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Delineation of Geothermal Aquifers by Magnetotelluric Methods in Besenova - Lucky Area, Northern Slovakia

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ABSTRACT

Two hydrogeothermal structures – structure of geothermal waters in Besenova and structure of mineral waters in Lucky are located close to each other in the Liptov Basin (northern Slovakia). Both of them are classified as open structures with infiltration, transition-accumulation and natural discharge areas. Geothermal wells ZGL-1, FGTB-1 and FBe-1 in Besenova showed that geothermal waters accumulate in Triassic carbonates of the Choc and Krizna Nappes. It is supposed that formation of geothermal water takes place in the Krizna Nappe carbonates. Mineral waters in Lucky are also bound to Triassic carbonates of the Krizna Nappe as proved by results of BJ-101 and HGL-3 wells in Lucky and HGL-2 well in Kalameny. No geological investigation was done in this area up to present to confirm or disprove the interconnection between both structures, which water is intensely utilized. The goal of the research was to delineate the relief of the pre-Palaeogene surface, to segment it into lithostratigraphic units and to confirm or disprove the interconnection between Besenova and Lucky water bearing structures. Controlled source audio-frequency magnetotellurics (CSAMT) was the main method used. This was the first utilization of the CSAMT method in geothermal research in Slovakia. Altogether 21 CSAMT points were measured. The effective depth reached during the investigation was 2 000 m. The results were interpreted in the form of resistivity profile, interpreted geophysical and finally geological profile. The results showed that the Pre-Palaeogene basement has a broken, tectonically disrupted relief. Both structures are isolated by Palaeogene sediments (claystone and siltstone) and in the deeper part also by marly carbonates and marlstones of the Jurassic age belonging to the Krizna Nappe. It was proven that the continual interconnection of geothermal aquifers in the area between the Besenova and Lucky-Kalameny does not exist. Therefore the mutual influencing of exploited geothermal water in Besenova and mineral water in Lucky was not proven yet, despite of more than 25 years of intense exploitation of geothermal water in both localities.

1. INTRODUCTION

The Liptov Basin is one of the 27 prospective geothermal areas of the Slovak Republic. This 611 km^2 large depression is located in the north-western part of Slovakia (Figure 1). It is elongated in the E-W direction and fringed by the Chocske vrchy Mts., Zapadne Tatry Mts., Velka Fatra Mts., Nizke Tatry,Mts. and Kozie Chrbty Mts. The possibilities of obtaining and utilization of the geothermal waters in Liptov depression were manifested in the past by a number of natural springs of mineral water in the area of Besenova, Lucky, Liptovska Stiavnicka, Liptovsky Jan and in other localities. Wells were drilled in all of these localities in the last century.

Figure 1: Location of the Liptov Basin

Two hydrogeothermal structures: (1) structure of mineral waters in Lucky and (2) structure of geothermal waters in Besenova are located close to each other in the western part of the Liptov Basin. Lucky are located on the north-western fringe of the basin in the Chocske vrchy Mts., Besenova is located in the central western part of the basin (Figure 2). The discharge area of geothermal water structure in Besenova is located at a distance of 4.0 – 4.5 km from the discharge area of mineral waters structure in Lucky.

