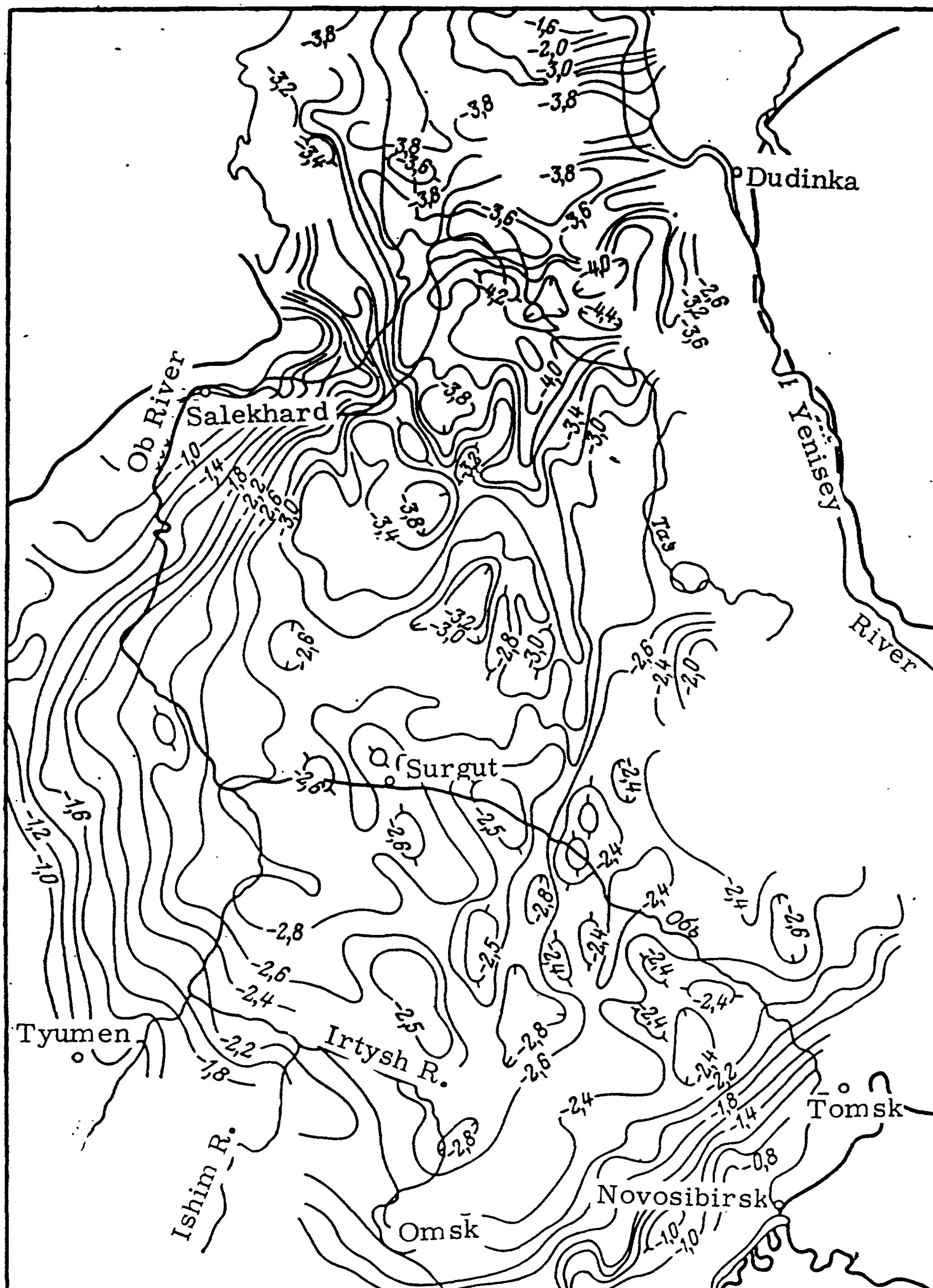


Fig. 5. Generalized structure map of the West Siberian platform on the Upper Jurassic Bazhenov Formation (from Surkov and Zhero, 1981).

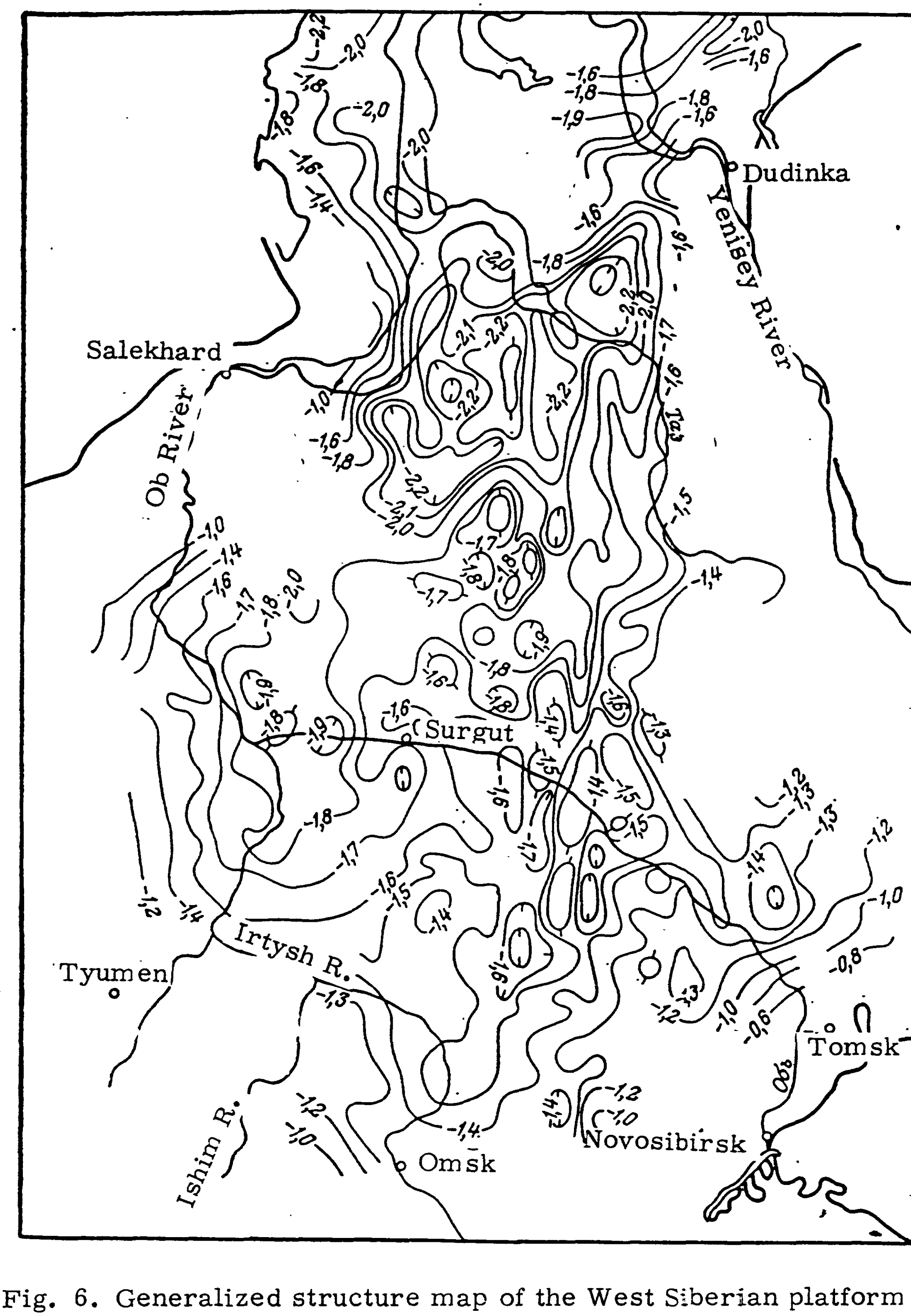


Fig. 6. Generalized structure map of the West Siberian platform on lower Aptian reflecting horizon II (from Surkov and Zhero, 1981)

TAYMYR MONOCLINE
YENISEY MONOCLINE
URAL MONOCLINE
KAZAKH MONOCLINE
Altay-Sayan monocline
54°
60°
66°
72°
78°
84°
90°
96°
102° - 72°
- 68°
- 64°
- 60°
+ 56°
- 52°
Sa
U
D
I
Su
Km
Se
T
K
N
Pe
O
Pa
S
0
300
500

Figure 7

Figure 7. Super-order and first-order structures of the West Siberian platform (from Surkov and Zhero, 1981)

First-order structures: 1- Kharasov-Bovanenkov anticline, 2-Arktich-Sab''yakh anticline, 3-Vostochno-Baydarats syncline, 4- Neytin-Seyakhin syncline, 5-Malygino-Peksed anticline, 6-Khabiyakhin syncline 7-Preobrazhen-Zelenomysov anticline, 8-Gyda anticline, 9-Detarak-Nyagam arch, 10-Solochno-Golchikhin arch, 11-Novoportov-Yamsovey anticline, 12-Yamburg anticline, 13-Tungus-Yakhin syncline, 14-Nerutin syncline, 15-Tazov anticline, 16-Urengoy anticline, 17-Bol'sheket depression, 18-Nizhnetazov depression 19- Chasel anticline, 20-Khangort anticline, 21-Gort syncline, 22-Poluy anticline, 23-Nizhnenadym syncline, 24-Yarudey anticline, 25- Visim anticline, 26-Altatump anticline, 27-Aksar anticline, 28-Vanzevat anticline, 29-Nergin-Mozyam anticline, 30-Yuil arch, 31-Verkhnenadym arch, 32-Pyakupur anticline, 33-Vyngapur anticline, 34-Karampur-Verkhnekolikegan anticline, 35-Verkhnetol'khin anticline, 36-Krasnoleninsk arch, 37-Lyamin arch, 38-Kazym depression, 39-Tanlov depression, 40-Frolov depression, 41-Surgut anticline, 42-Samatlor anticline, 43-Orekhov-Malorechen anticline, 44-Nazin anticline, 45-Kananak anticline, 46-Lymbel arch, 47-Vladimirov arch, 48-Stepanov arch, 49-Ket depressiom, 50-Tegul'det depressiom, 51-Alip depression, 52-Verkhtym depression, 53-Shaim anticline, 54-Salym anticline, 55-Tukan-Urnen anticline, 56-Larlomkin anticline, 57-Guzhikhin anticline, 58-Senkin anticline, 59-Kolpashev anticline 60-Aygol syncline, 61-Pudin anticline, 62-Kombar anticline, 63-Keng syncline, 64-Rakitin anticline, 65-Mezhov arch, 66-Nyurol depression, 67-Krasnogor anticline, 68-Dem'yan anticline, 69-Vorob'yev anticline, 70-Pologrudov anticline, 71-Vasis syncline, 72-Myromtsev syncline, 73-Bol'sheuk syncline, 74-Starosoldat anticline, 75-Georgiyev-Zubov anticline, 76-Irtysh syncline, 77-Vagay-Ishim depression, 78-Tobol anticline, 79-Tyumen syncline, 80-Severo-Sibirsk monocline, 81-Pakulikhin monocline, 82-Eloguy monocline, 83-Barabin-Pikhtov monocline, 84-Saranpaul monocline, 85-Khudutey trench, 86-Agan trench, 87-Ust'-Tym trench, 88-Chuzik trench, 89-Yamal trench block structures are to a great extent fault-controlled. These faults generally attenuate in the Jurassic and Cretaceous sediments.

The eastern block of the inner region of the West Siberian platform is divided into two sub-blocks by the Pyl-Karamin mega-arch (figs. 2,7). The trend of the structures of the eastern sub-block appears to reflect movements along Triassic rifts, except to the northeast in the Yenisey-Khatanga downwarp where they parallel the trends of that feature. In the western sub-block, the structures are similar to those of the western block of the inner region. The large structures of the basin are designated by numbers on the accompanying map (fig. 7).

Shale diapirs are common in the post-Cenomanian sedimentary rocks of the northern half of the West Siberian platform. Clay beds ranging in age from Turonian to lower Oligocene have been deformed plastically into domal structures that extend from depths of 3 km (10,000 ft) (Generalov, 1983). It seems possible that some of these structures might be impact induced.

Discussion

Geologic events that led to formation of the tectonic collage of the West Siberian platform are certainly not clear. Was the Ural geosynclinal trough an intra-cratonal feature that opened and then closed, or is the Ural fold system a zone of collision of two unrelated plates that were once at great distance from one another? What is the relationship of the late Hercynides of the Ural fold system to the late Hercynides of the Central West Siberian fold system?

First let us examine the Ural fold system. Gravity and magnetic anomalies in the southern part of the Uvat-Khanty-Mansiysk microplate (fig. 2) have an east-west trend. Anomalies of this same trend are tracked fragmentally westward into the central part of the Ural fold system and thence onto the eastern part of the Russian (East European) platform, suggesting thereby that the terranes east and west of the Ural fold system in these regions are part of the same plate. The northern part of the Uvat-Khanty-Mansiysk microplate appears to be a fragment of a Riphean fold system that once extended from the Timan-Pechora area (fig. 1) southeastward across the Ural fold system and thence through the whole of West Siberia (Surkov and others, 1983). This too suggests that the Ural geosynclinal trough was an intra-cratonal feature.

Paleomagnetic synthesis, however, does not support the intra-cratonal interpretation for the Ural geosynclinal trough. According to the paleomagnetic data, the Siberian platform was far removed from the Russian platform in Early Paleozoic time, and they became juxtaposed on a collision zone late in the Paleozoic forming the Ural orogenic belt (Hamilton, 1970; Kirschvink and Rozanov, 1984). According to this interpretation, the various terranes that compose the greater Ural-Mongolian-Okhotsk fold system were continental shelf deposits on the leading margins of continental plates that were destined to collide.

These are the "miogeosynclinal" deposits as defined by Hamilton (1970, p. 2554).

The collision hypothesis seems preferable to the intra-cratonal hypothesis because the paleomagnetic data seem more objective than the tracking of anomaly trends. If the data themselves are correct, the anomaly trends could still be fortuitous, whereas the paleomagnetic data would be more incontrovertible.

Any statements on the relationship between the late Hercynides of the Ural fold system and the late Hercynides of the Central West Siberian fold system are highly speculative. The Uvat-Khanty-Mansiysk microplate has Late Paleozoic platform sedimentary rocks resting on largely a Baykalide folded basement; consequently, it could be a segment of the Yenisey fold system to the east that was separated by the imposition of the Central West Siberian geosynclinal downwarp. The latter would in this case be intra-cratonal. It seems more likely that the Uvat-Khanty-Mansiysk and Salym blocks are simply microplates caught up in a Late Paleozoic collision of the Siberian craton with the Russian platform. They resisted being subducted, resulting in a "break back" of the subduction zone from their western borders to their eastern borders.

In contrast to the enigmatic Paleozoic tectonic history of the West Siberian platform, the Mesozoic and Cenozoic structures and processes leading to their formation are well understood. Beginning with the Triassic Period, the region of the West Siberian platform passed from a state of regional compression to one of regional tension. Long, narrow, generally north-south-trending blocks were downdropped forming structural trenches (fig. 3). The northern part of the Koltogor-Urengoy graben was actually a spreading center. Subsequently, in the Jurassic Period, the entire region began to sag, forming the West Siberian sedimentary basin.

The sagging during the Jurassic and subsequent geologic time was accompanied by renewed movement along the Triassic rifts and reactivation of faults bounding major basement features. The blocks between the grabens became regional highs in the Mesozoic sedimentary pile, and the areas of the grabens themselves became regional lows. For example, the Nizhnevartov regional high with the Samotlor anticline is bounded by the Agan trough on the west and the Koltogor-Urengoy graben on the east (fig. 3). Thus, regional highs commonly became sites of the large oil fields of West Siberia.

STRATIGRAPHY AND PALEOGEOGRAPHY

Introduction

The West Siberian basin occupies an area of approximately 3.5 million km^2 (1.3 million mi^2), including the South Kara Basin and part of the Khatanga basin, which geologically are a part of the West Siberian basin (figs. 8,9). The basin is bounded by the Uralian and Novaya-Zemlya uplifts on the west and northwest, the Kazakh and Altay-Sayan uplifts on the south and southeast, the Siberian craton and Taymyr uplift on the east and northeast, and the North Siberian sill on the north. Thickness of the Phanerozoic sedimentary cover ranges from approximately 3 - 5 km (10,000 - 16,000 ft) in the central parts of the basin to 8 - 12 km (27,000 - 40,000 ft) or more in the northern part (figs. 10-15). The post-Paleozoic basin (including the South Kara Sea and Khatanga basins) is filled with approximately 16 million km3 (4 million mi3) of Mesozoic-Cenozoic sedimentary rocks ranging in thickness from 3 - 4 km (10,000 - 13,000 ft) in the central area to 8 - 10 km (25,000 - 33,000 ft) or more in the north (figs. 15-19). The Mesozoic-Cenozoic fill is less than 1 km (3,300 ft) thick along the North Siberian sill, a basement high of Mesozoic age, which extends between the north end of the Novaya-Zemlya and the northwest part of the Taymyr uplift (figs. 9,16). On the southwest, the basin is connected with the Ust-Urt basin region through a narrow trough between the southern Ural Mountains and the Kazakh uplift. In latest Cretaceous and early Tertiary time, the West Siberian Sea was connected with the Tethys Sea through this passageway (fig. 9).

Basement

Granitic rocks of Precambrian and Paleozoic age have been encountered in deep wells, particularly in the central interior of the basin (fig. 11). Igneous and metamorphic rocks of Proterozoic (Riphean) age are present on the Khanty-Mansiysk massif in the central basin. Late Proterozoic greenschist and other metamorphic rocks are present in the Kazakhstan region in the southwestern part of the basin. In the Yenisey--Taz region on the east side of the basin, upper Proterozoic and lower Paleozoic carbonate rocks are present over a wide area. These rocks are strongly metamorphosed in the northern and southern parts of this area, but are relatively unmetamorphosed in the central part. Where present in the Middle Ob region, much of the Paleozoic section also is metamorphosed and can rightfully be considered as "basement." However, over parts of the basin Paleozoic rocks, particularly carbonates, where only lightly to moderately metamorphosed, may retain some reservoir and source rock characteristics.

Unmetamorphosed Paleozoic Rocks of Intermediate Complex

Paleozoic rocks that are not metamorphosed are widely distributed beneath the Mesozoic cover. Platformal and geosynclinal rocks several kilometers thick have been recognized in many areas, and distinct Paleozoic depositional basins and uplifts have been mapped on the basis

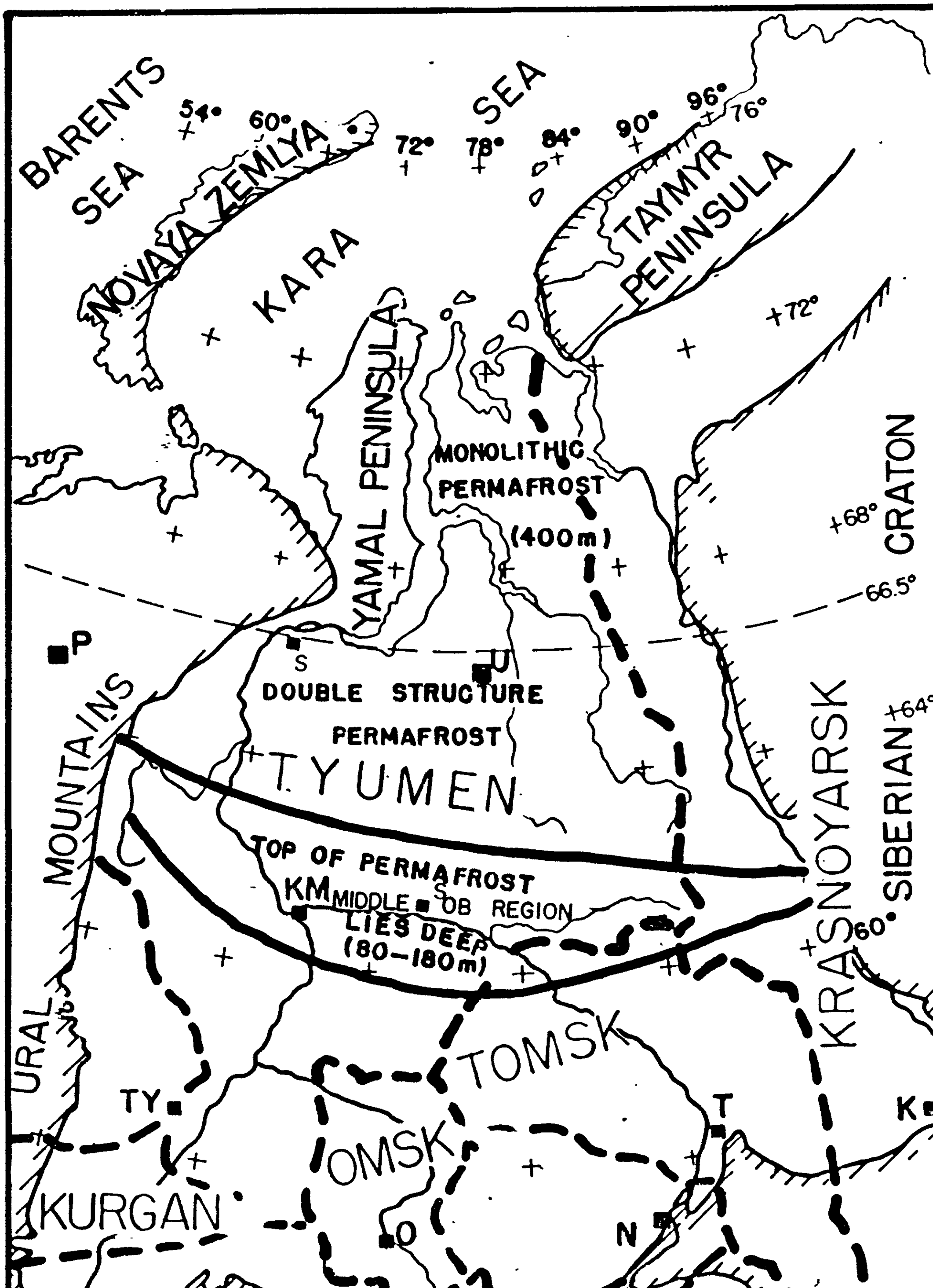


Figure 8. Geographic map of West Siberia showing political regions, main river systems, mountain ranges, and areas of fossil and Holocene permafrost (modified from National Geographic Society, 1981, and Ostryy, 1967

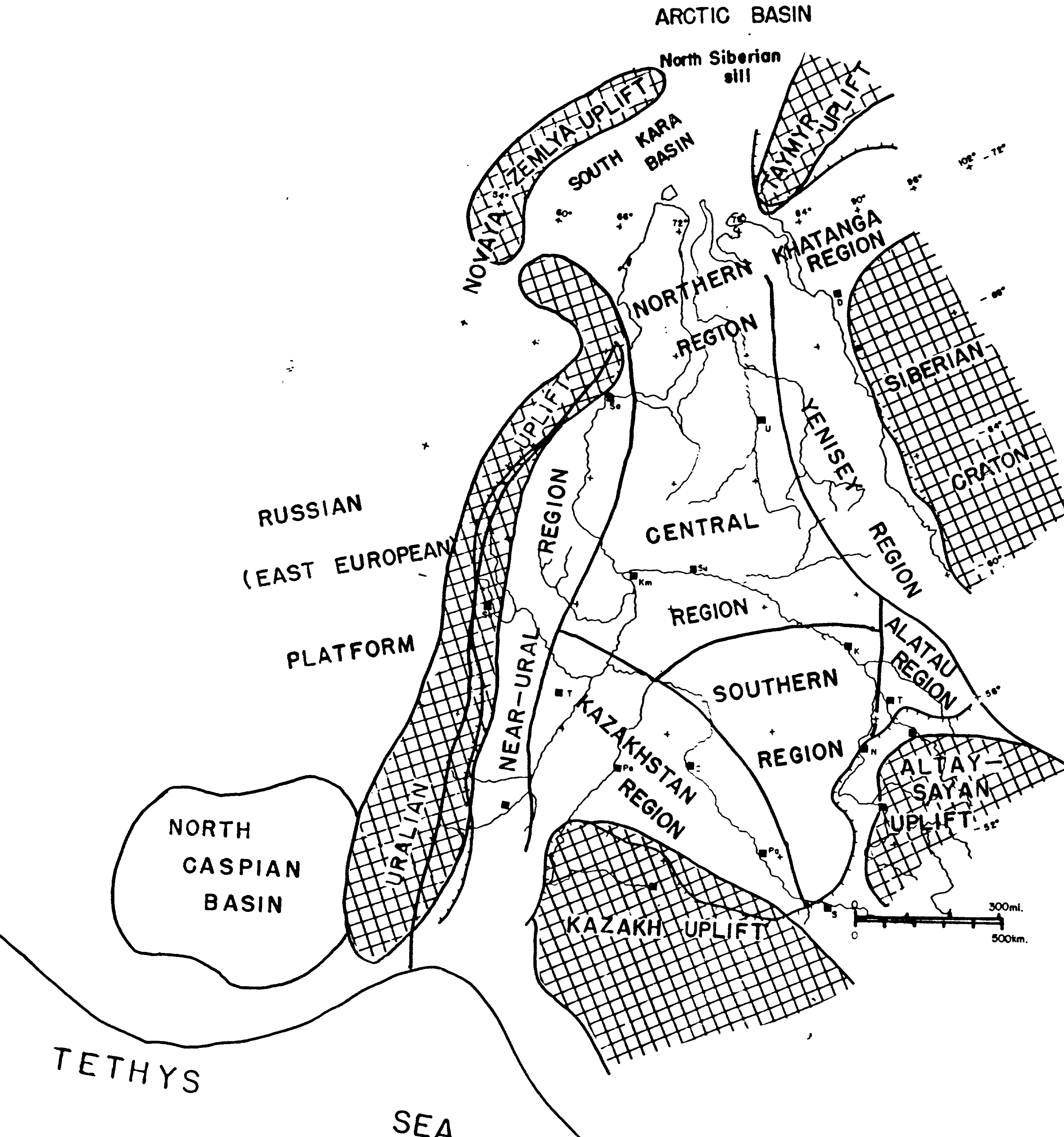


Figure 9. Mesozoic paleogeographic map of West Siberian Basin and adjacent areas

Figure 10. Stratigraphic section of West Siberian oil-gas province

Era	Period	Epoch	Age	Mega-cycle	Cycle	Formation
Cenozoic	Neogene	Holocene		Oligocene-Holocene		
		Pleistocene				
		Pliocene				
		Miocene				
	Paleog.	Oligocene				
		Eocene		Aptian-Oligocene		
		Paleocene				
Mesozoic	Cretaceous	Upper	Maastrichtian			
			Campanian			
			Santonian			
			Coniacian			
			Turonian			Kuznetsov
			Cenomanian		Pokur	Pokur
		Lower	Albian			
			Aptian		Sargat	Alym
			Neocomian: Barremian	Triassic-Aptian		Vartov
			Hauterivian			
			Valanginian		Poludin	Megion
			Berriasian			
	Jurassic	Upper	Volgian			Bazhenov
			Kimmeridgian			Georgiyev
			Oxfordian			Vasyugan
		Middle	Callovian		Zavodoukov	
			Bathonian			
			Bajocian			
			Aalenian			
		Lower	Toarcian			Tyumen
			Pliensbachian			
			Sinemurian			
			Hettangian			
	Triassic				Tampey	
Precambrian-Paleozoic	Permian and Triassic volcanic and clastic graben fills					
	Unmetamorphosed Paleozoic platformal carbonate and clastic rocks					
	Basement: metamorphosed Precambrian and Paleozoic rocks					

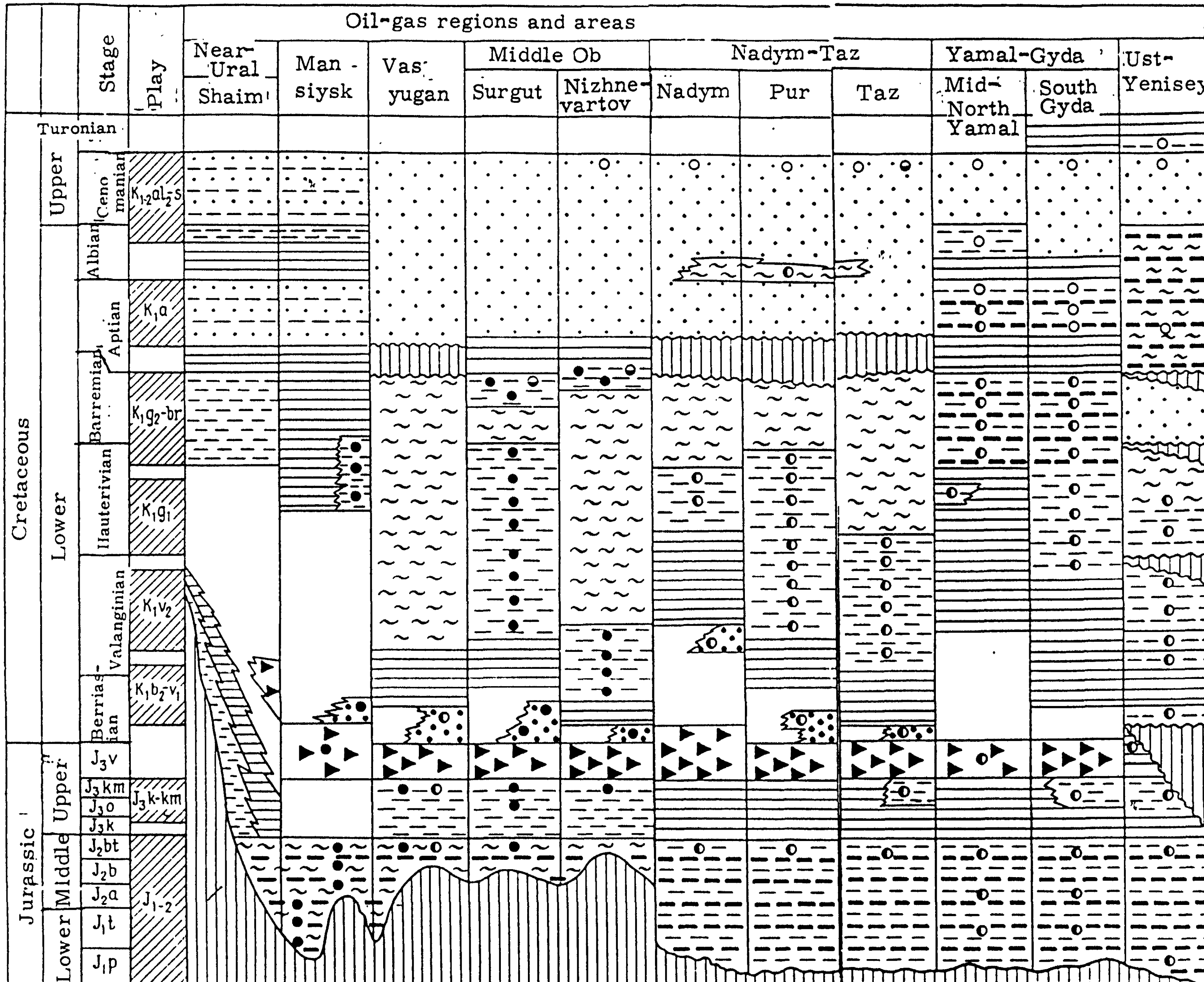


Figure 10a. Geologic sections of West Siberian oil-gas province (from Rudkevich, 1988). See figure 10b for location of areas.

Sediment types cf fig. 10a

Type 1. Deep-water-marine - dark, thin-bedded, bituminous clayey. Deposited in semi-closed seas.

Type 2. Gray and dark laminated and massive deep-water marine deposited in open sea.

Type 3. Dark, sand-silt with graded bedding deep-water marine deposited as turbidites.

Type 4. Massive, light siliceous and siliceous-clayey deep-water and shallow-water marine deposited in relatively deep-water marine basins.

Type 5. Light massive and coarsely bedded silt-clay shallow-water marine deposited in an open marine basin.

Type 6. Gray rhythmically bedded sand-clay shallow-water and near-shore marine deposited on shelves, beaches,deltas, bars.

Type 7. Gray horizontally bedded sand-silt near-shore marine deposited on beaches, deltas, continental slopes.

Type 8. Gray and green sand-silt-clay near-shore-marine and lagoonal deposited in bays, lagoons, and deltas.

Type 9. Gray and dark sub-coaly rhythmically bedded sand-silt-clay near-shore-marine and continental deposite in lakes and swamps.

Type 10. Gray and dark sub-coaly lens-bedded sand-silt-clay near-shore continental deposited in lakes, swamps, river basins.

Type 11. Gray, massive and cross-bedded silt-sand near-shore continental deposited in onshore parts of deltas and large river valleys

Type 12. Red and variegated lens-bedded sand-silt-clay continental deposited deposited in lakes swamps and rivers under arid climate

Type 13. Gray coaly coarse-bedded silt-clay-sand continental deposited in lakes, swamps, rivers of a hilly plain under humid climate.

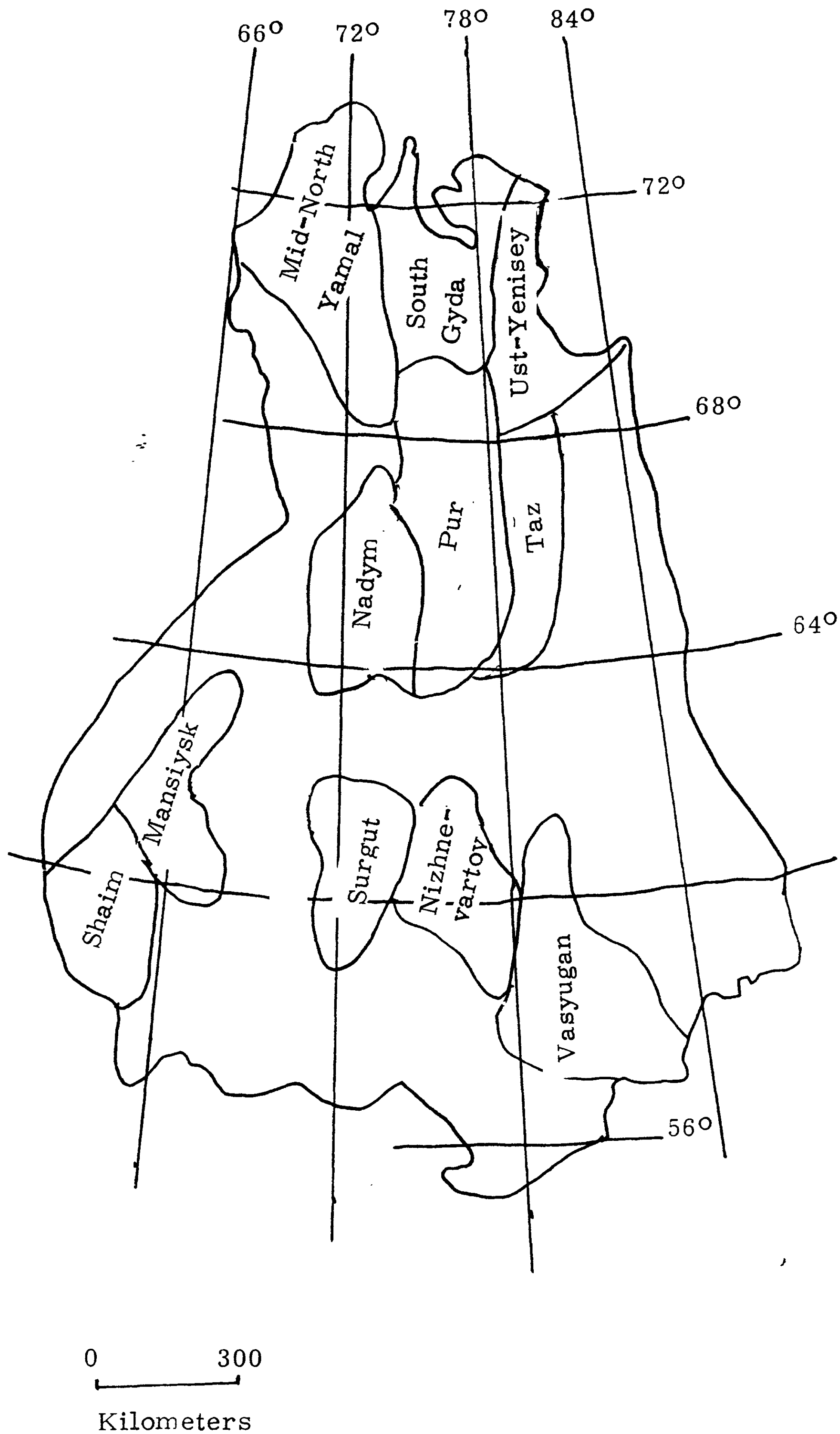


Figure 10b. Location map of sections shown in fig. 10a

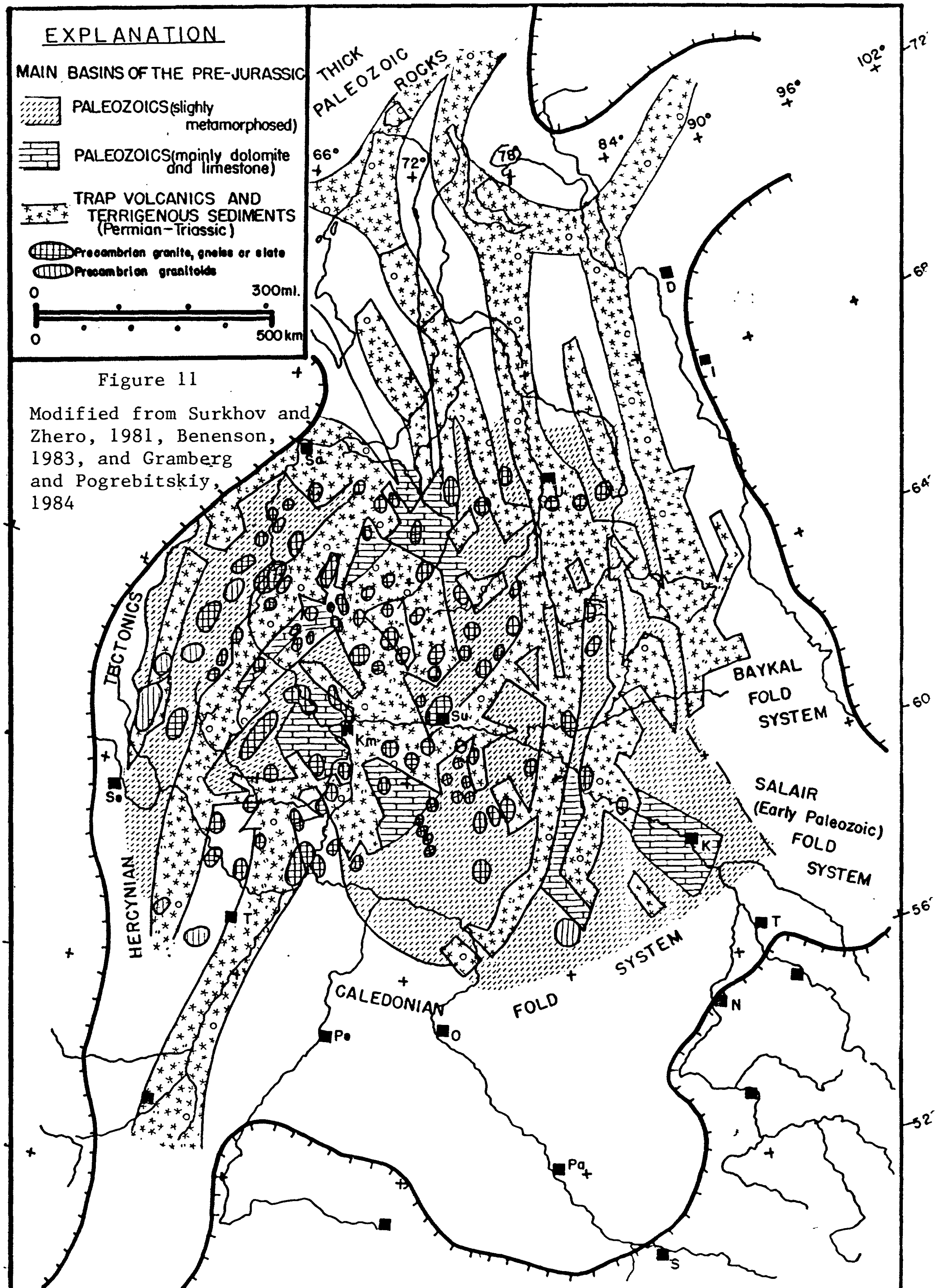


Figure 11

Modified from Surkhov and Zhero, 1981, Benenson, 1983, and Gramberg and Pogrebitskiy, 1984

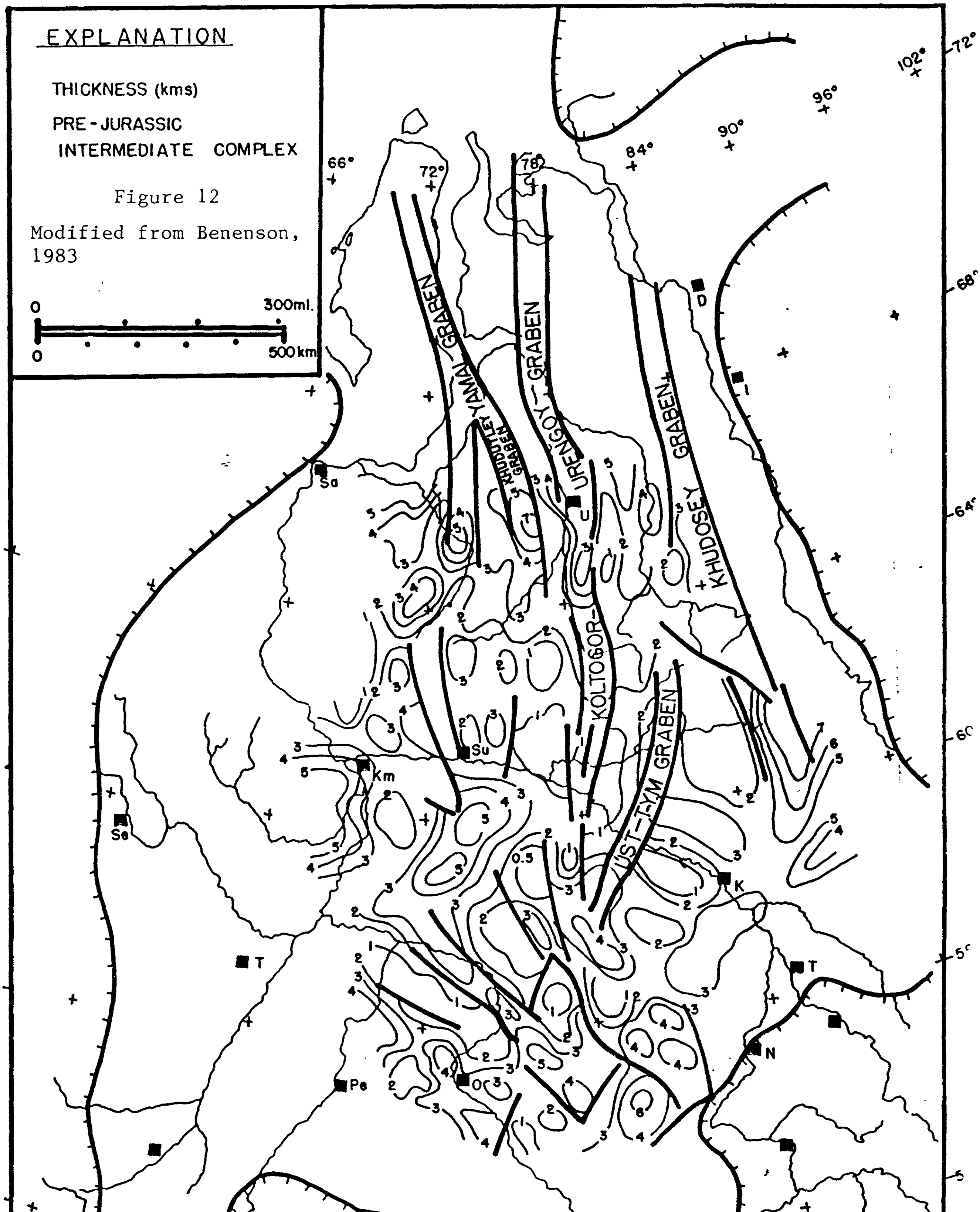
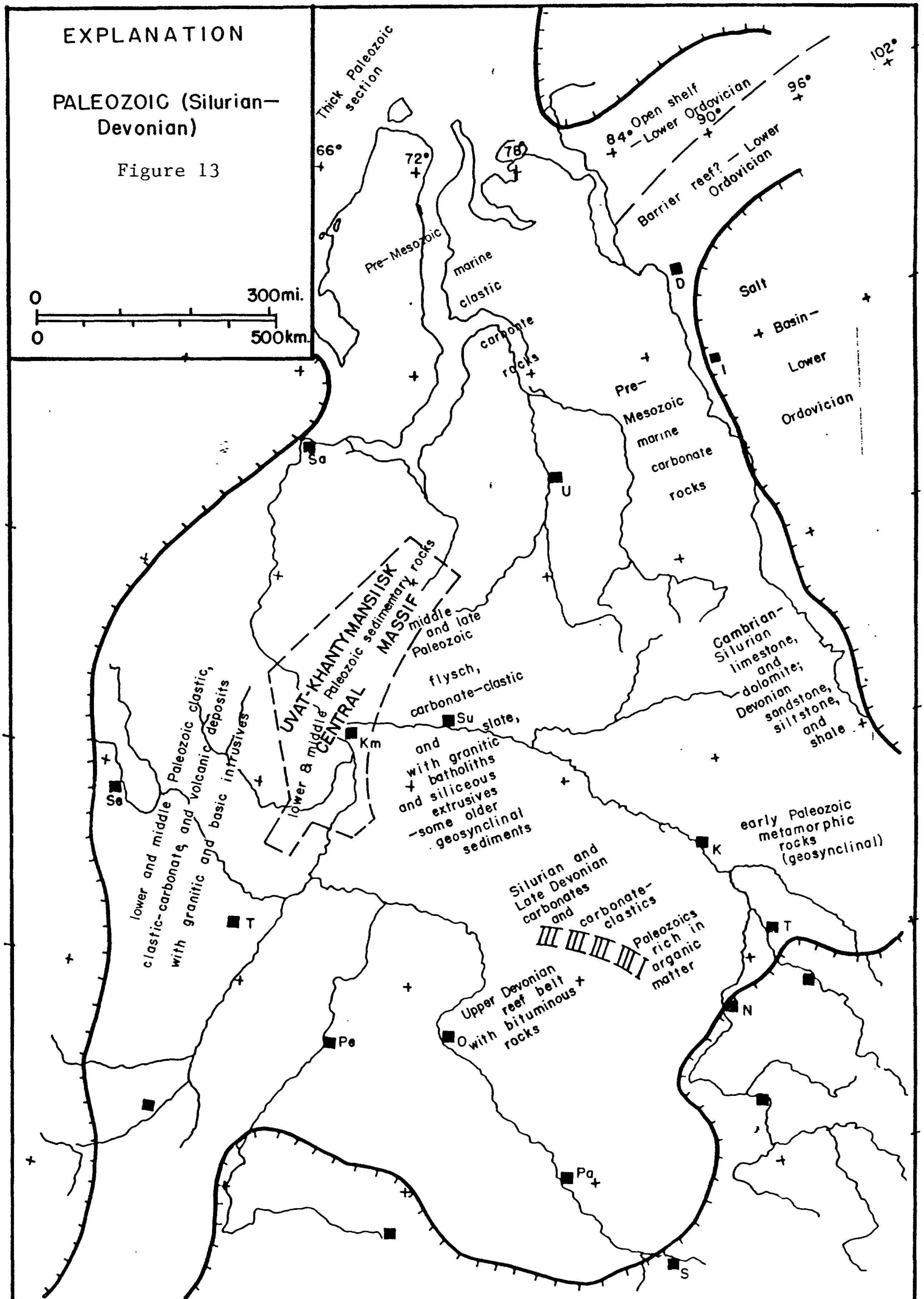


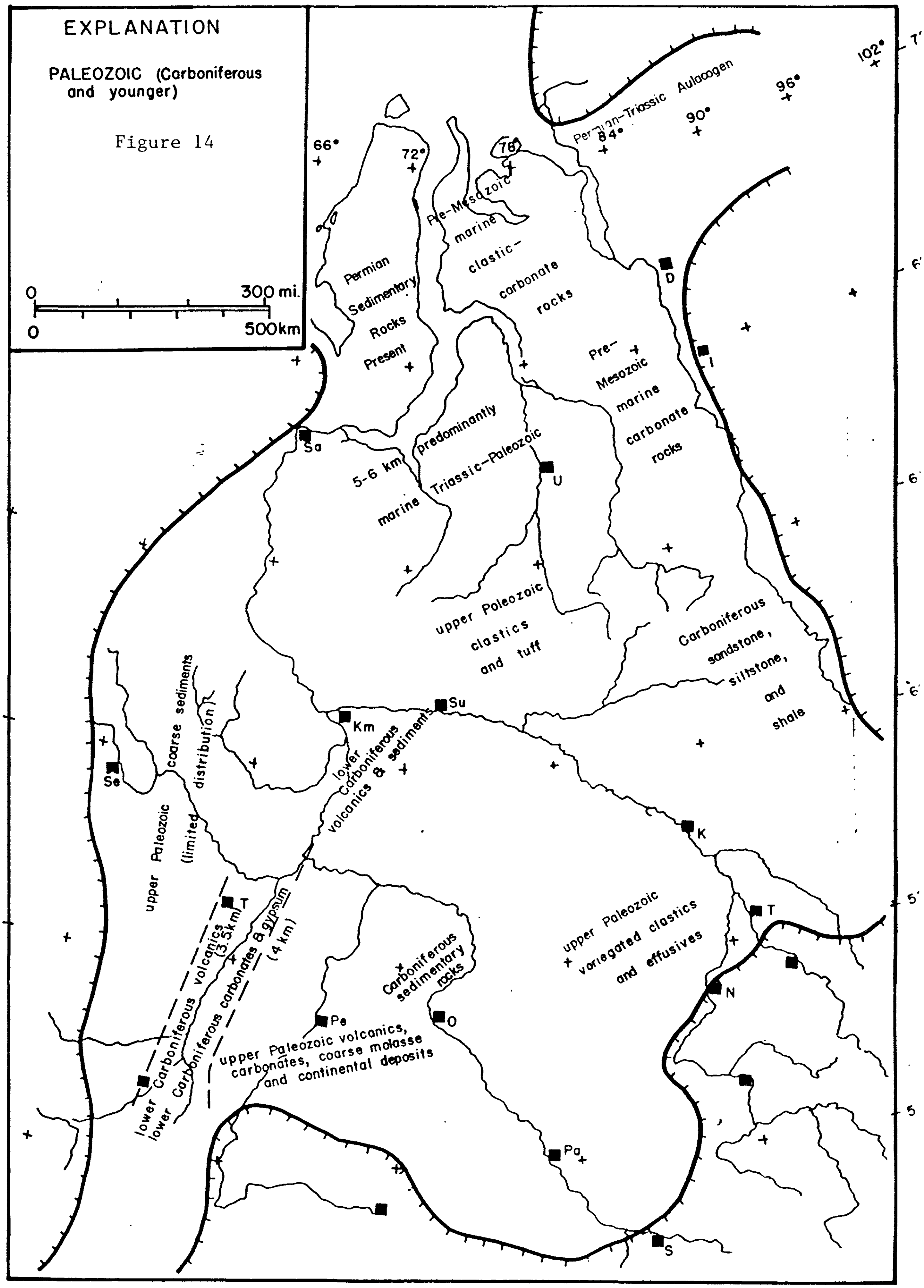
Figure 12

Modified from Benenson, 1983



PALEOZOIC (Silurian—Devonian)

Figure 13


EXPLANATION
PALEOZOIC (Carboniferous and younger)
Figure 14
0
300 mi.
0
500km
66°
72°
78°
84°
90°
96°
102°
Permian-Triassic Aulacogen
Permian Sedimentary Rocks Present
Pre-Mesozoic marine clastic-carbonate rocks
Pre-Mesozoic marine carbonate rocks
predominantly Triassic-Paleozoic
5-6 km marine
upper Paleozoic clastics and tuff
Carboniferous sandstone, siltstone, and shale
coarse sediments (limited distribution)
upper Paleozoic
lower Carboniferous volcanics & sediments
lower Carboniferous volcanics (3.5km)
lower Carboniferous carbonates & gypsum (4 km)
Carboniferous sedimentary rocks
upper Paleozoic variegated clastics and effusives
upper Paleozoic volcanics, carbonates, coarse molasse and continental deposits
Sa
U
D
I
Km
Su
Se
K
T
N
Pe
O
Pa
S

of drilling and geophysical information (figs. 11-14). Several stages of deposition have now been worked out by Soviet geologists, and preliminary depositional patterns are recognized. The Paleozoic section beneath the Mesozoic cover consists of both clastic and carbonate rocks; the latter are particularly widespread, especially in the southern part of the basin where reef trends and other depositional facies have been recognized in some areas (fig. 13).

