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COMPARATIVE ANALYSIS OF CORE TESTING RESULT FROM DEEP WELLS WITH ELECTRICAL LOGGING DATA

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Abstract

The electrical properties of wet rocks from the Saatli well, taken from a depth of 5-7 km, were studied at high pressures and temperatures.

Through a comparative analysis of the curves constructed from laboratory measurements and electrical logging data their differences were revealed at depths below 6 km, which could not be compensated by the laboratory modeling method. Thus, it was concluded that the identified difference may be associated with lower saturation of rocks under natural stratification conditions due to the replacement of water with the gas phase. Criteria for identifying the boundary of transition from “wet” to “dry” crust have been determined, which poses the need for a fundamentally new approach to the geological interpretation of electrical exploration data below and above this boundary.

Keywords: ultra deep well, electrical resistance, high pressure and temperature, electrocarotage, high temperature and pressure setting, moisture saturation, chemical content.

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The question of the degree to which laboratory parametric measurements of the physical properties of rocks correspond to their exact characteristics remains relevant to this day. The difficulties that arise in solving it are explained both by the complexity of the object under study and by the integral nature of geophysical information about the properties of the substance of the Earth's core. The expansion of the network of deep and ultra-deep wells, together with the organization of geophysical field and laboratory studies, opens new opportunities in assessing the relevancy of the quantitative use of laboratory material when interpreting field observation data.

The purpose of this work is to study the correspondence of laboratory modeling data of electrical characteristics taking into account the thermobaric conditions of occurrence of core material to lateral electrical logging data (on the example of Saatli DW-1).

The solution to this problem involved the creation of a special installation that would make it possible to simulate reservoir formations most accurately in laboratory conditions, that is conducting research at high pressures and temperatures, taking into account the hydrodynamic condition of rock occurrence.

It is known that experimental petrophysics is developing in two main directions. One direction is related to solving industrial problems, the other – "large-scale" Geophysics. In the first case, the reservoir properties of sedimentary rocks and their influence on the physical parameters of rocks under the influence of pressure and temperature are studied.

This involves the study of fluid-containing rocks, modeling of lithostatic and reservoir pressures. For this purpose, a hydrostatic method for transferring pressure to the test fluid-containing sample is used, which makes it possible to control pore (reservoir) pressure during experiments.

The limit of generated thermodynamic parameters is usually limited to 250 MPa (confining pressure) and 100 MPa (reservoir pressure) at a temperature of 250-300°C.

When modeling the conditions of deep bedding of rocks (mainly igneous), in relation to problems of "large-scale" Geophysics, quasi-hydrostatic high-pressure installations are used, where the pressure-transmitting medium is a solid body (pyrophyllite, lithographic stone, etc.). This type of installation involves the study of "dry" rocks.

Taking into account the specifics of the geological section of the Saatli superdeep well, it was planned to study moisture-containing volcanic rocks, which excluded the use of the types of installations noted above and required the creation of a new high-pressure installation.

Indeed, when studying moisture-saturated rocks of the sedimentary complex using hydrostatic installations, the presence of pore pressure makes it possible to study the influence of the latter on their physical properties.

The mechanism of the noted effect is that at high reservoir pressures, partial compaction of the solid skeleton of reservoirs occurs, and consequently an increase in pore space. A decrease in the volume of the solid skeleton of the rock, in turn, helps to reduce their electrical resistance and elastic wave velocities.

Correct assessment of the relationship between lithostatic and reservoir pressures during laboratory studies, along with the taking into account the specific depth of sampling of core material, can significantly increase the efficiency of electrical and acoustic logging methods.

Unlike highly porous reservoirs, the studied volcanic rocks have a total porosity of several percent [n≤3%]. Thus, their influence on the hard skeleton when simulating depths of 5-7 km is negligible. Consequently, when studying the physical properties of volcanic rocks, the determining factor is not its pressure in the pore space, but the presence of fluid in the rock.

Thus, for these purposes, the use of bulky and labor-intensive hydrostatic installations is not very effective, and quasi-hydrostatic installations are not sealed, and as a result are not intended for studying moisture-containing rocks at high temperatures.

To achieve the goal noted at the beginning of the article, it became necessary to develop a new high-pressure and temperature installation.

The diagram of this installation, designed to study the electrical properties of moisture-containing igneous rocks under conditions of a hydrodynamically closed system at pressures of 500 MPa and temperatures up to 300°C, is given in Figure 1.

The structure of the installation is based on modernized Bridgman anvils, the distinctive feature of which is the increased working volume of the chamber (Figure 1, matrix- 11) and the use of special hydro- and electrical insulating material as a container (Figure 1, -8) and a medium transmitting pressure.

