Sjournals
Scientific Journals
Scientific Journal of Pure and Applied Sciences (2012) 1(1) 22-29

Contents lists available at Sjournals
Scientific Journal of
Pure and Applied Sciences
Journal homepage: www.Sjournals.com

Original article

The complex magnetic scanning as an effective method to investigate the exposures of Precambrian Basement: example of Ukrainian Shield

M. Reshetnyk
Geological museum, National Nature Science Museum of NAS Ukraine, Kiev, Ukraine.

*Corresponding authors: Geological museum, National Nature Science Museum of NAS Ukraine, Kiev, Ukraine.

A R T I C L E I N F O

Article history:
Received 28 September 2012
Accepted 18 October 2012
Available online 30 October 2012

Keywords:
Magnetic scanning
Magnetic susceptibility
Magnetic field

A B S T R A C T

A new method of magnetic-depth research outcrops of rocks was proposed in this paper. This combination of methods for studying the magnetic field and magnetic properties "in situ" and laboratory measurements. As an example we present the results of other areas of the Ukrainian shield at the Southern Bug. Compilation of new data on the existing map allows you to combine two previously separate T-anomalies together into a new T-anomaly continued in the north-east. Logical to assume that the banks are on oppositebody (length 1000 m), which is the source of the anomalous T.

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Abbreviations: MS: Magnetic scanning; T: magnetic field; In: remanent magnetization; Ii: inductive magnetization; χ: magnetic susceptibility; ρ: density; T_q : temperature of Query.

1. Introduction

The most part of Precambrian Basement is high-metamorphisate (non-stratificate) and characterize by motley image of a magnetic field (on example we investigated region with such magnetic field, Fig. 1). The understanding of geological structure with such differentiated structure of basement requires a detailed study of small geological bodies (Kranendonk et al., 2007).Their size may be small to be resolved by standard geological survey, but these bodies are magnetic markers that reflect the geological structure. It let use a magnetic field for analysis of geological structure of basement. For authentic interpretation of a magnetic field it is necessary to study carefully magnetic properties of the geological environment and to identify sources of magnetic anomalies in places of their exposures. But now, the most part of geological investigations executed, as a rule, separately from geophysical "in situ" (on the field) and laboratory researches - there are two separate operations. It does impossible search of existing correlations of magnetic properties of rocks with their geological characteristics that so are necessary for mapping of Precambrian basement.

Therefore, the need of development of a modern technology magnetic study (for non-stratificate complexes) is obvious. In this paper, the new magnetic method - a Method of Magnetic Scanning is proposed.

1.1. Geological background of the southern bug river section

Figure 1 show the area, which is being investigated by the magnetic scanning method. The old geological map was published Laz'ko E.M. (Laz'ko, 1975), where geological structure consisted of interlayering gneisses kristalloslanets and quartz-garnet-magnetite rocks. The last geological map was published Dougan R. (2006), where geological structure consisted of array enderbites with lens gneiss and arcuate body kristalloslanets. Laz'ko E.M. research finds that the site consists of metamorphosed sedimentary rocks early Archean but Dougan R. research finds that the site consists of intrusive rocks (Proterozoic) and the remains of ancient sedimentary rocks. On the geological maps created it Dougan R. Positive anomalous magnetic field matches the kristalloslanets.

A map of anomalous magnetic field illustration on the territory of research is very motley imageof the magnetic field. Magnetic field unrecorded near rivers, where is Precambrian basement outcrops, therefore, the magnetic field above the outcrops have not been reported. So no one knows what creates the magnetic field anomalies.

Conventional methods of magnetic investigations is large-scale 1:25000 survey of the magnetic field of a rectangular network (the distance between the profiles between the pickets 100m 50m), recorded with the use of proton precession magnetometer (Antsiferov, 2008). Sampling of geological features when the geological description of the exposures. Magnetic properties were determined for different petrotypes, regardless of their selection, using classical laboratory methods (Collinson, 1983).

2. Materials and methods

Magnetic scanning MS - it is a complexed petro-magnetic method of detail investigation of rocks outcrops. Unlike other methods of magnetic scanning, in this method, laboratory and "in field" magnetic surveys carried out in direct relationship with each other, possibly for a team of geologists and geophysicists. At the first stage the basic materials are analyzed, and the obvious differences or correlations "Magnetic field - geological structure" appears. Thus, development of main directions of current research in this area is conducted. In the second stage, magnetometric investigations "in-field" are carried out. Their difference from the standard methods is as follows.

