ABSTRACT

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

Paleostructural and stratigraphic trapping are important aspects of West Siberian petroleum geology. Oil source rocks are mainly marine Jurassic and Lower Cretaceous bituminous shales. Gas source rocks are mainly Upper Cretaceous humic and coaly shales. Petroleum production in the basin occurs in four major areas: (1) **Middle Ob**: primarily oil from Lower Cretaceous deltaic-marine clastic reservoirs on broad regional uplifts; the Samotlor and other supergiant fields are located in this area; (2) **Near-Ural**: primarily oil in the south and gas in the north from Upper Jurassic and Lower Cretaceous clastic reservoirs in paleostructural-stratigraphic traps; (3) **Southern Basin**: oil and oil-gas from Jurassic clastic reservoirs, mainly on anticlines or arches inherited from basement highs; and (4) **Northern Basin**: gas primarily from Upper Cretaceous (Cenomanian) and gas-condensate from Lower Cretaceous and Jurassic clastic reservoirs on large anticlinal traps sealed by Cretaceous shales or permafrost. Urengoy, the world's largest gas field, and several other supergiant gas fields are located in this latter area.

Large parts of the basin are relatively unexplored, particularly the northern offshore segments. The interrelated paleostructural and depositional character of this enormous basin provides excellent prospects for stratigraphic trap accumulations. An estimated 70 billion bbl of oil and 1000 tcf (trillion cubic feet) of gas have been found in the basin. U.S. Geological Survey estimates (1987) of undiscovered, conventionally recoverable petroleum resources are 30 billion bbl of oil and 350 tcf of gas.

ABOUT THE AUTHORS

James A. Peterson was born in the midwest and attended elementary and high schools in Michigan and Indiana. He enrolled at Northwestern University in 1941 to major in Journalism and Science, a program interrupted by induction into military service in World War II, where he served in the U.S.A.A.F. as a meteorologist-weather forecaster. After military service, Peterson attended St. Louis University, from which he received the B.S. degree in Geophysics in 1948. He received the Ph.D. in Geology and Petroleum Engineering in 1952 at the University of Minnesota. From 1949 to 1952, he was geologist for the U.S.G.S. working on phosphate deposits and micropaleontology; he also taught at Washington State University in 1951. He joined Shell Oil Co. in 1952 and worked for 13 years as geologist, Division Stratigrapher, and Senior Geologist, primarily on Rocky Mountain and Great Basin exploration projects. In 1965 he joined the University of Montana as Professor of Geology, and he remains there as an Adjunct Professor. He rejoined the U.S.G.S. in 1976 as a Research Geologist with the Branch of Oil and Gas Resources and the Water Resources Division. His U.S.G.S. work has mainly involved domestic petroleum geology and resource assessment of several northern Rocky Mountain basins, the eastern Great Basin, and the Paradox basin. Since 1976, most of his work has been part of the U.S.G.S. World Energy Resources Program and has included geology and resource assessment studies of Mexico, China, North Africa, the Mediterranean, the Middle East, and the Volga, Ural, and West Siberian provinces of Russia—the latter in collaboration with J.W. Clarke.

Peterson is a member or fellow of several scientific societies, and has served on numerous professional committees and as an officer of several societies. He was awarded Honorary Membership in the Society for Sedimentary Geology (SEPM) in 1986 and received the AAPG President's Award in 1987. He is the author or co-author of more than 100 professional publications, and the editor of several geologic compilations, including AAPG Memoir 40. At present, he is an Associate Editor of the *AAPG Bulletin*.

James W. Clarke was born in Tennessee and grew up in Georgia, where he received his early education. His studies at Emory University in Atlanta were interrupted by World War II, in which he served as a rifleman in the 99th Infantry Division. Clarke then returned to Emory University, from which he received the B.A. in Geology and Chemistry in 1947. He received the Ph.D. in Geology in 1950 from Yale University, with Adolph Knopf as his thesis advisor. From 1950 to 1959, Clarke was Professor of Geology at Vanderbilt University, the University of South Carolina, and Duke University; he joined the U.S.G.S. in 1959. He was Project Chief for the group that prepared *Geophysical Abstracts, Abstracts of North American Geology*, and the *Bibliography of North American Geology*, until these publications were discontinued in 1970. Clarke then began structural and field mapping studies of sedimentary, igneous, and metamorphic rocks in the Appalachian region. From 1977 until his retirement from the U.S.G.S. in 1991, he was engaged in studies of the petroleum geology and resources of the Soviet Union, as part of the U.S.G.S. World Energy Resources Program. Clarke received the Survey's Superior Performance Award in 1975. For the past 30 years, he has also been translating and analyzing Soviet literature on petroleum geology and geophysics. This work has been summarized and regularly printed in his journal, *Petroleum Geology*, which is published privately on a non-profit basis and is widely distributed to American and foreign universities, oil companies, and consultants involved with Soviet geology and petroleum geology. Dr. Clarke has been publishing this journal since 1958.

Clarke is author of more than 60 scientific papers, mostly on Soviet petroleum geology, but also on the structure and history of the Appalachian region. At present, he is actively continuing his Soviet studies at the U.S.G.S. National Center in Reston, VA. He is a Fellow of the Geological Society of America, and a member of the American Association of Petroleum Geologists, the European Association of Petroleum Geologists, and the All-Union (Soviet) Association of Petroleum Geologists. He has been a member of the Washington Cosmos Club since 1975.

INTRODUCTION

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

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

The West Siberian oil-gas province has an area of 3.5 million km^2 (1.3 million mi^2) (Figure 1) and is the largest flat area on earth. More than 1000 km upstream on the Ob River, elevations are still less than 100 m above sea level. Although the winters are unrelentingly cold, it is during this time that work is best accomplished in many areas because in the summer, the upper part of the permafrost melts and the ground becomes very soggy. Furthermore, the rivers flow north, and spring melting takes place first in the upstream parts, causing downstream flooding over vast areas. This results in mosquito populations that are at best an extreme nuisance.

