Geometric Modeling and CAD System to Solve Tectonics-Related Tasks Using Core Pole

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Abstract. Proper and rational borehole utilization in various aspects of prospecting and outlining of mineral deposits is undoubtedly a vital task. Geometric modeling and a widespread use of a CAD system could facilitate the solution of various mining, geological, and engineering problems. The geometric modeling of boreholes improves the process of prospecting and outlining of mineral deposits and supports their assignment to automation system of project planning. This research addresses one of the aspects of subsoil geometry associated with widespread use of computers to solve various mining-and-geological and engineering problems. A core pole provides various data about the geological structure of a blanket deposit gap. It reveals mechanical and structural properties of mineral deposits and helps to evaluate mineral reserves. To obtain this data a number of exploration holes is bored on a studied gap of a mineral deposit. The geometric modeling of boreholes is based on their approximation to the classic geometric images. From the geometric point of view, a borehole is a cylinder. Therefore, some positional and metric problems could be solved on a core pole using descriptive geometry. A developed algorithm and its mathematical formulation contribute to designing of a program for automatic problem solving and measuring of strike and dip using a core pole.

Keywords: Geometric modeling · Mining and geological tasks · Borehole · Core pole

1 Introduction

From a geometric point of view, mineral deposits are a combination of various geometric images of many possible space forms. They could take forms of isolated irregular geometric bodies (e.g. lenses and stockworks), stretched irregular geometric bodies (veins) or stretched regular bodies confined by planes (blanket deposits) [1–3].

Diverse space forms of mineral deposits are most pronounced in the setting of mountainous terrain, which can be explained by genesis of accumulation and its tectonics. Surface irregularities have a great impact on the geometric structure of a subsoil mineral deposit, which is most noticeable in the setting of mountainous terrain. From a geometric point of view, blanket deposits have a simpler form that allows for a relatively accurate estimation of their metric characteristics and a higher quality mining.

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2 Recent Research and Publications Analysis

Research suggests that improved methods of geological analysis and project planning are key to proper and rational borehole utilization. Computer-aided design systems are now more and more often used in this field [4–10].

So for example, in the study of [7] a point is made that building of 3D geologic visual and computational models is of great importance for mining and geological projects. A 3D model can illustrate spatial properties of boreholes and a visual model transformed into computational provides for engineering analysis. A method of building a 3D geologic model of solid mine surface powered by AutoCAD is analyzed in [9]. The article reviews optimization issues based on a geologic model and technology mining. The author of [10] suggests a new visualization method based on spatial database and graphical analysis.

A core pole provides various data about geological structure of a blanket deposit gap. Core poles reveal mechanical and structural properties of mineral deposits and help evaluate mineral reserves [11, 12].

Moreover, boring of several exploration holes on a studied gap makes it possible to estimate the deposit shape, size and volume and, as a result, its reserves. This task is especially relevant for mineral deposits found in the setting of mountainous terrain.

3 Objective Statement

Computer-aided design systems are now frequently used in geology. To improve the results of mineral deposits prospecting and outlining the authors introduce computer programs addressing respective goals, which help to obtain information about deposit parameters before completion of prospecting and exploration operations and cut down material expenses for field observations and reduce time of data collection.

The goal was to solve the following problems:

- Research and analysis of geometric modeling of exploratory bores and methods for approximating the surfaces of mineral deposits with regular geometric shapes
- Development of geometric algorithms for solving exploration and outlining problems of mineral deposits by means of geometric modeling based on approximation techniques by regular geometric images (geometric algorithms are considered to be a sequence of geometric operations for solving a problem expressed in symbols)
- Investigation of the possibility of using the obtained geometric algorithms for the automated solution of exploration and outlining problems of mineral deposits
- Development of a mathematical description of the presented graphic algorithms for solving the tasks
- Development of algorithms for the automated solution of the main tasks of exploration and outlining of mineral deposits based on the completed mathematical description and software development

4 Main Part

Geometric modeling of boreholes is based on their approximation to the classic geometric images. From the geometric point of view, a borehole is a cylinder. So, some positional and metric problems could be solved using a core pole using descriptive geometry [13–15].

Suppose boreholes of 120–140 mm diameter are bored in solid rocks. Let us create a geometric model of a core pole on a complex diagram. A core pole in Fig. 1 has pronounced contact surface of materials shown as parallels prescribed by projections of ellipses.