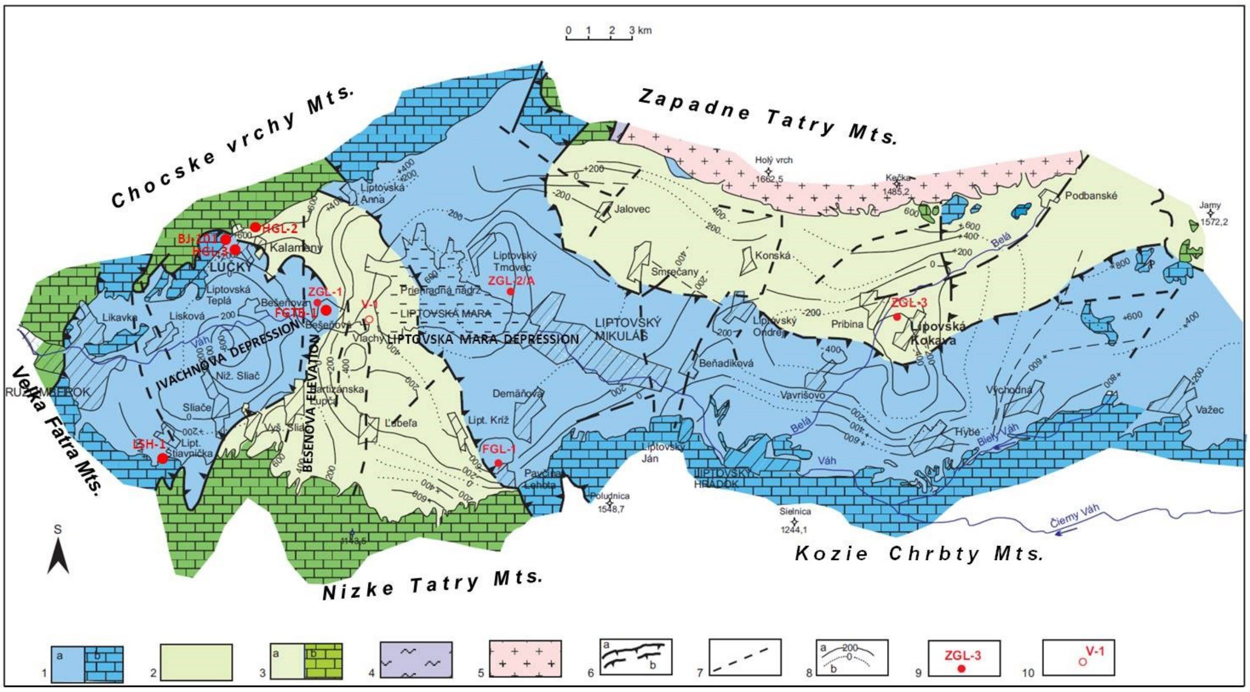

Figure 2: Geological conditions and location of objects of interest in the Liptov Basin. Explanation: 1 – Choc Nappe (a – bedrock, b – on the surface), 2, 3a – Krizna nappe (bedrock), 3b – Krizna Nappe on the surface, 4 – Envelope Unit, 5 – Crystalline, 6 – overthrust line (a – proved, b – assumed), 7 – Faults (assumed), 8 – isolines of the Palaeogene bottom in m a.s.l. (a – proved, b – assumed), 9 – geothermal borehole, 10 – oil borehole

Matej Bel, scientist and historian, described already in 1736 springs in Lucky, covered by wooden roofs, which were used as a spa by enormous number of farmers from the vicinity (Rebro, 1996). The history of use of these springs as a real spa began in 1761 when the count Adam Turjanský built the first spa building there. The first water analysis of thermal waters in Lucky was published by the Royal balneologist professor Cranz in 1777 (Fendek et al., 1999). The excellent reputation of the new spa with three baths and its successful treatment were soon spread around. In the 19th century Lucky became a part of the Likava manor. Wisner von Morgenstern - the prefect of the manor, had built a new building with a large dining room and 17 rooms for guests. In the first half of the 19th century a new spa house with a piscine (a pool with multi-perforated floor through which the water entered the bath) was ready. In the modern history, the Lucky Spa was focusing on the treatment of gynecological and oncological diseases since 1950; however in 2005 Spa returned to the treatment of the kinetic apparatus, also offering suitable conditions for prevention and treatment of the osteoporosis. Mineral water from the wells HGL-3 and BJ-101 (Valentina) is being used in all pools and separate spas. It is also suitable for drinking and available not only for the accommodated guests, but also for the general public.

Mineral waters in Besenova manifested themselves for centuries in the form of natural outflows producing young limestone deposits – travertines. These can be found in the surroundings of the village, e.g. in an abandoned travertine quarry, but also in travertine cascades, which were included into Slovak natural heritage list in 1951. Geothermal water exploration in Besenova started in late seventieth of the last century by drilling the well BEH-1 (Franko et al., 1979). Because of well casing corrosion, the well was destroyed and a new well ZGL-1 was drilled in 1987 (Fendek et al., 1988). This well was the base for building of geothermal facilities in Besenova, being complemented by two other wells FGTB-1 (Vandrova et al., 2011) and FBe-1(Hodak, 2006).

Since that time, the discussion on possible interferences of water utilization of both structures was raised. The use of mineral water for curative purposes is preferred to energetic use in Slovakia, as it is codified by Act. No. 538/2005 Z.z. on natural curative waters, natural curative spas, spa places and natural mineral water. Mineral waters in Lucky are bound to Triassic carbonates of the Krizna Nappe as proved by results of BJ-101 and HGL-3 wells in Lucky (Teplianka brook valley) and HGL-2 well in Kalameny, located in the neighbouring Kalamenianka brook valley. Results of geothermal wells ZGL-1, FGTB-1 and FBe-1 in Besenova showed that geothermal waters accumulate in Triassic carbonates of the Choc and Krizna Nappes. It is supposed that formation of geothermal water takes place in Krizna Nappe carbonates. Both structures (Lucky and Besenova) are classified as open structures with infiltration, transition-accumulation and natural discharge areas.

No geological investigation was done in this area up to present aiming to confirm or disprove the interconnection between both structures, which water is intensely utilized. The goal of the research was to delineate the relief of the pre-Palaeogene surface, to segment it into lithostratigraphic units and to confirm or disprove the interconnection between Besenova and Lucky water bearing structures. Controlled source audio-frequency magnetotellurics (CSAMT) was the main method used. This was the first utilization of the CSAMT method in geothermal research in Slovakia.

2. HYDROGEOTHERMAL CONDITIONS OF THE LIPTOV BASIN

The Liptov Basin is an intramontaneous depression in the Inner Western Carpathians. It is filled with Palaeogene sediments whose thickness ranges from 100 m (Besenova elevation) to 1,700 m (Liptovska Mara depression). Palaeogene flysch sediments are represented by alternation of clays and clayey shales with sandstones. Clays mostly prevail. On the base, basal conglomerates are developed.

