# 1. Geoelectrical Methods in the Past and To-Date in Slovakia

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**Abstract:** Geoelectric methods of Earth survey are an integral part of applied geophysics. For geologists, in addition to information obtained by gravimetry, magnetometry and seismics, important data on the electrical parameters of the geological environment, especially the resistivity, are provided. These indicators reflect the lithological properties of rocks. They help geologists in basic geological research and exploration, in refining the image of the geological environment in solving engineering geological and hydrogeological problems, solving environmental issues, etc. This contribution contains mainly information about the most used geoelectric method – vertical geoelectric sounding, its use in the geophysical survey of Slovakia, the processing and creation of a database of information. Whilst the practical application of the VES method has been in the agenda of powerful geophysical companies and organizations, the challenge of their systematic summarization has been taken up by employees of the SGIDŠ and the Geocomplex a.s. The result is relatively complex 2D information on resistivity characteristics of individual regions of Slovakia. Preferably, this is true of the Podunajská nížina Lowland area, where is covered by the highest density of VES measurements. At present, the VES method is often replaced by modern geoelectric methods, which are also discussed hereinafter, namely the CSAMT and the ERT methods.

**Keywords**: geoelectric methods, VES, resistance, database, CSAMT, ERT

## 1.1 Introduction

Geoelectric methods, unlike gravimetry and magnetometry, which, due to their effective reach, deal with depth-sensitive issues up to several kilometres, are focused closer to the surface. The geoelectrics in Slovakia currently solve problems in the Earth's crust to depths in the order of several hundred meters. In the past, in the regions of lowlands and depressions, it was also 2 km. It complements its "bigger sisters within the geophysical disciplines" when uncovering the surface of the Earth's crust. What is missing in the scope of the survey, is replaced by the details of the information. Nevertheless, recently there is a clear shift in the use of this method from regional investigations to local surveys. The more modern world, the more electromagnetic ballast is present in the natural environment and thus the false information. It is also worth mentioning the constraints resulting from the topography along with the time as well as the economic factor. Therefore, modern geoelectric methods (e.g. ERT method) are used which, when combining classical geoelectric sounding and profiling methods, achieve remarkable results mainly in solving engineering geological and hydrogeological issues and environmental problems. It is also worth mentioning in Slovakia the non-traditional magnetotelluric methods, which quite successfully replace the classic VES technique.

## 1.2. Division of geoelectric methods and brief theory of the most used VES method

Geoelectric methods represent a relatively wide range of geophysical methods, which can be characterized and classified according to various criteria. Certainly, the most commonly used method in the Slovak Republic is the vertical electrical sounding method, which uses a unidirectional current and examines the relative resistivity of the environment in the vertical direction. Its complement is a method of resistivity profiling in various geometric variants (symmetrical, combined, dipole, etc.), which examines the change of the average resistivity of the environment in the horizontal direction. Both of them are therefore called the **resistivity** ones. Table 1.1 gives a brief overview of the relative resistivity of basic rock types.

Tab. 1.1 Specific resistivities of rocks

| Rock type | **Specific resistivity $\rho_z$** (ohmm) |
|---|---|
| loam | $1 – 10^2$ |
| clay | $10 – 10^2$ |
| sand | $10^2 – 10^4$ |
| saturated sand | $1 – 10^1$ |
| sandstone | $10^2 – 10^4$ |
| limestone | $10^2 – 10^4$ |
| conglomerate | $10 – 10^4$ |
| granite, syenite | $10^2 – 10^5$ |
| diabase, basalt, gabbro | $10^2 – 10^5$ |
| schists | $10^2 – 10^4$ |
| claystone | $10 – 10^3$ |
| quartzite | $10^3 – 10^5$ |
| marble | $10^2 – 10^5$ |
| gneiss | $10^2 – 10^4$ |

In Slovakia, in addition to these two methods other geoelectric methods have been also used, which can be termed as **potential**. In the ore survey, but also in solving the engineering geological and hydrogeological issues, the

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method of the charged body and the submerged electrode method were applied. They use unidirectional current, but unlike the VES, they are exploring the distribution of the electric field potential.

Similarly, two geoelectric methods using the effects of **electrochemical processes** are used in ore exploration and environmental problems. It is a passive method of spontaneous polarization (**SP**) or the active method of induced (activated) polarization (**IP**) method. The first one examines the natural electric field generated in the oxidation-reducing environment, for instance of, sulphide deposits; the second one examines a temporary electric field induced by an electrical pulse. Both of these methods were often used in field geophysical surveys in the ore deposits areas of Slovakia.

In addition to these methods, which only examine the parameters of the electric field, geoelectric methods also include the so-called **electromagnetic methods**. These include, in the past the widely used very low frequency (VLF) method utilizing the signals of very long wave transmitters. It was used to locate the tectonics. It is also worth mentioning the ***turam*** and ***slingram*** methods used in ore exploration and localization of tectonic lines and zones. Electromagnetic methods also include the magnetotelluric sounding method, which examines the natural magnetotelluric field of the Earth, or artificial arrays of specific wavelengths according to the need of exploration. Nowadays, the Controlled Source Audio-frequency Magnetotellurics (**CSAMT**) method is gradually being promoted in Slovakia, which uses artificial active sources to detect a specific resistivity of the environment. These artificial sources produce magnetotelluric fields with a frequency of 1 – 8000 Hz and their reach is at a maximum of about 2 km. The CSAMT method has the ambition to replace the classic resistivity sounding – the VES method.

Given that the largest and most important volume of information on the resistivity conditions of the Slovak geological environment is contained in the data obtained from VES measurements, it is appropriate to briefly mention the basics of the VES method.

