

GEOLOGICAL FEATURES, GEOPHYSICAL MEASUREMENTS AND INTERPRETATION AT THE TELKIBÁNYA RESEARCH AREA

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Abstract: A lot of geophysical measurements (gravity, geomagnetic, geoelectric, airborne magnetic and radiometric) were carried out in the Tokaj Mountains in the 60's. They covered partly the Northern part of the Tokaj Mountains, the Telkibánya area too. Later, in 1997 detailed airborne magnetic and radiometric measurements covered the ore perspective part of the Telkibánya area. The well-known surface geology of the Telkibánya volcanic structure allows the interpretation of different geophysical data as indicating volcanic bodies, secondary alterations of volcanic formations and hydrothermal processes. There was only local field geophysical work on the area without a summary program of different time and different kind geophysical exploration works. The biggest one was the paleovolcanic reconstruction of the Tokaj Mountains financed by Hungarian Scientific Research Found (OTKA-022769). Unfortunately the Telkibánya area is located near the state boundary, which was a spatial limit of the old airborne surveys. Now, in this paper we summarize the results of geophysical interpretations of field gravity, airborne magnetic and radiometric data.

Keywords: gravity depth slicing, frequency filtering, magnetic analytical signal, potassium anomalies, thorium anomalies, caldera structures, volcano-tectonic lines

1. GEOLOGICAL STRUCTURE

1.1. Introduction

The surroundings of Telkibánya in the Tokaj-Eperjes (Zemplén-Szalánc [Zemplínske-Slanske]) Mts, according to the geology, are part of the Miocene volcanic arch of the Carpathian subduction. Its bordered by the tectonic zones of the Hernád [Hornád] River from W, of the Ronyva [Roňava] Creek from E and of the Bózsva Creek from S. The Hungarian part of the Mts. is an asymmetric tec-

tonic wedge structure. The rock outcrops are younging from E to W (from Lower Paleozoic metamorphosed rocks to Miocene volcanics and the unconsolidated Pannonian sediments) (Gyarmati, 1977). The old formations descended from E to W, from the Ronyva Creek towards the Hernád River at the beginning of the Miocene along NNW–SSE striking, from the Badenian-Sarmatian boundary along N–S striking tectonic steps down below 2 km.

1.2. Basement formations

The oldest formations are on the NE part of the Tokaj Mts, at Vilyvitány and Felsőregmec. A Lower Paleozoic (or Precambrian?), slightly metamorphosed gneiss – mica schist complex is cropping out. 1 km W from the outcrops, at Füzérradvány the same metamorphic rocks were reached by the exploration drillings 200–400 m deep in a downthrown position, under Miocene sediments and volcanics. Further on to W, the borehole Füzérkajata-2 reached at 1064 m a Gemic type Upper Carboniferous carbonatic-siliciclastic sedimentary rocks with coal traces after Miocene sediments and volcanics (Gyarmati, 1977; Ilkey-Perlaky, 1978b). At the median line of the mountain chain occur the more than 2 km thick volcano-sedimentary and volcanic (pyroclastite and lava) formations of the Middle-Late Miocene (Badenian-Sarmatian) archipelago volcanism (*Figure 1*). The Telkibánya-2 borehole did not reach the underlying basement down to 1240 m; magnetotelluric measurements indicated it at cca. 1400 m depth. In the Hernád Valley the borehole Hidasnémeti-1 traversed mainly Miocene sediments with some pyroclastite down to 1500 m (Molnár et al. 1999).

1.3. Neogene volcanism

The volcanism started on the whole area of the Tokaj Mts. and at Telkibánya as well with a calc-alkaline dacitic-rhyolitic volcanism contemporaneously with the sedimentation of an archipelago in the Late Badenian, according to the geological-paleontological (Széky-Fux, 1970, Gyarmati, 1977) and radiometric (Pécskay et al, 1987) age determinations. One of the N centres of this volcanism was at Telkibánya. The Badenian volcanics lie directly and discordantly on the metamorphosed basement in the E part of the Tokaj Mts. (e. g. at Füzérradvány and Füzérkajata) (Ilkey-Perlaky, 1978a). The Badenian clayey sediments with fauna vary with tuffites and pyroclastite flows of 300–400 m thickness. According to data from the Füzérkajata-2 and Telkibánya-2 boreholes intermedier (dacitic, an-