The substratum consists of the Mesozoic Choc and Krizna Nappes, which form elevated and sunken morphostructures. Choc Nappe is higher tectonic unit then the Krizna Nappe (Figure 2). The lowest tectonic unit, analogously to other Tertiary intramountainous depressions, is the Tatricum Envelope Unit (with the same rock composition as in the Krizna Nappe); however, its presence has not been proven yet by drilling works. The vertical, tectonically derived superposition of Mesozoic successions gave arise to aquifer-aquitard stratification. Krizna Nappe is referred as a bottom, while Choc Nappe along with the Sub-Tatric Group of Palaeogene flysch sequence is referred as a top system. Bottom system includes base aquiclude represented by Lower Triassic horizon typical in quartzites, sandstones and sandy shales (Werfenian shales) beneath bottom aquifer of Middle Triassic carbonates - limestones and dolomites complex. Atop, a bottom aquitard corresponds to Upper Triassic – Middle Jurassic organogene and detritic limestones overlapping to Middle Jurassic – Lower Cretaceous pelitic limestones (clayey, marly) that alternate spatially with radiolarites, nodular limestones, claystones and marlstones. Top hydrogeological system involves aquifers of Choc Nappe, represented by Middle Triassic carbonates hydraulically connected to Sub-Tatric Group represented by Middle – Upper Eocene Borove basal formation (Remsik et al., 1998) composed of breccias and conglomerates that pass to detritic carbonates and rare organogene limestones; beneath top aquifuge recognized as Upper Eocene – Oligocene formations of Huty (claystones dominated) and Zuberec (flysch dominated). Hydrogeological function of Quaternary cover varies regarding to grain size (Franko et al., 1979). The maximal thickness of the Choc Nappe sequence is up to 1,000 m. Krizna Nappe sequence reaches the maximal thickness of 1,500 m.

Spatial distribution of the Choc and Krizna Nappes in the substratum of the Palaeogene sediments is very variable. Both nappes are presented equally in the western part of the basin, they can occur next to each other. Choc Nappe dominates in the middle and southern part of the basin, Krizna Nappe sequence prevails in the northern part. Sequences of Choc and Krizna Nappes build mountain ranges which surround the basin and represent infiltration areas for the hydrogeothermal structures.

Hydrogeological conditions in the area are controlled by the geological-tectonic structure. Geothermal waters in the Liptov Basin are discharged through natural springs and wells. Beneath the Palaeogene filling there may be one to three hydrogeothermal structures positioned one above another in which geothermal waters are mostly associated with Triassic dolomites and limestones ("carbonates" throughout the following text) of the Choc and Krizna Nappes and, possibly, also of the Envelope (autochthonous) Unit (Figure 2). These hydrogeological structures are largely open (having recharge area on adjacent slopes of surrounding mountains, as well as transit-accumulation and discharge areas) or semi-open (discharge area is missing). The Triassic carbonate aquifers with geothermal waters are from 300 to 1,200 m thick.

Geothermal waters occurring in the Choc Nappe Triassic carbonates at depths 500 to 2,800 m have the temperature of 20 to 90 ºC while these in similar rocks of the Krizna Nappe at depths of 900 to 4,000 m could be 25 to 125 ºC hot. The temperature of geothermal waters occurring in Triassic carbonates of the Envelope Unit at depths of 2,500 to 5,000 m might amount 70 – 150 ºC.

The Liptov Basin is tectonically divided into a system of elevations and depressions. The Besenova elevation hydrogeothermal structure associates with N-S protuberant morphological elevation of the pre-Palaeogene basement in the western part of the Liptov Basin. The elevation is limited tectonically to the surrounding depressed structures on the west (Ivachnova depression divided by Besenova – Partizanska Lupca fault) and east (Liptovska Mara depression divided by Bukovina – Vlachy – Lubela fault system); or to surrounding mountains to the north (Choc Mts. divided by Ruzbachy fault system) and to the south, where fault swarms lineate a system to the Nizke Tatry Mts. The Besenova levation is considered the most active zone regarding geothermal activity (Remsik et al., 1998), with a mean heat flow density recalculated for 66.04 $mW.m^{-2}$ (Fricovsky, 2011) in comparison to a mean heat flux for the whole Liptov Basin geothermal field calculated for 55 $mW.m^{-2}$. Local maximum measured rises to 76.9 $mW.m^{-2}$ in ZGL-1 Besenova well within a centre, while local minimum decreases down to 55 $mW.m^{-2}$ towards the southern margin (Kral and Remsik, 1996).

Laterally, Bešeňová elevation is recognized as open hydrogeological structure (Fendek and Remsik, 2005). Infiltration zones are identified at distal northern slopes of the Nizke Tatry Mts. close to Demanova valley (Vrana et al., 2008) or at its southern margin considered as preference recharge area (Fricovsky et al., 2012), however there is the migration of fluids from the Liptovska Mara depression structure (located to the east) expected, as showed by analysing the regional piezometric level distribution (Remsik et al., 1998).

The infiltration area of the Lucky mineral water structure was placed by Vrana et al. (2008) to the area with occurrence of the Krizna Nappe carbonates in the upper part of the Sucha dolina valley and in the area of occurrence of Choc Nappe dolomites to the north-east of the Liptovske Matiasovce village. The transition-accumulation area was placed to the carbonate complex of limestone and dolomites of the Krizna Nappe in the Choc Mts. between the Sucha dolina valley and the Raztocne valley. The groundwater flows mostly along the Choc –sub-Tatry fault which divides the Chocske vrchy Mts. from the Liptov Basin.

The main Ca-Mg-HCO_3-SO_4 chemical type of geothermal/mineral water prevails in the basin, T.D.S. values amount to about 0.4 – 5.0 $g.l^{-1}$ (Table 1). Gases are represented mainly by CO_2. Sulphates in geothermal waters (Remsik et al., 1998) came largely from Lower Triassic formations with evaporates ($\delta^{34}S$ = 23.3 to 27.1 ‰); the isotopic composition of oxygen in geothermal waters shows that they are of meteoric origin. Data on selected geothermal wells in the basin are in Table 1.

