PETROLEUM GEOLOGY OF THE WEST SIBERIAN BASIN AND A DETAILED DESCRIPTION OF THE SAMOTLOR OIL FIELD

BY

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature The authors would appreciate comments and suggestions on the report.

1977

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INTRODUCTION

Purpose of Study. The ever increasing importance of energy availability to the world economy dictates that we understand known and potental energy resources. Resources of oil and gas can be better estimated if the geology of the producing region is taken into account and if suitable models for application to undiscovered areas are developed.

The present study is the first in a series of planned studies of important oil-gas regions of the world. It is a compilation, along with some interpretation, of the geology of the West Siberian Basin and a description of the Samotlor oil field, the largest field of the USSR. This study was made between May and October, 1977, and the four authors spent a total of about six man-months on its preparation.

The source material for the study was published literature in the U.S. Geological Survey Library in Reston, Virginia. Most of the source material is in the Russian language. Works in English on this subject are by Dickey (1972), International Petroleum Encyclopedia (1977), dMeyerhoff (1975), Rovnin et al (1975), Zhavrev et al (1975), Jordan (1976), King (1976) and Robertson Research International, Ltd. (undated).

Summary of Development. Post World War II petroleum exploration in the West Siberian Basin has been underway since 1948. Gas was discovered in 1953 at Berezovo in the northwestern part of the basin, and the first important oil discovery in the basin was in 1960 at Shaim, south of Berezovo, in a Jurassic sandstone reservoir. (See Figure 42 for location of fields.) The oil potential of the region became apparent in 1961 when a major discovery (Megion) was made in the region of the middle course of the Ob River from Lower Cretaceous sandstone reservoirs. In the same years, the giant Ust'-Balyk field was found on the Surgut dome. This field contains 16 Lower Cretaceous sandstone reservoirs with a total thickness of 100 meters (330 feet) (King, 1972). The giant Samotlor oil field, largest in the basin, was discovered in 1965. It produced 2,200,000 B/D in 1976--about 20 percent of total USSR oil production. Production is expected to peak eventually at 2,700,000 B/D (King, 1977, p. 1721; International Petroleum Encyclopedia, 1977, p. 213).

GEOGRAPHY

Location and environmental setting. The West Siberian oil and gas province occupies an extensive lowland of about three million square kilometers between the Ural Mountains on the west and the Yenisey River bounding the Central Siberian Platform on the east (See Figure 1). The recognized petroleum province extends 200-400 km northward offshore into the Kara Sea.

Many of the environmental factors significant to petroleum exploration and development such as permafrost, soils, and vegetation have a definite latitudinal zoning. North of the Arctic Circle, permafrost is extensive and thick, soils are highly organic, vegetation is sparse or limited to grassland and tundra, and the ground is frozen and snow-covered most of the year. Between the Arctic Circle and about 58°N, which includes the Samotlor oil field, dense forests and numerous peat bogs cover large areas, permafrost is not as extensive, climate is less extreme, and thawing starts earlier than in the Arctic zone. The southern margins of the area are characterized by higher, more dissected terrain without permafrost, cropland is predominant and conditions are more favorable for transportation than elsewhere in the area.

Landforms. Most of the area is a low (less than 100 m above sea level) flat to rolling saucer-like plain, tilted downward to the north, into which streams drain from the adjoining higher terrain.

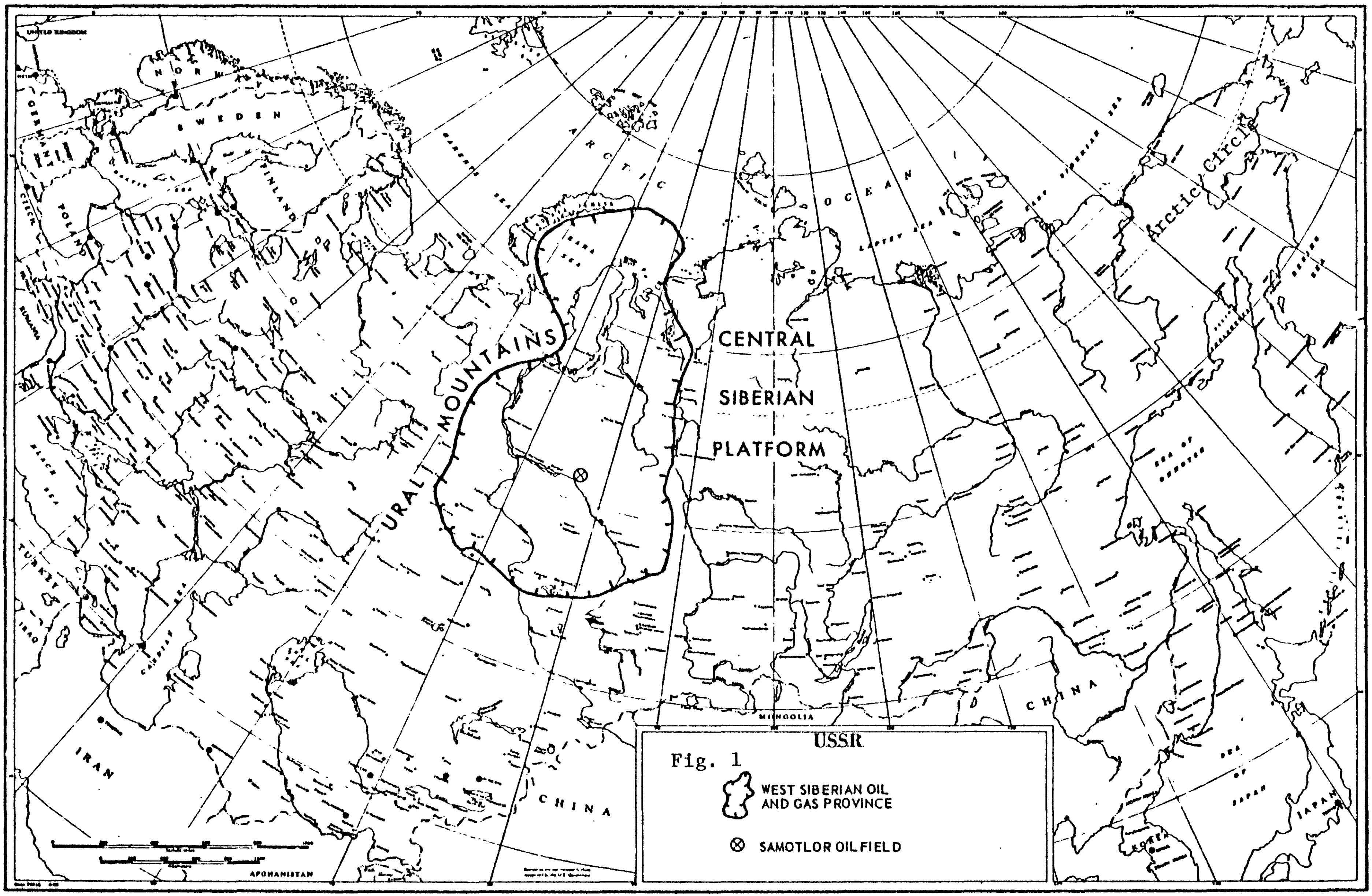


Figure 1. Location of West Siberian Basin and Samotlor oil fields
Modified from Kontorovich, 1975.

The major drainage is northward. Long, wide, deep rivers which meander across the vast marshy and forested, lake-strewn plain to the Arctic Ocean. The coastline is irregular, broken by long embayments and numerous close islands.

Soils and vegetation. Three distinctive zones are present: (1) North of the Arctic Circle, highly organic soils of peat over sand and clay are widespread and are especially thick along rivers. North of about 72°N, Arctic barrens have only spotty turf of dwarf grass, herbs, and lichens less than a foot tall and scattered shallow peat bogs. Southward, grassland, grassy tundra, and dense scrub tundra also include scattered shallow peat bogs. (2) South of the tree line, which is near the Arctic Circle, to the latitude of Tyumen and Tomsk, very deep sand, clay, and peat soils support dense evergreen and deciduous taiga forest. Numerous peat bogs with thick peat over sand and clay also characterize this zone. (3) In the southernmost areas, cropland with patches of forest and fields of grass are common on deep to very deep fine-grained soils. A few areas of very deep sand are also present.

Permafrost. Permafrost occurs in much of the area north of about 60°N in three zones: (1) North of the Arctic Circle, permafrost is mostly continuous and generally more than 200 m thick; the active layer is only .5 - 1.0 m thick. In places, the permafrost is more than 600 m thick. Along river valleys, the thickness of permafrost decreases. (2) From the Arctic Circle south to about 62°N, permafrost is not continuous, but commonly there are two layers of permafrost separated by unfrozen ground (talik). The upper (Recent) permafrost layer ranges from 10-100 m in thickness and the talik from 10-50 m. The top of the lower (Pleistocene) permafrost occurs at depths of 80-200 m, and extends down to 200-300 m below the surface. (3) Between 62°N and 60°N, only Pleistocene permafrost is present, the top is generally 150-200 m below the surface and its thickness is 100-200 m. In much of West Siberia, especially in areas with permafrost, icings (masses of surface ice formed in winter by freezing of ground-water seepage) are common, and they may attain a thickness of 10 m, cover several kilometers, and remain unthawed for several years.

Drainage characteristics. Riverflow regime and ice regime vary considerably from north to south. In most of the area, high water, ice jams, and extensive flooding occur from May to August or September. Floods rise as much as 20 m in the lower Yenisey River and extend over 48 km in width in the lower Ob' River. Large areas are more than 50 percent lake covered part of the year. Most rivers and lakes have 2 m of ice or are frozen solid from early December to late March and those in the extreme north freeze in October. The southernmost areas have interior drainage. Many streams and lakes are intermittent, having an abrupt rise after snowmelt in May and a swift fall in late May or mid-June. Many lakes are saline. Ice cover of less than one meter is common from early December to April or May.

Climate and state of the ground. West Siberia has a great annual range in temperatures (100°F to -70°F). January and February are generally the coldest months, and July and August are the warmest months. In most of the area south of the Arctic Circle, temperatures are above freezing from May through October; north of that latitude such temperatures occur only in July and August.

Precipitation is frequent but not abundant. The mean annual precipitation in most places is 60 cm, mainly snow in the cold months, and occurs on more than 175 days, mainly in fall and winter.

The ground is frozen and snow covered in most of the area from early September or October to May or June. Deepest snow in most of the area is about 40-50 cm. Comparatively thin snow but deep drifts occur along the Arctic Coast. During the warm season, the ground in the northern two-thirds of the area is chiefly moist with numerous intervening wet bogs and marshes; ground in the southern one-third is chiefly dry.

Kara Sea ice begins to form in late August to early September, rapidly develops along the coast, and drift ice 1.5 - 2 m thick nearly covers the sea by the end of the winter. Melting begins at the shore and occurs rapidly in mid-August; some ice remains in the sea year-round, however.

Transportation. Roads and railroads are lacking in most of West Siberia, and road construction and maintenance are difficult because of numerous bogs, marshes and lakes; large areas are subject to flooding. Special engineering techniques are required in permafrost regions and considerable clearing is needed in extensive dense forests. Off-road vehicular movement is commonly limited to winter months when the ground is frozen.

STRUCTURE

Introduction. The West Siberian Basin is one of the largest structural-sedimentary basins of the world, occupying an area of about 3,400,000 sq. km. According to Klemme's (1970) classification, the basin is a Cratonic Type II - intracontinental basin, which, next to the Type IV Intermediate extracontinental basins, is the richest in hydrocarbons. These basins are generally characterized by embayments where wide, flat-bottomed seaways spread over a cratonic platform. Type II basins generally have a disproportionately large share of gas. The North Sea basin and the Rocky Mountain province are also Type II basins.

Age of the basin. A singular aspect of the West Siberian Basin is that it is an almost completely preserved and intact sedimentary basin, relatively undisturbed by post-Triassic tectonism and little changed today from its initial gross form when Pliensbachian (late Early Jurassic) deposition began about 180 m.y. ago. In fact, the basin would become an epi-continental sea if the present icecaps were melted, because most of its area is less than 100 meters above sea level. The modern basin is bounded on the west by the Ural Mountains, on the east by uplands of the central Siberian platform, and on the south by several large plateaus and mountain ranges. To the north it opens into the Kara Sea and the Arctic Ocean. See Figure 1.

Structural subdivisions. Structurally the West Siberian Basin consists of basement rocks, an intermediate structural level of triassic sediments

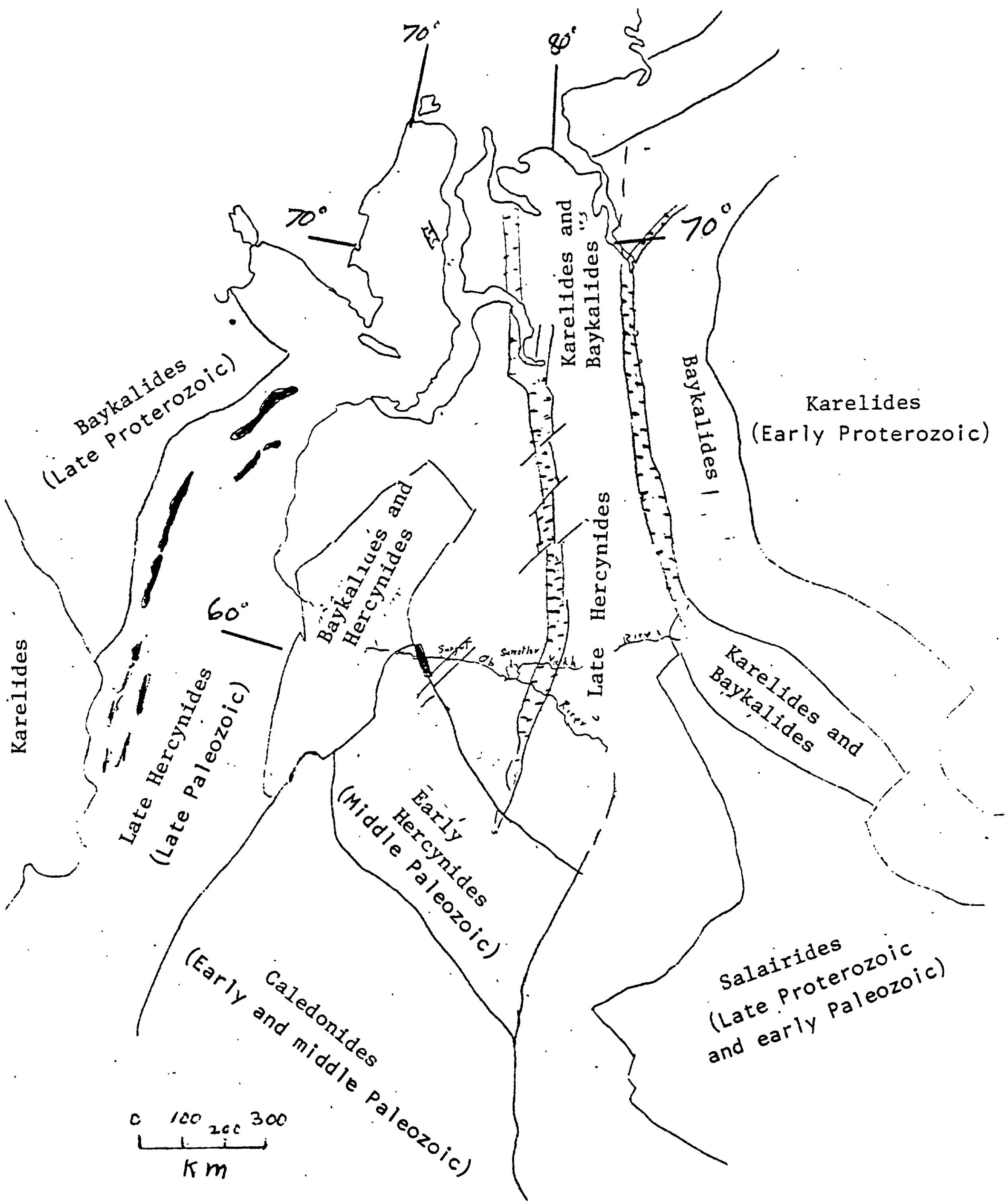


Fig. 2. Tectonic map of basement of the West Siberian Lowland (adapted from Surkov, 1974)

Ultramafics

Graben of post-Paleozoic age

and volcanics, and a sedimentary cover of Jurassic, Cretaceous, and Cenozoic sediments.

Basement rocks. Several structural zones are recognized within the basement of the West Siberian Basin (Figure 2). In the Soviet literature, the basement rocks are designated the lower stratural stage.

The oldest structural zones are two early Proterozoic Karelide zones, one on the far west and the other on the far east. Toward the interior of the basin, these are bordered partly (western zone) or entirely (eastern zone) by late Proterozoic Baykalide zones.

Next inward toward the center of the basin in the southeast part is a zone of late Proterozoic Salairide folding; this is the northern part of the Altay-Sayan fold belt.

An area of mid-Paleozoic Caledonides is present in the south central portion of the Lowland. Between the Caledonide zone and the older structural zones on the west and east are broad zones of late Paleozoic Hercynide folding.

The rocks of these zones are largely igneous and metamorphic; however, late Paleozoic unmetamorphosed sedimentary rocks are present extensively in the southern part of the region between Tyumen and Tomsk (See Figure 3 for general location). Late Hyercynian folding to an extent involved and remetamorphosed rocks of older zones. Ultramafic bodies exposed in the Urals and buried ultramafic bodies just west of Surgut suggest plate boundaries along the western edge of Hercynide zones.

The infrastructure of the basement as outlined above is provisional. These orogenic belts are buried beneath thousands of meters of younger sediment and have been penetrated by only a limited number of drill holes. The central Hercynide fold zone was in fact discovered only in 1967. As more information is gathered over the years, there may be substantial changes in concepts as to the nature of the basement.

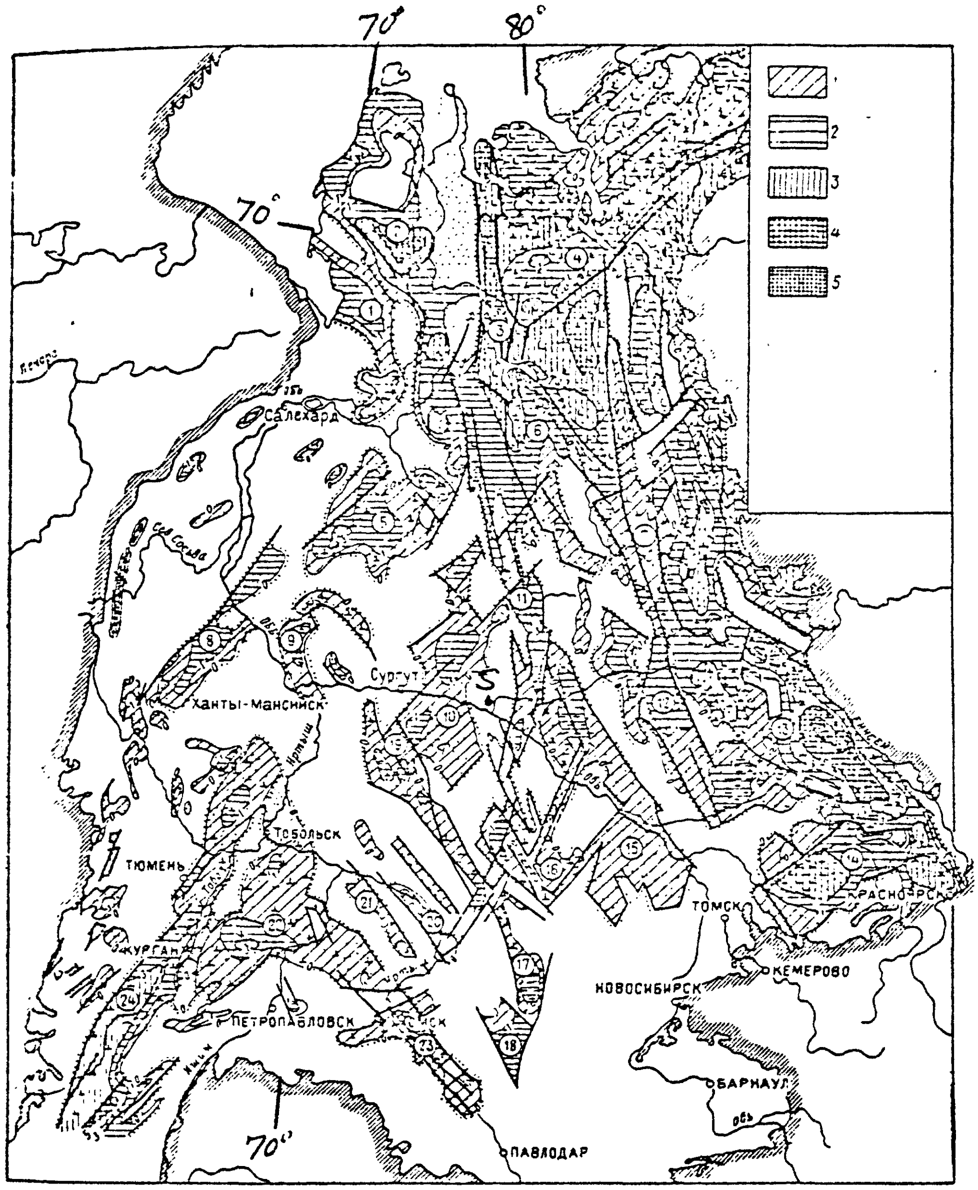
Intermediate Structural Level. Beginning in Early Triassic time, grabens formed on a Late Permian to Early Triassic erosional peneplane on the basement rocks in the southern half of the basin south of the 64th parallel (Kulikov, et al, 1972, p. 370). These grabens are filled by volcanic and continental sedimentary (molasse) deposits and basalts up to 4000 m thick; they are strikingly similar to the contemporaneous Triassic graben of eastern North America. The Triassic sediments in the graben are separated from the overlying Jurassic marine deposits by an angular unconformity of at least 30-45° and are in no way similar to the overlying Mesozoic rocks. The Triassic graben fills constitute a separate intermediate structural level. The southern part of the basin thus appears in fact to have been a highland area during the time of graben filling. The area which is now the site of the Nizhne-Vartov and Surgut domes was the northern part of these highlands. Uplift of the general area of these two domes during Middle and Late Triassic time is estimated at more than 4 km (Bochkarev and Rudkevich, 1973, Figure 2). See Figure 6 for position of Surgut and Nizhne-Vartov domes.

Contemporaneously with the graben filling to the south of the 64th parallel, platformal continental and marine deposition was taking place to the north. Several hundred meters of argillaceous sediments have been penetrated by the drill. Magnetotelluric profiling and seismic surveys indicate a total thickness of this section of 2-6 km (Bochkarev and Rudkevich, 1973, p. 181). These continental and marine deposits are generally conformable with the overlying Jurassic beds, differing only in having somewhat steeper dips (2-6°) on the flanks of folds (Bochkarev and Rudkevich, 1973, p. 183). Consequently, the assignment of the Triassic sediments north of the 64th parallel to the intermediate structural level may be debatable; these beds might more properly be assigned to the upper sedimentary cover. Figure 3 is a schematic map compiled by Surkov et al (1975) showing distribution of Triassic sediments on the West Siberian Basin. This map shows an areal extent of these sediments an order of magnitude greater than that shown on the tectonic map of 1969. Graben deposits are shown covering much of the northern half of the platform in Figure 3. Bochkarev and Rudevich (1973, p. 181) interpret the Triassic deposits in the north as downfaulted remnants of once more extensive blankets of sediments. This lack of agreement simply reflects the paucity of information on the nature and distribution of these rocks.

Sedimentary Cover. (Upper structural stage)

(1) Regional tectonic elements.

The upper structural stage of the West Siberian platform is divided into three large regional elements: Outer tectonic belt, Central tectonic



Approx. scale 1:17 million

Figure 3. Schematic thickness map of sediments of the intermediate structural level (Triassic) of the West Siberian basin. (from Kontorovich, 1975, p. 57). Thickness of sediments: 1 - 0-1 km, 2 - 1-3 km, 3 - 3-5 km, 4 - 5-7 km, 5 - greater than 7 km. Sedimentary basins (numbers in circles): 1-Baydarats, 2-Neytin, 3-Severo-Koltogor, 4-Nizhneyenisey, 5-Nadym, 6-Sredne-Koltogor, 7-Sredneyenisey, 8-Kondin, 9-Frolov, 10-Yuzhno-Pokur, 11-Yuzhno-Koltogor, 12-Tymsko-Ket, 13-Yuzhno-Yenisey, 14-Tegul'det, 15-Narymski-Kolpashev, 16-Nyurol, 17-Varabin, 18-Kupin, 19-Chekin, 20-Muromtsev, 21-Tevriz, 22-Vagay-Ishim, 23-Irtysh, 24-Turgay.

region, and Northern tectonic region (Kontorovich, 1975, p. 191; Rovnin, et al, 1975, p. 142). (See Figure 4.) The boundary between the central tectonic region and the northern tectonic region is a hinge line; the northern area subsided significantly more than did the central area throughout Mesozoic and early Tertiary time.

The Outer tectonic belt has an area of about 1,430,000 sq. km., and depth to basement as a rule does not exceed 2,000 m. Open or semi-closed structures, monoclines, and structural noses predominate here.

The Central tectonic region has an area of 950,000 sq. km. Structures are characteristically equidimensional (Rovnin, 1975, p. 142). "Domes" and "swells"* have amplitudes of 400-600 m on the basement surface; upward along the section into the Upper Cretaceous and Paleogene, however, closure decreases about ten fold and areal size increases greatly. The larger structures cover areas greater than 5,000 sq. km. and are in turn complicated by smaller structures, which have areas of closure up to 500 sq. km. These smaller structures developed largely during Neocomian time penecontemporaneously with sediment deposition. Areas of positive structures constitute about 40 percent of the total area of the Central tectonic region. (Kontorovich, 1975, p. 191).

The Northern tectonic region has an area of about 920,000 sq. km. It is characterized by north-south trending elongate structures that have amplitudes of 1,000-1,500 m on the surface of the basement and areas greater than 5,000 sq. km. Smaller closures on the larger structures are up to 1,500-2,000 sq. km. in area. These smaller structures formed largely

* See glossary for definition.

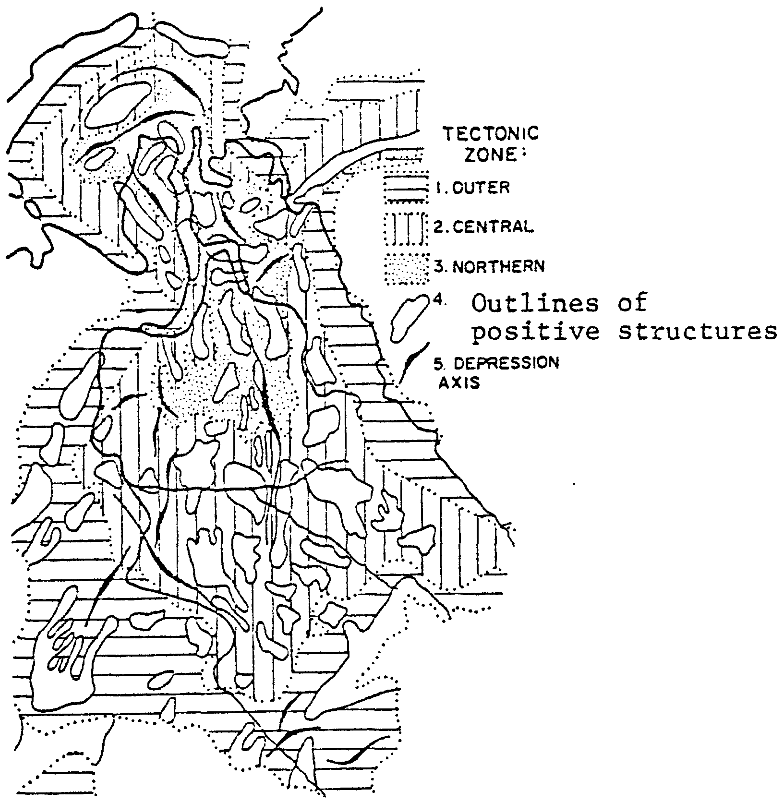


Fig. 4. Tectonic sketch map of West Siberian basin showing regional tectonic elements. (After Rovnin et al, 1975).

during Cretaceous and Paleogene-Neogene time. As noted above, a thick Triassic sedimentary section is present at the base of the sedimentary cover in the northern part of the Lowland.

(2) Thickness of sedimentary cover.

Figure 5 is a generalized map of thickness of the sedimentary cover of the West Siberian Basin. As the basin has hardly any relief, this thickness map is equivalent to the map of relief of the basement surface (Figure 8). The map shows the gentle northward thickening of the sediments in the Central tectonic region and the more abrupt thickening in the Northern tectonic region. The boundary between these regions is at about the 64th parallel.

(3) Structures within the regional tectonic elements.

Figure 6 is a generalized map showing the broad outline of the large structures within the West Siberian Basin. Structure is due largely to either differential compaction or to movement along faults within the basement; no salt domes and reefs have been reported.

The configuration of individual structures reflects the structural fabric of the basement to a degree: According to Kontorovich (1975, p. 211-212), the longer the time span between the orogeny and the beginning of deposition of the basin fill, the less the inheritance of the fold trend from the basement fabric and the greater the influence of later faults that cut across the basement fabric. In the Northern tectonic region, many of the linear folds in the sedimentary cover, have inherited

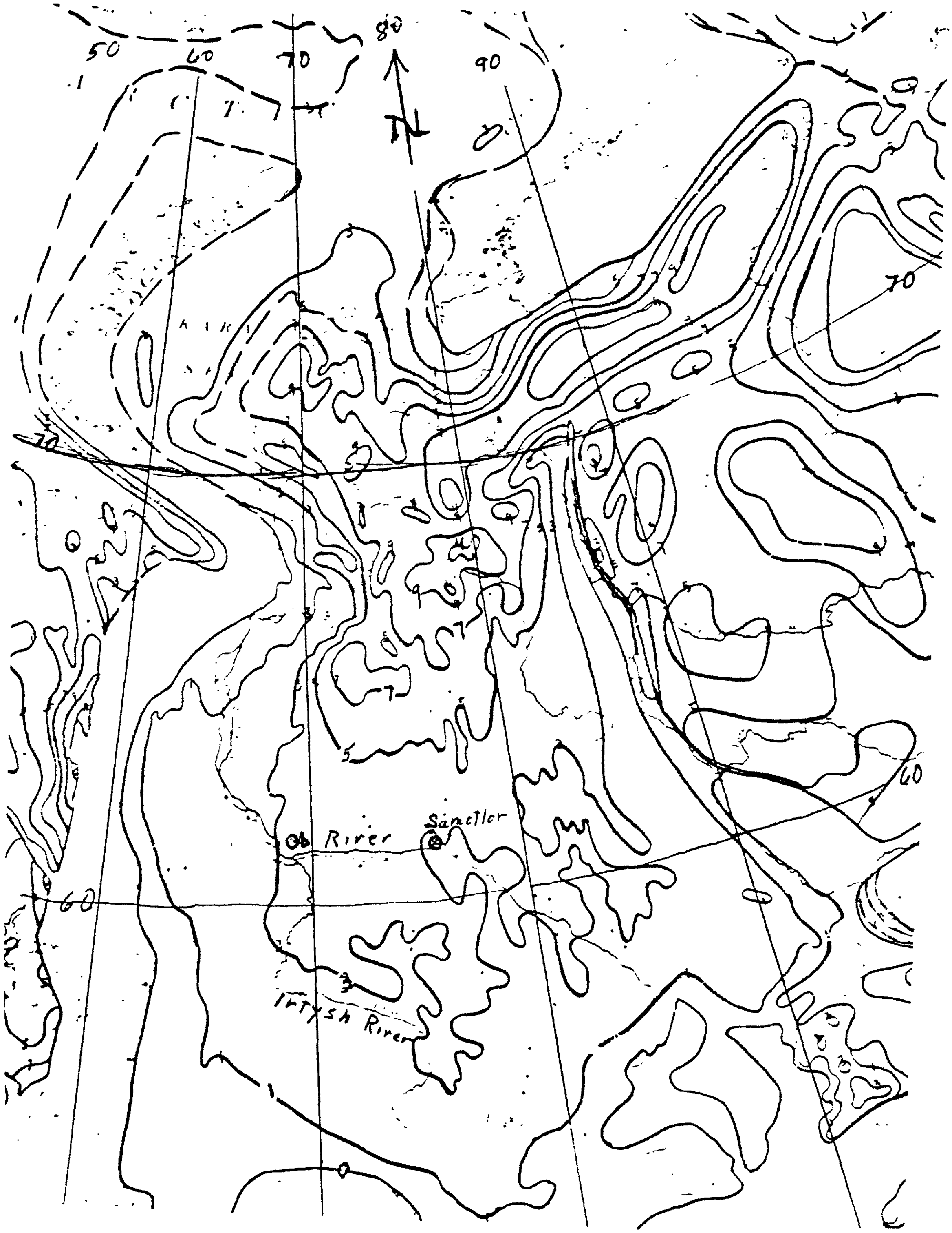


Figure 5. Thickness of sedimentarv cover of West Siberian Basin. Compiled by M. J. Terman in December 1975. Isopachs in km.

