Chapter R1

REGION 1 FORMER SOVIET UNION—SUMMARY

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INTRODUCTION

Region 1 for the U.S. Geological Survey World Petroleum Assessment 2000 covers 15 independent countries formed after breakup of the Soviet Union (Region 1 map). Region boundaries were adjusted to reflect geologic continuity of specific areas. Consequently, areas in northern Afghanistan (Amu-Darya basin) and northern Iran (South Caspian basin) were assessed in Region 1, whereas the Carpathian foldbelt and foreland of western Ukraine were assessed with the rest of the Carpathians in Region 4 – Europe.

Eighteen geologic provinces of the former Soviet Union (FSU) were evaluated for their undiscovered petroleum resource potential. Twenty total petroleum systems (TPS) were identified and subdivided into 46 assessment units (AU) (master code list). Of these provinces, 13 were considered priority provinces on the basis of known recoverable volumes of oil and gas; and 5 are boutique provinces with small or no reserves, but with significant undiscovered potential. Based on Petroconsultants database (1996), the petroleum provinces of the FSU contain 18.9 percent of known oil reserves and 37.5 percent of known natural gas reserves of all world provinces assessed in this study.

GEOTECTONIC SETTING

Region 1, or the former Soviet Union (FSU), occupies a vast area of eastern Europe and northern Asia and includes a large variety of major tectonic structures. The geotectonic backbone of the FSU is formed by two Precambrian cratons, the Russian (East European) craton west of the Ural Mountains and the Siberian craton east of the Urals, between the Yenisey and Lena Rivers. The craton basements are of Archean-Early Proterozoic age; however, the Russian craton also includes the Grenvillian to Baikalian (Late Proterozoic) Pechora-Barents plate that was accreted in latest Proterozoic time (Bogdanov and Khain, 1996). Both cratons were rifted in Riphean (Middle-Late Proterozoic) time and the rift grabens were filled by thick synrift sedimentary sequences. The overlying platform sedimentary cover is mainly composed of Paleozoic strata. Younger rocks are thick only in rifted basins where preserved oceanic crust underlies the sedimentary succession.

A mosaic of structures accreted through Paleozoic-early Mesozoic time adjoins the old cratons. Of special interest to petroleum geology is a wide belt of structural terranes that were accreted and deformed in late Paleozoic (Hercynian) time, rifted in the Late Permian-Triassic, and then truncated by the beginning of Jurassic time (Zonenshain and others, 1990). This structural belt borders the Russian craton along the southern edge, extends eastward across the central Caspian Sea into deserts north of the Kopet-Dag Range, and also occupies vast plains of West Siberia. Thick platform Jurassic-Eocene rocks were deposited in sedimentary basins that formed in this belt above the Hercynian basement and Triassic rifts.

The Alpine orogeny occurred south of the post-Hercynian platforms in Late Tertiary time. Thick Miocene-Quaternary orogenic clastics were deposited in foredeeps of the Great Caucasus and Kopet-Dag foldbelts above the Jurassic-Eocene platform sequences, thus forming a series of foreland basins (such as the Azov-Kuban and Middle Caspian basins) (Region 1 map). In some areas, the platform edges were involved in thrusting and uplift. Rifting inside the Alpine orogen opened the oceanic crust in the South Caspian and Black Seas and formed very deep basins with sediment thicknesses of 15-25 km.

East and southeast of the Siberian craton are a vast Mesozoic accreted terrane and the Pacific active margin. The Mesozoic accreted terrane is expressed as a number of foldbelts, which are composed of Paleozoic and Mesozoic rocks, and a few intervening basins with limited petroleum potential (for example, the Zyryanka basin, province 1251 (Region 1 map). Most of sedimentary basins of the active margin are offshore in the Japan, Okhotsk, and Bering Seas and are poorly understood. Only locally, do parts of these basins extend onshore as, for example, in the North Sakhalin basin (Province 1322). Basins of the active margin are mainly filled with Cenozoic sediments that were deformed with various intensity in Late Tertiary through Quaternary time.

DEVELOPMENT OF PETROLEUM SYSTEMS

The assessed TPS of Region 1 may be divided into three groups on the basis of the main features of their development. Development of the petroleum system in this context includes source rock deposition, burial and maturation, accumulation of hydrocarbons, and preservation of oil and gas fields. Geologic description of the studied TPS and the analysis of their undiscovered potential are contained in a series of reports available on the World Energy Program site at <http://greenwood.cr.usgs.gov/>.

