

Data Analysis in Studying the Geological Section

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Abstract

The article is devoted to developing a software module that allows interpreting field data, identifying locations of low and high resistance objects and evaluating them for the desired minerals.

Keywords: data analysis, geophysical data, interpretation.

Introduction

The rationale for this work is that interpreting received geophysical data has a high cost, long terms and inefficient outcome.

The goal of our work is to computerize interpreting data received with the long-wire method.

To achieve the stated goal, the following tasks were set:

- analyze the subject area;
- create a computer model;
- develop a software module;
- take into account ergonomic and psychological factors.

1 Source data preprocessing

Source data is field work materials taken with the long-wire method at the Barobinskiy exploration area in Kazakhstan (gold mineralization) by the alternating-current prospecting equipment developed by Krasnoyarsk geophysicists with contributions from the Chair of Radio-Electronic Systems of the Siberian Federal University [1]. Prospecting was carried out with a 3 km long wire rerouted each 1 km and a magnetic field survey from each wire position along orthogonal 1 km long profiles. The wire was powered by an alternating current of 312 Hz frequency. At the observation sites the horizontal component of the electromagnetic field H_y and the vertical H_z were measured.

The magnetic field intensity values, measured by the device, are total H^Σ , conditioned by the field of the wire H^w and anomalous objects H^{an} . It is possible to isolate anomalies at the observation profile only after subtracting the normal wire field from the measured values $H^\Sigma : H^{an} = H^\Sigma - H^w$. Due to the considerable complexity

of the theoretical definition of the normal wire field, this action is implemented by a practical technique in which the values H^Σ are averaged over all the profiles of $(\sum_{i=1}^n H_y)/n$. The effect of anomalous areas is minimized and the observation sites get anomalous values of the horizontal and vertical components at the observation sites - the formulas (1)-(2).

$$H_y^{an} = H_y - \frac{\sum_{i=1}^n H_y}{n}, \quad (1)$$

where n is a number of profiles; H_y is the measured value of the horizontal component.

$$H_z^{an} = H_z - \frac{\sum_{i=1}^n H_z}{n}, \quad (2)$$

where n is a number of profiles; H_z is the measured value of the vertical component.

As a matter of obtained anomalous values, further location analysis of the conducting objects is carried out. The analysis is based on the position [2], where the normals to the intensity vectors at the magnetic field observation sites indicate the place of its source, which is the region of eddy current concentration.

2 The computer model

The input parameters for the model are the measured values of the horizontal H_y and vertical H_z magnetic field components for pickets of various profiles and wire positions. The output parameters are the areas of occurrence of anomalous objects.

The full magnetic field vector is defined as the vector sum of the horizontal \vec{H}_y and vertical \vec{H}_z components with the coordinates $(H_y; 0)$ and $(0; H_z)$, respectively. As is known, if the vectors are given by their coordinates, then the sum of these vectors is a vector which coordinates are equal to the sum of the corresponding coordinates of the summand vectors. From here we find the formula for calculating the full vector coordinates - the formula (3).

$$\vec{H} = \vec{H}_y + \vec{H}_z = (H_y + 0; 0 + H_z) = (H_y; H_z), \quad (3)$$

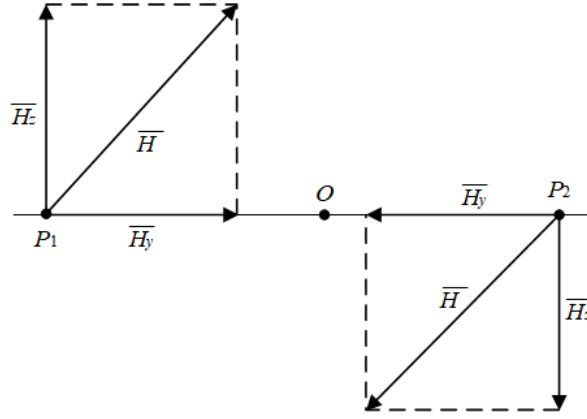
where H_y is the horizontal component value; H_z is the vertical component value.