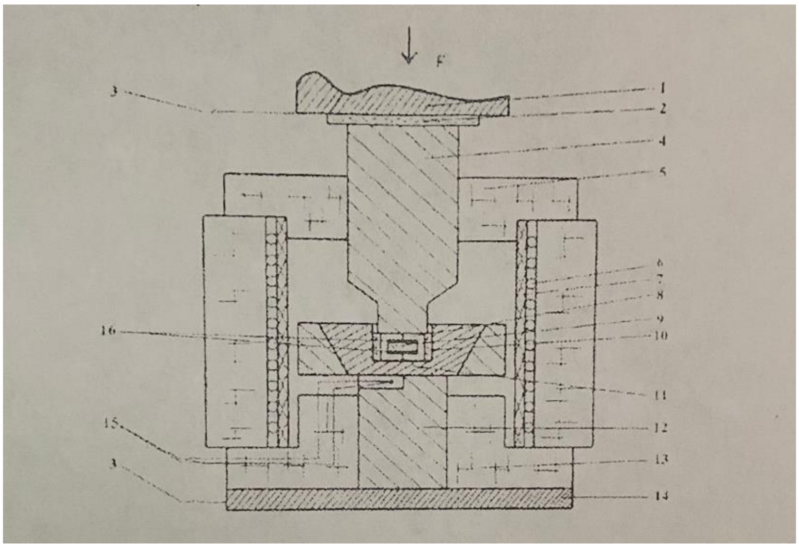

Figure 1. Diagram of high pressure (500 MPa) and temperature installation (300°C).

1 - movable traverse press, 2- asbestos electrical insulating gasket, 3- electrode leads, 4- poisson, 5, 13- heat and electrical insulating sleeves, 6- heater winding, 7- quartz tube, 8- container, 9- sample, 10- pyrophyllite disk, 11- matrix, 12- support cylinder, 14- base plate, 15- thermocouple leads, 16- electrodes.

The installation allows experiments with moisture-saturated and crystalline rocks under isobaric and isothermal conditions.

The conditions of the closed system were controlled by weighing the samples before and after the test, as well as by the absence of hysteresis in the graphs of the temperature dependence of resistance (ρ) during heating-cooling peaks carried out in isobaric mode.

12 samples of predominantly andesitic and basaltic compositions, representing the depth range of 4700-700 m, were studied. measurements were carried out in isobaric mode (p = 150 MPa, T = 20-250°C). the optimal pressure value was determined for a depth of 6000 m based on the value of its gradient of 0.0025 MPa/m and was taken as average for the depth interval under consideration. Initially, the samples were saturated with a 20% solution of sodium chloride, the resistance of which at room temperature is ρ_{ϕ} = 0,5 Ohm * m. The latter agrees with the data of other authors [2].

Figure 2 shows a diagram of the change in 1gp with depth, constructed according to laboratory research data(ρ_n), Taking into account temperatures at the corresponding depths. from a comparison of the diagram with a similar curve of changes in apparent resistivity (ρ_a), constructed from lateral electrical logging data, their good quantitative convergence is visible in the depth range of 4700-6000 m. Below 6000 m, the nature of the curves is identical, however, certain discrepancies are observed in the absolute values of resistance, i.e. the convergence is only qualitative. If we consider the lateral logging data to be equally reliable throughout the entire marked depth interval, including below 6000 m, then the reason for the noted discrepancies could be higher pressure gradients along the wellbore than those accepted; lower concentration of pore fluid in natural conditions; or partial dehydration of rocks with possible replacement of water by a high-resistivity gas phase. It should be noted that the depth integral under consideration coincides with the boundary of the transition from basic to felsic volcanics. But due to the weak influence of the chemical and mineral compositions of the high-resistivity rock skeleton on their electrical properties under conditions of fluid saturation, the noted factor cannot determine the observed divergence of the curves ρ_s and ρ_c.

In connection with the above, there was a need to conduct additional experiments taking into account the noted effects or their various combinations that do not contradict the actual conditions of rock occurrence. These issues were studied using the example of sample 5765 (depth interval 6958-6970).

