Forecasting of reservoir pressures of oil and gas bearing complexes in northern part of West Siberia for safety oil and gas deposits exploration and development

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Abstract. In the paper the features of reservoir pressures changes in the northern part of West Siberian oil-and gas province are described. This research is based on the results of hydrodynamic studies in prospecting and explorating wells in Yamal-Nenets Autonomous District. In the Cenomanian, Albian, Aptian and in the top of Neocomian deposits, according to the research, reservoir pressure is usually equal to hydrostatic pressure. At the bottom of the Neocomian and Jurassic deposits zones with abnormally high reservoir pressures (AHRP) are distinguished within Gydan and Yamal Peninsula and in the Nadym-Pur-Taz interfluve. Authors performed the unique zoning of the territory of the Yamal-Nenets Autonomous District according to the patterns of changes of reservoir pressures in the section of the sedimentary cover. The performed zoning and structural modeling allow authors to create a set of the initial reservoir pressures maps for the main oil and gas bearing complexes of the northern part of West Siberia. The results of the survey should improve the efficiency of exploration drilling by preventing complications and accidents during this operation in zones with abnormally high reservoir pressures. In addition, the results of the study can be used to estimate gas resources within prospective areas of Yamal-Nenets Autonomous District.

1. Introduction

Reservoir pressure is a pressure that formation fluids provide on the enclosing rocks. This is an important parameter characterizing the energy of oil and gas bearing complexes [1]. Information about the expected value of the reservoir pressure is the basis for the effective opening of productive deposits during drilling. Information about the pressure of subsurface conditions also is used in the design of the hydrocarbon deposits development.

There are the normal and abnormal reservoir pressures. The normal reservoir pressure corresponds to the hydrostatic pressure created by a column of water with the height from the ground to the depth of the producing formation. Abnormal formation pressures are characterized by deviations from the normal reservoir pressure [2].

Hydrostatic pressure is calculated as the product of the fluid density at the height of the fluid column. Mathematically, it is expressed as (Formula 1):

$$P_{hyd} = \rho g H \quad (1)$$

P_{hyd} - hydrostatic pressure, MPa; ρ - density of the liquid, g/m^3; g – gravity acceleration (9.81 m/s^2); H - the depth of the reservoir, m

Abnormal reservoir pressures are divided as abnormally high (AHRP) and abnormally low (ALRP). AHRP and ALRP are divided according to the measure of anomaly ratio (K_a). If $K_a \geq 1.3$ the pressure is abnormally high and abnormally low [3] if $K_a \leq 0.8$. K_a is calculated as (Formula 2):

$$K_a = \frac{P_m}{P_{hyd}} \quad (2)$$

P_m - measured reservoir pressure, MPa; P_{hyd} - hydrostatic pressure, MPa.

AHRP are most often noted at depths about 3.5-4.0 km. Usually AHRP exceed hydrostatic pressure by 1.3-1.8 times, rarely - by 2.0-2.2 times.

Abnormally high reservoir pressures are caused by many geological factors. The main reasons for their formation are connected with the seal of clay rocks, osmosis processes, catagenetic transformation of rocks and geothermal subsoil conditions. According to some researchers, the most important factor is, apparently, the temperature factor, because coefficient of the thermal expansion of fluids enclosed in isolated pores is much greater than thermal expansion coefficient of minerals rocks [4].

The AHRP zones located at great depths are characterized by regional distribution and are favorable from the point of view of localization of large oil and gas deposits [5]. The presence of AHRP in productive deposits positively affects their reservoir properties, increasing the time of the oil and gas fields natural development without using secondary intensification techniques. On the other hand, AHRP is a source of accidents during drilling [6]. Quantification of abnormally high reservoir pressures is an extremely important aspect of oil and gas exploration.

2. Obtained data and analysis.

In this paper are analyzed the features of the initial reservoir pressure distribution in the plan and in the section of the sedimentary cover in the northern part of West Siberia (Yamal-Nenets Autonomous District). For this study, authors used results of reservoir pressure measurements obtained from highly productive wells in the study area. The materials of hydrodynamic studies performed in prospecting and exploration wells of more than 200 oil and gas fields, opened within Yamal-Nenets Autonomous District are used.

The results of obtained data analysis show that reservoir pressure in the upper productive part of the section, folded with rocks of Aptian-Cenomanian age are typically hydrostatic and vary within the range 7.8 (718 m) to 16.9 (1738 m) MPa. A similar trend can be seen in the upper and middle parts of the Neocomian complex in the depth interval from 2300 to 3000 m, where pressures vary from 22.8 (2313 m) to 33.0 (3123 m) MPa.

