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APPLICATION OF 2D RESISTIVITY PROFILING FOR DELINEATION OF SPECIFIC LITHOLOGICAL BODIES

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Abstract

The present study aims to demonstrate the potential of 2D resistivity profiling in recognizing and determining the sediment successions in areas with lack of outcrops. Neogene Gotse Delchev Basin was chosen for a test area. Application of this method is a first attempt to delineate the diatomite deposits in SW Bulgaria. Diatomites from Baldevo Formation were clearly delineated according to their resistivity characteristics. Alluvial successions from Nevrokop Formation were recognized in 2D resistivity profiles and distribution of a Quaternary travertine layer was outlined.

Key words: resistivity profiling, Neogene, sedimentology

Introduction. Various geophysical methods are used for detailed logging of the surface-subsurface geological composition. Electrical surface geophysical methods can be used to detect changes in the electrical properties of the subsurface. The two-dimensional (2D) resistivity profiling method records a large number of resistivity readings in order to map lateral and vertical changes in material types along a survey line [1, 2]. Its advantage is the detail of measurements comparing to other resistivity methods.

The aim of the present study is to demonstrate the potential of 2D resistivity profiling in recognizing and determining of a specific sediment body among the sedimentary successions. We applied 2D resistivity profiling on areas built of diatomites and used the obtained data in delineating the diatomite bodies among other sediments.

2D resistivity profiling was applied to 6 sites located in Gotse Delchev Basin: near the villages of Ognyanovo, Kornitsa, Musomishta and north of the town of Gotse Delchev (Fig. 1).

For the present study, we chose two sites with diatomite deposits in Gotse Delchev Basin (Ognyanovo and Kornitsa) and two other sites without any (Gotse Delchev–North and Musomishta). The diatomites near the village of Ognyanovo in Gotse Delchev Basin are known since the first half of the last century. The

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well-studied geological context provides suitable conditions to perform our study: lithological succession is studied in detail [3–6], the occurrence and distribution of diatomite bodies are known, and this way we can try to obtain criteria for recognizing these bodies in less studied terrain as it is around the village of Kornitsa.

During our study, the multi-electrode system consisting of Terrameter – SAS 1000, electrode selector ES 10-64 C, multicabels (2 cables × 21 electrodes), electrodes and connecting cables was used. The survey was carried out by Wenner array of 200 m length of survey line and with 5 m electrode spacing for profiles Ognyanovo and Kornitsa, and 3 m electrode spacing for Gotse Delchev–North and Musomishta. To obtain comparative results, all profiles were measured by the same Wenner array. Measured apparent resistivity data were inverted using programme Res2Dinv with topographic corrections. An additional model refinement was applied, truncating the electrode spacing to 2.5 m. The results are shown as a profile representing the resistivity section in depth.

Geological setting. Gotse Delchev Basin is located in Southwestern Bulgaria and occupies the central and southern parts of Mesta Graben. It is filled in with predominantly alluvial deposits and partly lacustrine-marshal deposits of Neogene age, referred to the following formal lithostratigraphic units: Valevitsa Formation Baldevo Formation, Nevrokop Formation, and Sredna Formation [5, 6]. Baldevo Formation (Pontian–Dacian [7, 8]) is composed of typical lacustrine-marshal sedimentary succession – sandstones, siltstones, clays, diatomites and coal (Fig. 2). Diatomite covers the uppermost coal beds in Baldevo Formation. The diatom flora is represented chiefly by recent species – 91.5%, and fossil ones – 8.5%. The dominant complex of the investigated diatom flora is monotaxonic and consists of variable roughly-silicified *Aulacoseira* species. The flora comprises some species typical of the Late Miocene lakes, i.e. *Aulacoseira distans* var. *scala* (Ehr.)Ognjan., *Fragilaria leptostauron* var., *fossilis* (Pant.)Reh., *Eunotia polyglyphoides* Moiss., *Cymbella obtusa* Pant., and it is dated to the Late Miocene [6, 9]. Sediments of Baldevo Formation crop out in the northern and northwestern part of the basin and are surrounded and covered by sediments of Nevrokop Formation. Nevrokop Formation comprises conglomerates, fine- to coarse-grained sands, sandstones, siltstones and clays of alluvial origin in irregular alternation.