Rocks of this Paleozoic intermediate complex are preserved in places on crystalline basement and are overlain by Jurassic and younger rocks in large areas of the central and southern basin. Krylov and others (1981) and Sevost'yanov (1982) recognize three types of intermediate complexes in the floor of the basin: 1) flat-lying Paleozoic platformal complexes deposited on terranes of Baykalian (late Precambrian) age; 2) Paleozoic geosynclinal complexes of superimposed depressions in regions of fold systems of Baykalian (late Precambrian) and Salairian (early Paleozoic) age; and 3) Permian-Triassic-Liassic taphrogenic complexes in grabens that have developed on all fold systems from Baykalian to Hercynian age, particularly in areas of Hercynian consolidation.

<u>Yenisey Region</u> - Paleozoic rocks in the Yenisey region (fig. 9) on the east side of the basin range in age from Cambrian through Carboniferous (fig. 13-14). These rocks are folded and metamorphosed in the northern part of the region, and in parts of the southern part. In the central area, fossiliferous platform carbonates of Cambrian through Silurian age are present, overlain by mainly clastic rocks of Devonian and Carboniferous age.

<u>Alatau Region</u> - Metamorphosed geosynclinal rocks of late Precambrian and early Paleozoic age overlain by unmetamorphosed clastic redbeds beneath the pre-Jurassic erosion surface have been penetrated in wells drilled in this region, which is a northern extension of the Alatau-Sayan block, consolidated during late Proterozoic and early Paleozoic time.

<u>Southern Region</u> - Early Paleozoic rocks are not widespread in the southernmost region of the basin, which underwent Caledonian folding and uplift during this time. Middle and late Paleozoic carbonate and clastic rocks as much as 4 - 6 km (13,000 - 20,000 ft) thick are reported to be present in depressions which were formed in Middle and Late Paleozoic time (Zhuravlev, 1984). Middle Paleozoic rocks are thinned and rest on basement rocks on uplifted blocks of this region. Basic and intermediate volcanics are present locally. The middle Paleozoic section in places is almost entirely skeletal or reef-bearing limestone or dolomite. In other areas, sandstone, siltstone, shale, and argillaceous limestone are interbedded, and bituminous limestone or shale are reported. Devonian reef and off-reef or open-marine facies have been recognized in wells drilled in the Maloicha area on the west side of the Nyurol basin, where Upper Silurian and Devonian carbonate and carbonate-clastic rocks are more than 3,000 m (10,000 ft) thick (figs. 7,13,17). Lower Carboniferous rocks are relatively thin and apparently are only locally present. Drilling in the Nyurol basin area

has penetrated organic clayey limestone with sandstone, siltstone, and shale of Visean age in some places and variegated clastics and effusives in others.

Kazakhstan Region - Widely distributed in this region are Precambrian metamorphic rocks and lower Paleozoic granitic plutons and Proterozoic and early Paleozoic greenschists, which developed as a result of regional metamorphism of Precambrian and early Paleozoic sedimentary and igneous rocks during the early Paleozoic orogeny. Unmetamorphosed volcanic, carbonate, coarse-grained molasse and continental deposits of middle and late Paleozoic age are also present.

Central Region - Flysch, carbonate, carbonate-clastic and slaty deposits of middle and late Paleozoic age are present in this region, although Paleozoic rocks are absent in many places. Precambrian and Precambrian-Paleozoic metamorphic rocks, granitic intrusives, silicic intrusive rocks, and some older geosynclinal rocks also are present. The intermediate complex is thin or absent on high blocks where Jurassic rocks rest on igneous or metamorphic basement, particularly in the Middle Ob area, but is as much as 3 - 5 km (10,000 - 16,000 ft) thick in depressions (figs. 12, 18). In the region of the Mansiysk depression (fig. 18), lower and middle Paleozoic marine carbonate rocks as much as 2 - 3 km (6,500 - 10,000 ft) or more thick are preserved in basins beneath the Mesozoic-Cenozoic cover (Surkov and others, 1983). Lower Carboniferous volcanic and sedimentary rocks also are reported.

Northern and Khatanga Regions - Little is known of the Paleozoic rocks in these regions, which are covered by as much as 5 - 6 km (16,000 - 20,000 ft) of Mesozoic-Cenozoic sedimentary rocks. However, several kilometers of pre-Traissic sedimentary beds may be present, based on geophysical work (Aleinikov and others, 1980). As much as 4 - 6 km (13,000 - 20,000 ft) or more of Paleozoic carbonate and other platform sedimentary rocks are indicated in the vicinity of the Yamal and Gyda Peninsulas, based on seismic and other geophysical work (Gramberg and others, 1984). Permian-Triassic molasse deposits are reported in the Khatanga region adjacent to the Taymyr uplift of Hercynian age. Permian sedimentry rocks also have been encountered in wells drilled on the Yamal Peninsula. A Triassic section 1 - 2.5 km (3,300 - 8,000 ft) or more thick of probable continental-marine origin is indicated in the South Kara basin northwest of the Yamal Peninsula (Gramberg and others, 1984).

Mesozoic-Cenozoic Sedimentary Rocks

The post-rift Mesozoic-Cenozoic sedimentary cover of the West Siberian basin is as much as 8 - 10 km (25,000 - 33,000 ft) thick in the northern part of the basin, and averages about 3 - 4 km (10,000 - 13,000 ft) thick over the remainder of the basin, thinning to zero around the basin borders (figs. 15 -17). These rocks were deposited in a broad, shallow inland sea and have undergone only mild tectonic disturbance since deposition. The rocks are almost entirely clastic sediments (sandstones, siltstones, and shales) and were deposited in three major

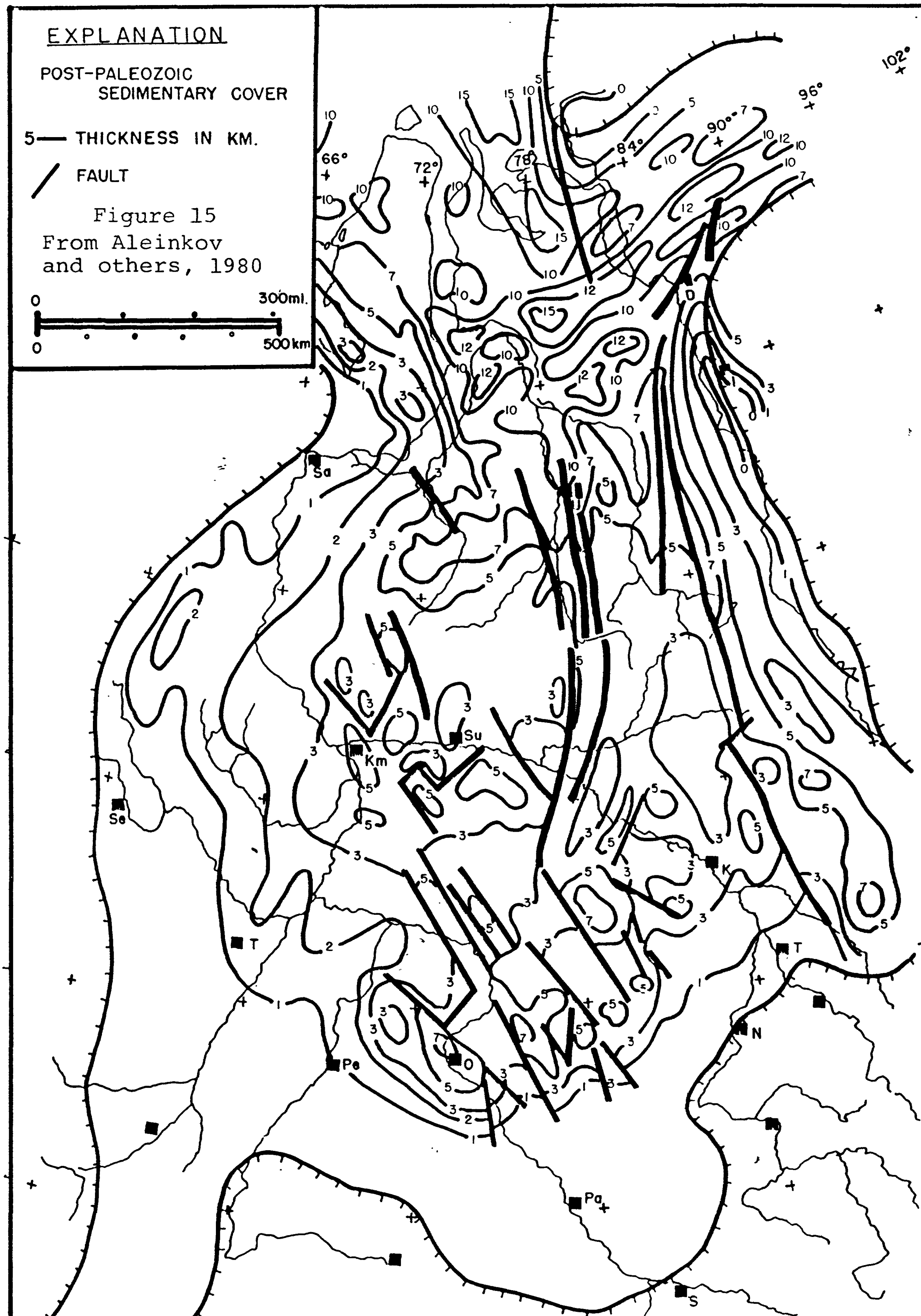
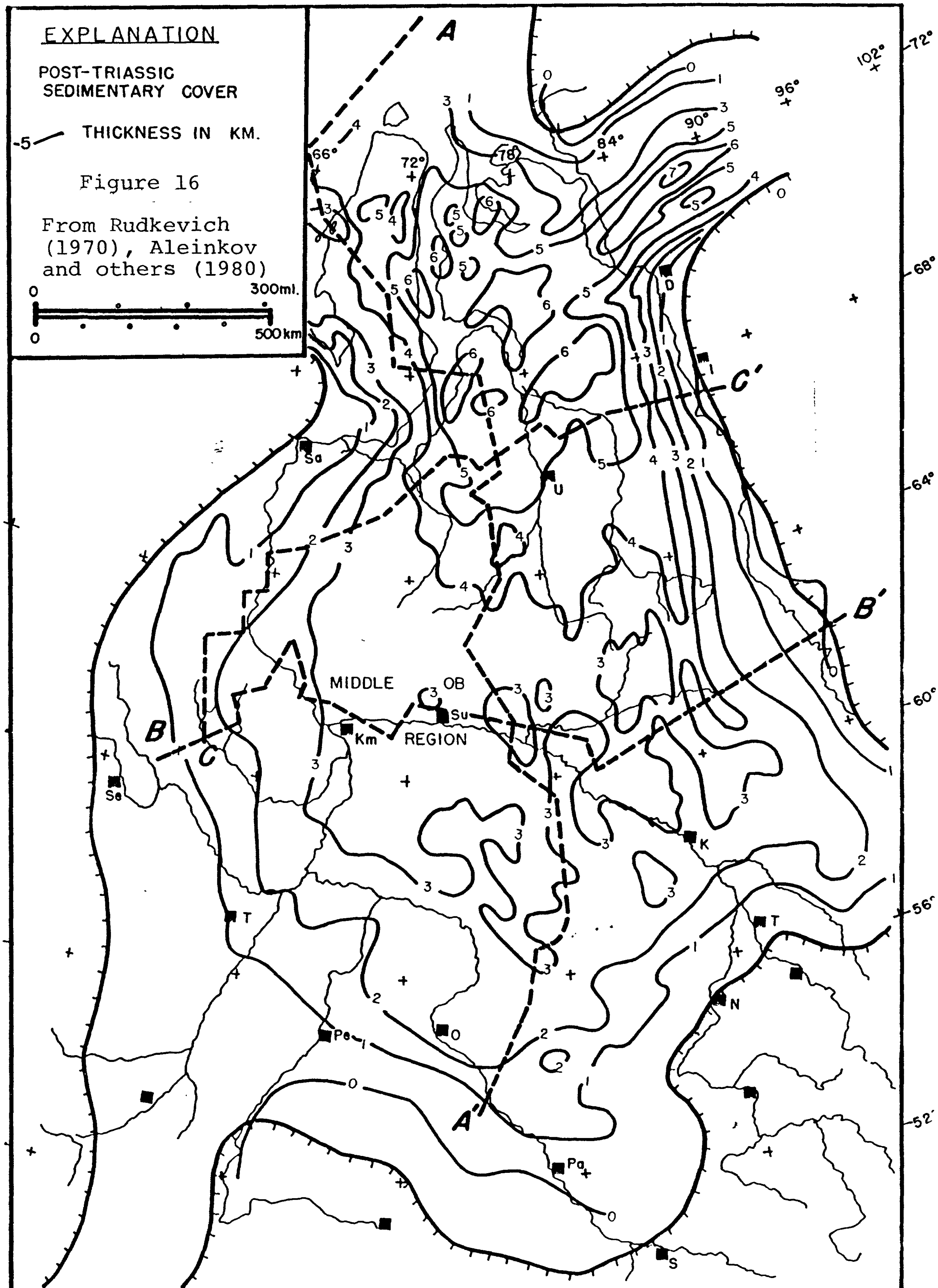
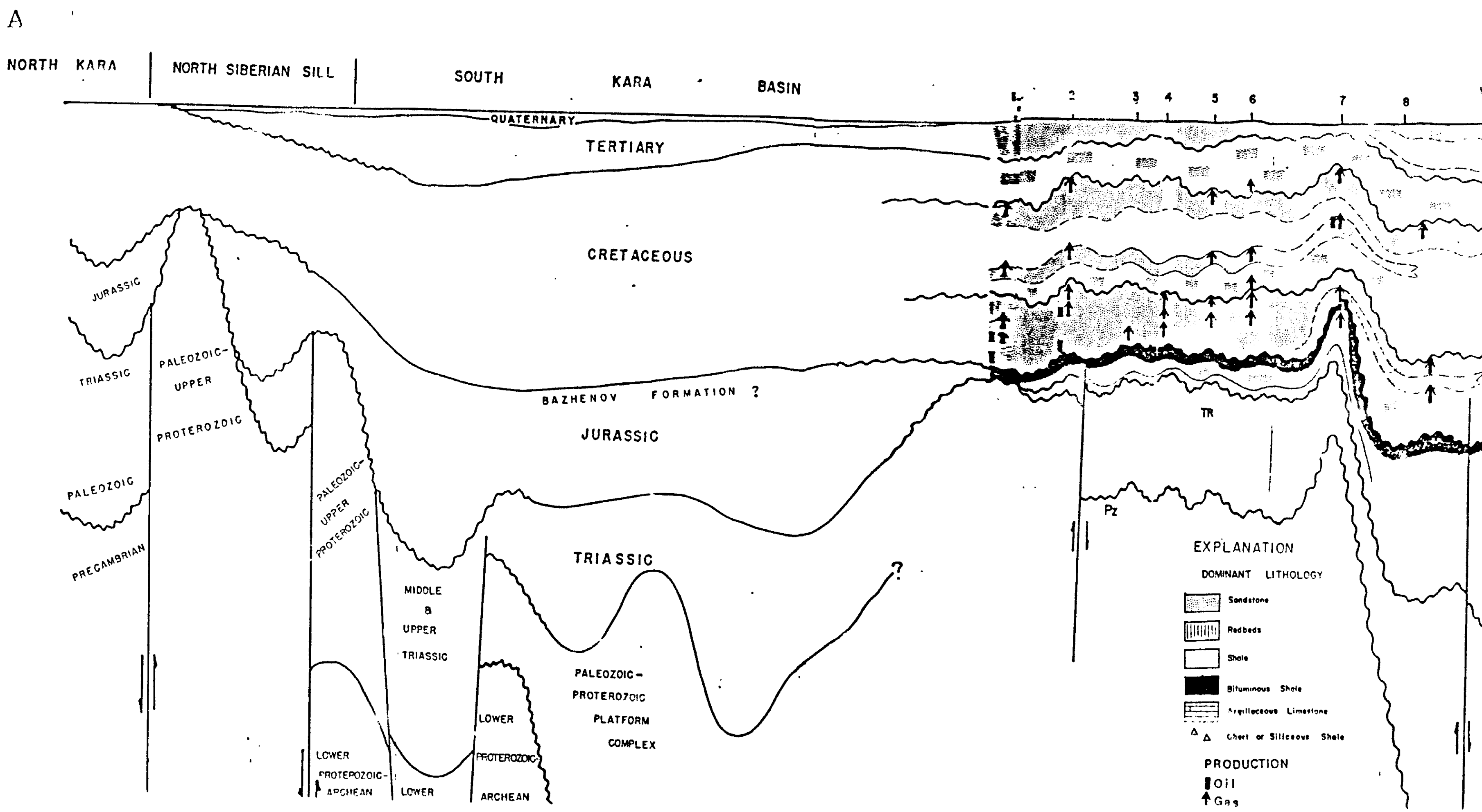


Figure 15
From Aleinkov and others, 1980


EXPLANATION
POST-TRIASSIC SEDIMENTARY COVER
-5 THICKNESS IN KM.
Figure 16
From Rudkevich (1970), Aleinkov and others (1980)
0 300mi.
0 500km
MIDDLE OB REGION
A
A'
B
B'
C
C'
72°
68°
64°
60°
56°
52°
66°
72°
78°
84°
90°
96°
102°
Sa
U
D
I
Su
Km
Se
K
T
T
N
Pe
O
Pa
S

Control points - oil and gas fields shown on figures 17, 18, 19.

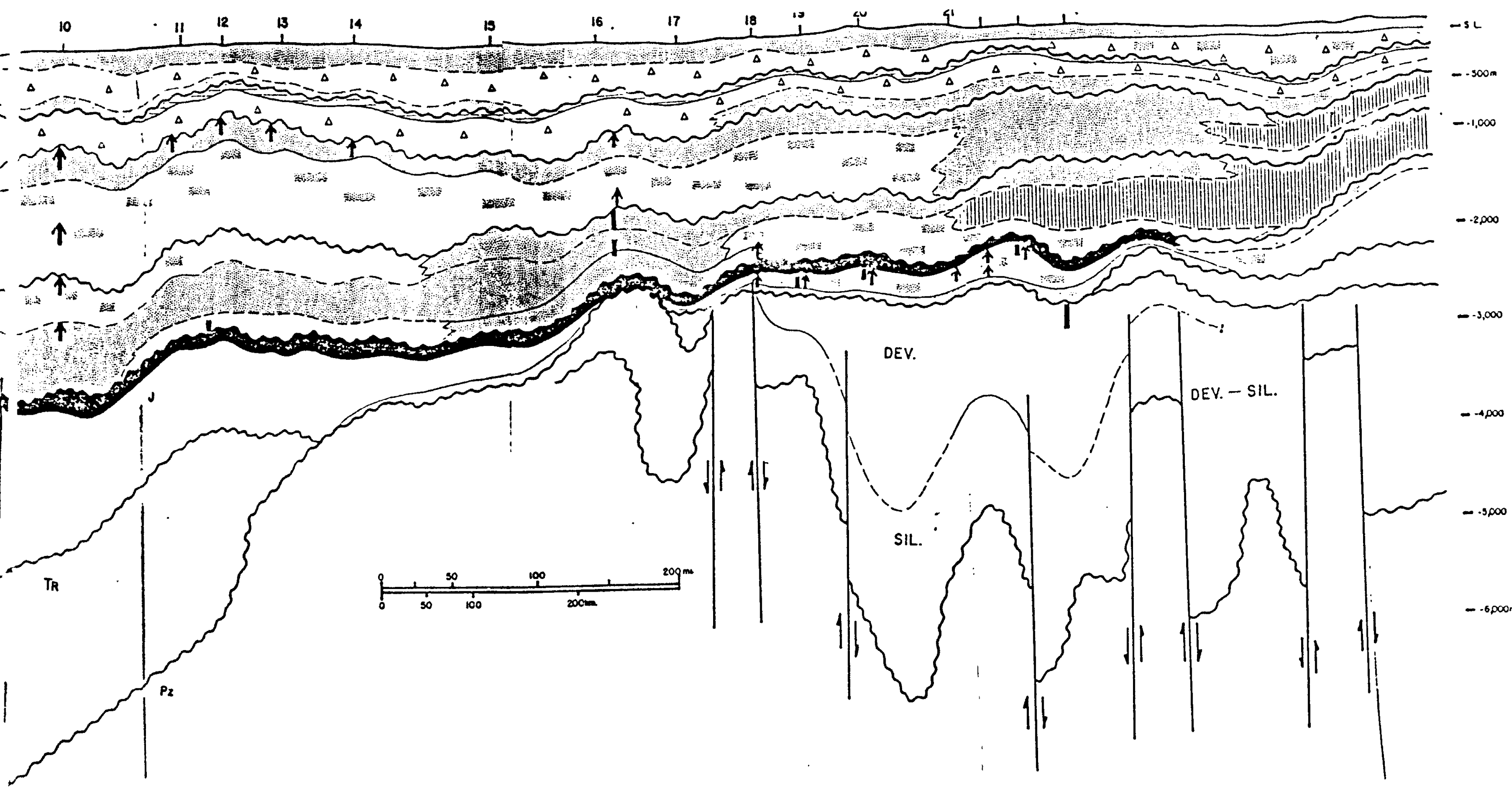
1. Kharasavey
2. Bovanenkov
3. Neytin
4. Arkteck
5. Sredne-Yamal
6. Nurmin
7. Novaport
8. Yamburg
9. Severo-Urengoy
10. Urengoy
11. Yamsovey
12. Gubin
13. Vengayahkin
14. Vyngapurov
15. Vatyegan
16. Samotlor
17. Alenkin
18. Myl'dzhin
19. Verkhne-Salit
20. Klychev
21. Kazan
22. Verkhne-Taz
23. Vostchno-Mezhev
24. Maloich
25. Shaim
26. Teterovo-Mortymin
27. Potanay
28. Lorbin
29. Kammenoye
30. Elizarov
31. Verkhne-Shapskin
32. Zapadno-Lempin
33. Pravdin
34. Ust-Balyk
35. Zapadno-Surgut
36. Lokosov
37. Severo-Pokur
38. Vatin
39. Sovet
40. Vakh
41. Luginet
42. Kiev-Egan
43. Potaney
44. Verkhne-Kondin
45. Ozernoye
46. Pungin
47. Severo-Igrim
48. Demin
49. Yuzhno-Alyesk
50. Pokkrom
51. Severo-Kazym
52. Yarudey
53. Nadym
54. Medvezh
55. Yubiley
56. Zapolyarnoye
57. Russkoye



Left side

Figure 17. North-south structural-stratigraphic facies cross-section A -A', South Kara Sea to south border of West Siberian basin. Sea level datum.

A'


10
11
12
13
14
15
16
17
18
19
20
21
S L
-500m
-1,000
-2,000
-3,000
-4,000
-5,000
-6,000m
J
TR
PZ
DEV.
SIL.
DEV. — SIL.
0
50
100
200ms
0
50
100
200km

Right side

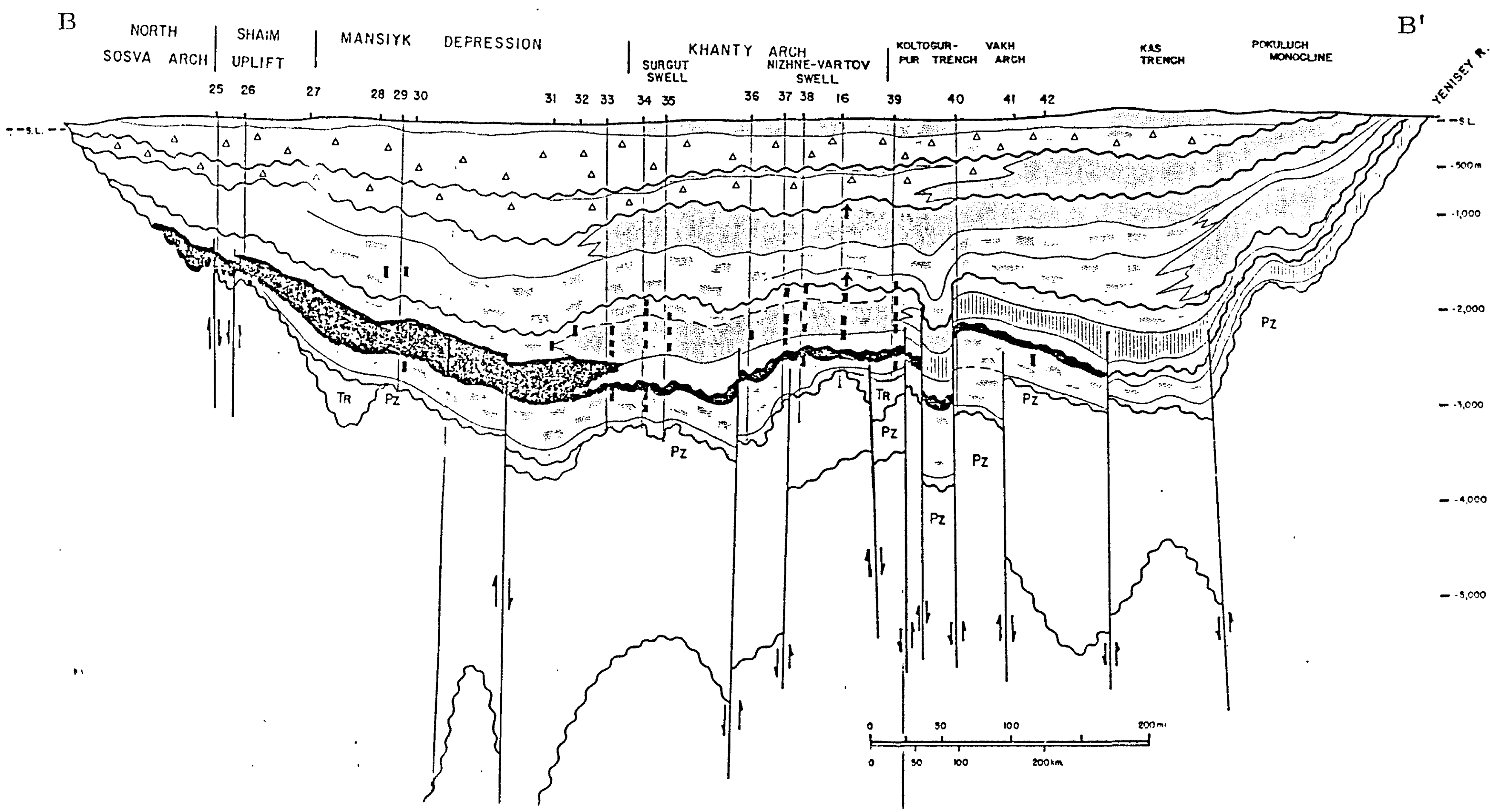


Figure 18. West-east structural-stratigraphic facies cross-section B-B', near-Ural region across Middle Ob region to eastern border of West Siberian basin.

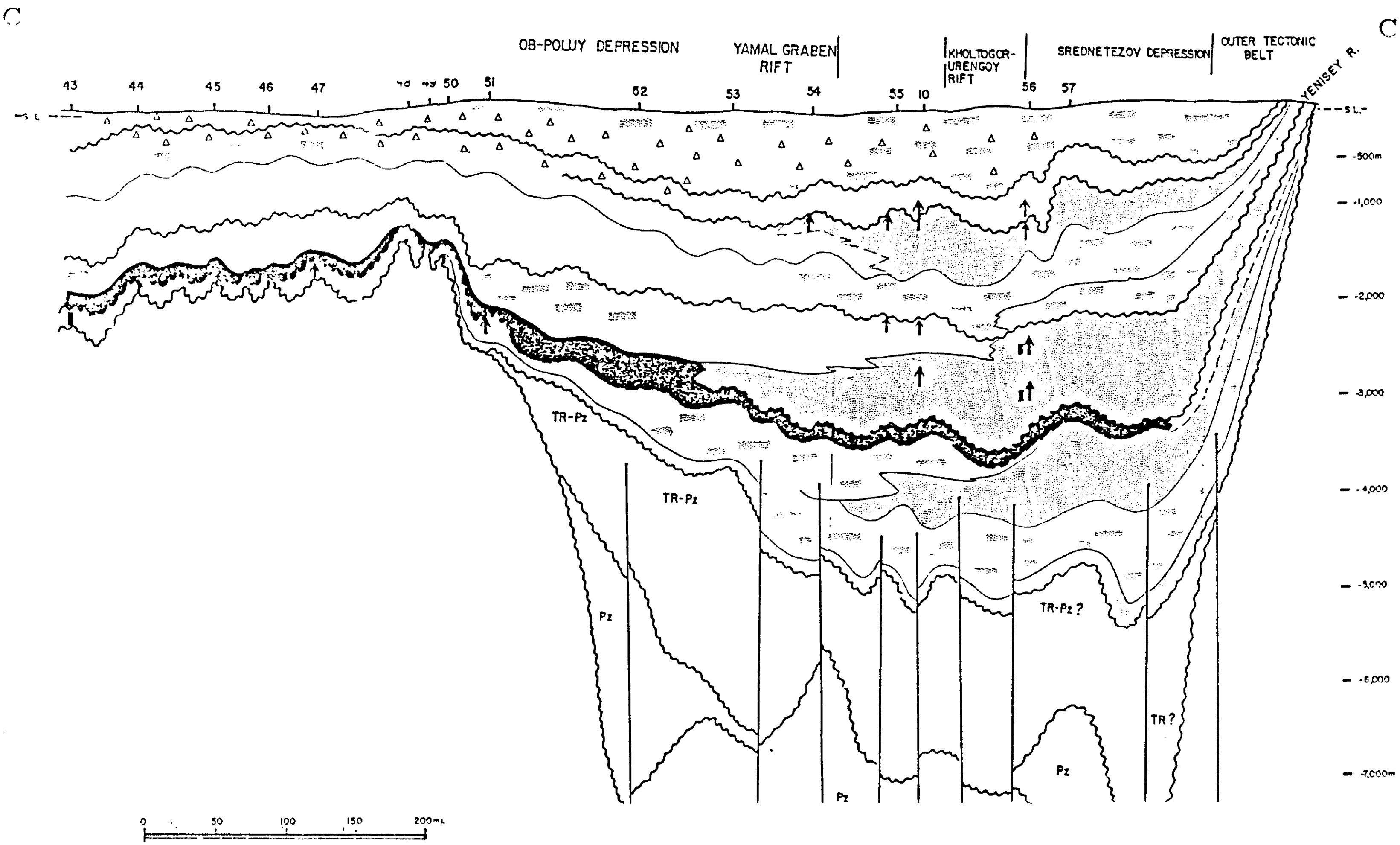


Figure 19. West-east structural-stratigraphic facies cross-section C-C', near-Ural region across Urengoy uplift area to northeast border of basin.

and several minor transgressive-regressive sedimentary cycles, each of which is separated by an unconformity of variable magnitude. The megacycles recognized are: Triassic-Aptian, Aptian-Oligocene, and Oligocene-Quaternary. Predominately continental sediments occur at the base of each megacycle grading to largely marine or nearshore sediments at the top. A similar breakdown of marine transgressive-regressive cycles is given by Aleinikov and others (1980) and by Rudkevich (1976, 1981): Triassic-Barremian; Aptian-Paleocene; and Eocene-Oligocene. Unconformities of variable extent are present at the base of the Triassic, Lower Jurassic, Upper Jurassic, Neocomian, Hauterivian, Aptian, Albian, Turonian, Paleocene, middle Oligiocene, and Miocene (Aleinikov and others, 1980). A total of 245 stratigraphic units were recognized in the Mesozoic-Cenozoic section as of 1967 (Kontorovich and others, 1975).

Major source areas for Mesozoic clastics were present on the southeastern and southern borders of the basin. Lesser but important sources of clastics were present in the Uralian and Taymyr uplifts. The Siberian craton on the east was apparently not a major source of detritus (fig. 20) because it was covered by Triassic basalt and Upper Proterozoic and Lower Paleozoic clastic sedimentary rocks, whereas the sedimentary fill of the West Siberian basin is arkosic, derived from a granitic terrane. Local uplifts within the basin also were minor sources at times during low sea level stages.

Triassic - Most of the central and southern part of the West Siberian platform was emergent during the Triassic, following late Paleozoic (Hercynian) uplift. The uplift here was followed by a period of tensional stresses in Late Permian and Triassic time, during which extensive deep-seated fracturing and rifting took place accompanied by graben and horst growth and basaltic magmatism (Kontorovich and others, 1975). The faults in these taphrogenic basins generally trend north-south or northeast-southwest and are present over most of the basin area, extending northward beneath the continental-marine post-rift Triassic and younger regional sedimentary cover in the northern basin (figs. 17 - 20). Grabens are filled with continental sedimentary and volcanic deposits as much as 3 km (10,000 ft) or more thick. Depth of the grabens increases to the north where they may contain as much as 5 km (16,000 ft) of Triassic sedimentary rocks. Within the grabens, variegated conglomerates, sandstones, and volcanic rocks predominate in the Lower and Middle Triassic deposits. The upper part is mostly sedimentary, and coal-bearing beds are present in many of the grabens. These rift basins became the locus of subsiding depressions during the succeeding basin fill stage of basin development.

North of approximately latitude 64° N, the basin contains a sequence of mixed continental and marine sandstone, siltstone and shale (the Tampey series) of Triassic age as much as 3 km (10,000 ft) or more thick (fig. 20). This sequence is similar to that of the overlying Jurassic deposits and represents the initial cycle of Mesozoic platformal marine sedimentation in the basin (Rudkevich and others, 1988). Seismic data indicate that these deposits may be more than 6 km

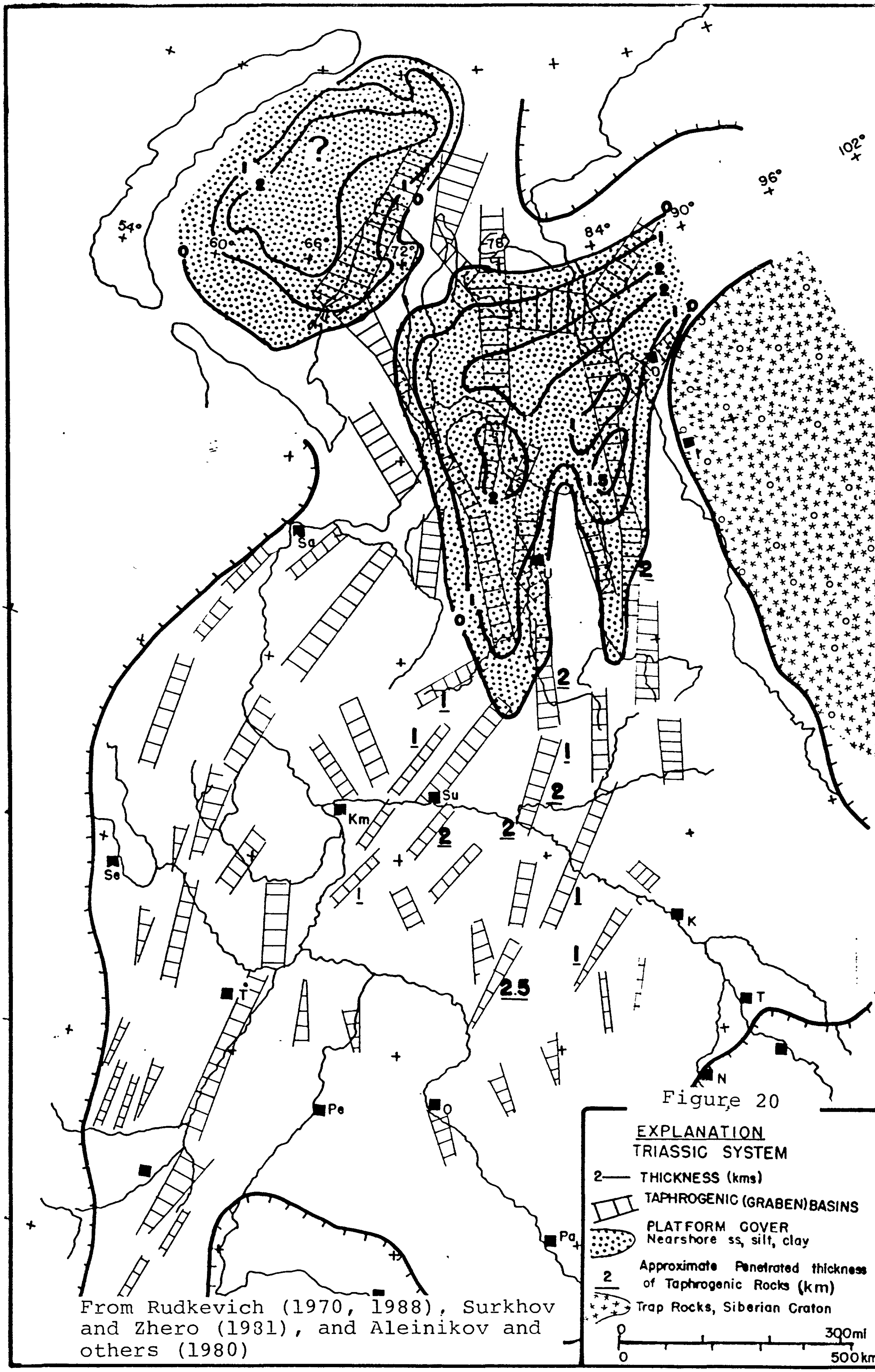


Figure 20

From Rudkevich (1970, 1988), Surkhov and Zhero (1981), and Aleinikov and others (1980)

(20,000 ft) thick in some depressions in the northern basin region. In the Khatanga region, as much as 3 km (10,000 ft) or more of clastic deposits of Triassic age are present, sourced from the Taymyr uplift region (fig. 20).

Lower and Middle Jurassic - Lower Jurassic rocks rest on Paleozoic or Precambrian rocks over most of the platform area, except where Triassic graben-fill rocks are present. In the north basin region, however, Lower Jurassic, mainly continental, including lacustrine, sediments rest on widespread Upper Triassic deposits (Tampey Series). Beginning with Early Jurassic time, the West Siberian basin began a steady subsidence, which has continued with minor interruptions to the present. The general pattern of Triassic graben subsidence and adjacent uplift continued into the Jurassic, with greater subsidence and thickening of the sedimentary cover occurring in the regions of Triassic subsidence, and thinning of the cover over the Triassic and older uplifts. The Early and Middle Jurassic marine transgressions progressed from the north along these subsided graben areas and spread outward from them to cover most of the platform. During the Early and Middle Jurassic, the Mansiysk depression region (figs. 2, 18), which had been a large area of Hercynian uplift, became a major area of subsidence, and continued as such throughout deposition of the post-Triassic sedimentary cover. It was a semi-starved basin west of the Khanty regional high. Thus, these inherited areas of uplift and subsidence became the sites of specific sedimentary facies deposition, particularly during the Late Jurassic and Cretaceous, a factor which helped to determine the positions of marine-nonmarine transitional facies development, shorelines, and shallow vs deeper water shelf deposits. During low sea level and continental sedimentation episodes, the subsiding areas above Triassic grabens became the sites of stream systems, which deposited fluvial and deltaic facies, whereas on the less rapidly subsiding areas erosion occurred. In the present-day basin, the basement blocks of Hercynian age, and particularly the rift zones, are characterized by higher heat flow (Surkov and others, 1982).

Lower and Middle Jurassic rocks are 2 km (6,500 ft) or more thick in the north part of the basin and are 500 m (1,600 ft) or less in the central and southern parts. These rocks comprise the Zavodoukov cycle (fig. 10). During the time of deposition of these sediments, the West Siberian platform was a continental interior or marginal basin, connected on the north with the Arctic basin across the North Siberian sill and through the Khatanga trough (figs. 17, 21-24). In late Mesozoic time, the southwestern part of the basin also was connected through a narrow passageway with the Tethyan Sea (fig. 9), although for the most part, this accessway was closed off and filled with continental sediments. By the end of Middle Jurassic time, the basin configuration was essentially in place.