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

In spite of the weather and logistical difficulties associated with the sheer size of the operation, the Soviets manage to produce 7 million bbl of oil per day in West Siberia and move it to European Russia. To maintain this level of production and at the same time prevent a drop in the production ratio, they must discover more than 4 billion bbl of new oil each year.

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

STRUCTURE

Introduction

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

Structurally, the West Siberian basin is a platformal basin, the largest on the planet, having an area of about 3.5 million km^2 (1.3 million mi^2). Its closest analog is the Great Artesian basin of Australia (Khain, 1979). Within the West Siberian basin, a thick Mesozoic–Cenozoic section of platform sediments rests on basement that is largely folded and metamorphosed rocks. Several small terranes within this basement consist of unmetamorphosed middle and upper Paleozoic carbonate and clastic sediments and Triassic clastic sediments and volcanic rocks. These unmetamorphosed Paleozoic and Triassic rocks are called the intermediate complex. In the northeastern part of the region, the West Siberian sedimentary basin overlaps onto the western part of the East Siberian craton (Figure 2). The suture between the West Siberian platform and the East Siberian craton is buried beneath the Mesozoic–Cenozoic sedimentary rocks of the West Siberian basin (Shablinskaya et al., 1990).

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

Magnetic surveys have been conducted over the entire West Siberian platform. Since the rocks of the Mesozoic–Cenozoic sedimentary cover have low magnetic susceptibilities, magnetic anomalies reflect the magnetic properties of the pre-Jurassic rocks. These data are used by the Soviets in compiling tectonic maps

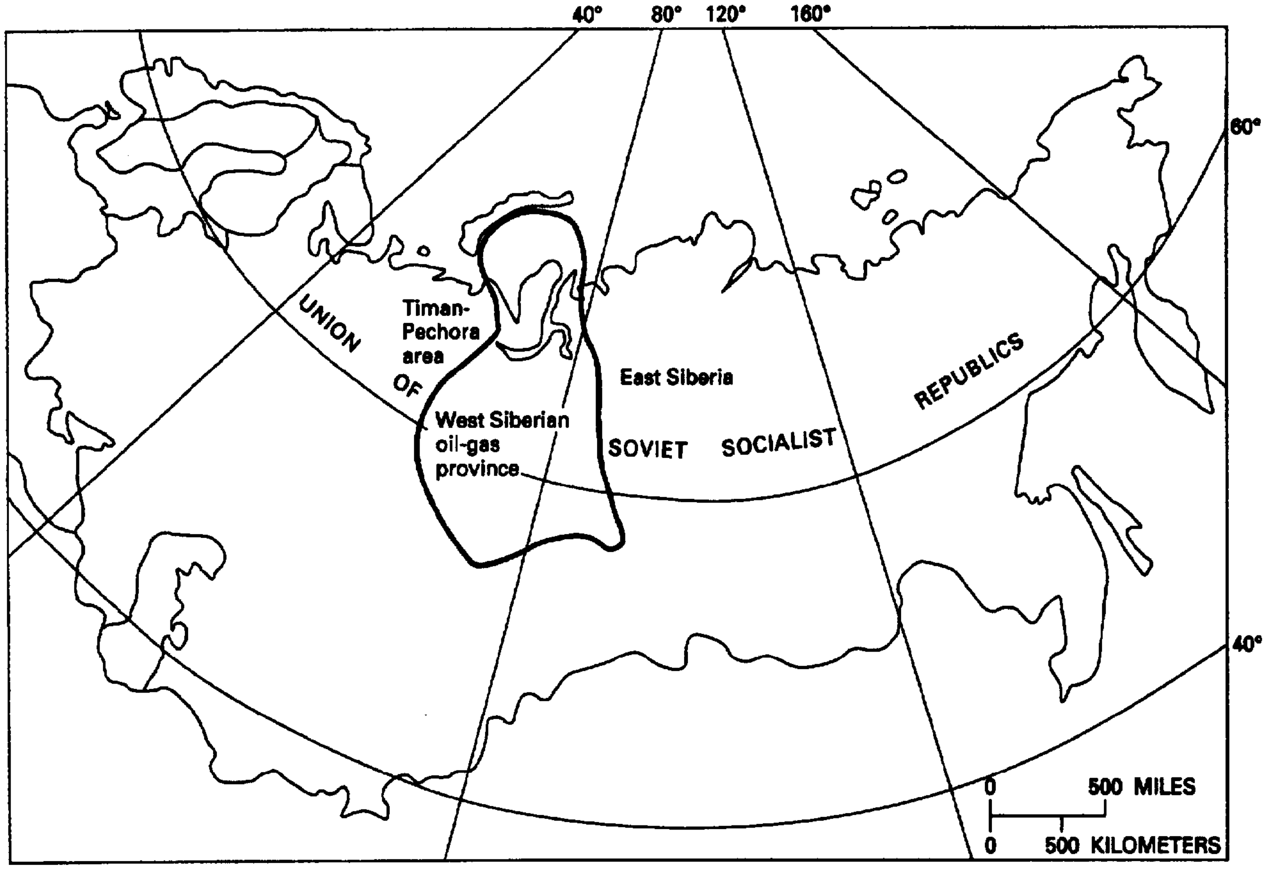

Figure 1. Location of West Siberian oil-gas province.

of the basement and intermediate complex (Krylov et al., 1981b).