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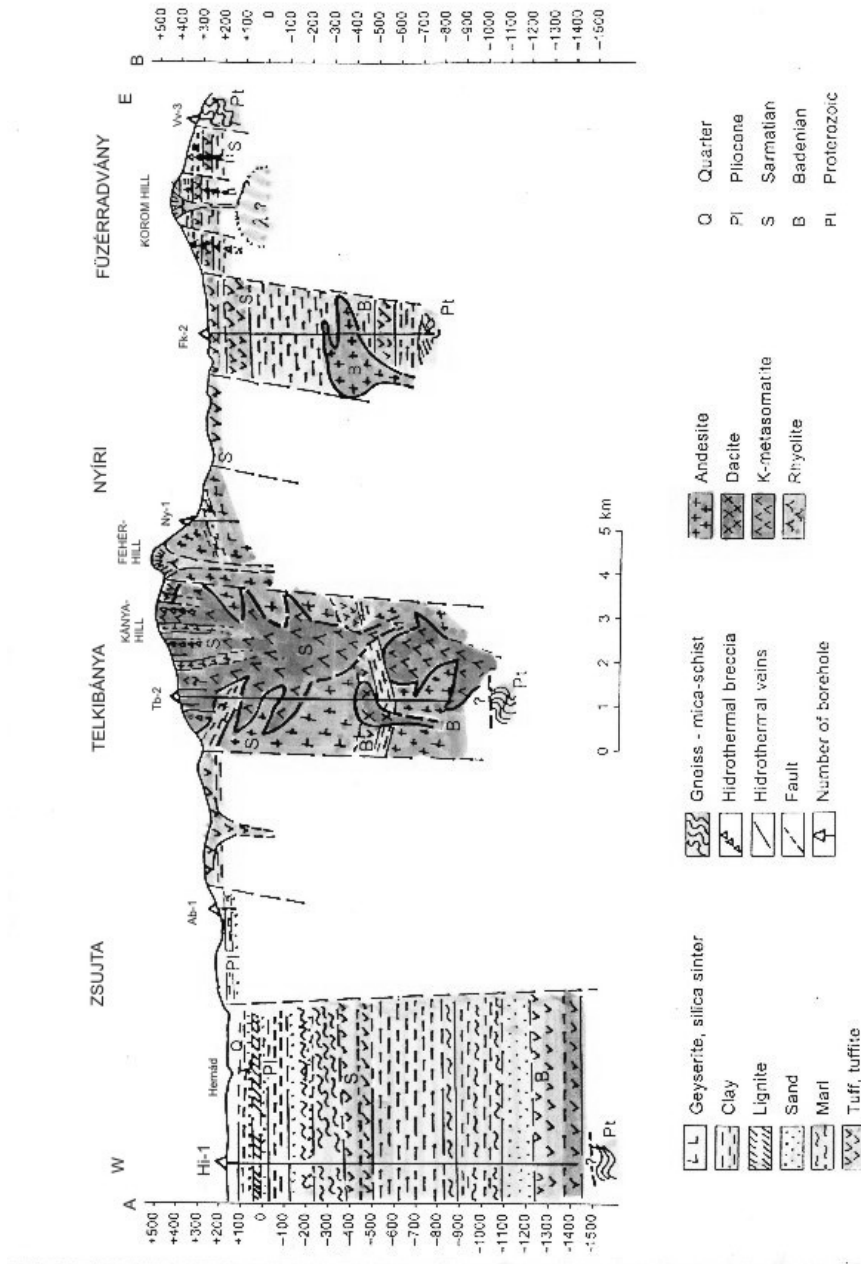


Fig. 1 E-W geological profile across the caldera structure.

desitic) subvolcanic bodies were intruded to these Badenian sediments and volcanoclastics, contactising them (Széky-Fux, 1970, Horváth et al, 1994). The rock material of the Badenian subvolcanic bodies became K-metasomatized, accompanied by an epithermal-hydrothermal vein-stockwerk type ore mineralization. In these ore zones polymetallic (Pb, Zn, Cu) ores were formed on deep levels (borehole Telkibánya-2 below 940 m, Széky-Fux, 1970) and precious metal (Au-Ag) ores on high levels (at Füzérradvány and Rudabányácska, Pécskay & Molnár, 2002, Zelenka, 1994).

The Sarmatian sediments and pyroclastics lie concordantly on the Badenian ones. The clay-conglomerate sediments, rhyolite tuffites, rhyolite flow tuffs with zeolites flown into water, submarine andesitic hyaloclastite breccias and intrusive peperites (Ilkey-Perlaky, 1978b, Kozák, 1994) were formed in 3-500 m thickness. A double-ring structured andesite stratovolcano with cca. 8 km diameter was formed between Telkibánya and Hollóháza (Zelenka, 1994). The andesite lava flows of the stratovolcano emerging from the archipelago were strongly propilitised. Later the top of the volcano collapsed, and two calderas were formed on its place. The caldera structure can be reconstructed by satellite imagery (Horváth et al. 1989, Molnár & Zelenka 1995, Zelenka, 2000) and by geophysical (gravity and magnetic) surveys as well. On the N escarpment of the caldera there are andesite and andesito-dacite parasitic cones of 1-2 km diameter (Nagy hill of Pányok, Lom and Szurok Hills of Kékéd, Hrabó and Május Hills of Hollóháza, Kövesbérc Hill of Nyíri). Inside the caldera there are rhyolite (Pál Hill and Ördögvár of Hollóháza) and rhyodacite (Fehér Hill of Nyíri, Király Hill of Telkibánya) to be seen (Figure 2). According to the volcanogenesis (Kozák, 1994, Zelenka, 1994) and the radiometric age determinations (Pécskay & Molnár, 2002) the andesite and dacite cones forming the caldera are 12.5–13.0 MA old, while the rhyolite domes and the silica-clay sediments of the postvolcanic thermal water basins (Korom Hill of Füzérradvány, Szurok Meadow of Hollóháza etc.) inside the caldera were formed 12.0–12.5 MA before present.

