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APPLICATION OF RESISTIVITY IMAGING METHOD FOR INVESTIGATION OF GEOLOGIC STRUCTURE OF PLEISTOCENE SEDIMENTS

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ABSTRACT
This paper presents the results of geophysical survey performed in the Pilawa River valley in the area of Middle Pomerania (Poland). The resistivity imaging method was applied. Resistivity profile measuring eight hundred metres allowed to investigate the geologic structure to the depth of 150 metres. The resistivity cross section shows the structure of Pleistocene sediments and the depth of Miocene – Pleistocene boundary. The significant lowering of the boundary is related to assumable ice-sheet margin range of Pomeranian phase of North Polish Glaciation. The lowering of the boundary may be a result of sediments compaction and the subglacial tunnel slope as well.

KEYWORDS: resistivity imaging, Pleistocene, geologic structure

INTRODUCTION

Modern surface geophysical methods are excellent tool for shallow geologic structure prospecting. Among geophysical methods, the resistivity imaging one is becoming increasingly significant. Multi-electrode electrical resistivity measurements enable to investigate continuouosly the geologic structure (Bernstone and Dahlin, 1999; Meads et al., 2003; Smith and Sjogren, 2003). The resistivity imaging survey can be a very useful method for investigation of the Pleistocene sediments structure especially in the areas where the bore-holes are in small numbers.

The studied area is situated in the Pilawa river valley on the border of Szczecinek and Drawsko lake districts in Middle Pomerania (Poland) (Fig. 1). The area is covered by Pleistocene sediments of the thickness of one hundred metres. The goal of the presented study was to recognize the structure of Pleistocene deposits and to estimate the depth of Miocene-Pleistocene boundary. The measuring profile was situated in the vicinity of the only one bore-hole in the studied area. Thus it was possible to compare the results of the geophysical measurements with geological data.

The Lund Imaging System ABEM equipment and RES2DINV software were applied. The measurements were performed along single 800 metres long profile. The results of interpretation are displayed as resistivity cross section. The maximum depth of penetration reached 150 metres under the surface.

GEOLOGY

The consolidated Pre-Cenozoic substratum of the Middle Polish Anticlinorium is discordantly covered by Cenozoic deposits consisting of Oligocene sandstones and mudstones, Miocene clays, sands, muds and various Pleistocene and Holocene deposits. The thickness of Cenozoic complex varies in the range 200 – 350 metres.

The lithology of Miocene sediments is variable. Three sedimentary cycles were observed within Miocene deposits. Sands at the begining of each cycle and clays, silts and brown coals were observed at the end of each cycle. The maximum thickness of Miocene deposits is 160 metres. The Miocene deposits together with Paleogene sediments are glaciotectonically deformed. Five glacial horizons composed of tills, fluvioglacial and limnoglacial deposits were observed in the studied area. Two lower glacial horizons represent South Polish Glaciation (Sanian 1 and Sanian 2 Glaciations). The next two succeeding glacial horizons represent Middle Polish Glaciation (Krznanian and Vartanian). The upper North Polish Glacial complex contains two or locally three till levels. Tills are accompanied by fluvioglacial sands with gravels and limnoglacial sands and silts occuring mainly in marginal zones. Holocene sands, river gravels, silts, gyttja, lacustrine chalk and peat are observed in the vicinity of lakes and in the local depressions. The thickness of Pleistocene and Holocene deposits varies in the 60 –200 metres range. Pre-Pleistocene morphology is considerably variable and undulating. The Pre-Pleistocene surface lowers

