

ON THE METHODS OF CONSTRUCTING A DIGITAL REGIONAL GEOLOGICAL AND MATHEMATICAL MODEL FOR THE WESTERN SIBERIA REGION

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Abstract: The article presents an approach to creating a detailed regional digital geological model for the territory of Western Siberia. The non-standard nature of such tasks is noted, and a conclusion is made about the need to develop specialized software for these purposes. The variational grid mapping method as a tool for constructing digital structural models and property fields is considered. The object-hierarchical approach is proposed as a method of data space managing, algorithmization and automation of calculations. The "GST Agent" technology as an instrument of expanding the functionality of the software is proposed. The digital model of the region includes a structural framework consisting of more than 30 stratigraphic boundaries, as well as detailed submodels for the most studied areas. The approach ensures the possibility of automated recalculation of the model and full compliance of the modeling results with all the original data.

Keywords: regional model, mapping, variational grid method, object-hierarchical approach, structural framework.

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1. Introduction

Problem of constructing detailed regional digital models is non-standard. The level of study of the territory, the quality and structure of the initial data play an important role in it. However, the development of well-known specialized software (Petrel, IRAP RMS, T-Navigator, etc.) occurs primarily in commercially profitable directions. It is focused on building models for deposit areas for further volumetrics or hydrodynamic modeling. For this and other reasons, regional digital models are often built on the basis of the research teams' own developments [Brekhtunsov et al., 2011; Ershov et al., 2009; Kontorovich et al., 2014; Krasavchikov, 2002; Sidorov, 2022c].

For over 20 years, the staff of the "V. I. Shpilman Scientific and Analytical Center for Rational Subsoil Use" have been systematically working to summarize a large volume of geological and geophysical information on the territory of Western Siberia. Methods and software tools are developed and implemented for solving problems of mathematical geology, in particular, regional modeling. As a result, a digital geological model is constructed, including a detailed structural framework and maps of the geological and physical properties of sedimentary cover rocks.

2. Methods

The modeling was made in the GST software, which was developed taking into account the specifics of regional problems. The main part of the mathematical kernel is the variational gridding method (VGM), based on the spline approximation approach [Plavnik et al.,

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2021]. The article [Plavnik *et al.*, 2024] discusses the use of the VGM in the construction of a digital structural framework; [Sidorov *et al.*, 2004; Sidorov, 2022a] demonstrate its capabilities in solving problems of mathematical physics and modeling the sedimentation process; in [Sidorov, 2020] an adaptation of the approach for constructing maps with faults is discussed.

The functional of the variational problem is formed from two parts: the “measurement model” and the “knowledge model”. The first one is a set of conditions for the gridding surface at given points. The second one determines the gridding surface in the entire modeling area. Both models are presented as a set of equations, the left and right parts of which are determined by linear differential operators with variable coefficients. The operator coefficients determine the physical meaning of the source data, and the weight coefficients indicate the quality of the measurements. These features make VGM a universal method for both structural gridding and mapping geological and physical parameters.

The module for algorithmization and automation of calculation processes, based on the object-hierarchical approach [Sidorov, 2022b], controls the mathematical kernel, export and import of information. The main semantic element of the theory is an object (Figure 1). It is described by a set of constant attributes, configuration parameters and a computational content. It is important that the computed content may not exist, i.e. the object may be “empty”. Each object characterizes a certain part of the initial, intermediate data or final results of calculations. A set of objects connected by reference links (Figure 1 on the right) forms a hierarchy tree. The spectrum of discrete states of an object, indicating the “constructing stage”, determines the dynamics of the hierarchy tree.

