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Expression of Shear-Fault Type Fractures (Ruptures) in the Geomagnetic Field (AR): The Example of the Lisagor Mineral Field

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Abstract: The article has discussed the possibilities of magnetometry (magnetic prospecting) for mapping shear-fault fractures and the regularities of their separation in a magnetic field. Geological-tectonic preconditions of occurrence of fractures and their significance are represented as mine control structures. Especially shear-fault fractures, in addition to mechanical changes in the domain structure of the environment, lead to disorientation of the magnetic moments of the domain and reduction of the magnetic moment. As a result, the intensity of the geomagnetic anomalous field decreases to a certain extent in the fracture zone, which is sometimes impossible to record during the magnetic survey, especially when the disturbance occurred in the area of complex sedimentary rocks with weak magnetism. The solution to this problem, especially in the folded region, is possible by the presence of a magnetically active horizon with a steep slope (basic dykes, magnetite sandstones, etc.), which has undergone a shear-fault rupture. The article presents the shear-fault type fractures detected by geomagnetic studies in the Lisagore mineral field of AR. These fractures are expressed in several sliding episodes of the magnetically active horizon of the argillites with sandstone interlayers, which is also described in the geological map. The argillites themselves do not have magnetic properties, so their magnetic activity is explained by the presence of magnetite sandstones thin interlayers, which are described by a series of high-intensity linear anomalies of T field that are interrupted and deviated from each other by the magnitude of the amplitude of the slide at the fracture sites.

Keywords: Tectonic Fracture, Shear-Fault, Magnetometry, Magnetic Anomaly

1. Introduction

Tectonic faults are the result of the displacement of earthquake masses, during which cracks, fissures, and displacements occur in the rocks. The tectonic fault is considered to be a massive fracture of the earth, with sufficiently large deep spread, significant length, and width. Fracture faults are unmoved (without crack) fault zones of rock integrity, with horizontal or vertical displacements along the fault line.

Fractures can occur within the same rocks and be expressed as fault zone, without the formation of secondary minerals, which will be expressed with lower values of ΔT in the structure of the magnetic field. With the access of hydrothermal fluids, new ferromagnetic minerals can form, as a result of which such faults will be expressed with increased values of ΔT in the magnetic field.

If the fracture is accompanied by the masses displacement – reversed (upthrow) fault, fault, shear-fault, etc., then in the first two cases, depending on the displacement amplitude of the magnetically active horizon, the magnetic field will be expressed by an abrupt change in the intensity of the anomaly. In the third case, a magnetically active horizon with a linear distribution, such as a dike, a vertical layer, etc., will have a shift in the axes of linear anomalies according to the amplitude of the shear-fault.

Tectonic faults in the geomagnetic field usually appear in the form of linear anomalies of ΔT, which have quite large linear distribution with a narrow zone or have the appearance of a chain of positive anomalies, as well as changes in the directions of magnetic anomalies axes distribution – azimuth changes. Fractures are also associated with condensations (gradient sites) of the ΔTisolines, abrupt change in the depth of magnetic rock occurrence, and fracture deviations of ΔT anomalies axes [1-4].

Fractures, in all their forms, within the ore field are often considered mine-controller structures, because fault zones are hydrothermal fluids pathways and mine-formation zones. Faults with different azimuths, which intersect in the mineral field, their spatial area of intersection being better and intensively cracked, become the most favorable path for the movement of hydrothermal fluids and favorable place for mine accumulation. Therefore, fracture mapping is very important in geological and geophysical studies [5-7, 11].

In terms of the structure of the fault-type fault zone, studies of tectonic evolution are considered to be essential components of geological surveys. The number of works on various aspects of fault-type tectonics is numerous, and it is challenging to navigate them. These studies should be considered a kind of guide in a complex range of data on the evolution of the structure, kinematics, and fault zones [8].

