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TOOLS DEVELOPMENT FOR VISUALIZATION OF THE GEOLOGICAL OBJECT’S DIGITAL MODELS IN GIS ARCVIEW 3.N ENVIRONMENT

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Modern research in the field of oil and gas geology necessarily ends with the construction of a three-dimensional geological model, which is the basis for technological and financial decisions. If the problem of building models of local objects can be considered solved, the question of building regional geological models, which include a large number of local objects and unexplored territory between them, remains open.

The subsystem of visualization of geoinformation system for construction and processing, first of all, of regional 2D - 3D geological models in the field of oil and gas geology and its functional filling, in particular visualization of structural and lithological sections, horizontal sections (maps), cubes by means of convenient and intuitive for geologist’s tools.

The system was studied at the geological objects of the Donetsk-Dnieper basin (DDZ), information about which is in the database of geological and geophysical information (BDGGI) of SE Naukanaftogaz. Relevant software is created in a GIS environment using compilers such as Delphy and Fortran. Software tools for model visualization are demonstrated on the example of a structural model of oil and gas stratum at one of the sections of DDZ.

Keywords: geoinformation system, 3-D visualization, computer graphics

РОЗРОБКА ЗАСОБІВ ВІЗУАЛІЗАЦІЇ ЦИФРОВИХ МОДЕЛЕЙ ГЕОЛОГІЧНИХ ОБ’ЄКТІВ В СЕРЕДОВИЩІ ГЕОІНФОРМАЦІЙНОЇ СИСТЕМИ ARCVIEW 3.n.

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Візуалізовано геоінформаційну систему (ГІС) для побудови і обробки регіональних 2D-3D геологічних моделей в галузі нафтогазової геології та її функціонального наповнення, зокрема візуалізації структурно-літологічних розрізів, горизонтальних зрізів (карт) та кубів за допомогою зручного і інтуїтивно зрозумілого для геологів інструментарію.

ГІС досліджено на геологічних об’єктах Дніпровсько-Донецької западини (ДДЗ). Відповідне програмне забезпечення створено в ГІС середовищі з використанням таких компіляторів, як Delphy і Fortran. Програмні засоби візуалізації моделей продемонстровано на прикладі структурної моделі нафтогазоносної товщі на одній із ділянок ДДЗ.

Ключові слова: геоінформаційна система, регіональні геологічні об’єкти, 3D-візуалізація, ДДЗ

РАЗРАБОТКА СРЕДСТВ ВИЗУАЛИЗАЦИИ ЦИФРОВЫХ МОДЕЛЕЙ ГЕОЛОГИЧЕСКИХ ОБЪЕКТОВ В СРЕДЕ ГЕОИНФОРМАЦИОННОЙ СИСТЕМЫ ARCVIEW 3.n.

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Визуализировано геоинформационную систему (ГИС) для построения и обработки региональных 2D-3D геологических моделей в области нефтегазовой геологии и ее функционального наполнения, в частности, визуализации структурно-литологических разрезов, горизонтальных срезов (карт) и кубов с помощью удобного и интуитивно понятного для геологов инструментария.

ГИС исследованы на геологических объектах Днепровско-Донецкой впадины (ДДВ). Соответствующее программное обеспечение создано в ГИС среде с использованием таких компиляторов, как Delphy и Fortran. Программные средства визуализации моделей продемонстрированы на примере структурной модели нефтегазоносной толщи одного из участков ДДВ.

Ключевые слова: геоинформационная система, региональные геологические объекты, 3D-визуализация, ДДВ

Introduction

At the present stage of development of oil and gas geology in the adoption of technological and financial decisions for further geological exploration (exploration) or geological-industrial (APR) work involves the construction of a three-dimensional geological model of the geological object. If the problem of building models of local objects can be considered solved, the question of building regional geological models, which include a large number of local objects and unexplored territory between them, remains open.

Regional geological objects are characterized by an uneven distribution of information, concentrated mainly on local objects that are part of them.

The 3D model of a geological object can be reduced to a so-called 2D + model, based on the assumption that the properties of the formation change literally and change little in its thickness. If the change in properties along the thickness of the formation is significant, it can be divided into two or more homogeneous layers.

The technology of modeling regional geological objects has its own features and is based on the extensive use of theoretical and practical (data from previous studies) a priori information.

Material and methods of research

The system was developed using GIS technologies, which are currently recognized as the best environment for modeling in the field of geology and other Earth sciences (Demers, 2006). The system belongs to the class of desktop systems, developed in the GIS environment ArcView 3.n, integrates methods created in other software environments (in the form of DLL-libraries) and is designed for data processing in oil and gas geology (Grebennikov, Lobasov, 2005; Dolinsky, 2015; Dolynsky, Lobasov, 2012, 2013). The system is open to new methods and technologies.

