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SOLUTION ANALYSIS OF MAGNETIC ANOMALIES FOR RESEARCH AND FORECASTING OF PETROLEUM FIELDS

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Abstract: *magnetic surveying is a geophysical method for solving geological problems, based on the study of the Earth's magnetic field, the Earth, as a cosmic body of a certain internal structure generates a constant magnetic field, called normal or primary. In this research, the mathematical interpretation of magnetic surveying data considered through digitization of maps, creation of new maps of magnetic anomalies, plan curvature map, first and second derivative maps, application of various filters, overlapping maps with the isolated structural elements, and all these information received geological justification. Also, the paper completely describes the relatively simple sequence of application of all methods used in the mathematical interpretation of magnetic surveying data, based on the results of the work performed, the prospects of this method were analyzed, the method is very efficient, and requires absolutely no investments.*

Keywords: *magnetic surveying, magnetic anomaly, mathematical interpretation, map of the regional magnetic anomaly, map of the first derivative, map of the second derivative, magnetization of rocks, plan curvature map*

МҰНАЙ КЕНОРЫНДАР ҮШІН МАГНИТТІК АНОМАЛИЯ ЗЕРТТЕУ МЕН БОЛЖАУДЫҢ ТАЛДАУЫ

Аңдатпа: *магниттік барлау дегеніміз – жердің магнит өрісіне негізделген геологиялық есептерді шығаратын геофизикалық әдіс. Жер белгілі ішкі құрылысы бар ғарыштық дене ретінде қалыпты немесе бастапқы деп аталатын тұрақты магнит өрісін түрлендіреді.*
Аталған жұмыста «Солтүстік Аққар» кенорны үлгісінде магниттік барлау деректерін карталарды цифрлау, магниттік аномалиялардың жаңа карталарын жасау, жоспарлы қисықтықты, бірінші және екінші туынды карталарды құру, түрлі геофизикалық сүзгілерді қолдану, құрылымдық элементтерді бөліп көрсету арқылы карталарды бір-біріне қабаттастыру арқылы математикалық түсіндіру қарастырылған. Сондай-ақ жұмыста магниттік барлаулар деректерін математикалық түсіндіруде пайдаланылған барлық әдістерді қолданудың қарапайым бірізділігі сипатталады, жүргізілген жұмыстардың нәтижелері бойынша аталған әдістің келешегіне талдау жасалған, әдіс нәтижелі болып табылады және ешқандай салымды талап етпейді.

Түйінді сөздер: *магниттік барлау, магниттік аномалия, математикалық интерпретациялау, аймақтық магниттік аномалия картасы, бірінші туынды картасы, екінші туынды картасы, тау жыныстардың магниттенгендігі, жоспарлы қисықтығы картасы*

АНАЛИЗ ИССЛЕДОВАНИЯ И ПРОГНОЗИРОВАНИЯ МАГНИТНЫХ АНОМАЛИЙ ДЛЯ НЕФТЯНЫХ МЕСТОРОЖДЕНИЙ

Аннотация: *магниторазведка – это геофизический метод решения геологических задач, основанный на изучении магнитного поля Земли. Земля, как космическое тело определенного внутреннего строения, генерирует постоянное магнитное поле, называемое нормальным или первичным. В данной работе на примере месторождения «Северный Аккар» рассмотрена математическая интерпретация данных магниторазведки посредством оцифровки карт, создания новых карт магнитных аномалий, плановой кривизны, первой и второй производных, применения различных фильтров, наложения карт* *друг на друга с выделением структурных элементов, и самое главное, всей полученной информации дано геологическое обоснование. Также, в работе полностью описывается относительно простая последовательность применения всех методов, использованных в математической интерпретации данных магниторазведки. По результатам проведённой работы были проанализированы перспективы данного метода, который является результативным и не требует абсолютно никаких вложений.*

Ключевые слова: *магниторазведка, магнитная аномалия, математическая интерпретация, карта региональной магнитной аномалии, карта первой производной, карта второй производной, намагниченность горных пород, карта плановой кривизны*

