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POLYMODAL DISTRIBUTION OF CHARACTERISTICS OF OPEN DYNAMIC SYSTEMS AS A SYSTEM ANALYSIS TOOL

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The mode in random distribution is the value that appears most often. It can be identified as a peak on the distribution function graph. Mode characterizes the most typical value of variable. If there is only one mode in the distribution, the distribution is called unimodal. Among unimodal distributions normal, lognormal, binominal and chi-squared distributions are most known and widely used. If there are two or more modes, the distribution is called polymodal (multimodal).

Consider an open system affected by some external factors. Stochastic and deterministic systems are distinguished. Factors affecting deterministic system are known functions thus the state of the system can be unequivocally modelled at any moment of time. However, factors affecting stochastic systems are completely random thus the current state of the system cannot be modelled precisely. To analyze stochastic systems statistical methods are used. One of the most commonly used method is analyzing the probability function graph of the affected by external factors characteristic of the system. Analyzing mode properties and polymodality is one of the tool to define affecting factors. Value of affected characteristic that appear most often can tell of external factor affecting the system on a regular basis or of some stable in time state of a stochastic system that it tends to transit. In its turn, if several most typical values appear in the distribution, the system is unsteady, time variant, and have more than one stable states. Time variant systems affected by external stochastic factors always have polymodal distribution of characteristics but only those that are affected and changed due the factors. To approve this thesis, some results of statistical researches of different types of open dynamical systems such as geological, geochemical, biological and hydrographical are to be considered.

System biology usually implies unimodal distributions such as already mentioned normal, binominal and Poisson distributions. Despite this some researches show that even biological systems are able to have polymodal distribution of some characteristics. For example, researches of lifecycle of Heleobia parchappii snail which are hosts of Diagenea parasites show polymodal distribution of snail sizes [7]. Study was conducted with aim to estimate ecological environment in the region based on these parasites. Polymodality of body size distributions appeared no matter the sampling interval. Influence of parasites and special aspects of genesial cycle were assumed as a reason of polymodality. In the researches of V. Sukhanov and O. Ivanov distribution of size and mass characteristics of epipelagic nekton of the Kurils [1]. During the processing of data, a regularity expressed in their non-uniform (polymodal) distribution was found. Each mode in the distribution form so called guild – a group in ecosystem with similar sizes and mass. Researchers was trying to interpret polymodality from the point of view of previous researches on guilds and their property to form geometric sequence but have not gone any further.

Another huge part of researches using polymodality as an analysis tool is grain size analysis. Initially polymodal distribution of grain sizes of sediments was mentioned by American school of geologists. R Folk and W Tanner in 1964 published works that clearly demonstrate polymodality of sands. This discovery allowed to suggest a new method to model transportation of sediments. Gail Ashley described using cumulative probability curves which is the graphical method of J Harding [8]. Using this method allowed to indicate and demonstrate polymodality in grain size distribution of samples compared to traditional methods providing only lognormal-like distribution. The used graphical method was too subjective and approximate compared to the numerical and functional being developed at that moment thus was heavily criticized. Despite that, even this imprecise method allowed to distinguish several modes from the distribution. To interpret results each mode and its parameters was correlated with sediment transportation processes. It allowed to distinguish processes themselves and their relative impact in particular.

Polymodality also has found its use in hydrogeology and hydrography to study river flows and water-level fluctuations. S Lobanov has significantly contributed the study of river flow polymodality. In his researches he modelled the formula named polymodality criteria expressing the occurrence probability of river flow polymodality and its degree [2]. The model was applied to the flow of 53 rivers and approved that they are all polymodal. In the D Zadoya dissertation ideas of Lobanov were developed [3]. Lobanov criteria along with Pierson criteria were used as a model to distinguish polymodality of Arctic basin of Siberia and Russia’s Far East. The research allowed to relate occurrence of polymodality with physico-geographical factors such as outlet section level, flow modulus, temperature, atmospheric circulation etc.

