UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Dnieper-Pripyat Oil-Gas Province, U.S.S.R.

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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Assessment of Energy Resources

The World Energy Resources Program of the U.S. Geological Survey (USGS) assesses reserves and undiscovered petroleum resources throughout the world. Initial program efforts have focused on the major producing areas of the world in order to gain a broad geological understanding of the characteristics of petroleum occurrence for purposes of resource assessment as well as for analysis of production potential. Investigations of reserves and production potential are carried out in cooperation with other U.S. Government agencies, especially the Foreign Energy Supply Assessment Program of the Department of Energy.

The program seeks to investigate resource potential at the basin level, primarily through analogy with other petroleum regions and does not necessarily require, therefore, current exploration information that is commonly held proprietary. In conducting the investigations, we have built a support base of publicly available data and geologic syntheses against which to measure the progress of exploration and thereby validate the assessment. Most of these investigations lead directly to quantitative resource assessments, which, like exploration, to be effective, must be ongoing processes taking advantage of changing ideas and data availability - the results produced are progress reports reflecting on a state of knowledge at a point in time. Because the program is coordinated with the USGS domestic assessment program and because both use similar techniques for assessment, the user can be assured of a thread of consistency permitting comparisons between the various petroleum basins of the world, including the United States, that have been assessed in the overall USGS program.

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Dnieper-Pripyat Oil-Gas Province, U.S.S.R.

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Abstract

The Dnieper-Pripyat oil-gas province in the Ukrainian SSR of the Soviet Union contains nearly 150 oil, gas, and gas-condensate fields. The stratigraphic section is largely Paleozoic in age, consisting of clastic and carbonate sedimentary rocks, two Upper Devonian salt units, and a Permian salt unit. The province is coincident with an aulacogen, in which the flanks dip gently into a deep central graben. The oil-prone Pripyat depression constitutes the northwest part of the aulacogen. Here the pools are trapped in reef carbonates beneath the upper salt unit of the Devonian. The central and southeast part of the aulacogen is the Dnieper-Donets depression, which contains gas pools in the southeast, passing to gas-condensate and then to oil pools on the northwest. Here the pools are trapped beneath Lower Carboniferous argillaceous rocks and Permian salt. Undiscovered oil in the province is assessed as 400 million barrels and gas at 6 tcf.

Introduction

The Dnieper-Pripyat oil-gas province coincides with the Paleozoic Dnieper-Pripyat aulacogen on the north flank of the Ukrainian shield. It is largely in the Ukrainian and White Russian republics. Total area exceeds 100,000 km^2 (figure 1), and the area favorable for oil and gas is 77,000 km^2 (Kurilyuk and others, 1986).

The Dnieper-Pripyat aulacogen consists of the Dnieper-Donets depression on the southeast and the Pripyat depression on the northwest, separated by the Chernigov-Bragin high (figure 2). The aulacogen formed during Hercynian tectonism from the Late Devonian to the Early Permian, and deposition was commensurate in scale with that of a geosyncline (Aksenov and others, 1985). The Paleozoic sedimentary section consists of clastic and carbonate sedimentary rocks, two Upper Devonian salt units, and a Permian salt unit. Above these are Mesozoic and Tertiary clastic sediments.

Oil exploration began in the province in the thirties after discovery of salt domes. The first discovery was a small oil pool in cap rock of a salt dome in 1936. The Radchenkov gas-oil and Shebelinka gas-condensate fields were discovered in 1950. By 1964 more than 20 oil and gas pools had been discovered (Dikenshteyn and others, 1983).

As of 1985, thirty-three fields had been discovered in the Pripyat depression (Solov'yev and others, 1985) and more than a hundred in the Dnieper-Donets depression, thirty-nine having been discovered in the latter during 1979-85 (Kurilyuk and others, 1986).

The Pripyat depression is oil-prone and nearly all the pools are in Devonian reef carbonates between the two salt horizons. The Dnieper-Donets depression is largely gas-prone, and the pools are on salt-assist structures (Devonian salt) and in clastic reservoirs beneath a Permian salt seal.

According to Dikenshteyn (1983) less than half the potential oil and gas resources of the Dnieper-Pripyat province have been discovered. Cumulative production as of 1981 was 230 million metric tons (1.65 billion barrels) of oil and condensate and 883.7 billion m^3 (31 tcf) of gas.

Structure

The Dnieper-Donets depression, Chernigov-Bragin high, and the Pripyat depression comprise the northwest-trending Dnieper-Pripyat aulacogen, which is located within the southwest part of the Russian platform. The aulacogen consists of a central graben bounded by high-displacement border faults and monoclinal flanks that dip toward the graben. The central graben is 900 km long and 70-130 km wide (Aksenov and others, 1985). Displacement on the north and south border faults is 3-4 km in the Pripyat depression, 0.5-1.5 km on the Chernigov-Bragin high, and 2-3 to 5-6 km and more to the southeast in the Dnieper-Donets depression (Dikenshteyn, 1983). Satellite imagery suggests that the border faults are not continuous lines, but rather they are zones about 20 km wide (Danilevskaya, 1985). These fault zones extend downward to show up on the M-discontinuity.

Fig. 1. Location of Dnieper-Pripyak oil-gas province.

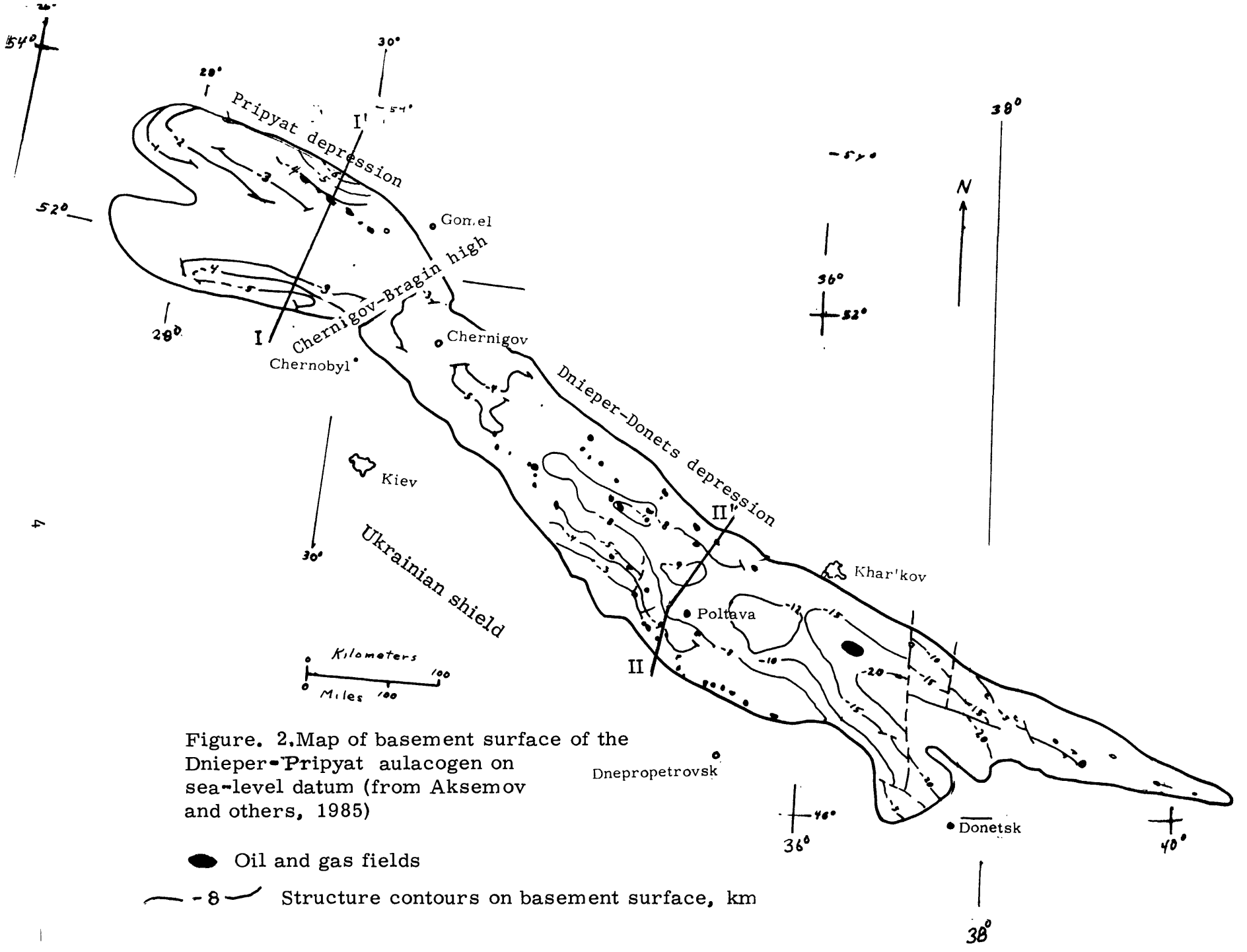

Figure. 2. Map of basement surface of the Dnieper-Pripyat aulacogen on sea-level datum (from Aksemov and others, 1985)