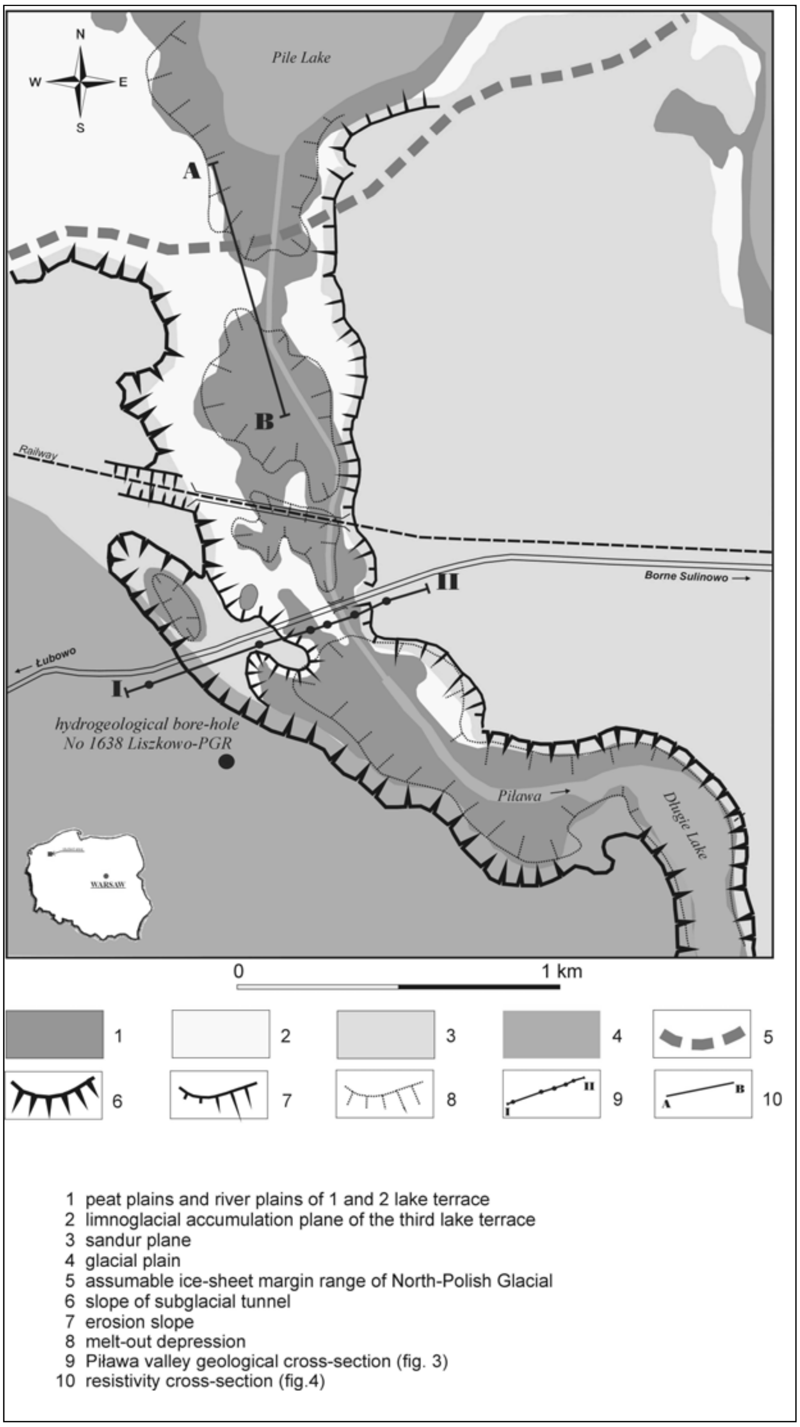

Fig. 1 Synthetic geomorphological sketch of Pilawa River valley.

into NW according to lowering of tectonic blocks of Pomerania Synclinorium. The Pleistocene floor lies at a depth of 20 – 50 metres a.s.l. (Dobracka and Piotrowski, 2002). The biggest fossil depressions are formed according to tectonic directions or they are the result of glacial erosion. The fossil depressions are mostly subglacial tunnels according to orientation of faults of Pre-Cenozoic substratum.

Pre-Pleistocene morphology is also caused by irreversible vertical glacial isostatic adjustment movements. The morphology is related to the structures of Mesozoic substratum modified by denudation, glacial erosion and glaciotectonics (Maksiak et al., 1978; Dobracka and Piotrowski, 2002).

The geophysical measuring profile was situated along the upper part of the Pilawa River valley. The glacial valley is the western border of the Pilawa sandur. The depth of the valley in relation to the neighbouring glacial plain in SW is 25 – 30 metres. The Pilawa sandur is a plane situated south of the Pile Lake. Its surface lowers to the south at a distance of 8 – 9 km with an average drop 1.7 – 2.1 m/km (Klimek, 2002). The total thickness of its sandy and gravels deposits is 10 –20 m (Lewandowski et al., 2000). There are many 100 - 200 metres wide melt-out depressions in the area of the Pilawa sandur. They are filled with 5-metre clayey and silty deposits. The Pilawa valley floor consists of many melt-out depressions filled with peats. The thickness of peats reaches 1.5 m. Lacustrine chalk of the several metres thickness is observed beneath the peats (Klimek, 2002). The geophysical measuring profile A-B was situated in the parts of two melt-out depressions.

