Research Journal of Applied Sciences 10 (12): 940-946, 2015
ISSN: 1815-932X

High-Precision Magnetic Prospecting Researches in the Territory of Bulgarian Historical and Architectural Memorial Estate

Bulat M. Nasyrtdinov, Ayrat N. Dautov and Artur V. Fattakhov
Kazan Federal University, Kreml St. 18, 420008 Kazan, Russia

Abstract: In the study, results of magnetic prospecting researches conducted by staff of geophysics and geographic information systems department of the Kazan (Volga) Federal University in the territory of Bulgarian State Historical and Architectural Memorial Estate are considered. The Bulgarian State Historical and Architectural Memorial Estate was entered in the list of the UNESCO world heritage in 2014. High-precision magnetic prospecting researches of the larger territories representing historical and archaeological value can in rather short term give important archaeological research information for many years ahead. Within this study, methods and results of interpretation of the obtained data are not considered. Nevertheless, it is possible to note that magnetometric researches of larger territories allow to reveal objects which are often invisible when studying small squares roads (especially ground), systems of channels, ditches, etc. In study techniques of carrying out field and cameral works allowing to reduce considerably influence of various factors on research accuracy are considered, allowing the chance for correct results comparison of magnetometric shootings for some years. As a result of the carried-out researches, the magnetic field anomalies map of Bulgarian Historical and Architectural Memorial Estate in the territory with a total area of 926,202 m^2 was made.

Key words: Magnetic exploration, magnetic anomalies, interpretation of geophysical data, magnetic variations, shootings

INTRODUCTION

The magnetic exploration is widely used in practice of archaeological researches due to big informational content and efficiency of this method. The main research objects are the brick bases and building walls, congestion of the burned ceramics, oddments of different function oven constructions (Boschian *et al*., 2003; Anonymous, 1981; Logachev and Zakharov, 1979).

Magnetic prospecting researches in the territory of Bulgarian ancient settlement are being conducted since 2011. The part of the territory with total area of 926,202 m^2 (Fig. 1) is being studied at the moment. In the research territory over hundred archaeological monuments of various historical eras are located, beginning from the top paleolith, the Bulgarian State and the Kazan Khanate. The Bulgarian State Historical and Architectural Memorial Estate was entered in the list of the UNESCO world heritage in 2014.

During researches some factors which had negative impact on quality of magnetometric shooting were revealed. Among them, high level of production and anthropogenic hindrances, technical measurement devices features of required high precision for magnetic field variations accounting.

In this regard, the technique of carrying out field researches which allows to reduce considerably influence of the specified factors on research results was developed.

MATERIALS AND METHODS

Carrying out field works technique: When carrying out magnetometric works two types of devices were used: proton magnetometer MMPOS-1 and quantum magnetometer GeometrixG-859 (Mikov, 1975; Sokolova *et al*., 2011). Sensitivity of measurement devices in absolute values of module magnetic induction (T) per 1 sec cycle makes for MMPOS1-0.05 nTd and for GeometrixG-859-0.01 nTd.

During methodical researches azimuthal error in indications of MMPOS-1 was revealed. Azimuthal dependence is the set of errors arising when changing movement direction. On indications of devices also change of the sensor angle to direction of field magnetic induction affects. The inclination of the sensor appears because the operator does not always go with 90° arrangement of the sensor concerning a terrestrial surface normal. In Fig. 2, the example of actual magnetometric shooting without an azimuthal tolerances of magnetic prospecting devices is given.