1. Sequentially continuous reading of magnetic information with modern appliances (KT-10 (Magnetic Susceptibility) POS-1 (Magnetometer instruction)). Interconnected simultaneously scanning the magnetic field T and magnetic susceptibility χ.
2. Location of sampling for laboratory studies (Collinson, 1983) and space to investigate a field T on the area defined by the results of measurements in accordance with "a priori" data.
3. The data are interpreted together and given data that obtained by other researchers.

In the offered method the author new matters are:

- Introduction to the practice field work of joint measurement of T and magnetic susceptibility χ.
- Speed and low-cost detailisation of "in-field" investigations. This makes it possible to use magnetic field data (and other magnetic properties), not as a source of anomalies, and as a way to study the entire geological environment.
- Use the full set of the performance of field and laboratory work, and the interpretation of the results in a system with "a priori" data.

Scanning of magnetic field by new method gives the chance to use high-frequency oscillations of the curves T (formerly dismissed as "noise" (Antsiferov, 2008)) to analyze the distribution of magnetic minerals in the surface layer and shows the real behavior of the magnetic fraction in rock.

3. Results and discussion

All the results obtained by the author of article. Features of the proposed method are tested on exposures of rocks of Precambrian Basement (Ukrainian Shield), in granulite fation of metamorphism. Executed "in field" ultradetailed shooting of T which that we das in moving allow:

- To fill by received data «a white spots» on existing maps of the magnetic field (along the river banks);
- Identify and analyze the structure of the sources of magnetic anomalies; to fix a detail morphology of magnetic field;
- To reveal and analyze properties of the bared (exposed) part of sources of a magnetic field anomalies.

3.1. Interval hashuvate-salkovo

"White spots" on the existing is investigation;

- Fixed the details of the morphology of the magnetic field;

- Species a granulite complex are studied in exposures on river (South Bug, Fig.1) banks on the interval Hashuvate-Salkovo (Ukraine, Kirovograd region, Gaivoron sector).

