Petroleum Geology and Resources of the North Ustyurt Basin, Kazakhstan and Uzbekistan

By Gregory F. Ulmishek

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Foreword

This report was prepared as part of the World Energy Project of the U.S. Geological Survey. In the project, the world was divided into 8 regions and 937 geologic provinces. The provinces were ranked according to their volumes of discovered oil and gas (U.S. Geological Survey World Energy Assessment Team, 2000). Then, 76 "priority" provinces (exclusive of the U.S. and chosen for their high rank) and 26 "boutique" provinces (exclusive of the U.S. and chosen for their anticipated petroleum richness or special regional economic importance) were selected for appraisal of oil and gas resources. The petroleum geology of these priority and boutique provinces is described in this series of reports.

The purpose of the World Energy Assessment Project is to aid in assessing the quantities of oil, gas, and natural gas liquids that have the potential to be added to reserves during the next 30 years. These volumes either reside in undiscovered fields whose sizes exceed the stated minimum-field-size cutoff value for the assessment unit (variable, but at least 1 million barrels of oil equivalent), or they occur as reserve growth of fields already discovered.

The *total petroleum system (TPS)* is the basic geologic unit of the oil and gas assessment. The total petroleum system includes all genetically related petroleum in shows and accumulations (discovered and undiscovered) that has been generated by a pod or by closely related pods of mature source rock. This petroleum exists within a limited mappable geologic space, together with the essential mappable geologic elements (source, reservoir, and seal) that control the fundamental processes of generation, expulsion, migration, entrapment, and preservation of petroleum.

An *assessment unit (AU)* is a mappable part of a total petroleum system, in which discovered and undiscovered fields constitute a single relatively homogeneous population such that the chosen methodology of resource assessment based on estimation of the number and sizes of undiscovered fields is applicable. A total petroleum system might equate to a single assessment unit. If advantageous, a total petroleum system is divided into two or more assessment units, such that each assessment unit is sufficiently homogeneous in terms of geology, exploration considerations, and risk to be assessed individually.

A numeric code identifies each region, province, total petroleum system, and assessment unit; these codes are uniform throughout the project and they identify the same item in each publication. The code is as follows**:**

Region, single digit	**3**
Province, three digits to the right of region code	3**162**
Total petroleum system, two digits to the right of province code	3162**05**
Assessment unit, two digits to the right of petroleum system code	316205**04**

The codes for the regions and provinces are listed in U.S. Geological Survey World Energy Assessment Team (2000).

Oil and gas reserves quoted in this report are derived from Petroleum Exploration and Production database (Petroconsultants, 1996) and other area reports from Petroconsultants, Inc., unless otherwise noted.

A map, figure 1 of this report, shows boundaries of the total petroleum system and assessment units. It was compiled using geographic information system (GIS) software. Political boundaries and cartographic representations were taken, with permission, from Environmental Systems Research Institute's ArcWorld 1:3 million scale digital coverage (1992). They have no political significance, and are displayed for general reference only. Oil and gas field centerpoints, shown on the map, are reproduced, with permission, from Petroconsultants, 1996.

Abstract

The triangular-shaped North Ustyurt basin is located between the Caspian Sea and the Aral Lake in Kazakhstan and Uzbekistan and extends offshore both on the west and east. Along all its sides, the basin is bounded by the late Paleozoic and Triassic foldbelts that are partially overlain by Jurassic and younger rocks. The basin formed on a cratonic microcontinental block that was accreted northward to the Russian craton in Visean or Early Permian time. Continental collision and deformation along the southern and eastern basin margins occurred in Early Permian time. In Late Triassic time, the basin was subjected to strong compression that resulted in intrabasinal thrusting and faulting.

Jurassic-Tertiary, mostly clastic rocks several hundred meters to 5 km thick overlie an older sequence of

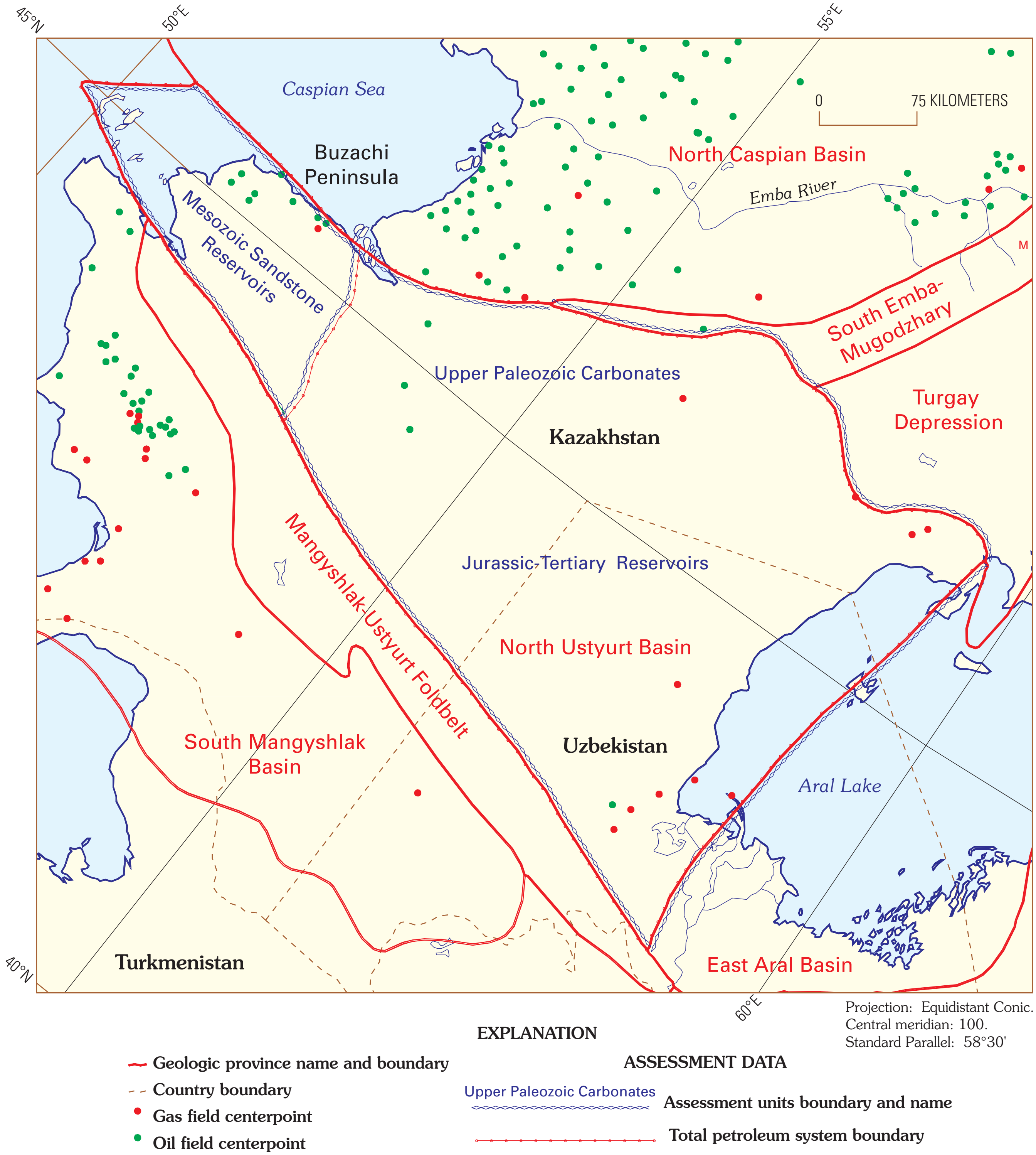

Figure 1. Petroleum systems and assessment units of North Ustyurt basin.