The first TPS group developed on old cratons. Most of the TPS are rich in hydrocarbons although they are primarily Paleozoic in age. Two of the TPS (120701 and 121001) are situated on margins of the Siberian craton adjacent to the Yenisey and Baikal-Patom foldbelts, respectively. On the Russian craton, six TPS were identified. They are located in the Timan-Pechora basin (100801), in the Volga-Ural province (101501 and 101502), in the Dnieper-Donets basin (100901), in the North Caspian basin (101601), and in basins of the eastern Barents Sea shelf (105001). Principal source rocks of these systems are of Late Devonian to Carboniferous age on the Russian craton and of Late Proterozoic age on the Siberian craton. Maturation of source rocks was achieved early, in Late Permian-Triassic time (during deposition of thick Hercynian orogenic clastics), on the Russian craton and in pre-Devonian time on the Siberian craton. Reservoir rocks are siliciclastics and carbonates, the latter commonly of reef origin, of late Paleozoic and Late Proterozoic-earliest Cambrian age on the two cratons, respectively. Preservation of hydrocarbons in some TPS was facilitated by regional salt seals (for example, Lower Permian salt of the North Caspian basin and Lower Cambrian salt in provinces of the Siberian craton). Total petroleum systems in which salt seals are absent contain substantial amounts of partially or fully biodegraded oils and are poor in gas. The oldest TPS on the Siberian craton

(120701 and 121001) are unusual in that the source kitchen areas were partially or fully destroyed by post-depositional tectonism in early Paleozoic time. However, source rocks had reached maturity and hydrocarbons had been expelled and had migrated into platform traps before destruction. Exceptionally long preservation of hydrocarbons was facilitated by the undeformed salt seal.

The second group of TPS is mainly Mesozoic in age and formed on post-Hercynian platforms. Two stacked TPS, the Togur-Tyumen system (117402) and the Bazhenov-Neocomian system (117401), are located in the southern West Siberian basin. One TPS occupies the northern part of West Siberia and adjacent South Kara shelf (117403). Two assessed TPS, South Mangyshlak (110902) and Stavropol-Prikumsk(110903), are in the eastern and northern parts of the Middle Caspian basin, respectively. The Amu-Darya basin contains a single large TPS (115401). Finally, three TPS identified in the North Ustyurt basin (115001, 115002, and 115003) are included in this group, although with some uncertainty. The principal source rocks of most of these TPS are Middle Jurassic continental to paralic shales and Upper Jurassic marine anoxic shales. In some petroleum systems, source rocks are also present in Triassic synrift sequences; they are the principal source of hydrocarbons in the South Mangyshlak TPS (110902). The main stage of maturation for this Mesozoic group of petroleum systems occurred in the Early Tertiary. Principal reservoir rocks are Jurassic and Cretaceous siliciclastics, but carbonates are also productive, especially from reef facies. Upper Cretaceous and Tertiary shales are extensive and thick and form sufficiently good seals for preservation of hydrocarbons. Salt seals play a subordinate role.

Two TPS of the West Siberian basin are exceptionally rich in hydrocarbons and contain the largest share of undiscovered resources in Region 1. The Bazhenov-Neocomian TPS (117401) is a classic example of a deltaic progradational system that deposited a number of shelf-to-basin clinoforms over pre-deltaic deep-water oil-source facies. Shelf, slope, and basinal turbidite facies of the clinoforms contain reservoir sandstones that are productive in both structural and stratigraphic traps. The northern West Siberian Mesozoic TPS (117403) contains nearly one-quarter of the original gas reserves of the world in a relatively small area. This TPS challenges our understanding of gas generation, migration, and accumulation. Source rocks for the gas are poorly identified. Traps, reservoir rocks, and seals are present, but the reasons for such exceptional richness of this TPS are not clear.

The third group of TPS is primarily of Tertiary age and developed in Alpine foldbelts and associated foredeeps. Four TPS of this group were identified. The Azov-Kuban Mesozoic-Cenozoic (110801) and Terek-Caspian (110901) TPS lie within foredeeps and adjacent foreland slopes of the Great Caucasus foldbelt. The Oligocene-Miocene Maykop/Diatom TPS (111201) encompasses the entire South Caspian basin. The North Sakhalin Neogene TPS (132201) occupies the paleo-Amur river delta on the Pacific active margin. Most effective source rocks of these systems are Oligocene-Miocene marine anoxic shales, although source rocks are also present in pre-orogenic Mesozoic platform sequences. Maturation of source rocks is recent, mostly Pliocene-Quaternary, and is related to the deposition of thick orogenic clastics. The main reservoir rocks are pre-orogenic Cretaceous carbonates and Miocene-Pliocene siliciclastics. Locally, oils are degassed and biodegraded, but the late formation of oil and gas fields has allowed for generally good preservation of hydrocarbons.