Corresponding Author: Bulat M. Nasyrtdinov, Kazan Federal University, Kreml St. 18, 420008 Kazan, Russia

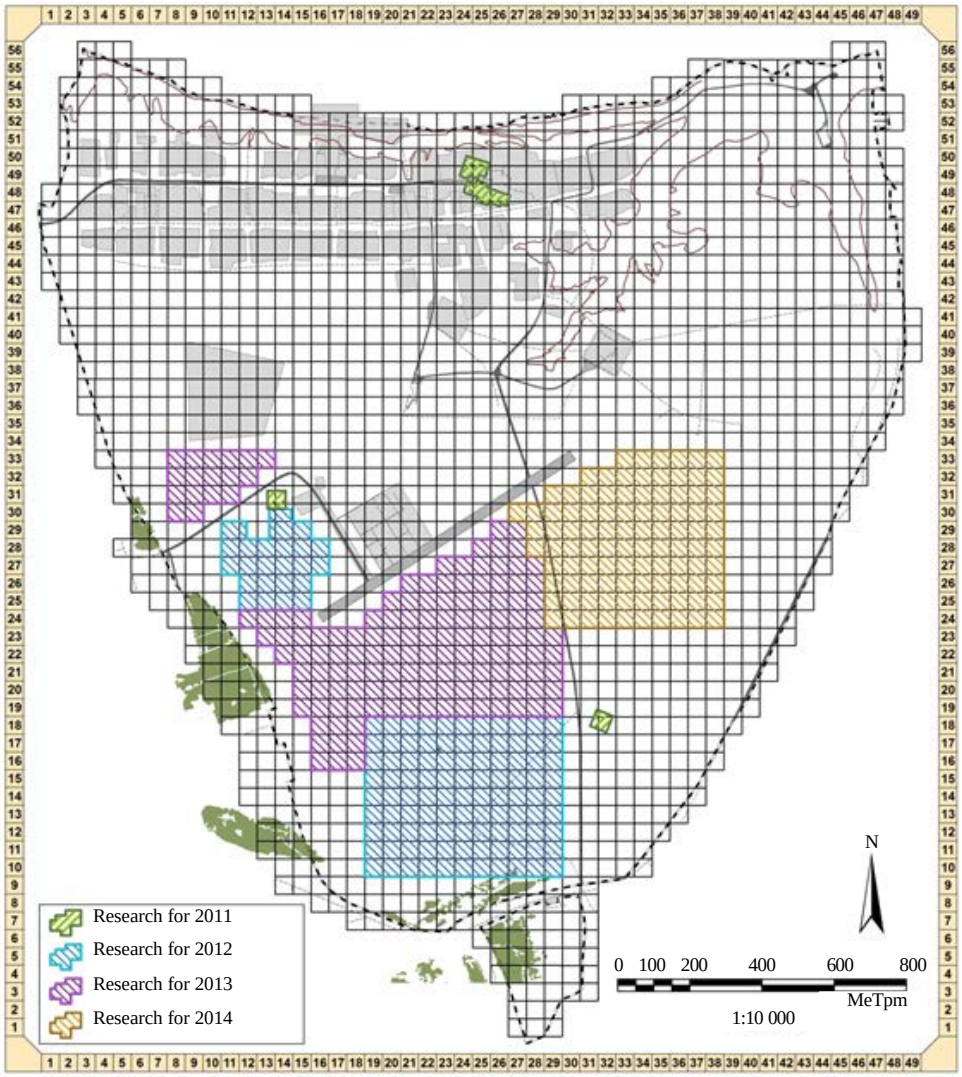

Fig. 1: The territory of the Bulgarian ancient settlement and the area investigated by high-precision magnetic exploration for different years

Proceeding, from above said, shootings by the MMPOS-1 device were carried out only in one azimuth (from West to East). In Fig. 3, the example of similar shooting is given.

The choice of control point location is one of the most important stages of carrying out magnetic prospecting researches (Boschian *et al*., 2003). As a rule, the majority of the work area represents areas with large number of different magnetic disturbances (highways, power lines, underground communications, etc.). In this regard, when choosing control point the following methodical receptions are applied: control points are set far from roads, pipelines and power lines; direct vision of stationary magnetic objects (metal subjects, tins, fittings, etc.) is carried out; magnetic shooting in radius of 50 m from estimated arrangement of variation station is carried out obligatory.

If in the studied radius, the magnetic intensity size differs no >3-5 nTd such point is considered suitable for control point arrangement.