Devonian–Middle Carboniferous carbonates, Upper Carboniferous–Lower Permian clastics, carbonates, and volcanics, and Upper Permian–Triassic continental clastic rocks, primarily red beds. Paleogeographic conditions of sedimentation, the distribution of rock types, and the thicknesses of pre-Triassic stratigraphic units are poorly known because the rocks have been penetrated by only a few wells in the western and eastern basin areas. The basement probably is heterogeneous; it includes Precambrian massifs and deformed Caledonian foldbelts. The basement is at depths from 5.5 km on the highest uplifts to 11 km in the deepest depressions.

Three total petroleum systems are identified in the basin. Combined volumes of discovered hydrocarbons in these systems are nearly 2.4 billion barrels of oil and 2.4 trillion cubic feet of gas. Almost all of the oil reserves are in the Buzachi Arch and Surrounding Areas Composite Total Petroleum System in the western part of the basin. Oil pools are in shallow Jurassic and Neocomian sandstone reservoirs, in structural traps. Source rocks are absent in the total petroleum system area; therefore, the oil could have migrated from the adjacent North Caspian basin.

The North Ustyurt Jurassic Total Petroleum System encompasses the rest of the basin area and includes Jurassic and younger rocks. Several oil and gas fields have been discovered in this total petroleum system. Oil accumulations are in Jurassic clastic reservoirs, in structural traps at depths of 2.5–3 km. Source rocks for the oil are lacustrine beds and coals in the continental Jurassic sequence. Gas fields are in shallow Eocene sandstones in the northern part of the total petroleum system. The origin of the gas is unknown.

The North Ustyurt Paleozoic Total Petroleum System stratigraphically underlies the North Ustyurt Jurassic system and occupies the same geographic area. The total petroleum system is almost unexplored. Two commercial flows of gas and several oil and gas shows have been tested in Carboniferous shelf carbonates in the eastern part of the total petroleum system. Source rocks probably are adjacent Carboniferous deep-water facies interpreted from seismic data. The western extent of the total petroleum system is conjectural.

Almost all exploration drilling in the North Ustyurt basin has been limited to Jurassic and younger targets. The underlying Paleozoic-Triassic sequence is poorly known and completely unexplored. No wells have been drilled in offshore parts of the basin.

Each of three total petroleum systems was assessed as a single assessment unit. Undiscovered resources of the basin are small to moderate. Most of the undiscovered oil probably will be discovered in Jurassic and Neocomian stratigraphic and structural traps on the Buzachi arch, especially on its undrilled offshore extension. Most of the gas discoveries are expected to be in Paleozoic carbonate reservoirs in the eastern part of the basin.

Introduction

The report describes the regional and petroleum geology of the North Ustyurt basin, Province 1150, in Kazakhstan and Uzbekistan. The location and boundaries of the province are shown in figure 1. According to Petroconsultants (1996), discovered volumes of hydrocarbons in the basin are slightly less than 2.8 billion barrels of oil equivalent (BOE), of which 85.5 percent is oil. Most of the discovered oil is in several fields on the Buzachi arch and on its flanks in the westernmost onshore part of the basin (fig. 2). On the basis of the discovered reserves, the basin is ranked 74th among 102 provinces that were designated for appraisal of undiscovered oil and gas resources by the U.S. Geological Survey (U.S. Geological Survey World Energy Assessment Team, 2000).

Three total petroleum systems (TPS) have been identified in the North Ustyurt basin (fig. 1). The Buzachi Arch and Surrounding Areas Composite TPS (115001) includes the entire sedimentary sequence, but discovered hydrocarbon accumulations are present only in Jurassic and Cretaceous rocks at depths of a few hundred meters to a maximum of 1,300 m. The TPS is conjectural because petroleum source rocks have not been identified. Oil and gas could have migrated from the adjacent North Caspian basin. If so, this TPS may actually be a part of the North Caspian Paleozoic TPS, although the stratigraphy and tectonics of the Buzachi arch relate it to the North Ustyurt basin. All of the discovered fields are in Jurassic and Neocomian sandstone reservoirs, in faulted anticlinal traps.

The North Ustyurt Jurassic TPS (115002) encompasses the part of the North Ustyurt basin east of the Buzachi Peninsula (fig. 1). Stratigraphically it includes Jurassic and younger rocks; it overlies the older TPS that includes Paleozoic and Triassic rocks in the same area. The two TPS are separated by the major pre-Jurassic unconformity. A relatively small amount of hydrocarbons has been found in the North Ustyurt Jurassic TPS. A few discovered oil fields are in Jurassic clastic rocks, in structural traps. Source rocks for the oil probably are lacustrine beds and coals in the continental Jurassic sequence. Most of the discovered gas is in shallow Eocene sandstones in the northern part of the TPS. The origin of the gas is unknown.

The existence of the North Ustyurt Paleozoic TPS is indicated by commercial flows of gas from Carboniferous carbonates in two fields and by oil and gas shows at several other sites in the southeastern basin area. Source rocks for the gas are not known; however, indirect data indicate that probable source rocks are Carboniferous deep-water basinal facies east of the discoveries and shows. The western extent of this TPS is unknown and its boundary in figure 1 is conjectural.

Except for the relatively densely drilled Jurassic-Cretaceous rocks of the Buzachi arch (fig. 2), all three TPS of the North Ustyurt basin are exploration frontiers. Only a small number of exploratory wells have penetrated Paleozoic rocks that underlie the Jurassic-Tertiary sequence over the entire basin area. No wells have been drilled offshore, either in the Caspian Sea or in the Aral Lake. Each TPS was assessed as a single assessment unit (AU). The results of the assessments are shown in table 1.

Province Overview

Province Location and Boundaries

The triangular-shaped North Ustyurt basin occupies the northern part of the Ustyurt Plateau in Kazakhstan and Uzbekistan and adjacent lowland areas. The basin area is approximately 250,000 km^2, most of which is onshore. Only small parts of the basin are in the Caspian Sea and Aral Lake (fig. 1). The northwestern basin boundary is concealed by thin Mesozoic and Tertiary sediments; it is drawn along the southern flank of the Paleozoic South Emba high (fig. 2). The high is marked by large positive gravity and magnetic anomalies that probably are related to the presence of Middle Devonian and older(?) volcanics (Kan and Tropp, 1996). Thick Upper Devonian–Visean deformed graywacke clastics occur between the volcanics and thin (500–600 m) Mesozoic sediments in the central zone of the high. The South Emba high plunges southwestward and the geophysical anomalies disappear in nearshore and offshore areas of

Table 1. North Ustyurt basin, Province 1150 assessment results summary—allocated resources.