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

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

Basement

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

Yenisey Fold System

This is the oldest foldbelt in the basement of the West Siberian basin; a geosynclinal prism was folded toward the end of the Precambrian during the Baykalian orogeny. The system extends along the eastern margin of the basin in a belt about 200–300 km (125–185 mi) wide and more than 2000 km (1250 mi) long (Figure 2). Granite plutons are present only in the south. Gravity data suggest that the system continues northward into the Yenisey-Khatanga downwarp along the northeastern margin of the Siberian craton. The Yenisey fold system is bounded on both the east and west by deep faults, but no ultramafic rocks have been mapped along these faults.

Associated with the Yenisey foldbelt are two Karelide blocks that were reworked by the Baykalian orogeny. On the southwest is the Verkhneket block, and on the northwest is the Nyadoyakh block (Figure 2). The Nyadoyakh block appears to be a node of inter-

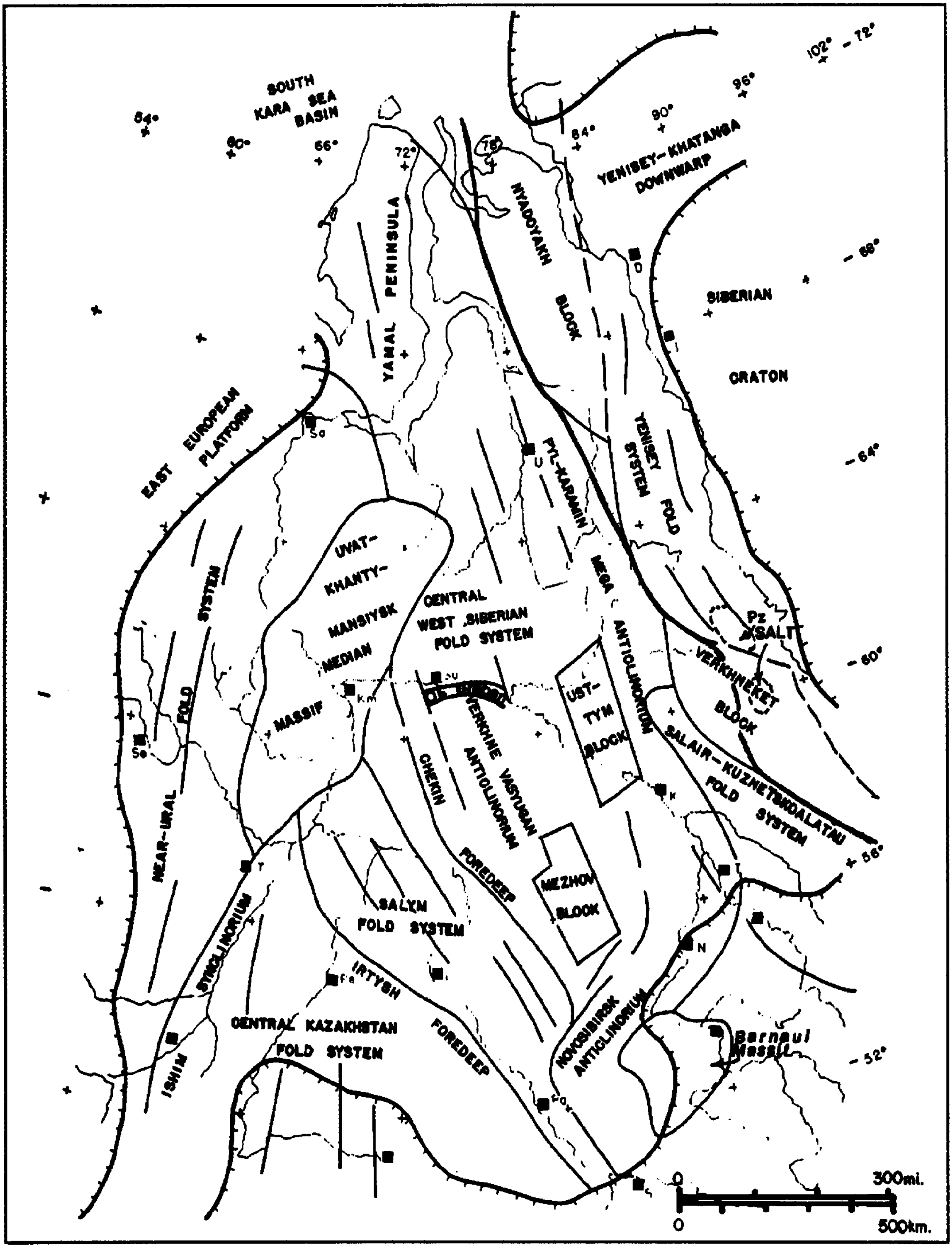

Figure 2. Structure of pre-Jurassic basement of West Siberian oil-gas province. Suture between the West Siberian platform and the East Siberian craton is shown by heavy line. Abbreviations of towns are as follows: Sa—Salekhard, D—Dudinka, I—Igarka, U—Urengoy, Su—Surgut, Km—Khanty—Mansiysk, Se—Serev, T—Tyumen, Pe—Petropavlovsk, O—Omsk, Pa—Pavlodar, N—Novosibirsk, K—Kolpashev.

section of the north–south structural trends of the main part of the West Siberian basin and the east–west trends of the Yenisey-Khatanga downwarp.

The Yenisey fold system is actually the western part of the East Siberian craton. In the southern part of this belt are undeformed sedimentary rocks that appear to be a continuation of the Proterozoic and lower Paleozoic platformal cover of the East Siberian craton (Figure 2). Gravity and seismic surveys indicate the presence of a 1-km-thick salt unit in this sedimentary section. This salt appears to have formed domes in places (Samoylyuk et al., 1990).