2. Statement of the Problem and Ways for Solution

The objective of the work is to map the fractures in the geomagnetic field in the AR Lisagore copper mining site and their allocation features. To achieve a set goal, the following methods and techniques of the geomagnetic survey were chosen.

Magnetic exploration was applied at the Lisagor copper mining site in the form of an aerial (surface) survey at an area of 1 km^2. As the area set for the survey was rectangular (1500 x700 m), it was fixed on the relief by three (M1, M2, M3) magistrals. The magistrals were taken along the stretched borders and centers of the site. The distance between the magistrals was 350 m, as the width of the site is 700 m. The points of the magistrals were fixed in the place with marked wooden stakes, the distance between which was maintained at 50 m. This distance was also chosen as the inter profile distance, both for magnetic and for other studies. Magnetometry monitoring profiles had 45° azimuths, starting (PK 1) on the M1 magistral within the boundaries of the site and ending on the M3 magistral. The magnetic survey pace on the profiles was maintained at 10m, that is the scale in the direction of the profiles was 1:1000 and 1:5000 in the vertical direction. The choice of a scale and azimuths of the profiles was conditioned by the size of the geological formations and their spreading directions.

The survey area has a rather complex relief, it is intersected by watersheds and ravines of different heights and depths, and the slopes of the relief reach 40°-50°.

Despite the difficulties of the relief and the severe shortage of roads, the survey was carried out with the required accuracy. That is, the parallelism of the profiles and the planned distances of 10m between the "ordinary points" were preserved. In several cases, when bypassing insurmountable obstacles (deep gorges, sheer cliffs, etc.), the coordinates of non-profiled points were recorded by GPS, which were later used to compile maps.

To ensure the intended accuracy of the survey, a checkpoint (CP) was set up outside the site, on sedimentary complex rock, where the field value (T = 48600 nT) is close to the normal field value of the region (T = 48650 nT). M1 և M3 magistrals on which the profiles start and end, as the intersections of the profiles with M2 magistral, are connected to the CP as a basenetwork by multiple magnetic field measurements. The creation of such bases allows surveying medium to high accuracy from measurements, as well as from double-measured field data checked by individual profiles.

The absolute value of the full vector of the electromagnetic field was measured in nanoteslas (nT). The measurements were made with a G-826 proton magnetometer manufactured by Geo Metrics, with an accuracy of +1 nT. After the survey, the mean square error was calculated to be m=± 7.5 nT, which allows field changes above 25 nT to be viewed as anomalies. The measured values were adjusted for daily field variations [1, 2, 15].

Geomagnetic field induction T isodynamic lines' 2D, 3D, and diagrams maps are listed, which are composed by Golden Surfer program M1:10000 scale, according to the results of a magnetic survey [15].

As is shown in the map of isodynamic lines (p. 1), in the northern and north-western parts of the site, positive anomalies of the T field are fixed with intensities of 100 nT to 1000 nT. Positive high-intensity (500¸1000 nT) field anomalies are described from the north-western to the south-eastern part of the area, as well as in the northern and southern parts.

In the range of positive anomalies described in the southern part of the site, a large anomalous area is recorded with T field reduced or ΔT field negative values, the intensity of negative anomalies varies (-500-1000 nT): These anomalies are also described in 3D maps of isodynamic lines and T diagrams (Figures 2 and 3).

According to the geological structure of the site, the positive anomalies registered with the average intensity of the geomagnetic field are conditioned by the intermediate and basic andesitic porphyrites with their dykes and tuffs, as well as oxidized tuff breccias and conventional "magnetic" sandstones, those according to geological map (Figure 4), are presented in the composition of Callovian argillites, as interlayers, and can cause positive high-intensity anomalies. Anomalies with reduced values of the T field should be expected within the complex of sedimentary rocks, tectonic fault zones, as well as in the areas of hydrothermally altered and mineralized rocks. These rocks are also present in the study area and ΔT negative anomalies should be associated with the spreading of hydrothermal and metasomatically altered rocks. The existence of altered rocks is explained by embedded igneous masses and hydrothermal fluids' movement through tectonic fractures. Under the influence of hydrothermal fluids, these rocks are mostly kaolinized, silicified, and pyritized [9-15].