Oil and gas fields

-8 Structure contours on basement surface, km

Depth to basement ranges from 2-3 to 5-6 km in the Pripyat depression; on the Chernogov-Bragin high it is 1-3 km; and in the Dnieper-Donets basin it is 4.5-6 km on the highs and 12-17 km and perhaps 20-25 km in the deepest parts (figure 2.)

On the monoclinal flanks the surface of the basement dips toward the central graben at angles of 1-2°, increasing to 7° on approaching the border faults. This surface then subsides stepwise toward the deepest parts of the graben.

The structure within the Dnieper-Pripyat aulacogen is controlled by faulting and salt tectonics. The basement beneath the aulacogen is cut into blocks by faults, which extend up into the sedimentary section where they die out.

Three salt units are present: the first in the Frasnian and the second in the Famennian, both of Late Devonian age, and the third in the Permian. The Devonian salt beds have formed piercement salt structures, some of which have risen to merge with Permian salt near the top of the section.

Pripyat depression. Three structural complexes are recognized within the Pripyat depression. The lower consists of sediments of late Proterozoic, Middle Devonian, Frasnian (including the first salt unit), and early Famennian age and occurs as structural steps or as horsts and grabens. The Frasnian salt here is not involved in salt tectonics. The middle structural complex includes sediments of late Famennian and Carboniferous age. The Famennian (second) salt of this complex forms salt domes, which produce anticlines in the overlying Carboniferous (figure 3). The upper structural complex is composed of Permian and younger sediment and repeats in subdued form the configuration of the middle complex. The Permian salt unit is not present in the Pripyat depression.

Dnieper-Donets depression. Five structural complexes are present here: the sub-salt Riphean-lower Frasnian; middle Frasnian-lower Visean (including first and second salt units), upper Visean-Lower Permian, Upper-Permian-Mesozoic, and Cenozoic. The boundary between the sub-salt and supra-salt parts of the section is drawn by Dikenshtyn (1983) at the base of the first Devonian (Frasnian) salt (figure 4). Others (Uspenskaya, 1966) divide the section into sub-salt, salt, and supra-salt.

In the sub-salt structural complex, elongate steps and blocks are characteristic of the north and south border zones, and large blocks of more equant form in the central part of the graben.

The structure of the supra-salt sedimentary rocks developed from movement along basement blocks and from salt tectonics largely by movement of the first Devonian salt unit. Salt tectonics began in late Frasnian time, and in some places the process has continued to the present (Buyalov and others, 1981). Some of the salt domes even reach the surface of the earth (Uspenskaya, 1966).

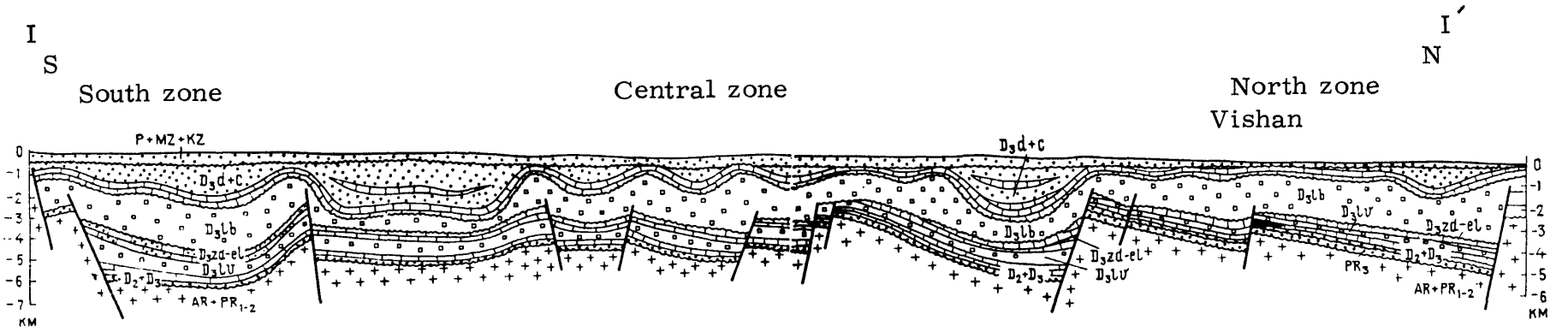

Fig. 3. Profile through Pripyat depression along line I-I′of fig. 2 (from Dikenshteyn and others, 1983)

Sandstone

Limestone

Salt

Basement

Oil pool

KZ - Cenozoic sediments
MZ - Mesozoic sediments
P - Permian sediments
D_3d+C - Upper Devonian Dankovo + Carboniferous sediments
D_3lb - Upper Devonian Lebedyan sediments
D_3zdel - Upper Devonian Zadon-Yeletsa sediments
D_3lv - Upper Devonian Liven sediments
D_2-D_3 - Middle and Upper Devonian sediments
PR_3 - Upper Proterozoic basement
PR_{1-2} - Lower and Middle Proterozoic basement
AR - Archean basement

