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INTERACTIVE COMPUTER-CREATIVE METHODS IN THE PROCESSING OF SEISMIC INFORMATION

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The article is devoted to one of the most important trends in modern geophysics - tomography, which is designed to investigate geological objects by studying the features of the passage through them of electromagnetic and elastic seismic waves.

To solve seismological problems, the quality of the initial data is important, in addition, when processing seismological information it is necessary to use several models of the medium under the assumption that each of them can induce experimental data of indirect measurements. The choice of solutions for each interpreter can be individual, and can depend on experience, intuition and other circumstances.

The paper outlines the problems that arise when solving theoretical problems and practical seismic investigations and ways of overcoming them through modern concepts and approaches.

Keywords: tomography, geotomography, kinematic problem, seismological information.

Tomography is widely used in different fields – Medicine, Engineering, and Geology. In this research we only touch upon the issues concerning geotomographie, the study of the solid Earth with seismic methods. The research of the last decades indicated two main directions of development and use of the method of transmission and emission tomography; and the methodology to develop two main areas: mathematical, based on the hard logic of quantitative methods of mathematics and physics, and heuristic, informal, widely used in Geology, experience and knowledge of the researcher, the intuition.

Despite the clarity of ideas, problems of the theory and processing of seismic data are challenging and non-trivial for classical techniques of computational mathematics and mathematical physics, so their solutions in different seismically active areas require a new or modification of known methods of interpretation of seismic fields.

In a particular seismic survey the problems may vary, the selection of solution with multiple options is often ambiguous.

The first practical problem faced by seismology is the choice of geological environment model and its mathematical image- mathematical model. At this stage the problem is simplified, the environment is usually considered to be elastic-linear, passive, stereoscopic in relation to the length of the probing wave heterogeneity, smooth boundaries between the layers and slow changes of seismic wave velocities in the layers.

However, the real environment is hierarchically heterogeneous, elastically nonlinear, seismically active, it not only absorbs, but also radiates seismic energy; there are still unknown circumstances related to the intangible fields acting on the material physical field [Belyakov et al., 2016; Vasiliev, Tataridu, 2014].

These impacts cannot yet be described quantitatively, but they are considered by informal interpretation of seismic wave fields, based on the experience of the interpreter: a selection of geological and mathematical models, the choice of mathematical algorithm of data processing of the several possible methods of solving mathematical problems.

The basis of these methods for all the variety of properties and characteristics of the environment models and methods of seismic data processing is a common approach created by many years of experience.

On the example of solving the kinematic problem, to determine the spatial distribution of the physical properties of the environment is adopted some point of the study area *S*, which implements the minimum functionality of the residuals:

$$S = \sum_{i=1}^{n} \left(t_i - \tilde{t}_i \right), \qquad (1)$$

where t_i and $\tilde{t}_i$ (t_i) are theoretical and observed travel times of seismic waves from the source to the recording stations, *n* is the number of seismic stations.

A characteristic feature of inverse kinematic problems is their instability, the ambiguity of their solution, i.e. incorrectness by Hadamar. It is necessary to solve the task if the problem has its mathematical formulation or whether the solution is the only one.

The equation expressing the bond of seismic observations with the environment settings are approximate due to random and systematic errors caused by errors of measurement, geological in homogeneities, variations of physical fields.

To overcome this mathematical difficulty by the «geologization» the solution of ill-posed problems, the choice of the many solutions to incorrect problems for those that are geologically more plausible than others, discarding from consideration geologically invalid, meaningless. Thus, the model of the environment in the general setting is only one or a few of the many, very different solutions satisfying the initial data.

These difficulties are fundamental, they are further complicating the formulation in the solution of processing seismic data. These include the discreteness of seismic information, the inability to determine the distribution law of random errors, since the error is caused not only by measurements but are also conditioned by local geological reasons.

When required the linear formulation of the problem, which is reduced to the solution of operational equations of the first kind is assumed:

$$Ax = b, \qquad x \in H_1 \quad b \in H_2$$

where H_ (1) and H_2 are metric space, *x* is the desired vector, *A* is the operator of the problem.

Of regularizing iterative processes good computational properties of the generalized modified method of Newton-Gauss [Avetisyan, Manukyan, 1996; Avetisyan et al., 2012]. This method finds the solution that satisfies the assumption that the weight of the deviations of experimental data from the theoretical solution is inversely proportional to the square of the deviation. In many practical cases, this is beyond the understanding of the nature and character of the errors.

The second problem of the study is the restoration of the environment characteristics with the known sources.