The earliest Jurassic deposits occur only in depressions, whereas later deposits also cover the uplifts. Alluvial and lacustrine deposits are characteristic of the Early Jurassic, some with coaly beds. Marine deposits are present only in the western and northwestern part of the

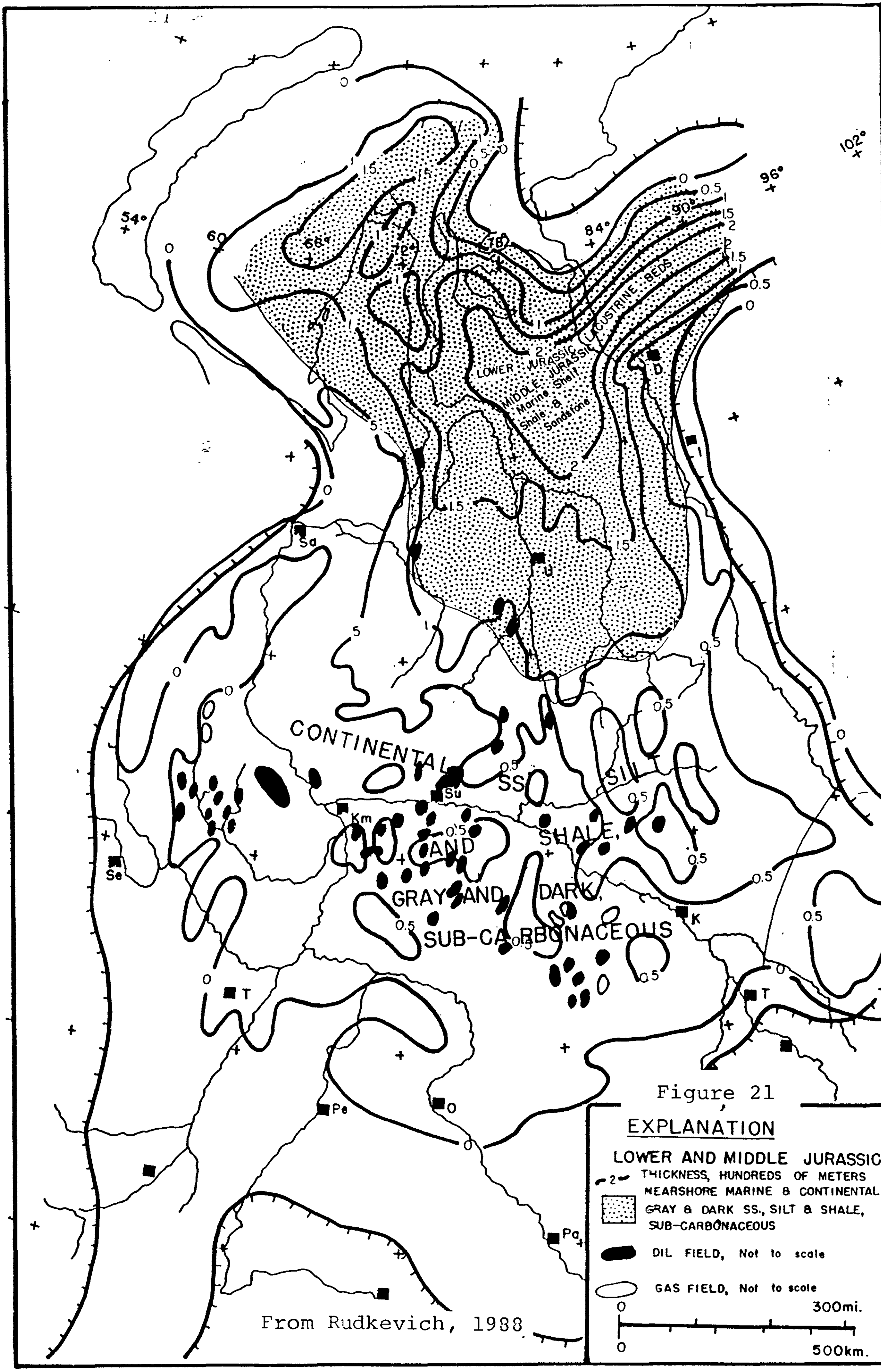


Figure 21

From Rudkevich, 1988

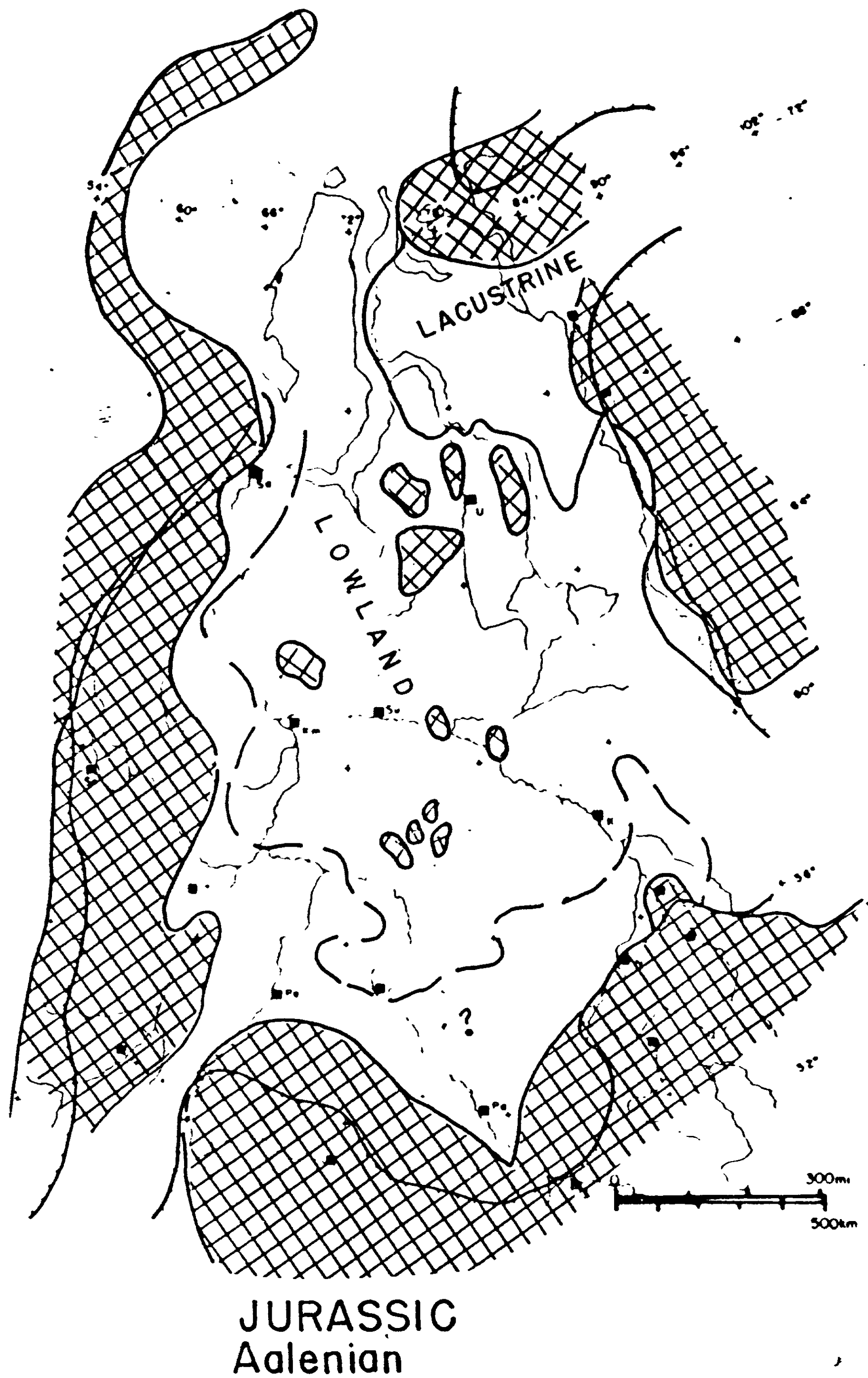


Figure 22. Paleogeographic-sedimentary environment map of Aalenian Stage (Modified from Academy of Sciences USSR, 1968)
Cross-hatching indicates uplift areas

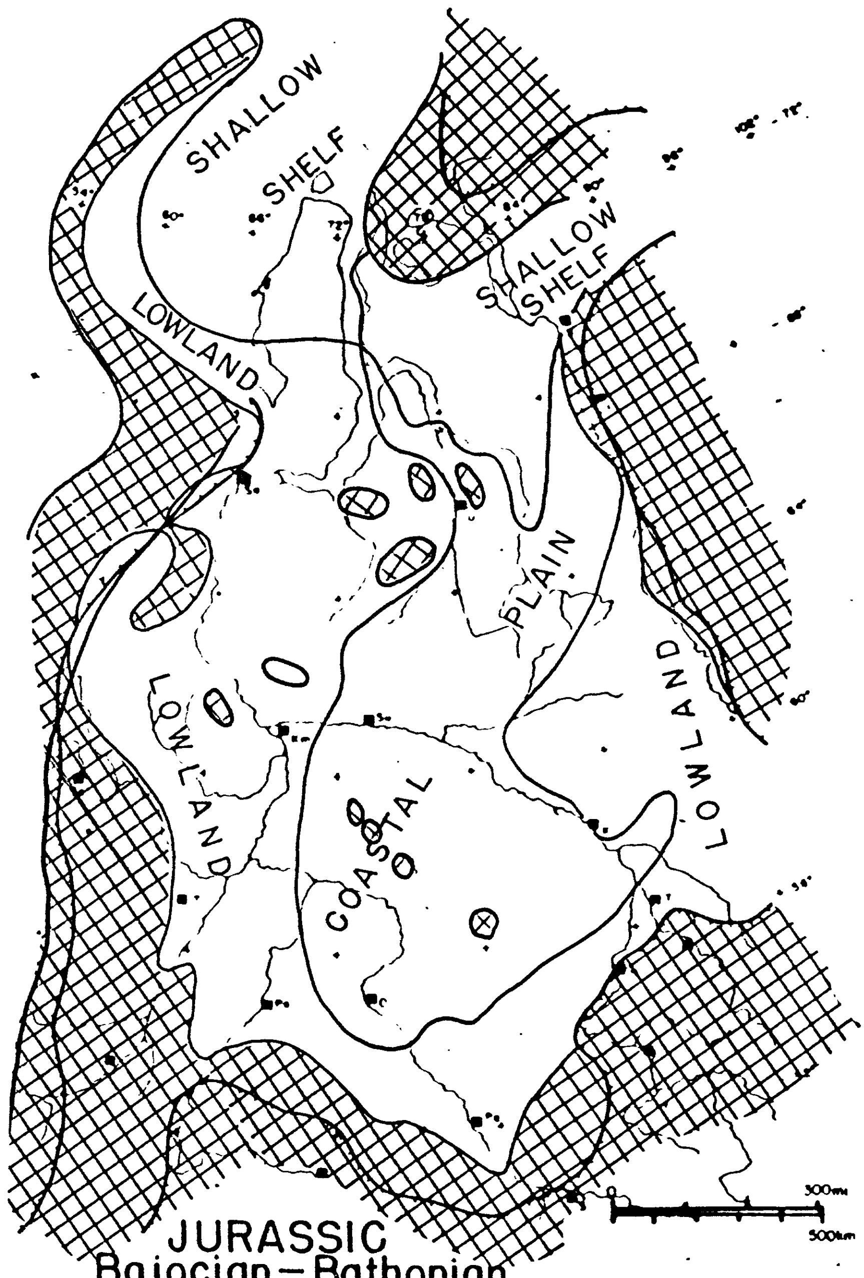


Figure 23. Paleogeographic-sedimentary environment map of Bajocian and Bathonian Stages. Cross-hatching indicates uplift areas (Modified from Academy of Sciences USSR, 1968

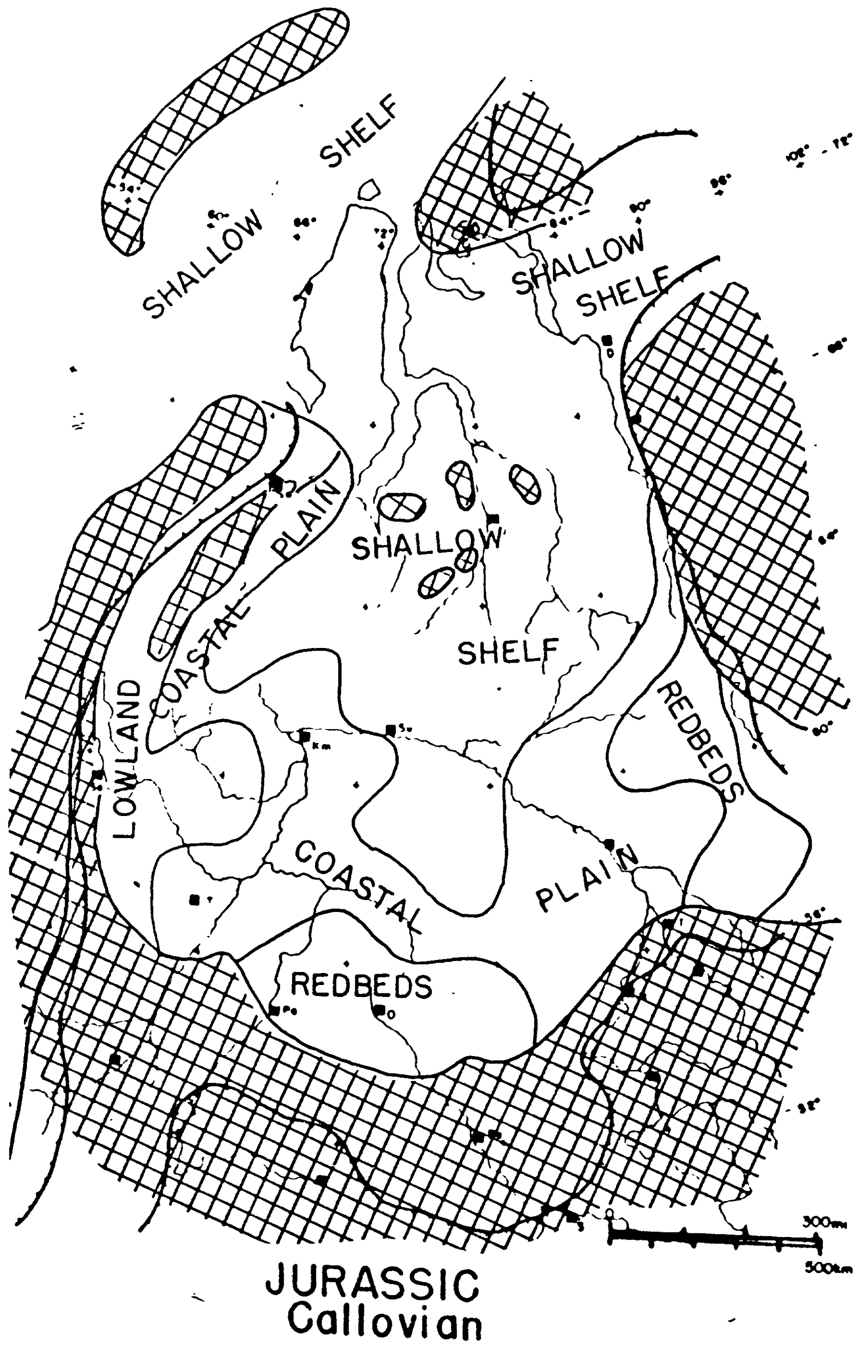


Figure 24. Paleogeographic-sedimentary environment map of Callovian Stage. Cross-hatching indicates uplift areas (Mofified from Academy of Sciences USSR, 1968)

basin (fig. 21). During the Middle Jurassic, the first major marine invasion of the basin from the north occurred and extended as far south as approximately 64° N latitude (fig. 23). Deposits south of that position are mainly coastal plain and lowland sandstone and shale on the east and southeast flanks of the basin. Shaly to sandy beds were deposited in the central and western areas. Sediment source areas during this time were the Siberian craton on the southeast, the Kazakhstan and Altay-Sayan uplifts on the south, the Taymyr uplift on the northeast, and, to a lesser degree, the Uralian uplift on the west (fig. 9).

The most widely distributed formation of the Lower-Middle Jurassic part of the section is the Tyumen Formation, which spans the time interval of the Hettangian, Sinemurian, Pliensbachian, Toarcian, Aalenian, Bajocian, and Bathonian stages of the Lower and Middle Jurassic and the lower part of the Callovian (fig. 10). The upper part of the Tyumen Formation is part of the Poludin cycle, which overlies the Zavodoukov cycle. The Callovian is placed in the Upper Jurassic by some Soviet geologists but is assigned to the Middle Jurassic by others as, for example, the Geological Society of America Time Scale.

<u>Upper Jurassic</u> - Upper Jurassic rocks, disconformable on Middle Jurassic rocks in parts of the basin, are 500 m (1,600 ft) or more thick in parts of the northern basin and in the Khatanga region on the northeast. Widespread marine incursions from the Arctic basin spread as far south as 54° N latitude at this time. Most of the basin was characterized by shallow and deep shelf clastic deposition, which included widespread bituminous shales in the more rapidly subsiding central part of the basin, ammonite-bearing marine glauconitic shelf sandstone and shale along the east and west flanks, and continental redbeds grading seaward into shelf shale and sandstone on the southeast and south flanks (figs. 25-27). Some conglomerate and limestone beds are present locally, particularly in the northeastern part of the basin.

The Upper Jurassic rocks are part of the Poludin cycle, which includes the section from the base of the middle Callovian to near the top of Valanginian stage of the Lower Cretaceous. This cycle includes the Vasyugan, Georgiyev, Bazhenov, and Megion formations (fig. 10).

The Vasyugan Formation consists of a lower dark gray shale member 37-45 m thick, at the base of which a sandstone is generally present. The upper part is largely sandstone but contains some coal beds and shale. Its thickness ranges from 19 to 53 m. (Gurari and Trushkova, 1972, p. 14).

The Georgiyev Formation is composed of dark gray to black, bituminous shale, which contains beds and lenses of pelitic limestone and a little glauconite. Thickness is 17 m.

At the top of the Jurassic section is the highly bituminous Bazhenov Formation, which was deposited over much of the basin area, grading to thin deposits of shelf sandstone and shale around the basin

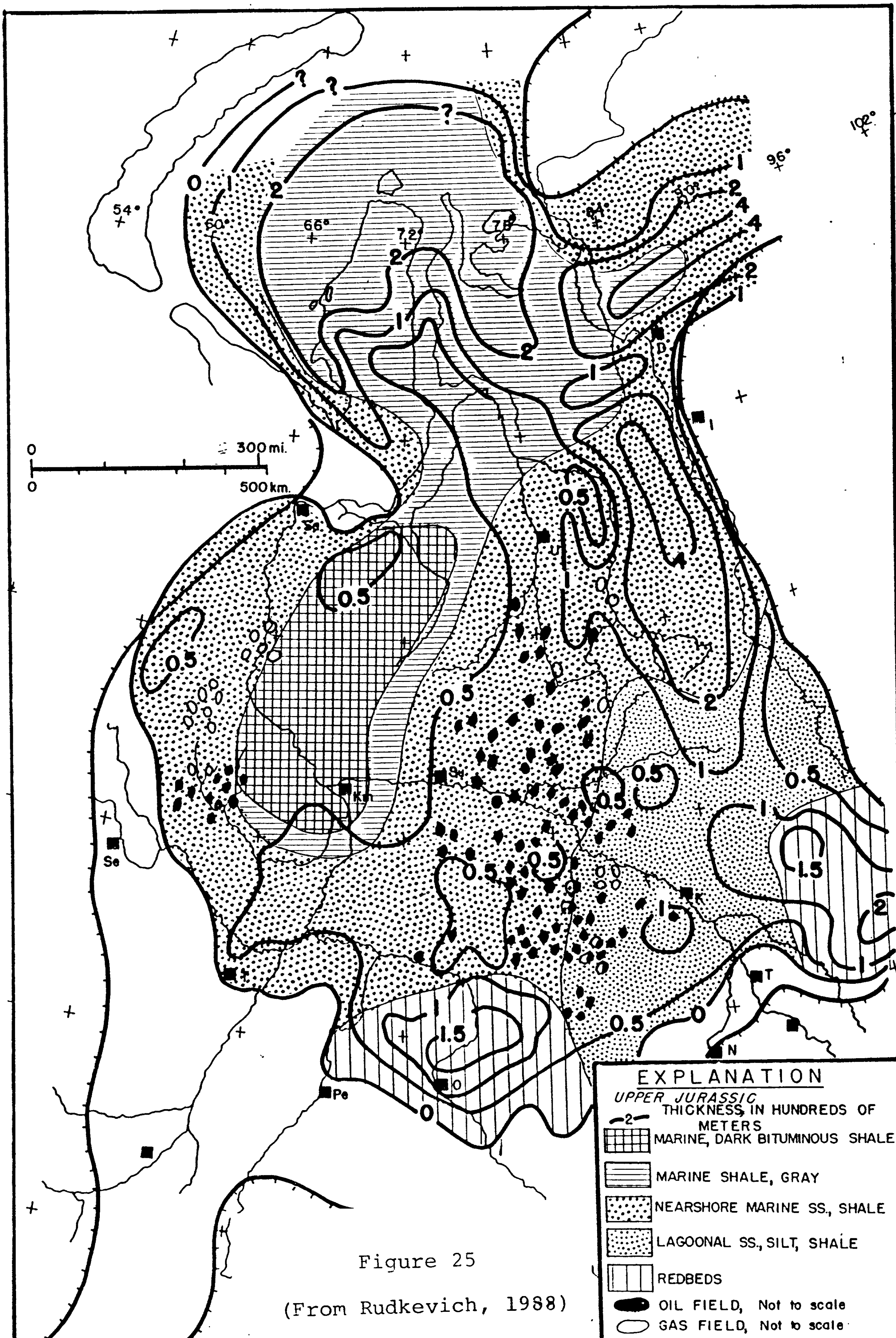


Figure 25

(From Rudkevich, 1988)

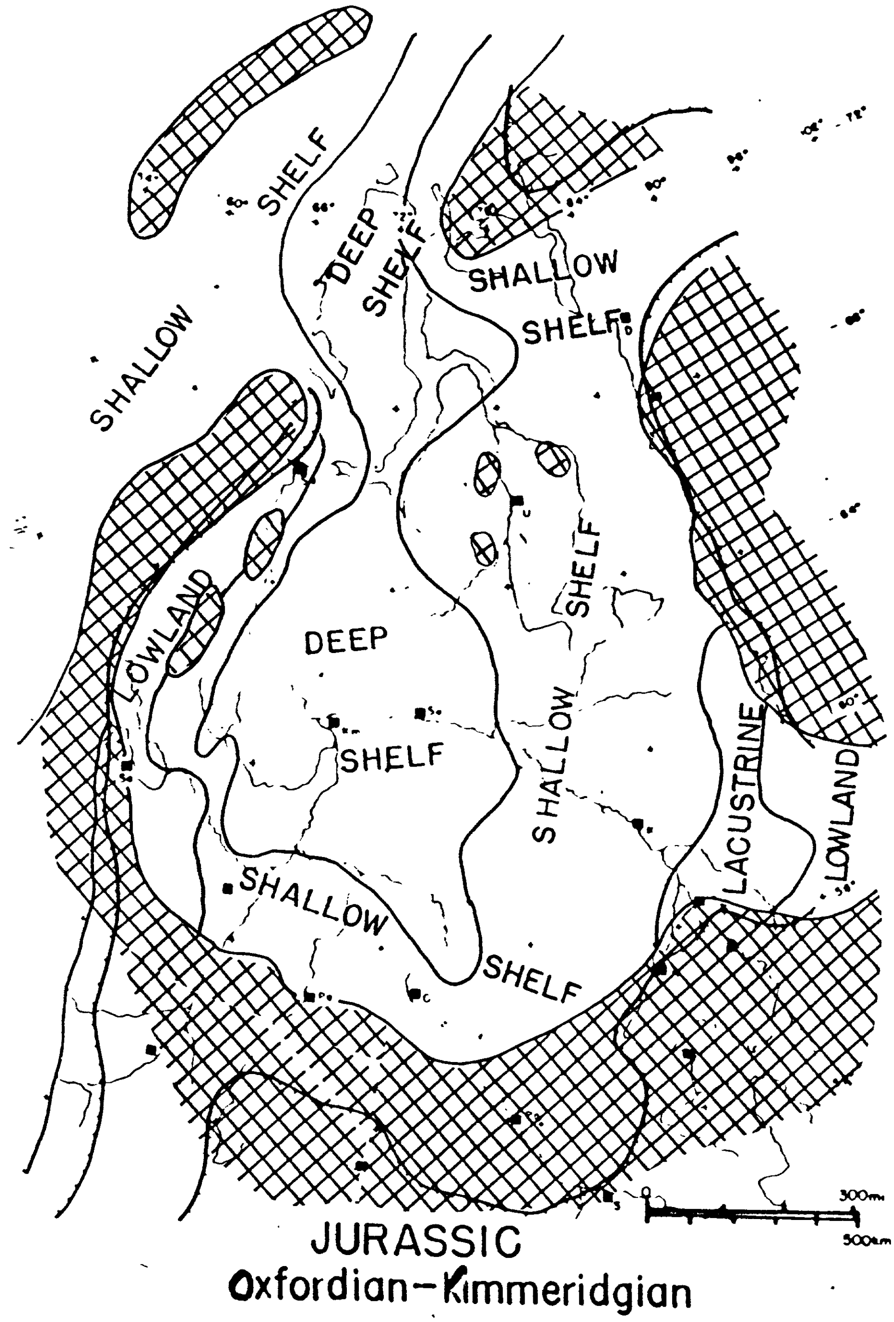


Figure 26. Paleogeographic-sedimentary environment map of Oxfordian and Kimmeridgian Stages. Cross hatching indicates uplift areas (Modified from Academy of Sciences USSR, 1968)

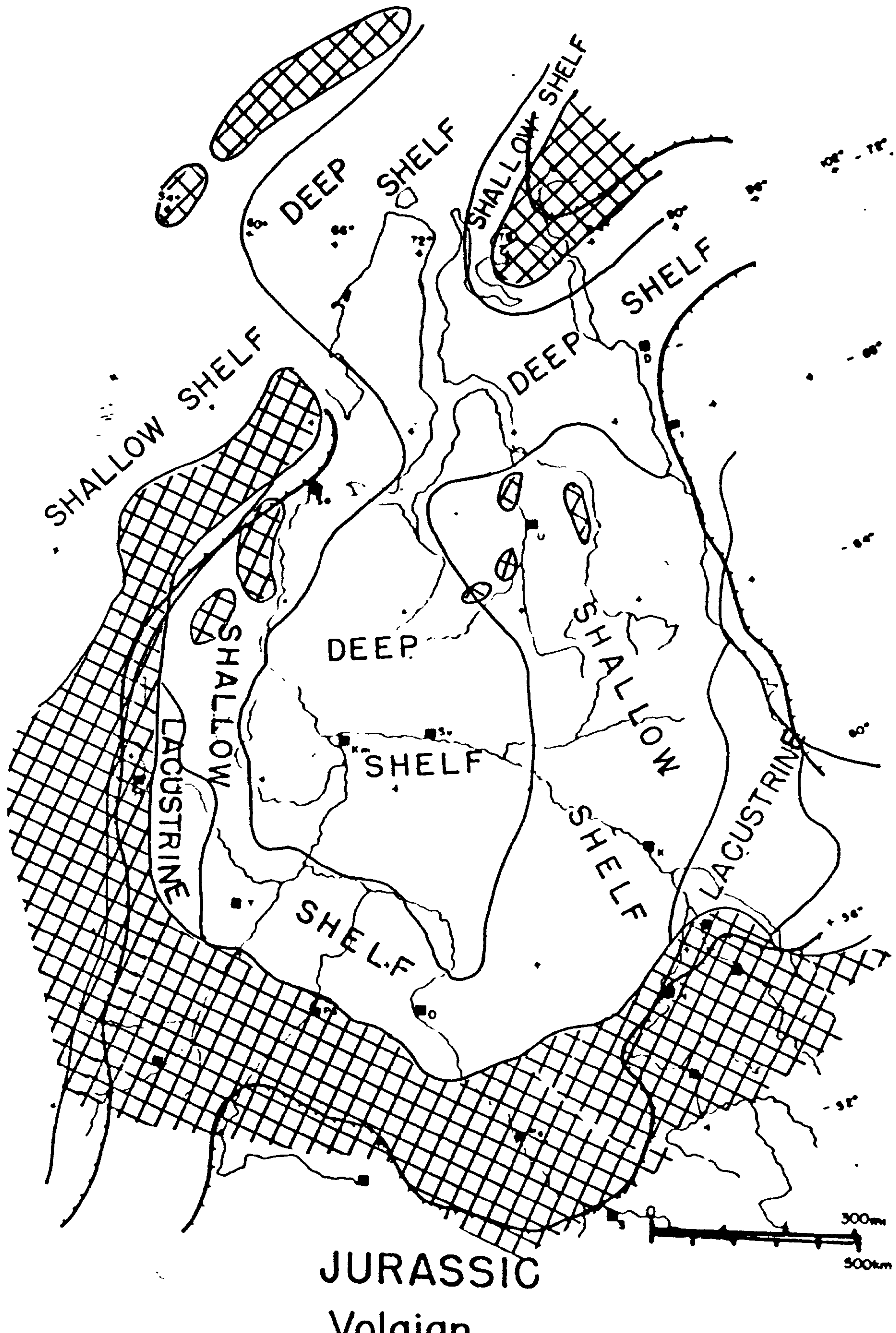


Figure 27. Paleogeographic-sedimentary environment map of Volgian Stage. Cross hatching indicates uplift areas (Modified from Academy of Sciences USSR, 1968)

borders. At this time, clastic influx was low, and a semi-starved basin condition existed, particularly in the central and western parts of the basin. During the Jurassic-Cretaceous transition, the regions around the borders of the basin were uplifted possibly in response to Laramide folding on the east flank of the Siberian craton (Rudkevich and others, 1984). Uplift and some erosion is particularly noticeable in the Khatanga region and in the southern part of the Yamal Peninsula (fig. 25). Thus, marine circulation from the north should have been diminished south of 68° N at this time, forming a partially restricted sub-basin in which organic matter was deposited at an abnormally high rate. Marine regression at the close of the Jurassic may have further restricted the basin area to the south. At the same time, the more uplifted parts of the basin probably were emergent. Geophysical work indicates the presence of erosional surfaces at the top of the Jurassic on several large structures in the northern region also. Jurassic rocks are thin to absent and Cretaceous rocks are thin along the crest of the North Siberian sill (Gramberg and others, 1984). The presence of high bituminous shale in the Bazhenov Formation on the Yamal Peninsula and probably in the South Kara Sea basin may be related to further restriction of basin circulation caused by the effect of the North Siberian sill.

<u>Cretaceous - Neocomian</u> (Berriasian, Valanginian, Hauterivian, and Barremian Stages) (figs. 28 - 36) - During Cretaceous time, the West Siberian basin continued in open connection with the Arctic basin, except briefly at times when it may have been partly or entirely cut off by the influence of the North Siberian sill. The amount and rate of detrital deposition increased sharply at this time as a result of intensive uplift of the basin margins (Rudkevich and others, 1984). Climatic change with increasing pluvial conditions also may account partly for the increase in coarser clastics. The large marine basin of Late Jurassic Bazhenov time began to be filled by large wedges of sand which prograded westward (Gogonenkov and others, 1988). The major transgression, which began in latest Middle Jurassic time, continued into the Neocomian (Aleinikov and others, 1980), reaching a climax during the early Valanginian when most of the basin was covered by shallow marine shelf deposition (figs. 26-32). Regression began in late Valanginian time, resulting in shrinking and shallowing of the marine basin for the remainder of Neocomian time. During the regression, the coastline retreated from southeast to northwest. Frequent minor transgressions occurred, during which deeper water clay deposition spread eastward, blanketing the shoreline sand deposits.

Neocomian rocks are 1500 m (5,000 ft) or more thick in the northeastern part of the basin, approximately 1,000 m (3,300 ft) in the central basin, and are 500 m (1,600 ft) or less around the basin margins (fig. 29). The general pattern of sedimentation during this time was: (1) marine bituminous shale and gray shale deposition in the more rapidly subsiding part of the basin (Khanty-Mansiysk depression region); (2) coastal plain and nearshore marine sand and clay deposits along the north-south Khanty paleoarch through the Middle Ob region of the central basin; (3) coastal plain deposits of sand and clay on the east-central

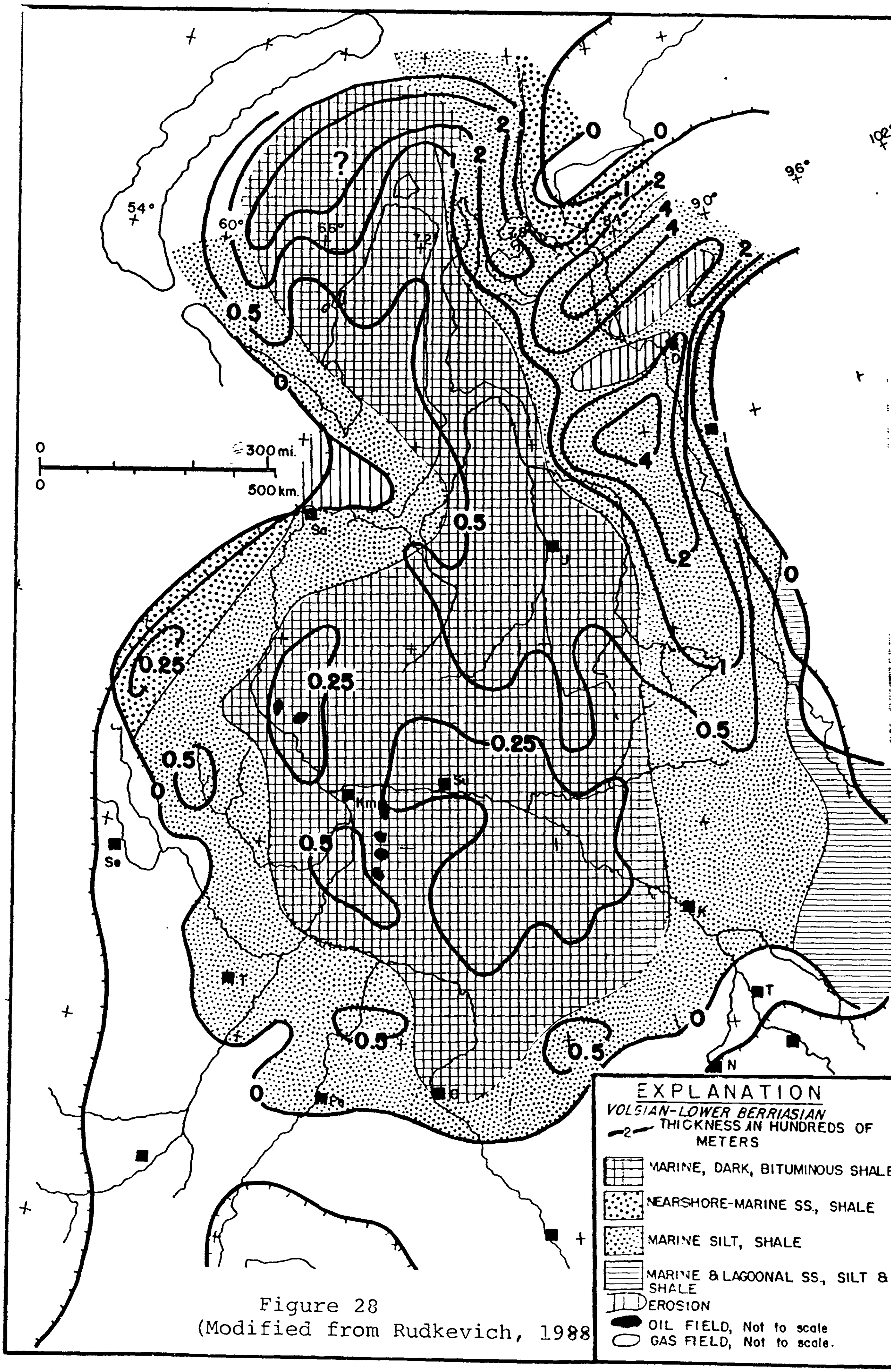


Figure 28
(Modified from Rudkevich, 1988

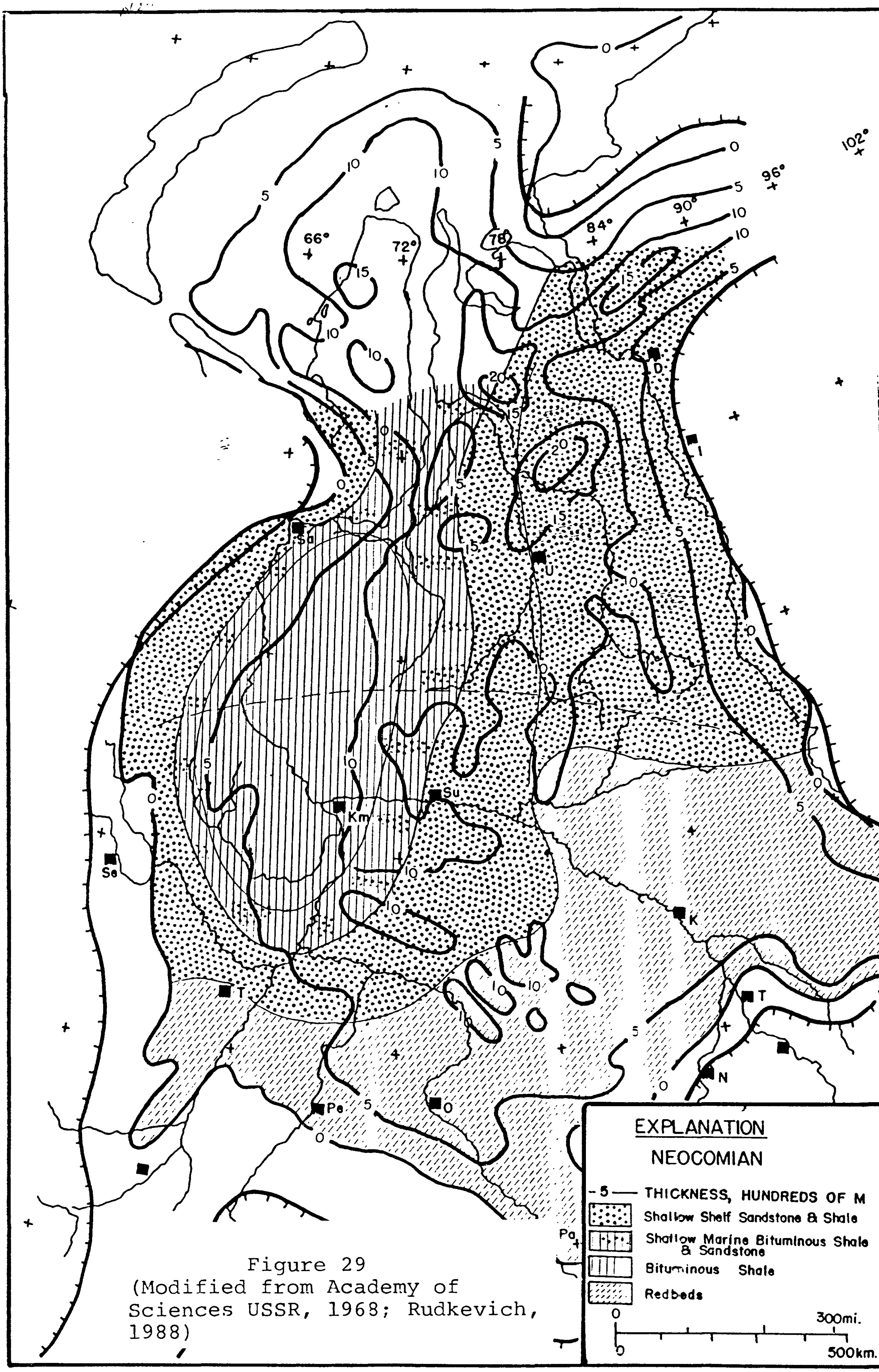


Figure 29
(Modified from Academy of Sciences USSR, 1968; Rudkevich, 1988)

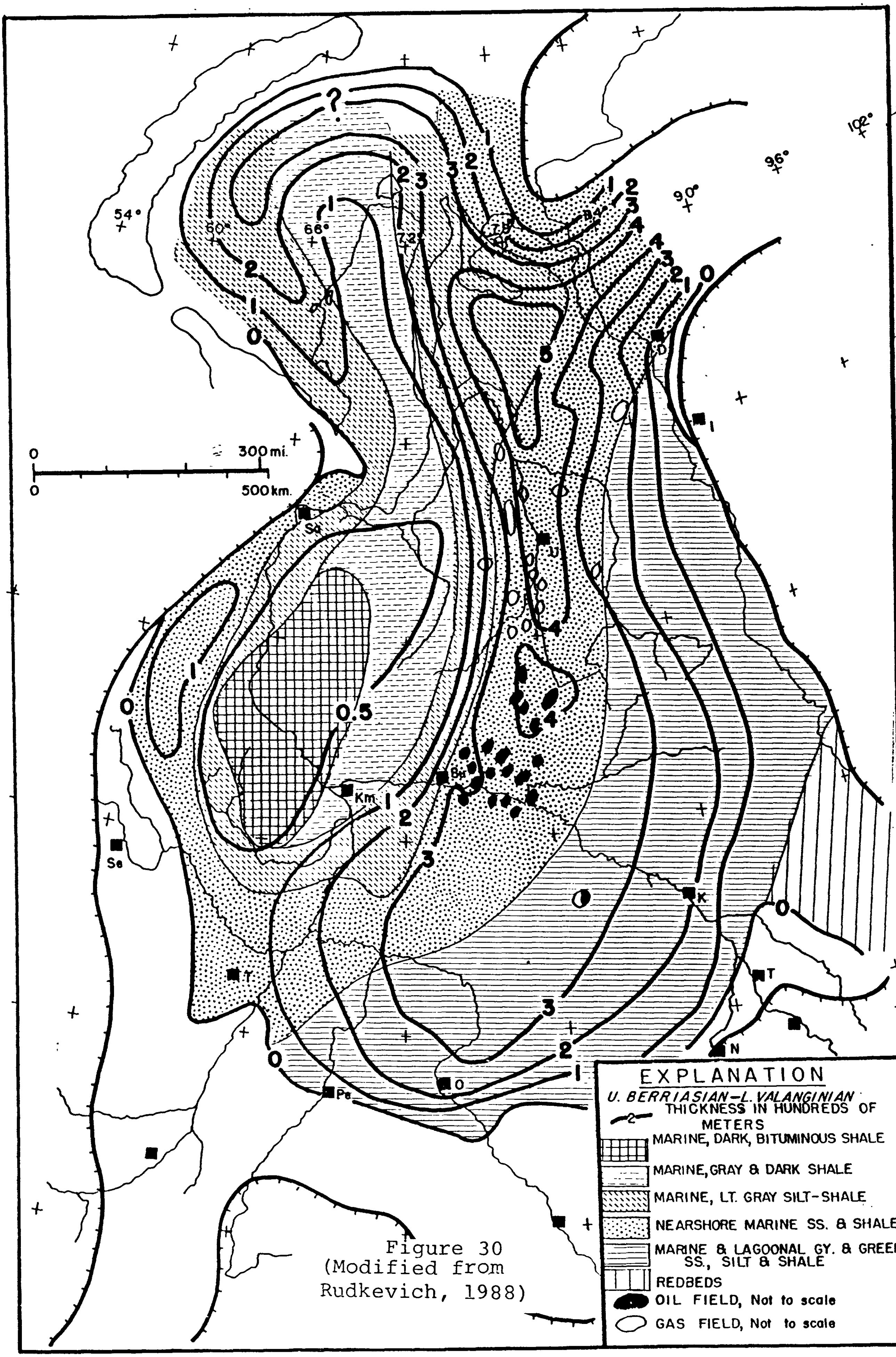


Figure 30
(Modified from
Rudkevich, 1988)

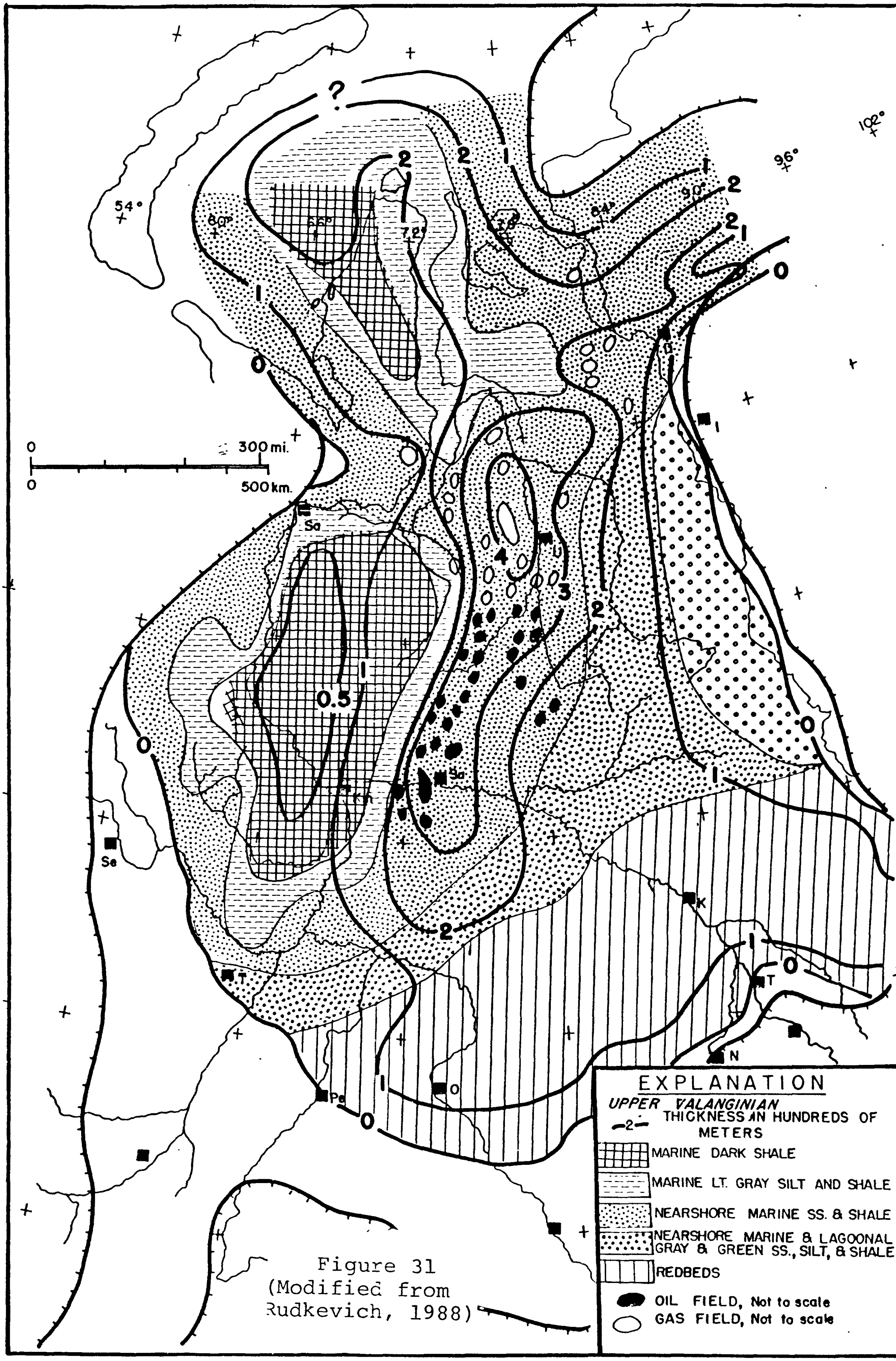


Figure 31
(Modified from
Rudkevich, 1988)

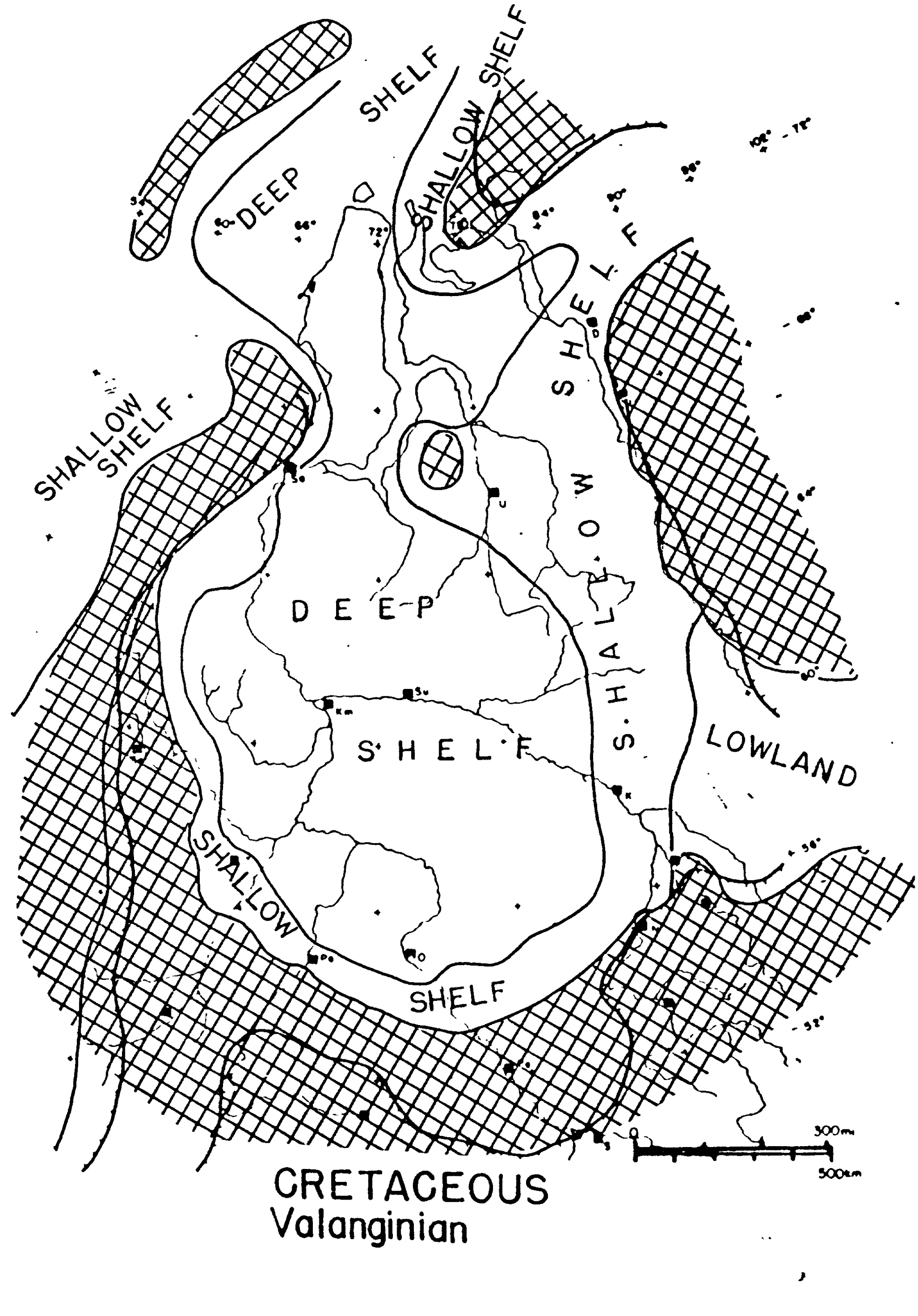


Figure 32. Paleogeographic-sedimentary environment map of Valanginian Stage. Cross hatching indicates uplift areas (Modified from Academy of Sciences USSR, 1968)