Measurement of VES consists in the creation of an artificial electric field using the so-called current electrodes, referred to as A and B (Fig. 1.1). These electrodes extend along the line from the measuring point, each to the opposite side, depending on the depth range. At the point of measurement there is a receiver that measures the voltage of the field by measuring electrodes known as M and N. From the values of the current I [mA] and the voltage ΔV [mV] between M and N and the constants for the given geometry of the arrangement, we calculate the apparent resistivity of the environment $\boldsymbol{\rho_z}$, which is a function of the depth of measurement, i.e. extension length AB.

$\rho_z = k \cdot \Delta V/I$

where $\mathbf{k = \pi \cdot (AM \cdot AN)/MN}$

**AM, AN, MN** are the distances among electrodes

In the past, the calculated values of $\boldsymbol{\rho_z}$ have been exported to bilogarithmic cross-sections and quantitatively interpreted using a set of theoretical curves – so-called

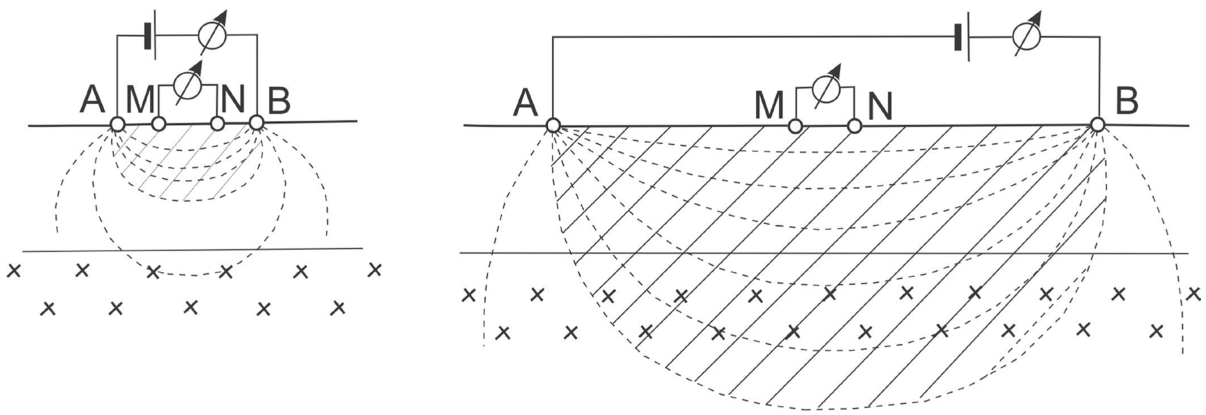


***Fig. 1.1*** *Electrode displacement diagram for VES measurement, dependency of depth reach upon spacing of current electrodes A – B (Mareš et al., 1979)*

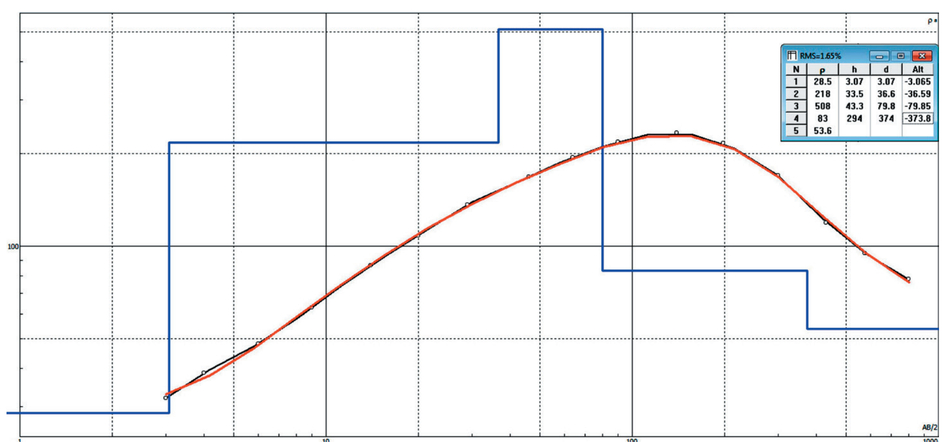


***Fig. 1.2*** *Quantitative interpretation of VES curves using IPI-2Win*

pallets. Currently, several programmes replace quantitative palette interpretation, for instance IPI2Win (Fig. 1.2).

The results of the interpretation are geophysical, or geophysical-geological 2D sections. By processing a larger number of VES measurements within certain area, the possibilities of construction of $\rho_z$ maps are created (Fig. 1.3). With a sufficient density of interpreted VES supplemented by information from wells, a 3D image of the environment can be constructed (Fig. 1.4).

## 1.3 Level of investigation of the territory of Slovakia by VES measurements

The basis for the assessment of level of investigation of the territory of the SR by geoelectric measurements (VES) provides the review presented in the framework of the task "Evaluation of Hydrocarbons in Selected Areas of the Western Carpathians" (Janků et al., 1996) as well as its evaluation in "Atlas of Geophysical Maps and Profiles"