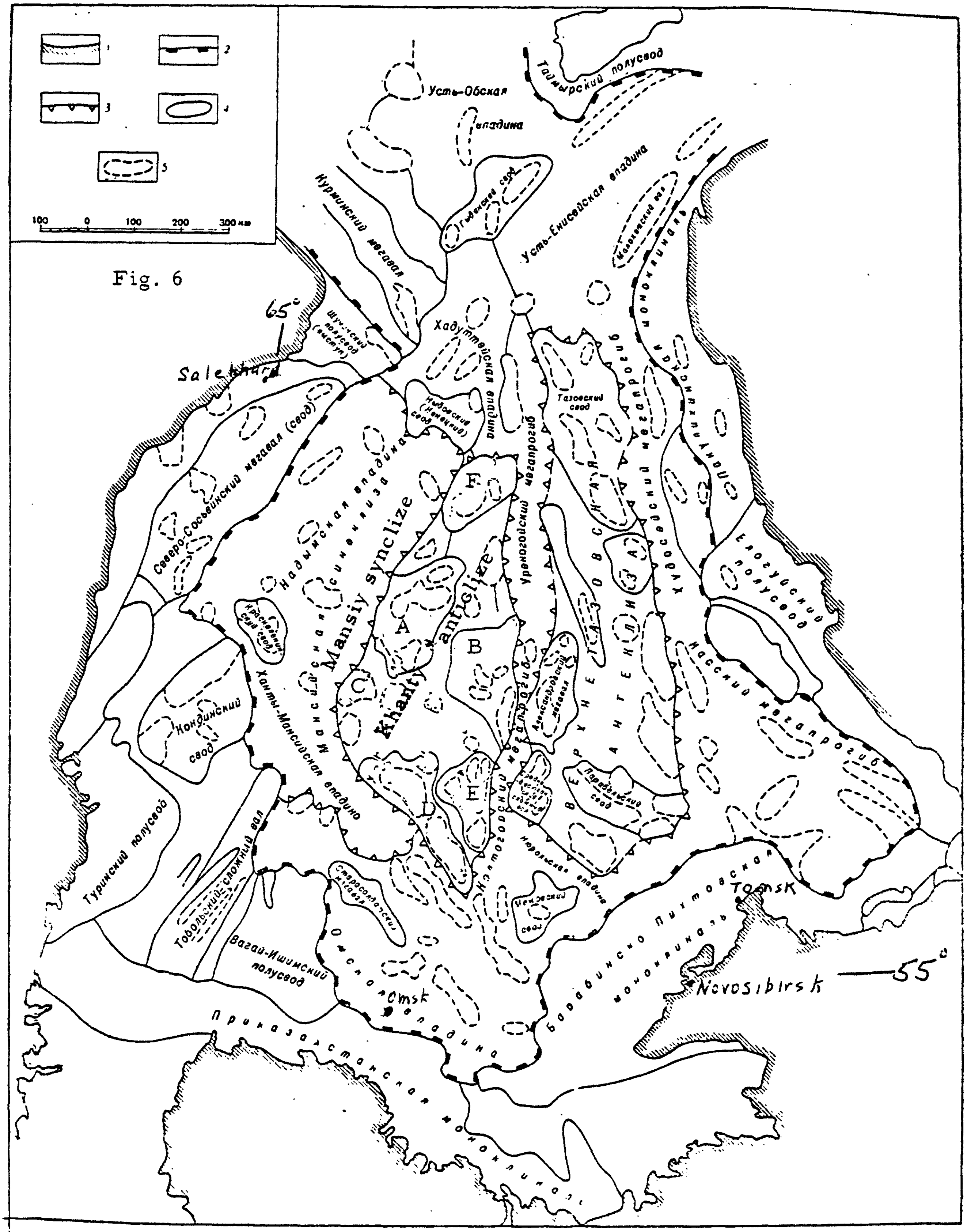
their trend from the late Hercynian folding; intervening time was only 80 million years. Consequently, the structure in the sedimentary cover reflects strongly the structural grain of the basement.

In the Central tectonic region, however, basement folding is early Hercynian and Caledonian. Thus, the intervening time span here between basement folding and beginning of basin filling was as much as 130-200 million years. Consequently, structures in the sedimentary cover of the Central tectonic region reflect more strongly the younger faulting patterns rather than the basement fabric, in contrast to the Northern tectonic region. (Kontorovich, 1975, p. 211-212). Figure 4 shows the contrast in shape of the structures: elongate in the north and more equant in the south.

Soviet geologists recognize the larger structures as being of first and second order types.* The lower limit on size appears to be 300 sq. km. Kontorovich, (1975, p. 196-200) lists 215 positive first and second order structures for the West Siberian platform, giving their type, azimuth of elongation, dimensions, ratio of axis lengths, and area.

Individual closures on first and second order structures are designated as third order structures (20-200 sq. km.) and are called local uplifts. Seismic surveys have outlined about 1200 local uplifts. Kontorovich, et al, (1975, p. 210) estimate that about 4500 local uplifts with a total area of more than 325,000 sq. km. are present in the Mesozoic sediments of the West Siberian Basin.

* See glossary for definition



1
2
3
4
5
100 0 100 200 300 км
Усть-Обская впадина
Таймырский полусвод
Усть-Енисейская впадина
Хадуттейская впадина
Тазовский свод
Северо-Сосьвинский мегавал (свод)
Надымская впадина
Mansiy synclize
Khanty anteclize
Уренгойский мегапрогиб
Ханты-Мансийская впадина
Кондинский свод
Туринский полусвод
Тобольский сложный вал
Вагай-Ишимский полусвод
Омская впадина
Приказахстанская моноклиналь
Барабинско-Пихтовская моноклиналь
Елогуйский полусвод
Касский мегапрогиб
Нюрольская впадина
Межовский свод
Пайдугинский свод
Колтогорский мегапрогиб
A
B
C
D
E
F
65°
55°
Salekhard
Omsk
Tomsk
Novosibirsk

Fig. 6

Figure 6. Generalized tectonic map of the sedimentary cover of the West Siberian Basin (after Ammosov and Gorshkov, 1969).

1 - Boundary of Paleozoic frame; 2 - boundary between inner and outer belts of the platform; 3 - boundaries of large structural elements (anticlizes and synclizes); 4 - positive structures of the first order (domes, swells, monoclines); 5 - positive structures of the second order. A - Surgut dome; B - Nizhne-Vartov dome; C - Salym uplift; D - Verkhne-Dem'yan mega-swell; E - Kaymysov dome; F - Purey dome.

Khanty anticlize.* An irregular triangular block within the basement shows up in varying degrees on all tectonic maps; this is the Khanty anticlize (Figure 6). It consists of five domes (Surgut, Purey, Nizhne-Vartov, Kaymysov, and Verkhne-Dem'yan) separated by depressions.

The Khanty anticlize is bounded by faults of different style and age. On the east is the Koltogor rift, which is a tensional feature that has been persistent from the Triassic up through the present (Figures 6 and 7). The present course of the Pur River to the north is controlled by this structure. In the southwestern part of Khanty anticlize are the Bol'she Yugan fault and the Dem'yan suture (Figure 7). These fractures appear to be junctions between plate slivers that were juxtaposed during the Hercynian orogeny. Ultramafic bodies occur on the Bol'she Yugan fault at Surgut (Figure 2). The northern boundary of the Khanty anticlize is not as well defined. This boundary may be a set of east-west faults marking the structural front between the Central and Northern tectonic regions, or it may be another suture bounding an Hercynian plate (Figure 7).

Whatever the origin of the Khanty anticlize, it appears to have been a structural entity throughout the Mesozoic, and it is quite clearly the center of oil occurence. During Jurassic time it was a topographic high that localized sands on its flanks. During the Cretaceous, it may from time to time have been expressed in the relief of the basin floor. Then during the Late Cretaceous and Tertiary when oil began to be generated by source rocks, it created a huge regional inverted saucer in the

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* See Glossary

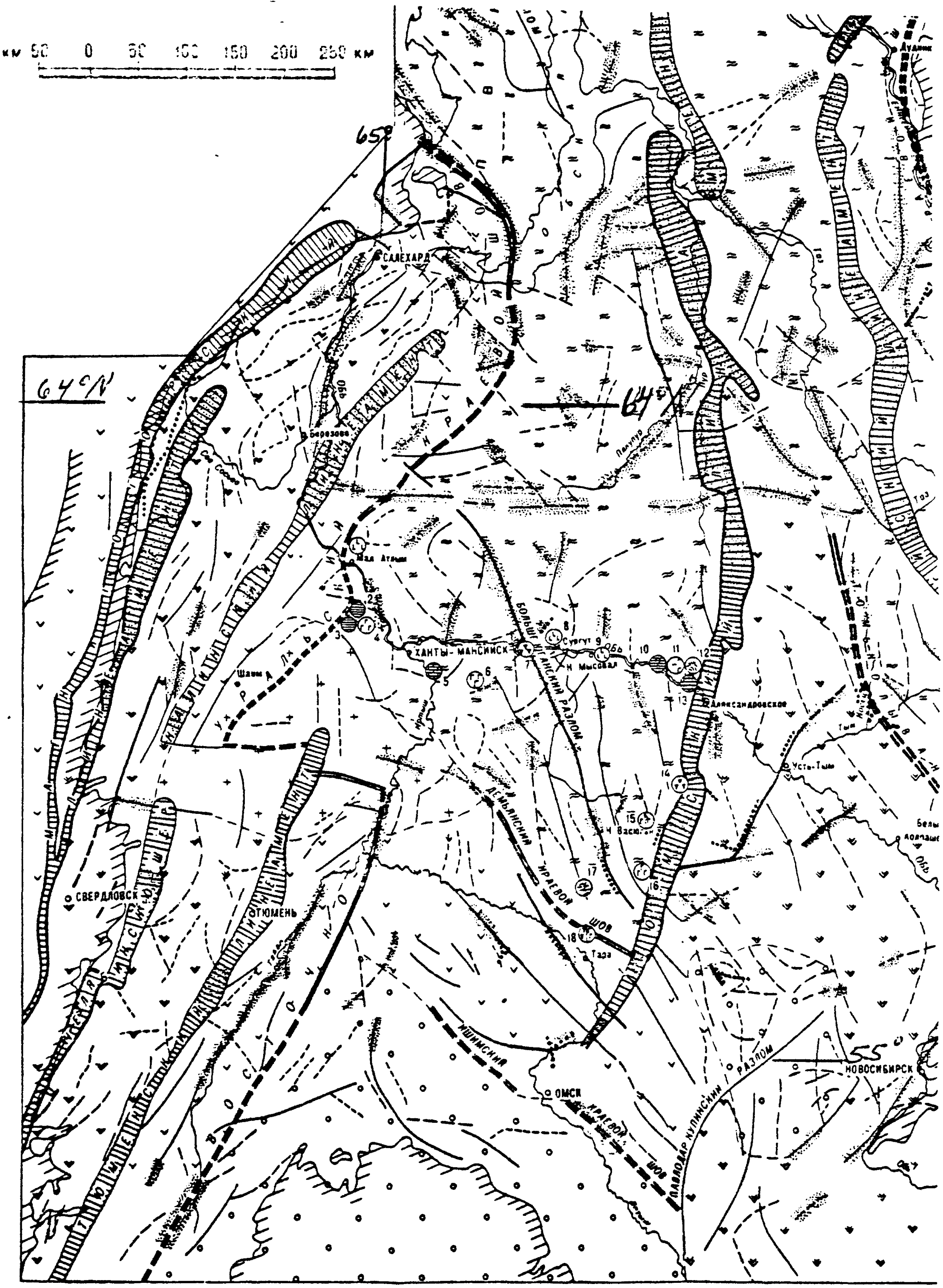


Fig. 7 Structure map of Khanty anticlize. The hinge line between the Northern and Central tectonic provinces near the 64th parallel is the site of deep faults that are expressed today at the surface. After Nalivkin, 1967, plate 1.

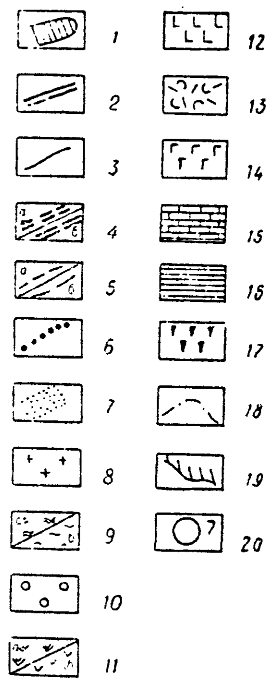


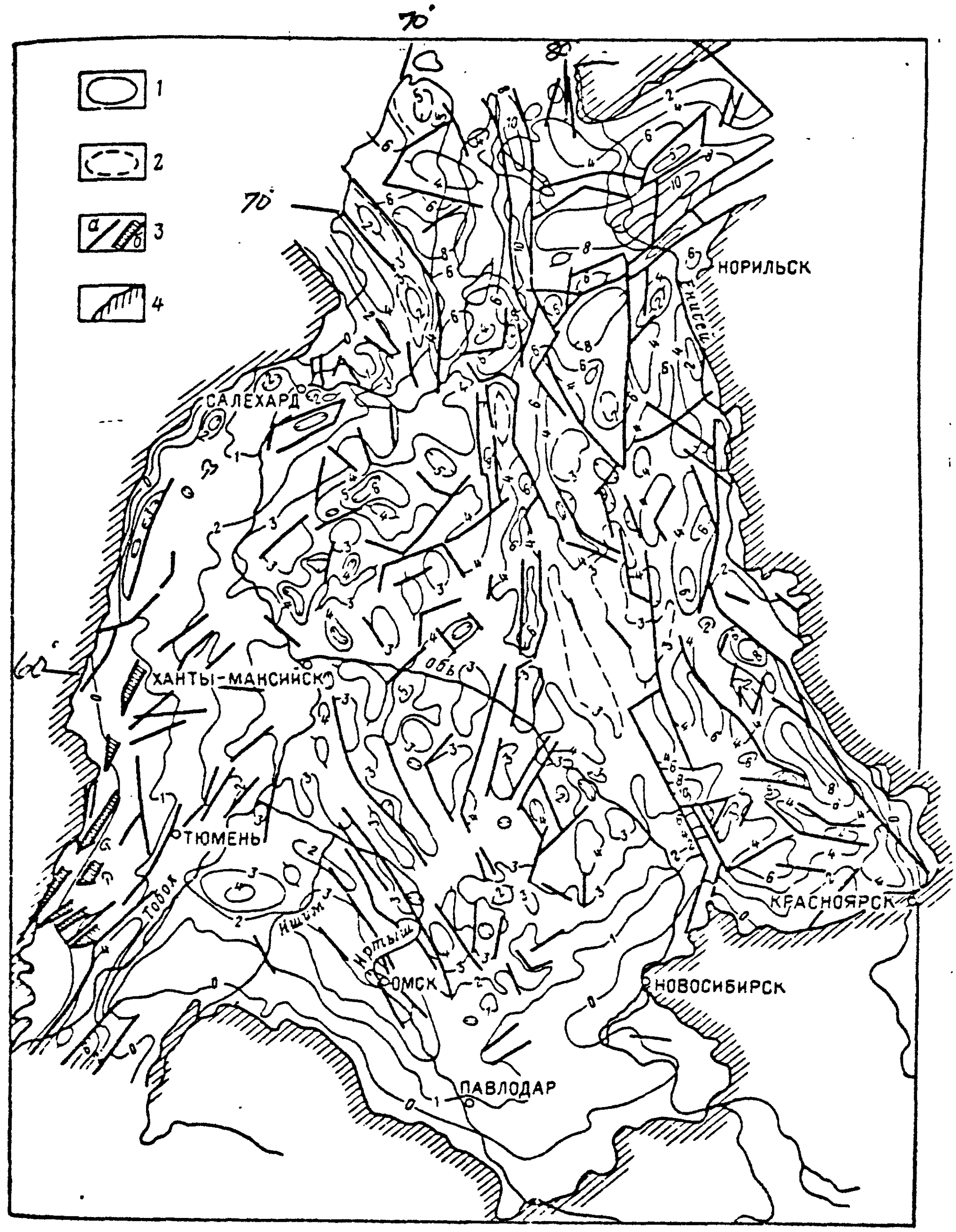
Figure 7 legend. 1 - Gravity and magnetic lineaments; 2 - marginal geosutures based on gravity and magnetic surveys; 3 - concordant and cross-cutting geosutures based on gravity and magnetic surveys. Probable faults in basement: 4 - marginal geosutures (based on: a - gravity, b - magnetics); 5 - concordant and cross-cutting (based on: a - gravity, b - magnetics). Normal faults in the Mesozic-Cenozoic cover: 6 - based on drilling and seismic surveys; 7 - sectors of faults in basement reflected in modern relief and stream system; 8 - areas of Archean fold system in basement; 9 - areas of Baykal fold system (a - eugeosynclinal, b - miogeosynclinal); 10 - areas of Caledonian folding; 11 - areas of Hercynian folding (a - eugeosynclinal, b - miogeosynclinal). Pre-Jurassic rocks penetrated by the drill: 12 - basalt; 13 - tuff; 14 - effusives; 15 - limestone; 16 - slate; 17 - serpentine. 8 - Boundaries of fold belts of different age in basement. 19 - Folded frame of basin. 20 - Areas where pre-Jurassic rocks have been penetrated by drilling in the central part of the basin.

Jurassic and Cretaceous strata above it, forming a regional petroleum migration system whereby the petroleum in the enormous fields of the Surgut and Nizhne-Vartov domes collected.

Faults. Study of faults in the West Siberian Basin is hampered by the Quaternary cover. A good idea of the distribution of faults has been gained, however, from gravity, magnetic, and seismic surveys, drilling, hydrogeological and geothermal data, and terrain analysis. The map in Figure 8 shows the principal faults; however, numerous east-west trending fractures are present but not shown on this map. See Figure 7 for examples of such faults.

Five categories of faults have been recognized. See Table 1. No reference to fault trapping of oil pools in the West Siberian Basin has been found in the literature; further, Arzhanov and Fain (1975, p. 40) state that no fault traps are present at Samotlor.

Present-day Structure. As noted earlier the persistence through geologic time of structural trends in the sedimentary cover that have been inherited from basement structure is a function of the age of the fold or block-fault structure of the basement. Where the basement structure formed during the late Hercynian, inherited movements have taken place on through the Paleogene. Where basement structure is Caledonian or early Hercynian, inherited structural movements persisted only into the Mesozoic. In the first situation beginning with the Neogene, and in the second beginning with the Late Cretaceous a new structural fabric



Approx. scale 1:16 million

Fig. 8 Schematic map of relief of the surface of the folded basement of the West Siberian Basin (from Kontorovich, et al, 1975, p. 213).

1 - Structure contours (in km) on the surface of the basement; 2- same, conjectural; 3 - faults (a) and graben (b); 4 - margin of basin.

Table 1.

Faults recognized in the West Siberian Basin (after Kontorovich, 1975, p. 192

TYPE	Number of faults		Total length of faults	
	Number	%	km	%
Faults in basement that do not penetrate into the sedimentary cover	199	9.42	11,028	10.51
Faults in basement, the penetration of which into the sedimentary cover is unclear	357	16.89	23,134	22.05
Faults in basement that penetrate into the sedimentary cover: continuous, cutting all units of the cover	222	10.51	15,044	14.34
dying out in various horizons of the cover	349	16.51	25.520	25.30
Faults disclosed at surface by geomorphic data but with unclear depth of penetration into the cover	986	46.67	29,116	27.80

developed in the upper part of the platform cover. This new fabric is not related to the older structural fabric of the basement (Kontorovich, 1975, p. 217-218).

The present-day structural fabric of the West Siberian Basin is shown in Figure 9. The most prominent features here are east-west belts of alternating uplift and subsidence. However, the north-south Koltogor graben is still prominent. The Pur River flows north within it.

The Sibirsko-Uval ridge is located at the approximate position of the hinge line between the Central and Northern tectonic regions for the Mesozoic-Cenozoic sedimentary cover (Figure 9). The question arises as to whether or not this ridge is a reflection of the hinge line between these tectonic regions. During the Mesozoic and early Cenozoic, the Northern tectonic zone subsided more than did the southern. During late Cenozoic, however, Rudkevich (1967) shows the situation reversed; the Northern tectonic region at times was uplifted with respect to the Southern.

Varlamov (1970, see Kontorovich, 1975, p. 216) depicts the Sibirsko-Uval ridge as a series of uplifts that extends for more than 1600 km in an east-west direction. Evidence for the hinge line, however, is found only in the middle portion of the Sibirsko-Uval ridge.

The map of surficial deposits of the USSR shows a belt of fluvio-glacial deposits coincident with the Sibirsko-Uval ridge. These appear to be reworked morainal deposits that resulted from continental glaciers that spread into this region from the north-west and northeast during

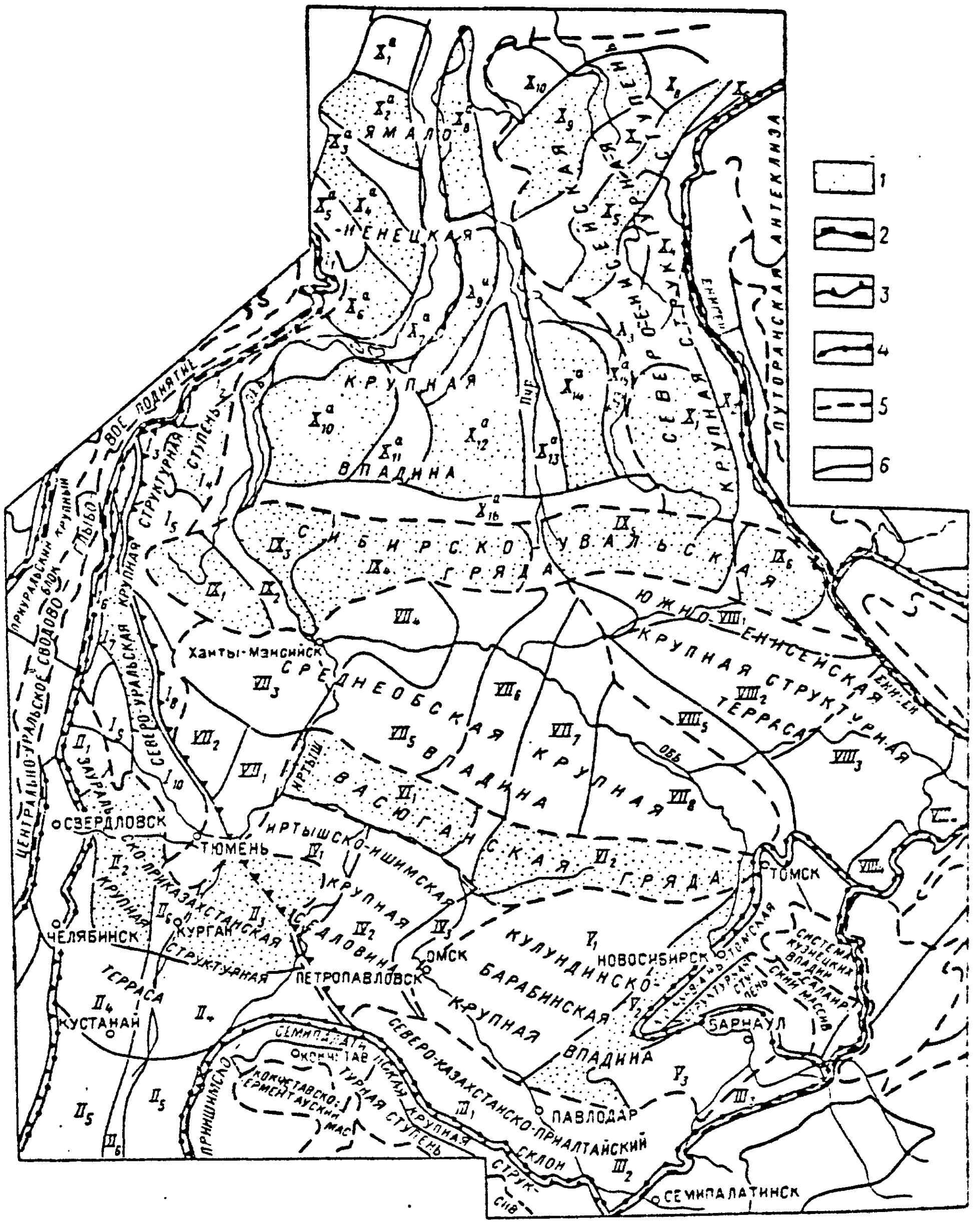


Figure 9. Sketch map of present day structural elements of the West Siberian basin. (After Varlamov, 1970; see Kontorovich, 1975, p. 216). 1 - Clearly expressed positive structures of the first order; 2 - normal and steep reverse faults; 3 - faults and flexures; 4 - boundary between geostructural regions; 5 - boundary between large structural elements of the geostructural regions; 6 - boundaries between structural elements of higher order.

epochs equivalent to the Nebraskan and Kansan of North America. The Sibirsko-Uval ridge may thus be a constructional feature and not reflect movement of basement blocks. If it does reflect movement of basement blocks, the structural elements involved may be associated with the old hinge line or with a more extensive set of younger east-west faults.

STRATIGRAPHY

Introduction. Three megacycles are recognized in the sedimentary section of the Mesozoic-Cenozoic platform sedimentary cover of the West Siberian Basin: Triassic-Aptian, Aptian-Oligocene, and Oligocene-Quaternary. Predominantly continental sediments occur at the base of each megacycle and largely marine or near-shore marine sediments at the top. The Triassic-Aptian megacycle consists of the Tampey, Zavodoukov, Poludin, and Sargat "series"*; the Aptian-Oligocene is composed of the Pokur, Derbyshin, and Nazyvayev series; and the Oligocene-Quarternary consists of the Nekrasov and Burlin series (Kontorovich, 1975, p. 81). See Table 2.

A total of 245 stratigraphic units were recognized in the Mesozoic-Cenozoic section as of 1967. This classification is, of course, the result of a long history of stratigraphic revision, a process that will no doubt continue (Kontorovich, 1975, p. 82-95).

Triassic-Aptian megacycle

Tempay series. A few drill holes in the northern part of the West Siberian Basin have penetrated Triassic marine and continental sandy-clayey sediments of the Tempay series. These beds appear to have a greater commonality with the upper sedimentary cover than with the intermediate structural stage. The section consists of alternating dark gray shales, siltstones, tuffaceous sandstones, and sandstones. Thicknesses of several hundred meters have been penetrated by the drill; however, seismic surveys indicate that thickness reaches 6000 m (Kontorovich, 1975, p. 96).

* See glossary

Comparative Stratagraphic Section

TABLE 2

	STAGE		United States Rocky Mts.	Canadian Rocky Mts.	Soviet Series	W. Siberia Formations
Neogene					Burlin	
Oligocene			White R. Fm.		Nekrasov	
Paleocene-Eocene			Wasatch Fm.; Ft. Union Fm.		Nazyvayev	Chegan; Lyulinvor; Talits
Upper Cretaceous	Danian		Lance Fm.	Willow Cr. Fm.	Derbyshin	Gan'kin
	Maestrichtian		Fox Hills Ss. (Mont.)	St. Marys R. Fm.		
	Campanian		Lewis Sh.; Mesaverde Fm. (Mont.)	Bearpaw Sh.; Belly R. Fm.		
	Santonian		Niobrara Fm. (Colorado)	Alberta Gp.		Berezovo
	Coniacian			Cardium Ss.		
	Turonian		Carlile Sh. (Colorado)			Kuznetsov
	Cenomanian		Frontier Fm. (Colorado)		Pokur	Pokur
Lower Cretaceous	Albian		Mowry Sh.; Muddy Ss.; Thermop. Sh.; Fall R. Ss.	Viking Ss.; Joli Fou Fm.		PK
	Aptian		Fuson Sh.; Lakota Cgl. (Kootenai Fm.)	Blairmore Fm.	Sargat	Alym AV_1
	Barremian	Neocomian	Kootenai Fm.			Vartov AV_{2-5}
	Hauteriv					AV_6
	Valanginian				Foludin	Megion BV_8 BV_{10}
	Berriasian					BV_{11}
Upper Jurassic	Portlandian	Malm	Morrison Fm.	Fernie Group		Bazhenov
	Kimmeridgian					Georgiyev
	Oxfordian		Sundance Fm.			Vasyugan JU_1
	Callovian					
Middle Jurassic	Bathian	Dogger	Gypsum Spring Fm.		Zavodoukov: Ubagan	Tyumen
	Bajocian					
	Aaliam		Nugget Ss.; Navajo Ss.			
Lower Jurassic	Toarcian	Liassic			Zavodoukov: Chelyabiriski	
	Pliensbachian					
	Sinemurian					
	Hettangian					
Triassic	Rhaetian	Upper	Popo Agie Fm.		Tampey: Tura	
	Norian		Jelm Fm.	Whitehorse Fm.		
	Karnian		Alcova Ls.			
	Ladinian	M.		Sulphur Mts. Fm.		
	Anisian		Chugwater Fm.			
	Scythian	L.	Dinwoody Fm.			

Zavodoukov series. This unit includes all the Lower and Middle Jurassic through the lowest sub-stage of the Callovian (Table 2). Over much of the basin this series consists of continental sediments; only in the north are they replaced by marine deposits. The Tyumen Formation is the thickest and most widespread unit of this series. It is 100-300 m thick on the domes and swells and up to 600 m thick in the depressions (Gurari and Trushkova, 1972, p. 8). In the northernmost part of the basin the thickness is up to 1000 m.

Poludin series. This series includes the section from the base of the middle Callovian of the Upper Jurassic to near the top of Valanginian stage. The sediments of this series were deposited largely under marine conditions (Kontorovich, 1975, p. 112). It includes the Vasyugan, Georgiyev, Bashenov, and Megion formations (See Table 2).

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.

The Bashenov Formation consists of dark brown bituminous shales along with beds of dark bituminous pelitic limestone. Thickness is 14-36 m.

The shales of the Bashenov and Georgiyev formations are an excellent electrical logging marker. They also serve as a seal for oil pools lower in the Jurassic section.

The Megion Formation is Lower Cretaceous. According to Gurari and Trushkova (1972, p. 19-21) 13 sandy reservoir strata (BV_{10} - BV_{22})* separated by impermeable shales are present. Total thickness of the formation ranges from 25 to 310 m; however, it seems to be typically about 250 m thick. The BV_{10} oil-bearing stratum of the Samotlor oil field is assigned to the upper part of the Megion Formation. Salmanov (1974, p. 152) and several other authors, however, include BV_8 as well in the Megion Formation and not in the overlying Vartov formation. The interpretation of Salmanov is followed in this presentation: BV_{10} is assigned to the middle of the Megion Formation and BV_8 to the upper part.

Sargat series. The sediments of this series represent the uppermost Valanginian, all the Hauteriv-Barremian, and most of the Aptian stages. See Table 2. Deposition was in a progressively shallowing marine basin. The series is up to 800 m thick, and in the Middle Ob region consists of the Vartov and Alym formations.

The Vartov Formation consists largely of greenish clays which alternate with sandstones and siltstones; some coal beds are present. Thickness of the formation is up to 350 m. In the Samotlor oil field, the AV_{2-3} and AV_{4-5} pay zones are within this formation.

The Alym is generally a shale that was deposited under marine or near-shore conditions. It contains sandy stratum AV_1, which is a pay zone over much of the Nizhne-Vartov dome. The basal sandstone of the Alym Formation rests in many places on an erosion surface and commonly includes detritus from the Vartov Formation (Gurari and Trushkova, 1972, p. 29).

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* See p. 55 for reservoir nomenclature

Aptian-Oligocene megacycle

Pokur series. The uppermost part of the Aptian and all the Albian and Cenomanian are included in this series. Over a large part of the region of the West Siberian Basin these sediments were deposited under continental conditions and consist largely of gray sandy material. Thickness is up to 600 m. The series is represented by the Pokur Formation in the Middle Ob region; this also constitutes the Aptian-Cenomanian oil-gas horizon.

Derbyshin series. This series consists of the post-Cenomanian Upper Cretaceous sediments. They were deposited during a time of marine transgression and consist largely of argillaceous rocks. The series is up to 700 m thick; it consists of the Kuznetsov, Berezovo, and Gan'kin Formations.

Nazyvayev series. Sediments of Paleocene, Eocene, and lowermost Oligocene age constitute this series. Thickness is up to 800 m, and the formations present in the Middle Ob region are the Talits, Lyulinvor, and Chegan.

Oligocene-Quaternary megacycle.

Nakrasov series. The Oligocene above its lowermost beds comprises this series. The sediments are alternating sands, silts, and clays with beds of brown coal; these are lake, swamp, and river deposits. Thickness reaches 300 m.

