ANNOTATION

dissertations for the degree of Doctor of Philosophy (PhD)
6D070600 – Geology and exploration of mineral deposits

Madisheva Rima Kopbosynkyzy

The study of the geodynamic conditions of sedimentation and formation of oil and gas potential of the pre-Jurassic complex of the Aryskum depression

Relevance of work. The South Torgai sedimentary basin according to the "Map of Kazakhstan's Oil and Gas Prospects" (2002) belongs to the Eastern Oil and Gas Geological Region and is one of the important oil and gas producing regions of the Republic of Kazakhstan. The oil and gas potential of the Aryskum depression is associated with lithologic-stratigraphic complexes of the Jurassic-Cretaceous deposits, the Devonian-Lower Carboniferous formations of the quasi-platform complex and disintegrated projections of the basement. It is assumed that there is a certain potential for the oil and gas potential of the Pre-Mesozoic formations, in connection with oil and gas manifestations, up to industrial oil inflows during their testing. Over more than 30 years, a huge amount of exploration has been carried out, as a result of which more than 35 oil and gas fields have been identified, most of which are currently at a late stage of development and are characterized by a high degree of reserves development. One of the important areas of exploration is the identification of new deposits in the pre-Jurassic complex. It is known that the effectiveness of the search and discovery of new fields is often associated with the problem of determining the source and nature of oil.

Therefore, the relevance of the work aimed at studying the oil and gas bearing pre-Jurassic complex, as one of the promising objects of replenishing the mineral resource base, increasing the economic potential of the country, is obvious.

The identification of probable oil-producing rocks is one of the initial tasks of a systematic approach in the search for new oil and gas deposits, therefore, this work is relevant, in light of the use of the data obtained, to develop methods for searching promising objects in the pre-Jurassic deposits of the Aryskum depression of the South Torgai oil and gas basin.

It is known that industrial accumulations of hydrocarbons mainly occur in the upper sedimentary shell of the earth's crust mainly in sands, sandstones, limestones and dolomites, since these rocks are characterized by increased porosity and represent natural reservoirs of liquid and gaseous hydrocarbons.

Nevertheless, such clusters are often found in fractured crystalline rocks - volcanic, intrusive-magmatic and metamorphic, and the hydrocarbon reserves in the crystalline basement, given its enormous area and thickness, may exceed known sedimentary cover reserves.

Possible ways of formation of deposits in the crystalline basement from the perspective of sedimentary-migratory origin of oil include: 1) migration of

hydrocarbon fluids from the surrounding sedimentary rocks into the cracks of the igneous body after it cools; 2) thermal destruction of dispersed organic matter upon contact with magma, the movement of hydrocarbons in the form of a gas phase or hydrothermal solutions, and subsequent condensation of fluids in relatively colder sections of the rock; 3) the condensation of organic matter inside xenoliths captured by magma and associated gas bubbles, turning into large tonsils-aggregates.

In the first case, the oil will have a traditional composition, reflecting the conditions for the formation of sedimentary rocks adjacent to the protrusions of the crystalline basement. The oil composition in the deposits formed according to the second and third options, suggesting a significant thermal effect on the organic matter, can differ significantly from the sedimentary oil.

A bright representative of the accumulation of oil in the rocks of the weathering crust is the Aryskum depression of the South Torgai oil and gas basin.

A study of the composition of oils in the Mesozoic sedimentary cover and adjoining pre-Mesozoic sediments will clarify their genesis, determine distinctive characteristics, broaden the understanding of the geochemical evolution of organic matter (OM), and subsequently, it is possible to develop new geochemical criteria for the search and exploration of oil deposits of the South Torgai basin in the deposits of the pre-Jurassic complex. All this determines the need and relevance of the study.

Purpose and objectives of the work.

The aim is to identify the oil sources of the Pre-Mesozoic complex and reconstruct the geodynamic conditions for the formation of the oil source sediments of the Aryskum depression.

To achieve this goal, it was necessary to solve the following tasks:

1. The study and synthesis of materials on the geological structure and oil and gas potential of the Paleozoic sediments of the Aryskum depression;

2. The study of the individual composition of biomarkers, as well as the study of the carbon isotopic composition of oils of the Mesozoic and Pre-Mesozoic deposits of the Aryskum depression using modern chromatographic and mass spectrometric methods;

3. Carrying out a comparative analysis of the carbon isotopic composition of oils and the composition of hydrocarbon biomarkers of oils occurring in pre-Jurassic deposits of the Aryskum depression and oils from sedimentary strata overlapping them;

4. Geological and geochemical interpretation of the results of studies of Mesozoic and Pre-Mesozoic oils to determine the types of initial organic matter (OM), the conditions of its accumulation, catagenetic maturity to identify potential source rocks of the Aryskum depression.