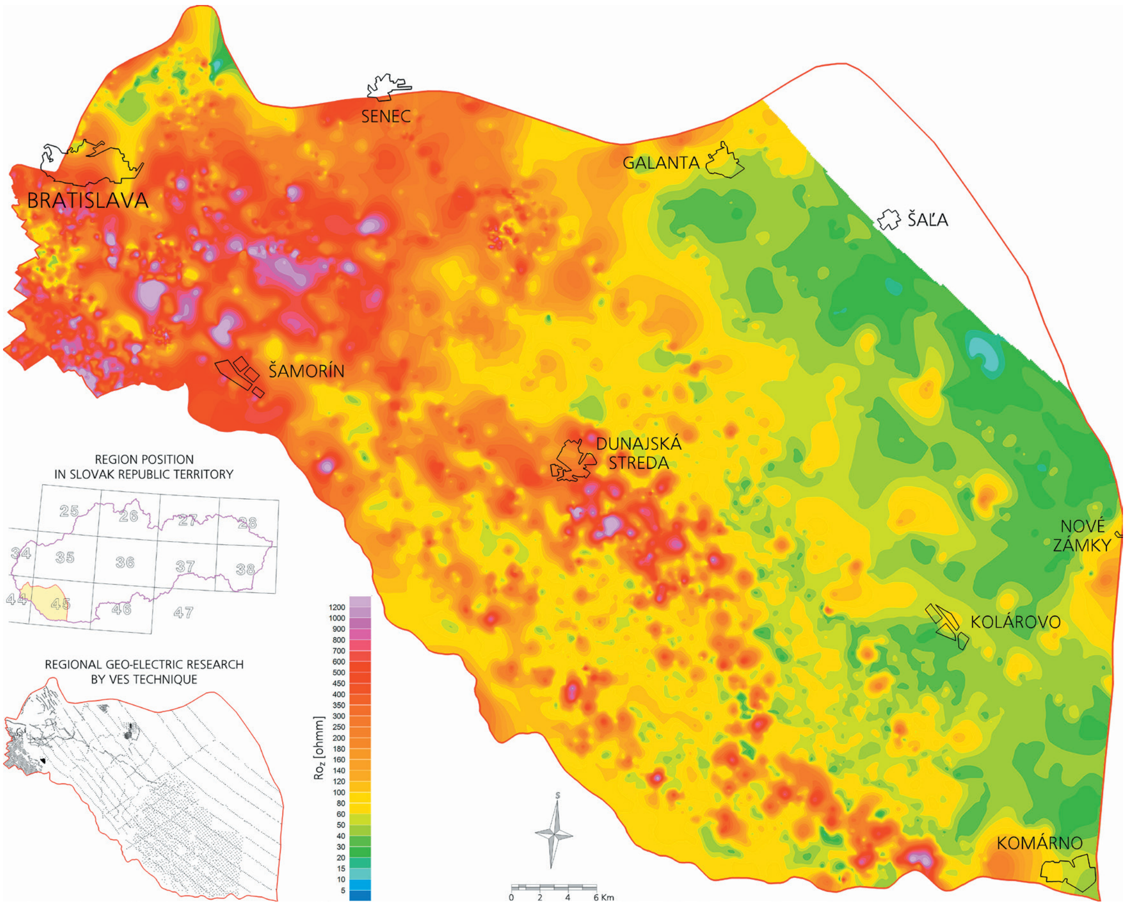


***Fig. 1.3*** *Podunajská rovina Flat; Map of apparent resistivity for AB/2 = 10 m (Kucharič et al., 2015)*

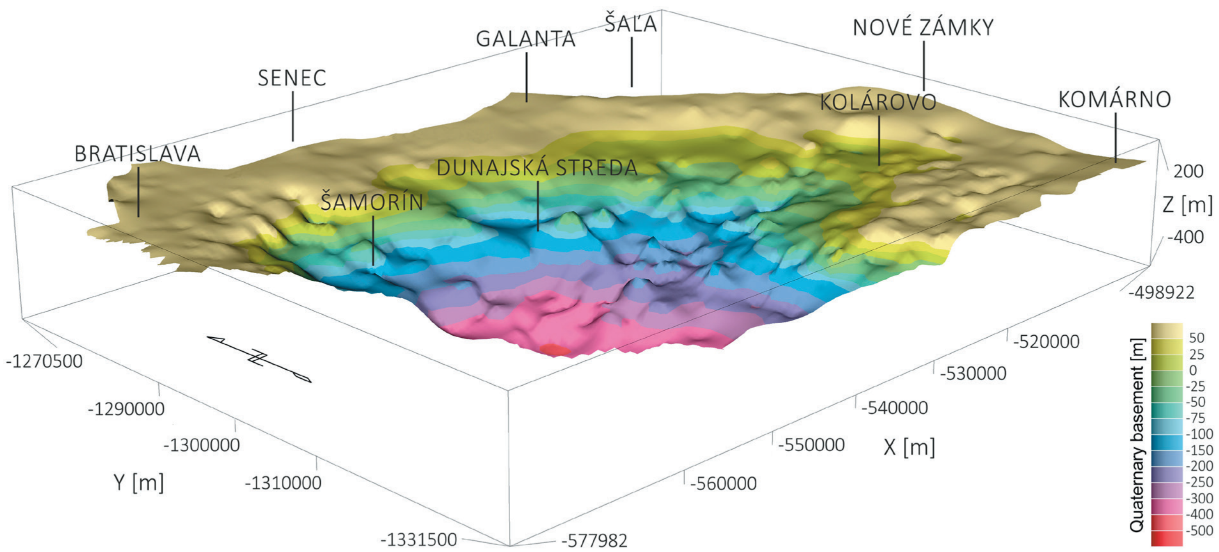


***Fig. 1.4*** *Podunajská rovina Flat; 3D map of the relief of the pre-Quaternary basement (Z = 20 x elevated)*

Kubeš et al., 2001, hereinafter Atlas). The VES measurements with AB intervals of two or more kilometres were performed for various purposes. The measurements were made mainly from the area of the depressions and the contact between the basins and the mountain ranges, or in the areas of exploration for mineral and thermal waters. The VES measurements with AB 4 km were mostly located only in the centres of the basins to map a relief of the fundament.

Another group was focused in the geological setting and ore prospecting, especially in the volcanites of the Western Carpathians. They were used mainly for the search of feeder systems and tectonics (Vtáčnik, Banská Štiavnica-Hodruša ore district, Javorie, Poľana, Slanské vrchy, Pezinské Karpaty Mts.)

A separate group was focused on survey of areas with coal horizons in order to solve the geological structure. The largest regional scope included VES with AB spacing 16 km to search for geological structures with oil and gas occurrences (Záhorská, Podunajská and Východoslovenská nížina Lowlands). These measurements belong among the oldest within the SR territory.