Considering that some objects located in the territory of Bulgarian ancient settlement, interesting from the point of view of archeology, have anomalies about 5-15 nTd, the error of shooting should not exceed ±2 nTd. For achievement of this requirement some padding methodical receptions were used. In Fig. 4 examples of magnetic field variograms with various times of readout sampling are presented. It is apparent that the schedule reflecting

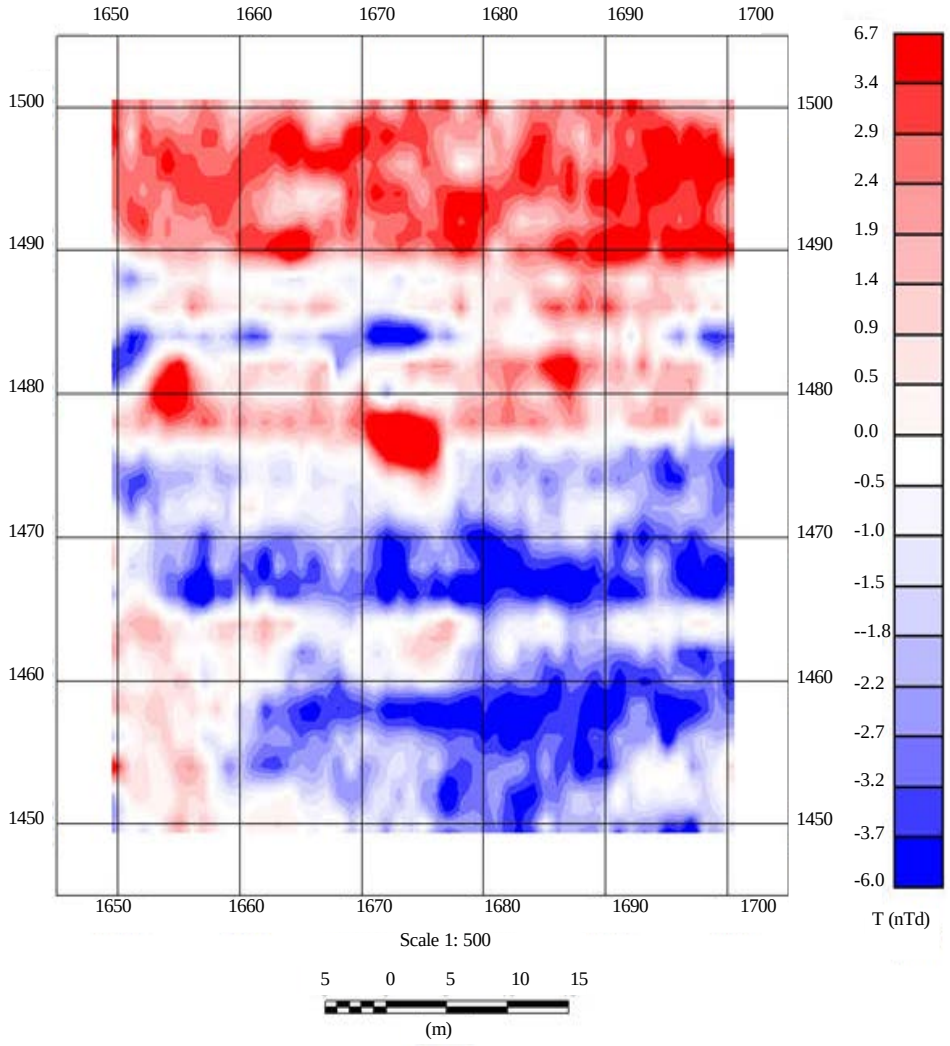

Fig. 2: Example of azimuthal dependence of the MMPOS-1 device

magnetic field change with an interval of 3 sec, most precisely describes short-period variations. In view of this fact and also that shooting of one picket, including transition from one point to another, takes about 3-4 sec, time of sampling when fixing magnetic field variations made 3 sec.