Scientific novelty.

1. For the first time in the oils of the Aryskum depression, the individual composition and relative content of alkanes, n-alkylbenzenes, naphthalenes, phenanthrenes, pentacyclic triterpanes and steranes were determined, geochemical parameters reflecting the specific conditions of the formation of oil source deposits were calculated;

2. For the first time in the oils of the South Ossetian National Hydrological Basin, the isotopic composition of the carbon of the oils of the sedimentary cover of the Mesozoic age and the weathering crust of the Pre-Mesozoic deposits of the Aryskum depression deposits was studied to solve the genetic problems of the formation of the Aryskum depression oils;

3. The most probable source of hydrocarbons in the deposits of the pre-Jurassic complex — the organic matter of the Mesozoic deposits of the Aryskum depression, obtained on the basis of the geological and geochemical interpretation of the composition of hydrocarbon biomarkers and data on the carbon isotopic composition and data on the carbon isotopic composition of oils;

4. The types of the initial organic matter were determined, the facies conditions of its accumulation for the Akshabulak graben syncline (sapropelic), Aksai horst anticline (sapropelic-humic), Bosingen graben syncline (humus-sapropelic) based on the individual composition of biomarkers, as well as carbon isotope oils of the Mesozoic and pre-Jurassic complexes.

The following main points are protected in the work:

1. The Aryskum depression oil source rocks were formed under various diagenesis conditions: in the deeper part of the sea and less oxidizing conditions within the Akshabulak graben synclinal and Aschisay horst anticline; in a salted lagoon within the Aksai horst anticline; in the desalinated delta zone within the Bosingen graben synclinal;

2. The oils of the Mesozoic and pre-Jurassic complexes within separate structures have a common genesis - K1nc1 and PR (from the Lower Cretaceous and Proterozoic) of the Akshabulak graben synclinal, as well as K1nc1 and Pz (from the Lower Cretaceous and Paleozoic) of the Aksai horst anticline;

3. The probable migration routes from the adjoining sedimentary sediments of the Mesozoic age of the Akshabulak graben — syncline through secant faults into the Pre-Mesozoic fractured reservoirs of the Ashchisai horst — anticlines, which make it possible to reasonably estimate the oil reserves of the pre-Jurassic deposits, were established.

The practical significance of the work. The identification of probable oil-producing rocks is one of the initial tasks of a systematic approach in the search for new oil and gas deposits, therefore, this work is relevant in light of the use of the results obtained to develop methods for finding promising objects in the pre-Jurassic deposits of the Aryskum depression of the South Torgai oil and gas basin.

The developed methodology for studying biomarkers allows for more accurate oil - oil correlations, and the evidence of oil generation by deposits of the Mesozoic complex allows a reasonable assessment of oil reserves of the Pre-Mesozoic deposits of the Aryskum depression deposits.

The results of the study can be used in conducting classes for undergraduates and doctoral students in the specialty "Geology and exploration of mineral deposits" and "Geophysical methods of prospecting and exploration" in the disciplines of studying the oil and gas provinces of Kazakhstan.

Approbation of work. The main research results were reported at the XXIII International Symposium of Students and Young Scientists named after Academician M.A. Usova "Problems of Geology and Subsoil Development" dedicated to the 120th birthday of Academician K.I. Satpayev, the 120th birthday of Professor K.V. Radugina (Tomsk, 2019).

Publications 9 works were published on the subject of the work, including 2 articles in journals included in the Scopus database, 3 articles in Kazakhstani journals included in the CCSON list, 4 reports in proceedings of international conferences.

The structure and scope of the dissertation. The dissertation consists of an introduction, 4 chapters, conclusions, a list of references from 110 items. The full volume of the dissertation is 99 pages, including 35 figures and 11 tables.

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The methods of gas-liquid and gas chromatography-mass spectrometry revealed similarities and differences between the composition of hydrocarbon oils occurring in the pre-Jurassic deposits of the Aryskum basement and oils from sedimentary strata overlapping them, and the features of facies conditions for the accumulation of oil source material on the territory of the Aryskum depression were determined.

The objects of study were three samples from sedimentary sediments of the Mesozoic (Jurassic, Cretaceous) and two samples from the pre-Jurassic complex of deposits of the Aryskum depression.

