ABSTRACT

of the dissertation for the degree of Doctor of Philosophy (PhD) in the educational program 8D07104 - "Oil and gas and ore geophysics"

of **Zhumagulov Almas Serikbaevich**

on the topic: **«Geological structure and prospects for oil and gas content of the Middle-Upper Paleozoic deposits of the Tasbulak trough based on geological and geophysical data»**

The relevance of dissertation research is determined by the need to expand the resource base of natural gas, due to the Decree of the Government of the Republic of Kazakhstan dated July 18, 2022 No. 488 «On approval of the Comprehensive Plan for the Development of the Gas Industry of the Republic of Kazakhstan for 2022 – 2026», insufficient knowledge, fragmentary nature of previous studies against the backdrop of favorable geological conditions for the formation and subsequent conservation of predominantly gas deposits in the Middle-Upper Paleozoic sediments of the Tasbulak trough of the Shu-Sarysu basin.

Objects of research: Middle-Upper Paleozoic hydrocarbon systems of the Tasbulak trough of the Shu-Sarysu basin.

Subjects of research: CDP-2D seismic survey data, parametric, appraisal and exploratory drilling (formation fluid samples, core, cuttings, logging, VSP), magnetic and gravity surveys, information on structural, historical-geological, lithological-stratigraphic, geochemical and thermobaric factors from published literature and archival data.

The research methodology consists of a systematic analysis of geological, geophysical and geochemical data using modern computer technologies for digitization and geological modeling; an integrated approach to the study of factors favoring the formation of hydrocarbon accumulation in the Middle-Upper Paleozoic sediments of the Tasbulak trough.

The purpose of the research is to study the geological structure and prospects for oil and gas content of the Middle-Upper Paleozoic deposits of the Tasbulak trough using a geological and geophysical dataset.

Geological tasks to be solved:

1. Collection, analysis and systematization, preparation and quality control of geological, geophysical and geochemical data;
2. Creation of a digital database (digitization of seismic profiles and well logs, well data and geological and geophysical maps) and loading them into Petrel 2021 software;
3. Reinterpretation of digitized CDP-2D seismic data;
4. Petrophysical correlation of digitized logging data in modern software;
5. Analysis of the spatial distribution of anomalies of magnetic and local gravitational fields;
6. Multidimensional geological modeling using drilling, logging and seismic data CDP-2D;
7. Construction of maps of oil and gas geological zoning and substantiation of recommendations for further exploration.

Research tools – «Petrel 2021» software for geological modeling and integrated interpretation of geological information. Additional software – «LogNumbering» and «tNavigator 22.4» for digitization and interpretation of well logs, «AquaSoft Vector SGY v3.0» software and «Corel PHOTO-PAINT» softwares for vectorization and interpretation of seismic sections.

The **scientific novelty of the research** lies in obtaining new ideas about the structure, formational composition, conditions of generation, accumulation and gas-oil content of the Middle-Upper Paleozoic sediments deposits of the Tasbulak trough, in the construction of multidimensional geological models for seven structural-formational units.

For the first time, in the Middle-Upper Paleozoic sediments of the Tasbulak trough, a large Central Tasbulak swell of northeastern strike has been identified, within which the development of «reef-type» carbonate structures is predicted.

The **practical significance of the research** lies in justifying the feasibility of resuming prospecting and detailed geological exploration in the Tasbulak trough in order to identify promising hydrocarbon objects in the Middle-Upper Paleozoic deposits, which will contribute to further effective planning and increasing the investment attractiveness of exploration.

The **completeness of the initial data** is determined by the collection of available documentation on the Shu-Sarysu depression, with an emphasis on the Tasbulak trough, directly in the State Geological Funds of the «Kazgeoinform» LLP.

The **reliability of the results obtained** is confirmed by a systematic approach and the comprehensive nature of the interpretation of historical information, magnetic survey data, gravity survey, CDP-2D seismic survey, logging and laboratory analyzes of core samples and reservoir fluid samples in wells.

In particular, the likelihood of the presence of carbonate structures of the «reef type» is confirmed by factual materials on organogenic-detrital limestones with high reservoir and filtration properties, identified from the results of drilling deep wells in deposits of the carbonate subformation of the Upper Visean-Lower Serpukhovian age on the Northern Izykyr structures (wells 1-P and 2-P) of the Tasbulak trough, Tamgalytar (well 1-G), Terekhovskaya (well 1-P) and Northern Ortanasyrly (well 1-C) of the Kokpansor trough, as well as Chuyskaya (well 1-C) of the Lower-Shu uplift.

