ANNOTATION

of thesis for the degree of Doctor of Philosophy (PhD) in the specialty "8D07104 - Oil, gas and ore geophysics"

Sabina Kudaibergenova

Modern technologies of geodynamic monitoring in the study and mapping of rapidly changing natural and technogenic processes in hydrocarbon deposits

The relevance of the thesis work is determined by the complexity, systematicity and multifactoriality of the problem of geodynamic safety of subsurface development in RK, which, firstly, determines the need for more in-depth study of the formation conditions of rapidly changing natural-technogenic events, given the great diversity of geodynamic and environmental risks, and, secondly, requires significant development of approaches to timely identification of these risks, as well as real assessments of the consequences of seismic deformation processes on p

In turn, this causes the urgent need to use a systematic approach with the application of theoretical, modeling, expert and other types of research on the results of geodynamic monitoring.

The objects of research are the oil and gas fields under development in Western Kazakhstan, the Russian Federation and foreign countries.

Subjects of research are variations of gravity, electrical resistivity of rocks, parameters of seismic and deformation processes, as well as anthropogenic processes in the near-surface part of the geological section.

Methodology - synthesis and system analysis, re-processing and re-interpretation, modelling of geological and geophysical data using modern software based on the results of a set of methods covering high precision gravity monitoring, electro-tomography, vertical electrical sounding, electromagnetic field formation sounding, frequency sounding, repeat accurate leveling, GPS measurements (partly radar interferometry and seismological monitoring).

Research tools are Grapher, Surfer, Didger (USA, Golden Software), ArcGIS&Esri (USA), COSCAD 3D, SiBER Tools (Novosibirsk, RF), RES2D (Geotomo softwear, Malaysia), Era, EMS (INGG SB RAS) and ZondTEM1D, etc.

Objective - on the basis of long-term monitoring of rapidly changing natural-technogenic processes associated with abnormal changes in geophysical field parameters (gravity, electrical resistivity) and associated deformation geodynamic parameters (subsidence, horizontal shifts, earthquakes) to study the features (patterns) of natural-technogenic seismo-deformation processes at hydrocarbon fields under development.

Tasks to be solved:

- collection, analysis and synthesis of available stock materials, published domestic and foreign literature, compilation of analytical reviews of the occurrence of deformation and seismic events at hydrocarbon fields under development;

- Analysis of methods, instrumentation and methodology for conducting geological and seismic surveys;

- evaluating the reliability of DB on complex geological and geophysical measuring of modern natural and technogenic processes at hydrocarbon fields;

- identifying patterns of occurrence and spatial and temporal development of various forms of natural-technogenic subsurface geodynamics;

- conducting geodynamic zoning of the hydrocarbon fields' territory - detection of the geodynamic risk zones and areas by a complex of geological and geophysical and geodesic research methods;

- substantiation of recommendations on optimisation of the complex GDM for solving tasks on siting of systems and facilities at hydrocarbon fields, which will allow avoiding possible emergency situations related to the geodynamic factor.

Protected provisions:

1. At the developed hydrocarbon fields, the presence of a technogenic factor manifests itself in the vault of local structures by a decrease of the local component of the gravity field, accompanied by an increase in the amplitude of vertical subsidence of the day surface and a decrease in reservoir pressure.

2. Relatively low values of gravity field anomalies correspond to zones of seismo-deformation processes (in the form of earthquake centers and zones of fault activation as a result of increased hydrocarbon production), which are associated with land surface subsidence and decreased reservoir pressure.

3. Integrated research by means of gravity survey, electrical survey and laboratory examination of core samples makes it possible to reveal zones of suffosion-karst sinkholes formation as a result of combined manifestation of surface factors and deep tectonics.

4. The system of monitoring by geological-geophysical and geodesic methods in the study and mapping of natural-technogenic seismo-deformation processes requires continuous improvement in methodology and instrumentation.

Scientific novelty of dissertational research consists in the analysis of long-term measurements and in generalization of methodology of complex monitoring of geophysical and geodynamic processes of earth crust in areas of oil and gas production with an assessment of man-made changes in the upper crust and their consequences; in establishment and confirmation of general and local features of oil and gas production influence on geodynamic processes and seismicity; in substantiation of a complex of geophysical methods as a part of gravity survey and electrical survey at study of suffosion-carbon dynamics of the earth crust. On the basis of the executed researches the modern technology of control of anthropogenic changes in dynamics of earth crust on the developed hydrocarbon fields by creation of geodynamic polygons is offered.