Salair-Kuznetsko-Alatau Fold System

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

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

Central Kazakhstan Fold System

The northern segment of this fold system forms the southwestern part of the basement of the West Siberian basin. Although this is a Caledonian terrane, it contains a large number of blocks of Archean and Proterozoic fold systems. In the northwestern part of this terrane is the Ishim synclinorium where Ordovician sedimentary and volcanic rocks are strongly folded and metamorphosed. An anticlinorium on the east of this synclinorium is the site of large granite intrusions. No ultramafic rocks have been mapped along the borders of this fold system.

Salym Fold System

This system consists of two megaanticlinoria separated by a megasynclinorium, all trending parallel to one another in a N30°W direction. The system is about 300 km (185 mi) wide and more than 1000 km (625 mi) long. It is separated from the Central Kazakhstan fold system by the Irtysh foredeep and from the Central West Siberian fold system by the Chekin foredeep. This latter boundary appears to be a major suture along which ultramafic bodies are present. The geosynclinal stage developed in the early Paleozoic, and the system was folded in the Devonian during early Hercynian orogenesis. Carboniferous and Permian sediments are platformal and are part of the intermediate structural stage; they consist largely of intermediate and basic volcanic rocks, but numerous granite plutons are present along both the megaanticlinoria and the megasynclinorium.

Central West Siberian Fold System

This fold system was first recognized in 1967. It extends north–south through the entire West Siberian basin. Information on its nature is spotty because it is exposed at the surface only at the south, and few drill holes have reached it. The system had its inception in Silurian or Early Devonian time on continental crust. Geosynclinal downwarping was intensive and deep, and the fill is largely clastic rocks. In the final phase of Hercynian orogenesis, these rocks were folded, granitized, and uplifted.

The western boundary of this late Hercynide belt is a deep fault or suture separating it from the Ural foldbelt, the Uvat-Khanty-Mansiysk block, and the Salym foldbelt. The east boundary is also marked by deep faults. The structure of this fold system trends south–southeast through its entire area to the vicinity of Novosibirsk where it swings at almost a right angle into the transverse Novosibirsk anticlinorium (Figures 1, 2).

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

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

Near-Ural Fold System

In the western part of the West Siberian basin, the basement is the subsided eastern part of the Ural geosynclinal trough, which was deformed during late Hercynian tectogenesis at the end of the Paleozoic to form the Ural fold system. In contrast to the

Hercynides of the Central West Siberian fold system, the Ural geosynclinal trough began in Riphean (Late Proterozoic) time and continued development throughout the Paleozoic. Volcaniclastic sedimentary deposits are characteristic of the fills of the downwarps of this system. Numerous basic and ultramafic intrusions are closely associated with the early and middle Paleozoic volcanism here. The geosynclinal rocks of the Central West Siberian fold system were deposited on granitic crust, whereas beneath the Ural geosynclinal system, the granitic crust is thin or absent altogether.

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

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

Uvat-Khanty-Mansiysk Median Massif or Microplate

This massif lies between the Near-Ural and Central West Siberian late Hercynian fold systems (Figure 2). In the southern part of the massif, the gravity anomalies have an east–west trend, whereas on the north, they strike northwestward as if a continuation of the trends from the northeastern part of the Russian (East European) platform. The massif was folded during Baykalian tectogenesis and restructured during the Hercynian.

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

Barnaul Median Massif or Microplate

This is a Baykalide terrane that was involved in the Caledonian and late Hercynian orogenies; it lies just within the bounds of the Mesozoic–Cenozoic sedimentary cover on the south margin of the West Siberian basin (Figure 2). Within the massif are several depressions filled by middle Paleozoic sedimentary rocks.

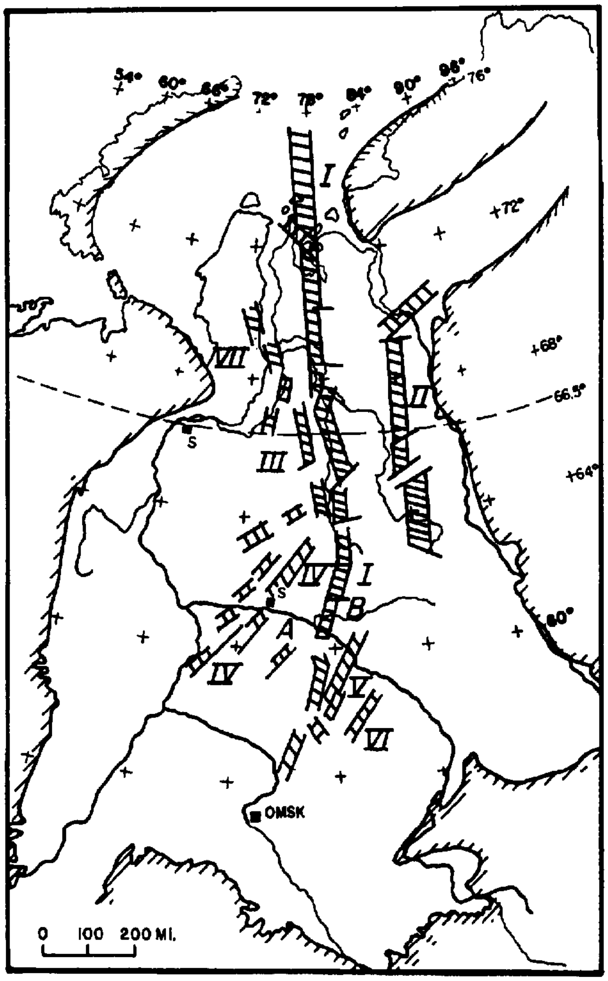

Figure 3. Rift systems of basement of West Siberia. (From Surkov and Zhero, 1981.) Grabens: I—Koltogor-Urengoy, II—Khudosey, III—Khudutey, IV—Agan, V—Ust-Tym, VI—Chuzik, VII—Yamal.