The site for testing the model visualization subsystem is the site within the Northern coastal zone (Dmitriyivsko-Gaivoronsky, Talalaivsko-Artyukhivsky and

Anastasiyivsko-Lipovodolinsky shafts) and the Northern side (Dobryansko-Trostyanetsky and Turutynsko-KhmelevskyDme). To build digital models of boundaries in the oil and gas bed of the Lower Carboniferous-Middle Permian (soles P_2, P_1, C_1, C_2, C_3) in the modeling system used data from stratigraphic breakdowns of 342 wells within the specified area, which opened the bottom of the Lower Carboniferous.

It should be noted that the obtained model does not claim to be complete and is intended only for testing the visualization subsystem. And although the construction of a model of oil and gas strata DDZ at the current technological level is relevant, but requires the use of new and review of all materials obtained during previous studies and the involvement of a team of geologists and geophysicists.

The main results of the study

The model visualization subsystem is based on three main principles:

1. Intuitive interface in terms of subject area.
2. A full-featured set of visualization tools for this subject area.
3. Maximum convenience of data preparation and efficiency of constructions.

The model visualization subsystem currently includes the following functionalities:

1. Construction of vertical sections along the routes of arbitrary configuration.
2. Construction of horizontal sections on arbitrary rectangular sections.
3. Construction of maps on arbitrary 2D surfaces.
4. Construction of axonometric projections on arbitrary rectangular sections.
5. Construction of 3D stratigraphic (lithological) cubes

Consider the methods of the visualization subsystem on the example of the selected area within the Dnieper-Donetsk basin (DDZ) (Fig. 1)

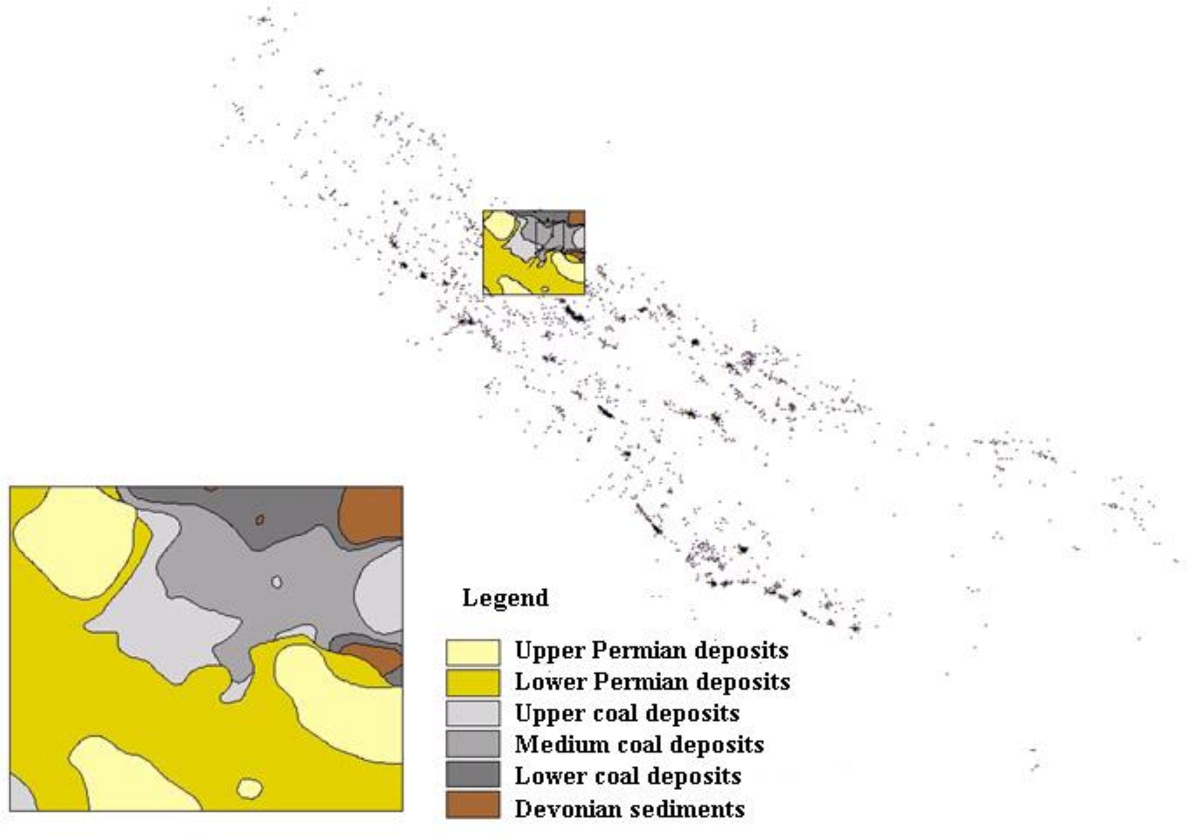

Figure 1. Model of oil and gas stratum DDz within a certain area (symbols to Fig. 1, 2, 4, 5, 6-8)