Four profiles were placed to characterize diatomite presence or absence in Baldevo Formation: profile Ognyanovo 1 near the village of Ognyanovo, profile Ognyanovo 2 near the coal mine of Kanina, and two parallel to each other (Kornitsa 1 and Kornitsa 2) south of the village of Kornitsa. Two more profiles were placed near the town of Gotse Delchev to characterize in depth the distribution of the sediments of Nevrokop Formation (Fig. 1).

Results and discussion. Profile Ognyanovo 1 is situated north of the village with SSE–NNW direction and 200 m length, electrode spacing of 5 m (Fig. 2*A*). Aiming to determine the resistivity of diatomites there, the measurements were carried out at a certain outcrop where diatomites cover the upper

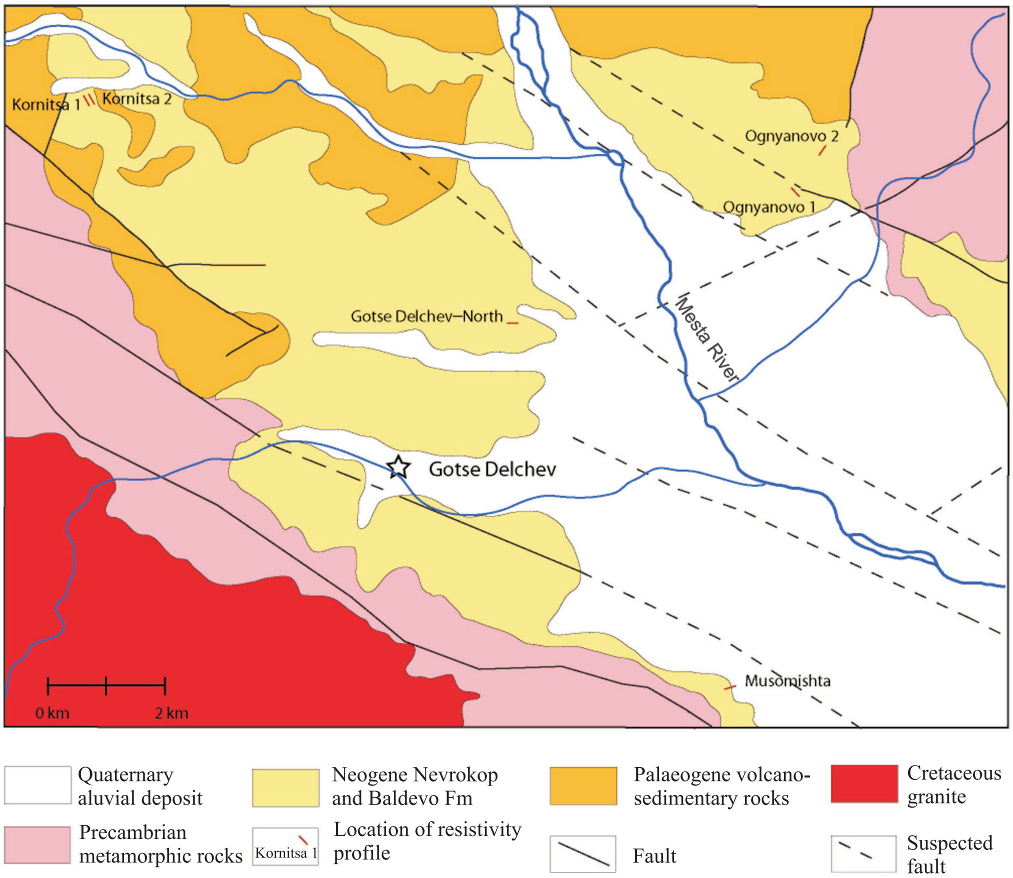

Fig. 1. Geological map (according to [10]) and location of the 2D resistivity survey lines