Introduction

According to the magnetic surveying which based on the measurement of the earth's magnetic field, which can be carried out both on land, in water, and in air, structural features of oil and gas deposits and crystalline basement can be predicted. Relying on that the depth of magnetic investigations does not exceed 50 km, accordingly conclusions will be made. By the using magnetic surveying following issues can be solved: 1) exploration of iron ore deposits, because they are distinguished by intense anomalies in hundreds and thousands in nT, also it`s of particular importance for polymetallic ores (copper-nickel, manganese ores, bauxites, placer deposits of gold, platinum, tungsten, molybdenum); 2) allocation of contours of mafic and ultramafic rocks; 3) identification and trace such intrusive bodies like dykes, large viens and fault zones in different geological conditions;4) identification of crystalline basement features such uplifts and deflections;5) for lithospheric plates researches and geological mapping; 6) conductionof studies at great depths (up to the Curie temperature); 7) allocation of contours of geological massive and differentiate according to magnetic property arrays of ultrabasic rocks among acidic, igneous or sedimentary deposits;8) making conclusions about the hypsometry of the studied region and the petrographic composition of rocks; 9) getting good results when prospecting diamondiferous kimberlite pipes; 10) obtaining information on the rock fractures based on a micromagnetic survey.All the data listed above, like in this work become informative after they pass through a large number of geophysical filters and mathematical interpretations.

Main part

Having field coordinates as shown at the picture below mining site of oil field where geophysical prospecting works were conducted can be constructedin Google Earth.

Figure 1 Map of the work region carried out based on known coordinates

Then we constructed a map of the region and marked the field territory in the form of a 6-gon, and the territory was identified on the map of the regional magnetic anomaly.

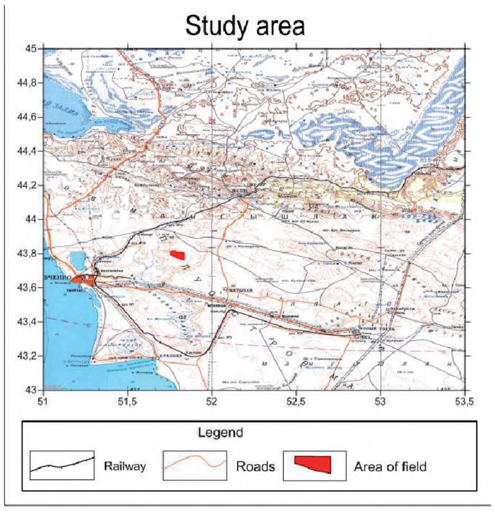

Figure 2 Map of the studied region

The creation of a regional magnetic anomaly map in digital format turned out to be more complicated. An image of the regional magnetic anomaly of the studied region was created using the "sea border" function. In the excel document, according to the color scale of the layer, shown in the magnetic anomaly "EMAG2: Earth Magnetic Anomaly (older version)" indicated in the ArcGIS program was digitized every mm of the studied area (44 profiles, 39 pickets).

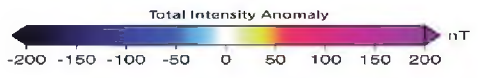

Figure 3 Color scale of magnetic anomaly (nT)

In map creation process we used selecting gridding method. Gridding method in geophysics is a method of averaging. Surfer - the program of creation of a contour, based on a grid. Gridding is the process of creating a Grid (.GRD file) or in other words, the process of calculating Z values for grid points of a regular grid where, in fact, no data exists, using the data stored in the XYZ (.DAT) file. In the process of building a map, it is necessary to choose the gridding method, the list below gives an overview of each gridding method and some advantages and disadvantages in choosing one or the same method.

Inverse Distance is fast gridding method, but it tends to generate "target apple" templates of concentric contours around data points.

Kriging is one of the more flexible methods and is useful for gridding almost any type of data set. With most data sets, Kriging with a linear variogram is perfectly effective. In general this is the method that would be recommended for the most frequent use. Kriging is the gridding method's default value. By default, it generates the best full interpretation (decryption) of most data sets. For large datasets, however, Kriging works quite slowly.

Minimum Curvature generates smooth surfaces and is fast for most data sets.

Nearest Neighbor is useful for converting XYZ data files with regularly available data to Surfer grid files, or when your data is almost a complete grid, with the exception of individual spaces (lack of data). This method is useful for inserting holes, or creating a grid file with a blanking value assigned to those parts of the map where data is missing.

