ABSTRACT

for the thesis for the degree of Doctor of Philosophy (PhD)
in the specialty "6D070600 – Geology and exploration of mineral deposits"

Madiyar M. ALIAKBAR

"Petrophysical modeling in study of prospects of the over-salt complex of the southern margin of Caspian depression"

The relevance of the studies is determined by their focus on improving the accuracy of estimates of the parameters of oil and gas reservoirs, through the use of results of a comprehensive analysis of geophysical data and laboratory core studies, which allow to simulate spatial patterns of changes in the properties of complex reservoirs. This significantly increases the reliability of determining the calculated parameters of productive horizons and technological characteristics of operational facilities.

Research purpose. Development of a scientific-methodological basis for petrophysical modelling of heterogeneous terrigenous reservoirs to increase the geological information content and reliability of constructing geological-technological models of suprasalt oil and gas fields.

Research tasks. Review and identification of features in the trends of modern petrophysical research in the study of properties and assessment of parameters of terrigenous reservoirs; development of a base of initial geological-geophysical data, ensuring the study of the detailed geological structure and the construction of petrophysical models of reservoirs in Kazakhstan fields; development of methodological support and justification for identifying the properties of terrigenous reservoirs with different filtration characteristics based on petrophysical modelling of well data.

Research objects are the suprasalt terrigenous complexes of the Prorva group of fields, formed in the coastal-marine and marine conditions of the Primorsky zone, located in the south- and south-eastern side part of the Caspian basin.

Factual material. Published and archieved materials from previous years and the latest geological-geophysical data on study methods, types and characteristics of the properties of heterogeneous reservoirs were used. The materials of drilling of exploration and production wells obtained in different years by subsoil users engaged in the search, exploration and development of oil and gas fields within the fields of the Prorva structure were analyzed.

Research methodology. The main methodological approach to studying the heterogeneity of terrigenous reservoirs was based on results of a detailed study of filtration-reservoir properties of reservoir rocks in the S. Nurzhanov and Western Prorva fields. Petrophysical modelling was carried out on representative collections of core samples, processed by methods of mathematical statistics; analysis of well survey data in the environment of modern computer programs. The variability parameters (coefficients of layer-by-layer and zonal heterogeneity) of filtration-reservoir properties and their influence on the nature of logging diagrams

were determined. The degree of differentiation of filtration-reservoir rocks was obtained upon establishing the distribution patterns of porosity and permeability, the influence of the content of clayey and silty material on filtration-reservoir properties and geophysical parameters.

Main scientific results. Analysis of well logs for more than 30 wells showed that productive horizons are confined to terrigenous deposits of the Upper Jurassic, Middle Jurassic and Middle Triassic, characterized by a high degree of dissection of productive strata and heterogeneity of reservoirs. Lithologically productive strata are represented by alternating sandstones, clayey siltstones and mudstones. According to core data, the reservoirs are fine- and close-grained clayey sandstones. They are characterized by lithological irregularity and high clay content. The coefficient of dissection varies between 1-3, averaging 1.2; sandiness coefficient is in the range of 0.2-1, on average 0.61.

The scientific novelty lies in the substantiation of geophysical criteria for studying the heterogeneity of terrigenous reservoirs of the Provinsky type: filtration properties have been differented upon analysing the traditional well survey complex and petrophysical modelling as per additional connections between clay content and porosity, clay content and permeability, porosity and permeability.

Practical significance. Detailed petrophysical studies can increase the stability of the forecast of parameters of terrigenous reservoirs of suprasalt complexes when solving inverse problems of geophysics, especially in fields at a late stage of development, in peripheral areas of fields, in poorly studied areas and new regions of Kazakhstan.

The main protected provisions submitted for defense:

1. The built-up database of hydrocarbon fields in Kazakhstan under the control of the developed application “DBMS Oil&Gas Resources" (OGR), installed on the file server of the Department of Geophysics of KazNRTU, ensured the generalization, processing and interpretation of geological, geophysical and field information on the fields of the Prorva group at a high quality level.
2. The use of scientifically based methods for constructing petrophysical models, based on the results of a comprehensive analysis of core material, interpretation of well logs and field data, has made adjustments to the understanding of the geological structure, increased the quality of determining the calculation parameters for building up and assessing the remaining oil reserves of the fields S. Nurzhanov and Zapadnaya Prorva.
3. The macroheterogeneity of the productive horizons of the Prorva group of deposits is determined by their association with terrigenous deposits of the Upper, Middle Jurassic and Middle Triassic horizons, characterized by a high degree of dissection of productive strata and heterogeneity of reservoirs. Lithologically productive formations are represented by alternating sandstones, clayey siltstones and mudstones. The reservoirs are silty-sandy rocks separated by clayey deposits.
4. A model was proposed of a intermittent oil reservoir having layer-by-layer and zonally-heterogeneous filtration properties. Taking into account the deposit parameter “the non-reservoir share” in terms of the area of strata and layers and

zonal heterogeneity in specific productivity significantly increases the reliability of the assessment of calculation parameters and technological development characteristics for complex reservoirs.

Publications. There are 8 works published on the dissertation theme: 3 articles in a journal with a non-zero impact factor (quartiles Q2), 2 articles in journals recommended by the RK MES, 3 articles in the proceedings of scientific international and republican conferences.

Structure and scope of the dissertation. The dissertation is presented on 165 pages of computer-typed text and consists of an introduction, 5 sections, and a conclusion, as well as 90 figures and 12 tables. The dissertation includes a list of 169 sources utilised.