The study of hydrocarbon oils by gas chromatography showed that the base and Mesozoic oils have a similar distribution of n-alkanes. Such a distribution may indicate the genetic unity of the oils from the Mesozoic and the pre-Jurassic complex.

The value of the P / F ratio, which is used as an indicator of the diagenesis conditions, indicates the similarity of oils from the Cretaceous and Proterozoic sediments of the Akshabulak graben synclinal (1.6 and 1.8), is also almost identical for oils from the Cretaceous and Paleozoic oils of the Aksai horst anticline (2.7 and 2.6) and slightly higher (3.1) in oil from the Lower Jurassic of the Bosingen graben-synclinal. This shows that the initial OM producing oil of the Akshabulak graben synclinal formed in the suboxidative, Aksai horst anticline and the Bosingen graben synclinal under oxidative conditions.

Based on the composition of normal and isoprenoid alkanes, geochemical parameters were calculated (the ratio of pristan to n-C17 and phytane to n-C18),

reflecting to a certain extent the maturity of the oils, showing that all the studied oils differ little in their thermal transformations and belong to the category of "mature".

The main class of biogenic organic compounds in the studied oils are alkanes. Their content among the identified compounds in the oils of the Bozingen and Akshabulak graben synclines is 92-94% and will increase in oils of the Aksai horst anticline to 98%.

The composition of one of the main groups of biomarkers - sterans, despite their low content in oils of the Aryskum depression, demonstrates the identity of the paleogeographic conditions for the formation of the initial oil source material of oils from Cretaceous deposits, deposited, apparently in marine, possibly shallow-water conditions, and oils from adjoining basement reservoirs.

The initial OM of the oil lying in the Lower Jurassic sediments of the Bosingen graben-synclinal in the east of the studied territory was accumulated, apparently, near the delta, which is consistent with the increased P / F ratio in this oil, indicating a higher redox potential in the sedimentation basin.

Oils from the Cretaceous and Proterozoic of the Akshabulak graben synclinal, along with a reduced P / F value, differ from those lying to the west with a lower content of the rearranged structures of diasterans in the composition of sterans. This may be due to an increase in the carbonate content and a decrease in the fraction of clastic material in the sediments generating oil in this area compared to the westward region of the Aksai horst anticline, and the heavier carbon isotopic composition in this direction indicates, in accordance with, the predominantly sapropelic initial OM Akshabulak oils and an increase in the proportion of the humus component in the west of the studied territory and within the Bosingen graben synclinal.

The main class among saturated cyclic biomarkers in the studied oils are pentacyclic triterpanes. They are represented by C27 (Ts and Tm), C29 and C30 hopanes, S and R epimers of homogopans C31-35 and gammaceran. The composition of pentacyclic triterpanes is identical for all oils, but insignificant differences are recorded in their distribution. So, against the background of the prevailing C30 hopane in their composition, the fraction of norgopan (C29) varies slightly in different oils, the high content of which corresponds to the carbonate-rich source rock.

For oils occurring within the Aksai horst anticline, an increased relative content of gamma-teran was recorded (gamma-teran index - G / H30 is 0.13-0.16), which indicates in accordance with a higher salinity of the basin area in which their initial OM accumulated. The minimum G / H30 value and, at the same time, the maximum P / F value are distinguished by oil from the Lower Jurassic, which indicates the accumulation of its initial oil source material in the conditions of a desalinated reservoir.

Cheilantans are present in all studied oils in trace amounts, showing a low contribution of algal material to the original oil source compared with prokaryotic organisms containing hopanes. In all oils, the presence of C24 tetracyclic terpan in a greater amount than tricyclic cheilants was recorded.

The data obtained indicate that the oil-producing stratum, most likely of the Cretaceous age, accumulated within the Akshabulak graben synclinal in the deeper part

of the sea than the uniform sediments of the Aksai horst anticline deposited, apparently under lagoon conditions, and the Lower Jurassic sediments of the Bozingen -synclines - in the desalinated delta zone.

The aromatic hydrocarbons of all the studied oils are dominated by bicyclic naphthalenes, which are mainly represented by naphthalene, monomethyl- (MN), dimethyl- (DMN) and trimethyl-substituted (TMN) naphthalenes.

Along with them, the presence of ethyl and methyl, propyl substituted naphthalenes was recorded. The distribution of the content of isomers inside the DMN and TMN for all oils, regardless of the age of the host sediments, is almost identical. At the same time, oils from the Cretaceous deposits and the Paleozoic of the Aksai horst anticline differ from the others in the increased proportion of monomethyl substituted compounds in the naphthalene composition, and among them, the significant predominance of 2-methylnaphthalene over its isomer (1-methylnaphthalene).