The geological section across the Pilawa River valley was elaborated on the base of the geological profile of hydrogeological bore-hole Liszkowo-PGR No 1638 (Fig. 2), situated at a distance of 1.5 km south of the measuring profile, and six soundings. The model is presented in Figure 3. Two till horizons separated with fluvioglacial sandy and gravel deposits can be seen in the cross-section. The valley is filled with silty and sandy fluvioglacial sediments.

The first aquifer is localized in sands and gravels covering tills. The water table of this aquifer is observed at a depth of 3 – 20 metres due to morphology (Madejski and Madejska, 1995). The value of coefficient of permeability is changing because of a variable form of impermeable till subsoil. Thus, the general direction of ground water flow to the Pile Lake and the Pilawa River may locally change (Soltysik and Rybka, 1993). According to the hydrogeological profile (Fig. 2) there are three confined aquifers. The aquifer roofs were observed at a depth of 103 m, 84 m and 78 m a.s.l.

METHODS

The resistivity imaging measurements were performed with ABEM Lund Imaging System. The 800 metres long measuring profile with constant 10-metre electrode spacing was set up along the Pilawa River valley. The coordinates of the profile extreme points were estimated with GPS measurements and branch marks of all grounded electrodes were determined with levelling instrument.

The hydrogeologic bore-hole Liszkowo PGR (No 1638) mentioned above was situated at a distance of 1.5 km south of the central point of measuring profile (Fig. 1, Fig. 2). The measurements were carried out using Wenner-Schlumberger protocol. The applied current intensity was in the 50 – 200 mA range. Some of the parametrs were fixed for each measuring point: acquisition delay (0.3s), acquisition time (1.0s), number of measuring cycles (2 - maximum 4) and maximum standard deviation between succeeding measuring cycles (5%).

The obtained values of standard deviation were low for particular measuring points. They varied in a range from zero to several percent. The highest values of standard deviation were only observed for the longest electrode distance. The results of measurements were automatically recorded by Terrametr SAS 4000 equipment. The RES2DINV software was applied to interpretation of measured data. The data inversion was calculated with the least squares robust model constrain inversion method (Claerbout and Muir, 1973). The method is specially recommended for distinguishing of geologic boundaries (Loke et al., 2003). Five iterations were calculated during inversion. The final absolute error value was 2.2%. The results of calculation were displayed as resistivity cross-section graphically illustrated by Oasis Montaj software (Fig. 4).

DISCUSSION

The resistivity imaging survey allowed to study Neogene sediments up to a depth of approximately 150 metres. Considering the significant depth of resistivity prospecting we may expect that especially the floor parts of resistivity cross-section contain certain errors resulting of small number of measuring data. The presented resistivity cross-section represents a compromise between the accuracy and depth of prospecting. One of the main goals of the study was to estimate the depth of the Miocene-Pleistocene boundary. The depth is relatively large therefore a long electrode array and consequently long spacing between particular electrodes had to be applied. Unfortunately, this assumption decrease the accuracy of the survey. In the near surface depth range the smaller electrode spacing is used, the higher accuracy is obtained. Hence it is possible to distuinguish smaller objects in the resistivity cross-section. For this reason, the presented resistivity cross-section is generalized to some extent. Only main sedimentary complexes were possible to distinguish. The complexes significantly differ in electrical resistivity from each other and their thicknesses are relatively large. Considering the accuracy of resistivity prospecting the number of strata shown at the