Author's personal contribution:

- collection and quality control of geological, geophysical and geochemical data on the Tasbulak trough in scientometric databases and State Geological Funds of the «Kazgeoinform» LLP;
- application of preliminary procedures to improve quality using the graphic editor «Corel PHOTO-PAINT» and vectorization of the results of CDP-2D seismic exploration using «AquaSoft Vector SGY v3.0» software, with the creation of digital vector information in the «SEG-Y»;
- digitization of well logs for wells 1-P Izykyr, 1-P S. Izykyr and 1-P Zhatyktau (RES, PS, Caliper, NGR-60, GR) using the «LogNumbering» software;
- digitization of drilling and seismic study maps of the Tasbulak trough in the «Petrel 2021» software;

- construction of inter-well lithological-stratigraphic correlation schemes using «tNavigator 22.4» software and linking drilling data, well logs, seismic logging observations, VSP and seismic surveys;

- interpretation of reflecting horizons, tectonic faults and supposed carbonate structures («reef type») from seismic sections;

- construction of a conceptual 3D static (structural-geological) model of the Tasbulak trough using «Petrel 2021» software.

Protected provisions:

1. Sediments of the quasi-platform sedimentary cover of the Tasbulak trough have a high gas and oil potential, which is confirmed by the inherited subsidence, weak dislocation and disturbance by faults, favorable structural features and lithological-formational composition of Middle-Upper Paleozoic sediments.

2. For the first time, in the constructed 3D model, a large northeast-trending swell was identified along nine reflecting horizons of the Middle-Upper Paleozoic, characterized by the distribution of undeformed or slightly deformed hydrocarbon systems, conformally occurring sediments of marine and lacustrine origin, which demonstrates the largely preserved original hydrocarbon potential.

3. Hydrocarbon systems of the Middle-Upper Paleozoic contain reservoirs with good filtration and reservoir properties, developed in non-structural traps (reef type) and low-amplitude anticlinal type traps.

4. In the sections of the Tasbulak trough, regional chemogenic deposits of the Lower Permian and sulfate-argillite strata of the Upper Devonian, zonal sulfate-argillite strata of the Upper Serpukhovian are distinguished, the lithological composition, increased thickness and area of development of which allows us to predict good insulating properties.

5. In the Upper Devonian and Lower Carboniferous sections of the Tasbulak trough, gas and oil source rocks formed in marine and lacustrine-marsh facies are distinguished.

Relationship of this work with other research works. The author took part in the compilation and development of:

- Report «Analysis of geological, geophysical and field characteristics of production wells and calculation of options for optimizing the development of the Amangeldy gas condensate field», CJSC AmangeldyGaz, 2006.

- Project No. AP19175313 «Petroleum systems and hydrocarbon potential assessment of Paleozoic deposits within Tasbulak graben of Shu-Sarysu basin under uncertainty by basin modeling» within the framework of grant funding for fundamental and applied scientific research of young postdoctoral scientists under the project “Zhas Galym” for 2023-2025 of Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan, «Satbayev University», 2023-2025.

Approbation. The main scientific provisions of the dissertation work were presented within the framework of: the international scientific and practical conference «Satpayev Readings» (2021); international scientific and technical conference «Current issues of growth of hydrocarbon resources and reserves» (2022); meetings of the Council of Young Scientists of the Institute of Geology and Oil and Gas Business (2021, 2023, 2024); sessions discussing the results of dissertation research of the

Geophysical Research Discussion Group (2021-2024); reports at the International Center for Deposits Analysis and Development (2021-2024); meetings of the department «Geophysics and Seismology» (2020-2024); hearings at the department of «Hydrogeology, engineering and oil and gas geology» (2024), at the School of Geology «KBTU» (2024), at the Kazakh Institute of Oil and Gas (2024); completing a scientific internship from May 29 to June 27, 2022 at the Sharif University of Technology in Tehran (Iran).

The main provisions of the dissertation work were published in 5 scientific works, 2 of which in journals (41%) included in the Scopus and Clarivate Analitics databases, 2 in publications recommended by the Science and Higher Education Quality Assurance Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan, 1 – in the proceedings of international conferences.

Factual database: Reporting and project documentation from the regional State Geological Funds of the «Kazgeoinform2 LLP of the «YuzhKazNedra». Information obtained from scientific works of national and international scientometric databases in the amount of 114 scientific articles, monographs, publications published since the 30s. XX century, of which 44 are indexed by the Scopus and WoS Core Collection systems.