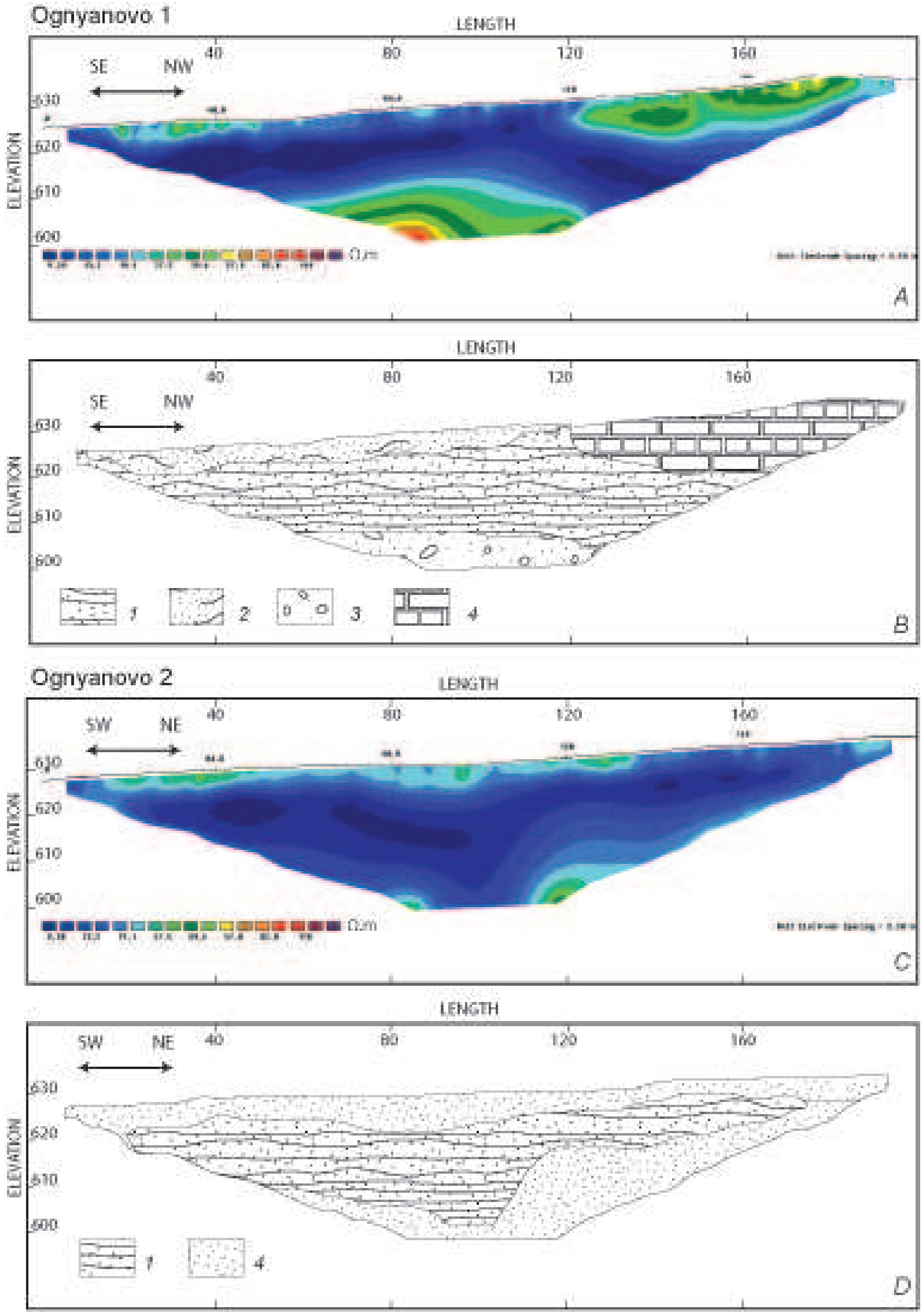

Fig. 2. Section, showing inversion results of resistivity data (*A*, *C*) and geological interpretation (*B*, *D*) of profiles near Ognyanovo. (Key: *1* – sandy clay; *2* – clayey sand and siltstone; *3* – coarse sand and gravel; *4* – diatomite)