The S collapsed caldera was intruded by subvolcanic andesite bodies (Gyepű Hill of Telkibánya, Tilalmas of Pányok, Kánya Hill, Jó Hill, Fehér Hill of Nyíri, broken through and thermally contactising the stratovolcanic andesite and the underlying Sarmatian clay marl, rhyolite tuff and conglomerate. The subvolcanic andesite bodies became mostly K-metasomatized (Széky-Fux, 1970); this process occurred according to K/Ar age determination 12.0–12.5 MA before present (Pécskay et al, 1987, Pécskay & Molnár, 2002). Fresh stratovolcanic andesite occurs on the Medve hill between the subvolcanic bodies.

On the Sarmatian-Pannonian boundary (10.5–11 MA), at the final volcanism nearly N-S striking, fresh pyroxene andesite dykes were formed. The Pannonian sediments lie discordantly on Miocene volcanics in the Hernád Valley.

1.4. Ore formation

More than 20 precious metal containing hydrothermal breccia dykes and epithermal veins were formed on the top of the subvolcanic bodies at Telkibánya, in exo- and in endo-situation, respectively (Zelenka et al, 2000). These 20-80 cm thick, 500-1000 m long, mainly NW-, NNW- and NNE-striking veins were the objects of the Medieval precious metal mining. The hydrothermal veins were exhausted vertically down to the level of the local base of erosion, about 250–300 m. The vein filling is silicified-quartzose on the top, argillic (illitic) downwards and carbonatic on their bottom levels (Széký-Fux, 1970, Horváth & Zelenka, 1994). The ore on the top comprises mainly porphyry native gold and silver-sulphides (argentite, pyrargirite, freibergite etc.) with minor disseminated pyrite. On lower levels a poor polymetallic ore occurs with galena, sphalerite and chalcopyrite minerals (Széký-Fux, 1970, Pécskay & Molnár, 2002). The veins are bordered by 2–3 m thick silicified hydrothermal breccia with 2-700 g/t disseminated Ag content in the roof. These were not mined underground. The

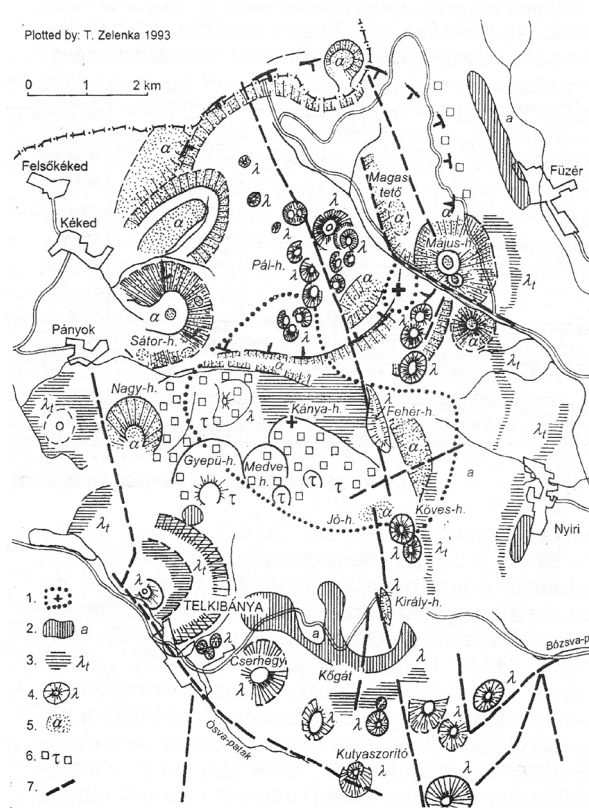


Fig. 2 Paleovolcanic structures interpreted on LANDSAT-5 satellite image. 1: Gravity maxima; 2: Sarmatian clay, clay marl; 3: Rhyolite tuff; 4: Rhyolite lava dome; 5: Andesite caldera, eruption centre; 6: K-metasomatised subvolcanic andesite.