The Oligocene-Miocene Maykop/Diatom TPS of the South Caspian basin is by far the richest TPS in this group. The TPS possesses several unique features that make it unusual. Extremely high sedimentation rate during Pliocene-Quaternary time averaging nearly 2 km/million years (“avalanche sedimentation” of Russian geologists) resulted in a very low geothermal gradient. The top of oil window occurs at a depth of about 8 km and its bottom may be as deep as 12 km. The second consequence of rapid sedimentation is undercompaction of thick Maykop shales, which contain the principal source rocks, and resulting high overpressure. The overpressure brought about widespread shale tectonics and intensive mud volcanism. More than 50 percent of world mud volcanoes, many of them explosive, are concentrated in the South Caspian basin. The majority of productive structures contain one or more mud volcanoes. The volcanoes discharge huge amounts of gas into the atmosphere. Their role in formation of oil and gas fields is not understood.

ASSESSMENT RESULTS

Assessment results by assessment units, total petroleum systems, provinces, and countries are presented in tables for each AU, TPS, province, and country, respectively. Original assessments were made for AU; numbers for TPS, provinces, and countries are results of either summation or allocation. The assessment results show that among the Regions of the world, Region 1 ranks 2nd, 1st, and 2nd in undiscovered mean estimates for oil, natural gas, and NGL, respectively.

SIGNIFICANCE OF RESULTS

In the following discussion, the current USGS world petroleum assessment estimates of undiscovered oil and gas resources at the basin or province levels are compared with analogous estimates reported by Masters and others (1997). However, the publication of Masters and others contains estimates of the FSU basins that were made in 1991-1993 (Ulmishek and Masters, 1993) and thus, they are almost a decade old. Exploration results during this decade explain some of the differences observed between the assessments.

Among the provinces on the old cratons, the large TPS of the North Caspian basin (101601) was assessed to contain the greatest amount of undiscovered oil resources. However, compared with the previous USGS assessment (Masters and others, 1997), the amount of undiscovered oil resources of the North Caspian basin decreased almost two-fold, from 45.4 to 23.3 BBO. The amount of undiscovered gas in this TPS decreased even more significantly from 261.2 to 74.5 TCF. This decrease reflects a continuous lack of success in discovering giant and large fields in the basin during about the last 15 years. Drilling activity in the basin in recent years was limited, but several significant prospects were drilled and appeared to be failures. However, a large degree of uncertainty in resource estimate as related to both the volumes of hydrocarbons and the type of hydrocarbons (oil versus gas) in subsalt prospects exists in this basin, where many untested prospects occur deeper than 5 km and commonly as deep as 6.5-7 km.

The Triassic TPS of basins on the eastern Barents shelf has long been recognized as strongly gas prone (Ulmishek, 1985). Two main factors can explain a large decrease in undiscovered gas resources as compared to the previous USGS assessment (264.2 TCF versus 717 TCF). First, the assessment by Masters and others (1997) included the entire eastern Barents and northern Kara shelves, whereas the current USGS assessment includes only the North and South Barents basins and intervening Ludlov saddle. Second, recent data indicate deterioration of reservoir quality of the principal Middle Jurassic reservoir formation toward the undrilled North Barents basin. Deeper Triassic rocks are orogenic in origin and their reservoir potential is much lower.

Among other assessed provinces of the Russian craton, the Timan-Pechora basin is sparsely drilled in its northern areas where significant potential lies for undiscovered resources of both oil and gas. The Volga-Ural province and Dnieper-Donets basin are in a mature stage of exploration and their undiscovered resources are relatively small. Oil and gas resource numbers for all three provinces changed insignificantly compared to the previous USGS assessment.

The current USGS assessment found that undiscovered volumes of both oil and gas in two TPS on the Siberian craton (120701 and 121001) are substantially lower compared with the previous assessment by Masters and others (1997) (2.8 BBO versus 11.3 BBO and 48.9 TCF versus 175 TCF). The previous assessment covered the entire Lena-Tunguska province that extends almost to the Arctic Ocean, whereas the two petroleum systems identified and assessed in the present study cover a much smaller area. However, the main reason for the difference in the assessments is an assumption that much of undiscovered resources of Masters and others (1997) will be accounted for by reserve growth in two discovered giant fields, the Yurubchen-Takhoma oil and Kovykta gas fields. Field growth in the current USGS assessment is considered separately and only on the world level.