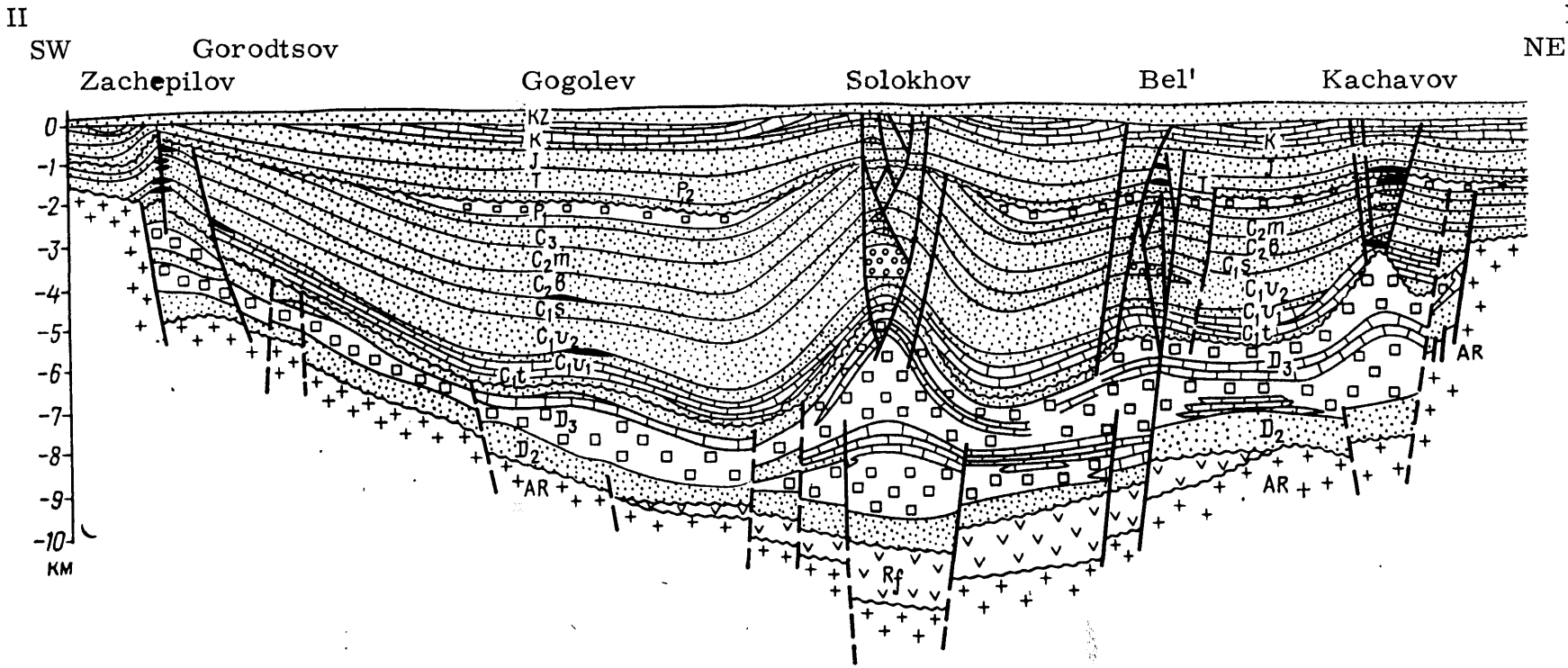

Fig. 4. Profile through Dneiper-Donets depression along line II-II' of fig. 2 (from Dikenshteyn and others, 1983). Symbols same as in fig. 3.

Sandstone

Limestone

Salt

Basement

Oil pool

KZ - Cenozoic
K - Cretaceous
J - Jurassic
T - Triassic
P_2 - Upper Permian
P_1 - Lower Permian
C3 - Upper Carboniferous
C_2m - Moskovian Stage
C_2b - Bashkirian stage
C_1s - Serpukhov horizon
C_1v_2 - Upper Visean horizon
C_1v_1 - Lower Visean horizon
C_1t - Tournaisian
D3 - Upper Devonian
D_2 - Middle Devonian
Rf - Riphean
AR - Archean

The supra-salt section in the Dnieper-Donets graben is subdivided into three main tectonic zones: north, south and central. No adequate map has been found to illustrate this subdivision, however.

The north tectonic zone is 15-20 km wide and has the most complete stratigraphic section of the supra-salt zones. The anticlinal structures are grouped in two lines parallel to the border of the depression. The structures of the outer (north) line are small and appear not to be salt-assisted. Those of the inner (south) line are large anticlines and salt domes associated with local depressions in the basement.

The south tectonic zone is 20-30 km wide and is characterized by thinning or complete absence of the upper Frasnian, Upper Carboniferous, Lower Permian, and Cretaceous sediments (left side of figure 4). Here the surface of the basement steps downward from a depth of 1.4 km to 6 km within a distance of 10 km in some places. Salt domes in this zone penetrate only the supra-salt Devonian sediments.

The central tectonic zone of the Dnieper-Donets depression is characterized by very thick Paleozoic and Mesozoic units. Geophysical surveys indicate that the basement consists of large blocks that are reflected in the structure of the Paleozoic rocks but not the Mesozoic. The anticlines of this zone are large, extending 60-70 km in length and 20 km in width. They are associated with faults that bound the basement blocks. Salt domes form the cores of some of these structures and pierce the flanks of others.

Stratigraphy

Deposition of the sediments now within the aulacogen began in the Middle Devonian and continued into the Quaternary.

Paleogeographic and paleotectonic conditions in the Middle Devonian and very beginning of the Late Devonian were similar to those on the East European platform, suggesting that the graben had not yet begun to form. The active graben formation was marked by an abrupt increase in rate of sedimentation.

Pripyat depression. Eighty percent of the volume of the sedimentary fill is Devonian. The section begins with sandy-clayey sediments of the Pyarnov, Narov, and Luzh horizons of Middle Devonian age (Table 1). Beds of dolomite and anhydrite are also present here (Mel'nik, 1968).

The Upper Devonian begins with sandstones of the Shchigorov horizon at the base of the Frasnian stage. Then upward in the Frasnian are the Petin-Semiluka, Voronezh-Yevlanov, and Liven horizons. The lithology of the Frasnian is quite variable; however, the lower part is largely sandy-clayey rocks, and the upper contains large amounts of sulfate and carbonate rocks. The Liven horizon at the top of the Frasnian is a salt unit up to 1000 m or more thick.

Table 1. Devonian stratigraphic section of Pripyat depression (from Mel'nik, 1968)

System	Stage	Horizon	
Upper Devonian	Famennian	Ozer-Khovan	
		Dankovo-Lebedyan	Supra-salt Salt Sulfate-carbonate
		Zadon-Yeletsa (Domanik)	
	Frasnian	Liven (salt)	
		Voronezh-Yevlanov	
		Petin-Semiluka	
		Shchigorov	
Middle Devonian		Luzh	
		Narov	
		Pyarnov	

Above the Liven salt are clayey carbonates of the so-called Domanik facies. They reach a thickness of 600 m and represent the Zadon-Yeletsa horizon of the lower Famennian stage. The overlying Dankovo-Lebedyan horizon is subdivided into three units: 1) sub-salt, represented by sulfate-carbonate rocks, 2) salt, and 3) supra-salt, composed of dark gray clays that contain beds of marl, limestone, and dolomite. At the top of the Famennian is the Ozer-Khovan horizon, which consists of sandy-clayey rocks.

Total thickness of the Devonian section ranges from 0 to 6 km.

The Carboniferous System of the Pripyat depression consists largely of variegated continental clastic sediments. The most complete section is about 1000 m thick.

The Lower Permian is composed of red-brown clays and marls as well as some sandstone and sulfate rock. Thicknesses range up to 340 m. The Upper Permian is represented by variegated sandstones and conglomerates up to 370 m thick. No Permian salt is present in the Pripyat depression.

The variegated clastic sediments of the Upper Permian continue on up into the Triassic System, which is in turn overlain by Jurassic sediments 165 m thick. The Cretaceous is thin, and the distribution of the Cenozoic deposits is uneven; these are clastic sediments and are a few hundred meters thick at most.

Dnieper-Donets depression. The sedimentary section of this depression consists of Palezoic, Mesozoic, and Cenozoic rocks. Deposition during the Late Devonian, Early Carboniferous (Tournaisian and early Visean), Late Carboniferous, and Early Permian age was confined to the graben, whereas the late Visean, Bashkirian, Moskovian, Late Permian, Mesozoic, and Cenozoic sediments were deposited in basins that extended beyond the graben.

In the northwest part of the depression the Devonian rocks dominate; toward the southeast, however, the Carboniferous begins to prevail and in the southeast part of the depression its thickness attains 10 km.

As in the Pripyat depression the earliest deposition was Middle Devonian and consists of clastics and some carbonates and evaporites.

Late Devonian deposition within the Dnieper-Donets depression was against a background of differential tectonic movement, strongly expressed sea-floor relief, and volcanic activity. Thickness and completeness of the Devonian section and the extent of salt deposition were controlled by the vertical movement of basement blocks, the sediments accumulating in the lows and thinning or pinching out on the highs.

Effusives, tuffs, and volcanogenic sandstones are distributed unevenly in the Upper Devonian. Most of the section, however, is composed of clastic, carbonate, and evaporite deposits. See Table 2.

Table 2. Devonian stratigraphic section of Dnieper-Donets depression (from Mel'nik, 1968)

	Stage		Horizon	
Devonian	Famennian	Supra-salt	Ozer-Khovan	Sand-clay facies
		Salt	Dankovo-Lebedyan	Sulfate-salt
		Inter-salt	Yeletsa	Domanik facies Carbonate-clay-sand
			Zadon	
	Frasnian	Salt	Liven	Carbonate-sulfate-salt
			Yevlanov	
			Voronezh	Carbonate clay-sand
		Sub-salt	Petin-Semiluka	Clay-sand
			Shchigorov	Clay-carbonate

Two salt units are present in the Upper Devonian. The lower salt is Frasnian in age; it is widespread and forms salt domes, the relief of some of which exceeds 10 km. On the northwest its age is Yevlanov-Liven, but to the southeast its lower part is Voronezh in age. The upper salt is Famennian in age and is less extensive than the lower salt. It is not subject to salt tectonics. The upper salt along with the supra-salt Devonian have been removed in places by pre-Carboniferous erosion.

