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Integrated archeological and geophysical studies in West Siberia

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Abstract

We present the most informative results of archeological and geophysical field studies of the Baraba forest–steppe over the last three years. The studies of the archeological sites of different types belonging to a wide time interval (~6000 BC–2000 AD) were carried out. Data on the presence, size, and configuration of archeological objects were obtained by magnetometry and electrometry. We studied contrast between the magnetic properties of the upper horizon of present-day soil and underlying substratum at archeological sites of different types and ages. Low contrast reduces amplitudes of magnetic anomalies above buried ancient structures. It has been shown that geoelectric methods are efficient in cases when magnetometry is not.

Keywords: archeology; resistivity method; electromagnetic profiling; magnetometry

Introduction

Achievements in the study of the earliest history depend heavily on the integration of different disciplines and correctly selected sets of methods for solving scientific problems. Interdisciplinary research, the aim of which is to unravel the historical realia of ancient societies and cultures, is fundamental in archeology. Archeological and geophysical exploration, which opens up new opportunities for ancient history studies, has been highly dynamic in recent years.

Geophysical methods have been applied in archeology for more than half a century. Resistivity methods and magnetometry have been applied in Europe since the 1950s (Aitken, 1974; Atkinson, 1952). Electromagnetic profiling and GPR survey were introduced in archeology in the 1980s–1990s (Dabas et al., 2000; Dalan, 1991). Significant advance in the magnetometry study of different archeological objects (including those in Siberia) has been made by our German colleagues (Becker and Fassbinder, 1999; Fassbinder and Gorka, 2010; Fassbinder et al., 2013; Gorka and Fassbinder, 2011; Molodin et al., 2010).

Archeological sites are highly diverse, with different electric, magnetic, hydrogeologic, lithologic, and other characteristics; hence the importance of a comprehensive approach combining different geophysical methods (Epov et al., 2012; Modin et al., 2014; Molodin et al., 2001, 2004a). The combination of geophysical tools and methods now permits obtaining significant information on the character and structure of archeological sites as early as before excavations.

In recent years, members of the Trofimuk Institute of Petroleum Geology and Geophysics and the Institute of Archeology and Ethnography have carried out extensive archeological and geophysical studies of ancient and medieval sites in southern West Siberia, on the Altai–Sayan Plateau, and in Mongolia (Balkov et al., 2006; Dyad'kov et al., 2005; Epov et al., 2012; Molodin et al., 2001, 2003, 2004a,b, 2012b; Tishkin et al., 2007). The experience of application of geophysical methods has shown not only its advantages but also the problems related to adequate comparison between archeological and geophysical data. First and foremost, this is true of the interpretation of results of magnetic survey. As artificial pits (graves, dwelling sites, middens, etc.) in subsoils are filled with humic soil, the amount of magnetic material

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increases; this leads to the appearance of positive magnetic anomalies above them. However, these anomalies are not always of distinct shape or well-defined with respect to the background values of the magnetic field. Sometimes, anomalies above archeological sites are not detected or turn out to be "false." Archeological exploration is impaired by the study of such "false" sources of anomalies and the impossibility of identifying archeological sites in faint anomalies. This is particularly important when most of the archeological sites are in a state of emergency, i.e., are destroyed by natural and human-induced factors.

Evidently, the main cause of the faint anomalies is the insufficient contrast between the magnetic properties of the humus layer and substratum (clay loams, sandy loams, and sands). As magnetometry is one of the most popular and productive methods for detecting archeologic complexes, the work was aimed at studying contrast between the magnetic properties of the upper layer of present-day soil and substratum at archeological sites by geophysical and geochemical methods to increase the efficiency of magnetometry.

The presence of objects with contrasting resistivity, when there is no magnetic contrast or magnetometry data are highly noisy, favors the application of resistivity methods as well as frequency electromagnetic soundings or profiling (portable ground version). The experience of integrated archeological and geophysical studies has shown that the vertical structure of an archeological site is determined exactly by the geoelectric methods.