The positive linear anomalies described in the 2D և 3D maps of isodynamics, as well as in diagrams maps, play a significant structural role. Especially, it is assumed that the cause of the anomaly may be the presence of magnetic dykes, or magnetite sedimentary layers (sandstones), which during the folding have received a near-vertical decline, and were subjected to various fracture faults (reversed (upthrow) fault, fault, shear-fault), which was recorded in the structure of the geomagnetic field. It should be noted that on the geological map shear-fault type fractures are described only by two such faults, and there are at least seven of them on the maps of the geomorphic field, which is due to the fact that the area is covered with young and recent sediments, which makes it impossible to record them by geological methods.

By the way, the intensity of linear positive anomalies gradually decreases from northwest to southeast, from 1000 nT to 500 nT, which is explained by the increase in the capacities of the magnetic horizon or the depth of their installation. This has been confirmed by quantitative interpretations of these anomalies.

Depth of location from northwest to southeast increases from 9-10 meters to 17-18 meters. This phenomenon has a topographic explanation, ie the source of the anomaly, the magnetic horizon, is located on the slope of the mountain and it is located in the north-west at the top of the slope, and to the south-east, it continues to the foot of the mountain; naturally, the capacities of the diluvial sediments change just like that.

The fault lines depicted on the diagram map (Figure 3) are drawn with the above-mentioned propositions, i.e. by the deviations of the magnetic horizons and their unconformities. Separated faults in the northern part of the site are propagated from northeast to southwest, and those recorded in the southern part are of southeast-northwest propagation and coincide with the propagation of the igneous rocks [15].

By the way, in the intermediate areas of the faults, abnormal reductions of the magnetic field were observed, while in the southern part a high-intensity negative anomaly is observed, which is conditioned by the existence of a junction of faults with various azimuths. The fault zones identified by the magnetic survey could be hydrothermal circulation pathways and, ultimately, an ore occurrence zone.