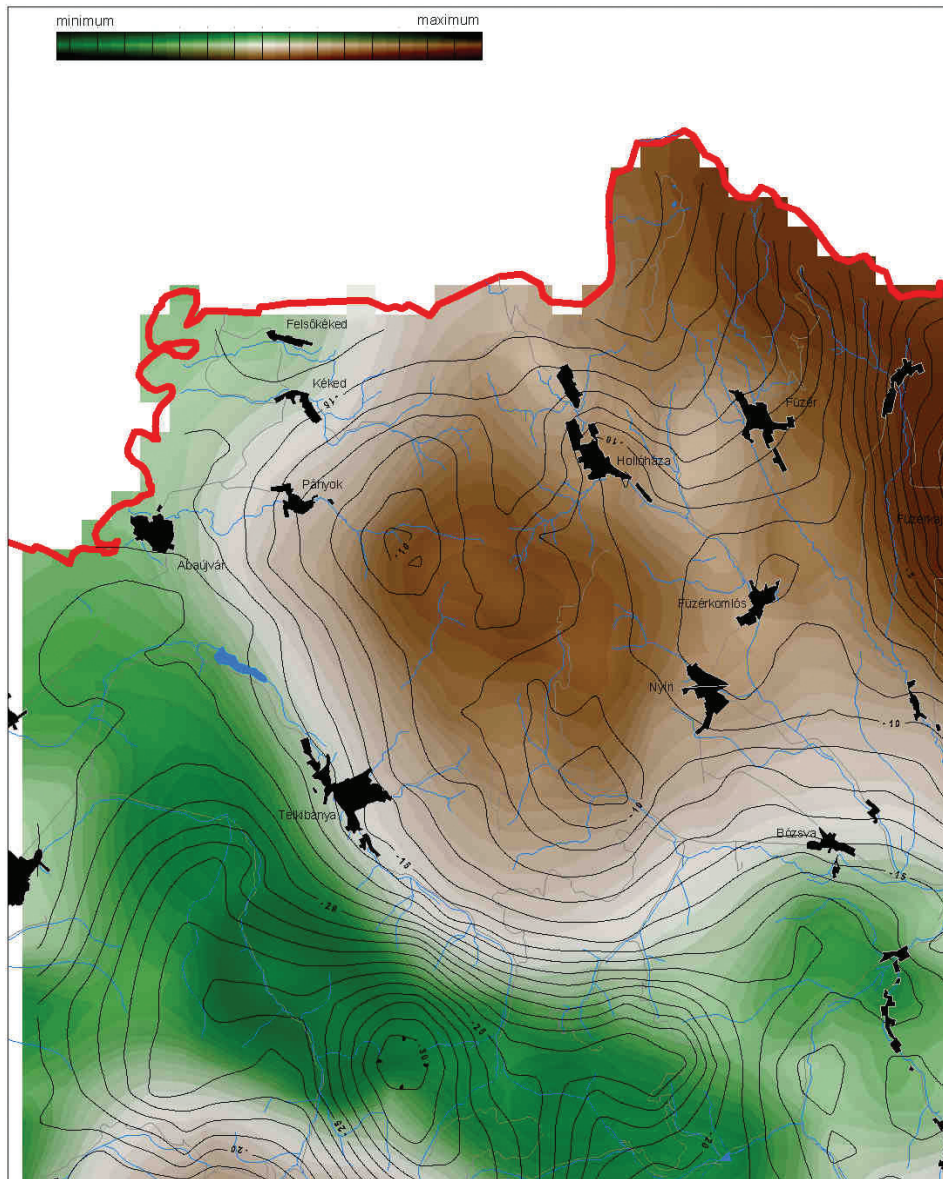


Fig. 3 Gravity Bouguer-anomaly map (colours from calculation by $\sigma=2.00 \text{ g/cm}^3$, isolines from $\sigma=2.67 \text{ g/cm}^3$).

Telkibánya precious metal mineralization is of epithermal low sulphidation type. (Molnár et al, 1999). The rock alterations are propilitic-epidotitic in andesite and K-metasomatic accompanied by quartz and sericite alteration in the subvolcanic bodies (Zelenka et al, 2000). In the hydrothermal zones the low temperature silicification is also accompanied by alunite alteration (Pécskay & Molnár, 2002). Over hydrothermal zones there are spots of lens-shaped silica sediments (chalcedony, opal, diatomite) and clay (illite, montmorillonite) deposits of postvolcanic thermal water ponds with Hg, As, Sb elements.

2. GRAVITY INTERPRETATION

The level of the Pre-Neogene basement at the Telkibánya research area was not reached by the 1000 – 1500 m deep boreholes. Here is one of the biggest negative gravity anomalies of Hungary, although there are some small gravity maxima in the area too. The gravity minimum is connected to the thick rubble and volcanosediment series. The Telkibánya caldera is in sharp contrast to this background and gives a local gravity maximum on the Bouguer anomaly map.

The correct Bouguer anomaly would be calculated with 2.0 g/cm³ reduction density for the whole area because of these thick sediments, but this Bouguer anomaly map would show very strong correlation with the topography, which effect is to be avoided (although in case of volcanic area sometimes it isn't a contradiction). The upper part of geological section, for example the lava rock has a density of 2.6 g/cm³ or even more, so to distinguish the different kind of volcanic formations or structures (as we want to identify these in the first place) we have to use the 2.67 g/cm³ reduction density value. The calculated gravity Bouguer anomalies with both reduction density values are presented on *Figure 3*.

The Bouguer anomaly map shows the combined effect of the deep crystalline basement and the high density volcanic lava formations. They have different depths and geometries of their locations, so using the gravity data we can distinguish their effect from each other.

The basement, which is on the surface near Vilyvitány and Felsőregmec, sinks stepwise into 1500 – 2000 m depth to the west. The deepening of the basement, the appearance of deep volcanic root and the near surface differentiation of lava and tuff can be separated by frequency filtering of the gravity map (*Fig. 4*). The filtered gravity map series starts with effects from the depth (lowpass filtering) into the direction of the surface (highpass filtering). The details of the caldera structure appear in increasingly better resolution at the highpass filtered gravity maps.