In recent years, substantial results on the structure of the Earth are obtained by seismic tomography that is using seismic waves passing through studied object in different directions from source to seismic stations [Nikolaev, 1977a, b].

The problem of tomography is a special case of a more general classical one in applied analysis – structural reconstruction may be an approximation, functions of a certain class of known values at these points [Bukhshtaber, Nikolaev, 1997].

As for solution of the general problem – defining the basic parameters of earthquakes and tomographic studies is based on the following principle: out of an admissible set of functions to choose the one that satisfies a certain ratio between the value that characterizes the quality of approximation of functions to a given aggregate empirical data, and the value characterizing the complexity of the approximating functions.

The results of indirect experiments are of great importance, when the sought function *f (x)* cannot be measured at the same point *x*.

This accessible dimension is another function F (y), which is associated with f (x) of the operator equation^

$$Af(x) = F(y). \qquad (2)$$

requires the results of measurements of the function *F (y)* at the points *y*_1, y_2,…, *y_n* find the function *f (x)*.

In the early 80-ies there was a complete transition to computer technology in the processing of seismic data.

The use of modern computers opens the prospect of creation of new methods of Natural Sciences, physics of the Earth, Applied Seismology. Academician A. S. Alekseev mentioned that they used more powerful means of computation and experiment, and natural philosophy, the point of the experiment goes into oblivion, that has a negative impact on the development of science and technology.

The issue of building image on the example of seismic ray tomography was considered in the works [Bukhshtaber, Nikolaev, 1997; Nikolaev, 1977a], where it is shown that to obtain reliable results it is necessary to develop confrontation trends.

Legalize individuality in solving a mathematical problem implementing the knowledge and talent of the best scientists, on the other hand to put under the strict control method to solve a mathematical problem.

It should be noted that in the processing of seismic data as a source, often are used arrival times of *P* or *S* waves. It is believed that with this case all is well and you can trust the bulletins of earthquakes or any other reports prepared by the specialists of data processing.

However, the situation is far not so. Currently, in some regions, in particular in Armenia, bulletins of earthquakes is not officially published, hence to talk about the quality and the reliability of the source data on the accuracy of the results processing is impossible.

A preliminary analysis obtained by different author's results, as compiled for the Armenia earthquake catalogs and bulletins far from being able to use the data for decisions relevant to the territory of Armenia problems of modern Geophysics [Burmin et al., 2006, 2016].

The increasing power of computational tools, the creation of supercomputers, the development of mathematical methods of processing seismic data create the impression that a well developed complex formalism can, and should displace creative, personal element of interpretation.

There are two trends for the interpretation of seismological data. The first is to formalize a method of solving math problems, processing data, to restrict interactive element, the role of the interpreter.

It should be noted that highly formalized method of data processing is necessary for the middle-level professional and creative initiative which should be limited. The second trend is to accept creativity, individuality, when of many solutions is chosen not that one which led to a mathematical formalism, and that (those) which is the most appropriate interpreter matches his experience, idea, intuition, creative imagination.

The challenge is to legalize individuality in the decision processing, the realization of creative talent and experience of the best scientists. This significantly will increase the depth of processing, the quality of the results. Processing geophysical data will always evolve in the confrontation of these two tendencies, the rigid formalism and a creative, individual approach in the interpretation of experimental data.

It is necessary to decide how to rebuild and computational mathematics, and computer equipment.

The world has entered a new stage of technological revolution, the solution to the challenges facing us requires, first and foremost, creative approaches to their solution, while supercomputers are necessary, but the priority will always remain on the side of intellect, experience and creativity.

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ИНТЕРАКТИВНАЯ КОМПЬЮТЕРНО-ТВОРЧЕСКАЯ МЕТОДИКА ПРИ ОБРАБОТКЕ СЕЙСМОЛОГИЧЕСКОЙ ИНФОРМАЦИИ

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Статья посвящена одному из важнейших направлений современной геофизики - томографии, которая призвана изучать геологические объекты путем исследования особенностей прохождения через них электромагнитных и упругих сейсмических волн.

Для решения сейсмологических задач важно качество исходных данных, кроме того при обработке сейсмологической информации необходимо использование нескольких моделей среды в предположении о том, что каждое из них может индуцировать экспериментальные данные косвенных измерений. Выбор решений у каждого интерпретатора может быть индивидуальным, и может зависеть от опыта, интуиции и других обстоятельств.

В работе обозначены проблемы, возникающие при решении теоретических задач и практических сейсмических исследований и пути их преодоления путем современных представлений и подходов.

Ключевые слова: томография, геотомография, кинематическая задача, сейсмологическая информация.