The model consists of 2D geological boundaries (grid): – sole of the upper perm; – sole of the lower perm; – upper carbon sole; – middle carbon sole; – lower carbon sole.

Construction of horizontal sections on arbitrary rectangular sections within the object

To build a horizontal slice of the model in the dialog, you must specify the slice mark. The boundary grids that are part of the model and should be reflected in the slice must be active. The result of construction on the section -2500m is shown in Fig. 2.

The slice construction algorithm is based on the use of grid-class methods ArcView 3.n. The first step in the construction is to create a horgrid with the value of the horizontal slice Hor:

horgrid = Grid.MakeFromNumb (Hor)

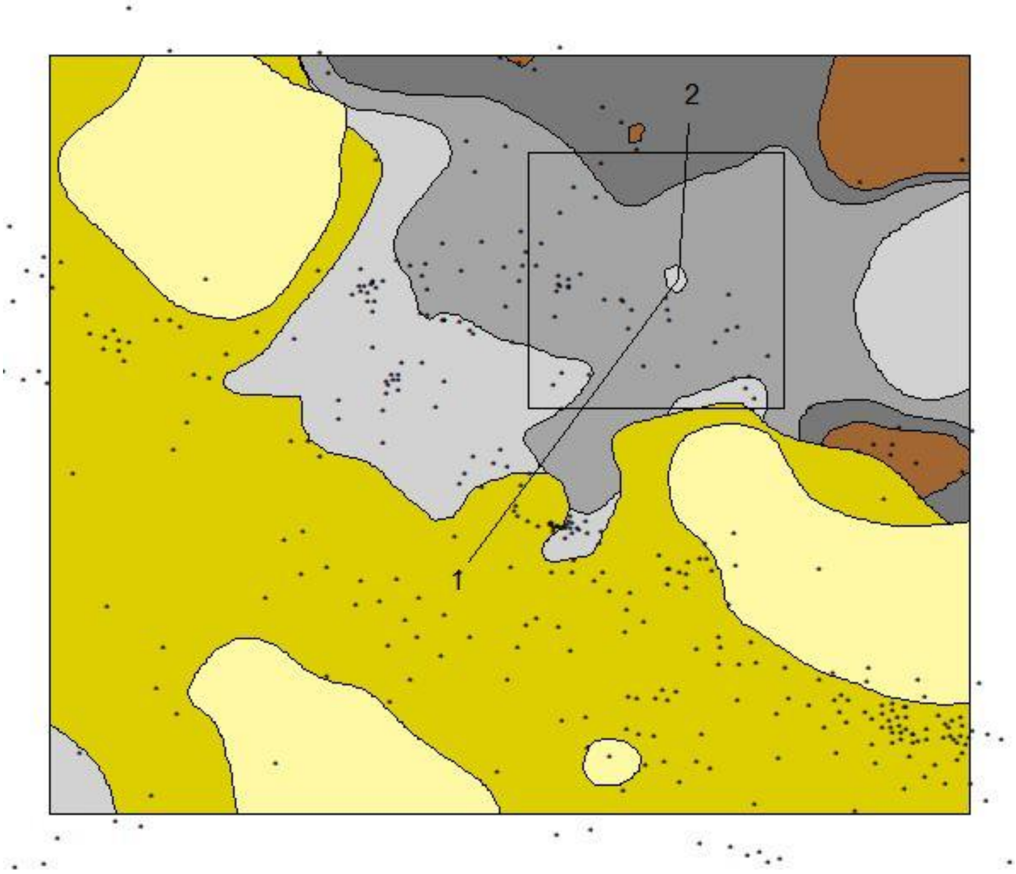

Figure 2. Model of oil and gas strata DDz at the cut -2500 m.

The main operation is to build an integer mapgrid using the GridsLessThan grid class method:

mapgrid = horgrid.GridsLessThan (g_list)

The value in the mapgrid node is numerically equal to the number of surfaces in the g_list, which in this node are below the mark of the horizontal slice horgrid. Thus, the value in the node is the number of the surface, if we start the numbering from the bottom, which is the sole of the layer that extends to the surface of the slice. The last operation is the generation of a polygonal theme that corresponds to the mapgrid built at the previous stage:restheme = mapgrid.AsPolygonFTab («c:\poltheme»). AsFileName, true, aPrj) (Fig. 3).