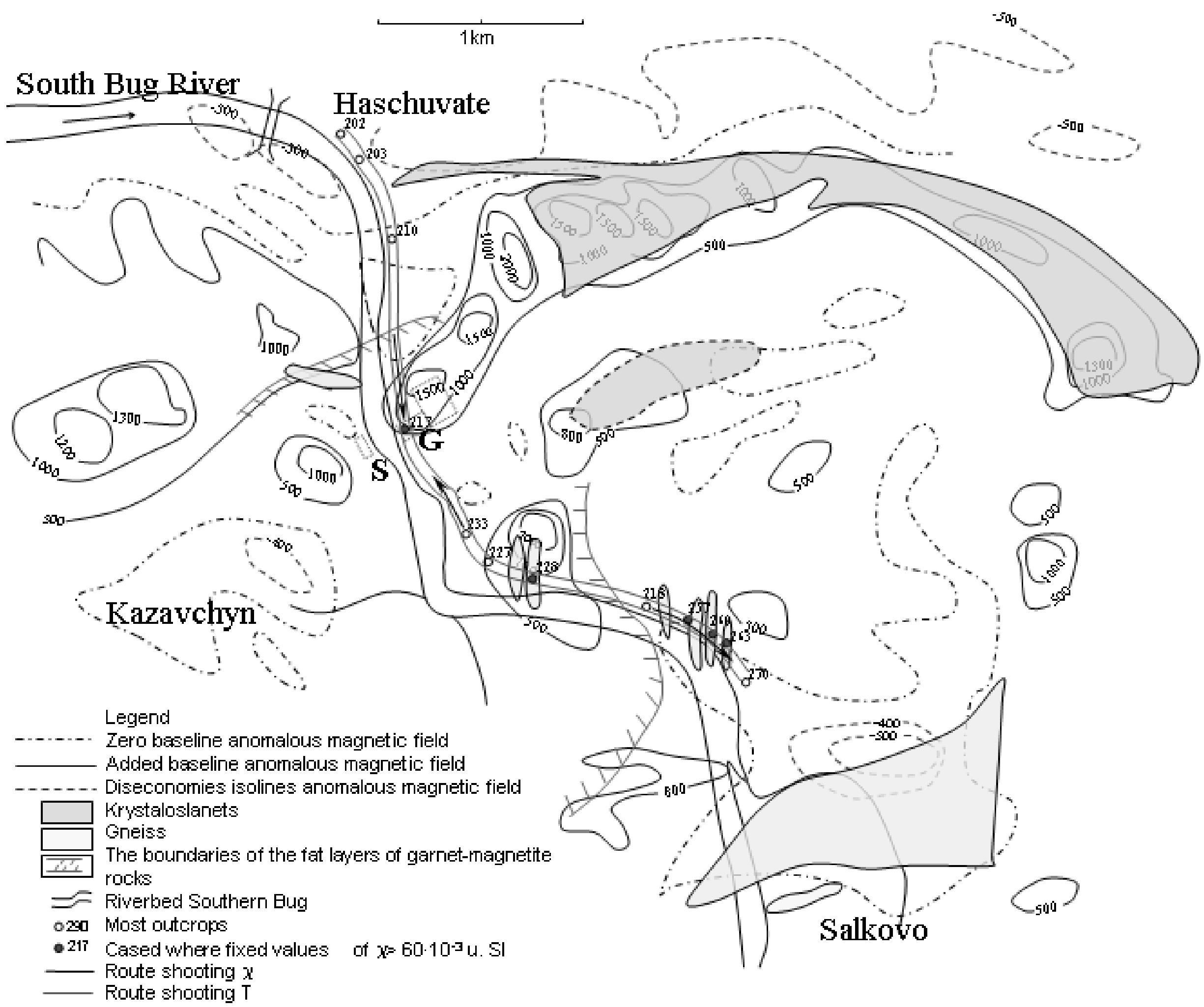

Fig. 1. Fragment of a map of abnormal magnetic field (1:50000, izolines in nTl) with inflicted on the contours of bodies of gneysses and krystallo-shales (according to (Dougan, 2006)), and with contours of massifs with layers of granae-magnetite breeds (according to (Laz'ko, 1975)).

As a result of the magnetic field T scan area 200-300 m with T> 49500 nTl (mean Tl 49000 nTl) were detected (Fig. 2). Observe the magnetic susceptibility in the outcrops (Fig. 3) and analysis of selected samples from these areas in conjunction with the analysis of aprioristic data allows to specify - where and how is location positive magnetic anomalies.