Table 1 Data on selected geothermal wells in the Liptov Basin

Well Locality	Aquifers	Perforated interval [m]	Discharge [$l.s^{-1}$]	Water temperature [ºC]	Thermal power [MW_t]	T.D.S. [$g.l^{-1}$]	Chemical type of water
FGL-1 Pavcina Lehota	Triassic limestones and dolomites[1]	1,315-1,570	6.0*	32.0	0.42	0.40	$Ca\text{-}Mg\text{-}HCO_3$
ZGL-1 Besenova	Triassic dolomites[2]	1,420-1,964	27.0**	62.0	5.30	5.30	$Ca\text{-}Mg\text{-}SO_4\text{-}HCO_3$
FGTB-1 Besenova	Triassic limestones and dolomites[2]	1,622-1,813	32.0**	66.9	6.83	3.02	$Ca\text{-}Mg\text{-}SO_4\text{-}HCO_3$
ZGL-2/A Liptovsky Trnovec	Triassic dolomites and limestones[1]	1,624-2,486	31.0**	60.7	5.89	5.90	$Ca\text{-}Na\text{-}Mg\text{-}HCO_3\text{-}SO_4$
ZGL-3 Liptovska Kokava	Triassic limestones and dolomites[2]	1,475-2,365	20.0*	43.5	2.42	2.40	$Ca\text{-}Mg\text{-}HCO_3\text{-}SO_4$
HGL-2 Kalameny	Tectonic disruption in Carpathian Keuper´s shale[2]	185-500	23.5**	33.4	1.77	2.90	$Ca\text{-}Mg\text{-}SO_4\text{-}HCO_3$
HGL-3 Lucky	Triassic dolomites[2]	322-476	25.0*	35.8	2.18	3.10	$Ca\text{-}Mg\text{-}SO_4\text{-}HCO_3$
BJ-101 Lucky	Triassic dolomites[2]	54-92	20.0*	32.0	1.42	2.80	$Ca\text{-}Mg\text{-}SO_4\text{-}HCO_3$
LSH-1 Liptovska Stiavnicka	Triassic dolomites[1]	89-165	10.0*	21.0	0.25	3.56	$Ca\text{-}Mg\text{-}HCO_3\text{-}SO_4$

[1] Choc Nappe, [2] Krizna Nappe, * pumping, ** free outflow

3. GEOPHYSICAL METHODS USED IN THE RESEARCH

CSAMT - Controlled source audio-frequency magnetotellurics belongs to magnetotelluric methods from the group of frequency domain methods. The reached depth is determined by the used frequency of electromagnetic signal. Use of the method is based on resistivity contrast in the rock environment, mapping the conductivity conditions in a quite wide range. CSAMT method used the transmission of controlled electromagnetic signal of suitable frequencies on the transmitter´s side and measurement of electric and magnetic field in the distant measured area on the receiver´s side. The distance between the transmitter and receiver during measurement is 5 to 15 km depending on geological conditions and measurement goals.

The method can be used by solution of geological and hydrogeological problems. The review paper of Munoz (2014) presents an update of the state-of-the-art geothermal exploration using EM methods, among them also the CSAMT method. The CSAMT method was used by Wang et al. (2013) for the research of coalbed methane enrichment region in the north Qinshui basin. The results show that the use of CSAMT method can effectively obtain electrical structure of strata, infer water content, and water-rich areas. Kalscheuer et al. (2012) developed a novel scheme to invert MT, RMT, and CSAMT data in the form of scalar or sensorial impedances and vertical magnetic transfer functions simultaneously for layer resistivities and electric and magnetic galvanic distortion parameters. Troiano et al (2009) did the CSAMT survey in the Pantano di San Gregorio Magno faulted basin, an earthquake prone area of Southern Apennines in Italy. They outlined the geological structure of the area using the inverted section, reaching up to 300 m below ground. Spichak et al. (2005) interpreted the CSAMT scalar data from the Minou fault zone (Kyushu Island, Japan) by means of Bostick transformation, 2-D inversion, and the artificial neural network expert system MT-NET. The resulting geoelectric models of the region were compared.

The geophysical apparatus METRONIX TXM-22/TXB-07 was used on the transmitter´s side, allowing to transmit the stable, artificial source of electromagnetic signal in the AMT range (0.5 Hz – 8 192 Hz). The maximum power of transmitters assembly can reach up to 40 A, depending on geological and conductive conditions of the locality. The grounded tripole (used instead of dipole) enables to rotate the current vector as necessary, without necessity to change the grounding location of electrodes. The length of each tripole was app. 600 m. The transmitter was located at Liptovske Beharovce village, at the distance of app. 10.5 km from the receiver profile. On the receiver´s side, the electric and magnetic field was registered by METRONIX ADU-7 device. This device is furnished with ten measuring channels, the standard configuration for the broadband MT and AMT is five low-frequency (LF) and five high-frequency (HF) channels. The electric compound is registered by four electrodes placed in the N-S and E-W direction, the magnetic compound is registered by three magnetic probes. Registered electric and magnetic signals are in the further pre-processing worked into *.edi files, from which, using the inversion process, the isoohmic profiles were created as the final product of measurements. TXM-22 and ADU-7 were fully synchronized by the GPS time during the measurements.

Possibilities to use the deep magnetotellurics were checked in the vicinity of the HGL-2 Kalameny well. These measurements could not be processed because of too intense noise, produced mostly by the railway track, water power-plant and high amount of high-voltage leads in the whole area. One magnetotelluric point was measured in Sucha dolina valley (Chocske vrchy Mts.), where the noise level was acceptable and measurements were interpretable.

