Geophysics

Electrical Prospecting in Dmanisi Settlement Area of the Oldest Eurasian Hominids

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ABSTRACT. The purpose of the study was to establish the efficiency of electrical prospecting methods on the territory of Dmanisi ancient settlement, where the oldest man of Eurasian continent – hominid's remains were discovered.

As a result of the study, an exact delineation of basalts under Quaternary cover was made. The morphology of the surface of basalts and of Pliocene palaeorelief was determined; Reconstruction and mapping of Mashavera and Phinezauri rivers paleovalleys was made. So, it is possible to conclude that the strong differentiation in electrical resistivity between rocks developed in the territory under study, specifically between Quaternary sediments, basaltic lavas and upper Cretaceous volcanic formations determines the effectiveness of the electrical prospecting for the solution of structural geology problems. *© 2009 Bull. Georg. Natl. Acad. Sci.*

Key words: *Dmanisi, electrical conductivity.*

On the Dmanisi site of ancient settlement the sensational discovery of oldest Eurasian hominids has been made [1]. We tried to apply geophysical methods in order to delineate promising areas for further investigations.

It is known that remnants of hominids were found in the clayey formations (5th layer by archaeological section - Fig. 1a.) overlying the volcanic ash layer, which in turn lies on basaltic lavas.

The studies show that due to fast sedimentation the irregular surface of the lavas was preserved [2,3]; the surface was covered by a lake, where the remnants-containing sediments were accumulated. Thus the mapping of the basaltic lavas and the cavities on its surface is very important for delineation of the 5th layer as far as they are closely linked with each other.

Of course, geophysical methods cannot reveal directly the buried bones of hominids and animals as they are too small to affect the physical field on the day surface. That is why it is necessary to use indirect methods, i.e. to find geophysical-geological criteria for mapping remnants-containing (or embedding) formations.

In Fig. 1a lithological section of archaeological excavation area, which is typical of this region, is presented [1]. The specific electrical conductivity of rocks in the layers was defined by parametric measurements on the outcrop. The corresponding diagram (Fig.1b) shows that the sedimentary layers, formed by lake-proluvial deposits (mainly sandy clays), have low resistivity, of the order of 100-130 ohm·m. The only exception is the third clayey layer with carbonate veins. The thickness of the layer is 20-40 cm; its resistivity is in the range 130-150 ohm·m. It is possible that in natural conditions the difference is smaller as this layer cannot be identified on the vertical electric sounding (VES) curves, which was performed close to the outcrop (Fig. 1c).

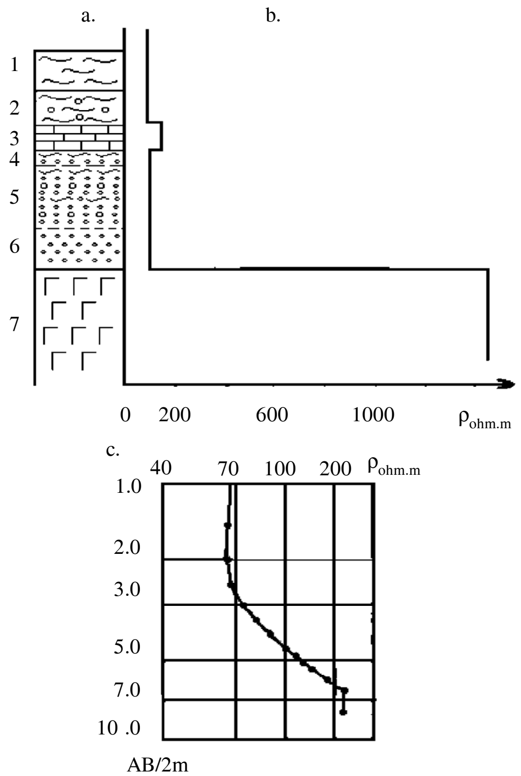

Fig. 1. a – Geologic section: 1. light brown clay; 2. light brown loamy clay, 3. carbonates, 4. brown loam, 5. dark brown loam with sand inclusions, 6. volcanic ash, 7. basalts. b – resistivity distribution with depth according to parametric measurements, c - vertical electric sounding (VES) curve.

