

ANNOTATION

of dissertation completed by Ainura Zhanserkeyeva
on the topic: «Geological setting and evaluating the hydrocarbon prospectivity of
the Paleozoic complex based on basin modeling results for the eastern margin of
the Precaspian Basin» presented for obtaining the Doctor of Philosophy (PhD)
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The Relevance of the Study. The Precaspian Basin as a one of the world's largest hydrocarbon provinces holds a key position in terms of the concentration of explored hydrocarbon reserves in Kazakhstan, characterized by uneven geological exploration both in terms of area and section. The state of the mineral resource base of hydrocarbons is marked by high exploration and involvement in the development of existing deposits, primarily associated with the pre-salt complex.

As of the present time, the Precaspian Basin (PCB) is covered by a dense network of seismic profiles spanning different years. The border zones have been extensively studied through drilling, whereas the central part of the PCB remains less explored. Drilling of deep exploratory, appraisal, and parametric wells in the early 1980s within the eastern margin led to the identification of oil and gas potential in the Lower Permian and Middle Carboniferous pre-salt deposits, resulting in the discovery of fields such as Zhanazhol, Kenkiyak, Alibekmola, and Kozhasay.

Since the early 1990s, there has been a sharp decline in the volume of geological exploration activities within the eastern margin, leaving the prospects of oil and gas potential in the deeply buried pre-salt complex largely underexplored. The most extensively studied area through drilling activities is the Zhanazhol-Tortkol carbonate platform.

Consequently, the geological and geophysical exploration of the eastern margin of the PCB exhibits unevenness both in terms of area and section. This necessitates a revision of the petroleum system formation model and the justification of further directions for geological exploration efforts.

Scientific analysis and improving the quality of scientific support for geological exploration (GE) and production activities are crucial for planning resource replenishment and exploration against the backdrop of the inevitable depletion of existing reserves. Given the high cost of parametric and exploration drilling, comprehensive justification of well locations and enhancing the quality of scientific support for GE enable the reduction of geological risks and increase the efficiency of exploration and production activities.

The relevance of the research is driven by the need to refine the hydrocarbon prospectivity within the research area through a revision and synthesis of both accumulated and new geological-geophysical and geochemical data. This refinement will be conducted through utilizing new methodologies and geological concepts.

Based on the accumulated extensive geological data (results of drilling deep parametric and exploratory wells, results of 2D and 3D seismic surveys, results of paleogeographic reconstructions), there is a pressing need to update the model of the structure of the Upper Paleozoic pre-salt complex deposits in the research area. This update will be based on lithofacies analysis, geochemical studies, and basin analysis methods. All of the aforementioned factors determine the relevance of the study.

The Aim of the Work. To determine the petroleum potential through comprehensive investigation of hydrocarbon systems within the Upper Paleozoic pre-salt complex of the eastern margin of the Precaspian Depression, and to assess the status and prospects of oil and gas potential based on refined petroleum geological zoning.

Research Objectives:

1. Collection, systematization, and study of the geological-geophysical characteristics of the pre-salt deposits of the Eastern PCB, comparison of lithostratigraphic sections of wells, and examination of sedimentation models.
2. Investigation of the tectonic position of the PCB and the structural-formational framework of the pre-salt complex, analysis of tectonic structure, and geothermal conditions.
3. Compilation, synthesis, and analysis of the geological-geochemical characteristics of the sedimentary succession and hydrocarbon source rocks, examination of the type and thermal maturity of organic matter, conducting advanced RockEval pyrolysis studies, and investigation of genetic relationships between oils and source rocks based on biomarker analysis.
4. Study of hydrocarbon systems in the pre-salt complex of the PCB, investigation of organic matter maturation processes, analysis of hydrocarbon generation and migration models based on the petroleum system concept.
5. Analysis of hydrocarbon potential, refinement and updating of the petroleum-geological zoning, and determination of prospective directions for hydrocarbon exploration in the study area.

Materials and Methods. Over the course of many years of work at KMG Engineering LLP, the author studied the primary geological documentation, deep well sections and the results of seismic studies of the eastern side zone of the pipeline, as well as the results of petrographic and micropaleontological studies. The author conducted a macroscopic study of the cores of the Kozhasay, Urichtau, East Urichtau, Shirak fields, and took representative core samples for petrographic, pyrolytic, and chemostratigraphic studies. The author directly participated in the sample preparation of 90 samples for isotope and pyrolytic studies, mastered the technique of lithological and petrographic studies of carbonate rocks. To study the hydrocarbon systems of pre-salt deposits, the results of the latest geochemical studies were collected and analyzed by the method of chromato-mass spectrometry of oil and organic matter extracts according to published and stock sources.