The measurements of regional significance include VES on the 2T and GI regional profiles (Fig. 1. 5), realized for the purpose of solving the deeper geological setting as well as measurements in the Spišsko-gemerské rudohorie Mts.

When designing a map of geophysical indices and interpretations (MGII), the VES measurement in regions were reinterpreted. In other areas outside the MGII regions, they have not yet been re-evaluated to the level of new geological knowledge.

As can be seen from the previous brief survey, over the past 70 years of the existence of geophysics, there were carried out around ten thousand VES profiles across the whole of Slovakia. Given that the information value of these primary data is still up-to-date, attention will be paid to the processing of these measurements and their preservation for further use in geological practice.

The widest network of VES measurements is in the Podunajská nížina Lowland region, and therefore the quality of information from the VES interpreted in this region is high. The last geophysical work of a regional character, which completed the field measurements in this region, was the Podunajsko-DANREG report (Kováčik, M., Tkáčová H. et al., 1996).

Apart from the Podunajská nížina Lowland, the authors also interpreted the southern part of the Záhorská nížina Lowland and the southern part of the Malé Karpaty Mts. The workload consisted of the Danubian Lowland, where, after completing measurements in locations with insufficient VES density, the resistivity maps for AB = 200 and 600 m were constructed. The main result of the interpretation of geoelectric measurements is the map of the thickness of the Quaternary at a scale of 1 : 100,000 and maps of the thickness of the Pannonian to the Pliocene at a scale of 1 : 200,000.

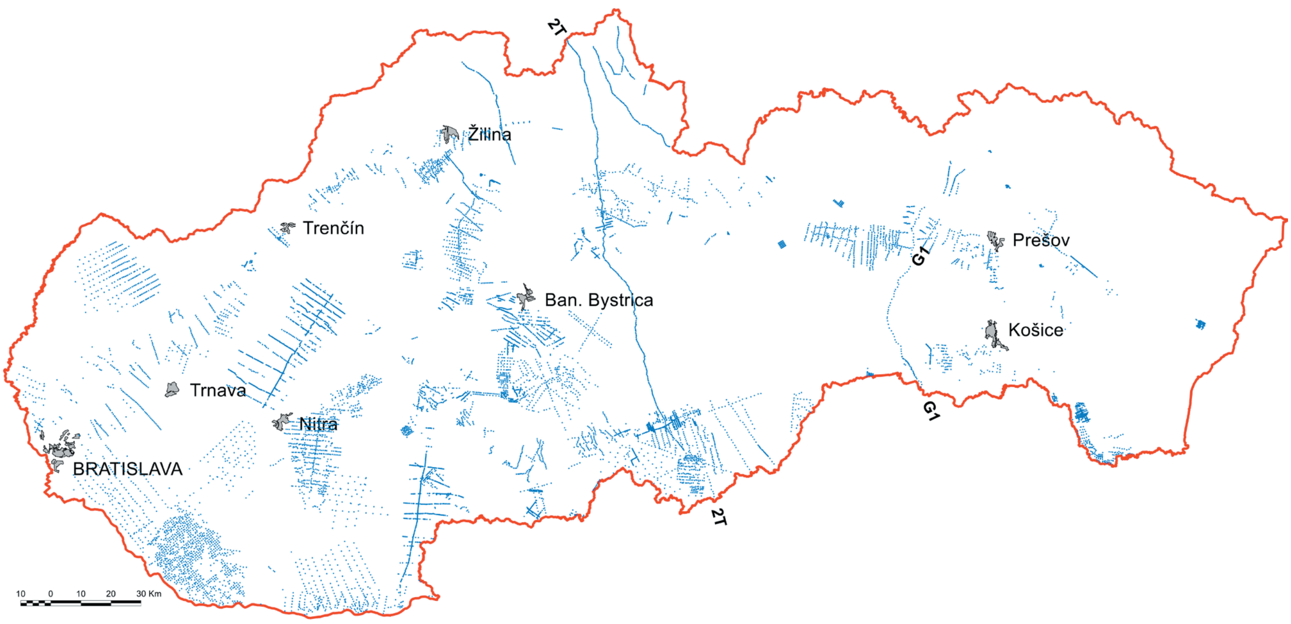


***Fig. 1.5** Arrangement of VES measurements processed in Atlas (Kubeš et al., 2001)*

Separate profiles with VES measurements are located in the Malá Fatra Mts.and Orava region, three profiles in the area of the Lipany deep boreholes and others in the elevation "Bystré" (Košice Basin). An important group of VES geoelectric measurements are measurements made in the scope of the exploration survey for the radioactive waste repository. These measurements were located in the mountain ranges of Tribeč, Žiar, Veporské and Stolické vrchy, Cerová vrchovina Upland and Rimavská kotlina Basin.

One of the first geophysical tasks with a goal to compile a VES measurement database, namely VES with an AB = 2,000 and larger spacing, was "Atlas of Geophysical Maps and Profiles" (Kubeš et al., 2001). In addition to VES data, the "Atlas" contains also gravimetric, magnetometric and radiometric measurements from the territory of

Slovakia. The processing of geoelectric measurements of VES in this report consisted of an archival excerpt. Individual VESs (carried out from 1966 to 1999) were selected from archives of geophysical workplaces across Slovakia (Geocomplex a.s. Bratislava) and the Czech Republic (Geofyzika s.p. Brno). The next step was the digitization of VES from the final reports. The reading and insertion of the parameters of the interpreted depths and resistivities on map sheets of SR 1 : 50,000 basic map was the next step. Altogether 11,185 VES were processed, of which 1,140 original materials are archived in Brno. From the obtained geoelectric parameters, the maps of the measured resistivity from the three selected regions were compiled for 3 depth levels along with vertical resistivity profiles. Following the re-interpetation of VES measurements, geophysical-geological sections were constructed.