The underlying basalts (the basic geoelectric horizon), according to many parametric measurements and soundings, are of high resistivity – 1500-2000 ohm·m (sometimes up to 3000 ohm·m).

Thus the geoelectric section is actually two-layer type with strong differentiation; this allows mapping of basalt surface under terrigenous sediments with high accuracy: the depth of basalts can be measured with only 5-10% error.

Geoelectric section (Fig. 2) shows that the thickness of deluvial-proluvial sediments varies in the range of 7-8 m. The electrical properties of the layer are highly variable: if in the central part the apparent resistivity ρ_a is in the range of 3-50 ohm·m, in the area of VES-7-10, ρ_a=200-800 ohm·m. This is caused by inclusions of old wall debris in the sediment layer.

Basaltic layer (ρ_a=1500-2000 ohm·m) gradually rises and on the bank of the river Mashavera it appears on the day surface. In the south, in the area of the VES-6 under the Quaternary sediment layer with 2 m thickness it lenses out and sets against volcanic layer of the Cretaceous age with resistivity ρ_a=200-250 ohm·m.

Geoelectric section II (Fig. 3a) reveals at the depth 3-3.5 m basalts (ρ_a=1800-2000 ohm·m). Again, in deluvial layer with ρ_a=20-50 ohm·m) there is a horizon with ρ_a=100-200 ohm·m) containing remnants of walls.

The same situation is in section III (Fig. 3b) where the surface of basaltic layer is strongly tilted.

To characterize the morphology of the surface of basaltic lavas, their extent, as well as Quarternary deposits a meridional profile has been drawn from the ravine of r. Mashavera to the motor road, 3-4 km to the west of the village of Vardisubani. According to corresponding geoelectrical section (Fig. 4) in the southern part of the profile there is an outcrop of basalts with ρ_a=2000-3000 ohm·m. To the north of the outcrop the deluvial cover with ρ_a=20-30 ohm·m appears; its thickness increases gradually and near the motor road it reaches 10 m. The surface of basalts in the central part of the profile is nearly horizontal. In the northern part of the profile the basaltic layer lenses out (between VES-es 24-21) and in the section appear underlying Cretaceous volcanic deposits with ρ_a=30-45 ohm·m. Here again a strong difference in resistivity allows exact mapping of the contact between basalts and volcanic sediments.

In order to map the contact surface (paleorelief) to a considerable depth the separation of current electrodes AB was increased (up to AB > 400 m), which increases the depth of investigations to 110-120 meters. According to these data in the central part in the area of VES-22 the thickness of Upper Cretaceous sediments exceeds 120 m [4].

It is natural to suppose that the area of maximal depth of paleorelief represents the old valley of r. Mashavera. The obtained results confirm earlier geological considerations on the location of the paleovalley of r. Mashavera to the north of its present location.

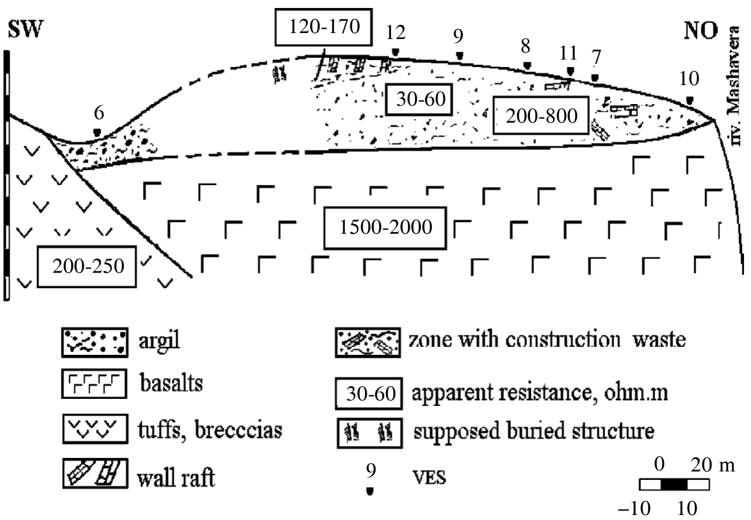

Fig. 2. Geoelectric section I in the area of old settlement.