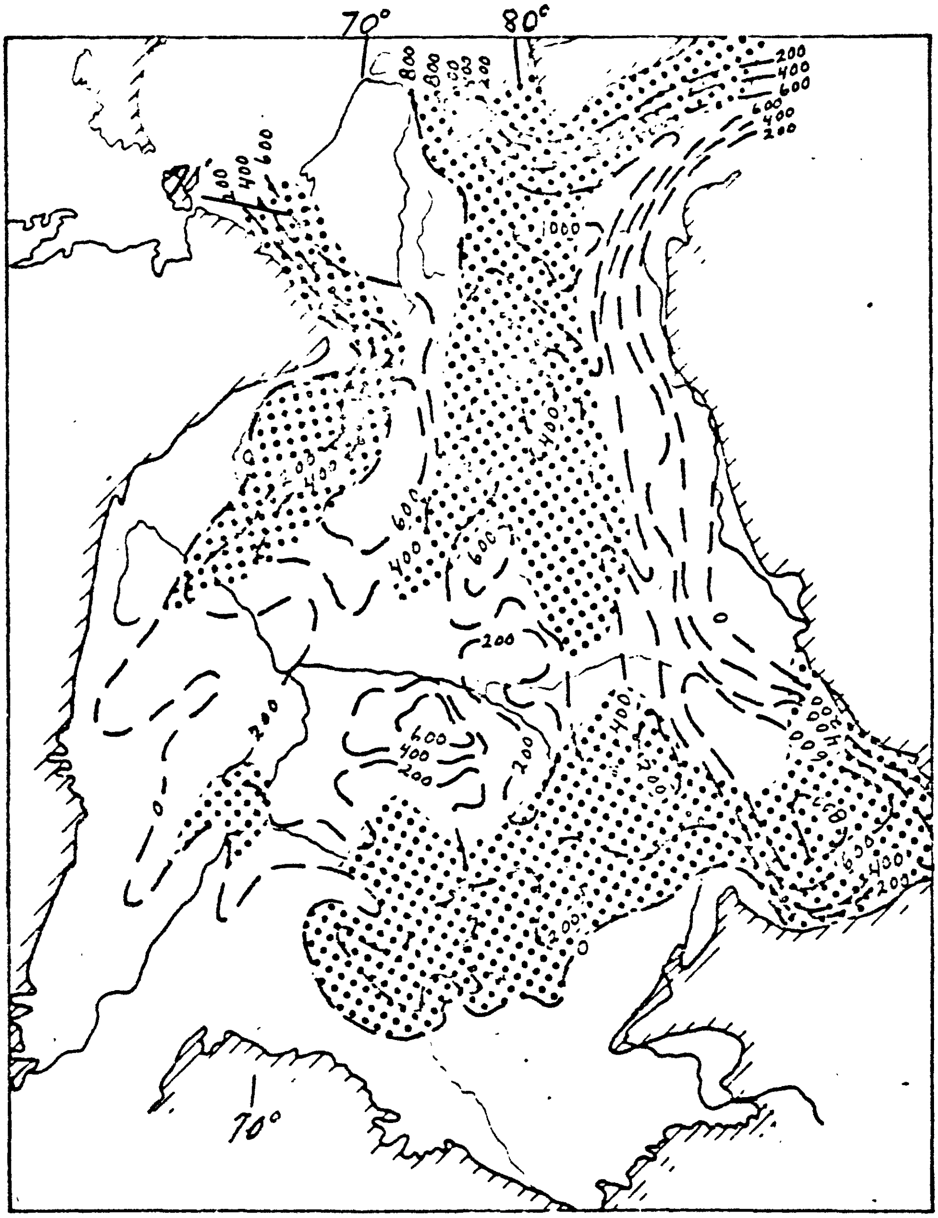
Burlin series. This series consists of the Neogene section. It is not present in the Middle Ob region.

Quaternary sediments blanket almost the entire West Siberian Lowland.

PALEOGEOGRAPHY AND FACIES DISTRIBUTION

Early-Middle Jurassic. Regional subsidence of the West Siberian Basin in the Early-Middle Jurassic resulted in the first major marine Mesozoic transgression; it spread southward over the northern two-thirds of the basin. The Tuymen Formation and equivalent beds are characterized by marine sapropelic shale and nearshore sandstones in the northern part of the basin, grading southward into a continental-deltaic-lacustrine facies that occupies the southern and eastern portions of the basin. The variation in thickness and the distribution of sandy facies are shown in Fig. 10. Several oil and gas accumulations have been found in Middle Jurassic sandstone reservoirs. Most of these are small, and the Lower-Middle Jurassic prospects have not been of great commercial interest.

Late Jurassic. The Late Jurassic (Callovian-Oxfordian) marine transgression spread across the entire basin, except for the extreme southern and southeastern borders where continental and nearshore marine sediments are present. These beds are known as the Vasyugan Formation; they consist entirely of marine, generally sapropelic shale and relatively persistent reservoir sandstones, most of which occur in the upper (Oxfordian) part of the formation. The Oxfordian sandstones are overlain by Georgiyev shales and by the bituminous shales of the Bazhenov Formation (uppermost Jurassic). The maximum marine sandstone complex of the Upper Jurassic tends to be concentrated in the Surgut-Nizhne-Vartov area, where the more important Upper Jurassic oil discoveries of the central part of the basin are located (see Fig. 11).



Approx. scale 1:17 million

Figure 10. Lower and Middle Jurassic in the West Siberian Basin. Isopachs in meters. Stipple areas contain more than 50 percent sandstone. White areas within zero isopach are less than 50 percent sandstone. Modified from Nesterov (1969, p. 204).

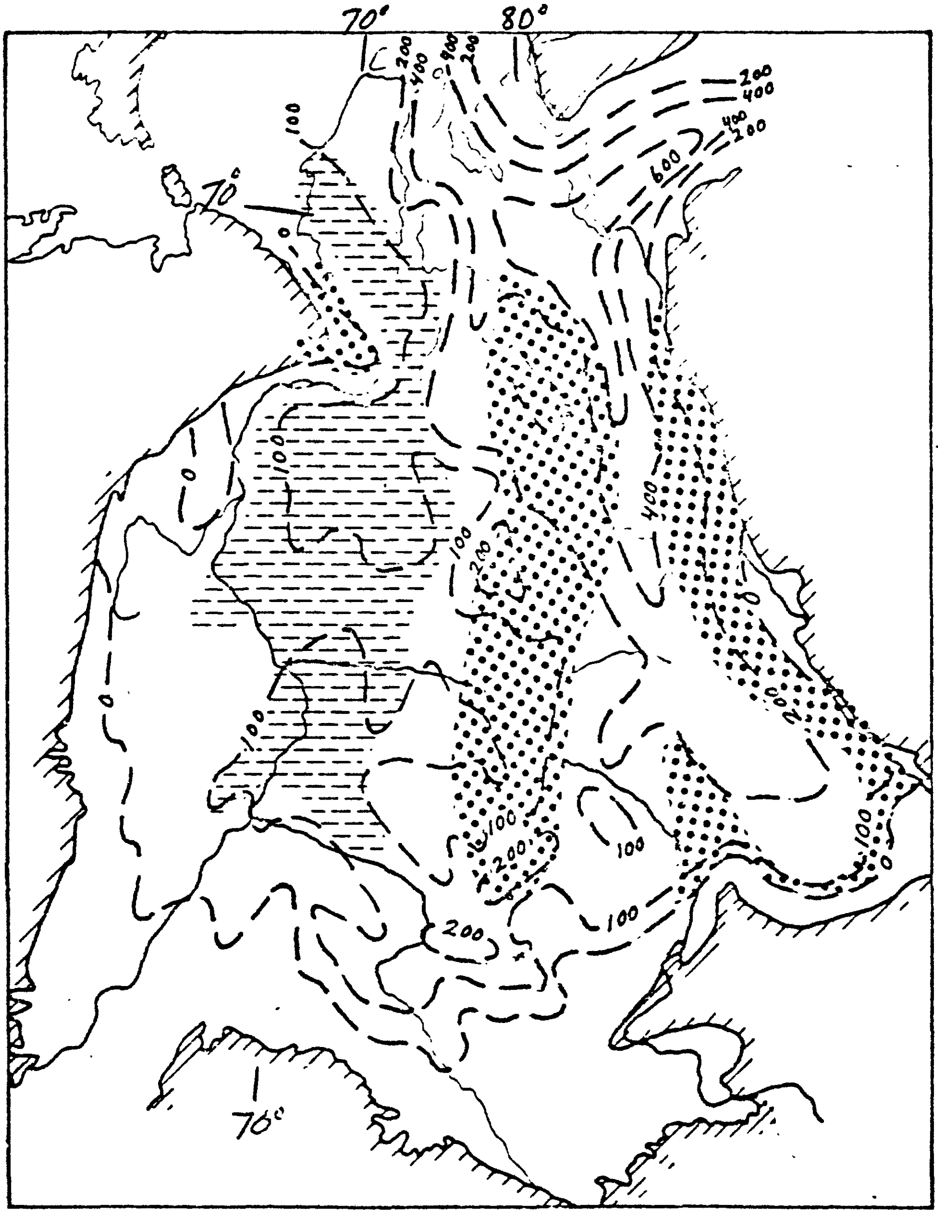


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Figure 11. Upper Jurassic in the West Siberian Basin. Isopachs in meters. Stippled areas contain more than 50 percent sandstone. Dashed areas contain no sandstone; they are largely dark marine shale. White areas within zero isopach are between 0 and 50 percent sandstone. Modified from Nesterov (1969, p. 231).

Cycles in Jurassic sedimentation. Zonn et al (1976, p. 6-10), examining the Jurassic as a whole, describe cyclic sedimentation consisting of alternating sandy-silty and clayey complexes; these act as reservoirs and seals, respectively. Sandy sediments of regressive stages (Pliensbachian, Aalen, Bathian, and upper Oxfordian) are largely reservoirs, and those of transgressive stages (Toarcian, Bajocian, Callovian, Kimmeridgean, and Volgian) are capping seals.

High concentrations of sandy beds are associated with proximity to source and with paleo-valleys related to negative structures. During much of the Jurassic there were two large river systems, the interfluve of which was in the general region of the Khanty anticlize.

Neocomian. Soviet geologists divide the Lower Cretaceous section into the Neocomian, Aptian, and Albian stages. The lower Neocomian (Berriasian-Valangininian) beds of the Khanty anticlize are the Megion Formation; these consist primarily of transgressive marine and nearshore marine sandstones and sapropelic shale. Marine sandstone content in this section is high on the Nizhne-Vartov and Surgut domes where at least 15 productive reservoir sandstones, as much as 30-40 meters thick, are present in the Megion Formation. See Figs. 12 and 13. The Megion beds and equivalents are 300-400 meters thick on the Kanty anticlize and up to 700 meters thick in the northern part of the basin. The major portion of the known lower Neocomian petroleum reserves of the basin are on the Nizhne-Vartov and Surgut domes, although substantial gas deposits have also been found in the northern part of the basin and some oil and gas in the southern portion. The restoration in Fig. 14 illustrates the deltaic environment of Early Cretaceous time.

The upper Neocomian (Hauterivian-Barremian) beds are the Vartov Formation and equivalents on the Khanty anticlize. These beds represent a somewhat more regressive phase of Lower Cretaceous deposition with the deltaic continental and lagoonal facies spreading farther west across the basin as far as the Khanty anticlize. See Figure 15. Relatively persistent nearshore marine sandstones and sapropelic shales make up most of the section in the Nizhne-Vartov and Surgut dome areas. This section includes 15 or more important reservoir sandstones up to 20-30 meters thick, which contain a major portion of the oil reserves of the central basin area. West of the Khanty anticlize, the upper Neocomian is composed largely of marine sapropelic shale. The major part of the known upper Neocomian petroleum reserves of the basin are the oil deposits on the Nizhne-Vartov and Surgut domes. Some oil and gas have been found in structures to the south, and several gas sands are present on the Yamal Peninsula in the extreme northwestern area of the basin.

Aptian-Albian-Cenomanian. The Aptian-Albian and Cenomanian (basal Upper Cretaceous) beds taken together make up a single major transgressive-regressive depositional cycle, with the Cenomanian continental and near-shore marine section making up the main regressive part of the cycle. These beds are known as the Pokar and Alym formations in the southern part of the Khanty anticlize and Omsk depression, and the Urengoy Formation to the north.

The Aptian beds consist mainly of marine shales, sandstones, and siltstones, with some local thin limestone beds. Albian sediments are primarily marine shales and siltstones. Together, the Aptian and Albian

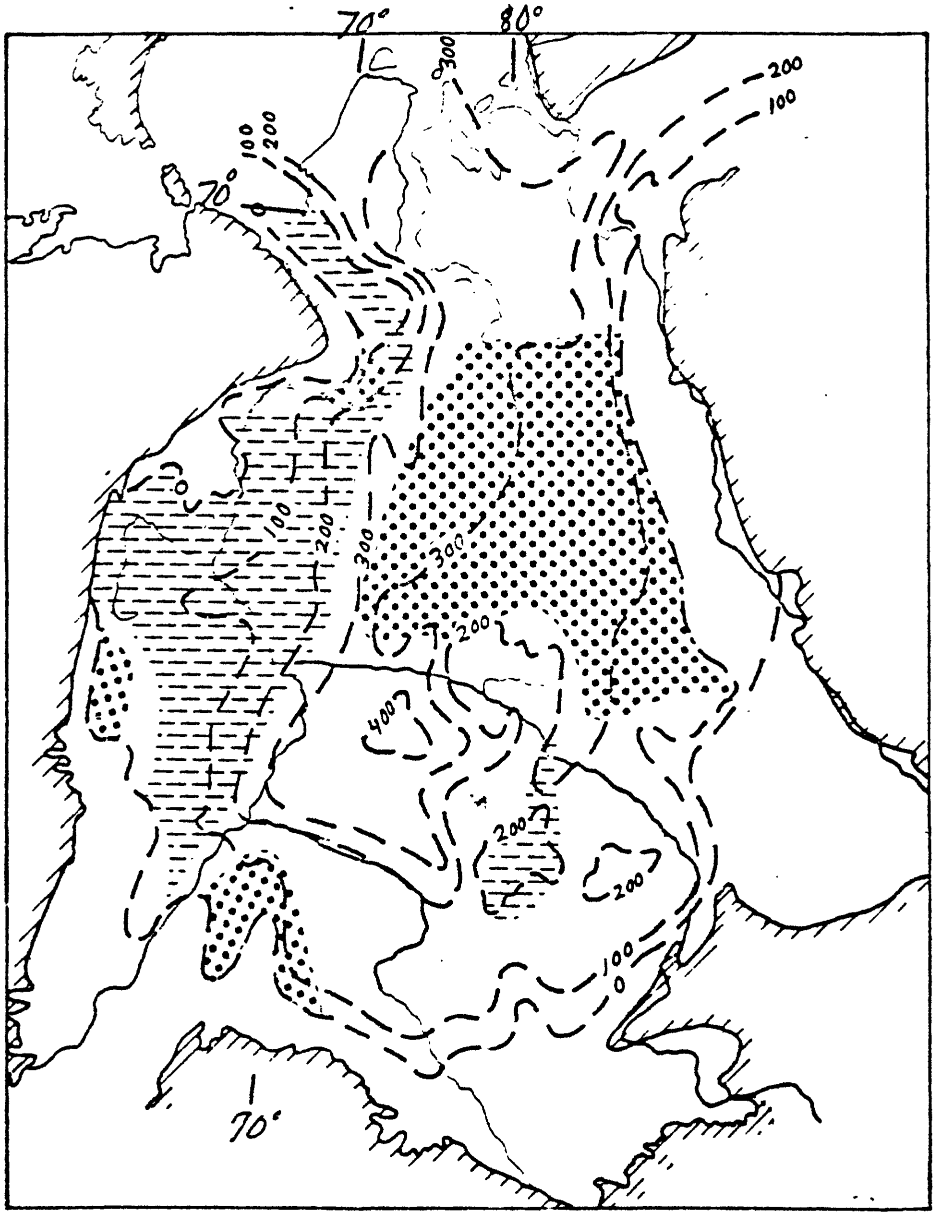
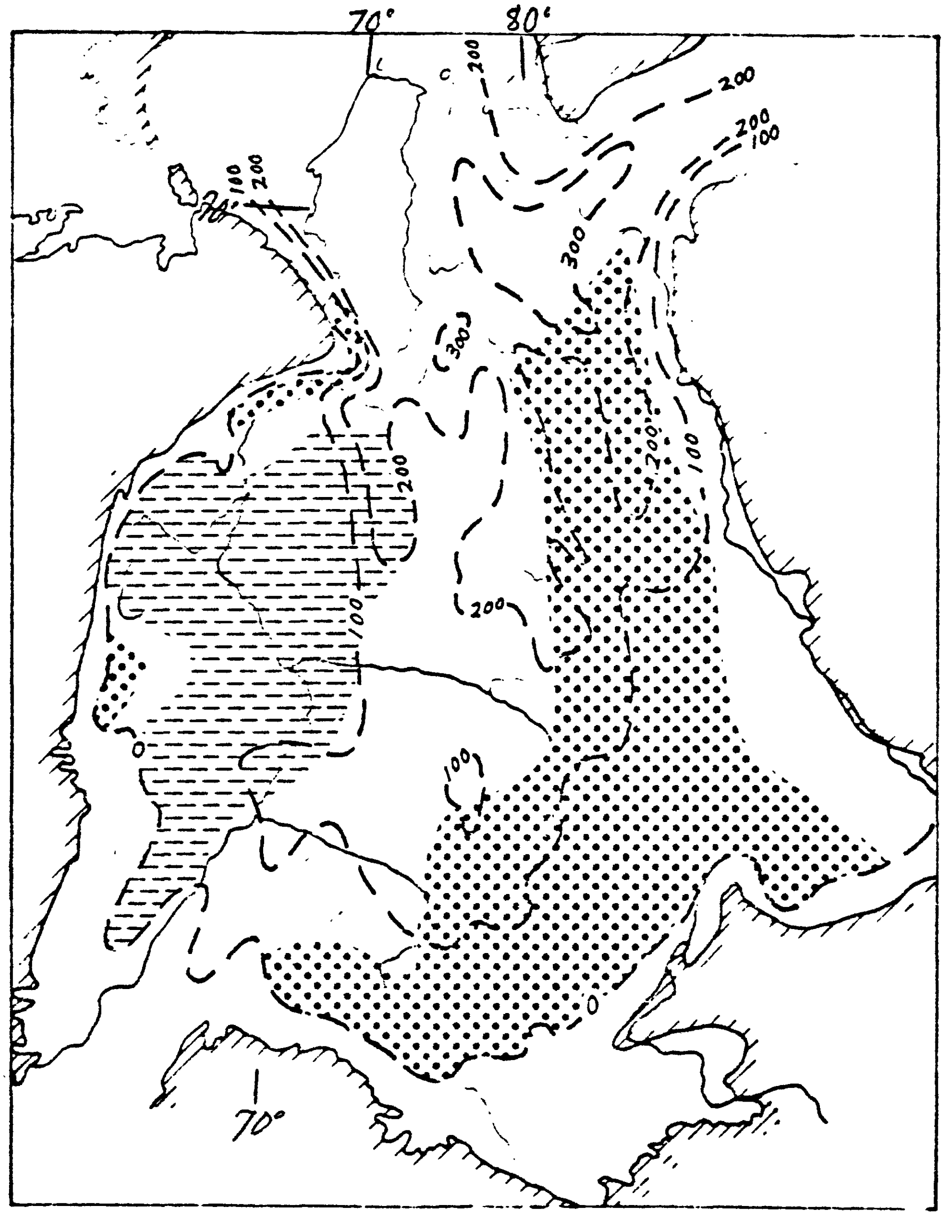


Figure 12. Lower and Middle Valanginian in the West Siberian Basin. Isopachs in meters. Stippled areas contain more than 35 percent sandstone. Dashed areas contain no sandstone; they are largely dark marine shale. White areas within zero ispachs are between 0 and 35 percent sandstone. Modified from Nesterov, (1969, p. 244).



Approx. scale 1:17 million

Figure 13. Upper Valanginian in the West Siberian Basin. Isopachs in meters. Strippled area is more than 50 percent sandstone. Dashed area contain no sandstone; they are largely dark marine shale. White areas within the zero isopachs are between 0 and 50 percent sandstone. Modified from Nesterov (1969, p. 254).

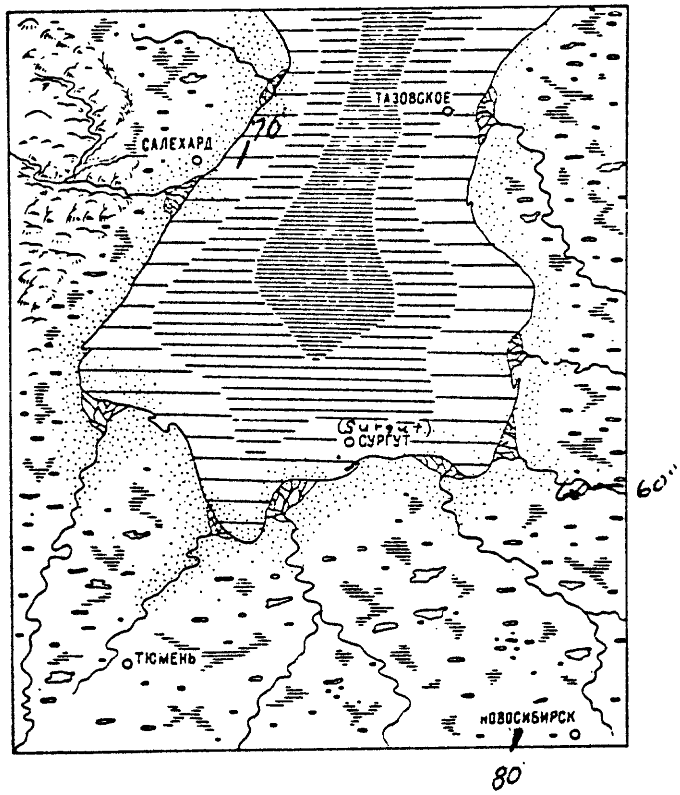


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Fig. 14.--Paleogeographic sketch map of restoration of West Siberia during Early Cretaceous time. (From Markovskiy, 1973, p. 287.)

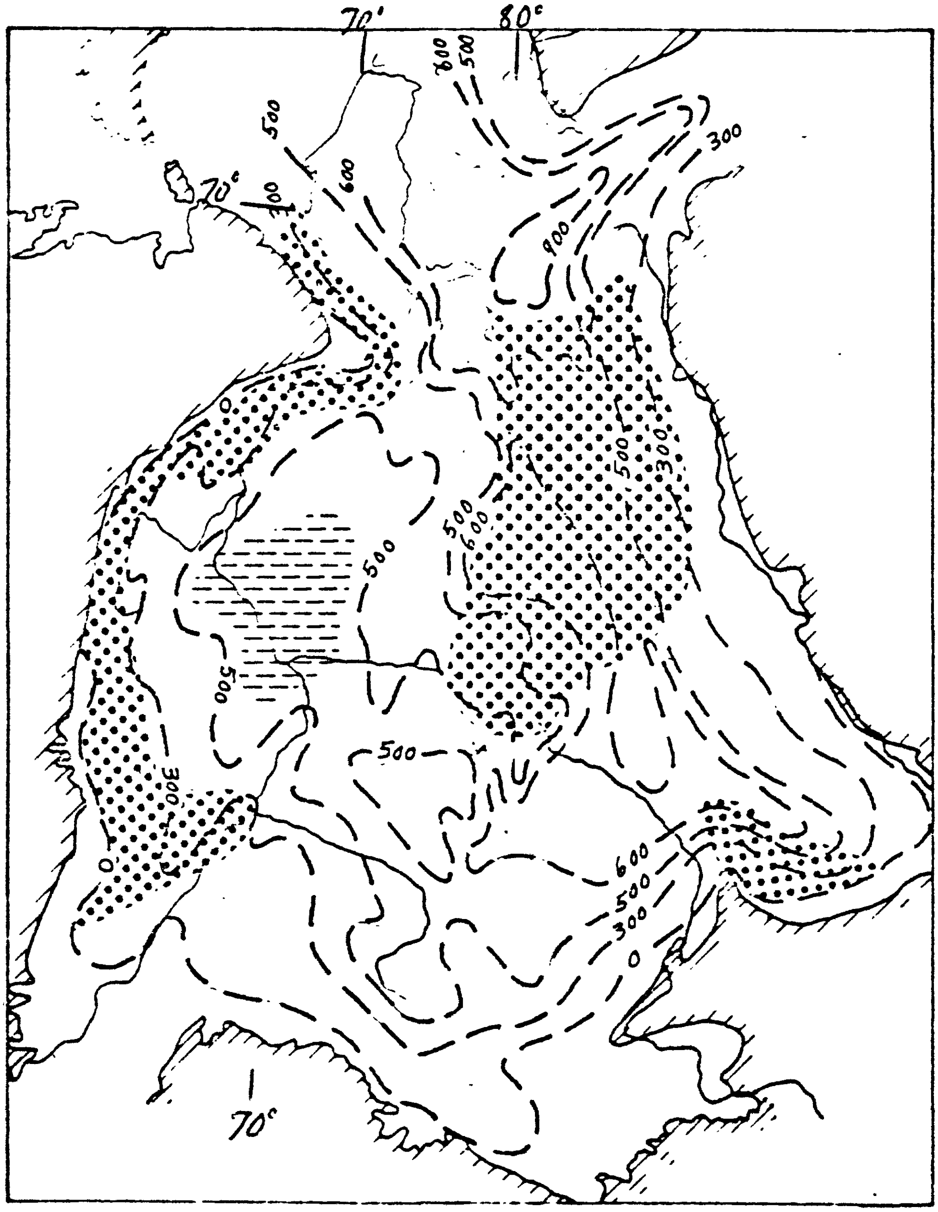

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Figure 15. Hauteriv-Barremian in the West Siberian Basin. Isopachs in meters. Stippled areas are more than 50 percent sandstone. Dashed areas contain no sandstone; they are largely dark marine shale. White areas within zero isopach are between 0 and 50 percent sandstone. Modified from Nesterov (1969, p. 266).

beds are 150 to 500 meters thick. Except for a few small oil fields west of the Surgut dome in the Maniysk depression and some oil and gas east of the Urengoy area, these beds are generally nonproductive of oil. Several Aptian-Albian gas reservoirs, however, are known in gas fields on the Yamal Peninsula in the northwestern area of the basin.

The total Aptian-Albian-Cenomanian section is 600-700 meters thick on the Khanty anticlize, up to 900 meters thick to the east, west, and south of this anticlize and more than 1000 meters thick to the north. See Figure 16. Cenomanian beds are predominantly continental and sandy over the eastern half of the basin where they are 300 meters or more thick. Sandstones of this section are persistent in extent and thickness and contain the major share of the basin's gas reserves, including the Urengoy gas field, the world's largest, with reserves of over 200 tcf. Some oil has also been found in Cenomanian beds east of the Urengoy field and south of the Nizhne-Vartov dome.

Turonian through Danian. The post-Cenomanian Upper Cretaceous beds present the final transgressive-regressive depositional cycle of the Mesozoic basin fill. These beds, less than 300 meters thick on the Khanty anticlize and more than 800 meters thick in the northern part of the basin, are predominantly marine throughout most of the basin. See Figure 17. A cherty marine sapropelic shale facies occupies most of the western half of the basin, grading eastward to a widespread nearshore marine shale and sandstone facies. This section has generally been nonproductive, although some gas has been found in the nearshore marine facies in the east central part of the basin.

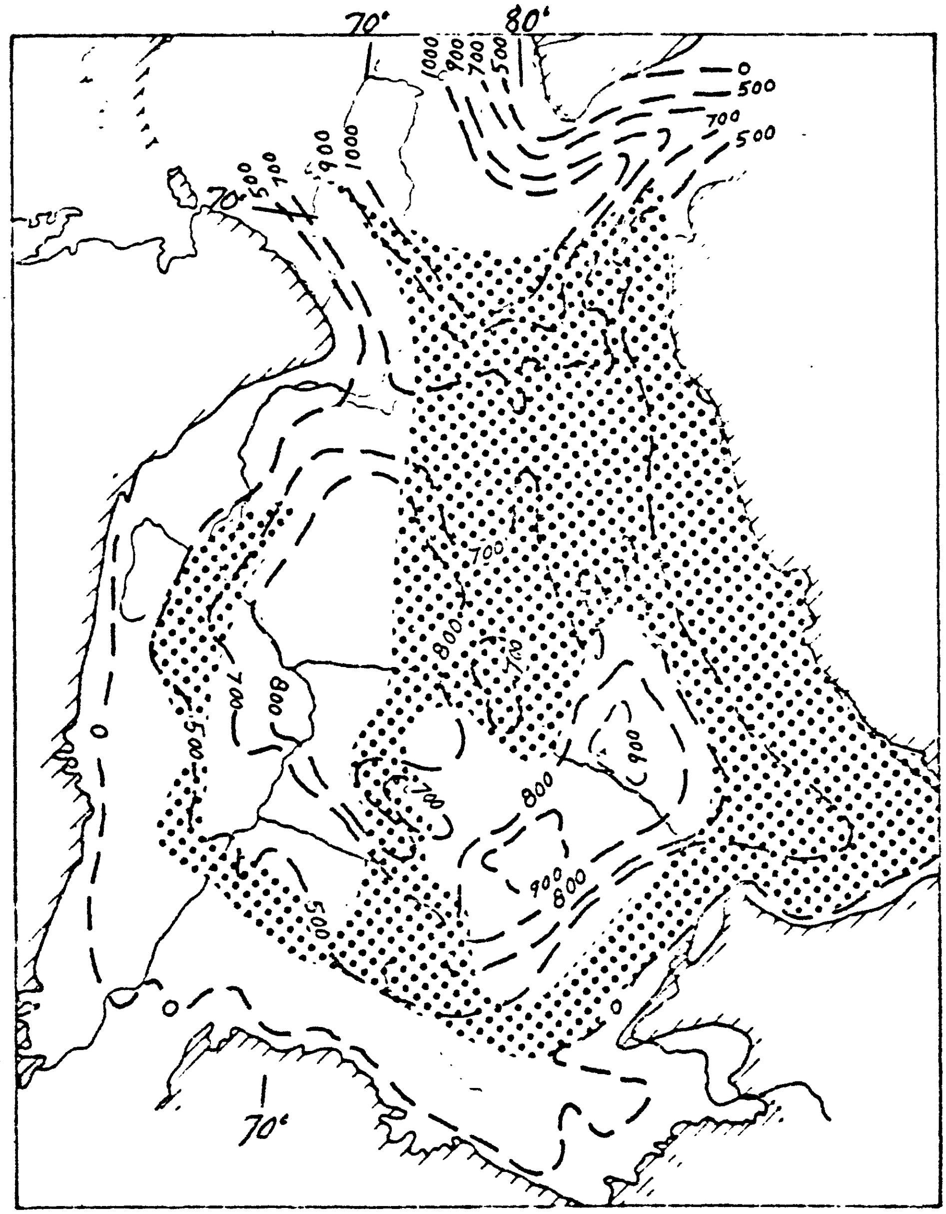

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Figure 16. Aptian, Albian, Cenomanian in the West Siberian Basin. Isopachs in meters. Stippled areas are greater than 50 percent sandstone. White areas within zero isopach are between 0 and 50 percent sandstone. Modified from Nesterov (1969, p. 290).

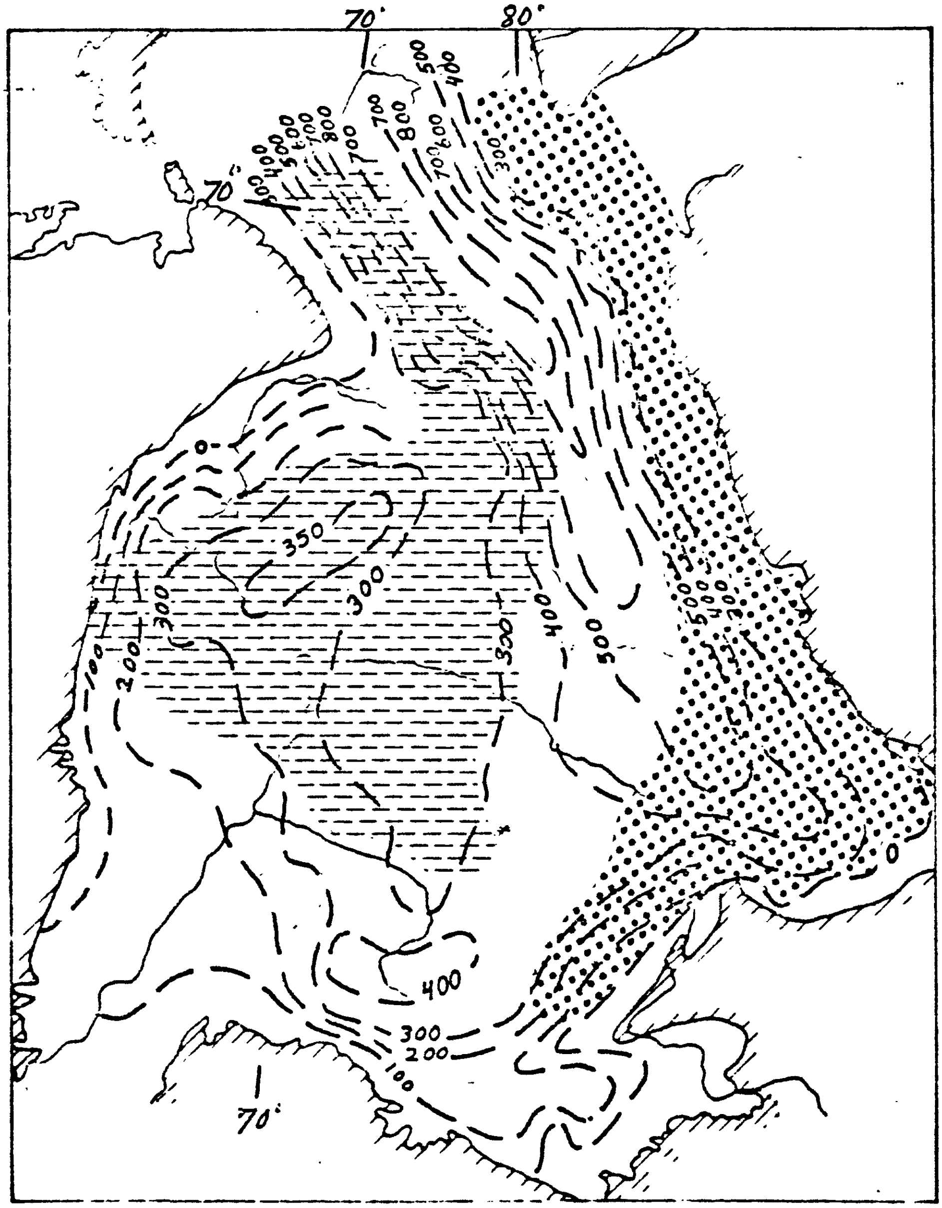

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Figure 17. Upper Cretaceous with Cenomanian in the West Siberian Basin. Isopachs in meters. Stippled areas are greater than 10 percent sandstone. Dashed areas contain no sandstone; they are largely shale. White areas within zero isopach are between 0 and 10 percent sandstone. Modified from Nesterov (1969, p. 304).