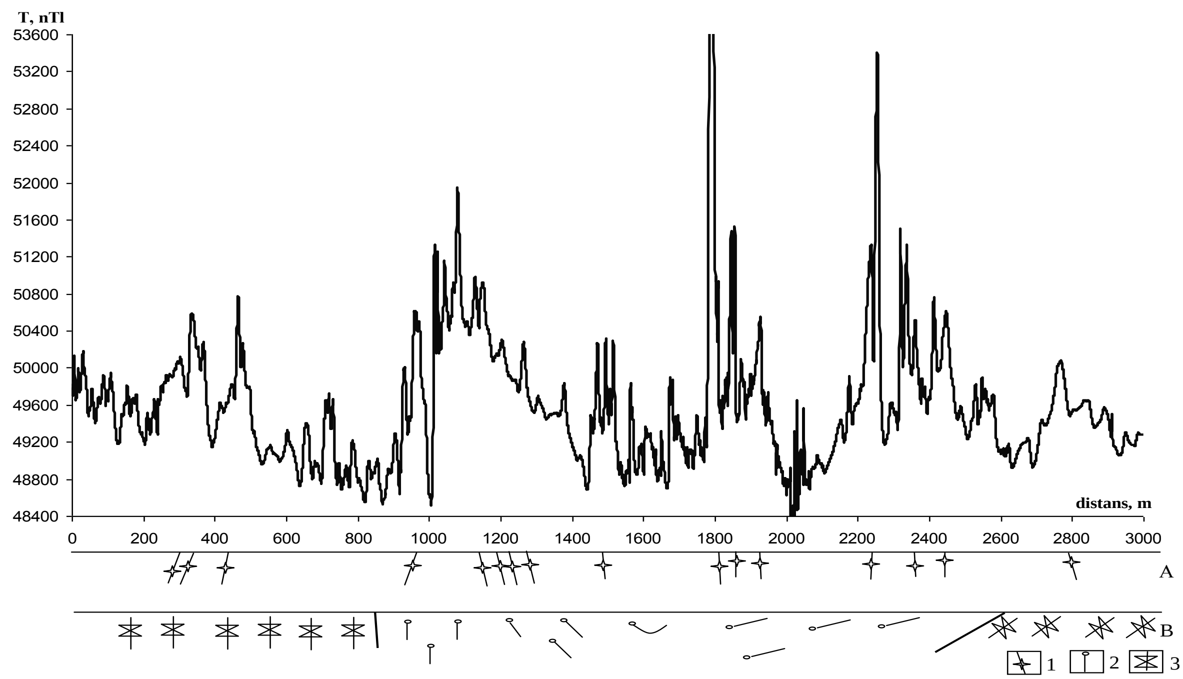

Fig. 2. T curve obtained by the Southern Bug River between Haschuvate and Salkovo A) scheme of the body ferruginous rocks on the results of MC B) scheme of the geological section for Laz'ko (1975). Legend: 1-breed high in magnetite, 2 - thickness, containing layers of iron species, 3 - thickness without ferruginous rock.

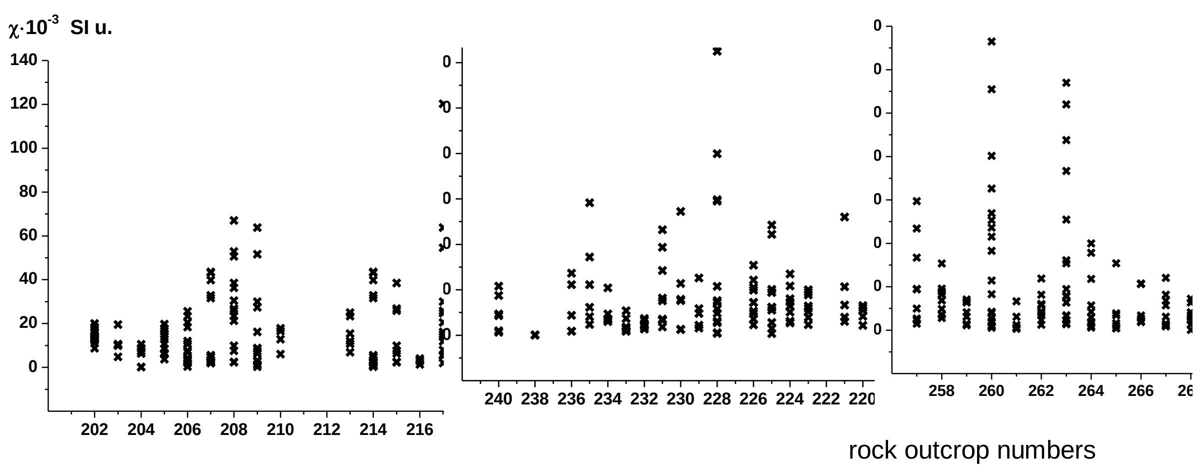

Fig. 3. The distribution of magnetic susceptibility of crystalline basement outcrops of rocks between Haschuvate and Salkovo on the right bank of the South Bug River (outcrops of rock numbers correspond to numbers indicated in Fig. 1).

3.2. Anomalies of magnetic field

As an example we present the results of one of the anomalies of its deployment at the South Bug River (Fig. 4). At the current map of magnetic field on the opposite banks of the river there are two positive anomalies T (width up to 200 m, Fig. 4). After scanning two banks of the river, similar T curves were obtained (Fig. 5). Compilation of new data on existing maps allows combining two previously separate T-anomalies among themselves in the new T-anomaly extended in a north-easterly direction (Fig. 4). Logical to assume that the two banks of the river is the body (many more than 1000 m), which is the source of the anomalous magnetic field naked.