This indicates a lesser degree of thermal transformation of organic matter, which produced oil from the Aksai horst anticline. In oil from the Lower Jurassic of the Bosingen graben synclinal, the relative content of naphthalene with a propyl substituent (2-methyl, 1-propyl-naphthalene) is notably higher, the source of which has not yet been determined, but the increased content of this compound may be due to the specific conditions of OM accumulation in sediments of the lower Jurassic.

All studied oils are characterized by a low content of monocyclic aromatic hydrocarbons (alkylbenzenes). Their composition for all oils is identical. They are represented by a set of homologues C10-C34 mainly with one alkyl substituent, among which C12-C14 prevail.

Unsubstituted phenanthrene dominates in the individual composition of phenanthrenes in all oils, among methylphenanthrenes - 9-methylphenanthrene, the predominance of which indicates marine conditions for the accumulation of the starting organic material.

The content of phenanthrenes — tricyclic aromatic hydrocarbons in the oils of the Aryskum depression is higher than alkylbenzenes, but lower than naphthalenes. The ratio of naphthalenes to phenanthrenes is increased in oils in the west of the study area in the Cretaceous and Paleozoic sediments of the Aksai horst anticline (4.0-4.4) compared with oils from the Jurassic, Cretaceous and Proterozoic of the Akshabulak and Bosingen graben synclines (2.4-2.6), indicating a peculiarity of the composition of the initial oil source material and, as a consequence, the oils of the western section.

A feature of the composition of oil phenanthrenes from the Lower Jurassic of the Bosingen graben synclinal is an increased proportion of 1,2,6-trimethylphenanthrene, the origin of which is associated with a ground source.

To solve genetic problems and clarify the features of the formation of oil fields in the Aryskum depression, we first measured the carbon isotopic composition of 14 oil samples kindly provided by the geologists of these fields.

For a comparative analysis, oil samples were taken from the Mesozoic, Paleozoic sediments, as well as from the zone of contact of the Paleozoic with the Mesozoic sedimentary cover.

Most of the Aryskum depression oils are paraffinic (paraffin content up to 15% or more), low-sulfur.

Deposits from which samples were taken can be divided into 4 groups according to territorial confinement:

The Bozingen group of deposits Sarybulak, Kaynar, Sorkol is located in the southern part of the Bozingen graben-synclinal, Middle-Lower Jurassic deposits of the Karagansai and Doshchansk suite (3 samples) are productive in these deposits.

The Ashchisay group of the Ashchisay and Arys deposits is located on the Ashchisay horst anticline. Samples in the amount of 2 samples were taken from the Proterozoic PR and the Jurassic horizon J-0.

The Aksay group of deposits of the Aksai horst anticline includes the Kenlyk, Karabulak, and South-Western Karabulak deposits, from which 7 samples were taken from the sedimentary cover (Aryskum lower Cretaceous horizon) and from pre-Jurassic formations (PZ).

Akshabulak group - 2 samples were taken from the Lower Cretaceous deposits (Aryskum horizon) and the pre-Jurassic complex (PZ) at the Akshabulak deposits, which is located on the Akshabulak graben-synclinal.

Variations in the carbon isotopic composition range from δ 13C: from -27.6 ‰ to: -30.7 ‰.

The oils of the Akshabulak and Ashchisay groups are the most isotopically light, with an interval of δ13C: -29.4 ‰ and -29.1 ‰ (Proterozoic deposits) and δ 13C: -30.7 ‰ and -30.3 ‰ (chalk and Upper Jurassic). According to isotope data, Cretaceous and Jurassic oils can be genetically associated with organic matter (sapropelic) of the sapropelic type (kerogen (type I, II) of the same age deposits of the Akshabulak synclinal. The oils occurring in the Proterozoic deposits represent their genetic group.

The Bosingen group of oils has a narrow range of variations in the carbon isotopic composition δ 13C: -28.0 ÷ -28.9 ‰, possibly they are formed from organic matter of the mixed type (humus-sapropelic) Jurassic deposits of the Bosingen grabensynclinal.

Variations in the isotopic composition of oils within the identified genetic groups can be caused by differences in the component composition formed in the formation of oil deposits. Additional clarification of the genesis can be carried out by comparing the component and isotopic composition of oils.

Findings:

One of the important areas of exploration is the identification of new deposits in the deposits of the pre-Jurassic complex. The effectiveness of the search and discovery of new oil and gas fields is often associated with the problem of identifying probable oil-producing rocks.