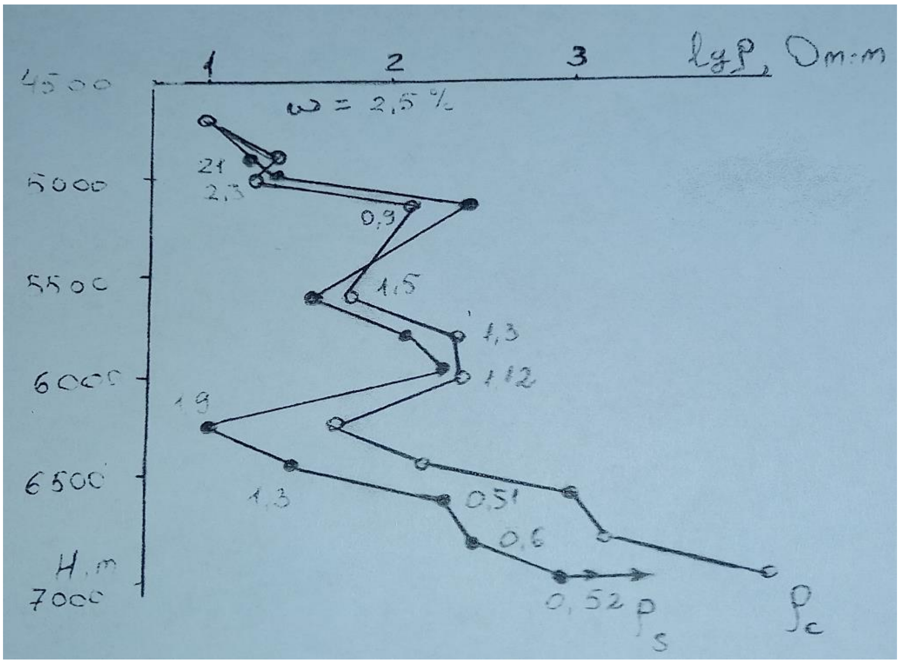

Figure 2. Distribution of electrical resistivity (ρ) with depth (H) along the Saatli DW-1 shaft according to laboratory studies (ρ_c) and lateral electrical logging data (ρ_s): ω - humidity, weight, %

A decrease in the concentration of sodium chloride solution from 20 to 0.3% under other identical thermodynamic conditions led to an increase in resistance at 132°C, corresponding to the sampling depth of a given core, by approximately 25% of the difference of $\lg\rho_c$-$\lg\rho_s$ at this point. Further increased pressure from 150 to 200 MPa led to an increase in $\lg\rho_s$ by another ~20%. Thus, the integral influence of changes in the concentration of saturated fluid and external pressure on the resistance of rocks, presented in the figure as horizontal arrows at the lowest point of the curve ρ_s and ρ_c, under the most favorable conditions, brings the curves closer by only 40-45%. At the same time, the weak dependence of the resistance on the concentration of the pore solution is explained by the fact that under conditions of low porosity, a significant contribution to the electrical transport of moisture-saturated rocks can be made by the mechanism of surface conductivity, which exhibits a similar dependence on the concentration of the solution.

The most likely reason for the observed discrepancy between curves ρ_s and ρ_c may be partial dehydration of rocks under natural conditions, with possible replacement of moisture and a high-resistivity gas phase. This can lead to a significant increase in resistance at the considered depths. Mentioned may be caused due to two processes. The first - by partial dissolution of water during hydrothermal metamorphism. it is known [3] that the latter is characteristic of the phenomena of metasomatism during contact metamorphism or auto metamorphism and is the result of the chemical activity of magmatic solutions. The second is the process of partial "drying" of rocks under the influence of temperature, which assumes the presence of conditions corresponding to a semi-closed system. In the latter case, based on experimental data, it can be assumed that the beginning of the moisture removal process will be shifted to the region of high temperatures and correspond to 120°C (temperature value at a depth of 6000 m). At the same time, the end of the desorption process under consideration will also be shifted to the region of higher temperatures, the lower limit of which is in the range of 150-160°C.

Thus, the interval of 120-160°C may determine the most likely temperature limit of the transition zone from "wet" to "dry" lithosphere. Therefore, the increase in resistance within the consolidated crust, caused by possible dehydration of the rocks, may continue to depths corresponding to temperatures of 160°C and above. Moreover, the narrower the temperature interval for the manifestation of this process, the greater the amplitude of the jump, because the resistance of dehydrated igneous rocks at temperatures of 105°C is of the order of 10^7 Ohm*m, which, compared to the ρ value of moisture-saturated rock №5765, equal to 10^4 Ohm*m, is significantly greater. The obtained data raise the need for a different approach to the geological and geophysical interpretation of electrical exploration materials in conditions of "moisture-containing" and "dry" lithosphere, since in the first case the electrical parameters are determined mainly by the properties of the saturating fluid, structural and textural features of the rocks, and in the second - by their mineral and chemical composition.

Conclusion

The article investigates the electrical peculiarities of moisture saturated rocks from Saatli superdeep well-1, representing the depth interval of 5-7 km, under high pressure and temperatures. With the use of the method of comparative analysis of the curves, plotted according to the data of laboratory measurements and lateral electrical logging, their difference in the depth of lower than 6 km, not subjecting to the compensation under the conditions of laboratory modeling has been established. It was concluded that the difference is the result of partial rock moisture saturation in natural bedding conditions with possible substitution of fluid by gas phase. The main criterions of definition of transfer boundary from "moisture saturated" crust to the "dry" one have been distinguished, which arises the necessity for principally a new approach to geological-geophysical interpretation of electrical prospecting materials over and lower the indicated boundary.

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