Triassic Rifts

In the central part of the West Siberian platform where the basement is late Hercynian in age are long, narrow Triassic rift systems that cut across the Hercynide trend (Figure 3) and are reflected by strong positive gravity and magnetic anomalies. On the surface of the basement, the rifts are deep grabens filled largely by basic intrusive rocks. In only the upper part of the graben fill are volcanic and sedimentary rocks present. Vertical displacement along the graben margins is 3–5 km (1.8–3 mi) (Surkov and Zhero, 1981). The Triassic rifts are clearly expressed in the geothermal field. At a depth of 1 km (0.6 mi), the temperature in the Mesozoic–Cenozoic sedimentary cover above the grabens is 3–4°C above background.

The largest of the Triassic rifts is the Koltogor-Urengoy graben, or megatrough, which extends north–south for 1800 km (1100 mi) from Omsk on the

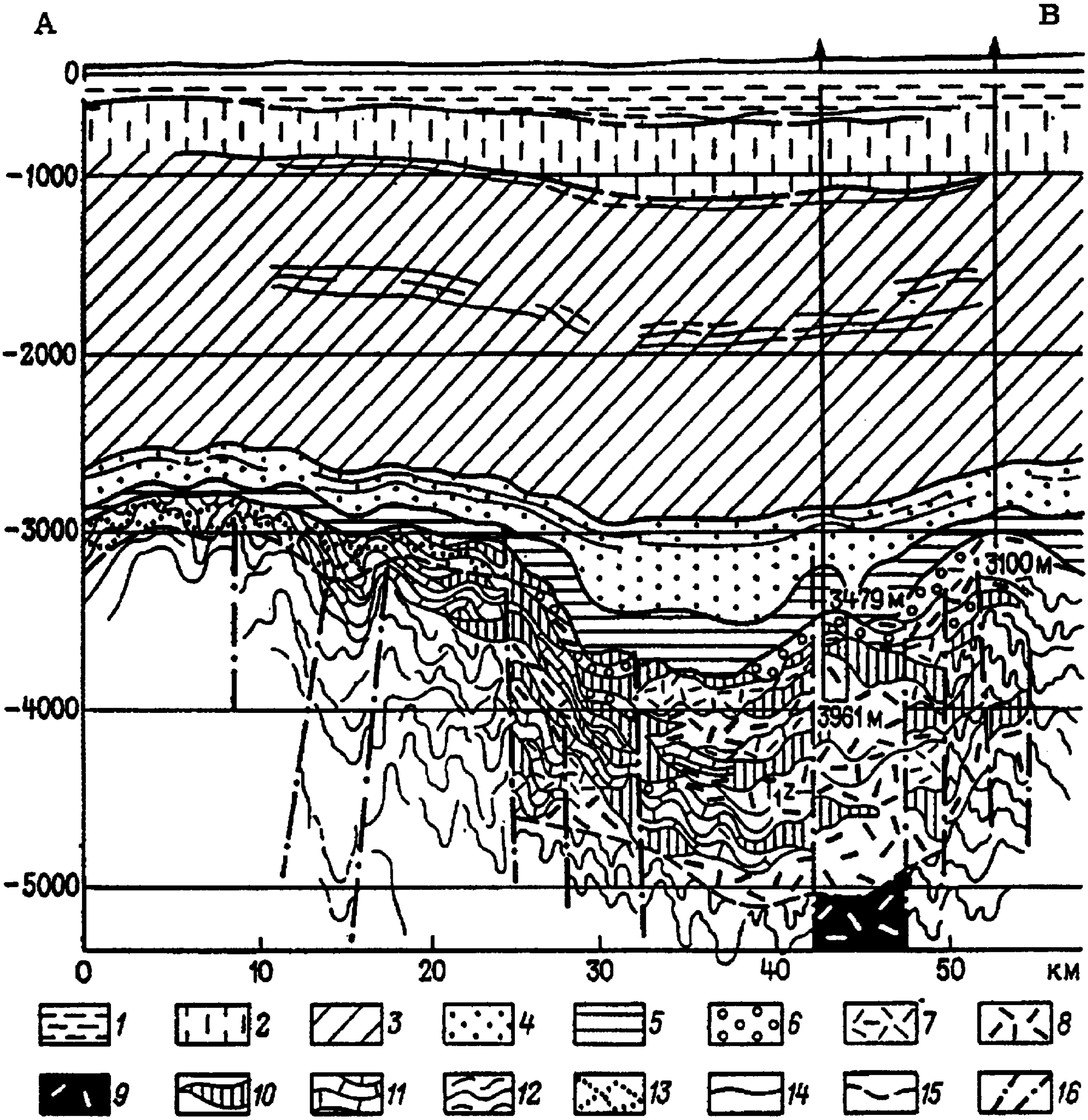

Figure 4. Geological–geophysical profile of the Koltogor–Urengoy graben along line A–B of Figure 3. (Modified from Surkov and Zhero, 1981.)

south to the Kara Sea on the north (Figure 3). Aligned with this graben in the Arctic Ocean is the Saint Ann Trough, which in turn opens into the deep-water Nansen Trench. The width of this graben increases from a few kilometers in the south to 80 km (50 mi) in the north. The complexity of this graben is shown diagrammatically in Figure 4.

The Triassic rifting as an event of partial spreading of the lithosphere was short lived. To the west of the Koltogor-Urengoy graben was a spreading center in latest Permian and Early Triassic time for 17 m.y. Symmetrical bands of alternating magnetic polarity indicate seven episodes of alternating normal and reversed magnetization during this spreading activity (Aplonov, 1986). The Triassic rifting was accompanied by intrusion of large volumes of basaltic magma not only in West Siberia but also on the Siberian craton and in the Barents Sea (Shipilov and Mossur, 1990).