Figure 1 shows the vectors for the pickets P_1 and P_2 located left/right of the wire position designated by the point O [2].

The next step is to plot normals passing through the observation points to the vectors.

The equation of line takes the form: $y = ax + b$, where a is the slope of the line, b is some real number. To construct perpendiculars we use the following property - the product of the slope ratios of two perpendicular lines is -1 . If $y = a_1x + b_1$ is the equation of the line which the vector lies along, and $y = a_2x + b_2$ is an equation of a perpendicular line, then $a_1 \cdot a_2 = -1$.

The equation of the line passing through two points $(x_1; y_1)$ and $(x_2; y_2)$ can be written as follows - the formula (4).


 Figure 1: The full magnetic field vectors \vec{H}

$$\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1} \quad (4)$$

Having made the transformations, we obtain the equation for the slope ratio a_1 in the equation of line $y = a_1x + b_1$, which the vector lies along - the formula (5).

$$a_1 = \frac{y_2 - y_1}{x_2 - x_1} \quad (5)$$

where $(x_1; y_1)$ - coordinates of the vector beginning; $(x_2; y_2)$ - coordinates of the end of the vector.

Then the slope ratio a_2 of the perpendicular line $y = a_2x + b_2$ can be calculated by the formula (6). The ratio b_2 can be expressed by substituting the coordinates of the observation point $(x_0; y_0)$ through which the normal passes - the formula (7).

$$a_2 = -\frac{1}{a_1} \quad (6)$$

$$b_2 = y_0 - a_2 \cdot x_0 \quad (7)$$

To construct a perpendicular, we need to know its end coordinate. The length of the perpendicular is equal to the product of the coefficient of proportionality k the length of the vector by the length of this vector l . Figure 2 shows an example of finding the end coordinate for the perpendicular to the full picket vector located to the left of the O wire. Using the Pythagorean theorem, you can make the following equation: $\sqrt{(x_0 - x_1)^2 + (y_1 - y_0)^2} = kl$, where k is the coefficient of proportionality, l is the vector length, $(x_0; y_0)$ are the origin coordinates, $(x_1; y_1)$ are the end coordinates. Since $y_0 = 0$, and the coordinate y_1 can be expressed in terms of x_1 using the line perpendicular equation $y = a_2x + b_2$, the equation can be converted to the following form $\sqrt{(x_0 - x_1)^2 + (a_2x_1 + b_2)^2} - kl = 0$.

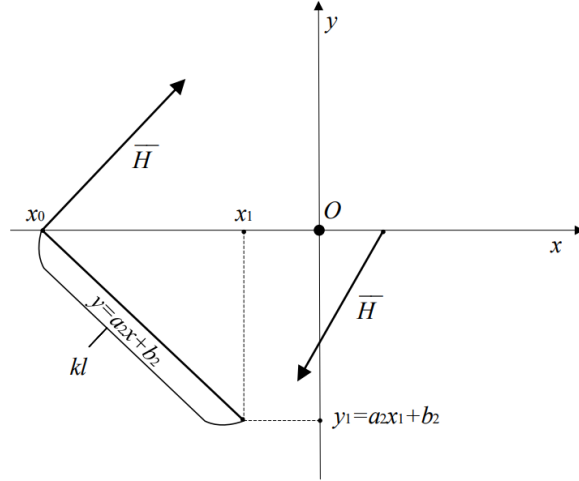


Figure 2: The example of finding the end coordinate for the perpendicular

The resulting equation is nonlinear, which can be solved using the bisection method.

The next step is to find the intersection points of the normals. To find the intersection point of two perpendiculars defined by the equations $y = a_1x + b_1$ and $y = a_2x + b_2$, we equate these equations $a_1x + b_1 = a_2x + b_2$ to the vectors and express x - the formula (8).

$$x = \frac{b_2 - b_1}{a_1 - a_2} \quad (8)$$

Substituting the obtained x value of the formula (8) into one of the two line equations that correspond to the perpendiculars, we obtain the coordinates $(x; y)$ of the intersection point.