Polynomial Regression processes the data so that in the underlying (main) large-scale trend display trend. This is used to analyze the surface trend. Polynomial Regression is fast method for any amount of data, but local details in the data are lost in the generated grid.

Radial Basis Functions is completely flexible, and like Kriging method, generates the best complete interpretation of most data sets. This method produces results that are completely similar to Kriging.

Shepard's Method is similar to the Reverse Distance, but has no tendency to generate templates such as a "bull's eye" templates, especially when the Smoothing factor is used.

Triangulation with Linear Interpolation is fast with all data sets. When you use small data sets, the triangulation generates distinct triangular faces between the data points. One of the advantages of triangulation is that, with sufficient data, the triangulation can store the interrupt lines defined in the data file. For example, if the fault is delineated by sufficient data points on both sides of the fault line, the grid generated by the triangulation will show an inhomogeneity.

In the creation of our map the Kriging method was chosen.

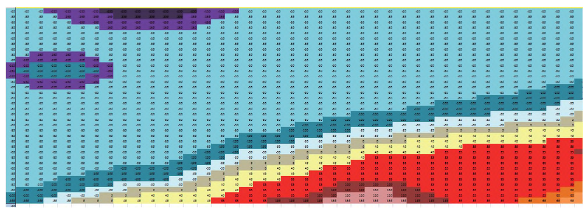

Figure 4 Digitization of data magnetic regional anomaly

Then a map of the regional magnetic anomaly was overlied on the map of the studied region, the action was carried out using the program "Surfer 13 - Golden Software", using the "stack maps" function - to apply one to another, using the "opacity" function, we adjust the transparency of the maps, to create lateral grids indicating the coordinates, the coordinates of the grid studied (top-51 °, 43 ° 166; bottom-53° 166, 44° 7788) were indicated in the coordinate system window.

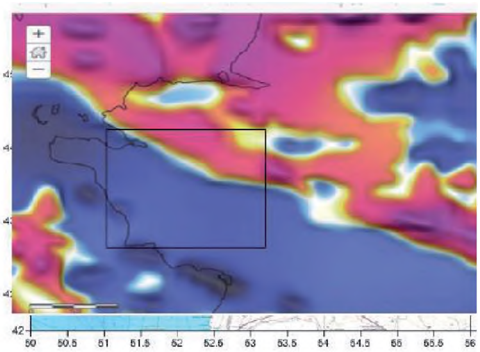

Figure 5 Map of the work area superimposed on the data of the regional anomaly obtained from the layer "EMAG2: Earth Magnetic Anomaly (older version)"

The resulting map of the magnetic anomaly was filtered out, the filters used to align the geophysical data, it is possible to detect and delete data defined as noise, it is possible to cut off the indices with too short wavelength and too large amplitude, it is also possible to remove shortwave geological components such as signals from the surface, etc. The main types of filters presented in Surfer Software:

• High pass filtering - high-pass filtering of the channel (increase in clarity);

• Low pass filtering - low-pass filtering of the channel (anti-aliasing);

• Band pass filtering - filtering of frequencies whose wavelength is greater than the cutoff of the long wave or less than the cutoff of the short wave;

• Convolution filtering - averaging of the spatial domain in the channel. This filtering method can be defined in a filter file or in a comma-delimited string;

• Difference filtering calculates the difference between the values in the channel. To determine the noise, it is useful to calculate the difference in the arithmetic progression of the four given differences;

• Polynomial filtering calculates the trend of the n-th (no more than ninth) order for the channel data by the method of the best polynomial approximation (smallest square). Then this trend is analyzed and placed in a new channel. You can also create an additional residual channel (trend at the input);

• The B-spline filtering calculates the B-spline data interpolation in the channel. The B-spline function allows you to control the smoothness of the spline and the voltage applied to the ends of the spline;

• Linear regression filtering applies a linear least-squares regression to an array of marked data in the channel and creates a report on the slope and intersection.

During mapping of the regional magnetic anomaly map, the Fourier transform was applied. During application of the filter - if the point is noise, it is simply cut off and replaced by an approximate value based on the surrounding dot data. Parts of the data that are not noise does not change at all.