Because of high level of electromagnetic noise, the transmitter's fluxes were maximized on the transmitter´s side, reaching the level of 30 – 40 Amp .Therefore the amplitudes reached the distinct conveyance from the background, which is the main indicator of the measured data quality and interpretation suitability. The results of the CSAMT measurements and previous geophysical methods were depicted in the resistivity section (result of 2D inversion of CSAMT measurements) and the interpreted geophysical section.

The test measurements, done within the maximum range of usable frequencies, allowed to select the range of 0.5 Hz – 8 196 Hz for the locality. The length of transmission for one measurement process (measurements in one point) was equal to app. 120 minutes. The receiving part of the apparatus moved along the profile with the step of app. 200 m on labelled fixed points. The entire profile length was 4 000 m (Figure 3). The protection of magnetic probes against oscillation was secured by their burying below the surface. All together, 21 CSAMT points were measured (one of them repeatedly - Site-600). Point No. 9999 was measured as parametric point close to HGL-2 well in Kalameny (Figure 3); point No. 4 000 was measured as parametric point close to ZGL-1 well in Besenova (Figure 3). The effective measurement depth of CSAMT reached up to 2 000 m. This was satisfactorily, because the deeper well (ZGL-1) has the depth of 1987 m. The wells HGL-2 Kalameny and ZGL-1 Besenova were utilised for realization of parametric measurements which enabled the segmentation of the Pre-Palaeogene basement into respective lithologic-tectonic units. The CSAMT profile was delineated in the field using the GPS-Trimble GEO XT improved with help of topo-corrections SKPOS, with the accuracy of 2 m.

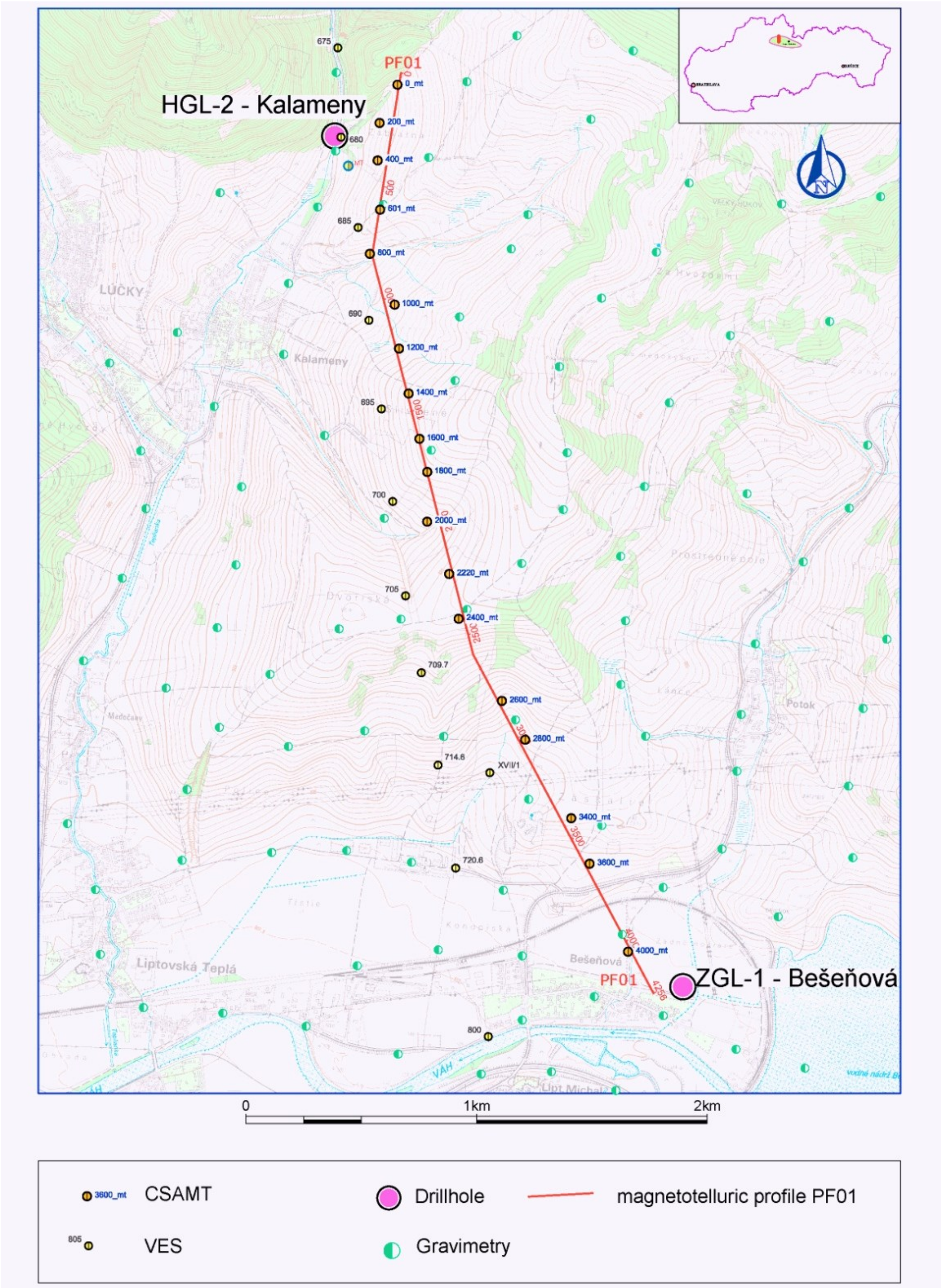

Figure 3: Location of CSAMT measured points and wells in Kalameny and Besenova

The existing data from the vertical electric sounding (VES), magnetometry and mainly gravimetry were also used to create the complex picture of the geophysical field. Based on them, the inverse 1D model from the available data on the total Bouger anomalies and topography data was created (Figure 4).