The choice of supervision network type was defined by two known provisions (Boschian *et al*., 2003); anomaly is considered authentically registered if it is noted from no less than three-five points of shooting, the over dense network of supervision considerably increases shooting time and depression of network profiles and pickets results in ambiguity in localization and interpretation of magnetic anomalies.

The experienced and methodical works which are carried out on known objects showed that the reference linear dimensions (periods) of magnetic anomalies usually make 5-6 m. Thus, observations were made on network 2×1 m. As a matter of convenience splittings profiles and the subsequent interpretation of these field works researcheswere conducted on squares 50×50 m. At the beginning of each field season, the territory meant for magnetometric works was covered by network of similar squares (Fig. 1). Initial coordinates of network clusters were primarely generated in geo-informational program complex ARCGIS10 on the basis of high-res aerial photographs. Carrying out network clusters to the actual square was carried out by high-precision satellite geodetic binding by means of Trimble R8GSM. Accuracy of network clusters positioning varied no more than a few centimeters. The location of each network knot was marked with a wooden peg.

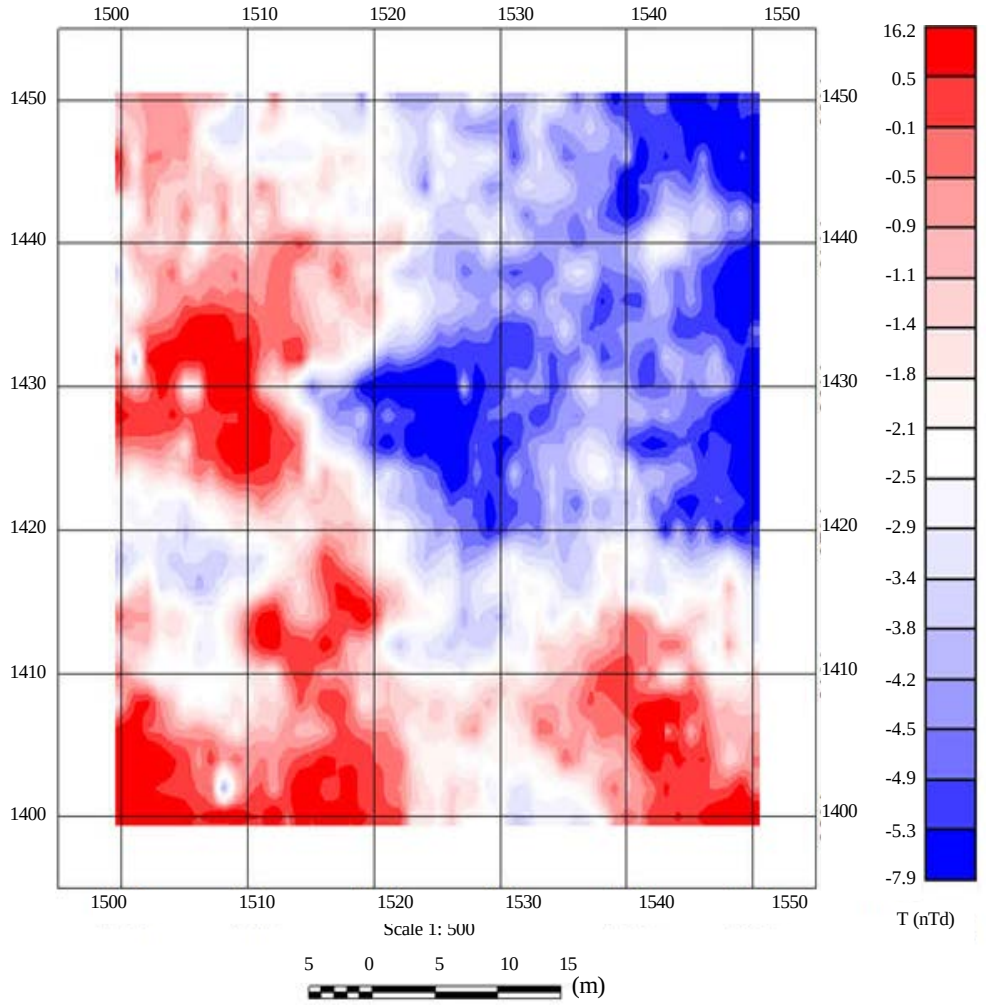

Fig. 3: Example of magnetic field map anomalies for MMPOS-1 received without azimuthal dependence