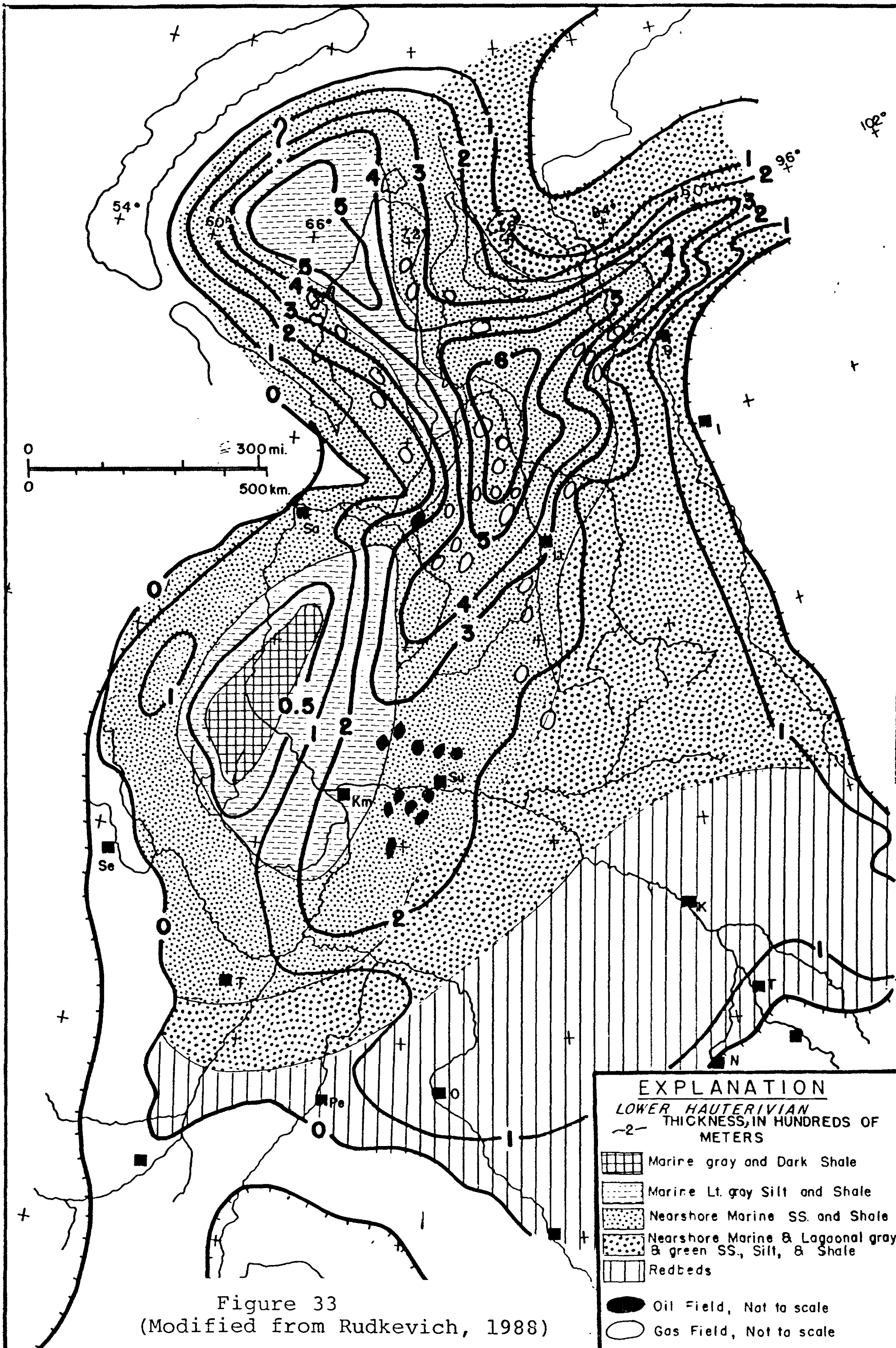


Figure 33
(Modified from Rudkevich, 1988)

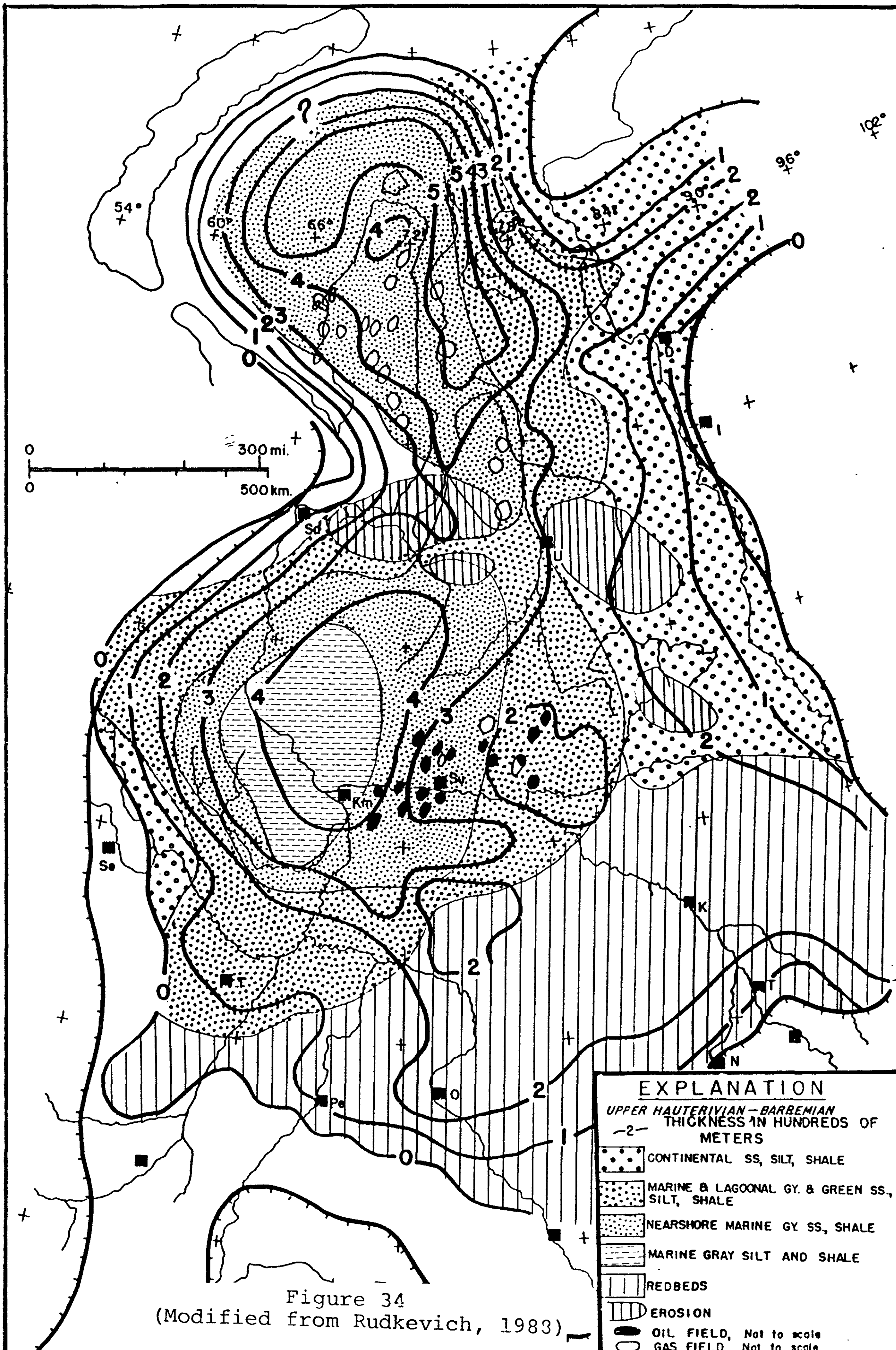


Figure 34
(Modified from Rudkevich, 1983)

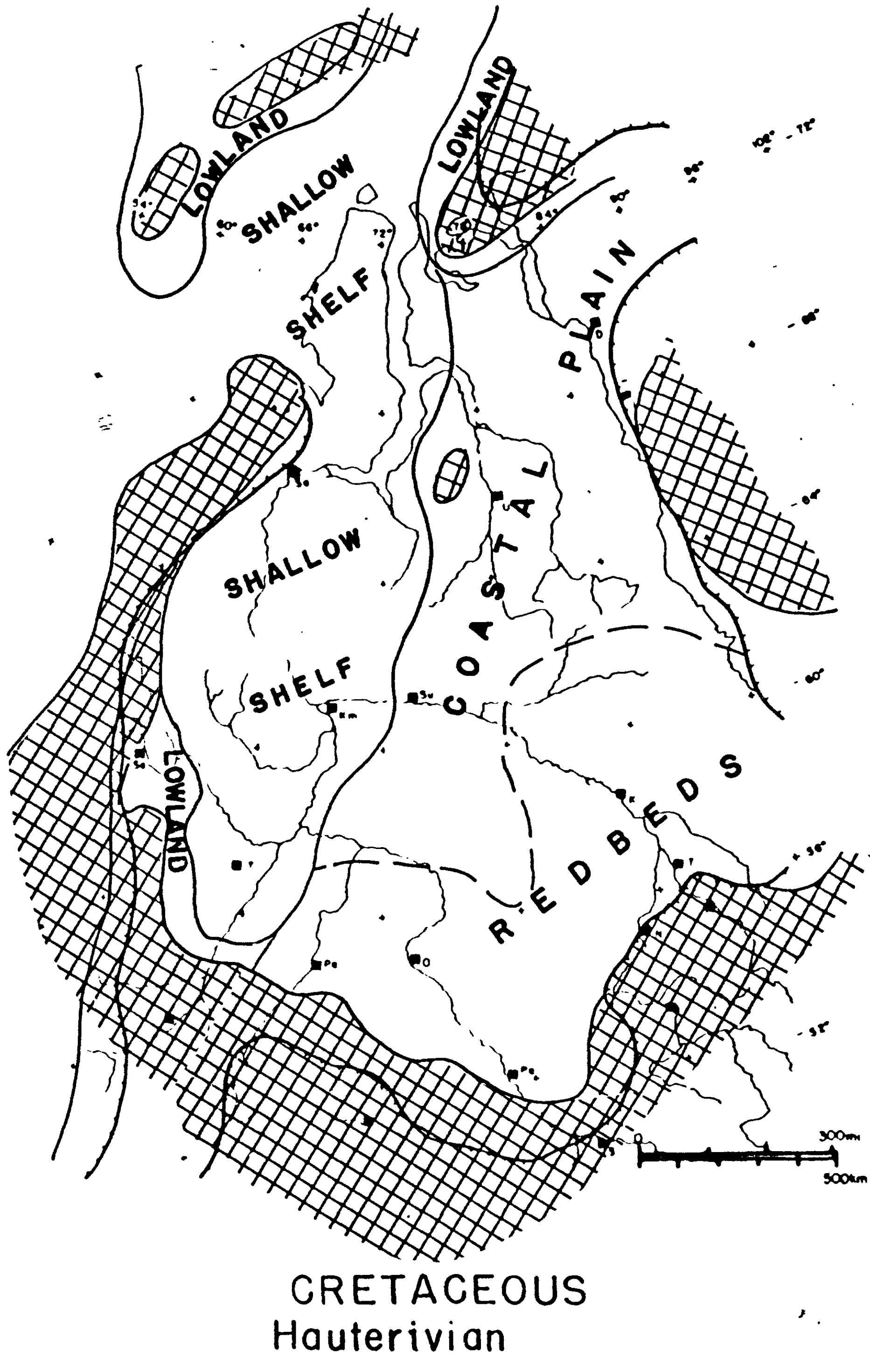


Figure 35. Paleogeographic-sedimentary environment map of Hauterivian Stage. Cross hatching indicates uplift areas (Modified from Academy of Sciences USSR, 1968)

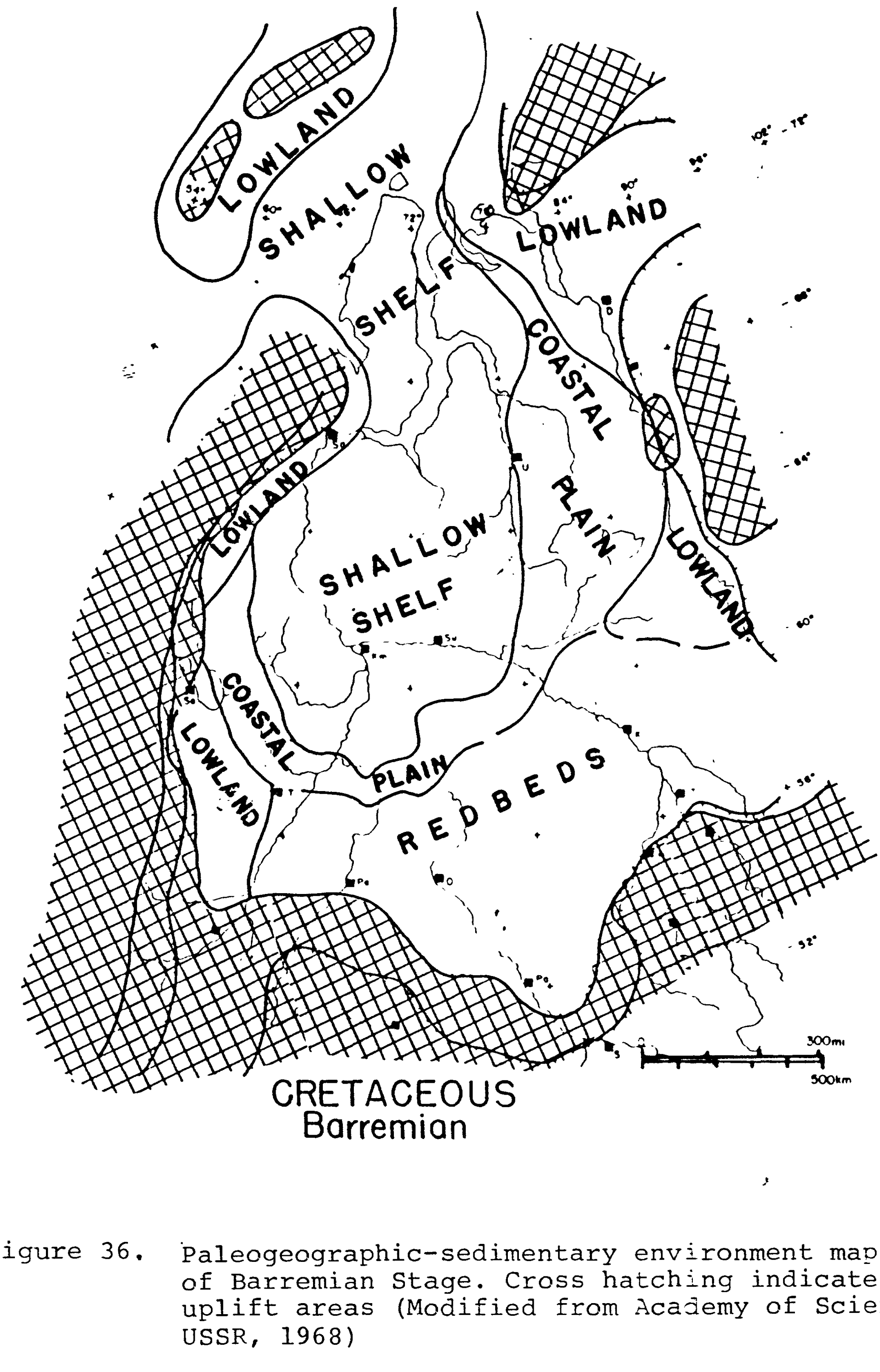


Figure 36. Paleogeographic-sedimentary environment map of Barremian Stage. Cross hatching indicates uplift areas (Modified from Academy of Sciences USSR, 1968)

basin flank; and (4) continental redbeds in a broad area in the south (figs. 29-35). A relatively narrow band of nearshore marine and coastal plain sand and clay facies also is present along the western border of the basin adjacent to the Uralian uplift.

Neocomian rocks in the West Siberian basin are represented by the upper part of the Poludin (Berriasian and lower Valanganian) and the lower part of the Sargat (upper Valangian-upper Aptian) Stage (fig. 10). The Sargat cycle itself consists of the uppermost Valanginian, all the Hauterivian and Barremian and most of the Aptian stages. The Berriasian and Valanganian are characterized by predominantly shallow water marine shale, siltstone and sandstone in the central and eastern basin regions, grading to deeper shelf high-bituminous shale in the Khanty-Mansiysk depression. Formations of regional distribution are the Megion (Berriasian and most of Valanganian) and Vartov (upper Valanganian, Hauterivian, and Barremian) Formations (fig. 10). These deposits are significantly thinned in the southern Yamal and the south Khatanga regions, suggesting that the North Siberian sill barrier of the Late Jurassic remained effective during part of this time, causing the restriction in basin circulation that aided deposition of the high bituminous shale facies.

During the Hauterivian and Barremian stages, marine deposition was restricted to the basin interior as the late Neocomian regression continued. Redbeds are dominant in the southern and southeastern parts of the basin at this time, while coastal plain, coal-bearing sandstone, siltstone, and shale deposits dominate the eastern flank. By Barremian time, marine deposition was more or less confined to the Khanty-Mansiysk region of subsidence, and the West Siberian sea was almost completely isolated from the Arctic basin.

<u>Cretaceous - Aptian, Albian, and Cenomanian</u>- Sedimentary rocks of this age are as much as 1,500 m (5,000 ft) or more thick in the northern basin where the main depocenter was located in the vicinity of the Yamal Peninsula (figs. 37-41). Equivalent beds are 800 - 1,000 m (2,500 - 3,000 ft) thick in the central basin, thinning relatively uniformly to zero around the basin borders. The Alym Formation of Aptian age consists largely of clayey rocks deposited under marine conditions. It consists of a lower member up to 100 m thick, and an upper 20-60 m thick. The Aptian-Cenomanian Pokur Formation (fig. 10) of marine and continental sandy clayey rocks is of regional distribution. The general patterns of sedimentation are somewhat similar to those of the Neocomian, with dark shale dominating in the Khanty-Mansiysk region of subsi-dence, and a broad area of coastal plain and shallow shelf sands, silts, and shales occupying the central basin. Continental sandstone, shale, and redbed facies are present over a wide area along the eastern and southern borders.

Marine deposition during the early Aptian stage was restricted to the west-central area of the basin as the late Neocomian regression culminated. In middle to late Aptian to Albian time, a major transgression began during the early phases of the Aptian-Oligocene

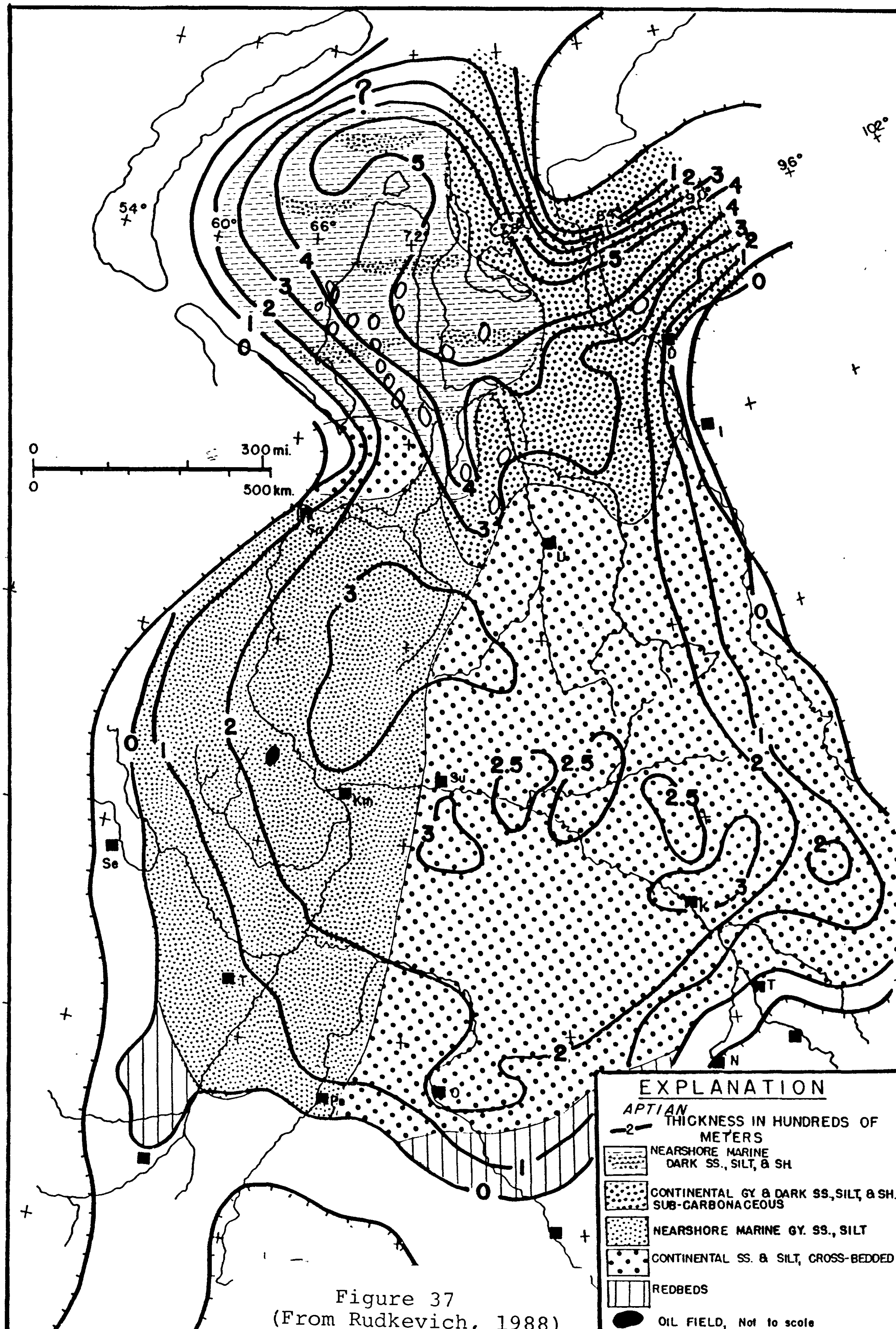


Figure 37
(From Rudkevich, 1988)

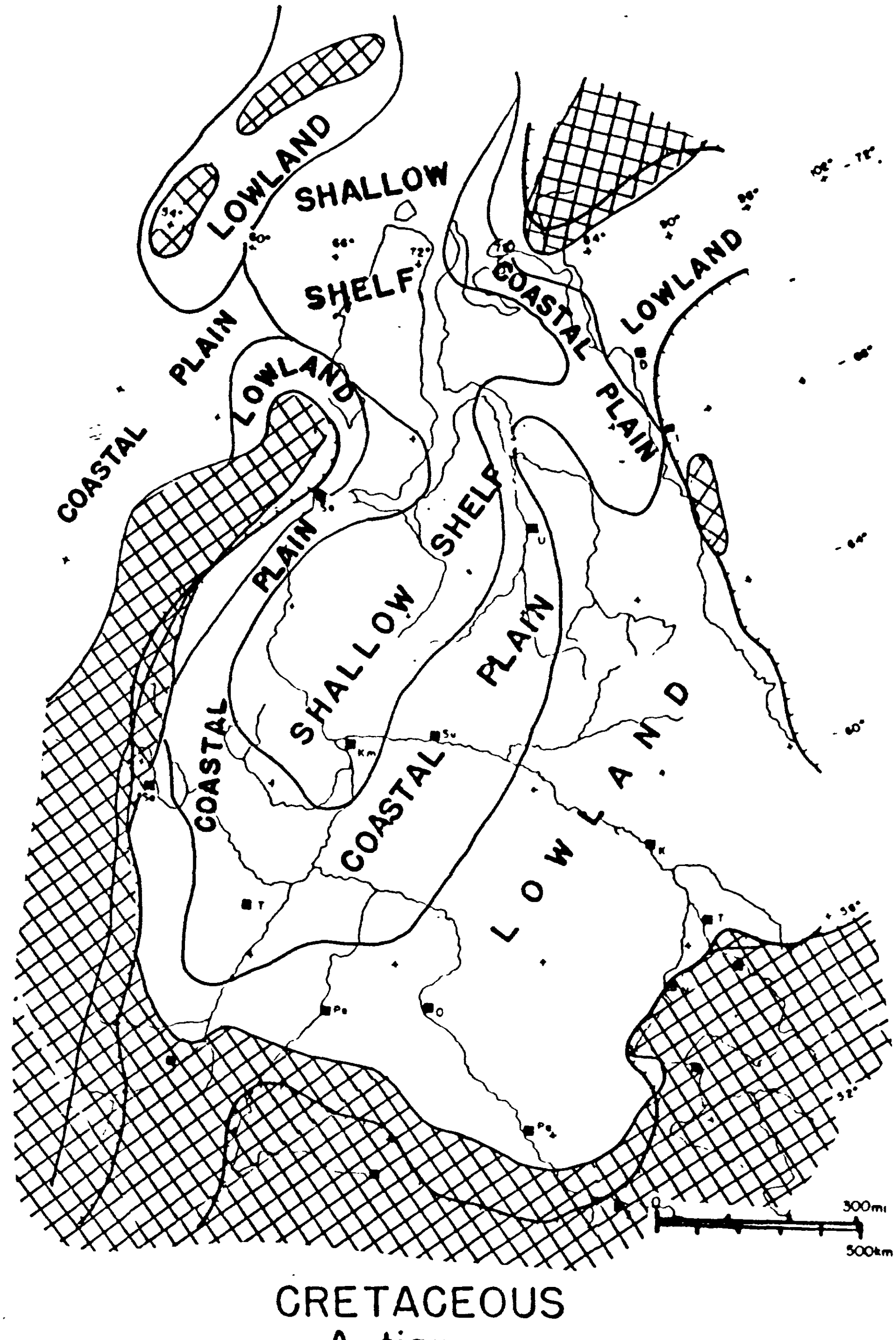


Figure 38. Paleogeographic-sedimentary environment map of Aptian Stage. Cross harching indicates uplift areas (Modified from Academy of Sciences USSR, 1968)

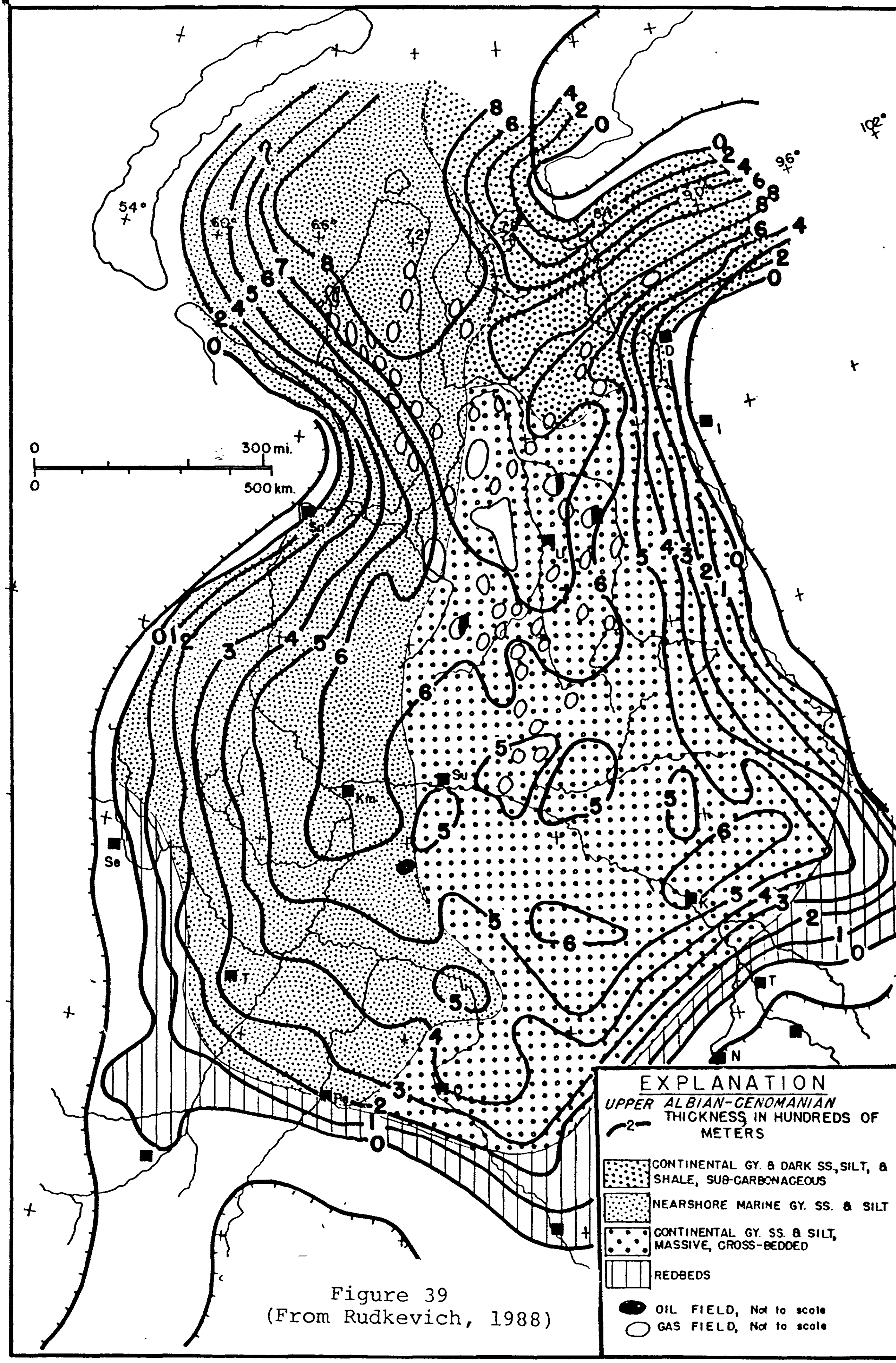


Figure 39
(From Rudkevich, 1988)

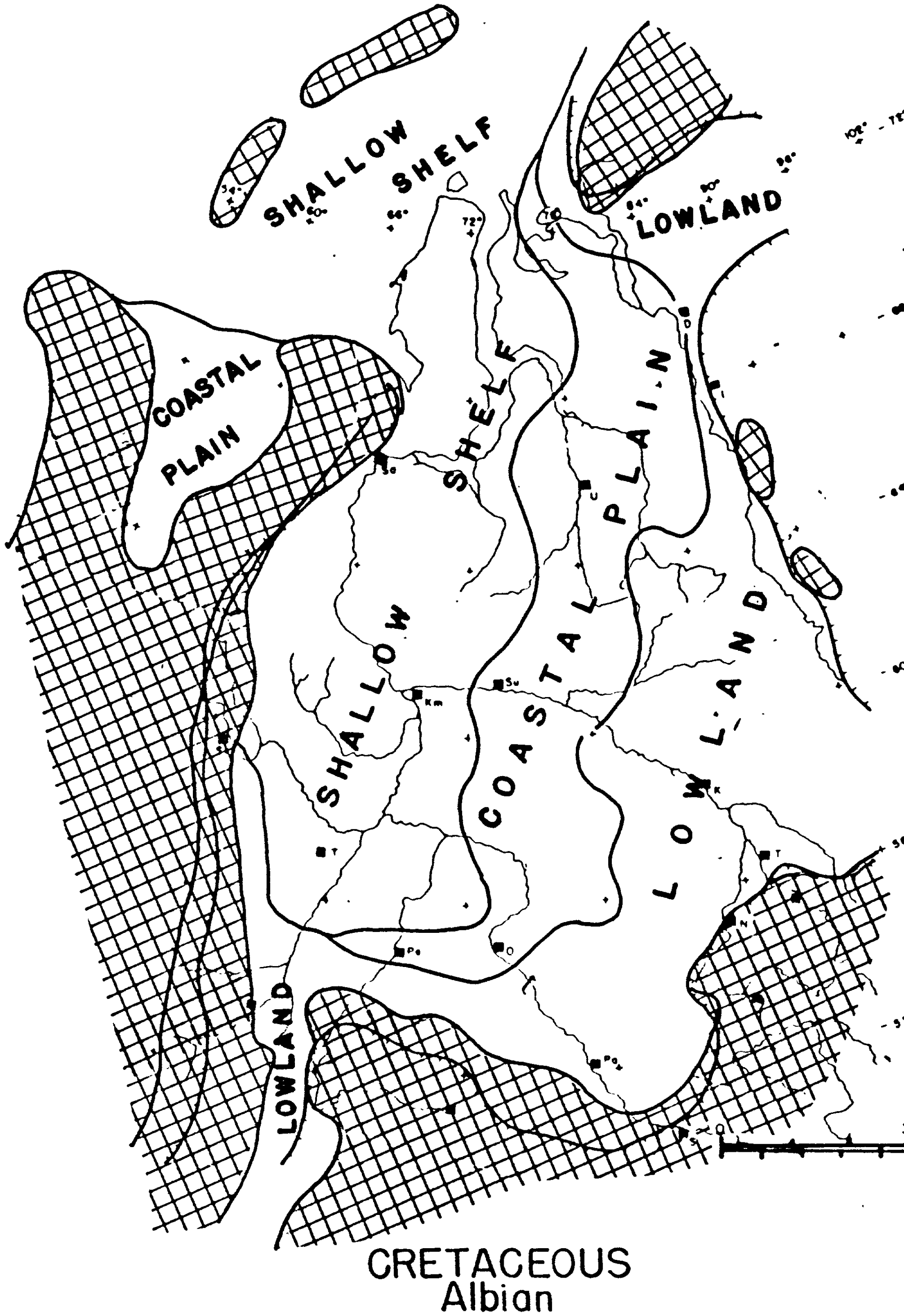


Figure 40. Paleogeographic-sedimentary environment map of Albian Stage. Cross hatching indicates uplift areas (Modified from Academy of Sciences USSR, 1968)

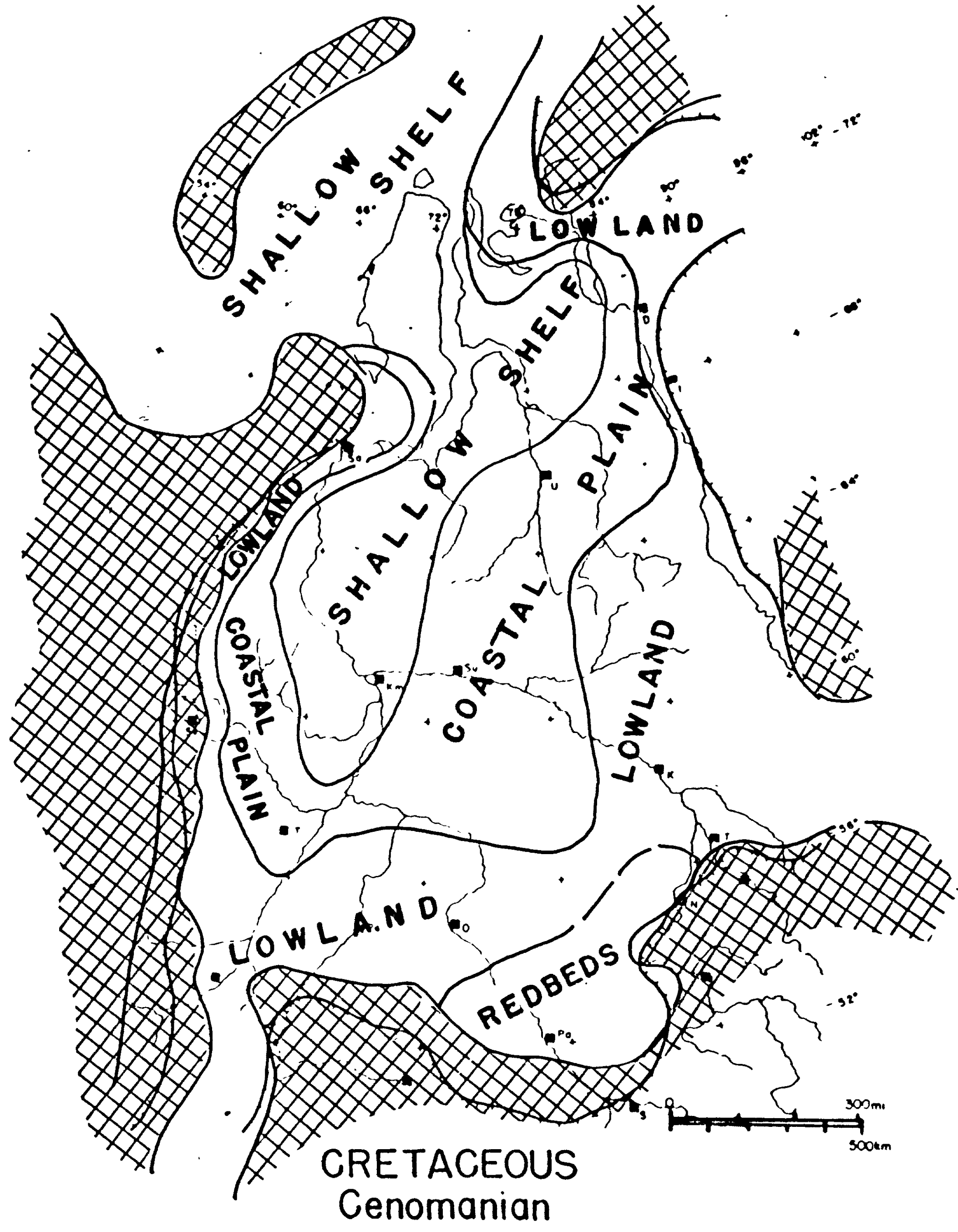


Figure 41. Paleogeographic-sedimentary environment map of Cenomanian Stage. Cross hatching indicates uplift areas (MOdified from Academy of Sciences USSR, 1968)

megacycle. During this transgression, a regional shale cover, the Alym Formation, was deposited in the basin, followed by the widespread marine and continental sandy clayey rocks of the Aptian-Cenomanian Pokur Formation (table 1). Regression again occurred late in Albian time and continued into the Cenomanian, when continental, lacustrine, and coastal plain sandstone and shale facies shifted westward to blanket the eastern, central, and southern parts of the basin, depositing the widespread upper part of the Pokur Formation. In the eastern regions, the proportion of sandstone in this section reaches 70-80 percent, dropping to no more than 20-30 percent to the west of the central basin region (fig. 39).

The Pokur cycle includes uppermost Aptian, Albian and Cenomanian (fig. 10).

<u>Post-Cenomanian Upper Cretaceous</u> - These rocks are as much as 1,000 m (3,300 ft) or more thick in the north basin, and 200-400 m (650-1,300 ft) in most of the basin interior (figs. 42-48). At the beginning of the Turonian, a major transgression from the north occurred, and by middle Late Cretaceous time the boreal marine West Siberian basin had expanded to reach its greatest extent. At this time, the Cretaceous seaway became connected with the Tethyan seaway on the southwest through a relatively narrow passage west of the Kazakhstan high. The Kuznetsov Formation of Turonian age consists largely of gray and dark gray clayey rocks.

The Late Cretaceous section is dominated by shale and siliceous shale or clay. Coarse clastic influx at this time was greatly diminished; total content of sandstone is little more than 10 percent. In the southern and southeastern parts of the basin, continental redbeds were deposited, although to a lesser extent than in previous Cretaceous cycles.

Regression again occured in late Campanian to Danian* time, and with lowering of sea level, land masses appeared along the eastern margin of the basin and in the vicinity of the Taymyr uplift (figs. 42-48). The diminished basin remained connected with the Arctic basin through a narrowing accessway west of Urengoy. In the central and southern parts of the basin, argillaceous limestone and marl were deposited over a widespread area (fig. 42). In the near Urals region, continental and lagoonal lacustrine deposits are interbedded with marine shales and glauconitic sandstones.

At the close of the Cretaceous, the connection with the Arctic basin was temporarily cut off, probably in the area of the North Siberian sill, to be restored during the Paleocene. At the same time, the eastern and southern basin margins became emergent.

<u>Early Cenozoic (Paleogene)</u> - Sedimentary rocks of this age are 600 m (2,000 ft) or more thick in parts of the central and northern basin and are less than 400 m (1,300 ft) thick on the basin flanks (figs. 49-53). Sedimentary facies at this time were dominated by marine shallow shelf

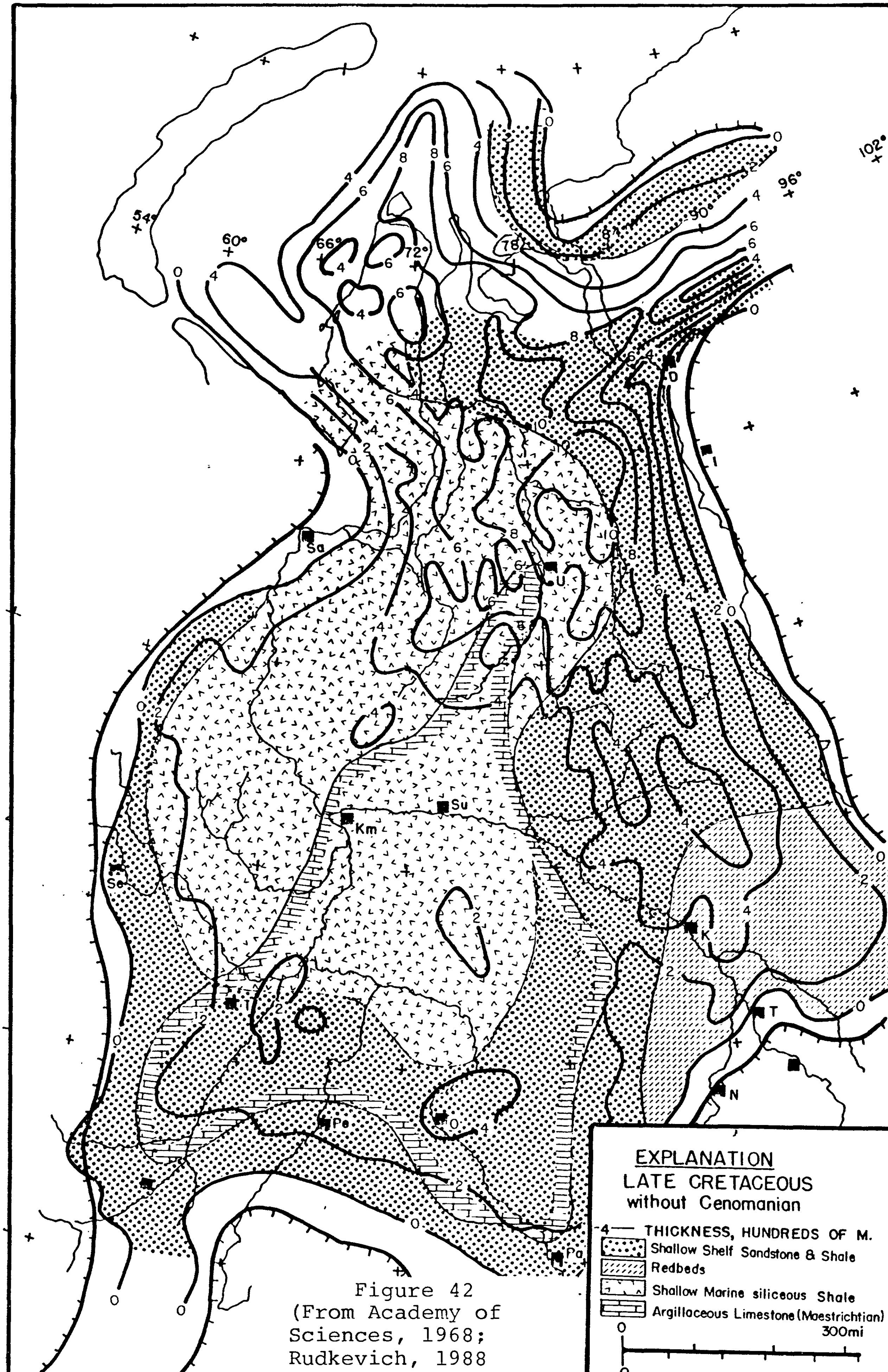


Figure 42
(From Academy of Sciences, 1968; Rudkevich, 1988

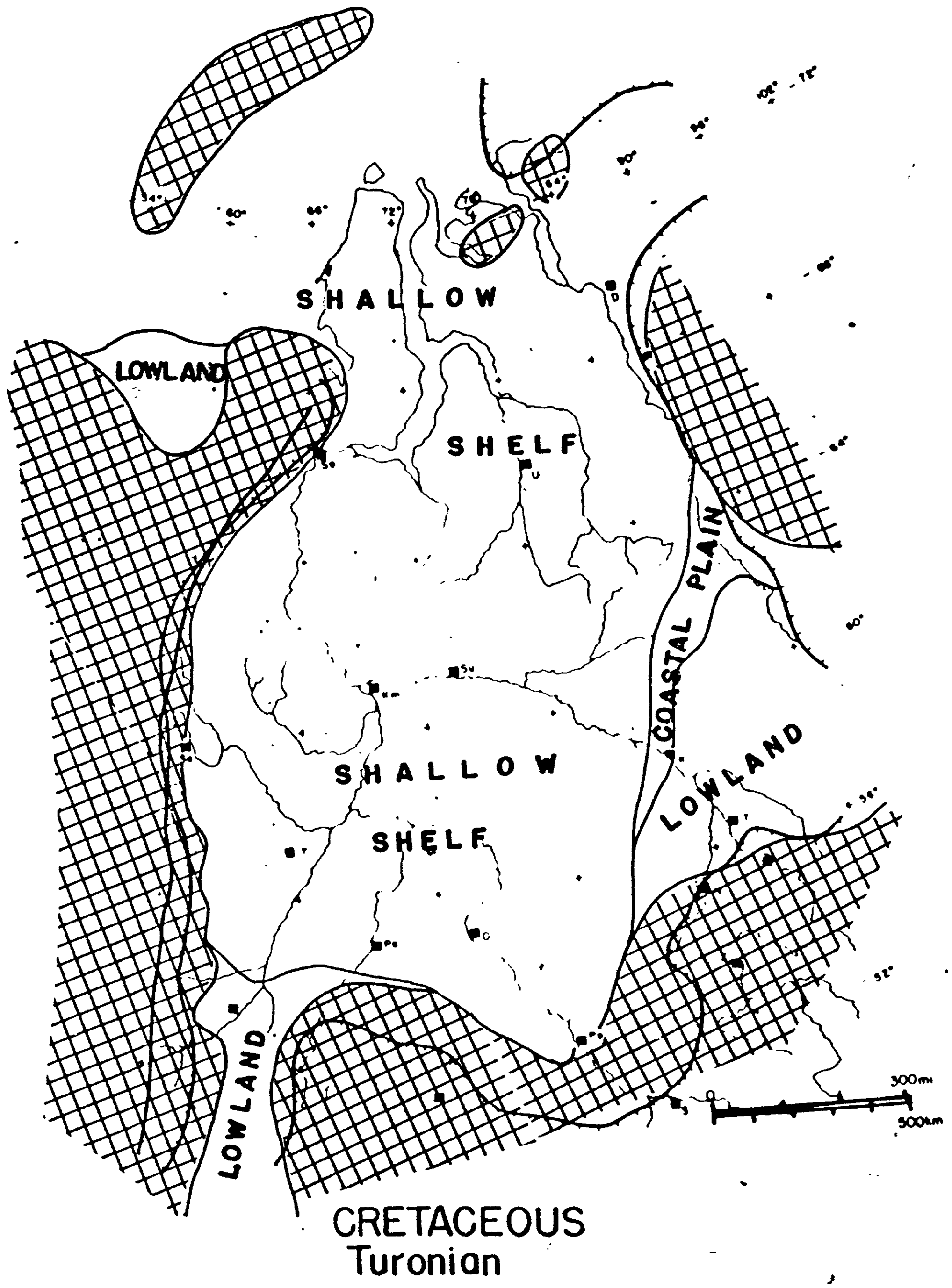


Figure 43. Paleogeographic-sedimentary environment map of Turonian Stage. Cross hatching indicates uplift areas. (Modified from Academy of Sciences USSR 1968)