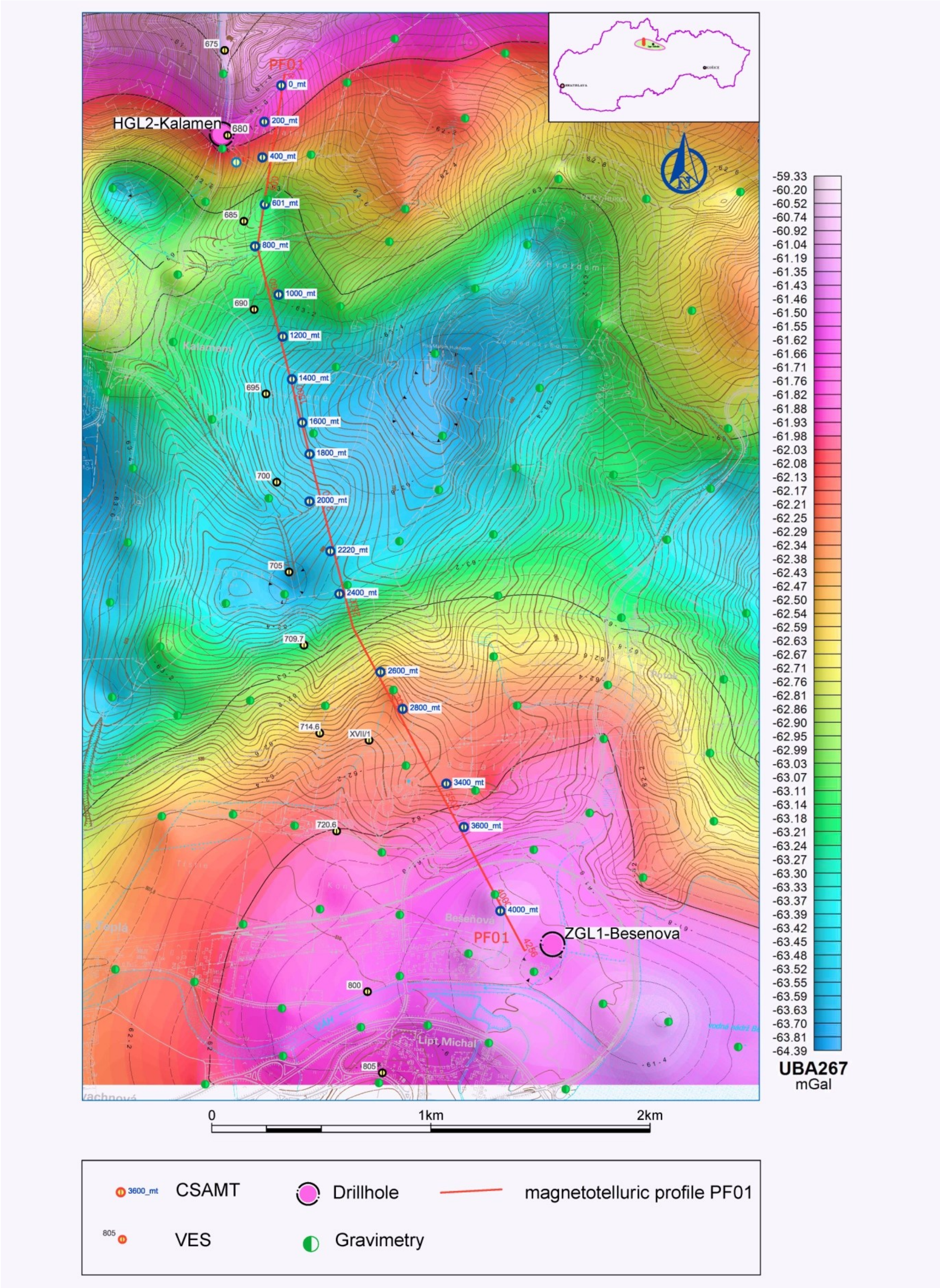

Figure 4: Gravimetric map of the total Bouger anomalies

The results of geophysical measurements were then used for interpretation of relationships among the geothermal water sources in Besenova and curative mineral water sources BJ-101 and HGL-3 in Lucky. The interpreted resistivity block model is in Figure 5, its geological interpretation is in Figure 6.