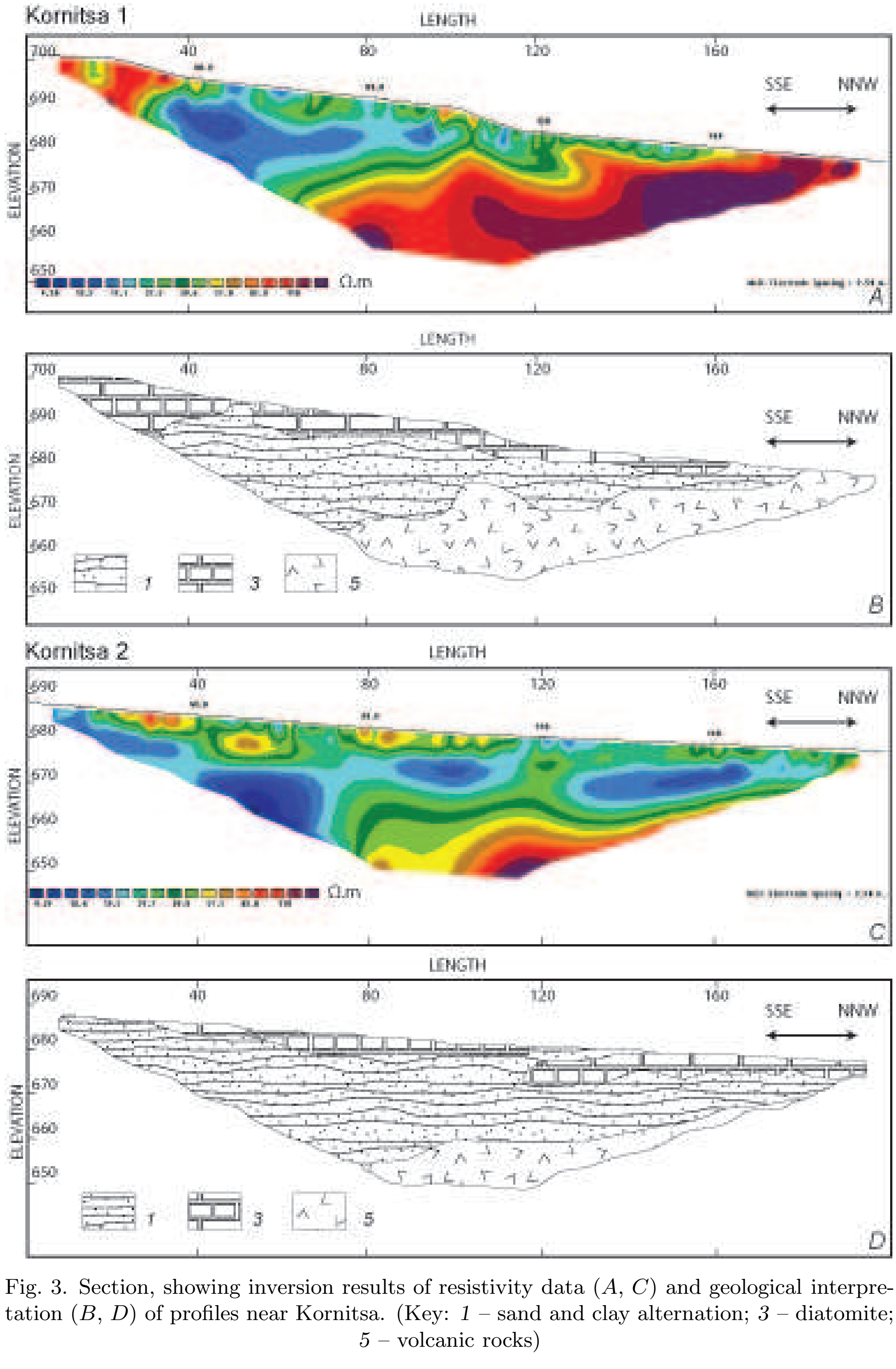

Fig. 3. Section, showing inversion results of resistivity data (*A*, *C*) and geological interpretation (*B*, *D*) of profiles near Kornitsa. (Key: *1* – sand and clay alternation; *3* – diatomite; *5* – volcanic rocks)