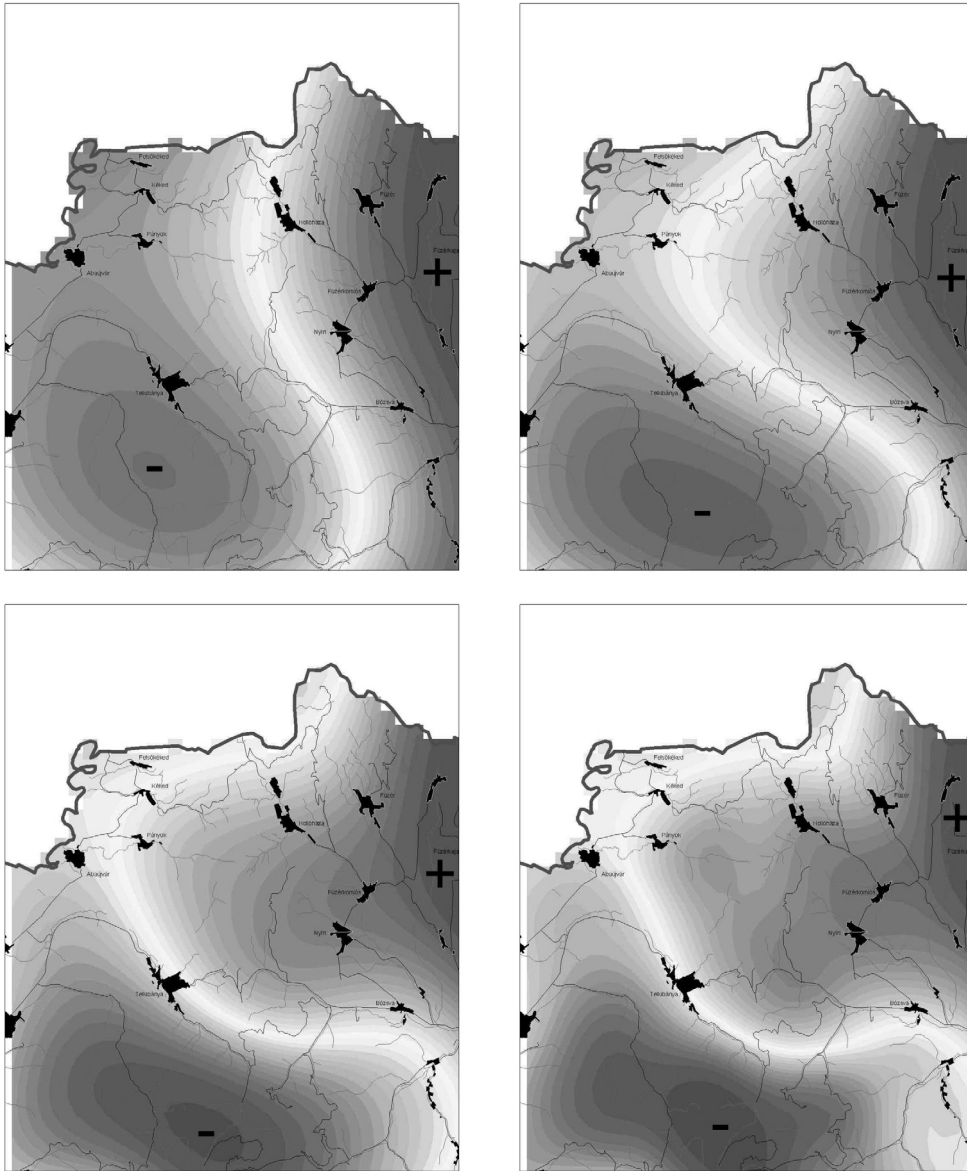
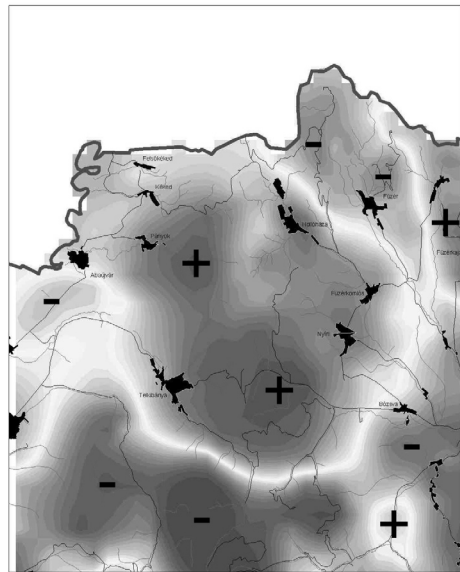
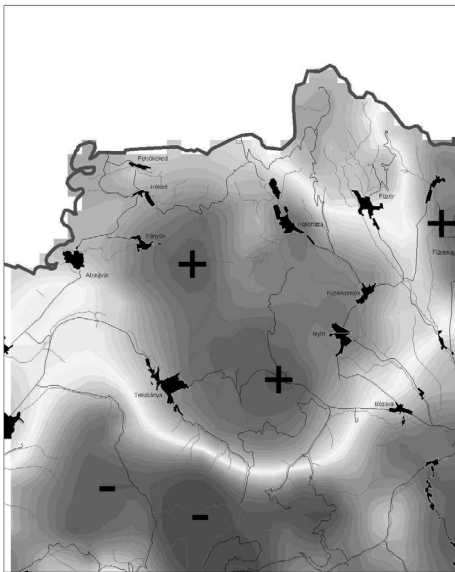
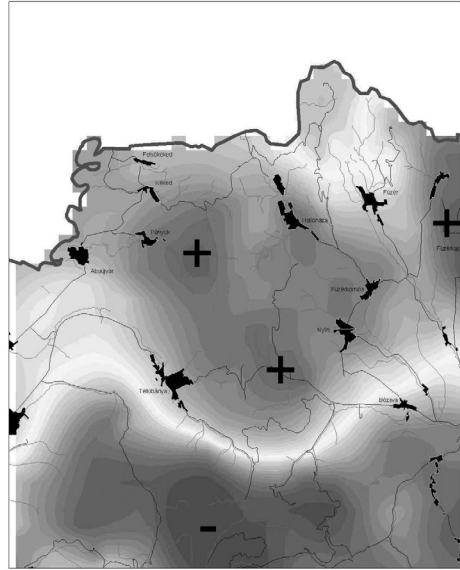
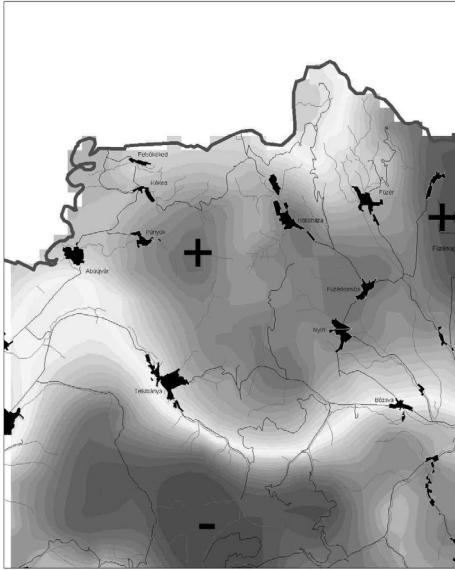
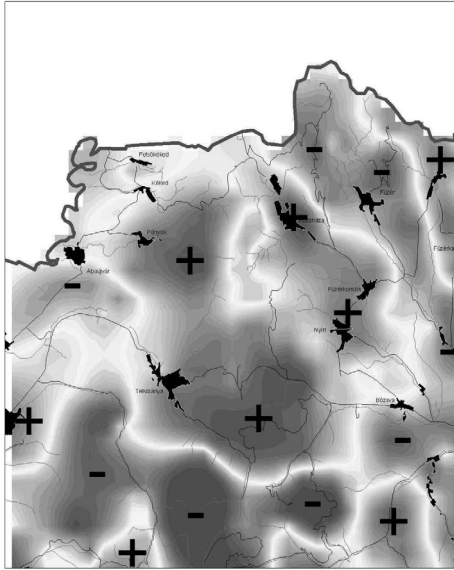