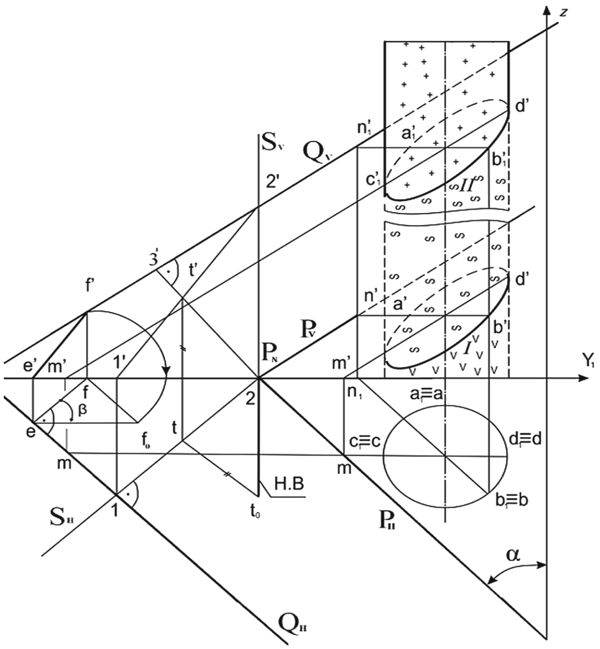

Fig. 1. Strike and dip measurements for blanket deposit using a core pole. Contact surfaces – parallels.

Suppose a mineral deposit is found between contact surfaces. With the help of descriptive geometry, we define deposit parameters.

Assume planes P and Q are contact surfaces of geological materials. Let us create diagonal lines $AB||H$, $A_1B_1||H$ and frontals $CD||V$, $C_1D_1||V$ in these planes. Then we form traces of contact planes: P_V and P_H – traces of contact plane P, Q_V and Q_H – traces of contact plane Q. We obtain angle α — an angle of stretch. We define angle β, an angle of dip, with the line of largest inclination. By dropping a perpendicular from plane P to plane Q we obtain $t_0 2$ – reservoir capacity.

While we know the coordinates of points *A, B, C, D* of contact surface and core pole diameter *D* we are able to provide an analytical description to the geometrical algorithm for solution of this problem.

We need to find angle of dip β and angle of stretch α.

To solve a problem represented by Fig. 1 we follow these steps:

1. Find coordinates of $n_1^{'}$, pierced by frontal trace Q_V of contact plane Q:

$$\left(\frac{x_b - x_a}{y_b - y_a} \cdot \left(x_a \frac{y_b - y_a}{x_b - x_a} - y_a\right); z_{a_1'}\right) \tag{1}$$

2. Define an equation of straight-line Q_V, prescribing frontal trace of contact plane Q:

$$z - z_{a_1'} = \frac{z_{d_1'} - z_{c_1'}}{x_{d_1'} - x_{c_1'}} \left(x - \frac{x_b - x_a}{y_b - y_a} \cdot \left(x_a \frac{y_b - y_a}{x_b - x_a} - y_a\right)\right) \tag{2}$$

3. Find vanishing point coordinates of Q plane trace on axis OX. Coordinates of point in question:

$$\left(x_a - y_a \frac{x_b - x_a}{y_b - y_a} - z_{a_1'} \frac{x_{d_1'} - x_{c_1'}}{z_{d_1'} - z_{c_1'}}; 0\right) \tag{3}$$

4. Define a straight-line equation of horizontal trace of Q_H hanging wall plane:

$$y = \frac{y_b - y_a}{x_b - x_a} \left(x - x_a + y_a \frac{x_b - x_a}{y_b - y_a} + z_{a_1'} \frac{x_{d_1'} - x_{c_1'}}{z_{d_1'} - z_{c_1'}}\right) \tag{4}$$

5. Angle of dip β is found from triangle $\Delta eff0$:

$$tg\beta = \frac{ff'}{ef} \Rightarrow \beta = arctg \frac{ff'}{tf} \tag{5}$$

6. We express a straight-line equation of horizontal trace of hanging wall plane P_H:

$$y = \frac{y_b - y_a}{x_b - x_a} \left(x - x_a + y_a \frac{x_b - x_a}{y_b - y_a} + z_{a_1'} \frac{x_{d'} - x_{c'}}{z_{d'} - z_{c'}}\right) \tag{6}$$

7. We find stretch angle α:

$$\alpha = arctg\left(-\frac{x_b - x_a}{y_b - y_a}\right) \tag{7}$$

8. Calculate reservoir capacity, equal to length of the segment $P_x t_0$:

$$m = |y_{px} - y_{t0}|, \tag{8}$$

where y_{px} and y_{t0} – ordinates of points P_x and t_0.