The results of the current USGS assessment indicate that the largest amount of undiscovered hydrocarbon resources, both oil and gas, is concentrated in the richest petroleum province, the West Siberian basin, despite the significant exploration maturity of this province. At the mean level, combined resources of three TPS in the basin constitute 47.6 percent of oil and 38.7 percent of gas resources of all petroleum provinces assessed in the FSU. For oil plus NGL and both free and associated gas these numbers are 44.3 percent and 38.9 percent, respectively. The largest portion of undiscovered oil (77.7 percent) occurs in the principal reservoirs of the Bazhenov-Neocomian TPS (117401). Only 13.6 percent of undiscovered oil is expected in much less explored pre-Upper Jurassic rocks of the Togur-Tyumen TPS (117402) mainly because of the commonly poor quality of reservoir rocks. Undiscovered gas resources are almost entirely placed in the northern TPS of the West Siberian basin (117403), especially offshore in the South Kara Sea. Compared with the previous USGS resource assessment (Masters and others, 1997), the amount of oil resources of the West Siberian basin determined from the current USGS assessment is similar. The volumes of undiscovered nonassociated gas decreased substantially from 1089.8 TCF to 517.4 TCF in the present assessment. This decrease mainly results from new data that indicate facies change of the Turonian shale seal to sandstones eastward from the Yamal Peninsula. Thus, this principal regional seal that caps all huge dry gas fields in Albian-Cenomanian reservoirs becomes ineffective in a large area of the Gydan Peninsula and eastern part of the South Kara shelf where large resources were estimated in the earlier assessment by Masters and others (1997).

The other assessed Mesozoic-Cenozoic basins on the Hercynian accreted terrane and in the Alpine foredeeps, except for the Amu-Darya basin, contain a relatively small portion of undiscovered oil and gas resources of the FSU (5.4 percent of oil and 3.8 percent of gas). The change compared to the previous USGS assessment is statistically insignificant. The Amu-Darya basin contains large gas reserves and was a major gas producing basin in the FSU, second only to West Siberia. Undiscovered gas resources in this assessment increased by 62 TCF compared to that reported by Masters and others (1997), from 100 to 162.1 TCF at mean level. This increase is related to recent recognition that the zone of highly productive Upper Jurassic reefs along the northeastern basin margin turns westward and extends along the southern margin at depths of 5 km and more.

Unlike in the previous assessment (Masters and others, 1997), which covered only shelf areas, the present assessment included the deep-water central part of the South Caspian Sea (AU 11120104). This resulted in a significant increase of resource numbers in the South Caspian basin, from 7.9 to 15.7 BBO for oil and from 39.3 to 120.4 TCF for gas. However, a large uncertainty exists in the assessment of the undrilled deep-water part of the basin. This uncertainty largely stems from a risk related to the main prospective lower-middle Pliocene turbidite reservoir rocks. The presence of these rocks that were deposited in the deep-water lake basin is interpreted from paleogeographic reconstructions, but the extension of the rocks and their reservoir quality in the absence of drilling data remain undetermined. Further complicating the assessment is the strong possibility that gas will constitute a large part of hydrocarbon resources in this central basinal area.

The amounts of undiscovered oil resources of the North Sakhalin basin in both assessments are similar, but the gas resources in the current USGS assessment are twice as large (44.5 versus 21 TCF). Much additional information on the northeastern shelf of Sakhalin is now available, and this information indicates a number of prospects farther offshore, where potential was deemed low in the previous assessment. The main uncertainty in the resource estimate is from insufficient data on the offshore extension of deltaic and turbidite sandstone facies and their transition into prodeltaic shales. Gas rich in condensate will probably dominate in the undiscovered resources in the southern and central areas of the shelf.

Combined, the assessed petroleum provinces of the FSU contain a significant portion of the world's undiscovered resources of both oil and gas. As compared to all world provinces covered in the current USGS assessment, provinces of Region 1 contain 26.8 percent of total undiscovered petroleum (oil, free and associated gas, and NGL) calculated in BOE at the mean level. This region holds 17.9 percent of oil resources, 34.4 percent of total (free and associated) gas resources, and 26.5 percent of NGL resources of the world. Compared to the previous USGS assessment (Masters and others, 1997), the estimated amount of undiscovered oil decreased somewhat from 140.8 BBO to 116 BBO in the present study mainly because of lower estimates for the North Caspian basin and provinces on the Siberian craton. Estimated undiscovered gas resources of this study are dramatically lower than in the previous assessment, 1338.5 TCF versus 2484.4 TCF for the same provinces in the previous assessment. A major portion of this decrease is in the northern West Siberian basin (including South Kara Sea) and on the Barents shelf. Much lower estimates of undiscovered free gas in the FSU strongly influenced the lower natural gas estimate for the entire world. However, according to the current USGS assessment, the FSU still holds the largest natural gas resources in the world.

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