ALRP of natural origin within the northern part of West Siberia are not observed. The minimum reservoir pressure anomaly coefficient equal to 0.9 is located in the Utrennee gas field. True ALRD (K_a<0.8) associated only with deposits that are in the late stages of development, and therefore have an anthropogenic genesis.

AHRP widespread in Jurassic sediments in Yamal-Nenets Autonomous District, as well as at the bottom and, in some cases, in the middle parts of the Neocomian productive complexes. AHRP can be noted in the depth interval of 1900-2100 m (Kharasaveyskoye and Bovanenkovo fields). It should be noted that the development of abnormal reservoir pressure in the middle part of Neocomian complex is a local process [7].

Anomaly ratio of reservoir pressure in the bottom of sedimentary cover (the bottom of the Neocomian and Jurassic productive complexes) increases from the south (the territory of Malopyakutinskoe and Vyngapurskoe fields, K_a = 1.1-1.3) to the north, in the direction of the central areas of the Nadym-Pur and Pur-Taz Oil and Gas Bearing Area (the territory of Urengoy and Yamburg oil and gas fields) (K_a = 1.9-2.0).

3. Zoning and forecasting of reservoir pressures features

The authors performed a Yamal-Nenets Autonomous District territory zoning according to the features of reservoir pressure changing both in the area and in sedimentary cover section, taking into account the peculiarities of the area tectonic construction. The territory was divided into 33 zones. The changes of abnormal and hydrostatic pressures with the depth in these zones are approximated by two linear equations (Formula 3):

$$P_r = aH \pm b \tag{3}$$

P_r - reservoir pressure, MPa; H - the depth of the reservoir, m; a and b - dimensionless numerical coefficients.

The first equation corresponds to the upper Aptian-Cenomanian part of the sedimentary cover. Within the most part of the Yamal-Nenets District territory, the reservoir pressure in this interval of the section is equal to the hydrostatic pressure.

The second equation describes a pattern of increasing of AHRP according the depth in the sediments of the Jurassic and Neocomian complexes.

The obtained equations make it possible to determine the initial reservoir pressure within areas that are not characterized by the exploration drilling. In addition, the list of equations allow determining the position of the upper boundary of the AHRP.

The figure 1 shows the results of the reservoir pressure measurements in Jurassic and Neocomian deposits for zones 1, 2, 8, 18 and 26. Zone 1 and zone 2 represent the northern and western territory of Yamal peninsula. Zone 8 equal to the southwestern part of Yamal-Nenets Autonomous District. Zone 18 characterize the territory of Nadym-Pur-Taz interfluve. Zone 26 is a part of southern territory of Yamal-Nenets Autonomous District. It can be seen from the graph that within the zone 8 the AHRP is not observed. For zone 1, the AHRP upper boundary lies at depth of 3100 m, for zone 2 - 1700 m, for zone 18 - 3300 m and about 3000 m for zone 26.