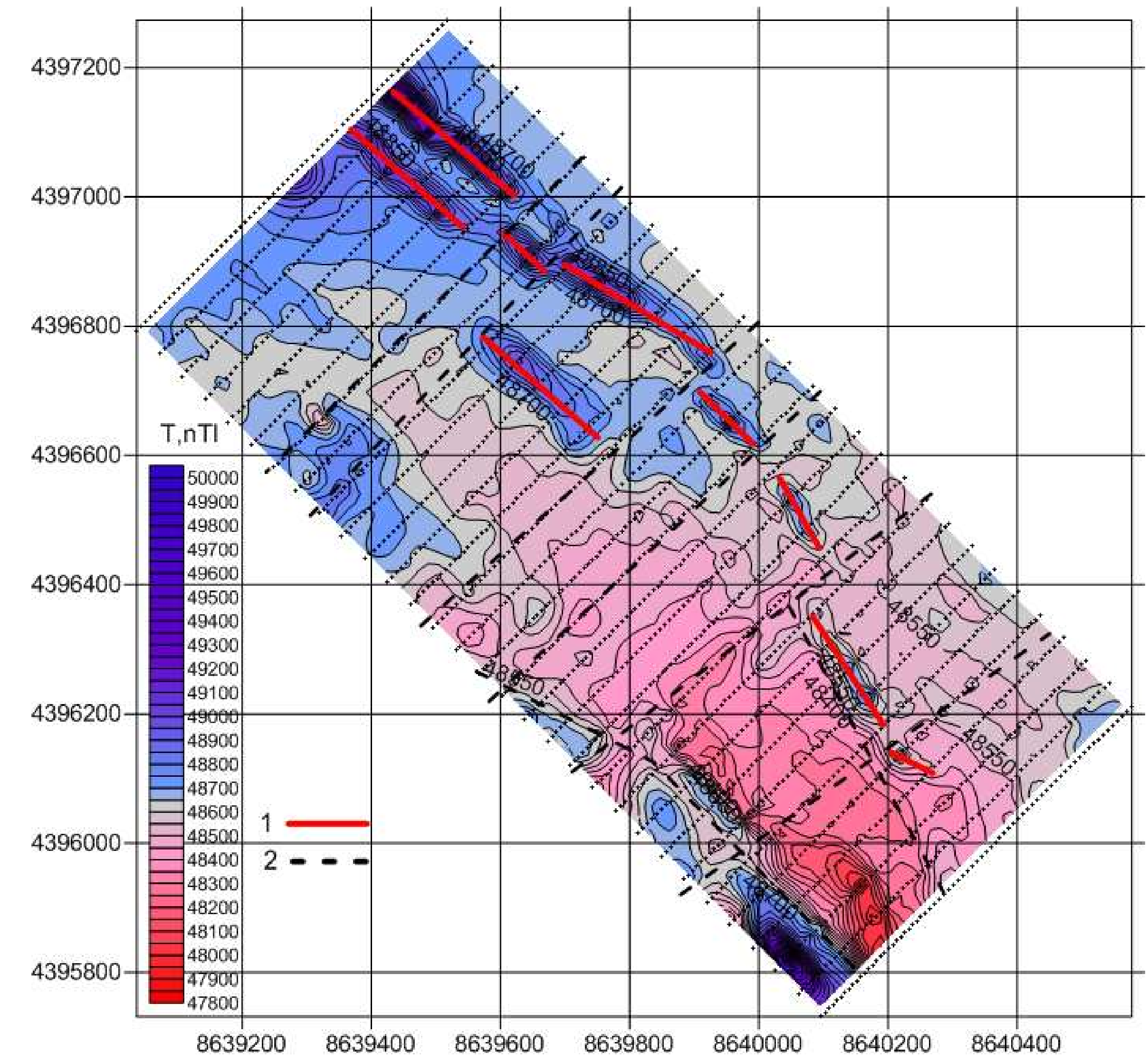

Figure 1. *T, nT2D map of isodynamic lines, M 1:10000; 1 – axes of linear anomalies, 2 – separated fractures.*