You can find the concentration point areas using the k-means clustering algorithm with the Euclidean distance metrics. For two points A and B with the coordinates $(x_1; y_1)$ and $(x_2; y_2)$ the Euclidean distance is defined as follows - the formula (9).

$$d(A, B) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (9)$$

3 The problem algorithm

Predicting anomalous objects in the depth of the studied geological section on the field survey materials using the long-wire method is performed according to the algorithm:

1. At each observation point the anomalous values of the vertical H_z^{an} and horizontal H_y^{an} magnetic field components are defined by subtracting the wire field H_z^{av} and H_y^{av} from the observed values of the total field H_z^{ob} and H_y^{ob} .

2. The sum vector $\overrightarrow{H^{an}}$ is defined by vector summation based on the calculated anomalous values of $\overrightarrow{H_z^{an}}$ and $\overrightarrow{H_y^{an}}$.
3. The normal to the vector $\overrightarrow{H_y^{an}}$ is defined at the observation point.
4. The listed actions are performed at all the observation points of the profile.
5. Vectors and normals are constructed over the entire profile. The points of the normal intersections closest to the surface are secondary current concentration areas, i.e. anomalously conducting objects. The points of normal divergence correspond to the areas of high-resistance rock growth.
6. The anomalous object location is distinguished with the k-means clustering algorithm.

4 Software implementation

The software module is written in C #.

To store data we use the database, the scheme of which is shown in Figure 3. Microsoft SQL Server is chosen as a DBMS.

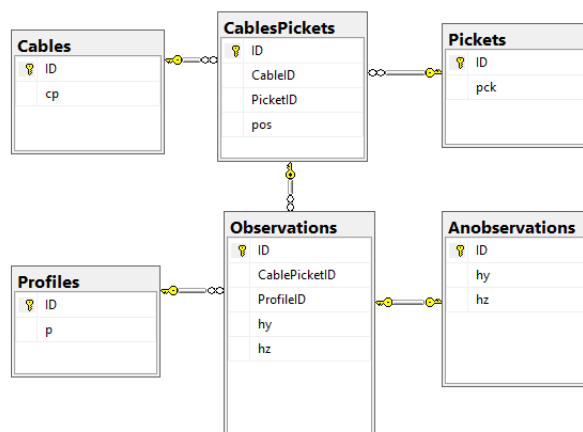


Figure 3: The database scheme

In the process, ergonomic and psychological factors were taken into account. A friendly user interface has been developed. For the convenience of geophysicists working with the software module, the created user guide comes with the description of operating with each module function.

Figure 4 shows the main window of the software module.

The interface allows a user to work with the database: add, modify, and delete records through the tab "Table". Figure 5 shows the form of interaction with the database for the "Observations" entity. In the DataGridView window, the observation values are displayed corresponding to the selected wire and picket position in the