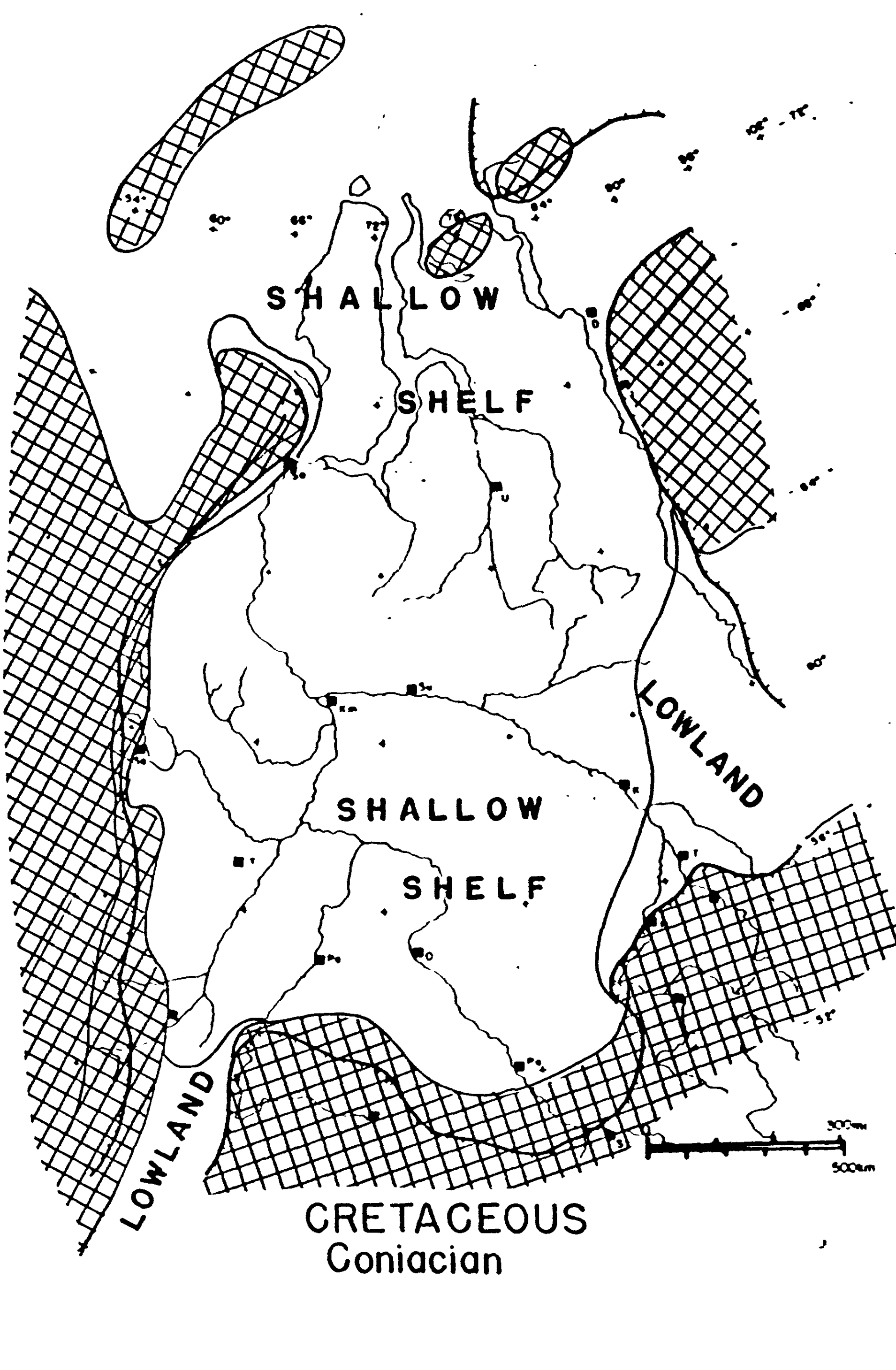


Figure 44. Paleogeographic-sedimentary environment map of Coniacian Stage. Cross hatching indicates uplift area. (Modified from Academy of Sciences USSR, 1968

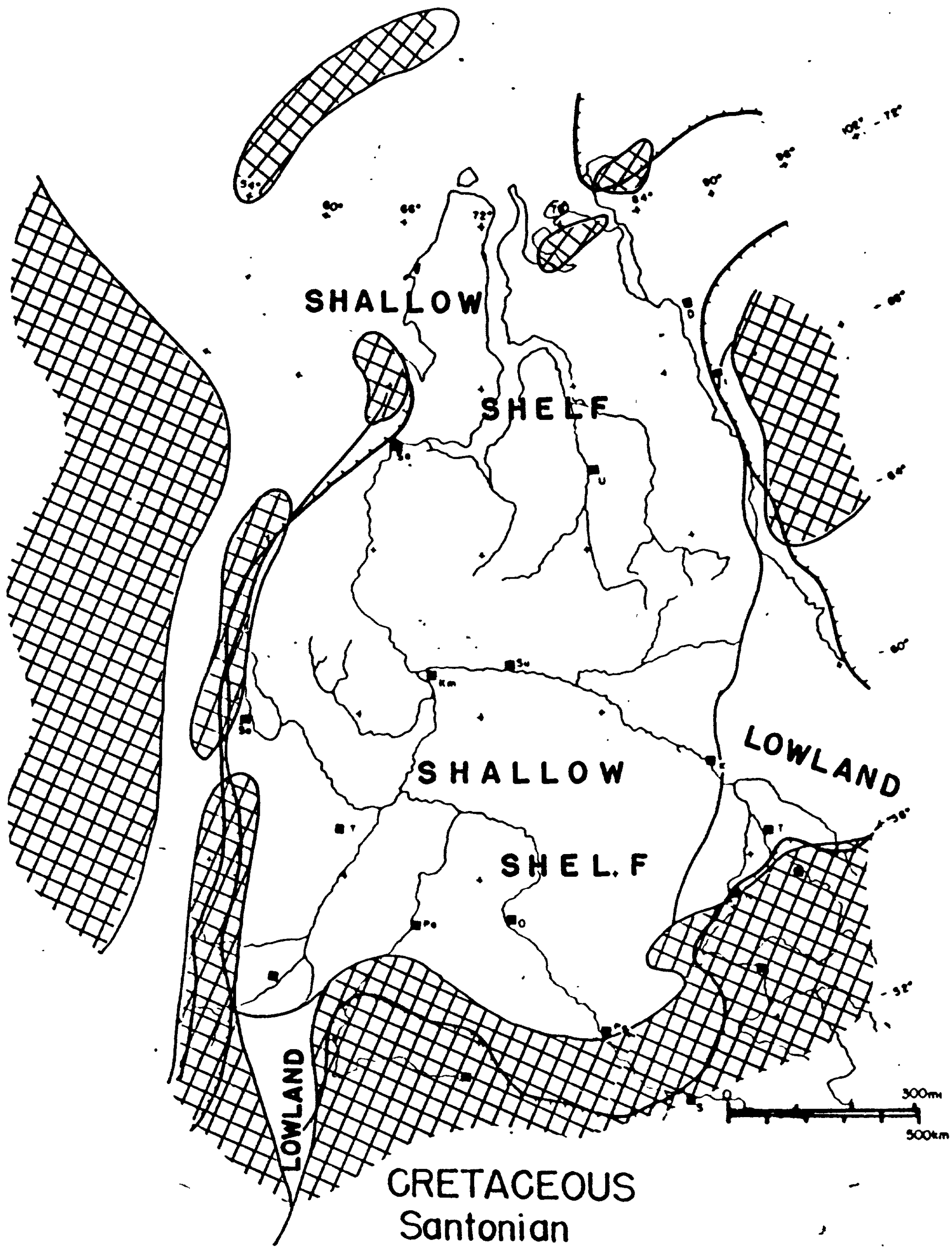


Figure 45. Paleogeographic-sedimentary environment map of Santonian Stage. Cross hatching indicates uplift areas (Modified from Academy of Sciences USSR, 1968)

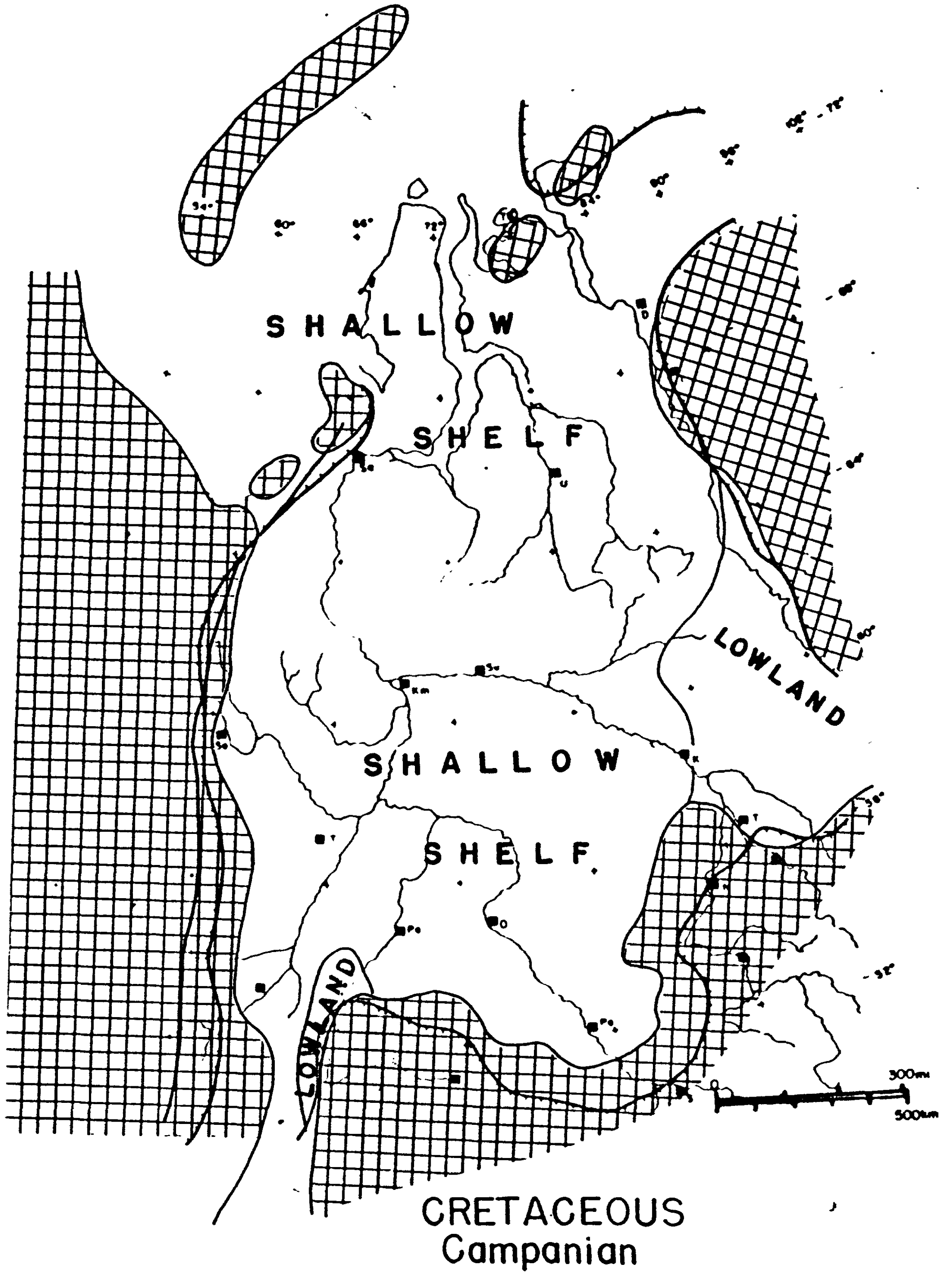


Figure 46. Paleogeographic-sedimentary environment map of Campanian Stage. Cross hatching indicates uplift areas (Modified from Academy of Sciences USSR, 1968)

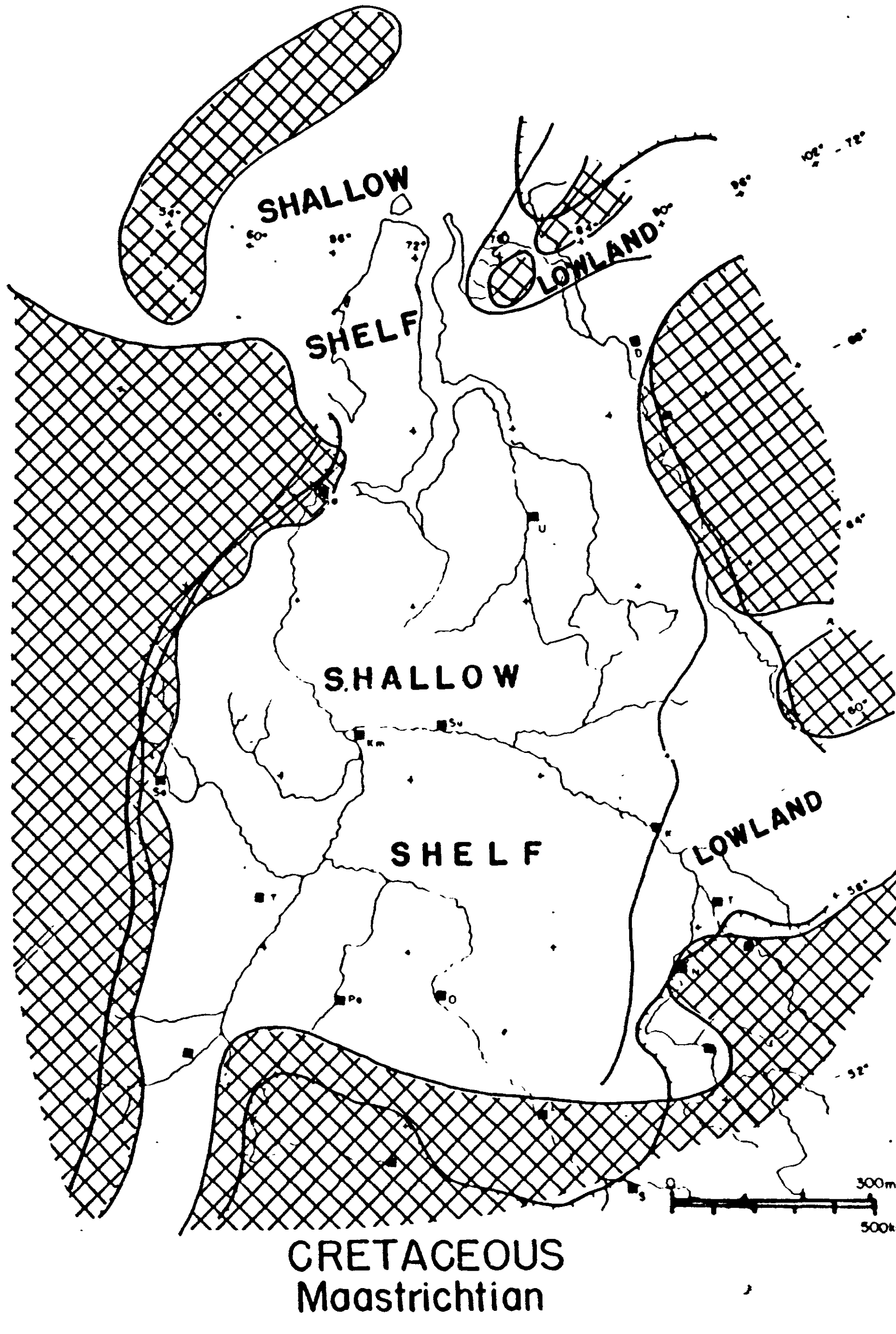


Figure 47. Paleogeographic-sedimentary environment map of Maastrichtian Stage. Cross hatching indicates uplift areas. (Modified from Academy of Sciences USSR, 1968)

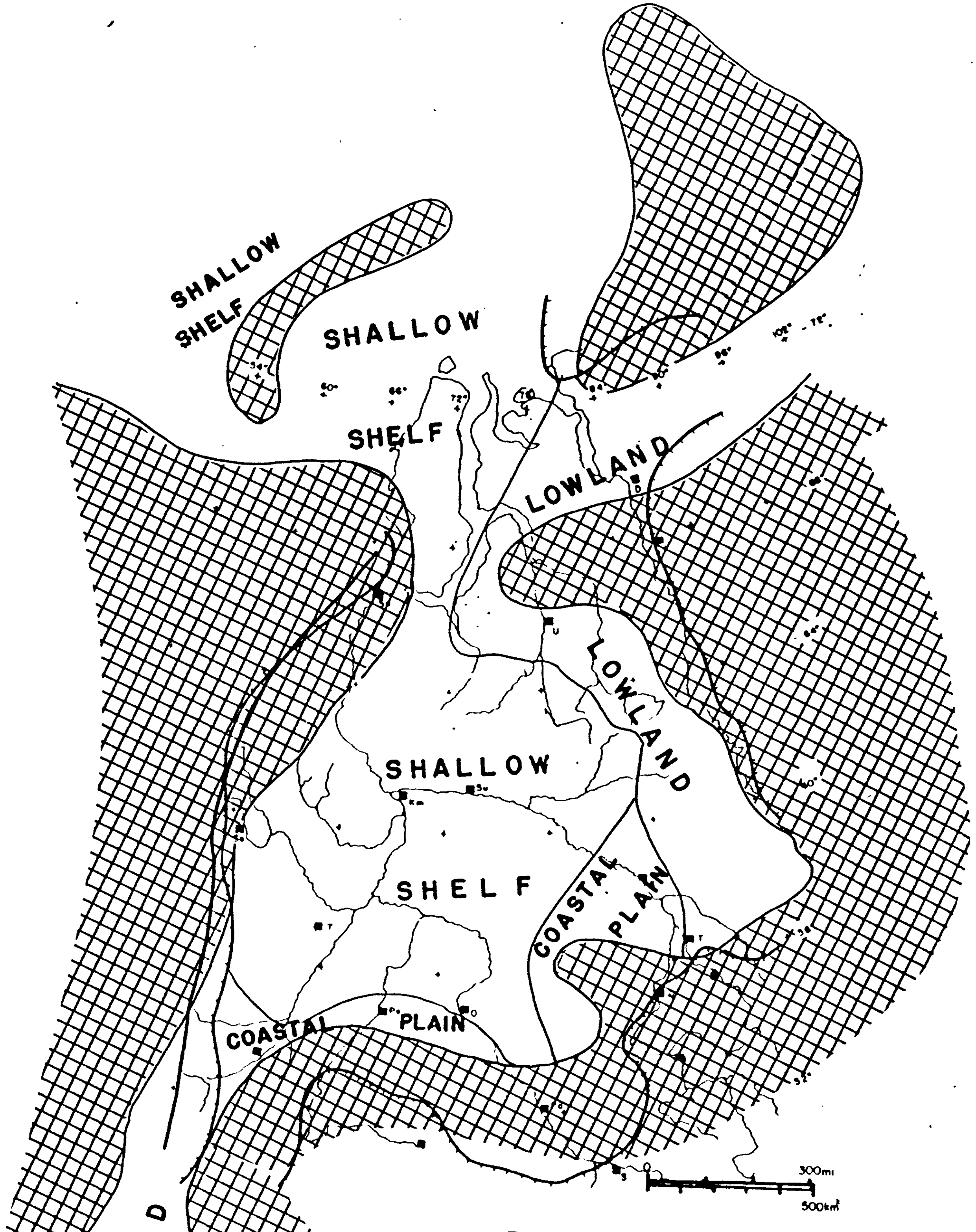
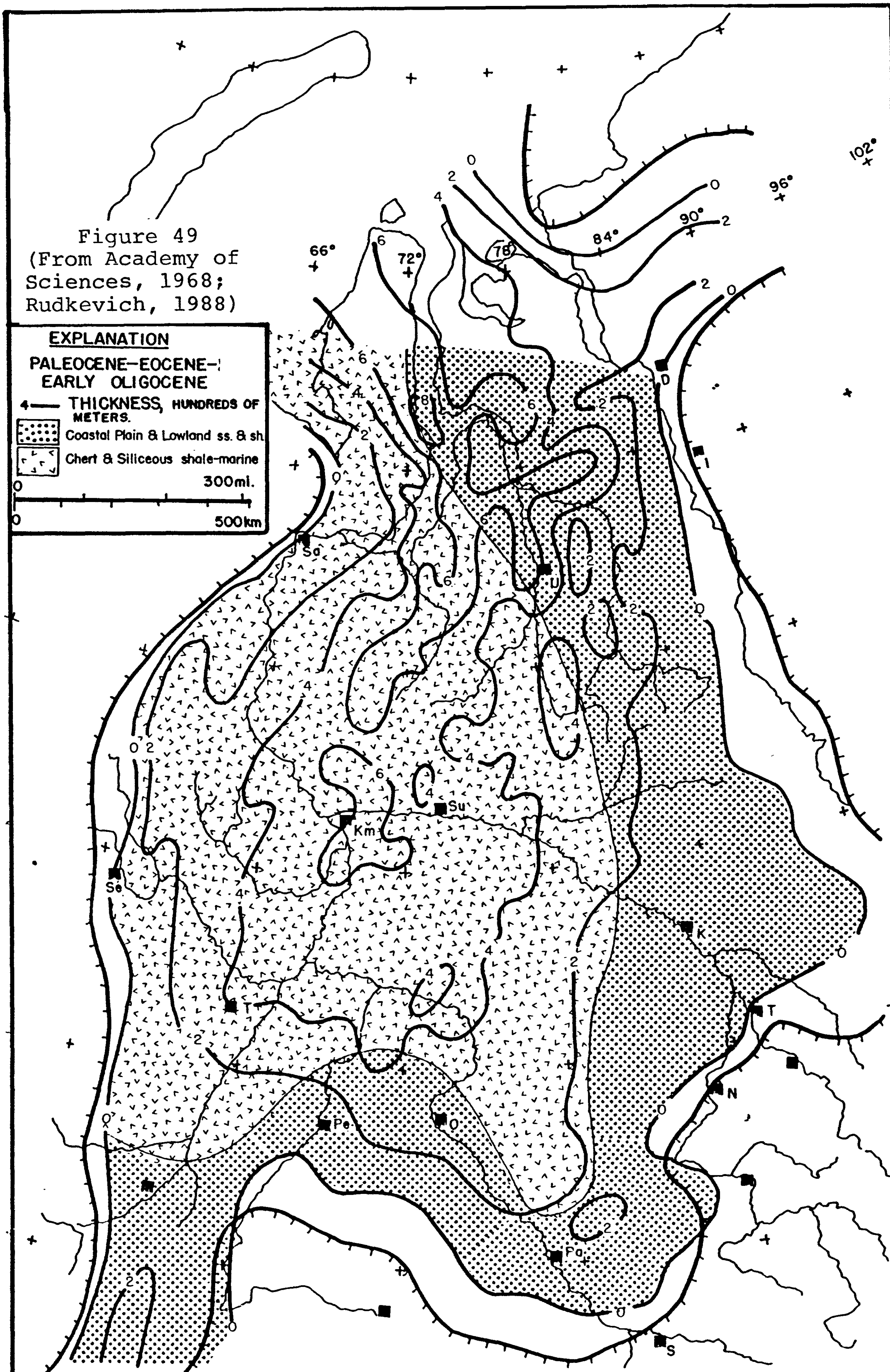


Figure 48. Paleogeographic-sedimentary environment map of Danian Stage. Cross hatching indicates uplift areas. (Modified from Academy of Sciences USSR, 1968)

Figure 49
(From Academy of
Sciences, 1968;
Rudkevich, 1988)



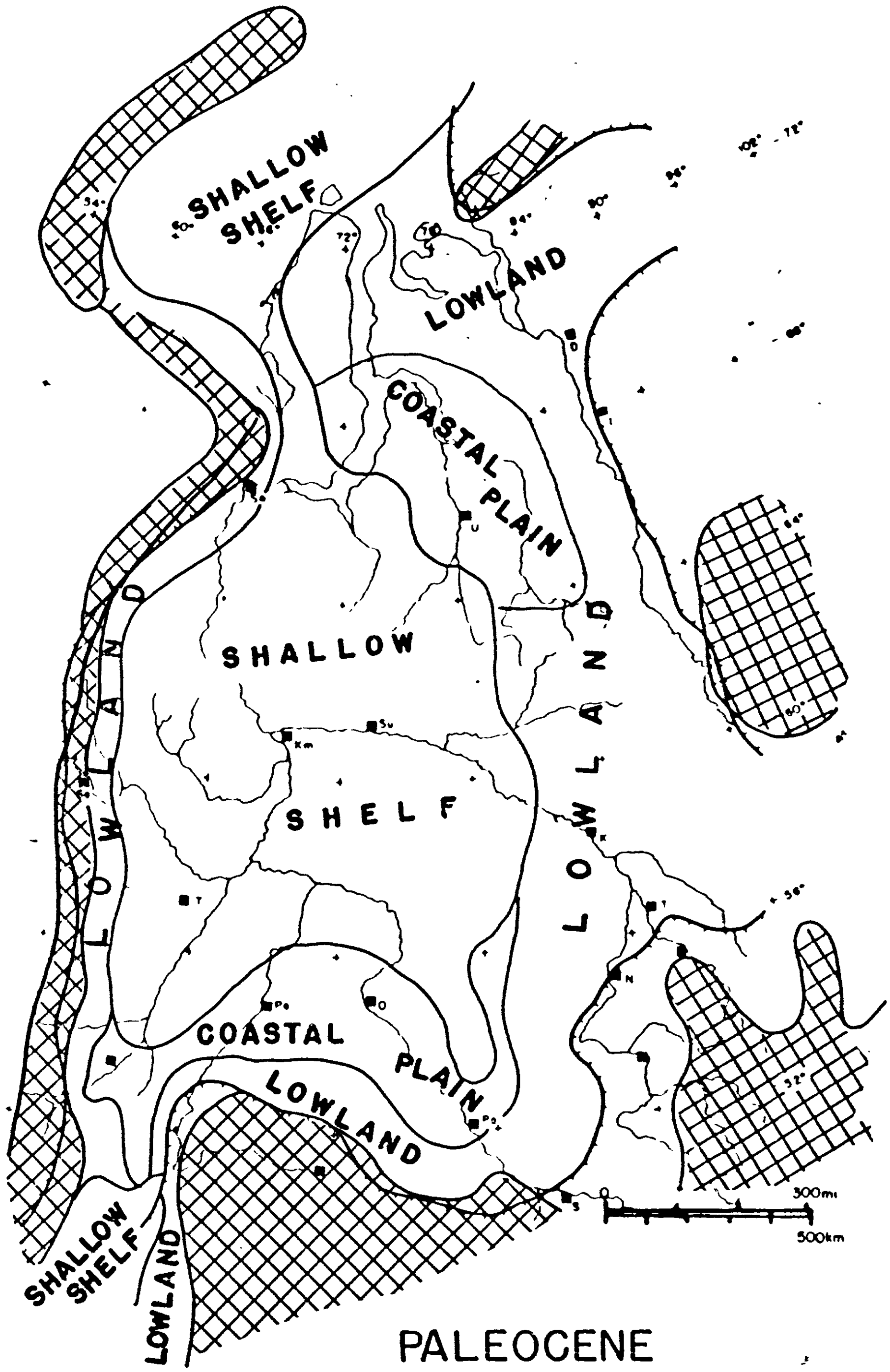


Figure 50. Paleogeographic-sedimentary environment map of the Paleocene. Cross hatching indicates uplift areas. (Modified from Academy of Sciences USSR, 1968)

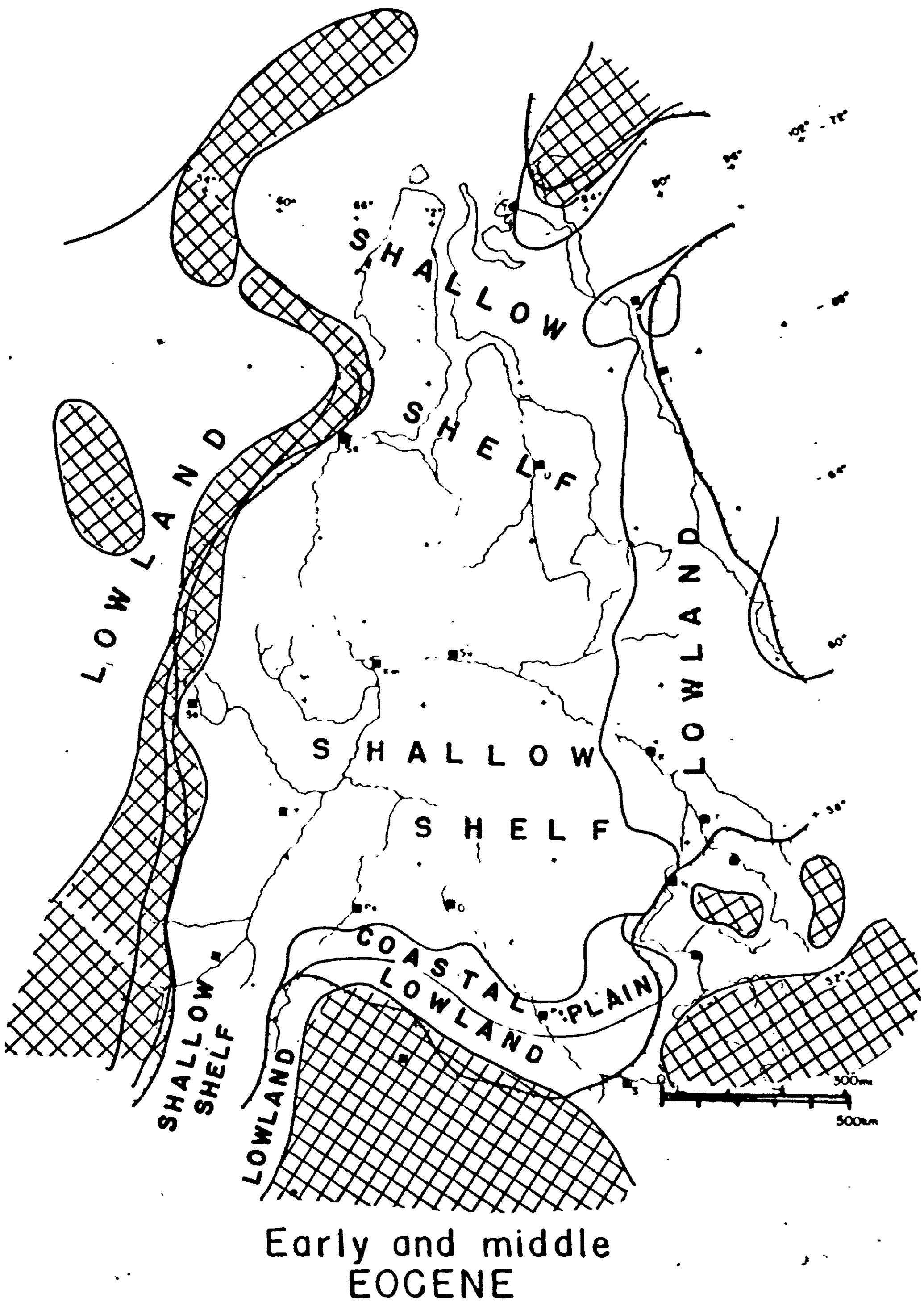


Figure 51. Paleogeographic-sedimentary environment map of the early and middle Eocene. Cross hatching indicated uplift areas (Modified from Academy of Sciences USSR, 1968)

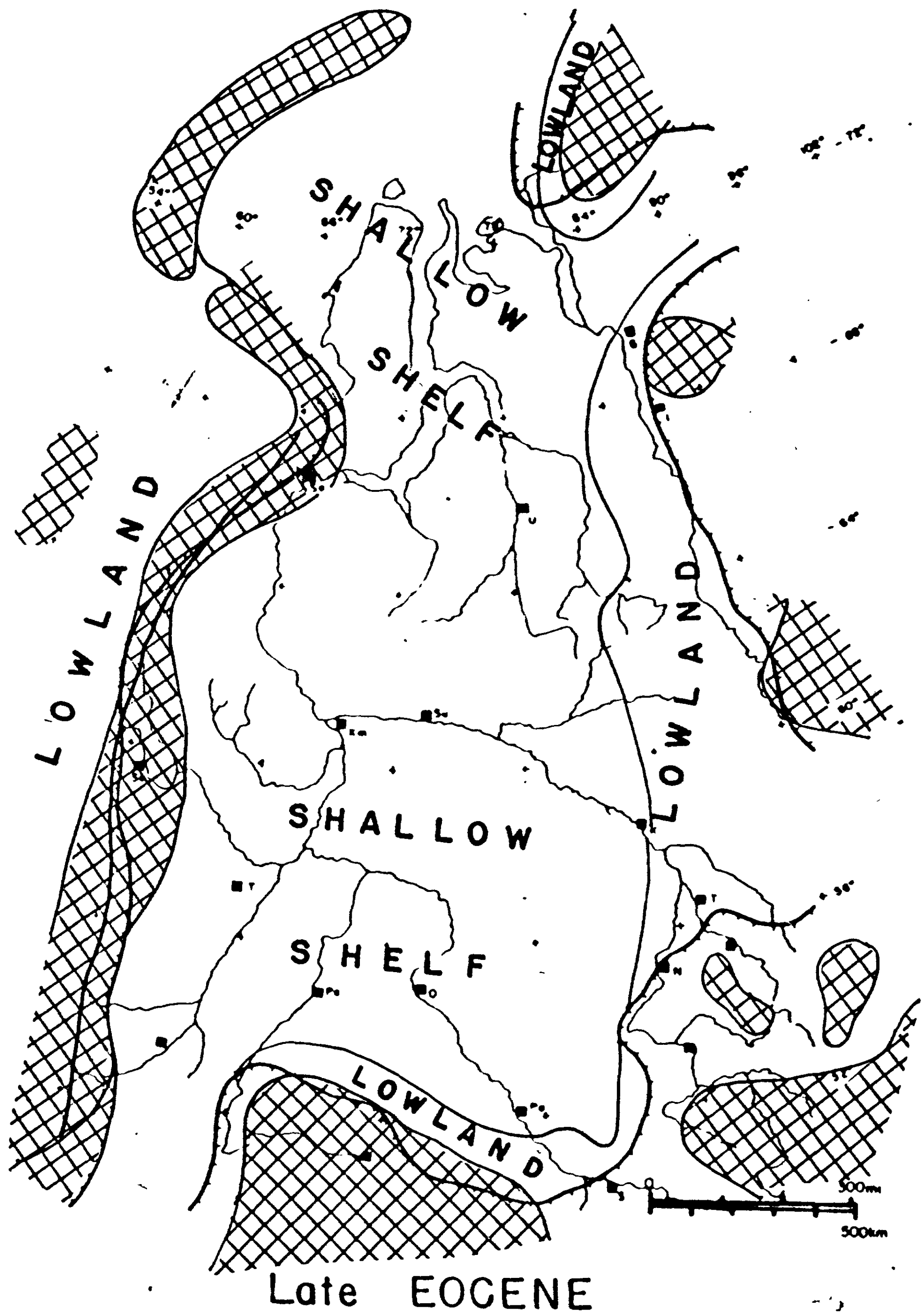


Figure 52. Paleogeographic-sedimentary environment map of the late Eocene. Cross hatching indicates uplift areas. (Modified from Academy of Sciences USSR, 1968)

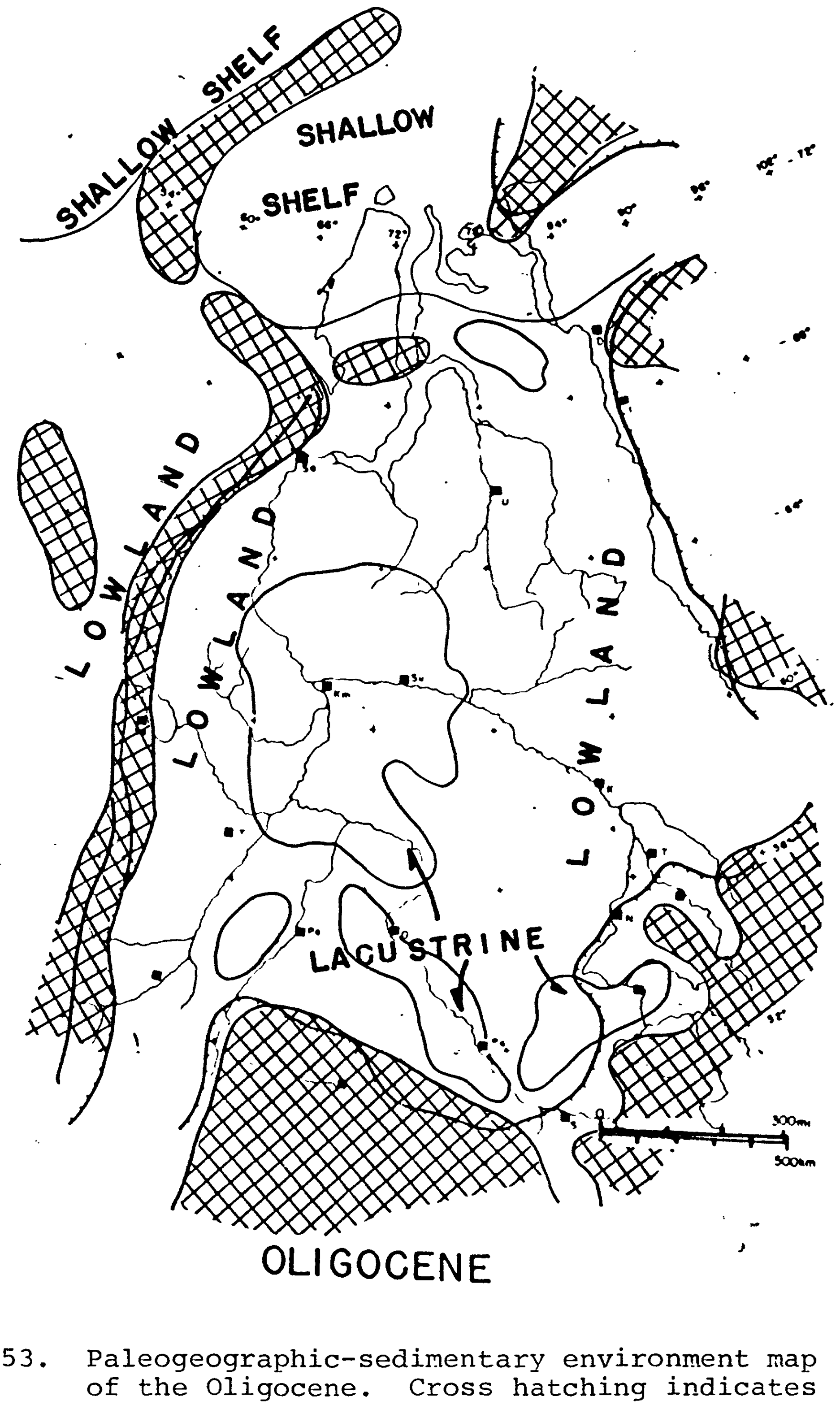


Figure 53. Paleogeographic-sedimentary environment map of the Oligocene. Cross hatching indicates uplift areas. (Modified from Academy of Sciences USSR, 1968)

argillaceous and cherty or siliceous-argillaceous deposits over most of the basin area. Coastal plain and continental sandstones are present on the eastern and southern flanks.

During Eocene time the southwestern connection with the Tethys Sea was restored. In early Oligocene time the eastern and northern parts of the basin were uplifted, and the connection with the Arctic basin was cut off. Approximately at this time an east-west central arch developed across the basin (fig. 53), and by middle Oligocene time the basin was completely cut off and became an interior continental basin. Subsiding areas became a series of lacustrine basins, fed by streams entering from highlands on the east, south, and west sides of the basin. Lacustrine deposits are particularly prevalent in the Khanty-Mansiysk region of subsidence and in the western part of the Middle Ob area.

Late Cenozoic (Neogene) - The northern parts of the West Siberian platform were emergent during the Neogene. Lacustrine and alluvial deposits 50-100 m (160-330 ft) thick were deposited in the southern part of the basin where numerous lakes were present among the many uplifted areas (figs. 54,55).

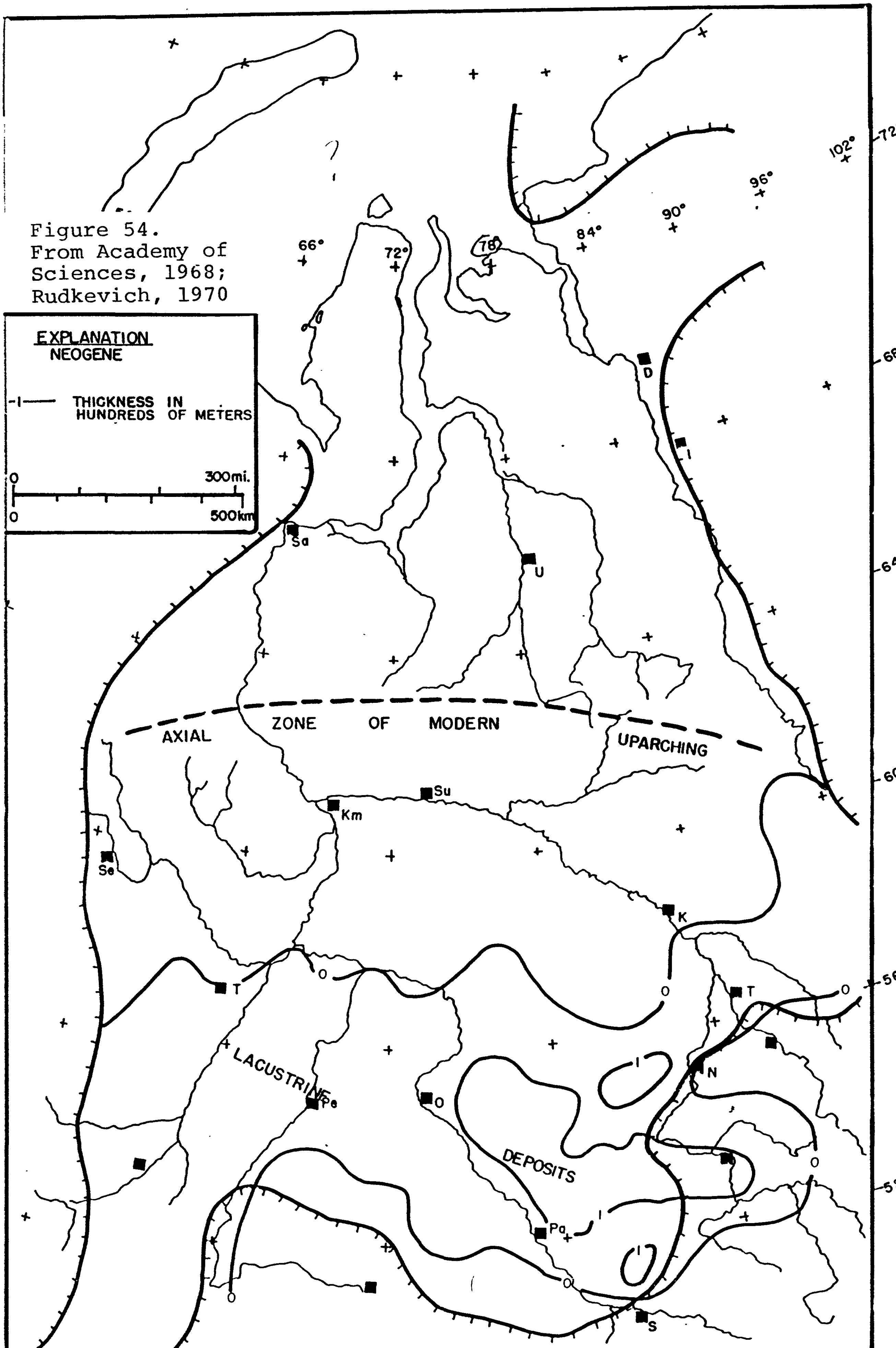


Figure 54.
From Academy of Sciences, 1968; Rudkevich, 1970

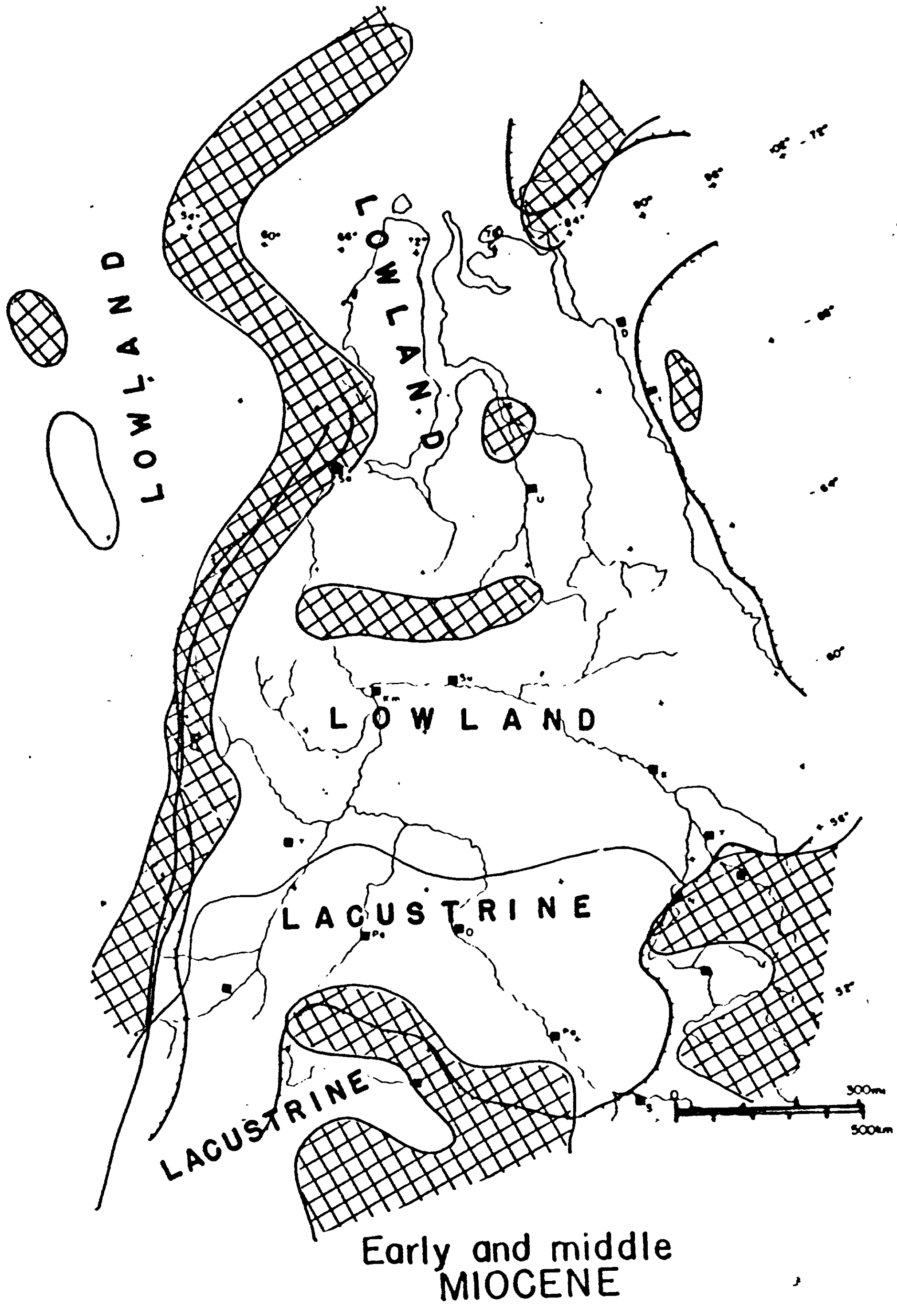


Figure 55. Paleogeographic-sedimentary environment map of the early and middle Miocene. Cross hatching indicates uplift areas. (Modified from Academy of Sciences USSR, 1968)

PETROLEUM GEOLOGY

Introduction

The West Siberian oil-gas province has been subdivided into oil-gas regions in various ways by different authors. The subdivision adopted in this report follows that of Maksimov and others (1987) (fig. 56). The oil and gas fields of the entire province are plotted at a small scale on figure 57, and those of each oil-gas region at a larger scale on figures 58-60.