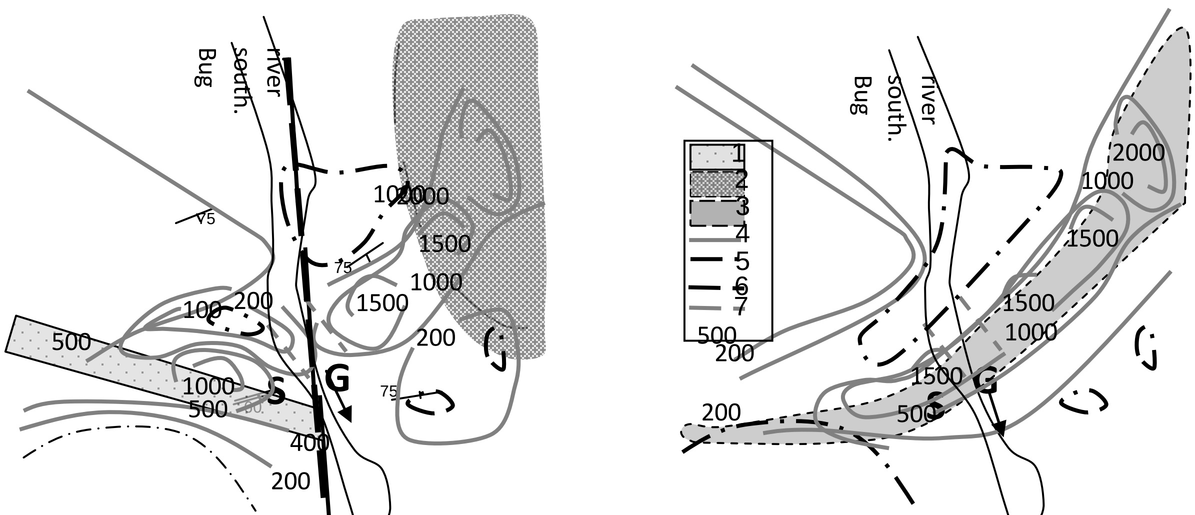

Fig. 4. Detail maps of the anomalous magnetic field (isolines held in nTl) in conjunction with the geological map outcrops S and G: a) before a magnetic scanning [3] and b) as amended as a result of MS. Legend: 1 - quartzite, 2 - amphibolites, 3 - the body of quartz-garnet-magnetite rocks, 4, 5 – icontours of the anomalous magnetic field is positive and zero, 6 - geological fault, 7 - outcrops S and G.

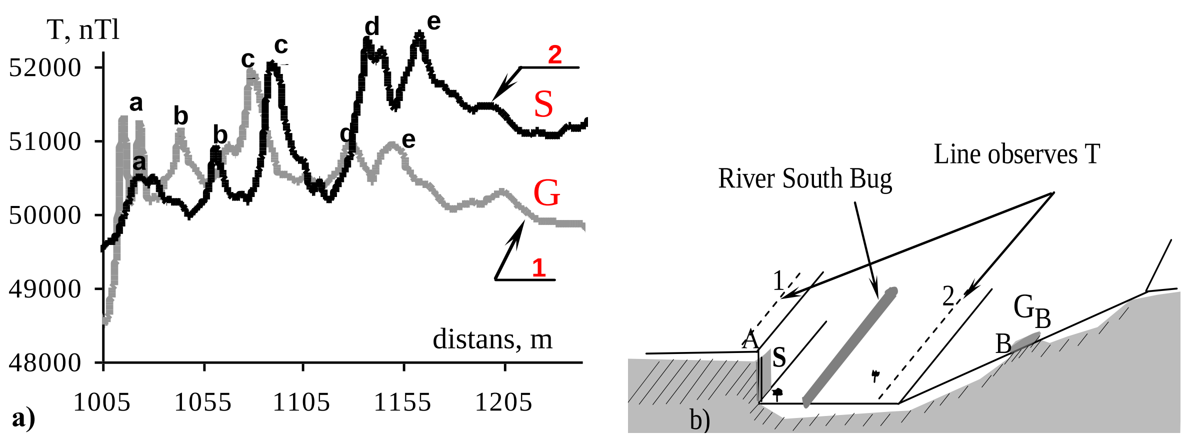

Fig. 5. a) T curves obtained by scanning parallel profiles on the left (curve 1) and right (curve 2) banks of the river, b) schematic geological section perpendicular to the surface of the river in this region are discussed.

Realized magnetic susceptibility measurements on outcrops 'S' of rocks showed Figure 6, 7 and Table 1.