Cenozoic. Cenozoic deposits up to 1000 meters or more thick are present over most of the basin area. Paleocene rocks disconformable above the Upper Cretaceous beds represent a regressive phase consisting of continental beds in the east and southern parts of the basin and marine dark gray shale beds to the west and north. The Eocene is characterized by transgressive marine beds over the entire basin, predominantly shaly with diatomite beds. The Oligocene section is regressive, consisting of green marine shale that grades into continental sandy and lignitic deposits to the south and east. Post-Oligocene Tertiary sediments consist of green argillaceous and gypsiferous beds, which grade to red, sandy and argillaceous beds in the southern part of the basin.

Quarternary glacial deposits up to over 200 meters thick cover much of the Siberian Lowland area.

Lithofacies cross sections. No satisfactory lithofacies cross sections of the West Siberian Basin were found in the literature. Using generalized lithofacies maps from Nesterov (1969), schematic cross sections were compiled and presented here as Figures 19, 20, and 21. The positions of the cross sections are plotted on Figure 18.

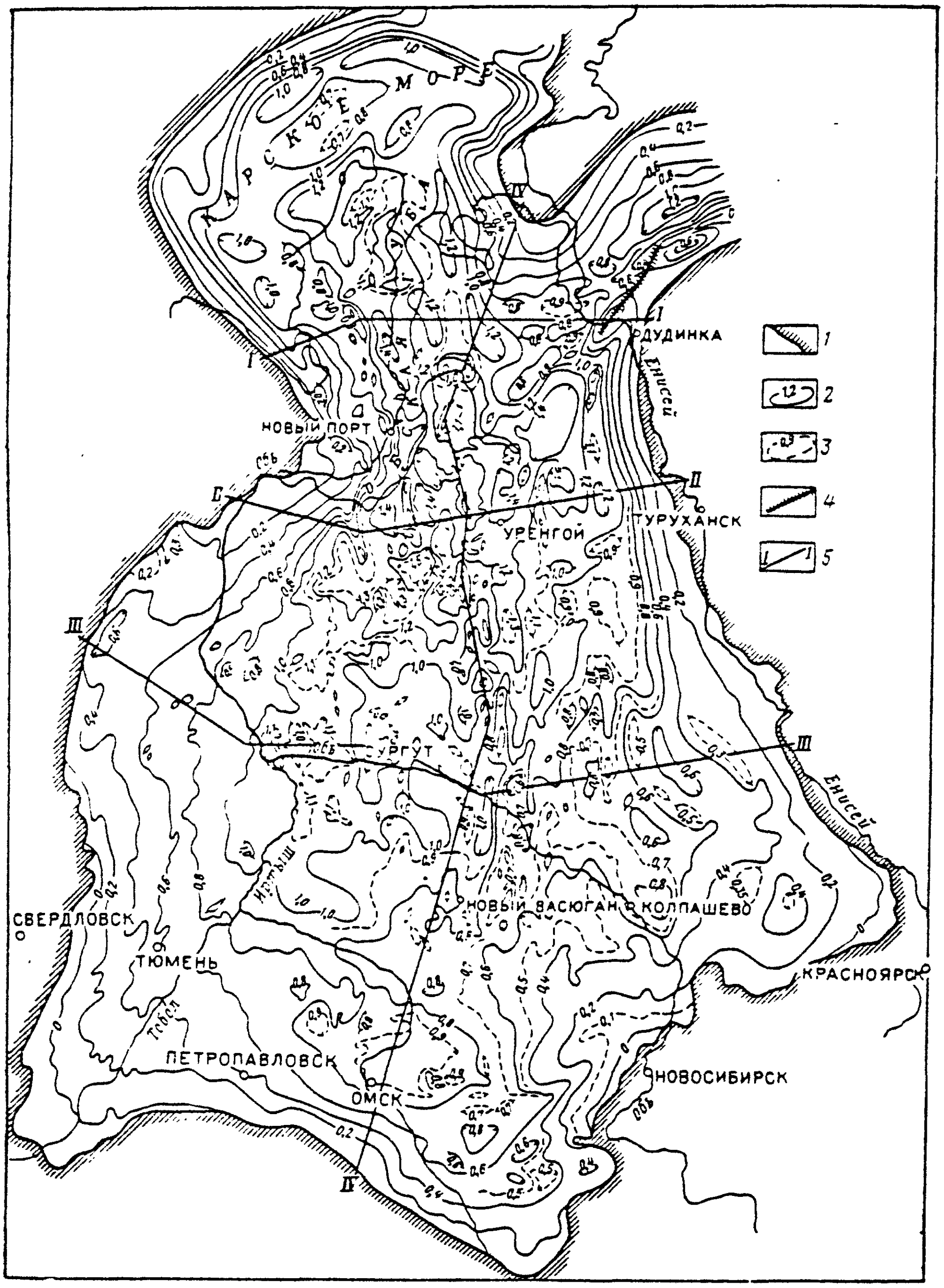


Figure 18. Structure map on the top of the Cenomanian stage of the West Siberian Basin (After Rudkevich, 1974, p. 7). 1 - Outer limit of distribution of Cenomanian sediments; structure contours on the top of the Cenomanian: 2 - at 0.2 km intervals, 3 - at 0.1 km intervals; 4 - faults; 5 - geologic profiles shown in Figures 19, 20, and 21.

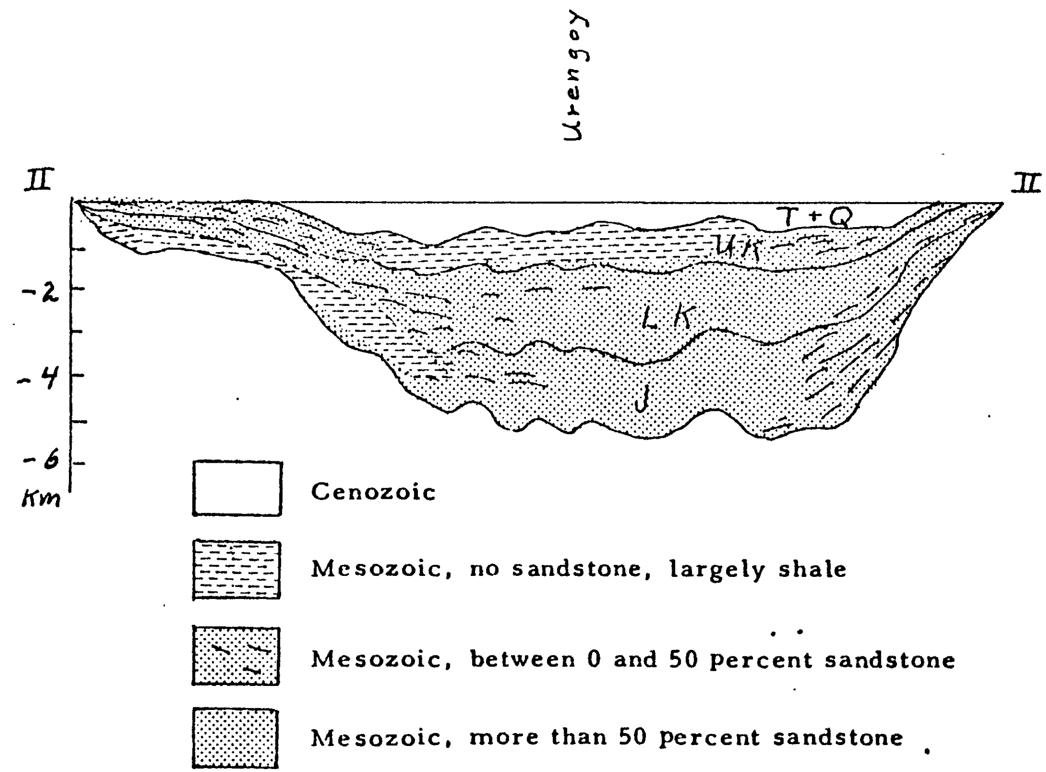


Figure 19. Generalized east-west lithofacies cross section compiled from Nesterov (1969). See Figure 18 for position.

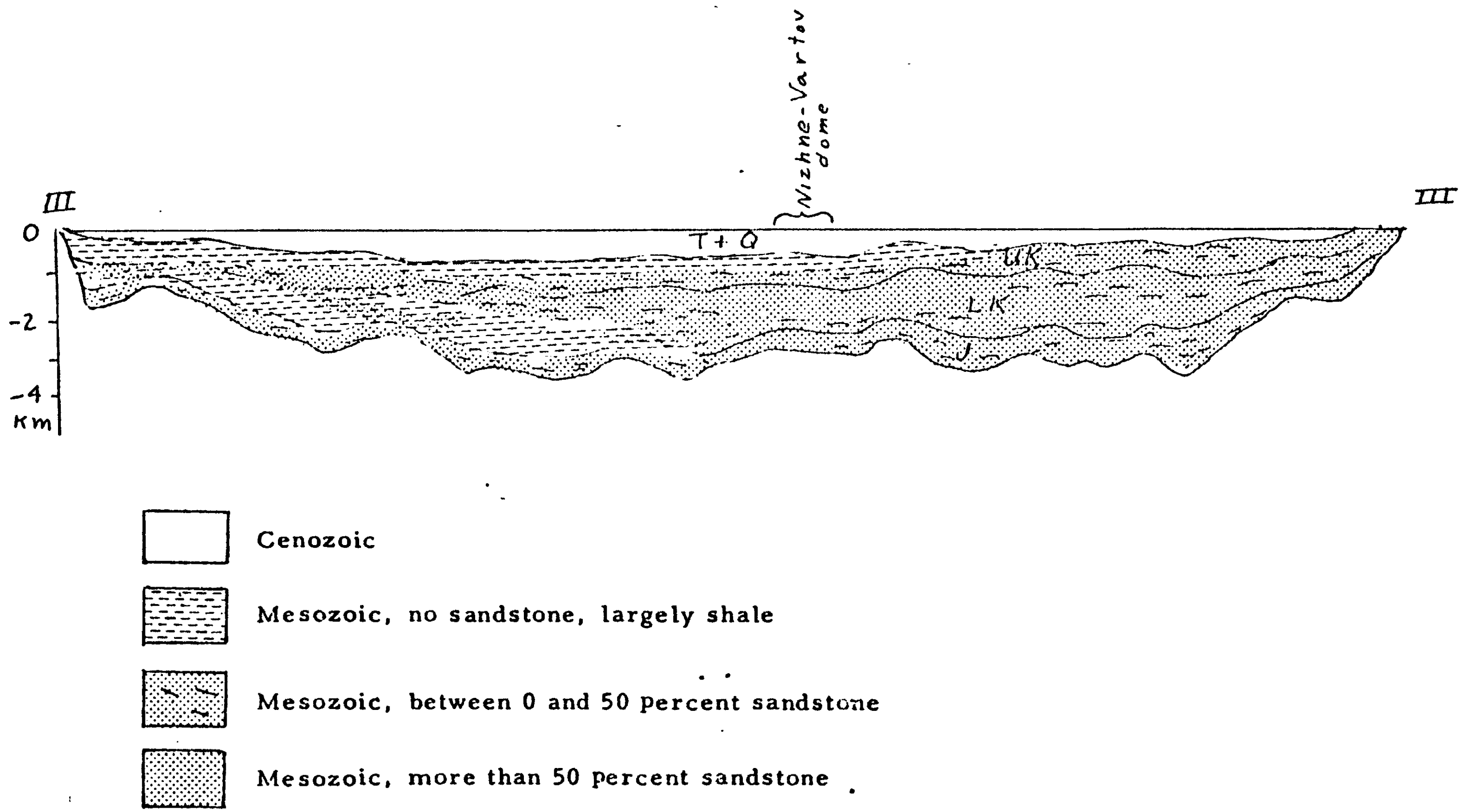


Figure 20. Generalized east-west lithofacies cross section compiled from Nesterov (1969). See Figure 18 for position.

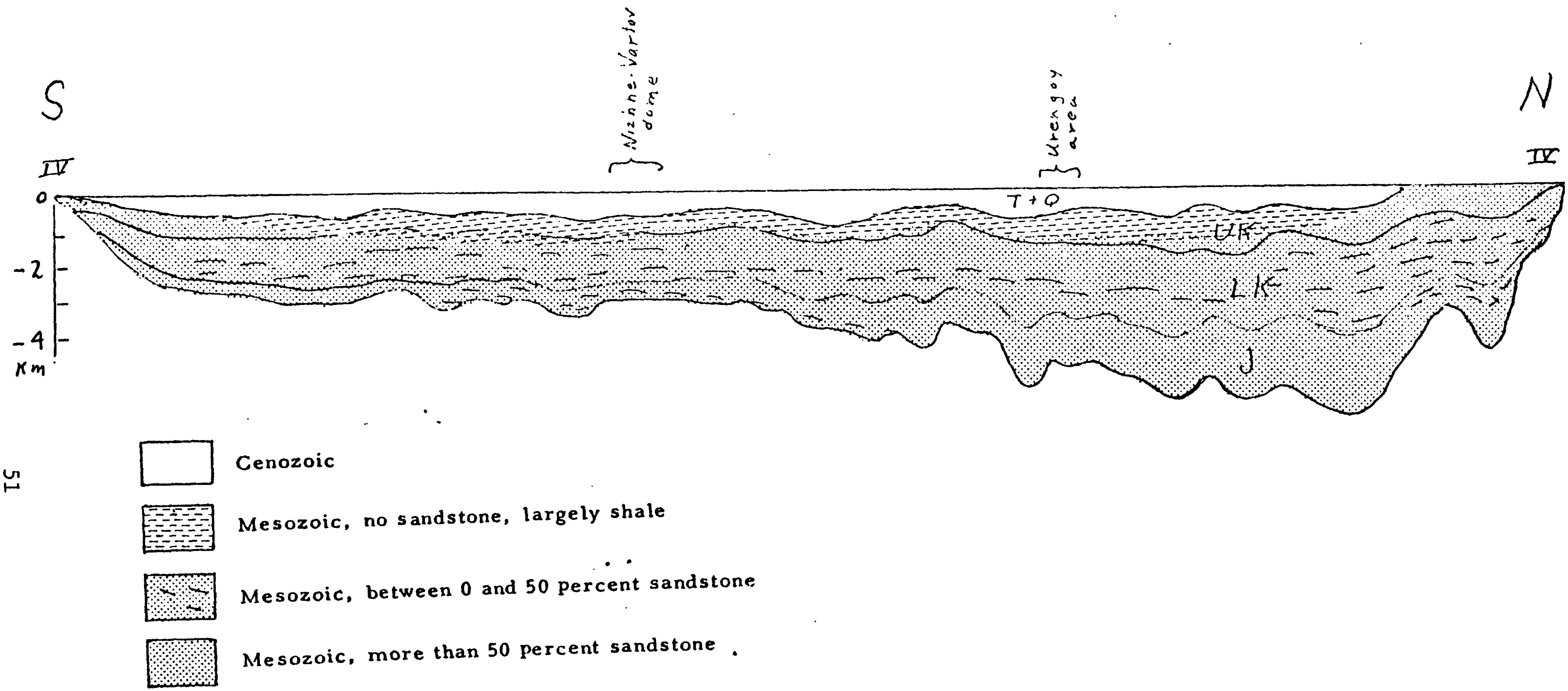


Figure 21. Generalized north-south lithofacies cross section compiled from Nesterov (1969).

See Figure 18 for position.

OIL AND GAS FIELDS OF THE WEST SIBERIAN BASIN

Producing Regions

The West Siberian Basin can be conveniently subdivided into three major productive areas based on age of the reservoir rocks, type of trap, and kind of hydrocarbons produced.

The first of these areas is the Near-Ural area in the western part of the basin (Figure 22, area IV). Production here is primarily from Upper Jurassic rocks; there is some Lower Cretaceous production. The trapping mechanism is structural-stratigraphic; reservoir rocks pinch out against high-standing basement rocks. (Figure 23.) This first area is mainly oil-productive in the south and gas-productive in the north.

The second major productive area is located in the Northern tectonic region. It includes the Yamal, Ust'-Yenisey, and northern areas (Figure 22, areas I, II, and III). Mainly gas is produced from Upper Cretaceous (Cenomanian) clastic rocks on anticlinal traps. Urengoy, the world's largest gas field, is located in this area (Figure 24).

The third major productive area is the Middle-Ob (Khanty anticlize) region (Figure 22 VI). Most of the production in this area is oil from Lower Cretaceous clastic rocks, mainly in anticline traps. However, the importance of stratigraphic trapping is being recognized increasingly. Two large regional uplifts here, the Surgut and Nizhne-Vartov domes, yield most of the oil produced in the West Siberian Basin. The super-giant Samotlor field, which is treated in detail in this report, is located on the Nizhne-Vartov dome.

Other producing regions of the basin are the Frolov, Kaymysovsko-Vasyugan, and Mezhovsko-Pudin areas (Figure 22, V, VII, and VIII).

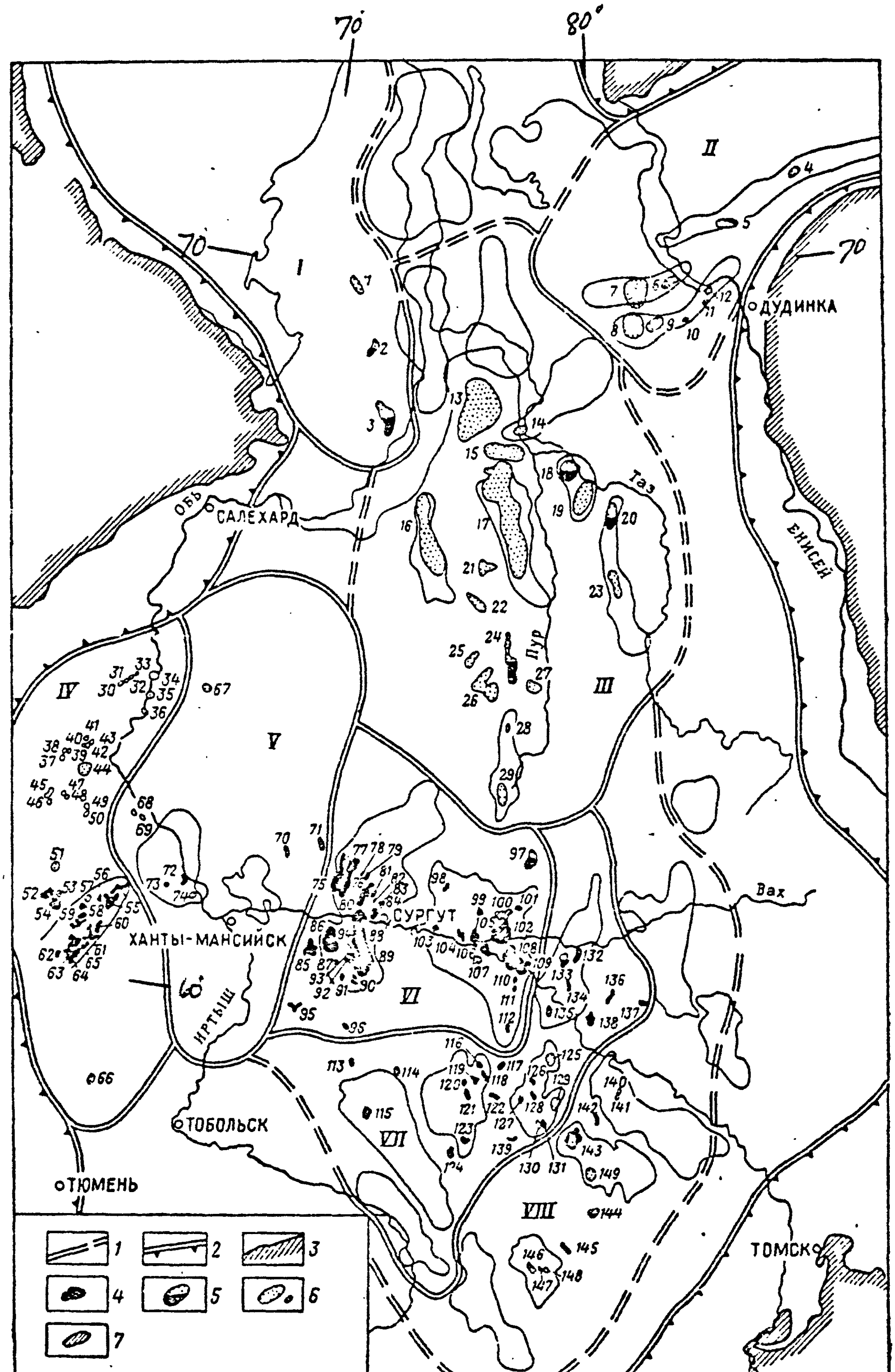
In general, the timing of trap development was probably different for the three regions. In the western region, high standing basement blocks were present prior to the deposition of the Jurassic reservoir rocks; the latter pinch out against these blocks. In the Northern tectonic region, the structural traps probably formed during the Tertiary when the entire area was uplifted. In the Middle-Ob region, however, traps formed penecontemporaneously with reservoir rock deposition. Differential compaction may also have had a significant effect on trap development in this region.

In addition to the oil-gas occurrences in the Jurassic and Cretaceous fill of the West Siberian Basin, hydrocarbon pools have been found over wide areas in pre-Jurassic (largely late Paleozoic) sediments. Flows of oil have been recovered from such rocks in not less than 12 areas (Trofimuk, 1976, p. 212), and commercial reserves have been proved (Geologiya i Geofizika, 1976, p. 3). These oils in the Paleozoics are not Mesozoic oil that has migrated there from Mesozoic rocks; they are geochemically distinct and were generated by the Paleozoic sediments (Ryzhkova, 1976, p. 122 and Trofimuk, 1976, p. 213). Deep seismic sounding indicates a great thickness of these unmetamorphosed Paleozoic rocks; in the Middle Ob region they are 3-4 km thick (Aleksin, et al, 1975, p. 6-10). According to Rigassi (1976, p. 123), "based on source rock analyses, Academician A. A. Trofimuk estimates oil generating potential of the Paleozoics of southwestern West Siberia to be between 60,000 - 148,000 barrels per acre, or more than that of the prolific Devonian in the Volga-Urals area, and of the Lower Cretaceous of the Mid-Ob region.

Nizhne-Vartov dome

Location and size. The general outline of the Nizhne-Vartov dome is plotted in Figure 22. The larger scale map in Figure 25 is an index map showing the location of the fields of the Nizhne-Vartov dome. See also Figure 32. According to Kontorovich (1975, p. 199) this major structure is 120 km by 260 km and covers an area of 22,200 sq. km. The Soviets go into great detail in naming each individual structure within the confines of large structures such as the Nizhne-Vartov and Surgut domes. On the Surgut dome, there are 71 uplifts on the top of the Jurassic, 53 uplifts on the base of the Aptian, and 38 uplifts on the top of the Cenomanian. The pattern is very similar for the Nizhne-Vartov dome. It is a normal structural situation for high standing basement rocks to lose their structural identity as thousands of feet of sediments are deposited over them. There is approximately 200 m of relief at the top of the Upper Jurassic and still approximately 40 m of relief on the Eocene for the Nizhne-Vartov dome. In Samotlor field, the area of the local structure at the top of the Cenomanian is roughly four times larger than the area of the same structure at the top of the Upper Jurassic, and the dip of the limbs of the uplift in Cenomanian beds is seven times less steep than in the underlying Jurassic beds.

Reservoir nomenclature. The principal producing units on the Khanty anticlize are designated A and B. Within the area of the Nizhne-Vartov dome these are designated AV and BV; the added V is for Vartov. These units are AS and BS on the Surgut dome.



Approx. scale 1:10 million

Fig. 22. [After Karogodin, 1974, p. 4]

Figure 22. Distribution of oil-gas areas and fields of West Siberia, Boundaries: 1 - oil-gas areas, 2 - favorable and unfavorable terrane, 3 - West Siberian Mesozoic-Cenozoic sedimentary basin. Fields: 4 - oil, 5 - oil and gas, 6 - gas, 7 - low-yielding. Oil-gas areas: I - Yamal, II - Ust'-Yenisey, III - Severnaya (northern), IV - Near-Ural, V - Frolov, VI - Sredne-Ob (Middle Ob), VII - Kaymysovsko-Vasyugan, VIII - Mezhovsko-Pudin. Fields: 1 - Arkticheskoye, 2 - Sredne-Yamal, 3 - Novoportov, 4 - Dzhangod, 5 - Ozer (north), 6 - Kazantsev, 7 - Pelyatkin, 8 - Solenin, 9 - Messoyakh, 10 - Zemnee, 11 - Nizhne-Khet, 12 - Malokhet, 13 - Yamburg, 14 - Yurkharov, 15 - Olikumin, 16 - Medvezh, 17 - Urengoy, 18 - Tazov, 19 - Zapolyar, 20 - Russkoye, 21 - Yubiley, 22 - Yamsovey, 23 - Yuzhno-Russkoye, 24 - Gubkin, 25 - Severo-Komsomol, 26 - Komsomol, 27 - Ayvasdeopur, 28 - Vengayakhin, 29 - Vengapur, 30 - Berezovo, 31 - Demin, 32 - Yuzhno-Alyasov, 33 - Severo-Alyasov, 34 - Pokhron, 35 - Chuel, 36 - Tugiyan, 37 - Yuzhno-Syskonsyn'in, 38 - Zapadno-Syskonsyn'in, 39 - Vostochno-Syskonsyn'in, 40 - Nulin-Tur, 41 Paul'-Tur, 42 - Yuzhno-Igrim, 43 - Severo-Igrim, 44 - Pungin, 45 - Gornoye, 46 - Ozer (west), 47 - Zapadno-Sykhtungort, 48 - Shukhtungort, 49 - Severnoye Sote-Yugan, 50 - Yuzhnoye Sote-Yugan, 51 - Verkhne-Kondin, 52 - Lem'in, 53 - Verkhne-Lem'in, 54 - Danilov, 55 - Potanay, 56 - Kartap'in, 57 - Kondyr, 58 - Filippov, 59 - Ubin, 60 - Semividov, 61 - Tolum, 62 - Mulym'in, 63 - Mortym'insko Teterev, 64 - Trekhozer, 65 - Vostochno-Teterev, 66 - Karabash, 67 - Severo-Kazym, 68 - Yuzhno-Yaganokurt, 69 - Karempost, 70 - Dekabr, 71 - Ay-Pim, 72 - Kamen, 73 - Lorbin, 74 - Zapadno-Yelizarov, 75 - Lyantor,

76 - Tanyaunov, 77 - Tutleym, 78 - Vachimov, 79 - Zapadno-Minchimkin, 80 - Bystrinsko-Vynchin, 81 - Yaunlor, 82 - Vershin, 83 - Severo-Surgut, 84 - Zapadno-Surgut, 85 - Salym, 86 - Pravdin, 87 - Sredne-Salym, 88 - Ust'Balyk, 89 - Mamontov, 90 - Sredne-Balyk, 91 - Severo-Balyk, 92 - Malo-Teplov, 93 - Teplov, 94 - Pyt'Yakh, 95 - Verkhne-Salym, 96 - Tukan, 97 - Var'yegan, 98 - Pokachev, 99 - Agan, 100 - Bol'shoye Chernogor, 101 - Maloye Chernogor, 102 - Samotlor, 103 - Lokosov, 104 - Severo-Pokur, 105 - Vatinsk, 106 - Megion, 107 - Yermakov, 108 - Sovetsk, 109 - Strezhev, 110 - Malorechen, 111 - Alenkin, 112 - Matyushkin, 113 - Ay-Yaun, 114 - Taylakov, 115 - Urnen, 116 - Olen'ye, 117 - Lomov, 118 - Ozer (south), 119 - Katyl'gin, 120 - Pervomay, 121 - Lontyn'yakh, 122 - Yuzhno-Cheremshan, 123 - Moiseyev, 124 - Krapivin, 125 - Severo-Vasyugan, 126 - Sredne-Vasyugan, 127 - Klynchev, 128 - Sredne-Yurol, 129 - Myl'dzhin, 130 - Verkhne-Salat, 131 - Yuzhno-Myl'dzhin, 132 - Vakh, 133 - Severnoye, 134 - Cheback'ye, 135 - Poluden, 136 - Vartov, 137 - Kiyev-Yegan, 138 - Nikol, 139 - Festival, 140 - Ust-Sil'gin, 141 - Sredne-Sil'gin, 142 - Sobolin, 143 - Luginets, 144 - Kazan, 145 - Verkhne-Tar, 146 - Mezhov, 147 - Vostochno-Mezhov, 148 - Veselov, 149 - Ostanin.

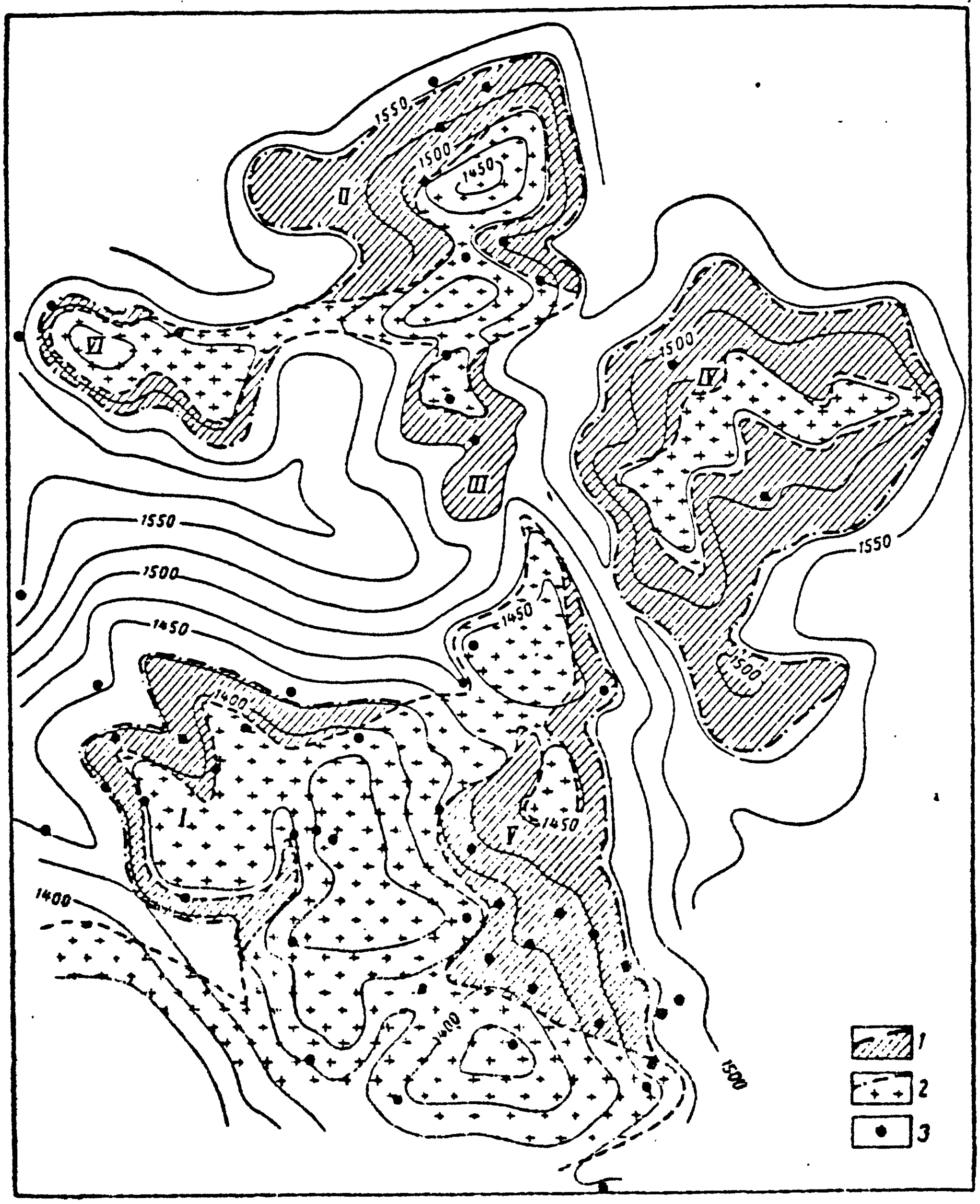


Figure 23. Structure contours of Shaim oil region on top of the productive stratum (where absent, the top of the basement surface was used in the construction). 1 - Areas of known and probable oil fields; 2 - sectors where productive stratum is absent; 3 - drill holes. Fields: I - Mulym'in, II - Mortym'in, III - Yuzhno-Mortym'in, IV - Teterev, V - Trekhozer, VI - Okunev area.