Chapter 1. *Prospects and main directions of oil exploration work in the suprasalt complex of the Kazakh part of the south of the Caspian basin.* A review of factual material on oil and gas content and the structure of the suprasalt complex on the territory of the depression and a critical analysis of the history of exploration work both in already discovered fields and in areas that gave negative results showed that the oil-bearing potential of suprasalt Mesozoic deposits has not been fully disclosed, and there is the possibility of significant further discoveries. In recent years, the focus of oil and gas exploration on suprasalt sediments, mainly Upper Permian-Triassic, has led to discovery of a number of new fields.

Chapter 2. *Brief historical review of petrophysical studies of complex terrigenous reservoirs.* Analysis of existing approaches to constructing petrophysical models of complex terrigenous reservoirs enabled the applying of a reservoir heterogeneity assessment method to the Prorva group of fields using well logging and core data, determining the content of various types of distribution of clay matter (scattered, layered and structural), studying the ratio of the coefficients of total porosity, volumetric clay content and permeability.

CHAPTER 3. *Conditions of formation and patterns of spatial distribution of natural reservoirs in the suprasalt complex of the Prorva oil and gas zone.* The Prorva group of deposits is a weakly disturbed structure of the Mesozoic-Cenozoic complex, associated with a weak manifestation of salt tectogenesis. The structure has several peaks along Jurassic and Triassic deposits with a single water-oil contact. According to new 3D and 2D seismic studies, a wider development of tectonic disturbances is observed at the Triassic level than in the Jurassic. In the fields, drilled wells exposed a thickness of Paleozoic-Meso-Cenozoic sediments up to 3530 m thick. In its section, rocks of the Permian, Triassic, Jurassic, Cretaceous, Paleogene, and Quaternary systems were identified. Characterized by widespread development of disjunctive faults, high heterogeneity of reservoirs in area and section. Productive horizons in the Jurassic lie at depths of 2175-2775 m, in the Triassic at 3104-3337 м. Deposits in fields of the type of natural reservoir are layered, domed, tectonically and lithologically shielded. Lithologically productive formations are represented by alternating sandstones, clayey siltstones and mudstones. The reservoirs are characterized by lithological irregularity and high clay content.

Chapter 4. *Development of a petrophysical model of heterogeneous sandy-silty reservoir rocks.* The main methodological approach to study the properties of terrigenous reservoirs of the S. Nurzhanov and Western Prorva fields was based on the results of a detailed study of the filtration-reservoir properties of sandy-silty reservoir rocks, using petrophysical modelling on representative collections of core samples, processing them by methods of mathematical statistics; analysis of well survey data in the environment of modern computer programs. To represent the structure of terrigenous reservoirs of the Prorva group of fields, a model of the textural heterogeneity of reservoir rocks was adopted as a conceptual one, characterized by thin layering and interlayering of sandy, siltstone and clayey varieties. At that, the type of distribution of clay matter in the rock was taken into account: layered clay or interlayers of clay in sandstone. An important component was to establish the influence of the content of clayey and silty material on the filtration-reservoir properties and geophysical parameters of sandy-siltstone-clayey rocks that make up the main productive horizons of the fields of the Prorva group.

Chapter 5. *Petrophysical models and prospects for their use in the fields of the Prorva group.* The study of macro- and microheterogeneity of reservoirs according to core and well logging data showed that the texture of the sandstone is layered-lenticular, intensively disturbed by bioturbation processes.

For Jurassic productive horizons, the coefficient of dissection, determined upon analysis of data from 30 wells, is quite high and varies from 1.3 for Yu-II to 2.5 for Yu-V.

The Yu-II horizon have the highest reservoir properties (23% according to core and 22% according to well logging). It is characterized by a sharp differentiation of sandiness, and, consequently, the capacitive properties of both Jurassic and Triassic productive horizons. In this case, the variation in the open porosity of reservoir rocks occurs in a narrow range of 18-22%. The sandiness coefficients have fairly high values for the Jurassic horizons. In Triassic horizons, sandiness coefficients vary widely, from 0.1 to 0.9.

According to the filtration characteristics, the reservoirs of the Triassic productive section are significantly worse than the Jurassic ones. The porosity of Triassic reservoirs, determined from core, varies between 11.0-29.0%, averaging 18%. According to the well log data, the average porosity value ranges from 15.9 (T-V horizon) to 22.5% (T-I horizon). The separation coefficient determined from the analysis of data for 23 wells reaches 2.2 with high values of the coefficient of variation reaching 0.82 compared to Jurassic reservoirs of 0.35.

Analysis of the standard porosity-permeability relationship showed that the permeability of reservoirs varies over large ranges, due to textural heterogeneity, a high degree of layering and clay content. A wide spread of the relative permeability parameter indicates the heterogeneity of reservoirs. With a slight variation in the porosity coefficient (18-22%), the relative permeability coefficient varies widely (more than 300 mD), which indicates lithological heterogeneity, thin layering and high clay content of complex reservoirs of both Jurassic and Triassic complexes. Reservoirs of Triassic productive horizons are characterized by

increased carbonate content, which also significantly reduces reservoir properties due to high permeability anisotropy.

Basing on geological structure and type of the collectors. a model of layer-by-layer and zonally heterogeneous in permeability and at the same time intermittent oil reservoir was proposed as a reservoir calculation model for determining technological development indicators. According to this model, an oil reservoir is represented by a set of layers of different permeability. Within each layer, zones are identical in shape and size, but differ in permeability. Within an individual zone, reservoir properties persist and change from zone to zone.