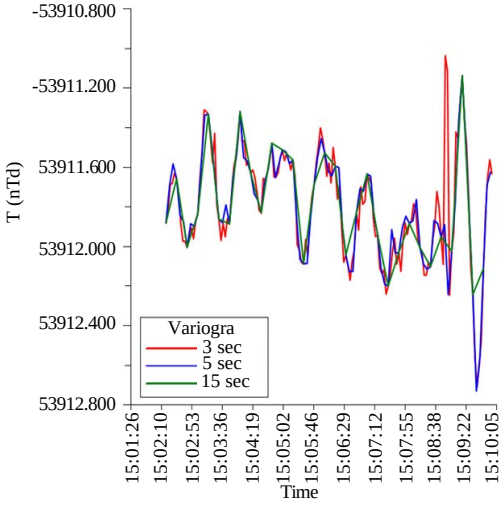

Fig. 4: Variograms of magnetic field with various times of readout sampling

In a square the area broke into 25 profiles on 50 pickets. For this purpose between basic pegs in the subwidth direction the 50 m roulette stretched and through each two meters the peg designating an ordinary profile was hammered.

Thus, each square had 1 common profile or 1 number of pickets with all next squares. This scheme allowed to carry out shooting of the territory with rather big efficiency, without loss of method informational content.

RESULTS AND DISCUSSION

Magnetic prospecting data pretreatment technique: Cameral works were carried out with use of software package Geosoft Oasis Montaj. All information on field researches were brought in the common database. The database includes the following parameters:

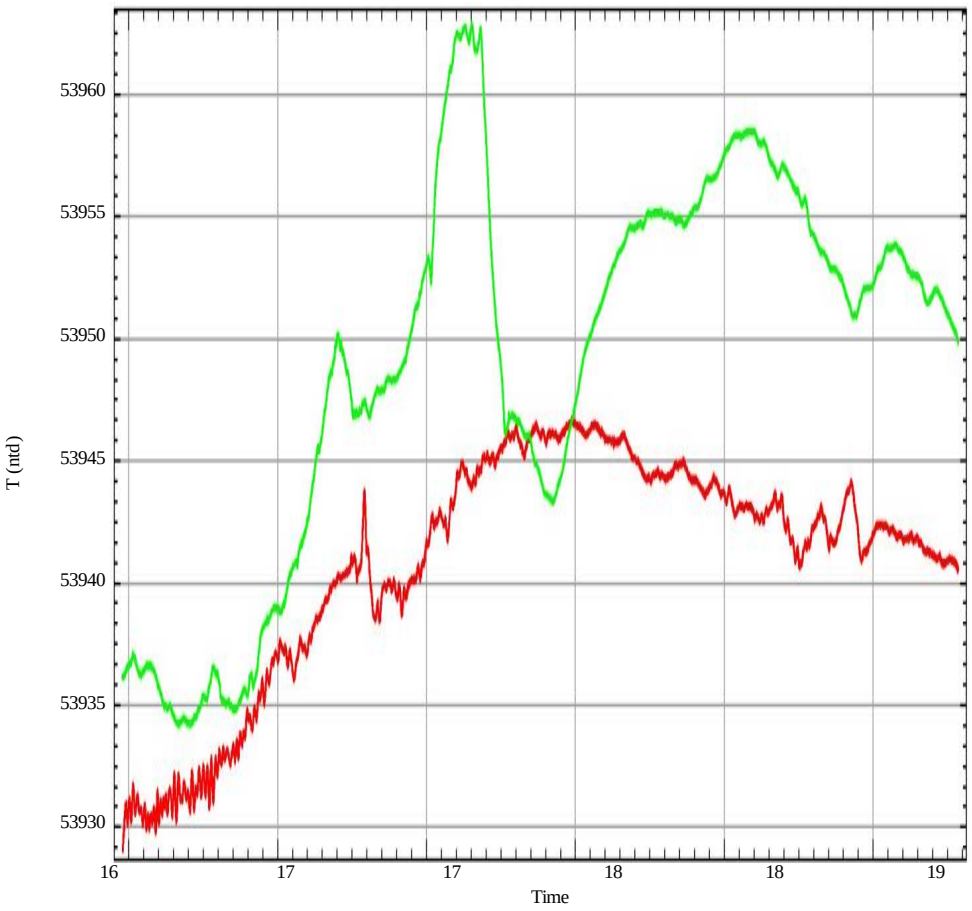

Fig. 5: Example of field variations distinction on two control points located 100 m apart from each other

- Values of complete magnetic displacement vector on ordinary points of supervision
- Values of complete magnetic displacement vector on control points of supervision (10% of total of supervision points)
- Measurements variation data for magnetic field
- Values of absolute geographical coordinates of all supervision points
- Dates of all taken measurements in a format year, month, day, clocks, minute, second
- Data of visual object observation-potential sources of technogenic hindrances (power lines, pipelines, high-voltage cables, etc.)

Further amendments for magnetic field variations were introduced, the main earth magneticfield and the mean squared error of measurements which made ±1.2 nTd were taken into account.

After creating the complete magnetic displacement vector on each square, selection and anomalies exception maps of technogenic nature was made. In order to create the common map of magnetic field anomalies coordination of all squares among themselves was required. At this, stage one more negative factor a nonuniform distribution of technogenic hindrance, both on the area and in time came to light (Fig. 5). In Fig. 5, the example of field variations distinction on two control points located 100 m apart from each other is shown. For correct coordination of separate squares approximation of field variations for magnetic field according to several (from 3-5) control points was carried out.

After amendments introduction for technogenic field inhomogeneity, there were errors bound to distinction in body height of operators, change of research area micro-relief, etc. As a rule, this type of errors was shown as shift of the average magnetic field level of one square in relation to the next. Despite the small amplitude of shifts (under 2 nTd), they created noticeable distortions of magnetic field on borders of the coordinated squares.

For distortion elimination serial linear shift of module mean value of each square magnetic induction concerning one basic, located in quiet magnetic field was carried out. After coordination of all squares the resultant magnetic field map was made (Fig. 6).