Total thickness of the Devonian section ranges from zero to 6 km.

During Tournaisian and early Visean time of the Early Carboniferous marine carbonates were deposited in the southeast part of the Dnieper-Donets depression. Their thickness is 1600-1800 m. Toward the northwest they thin and pass into clastic rocks and then into variegated continental deposits and pinch out on the Chernigov-Bragin high to appear again in the Pripyat depression.

During late Visean and Serpukhov time of the Early Carboniferous a broad transgression resulted in deposition of marine clasic sediments within and far beyond the boundaries of the depression. Thickness ranges from 4000 m in the southeast to 50-100 m on the northwest.

The marine basin became more restricted in the Middle Carboniferous, and sandstones are prominent in the section. Some sandstone members are more than 100 m thick. In the upper half of the Middle Carboniferous, the Moskovian Stage, continental sediments containing coal beds come into the section. In the southeast part of the section the thickness of the Middle Carboniferous is more than 2000 m, and in the northwest about 400 m.

The regression continued in Late Carboniferous time, and the section consists of clastic sediments that range in thickness from 2000 m in the southeast to 40 m in the extreme northwest.

Further regression in the Early Permian brought the basin of deposition to within the boundaries of the graben, and it took on the characteristics of a lagoon. First, variegated clastic sediments and redbeds were deposited, then salt. The latter is widely distributed in the southeast part of the depression where it is as much as 2000 m thick.

The Upper Permian consists of redbeds, which are 400 m thick in the central part of the graben and 60 m in the northwest part. They rest on an erosion surface that truncates various older units.

Triassic variegated sandy-clayey continental deposits extend over and beyond the Dnieper-Donets depression. In the center of the region their thickness is up to 450 m, but along the borders they thin to a few tens of meters.

All three divisions of the Jurassic are represented. The Lower Jurassic is present only in the eastern part of the depression, where it is composed of sand, clay, and brown coal 30-100 m thick. The Middle and Upper Jurassic

are widely distributed and consist of both marine and continental sandy, clayey, and carbonate rocks. Maximum thickness of the system is 800 m.

In the Early Cretaceous from the Valanginian to the Aptian the region stood above sea level, and no deposition is recorded. In the Aptian marine transgression gray sandy-clayey sediments were deposited. The Upper Cretaceous consists of sandy-clayey rocks of Cenomanian age and marly-chalky rocks of Cenomanian-Turonian age.

Broad warping, erosion, and planation at the end of the Mesozoic resulted in the Paleogene being deposited on a surface that truncates various older units. The Paleogene section consists of sandy-clayey sediments of Paleocene, Eocene, and Oligocene age, the thickness of which ranges from 80-100 m in the border areas to 400 m in the central part.

The Neogene and Quaternary deposits are continental clastic sediments; they are irregular in their distribution and but a few tens of meters thick.

Petroleum Geology

With increasing depth to the basement toward the southeast in the Dnieper-Pripyat aulacogen, the stratigraphic position of the main plays shift upward in the section: Devonian in the Pripyat depression, Lower Carboniferous in the central parts of the Dnieper-Donets depression, and Upper Carboniferous-Lower Permian in the southeast parts (Aksenov and others, 1985). In this same direction there is a change from oil fields to oil-gas-condensate to gas-condensate to gas fields. Areas of predominance of each phase state overlap.

Pripyat depression. Two independent plays are present here, one sealed by the lower (upper Frasnian) salt and the other by the upper (upper Famennian) salt. No oil accumulations nor even shows of bitumen are found above the upper salt (Aksenov, 1985) except for a few small accumulations in Upper Devonian clastics where the oil has migrated upward along faults from carbonates beneath the upper salt (Kononov and Drobyshera, 1983).

The area is subdivided into north, central, and south zones (figure 5). Twenty-eight oil fields and one gas-condensate field have been discovered in the north zone clustered on individual arches (Aksenov and others, 1985). Solov'yev and others (1985) state that 33 fields have now been discovered, 32 of which are in the north zone. Numerous shows and even small pools have been found in the central and south zones, but none are commercial. The names of the individual fields are given in figure 6. The structures shown on figure 5 and 6 are not identical; both are presented here, however, in the interest of recording alternate names that are designated for these structures.

Only four of the seventy known pools of the Pripyat depression are in the lower play. The reservoirs here are clastic sediments.

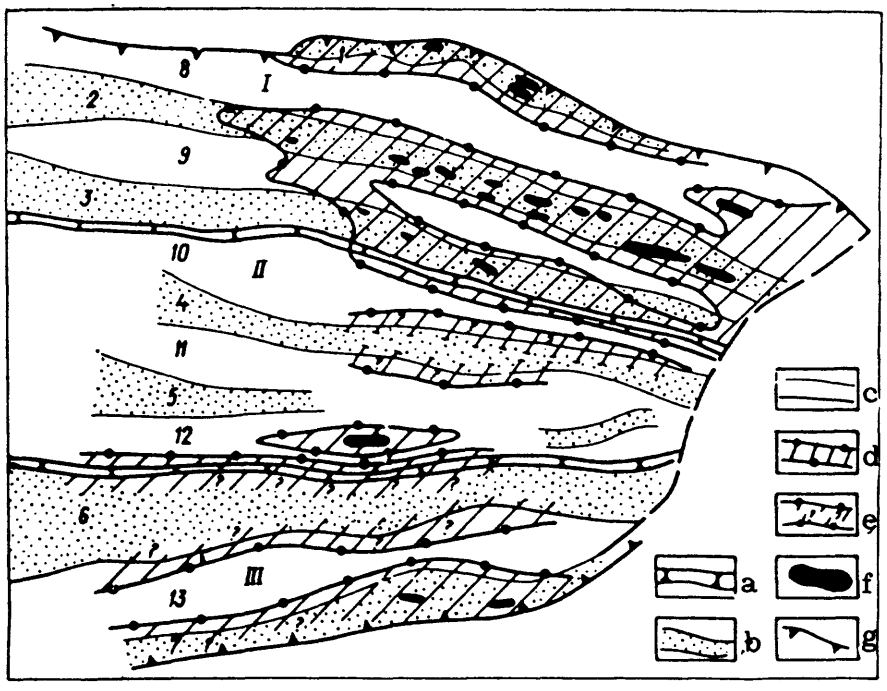

Fig. 5 Map of oil-geology regionalization of the Pripyat oil-gas region (from Kononov and Krishtopa, 1981).
a-Boundaries of the oil-gas regions: I-North, II-Central, III-South; b-arches: 1 - Kovchitsa-Berezin, 2 - Rechitsa-Vishan, 3 - Chervonoslobod-Malodushin, 4 - Gorokhovo-Dudich, 5 - Petrikov-Shestovich, 6 - Buynovich-Narovlyan, 7-Vysupovich; c-depressions: 8-Shatilkov, 9-Vasilevich, 10-Kopatkevich, 11-Kalinkovich, 12-Mozyr, 13-Yel'sk; d-known zones of oil accumulation; e-potential zones of oil accumulation in sub-salt sediments; f-oil fields; g-boundaries of the Pripyat downwarp.