[MMBO, million barrels of oil. BCFG, billion cubic feet of gas. MMBNGL, million barrels of natural gas liquids. MFS, minimum field size assessed (MMBO or BCFG). Prob., probability (including both geologic and accessibility probabilities) of at least one field equal to or greater than the MFS. Results shown are fully risked estimates. For gas fields, all liquids are included under the NGL (natural gas liquids) category. F95 represents a 95 percent chance of at least the amount tabulated. Other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. Shading indicates not applicable]

Code and Field Type	MFS	Prob. (0-1)	Undiscovered Resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
1150	**Total: Assessed onshore portions of North Ustyurt Basin Province**													
Oil Fields		1.00	85	379	1,063	451	30	115	312	136	1	6	16	7
Gas Fields							610	7,267	19,001	8,020	17	287	820	327
Total		1.00	85	379	1,063	451	640	7,382	19,313	8,155	18	292	835	333
1150	**Total: Assessed offshore portions of North Ustyurt Basin Province**													
Oil Fields		1.00	83	414	1,226	503	11	53	159	65	0	1	4	2
Gas Fields							70	2,304	6,259	2,550	2	95	281	109
Total		1.00	83	414	1,226	503	81	2,358	6,418	2,615	2	97	285	111
1150	**Grand Total: Assessed portions of North Ustyurt Basin Province**													
Oil Fields		1.00	168	793	2,289	954	41	168	471	201	2	7	20	8
Gas Fields							680	9,571	25,260	10,569	19	382	1,100	436
Total		1.00	168	793	2,289	954	721	9,739	25,731	10,770	21	389	1,120	444

Table 1—Continued. North Ustyurt basin, Province 1150 assessment results summary—allocated resources.

Code and Field Type	MFS	Prob. (0-1)	Undiscovered Resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
115001	**Buzachi Arch and Surrounding Areas Composite Total Petroleum System**													
11500101	Mesozoic Sandstone Reservoirs Assessment Unit (40% of undiscovered oil fields and 100% of undiscovered gas fields allocated to ONSHORE province 1150)													
Oil Fields	3	1.00	53	268	797	326	6	29	89	36	0	1	2	1
Gas Fields	18						0	0	0	0	0	0	0	0
Total		1.00	53	268	797	326	6	29	89	36	0	1	2	1
11500101	Mesozoic Sandstone Reservoirs Assessment Unit (60% of undiscovered oil fields and 0% of undiscovered gas fields allocated to OFFSHORE province 1150)													
Oil Fields	3	1.00	79	402	1,196	489	8	43	134	54	0	1	3	1
Gas Fields	18						0	0	0	0	0	0	0	0
Total		1.00	79	402	1,196	489	8	43	134	54	0	1	3	1
115002	**North Ustyurt Jurassic Total Petroleum System**													
11500201	Jurassic-Tertiary Reservoirs Assessment Unit (89.75% of undiscovered oil fields and 89.75% of undiscovered gas fields allocated to ONSHORE province 1150)													
Oil Fields	3	1.00	32	111	265	125	24	86	223	100	1	5	14	6
Gas Fields	18						610	1,705	3,577	1,857	17	50	114	56
Total		1.00	32	111	265	125	634	1,791	3,800	1,957	18	55	128	62
11500201	Jurassic-Tertiary Reservoirs Assessment Unit (10.25% of undiscovered oil fields and 10.25% of undiscovered gas fields allocated to OFFSHORE province 1150)													
Oil Fields	3	1.00	4	13	30	14	3	10	25	11	0	1	2	1
Gas Fields	18						70	195	409	212	2	6	13	6
Total		1.00	4	13	30	14	72	205	434	223	2	6	15	7

Table 1—Continued. North Ustyurt basin, Province 1150 assessment results summary—allocated resources.

Code and Field Type	MFS	Prob. (0-1)	Undiscovered Resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
115003	**North Ustyurt Paleozoic Total Petroleum System**													
11500301	Upper Paleozoic Carbonates Assessment Unit (100% of undiscovered oil fields and 72.5% of undiscovered gas fields allocated to ONSHORE province 1150)													
Oil Fields	10	0.80	0	0	0	0	0	0	0	0	0	0	0	0
Gas Fields	60						0	5,562	15,424	6,163	0	236	705	271
Total		0.80	0	0	0	0	0	5,562	15,424	6,163	0	236	705	271
11500301	Upper Paleozoic Carbonates Assessment Unit (0% of undiscovered oil fields and 27.5% of undiscovered gas fields allocated to OFFSHORE province 1150)													
Oil Fields	10	0.80	0	0	0	0	0	0	0	0	0	0	0	0
Gas Fields	60						0	2,110	5,850	2,338	0	90	268	103
Total		0.80	0	0	0	0	0	2,110	5,850	2,338	0	90	268	103