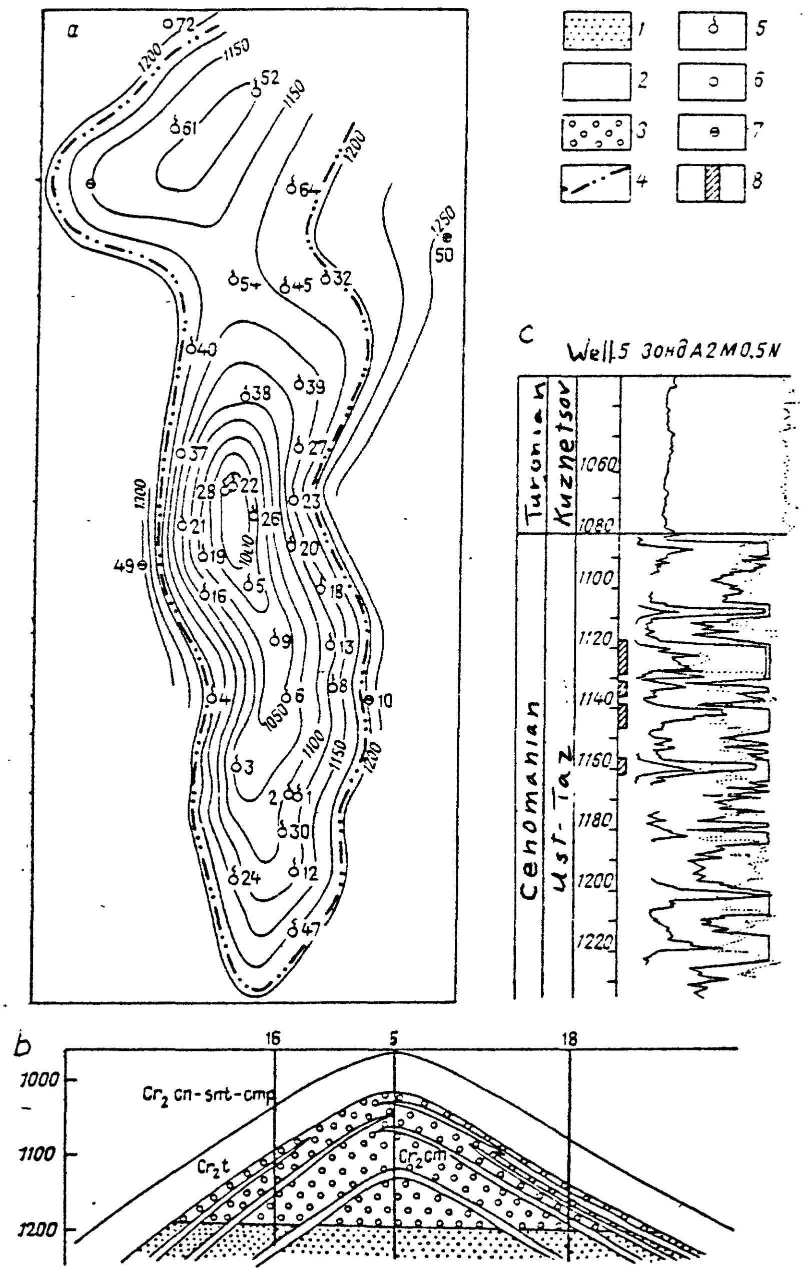
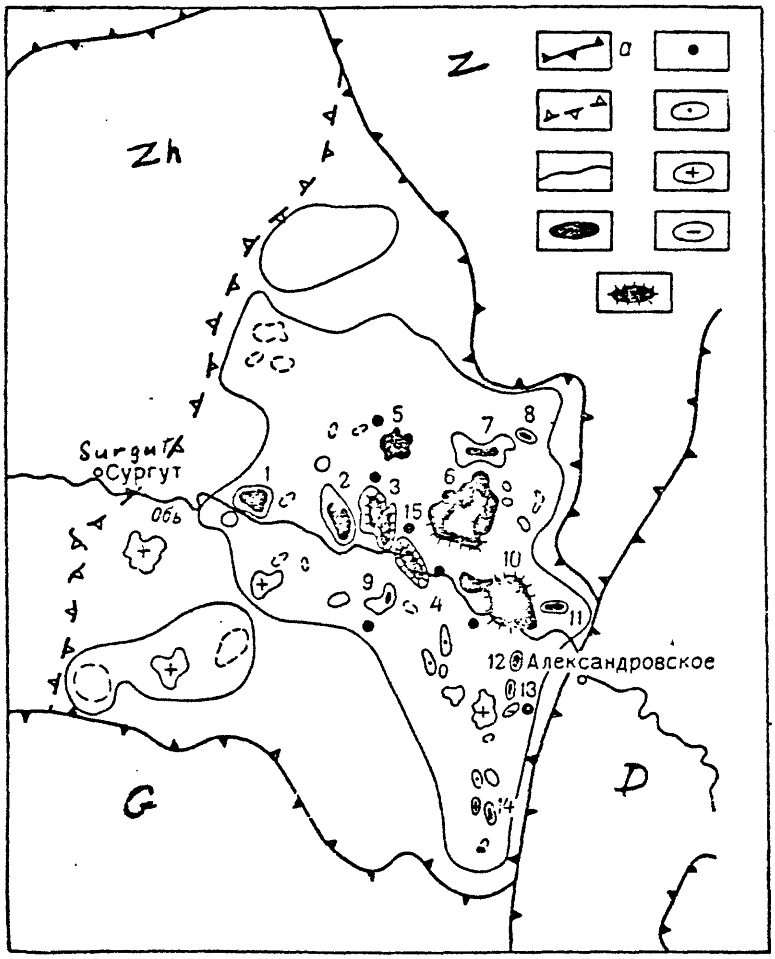


Figure 24. Urengoy gas-condensate field. a - Structure contours on top of Cenomanian productive stratum; b - geologic profile; c - geological-geophysical section of the productive part of the Cenomanian sediments; 1 - sandstone; 2 - clay; 3 - gas pool; 4 - margin of gas pool; 5 - wells yielding gas; 6 - wells yielding water; 7 - wells that have not been tested; 8 - interval of testing. (After Bliznichenko. et al, 1972, p. 114).



Approx. scale 1:4 million

Figure 25. Sketch map of distribution of oil fields of the Nizhne-Vartov region of the Middle Ob oil-gas region (after Nesterov, et al, 1971, p. 327). See Figure 42 for geographic location. Boundaries: a - oil-gas areas (G - Kaymysov, D - Vasyugan, Zh - Middle Ob, Z - Nadym-Pur); b - oil-gas regions, c - positive tectonic structures of order I and II; local uplifts: d - with oil pools, e - with oil showings, f - in exploration stage, g - drilling data not decisive, h - drilling data negative, i - with gas fields in production. Fields and oil showings: 1 - Lokosov, 2 - Severo-Pokur, 3 - Vatinsk, 4 - Megion, 5 - Agan, 6 - Samotlor, 7 - Bol'shoye Chernogor, 8 - Chernogor, 9 - Yermakov, 10 - Vartovsko-Sosnin, 11 - Strezhev, 12 - Malorechen, 13 - Alenkin, 14 - Matyushkin, 15 - Mykhpay.

Facies distributions on dome. The reservoirs for the main oil and gas pools within the Nizhne-Vartov dome were deposited during the Valaginian, Hauteriv, Barremian, and Aptian stages of the Early Cretaceous. See Table 2 for the stratigraphic position of the various A and B horizons discussed below. During this time, the area of the modern Nizhne-Vartov dome was a part of an interior basin high, across which the Early Cretaceous shoreline fluctuated repeatedly; apparently the area of the dome was neither completely flooded nor drained, and the average position of the marine-nonmarine transition was located approximately north-south across the central part of the dome area.

The clastic material for all the Lower Cretaceous productive horizons of the dome was supplied largely by rivers entering the basin from the east and southeast. (Figure 14). The distribution of clastic particles was controlled not only by the fluvial deltaic and marine environments of the transitional zones but was also influenced by differential tectonic movements of the floor of the sedimentary basin.

In several Early Cretaceous intervals on the dome there is an abrupt west to east increase in the number and thickness of the sandy and silty beds. The eastern part of the dome is characterized by a predominance of subaerial sediments and "kultuk" (deeply indented shallow bay) deltas; these are largely sandstones and siltstones. In the western part of the dome these same beds change to essentially marine clays. See Figure 26.

In stratum A_1^2, the boundary between the deltaic and the marine clay facies on the northwest runs between the Bol'shoye Chernogor uplift, where average sandstone content is 65 percent, and the Chernogor uplift, where clayey sandstones and siltstones compose 27% of the rock (Figure 26a).

In stratum A_2 among the rocks of the deltaic complex there is a predominance of subaerial facies. The shore line for this time was well defined (Figure 26b). Horizon A_2 is eroded on the southeast of the dome (Sovetsk uplift).

Sandy stratum A_3 is relatively thin. Deltaic facies here are represented largely by open and kultuk deltas. They occur mainly in the territory of the Samotlor local uplift and immediately adjacent areas. See Figure 26c.

Strata A_{4-5} are genetically a single thick complex of deltaic sediments. No map of replacements by marine sediments was constructed because of unsatisfactory differentiation of these horizons.

The sandstones of stratum B_{10} are found only in the deltaic complex in the eastern part of the dome. (Figure 26d) (Melik-Pashayev and Yusufzade, 1974, p. 28-31).

The configuration of the surface at successively higher stratigraphic levels on the Nizhne-Vartov dome changes from complex to simple; the number of individual closures decreases upward along the section.

According to Nesterov, et al (1971, p. 328-329) during Jurassic time the region of the Nizhne-Vartov dome was a monocline, which dipped to the southwest; the structure did not exist yet as a closure. The isopach

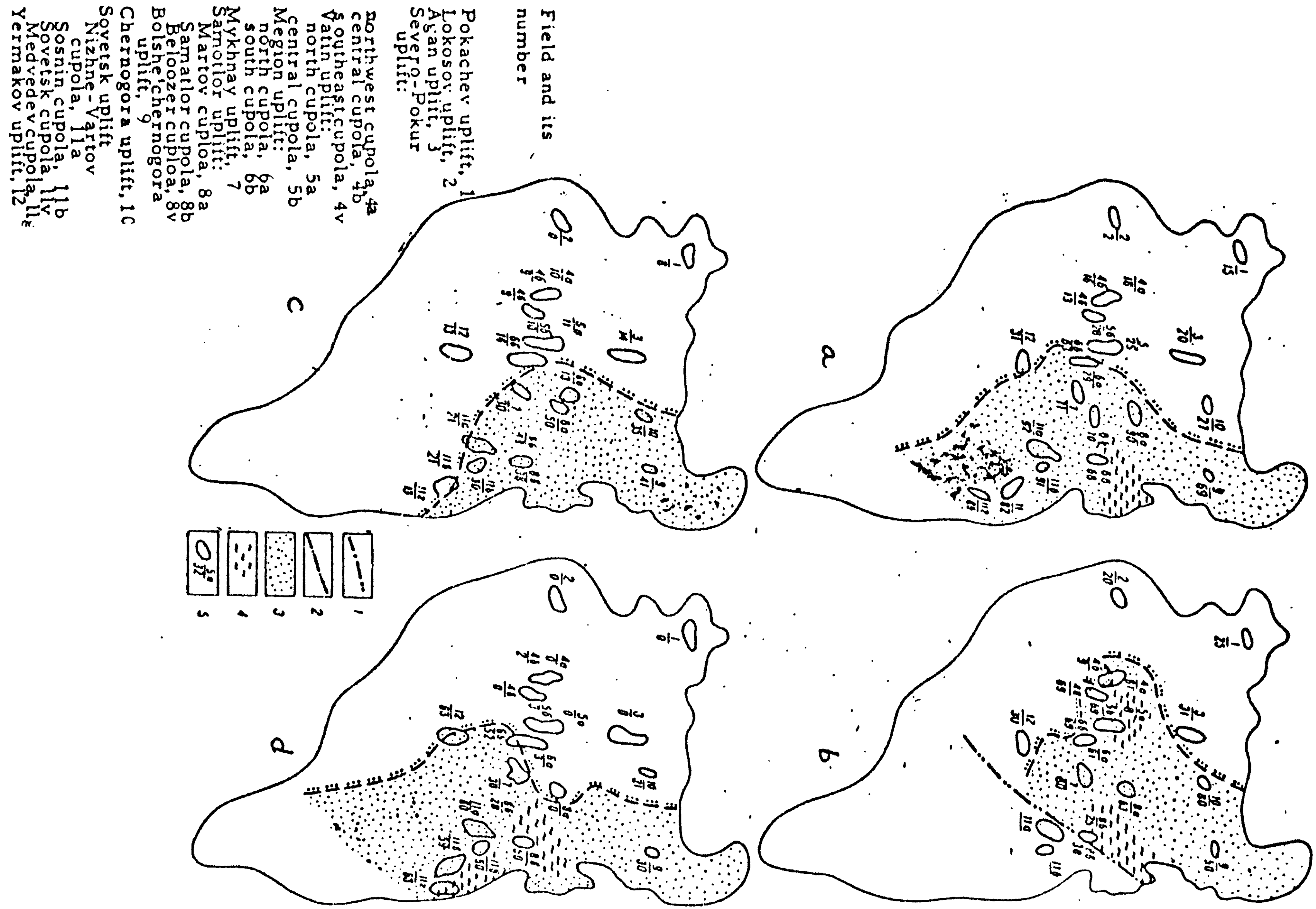


Fig. 26. Replacement of sandy sediments of the deltaic type by clayey rocks of marine origin on the Nizhne-Vartov dome. Strata: a-A^2_1, b-A_2, c-A_3, d-B_{10}. 1-Line of pinchout of horizon A_2; 2-line of replacement of sandy sediments of deltaic type; 3-sandy sediments of deltaic type; 4-lacustrine-swamp deposits; 5-numerator-number of field (see Table 2), denominator-sandiness of horizon, percent of total thickness of rock.

(After Melik-Poshayev and Yusufzade, 1974, p. 28-31) maps, however, show thinning of the Jurassic beds in the general area of the Nizhne-Vartov dome, suggesting that some closure was present during this time on a larger area that included the Nizhne-Vartov dome. Beginning with the Berriasian and particularly in the Valanginian, the main characteristics of the dome took shape. At the beginning of the Aptian, the paleo-amplitude on the top of the Tyumen formation had reached about 50 percent of its present magnitude. This was a period of about 50 m. y. from 165 m. y. to 110 m. y. During Aptian-Albian, Late Cretaceous, and Paleogene time growth was slower. The increase in amplitude of the dome on the top of the Tyumen formation during this time was about 25 percent of the present magnitude. This time interval was from 140 m. y. to 23 m. y., which is 87 m. y. The last 25 percent of growth of the structure took place during the 23 m. y. of the Neogene. (Nesterov, et al, 1971, p. 328-329).

Exploration began on the Nizhne-Vartov dome in 1957. The first field, Megion, was discovered in 1961, and the super-giant Samotlor in 1965.

Table 3 lists the fields of the Nizhne-Vartov dome and the depths to the water-oil contacts of the pay zones.

Samotlor Field

General statement. Samotlor field, the largest oil field in the USSR, is located in the Middle-Ob region on the Nizhne-Vartov dome; it was discovered in 1965 by the first wildcat well. Geologically, the field is typical of most giant fields of the world with respect to reservoir rock

TABLE 3.

DISCOVERY DATE, RESERVOIRS, AND WATER LEVELS OF FIELDS OF THE NIZHNE-VARTOV DOME (From Kontorovich, 1975, p. 443-444)

SAMOTLOR (1965)

Reservoir	Water level (meters)
AV_1	1693
AV_{2-3}	1693
AV_{4-5}	1750
AV_6	2076
BV_8	2200
BV_{10}	2157
BV_{11}	2167

BOL'SHECHERNOGOR (1969)

Reservoir	Water level (meters)
AV_1	1685
AV_2	1685
BV_8	2108
BV_{10}(w)	2200
BV_{10}(e)	2230
Ju_1	2435

SEVERO-POKUR (1964)

Reservoir	Water level (meters)
AV_1	1697
AV_2	1697
AV_4	1759
BV_0	1915
BV_6(w)	2110
BV_1	1938
BV_6(c)	2095
BV_6(e)	2093
BV_8(w)	2215
BV_8(e)	2191
BV_9	2191

VATINSK (1963)

Reservoir	Water level (meters)
AV_1	1693
AV_2	1690
BV_0	1859
BV_1	1876
BV_4	1950
BV_6(c)	2017
BV_6(n)	2050
BV_7	2050
BV_8(n)	2125
BV_8(s)	2131
Ju_1	2402

MYKHPAY (1969)

Reservoir	Water level (meters)
AV_1	1683
AV_2	1683
BV_8(w)	2110
BV_8(e)	2110
BV_{10}(e)	2200
Ju_1	--

SOS'NIN (1962)

Reservoir	Water level (meters)
AV_1	1652
AV_{2-3}	1671
AV_4	1715
BV_1	1870
BV_2	1903
BV_{4-5}	1977
BV_7	2000
BV_8	2030
BV_{10}(e)	2115
BV_{10}(s)	2140
BV_{10}(w)	2140
Ju_1	2410
Ju_2	2486
Ju	2675

MEGION (1961)

Reservoir	Water level (meters)
AV_1	1693
AV_2(e)	1693
AV_2(s)	1693
AV_8(n)	2109
AV_8(s)	2121
Ju_1	2435

AGAN

Reservoir	Water level (meters)
AV_1	1693
B_6	2055
BV_8	2178
BV_9	2178
BV_{19}	2336
BV_{22}	2345

type (sandstone), trap type (anticlinal), age of reservoir rock (Cretaceous), average depth of pay (5000'-7000'), deepest pay (7000'), depositional environment (shelf-Shallow marine), and average net feet of pay (<100'). Samotlor field is atypical with respect to magnitude of accumulation (>10 billion bbls) and the area of production (>200,000 acres).

Samotlor produced about 2.22 million b/d in 1976; this was 61 percent of the total production for West Siberia. Cumulative production as of January 1, 1977, was 2,510 million barrels. (International Petroleum Encyclopedia, 1977, p. 212, 238).

Oil pools have been found in "strata" ranging in age from Late Jurassic to Cenomanian. These are strata Yu, (Late Jurassic); BV_{11}, BV_{10}, and BV_8 (Valanginian); and AV_6, AV_{4-5}, AB_{2-3}, and AV_1. (Hauteriv-Barremian-Aptian). A gas pool occurs in stratum PK (Cenomanian), and gas caps are present in association with the oil pools of the AV strata. (Nesterov, 1975, p. 106). Depth to basement in the field is 2700 m. (Muravlenko, et al, 1973, p. 1).

Detailed descriptions of Samotlor field are given by Nesterov, et al, (1971, p. 350-355), Karogodin, et al (1972, p. 136-139), Salmanov (1974, p. 151-154), Trebin, et al (1974, p. 374-375), Kontorovich et al (1975, p. 488-491), and Nesterov, et al, (1975, p. 103-108).

Extent of field. The actual area that is included in the Samotlor field is not clearly defined in the Soviet literature. The Samotlor, Belozer, Martov, Malosamotlor, and Pauy local uplifts are consistently included in the field. See Figure 32 for location of the local uplifts.

The Mykhpay local uplift is included in the Samotlor field by Kontorovich et al (1975, p. 488), Rovin (1975, p. 146), and Salmanov (1974, p. 151). Kunin (1976, p. 39) states, however, that the Mykhpay local uplift, which had shown up as a closure on the seismic survey maps, failed to be confirmed by drilling; yet Kornev (1976, p. 17) lists Mykhpay as one of the fields discovered in 1971, and Fain (1977, p. 13) treats it as a separate field.

The Bol'shoye Chernogor field and the Chernogor uplifts are generally not included in the Samotlor field (Salmanov, 1974, p. 57, 124; Kontorovich, 1975, p. 444). Svishchev and Ishayev (1974, p. 12) discuss the Chernogor field as a "satellite-field" of Samotlor and include within it the Zapadno-Chernogor, Bol'shoye Chernogor, Maloye Chernogor, Chernogor, and other uplifts. This same paper describes Mykhpay also as a satellite-field. Musin, et al (1972, p. 1), however, include Bol'shoye Chernogor in the Samotlor field, and Arzhanov and Fain (1975, p. 38) include the Chernogor uplift.

The most recent authoritative definition of the limits of Samotlor pool appears to be that of Salmanov (1975, p. 20). See Figure 27. The area designated here includes the eastern half of the earlier proposed Mykhpay structure and all the Chernogor group of structures. This larger area is commensurate with the 900 sq. km. area of Samotlor field given by Kunin (1976, p. 38).

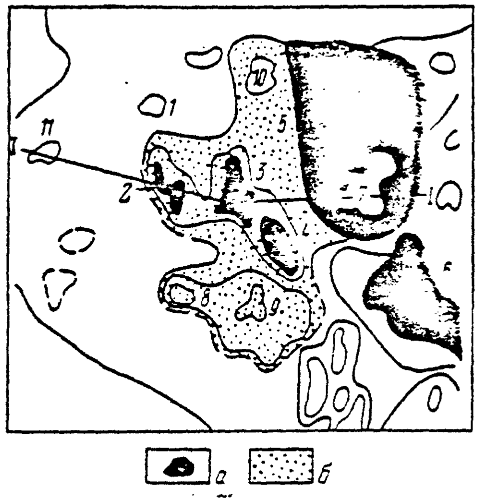


Fig. 27. Distribution of oil pools in the central part of the Nizhue-Vartov dome.

a - Areaswith demonstrated oil-gas productivity of horizon AV_1: 1 - Ur'yev, 2-Severo-Pokur, 3- Vatinsk, 4-Megion, 5-Samotlor, 6-Sovetsk, 7-gas cap of Samotlor field; b - areas of probable oil productivity of horizon AV_1: structures: 8-Orekhov, 9-Yermakov, 10-Agan, 11-Lokosov. (After Salmanov, 1975, p. 20).

Reservoir rocks. The reservoir rocks of Samotlor field occur within a section more than 600 m thick (Markovskiy, 1973, p. 269). Fine- to medium-grained deltaic sandstones and siltstones alternate with shales and also grade laterally into shales. The sandstones and siltstones are polymict (mixed composition); they contain 25-60% feldspar, which is strongly altered to various clay minerals and sericite. The remainder is largely quartz. The reservoirs are characterized by high contents of combined water and the presence of broad transition zones that contain both loosely bound and free water (Sanin, et al, 1974, p. 31). Characteristics of the various reservoir strata are listed in Table 4. See Table 2 for stratigraphic position of the reservoir strata. See Plate 1 for detailed parameters of field.

Three cross sections of the field are shown in Figures 28, 29, and 30. These illustrate the rapid facies changes that are so common in the field.

Stratum Ju_1. Two oil pools have been found in Upper Jurassic rocks in the northeast part of the Samotlor field. One of these is on the Maloye Chernogor local uplift*; the water-oil contact is at -2470 m. The second pool occurs on Bol'shoye Chernogor local uplift, and the water-oil contact is at -2430 m. The stratum is 7-10 m thick, and yields of wells reach 35-110 tons of oil per day (Svishchev and Iskayev, 1974, p. 13).

The reservoirs here are sandstones, which contain lenses of siltstone and shales (Nesterov, et al, 1975, p. 106).

* See glossary

Thickness of oil column is 50 m; formation pressure is 245 kgs/cm^2, formation temperature is 88°C; and thickness of the seal is 40 m (Salmanov, 1974, p. 124-125).

The Mykhpay local uplift also has a pool in stratum Ju_1 (Kornev, et al, 1976, p. 16).

Stratum BV_{11}. An oil pool occurs in Valangiaian stratum BV_{11} on the Samotlor local uplift; this is in the middle of the Megion Formation. The stratum consists of sandstones that contain siltstone and shale beds. To the northeast and northwest these sandstones pass into shale. The clay seal is 5-6 m thick. Reservoir porosity of the stratum is 21-26 percent, and permeability is up to 500 md (Salmanov, 1974, p. 150).

Stratum BV_{10}. Stratum BV_{10} occurs in the middle of the Megion formation. An oil pool is present in this stratum on the Samotlor, Belozer, and Mykhpay local uplifts. Figure 31 is a structure map of this stratum that shows the boundaries of the pool. The position of the cross section of Figure 29 is also plotted on this map. The stratum is composed of sandstone and lenses of shale; however, it passes into shale within the structure, and the pool does not extend to the west into the area of the Martov local uplift (area of wells 17, 31, and 16 of Figure 31). See also Figures 26 and 33.

The areal extent of the oil pool in BV_{10} is also plotted in Figure 33. Planimetric measurement of this area yielded a value of 250 sq. km. This calculation assumed a scale for this map that was based on a scale of a much smaller-scale map; consequently, this value might be as much as 10 percent different from the correct value.

Reservoir porosity of the stratum is 21-26 percent, and permeability is up to 500 md and more. Clayey rocks of the Megion Formation 60-70 m thick act as the seal for the pool. Formation pressure is 220 kgs/cm^2, and formation temperature is 75°C. Gas-oil ratio is 100 m^3/m^3. The height of the oil column is 95-100 m (Nesterov, 1975, p. 106).

A separate oil pool is present in stratum BV_{10} on the Mykhpay local structure (Kornev, 1976, p. 171).

Figure 32 is a structure map on stratum BV_{10} for the entire Nizhne-Vartov dome. The position of the water-oil contact is successively higher toward the south, southeast, and southwest, in spite of downward dip of stratum BV_{10} in these directions. This indicates that the main source of generation of hydrocarbons in these sediments lies to the north of the dome, according to Nesterov (1969, p. 193).

Stratum BV_8. This is the principal producing stratum of Samotlor field; according to Muravlenko, et al (1973, p. 59) it contains 41 percent of the reserves of the field. The main pool is shown in Figure 33; it covers 334 sq. km., assuming the same scale noted for BV_{10} above. This pool extends over the Samotlor, Martov, Pauy, Maloye Chernogor, and Belozer local structures (Nesterov, 1975, p. 100). The areal extent of the main BV_8 pool is also shown in Figures 34, 35, and 37. Note differences in shape of the pool on these three maps. A separate pool occurs in BV_8 on the Mykhpay local uplift (Kornev, et al, 1976, p. 17).

TABLE 4

Characteristics of Samotlor Reservoir Rocks

Index of strata	Number of beds		Thickness of beds		Percent of sandstone	Number of determinations	Permeability, md.			Combined water				Residual oil saturation			
										Gas saturated zone		Oil saturated zone		Gas saturated zone		Oil saturated zone	
	Range	Average	Range	Average			Min.	Max.	Average	Number of determinations	Average, %	Number of determinations	Average, %	Number of determinations	Average	Number of determinations	Average, %
A_1^1	0—13	6	0,4—10,4	2,5	54,8	421	3,7	939,3	33,4	210	65,2	157	70,0	36	10,3	42	15,0
A_1^2	0—14	3	0,4—10,6	2,5	52,0	429	45,1	4328,0	438,0	113	29,3	308	30,5	38	9,0	137	17,4
A_2	1—12	5	0,4—12,2	2,0	72,8	429	19,0	1591,7	495,0	23	27,6	396	29,2	14	8,5	204	17,2
A_3	0—8	4	0,4—13,6	1,6	47,0	184	3,6	944,3	423,6	—	—	174	32,2	—	—	67	15,3
A_{4-5}	4—24	11	0,4—21,6	2,8	71,0	462	19,0	2335,6	1087,4	—	—	439	23,2	—	—	215	18,7
$Б_8^0$	0—7	3	0,4—7,8	1,2	35,7	93	9,1	945,0	346,1	—	—	92	31,5	—	—	36	18,5
$Б_8^1$	2—10	5	0,4—20,4	3,6	82,0	876	10,9	1939,6	595,3	—	—	871	25,1	—	—	380	16,8
$Б_8^2$	0—7	2	0,4—3,8	0,9	26,7	40	11,5	286,6	81,8	—	—	39	35,8	—	—	13	16,6
$Б_{10}^0$	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
$Б_{10}^1$	0—12	4	0,4—9,2	1,5	39,8	134	6,5	774,1	223,8	—	—	131	32,2	—	—	77	15,1
$Б_{10}^2$	0—11	3	0,4—10,4	1,2	37,8	29	11,4	159,0	69,6	—	—	29	43,0	—	—	15	13,2

After Musin, 1972, p. 2

Commas are decimals.

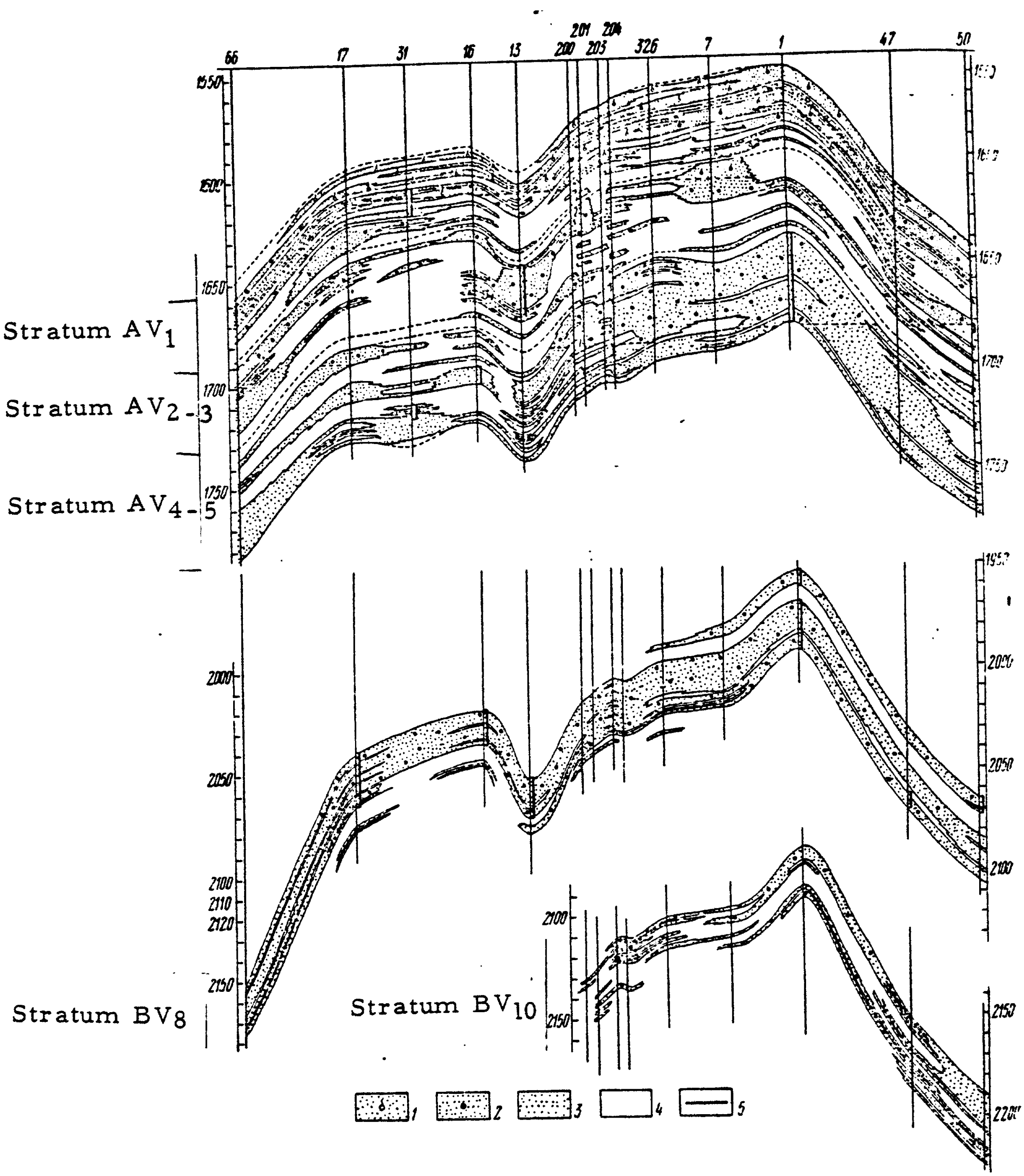


Fig. 28. Geologic cross section through Samotlor field.

