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Sh. A. Guberman, M. L. Izvekova, A. I. Kholin, Ya. I. Khurgin

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Abstract

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GEOPHYSICS

Sh. A. Guberman, M. L. Izvekova, A. I. Kholin, Ya. I. Khurgin

USING A PATTERN-RECOGNITION ALGORITHM TO SOLVE PROBLEMS OF PRODUCTION GEOPHYSICS

(Presented by Academician A. I. Berg, 21 X 1963)

As is well known, the tasks involved in studying boreholes by geophysical methods include: a) subdividing the rocks penetrated by the borehole into separate beds corresponding to different lithological varieties; b) identifying beds that contain minerals, and determining their material composition and physical properties; c) correlating beds in the sections of different boreholes from geophysical data in order to solve geological, geophysical, and production problems.

To solve these questions, at present a fairly large number of parameters are measured in boreholes that characterize the beds penetrated by the borehole; in particular: 1) the apparent electrical resistivities of beds when measured with probes of different lengths (the KS method); 2) the spontaneous-polarization potentials of rocks (the PS method); 3) the intensity of natural and neutron-induced gamma radiation; 4) temperature, etc.

Each of the parameters measured in the borehole is an indirect and ambiguous characteristic of the rock properties of interest to us. Therefore, in most cases none of the tasks listed above can be solved from the data of any single method. In this connection, when solving geophysical problems it is necessary to carry out a joint analysis of the entire set of parameters measured in the borehole.

However, existing methods of "manual" interpretation make it possible to carry out such a joint analysis in each particular case only for a small part of the available data, and in many cases this analysis is based on a very schematic conception of the relationships among the readings of individual methods. Naturally, in this process a large amount of information contained in the original data is lost, as a result of which the effectiveness of geophysical work is reduced. Therefore an urgent task in the field of borehole investigation is the development of methods for the comprehensive interpretation of all available geophysical data, making it possible to use to the maximum the information contained in them.

In this respect, the use of advances in cybernetics achieved in the development of the problem of pattern recognition proves to be highly promising. Its essence is that the machine is assigned the task of dividing a set of objects presented to it into several classes. Each object is supplied to the input of the machine in the form of a set of parameters (an input vector). In this case no features that determine in advance the membership of the object in one class or another are built into the machine. The training process consists in showing the machine a certain number of objects belonging to each of the classes. The machine itself develops criteria for dividing objects into classes and subsequently recognizes new objects presented to it.

Such a formulation of the recognition problem makes it possible to regard the task of comprehensive interpretation of borehole-investigation data as a pattern-recognition problem. In this case the task of determining the parameters of a bed from geophysical data may be formulated as follows. There is a set of parameters obtained as a result of measurements in a borehole and characterizing the given bed. From this set of parameters it is required to determine the membership of the bed in one class or another.

Such classes, depending on the problem posed, may, for example, be: clay, sandstone, limestone, etc. (when subdividing rocks by lithology); oil-saturated, gas-saturated, and water-saturated rocks (in the search for oil and gas); beds of low, medium, and high porosity (when determining the physical properties of a bed), etc.

The problem of picking bed boundaries from a set of methods with the aid of a program that recognizes patterns can be solved in the following way: a sequence of input vectors corresponding to successive depths of the section is fed into the machine, and the positions at which its output state changes are recorded, i.e., transitions of the input vector from one class of rocks to another.

Closely related to pattern recognition is the problem of correlating well sections by individual geophysical methods (curves of KS, PS, NGM, GM, etc.), i.e., matching intervals of curves that characterize individual beds or packages of beds. In this case beds in different wells belonging to one and the same stratigraphic formation must be assigned to one class. In the case of correlation using a set of geophysical data, the input vector is formed from the set of curves characterizing the given interval of the section.

In the form in which it was formulated above, the use of a learning program is assumed for solving the purely geophysical aspect of petroleum geophysics problems. Naturally, the results obtained must be correlated with all available geological and production data.

In some cases it may prove expedient to include these data in the initial information presented to the machine.

The pattern-recognition algorithm can be used not only for a qualitative solution of problems, but also for quantitative determinations of bed parameters from the entire set of data, in particular for determining the percentage content of a useful mineral in the rock, the density of the rock, its porosity coefficients, permeability, etc. In this case the classes will differ by a quantitative attribute: to one class, for example, sandstones with porosity from 10 to 12% will be assigned, to another—from 12 to 14%, etc. It is natural to expect that such a problem will be solved by the machine more accurately than it is done at present, when, for determining bed porosity, a single parameter is often used (either ρ_{p}, or U_{sp}, or $I_{\mathrm{n}\gamma}$).

The use of a pattern-recognition program for the integrated interpretation of geophysical data makes it possible to estimate the informativeness of various geophysical methods and to solve the problem of selecting a rational set of measurements in a well.

It should be noted that the informativeness of any method in solving a particular problem depends on the preliminary information obtained in the course of investigating the well by other methods, i.e., on the set that has been used. Such conditional informativeness can be determined by carrying out recognition with the aid of a specified set of methods, and then adding a new method to it and carrying out recognition again. The informativeness of the new method will be assessed by how the number of erroneous conclusions issued by the machine changes.

M. G. Latyshova and E. A. Neiman took an active part in the discussion of a number of questions raised in the present article.

Moscow Institute of the Petrochemical and Gas Industry
named after I. M. Gubkin

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Note: Figure translations are in progress. See original paper for figures.