The studies of I. Melnik show that intensities of secondary mineral formation in the reservoirs affected by fluids are polymodal. This property of geological reservoirs as open dynamical systems with stochastic actions lead the author to develop interpretation method of polymodality based on state of the processes. In his method, it is the state of the processes of system transformation in time that is considered, not the state of the system itself. The state of the process (not object) of system transformation is the stable values of relative time variable parameters characterizing transformation of system elements and the span of external components impacting these elements. Each mode is associated with some fundamental, basic process. The theory is described in detail in the work [4]. In this work this theory is applied to model geochemical processes that lead to form secondary minerals. In the work [5] the method is applied to study “geochemical trace” that occur due to fluid migration. Application of this method allowed to model the fluid flow and its conservation in reservoirs. The method is based on several principles. First, the conditions of system transformation based on the time characteristics of impact of external elements and of transformation of internal elements. Second, seven universal states of the processes, three basic and four transient states, determined by mathematical expectations of modes in the distribution, were defined. The mathematical expectations were obtained from the equations derived by means of graphical approximation of the processes on the orthogonal system of time coordinates, and the subsequent calculations were based on the system transformation conditions. Third, the correctness of the obtained mathematical expectations is ensured by unification of the values of the modeled intensities in order to bring the calculated mathematical expectations in accordance with the processes of transformation of systems.

Complex stochastic systems are characterized by polymodal distribution of their characteristics. As it is associated with the characteristics subject to the influence of external factors, the systems have to be open. These characteristics can reflect influencing factors. There is no definite and unified concept among researchers about the relationship between modes in distributions and influences on the system. Mode can be considered as an attractor or an indicator of the presence of a steady state. The degree of polymodality, accordingly, can state the number of steady states between which the system is able to pass, and polymodality in general can state variability of the system in time. The system, subjected to the influence of external factors, transits to a certain chaotic state. Since the influences are constant and are themselves also systemic, a stable state will inevitably occur. Such processes of transition from a chaotic state to a stable state are cyclical. The polymodal distribution of probability densities can tell us about the number of such key factors and the degree of influence of a particular factor.

Despite we can state that complex open systems subject to stochastic influence have polymodal distribution of their characteristics, the meaning of each mode and its properties in terms of interpretation is still an open question. In each case, a different model for interpretation is used. For example, in grain size analysis, each mode is associated with a sediment transportation process; in hydrography, with a factor influencing river flow; in biological studies, with natural selection or ecological factors. Regardless of the type of system, in order to put forward a model describing the relationship of modes in the distribution with certain processes, it is necessary to know and understand all the processes that influence the system. Even in case of application of some universal principles, for each system in particular it is necessary to consider all possible factors to build a model. This is impossible in isolation from the system. Thus, even if there is a universal method for interpreting polymodality, each system must be considered separately, and for each system a different model must be put forward.

The problem in identifying polymodal probability densities and reconstructing the distribution function is repeatedly mentioned. Due to the complexity of distribution laws, researchers resort to simplifications and approximations, and often such approximations are based on unimodal assumptions. The works of V Kulikov reflect the criticism of the simplified approach to the identification of probability densities. His dissertation [6] describes in detail his approach to recover polymodal distributions in complex stochastic systems based on solving incorrectly posed problems.

During statistical processing of reservoir properties of the Samotlor oilfield bimodal distributions of porosity (Fig. 1) and permeability (Fig. 2) were obtained. Information on the AV (1-8) and BV (1-22) formations from more than 30 wells was used.