Reservoir rocks: 1 - gas-bearing, 2 - oil-bearing, 3 - water-bearing, 4 - non-reservoir rocks, 5 - intervals of perforation in step-out wells. (from Muravlenko, et al, 1973, p. 2)

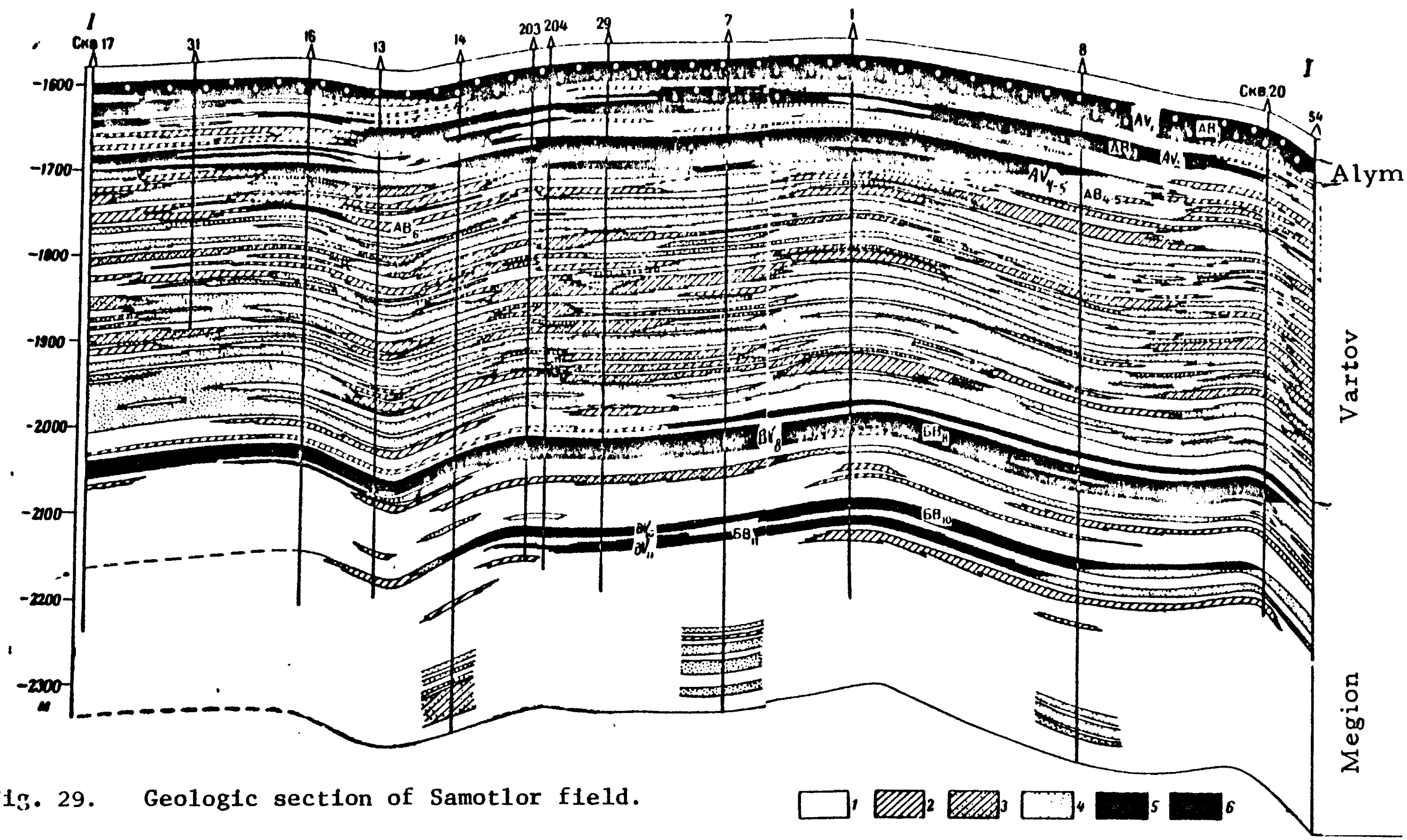


Fig. 29. Geologic section of Samotlor field.

1 - clay, shale; 2 - siltstone; 3 - alternating clay, siltstone, and sandstone (sand); 4 - sandstone; 5 - oil pools; 6 - gas pool. See Fig. 31. for location of cross section (from Nesterov, et al, 1971, p. 352-353).

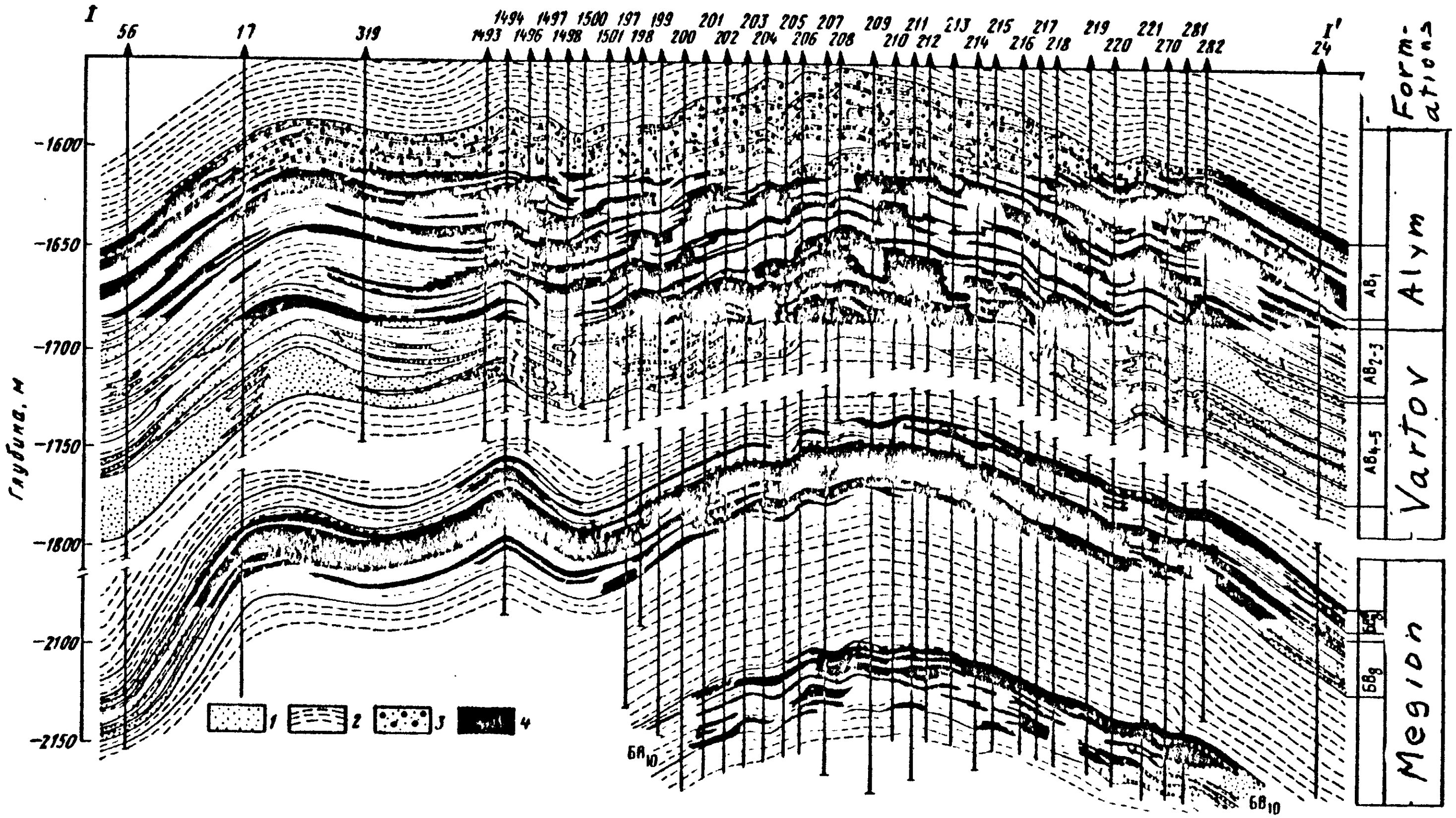


Fig. 30. Geologic profile of Samotlor field.

1 - Predominately sandy rocks, 2 - predominately clayey rocks, 3 - gas, 4 - oil. See Fig. 45. for location of cross section (from Nesterov, et al, 1975, p. 105).

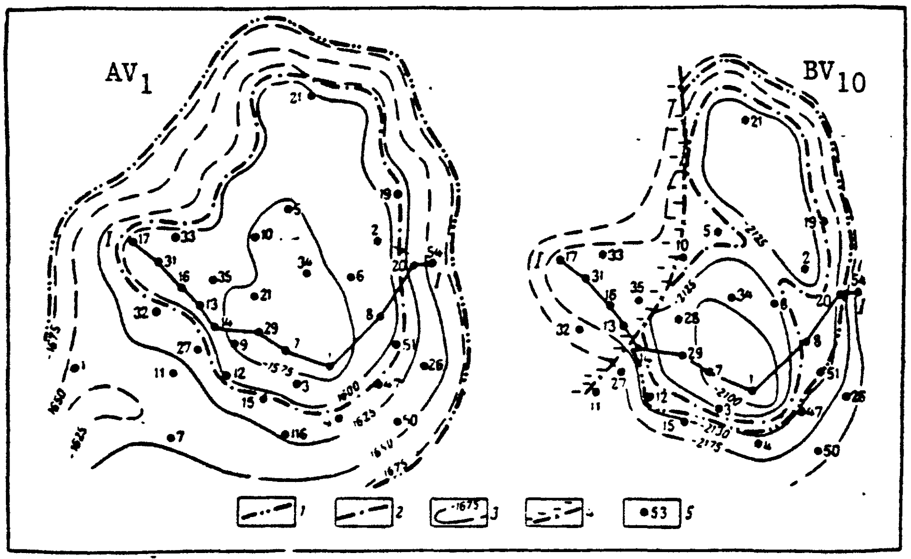


Fig. 31. Structure maps of Cretaceous sediments of Samotlor field. (after Nesterov, et al, 1971)
1 - Outer boundary of oil pools*; 2 - inner boundary of pools*;

3 - structure contours on top of strata AV_1 and BV_{10}; 4 - line of

replacement of BV_{10} by shale; 5 - drill holes.

*See glossary

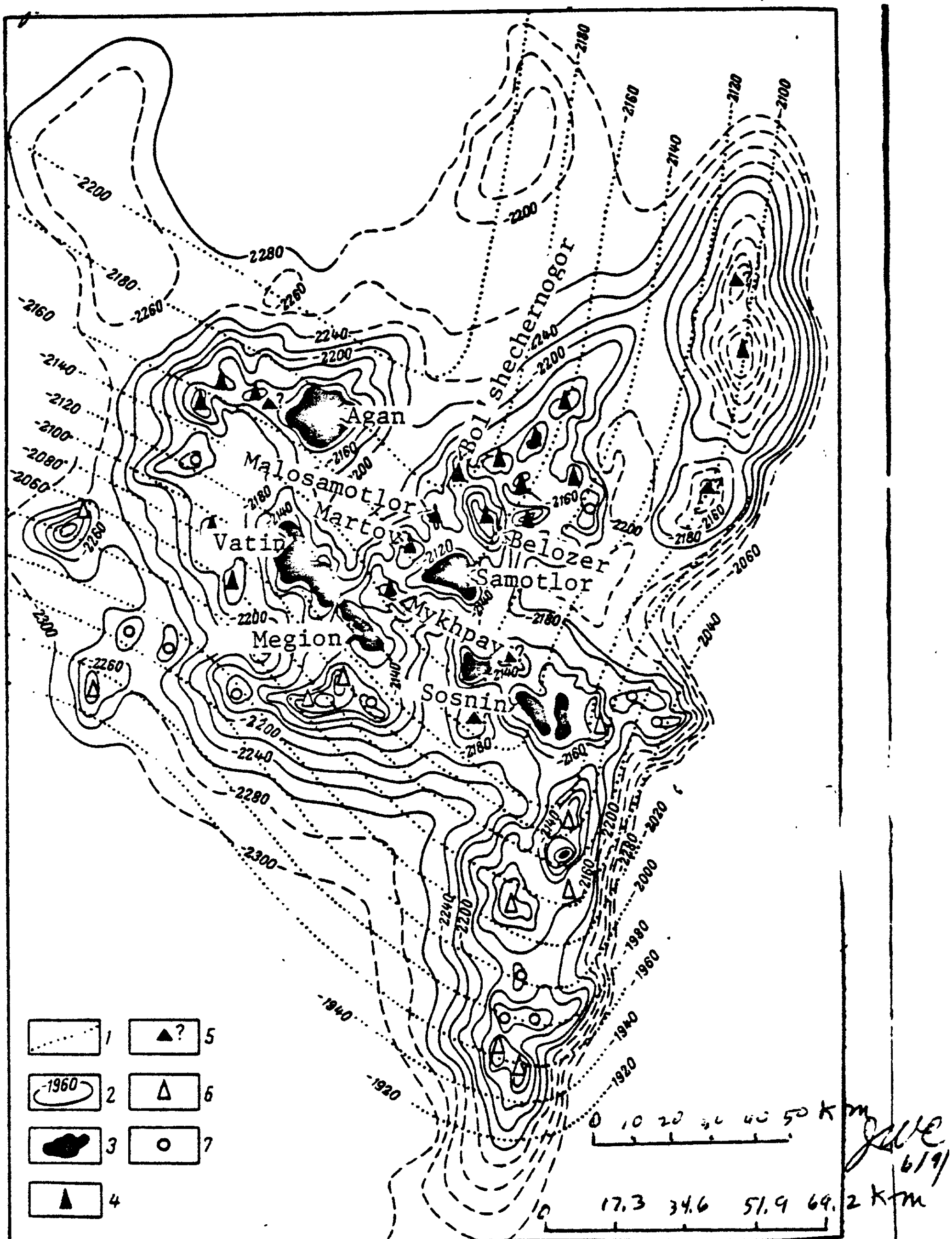


Fig. 32.
Water-oil contact in Megion stratum B_X (BV_{10}) of the Nizhne-Vartov dome. (From Nesterov, 1969, p. 194)

1 - Contours showing equal depths of the water-oil contact in stratum $B_X(BV_{10})$; 2 - structure contours on top of the Megion Formation; 3 - oil pools within the Megion Formation; 4 - same, probable; 5 - structures of unclarified favorability; 6 - structures for which results were negative for the Megion Formation; 7 - structures on which the Megion Formation is probably water-bearing.

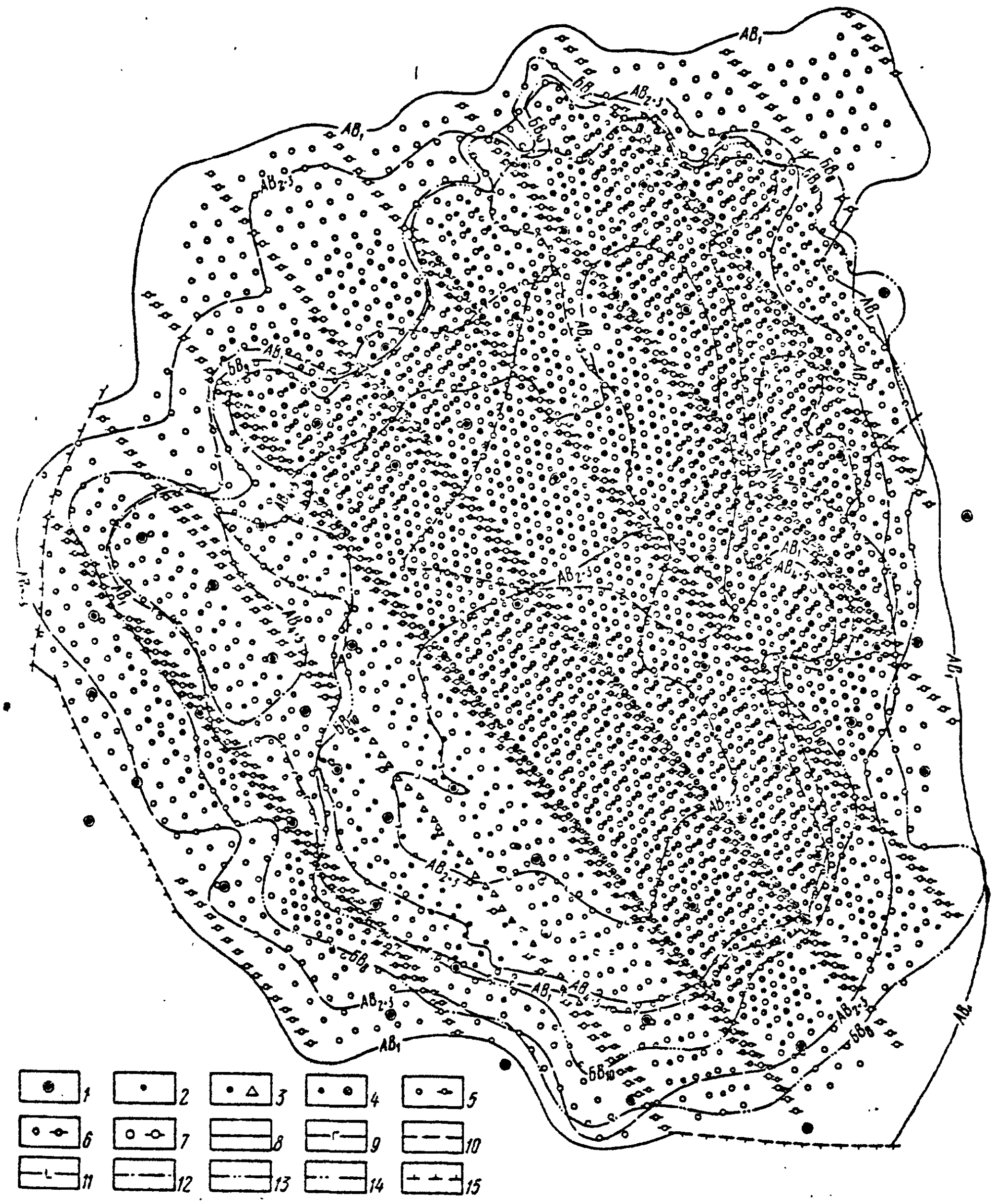


Fig. 33. Distribution of production and injection wells on production objectives of Samotlor field. Wells: 1 - outlining, 2 - production, drilled on objective A, 3 - production and injection wells drilled on objective B, 4 - planned production and injection wells on stratum BV_{10}, 5 - planned production and injection wells on stratum BV_8, 6 - planned production and injection wells on stratum AV_{2-3}, 7 - planned production and injection wells on stratum AV_1, and AV_{4-5} in five-row blocks and on objective A in three-row blocks; outer boundary of: 8 - oil pool in stratum AV_1, 9 - gas cap of oil pool in stratum AV_1, 10 - oil pool in AV_{2-3}, 11 - gas cap of oil pool in stratum AV_{2-3}, 12 - oil pool in stratum AV_{4-5}, 13 - oil pool in stratum BV_8, 14 - oil pool in stratum BV_{10}, 15 - line of facies change in sandstone of stratum BV_{10}. (After Muravlenko, et al, 1973, p. 5.)

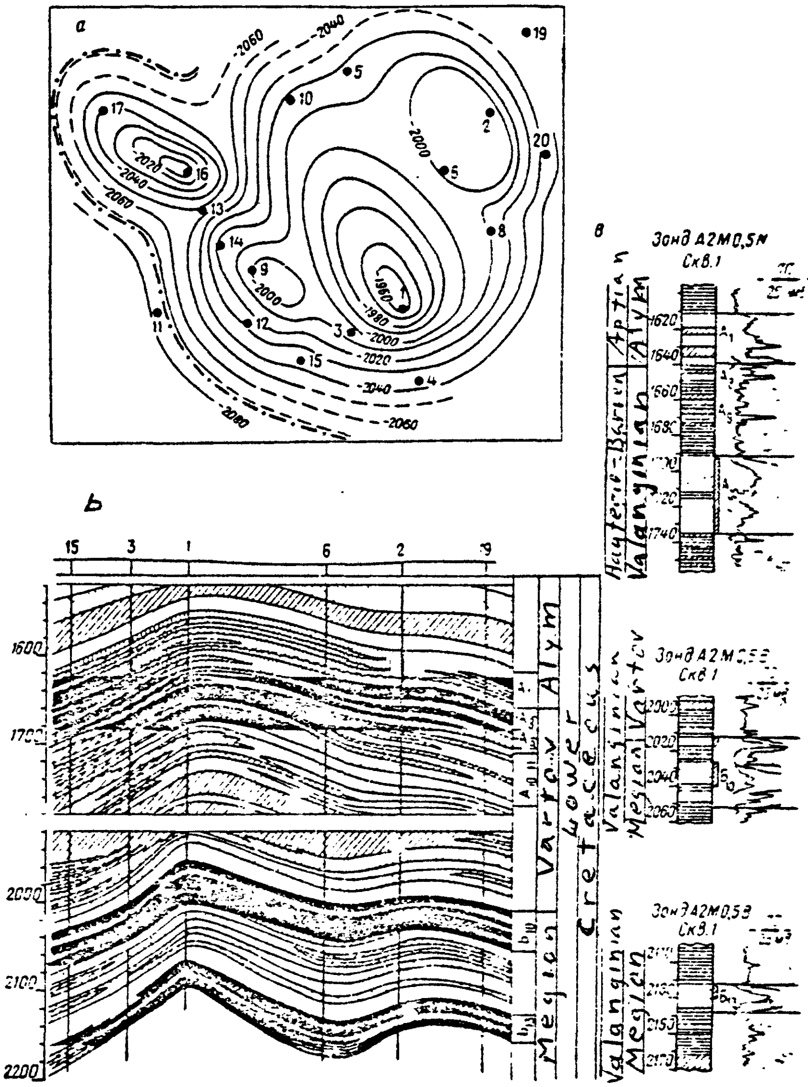


Fig. 34. Samotlor field (from Bliznichenko, et al, 1972, p. 137).

a - Structure map on the top of producing stratum BV_8; b - geologic profile; c - geological-geophysical sections of producing strata. 1 - Structure contours on reflecting horizon II^a [not on this map]; 2 - structure contours on top of BV_8 ; 3 - margin of oil pool; 4 - margin of gas pool [not on this map]; 5 - shale; 6 - siltstone; 7 - sandstone; 8 - weathered zone [not in this section]; 9 - Paleozoic basement [not in this section]; pools: 10 - oil, 11 - gas, 12 - probable oil [not in this section]; 13-16 - [not in this section].

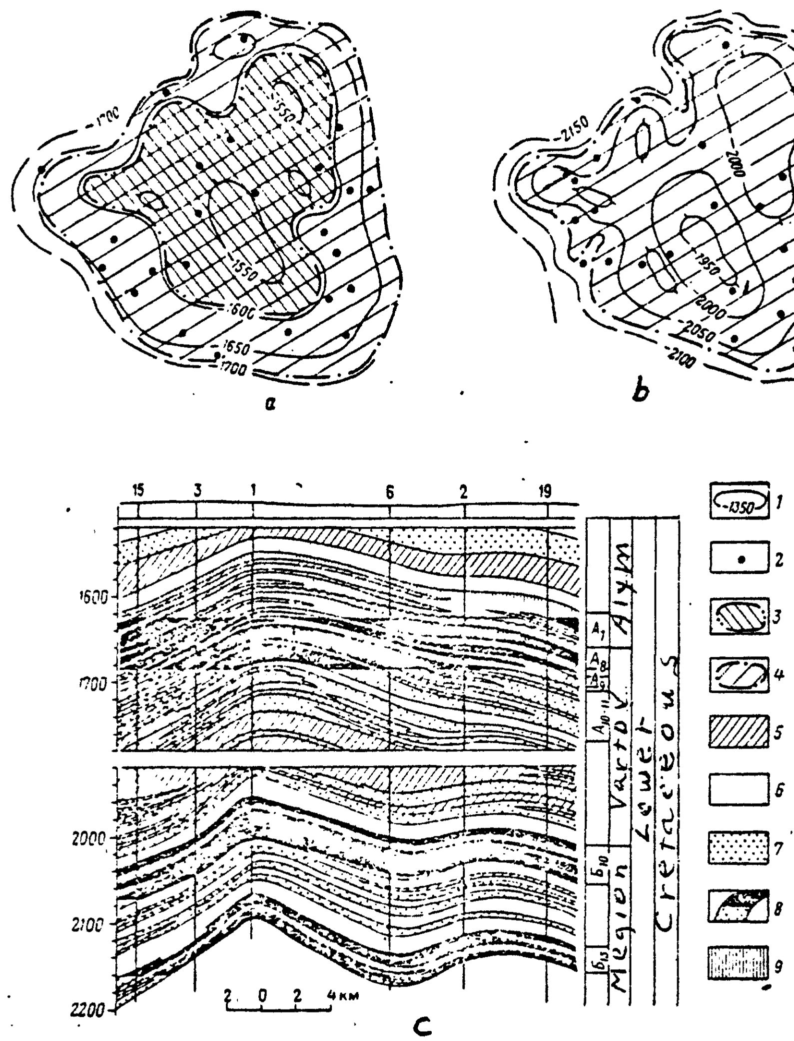


Fig. 35. Samotlor oil field (after Karogodin, 1974, p. 106).

Structure map on top of producing strata:
a - Aptian AV_1, b - Valanginian BV_8 ; c - geological profile. 1 - Structure contours on producing strata; 2 - drill holes; 3 - margin and area of gas pool; 4 - margin and area of oil pool; 5 - shale; 6 - siltstone; 7 - sandstone; 8 - oil pools; 9 - gas pools.

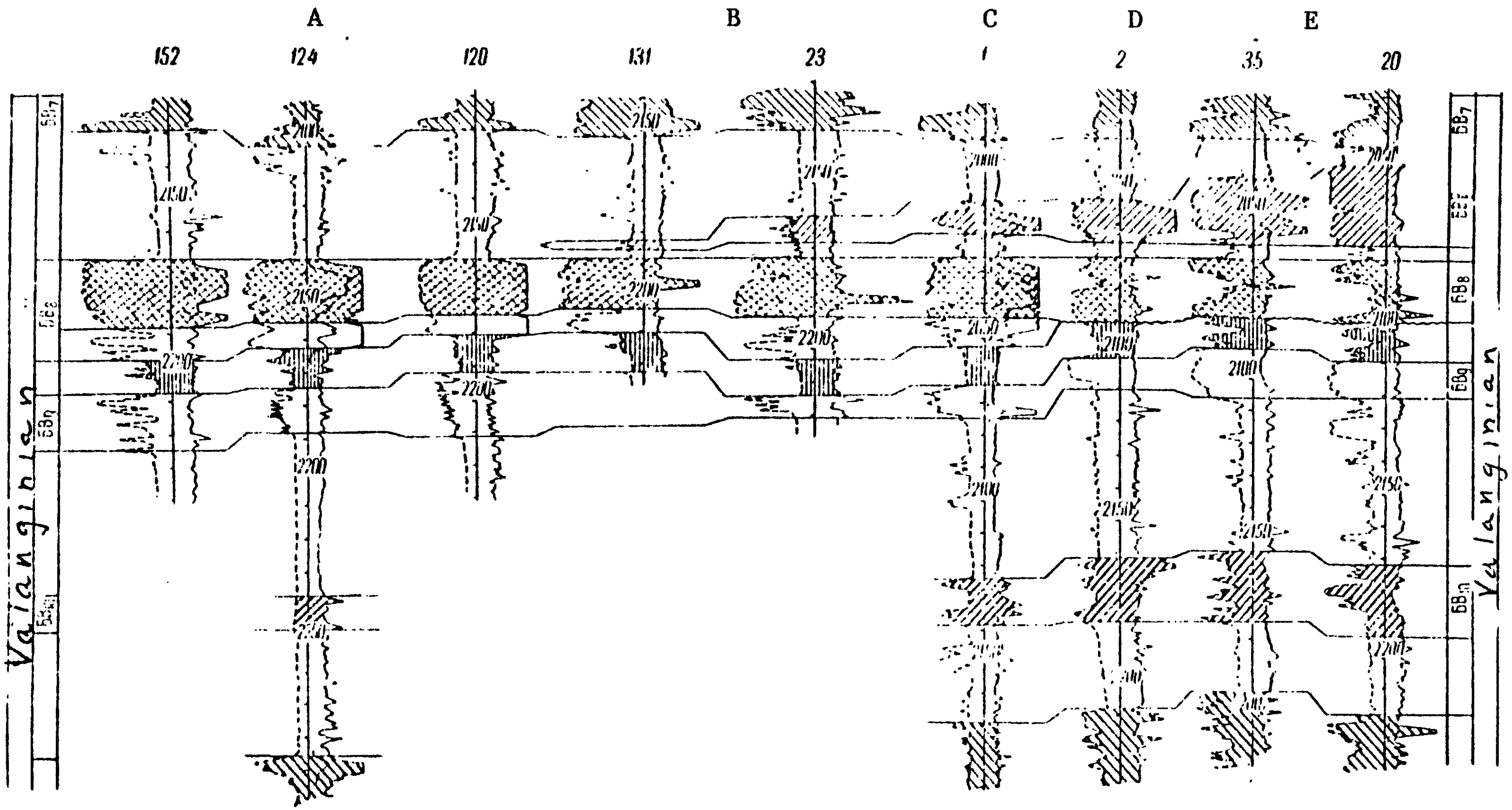


Fig. 36. Correlation of sections of the upper part of the Valanginian on the Nizhne-Vartov dome (after Khafizov, 1969, p. 44).

Areas: A - Vatinsk, B - Megion, C - Samotlor, D - Nizhne-Vartov, E - Sosninsko-Sovet.

Stratum BV_8 occurs at the top of the Megion Formation. It consists of polymict sandstones that contain 25-35 percent quartz, 40-60 percent feldspar, and 15-30 percent rock fragments. The grains are semi-rounded, rarely rounded; grain size is 0.1-0.25 mm. Dense, limey sandstones are present among the sandstone reservoirs; these are characterized by higher resistivity. See Fig. 36. Also present in stratum BV_8 are thin beds of clayey-silty rock, which are subordinate in volume and are not extensive areally (Khafizov, 1969, p. 43).

The water-oil contact of the pool in stratum BV_8 is inclined to the east at depths of 2071-2076 m; the oil column is 110-115 m high. Formation pressure is 210-218 kgs/cm^2, formation temperature is 65-77°C, gas-oil ratio is 70-100 m^3/m^3.

The BV_8 pool has a distinct zonality. See Fig. 37. At the crest there is a zone of relatively light (0.845) oil. In the next lower interval the oil is heavier; specific gravity is 0.855 to 0.865. Yet lower, the oil is again lighter, the density being 0.834 to 0.849. Then along the margins of the pool the oil is heavier, having a density of 0.850-0.860.

A zonality was also noted in the composition of the oils and in other physical properties. The amount of gas dissolved in the oil is at a maximum at the crest of the pool; it then drops in the zone of occurrence of heavier oils from 92-96 m^3/m^3 to 76-82 m^3/m^3. Toward the margins of the pool this tendency is reversed, and this parameter rises to 92-103 m^3/m^3. At the edge of the pool, however, it drops to 55 m^3/m^3.