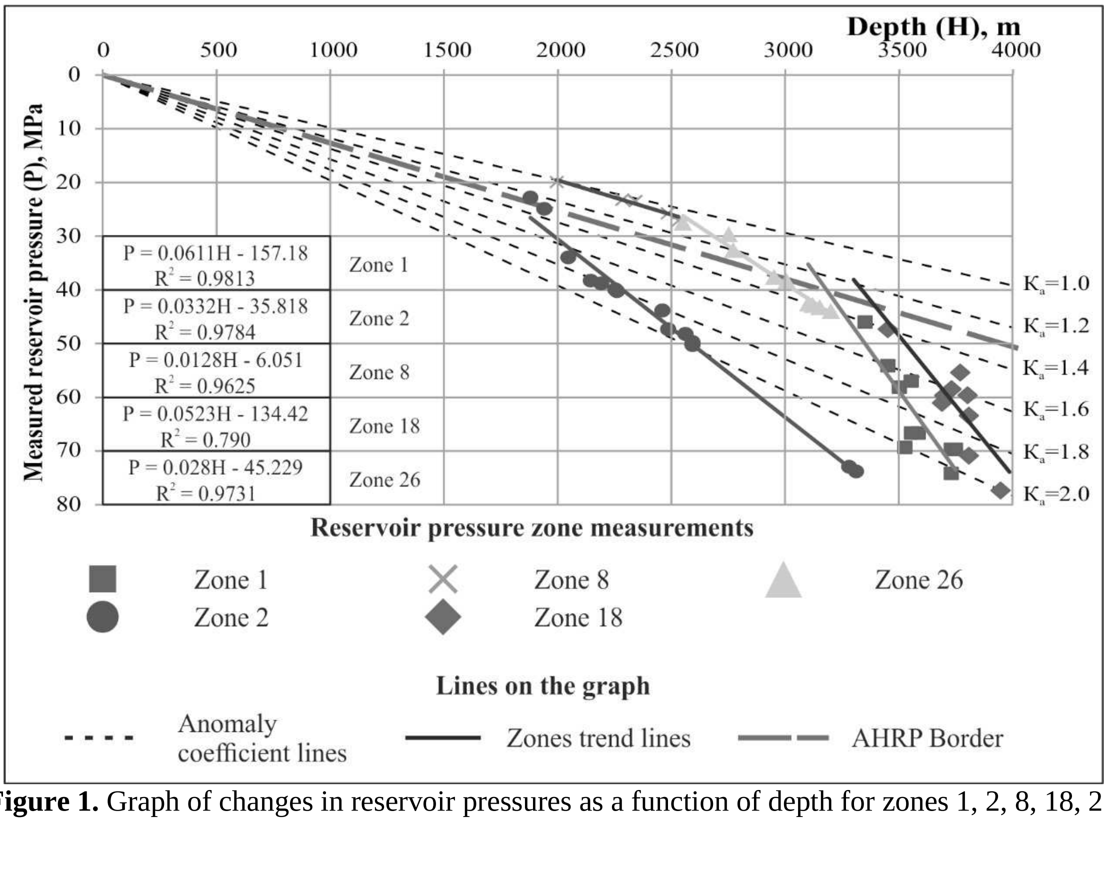

Figure 1. Graph of changes in reservoir pressures as a function of depth for zones 1, 2, 8, 18, 26

The identified patterns of reservoir pressures are the basis for the regional forecast of barometric conditions of oil and gas complex in the study area. To solve the problem of pressure prediction, the authors created a set of regional structural maps of scale 1: 500 000 for tops of Cenomanian, Aptian, Jurassic and Neocomian productive complexes within Yamal-Nenets Autonomous District [8].

At the next stage, the structural surfaces obtained were converted into the maps of the initial reservoir pressure of the basic productive complexes tops. The conversion was carried out on the basis of the Yamal-Nenets Autonomous District zoning according to the features of reservoir pressure. One of the maps that show the reservoir pressures changes in the Aptian productive complex is represented in figure 2

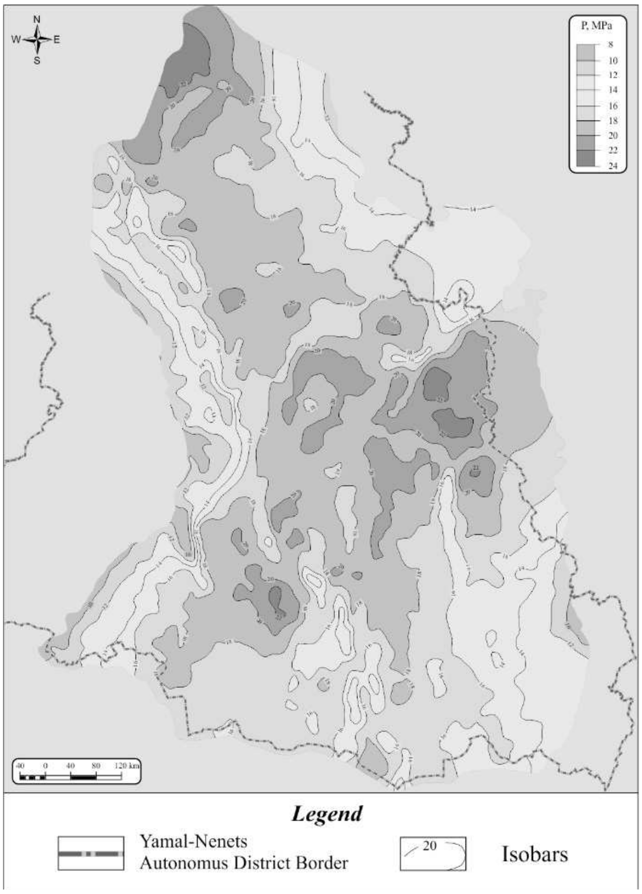

Figure 2. Map of the reservoir pressures in the Aptian productive complex

4. Conclusion

The identified patterns of reservoir pressures and the maps of the initial reservoir pressures allow one to perform a preliminary assessment of the gas resource of prospective structures, identified by the the seismic survey results. In addition, this information is extremely important for the mud parameters calculation for the exploration of oil and gas deposits within the territory of Yamal-Nenets District. The correct calculation of the mud parameters should increase the safety of drilling operations by preventing accidents associated with AHRP.

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