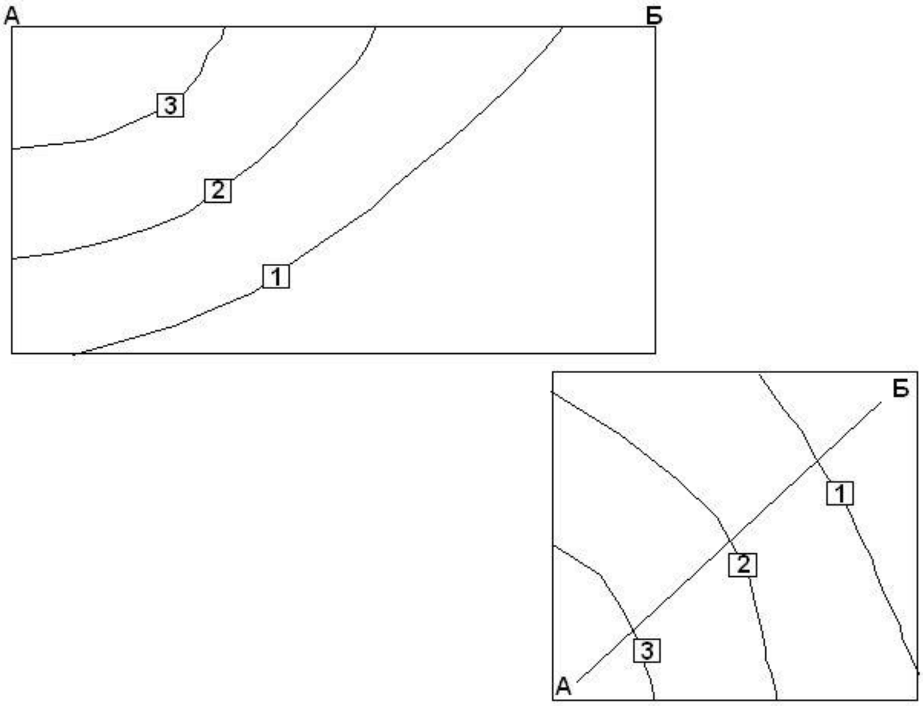

Figure 3. Numbering of geological boundaries and layers between them, in the problem of constructing a map on a horizontal section (top - section, bottom - the corresponding plan with the line of section)

Construction of vertical sections along the routes of arbitrary configuration

The route of section A1 - A2 (fig. 2) is set by a broken line by means of standard graphics ArcView. All cut points must be within the rectangle of the model. In the dialog it is necessary to indicate the step along the route of the section, the ratio of horizontal to vertical scale and list in order from top to bottom the geological boundaries that should be reflected in the section (Fig. 4).

The procedure for constructing a vertical section involves a series of sequential operations.

1. Calculation of the values of all grid surfaces at points regularly located on the section route with a step dl.

2. Recalculation of points in the coordinate system of the section (Fig. 5), where the 0-abscissa corresponds to the beginning of the section line, 0-ordinate - 0-absolute mark. Coordinates X1, Y1 are calculated by the formulas:

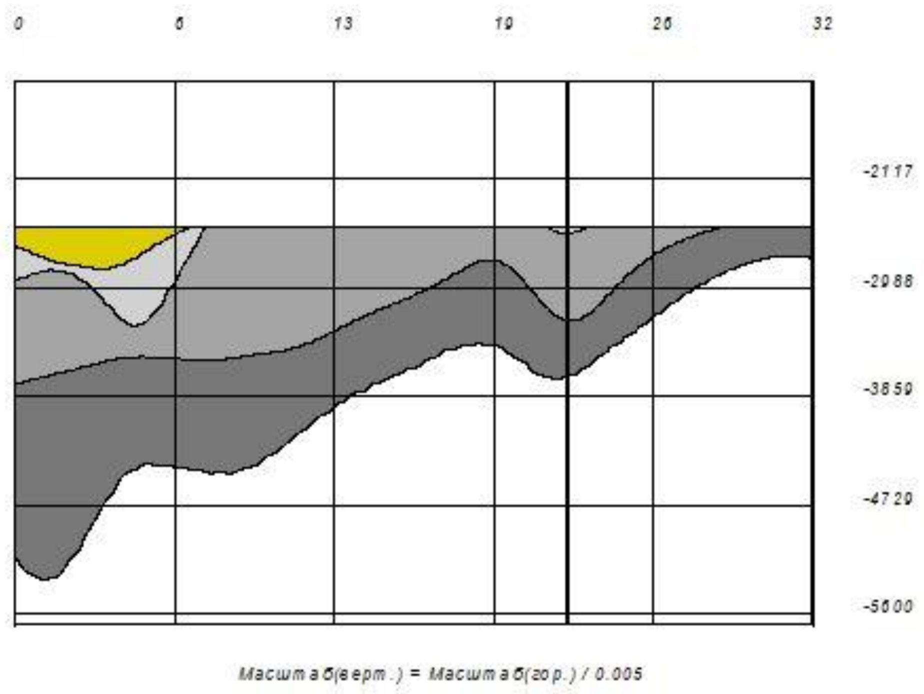

Figure 4. Geological section of the model along line 1-2 (Fig. 2)

$$Xi = (i-1)*dl\,, \quad Yi = Zi$$

Where dl is the sampling step along the section line, i is the step number, Zi is the mark of the i-th boundary at the point Xi, Yi.

Construction of maps on arbitrary 2D surfaces within the object

To build a map on a certain arbitrary surface in the dialog, you must specify the grid surface from the proposed list. The boundary grids that are part of the model and must be displayed on the map must be active. The algorithm for constructing a map on an arbitrary surface does not differ from the algorithm for constructing a map on a

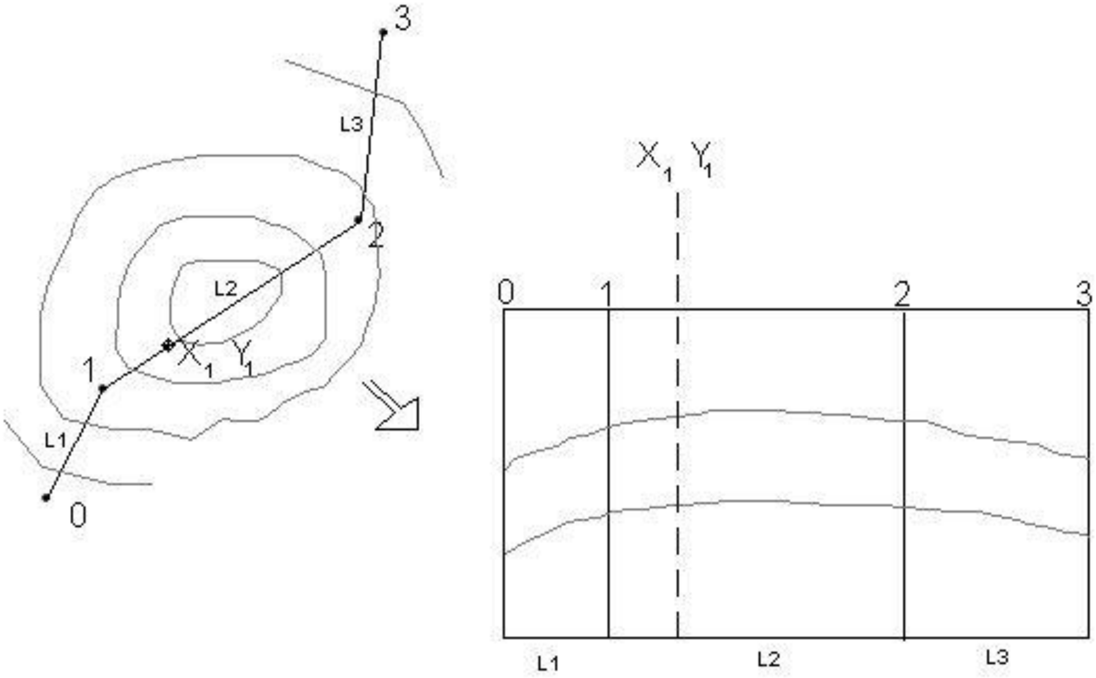

Figure 5. Conversion of points on the section into the coordinate system of the section

horizontal section. Instead of the Hor parameter, the grid of the surface on which the map is built is substituted into the expressions of item 1. The result of construction on the sole of the lower Permian is shown in Fig. 6.

Construction of axonometric projections on arbitrary rectangular sections within the object

Dialogue for constructing an axonometric projection is no different from dialogue for constructing a vertical section. Additionally, the mark of the cut of the upper face is indicated. The rectangular area for construction of a projection (programmatically reduced to square) is defined arbitrarily by standard graphics ArcView 3.n and is shown in fig. 2.6. It is assumed that the point of view of the cube, for which the axonometric projection is constructed, is opposite the lower right vertex of the square (focus) at azimuth 135° (Dolinsky, 2015, 2014).