No relationship is found between the zonality in the pool and the dis-

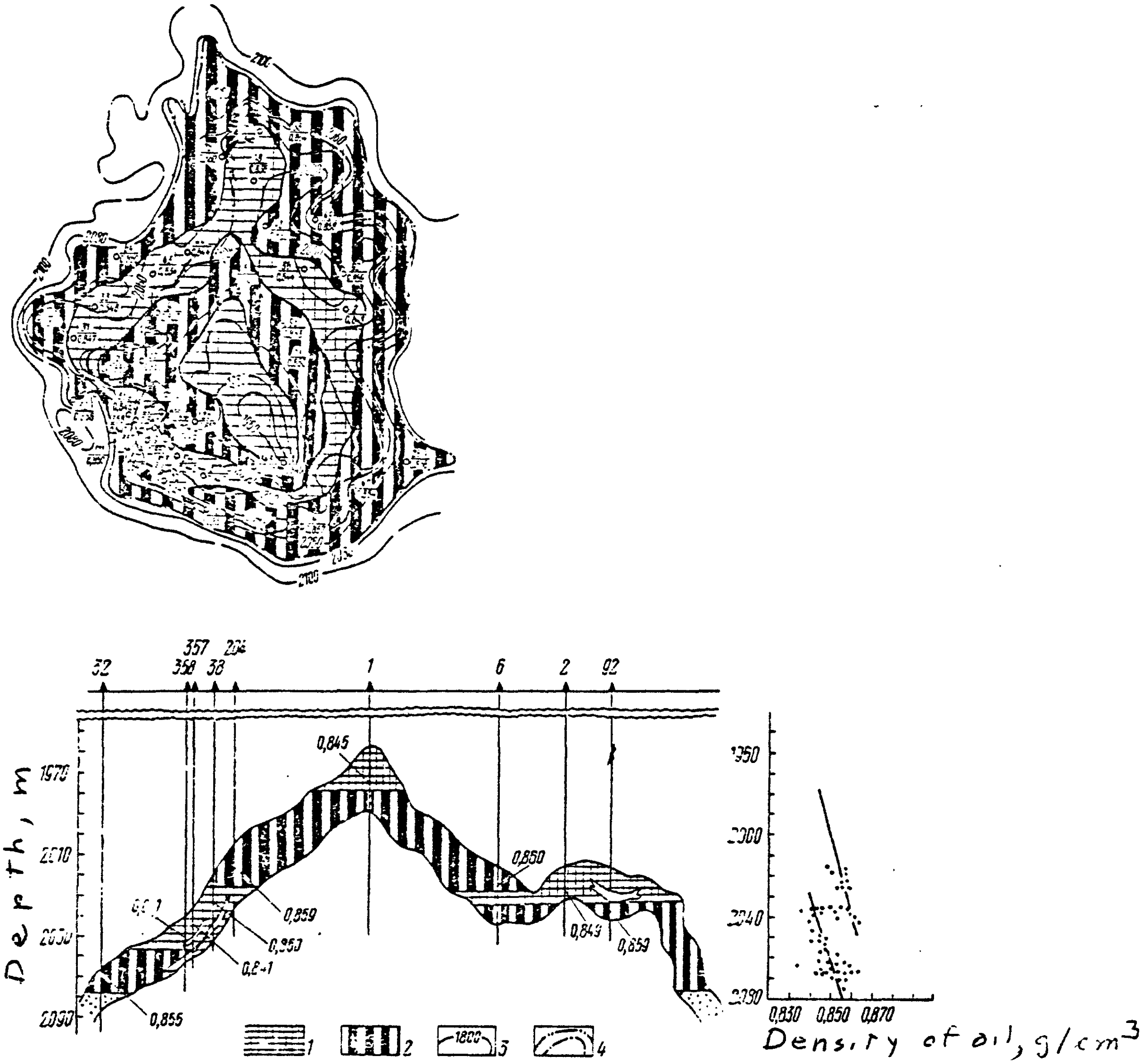


Fig. 37. Zonality in variation of density of the oil of the pool in stratum BV_8 of Samotlor field (after Shchepetkin, et al, 1974, p. 37).

Zones of distribution of oils: 1 - with low density, 2 - with higher density, 3 - structure contours on top of stratum BV_8, 4 - outer and inner margins of the pool.

tribution of formation temperature.

The zonality appears to be due to different stages of formation of the pool. The upper part formed and had its oil-water contact at the base of the upper zone of heavier oil. Subsequently a second phase of pool development took place and the two lower zones formed. (Shchepetkin, 1974, p. 37-39).

Stratum AV_6. The pool in this stratum occurs at the base of the upper part of the Vartov Formation. The stratum consists of sandstones and subordinate siltstone and clay. Formation pressure is 174 kgs/cm^2, and formation temperature is 62°C. The pool occurs on the flank of the Martov local uplift and is contained in part by stratigraphic trapping. This pool is shown on the left side of the cross section in Fig. 29.

Stratum AV_{4-5}. This stratum is in the middle of the upper part of the Vartov formation. The water-oil contact is inclined to the east at depths of 1685-1693 m, and the oil column is 55-63 m thick (Salmanov, 1974, p. 152-153). The configuration of this pool is shown in Figs. 33 and 41. This pool contains about 20 percent of the oil reserves of Samotlor field.

The section of stratum AV_{4-5} is extremely inhomogeneous. It consists of polymict sandstones, which are clayey in places, and a few beds of limey, silty, and clayey rocks. In some drill holes the section consists of uniform sandstones, whereas in others the upper and lower parts of the section are entirely shale. In general, the upper third of the section is more shaly, lower in carbonates, and has a lower permeability (average of 809 md). The lower two-thirds is largely sandstone, has a high content of carbonate

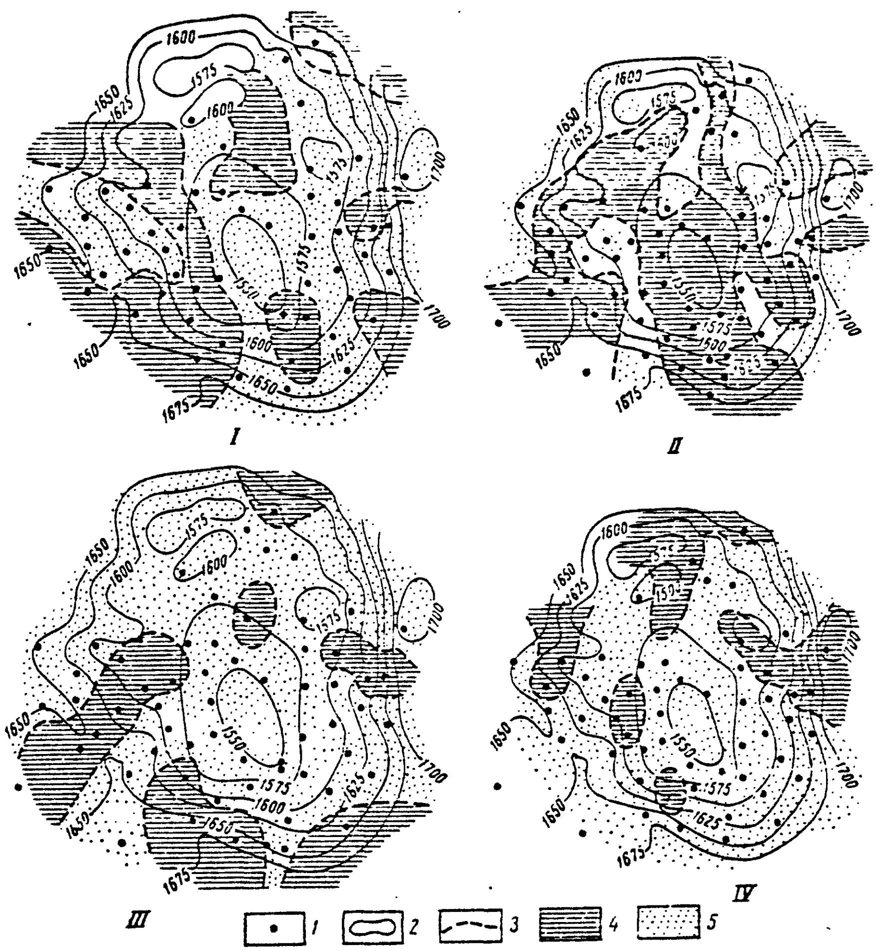


Figure 38. Distribution of productive strata of the AV group in the Samotlor oil field (After Markovskiy, 1973, p. 271) Strata: I - AV_2; II - AV_3; III - AV_4; IV - AV_5. 1 - Wells; 2 - structure contours on these strata (sic; all the contours appear to be on AV_1.); 3 - boundaries between lithologic varieties; 4 - predominantly clayey sediment; 5 - sandy sediments.

cement, and an average permeability of 1129 md. (Chernomorskiy, et al, 1971, p. 13). See Fig. 43.

The sandstones of stratum AV_{4-5} are comparatively well sorted, and the grains are semi-angular to angular. Predominant grain size is 0.1-0.25 mm. (Markovskiy, 1973, p. 270). Average open porosity for AV_{4-5} based on core analysis is 28%, and average permeability is 1087.4 md (Nelepchenko, et al, 1972, p. 199).

Facies distribution of AV_4 and AV_5 are shown individually in Figure 38. Chernomorskiy, et al (1971, p. 13) note that it is not possible to find any areal zonality in the facies distribution. Afanas'yev and Bachurin (1971, p. 16), however, state that stratum AV_{4-5} is replaced by siltstone and shales along the periphery of the field.

Fig. 39 is a well log from Samotlor field that shows the high sandstone content of Stratum AV_{4-5}. The paired well logs in Fig. 40 illustrate the inhomogeneity of this stratum. For example, wells 10 and 10a are only 50 m from one another; yet, the total thickness of the reservoirs of AV_{4-5} in these wells is 37.4 and 19.8 m, respectively.

One of the features of the pool in AV_{4-5} is a gas cap at the crest of the structure. Geophysical well logging first showed the position of the gas-oil contact at sea level of -1615.0 m. Other wells picked up gas at other levels, however. See Fig. 41.

As of October 1, 1975, gas had been found in more than 100 wells in various parts of the pool. These accumulations are controlled largely by structural-lithologic traps. See Figs. 42.

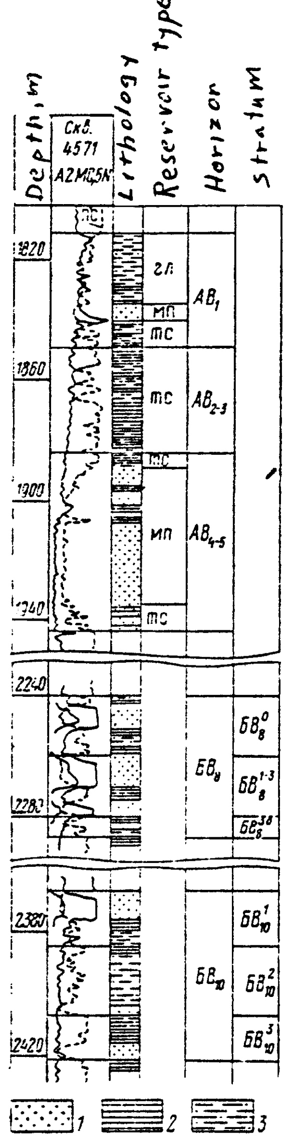


Figure 39. Types of reservoirs of Samotlor field (After Sanin, et al, 1974, p. 31). 1 - Sandstones, 2 - shales, 3 - siltstones. Sandstones: гл - clayey, мс - thin-bedded; мп - massive.

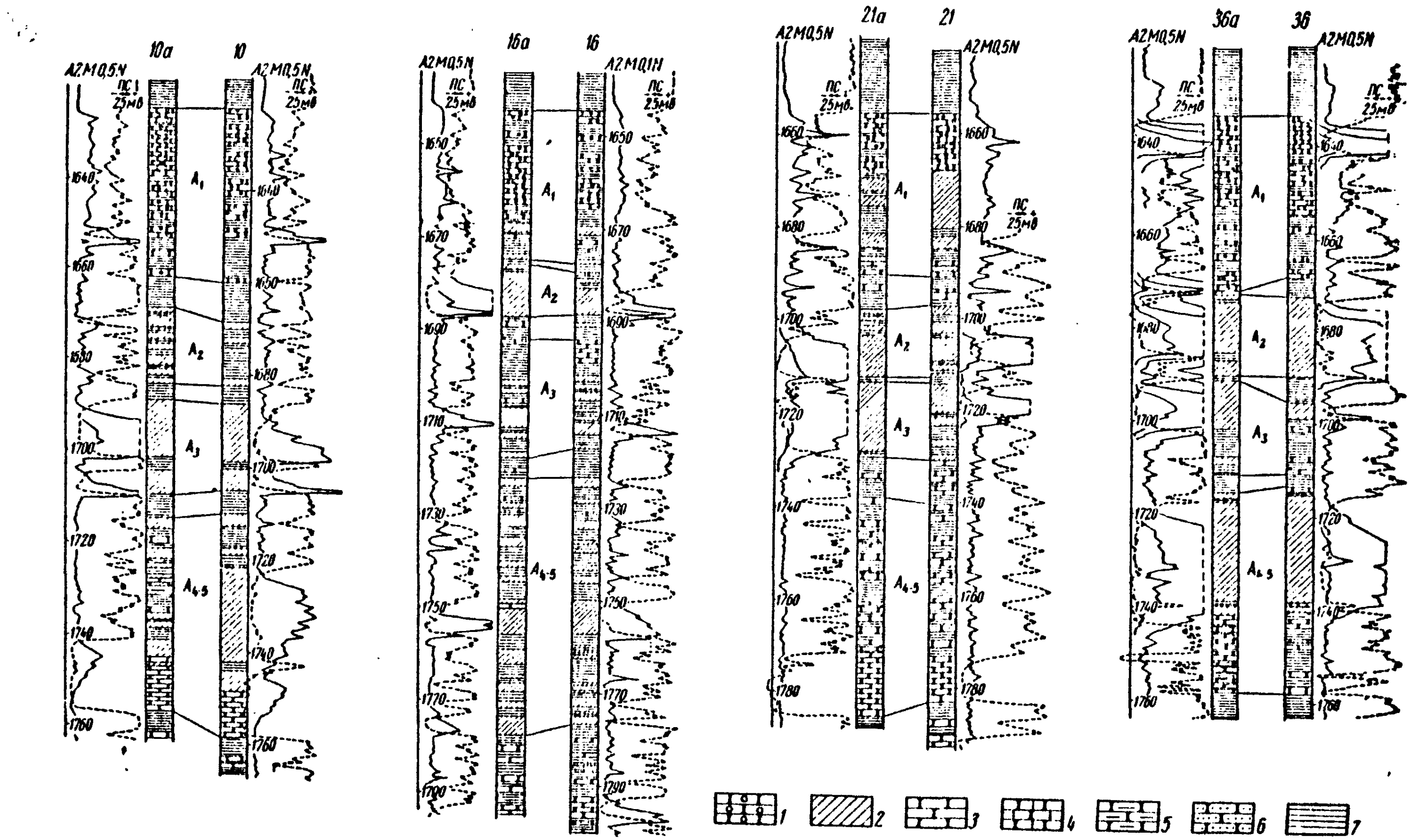


Figure 40. Geologic sections of the strata A group of Samotlor oil field for several wells and their doubles (After Musin, et al, 1972, p. 4).

Sandstones: 1 - gas-bearing, 2 - oil-bearing, 3 - water-bearing, 4 - limey, 5 - clayey; 6 - siltstones; 7 - shales.

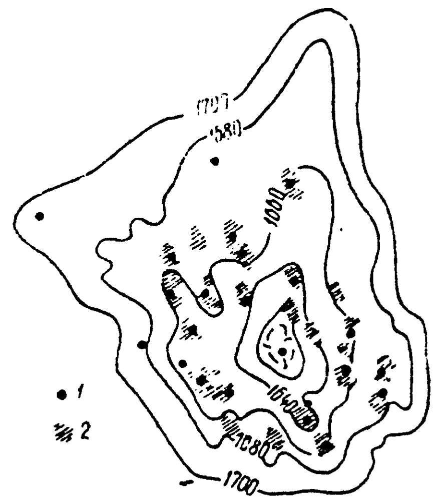


Figure 41. Schematic structure map on top of producing stratum AV_{4-5} (After Litvakov, 1976, p. 27).

1 - Drilled wells, 2 - sectors of gas accumulation.

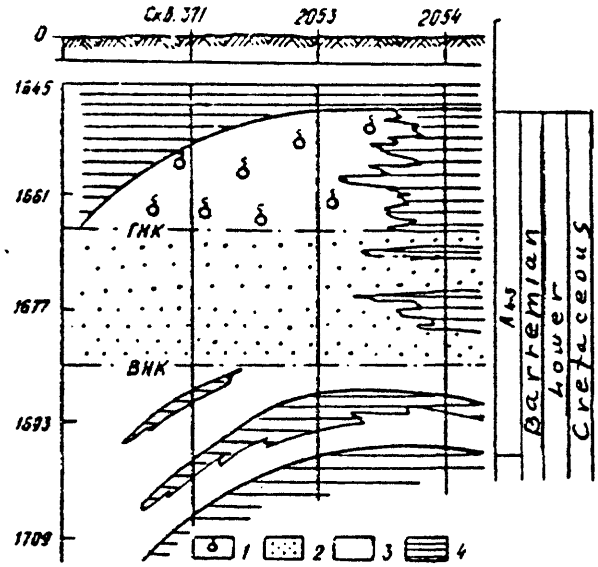


Figure 42. Geologic profile of producing stratum AV_{4-5} (After Litvakov, 1976, p. 27)

Strata: 1 - gas-bearing, 2 - oil-bearing, 3 - water-bearing, 4 - dense.

Figure. 43. Samotlor field, Average for entire field. (After Chernogorskiy, et al, 1971, p. 10-11)

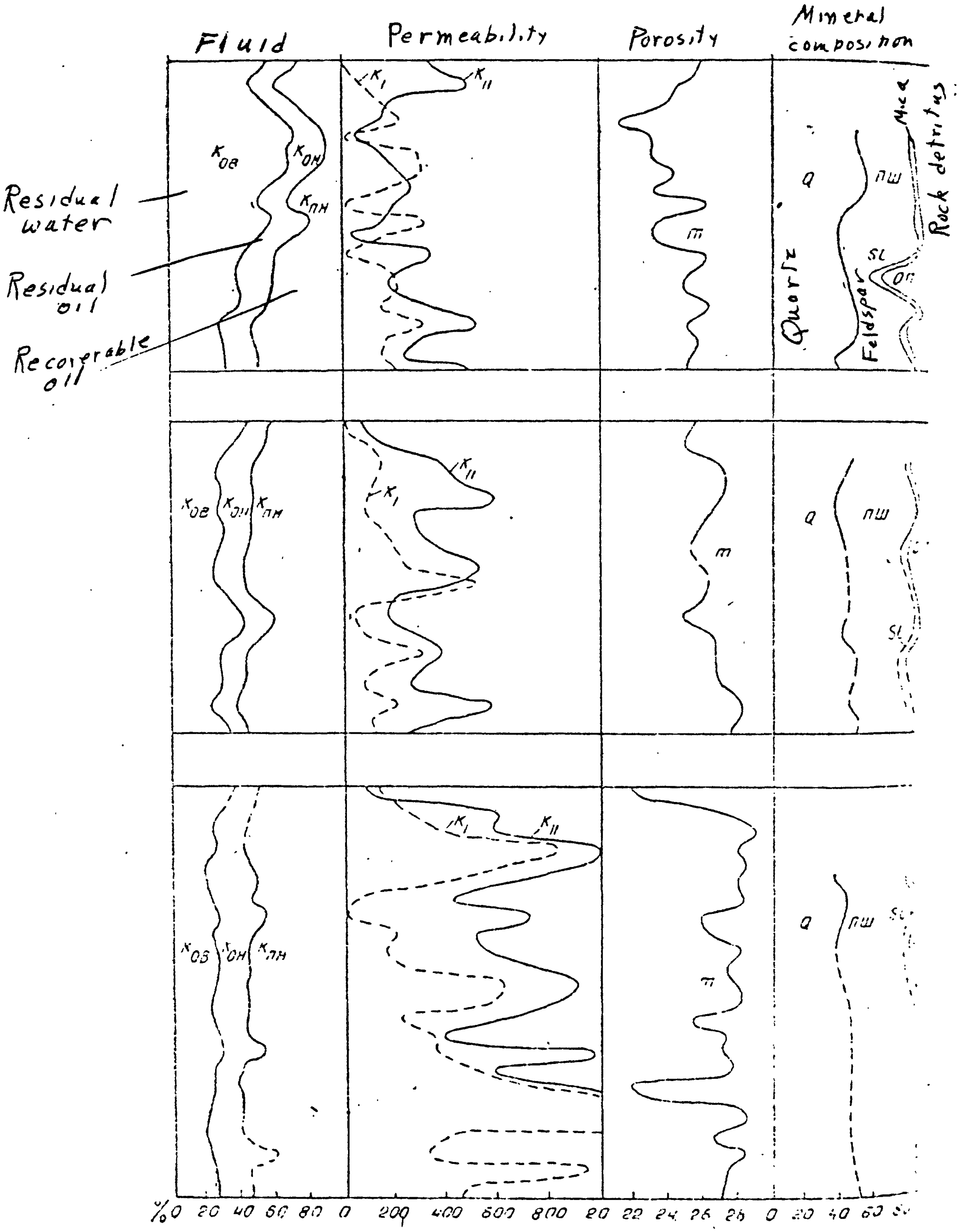
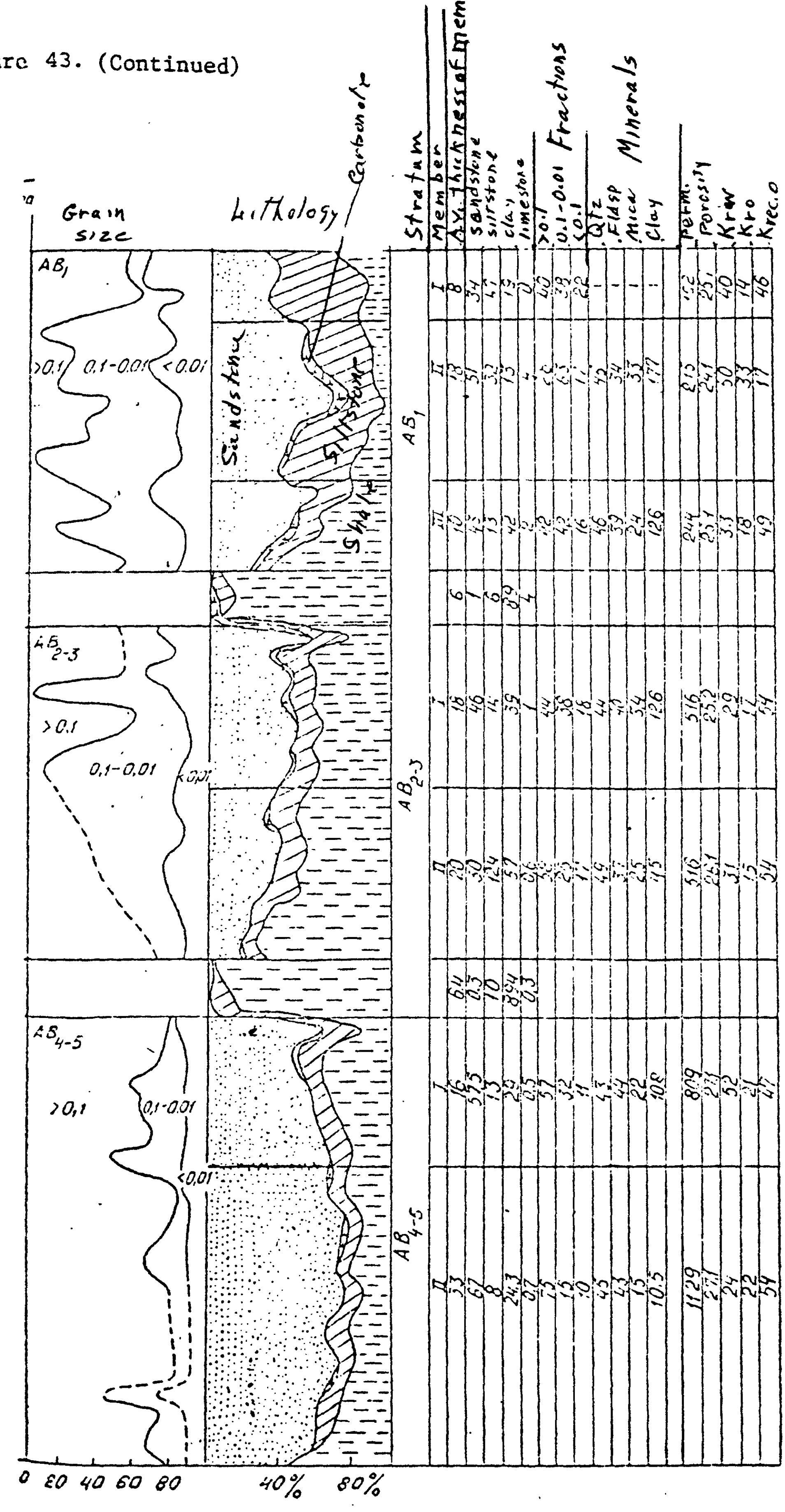


Figure 43. (Continued)



The gas traps are small: 0.2-5.5 km long and 0.2-0.6 km wide. Their trend is northwest. Thicknesses of the gas column range from 0.8-7.8 m. The position of the gas-oil contact ranges from -1615.0 to -1675.0 m sea level.

The gas reserves in these traps are greater than 50 million m^3. The volume of these reserves is approximately 1.5% of the volume of the oil-saturated rocks of the pool.

It was thought originally that the gas cap was due to gas leaking from the gas cap of stratum AV_{1-3} upward into the pool in stratum AV_{4-5}. Production data indicate, however, that no such connection exists. The separation of the gas from the oil in this pool is now believed to have taken place due to intensive uplift of the beds after or during formation of the pool (Litvakov and Mukhametzyanov, 1976, p. 26-28).

The oils in the eastern part of the AV_{4-5} pool have an anomalous composition in comparison with those of the rest of this pool: They have a higher density and viscosity, contain more tar and asphalt, and are lower in paraffin. The composition of the alkane hydrocarbons differs in that they contain on the whole more isomers, whereas normal alkanes contain insignificant amounts. Further, a greater content of cyclic naphthenes is observed in the high-boiling fraction. These anomalous oils are thought to have a different age and different zone of generation from those of the western part of the pool. On a basis of their chemistry, the anomalous eastern oils are thought to be older and to have migrated vertically along faults into the present trap. (Ivanov, 1972, p. 40-47).

Stratum AV_{2-3}. This stratum occurs in the upper part of the Vartov formation on the Samotlor, Martov, Pauy, and Belozer uplifts. The outline of this pool is shown in Fig. 33 and a cross section in Figs. 28, 29, and 30. Strata AV_2 and AV_3 are recognized as separate stratigraphic units; however, they constitute a single production reservoir.

Stratum A_3 is separated from AV_{4-5} by a 10-meter shale bed. The reservoirs in AV_3 are gray, fine-grained, clayey, arkosic sandstones. The detritus is quartz, feldspar, mica, and rock fragments; these compose 70-80 percent of the rock. Sorting is medium. Clay fractions do not exceed 12.5 percent (Musin, et al, 1972, p. 5).

The broader facies distributions of stratum AV_3 are shown in Fig. 26. Deltaic and lacustrine facies are present within the area of Samotlor field. Fig. 38 shows the facies changes in greater detail.

Maximum thickness of AV_3 sandstones occur on the southwest part of the Martov local uplift and on the northwest end of the Samotlor local uplift (20.6 m in well 14). These sandstones are thick also at the crests of the Belozer (11.6 m in well 55) and Severo-Samotlor local uplifts (15.2 m in well 10). Thickness ranges from 1.5 to 12 m in the central part of the field.

Horizon AV_2 is composed of brownish gray, fine-grained, predominantly arkosic, rarely polymict sandstones. The detritus is quartz, feldspar, and rock fragments. Sorting is medium, in some places good. The cement does not exceed 5-10% (Musin, et al, 1972, p. 5).

The general distribution of facies is shown in Fig. 26. Stratum AV_2 pinches out near the southeastern margin of Samotlor field. More detailed facies distributions are shown in Fig. 38. Thickness ranges from as much as 20 m in the western, southern, central, and eastern parts of the field to a minimum of 1 m in the downwarp between the Severo-Samotlor and Belozer uplifts (Musin, et al, p. 5).

The types of sediments that compose the section of stratum AV_{2-3} are depicted schematically in Fig. 43 as well as on the well logs in Fig. 40.

Formation pressure in stratum AV_{2-3} is 169-182 kgs/cm^2, and formation temperature is 57-62°C. Gas-oil ratio is 160. The water-oil contact is at -1693 m, and the oil column is 100-108 m high (Kontorovich, et al, 1975, p. 490). Additional parameters are listed in Table 4, and shown diagrammatically in Fig. 43.

Stratum AV_1. The AV_1 reservoir occurs in the lower part of the Alym Formation, which was deposited on an erosion surface that cuts across the entire Barremian and into the Hauteriv on the Samotlor uplift. See Fig. 44. Stratum AV_1 is in contact with AV_2 through this erosional window in Samotlor field. Actually, the entire AV groups of reservoirs intercommunicate and have a common water-oil contact at a depth of about 1690 m. See Figs. 28, 29, and 30.

Oil occurs in stratum AV_1 over a very extensive area; it forms a continuous blanket over the Samotlor, Agan, Severo-Pokur, Vatinsk, Megion, Orenkhor, and Yermakov structures. See Fig. 27. The AV_1 reservoir fills the Samotlor structure to the spill point on the saddle at the southeastern margin. See Fig. 45. The Sosnin structure just to the southeast of the saddle, however, is not filled to the spill point, suggesting that the AV_1

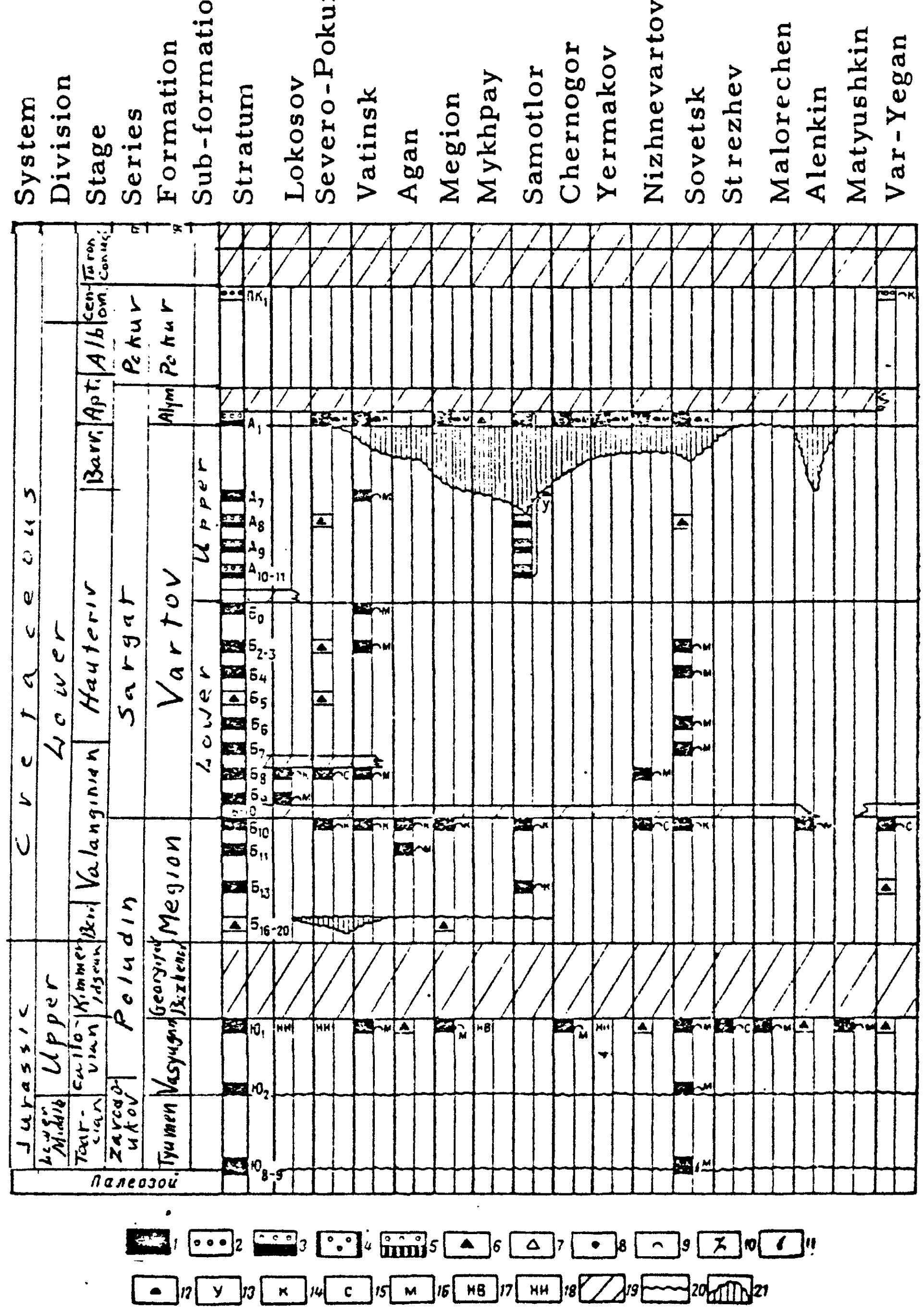


Figure 44. Distribution of pools and oil-gas showings in the Middle Ob oil-gas region (Nizhne-Vartov dome) (After Bliznichenko, et al, 1972, p. 131). Pools: 1 - oil, 2 - gas, 3 - gas-oil, 4 - gas with oil ring, 5 - gas condensate; noncommercial flows: 6 - oil, 7 - gas; 8 - rock saturated with oil; types of traps: 9 - anticlinal, 10 - fault, 11 - lithologic, 12 - massive; reserves of pools: 13 - unique, 14 - large, 15 - medium, 16 - small; 17 - stratum not penetrated; 18 - stratum not tested; 19 - regional cover; 20 - regional stratigraphic erosional disconformity; 21 - local erosion.

Figure 45. Structure map of the central part of the Nizhne-Vartov dome compiled on the top of stratum AV_1 (After Nesterov, 1975, p. 104).

stratum on this structure was filled, although not completely, by spill from the Samotlor structure.

Although oil occupies stratum AV_1 over this huge area, the deposit does not seem to be a single, hydrodynamically connected pool. The water-oil contact is different on the various structures due to abrupt changes in reservoir properties of the stratum (Salmanov, et al, 1975, p. 22).

A gas cap is present in stratum AV_1 in Samotlor field. The nature, or even existence of this gas cap was long questioned because no pure gas was ever recovered; some oil always accompanied the gas. Further, cores from the gas zone always contained oil. Neutron-gamma logging, however, established the presence of a gas cap with a gas-oil contact at a depth of 1610 m (Basin, et al, 1971, p. 35).