Structure and scope of the dissertation. The dissertation is presented on 141 pages of computer typesetting and consists of an introduction, nine sections, a conclusion and a list of literature sources used, consisting of 114 titles. The dissertation includes 68 figures and 13 tables.

Main results of dissertation research. The dissertation research examined the geological structure and oil and gas potential prospects of the Middle-Upper Paleozoic deposits of the Tasbulak trough using a set of geological and geophysical data, including CDP-2D seismic and drilling data (core, cuttings, logging, VSP), magnetic and gravity surveys, information on structural, historical-geological, lithological-stratigraphic, geochemical and thermobaric factors from published literature and archival data.

There is insufficient knowledge, deficiency and fragmentary nature of the existing base of geological, geophysical and geochemical data collected directly from the State Geological Funds of the «Kazgeoinform» LLP of the «YuzhKazNedra».

In order to compensate for the deficit in the database, information was drawn from scientific works of national and international scientometric databases, monographs, publications published since the 30s. of the XX century, of which 42 are indexed by Scopus and WoS Core Collection.

It is this circumstance that determines the choice of the dissertation research methodology - a systematic analysis of available data using modern computer technologies for digitization and geological modeling; an integrated approach to the study of factors favoring the formation of hydrocarbon accumulation in sediments of Middle-Upper Paleozoic of the Tasbulak trough.

The high level of complexity of the geological tasks being solved required the use of Hi-Tech software – «Petrel 2021» for: a) interpretation of reflecting horizons, tectonic faults and supposed carbonate structures («reef type») from seismic sections; b) constructing a conceptual 3D static (structural-geological) model of the Tasbulak trough.

tNavigator 22.4 software was used to construct interwell lithological-stratigraphic correlation schemes and linkage of drilling data, well logging, seismic logging observations, VSP and seismic surveys.

In order to fully involve the collected geological, geophysical and geochemical data in the interpretation and modeling of modern software, the dissertation uses a set of quality improvement procedures using the «Corel PHOTO-PAINT» graphic editor, interpretation and vectorization of CDP-2D seismic sections on paper in «AquaSoft Vector SGY» software with the creation of digital information in the «SEG-Y»; on digitization of well logs in «LogNumbering» software, digitization in «Petrel 2021» software of drilling and seismic study maps of the Tasbulak trough.

Based on the results of dissertation research, new ideas about the structure, formational composition, conditions of hydrocarbons generation and accumulation, and gas-oil content of Middle-Upper Paleozoic deposits of the Tasbulak trough are substantiated.

For the first time, in the Middle-Upper Paleozoic deposits, in the constructed 3D model of this trough, a large Central Tasbulak swell of northeastern strike was identified, characterized by the distribution of undeformed or slightly deformed hydrocarbon systems, conformally occurring sediments of marine and lacustrine origin, which demonstrates the largely preserved original hydrocarbon potential.

Within this swell, the development of carbonate structures («reef type») is predicted.

In addition, the fundamental scientific novelty is characterized by the concept according to which the deposits of the quasi-platform sedimentary cover of the Tasbulak trough have a high gas and oil potential, which is confirmed by the development of reservoirs with good filtration and reservoir properties, the presence of regional and zonal chemogenic and sulfate-argillic cap rocks of increased thickness, distribution of gas and oil source formations.

A new concept about the geological structure and prospects for gas and oil content of the Tasbulak trough made it possible to justify the feasibility of resuming prospecting and detailed geological exploration work in order to identify promising hydrocarbon objects, which will contribute to further effective planning and increasing the investment attractiveness of exploration.

The main conclusions of the dissertation are presented in Table 1.

Table 1 – Comparative analysis of the geological and geophysical data base for the Tasbulak trough before and after dissertation research.

DB FOR THE TASBULAK TROUGH BEFORE DISSERTATION RESEARCH	DB FOR THE TASBULAK TROUGH AFTER DISSERTATION RESEARCH
Data shortage on: • well and seismic data. **Absence of:** • digitized well and seismic data.	**Using modern software, a digital database was created, including:** - seismic sections (700 linear km) and well logs (28,000 linear meters), well data and maps of geological and geophysical study were digitized.