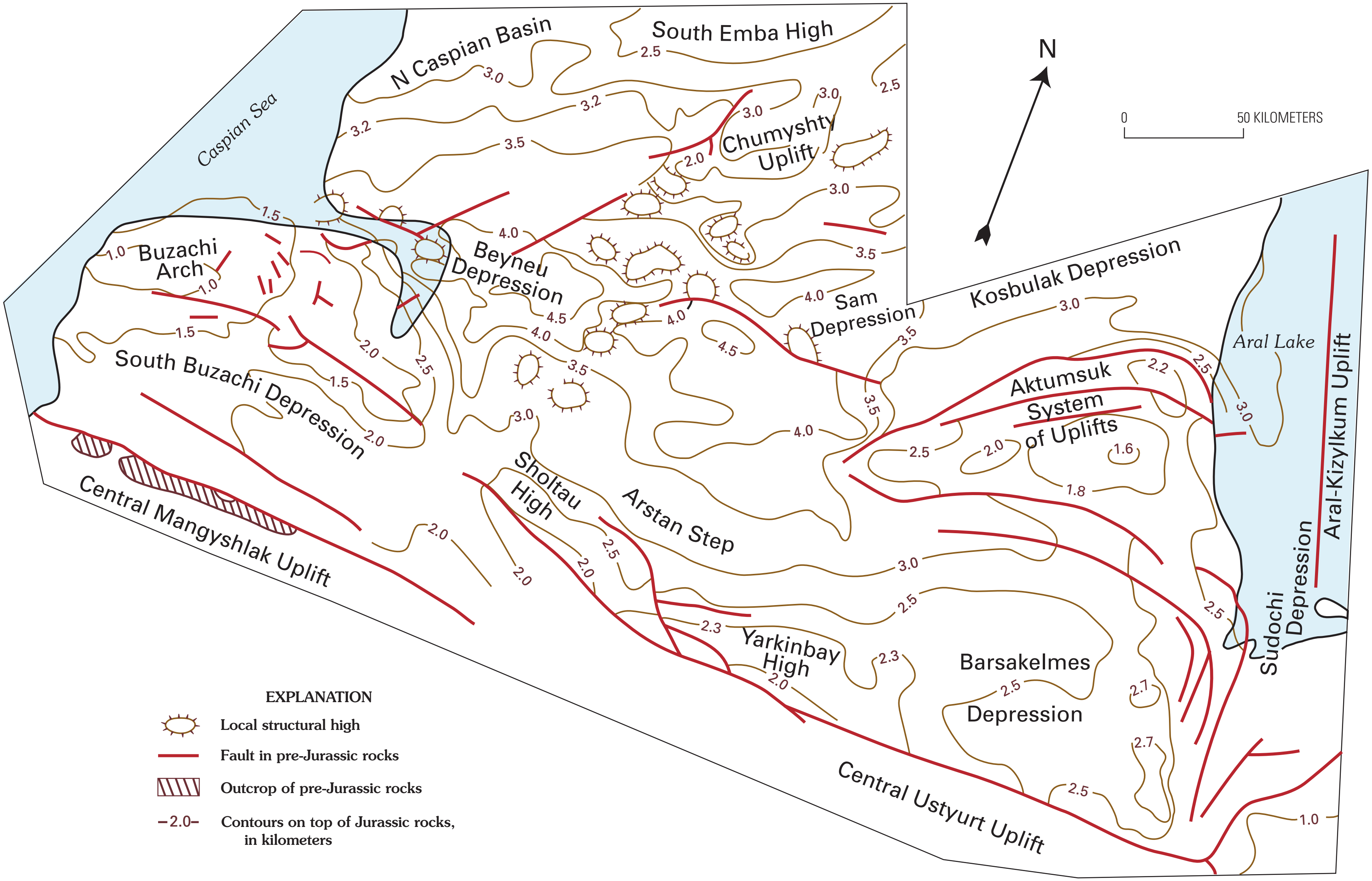

Figure 2. Principal structural units of North Ustyurt basin. Modified from Babadzhanov and others (1986). Scale is approximate.

the Caspian Sea, where the boundary between the North Ustyurt and North Caspian basins is poorly defined. This boundary is drawn conditionally along the pinch-out zone of Kungurian (Lower Permian) salt. The exact location of the pinch-out zone is difficult to determine from seismic sections; some geologists have suggested that the salt extends into the marginal areas of the North Ustyurt basin (Babadzhanov and others, 1986).

The southern basin boundary extends along the Central Mangyshlak and Central Ustyurt uplifts (fig. 2). The central Mangyshlak uplift is a structurally inverted and deformed Late Permian–Triassic rift. In the present-day structure, it is a foldbelt composed of a series of thrust anticlines. Synrift clastics are exposed in cores of the structurally highest anticlines. The Central Ustyurt uplift is a Hercynian suture that is covered by thin Jurassic-Cretaceous sediments. Below these sediments, several wells penetrated middle Paleozoic(?) partially metamorphosed clastic, carbonate, and volcanic rocks (Letavin, 1980). The western continuation of the suture is unknown; probably it is buried beneath the younger Central Mangyshlak rift.

The eastern basin boundary has not been drilled; most of it is offshore in the Aral Lake. On the basis of seismic data, the basin is bounded by the north-trending Aral-Kizylkum uplift (fig. 2). Across this uplift, upper Paleozoic platform formations of the North Ustyurt basin are in contact with contemporaneous deformed and metamorphosed basement rocks of the East Aral basin, whereas Jurassic and younger formations are continuous between the basins.

Tectono-Stratigraphic Development

The North Ustyurt basin is a simple, deep, Jurassic-Tertiary sag that unconformably overlies more complex and poorly known pre-Jurassic structures. The age of the basement is not known; age estimates include Early Proterozoic, similar to the age of basement of the Russian craton (Khain, 1977), Late Proterozoic (Milanovsky, 1987), or late Paleozoic Hercynian (Letavin, 1980). Seismic and limited drilling data indicate that the basement of the basin probably is not a homogeneous block (Babadzhanov and others, 1986). The southern zone of relative uplifts, where the basement is at depths of 5.5–8 km (Sholtau and Yarkinbay highs, Arstan step, and Barsakelmes depression in fig. 2), forms a stable block of granite crust of possible Precambrian age (Babadzhanov and others, 1986). The northern zone of deep (9–11 km) basement (Beyneu, Sam, and Kosbulak depressions in fig. 2) possibly has oceanic or thinned transitional crust. Limited drilling and seismic data indicate that the basement of the Sudochi depression is Caledonian in age. It is composed of thick, lower Paleozoic, slightly metamorphosed, deep-water shales and small blocks of Precambrian crust. These rocks were deformed in the Early Devonian; they were overlain by Early–Middle Devonian orogenic molasse clastics and were intruded by granites (Abidov and others, 1997). This basement composition is similar to that of the Central Kazakhstan high (Paleozoic Kazakhstan continent), indicating a possible genetic affinity of this high with the North Ustyurt block.

During Late Devonian through Early Permian time, the North Ustyurt basin developed as a cratonic block. Rocks of that age are platform-type carbonates and clastics that unconformably overlie various older deposits. Seismic data show development of a relatively deep water Carboniferous basin in the Sudochi depression and offshore in the southern Aral Lake (Pilipenko, 1990). The collision time of the North Ustyurt block with the Russian craton margin along the South Emba suture is poorly defined. Judging from the geology of the northwest slope of the South Emba high in the North Caspian basin, the time of collision probably was pre-late Visean; alternatively it may have been Early Permian (Artinskian). Collision along the southern basin suture occurred in Early Permian time. The eastern boundary suture also is Hercynian (Late Carboniferous–Early Permian); it was formed by collision of the Kazakhstan continent and the Russian craton. Hercynian deformations in the North Ustyurt basin are deeply buried and poorly known. Significant uplifts may be deduced from the presence of thick Artinskian clastic clinoforms north of the South Emba high (Sapozhnikov and others, 1986). The clastic material was derived from the North Ustyurt block.

Late Permian–Triassic rifting in the area of the present Central Mangyshlak uplift along the southern border of the North Ustyurt block indicates post-collisional relaxation and north-south extension. However, thick continental clastic sediments of the same age were derived from the Hercynian terrane on the east, where orogeny apparently continued. The next and most important stage of deformation in the basin took place in latest Triassic or earliest Jurassic time; it was related to closing of paleo-Tethys in the south and collision of the Iran and other continental blocks with the Eurasian Tethyan margin. The Central Mangyshlak rift was compressed, inverted, and deformed, and thrusting occurred in some areas of the North Ustyurt block. Especially intense thrusting took place on the Buzachi Peninsula and offshore (fig. 3); however, reverse faults and thrusts in Triassic rocks also are known from seismic surveys in more eastern basin areas. Since Jurassic time, the North Ustyurt basin developed as a gentle sag, in which sediments as thick as 5 km were deposited. Only mild deformations, some of which were rejuvenated movements along Triassic thrusts, are known. Uplift and formation of the present-day Ustyurt Plateau took place in post-Sarmatian time. Dense Sarmatian (upper Miocene) limestones and sandstones armor the surface of the plateau and prevent it from erosion.