The basin has four major productive areas based on age of the reservoir rocks, type of trap, and kind of hydrocarbons produced. These are 1) the Middle Ob, 2) Near-Ural, 3) Southern Basin, and 4) Northern Basin.

<u>Middle-Ob</u> (includes the Middle Ob region of figure 56) - Most of the production in this area is oil from Lower Cretaceous clastic rocks, mainly in anticlinal traps within a deltaic-marine transitional sedimentary complex. Stratigraphic trapping is also a major component of the trapping mechanisms. Two large regional uplifts dominate this area, the Surgut and Nizhnevartov arches (fig. 18), which yield a major share of the oil produced in the West Siberian basin. The supergiant Samotlor field and other supergiant oil fields are located in this area.

<u>Near-Ural</u> (includes the Near-Ural and Frolov regions of figure 56) - Production in the Near-Ural region in the western part of the basin is primarily from Upper Jurassic clastic rocks; there is some production also from Lower Cretaceous clastic reservoirs and some from weathered basement. The trapping mechanism is paleostructural-stratigraphic; reservoir rocks pinch out against high-standing basement rocks. The Near-Ural area is mainly oil-productive in the south and gas-productive in the north.

<u>Southern Basin</u> (includes the Kaymysov, Vasyugan, and Paydugin regions of of figure 56) - Most of the production here is oil and oil-gas from Jurassic clastic reservoirs mainly on anticlines or arches inherited from basement highs. Some production also is obtained from middle and upper Paleozoic carbonate reservoirs.

<u>Northern Basin</u> (comprises the Yamal, Gyda, Nadym-Pur, and Pur-Taz regions of figure 56) - Gas and gas-condensate are produced from mainly Upper Cretaceous (Cenomanian) clastic rocks on anticlinal traps. Urengoy, the world's largest gas field, and several other supergiant gas fields are located in this area.

In general, the timing of trap development was somewhat different for these four major productive areas. In most of the basin, uplifted basement blocks were present prior to the deposition of the Jurassic and Cretaceous reservoir rocks. In the Near-Ural and southern basin areas, Jurassic reservoirs commonly pinch out against these blocks. In the northern basin area, the paleostructural traps probably formed early in

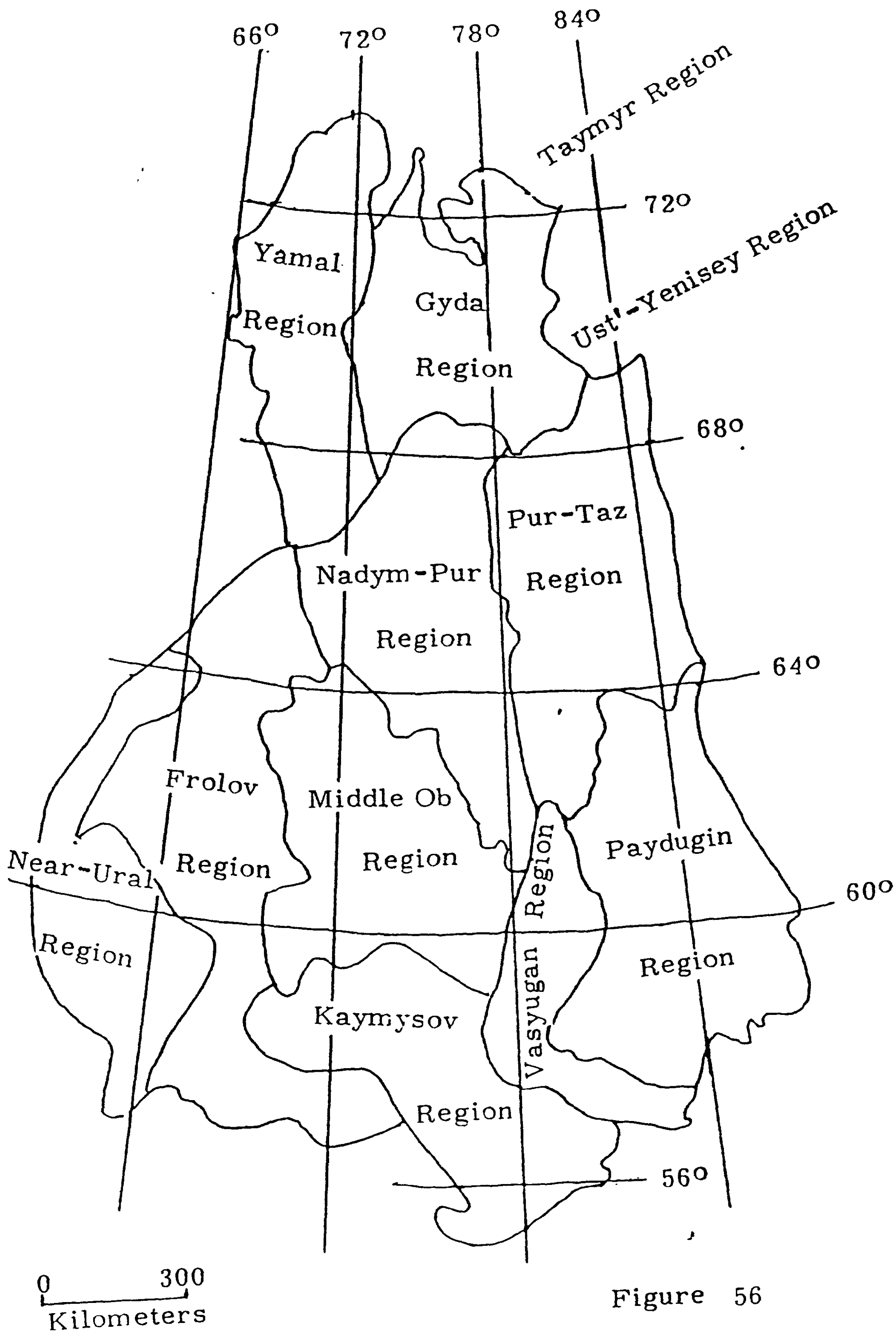


Figure 56. Petroleum regions of the West Siberian basin (from Maksimov and others, 1987)

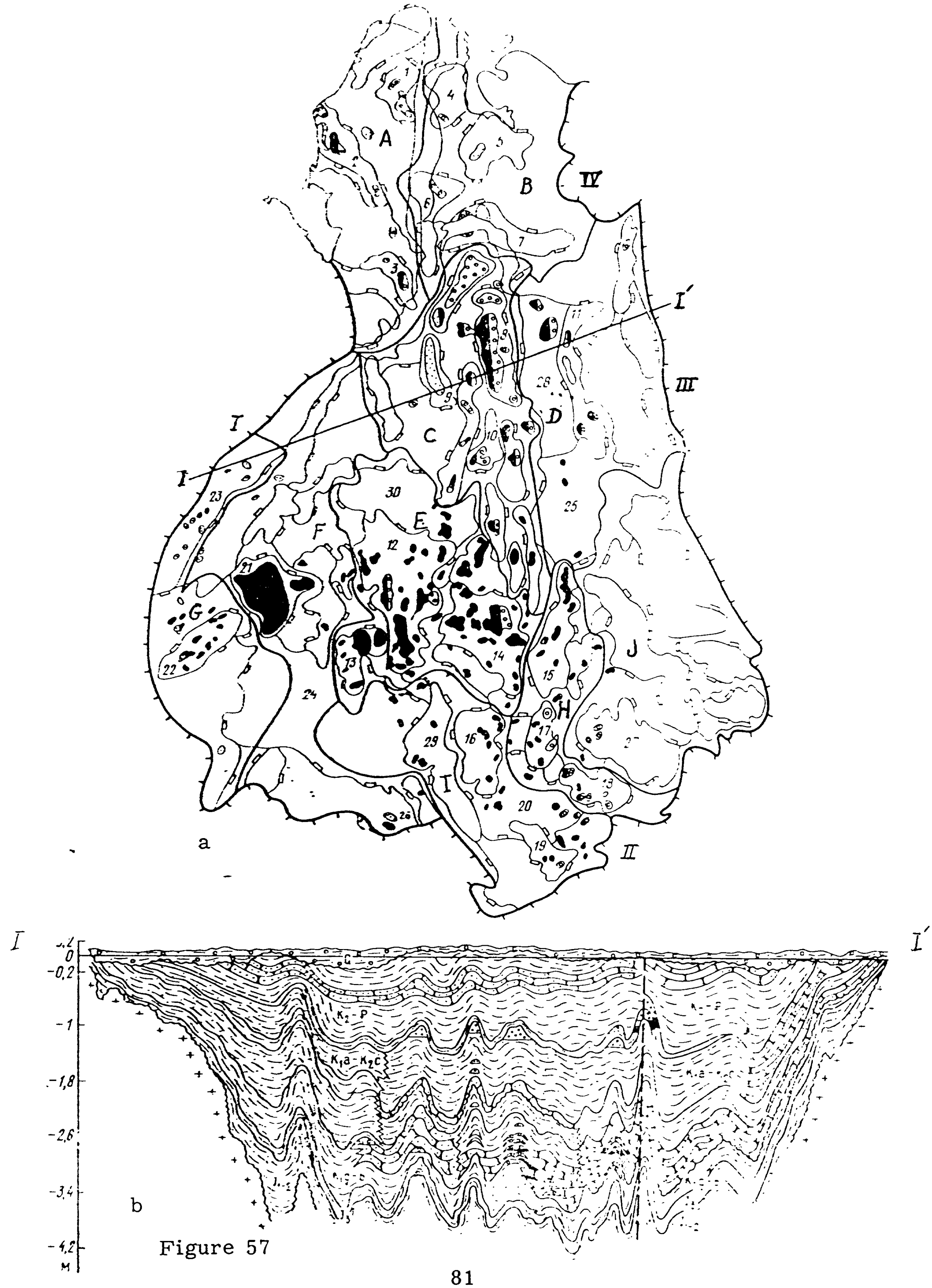


Figure 57

Figure 57. West Siberian oil-gas province (from Maksimov and others, 1987)

a-Schematic map, b-geologic profile.

Very large tectonic features: I-Ural fold belt, II- Kazakh shield, III-Siberian craton, IV-Yenisey-Khatanga mega-downwarp. Large tectonic features: 1-Sredneyamal arch, 2-Nurmin mega-arch, 3-Yuzhno-Yamal mega-arch, 4-Yurats arch, 5-Gyda arch, 6-Napalkov mega-arch, 7-Nizhnemessoyakha, mega-arch, 8- Urengoy mega-arch, 9-Medvezh mega-arch, 10-Severnyy arch, 11-Russko-Chasel mega-arch, 12-Surgut arch, 13-Salym arch, 14-Nizhnevartov arch, 15-Aleksandrov mega-arch, 16-Katmysov arch, 17-Srednevasyugan mega-arch, 18-Pudin mega-arch, 19-Mezhov mega-arch, 20-Nyurol depression, 21-Krasnoleninsk arch, 22-Shaim mega-arch, 23-Berezovo monocline, 24-Khanty-Mansiysk depression, 25-Kharampur monocline, 26-Bol'sheuk monocline, 27-Parabel mega-arch, 28-Khadyr'-Yakhin monocline, 29-Dem'yan mega-arch, 30-Severo-Surgut monocline. Oil-gas regions: A-Yamal, B-Gyda, C-Nadym-Pur, D-Pur-Taz, E-Middle Ob, F-Frolov, G-Near-Ural, H-Vasyugan, I-Kaymysov, J-Paydugin.

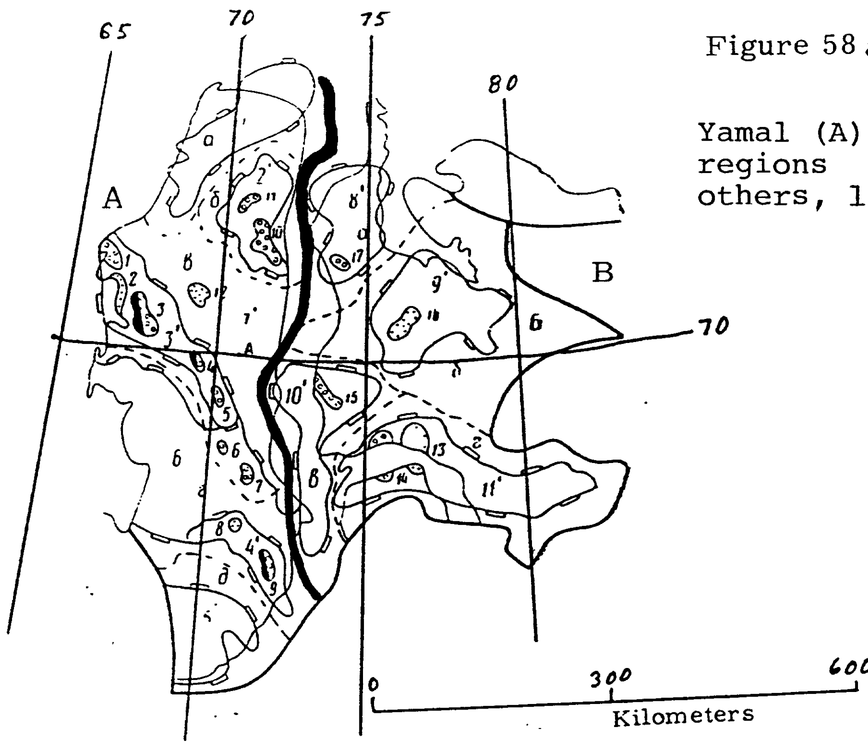


Figure 58 a

Yamal (A) and Gyda (B) oil-gas regions (from Maksimov and others, 1987)

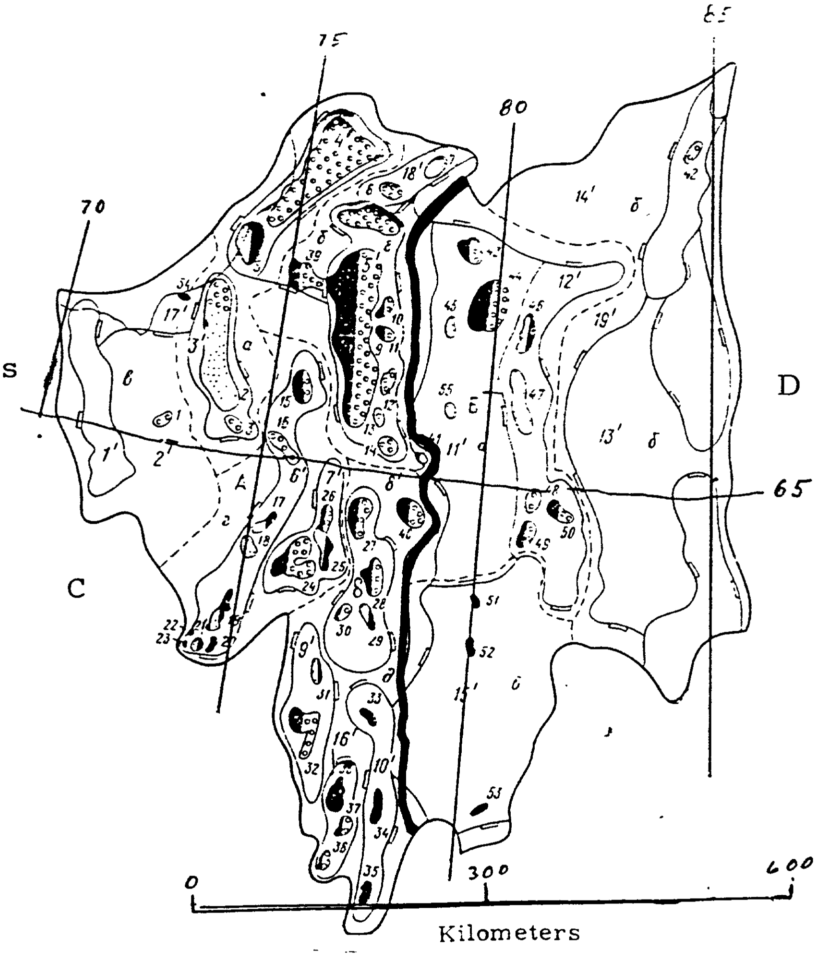


Figure 58 b

Nadym-Pur (C) and Pur-Taz (D) oil-gas regions (from Maksimov and others, 1987)

Figure 58a Fields of Yamal oil-gas region (A) and Gyda gas region (B) (from Maksimov and others, 1987).

Large tectonic features: 1'-Severo-Yamal mega-arch, 2'-Sredneyamal arch, 3'-Nurmin mega-arch, 4'-Yuzhno-Yamal mega-arch, 5'-Shuch'yan high, 6'-Yuribey monocline, 7'-Olen'ya saddle, 8'-Yurats saddle, 9'-Gyda arch, 10'-Napalkov mega-arch, 11'-Nizhnemassoyakha mega-arch.

Oil-gas areas. Yamal oil-gas region: a-Malygin prospective gas-oil area, b-Tambey gas area, c-Nurmin gas-oil area, d-Yuzhno-Yamal oil-gas area, e-Shuch'in porspective oil-gas area. Gyda gas region: a-Severo-Gyda gas area, b-Gyda gas area, c-Napalkov gas area, d-Messov gas area.

Fields: 1-Kharasavey, 2-Kruzenshtern and Yuzhno-Kruzenshtern, 3-Bovanenkov, 4-Neytin, 5-Arkticheskoye, 6-Nurmin, 7-Sredneyamal, 8-Maloyamal, 9-Novoportov, 10-Yuzhno-Tambey, 11-Severo-Tambey, 12-Verhkneteutey, 13-Antipayutin, 14-Semakov, 15-Geofizicheskoye, 16-Gyda, 17-Utren.

Figure 58b. Fields of Nadym-Pur oil-gas region (C) and Pur-Taz oil-gas region (D) (from Maksimov and others, 1987).

Large tectonic features: 1'-Yarudey mega-arch, 2'-Tanlov depression, 3'- Medvezh mega-arch, 4'- Yamburg mega-arch, 5'-Urengoy mega-arch, 6'-Tanlov mega-arch, 7'- Severnyy arch, 8'-Verkhnepur mega-arch, 9'-Vengapur mega-arch, 10-Var'yegan-Tagrin mega-arch, 11'-Khadyr'-Yakhin monocline, 12'-Russko-Chasel mega-arch, 13'-Krasnosel'kup mega-arch, 14'-Bol'shekhet depression, 15'-Kharampur monocline, 16'-Ver'yegan arch, 17'-Nadym monocline, 18'-Yurkharov arch, 19'- Nizhnetazov mega-downwarp.

Oil-gas areas. Nadym-Pur oil-gas region: a-Nadym, b-Urengoy, c-Yarudey, d-Gubkin, e-Vengapur. Pur-Tazov oil-gas region: a-Tazov, b-Sidorov, c-Tol'kin.

Fields: 1-Nadym, 2-Medvezh and Nydin, 3-Pangodin, 4-Yamburg, 5-Kharvutin, 6-Yurkharov, 7-Nakhodkin, 8- Severo-Urengoy, 9-Urengoy and Yen''yakhin, 10-Samburg, 11-Yuzhno-Samburg, 12-Vostochnoye Urengoy, 13-Yevo-Yakhin, 14-Pyrey, 15- Yubiley, 16-Yamsovey, 17-Severo-Komsomol, 18-Verkhnepurpey, 19-Muravlenko, 20-Pul'puyakh, 21-Surtomon, 22-Krayneye, 23-Vostochno-Pyakutin, 24-Komsomol, 25-Gubkin, 26-Severo-Gubkin, 27-Zapadno-Tarkosalin, 28-Tarasov, 29-Yetypur, 30-Vengayakhin, 31-Novogodneye, 32-Vengapur and Yuzhno-Vengapur, 33-Yarayner, 34-Tagrin, 35-Novomolodezh, 36-Severo-Var'yegan, 37-Var'yegan and Zapadno-Var'yegan, 38-Van'yegan, 39-Pestsov, 40-Vostochno-Tarkosalin, 41-Yuzhno-Pyrey, 42-Suzun, 43-Tazov and Vostochno-Tazov, 44-Zapolyar, 45-Zapadno-Zapolyar, 46-Russkoye, 47-Yuzhno-Russkoye, 48-Kyn, 49-Verkhnechasel, 50-Ust'-Chasel, 51-Kharampur, 52-Yuzhno-Kharampur, 53-Verkhnekolik''yegan, 54-Sandibin, 55-Beregov.

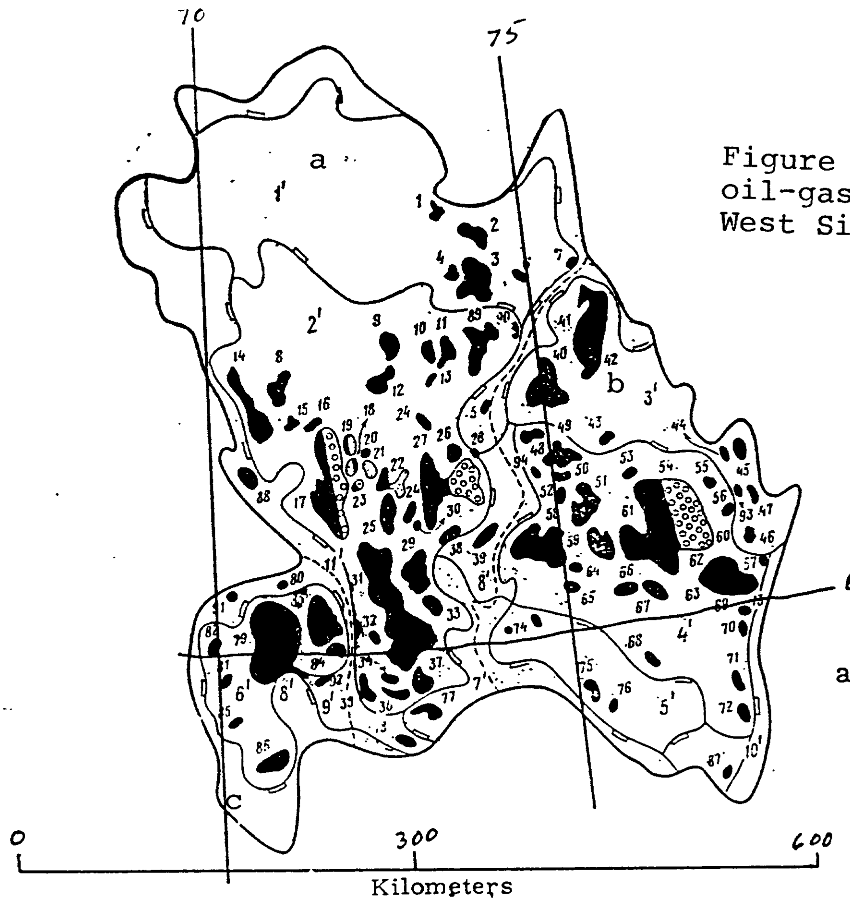


Figure 59a. Middle Ob oil-gas region of West Siberia

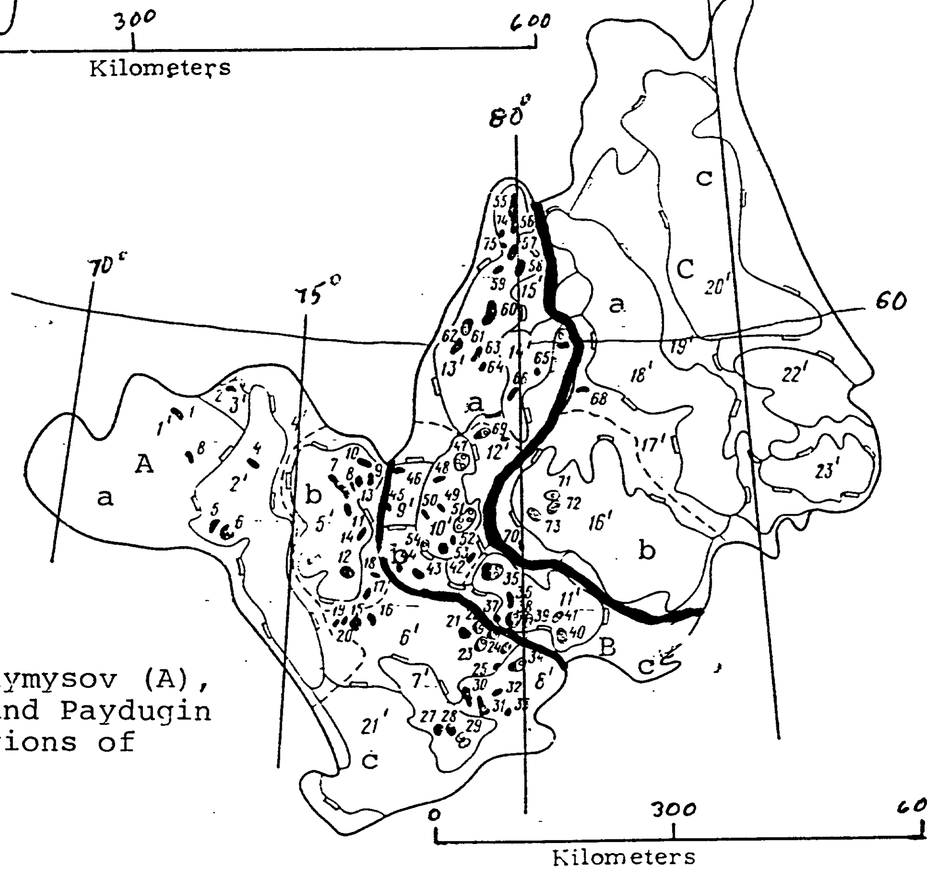


Figure 59b. Kaymysov (A), Vasyugan (B), and Paydugin (C) oil-gas regions of West Siberia

Figure 59a Fields of Middle Ob region (from Maksimov and others, 1987).

Large tectonic features: 1'-Severo-Surgut monocline, 2'-Surgut arch, 3'-Severo-Vartov monocline, 4'-Nizhnevartov arch, 5'-Yuzhno-Vartov monocline, 6'-Salym arch, 7'-Yugan depression, 8'-Yarsomov mega-downwarp, 9'-Chupal saddle, 10'-Koltogor mega-downwarp, 11'-Tundrin depression.

Oil-gas areas:a-Surgut, b-Vartov, c-Salym.

Fields: 1-Severo-Soimlor, 2-Karamov, 3-Kholmogor, 4-Ikilor, 5-Vostochno-Yagun, 6- Pogranich, 7-Byintoy, 8-Nizhnesortym, 9-Kochev, 10-Tevlin, 11-Kogolym, 12-Konitlor, 13-Sorym, 14-Aypym, 15-Kamyn, 16-Alekhin, 17-Lyantor, 18-Taybin, 19-Tutlin,, 20-Kar'yaun, 21-Vachim and Taplor, 22-Minchimkin and Severo-Minchimkin, 23-Saporkin, 24-Russkin, 25-Vystrin, 26-Savuy, 27-Fedorovo, 28-Raven 29-Zapadno-Surgut, Yaunlor, 30-Vershin, 31-Mamontovo, Ust'-Balyk 32-Teplov, 33-Yuzhno-Surgut, Saygatin, 34-Yuzhno-Balyk, 35-Malobalyk, 36-Srednebalyk, 37-Maysk, 38-Vostochno-Surgut, 39-Shirokov, 40-Vat'yegansk, 41-Povkhov, 42-Bol'shekotukhtin, 43-Kurragan, 44-Gun'yegan, 45-Tyumen, 46-Pylin, 47-Yershov, 48-Non"yegan, 49-Pokachev and Severo-Pokachev, 50-Yuzhno-Pokachev, 51-Yur'yev, Potoch, and Severo-Potoch, 52-Las"yegan, 53-Agan, 54-Bol'shechernogor, 55-Malochernogor, 56-Sorom 57-Strezhev, 58-Lokosov, Pokamasov, and Chimpas, 59-Severo-Pokur, 60-Samatlor, Megion, and Mykhpay, 61-Vatinsk, 62-Nizhnevartov, 63-Sovetsk, 64-Severo-Ostrov, 65-Ostrov, 66-Orekhov, 67-Yermakov, 68-Nezhdan, 69-Vartov-Sosnin, 70-Alenkin, 71-Kvartov, 72-Motyushkin, 73-Malorechen, 74-Novopokur, 75-Maloyugan, 76-Achinov, 77-Severo-Chupal, 78-Chupal, 79-Salym and Severo-Salym, 80-Tundrin, 81-Sredneshapshin, 82-Verkhne-shapshin, 83-Pravdin, 84-Srednesalym, 85-Nizhneshapshin, 86-Verkhnesalym, 87-Ledov, 88-Studenoye, 89-Yuzhno-Yagun, 90-Grib, 91-Priob, 92-Petelin, 93-Ruf'yegan, 94-Nivagal.

Figure 59b. Fields of Kaymtsov oil-gas region (A), Vasyugan oil-gas region (B), and Paydugin oil-gas region (C) (from Maksimov and others, 1987).

Large tectonic features: 1'-Khanty-Mansiysk depression, 2'-Dem'yan mega-arch, 3'-Chupal saddle, 4'-Yugan depression, 5'-Kaymysov arch, 6'-Nyurol depression, 7'-Mezhov mega-arch, 8'-Verkhnetar monocline, 9'-Lomov saddle, 10'-Srednevasyugan mega-arch, 11'-Pudin mega-arch 12'-Olen saddle, 13'-Aleksandrov mega-arch, 14'-Okunev saddle, 15'-Lar'yak mega-downwarp, 16'-Parabel mega-arch, 17'-Ust'-Tym depression, 18'-Pyl'-Karamin mega-arch, 19'-Korlikov mega-downwarp, 20'-Karal'kin mega-arch, 21'-Tar monocline, 22'-Tym mega-arch, 23'-Vladimir arch.

Oil-gas areas. Kaymysov oil-gas region: a-Dem'yan, b-Kaymyson, c-Mezhov. Vasyugan oil-gas region: a-Aleksandrov, b-Vasyugan, c-Pudin. Paydugin oil-gas region: a-Paydugin, b-Sil'gin.

Fields: 1-Tukan, 2-Multanov, 3-Ayyrun, 4-Taylakov, 5-Urnen, 6-Usanov, 7-Pervomay, 8-Katyl'gin, 9-Ozer, 10-Olen'ye, 11-Lontyn'yakh, 12-Moiseyev, 13-Zapadno-Katyl'gin, 14-Poselkov, 15-Igol, 16-Talov, 17-Pon'zhev, 18-Glukhov, 19-Karay, 20-Zapadno-Karay, 21-Urman, 22-Gerasimov, 23-Nizhnetabagan, 24-Severo-Kalinov, 25-Kalinov, 26-Yuzhno-Tabagan, 27-Mezhov, 28-Vostochno-Mezhov, 29-Veselov, 30-Maloich, 31-Verkh-Tar, 32-Rakitin, 33-Tay-Das, 34-Kazan, 35-Luginets, 36-Severo-Ostanin, 37-Zapadno-Ostanin, 38-Ostanin, 39-Mirnoye, 40-Verkhnekambar, 41-Selimkhanov, 42-Shingin, 43-Festival, 44-Chvorov, 45-Yuzhno-Cheremshan, 46-Lomov, 47-Severo-Vasyugan, 48-Srednevasyugan, 49-Srednenyurol, 50-Klyuchev, 51-Myl'zhinsk, 52-Yuzhno-Myl'zhinsk, 53-Verkhnesalat, 54-Rechnoye, 55-Severo-Siktor, 56-Severo-Khokhryakov, 57-Khokhryakov, 58-Permyakov, 59-Kolik''yegan, 60-Vakh, Severo-Vakh, and Yuzhno-Vakh, 61-Severnoye, 62-Protoch, 63-Chebach'ye, 64-Kondakov, 65-Vartov, 66-Nikol, 67-Liney, 68-Kiyev''yegan, 69-Chkalov, 70-Sobolinoye, 71-Severo-Sil'gin, 72-Ust'-Sil'gin, 73-Srednesil'gin, 74-Vonter, 75-Enitor.

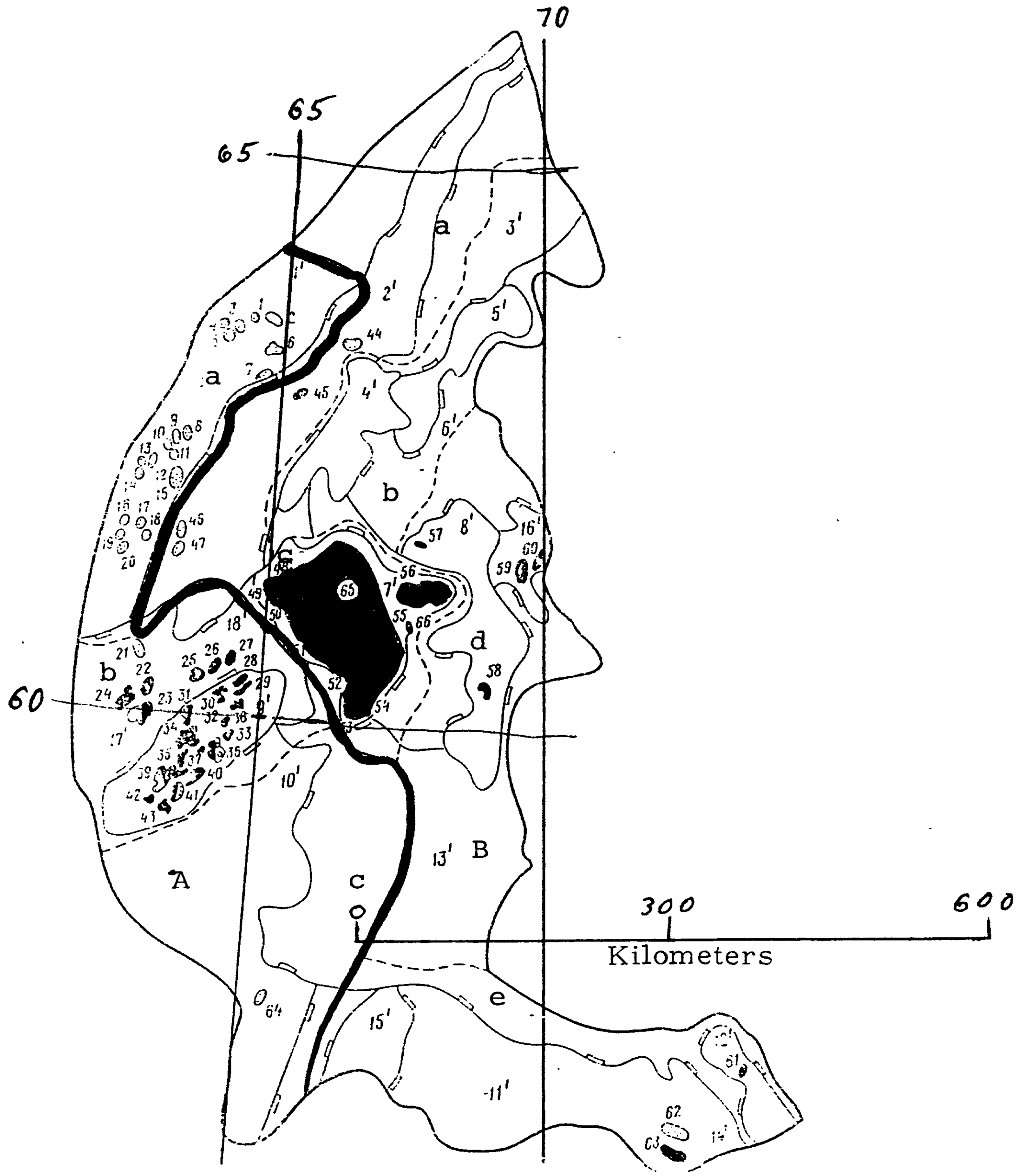


Figure 60. Near-Ural (A) and Frolov (B) oil-gas regions of West Siberia

Figure 60. Fields of Near-Ural oil-gas region (A) and of Frolov oil-gas region (B) (from Maksimov and others, 1987).

Large tectonic features: 1'-Berezovo monocline, 2'-Verkhnepoluy monocline, 3'-Nadym depression, 4'-Pomut mega-arch, 5'-Yuil saddle, 6'-Vynglor depression, 7'-Krasnoleninsk arch, 8'-Zapadno-Lyamin mega-arch, 9'-Shaim mega-arch, 10'-Vostochno-Turin monocline, 11'-Turtas monocline, 12'-Pologrudov mega-arch, 13'-Khanty-Mansiysk depression, 14'-Bol'sheuk monocline, 15'-Tobol mega-arch, 16'-Gornoye, 17'-Verkhnekondin mega-downwarp, 18'-Sherkalin mega-downwarp.

Oil-gas areas. Near-Ural oil-gas region: a-Berezovo gas area, b-Shaim oil area, c-Karabash gas area. Frolov oil-gas region: a-Kazym gas area, b-Yuil prospective gas area, c-Krasnoleninsk oil area, d-Lyamin oil area, e-Tobol oil-gas area.

Fields: 1-Severo-Alyasov, 2-Pokhrom, 3-Yuzhno-Alyasov, 4-Demin, 5-Berezovo, 6-Chuel, 7-Tugiyan, 8-Severo-Igrim, 9-Yuzhno-Igrim, 10-Paul'Tur, 11-Nulin-Tur, 12-Vostochno-Syskonsyn'in, 13-Zapadno-Syskonsyn'in, 14-Yuzhno-Syskonsyn'in, 15-Pungin, 16-Gornoye, 17-Zapadno-Shukhtungort, 18-Vostochno-Shukhtungort, 19-Zapadno-Ozer, 20-Vostochno-Ozer, 21-Verkhnekondin, 22-Verkhnelem'in, 23-Danilov, 24-Lem'in, 25-Zapadno-Lovin, 26-Lovin, 27-Yakhlin, 28-Severo-Potanay, 29-Yuzhno-Potanay, 30-Zapadno-Kartop'in, 31-Filippov, 32-Kayumov, 33-Vostochno-Semividov, 34-Severo-Ubin, Zapadno-Ubin, Maloubin, and Yuzhno_ubin, 35-Srednemulym'in, 36-Tolumsko-Semividov, Yuzhno-Tolum, Vostochno-Tolum, 37-Severo-Tolum, 38-Kartop'ya-Okhan, 39-Severo-Mortym'in, Zapadno-Mortym'in, Mortym'in-Teterev, Severo-Teterev, Yuzhno-Mortym'in, Severo-Trekhozer, 40- Vostochno-Teterev, 41-Yuzhno-Teterev, 42-Mulym'in, 43-Trekhozer, 44-Severo-Kazym, 45-Lykhmin, 46-Severo-Sote-Yugan, 47-Yuzhno-Sote-Yugan, 48-Sosnovomys, 49-Yem"yegov, 50-Talin, Pal'yanov, 51-Ingin, 52-Lorbin, 53-Kamen, 54-Yelizarov, 55-Novoyendyr, 56-Srednenazym, 57-Aprel, 58-Khanty-Mansiysk, 59-Dekabr, 60-Verkhnalyamin, 61-Taytym, 62-Tevriz, 63-Prirakhtov, 64-Karabash, 65-Lebyazh'ye, 66-Galyanov.

the Mesozoic and were enhanced by regional uplift in Tertiary time. In the Middle-Ob area, traps more commonly formed penecontemporaneously with reservoir rock deposition. Differential compaction may also have had a significant role on trap development in most areas. A significant stratigraphic facies aspect is important in reservoir, source rock, and trap development in almost all parts of the basin.

In addition to the main oil-gas occurrence in the Jurassic and Cretaceous fill of the basin, hydrocarbon pools have been found in several areas in pre-Jurassic (largely Middle and Late Paleozoic) sediments. Flows of oil have been recovered from such rocks in not less than 12 areas (Trofimuk, 1975), and com-mercial reserves have been proved. These oils are chemically distinct from Mesozoic oils and apparently were generated by Paleozoic sediments (Ryzhkova, 1976; Trofimuk, 1976; Rigassi, 1986). Deep seismic sounding indicates a great thickness of these unmetamorphosed or lightly metamorphosed rocks in several parts of the basin. In the Middle Ob region, they are 3 - 4 km (10,000 - 13,000 ft) thick (Aleksin and others, 1975), and are as much as 5 - 7 km (16,000 - 23,000 ft) thick in other parts of the basin (figs. 12-14, 17, 19).

The West Siberian basin covers an area of approximately 3,500,000 km^2 (1,300,000 mi^2) and contains a Mesozoic-Cenozoic basin fill of approximately 16,000,000 km^3 (4,000,000 mi^3), including the South Kara basin area (figs. 9, 17). Thickness of the post-Triassic sedimentary cover ranges from 3 - 4 km (10,000 - 13,000 ft) in the central and south to 8 - 10 km (25,000 - 33,000 ft) or more in the north (figs. 16, 17-19). The main oil-gas complexes are in clastic sediments of the Jurassic, Neocomian, and Aptian-Cenomanian. Each of these complexes is overlain by thick regional shale deposits of Kimmeridgian-Valanganian, Aptian-Albian, and Turonian-Oligocene ages, respectively. The chemistry of the oils indicates that each complex is an independent petroleum unit (Yermakov and Skorobogatov, 1984). Distribution of the oil and gas areas of the basin appears to be directly related to the type of organic material present in the different complexes. Thick and widespread source rock units of either the sapropelic or the humic type and mixtures of both are present in each of the complexes. Additional unexplored potential oil and gas complexes are present in clastic sediments of the Triassic in the northern region and in the Paleozoic-basement complex of the southern, central, eastern, and western basin areas.

Geothermal gradients in the basin are near normal in most areas (fig. 61). Lowest values (2.8 - 3.0°C per 100 m) are in the southeastern part of the basin; highest values (greater than 4.5°C per 100 m) are in the Near-Urals western region; values of 3.3 - 4.2°C per 100 m are characteristic of the remainder of the basin (Yermakov and Skorobogatov, 1984). Present-day temperatures at the top of the Middle-Upper Jurassic Tyumen Formation, based on 3,200 wells, range from 30-50°C near the line of pinchout to 100-130°C in the central and north parts of the platform (fig. 62). Values at the top of the Neocomian range from 30-60°C to 80-100°C; at top of Cenomanian from 10-20°C to

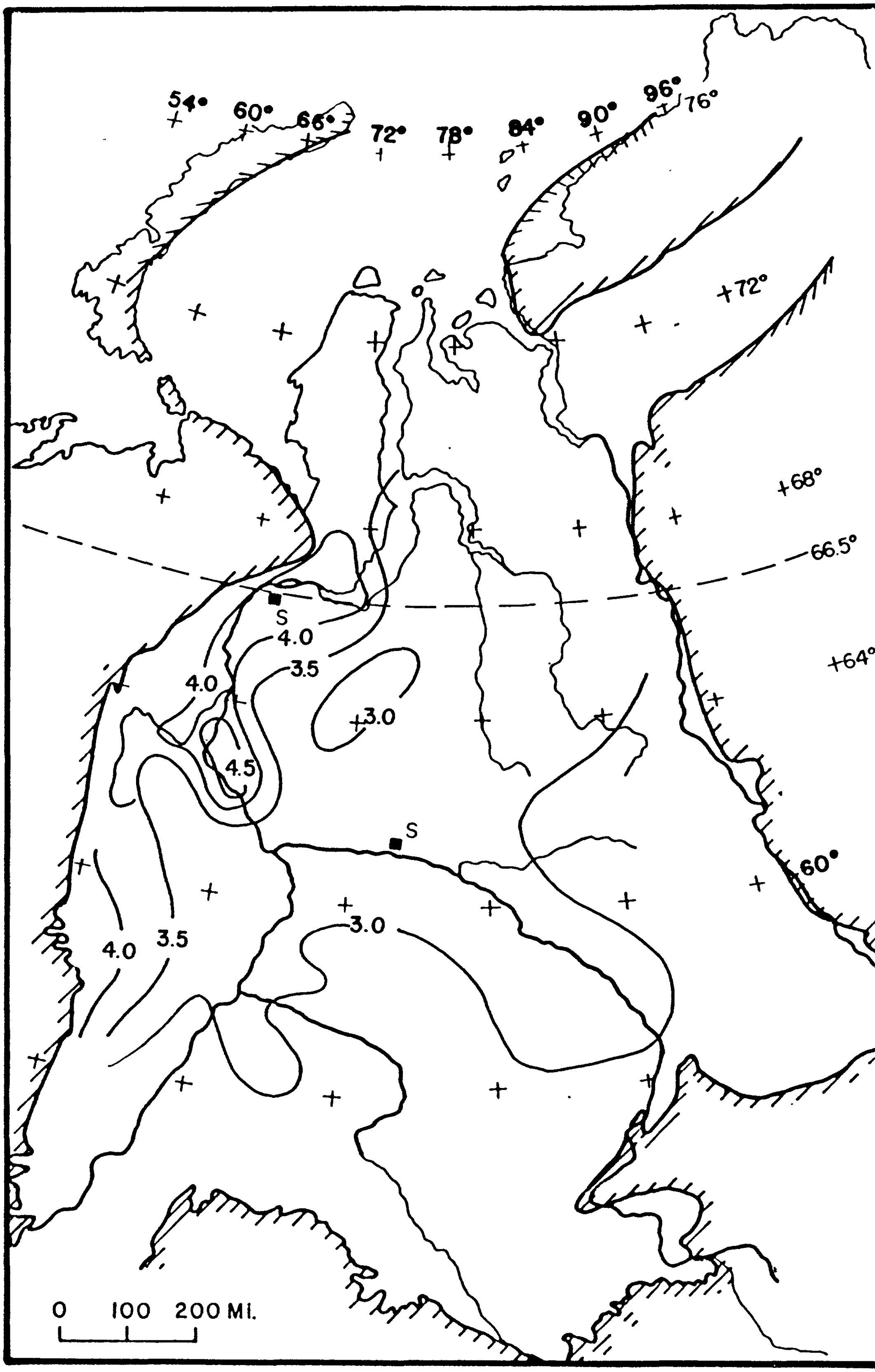


Figure 61. Geothermal gradient, °C/100 m (from Sergiyenko, 1978)

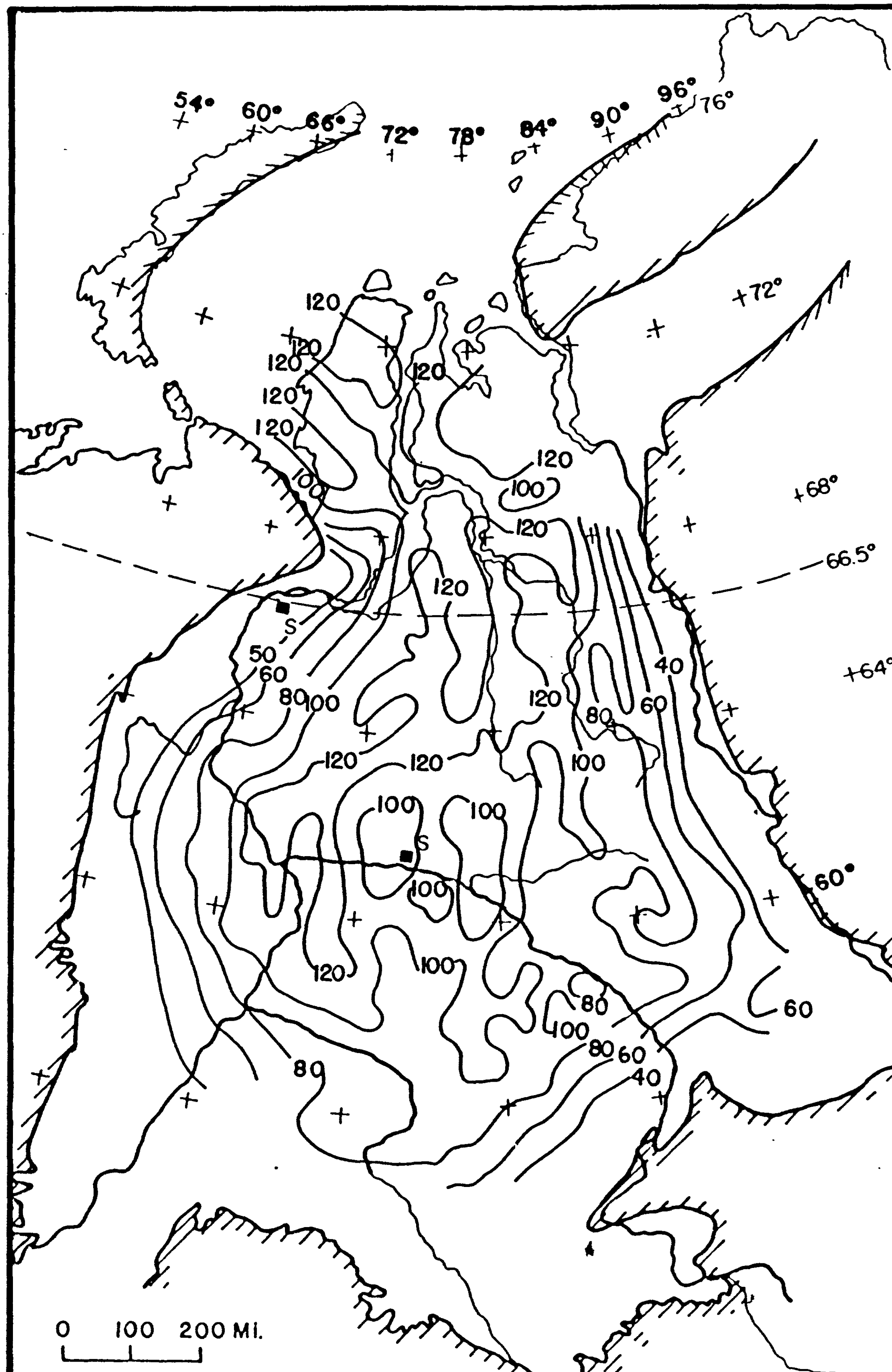


Figure 62. Present-day temperature (°C) at top of Tyumen Formation (Middle-Upper Jurassic) (from Yermakov and Skorobogatov, 1984)

55°C (fig. 63). The time of maximum paleotemperature was at the end of the Chegan Stage of the early Oligocene, after which temperatures began to drop because of regional uplift (Yermakov and Skorobogatov, 1984). Pure gas pools (mainly methane) in Jurassic rocks are found for paleotemperatures below 80°C, and a variety of oil-gas-condensate accumulations are present in the 80°-145°C range. Above a paleotemperature of 150°C, the probability of oil being preserved is much less. No hydrocarbon deposits have yet been found in the West Siberian basin where paleotemperatures have exceeded 180°C (Yermakov and Skorobogatov, 1984e), although gas and gas-condensate pools are possible above 180°C.