Fig. 4 Gravity data processing at Telkibánya (depth slicing — separation of gravity effects of different gravity sources). 1: Gravity effect of the basement surface, 2: Appearance of volcanic root effect, 3: The effect gets stronger, 4: Some differentiations,

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5: A caldera structure is drawing out, 6: The caldera and parasite cones, 7: Secondary alterations, 8: The volcanic maximum is separated,



The results of gravity depth slicing show that the volcanic superstructure lies directly on the basement (Fig. 4/2–3), and has broken through (or was formed together with) the young sediments, up to the surface (Fig. 4/9). Using the gravity frequency filtering techniques the location of high density volcanic formations becomes traceable across different depth intervals.

9: The gravity effect of the upper part.

Type of filter	Wavelength cut off		
	LP	30 km	20 km
LP, HP, HP	5 km	100 km	50 km
HP	30 km	20 km	10 km

Table 1. Parameters of frequency filtering (LP — lowpass, HP — highpass)

Anomalies of given wavelengths (spatial frequency) were cut out from the map by the filtering process (Table 1, Fig. 5). As a result, the geometric resolution of the map of high frequency (short wavelength) anomalies is better than the low frequency (long wavelength) one.

The sampling interval of gravity field measurements determines the smallest detectable structure and the size of the exploration area determines the biggest penetration depth — the biggest wavelength of gravity anomalies (Fig. 5). Gravity measurements were carried out along roads, the distance between the stations was about 0.5 – 3.0 km. The sampling distance along the road was about 500 m, and it was approximately 3 km between the roads. The size of the area is 16×20 km. The biggest depth which can be determined is about 2 km, as a thumb rule