Present-Day Structure

The main features of regional structure of the Jurassic-Tertiary sedimentary cover are shown in figure 2. The southern and central zones of the basin are relatively uplifted. In these zones, the surface of Jurassic rocks gently dips northward from depths of 2–2.5 km in the south to 3–3.5 km in the north. Farther north, the uplifted zones are bordered by a system of depressions, in which the Jurassic surface lies at depths of 4–4.5 km and the base of the Jurassic is at 5 km and deeper. The system includes the Beyneu, Sam, and Kosbulak depressions (fig. 2). Still farther to the north, the depressions grade to the gentle southern slope of the South Emba high.

Post-Triassic structure of the Buzachi Peninsula has been mapped in detail because this area contains most of the discovered petroleum reserves of the North Ustyurt basin. The core of the structure is the Buzachi arch (fig. 3), with closure of about 3 km. On the crest of the arch, the base of Jurassic rocks is at a depth of less than 1 km, and Cretaceous rocks crop out. The arch dips northward abruptly into the Beyneu depression and its offshore continuation and dips gently southward into the South Buzachi depression. Both the arch and the South Buzachi depression contain several zones of linear asymmetric anticlines that are expressed in Jurassic and younger strata (fig. 3). The anticlinal zones are underlain by blind thrusts in Triassic rocks and extend offshore. The structural framework of older parts of the sedimentary cover is virtually unknown because the thickness of Upper Permian–Triassic red beds is great (2.5–3 km) and older rocks have been penetrated by only a few wells.

Total Petroleum Systems

Available data, although scarce and commonly of uncertain reliability, suggest that there are three total petroleum systems (TPS) in the North Ustyurt basin. One composite petroleum system is identified in the Buzachi region in the western part of the basin, and two other stratigraphically stacked TPS cover the rest of the basin area (fig. 1).

The Buzachi Arch and Surrounding Areas Composite TPS produces oil from Jurassic and Cretaceous reservoirs and contains most of the hydrocarbon reserves of the basin. The TPS is defined conjecturally because the source rocks for the oil are unknown and probably are absent from the area. If hydrocarbons migrated from the north, as interpreted herein, the Buzachi Arch and Surrounding Areas Composite TPS may actually be a part of the North Caspian Paleozoic Total Petroleum System, although geologically the area is part of the North Ustyurt basin.

The North Ustyurt Jurassic TPS encompasses Jurassic and younger sedimentary rocks of the basin area east of the Buzachi Arch and Surrounding Areas Composite TPS. A few small oil and gas discoveries are mainly in Jurassic sandstones. Source rocks are Jurassic continental coaly shales and possible intervening lacustrine beds. Dry gas in four fields in the northern part of the basin is in shallow Eocene sandstone reservoirs, and the origin of this gas is uncertain. Possibly it is from the same Jurassic source, or it is biogenic in origin.

The existence of the North Ustyurt Paleozoic TPS, as a separate and distinct petroleum system that underlies the North Ustyurt Jurassic TPS, is indicated by commercial flows of gas from Carboniferous carbonates in two fields in the southeastern part of the basin. Source rocks for the gas are unknown. The extent of the North Ustyurt Paleozoic TPS to the west is uncertain, and the western boundary of the TPS shown in figure 1 is conjectural.

Buzachi Arch and Surrounding Areas Composite Total Petroleum System

Discovery History

Drilling for oil and gas was not conducted in the Buzachi Arch and Surrounding Areas Composite TPS (115001) prior to the middle 1970's because of the shallow occurrence of Triassic rocks that were considered to be an economic basement. In 1974, a well drilled on the Karazhanbas anticlinal uplift (fig. 3) unexpectedly produced an oil flow from a depth of slightly more than 200 m. Several more fields were discovered in similar structural traps during the next several years. No discoveries have been made since the early 1980's, although a number of prospects were drilled. Seismic surveys indicate the presence of structures in the offshore part of this TPS, but no wells have been drilled there. Only two oil fields of the TPS have been developed; one of them produces with steam injection.

Petroleum Occurrence

Several oil fields and a single small gas field are known in the Buzachi Arch and Surrounding Areas Composite TPS (fig. 1). All of the fields are on the Buzachi arch, but no hydrocarbon accumulations are known to be present in the South Buzachi depression. Each field contains several pools in sandstone beds of Middle Jurassic and Neocomian age. Aptian shales form a regional seal. The shallowest reservoir is at a depth of only 238 m in the Karazhanbas field, and the deepest reservoir is at a depth of almost 1,300 m in the Arman field (fig. 3).

Oils in all of the fields are partially biodegraded; they are heavy, sulfurous, and paraffinic. Oil density varies from 18.5° API at depths of 450–600 m in the Karazhanbas field to 29° API at a depth of 1,300 m in the Arman field. The content of sulfur in some fields is as high as 2.4 percent. Gas-oil ratios are low, and the composition of dissolved gas varies widely. Some productive beds contain gas caps, and purely gas pools are present in upper pays of some fields (for example, in the Kalamkas field).

Stratigraphic Section

Several stratigraphic tests drilled to more than 5,000 m depth penetrated pre-Upper Permian rocks on the Buzachi Peninsula. These rocks include Upper Devonian, Carboniferous, and Lower Permian marine carbonates and clastics. Numerous diabase dikes are present in the Upper Carboniferous–Lower Permian shale section on top of the Buzachi arch. Thicknesses of specific stratigraphic units vary widely in wells drilled on top of the arch and on its slopes (Kozmodemyansky and others, 1995), suggesting a complex structural history of the arch and possibly that it has an inverted tectonic origin. The Upper Permian–Middle Triassic red and variegated clastic rocks are more than 3,000 m thick, and they unconformably overlie various older strata (Lipatova and others, 1985). Upper Triassic dark-gray coaly shales 720 m thick are present only in the South Buzachi depression.

Lower Jurassic rocks are absent and Middle Jurassic continental, coaly, clastic rocks unconformably overlie the eroded surface of Triassic strata. On top of the Buzachi arch, Middle Jurassic rocks are about 250 m thick; they thin on local uplifts and thicken to 500 m on the northern slope of the arch. The Upper Jurassic is absent over most of the TPS area. Neocomian rocks are primarily marine clastics, and they also include some