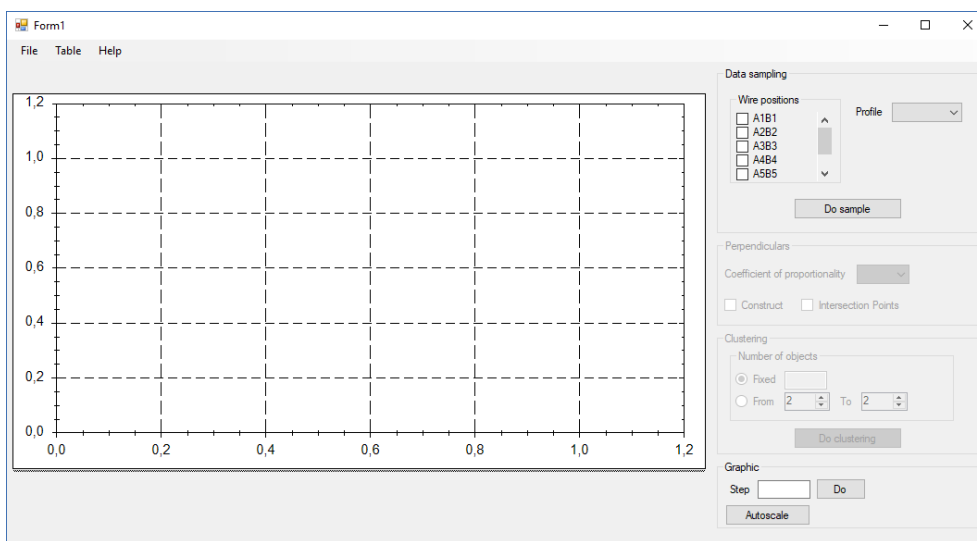


Figure 4: The main window of the module

ComboBox controls. The anomalous values of the horizontal and vertical components for observations are calculated after closing the form - the formulas (1)-(2) and added to the "Anobservations" table. The "Observations" and "Anobservations" tables are related one-to-one.

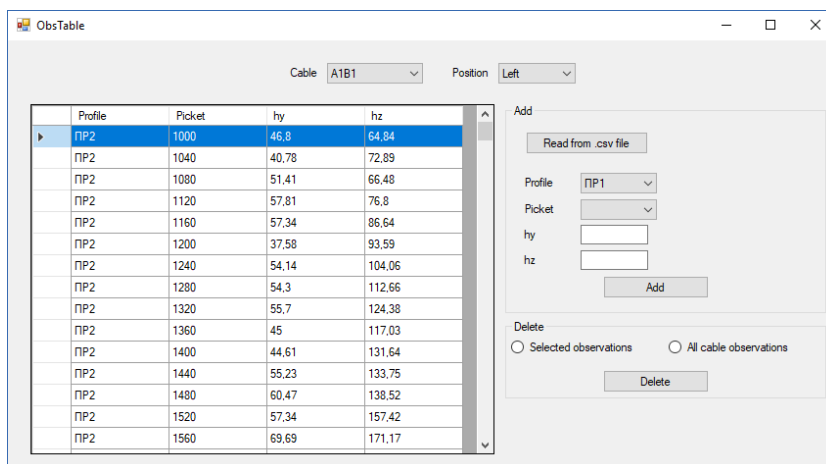


Figure 5: The "Observations" form

The right pane of the main window (Figure 4) contains the options available for selection.

Based on "Wire positions" and "Profile", the input data in the Sample () function is formed by sampling from the database. Figure 6 shows a chunk of the input data - the observations for Wire A1B1 of Profile 1.

After sampling the observations, we call the Vectors () function and construct full vectors.

| | ID | CablePicketID | ProfileID | hy | hz |
|---|------|---------------|-----------|--------|-------|
| 1 | 5025 | 66 | 1 | 163,91 | 115 |
| 1 | 5026 | 67 | 1 | 132,66 | 110 |
| 1 | 5027 | 68 | 1 | 142,11 | 115 |
| 1 | 5028 | 69 | 1 | 142,81 | 85,94 |
| 1 | 5029 | 70 | 1 | 110,16 | 95,94 |
| 1 | 5030 | 71 | 1 | 110,31 | 92,97 |
| 1 | 5031 | 72 | 1 | 80,39 | 81,88 |
| 1 | 5032 | 73 | 1 | 99,38 | 96,72 |

Figure 6: The chunk of input data

When a user selects the value of constant of proportionality, for each of perpendiculars the end coordinate is calculated. The coordinates are recalculated every time the user selects a new value.

Right after calculating, the "Construct" and "Intersection Points" elements become available for selection, and then the Perpendiculars () and Interpoints () functions are called, respectively. Perpendiculars to vectors are constructed with the Perpendiculars () function, and the Interpoints () function is used to find the intersection points of the perpendiculars.