In the database, the VES designation is based on the original scrapbook, the coordinates in the S-JTSK geographic coordinate system, the AB electrode stretch azimuth, the numerical code of the final report and the implementing organization, the type and quality of the measurements, the depth and resistivity interpreted and its value measured in three to five AB/2 = 300, 600, 1,000, 1,300 and 1,600 m (Geocomplex a.s., Bratislava) or AB/2 = 200, 500, 1,100, 3,100 and 6,500 m (Geofyzika a.s., Brno). The authors of the database assumed that the most utilised parameters would be the AB/2 levels and the measured resistivity at the given level. From these parametres, it is possible to construct resistivity maps for individual depth levels.

A sufficiently dense network of measurements is projected for the construction of a robust resistivity map, flatly distributed over time. These conditions are mainly met by VES measurements in the lowlands and basins. Most measurements are located in Podunajská panva, Lučenská and Rimavská kotlina, Turčianska kotlina, Hornádska kotlina Basins and Žitavská pahorkatina Upland (Fig. 1. 5). Three regions – Podunajská nížina Lowland, Lučenská and Rimavská kotlina and Turčianska kotlina Basins – were selected for the compiling the resistivity maps. In these regions, the density of the VES distribution is sufficient to be theoretically interpolated between the measured values. The resistivity maps are designed for AB/2 = 300, 600 and 1,000 m, representing the depth ranges 120 – 150 m, 250 – 300 m and 400 – 500 m.

Another important project focused in the database processing of geoelectric measurements was completed in 2008. The geophysical archive, register and databases of geophysical data were created, which includes a database of VES measurements (Gluch et al., 2003). The GEOMIND project has also been involved in this task in order to build an international metadata database, including the VES AB = 200 to 6,000 m probes processed to solve the project in question.

The last work on the creation of the VES database was the project "VES Database – Turčianska kotlina Basin and part of the Podunajská pahorkatina Upland" (Gluch et al., 2013). The outline of this database is presented in Fig. 1. 6. Its content has a high informative value, which hides complex work with archival data of various nature. Two working groups were collaborating in parallel, one of which was made up of GEOCOMPLEX staff and the other employees of the SGIDŠ.

At the GEOGOMPLEX's workplace site-specific sketches were collected. The VES positions were redrawn into topographic maps of the same scale as those reported in the reports. From the Archive of Geofond and GEOCOMPLEX, individual reports were subsequently selected and, after the analysis, they were handed over to SGIDŠ workers to scan various graphic, text and table documents. The documents were scanned at 150 dpi (text attachments), or 300 dpi (graphical attachments and necessary computer processing (rotation, cropping, digital filtering, and grooming) were archived on optical media in TIFF or JPEG formats. All-in-all 27 individual reports were scanned and processed, representing a total of 1,661 graphical raster files from A4 to A0 format, with a volume of nearly 30 GB of data (before digital processing and raster compression).

A review of geoelectric sounding investigation level with designation of VES objects was carried out, along with drawing out the probe profiles from each reviewed report and showing the azimuth of the extension of the electrodes. The data were processed in the MicroStation CAD software. In the course of solving the geological task in question, all available archived relevant bases of

| X | Y | Z | Map | OBJECT | VES | Profile | Site | Year | Azimuth | VES type | Spacing | Quality | Arch. No. | Ro1 | H1 | Ro2 | H2 | Ro3 | H3 | Ro4 | H4 | Ro5 | H5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -500845 | -1266936 | 140.12 | 45-21 | VES_VII-19 | 19 | VII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 9.0 | 2.5 | 117.0 | 5.0 | 19.0 | | | | | |
| -500765 | -1266869 | 140.17 | 45-21 | VES_VII-20 | 20 | VII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 9.0 | 2.2 | 108.0 | 3.3 | 25.0 | | | | | |
| -500698 | -1266806 | 140.00 | 45-21 | VES_VII-21 | 21 | VII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 12.0 | 2.3 | 207.0 | 4.5 | 21.0 | | | | | |
| -500628 | -1266749 | 139.58 | 45-21 | VES_VII-22 | 22 | VII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 12.0 | 2.6 | 144.0 | 7.4 | 19.0 | | | | | |
| -500539 | -1266691 | 138.43 | 45-21 | VES_VII-23 | 23 | VII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 11.5 | 3.0 | 115.0 | 6.0 | 22.0 | | | | | |
| -500463 | -1266635 | 138.57 | 45-21 | VES_VII-24 | 24 | VII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 11.0 | 2.0 | 132.0 | 4.0 | 20.0 | | | | | |
| -500383 | -1266569 | 142.93 | 45-21 | VES_VII-25 | 25 | VII | Nitra | 1966 | 140 | 1 | 200 | 1 | 01-17539 | 34.0 | 3.0 | 306.0 | 1.5 | 30.0 | | | | | |
| -502183 | -1267743 | 139.92 | 45-21 | VES_VIII-03 | 3 | VIII | Nitra | 1966 | 140 | 1 | 200 | 1 | 01-17539 | 17.0 | 3.0 | 153.0 | 3.0 | 21.0 | | | | | |
| -502137 | -1267704 | 140.01 | 45-21 | VES_VIII-04 | 4 | VIII | Nitra | 1966 | 130 | 1 | 200 | 1 | 01-17539 | 14.0 | 3.3 | 126.0 | 3.3 | 20.0 | | | | | |
| -502075 | -1267645 | 140.24 | 45-21 | VES_VIII-05-03 | 5-03 | VIII | Nitra | 1966 | 130 | 3 | 200 | 1 | 01-17539 | | | | | | | | | | |
| -502075 | -1267645 | 140.24 | 45-21 | VES_VIII-05 | 5 | VIII | Nitra | 1966 | 130 | 1 | 600 | 1 | 01-17539 | 25.0 | 3.2 | 58.0 | 3.2 | 21.0 | 57.0 | 100.0 | | | |
| -502001 | -1267581 | 140.27 | 45-21 | VES_VIII-06-04 | 6-04 | VIII | Nitra | 1966 | 45 | 4 | 200 | 1 | 01-17539 | | | | | | | | | | |
| -502001 | -1267581 | 140.27 | 45-21 | VES_VIII-06 | 6 | VIII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 17.0 | 3.5 | 153.0 | 3.5 | 20.0 | 60.0 | 60.0 | | | |
| -501926 | -1267522 | 140.07 | 45-21 | VES_VIII-07-04 | 7-04 | VIII | Nitra | 1966 | 45 | 4 | 600 | 1 | 01-17539 | | | | | | | | | | |
| -501926 | -1267522 | 140.07 | 45-21 | VES_VIII-07 | 7 | VIII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 15.0 | 5.5 | 136.0 | 1.5 | 10.0 | 4.5 | 150.0 | 5.0 | 11.0 | 27.0 |
| -501847 | -1267460 | 140.00 | 45-21 | VES_VIII-08 | 8 | VIII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 11.0 | 1.3 | 44.0 | 1.7 | 14.0 | 3.8 | 45.0 | 7.0 | 10.0 | |
| -501771 | -1267402 | 140.00 | 45-21 | VES_VIII-09 | 9 | VIII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 17.0 | 4.0 | 170.0 | 4.0 | 20.0 | | | | | |
| -501698 | -1267330 | 140.00 | 45-21 | VES_VIII-10 | 10 | VIII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 11.0 | 2.2 | 99.0 | 4.4 | 21.0 | | | | | |
| -501616 | -1267264 | 140.00 | 45-21 | VES_VIII-11 | 11 | VIII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 14.0 | 4.6 | 112.0 | 9.2 | 23.0 | | | | | |
| -501537 | -1267196 | 140.00 | 45-21 | VES_VIII-12 | 12 | VIII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 11.5 | 3.5 | 105.0 | 7.0 | 12.0 | 7.5 | 104.0 | 6.0 | 20.0 | |
| -501463 | -1267132 | 140.00 | 45-21 | VES_VIII-13 | 13 | VIII | Nitra | 1966 | 45 | 1 | 200 | 1 | 01-17539 | 15.0 | 3.7 | 135.0 | 3.7 | 16.0 | 2.0 | 73.0 | 7.0 | 22.0 | |