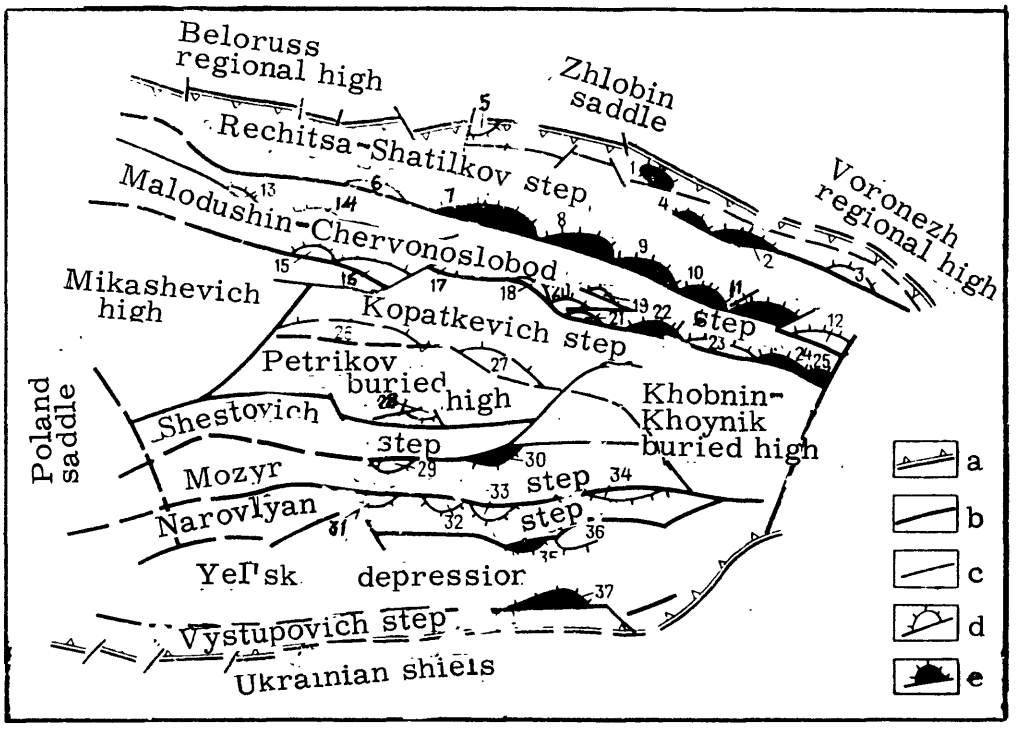

Figure 6. Tectonic map of Pripyat graben showing location of oil fields (from Bakirov, 1979).

a- Border faults of graben; b- faults bounding structural steps; c- other faults; d- positive structures; e- structures and oil fields: 1- Berezin, 2- Vostochno-Pervomay, 3- Aleksandrov, 4- Pervomay, 5- Kovchitsa, 6- Borisov, 7- Vishan, 8- Davydov, 9- Ostashkovich, 10- Tishkov, 11- Rechitsa, 12- Vetkhin, 13- Lyuban, 14- Severo-Kalinov, 15- Kalinov, 16- Chervonoslobod, 17- Oktyabr, 18- Severo-Domanovich, 19- Pritok, 20- Yuzhno-Donanovich, 21- Nikulin, 22- Zolotukhin, 23- Malodushin, 24- Barsukov, 25- Nadvin, 26- Kopatkevich, 27- Gorokhov, 28- Skrygalov, 29- Skoladin, 30- Kamen, 31- Buynovich, 32- Anisimov, 33- Zaozer, 34- Narovlyan, 35- Yel'sk, 36- Vostochno-Yel'sk, 37- Vostochno-Vystuepovich.

In the upper (inter-salt) play the reservoirs are porous fractured dolomitized limestones. The key factor to the oil occurrence here is the presence of thick clayey carbonate "Domanik" facies along with carbonate buildups. The similar Domanik Formation is the main source rock of the Volga-Ural oil-gas province to the northeast.

The oils of the Pripyat depression are low in sulfur and paraffin. They range from heavy (density of 0.87-0.89) to light (0.78-0.79) and are undersaturated by gas. The gas itself contains up to 45 percent heavy (ethane-pentane) components. The gas-oil ratio increases with greater depth. The oils of the two plays differ from one another. That of the lower play has a lower density and less tar, sulfur, and naphthene-aromatic fractions. They differ also in their sulfur isotopes and pollen assemblage.

The occurrence of all the commercial pools in the north zone is the result of several factors. Deposition of the lower salt was in relatively shallow water on a smooth sea floor. No highs were expressed on this surface to form traps beneath the salt. Before deposition of the second salt, however, the basin subsided to form a deep-water uncompensated depression with strong erosional-tectonic relief. Dark clayey-carbonate (Domanik) depression facies were deposited in the deep central part of the basin and shelf carbonates and reefs were deposited on the north (Sinichka and others, 1985; Makhnach and others, 1983). The upper salt was then deposited on this high-relief sea floor. The salt draped over the reefs and smoothed the relief. Consequently, highs of sedimentary origin (reefs) are present in the north zone but not in central and south zones.

The reef buildups of the north zone consist of bioherms with typical dimensions of 4 by 6-10 km and thicknesses up to 260 m. Biostromes here are stratum-like buildups 30-40 m thick (Kotel'nikov, 1983). The reefs are fault-associated.

Vitrinite reflectance shows that maturation of the organic matter increases from south to north (Grechishnikov, 1985). The inter-salt source beds hardly reached the oil window in the south, where maximum paleo-temperatures were not more than 70°C. On the north, however, they were well within the oil window, temperatures reaching 90-145°C.

Generation of oil in the source beds took place earlier in the north zone than to the south. Since the structures had already formed, the oil got into the reservoirs before porosity closed up. In the central and south zones where maturation was later and less, and the structures formed later by tectonic processes, lithification took place before the oil could accumulate in pools (Kononov and Krishtopa, 1981). Besides, the clayey carbonates in the central and south zones are a depression facies, which makes poor reservoirs.

The south zone is, however, still favorable for new discoveries at greater depths (Kononov and Drobysheva, 1983; Solov'yev and others, 1985). Here the non-commercial pools of heavy oil may grade downward into lighter oil with commercial reserves. An exploration guide in the region is the

distribution of potassium salt deposits in the upper salt. These deposits collected in lows within the salt basin and are consequently located between highs, which are exploration targets (figure 7) (Simichka and others, 1985).

Dnieper-Donets depression. Commercial oil and gas are present through a great stratigraphic range from Devonian to Jurassic, inclusively. More than 99 percent of this is below the Lower Permian salt seal, or an Upper Permian clay seal in the northwest part of the depression. Only where these seals are absent or faulted have hydrocarbons migrated upward into Triassic or Jurassic rocks (Aksenov and others, 1985). The fields of the northwest part of the depression are oil and condensate, whereas those on the southeast are largely gas (figure 8).

Four plays are recognized below the Permian seal: Devonian, Lower Carboniferous, Middle Carboniferous, and Upper Carboniferous-Lower Permian.

The Devonian sediments occur in the deepest and structurally most complex parts of the depression. Although some commercial flows have been recovered, the potential of this play is not assessed very high. The basin of deposition was confined to the graben, and volcanics are present at many places instead of clastics. Further, parts of the Devonian section were removed by erosion at the end of the Devonian.

The Lower Carboniferous is an important play in the Dnieper-Donets depression; it is productive throughout a very large area. The pools occur in a variety of traps--closed structures and monoclines, on highs and in depression zones, sealed by closure, faults, or lithologic change (Bilyk, 1986).

Of the 550 pools that have been discovered in the Lower Carboniferous only a few are in carbonate rocks; most occur in sandstones and siltstones. About 40 sand-silt horizons capable of holding hydrocarbons are recognized. Their depth of occurrence ranges from 700 to 5600 m. Pore permeability prevails at depths of 2-3 km; pore and fracture permeability are present at depths of 3-4.5 km; and then fracture permeability becomes dominant at 4.5-5 km.

The share of oil in the pools of the Lower Carboniferous decreases from northwest to southeast; on the whole, however, gas-condensate pools predominate. The condensate content of the gas ranges from 30 to 1140 g/m^3. The free gas is largely methane. The oil is the methane-naphthene type.

The Lower Carboniferous pools are not in contact with the Lower Permian salt seal; rather, they are held in by argillaceous rocks (Galchenko and others, 1985). The reservoir properties of the sandstone-siltstone reservoirs are not very good; consequently, the high productivity of these beds is due to good source-rock quality (Aksenov and others, 1985).

The source beds of the Lower Carboniferous play in the southeast part of the depression are upper Visean and Serpukhov sediments, which contain 0.5 to 5 percent humic organic matter. In the northwest part of the depression these sediments contain sapropelic organic matter (Solov'yev, 1986).