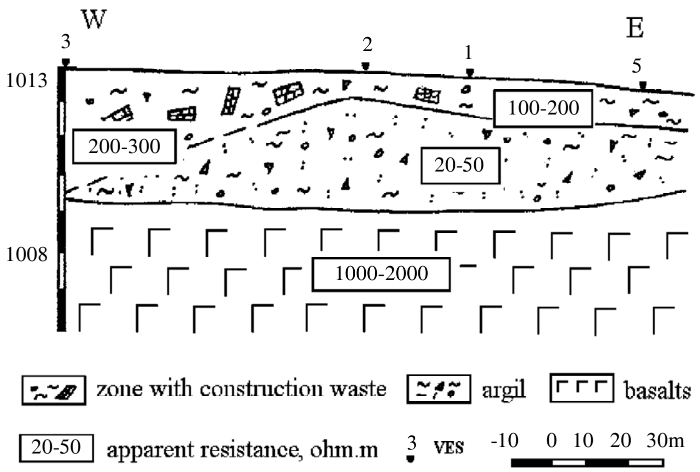

Fig. 3a. Geoelectric section II, the territory of old settlement.

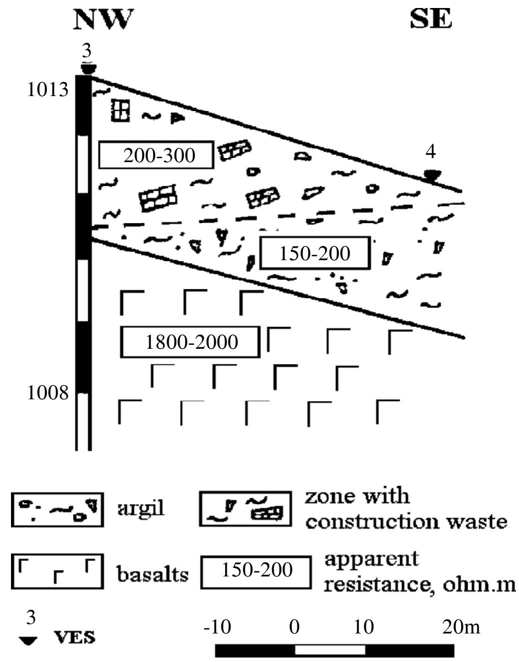

Fig. 3b. Geoelectric section III, the territory of old settlement

For a more effective search of hominid remnants very detailed geophysical exploration using modern methods is needed. The point is that the remnants are found in the clay layer filling small depressions of the basaltic layer surface. It seems that the optimal methods for detailed study of shallow subsurface are Ground Penetrating Radar (GPR) and magnetic gradiometer (MG). In order to check the efficiency of GPR and MG for a given area it is necessary to study the dielectric and magnetic properties of rocks and find the degree of differentiation of these properties.

The samples from the five main layers of Dmanisi area were taken with care for conservation of their natural humidity and investigated in the IG TUC in the laboratory of Prof. A. Weller. The layers are: 1 – clay, 2 – carbonate clay; 3 – dark clay; 4 – volcanic pebble; 5 – basaltic lava. The dielectric spectra (real and imaginary components of complex dielectric constant) of these samples were measured in the frequency range from 1.1 MHz to 1.28 GHz in order to find optimal differentiation domain. The equipment used was Hewlett-Packard HP 8712B and special measuring cell.