***Fig. 1.6** Database VES – Turčianska kotlina Basin and part of Podunajská pahorkatina Upland (cut-out)*

measurements of VES with AB range from 200 to 4,000 m in defined interest areas were completed. All the primary materials were collected in one place and were gradually inserted into input forms (MS Excel format), in the structure and physical content designed to solve the geological task of a similar focus (Gluch, A., 2008). In parallel, data of all VES objects were digitalized from the original map – in the S-JTSK geographic system (Křovák's projection). The altitudinal elevations of the individual objects (Z [m a.s.l.]) were added to the unified VES measurement database from the digital terrain relief model (DMR, grid 50 x 50 m, in Kubeš, P. et al., 2001).

The VES database contains 1,348 VESs from the area of Turčianska kotlina Basin (area approx. 359 km$^2$) and 3,957 VESs in the part of the Podunajská pahorkatina Upland (area approx. 3,100 km$^2$), i.e. together 5,305 VES in both areas of interest, with all the necessary data and information to be applicable to their possible (re) interpretation. In addition to the VES measurement database, scale 1 : 50,000 topographic documents were produced, in which the outputs of the task solution were finalized and visualized in graphical (printed) form. In electronic form (in the OASIS montaj GIS environment), the results are presented for individual interest areas at scale 1: 50,000.

After taking into account the outputs of the previously realized geological task "Database of Geophysical Measurements – Vertical Electrical Sounding" (Gluch, A., 2008), a complex area of 8,328 km$^2$ (Podunajská rovina Flat and part of Podunajská pahorkatina Upland) with 10,939 VES probes has been assessed. The Geophysical Information System provides comprehensive and reliable background information and data on VES measurement and results.

The importance and quality of data processing from VES measurements in such database could be evaluated and evaluated in the reinterpretation of these data within the task "Map of Geophysical Indices and Interpretations, Podunajská rovina Flat Region" (Kucharič et al., 2015). In addition to maps of apparent resistivity for AB/2 = 10 m (Fig. 1. 3), 50 m, 100 m and 300 m, providing information on the geoelectric quality (≈ lithology) of the environment at different depths, a map of the thickness of the Quaternary (Fig. 1. 7) was compiled, which is the result of a quantitative reinterpretation of VES measurements from the territory in question. Similarly to the maps of apparent resistivity, this map was constructed at a scale of 1 : 100,000. For a given scale, the density of information was 1 VES/km$^2$. After selecting individual VESs, these were fully reinterpreted by a single methodology using IPI2win. The built-in database was graphically processed in applications of Oasis montaj and MicroStation environ into the map of Quaternary deposits thicknesses. The map itself gives an interesting picture of the thickness of gravels/sands, whose importance lies primarily in the accumulation of high-quality groundwater. It confirms the well-known fact that the thickness of these sediments is in the order of hundreds of meters with a maximum in the Horný Bar Village where, according to VES measurements, it exceeds 500 m.