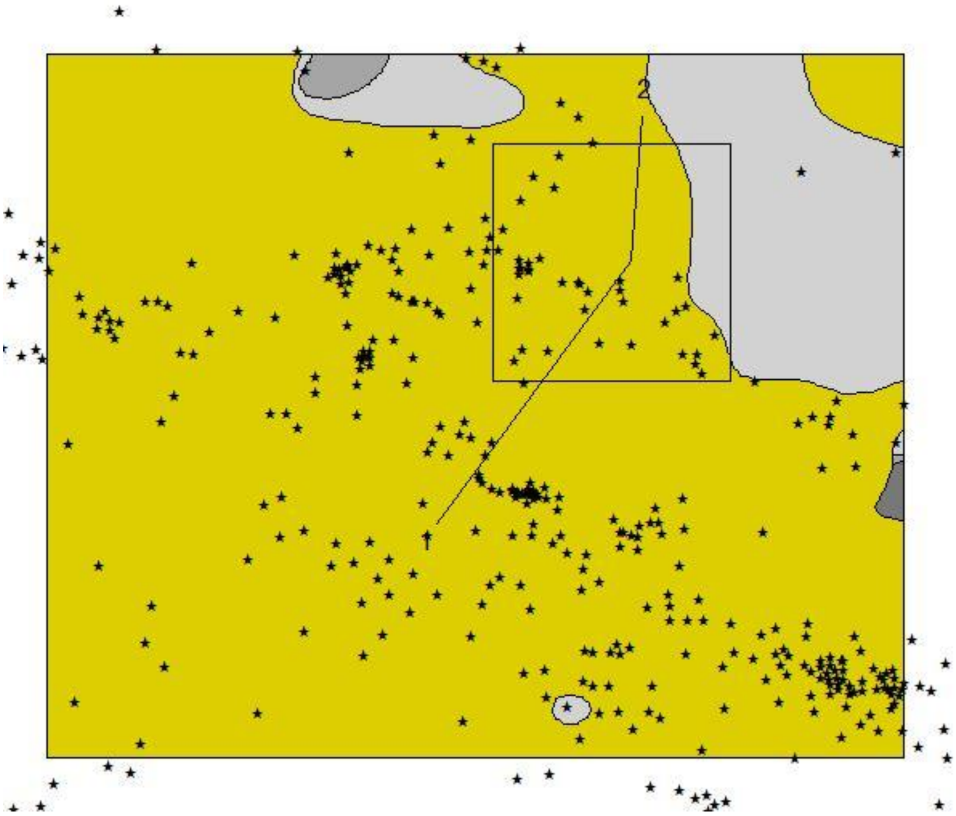

Figure 6. Map of the outputs of the layers of rocks on the sole of the upper Permian

The construction algorithm is as follows.

First, a horizontal section of the upper face and vertical sections to the left and right of the focus are constructed.

In the next step, the coordinates of the section and sections are listed in the coordinate system of the axonometric projection. Point x, y is converted to point x1, y1 by the formulas:

upper face here

$$x_1 = x_0 + x_0 * \cos(L) + y_0 * \sin(L)$$

$$y_1 = y_0 + y_0 * \cos(L) - y_0 * \sin(L) + y_m$$

$$x_0 = (x - x_{dr}) + (y - y_{dr}) * \sin(L)$$

$$y_0 = (y - y_{dr}) - (y - y_{dr}) * \sin(L) * \cos(L) * (1 - \cos(L))^{-1}$$

ym is the value of the horizontal cut, xdr, ydr are the coordinates of the focus, L = 45^0

left side here

$$x_1 = -(D_1 - x_0) * \cos\left(\frac{L}{2}\right)$$

$$y_1 = y_0 + (D_1 - x_0) * \sin\left(\frac{L}{2}\right)$$

$$x_0 = \frac{(x - x_{\min}) * D_i}{x_{\max} - x_{\min}}$$

$$y_0 = y$$

Dl is the semi-diagonal of the axonometric projection,

xmax, xmin - maximum and minimum horizontal coordinates in the section of the left face

right edge

$$x_1 = x_0 * \cos\left(\frac{L}{2}\right)$$

$$y_1 = y_0 + x_0 * \sin\left(\frac{L}{2}\right)$$

$$x_0 = \frac{(x - x_{\min}) * D_i}{x_{\max} - x_{\min}}$$

$$y_0 = y$$

The result of the construction is shown in Fig. 7.