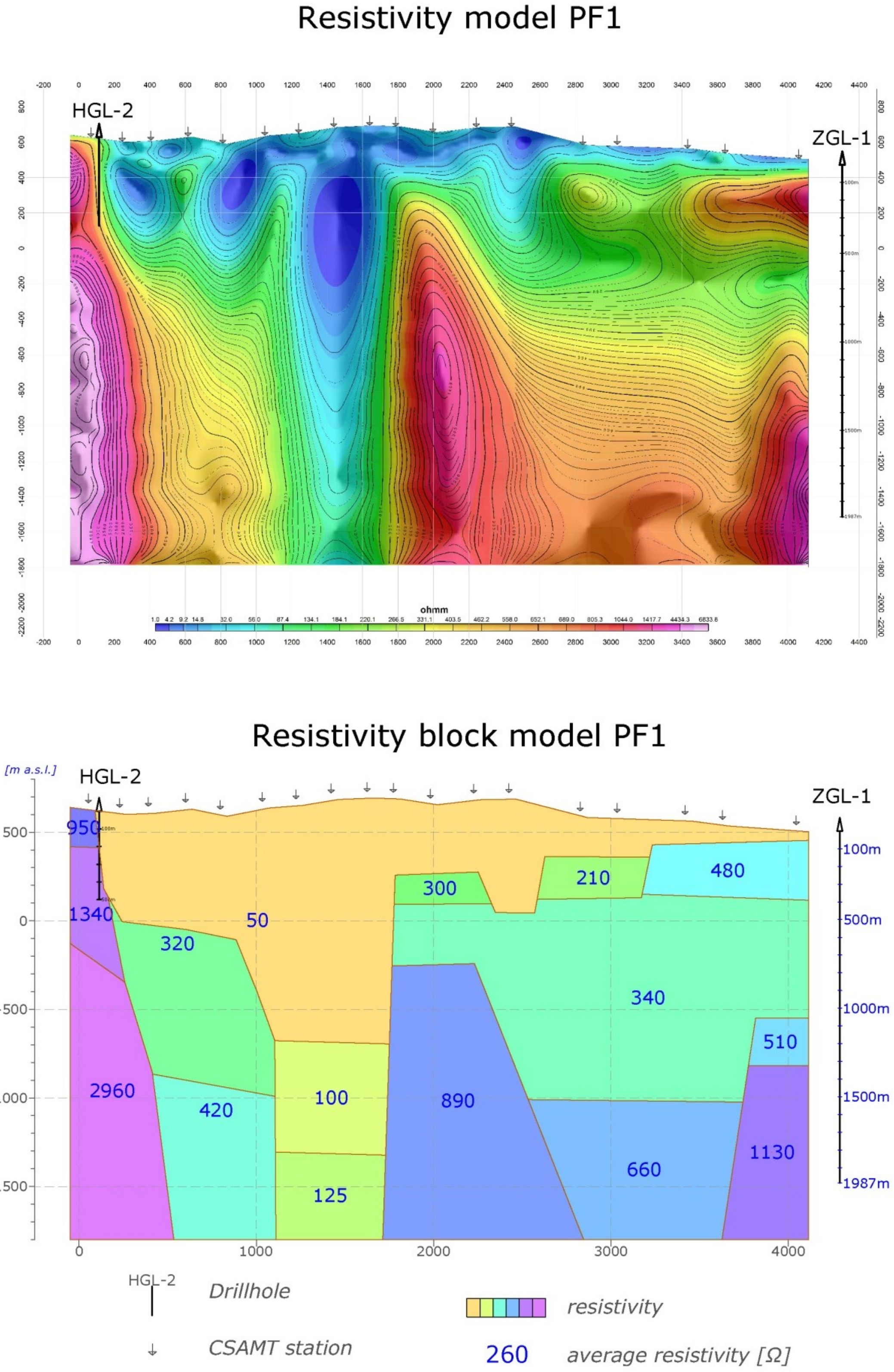

Figure 5: Geophysical isoohmic profile and resistivity values obtained by magnetotellurical measurements

4. RESULTS AND DISCUSSION

The results in Figure 5 show that there is a low-resistivity layer close the surface, representing the Palaeogene sediments with typical high content of clayey compound and low resistance values. The Palaeogene sediments were proven by all wells drilled in the Liptov Basin, and also interpreted by other geophysical works (Kubes et al., 2001). Very distinct is also the vertical low-resistivity anomaly around the depth of 1 100 – 1 600 m to the south of the Kalameny well. This anomaly is probably caused by large thickness of Palaeogene sediments under-bedded by marls and marly limestones of the Lower Jurassic and Cretaceous. They also contain a high proportion of clayey compound which manifests itself by low resistivity values. The measured anomaly isolates the Triassic carbonates of the Krizna nappe occurring Kalameny-Lucky area from the carbonates occurring in Besenova elevation. There are Mesozoic rocks, mostly dolomites, underneath the Palaeogene sediments in the wider surroundings of ZGL-1 and FGTB-1 wells in Besenova. These carbonates tectonically belong to the Choc Nappe. Dolomites have several-times higher apparent resistivity than marls, marly limestones, or shales and anhydrites of the Krizna Nappe. The high-resistivity layer, occurring at the larger depths in the beginning of the section (HGL-2 well), could represent either compact Triassic dolomites, which disintegration degree decreases with the depth, or Lower Triassic quartzites of the Luzna sequence, which were drilled by geothermal wells ZGL-3 Liptovska Kokava and FGL-1 Pavcina Lehota (Figure 2).