Availability of: • information on wells, geological sections and maps on hard copy; • structural maps for 4 horizons on hard copy. **Absence of:** • 1D, 2D and 3D digital geological models; • thickness maps of reservoir rocks and cap rocks; • integrated interpretation of geological and geophysical data using modern software.	**Constructed:** - 1D, 2D and 3D digital geological models; - 3D structural plans for 9 RHs (I, II, IIIs, IIIk, III, IIIb, IV, V, VI) with elements of fault tectonics; - 3D thickness maps for 7 target structural-formational units (D3fmPre-salt – P1salt); - thickness maps of reservoir rocks and cap rocks. **For the first time in 3D models:** - a large swell of north-eastern strike is identified along all horizons.
Availability of: • ideas about the areal and depth development of reservoir rocks and cap rocks based on data for the Shu-Sarysu basin. **Absence of:** • data on the areal and depth development of reservoir rocks and cap rocks along the Tasbulak trough.	- the areal development and depth of occurrence of regional, zonal and local cap rocks have been established; - the contours of the supposed carbonate structures of the reef type with increased reservoir properties have been clarified.
Data shortage on: • Information on the generation potential of Middle-Upper Paleozoic sediments of the Tasbulak trough.	- the constructed digital geological models were saturated with information on the geochemical features; - the DOM concentrations, type and availability potentials to generation of hydrocarbons have been clarified.
Lack of research on: • integration of data on historical, geological and structural features in a 3D model; **Data shortage on:** • hydrocarbon systems, including settings for the formation of oil and gas source rocks, reservoir rocks and cap rocks.	• A comprehensive analysis of the evolution and geological structure was carried out together with structural 3D constructions; • A forecast was given for the conditions of formation of oil and gas source rocks, reservoir rocks and seal rocks. • The hydrocarbon potential was assessed using 3D models of 7 Middle-Upper Paleozoic units (thicknesses, sedimentation rates, analysis of structural plans etc. were calculated). • The preservation of the initial hydrocarbon potential of Middle-Upper Paleozoic sediments, weak deformation of hydrocarbon systems and the presence of 3 gas and oil promising units have been established.

Absence of: • Information on the existence of the Central Tasbulak swell for all 9 horizons of Middle-Upper Paleozoic deposits; • Linkage the predicted carbonate structures to the Central Tasbulak swell.	• New ideas about the tectonic and geological structure of the Central Tasbulak swell have been formed. • The concept of the favorable gas and oil potential of Middle-Upper Paleozoic sediments, including carbonate structures (Middle Visean – Lower Serpukhovian, Lower Carboniferous), is substantiated.
Absence of: • Maps and models of predicted hydrocarbon accumulation areas in 2D and 3D; • Maps of oil and gas geological zoning, even at a qualitative level.	• The areas most likely to accumulate hydrocarbons were identified through the study of paleohydrogeological features, potential routes of hydrocarbon migration, 2D and 3D models of Middle-Upper Paleozoic sediments. • Maps of oil and gas geological zoning were compiled, recommendations for further study of Middle-Upper Paleozoic deposits were substantiated.

List of publications:

1 Abetov A.E., Zhumagulov A.S. Geochemical and hydrogeological indicators of oil and gas content in the Middle-Upper Paleozoic sediments of the Shu-Sarysu depression. Proceedings: «Satpayev's Readings», section « Current problems of oil, gas and ore geophysics». V1, 2021, pp. 803-807, ISBN 978-601-323-247-8.

2 Zhumagulov A.S., Manzari M.T., Issayev S.A. Petroleum plays and prospectivity of the Shu-Sarysu basin. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. T 6, № 456, 2022, pp/ 261–275, ISSN 2224-5278 (Print), ISSN 2518-170X (Online). https://doi.org/10.32014/2518-170x.254

3 Zhumagulov A.S., Manzari M.T., Kezembayeva G.B., Nurmakova S.M., Mukanov D.B. Tectonic evolution and hydrocarbon accumulation controlling characteristics of the Shu-Sarysu basin. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. T 5, № 455, 2022, ст 289–305, ISSN 2224-5278 (Print), ISSN 2518-170X (Online). https://doi.org/10.32014/2518-170X_2022_5_455_289-305

4 Zhumagulov A.S., Ismailova J.A. Stratigraphy and lithology of the paleozoic deposits in the Tasbulak graben, Shu-Sarysu basin – Astana: Oil and gas. V5, № 137, 2023, pp. 6-16, ISSN 1562-2932 (Print), ISSN 2708-0080 (Online) https://doi.org/10.37878/2708-0080/2023-5.01

5 Zhumagulov A.S., Ismailova J.A. Geological and geophysical studies and exploratory drilling of paleozoic sediments in the Tasbulak graben – Astana: Oil and gas. V6, № 138, 2023, pp. 32-42, ISSN 1562-2932 (Print), ISSN 2708-0080 (Online) https://doi.org/10.37878/2708-0080/2023-6.08