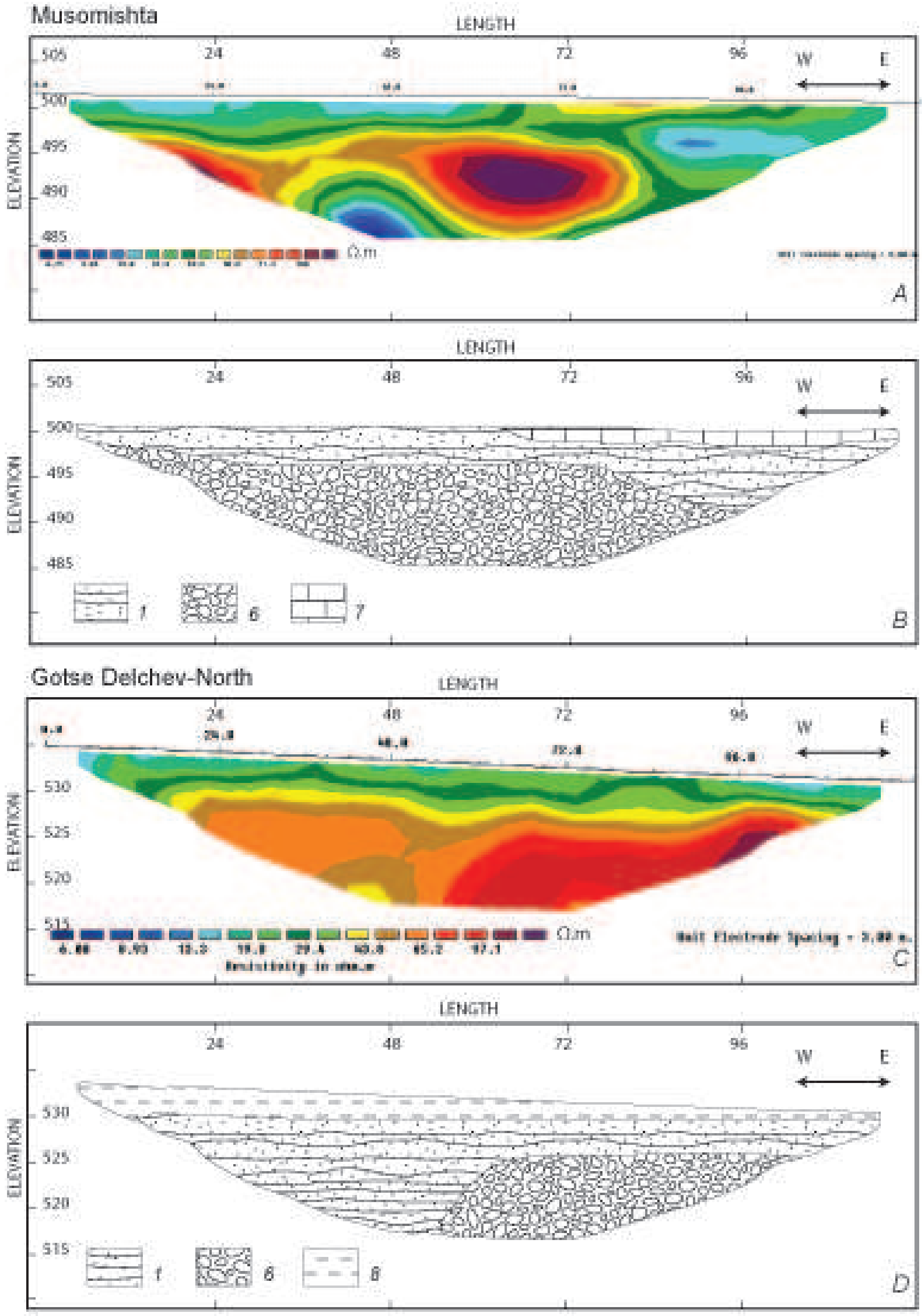

Fig. 4. Section, showing inversion results of resistivity data (*A*, *C*) and geological interpretation (*B*, *D*) of profiles Musomishta and Gotse Delchev–North. (Key: *1* – sand and clay alternation; *6* – conglomerate; *7* – travertine; *8* – clay)

northern part of the profile (metre 120–200). Their resistivity ranges from 40 to 60 Ω.m. The thickness of the diatomite body here is between 14 and 17 m. In the southern part of the profile, between metres 0–120, a zone with resistivity of 15–40 Ω.m appears, which could be interpreted as clayey sands and siltstones. Its thickness varies from 7 to 10 m. Below this zone, a low resistivity layer (1–13 Ω.m) which corresponds to sandy clays, is shown. Between metre 50 and up to metre 105, and below 20 m in depth, a high resistivity layer is drawn, which is interpreted as conglomerate and sand. This interpretation corresponds to the outcrop in the coal mine of Kanina, described by YANEVA and YANEVA et al. [9, 10].