Fourier Filters perform the following functions:

• Processing of profile data for interpretation and modeling purposes;

• Rapid application of filters to one or more data profiles;

• Interactive selection of filtering parameters, spectral density display and determination of optimal filters for processing and interpretation;

• Automatic analysis of distance or, if necessary, starting points.

Due to the Fourier transform, the data can be analyzed by wave number or wavelength. Thus, a number of operations can be used to improve useful data, and / or delete unnecessary data, and / or transform data.

The map that passed through the filter becomes more distinct, sharp transition between the lines of the magnetic anomaly and their direction is seen. As noted earlier, the filter clears the map from noise, smooth transitions in the values makes it abrupt, and is applicable to the interpretation of structural type objects such as: faults, dislocation systems such as anticlinal zones, shafts, synclinal zones, deflections, tectonic steps, depressions, uplifts, etc. In Surfer Software, the Fourier transform was implemented using the functions grid => filters => Fourier filter => rows-7, cols-7 => number of passes-1.

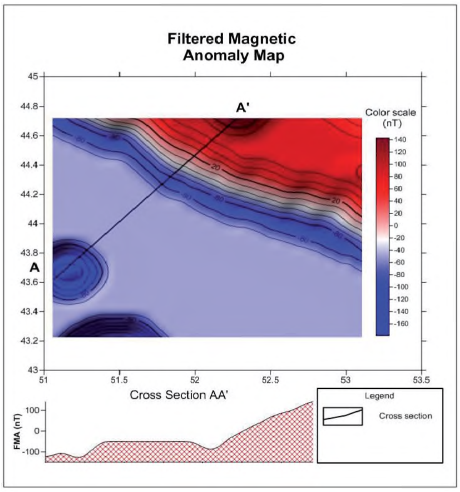

Figure 6 Map of the regional magnetic anomaly passed through the filtering

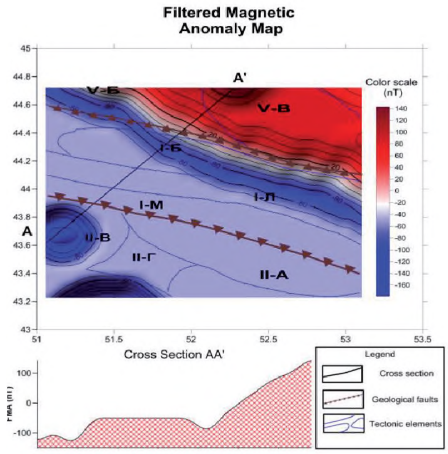

Figure 8 Filtered map of the regional magnetic anomaly with isolated structural elements

Map of the regional magnetic anomaly, physical map of the region and the tectonics map covering the field and surrounding area were superimposed on each other, in order to isolate all structural elements and faults using the Surfer program.

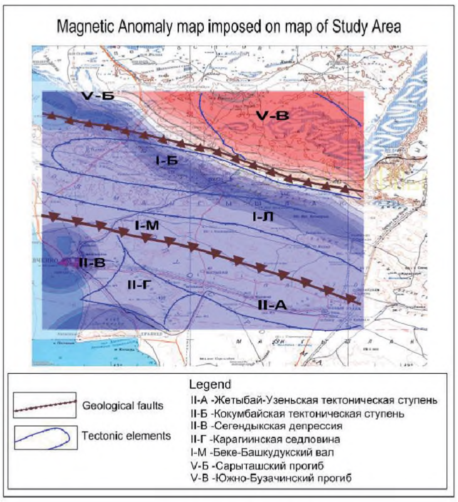

Figure 7 Map of the regional magnetic anomaly imposed on the map of work area, with selected tectonic elements