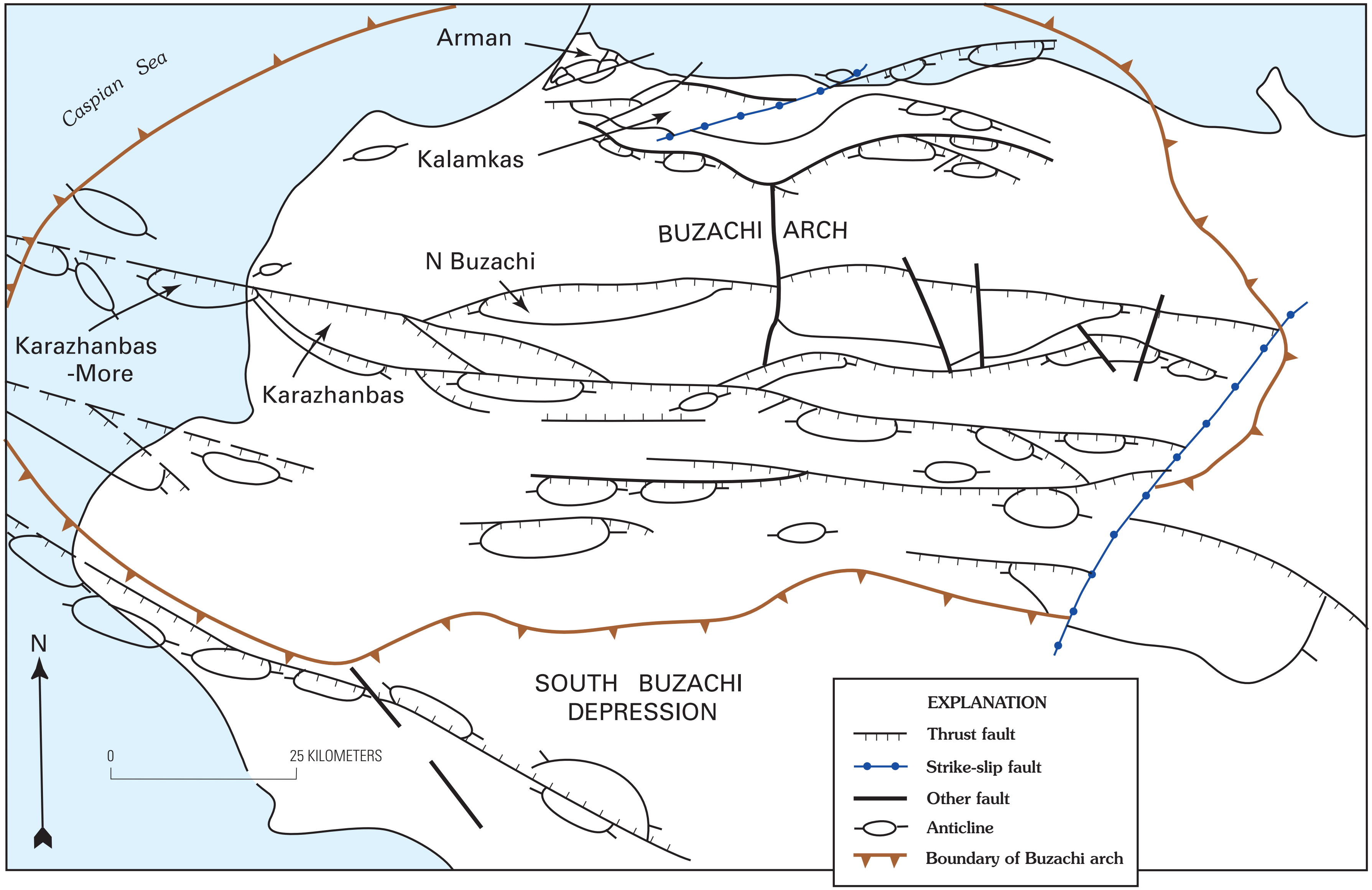

Figure 3. Generalized structure of Buzachi arch and adjacent areas. Modified from Popkov (1991). Map shows westernmost area of North Ustyurt basin depicted in figure 1. Scale is approximate. Faults dashed where inferred; hachures on upthrown side of thrust faults.

carbonates in the Valanginian section and red beds in the Barremian section. The Aptian Stage is represented by a shale bed 100–150 m thick. Younger Cretaceous rocks crop out on the surface. They are 150–450 m thick.

Source Rocks

Source rocks have not been identified in the drilled sedimentary sequence of the Buzachi Arch and Surrounding Areas Composite TPS. Productive Jurassic rocks, although enriched in coaly organic material (the content of total organic carbon (TOC) is as high as 2.8 percent), were not buried to the oil generation window. Some geologists proposed that oil accumulations in Jurassic and Cretaceous strata were formed by vertical migration of hydrocarbons from pre-Upper Permian marine rocks (Kozmodemyansky and others, 1995); however, geochemical data for these rocks are not available. Slight gas shows were recorded in pre-Upper Permian rocks during drilling, but testing was unsuccessful. Those rocks are separated from producing Jurassic strata by about 3,000 m of Upper Permian–Triassic red beds that are intensely compacted (especially the Upper Permian) and devoid of shows. Vertical migration through the red beds is unlikely. In addition, significant compaction of pre-Upper Permian rocks and the presence of numerous diabase dikes indicate that the rocks passed through the oil window long before Jurassic time.

A more probable scenario of formation of the oil and gas fields implies migration of hydrocarbons laterally from the North Caspian basin. Source rocks for hydrocarbons in the North Caspian basin are in the deep-water basinal facies of the subsalt Paleozoic sequence. From there, oil possibly migrated vertically into post-salt rocks and then updip through continuous Mesozoic strata onto the Buzachi arch. The presence of oil and gas fields on the northern slope of the arch and their absence on the southern slope support this model. If the model is correct, the Buzachi Arch and Surrounding Areas Composite TPS is actually a part of the North Caspian Paleozoic TPS, although the Paleozoic stratigraphy and tectonic history of the area relate it to the North Ustyurt basin.

No inferences about the present state of maturity and time of maturation of source rocks can be made because the exact location of the source rocks is unknown. However, the timing of trap formation, the very shallow occurrence of pools, and partial biodegradation of oil indicate that migration of hydrocarbons and the formation of fields were recent—probably not earlier than Miocene.

Reservoir Rocks

All oil pools of the Buzachi Arch and Surrounding Areas Composite TPS are in Middle Jurassic (principally Bathonian) and Neocomian sandstones. The fields contain a maximum of 12 pays (Kalamkas field), varying in thickness from a few to 40 m and separated by shale beds. Reservoir properties of the sandstones at shallow depths are good. Porosity ranges from 22 to 29 percent, and permeability ranges from tens to many hundreds of millidarcies.

The potential for the presence of reservoir rocks in the Triassic section is limited. On most of drilled structures, Triassic rocks compose the leading edges of thrust plates (Popkov, 1991). The rocks are significantly deformed and compacted; their porosity does not exceed 4 percent. Somewhat better reservoir potential has been reported for Middle Triassic rocks on the northern slope of the Buzachi arch (Lipatova and others, 1985). In some sandstone samples from the Kalamkas field, measured porosities were as high as 22 percent. No potential reservoirs have been identified in older rocks.

Traps

All discovered fields of the Buzachi Arch and Surrounding Areas Composite TPS are in structural traps. The traps in Jurassic and Cretaceous rocks are elongated east-to-west anticlinal structures with steep northern flanks that commonly are cut by reverse faults. The southern flanks of the anticlines are much more gentle. Oblique normal faults also are present. The anticlines are arranged in several linear zones that extend offshore (fig. 3). The Jurassic-Cretaceous anticlinal zones are underlain by the leading edges of thrust sheets composed of Triassic rocks. The detachment surface probably is near the base of Upper Permian–Triassic clastics (Popkov, 1991). The Jurassic-Cretaceous anticlines were formed by mild compression and rejuvenation of movements along pre-Jurassic thrust planes. Three major compressional events took place in pre-Neocomian, pre-Tertiary, and pre-middle Miocene time.