For the latest pyrolytic and geochemical studies, core samples were used from 7 wells drilled within the eastern side zone of the pipeline and penetrating deep pre-salt deposits from the Upper Devonian to the Lower Permian.

Scientific Novelty:

1. The consolidation of scattered geochemical data and correlation of oils from pre-salt deposits within the stratigraphic range from the Upper Devonian to the Lower Permian in the Eastern Margin of the Pre-Caspian Basin is conducted for the first time. Genotypes of oils are identified, and a classification of hydrocarbon systems is carried out based on geological and geochemical criteria.

2. Original litho-geochemical data for the core material of the Urykhtau-5 well are obtained. Variations in geochemical indicators of Rock-Eval pyrolysis and the isotopic composition of carbon and oxygen for KT-III, MKT, and KT-II are established using Atomic Emission Spectrometry (AES) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) methods.

3. Within the northern margin of the Zhanazhol-Tortkol carbonate platform, three large Devonian-age structures are distinguished: Urikhtau, confirmed by drilling at well U-5, to the east of which are the provisionally named West Zhanazhol Devon (WZD) and East Zhanazhol Devon (EZD) structures, as shown in Figure 5.2.

4. For the first time, algae microfossils *Renalcis* and *Epyphyton* have been identified and described based on petrographic studies of KT-III microbial limestones in the Urikhtau-5 well. Additionally, for the first time, microfossils of *Paleozoic calcispheres* with a round shape and diameters ranging from 0.03 to 0.12 mm have been identified.

5. A high generative potential of the Lower Carboniferous deposits in the Akzhar East area has been established. Based on a complex of pyrolytic parameters, the argillites exhibit very good to excellent generative potential (TOC reaching 5.06%, $S_1+S_2=22.57$ mg/g, hydrogen index HI of 425 mg HC/g TOC, pyrolysis index $PI = 0.05$). The degree of catagenetic maturity corresponds to the MK_1 - MK_2 gradations.

Thesis Statements:

1. The petroleum systems in the conjunction of the Precaspian Basin (PCB) and the Sakmar-Kokpekty segment of the Southern Ural orogenic fold and thrust belt was controlled by the geodynamic regime and the evolution of collisional tectonics. Faults may have played a significant role as migration pathways for the Zhanazhol-Tortkol carbonate complex and the eastern slope of the Temir carbonate platform.
2. The pre-salt complex of the eastern PCB is characterized by the following geological and geochemical criteria of the hydrocarbon potential:
 - a) Potential clayey-carbonate petroleum source rocks within the Zhanazhol-Tortkol zone are characterized by extensive areal development in the Devonian to Lower Carboniferous stratigraphic interval, which is associated with the development of the Zhanazhol-Tortkol petroleum system. The deposition of organic-rich facies presumably occurred under marine relatively deep-water reducing conditions;
 - b) Established hydrocarbon accumulation zones are linked to elevated geothermal conditions, with the onset of hydrocarbon generation being most probable for the Middle-Upper Devonian and Lower Carboniferous potential petroleum source rocks. Thermal maturity of potential petroleum

source rocks increases from east to west and is controlled by thrust tectonics;

- c) Lower Carboniferous terrigenous deposits of the Borzher-Akzhar structural zone have partially undergone through oil window and are currently inactive; hydrocarbon accumulations are controlled by paleogeographic conditions. Based on comprehensive analysis, the Lower Carboniferous Borzher-Akzhar petroleum system has been identified, with the source rock being of sapropelic Type II, prompting to generate liquid hydrocarbons. The depositional environment for the source rocks are presumed to be associated with lacustrine environments.
3. A refined scheme of petroleum and gas geological zoning and prospects for hydrocarbon potential within the eastern margin of the Precaspian depression have been proposed, reflecting the current status of geological and geochemical research of the petroleum systems.

Connection of this work with other research projects. The author of the dissertation took part in the grant project of the Minister of Science and Higher Education of the Republic of Kazakhstan, No. 00025 "Regional basin model and the geological structure of the territory of the Precaspian sedimentary basin of Kazakhstan" (2020-2022) as a responsible specialist (senior researcher).