Regional facies distribution of stratum AV_1 on the Nizhne-Vartov dome is shown in Fig. 26. The outline of the pool in AV_1 on the main Samotlor structure is shown in Figs. 31, 33, and 35.

Chernomorskiy, et al, (1971, p. 11) distinguish three members within AV_1: an upper clayey-sandy member, a middle sandy member, and a lower clayey-sandy-silty member; these represent a single cycle in deposition - See Fig. 43.

Musin, et al, (1972, p. 5-6) divide stratum AV_1, into two members: lower and upper.

The lower member AV_1^2 is developed predominantly on the higher sectors of the local uplifts within the larger Samotlor structure. It consists of arkosic fine-grained sandstones and coarse-grained siltstones; these are in less degree quartzose and polymict. The detritus is quartz, feldspar, and rock fragments. Sorting is medium to good. Clay fractions do not exceed 16 percent. The greatest thickness of reservoirs is found on the Belozer (30.4 m) and Samotlor (19.4 m) local uplifts. On the latter, however, the reservoirs shale out to the west on over a large part of the Martov local uplift.

The upper stratum A_1^1 is present in the southern, eastern, northern, and central parts of the Samotlor structure. It consists of thin alternating discontinuous lenses of sandstone, siltstone, and shale. The reservoirs are fine-grained sandstones and siltstones; the latter predominate somewhat. These are polymict, rarely arkosic or quartzose. Sorting is poor but in places medium. Clay fractions in the reservoirs are up to 25 percent. Maximum total thickness is 28.7 m. Fig. 40 shows lithologic columns for stratum AV_1 undivided.

Formation pressure in the pool in stratum AV_1 is 172 kgs/cm^2, and formation temperature is 63°C. The thickness of the pool is 145 m. Permeability and other parameters are listed in Table 4.

Stratum PK. During development drilling in 1971 a gas pool was discovered at the crest of the Samotlor structure in the Pokur Formation of Cenomanian age. The pool is 7 by 13 km in area and 19 m high. See Fig. 46. As of 1973 gas had been determined only at the top of the Pokur Formation. By 1976, however, 25 separate strata that have high resistivity had been found in this formation. These carry oil and/or gas (Litvakov and Mukhametzyanov, 1976a, p. 27).

Some investigators have interpreted the gas in the Pokur Formation as

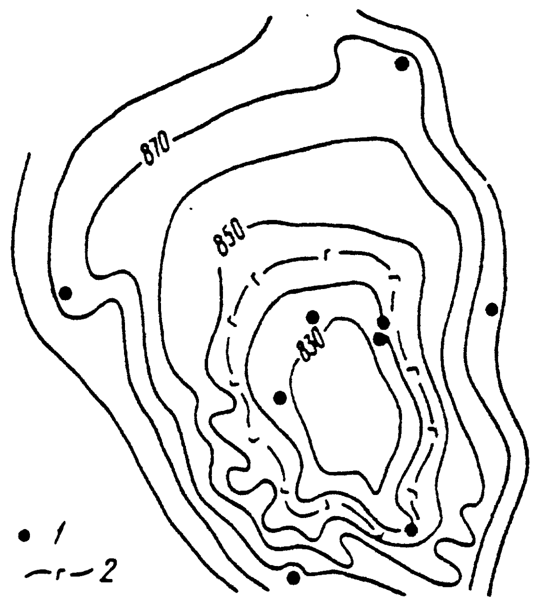


Figure 46. Schematic structure map on top of the sediments of Cenomanian age, 1 - Drill holes; 2 - outline of gas pool in stratum PK. (After Kitvakov and Mukhametzyanov, 1976a, p. 25).

having formed by breakout in drill holes where cementing was poor. Litvakov and Mukhametzyanov (1976a, p. 29), however, explain these deposits as being the result of post-Paleocene tectonic activity. Intensive growth of the Samotlor structure during this time led to a drop in hydrostatic pressure; this caused oil and gas, which was dissolved in formation water, to separate into free phases. Another possible explanation would be that the gas was generated by younger source rocks higher in humic organic matter, as appears to be the case with the younger Cretaceous section of the basin in general, e.g. in the area of the Urengoy field.

Development of the field

Production objectives. Five independent production objectives are recognized in Samotlor field: BV_{10}, BV_8, AV_{4-5}, AV_{2-3}, and AV_1. Drilling of five nets of production wells was just not practical, however. Instead, these pay zones were grouped into three production objectives: BV_{10}- BV_8, AV_{4-5} and AV_1, and AV_3 - AV_2. Although the pool in BV_{10} is equal to a large field, it is to be held in reserve and will be produced in later years by deepening the wells drilled on BV_8. As the area covered by the pool in AV_{4-5} is less than that of the gas cap of AV_1, these pay zones were combined into a single production objective. After the pool in AV_{4-5} has been depleted, the production wells will then be perforated higher to recover the oil and gas from stratum AV_1 (Musin, et al, 1972, p. 7).

Drilling Program. According to Maksimov (1976, p. 32-33) a total of 3289 production wells are planned for Samotlor field. Projected yields of these wells are listed in Table 5. This drilling program was 50 percent complete in 1975 and is probably near completion now (Semenovich, 1976, p. 5).

The production wells are spaced on a grid of 650 by 650 m (Musin, et al, 1972, p. 9). Due to the swampy conditions the wells are drilled in clusters of 12-18 holes from a single "island." Directional drilling is used in order that the pay zones are intersected at the desired spacing.

The field has been sectioned off into nine blocks by rows of injection wells. Within seven of these blocks the production wells are in five-row nets, and in two blocks they are in three-row nets (Arzhanov and Fain, 1975, p. 40).

As of January 1, 1975, a total of 166 outlining wells had been drilled. Average depth was 2174.5 m and the spacing was 1.4 - 4.5 km (Arzhanov and Fain, 1975, p. 40).

Production characteristics. Production in the field was initially entirely by water drives, and formation energy was maintained by a net of injection wells. Injected water, however, tended to move more freely through water-oil- and water-saturated beds, bypassing oil-saturated beds and coning at the production wells (Mukhametzyanov and Litvakov, 1976, p. 17).

Further production difficulties were occasioned by clayey material becoming suspended in the production. The reservoir rocks contain large amounts of feldspar that has altered largely to various clay minerals. The montmorillonite component of these clays swell, and this and other clays wash out to be redeposited, thereby reducing permeability considerably (Dobrynin, et al, 1973, p. 34). Deposition of various salts also hampers production (Arzhanov, et al, 1976, p. 51).

Table 4. Possible recoveries of liquid by wells during first stage of working Samotlor field (After Maksimov, 1976, p. 33).

TOTAL 5

Bbls oil per day per completion	<630	630-1240	1240-1890	1890-2520	2520-3150	3150-3780	>3780	Total
RESERVOIR	NUMBER OF ~~WELLS~~ COMPLETIONS							
AV_1	206	262	128	31	—	—	—	62[illegible]
AV_{2-3}	124	620	100	20	3	—	—	86[illegible]
AV_{4-5}	37	45	68	75	40	54	56	375
BV_{7-8}	41	50	105	110	112	113	380	911
BV_{10}	366	133	10	—	—	—	—	509
							Total	328[illegible]

Use of surfactants to increase production has been successful (Vashurkin), et al, 1976, p. 23). This method seems to be in only experimental use, however.

The gas-lift method is apparently going to be relied on to increase production at Samotlor. The gas from the gas cap on the AV_1 pool will supply the gas for this procedure (Vashurkin, et al, 1977, p. 35). Imported Reda pumps with a 1000 m^3/day capacity are being installed (Arzhanov and Fain, 1975, p. 44).

Potential of field and region. Samotlor field as well as all the fields of the Middle Ob region occur in an area which in the Late Jurassic and Early Cretaceous was intermediate between a vast alluvial deltaic plain and a marine basin where prodelta deposits accumulated extensively (Markovskiy, 1973, p. 120-125). This shoreline was stable enough for a thick pile of excellent reservoir rocks to be deposited, and exploration targeted on this old shoreline is continuing. This particular shoreline, however, was certainly not the only shoreline in the Mesozoic section of the Lowland. The depositional history was one of continual incursion and retreat of the sea. Megarhythms are made up of macro-, meso-, and micro-rhythms, each of which had its transgressive and regressive parts (Karagodin, 1968, p. 119-120). The search for these old shorelines seems to be yet in an early stage.

The reserves of Samotlor field were estimated at about 15 billion barrels by Meyerhoff (1974, p. 81) and Shabad (1975, p. 549) but Meyerhoff (1977, p. 85) has now lowered this estimate to 11 billion barrels. What, however, is a realistic expectation for the Samotlor area and the Middle Ob region in general? This question can be approached from the allocation of drilling during the last decade as well as by the geology of the region.

The discoveries in the Middle Ob region during the Sixties were so huge that the drilling capibility during the early Seventies was simply taken up by outlining the new fields. The rate of exploration for other new fields was reduced (Trofimuk, 1974, p. 35). Exploration in the immediate vicinity of the large fields appears still to have high priority (Fain, et al, 1977, p. 19). Once the drilling capacity now tied up in outlining known fields and in drilling thousands of production wells is freed, exploration for new fields will receive new attention. Rigassi (1977, p. 127-138) estimates that less than 15 percent of the total exploratory drilling required for the West Siberian Basin has been accomplished. The finding rate is such that the renewed exploration can be expected to have a high success ratio.

Another factor occasioned by the huge size of the fields in the Middle Ob region is that a large number of medium-reserve fields have not yet been developed (Shabad, 1977, p. 266). These can be brought on-stream as demand requires.

The most important factor, however, as an indicator of potential for the Middle Ob region is the geology of the West Siberian Basin. The exploration of the Sixties that discovered the giant fields consisted of drilling on structural highs that had been outlined by seismic surveys. In spite of the exploration being directed entirely toward anticlinal structures, large reserves were found in stratigraphic traps.

This oil was indeed found accidently and not as the result of exploration being directed toward its particular habitat. The oil reserves found in stratigraphic traps on the Surgut dome are 23 percent of the size of those in structural pools, and in the Yuzhno-Surgut field the stratigraphic traps contain 60 percent of the reserves of the field. (Mamleyev, et al, 1976, p. 13-15). This high frequency of finding stratigraphic traps when they were not even being sought suggests persuasively that important reserves are yet to be found in such non-structural traps associated with the Mesozoic shorelines whose spatial distribution is yet to be determined.

SUMMARY OF PETROLEUM GEOLOGY AND POSSIBLE ANALOGS

West Siberian basin

Among the world's petroleum provinces, the West Siberian basin is geologically distinctive in several respects. The factors of basin size, paleostructural history, continental-marine facies interchange and cyclic depositional history, ample source rock and reservoir facies, and preservation conditions combine to make it one of the world's foremost petroleum generating and producing basins. This enormous basin, one of the world's largest cratonic basins, underwent a remarkably stable, but mildly-active paleostructurally, 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 east and southeast, was sufficiently great for coarse clastic materials to spread widely across the eastern half of the basin area and intertongue with the 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 a partially starved-basin condition in much of the west half of the basin, where as much as 2,500-3,000 m (8,000-10,000 feet) of dark, highly organic marine shale was deposited between Middle Jurassic and early Tertiary time. During much of Early Cretaceous time, the site of the deltaic-open basin transition was across the central basin area, the Khanty anticlize, a regional paleostructural feature of the basin apparently inherited from Hercynian Paleozoic tectonic activity. Continuous but mild paleostructural growth of the Khanty anticlize and associated smaller structural elements provided a broad shallow-water intrabasin shelf where the immense deltaic and continental eastern facies spread out along the fluctuating Lower Cretaceous shoreline belt. Minor transgressive-regressive cycles of sealevel change and paleostructural growth in this environmental setting provided optimum conditions for reworking and winnowing the feldspathic deltaic 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 deltaic fringe, longshore, and channel sand bodies to provide a remarkably efficient source rock-reservoir trap interrelationship.

Continuous mild paleostructural 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 Nizhne-Vartov, Surgut, and other areas of the central basin. The extensive data on source rock parameters published by Soviet geologists suggest that the source rock quality of the basin was unusually high. This aspect may be related to regional paleostructure of the basin, with relatively rapid subsidence of the western basin trough providing a semi-starved basin where accumulation of marine plankton under toxic deeper-water bottom conditions allowed preservation of unusually large amounts of marine organic material for ultimate oil generation. The organic content of the entire basin may have been unusually high, judging from published data. This may have been partly related to the open-basin condition to the north, which would allow southward circulation of cooler nutrient-rich marine waters into the warmer water broad shallow shelf areas, thus stimulating plankton production to a high degree.

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 very mild, 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.

No exact analog to the West Siberian basin is immediately apparent among other sedimentary basins of the world. The Cretaceous "epicontinental" basin or seaway of western North America is perhaps the closest analog, particularly from the standpoint of basin size and setting, depositional environments, stratigraphic cyclicity, and perhaps paleostructural history.

Rocky Mountain Cretaceous basin

Basin size and setting. Figure 47 is a generalized paleogeographic map of the western interior North American Cretaceous seaway, showing sediment source areas, the position of important deltaic areas, and the main petroleum areas, including the Canadian heavy oil deposits. By way of comparison, an outline of the West Siberian basin is drawn at the same scale on the northern portion of the map. Although the total western North America Cretaceous seaway is much larger, its general size and continental setting is quite comparable with the West Siberian basin, particularly the Canadian and northern United States portion. Both basins have major source areas to the east and west, with a Precambrain shield area on the east and an elongate, less stable, source area on the west. If

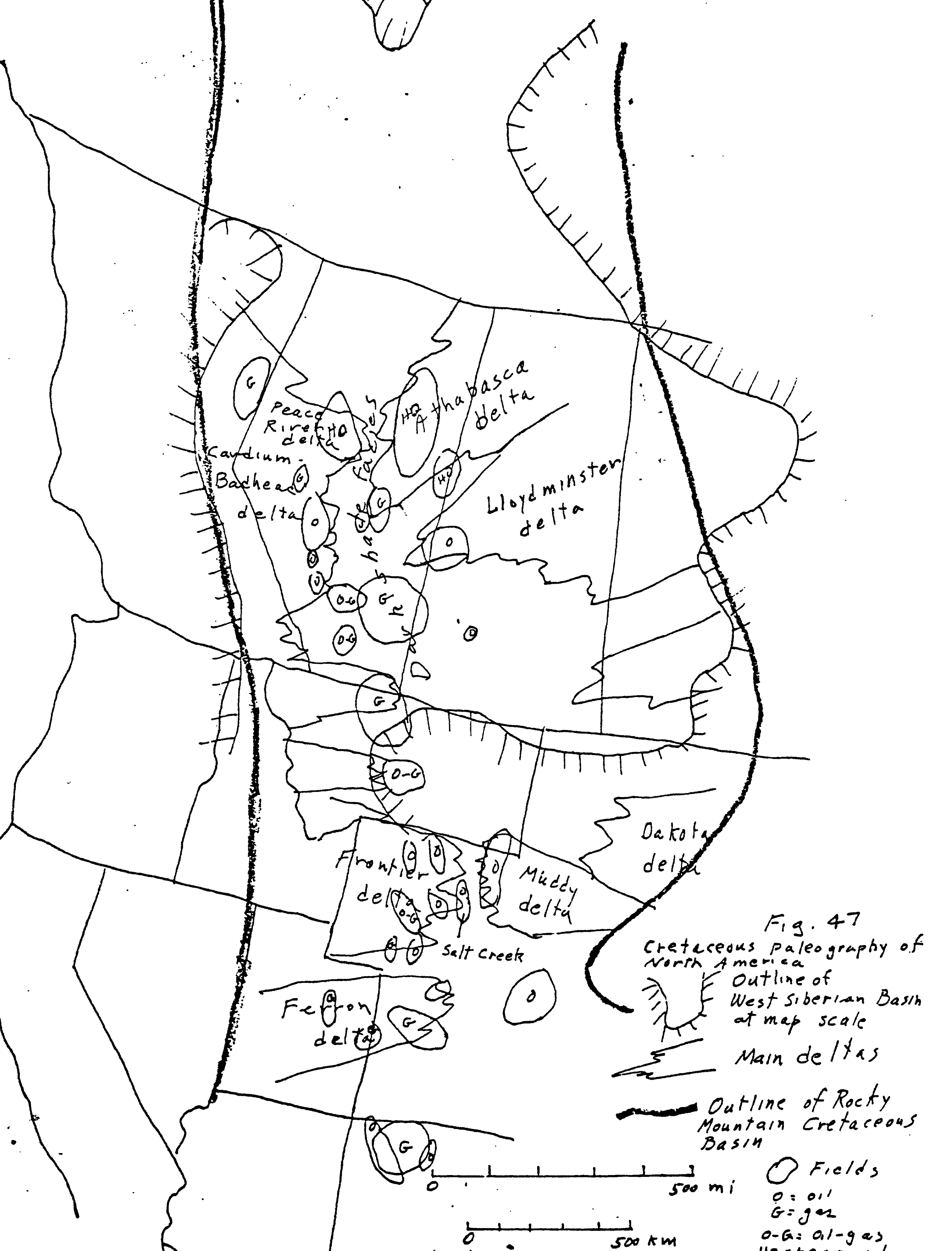


Fig. 47
Cretaceous paleography of North America

only the Neocomian portion of basin history is considered, the West Siberian basin compares very closely in size and setting with the Canadian Neocomian seaway, which extended about as far south as the southern Alberta plains. It is interesting to note also that in both the West Siberian and western Canadian basins, the Neocomian contains most of the oil deposits, if the Canadian heavy oil deposits are included.

Tectonics. The tectonic history of the Rocky Mountain and West Siberian Cretaceous basin areas is dissimilar in many respects, but there are many valid comparisons from the standpoint of basin fill paleostructure. Evidence of internal basin paleostructural growth and its influence on sandstone reservoir quality and distribution and petroleum accumulation is well documented for both the West Siberian and Canadian basins. For example, in the case of the main Canadian Cretaceous petroleum deposits (Athabasca, Peace River, Cold Lake, Lloydminster, Pembina), there is evidence of paleostructural trends that cross deltaic sand complexes to coincide with major petroleum accumulations. Similar conditions can also be shown to exist in many of the important areas of Cretaceous petroleum deposits of the United States' Rocky Mountain province.

The post-depositional tectonic history of the two basins, however, is highly dissimilar in intensity. Both basins underwent Tertiary episodes of changing tectonic patterns. In the West Siberian basin, these events were of a relatively minor nature, and except for probable remigration patterns, had little effect on earlier formed petroleum accumulations. For this reason, the Mesozoic and perhaps other petroleum deposits in this basin are essentially intact today. In western North America, however, the broad and extensive Mesozoic cratonic basin has been thoroughly restructured by Rocky Mountain tectonic activity, much of which was of mountain building intensity. Consequently, many of the major early petroleum accumulations have been either destroyed by erosion or altered to residual heavy oil deposits. This is particularly true in the most prolific Rocky Mountain Cretaceous petroleum generating province, the Lower Cretaceous of the western Canadian basin, where known Lower Cretaeous heavy oil deposits total as much as 600-700 billion barrels of oil in place.

Stratigraphy and depositional history. As mentioned above, the depositional setting of both the West Siberian and the Rocky Mountain Cretaceous basins is quite similar, although there are differences in degree. Both basins are filled almost exclusively with terrigenous clastic sediment, with only minor amounts of carbonate rocks. Continental and deltaic facies spread into each basin from source areas on both the east and west sides of the basins. Intensity of overall sediment influx, however, is much greater from the eastern and southern source areas in West Siberia, whereas in the Rocky Mountains the western source area is more prominent during much of the Cretaceous.

The Jurassic depositional history of the two basins is remarkably similar. In both cases, major basin filling appears to have begun with the Early and Middle Jurassic transgressive-regressive cycles of marine invasion from the north ("boreal seas"). The Middle Jurassic transgression extended southward over only the northern half of each basin area, and in both cases the Oxfordian transgression is the most widespread Jurassic cycle. Likewise, marine clastic facies patterns are generally similar, but the organic content of the West Siberian Jurassic shale facies is much higher. Perhaps for this reason, the Jurassic petroleum potential appears much greater there than in western North America.

Likewise, the Cretaceous depositional history of both basins shows many similarities, dominated by transgressive-regressive continental, deltaic, and nearshore marine cyclic deposits that grade to dark shale facies toward the center of the marine basin (Figure 67). Coarse clastic distribution patterns are governed by rates of terrigenous sediment supply, rates of downwarping, interbasin paleostructural growth, and probable eustatic sealevel fluctuations. Reservoir bodies and the larger petroleum accumulations are usually found in outer deltaic and nearshore marine transitional facies along fluctuating shoreline belts. Reservoir sandstones are generally quartzose but appear to be higher in feldspar content in the West Siberian basin. For this reason, overall reservoir quality may be somewhat better in the western North American Cretaceous sandstones, although sufficiently detailed comparisons have not been made at this time, and no doubt there are many exceptions to this hypothesis.

Petroleum accumulations are found, to some extent at least, in all parts of the western North American and West Siberian Cretaceous sections. A great share of the major oil accumulations in both basins, however, if heavy oil deposits are included, are in Lower Cretaceous reservoirs. From the standpoint of petroleum source, as to be expected, there is some differences of opinion in both cases on the question of indigenous vs. non-indigenous petroleum. However, the evidence and reasoning favoring an indigenous source for petroleum deposits in the western North American Cretaceous is now almost conclusive, even in the case of the Canadian heavy oil deposits.

The question of indigenous vs. non-indigenous petroleum genesis may be more than academic in considering the potential reserves of the West Siberian basin. The western Canadian Cretaceous basin, of comparable size and general character to the West Siberia basin, has probably generated at least one trillion barrels of Cretaceous oil in place. Much of this, of course, has been lost by subsequent tectonic and erosion effects, but some estimation can be made of theoretical potential recovery of fluid oil from these accumulations if they were still preserved in the subsurface. Recovery ratios of no more than 20-25 percent would rank the western Canadian Cretaceous basin, as a petroleum generating province, in close comparison with the Middle East, for example. The many similarities between the Canadian and West Siberian giant basins should justify a degree of reasonable comparison in attempting to estimate the potential of the West Siberian basin.

Salt Creek, Wyoming

At least partial analogs can be made between the giant Samotlor oil field and several large Cretaceous oil accumulations in the western interior North America, e.g., Pembina, Lloydminster, and the Athabasca, Peace River, Cold Lake, and perhaps other large tar sand deposits of Canada, and the Salt Creek, Bell Creek, Raven Creek, Fiddler Creek, Bisti and other fields in the United States. Among these, a close comparison, from the structural, stratigraphic, and reservoir aspects, appears to be the Salt Creek oil field, Wyoming, with reserves of about 500 million barrels, relatively small in comparison with Samotlor's 10-15 billion barrels. However, almost all of Salt Creek's oil is from a single relatively thin sandstone body, and in this sense it may be a reasonable comparison with one or more of the many Samotlor productive intervals, taken separately.

The location of the Salt Creek field at the outer edges of the Frontier delta and along the large-scale interbasin paleostructural trend of the ancestral Bighorn Mountains offers many similarities to geologic conditions at Samotlor and the central basin area in West Siberia. The major share of the Samotlor oil pools, like the Second Frontier pool at Salt Creek, are recognized by Soviet geologists as combined structural-stratigraphic traps in discontinuous outer deltaic sandstone bodies. Very similar conditions are recognized at Salt Creek, as well as at numerous other areas of petroleum in the western interior North America Cretaceous basin.

RESOURCE ASSESSMENT

Halbouty (1970) lists 9 giant oil fields (>500 million bbls oil recoverable) and 20 giant gas fields (>3.5 TCF recoverable) for the West Siberian basin. The ultimate recoverable reserves for these fields total approximately 32 billion bbls of oil and 600 TCF gas. More giant oil and gas fields have certainly been discovered since 1970. The resource potential for undiscovered oil and gas for the West Siberian Basin looks favorable. Although we did not have access to detailed geological and geophysical information, a resource assessment based strictly on basin analogue can be made. As previously stated, the West Siberian Basin is a Cratonic Type II basin. Using the estimated recovery of oil and gas per cubic mile of sediment for Type II basins (Halbouty, 1970) the following resource assessment can be made for the West Siberian Basin.

bbls[1] / cu mi of sediment in basin:	low yield - 40,000
	average yield - 100,000
	high yield - 170,000
cubic mile of sediment in basin[2]:	1,400,000
low yield resource assessment:	56 billion bbls
average yield resource assessment:	140 billion bbls
high yield resource assessment:	230 billion bbls

As indicated above, incomplete exploration of the West Siberian Basin has led to discovery of al least 29 giant oil and gas fields. Because of the apparent richness of the basin, the high yield resource assessment would probably be realistic. Type II basins also have the highest percent

[1]Based on oil (or gas equivalent - 6,000 cu. ft. = 1 bbl)
[2]Planimetered from isopach map published by Dickey, 1974

of gas in giant fields (65 percent). Assuming that 65 percent of the basin's hydrocarbons are gas, then the high yield resource assessment could be 900 trillion cubic feet of gas and 80 billion bbls of oil. Assuming 32 billion bbls of oil and 600 TCF of gas has been found, then based on the above assumptions, 48 billion bbls of oil and 300 TCF of gas remain to be discovered in the West Siberian Basin. These values might be too low, based solely on a sediment-volume yield.

Recent drilling and seismic data suggest that the volume of sediments in the basin, especially north of the hinge line, are considerably greater than originally suspected. The bulk of the additional sediment thickness is probably made up of marine Triassic rocks and unmetamorphosed Paleozoics. Where would the additional oil and gas resources likely to come from? With an area of approximately one-half the size of all the United States' lower 48 onshore basins, the West Siberian basin could not have been thoroughly explored by the drill or even by seismic methods since exploration began there in the late 1940's. The Soviets' drilling thrust in the West Siberian basin has been in development and exploitation drilling, not exploratory drilling. New discoveries are certainly to be made by deeper drilling north of the hinge line. Oil has been discovered below Upper Cretaceous gas fields in Lower Cretaceous rocks, with many more oil and gas discoveries likely. One of the most attractive areas for future exploration would be near the hinge line (near 64° parallel) where a tremendous wedge of Triassic and older rocks pinch out north of the NizhneVartov and Surgut uplifts. See Figure 48. Deeper drilling in the Middle Ob region looking for stratigraphic pinch outs similar to the traps that produce in the western flank

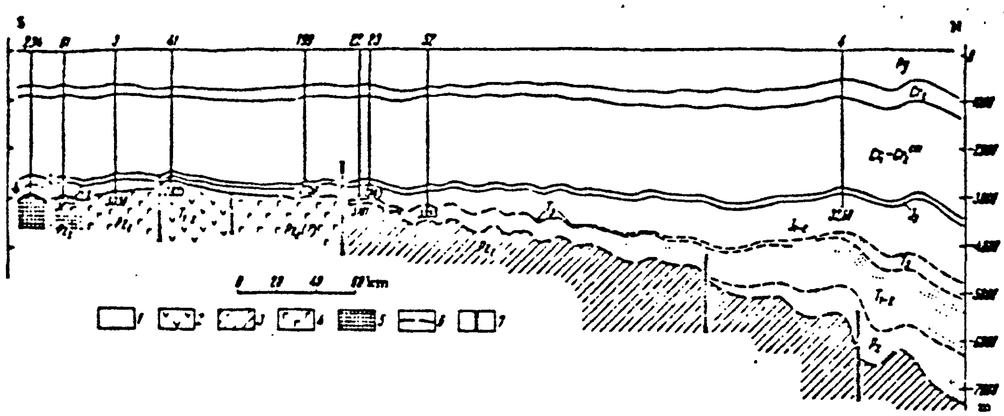


Figure 48. Geologic section across the northern part of the Surgut dome. 1) Upper structural level of sedimentary mantle; 2) lower platform level (Triassic Turn series); 3) Paleozoic folded basement; 4) Middle Paleozoic basic effusives; 5) Middle Paleozoic serpentinies; 6) unconformity; 7) probable faults. From Bochkarev

of the basin appear to have potential. A possible problem there is the lack of good reservoir rocks. Oil and gas shows in pre-Jurassic rocks south of the hinge line appear to be encouraging (see King, 1976).

In summary, the overall geology of the West Siberian Basin in addition to its tremendous size, the infancy of Soviet exploration with emphasis on development drilling, the size of the reserves and the encouragment from recent drilling suggest that large oil and gas accumulations remains to be discovered.

GLOSSARY

Anticlize - A very broad positive uplift on a platform that is tens of thousands of sq. km. in area.

Dome - An equidimensional positive structure with an area of more than 5,000 sq. km. (Svod in Russian).

Swell - An elongate positive structure with an area of more than 5,000 sq. km. (Val in Russian).

First order structure - A positive or negative structure on a platform that is more than 5,000 sq. km. in area.

Local uplift - A positive structure of less than about 200 sq. km. in area.

Second order structure - A positive or negative structure on a platform that is between about 200 and 5,000 sq. km. in area.

Series - The term "series" is used here for the Russian term "seriya"; it is in general equvalent to the stratigraphic "group."

Outer margin of pool - The line formed by the intersection of the water-oil contact with the top of an oil-saturated reservoir stratum (Figure 69a).

Inner margin of pool - The line formed by the intersection of the water-oil contact with the bottom of an oil saturated stratum (Figure 49b).

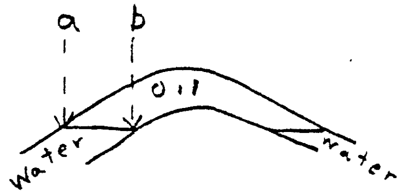


Fig. 49.

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SAMOTLOR OILFIELD

Plate 1

Stratum	Stage	Formation	Depth interval	Local uplifts: Samotlor	Martov	Belozer	Mykhpay	Malosamotlor	Pauy	Lithology	Facies changes	Seal	Porosity %	Permeability md	Formation pressure kgs/cm^2	Formation temperature °C	[illegible]
PK$_1$	Cenomanian	Pokur (top)	1610-1780	X													
AV$_1$	Aptian	Alym (bottom)	1610-1980	X	x	x	x	x	x	Sandstones with clays and siltstones	To impermeable on Samotlor local uplift	20-25 m clay	23-28, av. 24	Av. 86	172	63	98
AV$_{2-3}$	Barremian	Vartov (top)	1640-1760	X	x	x			x	Alternating sandstones, clays and siltstones	To impermeable on Samotlor local uplift	2-5 m green clay	Av. 22	Av. 470	169-182	57-62	1[illegible]
AV$_{4-5}$	Barremian	Vartov (top)	1685-1748	X	x	x	x	x	x	Sandstones with clays		20-40 m clay	19-29, av. 22	Av. 510	169	65	76
AV$_6$	Hauteriv	Vartov (top)	1793-1798							Sandstones with clays and siltstones			Av. 25		174	62	
BV$_8$	Valanginian	Megion (top)	2020-2140	X	x	x			x	Sandstones with clays and siltstones		5-8 m clay	17-25, av. 18	Av. 114	210-218	65-77	90-100
BV$'_{10}$	Valanginian	Megion (middle)	2125-2220	X	x	x	x	x	x	Sandstones with clays	Replaced by clay toward northwest on flank of Martov uplift	60-70 m clays	21-26, av. 21	Up to 500 Av. 135	220	75	1[illegible]
BV$_{10}$	Valanginian	Megion (middle)		X		x	x										
BV$_{11}$	Valanginian	Megion (middle)	2150-2230	X						Sandstones with siltstones and clays	Replaced by clays to northwest and northeast	5-6 m clay	21-26 Av. 18	Up to 500 Av. 88			82

Stratum	Saturation pressure of gas in oil kgs/cm^3	Level of water-oil contact	Height of pool, m	Net pay, m	Initial production, m^3/day (choke)	Closure, m	Specific gravity, g/cm^3	Sulfur, % wt	Nitrogen, % wt	Tars, % wt	Asphalt, % wt	Paraffin, % wt	Paraf. melting, °C	Boiling, °C	Distillate, % vol. to 200°C	Distillate, % vol. to 300°C	Average daily production per well, tons/day	Viscosity of oil, cp, under formation conditions
PK$_1$						50												
AV$_1$	170	-1693	145	15.6	66 (8 mm)	100	0.809-0.887	0.82	0.14	8.28	0.91	2.50	52.5	78	23.5	47.0	2.4	1.60
AV$_{2-3}$	97	-1693	100-108	9.5	66-137 (8 mm)	100	0.757-0.880					2.70					16.4	1.71
AV$_{4-5}$	86	-1693	55-63	15.0	93-162 (8 mm)	100	0.788-0.883	0.85				3.50					19.4	1.97
AV$_6$			10	5	58 (8 mm)	100												
BV$_8$	100-110	Inclined at -2071 to -2076	110-115	30	100-200 (8 mm)	100	0.834-0.865	0.76	0.14	6.86	0.76	4.42	50.0	62	28.0	50.0		1.01
BV$'_{10}$	100-110	Inclined at -2152 to -2157			52-160 (8 mm)									59.5	31.0	55.2	3.5	0.88
BV$_{10}$			95-1[illegible]	25		100		0.58	0.11	[illegible].56	0.65	2.51	53.0					
BV$_{11}$		-2167		20-25														

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