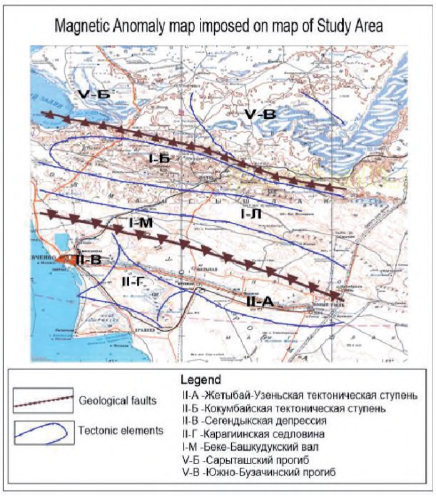

Figure 9 Map of the work area with the highlighted structural elements

In Figure 7 three maps superimposed on each other and faults are shown, in the course of the work, to select the structural elements we needed, a polylinefunction, in the range of options for whichwe selected color, thickness, style of designation, etc., Thus, thanks to this function, the location and direction of the structural elements can be traced on the maps of the magnetic anomaly and the map of the region, and help us to come to certain conclusions.

First and second derivatives are very effective during the process of isolating structural and petrophysical features on the magnetic anomaly map, they are used to increase the anomalies, since many of them have small amplitudes and are easily obscured by the magnetic or gravitational field. Application of these methods allows to observe nuances invisible in the filtered map of the regional magnetic anomaly. The first derivative is implemented by a chain of actions: Grid => grid calculus => directional derivative => first derivative => angle (0); Grid => grid calculus => directional derivative => first derivative => angle (-90). Second derivative can be applied by the following chain of actions: Grid => grid calculus => directional derivative => second derivative. After creating each of the maps, to themwas applied Moving Average (7x7; number of passes-1) filter. Moving Average Filter it`s a kind of low-pass filtering, usually used to smooth out an array of signals, it takes M input samples at a time and takes the average of these M-samples.

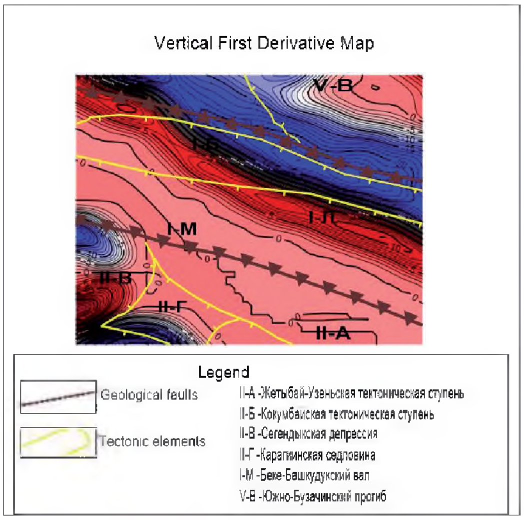

Figure 10 First vertical derivative map

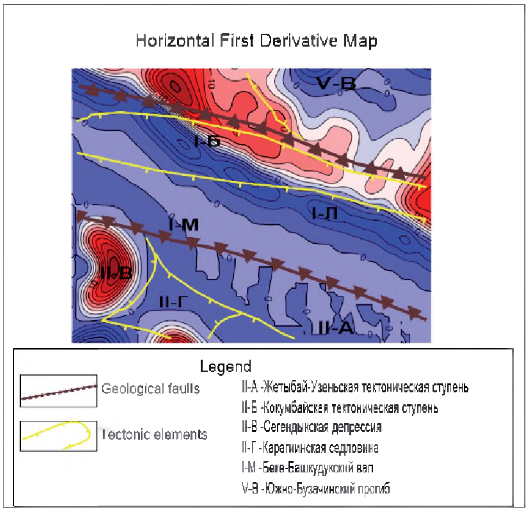

Figure 11 First horizontal derivative map
These maps were filtered by the moving average filter, first derivative map of the regional magnetic anomaly: a) horizontal (0 °) b) vertical (-90 °).