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

Mesozoic–Cenozoic Sedimentary Cover

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

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

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

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

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

The inner region of the West Siberian platform is subdivided by the Koltogor-Urengoy graben into western and eastern blocks. The Cretaceous System is somewhat thicker on the western block than on the eastern, whereas the Jurassic is thicker on the eastern block than on the western. Closure on structures of the western block is much less than for corresponding structures of the eastern block. These eastern block structures are to a great extent fault controlled. These faults generally attenuate upward in the Jurassic and Cretaceous sediments.

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

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

Satellite photographs indicate the presence of a graben of recent origin along the east–west stretch of the Ob River (Figure 7). The Ob graben is about 200 km long and 15–40 km wide (Glavinskaya, 1990).

Discussion

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

First, let's examine the Ural fold system. Gravity and magnetic anomalies in the southern part of the Uvat-Khanty-Mansiysk microplate (Figure 2) have an east–west trend. Anomalies of this same trend are tracked fragmentally westward into the central part of

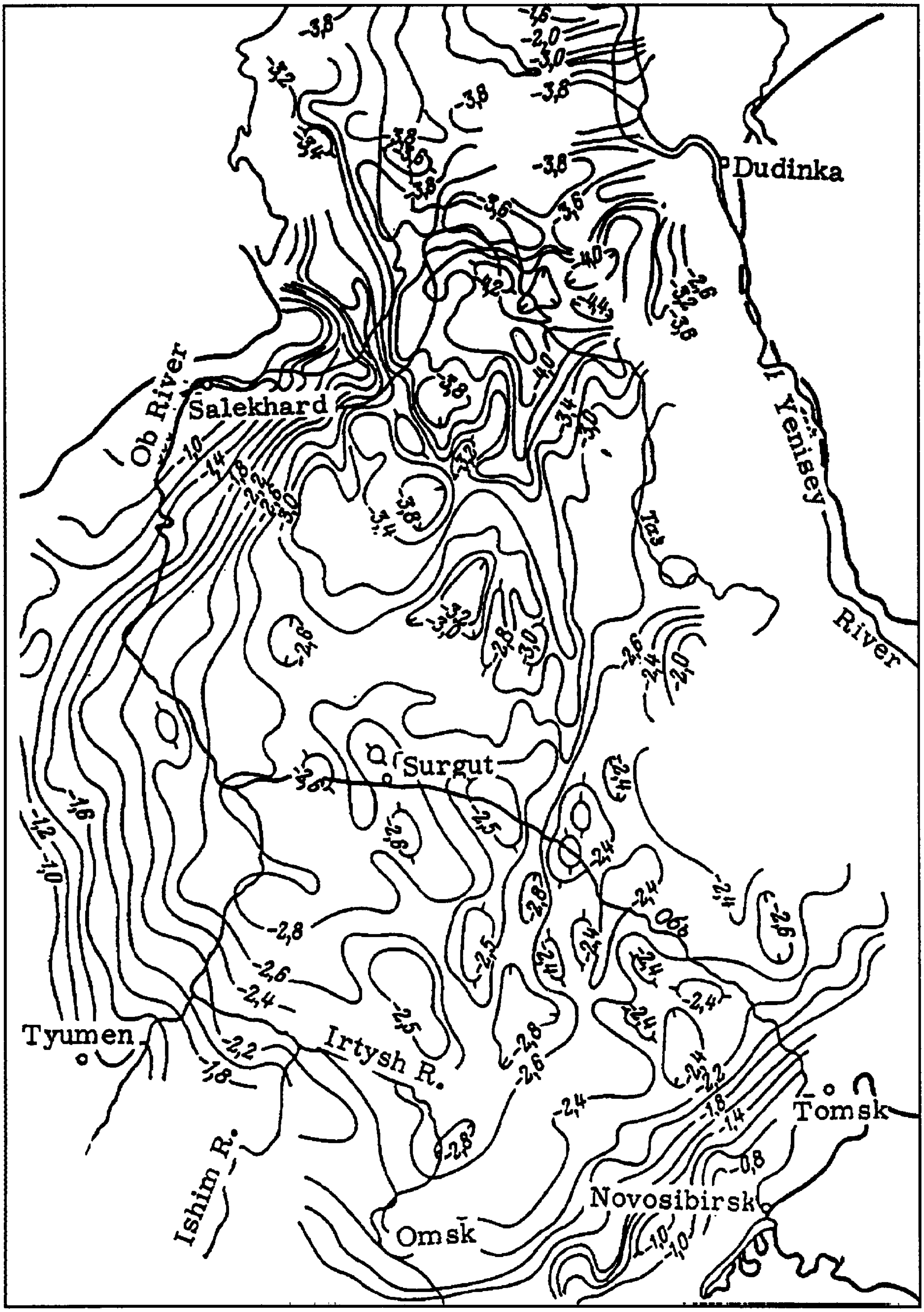

Figure 5. Generalized structure map (contours in kilometers). Mean sea level on the Upper Jurassic Bazhenov Formation. (From Surkov and Zhero, 1981.)

