

Petroleum Geology and Resources of the North Caspian Basin, Kazakhstan and Russia

By Gregory F. Ulmishek

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basin margins. Basinward, these rocks grade into deep-water anoxic black shales and turbidites. The Kungurian salt formation is strongly deformed into domes and intervening depressions. The most active halokinesis occurred during Late Permian–Triassic time, but growth of salt domes continued later and some of them are exposed on the present-day surface. The suprasalt sequence is mostly composed of clastic rocks that are several kilometers thick in depressions between salt domes.

A single total petroleum system is defined in the North Caspian basin. Discovered reserves are about 19.7 billion barrels of oil and natural gas liquids and 157 trillion cubic feet of gas. Much of the reserves are concentrated in the supergiant Tengiz, Karachaganak, and Astrakhan fields. A recent new oil discovery on the Kashagan structure offshore in the Caspian Sea is probably also of the supergiant status. Major oil and gas reserves are located in carbonate reservoirs in reefs and structural traps of the subsalt sequence. Substantially smaller reserves are located in numerous fields in the suprasalt sequence. These suprasalt fields are largely in shallow Jurassic and Cretaceous clastic reservoirs in salt dome-related traps. Petroleum source rocks are poorly identified by geochemical methods. However, geologic data indicate that the principal source rocks are Upper Devonian to Lower Permian deep-water black-shale facies stratigraphically correlative to shallow-shelf carbonate platforms on the basin margins. The main stage of hydrocarbon generation was probably in Late Permian and Triassic time, during deposition of thick orogenic clastics. Generated hydrocarbons migrated laterally into adjacent subsalt reservoirs and vertically, through depressions between Kungurian salt domes where the salt is thin or absent, into suprasalt clastic reservoirs.

Six assessment units have been identified in the North Caspian basin. Four of them include Paleozoic subsalt rocks of the basin margins, and a fifth unit, which encompasses the entire total petroleum system area, includes the suprasalt sequence. All five of these assessment units are underexplored and have significant potential for new discoveries. Most undiscovered petroleum resources are expected in Paleozoic subsalt carbonate rocks. The assessment unit in subsalt rocks with the greatest undiscovered potential occupies the south basin margin. Petroleum potential of suprasalt rocks is lower; however, discoveries of many small to medium size fields are expected. The sixth identified assessment unit embraces subsalt rocks of the central basin areas. The top of subsalt rocks in these areas occurs at depths ranging from 7 to 10 kilometers and has not been reached by wells. Undiscovered resources of this unit did not receive quantitative estimates.

Introduction

This report describes the regional and petroleum geology of the North Caspian (in some publications Precaspian, Pricaspian, or Peri-Caspian) basin in Kazakhstan and Russia. The location and boundaries of the basin are shown in figure 1. Discovered petroleum volumes in the basin are listed at 45.8 billion barrels of oil equivalent (BBOE) in the Petroconsultants (1996) file, of which 57 percent is gas. The basin is ranked 12th among 102 provinces designated for appraisal of undiscovered oil and gas

resources by the U.S. Geological Survey (U.S. Geological Survey World Energy Assessment Team, 2000). The recent, potentially supergiant oil discovery in the Kashagan prospect in the northern Caspian Sea can substantially increase the amount of the basin's reserves.

A single total petroleum system (TPS), the North Caspian Paleozoic TPS, was defined in the basin. The TPS encompasses the entire North Caspian basin area and includes both subsalt (Upper Devonian–Lower Permian) and suprasalt (Upper Permian–Tertiary) stratigraphic sequences separated by the Kungurian (uppermost Lower Permian) salt formation. Both sequences were charged with hydrocarbons that were generated from Paleozoic deep-water black-shale facies. These facies are developed in the central basin areas and are stratigraphic equivalents of carbonate platform formations of the basin margins. The peak of hydrocarbon generation probably occurred in Late Permian–Triassic time, contemporaneously with deposition of thick orogenic clastics and after deposition of the Kungurian salt seal. Major hydrocarbon reserves of the basin occur in subsalt carbonate reservoirs, largely in various carbonate buildups (atolls, pinnacle and barrier reefs).

Despite almost 100 years of exploration history, the North Caspian basin remains an exploration frontier. Six assessment units (AU) were identified for resource appraisal; four include subsalt rocks of the basin margins and the fifth includes suprasalt clastic rocks of the entire basin and TPS area. The sixth AU, encompassing subsalt rocks of the basin central area, occurs at depths exceeding 7 km and was not quantitatively assessed. Definitions of the TPS and AU are given in the Foreword, and the assessment technique and procedure are described in U.S. Geological Survey World Energy Assessment Team (2000). The results of the assessment are shown in table 1. The largest portion of undiscovered petroleum resources is expected in Paleozoic carbonate reservoirs of the south basin margin.

Province Overview

Province Location and Boundaries

The North Caspian Basin province (1016) occupies the northern part of the Caspian Sea and a large plain to the north (figs. 1, 2); it covers about 500,000 km². The basin is bounded to the east by the Ural foldbelt and the Mugodzhary zone, the latter being a southern continuation of the Urals that is partially buried beneath a thin section of Mesozoic rocks. Hercynian deformation in the foldbelt began in Late Carboniferous time after collision of the Russian (East European) craton with the Kazakhstan continent. The Paleozoic South Emba high (fig. 2) borders the basin to the southeast. The high is covered by flat-lying Mesozoic sediments, and its geology is poorly understood. The crest of the high is marked by large gravity and magnetic anomalies and is probably composed of Lower and Middle(?) Devonian volcanics (Kan and Tropp, 1996). Younger Paleozoic sedimentary rocks form the northwestern flank. The high is structurally expressed as an uplift of upper Paleozoic strata but is underlain by a deep trough in the basement surface. Possibly,

Figure 2. Structural map of North Caspian basin (modified from Solovyev, 1992). Contours are on top of basement. Hydrocarbon fields shown by red numbers; 1, Orenburg; 2, Karachaganak; 3, Zhanazhol; 4, Tengiz; 5, Astrakhan; 6, Kenkiyak.

Figure 4. Cross section through Karachaganak carbonate buildup (modified from Golov and others, 1983). D₃, Upper Devonian; C₁, C₂, and C₃, Lower, Middle, and Upper Carboniferous; P₁, Lower Permian (Asselian-Artinskian); C_{1t}, Tournaisian; C_{1v-s}, Viséan–Serpukhovian.

Figure 6. Cross section of Karaton-Tengiz zone (modified from Lisovsky and others, 1992). D₂ and D₃, Middle and Upper Devonian; C₂, Middle Carboniferous; P₁ and P₂, Lower and Upper Permian; Tr, Triassic; K, Cretaceous; Cz, Cenozoic.

Figure 7. Carbonate buildups of northern Caspian Sea (modified from Murzagaliev, 1995). Scale approximate.

Figure 8. Cross section of Astrakhan arch (modified from Brodsky and others, 1994). The arch constitutes westernmost segment of Astrakhan-Aktyubinsk system of highs shown in figure 2. Scale is not available. Total length of section is about 60 km. AR, Archean; PR, Proterozoic; PZ, Paleozoic; D, Devonian; C, Carboniferous; P, Permian. Subscripts 1, 2, and 3 denote lower, middle, and upper subunits. Symbols *B*, *I P*, *II P*, *II P'*, and *F* are referred to seismic reflectors.

Figure 9. Events chart of North Caspian Paleozoic Total Petroleum System. Queries indicate uncertainties in extent or identification.

Figure 10. Tectonic map of northern part of east basin margin and adjacent Ural foldbelt (modified from Kan, 1996).

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