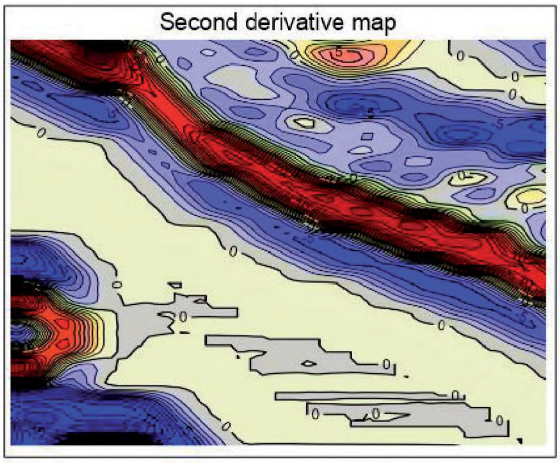

Figure 12 Second derivative map

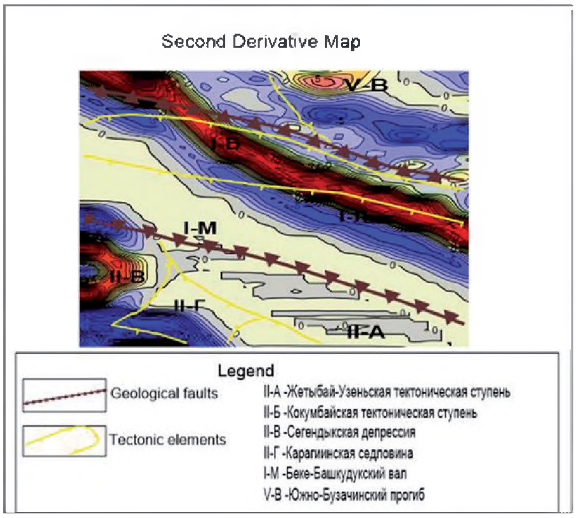

Figure 13 Second derivative map filtered by Moving Average filtering with highlighted structural elements

In addition to the done work, thePlan Curvature method was applied. This method is used in terrain modeling. Plan Curvature reflects the degree of change in the angle of the terrain aspect when viewed in the horizontal plane and it is a measure of the curvature of the isolines on the contour map. Sequence of applied operation: Grid => grid calculus => terrain modeling => plan curvature => angle (0).

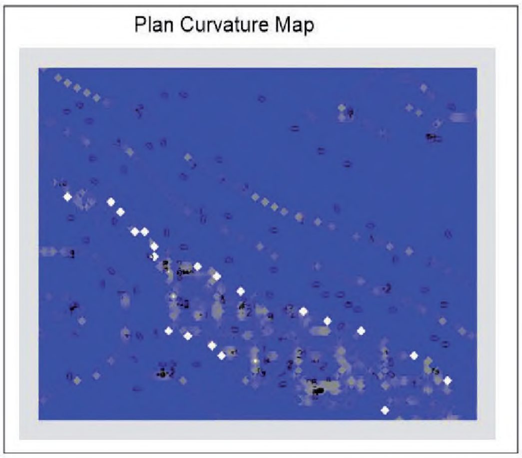

Figure 14 Plan curvature map

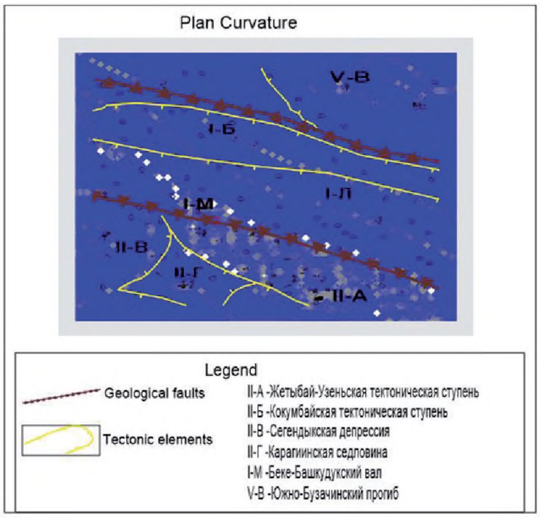

Figure 15 Plan curvature map with highlighted structural elements

Conclusion

1) When overlaying a tectonics map and a filtered map of a regional magnetic anomaly, one can observe that the direction of the faults and the direction of the magnetic lines coincide.

2) The first derivative (first derivative-gradient) shows the rate of change of the function expressing the anomaly. If in the case of the second derivative map, both the vertical derivative and the horizontal derivative give the detection of small anomalies, then the results of the first and second derivatives are separately important. It is shown that the functions of the magnetic field derivatives in many cases allow much more localization of causative bodies than the initial function of the magnetic field. In this case, the vertical derivatives localize the upper edges of the causative bodies, while the horizontal derivatives - their lateral boundaries and contacts.