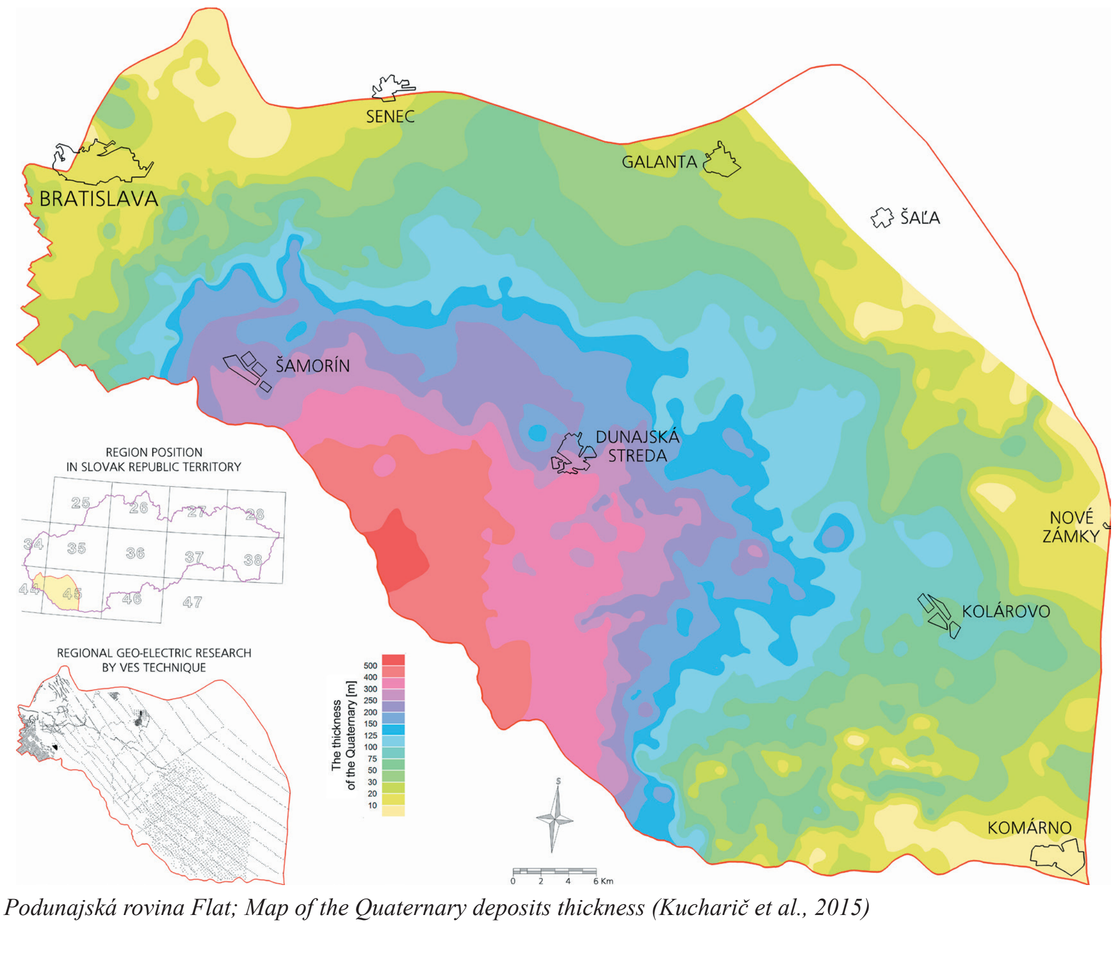


*Fig. 1.7 Podunajská rovina Flat; Map of the Quaternary deposits thickness (Kucharič et al., 2015)*

## 1.4 Use of geoelectric methods at present – new trends

At present, geoelectric methods are used differently when compared to the past (about 25 years back). Given the fact, that the volume of finances in the environmental sector has been decreasing regularly, the focus of work with the use of costly VES geoelectric measurements with deep reach has shifted to less expensive geoelectric measurements. It is a survey of the shallow parts of the Earth's crust, the first tens of meters, of the engineering geological and hydrogeological conditions of the geological environment, the archaeological survey and the research aimed at the protection of the environment. The exception is a geoelectric survey aimed at studying the suitability of the environment for radioactive waste disposal, $CO_2$ storage and geothermal energy sources exploration search, addressing the geological problems in the depths of hundreds of meters or more. Here too, VES measurements with deep reach are used, but they are limited by the presence of artificial electromagnetic fields – dispersion currents. This is why the magnetotelluric sounding method – CSAMT (magnetotelluric sounding with a frequency of 1 – 8,000 Hz), which offers a "X-ray" view of the distribution of resistivity in the rock environment, is increasingly being promoted. Similarly to the VES method, but in shorter time, less costs, and without the impact of topography and interfering electromagnetic fields, it can divide the rock environment according to the interpreted resistivity. In Fig. 1. 8 is a schematic sketch of the transmitter-receiver arrangement at measuring by this method.

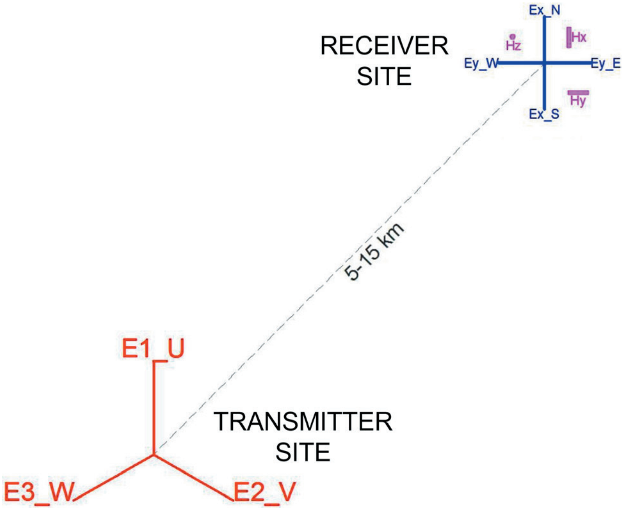


***Fig. 1.8*** *Scheme of CSAMT measurement*

The depth range of the CSAMT is within 1.5 km, under ideal conditions approximately 2 km. It depends on the frequency of the active transmitter, which can vary in the range of 1–8,192 Hz. The measurement time depends on the measurement conditions and ranges from 20 to 120 minutes. In addition to exploring the deeper levels of the geological environment, the CSAMT method also finds its firm place in geological survey, mapping of geological structures, impregnation zones, delimitation of the deposit body, and determination of homogeneity of rock formations. It can also be used in depth engineering geological surveys before tunnel construction and hydrogeological and geothermal exploration.