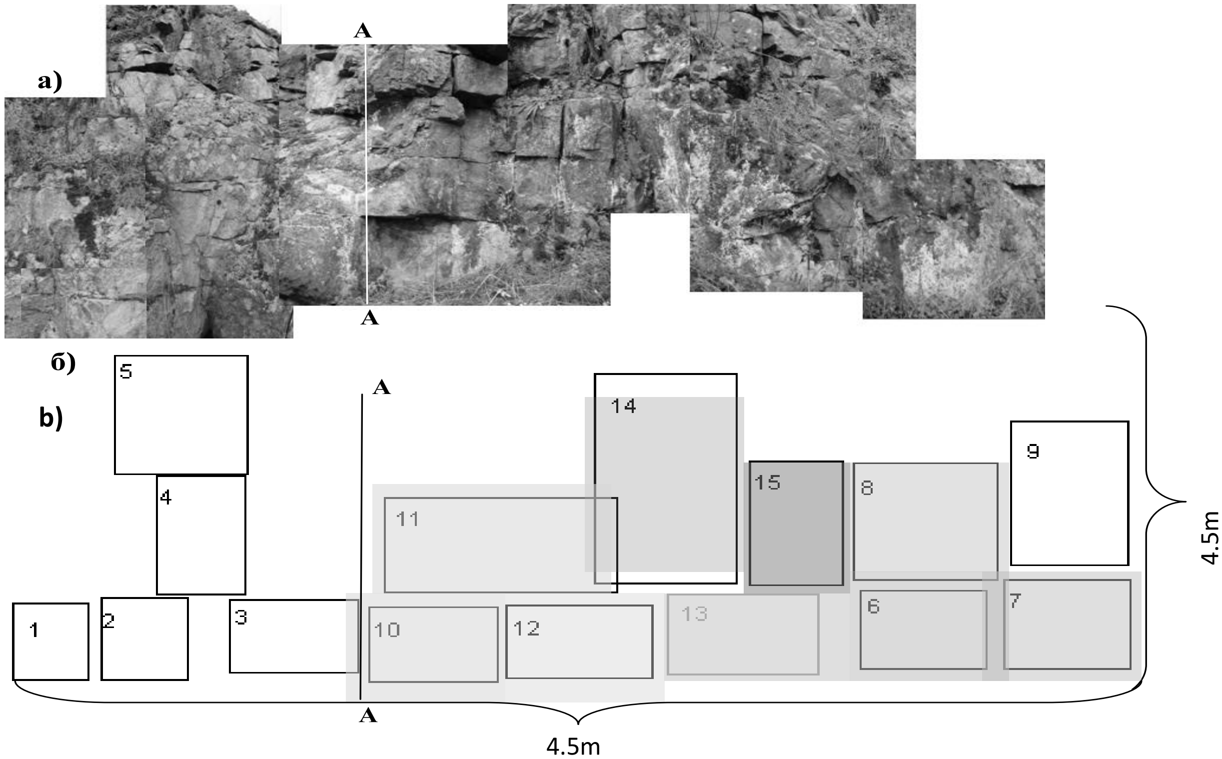

Fig. 6. a) Combination photo vertical wall outcrops S, b) schematic diagram of the distribution of outcrops □ mulberry, most magnetic zones with most saturated red. Most of each area indicated in the upper left corner of the rectangle corresponds to the number of zones Table 1.

Table 1
Distribution χ on the wall of vertical outcrop S.

№ zone	**$\chi \cdot 10^{-3}$ .SI u.**												
											χ_{min}	χ_{max}	χ_{avr}
1	1.9	1.9	0.87	1.3							1	1	2
2	2.8	6.4	4.3	0.64	0.1	0.16	0.03				2	0	6
3	37	39	1	6	20	17	10	4.8	40	45	22	1	45
4	5.2	3.5	0.57	0.73	0.1						2	0	5
5	4.5	0.4	0.6	0.01	0.6						1	0	5
10	7.1	49	11	20	68						31	7	68
11	98	170	160	100	210						148	98	210
12	230	190	300	180	44	350	59				193	44	350
13	280	200	110	36							157	36	280
14	220	200	170	250	170						202	170	250
15	400	420	710	500	640						534	400	710
6	481	160	26	6.9	23	77	120	75			121	7	481
7	37	85	72	31	180	250	620	54			166	31	620
8	280	340	360	340	21						268	21	360
9	26	21	22	24							23	21	26

Zone number corresponds to the number of zones as illustrated in Figure 6.