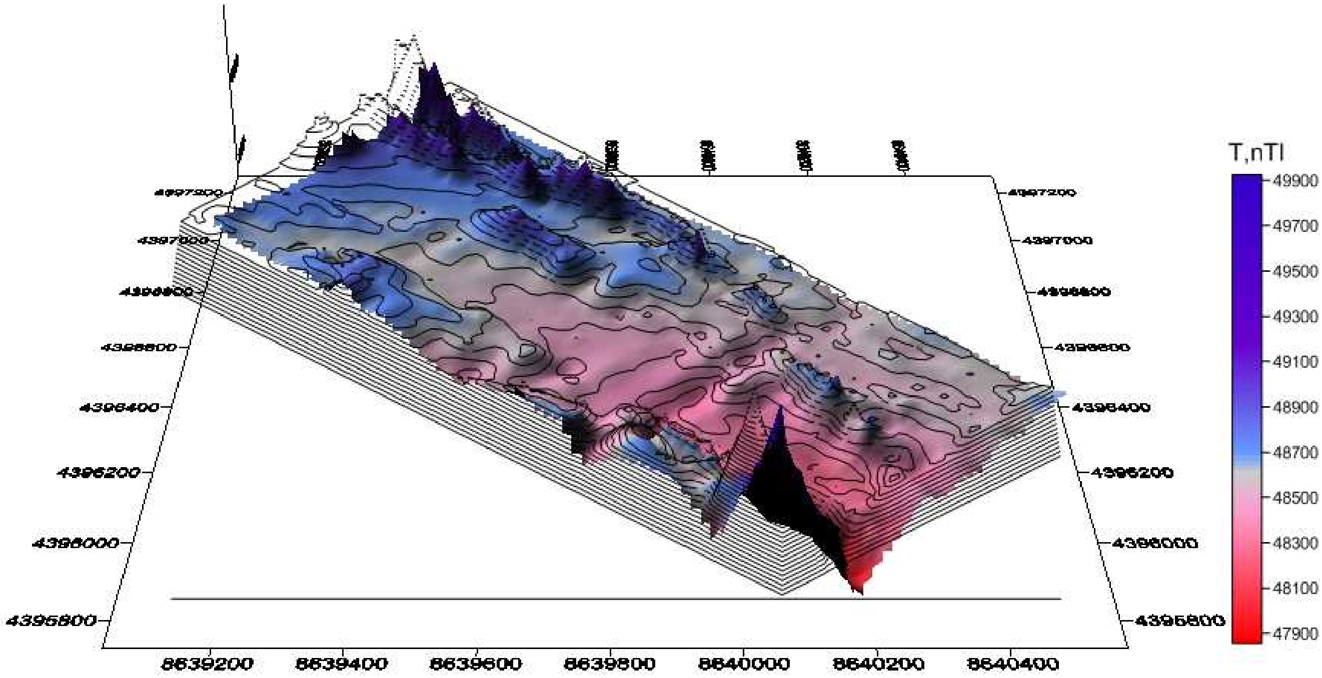

Figure 2. *T,nTl 3D map ofisodynamic lines, M1:10000.*

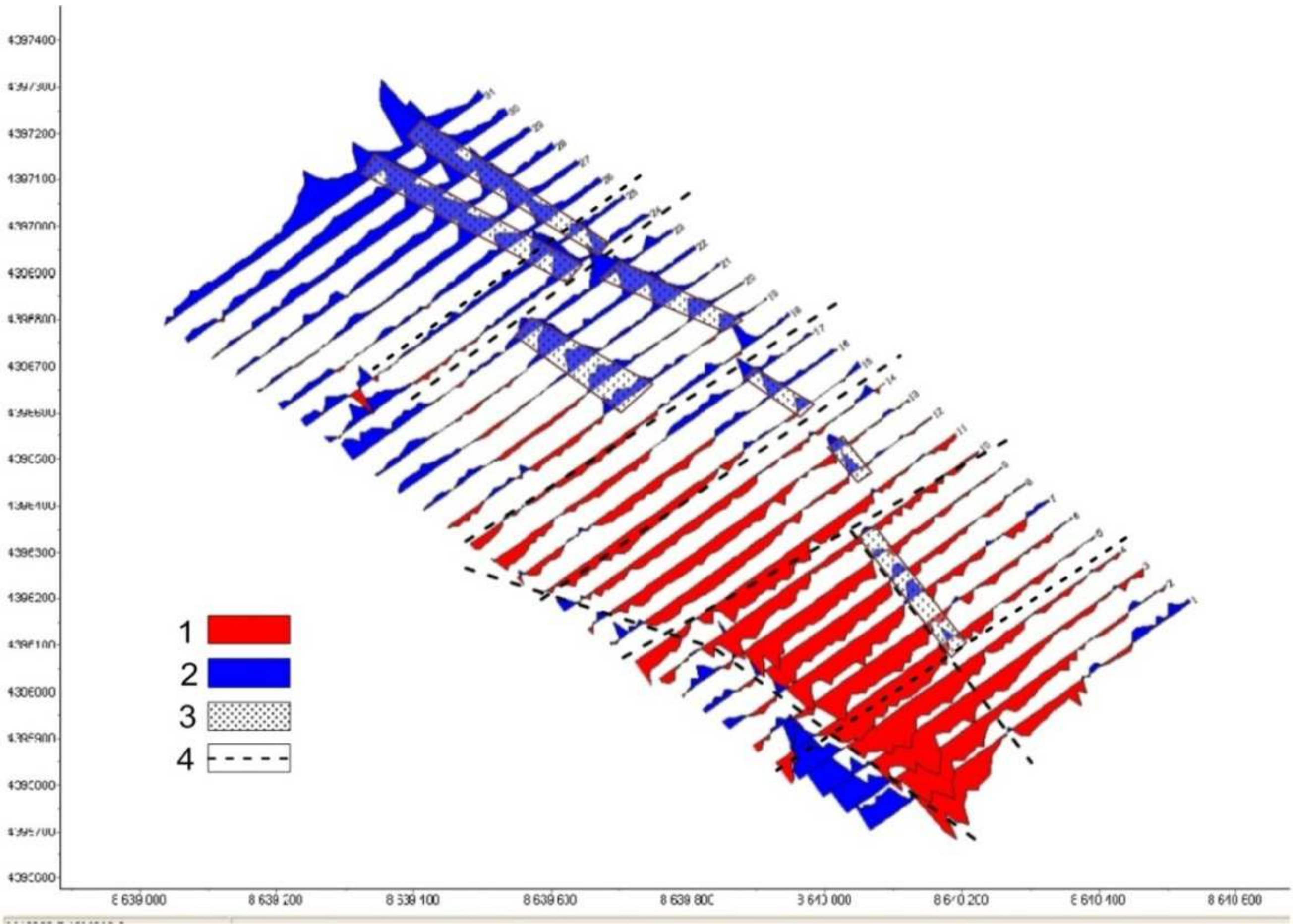

Figure 3. *ΔT,nT Diagrams map, M1:10000; 1- ΔT negative values, 2- ΔT positive values, 3- «magnetite sandstones», 4- fracturtes.*