Practical Significance - the received conclusions confirm a principal possibility of the estimation of various scenarios of geodynamic situations and the ecological risks connected with development of hydrocarbon fields, are recommended measures for the purpose of reduction of these geodynamic risks.

The results of the thesis research are of practical interest for the companies carrying out operational and service activities at hydrocarbon fields in Kazakhstan.

Approval

Main scientific positions of dissertational work were reported at the international forum "Carbonate basins of Kazakhstan and adjacent territories" (Turkestan, May 2022), at international scientific conference "Fundamental and applied aspects of geology, ecology and chemistry using modern educational technologies" (Almaty, February 2022).), at the 17th Conference of the European Association of Geoscientists and Engineers (Gelendzhik, April 2021), at SMU IG&NGD (April 2021, January 2023.), at SMU SU (January 2023), at the Institute of Seismology Ministry of Emergencies RK (January 2023).), at the Department of "Surveying and Geodesy" (January 2023.), at the International Center for SU field analysis and development (February 2023.) and at internal departmental meetings.

From April 6 to 30, 2022 a research fellowship was conducted at Erciyes University, Kayseri, Turkey under the supervision of Prof. Dr. Abdurahman Gaimen.

The main provisions of the thesis have been published in 9 scientific papers, including 4 articles published in the journals included in the database Scopus and Web of Science, 1 article in other scientific journals and publications, 4 publications - in the published proceedings of international conferences, Kazakh and foreign.

Structure and scope of the thesis

The thesis is set out on 174 computer typed pages and consists of an introduction, seven sections, a conclusion and a list of references comprising 201 titles. The thesis is illustrated with 45 figures and 7 tables.

Factual base

Factual base of the dissertation research included published materials of the author's research, published articles and monographs in domestic and foreign editions, as well as stock reports on the dissertation subject.

In the first chapter, taking into account the target area of research characterized natural and man-made destructive factors of geodynamic and geoecological risks in areas of intensive hydrocarbon production in the volume sufficient to understand the subsequent presentation of the work.

In the second chapter materials on modern geodynamics of platform areas, on formation and development of ideas on geodynamic activity of oil and gas-bearing areas are stated in detail. Of particular interest is an analytical review of the occurrence of seismo-deformation events in the developed hydrocarbon fields, illustrated by various drawings of the manifestation of the modern geodynamics of the subsurface and a summary table. Examples of negative consequences of manifestation of strong seismo-deformation events at hydrocarbon fields are given and the main regularities of occurrence and development of geodynamic events are revealed. Four possible models of formation of anthropogenic and anthropogenic-induced seismicity are substantiated by generalization of the results of seismological monitoring at the hydrocarbon fields under development.

The third chapter is devoted to the study and analysis of foreign and domestic experience in organizing and conducting geodynamic monitoring of the

subsurface at hydrocarbon fields. The chapter shows and describes in detail a history of geodynamic researches in Kazakhstan, the Russian Federation and far-abroad countries (the priority belonged to fields of the USA, France and others) concerning development of geodynamic polygons. The main attention is concentrated on a complex of methods including repeated high-precision gravimetric, repeated accurate leveling and GPS-measurements, partly seismological and space monitoring. The important role of complex approach to creation of geodynamic polygons and geodynamic monitoring is shown, it is proved that all positive experience of works in various aspects of solution of this problem can be used in conducting geodynamic monitoring and interpretation of results in the Republic of Kazakhstan.

The fourth chapter provides brief information on the geological structure and tectonics and other features of the studied objects. Generalized information on the geological structure of the Karachaganak oil and gas condensate field (KOGCF) and gas-oil field Bozashy North (OGFBS) is given in the composition and volume, which allowed formulating the geodynamic risk factors of natural genesis in order to justify the methods of geodynamic observations. Description of the geological structure is made using the Atlas of Oil and Gas Fields of the Republic of Kazakhstan (Turkov O.S. et al., 2020).