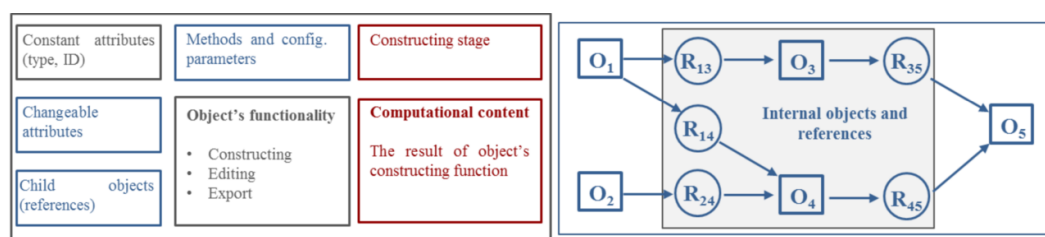


Figure 1. Schematic representation of an object and a hierarchy tree (O_i – objects containing initial, intermediate and final data, R_{ij} – reference links).

This approach helps to build a problem solving algorithm, compose and modify the project graph through operations of copying objects groups, and perform automated calculations. It ensures that the modeling results correspond to the initial data and calculation parameters. Any source data modification is passed up the hierarchy and transfers objects to a stage that requires re-building.

Practical experience has shown that the optimal way to work with large tasks, such as building a regional model, is to break the task down into “algorithm blocks” (projects). The “GST Agent” technology, implemented in stand-alone module (in dll, as well), provides asynchronous data and commands exchange between applications that support this technology (Figure 2). The approach is based on the “request-response” scheme, where messages are a structured byte stream containing both the “body” of the request or response, and a block with source data and calculation results. The Agent module dispatches requests and responses between applications. This technology solves several problems: expanding functionality through writing calculation modules and implementing interaction with external software, as well as managing calculations in a group of projects.

3. Results

Figure 3 shows a scheme of a digital permanently operating geological model of the sedimentary cover of the Western Siberia. The model is most complete in the central part, which includes the territory of the Khanty-Mansiysk Autonomous Okrug; main seismic horizons and structural surfaces of Jurassic interval are mapped throughout the entire region of the oil and gas province. The basic detail structural framework, which includes



Figure 2. Scheme of interaction of GST instances and external applications.

maps of more than 30 stratigraphic surfaces, is built on grids with 500×500 meter cells. For areas with a complicated structural forms, provided with 3D seismic data, detailed sub-models with 250 or 125 meter cells are created. They are merged to the base model using the “smooth inserts” method [Plavnik *et al.*, 2024].

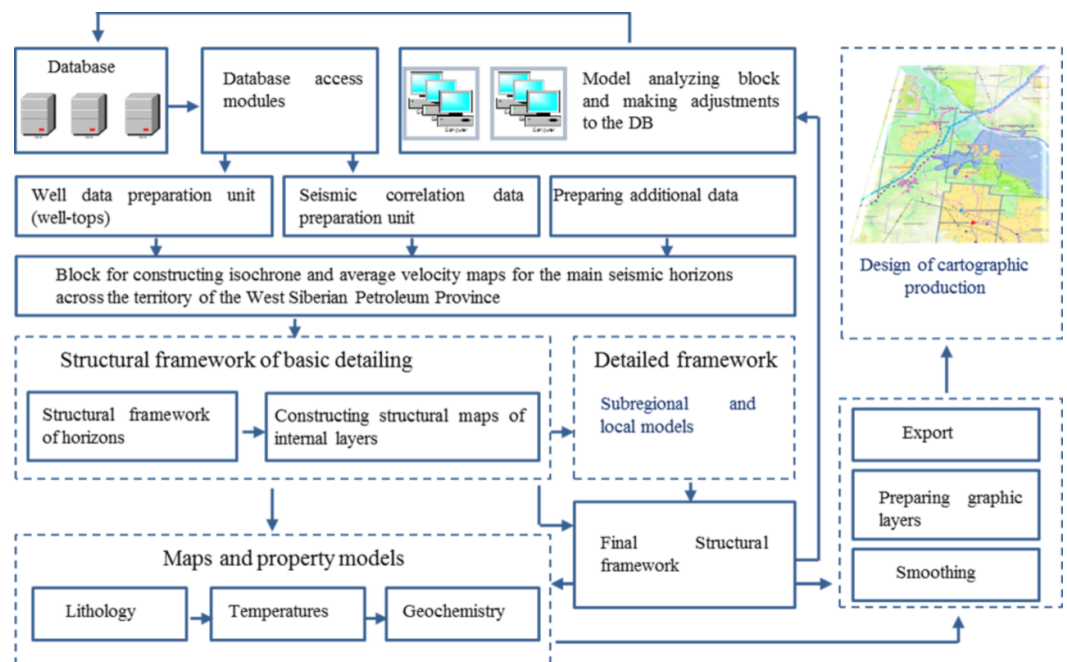


Figure 3. Scheme of the digital permanently operating geological model for the central part of Western Siberia.