Another method, which has a relatively wide scope, is the Electrical Resistivity Tomography (ERT). It is a complex resistivity measurement system with a larger number of electrodes. The spacing of the electrodes is determined depending on the detail and the required depth range, the

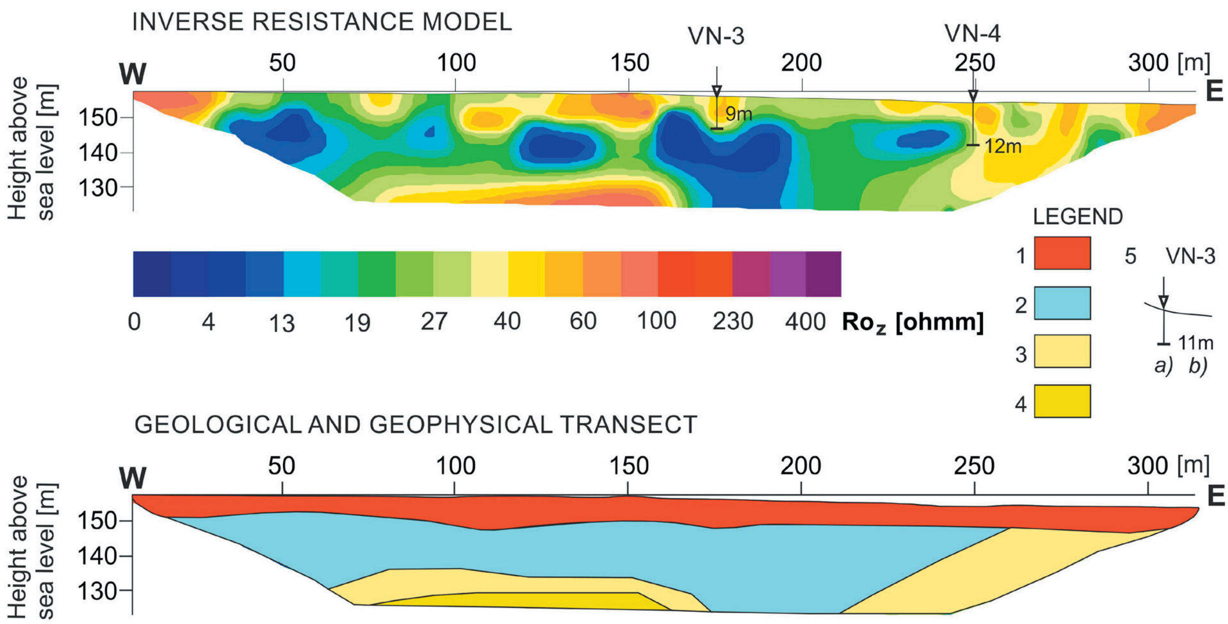


***Fig. 1.9*** *Geological survey of environmental burden at the Devínska Nová Ves site (Volkswagen landfill) – results and interpretation of ERT (measurements on profile P3, Slaninka, et al., 2015)*

**Legend – 1:** anthropogenic sediments; **2**: sediments with predominantly clay component; **3**: sediments with prevalence of sand component; **4**: undivided cemented sediments (clay, silt, sandstone, conglomerate); **5**: label of geological-exploration well, a: borehole on profile, b: borehole depth [m] electrodes serving alternately as source or measuring. Due to the fact that the measurements are carried out using a series of electrodes extended with a relatively dense step (max. about 5.5 m) and a computer-controlled addressing of the current and voltage reception, a relatively detailed picture of the apparent resistivity in vertical section along the measured profile can be retrieved. Subsequent computer processing allows the measured data to be transformed into a set of realistic resistivity values and, by using available geological documentation from exploratory wells, to obtain an image of the local site of the rock environment along the measured geophysical profiles (Fig. 1. 9).

## 1.5 Conclusions

The geoelectric methods used in Slovakia currently reflect the current state of Slovak geophysics. In practice, financially less costly methods are used, since companies dealing with geoelectric measurements and geophysics are generally small, staffing and capital considerably less stable than they used to be in the past. The original system, built on a single state organization that dealt exclusively with geophysics and geophysical groups at powerful geological companies, had given geoelectric methods greater scope for use, especially in terms of workload and thus practical experience. At present, geoelectricity in Slovakia is significantly atomized. Groups of geophysicists are small, although they are able to respond to the diverse needs of the Slovak customers, but larger state orders and the needs of foreign clients where financially demanding geoelectric methods are to be used, are solved with large difficulties. Therefore, the geoelectricity in Slovakia has now shifted the focus of its exploration into the shallow parts of the geological environment or into the office for statistical processing.

At the SGIDŠ the work on geoelectrics is mainly based on the geoelectric data, which are contained in geophysical reports. These include, in particular, their database processing, the creation of a VES measurement database and a meaningful assignment to regional geological works in the form of maps of geophysical indices and interpretations (MGII). Small-scale field geoelectric work, which mostly addresses the problems of engineering geological and hydrogeological character, is also worth mentioning.

The future of geoelectrics and geophysics is, in general, hidden, as in other human activities, in the youth and in its interest in this discipline. Therefore, greater emphasis should be placed on the promotion of geological and environmental science disciplines. They also supply associated geological sciences, such as geoelectrics and geophysics in general, to address their roles and needs.

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