Exploration for stratigraphic traps has not been conducted in the TPS. Many stratigraphic traps are predicted to be present in pinch-out zones of Middle Jurassic rocks that unconformably onlap the Triassic sequence on the southern slope of the Buzachi arch. Stratigraphic pinch-out traps around local Triassic uplifts were mapped in Jurassic rocks of the eastern Buzachi Peninsula (Rakhmetova and others, 1986). On the northern slope of the arch, Middle Jurassic rocks possibly contain traps that are sealed by west-trending reverse faults on the northern limbs of anticlinal folds.

Assessment Unit

The Buzachi Arch and Surrounding Areas Composite TPS includes a single assessment unit (AU)—the Mesozoic Sandstone Reservoirs AU (11500101). The principal petroleum potential of the AU is related to Jurassic and Neocomian rocks of the undrilled offshore extensions of anticlinal zones. The offshore area is a direct continuation of the exploration play that presently contains all hydrocarbon reserves of the AU. The model of hydrocarbon migration from the North Caspian basin, proposed here, suggests that the principal, and possibly entire, offshore potential is limited to the northern slope of the Buzachi arch and its crest. However, developing and producing heavy oil offshore, using steam injection or other tertiary recovery techniques, may be uneconomic at present. Onshore, some structural prospects have not been drilled (Kolomiyets and Polifosov, 1998); however, most of them are on the southern slope of the arch, where no discoveries have been made, probably because of the absence of hydrocarbon charge. Some oil accumulations, primarily of small size, possibly are present in the AU in stratigraphic and fault-sealed traps.

The petroleum potential of the thick Upper Permian–Triassic red beds probably is low because of the poor quality of reservoir rocks and the absence of indigenous source rocks. A model of long-distance lateral migration, similar to that proposed for Jurassic fields, is not applicable for Upper Permian–Triassic rocks in this region. In the North Caspian basin, these rocks fill deep local depressions that are separated by salt domes and ridges, and thus they do not provide avenues for lateral migration of hydrocarbons. Pre-Upper Permian rocks of the AU occur at great depths, and their potential probably is low. Undiscovered resources of the AU are shown in table 1. Complete statistical data on assessment of this AU and other assessment units are included in U.S. Geological Survey World Energy Assessment Team (2000).

North Ustyurt Jurassic Total Petroleum System

Discovery History

Exploratory drilling in the North Ustyurt Jurassic TPS began in 1963, and during the following year several gas fields were discovered in the northern part of the basin (fig. 1). Some of these fields have produced gas since the late 1960's; others have not been developed, apparently because of economic considerations (Abdulin and others, 1993). A few oil accumulations in this TPS were discovered during the late 1960's and in 1970's. Only two small gas fields in the southeastern part of the TPS were found during the last decade.

Petroleum Occurrence

All hydrocarbon discoveries in the North Ustyurt Jurassic TPS are located in three areas. Three oil fields in the western part of the TPS, and one oil field and several gas fields in the southeastern part of the TPS, are in Jurassic clastic reservoirs at depths commonly greater than 3,000 m. Gas fields in the northern part of the TPS are relatively large; their combined original reserves are about 1 trillion cubic feet (TCF). The fields are in Eocene sandstones at depths of only a few hundred meters.

Oils of the TPS are light, low sulfurous (0.2–0.3 percent), and paraffinic (3–5 percent). Gas in the northern gas fields is dry. The hydrocarbon components of the gas are methane and very small amounts of ethane. Heavier hydrocarbon gases are absent.

Stratigraphic Section

Lower–Middle Jurassic rocks at the base of the North Ustyurt Jurassic TPS compose a continental, coal-bearing, clastic formation. Coarse and fine clastic lithologies commonly are arranged in cycles that include alluvial and lacustrine rocks and coal beds. The presence of nearshore marine facies in the Bathonian section is possible. Coarse clastic rocks, including conglomerates, are predominant in the lower part of the sequence, especially in the Lower Jurassic, and they grade upward into finer clastics. The thickness of Lower–Middle Jurassic rocks in depressions exceeds 1,000 m, and it decreases to 500–700 m on regional highs (Ozdoev, 1977). Upper Jurassic rocks are 100–300 m thick. They consist of Callovian-Oxfordian marine shales and a bed of Kimmeridgian-Tithonian limestone that is 50–100 m thick.

The Cretaceous section in the TPS area is thick. In the Kosbulak depression (fig. 2), the maximum thickness is 2,600 m, and thickness decreases to 1,200–1,400 m on the crests of the southern system of uplifts. Cretaceous rocks are primarily marine clastics. The Barremian Stage is represented by continental variegated rocks that record a relatively short regression event. Beds of limestone, chalk, and marl constitute much of the Campanian-Maastrichtian section. The Tertiary sequence is separated into two parts by a pronounced pre-middle Miocene unconformity. Paleocene–lower Miocene rocks are thick (maximum 1,400 m in the Kosbulak depression) marine sandstones and shales that include carbonate beds. The middle Miocene–Pliocene sequence is comparatively thin; it is composed of clastic rocks and widespread Sarmatian-Pontian limestones and marls.

Source Rocks

Source rocks for the North Ustyurt Jurassic TPS probably are continental coaly shales and coals in the Middle Jurassic sequence. The sporadic presence of lacustrine beds that are relatively enriched in type II kerogen is probable. Total organic carbon (TOC) in some samples of shales exceeded 4 percent (Ozdoev, 1977). The TOC contents are significantly lower in Lower Jurassic rocks, as well as in the Upper Jurassic and Neocomian rocks. In most of the TPS area, Middle Jurassic strata are in the oil window, and possibly also in the upper part of the gas window. The main stage of maturation took place in Tertiary time.

Reservoir Rocks

Oil and gas fields in the Jurassic section are in Middle Jurassic continental and upper Callovian-Oxfordian shallow-marine clastic rocks. Middle Jurassic sandstones that occur at depths exceeding 2,500 m are characterized by relatively poor reservoir properties. Porosity of the sandstones ranges from 8 to 14 percent and permeability ranges from a few millidarcies to several tens of millidarcies. Commonly, sandstone beds are laterally discontinuous. Callovian reservoir rocks that are commercially productive in one field are of somewhat better quality; porosity is 16–18 percent and permeability is as high as 100 mD. Eocene sandstones that contain dry gas of uncertain origin in northern areas of the TPS occur at depths of several hundred meters. Their reservoir properties are excellent; porosity commonly exceeds 30 percent and permeability is several hundred millidarcies.