The next profile – Ognyanovo 2, is situated just above the eastern border of the coal mine of Kanina. The measurements were accomplished in the same scheme as profile Ognyanovo 1. Resistivity varies from 3 to 35 Ω.m, which definitely excludes the presence of diatomites there (Fig. 2*C*). These data are confirmed by data published earlier by OGNJANOVA-RUMENOVA and YANEVA [9]. During our previous studies, diatomites cropped out at the southern border and did not crop out at the eastern one. Layers with resistivity of 3–13 Ω.m were identified as sandy clay, and those with higher resistivity of 13–35 Ω.m – as sand.

Diatomites south of the village of Kornitsa have been studied in detail. Two parallel profiles were performed above the diatomite outcrops. They show very similar resistivity patterns: apparent resistivity varies from 12 Ω.m (for Kornitsa 1, Fig. 3*A*) and 6.5 Ω.m (for Kornitsa 2, Fig. 3*C*) to 315–322 Ω.m respectively. Diatomites in both profiles show resistivity in the interval of 40–75 Ω.m and have built a layer with more than 200 m length and thickness between 2 and 12 m (Kornitsa 1) and 4–10 m (Kornitsa 2). The layers with apparent resistivity of less than 40 Ω.m are interpreted as clay and sand, and those with more than 80 Ω.m – as bedrock of volcanic rocks. This interpretation of the rock content could be observed in the outcrops around the village.

The results from 2D resistivity profiling of diatomites show that diatomite bodies in Ognyanovo area are thicker than those in Kornitsa area, whereas higher apparent resistivity in Kornitsa leads to the conclusion that diatomites here are purer (containing more diatom cells per cm^3), which is proved later during the diatom analysis.

Sediments from Nevrokop Formation, which fill the westernmost parts of Gotse Delchev Basin, were studied by methods of 2D resistivity profiling, too. Two sites were studied – one south of Gotse Delchev – near the village of Musomishta, and the other north of the town. At the site of Musomishta, Neogene and Quaternary sediments are described [10]. The profile length was 120 m with electrode spacing of 3 m and W-E direction. The western part should cover Neogene Nevrokop Formation, whereas the eastern one – Quaternary deposits. Resistivity varies from 5 to 180 Ω.m (Fig. 4*A*). In the western part, an alternation of low- and high-resistivity zones is observed. This corresponds to the composition of Nevrokop Formation – clays and water saturated clayey sands (30 Ω.m), which could be traced as 6–10 m thick layer along all profiles' length, and gravels and conglomerates in depth (65–180 Ω.m) with thickness about 10 m. At the uppermost zone of the eastern part of the profile, a layer with resistivity of about 30–65 Ω.m appears. It is in a good correlation with data observed on field – easter of the profile, an outcrop of travertine is found. Thus the eastern part between metre 65 and 120 shows travertine deposits formed above the Neogene sands and gravels, and the western part (from 0 to 65 m) shows Neogene sediments.

The next profile of "Gotse Delchev–North" was done in same conditions as the previous one. It is located above the Neogene sediments (Fig. 4*C*). The upper part shows the almost continuous layer with thickness of about 4–6 m and resistivity of 10–30 Ω.m, which is interpreted as clays and sandy clays. In depth in the western part, a zone with resistivity of 30–70 Ω.m is outlined. It is interpreted as sand and gravel layer. To the east, it bounds with higher resistivity zone (65–120 Ω.m), which is interpreted as conglomerate with sand and gravel fill. This interpretation reflects to a certain degree the geological composition of Nevrokop Formation there – typical alluvial succession – gravels and conglomerates shifted horizontally to sands and covered by sandy clays.

Conclusion. The pilot studies presented above have shown that the use of 2D resistivity profiling for the purposes of sedimentology and stratigraphy of diatomite deposits is appropriate. The results are more reliable when we have a reference section to tie it up to the results of geophysical measurements. Implementation of various arrays with different electrode spacing and other methods of measurement (e.g. induced polarization) can detail the future studies and lead to more concrete conclusions.

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