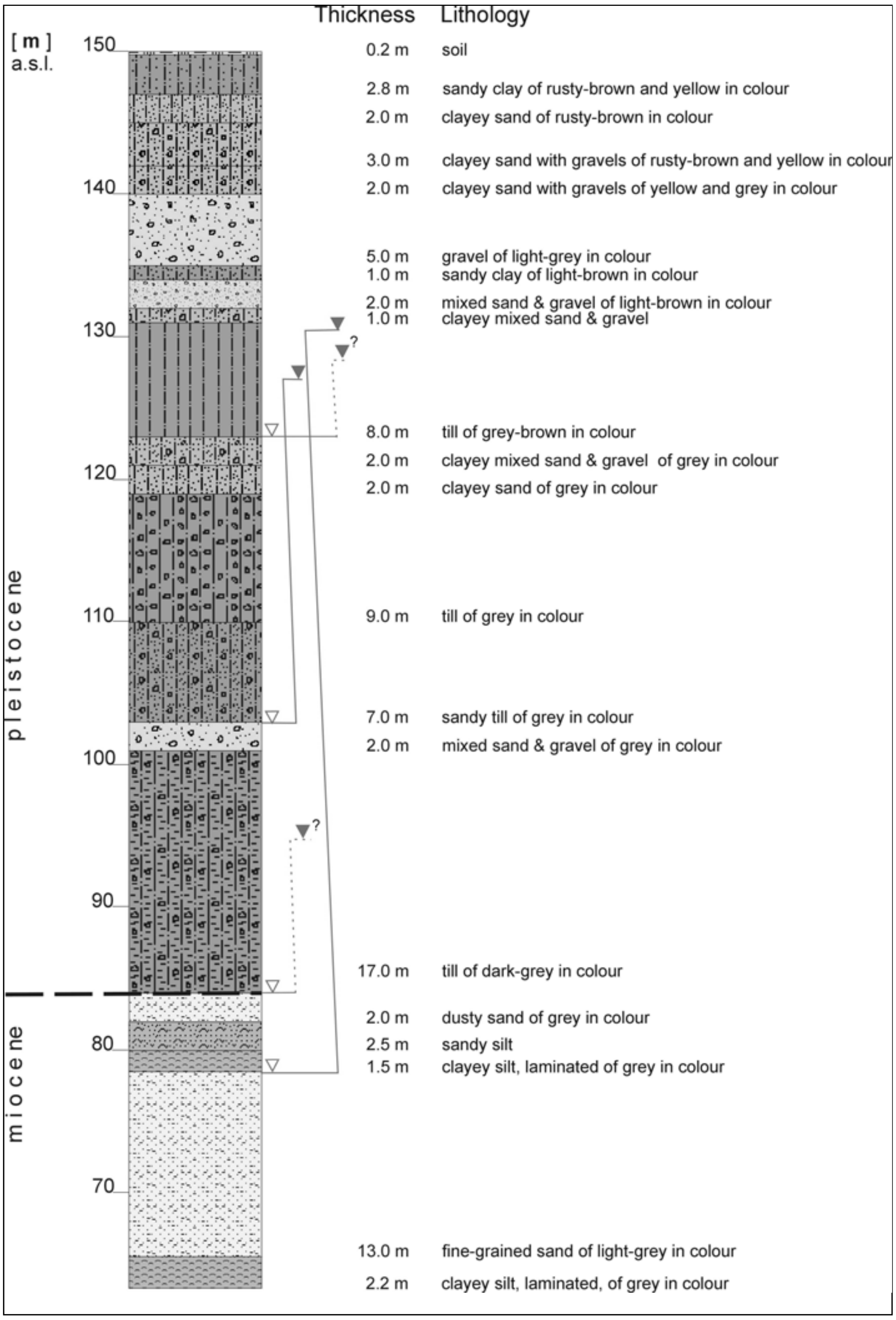

Fig. 2 Geological profile of Liszkowo-PGR No 1638 bore-hole with piezometric levels of individual aquifers.

Liszkowo PGR bore-hole profile (Fig. 2) is higher than in resistivity cross-section (Fig. 4). Moreover, the branch mark of the bore-hole is 150 metres a.s.l. and the measuring profile datum is 132 m a.s.l. Therefore it is possible that the strata shown in the upper part of bore-hole profile do not occur at the place of geophysical profile. Furthermore, due to 10 metres electrode spacing the resistivity cross-section starts with the depth of approximately 3 metres. However the obtained resistivity cross-section clearly presents the shallow geologic structure of the the Pilawa River valley to a depth of approx. 150 metres. Basing on Liszkowo bore-hole geological profile and electrical resistivity cross-section the geoelectrical model of the studied area has been created. the model consists of four resistivity layers corresponding to sedimentary complexes. The common feature of all distinguished layers is low electrical resistivity in the 30 – 190 Ωm range. Four distinguished sedimentary layers differ in electrical resistivity each other. The difference is the