Traps

All known hydrocarbon accumulations in the North Ustyurt Jurassic TPS are in structural traps, although outlines of particular pools commonly are affected by pinchout of sandstones and by faults. The traps are local anticlinal uplifts with closures of several tens of meters to 150 m. Average sizes of anticlines are 5–8 km in width by 10–20 km in length. The anticlines are gentle structures; their limbs dip at angles of a few degrees in Jurassic rocks to tens of minutes in Tertiary rocks. Kimmeridgian shales and carbonates constitute a regional seal that is highly effective over most of the TPS area. The effectiveness of the seal is demonstrated by the virtual absence of oil or gas shows in Neocomian sandstone beds that alternate with shales. The timing of structural growth is not certain. Limited data and analogy with the South Mangyshlak subbasin suggest that important stages of formation of structures could have been associated with pre-Cretaceous, pre-Tertiary, and pre-middle Miocene erosional events that are reflected by unconformities.

Assessment Unit

The North Ustyurt Jurassic TPS includes a single assessment unit, Jurassic-Tertiary Reservoirs AU (11500201). The petroleum potential of the AU probably is low (table 1). Approximately 30 to 40 prospects, mainly in Jurassic rocks, have been drilled, but only several small oil and gas fields were found. The negative characteristics of the AU are the poor quality of Middle Jurassic reservoir rocks and the apparent low effectiveness of source rocks. Several tens of structural prospects identified by seismic surveys more than two decades ago (Ozdoev, 1977), still have not been tested, and reconstructed paleogeographic conditions of sedimentation in Jurassic time suggest that many stratigraphic traps probably are present. However, because of the generally negative results of previous exploration in Jurassic rocks and the relatively large drilling depths, these prospects are unattractive at the present time.

The potential for additional shallow gas discoveries in Eocene reservoir rocks apparently also is limited. Although specific data are not available, most significant structural prospects that occur at depths of only 400–700 m probably have been tested in areas adjacent to the discoveries. South of those areas, Eocene sandstones pinch out and the Paleogene sequence is composed entirely of shales. New discoveries may be expected in smaller structural and stratigraphic traps.

North Ustyurt Paleozoic Total Petroleum System

Discovery History and Petroleum Occurrence

In the 1980's, gas flows were obtained from the upper part of pre-Upper Permian rocks in two fields; these discoveries are the basis for identification of the North Ustyurt Paleozoic TPS (115003). A significant oil show was recorded in the Karakuduk deep stratigraphic test, below a thin (27 m) Upper Permian bed. In 1989, a gas flow was tested in the Karakuduk field in the southeastern part of the TPS area. Shortly afterward, several wells confirmed the presence of a commercial gas accumulation (Ubaykhodzhaev and others, 1992).

A gas discovery and oil and gas shows also were recorded in the southeastern part of the TPS area, on the Paleozoic Kuanysh-Koskalin uplift (the eastern part of the Mesozoic Barsakelmes depression in fig. 2). Gas flows were tested from the weathered upper zone of Lower–Middle Carboniferous carbonate rocks in erosional highs that were mapped on the surface of the carbonate rocks.

Stratigraphic Section

Only general features of the stratigraphy of pre-Jurassic rocks are known from scarce well data. The drilled pre-Jurassic sequence of the TPS consists of three formations (Babadzhanov and others, 1986). The lower formation is composed primarily of Upper Devonian (?) and Lower–Middle Carboniferous carbonate rocks. The carbonates contain some shale and sandstone beds; the number and thicknesses of these beds increase westward. Eastward, into the Sudochi depression (fig. 2), the carbonates form an east-facing clinoform and grade into deep-water basinal shales (Pilipenko, 1990). The zone of pure carbonate rocks probably is the Carboniferous shelf margin, which likely contains a barrier reef at the boundary with a deep-water basin to the east. A similar shelf-edge reef was interpreted from seismic data offshore, on the northern slope of the Sudochi depression (Pilipenko, 1990).

The middle formation probably is Late Carboniferous–Early Permian in age. Its maximum drilled thickness is about 800 m, but on Paleozoic uplifts the rocks were completely removed by erosion. This formation consists of clastic rocks, some carbonate beds, tuffs, and, in places, thick porphyrites. The stratigraphic relationships among these rock types change across the TPS. The Upper Carboniferous–Lower Permian sequence or Lower–Middle Carboniferous carbonates are overlain unconformably by Upper Permian–Triassic red beds that constitute the upper formation. The thickness of the red beds varies from tens to hundreds of meters, and it is substantially less than the thickness of similar rocks of this age on the Buzachi Peninsula.

Source Rocks

Hydrocarbon source rocks of the North Ustyurt Paleozoic TPS, which produced hydrocarbon fields and shows, have not been identified. The presence of source rocks among the Lower–Middle Carboniferous deep-water basinal facies that have been seismically mapped in the Sudochi depression and offshore in the Aral Lake (Pilipenko, 1990) is highly probable. Hydrocarbons could have migrated into the adjacent shallow-shelf carbonates where oil and gas were tested. On the basis of indirect evidence (significant diagenetic alteration of carbonates and clastics and the presence of volcanics), the source rocks probably are overmature with respect to oil generation. The availability of source rocks in the Paleozoic sequence of more western areas of the TPS is uncertain.

Reservoir Rocks

All flows of hydrocarbons in the North Ustyurt Paleozoic TPS were obtained from the upper part of the Carboniferous carbonate sequence. All tested hydrocarbon accumulations are in carbonate reservoirs that subcrop under the pre-Upper Permian unconformity in areas where Upper Carboniferous–Lower Permian volcanics and clastics are absent. The reservoir rocks are fractured and leached limestones with vuggy porosity. The porosity of the rock matrix below the zone of weathering is low (1–3 percent) and permeability is negligible (Ubaykhodzhaev and others, 1992). Potential clastic reservoir rocks have not been identified in either Upper Carboniferous–Lower Permian marine or Upper Permian–Triassic continental formations.

Traps

Although the pre-Jurassic sequence contains several regionally identifiable reflectors (Babadzhanov and others, 1986), the resolution of seismic data is insufficient to permit detailed mapping of the structure of rocks below the pre-Jurassic unconformity. Only locally the eroded surface of carbonate or volcanoclastic rocks directly beneath Upper Permian–Triassic red beds can be mapped for structural prospects. The mapped and drilled prospects are erosional highs on the surface of Carboniferous carbonates that are overlain unconformably by the red beds. Closures of several mapped highs vary from 100 to 250 m. The highs are not expressed in the structure of the base of Jurassic rocks. Upper Permian clastic rocks form a seal.

Assessment Unit

The North Ustyurt Paleozoic TPS includes a single Upper Paleozoic Carbonates AU (11500301). The petroleum potential of this AU is highly speculative because of the extreme scarcity of data. The only exploration play that has been identified at present is a zone of Lower–Middle Carboniferous carbonate rocks that extends northward across the eastern part of the Barsakelmes depression (fig. 2). The zone then turns eastward and continues offshore along the northern margin of the Sudochi depression. The zone probably contains shelf-edge carbonates, including a barrier reef complex. At least in part of that zone, carbonate rocks subcrop under the pre-Upper Permian unconformity, or they occur stratigraphically close to it. Leaching and fracturing formed reservoir rocks at the top of the carbonate formation. The play is strongly gas prone (table 1).

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