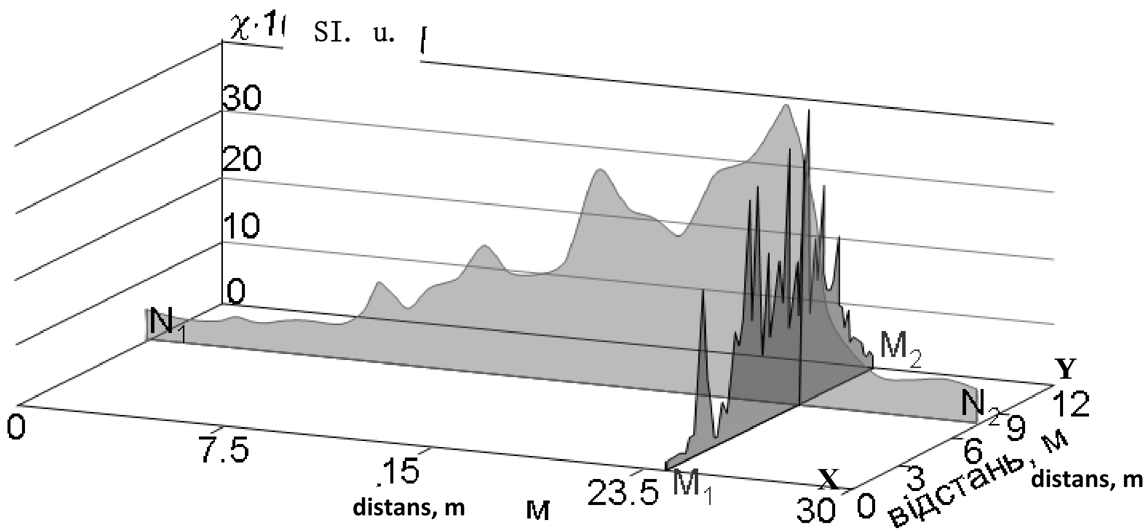

Fig. 7. Distribution values of χ the surface outcrops G. On the x-axis distance marked on the profile, which is located along the outcrop magnetic zones on Y-axis marked distance from the starting point shooting an account that is perpendicular stretch the body.

Specific dimensions and limits of magnetic field sources are recorded when scanning magnetic susceptibility. High values ⍰ for exposure surfaces are allocated on the surface of the body in the form of bands or layers (sometimes they have a size from centimeters to several meters). Their thick high-magnetic bodies can create congestions, areas of frequent interlaying with not-magnetic bodies.

3.2.1. Laboratory analysis

The results of petrographic analysis showed that most magnetic rocks are garnet-magnetite quartzite. In earlier geophysical work was thought that the magnetic anomalies formed crystalline schist. Placing rock riddled with garnet-magnetite quartzite, have following properties: $10•10^{-3}$u.SI<χ<$30•10^{-3}$ u.SI, 0,3A/m<In<3A/m, Q>1, 2.6<ρ≤2.8 g/sm^3.

For low-magnetic rocks who contact with high-magnetic rocks, the presence of two ferromagnetics are detected – they are pirotin (T_q=300 °C) and magnetite (T_q=580°C). Garnet-magnetite-quartz rocks contain 10-15% magnetite, leading to its high density of 3.1<ρ≤3.5 g/sm^3. These rocks have very high values of remanent magnetization I_n>3 A/m, which is much more than inductive magnetization Ii (Q=In/Ii>>1). The vector $\mathbf{I_n}$ have a chaotic orientation. Thus, in formation of abnormal magnetic field the important role causes Residual magnetization, and his chaotic orientation can make important differences of T. It shows that abnormal magnetic field is caused by specific distribution of magnetic minerals in mountain rocks and by non-homoheneity of their Residual magnetization.

4. Conclusion

Early, before our magnetic-scanning investigations, the geological map of investigated area showed homohene mass of rocks, with fracture along river bed. After executed magnetic-scanning investigations, the thick granate-magnetite quarzites can select on the map.

Similar structures everywhere penetrate the Precambrian basement in the territory between cities Gaivoron and Zavallja, although in this territory geological maps shows few different formations. The dimensions of granate-magnetite quarzites bodies are not essential, that's why for scale 1:50000 there is very small (because they were not shown in geological maps). Just there bodies are responsible to intensive positive magnetic anomalies in the investigate field. They have a small capacity and observe by character of magnetic field like armature in ferrobeton constructions on expanded intervals (>1000 km).

1. The new proposed method of "Magnetic Scanning" (MS) allows you to show that the anomaly-formed breeds are distributed on all territory of researches independent of their formation origin. For the first time the physical properties are studied in relationship: amplitude and gradient of magnetic field, correlation “magnetic field - residual magnetization”, dependences residual magnetization – quantity/quality of magnetic minerals.

2. The proposed method allows to traditional disproportion in obtaining and processing of geological, magnetic and petrophysical studies. The practice result of the new method is its ability to precise maps of the magnetic field and geological maps.

3. According to the survey, the necessary amendments and clarification of existing maps in region of Ucrainian Shield were developed.

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