Figure 7 shows an example of constructing the perpendiculars and their intersection points. The coefficient of proportionality is 3, wire A1B1, profile 2.

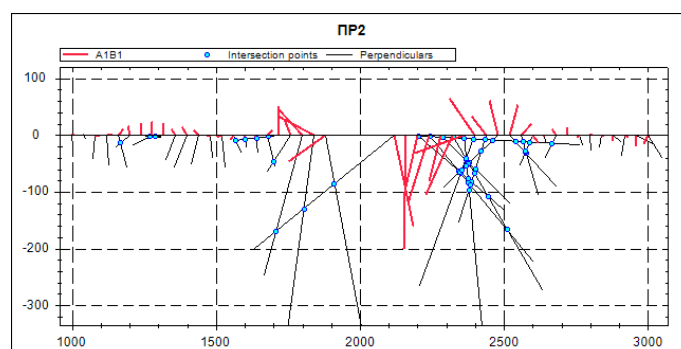


Figure 7: The perpendiculars to the full magnetic field vectors and their intersection points

To isolate concentration areas of the points that correspond to the predicted low-resistance and high-resistance objects when studying the geological section with the alternating-current long-wire method, the k-means clustering method was used. Figure 8 shows the program output.

The secondary field sources are concentration areas of eddy currents, arising in the development areas of highly conducting objects such as sulfide and magnetite ores or ground saline water. Areas without secondary electromagnetic field sources correspond to low-conducting rocks such as stone masses and gem stone deposits [3]. Each anomalous object is of interest for constructing a geological section. The geological nature of anomalous objects is determined with the assistance of auxiliary geological and mineralogical information.

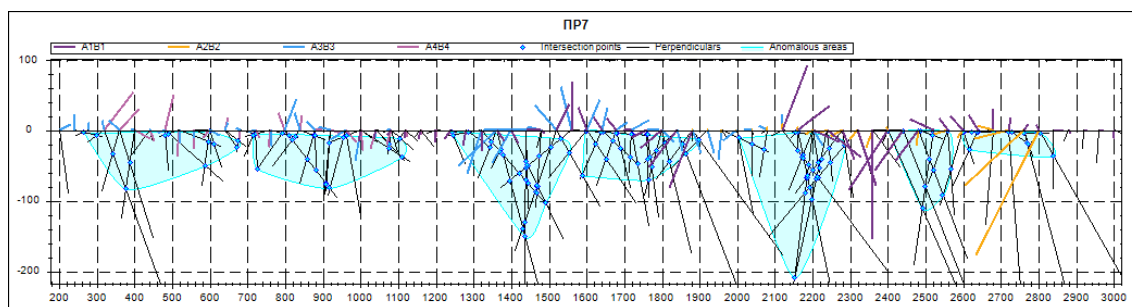


Figure 8: Predicting a conducting object in the geological section

Conclusions

The developed software module allows identifying locations of anomalous objects in the geological environment, to analyze the obtained locations of low or high electrical resistance, which is geophysical information as part of geological prospecting and exploration. In this case, the source information was processed and a geoelectric section was constructed for the Barobinskiy gold mineralization area. Computer-aided processing of large data volumes shows that there are low and high resistance areas in the section, which are of interest for prospecting and interpreting with the assistance of related G&G data. At the surface in the 800 - 1600 m spacing of the profile, fragments of quartz with gold were found, according to which it is assumed that we may find a series of gold-bearing quartz veins and stock work at the depth that correspond to high resistance areas. Low resistance areas may have sulfide mineralization. The eastern part has mostly near-surface highly conducting salt marsh. This software module helps significantly reduce the calculating time when processing materials. The processing tool increases transmission distance using the long-wire method and isolate anomalous zones. Goal-oriented well drilling of these zones allows reducing the financial and time expenditures of geological prospecting and exploration.

References

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