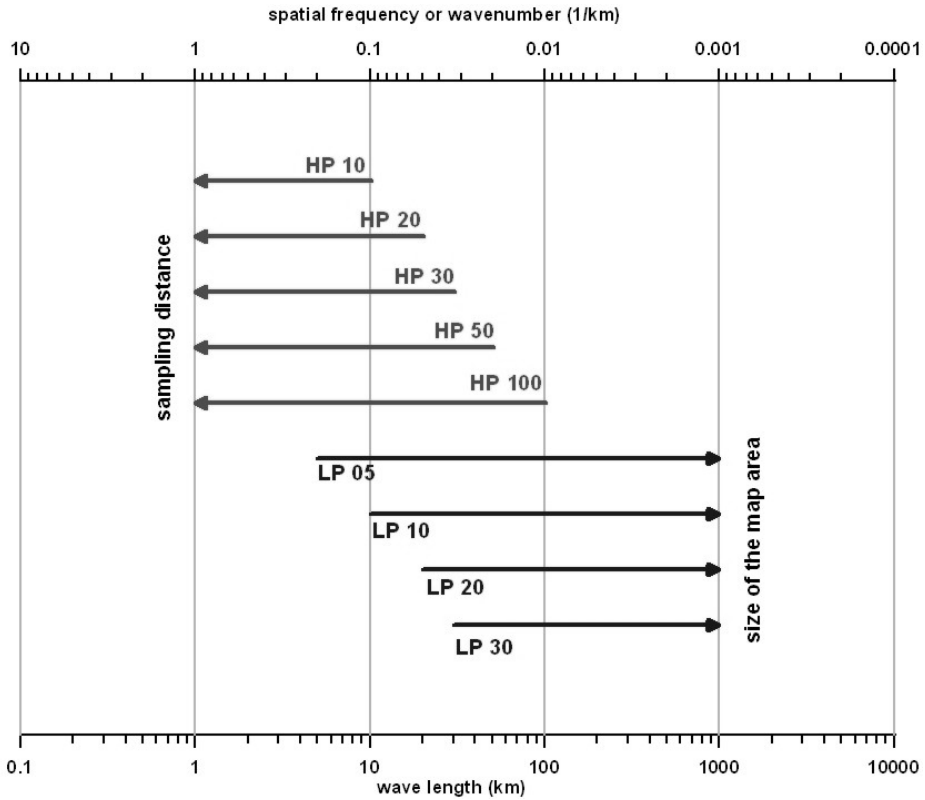


Fig. 5 Passed and rejected wavelengths at the frequency filtering.

of spectral depth estimation from the gravity map says the horizontal extension should be ten times larger. So the depth of the basement on the West side of the area is probable more than 2 km.

The diameter of the volcanic caldera structure based on the gravity anomaly map is about 5 – 8 km. The collapsed caldera appears as a local minimum between the surrounding maxima.

2. RESULTS OF AIRBORNE SURVEYS

The subvolcanic bodies have been altered by K-metasomatism and precious metal ore zones were created by hydrothermal processes. The potassium map of airborne gamma-spectrometry outlines these K-metasomatic zones (Fig. 6).

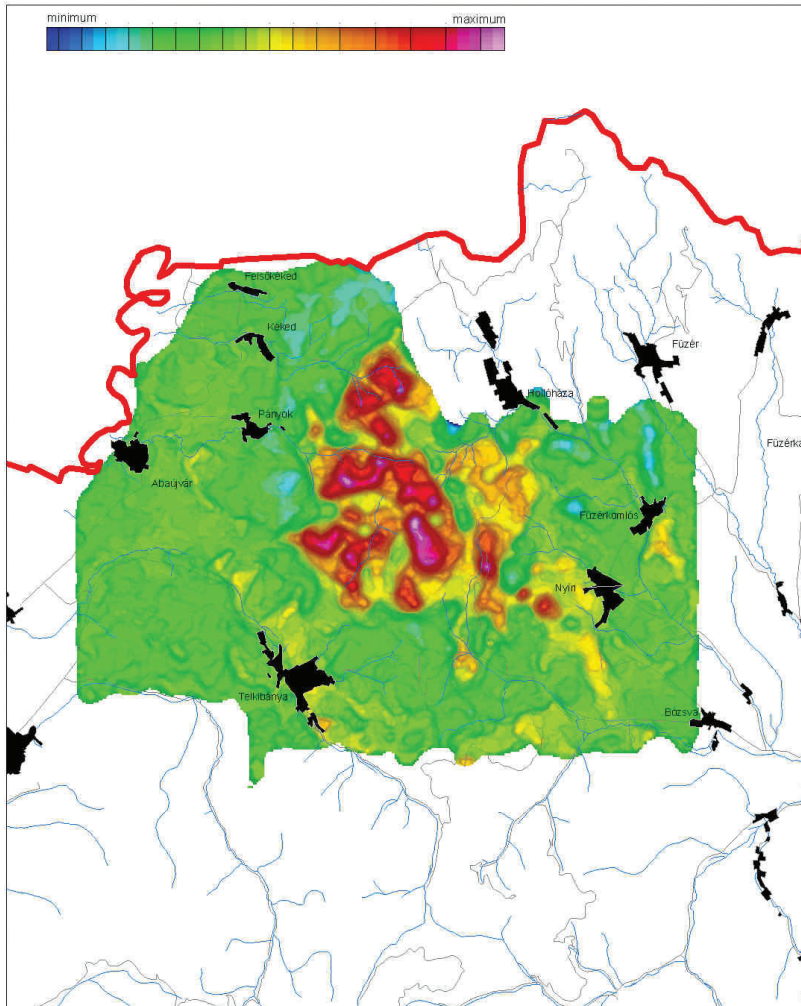


Fig. 6 Potassium map (based on airborne survey of 1997).

The K-metasomatic rock-formations are located in the internal caldera structure. At this part of the area the Th-content gives a minimum zone. This is the place of volcanic series without a considerable amount of volcano-sediment rocks. The external part of the caldera has maximum thorium anomalies because of the surface tuffs (Fig. 7).