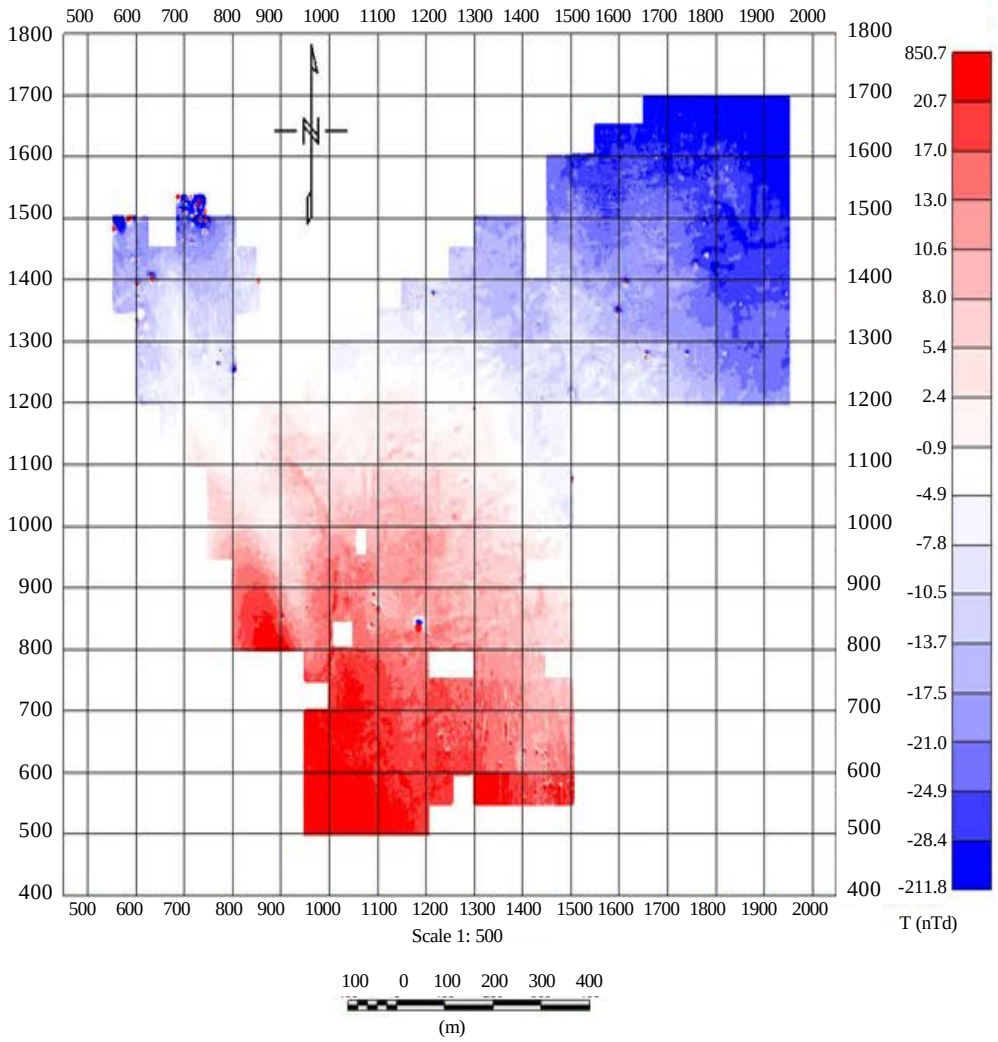

Fig. 6: Anomalies map of magnetic induction module absolute values (2011-2014)

Summary: On the basis of the carried-out magnetic prospecting works it is possible to draw the following conclusions for obtaining qualitative magnetic prospecting data with a margin error, not exceeding ±2 nTd, in conditions of high level electromagnetic disturbances, it is necessary to consider factors such as: azimuthal error in devices readings; high-pitched variations of magnetic field; nonuniform distribution of technogenic hindrances in the research area; microland relief and body height of the operator. Considering the specified factors gives the chance of correct result comparison of magnetometric shootings for some years.

CONCLUSION

High-precision magnetic prospecting researches of the larger territories representing historical and archaeological value can in rather short term give important archaeological research information for many years ahead.

Within this study, methods and results of interpretation of the obtained data are not considered. Nevertheless, it is possible to note that magnetometric researches of larger territories allow to reveal objects which are often invisible when studying small squares roads (especially ground), systems of channels, ditches, etc.

ACKNOWLEDGEMENT

The research is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

REFERENCES

Anonymous, 1981. Instruction to magnetic exploration. Publisher "Nedra", Leningrad, pp: 263.

Boschian, G. and R. Langohr, S. Limbrey and R.I. Macphail, 2003. Eds. Sec. International Conference on Soils and Archaeology, Pisa 12-15th May. Extended Abstracts.Dipartimento di Scienze Archeologiche, Universit, di Pisa: Pisa, pp: 60-63.

Logachev, A.A., V.P. Zakharov, 1979. Magnetic exploration. Publisher Nedra, Moscow, pp: 145.

Mikov, D.S., 1975. Interpretation methods of magnetic anomalies. Publishing house of Tomsk State Univ., Tomsk, pp: 179.

Sokolova, T.B., A.A. Bulychev, I.V. Lygin, A.V. Starovoytov, Tevelev, N.V. Shalaev, 2011. Interpretation of geophysical materials. Manual. Publisher GERS, Tver, pp: 208.