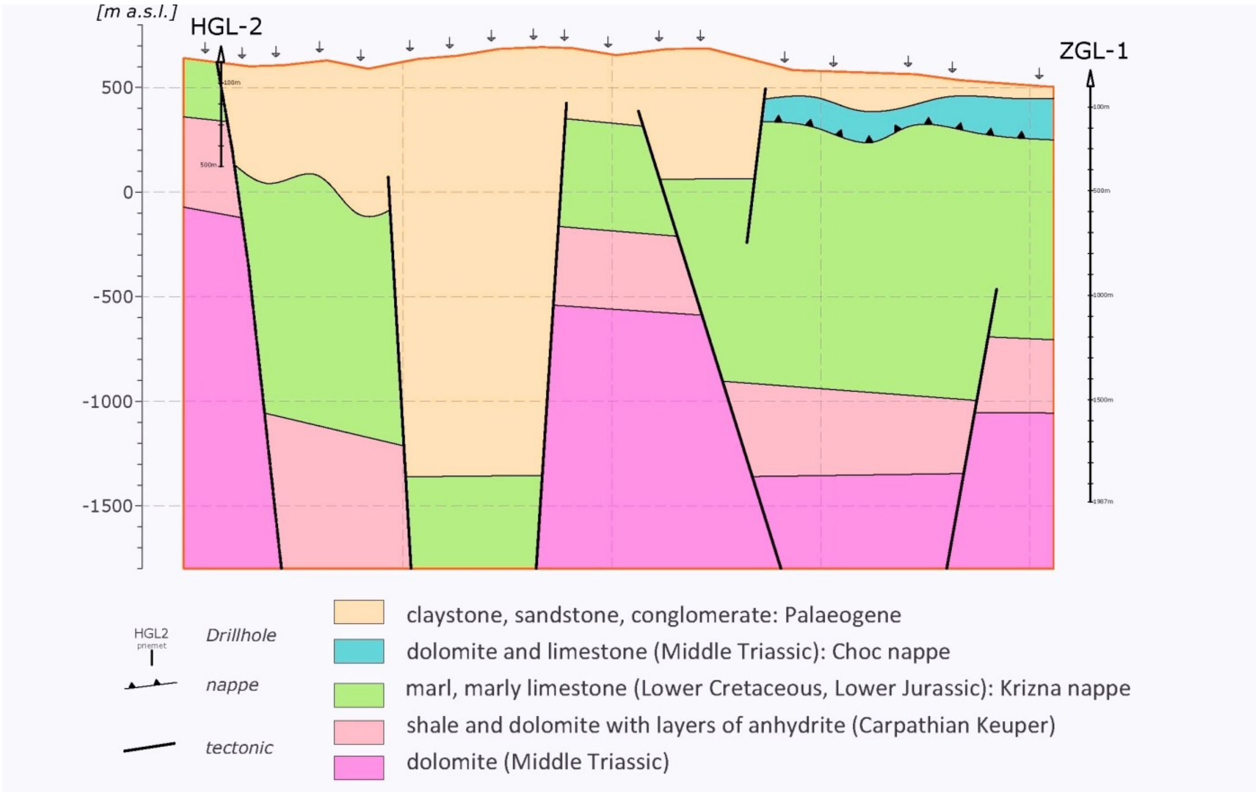

Figure 6: Geological interpretation of the geophysical isoohmic profile

The pre-Palaeogene basement has a markedly disturbed and tectonically broken relief, as it can be seen from the measured resistivity values of Mesozoic rocks (Figure 5). The geological interpretation (Figure 6) shows that the Choc Nappe is not extended continuously in the Besenova elevation. The same is valid also for shales of the Carpathian Keuper, which are in the central part of the profile isolated by Palaeogene sediments from the north and by marls and marly limestone of the Lower Jurassic – Lower Cretaceous from the south. The continuation of the Middle Triassic dolomites from the Besenova elevation towards the Kalameny-Lucky is disconnected by Palaeogene sediments in the deeper part also by marls and marly limestone of the Jurassic-Cretaceous ages, which are in the regional view considered as hydrogeological isolators. The section was delineated in the elevation part of the Palaeogene basement. There is the Ivachnova depression stretching to the west and the Liptovska Mara depression to the east. The thickness of Palaeogene sediments increases markedly in both of these depressions.

The radiocarbon ages were also estimated for waters in the Liptov Basin. The age of geothermal water was estimated by Franko (2002) on 27 000 years with the infiltration time during the Paudorf interstadial (Wurm 2-3 glaciations) for the Besenova area (ZGL-1 well) based on the ^{14}C isotope concentrations, whereas the age of mineral waters in Lucky and Kalameny was estimated on 23 000 and 18 300 years respectively, responding to colder time period in Wurm 3 glaciation. The isotopic composition of oxygen $\delta^{18}O$ in geothermal water from wells ZGL-1 Besenova, ZGL-2A Liptovsky Trnovec and in mineral water in LSH-1 well in Liptovska Štiavnicka is different from the isotope composition of oxygen in BJ-101 and HGL-3 sources in Lucky, HGL-2 in Kalmeny and also in the main inflow to the well ZGL-3 Liptovska Kokava.

Another argument confirming the existence of two separated structures is that there was no influence of long-term hydrodynamical testing of the drillhole FGTB-1 in 2012 on discharges in Lucky area, and also no influence observable on mineral water sources during the more than 25-years long intense utilization of geothermal water in Besenova geothermal facilities.

5. CONCLUSION

The interpretation of geophysical data available for the western part of the Liptov Basin, together with the interpretation of the CSAMT method results confirmed, that there is no interconnection between the Lucky mineral water structure and the Besenova geothermal water structure. Both structures are separated by huge thickness of Palaeogene sediments and, at the larger depths, also by marls and marly limestones of the Krizna nappe, which are in the regional scale considered as hydrogeological isolators. It was proven that the continual interconnection of geothermal aquifers in the area between the Besenova and Lucky-Kalameny does not exist. Therefore the mutual influencing of exploited geothermal water in Besenova and mineral water in Lucky was not proven yet, despite of more than 25 years of intense exploitation of geothermal water in both localities.

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