The studies using complex geochemical methods allowed a comparative analysis of the possible genetic relationships of the sedimentary cover oils of the Mesozoic age and oils from the Pre-Mesozoic deposits of the weathering crust of the crystalline basement.

As a result of the study, the following tasks were solved:

- Materials on the geological structure and oil and gas potential of the Paleozoic deposits of the Aryskum depression were studied and generalized;

- The geodynamic model of the formation of the South Torgai sedimentary basin is considered;

- The individual composition of the oils of the Mesozoic and Pre-Mesozoic deposits by modern chromatographic and mass spectrometric methods and a comparative study of the composition of n-alkanes of oil hydrocarbons occurring in the pre-Jurassic deposits of the Aryskum depression and oils from sedimentary strata overlapping them at the Institute of Petroleum Chemistry named after A.A. Trofimuka (Siberian Branch of the Russian Academy of Sciences, Tomsk)

- The carbon isotopic composition of the oils of the Aryskum depression was measured in the Tomsk branch of the Siberian Research Institute of Geology, Geophysics and Mineral Raw Materials;

- A geological and geochemical interpretation of the data on the individual composition of the Mesozoic and Pre-Mesozoic oils was carried out. A biomarker analysis was carried out to determine the types of initial organic matter, the conditions of its accumulation, catagenetic maturity for reconstructing the paleogeographic conditions of sedimentation of source rocks of the Aryskum depression.

As a result of the study, it was found that:

1. Isotopically light oils of the Akshabulak and Ashchisay groups can be genetically associated with organic matter of the sapropel type (kerogen I, type II); Mesozoic oil deposits of the Aksai group can be formed organic matter mixed (sapropelic-humic) type; the oils lying in the Paleozoic foundation may have been formed due to the influx of hydrocarbons from the Aryskum graben-synclinal; The Bosingen group of oils, which has a narrow range of variations in the carbon isotopic composition, is probably formed from mixed organic matter (humus-sapropelic) Jurassic deposits of the Bosingen graben-synclinal.

2. According to the geological section of the trough, the Akshabulak graben and Aschisay horst are complicated by secant faults, which could serve as migration channels for hydrocarbons. Based on this fact, it can be assumed that the isotopically close values of the carbon oils of the Ashchisai horst anticline indicate their genetic relationship with the oils of the Akshabulak graben and have one source of generation from one organic substance.

3. Close values of geochemical parameters and the same distribution pattern of n-alkanes, steranes, heilanthanes, pentacyclic terpans, alkylbenzenes, naphthalenes and phenanthrenes in oils from the Mesozoic and pre-Jurassic complexes within separate structures indicate the genetic unity of the Lower Cretaceous and Proterozoic oils of the Akshabulak hornbeam synclines, as well as the genetic unity of the Lower Cretaceous and Paleozoic oils of the Aksai horst anticline.

4. The oils occurring in the Lower Cretaceous and Proterozoic sediments within the Akshabulak graben synclinal differ from the others in the increased content of norgopan, indicating a greater contribution of carbonates to the rocks that generated them. These oils are characterized by lower values of the ratio of pristan to phytan, indicating the formation of the initial organic matter under less oxidizing conditions

than on the territory of the Aksai horst anticline, the oils of which occur in the Lower Cretaceous and Paleozoic, are characterized by a higher content of gammaceran and diasterans, which indicates the increased salinity of the basin, which was probably a saline lagoon, in which the clayey source layer was deposited.

5. The compositional features of hydrocarbon oil from the Lower Jurassic of the Bosingen graben synclinal are the absence of cheilants and C24 tetracyclic terpan in it, as well as the low proportion of C27 steranes, indicating an insignificant contribution of algal material to the parent oil source, an increased proportion of phenanthrenes 1,2, 6-trimethylphenanthrene, the origin of which is associated with a terrestrial source, the maximum value of the ratio of pristan to phytane, which characterizes the oxidative conditions in the diagenesis, and a very low content of gammacerane. Apparently, oil from the Lower Jurassic of the Bosingen graben synclinal is generated by sediments formed in the desalinated delta zone.

Understanding the processes of oil formation, where and from what sources it was formed, is of great theoretical and practical importance from the point of view of searches for oil fields and the renewal of oil reserves.

This work is relevant in light of the use of the results to develop methods for searching promising objects in the pre-Jurassic deposits of the Aryskum depression of the South Torgai oil and gas basin. The obtained evidence of oil generation by sediments of the Mesozoic complex will allow a reasonable assessment of the oil reserves of the Pre-Mesozoic deposits of the Aryskum depression deposits.