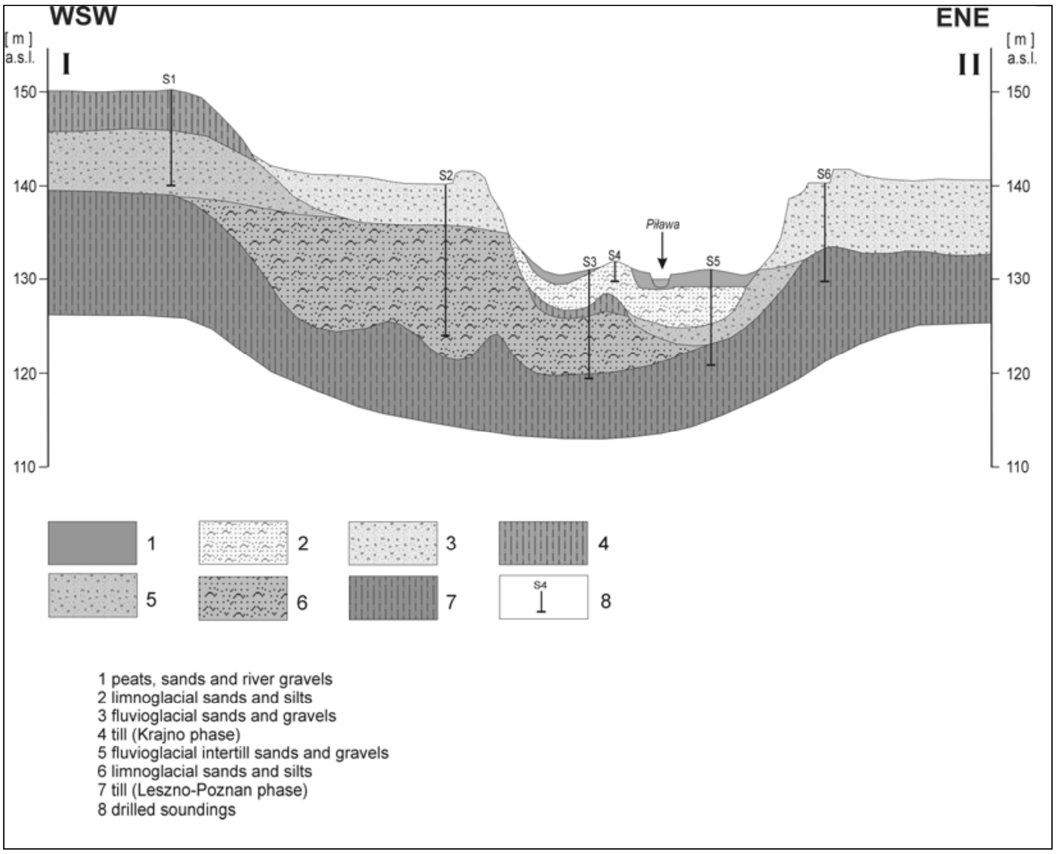

Fig. 3 Pilawa River geological cross-section (Klimek and Lewandowski, 2002 modified).

consequence of different lithology and moisture. The resistivity of the upper complex varies in the 30 –70 Ωm range. Its maximum thickness is 15 metres. The complex is not observed along the whole profile but only at distances 30 – 220 metres and 520 –770 metres. This complex correlates with melt-out depression very well. This saturated complex includes peats and lacustrine chalk. The floor of this complex is marked with dotted line (Fig. 4). Underneath, the higher resistivity complex is observed. Its resistivity varies from 70 to 190 Ωm. The complex is composed of sands, gravels and sandy and clayey sediments. Its floor undulates in the range 15 - 45 m. The resistivity of underlying sedimentary complex is in the range of 30-70 Ωm. It contains tills with sand and gravel interbeddings. The depth of its undulating floor (marked as dashed line in Fig. 4), at a distance of 260 – 610 m varies in the range 60 – 80 m. The floor significantly lowers from 260 metre to NNW. The floor is considered as Miocene-Pleistocene boundary. The zone of distinct lowering of the floor correlates with assumable ice-sheet margin range of of Pomeranian phase of North-Polish Glacial (Lewandowski et al, 2000). It seems to be a result of unconsolidated sediments compaction and the subglacial tunnel slope as well. Many subglacial tunnels with the depths exceeding 100 m were observed in Middle Pomerania (Dobracka and Piotrowski, 2002). The lowest Miocene sedimentary complex is composed of sands, silts and dusts. The resistivity of this complex is higher than above lying Pleistocene tills and varies in the range of 70 – 190 Ωm. Thus Miocene – Pleistocene boundary was estimated according to the increase of electrical resistivity.