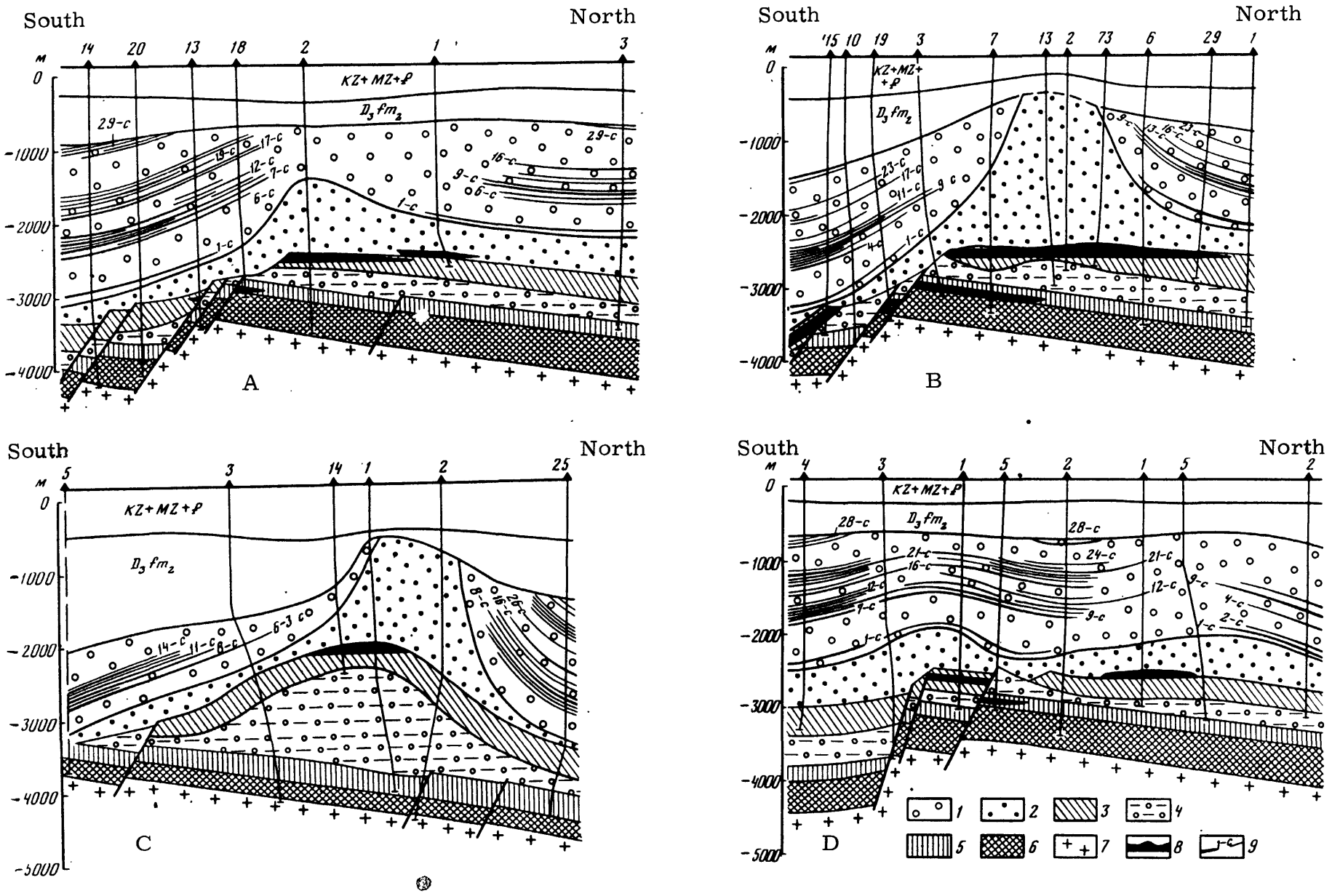

Figure 7. Geologic sections through the Davydov (A), Ostashkovich (B), Zolot·khin (C), and Marmovich and Poles (D) oil fields of the Pripyat depression (from Sinichka and others, 1985)
Fields A, B, and C are located on figure 6.

1-Potassium salts; 2-halite; 3-inter-salt unit; 4-upper Frasnian salt; 5-carbonate sediments; 6-clastic sediments; 7-crystalline basement; 8-oil pools; 9- potassium-salt horizons.
Note tendency for potassium salt horizons (1-c through 29-c) to pinch out on flanks of highs.

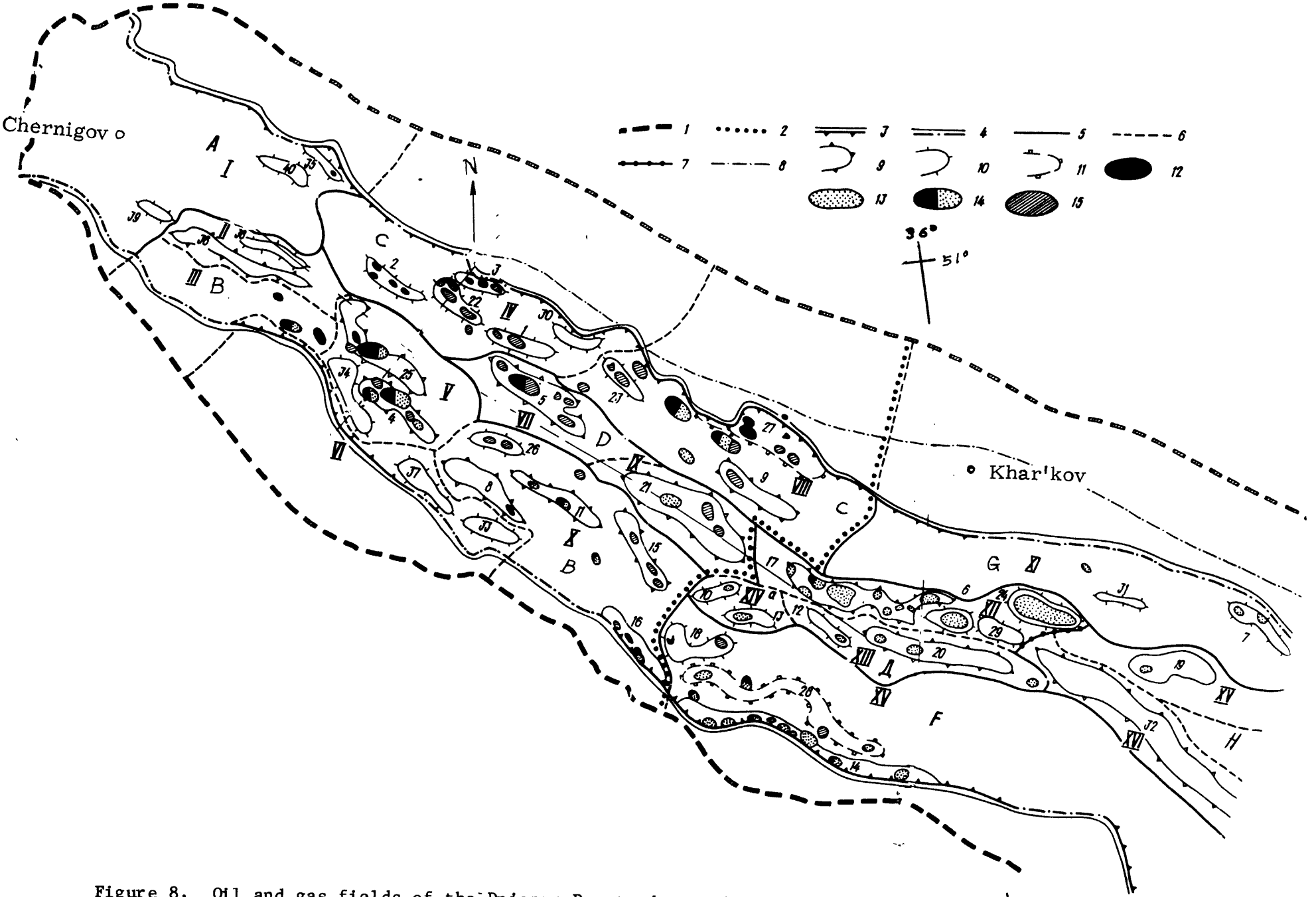

Figure 8. Oil and gas fields of the Dnieper-Donets depression (from Kabyshev, 1982).