Seismic correlation (more than 2000 surveys), “well-tops” and other source data are loaded into the model from the database using automated importing, filtering and categorizing procedures. The modeling results are analyzed using visualization projects that have direct access to the model based on the “linked projects” technology [Sidorov, 2022b,c].

As an example of the modeling results the basement structure regional map for the territory of Western Siberia is shown on Figure 4. The detailed fragment shows paleosurface (Lower Jurassic) of the basement in the area of Talin oilfield and the paleochannel. The level of detail, shown in the zoomed image, is typical for all surfaces of the digital structural framework.

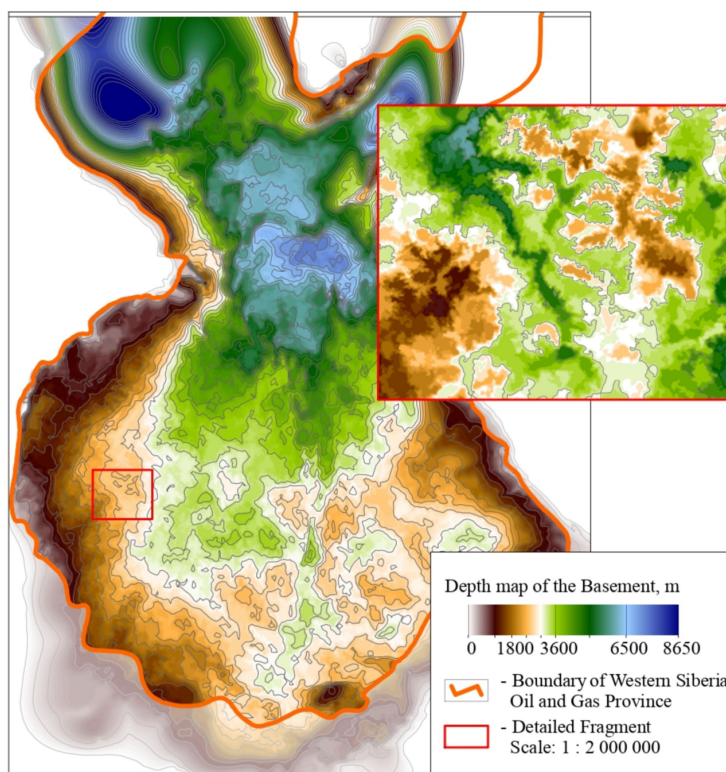


Figure 4. An element of the Digital structural framework: depth map of the Basement for the Western Siberia region and the detailed fragment with paleochannel.

The model consists of more than fifty projects, each of which describes the solution to the corresponding block of the problem. The entire calculation cycle from importing initial data from the database to obtaining the final result is performed automatically using a task script and “GST Agent” technology. The use of object-hierarchical approach ensures automated multi-threaded execution of the entire technological chain and full compliance of the calculation results with the initial data and modeling parameters.

4. Conclusion

The combined use of the object-hierarchical approach and “GST Agent” technology helps to solve regional modeling problems and handle large volumes of permanently changing initial geological and geophysical information. The hierarchical, object-oriented structure of projects significantly simplifies and accelerates the model’s modification in case of updating the source data, changing the calculation methodology, or adjusting the very concept of the model.

Model evolution – detailing or adding new elements to the model is carried out by embedding new semantic blocks (projects) into the calculation scheme. Currently, the structural framework is being regularly refined by including detailed subregional and local submodels in the calculation scheme.

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