The developed algorithm and its mathematical formulation help to design a program for automatic solving of this problem [16–20].

Figure 2 is a flow diagram of automatic strike and dip measurement using a core pole when contact surfaces of materials are parallel.

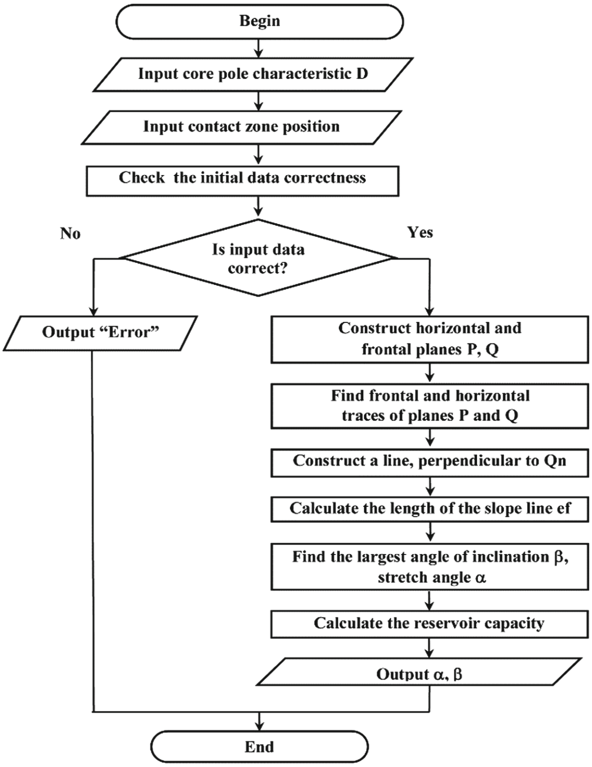

Fig. 2. Algorithm for strike and dip measurement by contact surface on a core pole. Contact surfaces – parallel.

When contact surfaces are non-parallel solution algorithm is the same. Suppose a middle section of a core pole between contact surfaces is where a mineral deposit crosses a borehole.

In Sect. 1 we establish a horizontal *DE* and frontal *DF* to find traces of *Q* plane. Largest angle of inclination on β_1 plane defines a dip and direction of horizontal line and horizontal trace demonstrate its strike α_1.

We find traces of *P* plane in Fig. 3 with horizontal *AB* and frontal *BC*. Piercing of planes *P* and *Q* characterizes pinching-out of a deposit constrained by these planes. Angle α_2 defines the strike, and β_2 is angle of dip.

Geometric algorithm for solving of this problem:

1. A, B, C Є P; 1-2 ⊥ PH; 1-2 — line of largest inclination *P*; β - angle of dip of plane *P*;
2. *D, E, F* Є *Q; 3-4* ⊥ Q_H; 3-4 — line of largest inclination *Q*; β_1 — angle of dip of plane *Q;*
3. *P* ∩ *Q* = *6-7*; 6-7 — line of deposit pinching-out; β_2 dip angle of pinching-out line; $o_1h \perp$ *6-7;* $o_1h = L$ — cross-cut between borehole axis and pinching-out line.

Figure 4 is a geometrical algorithm and a mathematical formulation for problem solution when contact surfaces of materials are non-parallel.

As a result of the research, software modules for solving the main problems of exploration and outlining of mineral deposits are presented in Fig. 5.

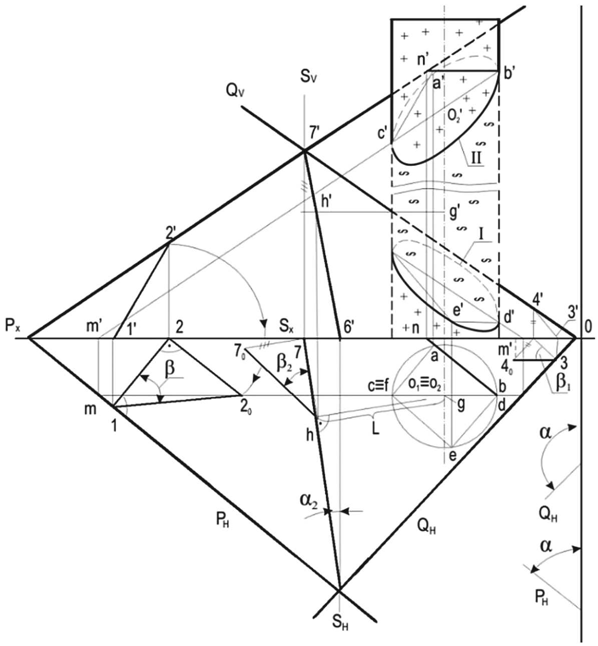

Fig. 3. Strike and dip measurement for cross beds of a core pole.