Regionally, the distribution of oil and gas accumulations in the basin shows a relatively well defined pattern (figs. 56,64). Accumulations of predominantly gas or gas-condensate are found in the Yamal, Gyda, Nadym-Pur, Pur-Taz, northern Near-Ural and Ust-Yenisey regions; predominantly oil is found in the Middle Ob, Frolov, southern Near-Ural and Kaymysov regions; and mixed oil and gas in the Vasyugan and Paydugin regions. Mixed oil and gas are projected for the Taymyr potential oil-gas region (fig. 55).

The following sequence of petroleum generation and accumulation stages has been proposed for the Jurassic sediments (Yermakov and Skorobogatov, 1984; Lugovtsov and Moskvin, 1980):

1. Biogenic gas began to be generated in the Lower-Middle Jurassic sediments in the northern region in Middle Jurassic time. Much of this gas was lost because of lack of seals. The lower parts of the Jurassic section may have already been in the oil window by Late Jurassic time (figs. 17-19).

2. During Early Cretaceous time, the lower part of the Jurassic was involved in oil-gas generation over practically all of the West Siberian platform.

3. After Cenomanian time, the maturation process in the Jurassic sediments probably diminished and a large part of the north basin was at temperatures greater than 145-150°C.

4. Regional uplift and geothermal reversal in Neogene time caused a drop in reservoir pressures, some gas was released from solution, and the formation of new pools and redistribution of old pools occurred.

Intermediate Stage

The Intermediate Stage as used here consists of pre-Jurassic Paleozoic, weathered basement-surface, and Permian-Triassic-Liassic taphrogenic graben rocks in the basin area south of approximately 64° N. North of here, Paleozoic rocks become buried too deeply for economic plays at this time, other than possible gas deposits. Marine, lagoonal, and continental Triassic sedimentary rocks are widespread and thicken

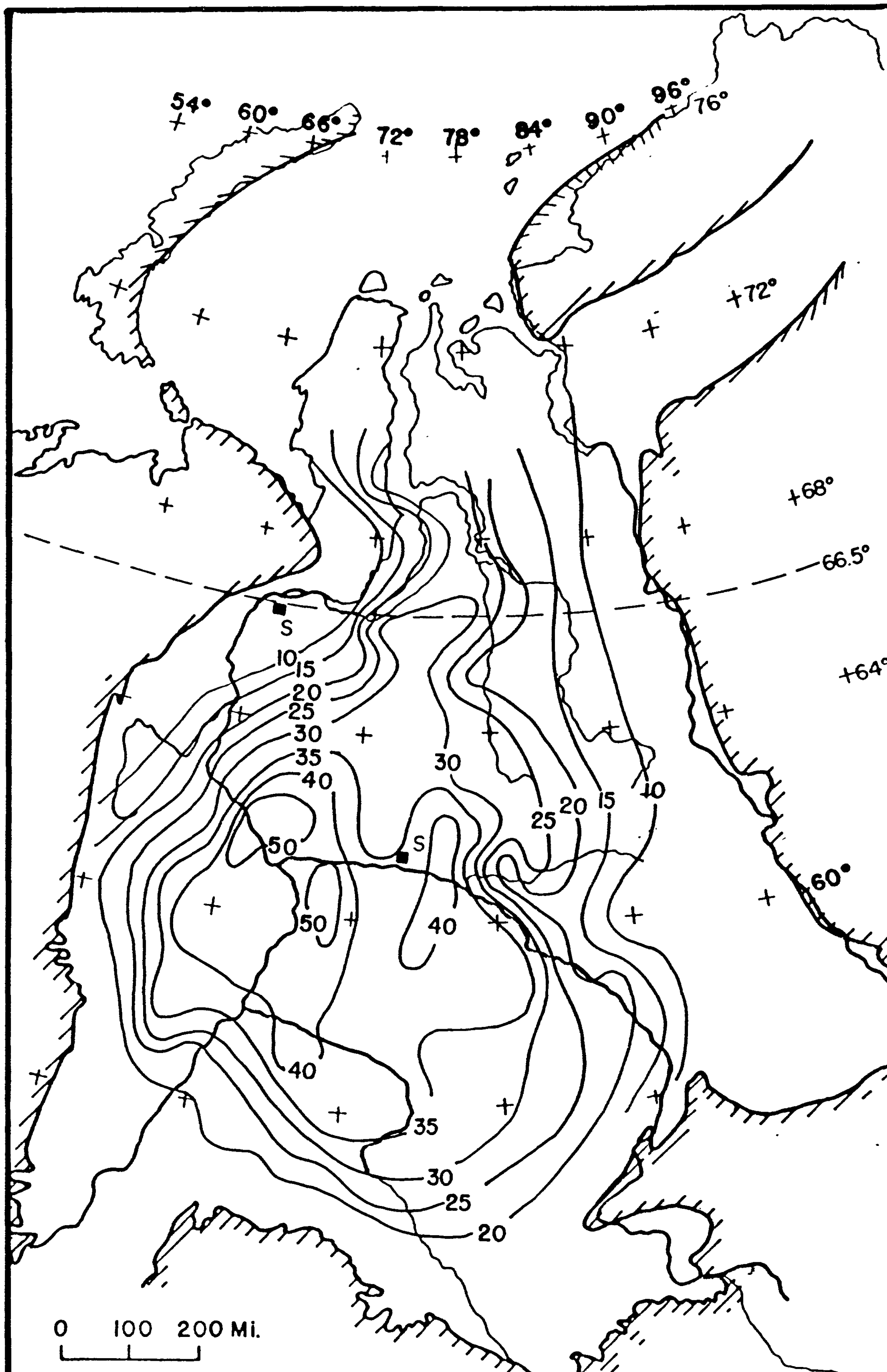


Figure 63. Present-day temperature (°C) near top of Cenomanian (Upper Cretaceous) (after Yermakov and Skorobogatov, 1984)

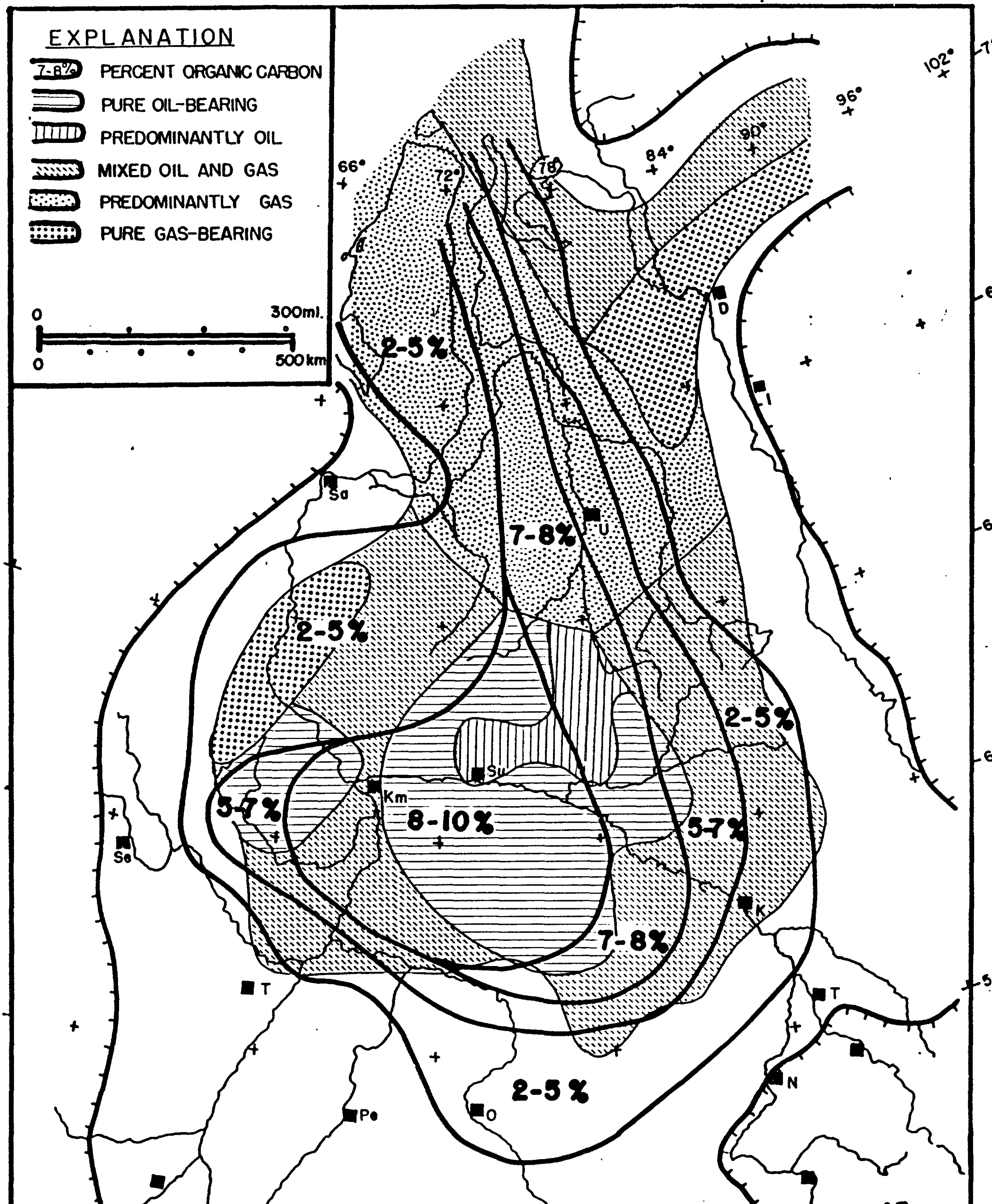


Figure 64. Distribution of organic carbon in bituminous sediments of the Jurassic and Neocomian of the West Siberian oil-gas basin, showing main areas of oil, oil-gas, and gas condensate from Jurassic and Cretaceous reservoirs (from Ushatinskiy, 1980, and Ozeranskaya, 1983)

rapidly in the northern area (fig. 20). These rocks are more properly included with the Mesozoic-Cenozoic cover (Zhuravlev, 1984).

The Permian-Triassic-Liassic graben basins are filled with thick deposits of volcanic, volcanogenic-sedimentary, and some alluvial-lacustrine rocks; these are present in several areas of the Middle Ob and southern areas (figs. 11,17,18,20). These generally are not oil-gas prospective sequences, except as remote possibilities for hydrocarbons migrated into these rocks from post-unconformity Jurassic rocks, or in some cases Paleozoic carbonate or clastic rocks on adjacent uplifts. Petroleum accumulations in these basins are likely to be small and difficult to find.

These rift basins may be more widespread than originally thought. They are commonly not recognized without good deep seismic data. Well control is limited because deeper drilling thus far has generally been for Mesozoic reservoirs on uplifts rather than in the graben regions. Triassic rocks with vitrinite reflectance indicating paleotemperatures not exceeding the oil window have recently been reported along the Irtysh River near Omsk (fig. 17). Matured Carboniferous rocks have been reported to the southwest in the vicinity of Kurgan (Fomin, 1987).

In several parts of the middle and southern areas of the province, oil and gas shows are widespread, and commercial fields have been found in weathered and fractured rocks below the Jurassic unconformity, including Paleozoic reefs and other carbonate rocks. In some cases, particularly on the west side of the basin, accumulations are related to migration and trapping of oil or gas sourced by the overlying Jurassic or Lower Cretaceous organic rich rocks. However, in the southeastern basin area, oil and gas pools are present in Paleozoic carbonate and clastic reservoirs, apparently sourced by high-organic Paleozoic rocks (Ryzhkova, 1976; Trofimuk, 1976; Aleksin and others, 1975; Rigassi, 1986; Vyshemirskiy and others, 1972; Zapivalov and others, 1980; Krylov and others, 1981; and Sevost'yanov, 1980, 1982). Carbonate and clastic rocks of Middle and Late Paleozoic age have been drilled below the Jurassic unconformity in most parts of the central, southern, and eastern areas of the basin, particularly on structurally high areas adjacent to Late Permian-Triassic grabens. Most of these rocks are fractured and metamorphosed to varying degrees, but areas of relatively unaltered rocks also are reported (Krylov and others, 1981; Surkov and others, 1983; Vyshemirsky and others, 1972). A large area of particular interest is the Khanty-Mansiysk depression, where a central massif of Paleozoic age (fig. 13) has been outlined (Surkov, and others, 1983).

According to Sevost'yanov (1982), pre-Jurassic structure is very complex in most of the basin, and oil or gas pools will probably be small. In most areas, Paleozoic rocks have been over-heated, generally above 160^{o}C. Two kinds of petroleum accumulations in Paleozoic reservoirs are possible: 1) on pre-Jurassic erosional highs, and 2) within isolated pre-Jurassic reservoirs. Three structural-stratigraphic complexes are recognized in the pre-Jurassic of the central and southern areas of the basin (Sevost'yanov, 1982): 1) a Paleozoic geosynclinal complex; 2) a Paleozoic platform complex, in the Yenisey-Taz regions; and 3) the Triassic-Liassic taphrogenic complex, found in grabens south of the Triassic blanket cover of the north basin.

According to Zhuravlev (1984), areas of greatest promise for Paleozoic oil or gas include the Nyurol, Khanty-Mansiysk, Yugansk (eastern part), Ust-Tyrreskaya, Nadym (north part), Tanlov, and Yenisey depressions, the develop-ment of which began in the Late Paleozoic and continued through the Triassic or later. Negative factors are as follows: (1) adverse thermal conditions, with high paleotemperatures and the probability that there would be widespread destruction of oils; (2) active tectonism for more than 100 my and widespread magmatic activity; these conditions would cause vertical migration or destruction of earlier oil accumulations; (3) poor reservoir quality in almost all rocks; (4) absence of good seals, such as evaporites and thick clays. Three possible objectives are listed: (1) Middle Paleozoic geosynclinal and platform (to the east) complex - very low potential, except for possibly the Yenisey-Taz block; (2) upper Paleozoic orogenic and platform (to east) complex - some (non-commercial) accumulations of gas and some oil are possible in the troughs in the Ob area and some in the Yenisey-Taz block, but it is very difficult to find these troughs; (3) Triassic-Liassic taphrogenic complex within narrow grabens - only non-commercial secondary accumulations of oil and gas may be present, and these will be difficult to find. The overall appraisal is that the intermediate section is poorly prospective.

Platformal Triassic

The Permian-Triassic taphrogenic rifts extend northward into and across the north basin area (fig. 20). In this area the rift deposits are overlain by thick lagoonal and marine sedimentary rocks, which cover most of the northern part of the basin (Zhuravlev, 1984). These platformal Triassic rocks thicken rapidly northward to more than 2 - 3 km (6,500 - 10,000 ft), possibly reaching more than 5 km (16,000 ft) in places (Kontorovich, 1975). These rocks are buried deeply beneath as much as 6 km (20,000 ft) or more of Jurassic and younger sediments north of the Urengoy-Yamburg region (figs. 15, 16, 17, 19). The lithologic nature of the Triassic rocks here is not yet well known. Wells drilled into the Triassic in the north basin have penetrated a section of alternating dark gray shales, siltstones, sandstones, and tuffaceous sandstones (Kontorovich and others, 1975). The presence of a large area of Triassic clastic deposits in the Khatanga downwarp near the Taymyr uplift (fig. 20) (Rudkevich, 1976) suggests that clastic reservoirs, in part marine, should be present to the northeast and perhaps in other parts of the northern region (fig. 20). A relatively thick section of Triassic rocks is identified on seismic sections across the South Kara basin to the northwest. The possibility of good clastic reservoirs and source rocks in the Triassic system of the north basin area appears to be reasonable, although, except for the northeastern region near the Taymyr uplift and in the Khatanga trough, these rocks may be buried in most places to depths within or below the thermal gas window. Good shale seals should be present within and overlying the Triassic beds in all of this area, and adequate source rocks should be present in the Triassic marine, lagoonal, and lacustrine beds. According to Yermakov and others (1979), Triassic rocks in the north are definitely favorable for gas.

Jurassic

Sandstone and siltstone reservoirs of Jurassic age are productive in scores of oil and gas fields in the West Siberian province. Several fields also produce oil from fractured reservoirs of the highly organic, limy sili-ceous, argillaceous Bazhenov Formation. As many as 20 Jurassic pays are identified (Yermakov and Skorobogatov, 1984).

Jurassic rocks tend to be oil-prone, although a large area of gas production is present in the Berezovo area on the west side of the basin, and associated gas is commonly present in many of the oil fields (figs. 65-67). Gas and some oil also have been found in Jurassic sandstone and siltstone reservoirs in a few north basin fields, all of which also produce gas condensate from Cretaceous reservoirs. However, the Jurassic in the north basin area probably has not been heavily explored because of depth constraints in most areas, plus an abundance of already developed gas reserves in Cretaceous reservoirs.

Thus far, many more pools have been found in Upper Jurassic reservoirs than in the Lower and Middle Jurassic. Three main Upper Jurassic plays are recognized (Skorobogatov, 1980): 1) the Upper Jurassic Vasyugan Formation sandstones; 2) the Vogulkin Formation sandstones and limestones; and 3) the Bazhenov Formation organic-rich, sapropelic, siliceous, limy shale. Vasyugan sandstone and siltstone beds are important reservoirs in the southeastern, central and north regions of the basin. The Bazhenov Formation is commonly 10-40 m (33 - 100 ft) or more thick and is widespread over much of the interior basin. Important production is obtained from fractured reservoirs in this unit in parts of the central basin area, particularly in the Salym and adjacent areas. However, Bazhenov discoveries also have been made in recent years in the Tomsk region (fig. 8), in the north basin area, and in several other areas. Bazhenov reservoirs are fractured and generally over-pressured, particularly in areas of higher temperatures. Many of the associated production problems have not yet been resolved, and partly for this reason the Bazhenov has not been thoroughly explored. However, this unit is potentially one of the most promising future reserve plays of the basin as technology improves (Skorobogatov, 1984). Horizontal drilling may increase production significantly from the Bazhenov (Izvestiya, January 29, 1986). Promising areas are in the Salym and adjacent region, the Khanty-Mansiysk depression, the northern Middle Ob region, and the Yamal Peninsula.

Sandstones of the Jurassic system are moderately high in feldspar content (30-50 percent or more), contain 20-45 percent quartz, and 1-12 percent mica, becoming somewhat more micaceous in the northern region. Upper Jurassic sandstone reservoirs in the southeast part of the basin are associated mainly with an elongate south-north trend of deltaic and

Figure 65. Percent sandstone, Lower and Middle Jurassic rocks, showing areas of predominantly sapropelic organic matter, and general distribution of oil and gas fields producing from Lower and iddle Jurassic reservoirs (from Nesterov, 1976, Ronkina and Bro, 1984). Arrows show direction of transport

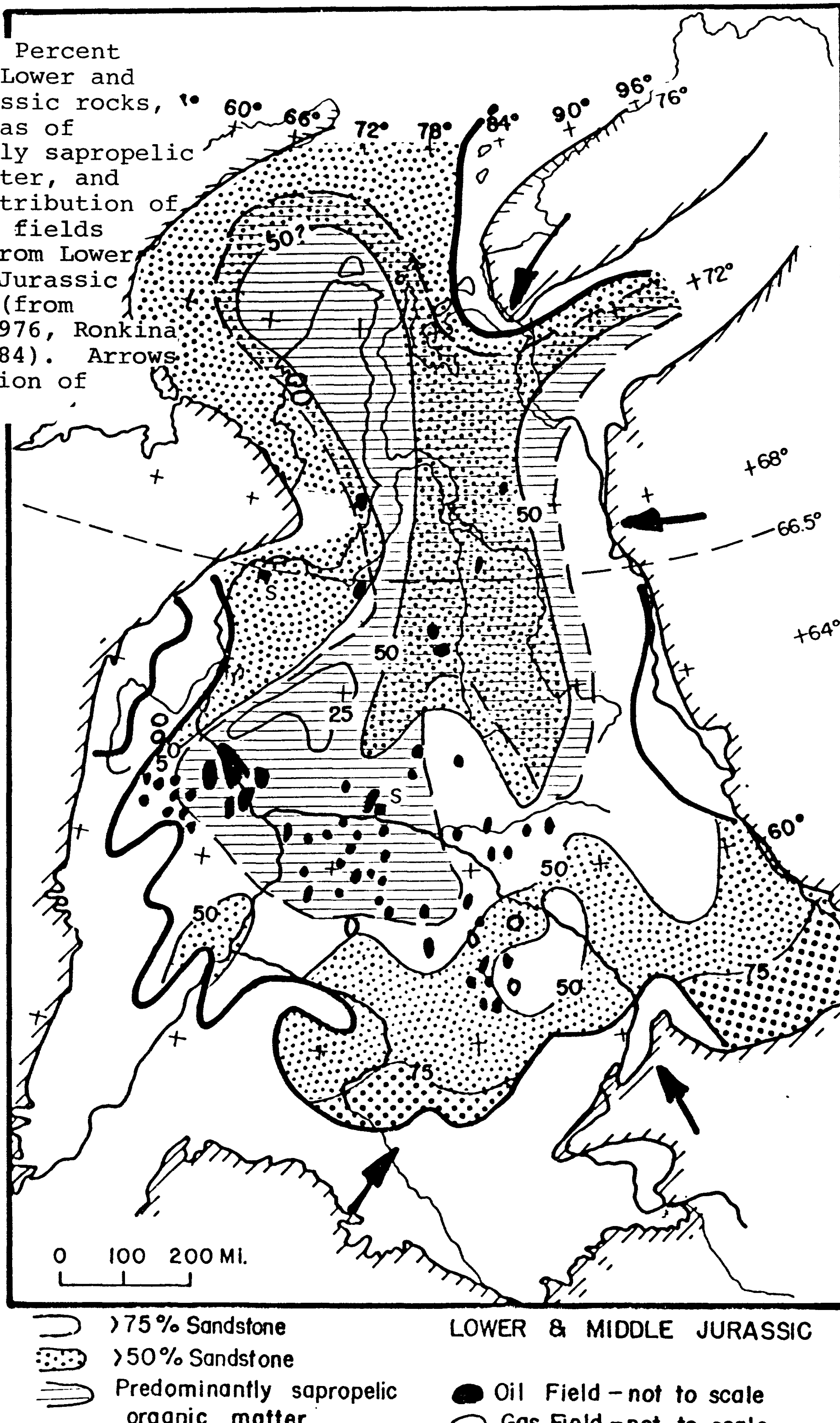
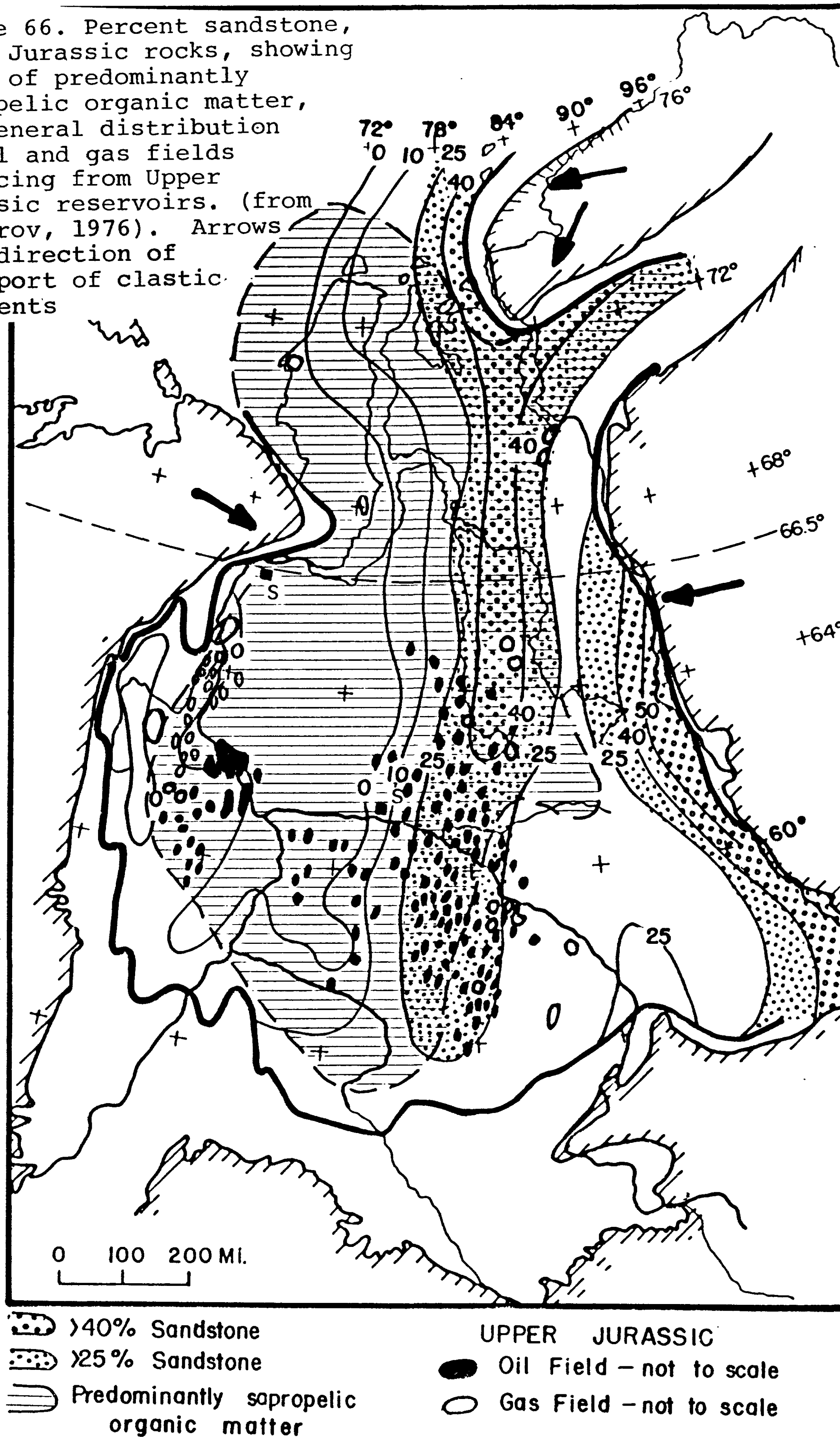


Figure 66. Percent sandstone, Upper Jurassic rocks, showing areas of predominantly sapropelic organic matter, and general distribution of oil and gas fields producing from Upper Jurassic reservoirs. (from Nesterov, 1976). Arrows show direction of transport of clastic sediments



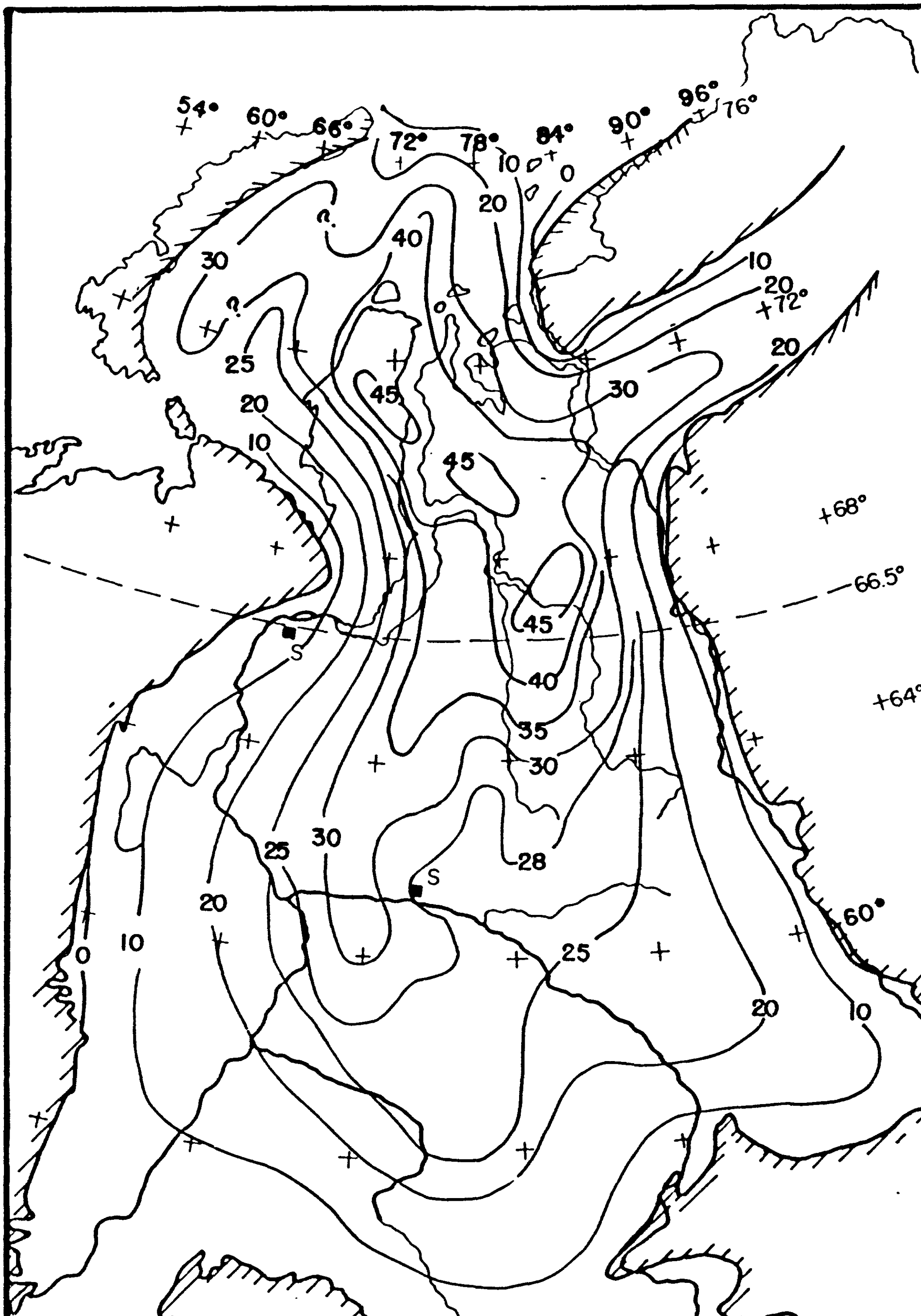


Figure 67. Thickness of post-Jurassic rocks; approximately equals drilling depth to top of Jurassic rocks

POST-JURASSIC ROCKS
Thickness in hundreds of m.

foredelta facies extending along the eastern border of the Middle Ob region (figs. 25, 66). Within this belt are found the thickest and most porous sandstone reservoirs, many with a north-south channel-sand configuration. The deltaic facies grades westward into organic-rich marine argillaceous beds with a low sand content (Filina, 1974; Ovanesov and others, 1975). A similar deltaic facies is present in the Lower-Middle Jurassic Tyumen Formation, but much of this facies includes lacustrine and swamp deposits, and the sandstones are generally of low permeability and porosity, although some channel sandstones of higher porosity are present. Jurassic rocks, particularly those of the Upper Jurassic, are exceptionally high in organic material, predominantly sapropelic in the basin interior (figs. 21, 25, 28, 64-66). Lower-Middle Jurassic rocks are characterized by mainly humic organic material, with coal beds prominent in the central and southern basin, where lacustrine and swampy beds are common. Marine sapropelic organic matter is particularly abundant in Upper Jurassic rocks over much of the basin, except for the eastern and southern areas, where humic matter and some coals are present (fig. 66). The following table is from Yermakov and Skorobogatov (1984):

Average content of total organic carbon (percent) in Jurassic of West Siberia:

	Clays and argillites	Sandstones and siltstones
Volgian	6.85%	--
Kimmeridgian	2.85%	--
Callovian-Oxfordian	1.76%	1.12%
Lower & Middle Jurassic	2.62%	1.26%

Average total organic carbon content of Upper Jurassic rocks is also given as follows (Skorobogatov, 1980):

Vasyugan Formation & equivalents	1.91%
Georgiyev Formation	2.85%
Bazhenov Formation	7.12% (10-12% in the Mansiysk region; 3.4-5.5% in the north basin area)

Regional shale seals are present in the upper part of the Upper Jurassic section (Bazhenov and Georgiyev Formations and the upper part of the Tyumen Formation). Seals tend to be discontinuous in the Lower and Middle Jurassic section, although persistent clay or shale intervals are present in the middle and lower part of the Tyumen Formation.

Because of high quality source rocks, the Jurassic section has a high generating capacity, but because of poorer reservoir development, it contains much fewer large fields than does the Cretaceous section (Yermakov and Skorobogatov, 1984c). Because of better reservoirs and a better overlying seal (Bazhenov Formation and lower Neocomian shale), greater reserves are found in the Upper Jurassic Vasyugan Formation reservoirs and their equivalents than in the Lower and Middle Jurassic Tyumen Formation reservoirs.

Several main areas of Jurassic production or potential production are delineated in the West Siberian basin (Rudkevich and Ozeranskaya, 1983): Kaymysov, Vasyugan, and Paydugin regions - Sixty-five or more oil and oil-gas fields productive from Jurassic reservoirs or from weathered granitic- metamorphic rocks are located in these three regions in the southeastern part of the basin (figs. 55, 56, 64-66). Most of the fields are located on domal or anticlinal structures that reflect basement highs or buried hills beneath the Jurassic unconformity. Production is mainly from sandstone and siltstone reservoirs in the Vasyugan Formation (Upper Jurassic), and in some fields from Middle Jurassic sandstone or siltstone reservoirs of the Tyumen Formation. Reservoirs are present also as updip stratigraphic trap pinchouts on weathered granite hills beneath the unconformity. A few fields, particularly in the Nyurol and southern Vasyugan regions, are also productive from Paleozoic carbonate reservoirs and weathered basement rocks. Some minor production in these regions comes from Neocomian sandstone or siltstone reservoirs.

Middle Ob and southern parts of Nadym-Pur and Pur-Taz Regions - A large number of fields produce oil or oil-gas from Jurassic sandstone and siltstone reservoirs in these regions of the central basin area (figs. 17, 18, 55, 56, 58, 59, 65, 66). The Lower-Middle Jurassic beds are mainly continental in this region (Brushtov and others, 1975; Filina, 1974), and pools are small. The Upper Jurassic beds are mainly marine and littoral-marine deltaic and foredeltaic deposits with relatively persistent sandstones, many with good porosity and permeability, interbedded with shale. Shale content increases rapidly from east to west across the region. The sandy facies is most prevalent on the Nizhnevartov arch and on other structures to the north and south, becoming increasingly discontinuous and more shaly toward the west in the area of the Surgut arch. Most of the oil pools are on the periphery of the Nizhnevartov arch, and traps are mostly stratigraphic-structural. Sandstone reservoirs commonly wedge-out updip on domes or anticlines, and at least half of the traps are classed as stratigraphic (Buurshtk and others, 1975).

Organic-rich marine sapropelic beds are prominent in most of the Jurassic section across the entire Middle Ob area, particularly in the Upper Jurassic, where the Bazhenov Formation makes a regional seal as well as rich source rock for Jurassic oil (figs. 17, 18, 64-66). The relatively thick overlying lower Neocomian shale section also provides an additional regional seal for Jurassic sandstone pools, as well as for fractured shale pools in the Bazhenov.

Near-Ural and Frolov regions - These productive regions occupy the western part of the West Siberian province. In the early 1950's, the first discoveries in this province were made here. The area stands apart geologically from the rest of the province in that the prolific deltaic and other nearshore sandstones of the central and northern regions are not present, having shaled out westward into the Mansiysk depression (figs. 55, 60, 65, 66). Parallel with the facies changes, however, is the appearance of a widespread Lower-Middle Jurassic western sandy reservoir facies of the Tyumen Formation that commonly pinches out against erosional residuals on the pre-Jurassic surface. These deposits are mainly continental sand-clay coal-bearing rocks derived from ancestral Ural highlands on the west. Toward the east, they grade into coastal plain and marine deposits. Overlying the Tyumen Formation are Upper Jurassic argillaceous rocks of the Vasyugan, Georgiyev, and Bazhenov Formations (Dikenshteyn, 1977). These rocks become sandy on the west toward the Ural source area. Dark gray, commonly sapropelic, clay or shale formations of Neocomian Cretaceous age rest conformably on the Bazhenov Formation in most of the area.

Most oil and gas fields in this area occur in stratigraphic and draped traps over the basement highs. The Berezovo gas area contains 20 or more gas fields. Most reservoirs are basal sandstones of Late Jurassic age, which pinch out against basement highs (Dikenshteyn, 1982; Clarke, 1984). Weathered basement rocks are productive in a few fields. Small gas pools also have been found in sandstone and siltstone reservoirs of late Neocomian age.

The Shaim oil area includes the Shaim arch and a large region of smaller highs to the northwest. Oil pools are in Upper Jurassic basal sandstones, which rest transgressively on and pinchout against buried hills that were islands in the Late Jurassic sea (Ryabukhin, et al, 1969; Clarke, 1984).

In the Frolov oil region, the Krasnoleninsk arch contains several fields, which are depicted as one large field in figure 60.

Northern area, (Yamal, Gyda, Nadym-Pur, Pur-Taz, Ust'-Yenisey, and Taymyr regions) - As of 1979, 50 wells had penetrated to Jurassic rocks in the northern area; only six had reached 4,000 m (13,000 ft) or deeper.

Jurassic rocks are high in sandstone content across most of the Ust'-Yenisey, Taymyr, and Yamal and Pur-Taz regions (figs. 21, 25, 65, 66). Sapropelic marine shale beds are also widespread, particularly in the central and eastern parts of the northern area, grading into and intertonguing with the adjacent bordering sand facies. For these reasons, significant oil, oil-gas, or gas-condensate accumulations should be present in these rocks. The Jurassic section, however, is buried deeply in much of the northern area and has not been adequately explored (fig. 67). Gas production is reported from Middle and Upper Jurassic sandstone reservoirs in the south part of the Ust'-Yenisey region, and gas has been encountered in at least one field in the Yamal region. Gas-condensate and some oil are found in Jurassic reservoirs in other parts of the north basin. Oil pools are reported in the Vasyugan Formation in the Gubkin, Severo- and Yuzhno-Kharampur, and Verkhnechasel'ka fields and in the Tyumen Formation in the Yuzhno-Kharampur field (Yermakov and Skorobogatov, 1984). According to these authors, favorable areas for Jurassic exploration are in the Nadym-Pur and Pur-Taz regions, between the Nadym and Taz Rivers, although prospects are likely to yield only small to medium-size gas pools. Lower and Middle Jurassic reservoirs are considered favorable for gas-condensate pools, and Upper Jurassic reservoirs for light oil.

According to Yermakov and Skorobogatov (1984), the most probable time of formation of oil and gas pools in the Jurassic rocks of the northern area was in the Neocomian-Albian. Subsequently, the accumulation potential of the Jurassic rocks was decreased considerably due to deterioration of reservoir properties accompanying subsidence and compaction. The possibility for migration of hydrocarbons was reduced sharply. Therefore, the hydrocarbons generated after the Albian were not able to collect in pools but are scattered in a myriad of non-commercial accumulations.

Neocomian

<u>Reservoirs</u> - Reservoirs of Neocomian age are the main oil producers in the West Siberian basin. Neocomian beds are strongly oil-prone in the central part of the basin (Middle Ob region), where the main oil deposits are located, but are largely gas-prone where productive in the northern area (figs. 55-57, 68-71).

The Neocomian section ranges in thickness from about 800 m (2,500 ft) in the south to more than 1,500 m (5,000 ft) in the north (fig. 29). At least 30 sandstone and siltstone productive horizons separated by clays or shales are present (Yermakov and Skorobogatov, 1984c), including the B1 - B22 horizons of Valanganian-Hauterivian age and the A1 - A12 horizons of upper Hauterivian-Barremian age (Ozeranskaya, 1979). Most of the reservoirs shale out from east to west; the sandstone content of the Neocomian is 60% or more on the east side of the basin, 25-40% in the Middle Ob region, and less than 10% in the west side of the basin (figs. 30-34, 68-71).