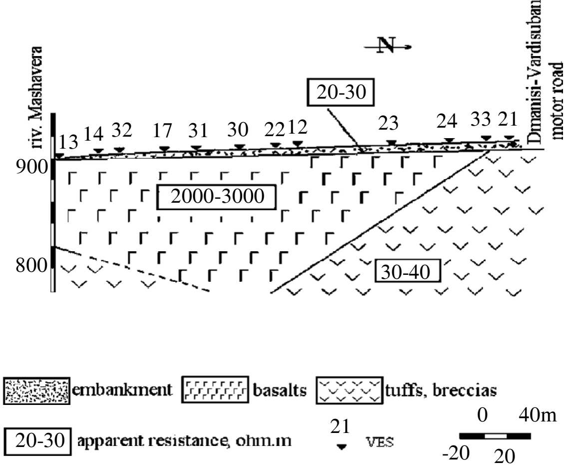

Fig. 4. Geoelectric section, the territory between riv. Mashavera and motor road.

The samples were powdered (except samples from layers 3 and 5) and placed in cylindrical plastic holder; the diameter and the thickness of samples were in the range 12-13 mm in and 4-5 mm respectively.

The results of experiments show that for the consecutive layers 1, 3 and 4 the real part of complex dielectric constant (real DC) is (15-13.7); (18, 45-19.99) and 17.26 at the frequency 1.1 MHz respectively. The imaginary part (Im. DC) is respectively for the same layers: (9.65-10.25); (33.87-27.89) and 24.94 at 1.1.MHz.

At high frequencies the degree of differentiation decreases and at the frequency 1.2 GHz real DC-values are respectively (3.82-3.5), (4.23-4.45) and 3.47 for layers 1, 3 and 4. Corresponding values of imaginary DC are (0.55-0.43), (0.55-0.54) and 0.4.

Thus the experiments show that the optimal differentiation of electrical properties of layers is observed at low frequency, at 1.1 MHz. This means that the GPR technique should be used in a low-frequency modification, with 1 MHz antenna.

In addition to DC magnetic properties of samples were measured in order to assess the potential of magnetic prospecting in Dmanisi area.

CONCLUSIONS

1. The strong differentiation in electrical resistivity between rocks developed in the territory under study, namely between Quaternary sediments, basaltic lavas and

Upper Cretaceous volcanic formations, provides grounds for successful application of electrical prospecting methods in the following directions of structural geology:

1.1. Exact delineation of basalts under Quaternary cover;

1.2. Refinement of the morphology of the surface of basalts and detection of the surface depressions;

1.3. Reconstruction of Pliocene palaeorelief and mapping of rivers Mashavera and Phinezauri paleovalleys.

2. The most promising areas for revealing fossils are depressions in the surface of basaltic layer and future investigations should be focused in these areas.

3. The basis for future prospecting by georadar and magnetic gradiometer was prepared, namely the dielectric constants and magnetic properties of all characteristic rocks were measured in laboratory. We conclude that GPR technique should be used in a low-frequency modification, with 1 MHz antenna.

გეოფიზიკა

ელექტრომეტრული კვლევები დმანისის ნაქალაქარის ტერიტორიაზე

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კვლევის მიზანი იყო ძიების ელექტრული მეთოდების ეფექტურობის დადგენა დმანისის ნაქალაქარის ტერიტორიაზე იქ, სადაც მიკვლეულ იქნა ევრაზიის კონტინენტზე უძველესი ადამიანის – ჰომინიდის ნაშთები.

კვლევის შედეგად განისაზღვრა ბაზალტების გავრცელების ზუსტი კონტურები მეოთხეული საფარის ქვეშ; დაზუსტდა ბაზალტების ზედაპირის მორფოლოგია, პლიოცენური პალეორელიეფი, გამოიყო მდ. მაშავერას ძველი კალაპოტის ადგილმდებარეობა.

ამგვარად, შეგვიძლია დავასკვნათ, რომ საკვლევ ტერიტორიაზე გავრცელებული ქანების, კერძოდ, მეოთხეული ნალექების, ბაზალტური ლავებისა და ზედა ცარცული ვულკანოგენური წყების, ხვედრით ელექტრულ წინაღობას შორის არსებული მკვეთრი დიფერენციაცია განაპირობებს ელექტრული ძიების ეფექტურობას აღნიშნულ ტერიტორიაზე სტრუქტურული გეოლოგიის ამოცანების გადაწყვეტისას.

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