Practical Significance. The conclusions and results of dissertation studies are of significant interest to oil geologists in planning exploration and are recommended for further application in order to improve the quality of scientific support for exploration. Based on the current state of geological and geochemical knowledge, the scheme of oil and gas geological zoning of the eastern side of the Precaspian Depression has been updated. Systematization and generalization of disparate data on geological and geochemical characteristics of pre-salt sediments and associated liquid HCs in the study area was performed. Oil correlations and biomarker analysis performed made it possible to substantiate HC systems in the pre-salt complex and to clarify oil and gas geological zoning.

The author's personal contribution to the study. The author independently conducted literature review in both Russian and English on the dissertation topic and identified the research major objective and tasks. The results of structural-facies zoning of the pre-salt complex were summarized, indicator diagrams of geochemical parameters were built, and the catagenetic zonality of potential source rocks was assessed.

With the guidance of Professor Nereo Preto from the University of Padua, the author was able to identify and define for the first time the microfacies of limestone KT-III and KT-II (in the Urikhtau area). The author participated in lithological-facial studies, discussions, and interpretation of results during a research internship at the Laboratory of Isotopic Studies, Faculty of Geological Sciences, University of Padua, Italy. These contributions demonstrate the author's active involvement in various aspects of the research, including literature review, data analysis, and collaboration with international experts, thereby enriching the overall quality and depth of the study.

For the first time, a synthesis and systematization of the latest geochemical research results of oils in the study area were conducted, based on published and archival sources. Key geochemical criteria were identified for comparing oils, and indicative diagrams were constructed to characterize the source rock. Through comprehensive analysis, the dissertant reconstructed the thermal history using well-studied well sections, calibrated the results of modeling, and analyzed the obtained results.

The author of the dissertation research actively participated in the selection and preparation of samples and conducted geochemical analyses in collaboration with laboratory specialists. The author also engaged in active scientific work on the thesis topic to ensure the timely publication of research results. With the support of academic supervisors, the author prepared scientific conclusions and recommendations for fulfilling the hydrocarbon potential of the pre-salt complex of the Precaspian Basin.

Publications and Conferences. The research results of the dissertation were presented and discussed at the SPE Annual Caspian Technical Conference 2021 and the series of international geological and geophysical conferences "GeoEurasia-2020: Modern Technologies for the Study and Development of Eurasian Subsoil," "GeoEurasia-2021: Geological Exploration in Modern Realities," and "GeoEurasia-2022: Geological Exploration Technologies: Science and Business" (Moscow, 2020, 2021, and 2022). Additionally, the results were also presented at the International Geological Forum and Conference "Features of Carbonate Rocks and Reservoir Modeling" (Turkestan, 2022).

Regarding publications, 7 papers have been published on the topic of the research. Six of them were published in journals recommended by the Committee on Control of the Ministry of Science and Higher Education of RoK, while one publication appeared in a peer-reviewed Scopus-indexed journal with a Q2 quartile.

Reliability of the Research Results. The data from geological and geophysical studies of recent years were utilized based on published and archival sources. These included seismic interpretation results, findings from stratigraphic analyses of well sections that penetrated the pre-salt complex of formations, outcomes of geophysical surveys of deep wells (comprising reservoir temperature measurements), microphotographs and detailed descriptions of cores and thin sections, mineral composition data, petrophysical properties of rocks, results from biostratigraphic studies, and data on hydrocarbon composition of oil obtained through chromatography-mass spectrometry.

The laboratory-analytical investigations were conducted utilizing state-of-the-art equipment and methodologies. Pyrolytic analyses were carried out using the Rock-Eval 6 Turbo analyzer, with verification against the standard IFP 160000 samples at the Oil and Gas Field Laboratory of the National Research Tomsk Polytechnic University (TPU). Distinction and comparison of various oil genotypes were based on the results of comprehensive geochemical studies employing gas chromatography and mass spectrometry (GC, GC-MS). Determination of stable carbon and oxygen isotopes was performed using the Delta V Advantage mass spectrometer calibrated against international standards. Mineralogical and trace

element composition determination was conducted using the ICP-MS method at the Regional Center for Collective Use of the National Research Tomsk State University (TSU) following certified protocols. Thermal history modeling and burial reconstruction utilized the Petromod software. Statistical data processing was carried out using modern analytical methods.

A representative collection of thin sections and high-resolution photographs was prepared from the core material of the Urikhtau-5 well, utilizing equipment from the Geological Faculty of the University of Padua.

Structure and Scope of the Dissertation.

The structure and scope of the dissertation encompass an introduction, 5 sections, a conclusion, spanning 155 pages. It is supplemented with 62 illustrations, comprising 10 tables, 7 appendices, and accompanied by a bibliography listing 123 references.

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