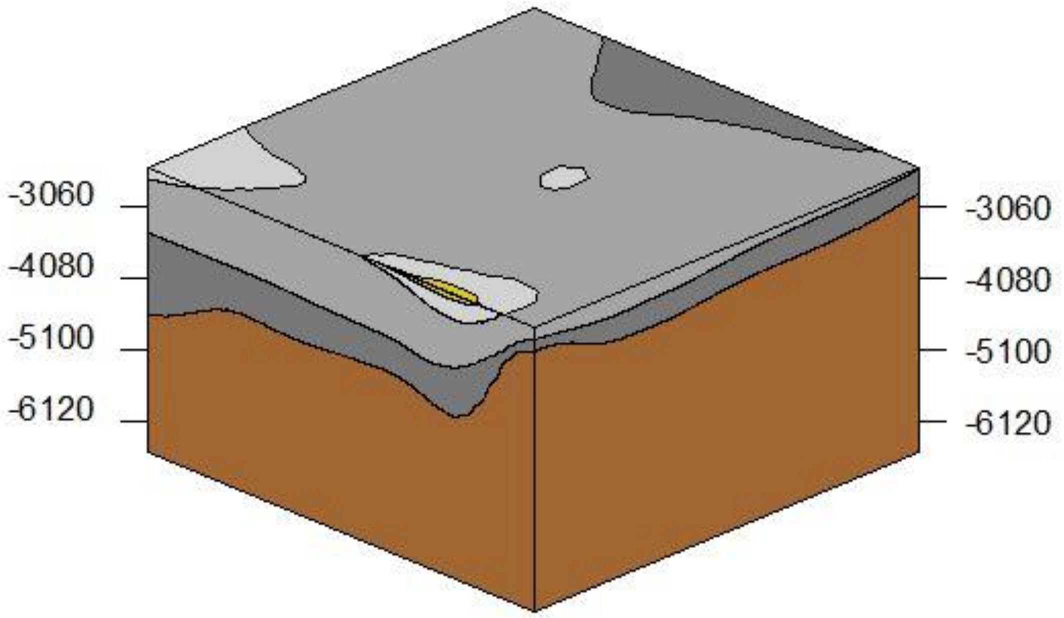

Figure 7. Axonometric projection of the model area. The cut of the upper face = -2500 m

Construction of 3D cubes

Construction of a stratigraphic (lithological) cube is implemented in the Delphy environment and integrated into the system in the form of a DLL library. The area of the cube is determined in the same way as the area of the axonometric projection (Figs. 2, 6). The cube is displayed in a special window with its own interface. The constructed cube can be rotated arbitrarily and the outputs of the rock layers on all its faces can be viewed (Fig. 9). In addition to the axonometric projection, in which we see only three faces of a static cube, you can build a three-dimensional cube, all faces of which are available for inspection with it in different planes. Only 3 faces are visible at a time. In fact, this is an infinite number of axonometric projections from which we can, rotating the cube, select a projection with the desired faces in the field of view (for example, a projection on which the lower face of the cube is visible). The lithological-stratigraphic cube visualization program is developed in the Delphi environment with the interface for site selection on the map and preparation of information for construction of a cube in ArcView. Communication between software environments is implemented through DLL technology. The exchange of information between the ArcView and the DLL-procedure is carried out through a text file, which is programmatically created in a temporary working directory. The legend for the cube layers is inherited from the geological map used to determine the study area. After preparing the information and calling the DLL-procedure, the latter loads a window with its own interface, the elements of which are designed to control the rotation of the cube (Dolinsky, Lobasov, 2012; Dolinsky, 2015; Guide 2006; Skvortsov, 2002).

The source information for the construction of a stratigraphic cube is a text file that contains the coordinates of the polygons formed by the intersection of the faces of the cube layers of the thickness of the geological body and their color codes according to the stratigraphic legend. The program for creating the source text file as a source of information uses a set of grid geological boundaries.

Visualization of the stratigraphic cube, formally represented by the text file created at the previous stage, is performed (after activation of the corresponding function) in a special window with its own interface (Fig. 9). The window has the necessary controls to rotate the cube in three planes and adjust the speed of rotation

To calculate the new coordinates of all objects located on the faces of the cube after one act of rotation around the Z axis, use formula 1:

$$C1 = TC$$

where $C1 = [x1, y1, z1, 1]$, $C = [x, y, z, 1]$.

$$\mathbf{T} = \begin{bmatrix} \cos\theta & \sin\theta & 0 & 0 \\ -\sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad 1$$