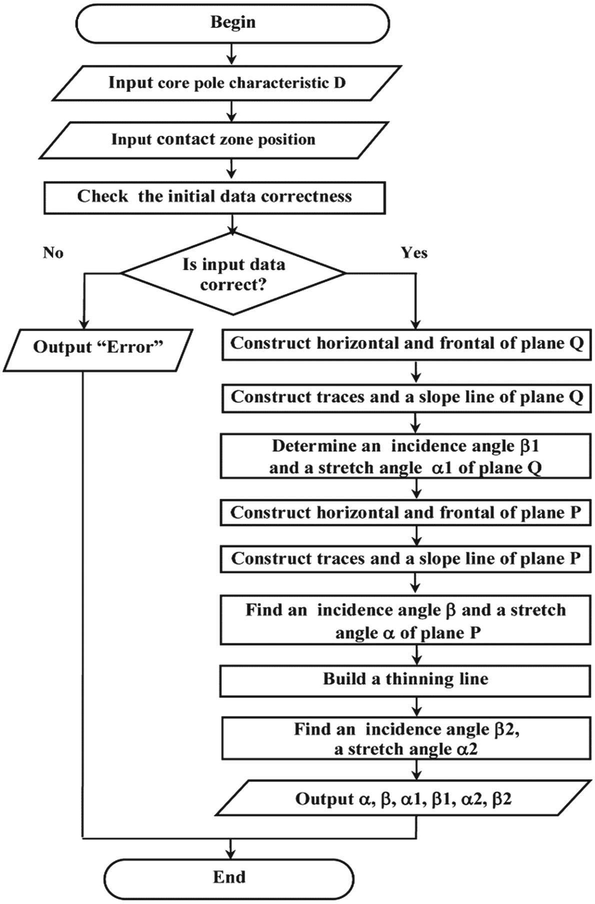

Fig. 4. Algorithm for strike and dip measurement by contact surface on a core pole. Contact surfaces - non-parallel.

The developed automated system for solving the main problems of exploration and outlining of mineral deposits consists of the following subsystems:

- The input data input subsystem, responsible for input data and verification of their correctness
- The subsystem for creating graphic images allows you to define (build) a front and a horizontal projection of the original data
- A subsystem of calculations, in which the solution of such problems as determination of the intersection points of the bores with contours of the mineral deposit, determination of the elements of bedding along the pole core, determination of the boundaries and parameters of the deposit output to the earth’s surface are realized

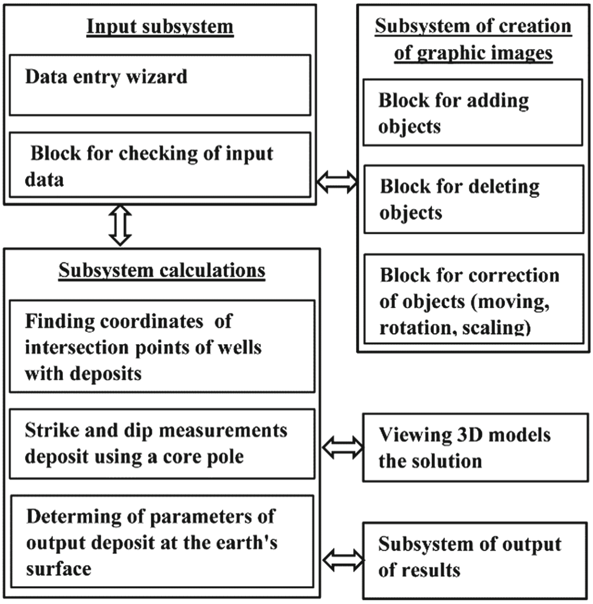

Fig. 5. Structure of software modules.

5 Conclusion

To conclude, geometric modeling helps solve the problems related to deposits of minerals by methods of descriptive geometry. This makes the application of CAD system possible and reduces the costs of field observations.

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