Figure 8.

1- Boundaries of the basin; 2- boundary between the west and east sub-basins; 3- boundaries of the Dnieper-Donets graben; 4- same, but less well known; 5- boundaries of oil-gas areas; 6- boundaries of oil-gas sectors,* which do not correspond with boundaries of oil-gas areas (sectors are designated by Roman numeral); 7- boundaries of sectors that developed only in the inversion stage (Late Permian time); 8- boundaries of favorable areas on the north border; 9- zones of oil-gas accumulation of the anticlinal type with traps of double**structural control; 10- same, with one and a half structural control; 11- same, of the non-anticlinal type. Fields: 12- oil, 13- gas, 14- oil-gas and gas-oil, 15- gas-condensate. Oil-gas areas: A- Chernigov-Bereznyan, B- Nezhin-Mirgorod, C- Talalayev-Akhtyr, D- Glin-Solokhov, E- Mashev-Shebelinka, F- Sukhodolov, G- Ryabukhino-Severo-Golubov, H-Kal'mius-Bakhmut. Oil gas zones (established): 1- Anastas'yev-Lipovodolin, 2- Sofiyev-Yaroshev, 3- Velikobubnov, 4- Gnedintsev-Chernukhin, 5- Glin-Rozbyshev, 6- Yefremov, 7- Zaytsev-Ol'gov, 8- Isachkov-Ramodanov, 9- Kotelev-Berezov, 10- Kopylov-Vostochno-Poltava, 11- Malosorochnin-Ryadchenkov, 12- Mar'yanov-Lannov, 13- Mashev-Yelizavetov, 14- Mikhaylov-Leventsov, 15- Petrenkov-Abazor, 16- Potichan-Zachepslov, 17- Raspashnov-Melikhov, 18- Reshetnyakov-Sukhodolov, 19- Spivakov-Krasnooskol, 20- Sosnov-Belyayev, 21- Solokhov-Dikan, 22- Talalayev-Artyukhov, 23- Timofeyev-Martynov, 24- Shebelinka, 25- Shurov-Lelyakov, 26- Yablunov-Yarov, 27- Akhtyr, 28- Rudenkov-Bogatoy; (probable): 29- Alekseyev, 30- Afanas'yev-Kolyatsintsev, 31- Balakley-Savintsev, 32- Volvenkov-Druzhkov, 33- Vergunov-Petrivtsev, 34 - Zhuravkov-Antonov, 35- Yadutovo-Kinashev, 36- Krasnopartizan-Schnyan, 37- Kolaypintsev-Tarnavshchin, 38- Nezhin-Severo-Dorogin, 39- Olishev-Khreshchatin, 40- Kholm.

*Areas within which, but not beyond which, migration takes place.
**A small high on a larger high.

The Middle Carboniferous is host to oil and gas pools in more than 40 areas. The fields and pools are small and are largely gas; they are almost entirely in clastic reservoirs. The Bashkirian and Moskovian sections contain 18 sandstone-siltstone reservoir beds. These are not widespread, however, and pinch out by facies change.

Methane predominates in the Middle Carboniferous gas, and its condensate content ranges from 40 to 800 g/m^3. The oil is the methane-naphthene type and has a density of 0.74-0.93.

The Middle Carboniferous is productive only on those structures where the Lower Carboniferous is also productive and where the structure is faulted. Where no faults are present, good Middle Carboniferous reservoirs are not productive even though the Lower Carboniferous is. The oil and gas of the Middle Carboniferous seem apparently to have migrated vertically from the Lower Carboniferous source beds.

The Upper Carboniferous-Lower Permian play is oil-prone in the northwest half of the Dnieper-Donets depression and gas-condensate-prone in the southeast. Most of the pools occur in sandstone and siltstone. The oil is the methane-naphthene type, and its density is 0.80-0.87. The condensate content of the free gas is up to 60 g/m^3.

The pools of the Upper Carboniferous-Lower Permian play are secondary. The sediments of the play are continental redbeds and have a low source-bed potential. The amount of productive area is small in comparison with that of the Middle Carboniferous, and particularly, the Lower Carboniferous. Yet more than 50 percent of the proved hydrocarbon reserves of the depression are in this play. The oil and gas migrated upward along faults created by salt tectonics and were trapped beneath Permian salt in the central and southeast parts of the depression and beneath Permian clays in the northwest (figure 9).

Oil may once have occupied the traps in the gas-prone southeast part of the depression. This oil may have been destroyed by catagenesis in the gas window; it may have become dissolved in the gas; or it may have been expelled from the traps by gas that was generated when deeper sediments entered the thermal gas window.

Exploration in the Dnieper-Donets depression continues to be successful. Thirty-nine new fields were discovered during the period 1979-85, and the lower limit of oil and gas occurrence has not yet been reached (Kurilyuk and others, 1986). Gravity surveys and satellite photography have been combined to disclose new salt-dome targets (Gavrish and others, 1986). The monoclinal flanks of large structures are also now being explored (Ploshko and Mrozek, 1985). Twenty of the fields of the depression are at depths greater than 4,500 m, a fact which is encouraging for deep exploration (Dem'yanchuk, 1983).

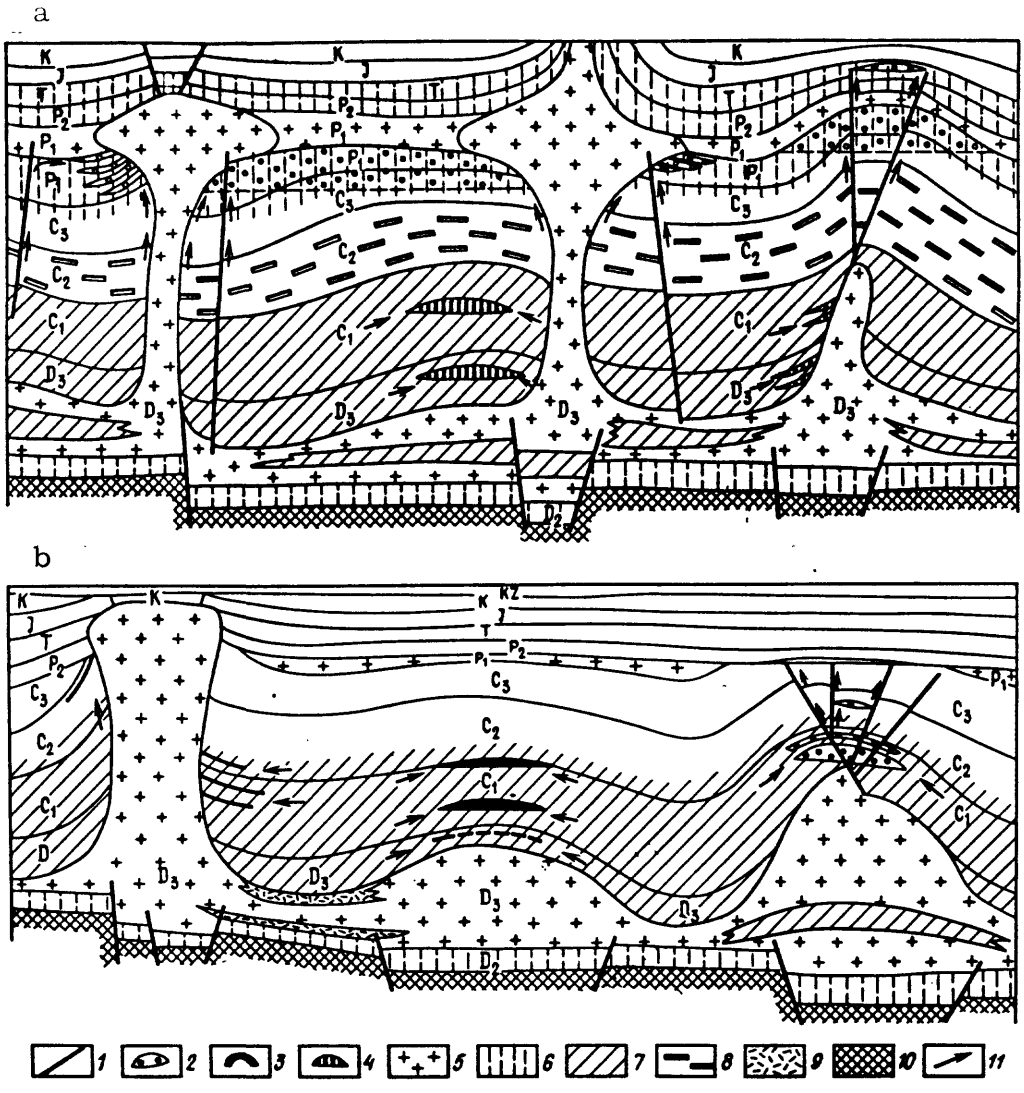

Figure 9. Theoretical model of formation of hydrocarbon pools in the Dnieper-Donets depression (from Solov'yev, 1986)

a-Southeast part of basin, b-northwest and central parts of basin; 1-faults; 2-gas pools; 3-oil pools; 4-probable gas pools; 5-salt; 6-redbeds; 7-oil-source rocks; 8-coal-bearing rocks; 9-effusive rocks; 10-crystalline basement; 11-direction of migration of hydrocarbons.