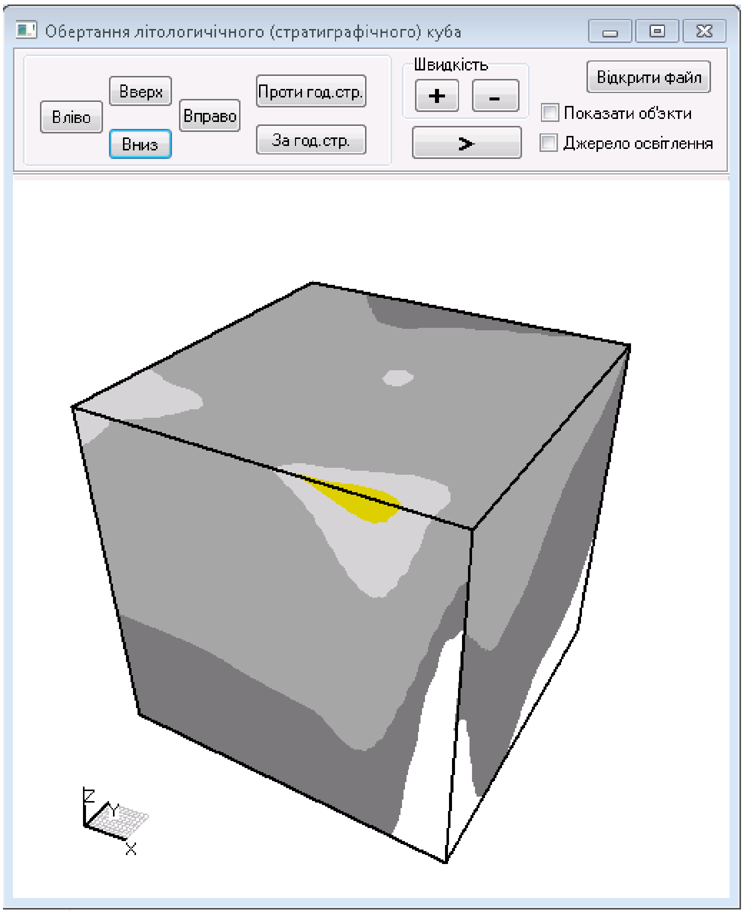

Figure 8. Stratigraphic cube in the area of Fig. 2, 6.

The same formula is used to calculate the coordinates when rotating around the X axis at an angle c, the matrix T has the form:

$$\mathbf{T} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\psi & \sin\psi & 0 \\ 0 & -\sin\psi & \cos\psi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}. \qquad 2$$

In the case of rotation around the Y axis at an angle f, the matrix T has the form:

$$\mathbf{T} = \begin{bmatrix} \cos\phi & 0 & -\sin\phi & 0 \\ 0 & 1 & 0 & 0 \\ \sin\phi & 0 & \cos\phi & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}. \qquad 3$$

The angle of rotation is considered positive if the cube rotates around the X, Y, or Z axis clockwise, if viewed from the center of coordinates in the direction of the corresponding axis (right-hand rule). The center of coordinates coincides with the center of the cube, and the axes are oriented perpendicular to the faces.

At each point in time we see from one to three faces. It is these faces that need to be redrawn. To do this, we use an algorithm for removing invisible lines and surfaces (Rogers, 2001), which is as follows: for each face in each act of rotation we find the vector of the normal, the coordinates of which are determined by the formulas:

$$xn = A.y*(B.z - C.z) + B.y*(C.z - A.z) + C.y*(A.z - B.z)$$

$$yn = A.z*(B.x - C.x) + B.z*(C.x - A.x) + C.z*(A.x - B.x)$$

$$zn = A.x*(B.y - C.y) + B.x*(C.y - A.y) + C.z*(A.y - B.y)$$

where A, B, C - points, which are located on the same face

A.x, A.y, A.z - coordinates of point A

B.x, B.y, B.z - coordinates of point B

C.x, C.y, C.z - coordinates of point C

The visibility of a certain face is determined by the angle between the vector of the direction of view and the normal of the face. If the cosine of the angle is greater than 0 (corresponding to the angles of rotation in degrees 0 - -90, 0 - +90) the face is visible, if less than 0 (corresponding to the angles of rotation -90 - -180, +90 - +180 degrees) - the face invisible.

Conclusions

The presented subsystem of visualization of the digital model of the regional geological object covers most of the capabilities required by the geologist. Geological (rods, tectonic faults) and technological (wells, seismic survey routes) objects can be placed on all drawings in the automated mode. The subsystem provides numerous image editing tools. The subsystem was tested on materials stored in the BDGGI of SE «Naukanaftogaz» and proves its effectiveness.

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