The resistivity method as conventional VES or electrical profiling is characterized by low productivity and insufficient resolution. Automated application of multielectrode apparatus as electrical tomography in the resistivity method (Bulgakov and Manshtein, 2006) considerably improves these characteristics. Therefore, the potential of electrical tomography for detecting archeological complexes with the use of Skala high-productivity multichannel apparatus (developed at the Trofimuk Institute of Petroleum Geology and Geophysics) (Balkov et al., 2012) should be studied.

The long-term application of frequency electromagnetic sounding (EMS) and electromagnetic profiling (EMP) has repeatedly confirmed their efficiency (Balkov et al., 2006; Manshtein et al., 2000), but some problems have been detected (Balkov, 2011a). The standard geoelectric sections of the Baraba and Cis-Altai Plains and Gorny Altai show high resistivities. This results in the low level of EMS signals, which considerably distorts sounding curves; therefore, EMS is widely applied for EMP.

The selection of geophysical methods and equipment for the optimum exploration of archeological sites is the main goal of archeological and geophysical studies. It has many specific features, because each archeological complex has a set of different physical characteristics. Physical properties are formed both by natural processes determined by landscape and climatic conditions and by human-induced factors. The latter is expressed in the transformation of the environment by ancient and present-day population. Studies were carried out by different methods at archeological sites of different types and ages in the Baraba forest–steppe to achieve the set goals and to optimize methods of archeological and geophysical research.

Methods

Magnetometry. The physical basis of the magnetometry method for searching for and exploring archeological complexes is the inhomogeneity of the magnetic properties of objects under study and the host medium. Note the high differentiation between the magnetic susceptibility and remanent magnetization of different grounds, rocks, and artifacts (Dyad'kov et al., 2005; Gershanok, 2011). To detect magnetic anomalies, the induction vector of the geomagnetic field and its elements or the modulus of this vector are measured at archeological sites. The high sensitivity and precision of modern devices (proton and quantum magnetometers) permit recording extremely low spatial variations in the magnetic field, which are, in turn, due to weak variations in the magnetic properties of the medium.

The studies were made using G-858G (Geometrics), GSMP-35G (GEM), and MMPG-1 (Geologorazvedka) quantum and proton gradiometer magnetometers as well as MM-61 (Kazgeofizpribor), MV-08, and MV-07 (Geomer) proton magnetometers and geomagnetic-variation systems. The sensitivity of G-858G was 0.01 nT with a measurement cycle of 0.1 s and 0.01 nT with a cycle of 1 s, absolute accuracy being ~0.5 nT. The sensitivity of GSMP-35G was 0.0025 nT, absolute accuracy being ±0.1 nT. Both gradiometer sensors synchronously measure the magnetic-induction vector modulus. A single measurement yields the difference between synchronous values of the magnetic field determined with the use of two spaced sensors. The high operation speed (10–20 measurements/s) permits sensing in motion, without stopping at each point.

The measurements were usually taken by the vertical-gradient method. According to observations, such data are more informative and easier to interpret, particularly for the search for small archeological sites (e.g., graves). They reflect changes in the magnetic properties of the medium below the measurement point, whereas the horizontal gradient permits somewhat better delineation of bodies (e.g., construction pits).

Magnetic studies of rocks included the areal mapping of the magnetic susceptibility of soils and measurement of magnetic susceptibility on the vertical profiles of present-day soils and bedrocks. The areal mapping was carried out using a KT-5 susceptibility meter after the removal of sod at intervals of 2.5–5.0 m.

Samples for laboratory studies were recovered from the filling of archeological sites of different ages and from vertical profiles in the shafts and walls of excavations to the maximum possible depth at intervals of 0.05–0.10 m. The measurements were taken using a Bartington MS2 system. It was applied to measure volume magnetic susceptibility in the laboratory at low (0.47 kHz, XLF) and high (4.7 kHz, XHF) frequencies, and relative frequency difference of magnetic susceptibility