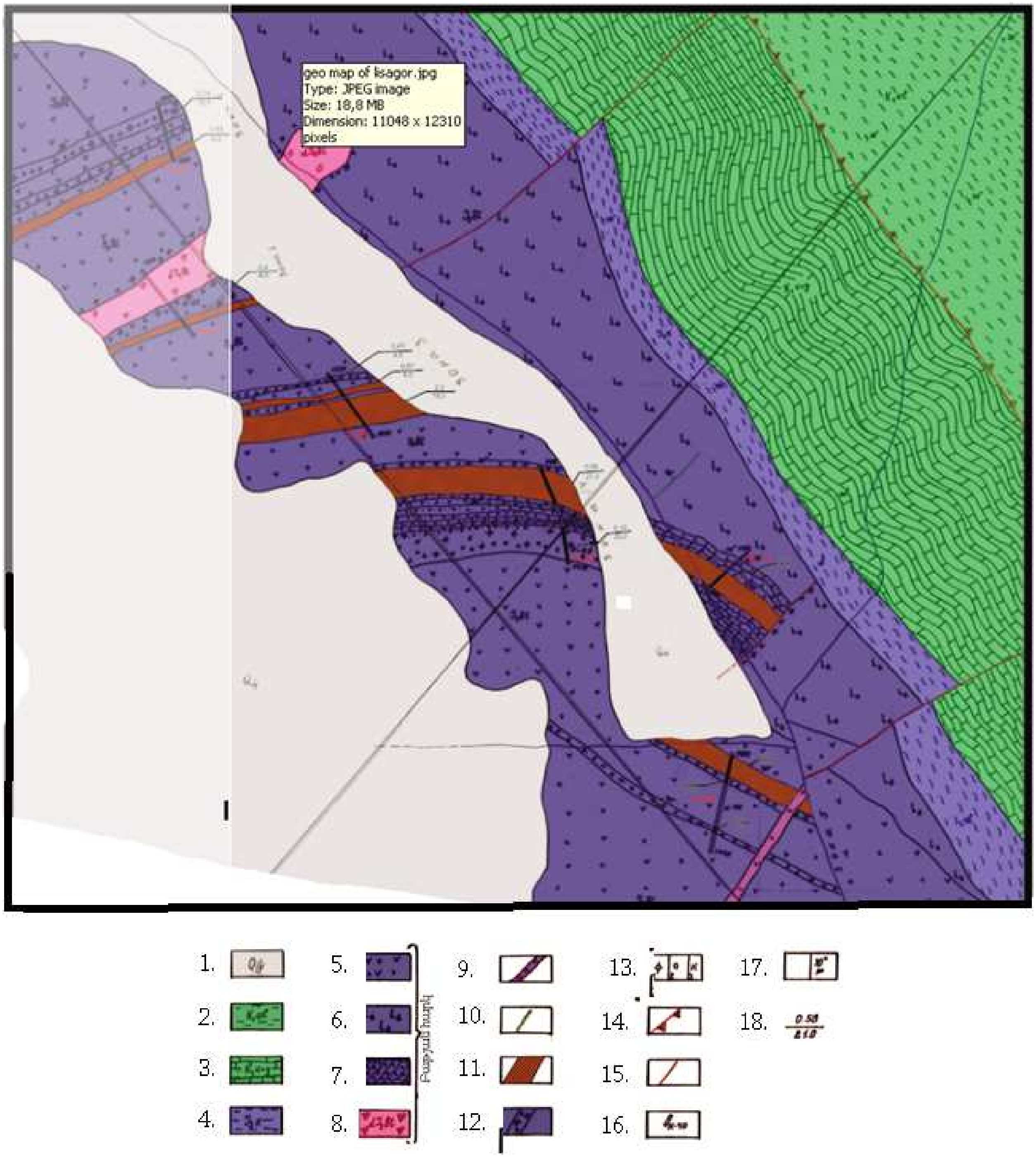

Figure 4. *Geological map ofLisagore copper ore occurence, 1:10000 (by S. V. Voskanyan).*

1. Recent sediments – eluvial, deluvial (loam, loamy sand, clay, sand etc). 2. Alpine stage: gray-blue crushed argillites with schistosed clay sandstones. 3. Valanginian-Hauterivian stage: siliceous broken limestones. 4. Callovian stage: argillites with sandstone interlayers. Bathonianstage: 5. Andesitic porphyrites and their tuffs. 6. Andesite-dacite lava-brecccias strongly siliceous and epidotized. 7. Tuff-sandstones – siliceous, caolinisated, and lightly oxidated. 8. Highly destroyed subvolcanicandesitic-dacites. 9. Andesitic-porphyrite dykes. 10. Quartouz vein. 11. Hydrothermalllyalterred (quartouz, caolinisated, sericitizated) rocks mineralized with copper oxides (malachite, azurite, chalcosite, etc.). 12. Fault zone rocks (siliceous, brecciated, caolinisated, oxidized). 13. 1). Limonitizated, 2). quartouz, 3). caolinisated. 14. Berdzor-Galik deep-seated fault. 15. Fracture. 16. Prospecting channel with their numbers. 17. Elements of occurrence. 18. Copper content in% / width in meters.

3. Conclusion

Summarizing the results of magnetic exploration, we can conclude that positive T-field anomalies are mainly obtained within the distribution of unchanged or slightly altered igneous rocks, as well as on magnetically active dike-like geological formations. Negative anomalies coincide with faults and fault zones, as well as with the contact of the distribution of igneous and hydrothermally altered rocks.

In the magnetic field, fractures have been recorded as linear distributed positive anomalies whose axial spreading azimuths have been changed as a result of magneto-active dykes, or fractures of magnetite sedimentary layers having vertical decline during folding (reversed (upthrow) fault, fault, shear-fault), which is recorded in the structure of the geomagnetic field. In our opinion, the results of this article are applicable to areas with a similar geological structure, for mapping shear-fault type fractures, magnetometry is considered an effective method.

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