Most reservoirs are nearshore marine deltaic, interdeltaic, or fluvial sandstone bodies derived from source terranes on the southeast

Figure 68. Percent sandstone, Lower Cretaceous, lower and middle Valanginian rocks, showing areas of predominantly sapropelic organic matter (from Nesterov, 1976). Arrows show transport direction of clastic sediments

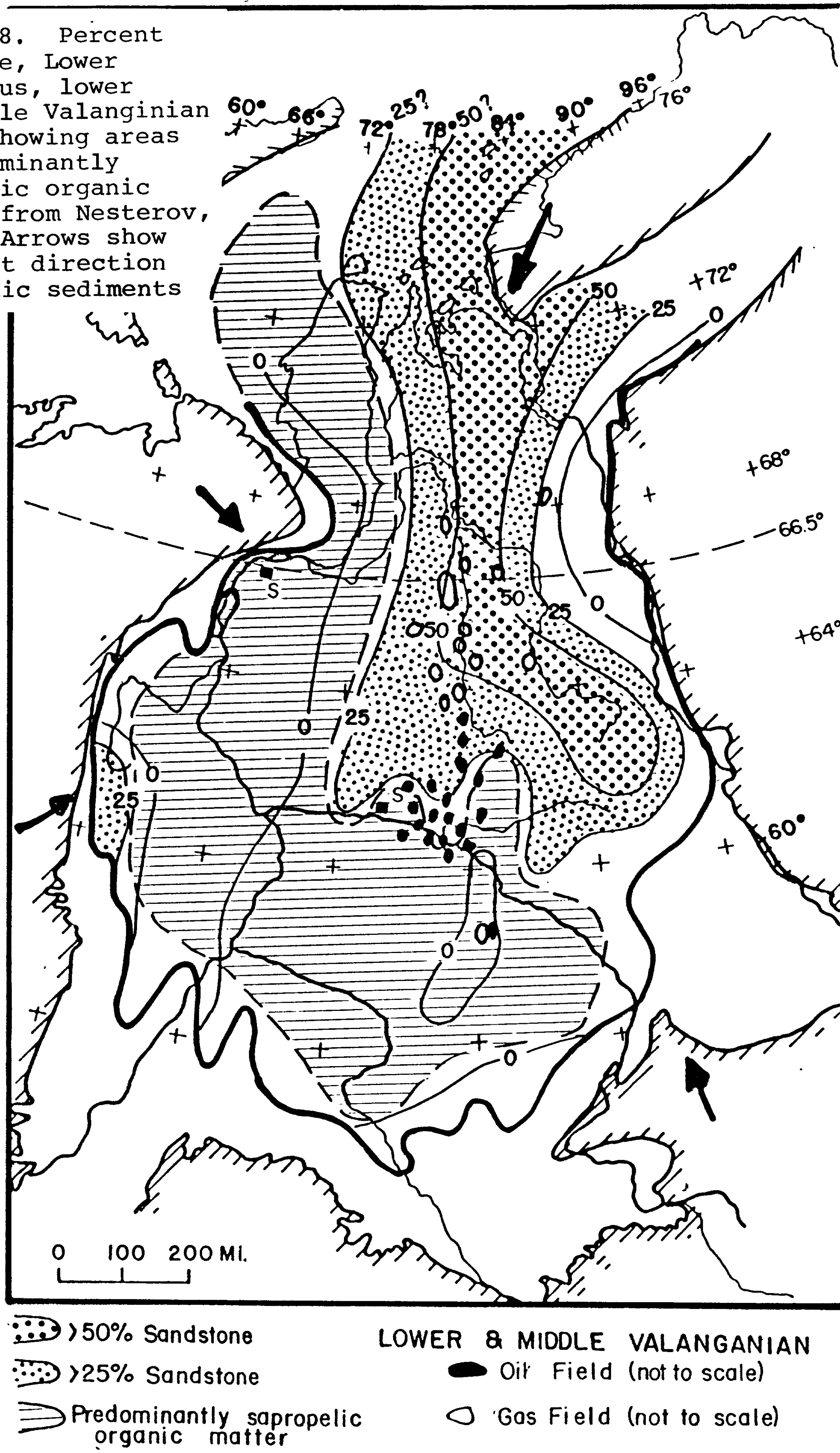
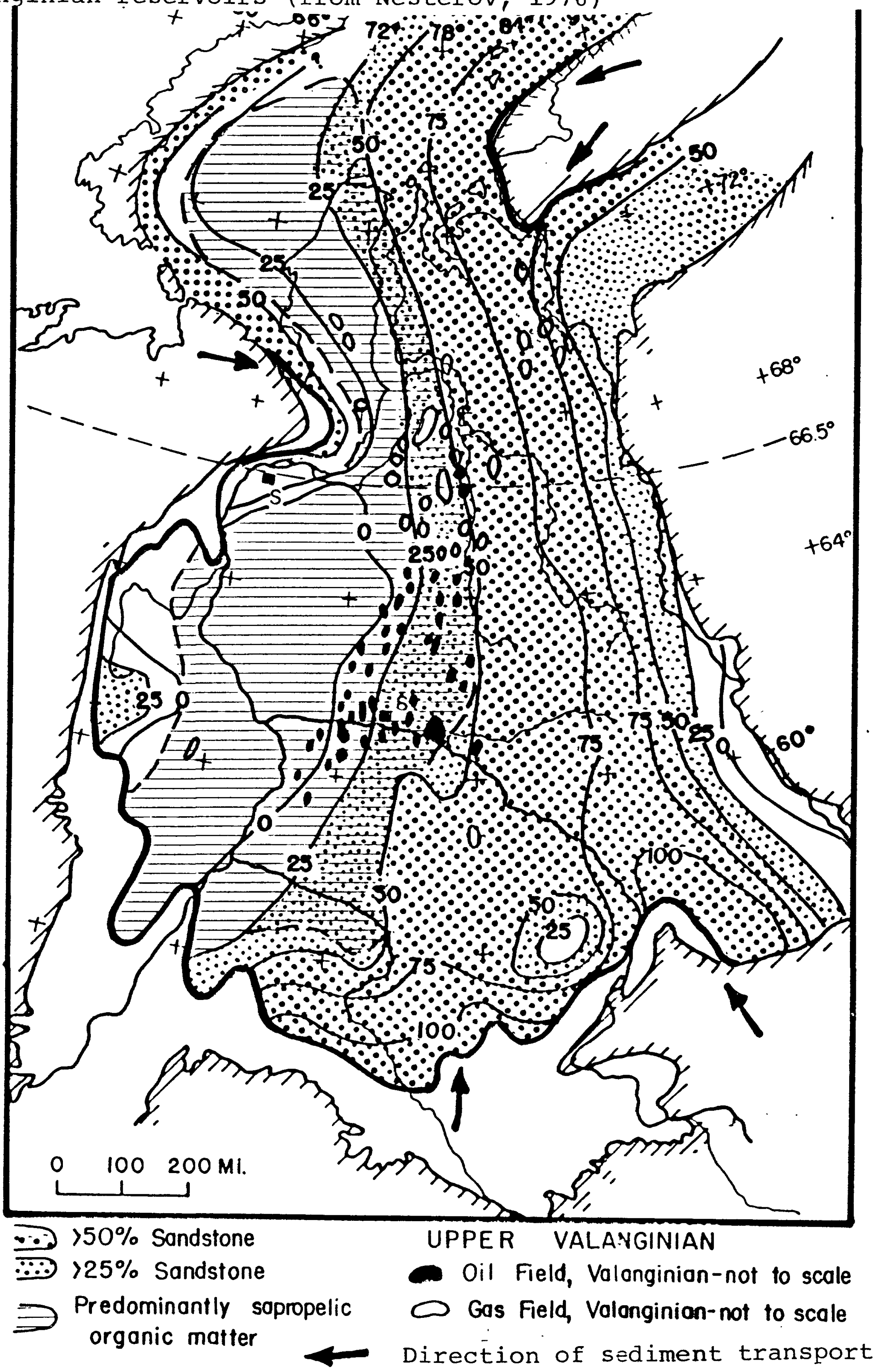


Figure 69. Percent sandstone, Lower Cretaceous, upper Valanginian, showing areas of predominantly sapropelic organic matter, and general distribution of oil and gas fields producing from Valanginian reservoirs (from Nesterov, 1976)



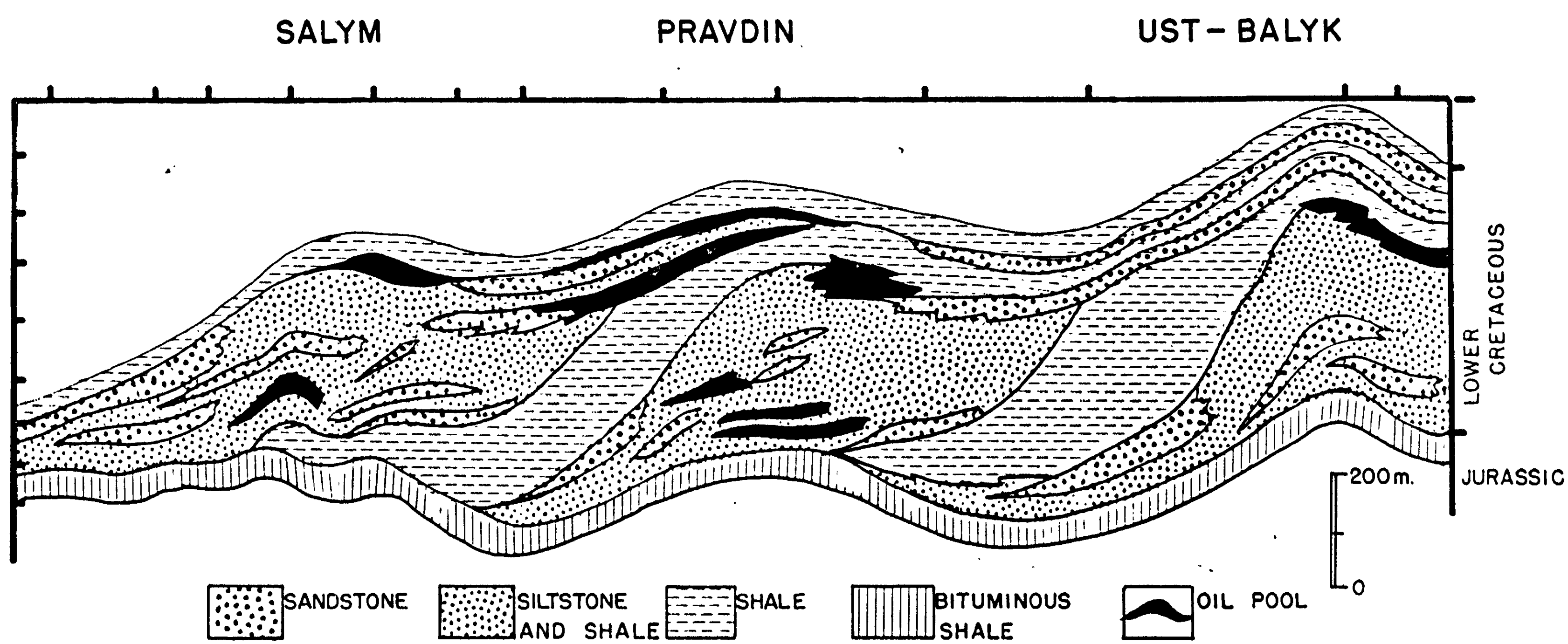
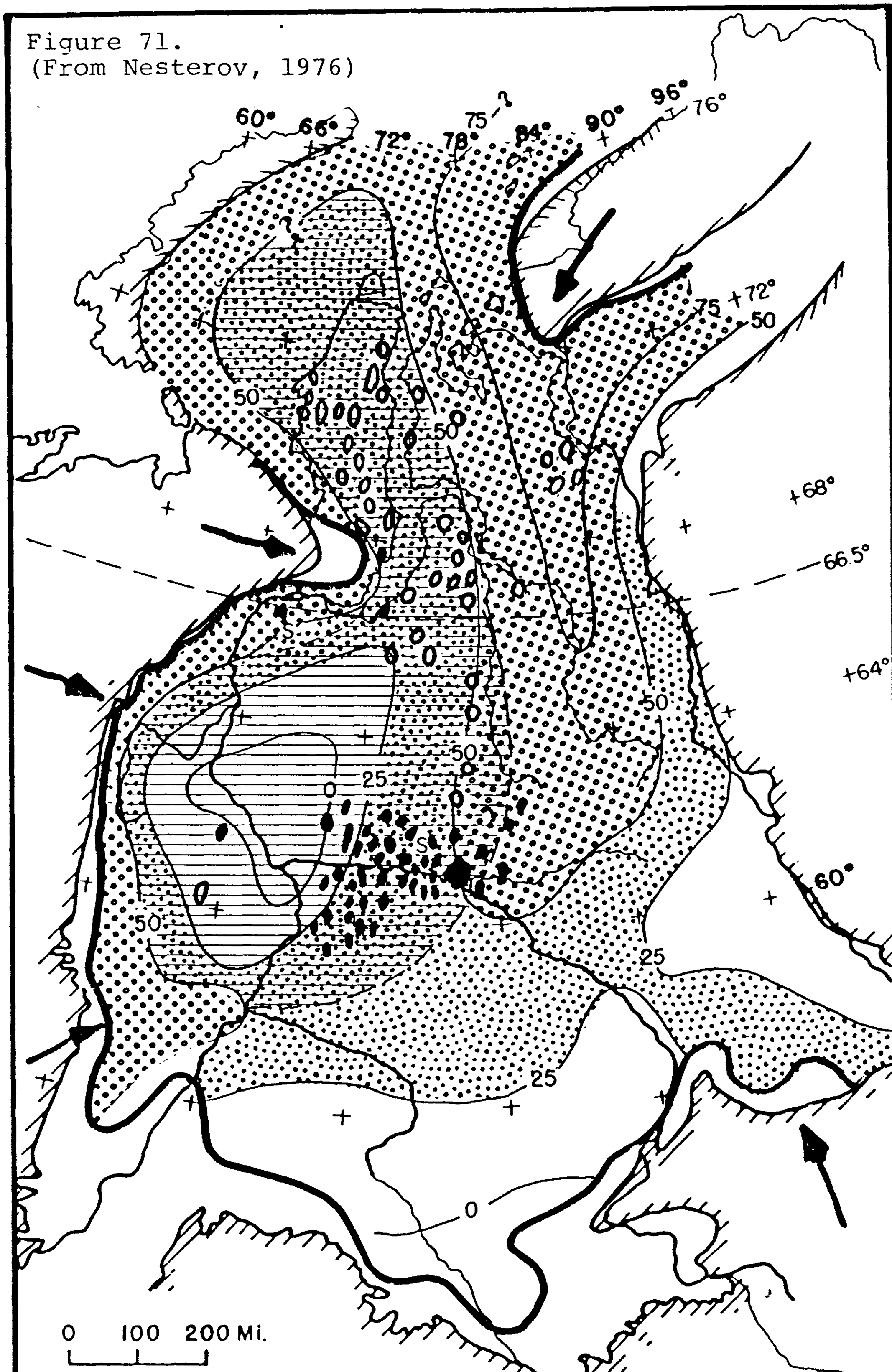


Figure 70. East-west cross section across part of the Middle Ob region, showing intertonguing sandstone, siltstone, and shale facies and oil pools (from Rudkevich, 1988)

Figure 71.
(From Nesterov, 1976)



>50% Sandstone

>25% Sandstone

Predominantly sapropelic organic matter

HAUTERIVIAN–BARREMIAN–APTIAN

Oil Field–not to scale

Gas Field–not to scale

and south. There was very little source area on the east because drainage of the Siberian craton was to the east, leaving very little area between the West Siberian basin and the Siberian craton immediately on its east for supply of detritus westward. Further, the western part of the Siberian craton was covered with Triassic basaltic flows, or had sedimentary rocks exposed, and consequently could not have supplied the arkosic sands for the West Siberian Neocomian deposits. Judging from coarse clastic distribution, another important source area was present in the Taymyr uplift region on the northeast border of the basin (figs. 30-34, 68-71). A less prominent source area that supplied clastic material was the Ural Mountain uplift. The main reservoir facies was deposited near the Neocomian shoreline, which fluctuated east and west across a major northsouth central basin paleo-platform region (Khanty regional high) (Erv'ye, 1974; Yermakov and Skorobogatov, 1984). This paleogeographic pattern resulted in deposition of a thick complex of sandstone and siltstone reservoir beds, separated by transgressive marine shale tongues, many of which are of source rock quality (figs. 30-34, 68-71). These facies changes are well exemplified on the Nizhnevartov and Surgut arches, major segments of the paleo-platform, which contain the bulk of Neocomian oil reserves of the Middle Ob region. Foredelta, shallow bay, and subaerial plain sediments are recognized in the eastern part of the Nizhnevartov arch, grading westward to mainly open marine shaly facies in the western part of the arch. Upward, the section becomes more brackish, lagoonal, and lacustrine, and the maximum sandstone and siltstone content shifts westward, a consequence of regressive conditions late in the Neocomian. Clay content of individual horizons generally decreases from west to east, while sand sorting and reservoir porosity-permeability increase. Porosity and permeability also increase upward in individual horizons because of lower clay content and better sorting. The distribution of clastic sediments was controlled not only by the shifting fluvial-deltaic and marine environments, but also was affected by gentle tectonic movements of the floor of the sedimentary basin. Undoubtedly, superimposed eustatic sea level fluctuations also influenced distribution of the coarser reservoir and associated facies.

Neocomian reservoir sands in the Middle Ob region are composed of 25-40% quartz, 30-55% feldspar, and 3-6% mica, and are of 0.09-0.18 mm grain size. To the north (Urengoy and Gubkin fields), these sands are 25-50% quartz, 30-50% feldspar, and 3-10% mica and are of 0.1-0.14 mm grain size (Zaripov and Kulskhnetov, 1974).

Pools in the Middle Ob region are almost all oil or oil-gas. Only in the Cenomanian reservoirs in this area are pure gas pools found (e.g., Samotlor field). Residual oil in these gas pools suggests that the traps were once filled entirely by oil, and that oil was later displaced out of the traps by thermal gas resulting from greater subsidence of the source beds or by gas liberated from solution as a result of Tertiary uplift, erosion, and reduction of formation pressure.

With depth, there is a general decrease in oil density, tar, asphalt, and sulphur, and an increase in paraffin content (Ozeranskaya, 1979). Most stratigraphic traps are found within the regional pinchout (shaleout) zones of the sandstone horizons. Regionally, the shaleout zones run southwest to northeast across the approximate basin center (figs. 68-71) (Binshtok, 1980).

Stages of oil-gas accumulation in Neocomian reservoirs of the Middle Ob region are analyzed by Ozeranskaya (1979) and Schepetkin (1980) as follows:

First stage - early Turonian time; first phase of oil-gas accumulation in the Middle Ob region.

Second stage - oil filling completed by the end of the Mesozoic.

Third stage - Migration of gas-condensate and gas from depressions to the north of the Middle Ob region, related to neotectonic uplift and separation of gas from solution in formation waters. This process resulted in formation of the gas caps.

Source Rocks - Neocomian rocks, mainly clays or shales, are dark colored and bituminous, particularly in the lower part, in much of the western and central basin areas. Humic organic material is present in variable amounts in the eastern and southern parts of the basin and in parts of the Near-Ural western fringe of the basin (figs. 30-34, 64, 68, 69, 71). Higher values generally are found in the Berriasian and Valanganian section, but values as high as 1% or more also are present in the Hauterivian-Barremian section. In general, reported values are higher in the north basin. Calculations on type and distribution of organic matter in the basin are given by Yermakov and Skorobogatov, (1984d):

Berriasian-Valanginian

West and central regions of platform (predominantly sapropelic and humic-sapropelic disseminated organic matter)	0.5-2.0% (av. 0.66%) in clays; 0.3-0.6% (av. 0.5%) in sandstones and siltstones
Northern region (humic components are greater and coal beds are present)	1.05% av. in clays; 0.65% av. in sandstones and siltstones

Hauterivian-Barremian

Middle Ob and Mansiysk region (sapropelic-humic disseminated organic matter, grading to sapropelic)	0.3% in east to 1.0% in west (av. 0.49%) in clays; 0.2-0.6% (av. 0.35%) in sandstones and siltstones
Northern region	0.89% av. in clays; 0.70% av. in sandstones and siltstones

Aptian-Cenomanian

(mostly humic disseminated organic matter)	1.11% av. in clays; 1.02% av. in sandstones and siltstones Concentrated organic matter (coal beds) comprises 3-5% of total organic matter in Aptian-Cenomanian.

Thickness of beds of concentrated organic matter (coal) in the Neocomian-Cenomanian sediments of the north of West Siberian basin ranges from 10 to 15 m (33 to 50 ft) along the margins of the basin to 30 m (100 ft) in the central parts. The total mass of organic matter in West Siberia is as follows:

Berriasian-Valanginian, 6.7 x 10^{12} tons; Hauterivian-Barremian, 10.0 x 10^{12} tons; and Aptian-Cenomanian, 48.4 x 10^{12} tons.

Yermakov and Skorobogatov (1984) give the following calculations:

Oil-gas complex	Disseminated organic matter	Total content of organic matter (10^{12} tons)	Hydrocarbons generated 10^{12} tons		
			Methane	Bituminoids	Total
Aptian-	Humic	17.10	0.230	0.049	0.279
Cenomanian	Sapropelic	4.27	0.097	0.307	0.404
Neocomian	Humic	11.22	0.273	0.063	0.336
	Sapropelic	11.22	0.385	1.406	1.791

According to Yermakov and Skorobogatov (1984), maximum temperature achieved in the Neocomian beds was 90-140°C, and the type of hydrocarbon was controlled largely by the type of organic matter. From south to north in the central basin area, the composition of disseminated organic matter changes from 60-90% sapropelic and humic-sapropelic in the Middle Ob area to 30-40% in the Nadym-Pur and Pur-Taz regions, to 20-30% on the Yamal and Gyda Peninsulas, accompanied by a northward change to less marine material. In the same direction, a shift occurs from predominantly oil in the Middle Ob region to gas-condensate-oil immediately north of the Middle Ob area, then to gas- condensate farther north. Small oil rings are present in the Urengoy, Taz, and Yamburg areas.

Seals - Shale (clay) units of both marine and nonmarine origin and of both regional and local extent are common within and overlying the Neocomian section. Most widespread are the marine shale units deposited during major transgressions following deposition of deltaic, interdeltaic, and alluvial plain regressive facies, which contain the main reservoir sandstone and siltstone units. Within the Neocomian-basal Aptian sandstone complex, individual sandstone reservoirs were locally sealed contemporaneously by interbedded clay units deposited during brief minor transgressive stages following coarser clastic deposition. Regional sealing of the Neocomian sandstone complex was completed by deposition of the thick transgressive marine shale of the Alym Formation. No evaporite seals are known in the West Siberian basin.

Traps - Almost all petroleum accumulations in Neocomian rocks thus far have been found on anticlines or arches, many of them inherited from older basement uplifts. However, few of the reservoir bodies are continuous over long distances but rather tend to be highly irregular in thickness, extent, grain size, and clay content within a given horizon. Thus a strong stratigraphic trapping aspect is present in most fields, and many pool traps are located on the flanks of structures as well as on the crest. In the Surgut arch region, Mamleyev (1976) recognized 19 stratigraphic pools containing three giant, two large, and one medium-sized accumulations. Twenty-three percent of the reserves on this arch are estimated to be from such stratigraphic traps. Most structural traps occur in the regional northwesterly and westerly pinch-out zones of the reservoirs and complexes. Pinchouts (or shaleouts) of the sands are currently being mapped by common depth point seismic surveys (Binsktok, 1980).

In horizon BV-10 on the Nizhnevartov arch, at least 20 productive sands are present, most of which shale out in short distances (Lysyanskiy, 1981). Thickness of individual sands is highly variable, and clay sections occur between sands. In one single interval (Horizon BS-10) of the Surgut arch region, a large area of potential stratigraphic trap accumulations is being outlined in a north-northeast belt 30 to 80 km (20 to 50 mi) wide and 300 km (200 mi) long between the Mamontovo field on the south and the Muravlenko field on the north (Nesterov and others, 1985). Within this belt, there are 16 pay zones in the lower Cretaceous, as well as additional pays in the Jurassic. The combination of continuous paleotectonic growth and shifting depositional environments characteristic of the West Siberian basin combine to make the prospects for finding significant stratigraphic trap pools of major importance for future exploration.

Middle Ob Region - The Middle Ob is the most important oil-producing region of the West Siberian province. Approximately 94 oil and oil-gas fields are present in this region, most of them productive from one or more of approximately 30 or more reservoir horizons in the Lower Cretaceous, primarily Neocomian sandstone and siltstone sections. Two large regional uplifts, the Nizhnevartov and Surgut arches, contain the major oil reserves of the province. Exploration began in the Nizhnevartov arch area in 1957. The first field, Megion, was found in 1961, and the supergiant Samotlor field in 1965. On the Surgut arch, there are 71 structural closures on the top of the Jurassic, 53 on the base of the Aptian, and 38 on the top of the Cenomanian. The pattern is very similar for the Nizhnevartov arch. Most pools are on anticlinal or domal structures, although a strong stratigraphic aspect is associated with most fields. Sandstone horizons are interbedded with shales in the Middle Ob region, and many traps formed penecontemporaneous with deposition as a result of sandstone lensing, pinchouts, shaleouts (facies changes), and differential compaction. As of December, 1984, the Samotlor field, largest in the Soviet Union, had produced 14.7 BB oil. The field peaked in 1980 at 3.0 MMB/D and for 1985 was at 2.8 MMB/D. Cumulative production by January, 1986 was 12,825 MMB (International Petroleum Encyclopedia, 1987). According to the Oil and Gas Journal (8/12/85), the field has been vastly overdeveloped and damaged in attempts to maintain planned growth of Soviet oil production. A detailed analysis of the Samotlor field is found in Nesterov and others, 1971; Clarke and others, 1977.

<u>Northern area</u> - The Neocomian beds are largely gas prone in the north basin area, related to the increase in humic organic material north of the Middle Ob region. North of the Middle Ob region, Neocomian sandstone and siltstone reservoirs of horizons BU_{8-12} of the Megion Formation (Upper Valanginian-lower Hauterivian) are productive of gas and condensate in several fields, all of which also contain gas accumulations in Aptian-Cenomanian reservoirs. Horizon TP_{1-6} of the Tanopchin Formation (Aptian) also contains gas accumulations on the Yamal and Gyda Peninsulas. Fields in the northern area are all on anticlines or arches, some of large areal extent.

Neocomian reservoirs are productive of gas-condensate and some oil in several fields in the Nadym Pur and Pur-Taz regions, including the supergiant Urengoy field, which now has oil production probably from Valanginian sands. Oil as well as gas-condensate pools also are present in the Novoport field in the southeastern Yamal Peninsula area. Farther northwest on the Yamal Peninsula, numerous gas-condensate pools and several oil pools in Valanginian, Hauterivian, and Berriasian sands are present in several fields, which also are gas-productive from Cenomanian sands (figs. 17, 31-34, 73).

In the Ust'-Yenisey region of the northeastern basin, several gas fields are present, some of which contain gas-condensate pools in Valanginian and Hauterivian reservoirs as well as Cenomanian reservoirs. All of these fields are on anticlinal or domal structures in a region of

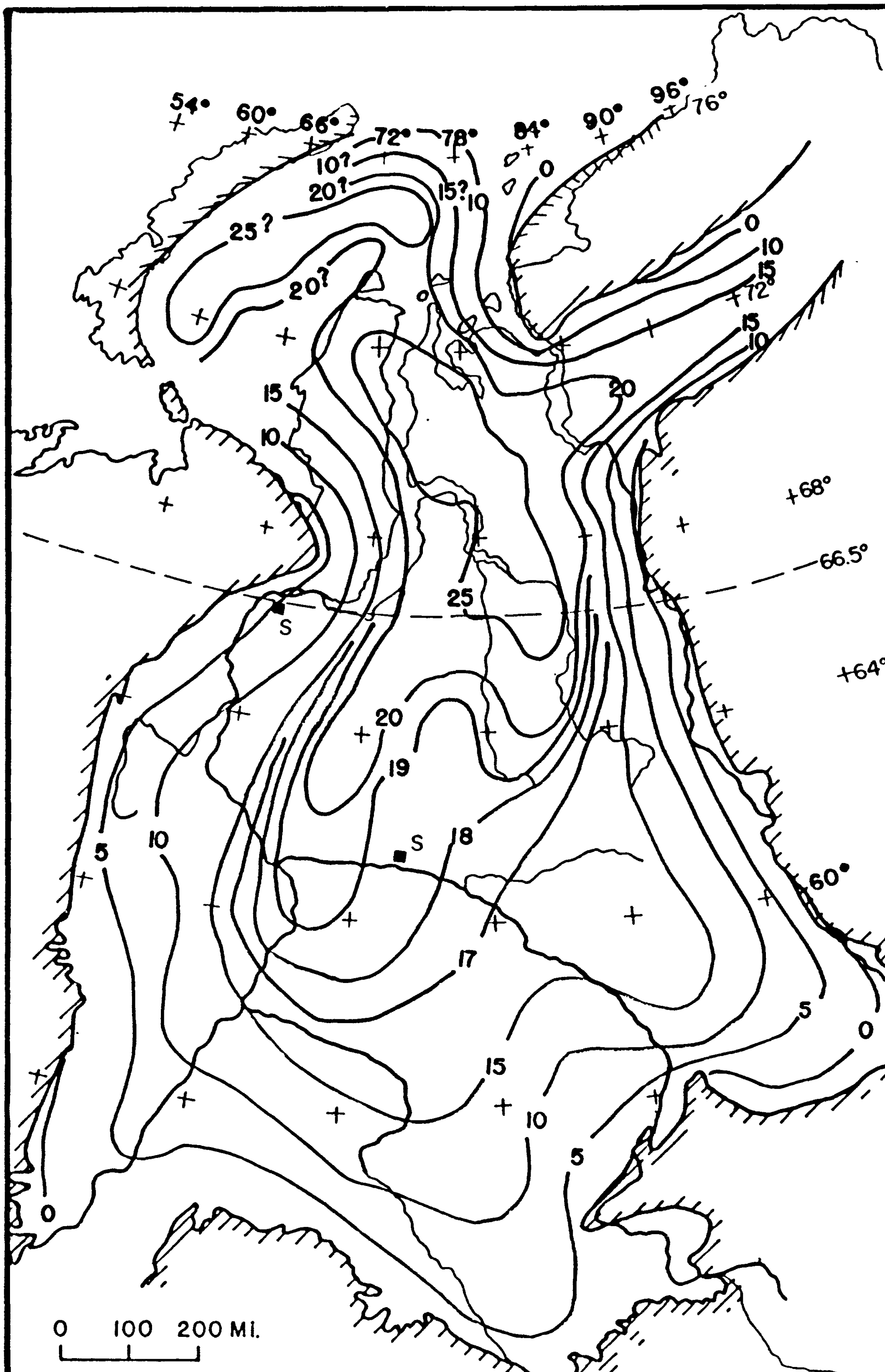
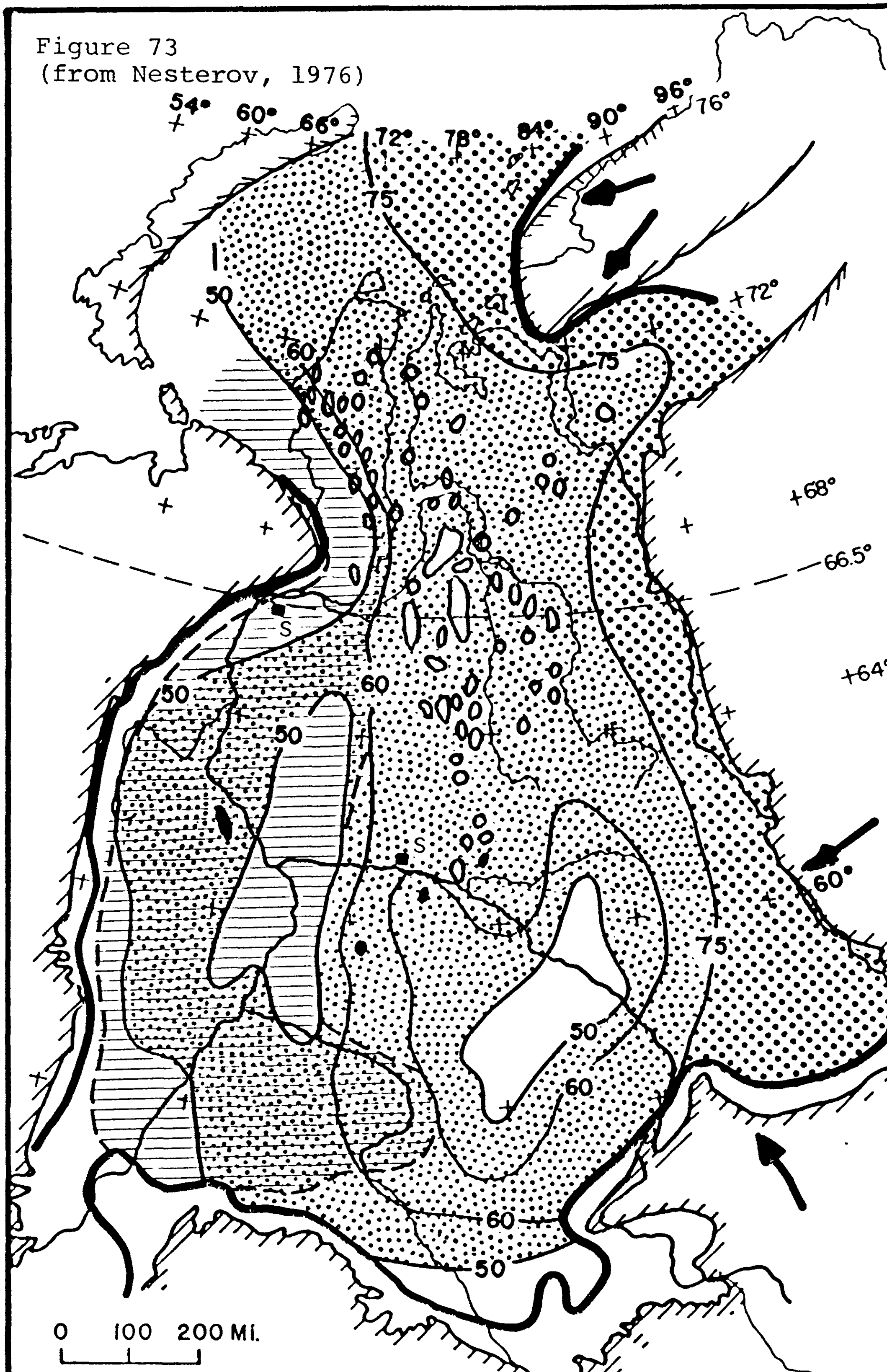


Figure 72. POST-NEOCOMIAN ROCKS
Thickness, hundreds of m.

The thickness approximately equals depth to top of Neocomian rocks.

Figure 73
(from Nesterov, 1976)



APTIAN-ALBIAN-CENOMANIAN

>75% Sandstone

>50% Sandstone

Predominantly sapropelic organic matter

Oil Field-not to scale

Gas Field-not to scale

Direction of sediment transport

the province where Neocomian rocks are high in sandstone content and contain primarily humic-type organic material (figs. 29-34, 68, 69, 71).

Many of the sandstone-siltstone reservoirs in all these fields are dis-continuous in nature and are interbedded with clay or shale beds, which provide local seals. The thick Aptian-Albian shale section provides an effective regional seal for pools in all of the northern area (figs. 17, 18). In most of the northern area, Neocomian reservoirs are buried to depths of 1,500 to 3,000 m (5,000 to 10,000 ft) or greater (fig. 72).

Aptian - Albian - Cenomanian

Hydrocarbon production from post-Neocomian, primarily Cenomanian, reservoirs is almost entirely gas or gas-condensate in fields north of the Middle Ob region (figs. 37, 39, 56, 73). Approximately 60 gas and gas-condensate fields have been found, many of them of giant or supergiant size. Approximate size of the largest are: Urengoy, 200 by 20-30 km; Medvezh'ye, 120 by 25 km; Yamburg, 170 by 45 km; Zapolyar, 50 by 30 km; and Taz, 26 by 15 km. Production is from thick, loosely-compacted, friable sandstone and siltstone reservoirs interbedded with silty clays containing terrestrial plant remains and coal beds. Total thickness of permeable beds is as much as 500-800 m (1,600 - 2,500 ft). Sandstone content increases from west to east, reaching 60% or more to as much as 80% over a broad area of the eastern basin (fig. 42). Eighteen main pays are present (PK_1 - PK_{18}) at 500-1,800 m (1,600 - 6,000 ft) depths (figs. 74, 75). Most deposits are in the massive pools of the PK_1 - PK_6 reservoir units in the upper part of the Pokur Formation (Yermakov and Skorobogatov, 1984).

The largest is the pool in PK_1, where the gas column is 213 m (700 ft) high. The Cenomanian pools are massive blanket sandstone deposits laid down during the major Albian-Cenomanian regressive stage of basin evolution, occuring just below the thick Turonian. Sixty-two percent of the proven reserves of non-associated gas in the West Siberian basin are in these reservoirs. These gases differ greatly from those of the Lower Cretaceous and Jurassic, which contain a wide range of heavier hydrocarbons, reaching a maximum of 30% or more C_2H_6 in the Middle Ob region. Gases in the post-Neocomian are mainly dry methane with only a small percentage of higher gases, mainly ethane and almost no N, CO_2, or H_2S, a composition related to generation from humic organic matter at the B_2-B_3 stage or coalification or to bacterial destruction of all gases heavier than methane. The gases are low in condensate, e.g. at Urengoy, 0.20 g/cm^3 gas and Medvezh'ye, 0.25 g/m^3 gas. The gases in the Lower Cretaceous, however, are very high in condensate, values ranging from 56 to 610 g/m^3. Very high reserves of condensate are found in some fields.

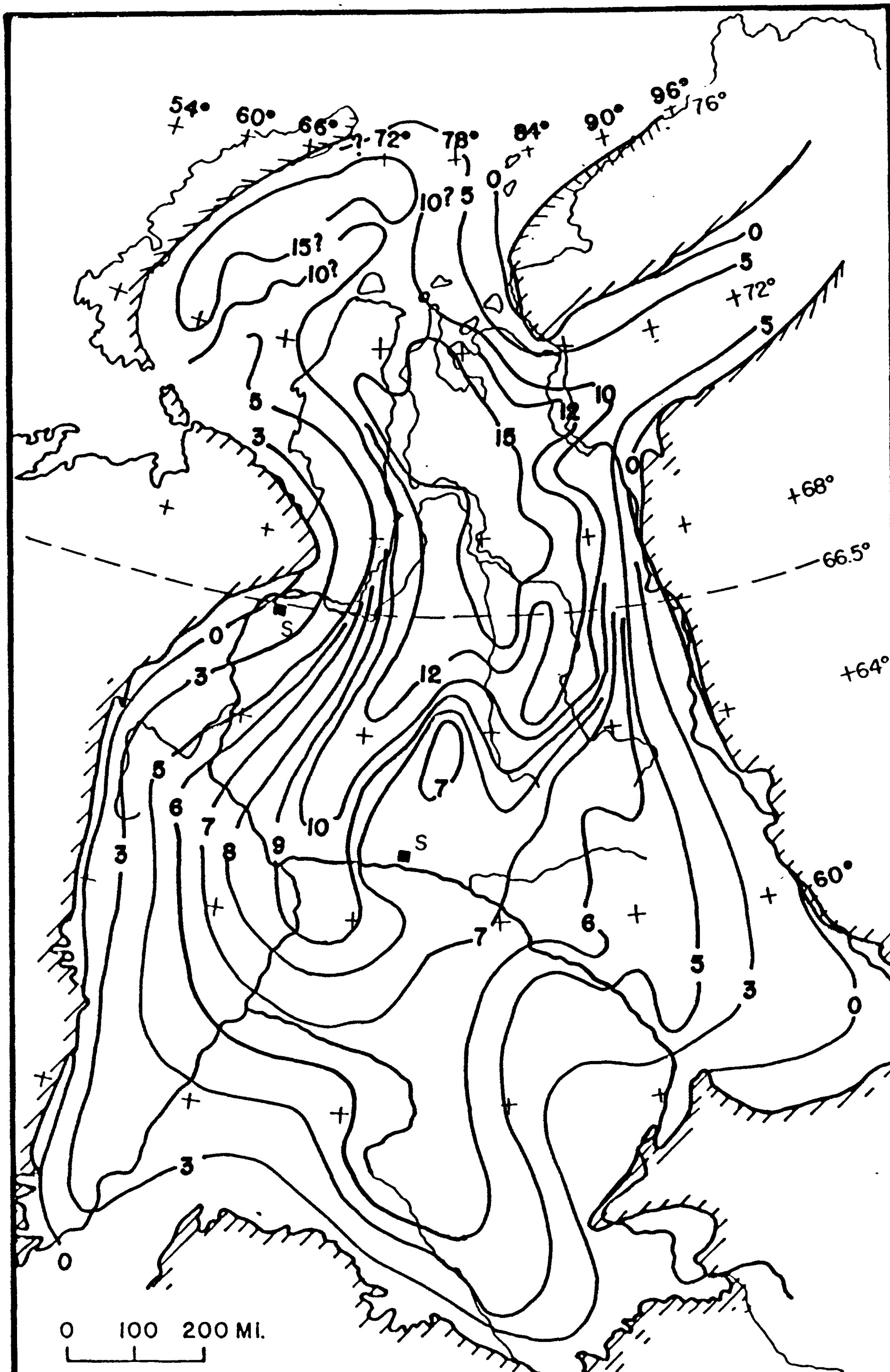


Figure 74. POST-CENOMANIAN ROCKS
Thickness, hundreds of m.

Thickness equals approximate drilling depth to top of Cenomanian

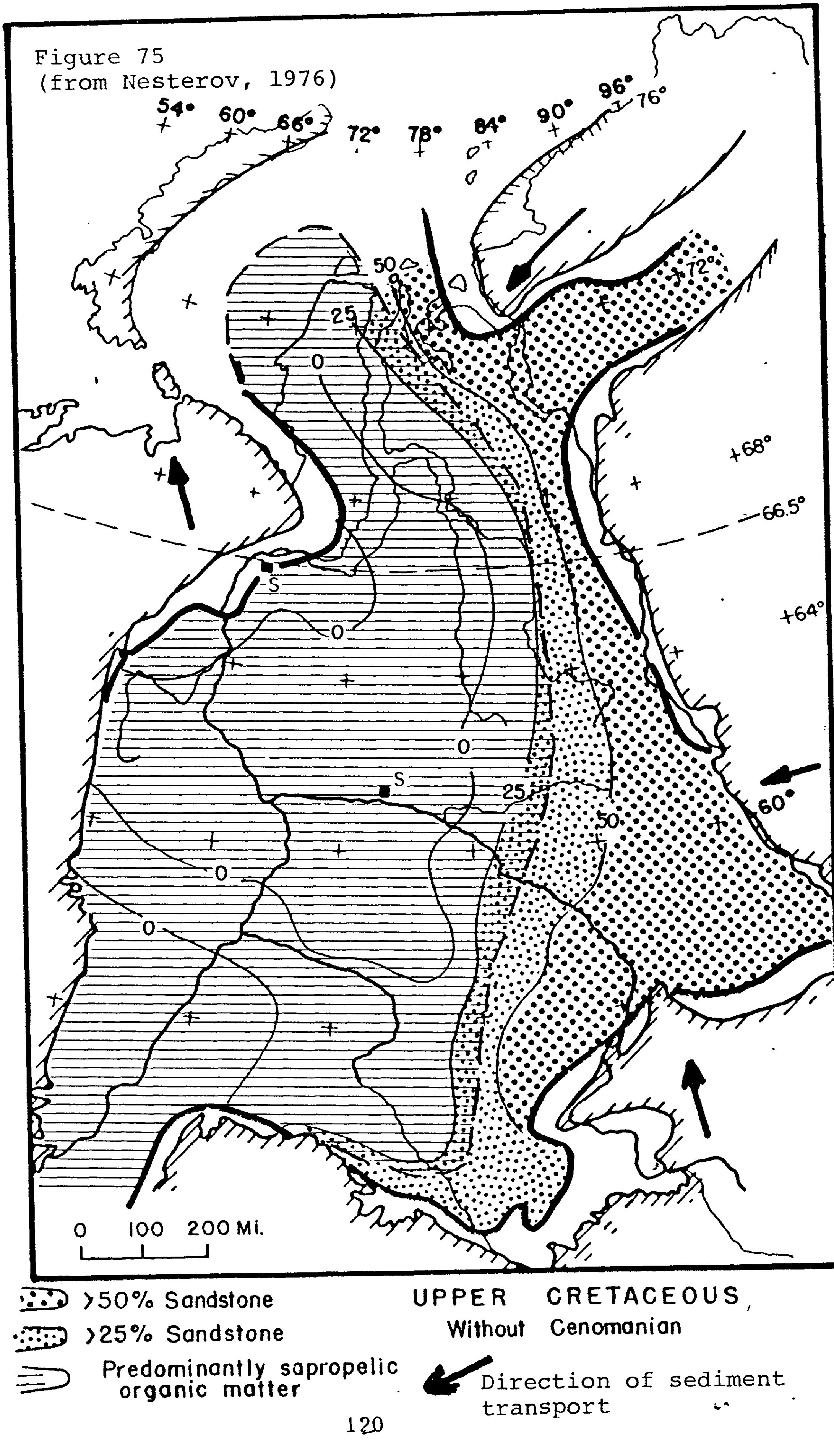


Figure 75
(from Nesterov, 1976)

According to Yermakov and Skorobogatov (1984), the main factors accounting for the huge reserves of gas in the north basin are:

1. High contents of disseminated and concentrated (coal) organic matter of humic composition matured at subbituminous stage of catagenesis to form large quantities of gas.

2. Large volumes of source and reservoir rocks in which migration capacity was high.

3. Large structures with great closure far from the borders of the basin.

4. The presence of thick seals.

5. Relatively "young" age of formation of the gas accumulations.

These genetic conditions are best for the Hauterivian-Cenomanian sediments of the central part of the northern region (Urengoy, Yamburg, Taz, and Nadym) and to a lesser degree for the Valanginian sediments of the Nadym-Taz interfluve and also the Neocomian-Aptian and Albian-Cenomanian sediments of the Yamal and Gyda oil-gas regions. The differences in vertical distribution are governed by the presence of seals in the section (Yermakov and Skorobogatov, 1984).

Calculations show that at the end of the Cenomanian the organic matter of the Hauterivian-Cenomanian sediments reached the middle brown coal stage. High concentrations of coaly material led to generation of large amounts of methane. Most of this gas was lost, because no seal was yet in place. A second stage of generation began in the Turonian after the Cenomanian and older reservoirs were well sealed by the overlying regional Turonian clays. Gas did not migrate from deeper horizons at this time because it was sealed by Aptian-Albian and Neocomian clays. Between Turonian and middle Oligocene time, gas generation continued as organic matter reached the early long flame coal stage. This gas was trapped in Cenomanian and older reservoir sands. The lower part of the thick Turonian clays may have generated substantial amounts of biogenic gas which, unable to escape upward, migrated downward to contribute to the almost pure methane in the Cenomanian reservoirs. In the middle Oligocene and Neogene, gas generation essentially ceased because of regional uplift, but redistribution of the earlier trapped gas accumulations occurred. The decrease in pressure accompanying the late Tertiary uplift and erosion certainly led to release of gas from solution in the formation waters of the Mesozoic sediments, thereby adding yet more gas to that already present in the reservoirs. Still other quantities of gas may have been supplied from the formation waters as a result of freezing to great depth during glacial times. As the rock became frozen, the gas in water solution would have gone into the gas hydrate stage. On subsequent thawing during interglacial time, part of the gas released by melting of the hydrates would remain as free gas to collect in the reservoirs.

CONCLUSION

Among the world's petroleum provinces, the West Siberian basin is geologically distinctive in several aspects. The factors of basin size, paleostructural history, continental-marine facies interchange and cyclic depositional history, abundant source rock and reservoir facies, and efficient petroleum generation and preservation conditions combine to make it one of the world's foremost petroleum provinces. This enormous basin, the world's largest intracratonic basin, underwent a remarkably stable, but paleostructurally mildly-active, Mesozoic depositional history of slow subsidence and basin filling, all of which combined to provide optimum environmental conditions for petroleum accumulation and preservation. Terrigenous sediment influx, mainly from the southeast, was sufficiently great for coarse clastic materials to spread widely across the eastern half of the basin and intertongue with marine sapropelic facies of the open basin to the west. At the same time, the basin was sufficiently large and subsidence rates were great enough that terrigenous sediment influx did not fill it entirely. This imbalance allowed the development of partially starved-basin conditions in much of the west half of the basin, where as much as 2,500-3,000 m (8,000-10,000 ft) of dark marine shale, much of it rich in organic matter, was deposited between Middle Jurassic and early Tertiary time. During most of Early Cretaceous time, the site of the deltaic-open basin transition was across the central basin area, the Khanty regional high, a regional paleostructural feature of the basin apparently inherited from late Paleozoic Hercynian tectonic activity. Continuous but mild paleostructural growth of the Khanty regional high and associated smaller structural elements provided a broad shallow-water intrabasin platform where the immense deltaic and continental eastern facies spread out along the fluctuating Lower Cretaceous shoreline belt. Minor transgressive-regressive cycles of sea level change and paleostructural growth in this environmental setting provided optimum conditions for reworking and winnowing the feldspathic deltaic and interdeltaic sands, with consequent improvement of reservoir characteristics. During transgressive phases of the minor cycles, the outer deltaic belt shifted eastward, and marine sapropelic muds were deposited over and intertongued with deltaic fringe, longshore, and channel sand bodies to provide a remarkably efficient source rock-reservoir-seal interrelationship.

Continuous mild structural growth of the central basin was a major factor in allowing this combination of circumstances to exist for sufficient length of time to construct such a regionally extensive reservoir-source rock complex as exists in the Nizhnevartov, Surgut, Urengoy, Yamburg, and other areas of the central basin. The extensive data on source rock parameters published by Soviet geologists show that the source rock quality of the basin is unusually high. This aspect appears to be related in part to the regional paleostructure of the basin, with relatively rapid subsidence of the western basin trough providing a semi-starved restricted circulation depression where accumulation of marine plankton under anoxic deeper-water bottom conditions allowed the preservation of unusually large amounts of marine organic material for ultimate oil generation. The high organic content of the basin may have been partly related to the paleogeographic setting of the basin with respect to the broad, silled connection with the open-ocean Arctic basin on the north. Southward circulation of cooler nutrient-rich marine waters across the North Siberian sill into the warmer-water epicontinental basin would have stimulated the production and accumulation of plankton-derived organic matter to an unusually high degree, particularly during regressive stages of lower sea level.

Aside from these sedimentary and paleostructural factors, a most important aspect of the West Siberian basin is the fact that the entire basin remains essentially intact today. Post-depositional tectonic activity has been only mildly epeirogenic, compared with many other sedimentary basins of the world, so that the early accumulations of petroleum in stratigraphic and structural traps remain relatively undisturbed and therefore preserved.

Over the past 20 years, the West Siberian basin, particularly the central part, has undergone relatively intensive exploration. However, large segments of the basin region are relatively unexplored, particularly the South Kara Sea basin and the Yenisey-Khatanga trough. Both these areas are promising, especially for natural gas and probably oil. Burial depths for Jurassic rocks are greater than 4 to 5 km in the deeper parts but are probably less than 3 km in much of these areas (fig. 67). The major Jurassic and Cretaceous source rock facies should extend northward into both these regions (figs. 17, 25-42). The Taymyr uplift and probably Novaya Zemlya were clastic source areas during most of Mesozoic time. Reservoir sands sourced from these uplifts should be present in stratigraphic relationship with source rock facies and seals, not unlike that of the productive areas to the south.

Most of the basin reserves of both oil and gas have been found in local structures on regional highs, but many of the pools are stratigraphic (lithologic of Soviet authors) or combination structural-stratigraphic. The intertonguing cyclic sequence of deltaic and nearshore marine sandstone, siltstone, and bituminous shale facies characteristic of much of the basin deposition should provide excellent prospects for stratigraphic trap accumulations. Important resources of undiscovered oil and gas will undoubtedly be found in such traps, similar to many of those already found in the Middle Ob area (figs. 17, 18, 70).

U.S. Geological Survey modal estimates of undiscovered conventionally recoverable petroleum resources for the West Siberian basin (1987) are 30 BBO (billion barrels oil) and 350 TCF (trillion cubic feet) gas.

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