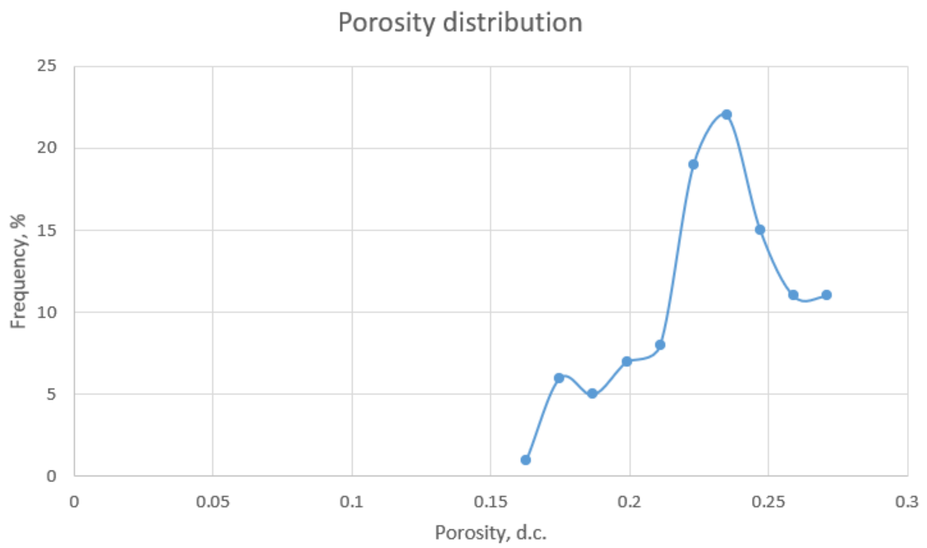

Figure 1. Porosity distribution of the Samotlor oilfield reservoirs

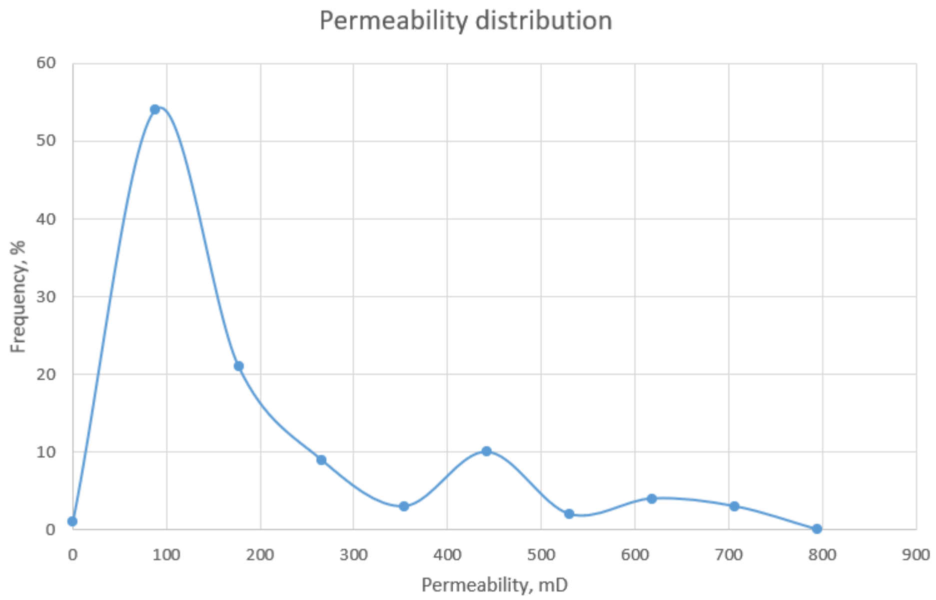

Figure 2. Permeability distribution of the Samotlor oilfield reservoirs

Based on the above theses, we can assume that there are two stable states in the distribution of these characteristics. In accordance with Melnik's theory, one of the states must necessarily be initial, stable. The nature of the second state, resulting from the external impact on the system, should be determined on the basis of the methods described in [4,5]. After determining the type of the states, the next stage of interpretation of the results will be the search for the relationship between the states and the actual processes of impact on the reservoirs. First of all, it is necessary to determine the correlation between the studied parameters and the intensities of geochemical and geodynamic processes, since they can have a significant impact on the reservoir properties of the rock after the stage of its formation.

Заключение

This work was aimed mainly at studying and analyzing the main scientific works devoted to the study of polymodality phenomena in various subject areas. The following conclusions were made: firstly, polymodality of distribution is not an anomaly, but rather a property of open systems with stochastic interactions, thus allowing us to use it as a tool for analyzing these systems; secondly, the existence of a problem in linking the polymodality of the distributions to processes affecting the system; thirdly, the complexity of identification of polymodality in small data samples. The polymodal distribution was also obtained as a result of studying the characteristics of reservoirs of the Samotlor oilfield (Figures 1 and 2). Further studies will be aimed at finding relationships between the modes in these distributions and processes affecting the reservoirs.

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