3) In the first horizontal derivative, inflection points are points whose anomaly values are at their maximum, i.e. where the horizontal gradient changes most rapidly. Inflection points can provide useful information about the nature and boundaries of the anomalous body, because the value of the magnetic anomaly is strongly influenced by the rocks of the crystalline basement, because the foundation rocks are highly magnetized with respect to the overlying rocks. Consequently, the inflection points are located at the boundary of the blocks of the crystalline basement which are hypsometrically arranged at different levels.

4) As it was mentioned earlier, the most deep-lying structure that magnetic exploration can show is the hypsometry of the crystalline basement, it can be observed most precisely with the use of the first derivatives. The higher the order of the derivative, the faster the decay process; the higher the degree of attenuation of the anomaly, the less its influence must be transferred to the range of action of other neighboring objects; therefore, on the maps of the derivations of the location of shallow-lying individual objects in the plan, they are clearly localized; influence of deep-lying, even large sources, has little effect on the values of derivatives of higher orders.

The vertical gradient of the first derivative, unlike the horizontal one, dims the zero values, thereby showing a sharper transition between the magnetic lines.

Also, the vertical gradient of the first derivative is closer than the horizontal gradient to the outline and direction of the structural elements.

5) The second derivative map is usually used for interpretation, as it emphasizes the presence of anomalies associated with small-sized bodies.

On the second derivative map, it is obvious that the anomaly zone, the part with pronounced high values after the transformation, shows a lot of small anomalies, which may be due to the presence of small structures whose magnetization values are higher than the rocks surrounding them.

The second derivative map is effective at finding the limiting depth which is the maximum depth at which the upper part of the body is capable of causing the observed gravitational or magnetic anomaly.

6) Plan Curvature is the method used in terrain modeling, and it was applied on the filtered map of the magnetic anomaly.This method - reflects the degree of change in the angle of the terrain aspect when viewed in the horizontal plane and is a measure of the curvature of isolines on the contour map.

The main distinguishing feature of Plan Curvature Method is its multifunctionality. When the Plan Curvature contour map is obtained in our case, it is possible to obtain data about the direction of the faults, the direction of the magnetic lines, the contoured anomalous areas,zones of elevation or immersion.

Plan Curvature does not show the specific values of the magnetic anomaly in a particular area, but at the same time Plan Curvature generalizes all previously proposed assumptions about the structural and other features of the studied territory.

As shows first derivative, second derivative and Plan Curvature map, in addition to the magnetic lines extending at the top of the map, a clear, rounded anomaly is seen in the lower left corner. According to the tectonics, the area of this anomaly is the Segendykian depression. Segendykian depression looms in the western part of the southern Mangyshlak and opens into the sea. It`s dimensions are within the land of 50X40 km. The depth of the crystalline basement is 9000-10000m. In the Segendykian depression, the subduction lithosphere is the main source of hydrocarbon genetics. For the study of subduction zones, the following methods are used: seismology, seismic exploration, gravity prospecting, magnetic surveying, geothermal exploration and magneto-telluric sounding. Subduction zones in the maps of magnetic anomalies are distinguished by linear zones.

In all the above methods, on the northwestern part, the mismatching of structural elements, this discrepancy can be explained:

A) Distortion of the map of the regional magnetic anomaly, which can be explained by the variation of the magnetic field, caused by various factors,

B) Distortion of the tectonics map.

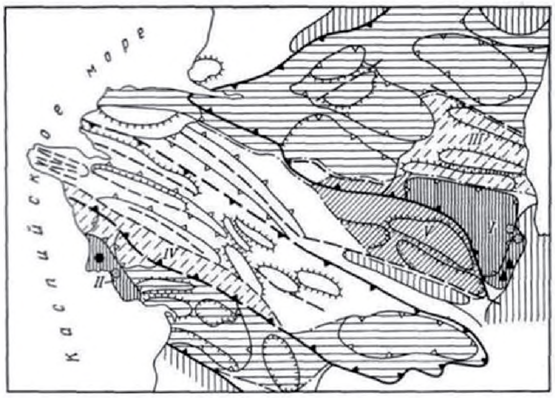

Figure 16 Tectonics map with another faults direction

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