K - Cretaceous
J - Jurassic
P_2 - Upper Permian
P_1 - Lower Permian
C_3 - Upper Carboniferous
C_2 - Middle Carboniferous
C_1 - Lower Carboniferous
D_3 - Upper Devonian
D_2 - Middle Devonian
D - Devonian

Assessment

My assessment of the undiscovered oil in the Dnieper-Pripyat oil-gas province is 400 million barrels as the most likely, 50 million at the 95 percent confidence level, and 1 billion at the 5 percent level. Undiscovered gas of the inferred category (C_2, undiscovered but in known fields) as of 1980 is placed at 9 tcf by Zhabrev and others, 1983. I estimate that additional undiscovered gas is 6 tcf as the most likely, 2 tcf at the 95 percent confidence level and 15 tcf at the 5 percent level.

Selected References

Aksenov, A.A. and others, 1985, Dnieper-Donets depression [in Russian], in Neftegazonosnost' podsolevykh otlozheniy: Moscow, Nedra, 205 p. (summary in Petroleum Geology, v. 22, no. 6).

Bakirov, A.A., 1979, Oil-gas provinces and regions of the USSR [in Russian]: Moscow, Nedra, 456 p.

Bilyk, O.D., 1986, Localization of lithologically sealed hydrocarbon pools of the Serpukhov complex of the Dnieper-Donets depression [in Russian]: Neftyanaya i gazovaya promyshlennost', no. 1, p. 6-8.

Buyalov, N.I., Bakarchuk, G.I. and Savchenko, V.I., 1981, Tectonics of the Devonian sediments and history of its development in the zone of junction of the Pripyat and Dnieper-Donets depressions [in Russian]: Neftegazovaya Geologiya i Geofizika, no. 7, p. 9-13 (summary in Petroleum Geology, v. 19, no. 1).

Danilevskaya, D.M., 1985, Pripyat and Dnieper-Donets depressions [in Russian], in Stroyeniye neftegazonosnykh oblastey SSSR, Klubov, V.A., ed.: Moscow, Nauka, p. 33-35.

Dem'yanchuk, O.V., 1983, Question of oil-gas prospects of Lower Carboniferous of axial zone of Dnieper-Donets depression [in Russian]: Geologicheskiy Zhurnal, no. 5, p. 34-38, (summary in Petroleum Geology, v. 22, no. 1).

Dikenshteyn, G.Kh., ed., 1983, Oil-gas provinces of the USSR [in Russian]: Moscow, Nedra, 272 p.

Galchenko, V.A., Krivosheyeva, M.G., Nestor, R.M., Ral'chenko, N.O. and Silich, G.A., 1982, Reservoirs of the lower Visean-Tournaisian oil-gas complex of the northwest part of the Dnieper-Donets depression [in Russian]: Neftyanaya i Gazovaya Promyshlennost, no. 3, p. 2-5 (in English in Petroleum Geology, v. 21, no. 3, p. 134-136).

Gavrish, V.K., Nedoshovenko, A.I., Demidova, J.A., and Kalamkarov, L.V., 1984, New data on the geology of the Dnieper-Donets depression and prediction of oil-gas traps [in Russian]: Geologiya Nefti i Gazi, No.1, p.15-22.

Grechishnikov, N.P., 1985, Causes of selective distribution of oil pools of the Pripyat depression from vitrine thermometry [in Russian]: Geologiya Nefti i Gaza, no. 2, p. 11-14.

Kabyshev, V.P., 1982, Large-scale oil-geology regionalization on a genetic basis [in Russian] in Perspektivy rasshireniya resursov nefti i gaza v Ukrainskoy SSR: Kiev, Naukova Dumka, p. 126-133 (English summary in Petroleum Geology, v. 22, no. 11).

Kononov, A.I. and Drobysheva, V.G., 1983, Principle of differential entrapment of hydrocarbons in oil-gas regions with carbonate rocks in the example of the Pripyat downwarp [in Russian], in Osnovnyye printsipy formirovaniya zalezhey nefti i gaza: Moscow, Nauka, p. 212-218 (English summary in Petroleum Geology, v. 21, no. 4, p. 187-189).

Kononov, A.I. and Krishtopa, N.A., 1981, Genetic relation of conditions of formation of sub-salt oil pools of the Pripyat downwarp to their geologic history [in Russian]: Trudy VNIGNI, no. 231, p. 69-75 (English summary in Petroleum Geology, v. 21, no. 7, p. 299-300).

Kotel'nikov, I.Ye. and others, 1983, Geologic criteria for predicting buried organic buildups in the Pripyat depression [in Russian], in Metody poiskov i razvedki pogrebennykh rifov: Moscow, Nauka, p. 71-74 (English summary in Petroleum Geology, v. 21, no. 10, p. 457-459).

Kurilyuk, L.V., Myasnikov, V.I., Kabyshev, B.P., and Roslyy, I.S., 1986, Main results of exploration in the Dnieper-Donets depression for 1979-85 [in Russian]: Geolgiya Nefti i Gaza, no. 1, p. 11-15.

Makhnach, A.S., Kruchek, S.A., Ur'yev, I.I., and Levkova, T.I., 1983, Paleogeographic criteria for predicting distribution of organic buildups in lower Famennian inter-salt sediments of the Pripyat depression [in Russian], in Metody poiskov i razvedki pogrebennykh rifov: Moscow, Nauka, p. 54-58 (English summary in Petroleum Geology, v. 21, no. 10, p. 451-453.

Mel'nik, A.F., ed., 1968, Regularities in the distribution of oil and gas fields of the Dnieper-Donets oil-gas province [in Russian]: Kiev, Naukova Dumka, 214 p.

Ploshko, Vad.V and Mrozek, L.G., 1985, Prospects for exploration for hydrocarbon pools of lithologic type on monoclines of the Dnieper-Donets depression [in Russian]: Geologicheskiy Zhurnal, no. 3, p. 10-16 (summary in Petroleum Geology, v. 23, no. 1).

Simichka, A.M., Vysotskiy, E.A., and Kislik, V.Z., 1985, Use of potassium-salt horizons to predict hydrocarbon deposits [in Russian] in Litologo-fatsial'nyye i geokhimicheskiye problemy solenakopleniya: Moscow, Nauka, p. 111-119 (summary in Petroleum Geology, v. 22, no. 7).

Solov'yev, B.A., 1986, Conditions of formation of gas fields of Dnieper-Donets basin [in Russian]: Geologiya Nefti i Gaza, no. 2, p. 32-35.

Solov'yev, B.A., Keller, M.B., and Snegireva, O.V., 1985, Prospects for exploration in the Pripyat downwarp [in Russian]: Geologiya Nefti i Gaza, no. 6, p. 7-11.

Uspenskaya, N.Yu. and Tabasaranskiy, Z.A., 1966, Oil-gas provinces of the USSR [in Russian]: Moscow, Nedra, 495 p.

Zhabrev, I.P., ed., 1983, Gas and gas-condensate fields - a reference book [in Russian]: Moscow, Nedra, 375 p.