The fifth chapter is devoted specifically to the methodology and instrumentation of geodynamic monitoring at hydrocarbon fields in Kazakhstan. The chapter consists of three sections. In the first section, a reasonable allocation of four information interrelated subsystems: geophysical, seismological, deformation and fluid-geochemical, in the form of a table collected and presented detailed information on the types and scope of geodynamic monitoring in the fields of hydrocarbon deposits of Kazakhstan. The accuracy of the executed works is characterized. The second section presents the methodology of geodynamic monitoring on the example of KOGCF and OGFBS, where repeated: gravimetric measurements, levelling of II class of higher accuracy and GPS observations were carried out. In addition to the above-mentioned basic methods, for these hydrocarbon fields, the thesis partly used data on seismological observations, radar interferometry and specific electrical exploration methods (electrotomography, vertical electrical sounding, electromagnetic field formation sounding, frequency sounding). Information is given on the reprocessing of digital material to assess the validity of the results obtained by each method. The third section presents advanced technologies in geodynamic monitoring. It is shown that obtaining reliable data on the geodynamic state of monitoring objects and solving problems of geodynamic monitoring is provided by reliable, trouble-free functioning of measuring and information-communication monitoring systems. As the basic principle of creation of GDM system is unification of the applied equipment, methods of measurements and processing of the received information, the important role of conformity of the applied hardware to the set tasks is shown.

The sixth chapter formulates groups of geodynamic risk factors in the development of hydrocarbon fields, these are tectogenic (natural) and anthropogenic, associated with the development of fields. The content of the

section provides indicators and parameters of modern natural-technogenic geodynamics of the subsurface in the developed hydrocarbon fields of the RK. All geodynamic risks are considered through the prism of the Karachaganak oil and gas condensate field and the Bozashy Severny gas and oil field. The section is devoted to the study and analysis of geodynamic parameters (gravity variations, seismicity, vertical movements of the day surface, horizontal movements) and factors of Suffosion-Karst processes development in the territory of Karachaganak Field on the basis of detailed study of all previously conducted geological and geophysical surveys in the area of Suffosion-Karst formations of Karachaganak Field development. For OGFBS the results on the integrated analysis of geodynamic monitoring are shown, illustrated by the graph of current vertical movements of the day surface, gravity variations, volumes of oil, gas and fluid production, fluid injection and reservoir pressures (Fig. 6.20) and a comparison of the observations of ground-based instrumental and remote methods is made and their high convergence is established (Fig. 6.21). It is concluded that radar surveys may gradually become a key source of obtaining conditioned information on vertical displacements of the day surface and, if not completely replacing leveling, may reduce the volume of the labour-intensive method.

The seventh chapter contains conclusions and recommendations for further geodynamic monitoring at KOGCF and OGFBS. The analysis of the results of the comprehensive geodynamic monitoring (repeated high-precision gravity measurements, seismological monitoring, accurate leveling, high-precision satellite (GPS and radar) measurements) has shown that in the territory of the West Kazakhstan HCF fields, significant variations of gravity and earth surface movement in time and space associated with the HCF production processes and fluid injection into productive formations to maintain reservoir pressure and increase oil It is assumed that the uneven volume of production and variability of the reservoir rock properties on the territory of hydrocarbon fields leads to a complex process of spatial and temporal variations of geodynamic parameters and the causes of movements of the Earth's surface are caused by natural-technogenic factors.

Based on the results of investigations of suffosion-karst phenomena by means of area gravimetric and electrometric surveys (vertical electrical sounding, electromagnetic sounding, electromagnetic field sounding) the locations of zones of potential development of subsidence are predicted. Cross-sections and maps of electrical resistivity distribution at different depths, three-dimensional geoelectric models for both near-surface and deep parts of the investigated area are given. As a result of geological interpretation of the data, zones (according to the resistivity parameter), to which the existing sinkholes are confined, and the direction of outcrop of destroyed (eroded) rocks were determined. The structures associated with the zones of development of suffusion and subsidence processes are identified and the possible causes of their formation are formulated. The effectiveness of a set of electromagnetic methods used in the area with destructive phenomena has been proved.

As a result of the conducted research, it was concluded that the main mechanism of sinkholes formation is connected with washout of limestone and salt "cement" from Neogene-Quaternary sediments, with further unloading into deeper watered horizons. It is recommended that this set of works may be used for solving similar problems in other regions, where there are zones of suffosion processes manifestation, as well as for monitoring of their development. The results are justified on the basis of analysis and comparison of the electrical survey data with a priori geological data.

Thus, the thesis research indicates that the proposed results of the integrated monitoring of seismo-deformation processes at hydrocarbon deposits may become an effective method of geodynamic safety in the general system of management and control over the development of these deposits, as well as in the system of subsurface and environmental protection.