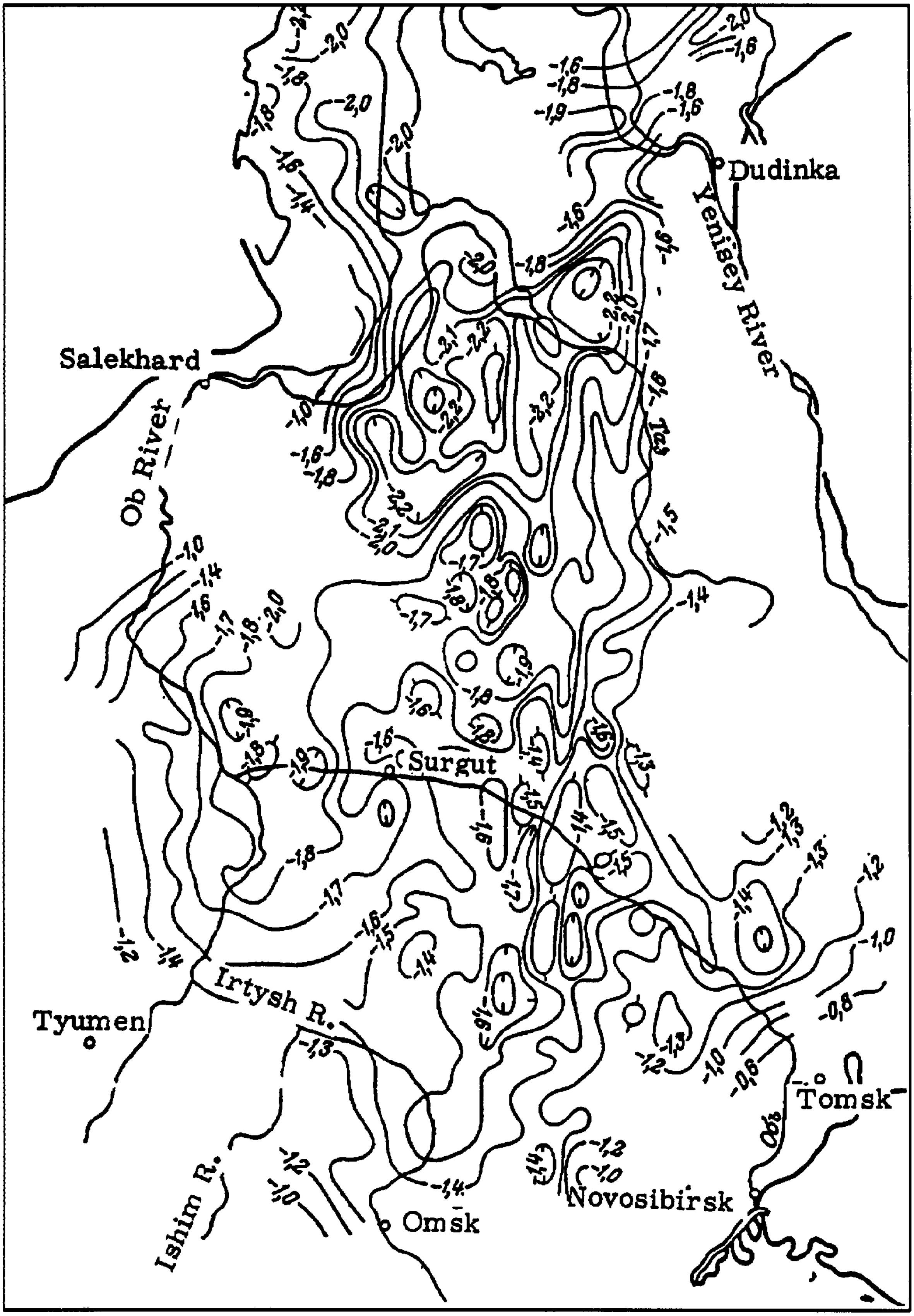

Figure 6. Generalized structure map (contours in kilometers). Mean sea level on the lower Aptian reflecting horizon II. (From Surkov and Zhero, 1981.)

Figure 7. ***(Caption on facing page.)***

the Ural fold system and thence onto the eastern part of the Russian (East European) platform, thereby suggesting that the terranes east and west of the Ural fold system in these regions are part of the same plate. The northern part of the Uvat-Khanty-Mansiysk microplate appears to be a fragment of a Riphean fold system that once extended from the Timan-Pechora area (Figure 1) southeastward across the Ural fold system and thence through the whole of West Siberia (Surkov et al., 1983). This, too, suggests that the Ural geosynclinal trough was an intracratonic feature.

Figure 7 *(facing page)*. Super-order and first-order structures of the West Siberian platform. (Modified from Surkov and Zhero, 1981.) Middle Ob graben shown by heavy lines. First-order structures: 1—Kharasov–Bovanenkov anticline, 2—Arktich–Sab"yakh anticline, 3—Vostochno–Baydarats syncline, 4—Neytin–Seyakhin syncline, 5—Malygino–Peksed anticline, 6—Khablyakhin syncline, 7—Preobrazhen–Zelenomysov anticline, 8—Gyda anticline, 9—Detarak–Nyagam arch, 10—Solochno–Golchikhin arch, 11—Novoportov–Yamsovey anticline, 12—Yamburg anticline, 13—Tungus–Yakhin syncline, 14—Nerutin syncline, 15—Tazov anticline, 16—Urengoy anticline, 17—Bol'sheket depression, 18—Nizhnetazov depression, 19—Chasel anticline, 20—Khangort anticline, 21—Gort syncline, 22—Poluy anticline, 23—Nizhnenadym syncline, 24—Yarudey anticline, 25—Visim anticline, 26—Altatump anticline, 27—Aksar anticline, 28—Vanzevat anticline, 29—Nergin–Mozyam anticline, 30—Yuil arch, 31—Verkhnenadym arch, 32—Pyakupur anticline, 33—Vyngapur anticline, 34—Karampur–Verkhnekolikegan anticline, 35—Verkhnetol'khin anticline, 36—Krasnoleninsk arch, 37—Lyamin arch, 38—Kazym depression, 39—Tanlov depression, 40—Frolov depression, 41—Surgut anticline, 42—Samotlor anticline, 43—Orekhov–Malorechen anticline, 44—Nazin anticline, 45—Kananak anticline, 46—Lymbel arch, 47—Vladimirov arch, 48—Stepanov arch, 49—Ket depression, 50—Tegul'det depression, 51—Alip depression, 52—Verkhtym depression, 53—Shaim anticline, 54—Salym anticline, 55—Tukan–Urnen anticline, 56—Lariomkin anticline, 57—Guzhikhin anticline, 58—Senkin anticline, 59—Kolpashev anticline, 60—Aygol syncline, 61—Pudin anticline, 62—Kombar anticline, 63—Keng syncline, 64—Rakitin anticline, 65—Mezhov arch, 66—Nyurol depression, 67—Krasnogor anticline, 68—Dem'yan anticline, 69—Vorob'yev anticline, 70—Pologrudov anticline, 71—Vasis syncline, 72—Myromtsev syncline, 73—Bol'sheuk syncline, 74—Starosoldat anticline, 75—Georgiyev–Zubov anticline, 76—Irtysh syncline, 77—Vagay–Ishim depression, 78—Tobol anticline, 79—Tyumen syncline, 80—Severo–Sibirsk monocline, 81—Pakulikhin monocline, 82—Eloguy monocline, 83—Barabin–Pikhtov monocline, 84—Saranpaul monocline, 85—Khudutey trench, 86—Agan trench, 87—Ust'–Tym trench, 88—Chuzik trench, 89—Yamal trench.