The profile of the hydrogeological bore-hole Liszkowo-PGR No 1638 reveals the existence of three aquifers under the tills and one aquifer under silts. The resistivity survey did not allow for such detailed prospecting of hydrogeological conditions. Considering the main goal of the study, the maximum electrode spacings were applied. However it was possible to distinguish the first aquifer in the floor of melt-out depressions and second aquifer (Fig. 4). The distinguished aquifer under Pleistocene tills is probably related to the third and fourth aquifers in hydrogeological bore-hole Liszkowo-PGR.

FINAL REMARKS

The resistivity imaging survey allowed for study of geological structure of the Pleistocene sediments. The results of geoelectrical measurements correlate with geological data very well. It was possible to estimate the depth of the Miocene-Pleistocene boundary continuouosly. The lowering of the boundary may be a result of sediments compaction or the begining of subglacial tunnel slope. Moreover the main Pleistocene sedimentary complexes and aquifers were distinguished.

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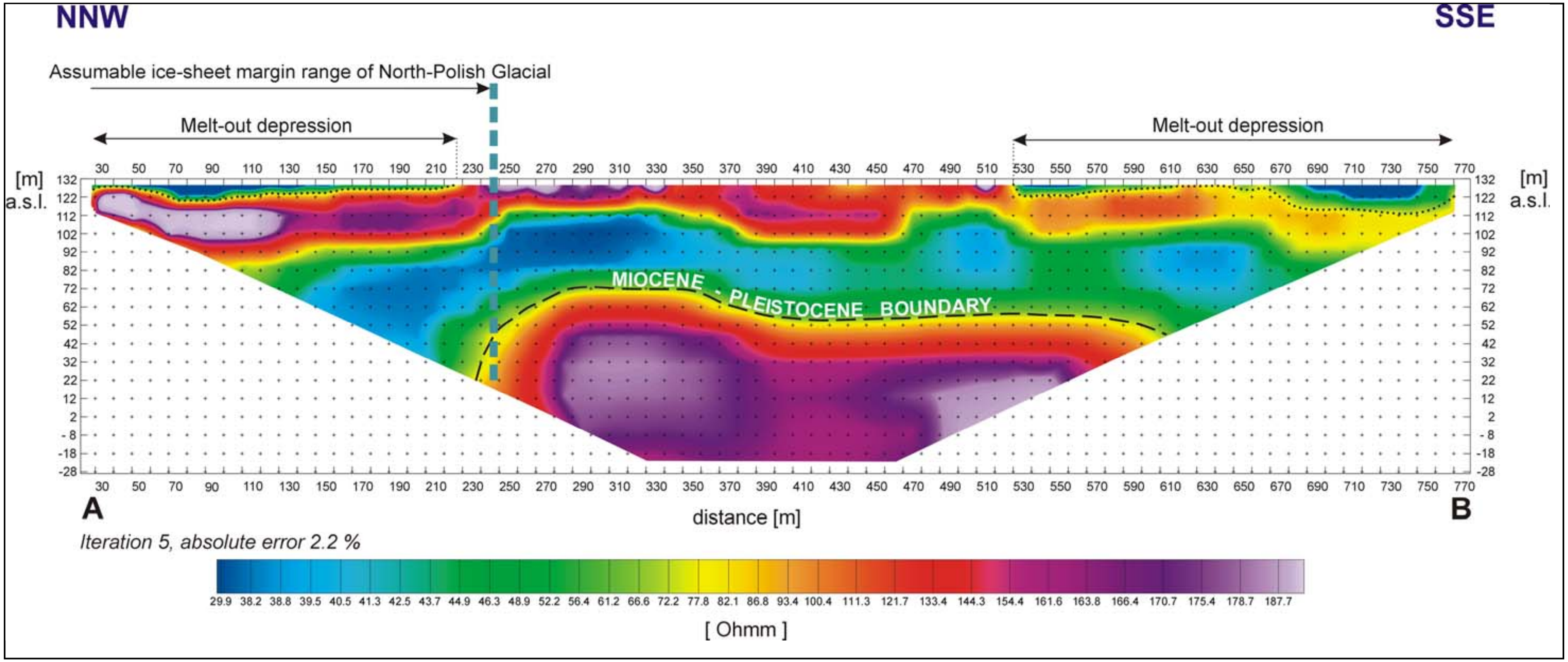

Fig. 4 Electrical resistivity cross-section along the Pilawa River valley.