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

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

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

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

The sagging during the Jurassic and subsequent geological time was accompanied by renewed movement along the Triassic rifts and reactivation of faults bounding major basement features. The blocks between the grabens became regional highs in the Mesozoic sedimentary pile, and the areas of the grabens themselves became regional lows. For example, the Nizhnevartov regional high with the Samotlor anticline

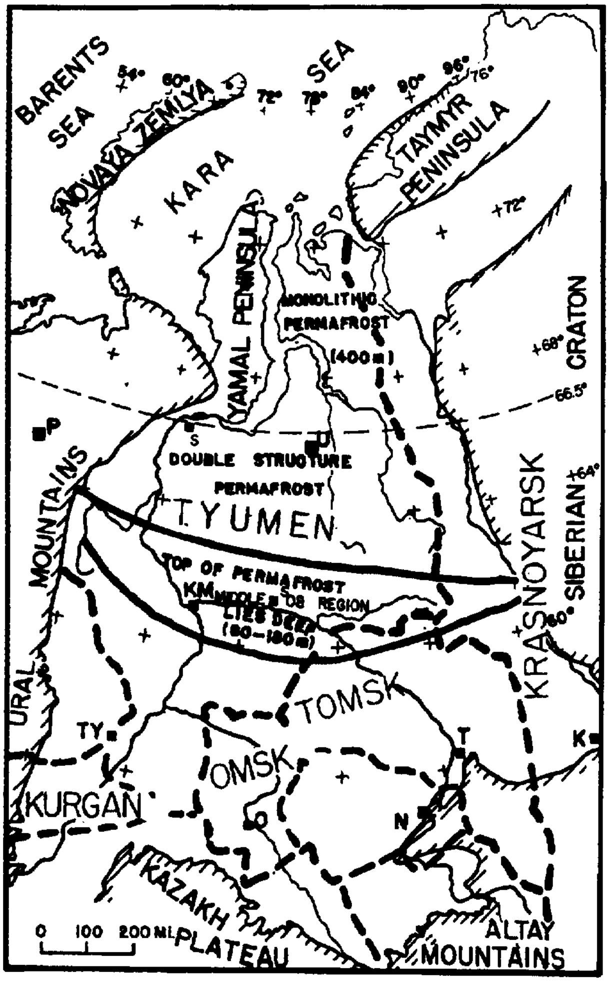

Figure 8. Geographic map of West Siberia showing political regions, main river systems, mountain ranges, and areas of fossil and Holocene permafrost. (Modified from National Geographic Society, 1981; Ostryy, 1967.)

is bounded by the Agan trough on the west and the Koltogor-Urengoy graben on the east (Figure 3). Thus, regional highs commonly became sites of the large oil fields of West Siberia.

STRATIGRAPHY AND PALEOGEOGRAPHY

Introduction

The West Siberian basin occupies an area of approximately 3.5 million km^2 (1.3 million mi^2), including the South Kara basin and part of the Khatanga basin, which geologically are a part of the West Siberian basin (Figures 8, 9). The basin is bounded by the Uralian and Novaya-Zemlya uplifts on the west and northwest, the Kazakh and Altay-Sayan uplifts on the south and southeast, the Siberian craton and Taymyr uplift on the east and northeast, and the North Siberian sill on the north. Thickness of the Phanerozoic sedimentary cover ranges from approximately 3–5 km (10,000–16,000 ft) in the central parts of the basin to 8–12 km (26,000–40,000 ft) or more in the northern part (Figures 10–15). The post-Paleozoic basin (including the South Kara Sea and Khatanga basins) is filled with approximately 16 million km^3 (4 million mi^3) of Mesozoic–Cenozoic sedimentary rocks ranging in thickness from 3–4 km (10,000–13,000 ft) in the central area to 8–10 km (26,000–33,000 ft) or more in the north (Figures 15–19). The Mesozoic–Cenozoic fill is less than 1 km (3300 ft) thick along the North Siberian sill, which is a basement high of Mesozoic age extending between the northern end of the Novaya-Zemlya and the northwestern part of the Taymyr uplift (Figures 9, 16). On the southwest, the basin is connected with the Ust-Urt basin region through a narrow trough between the southern Ural Mountains and the Kazakh uplift. In latest Cretaceous and early Tertiary time, the West Siberian Sea was connected with the Tethys sea through this passageway (Figure 9).

Basement

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

Unmetamorphosed Paleozoic Rocks of the Intermediate Complex

Paleozoic rocks that are not metamorphosed are widely distributed beneath the Mesozoic cover. Platformal and geosynclinal rocks several kilometers thick