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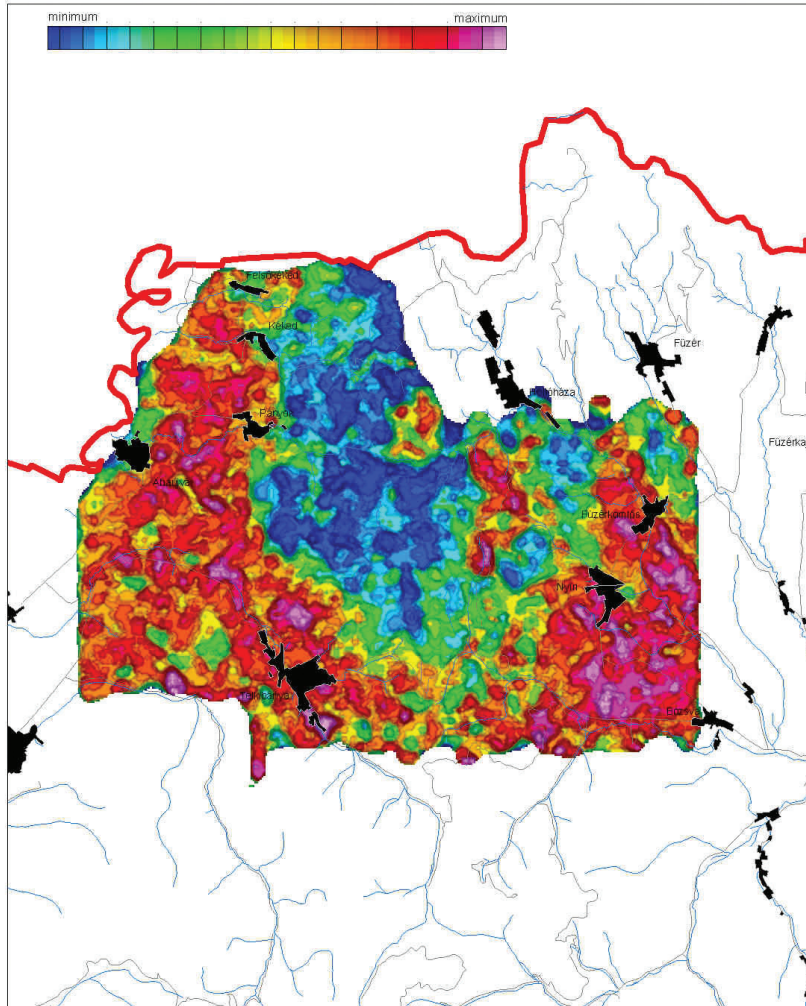


Fig.7 Thorium map (based on airborne survey of 1997).

Based on the results of airborne measurements of 1997, there are local magnetic anomalies inside the caldera structure connected to andesite dykes. Although it is hard to realize these features on the ΔT magnetic anomaly map, these maxima of andesites can be followed very well on the analytical map. There is a good differentiation of mafic and felsic volcanic formations. Using the analytical

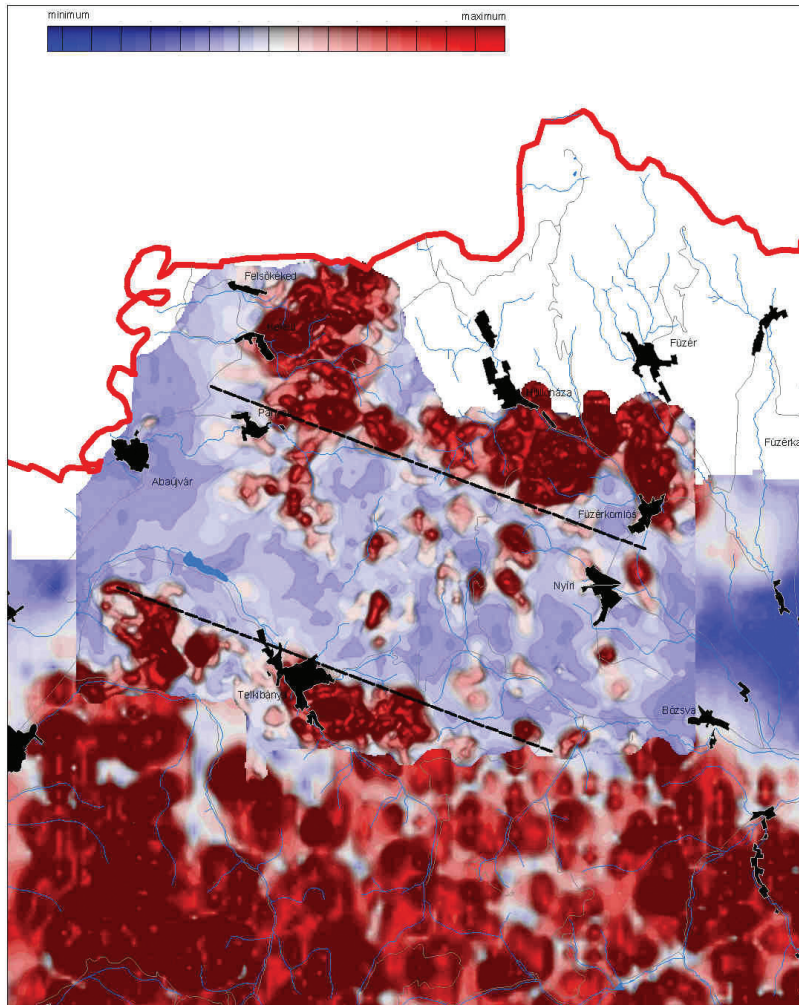


Fig. 8 Magnetic analytical signal map (based on airborne survey of 1967 and 1997).

signal map we can determine two parallel volcano-tectonic lines, one of them South from the Bózsva Creek and another one North from the Nyíri – Pányok axis (Fig. 8). Between these two lines there is a zone with low magnetic gradients, showing altered, more felsic volcanic formations, which are sometimes broken through by thin andesite dykes. Many significant magnetic anomalies show that

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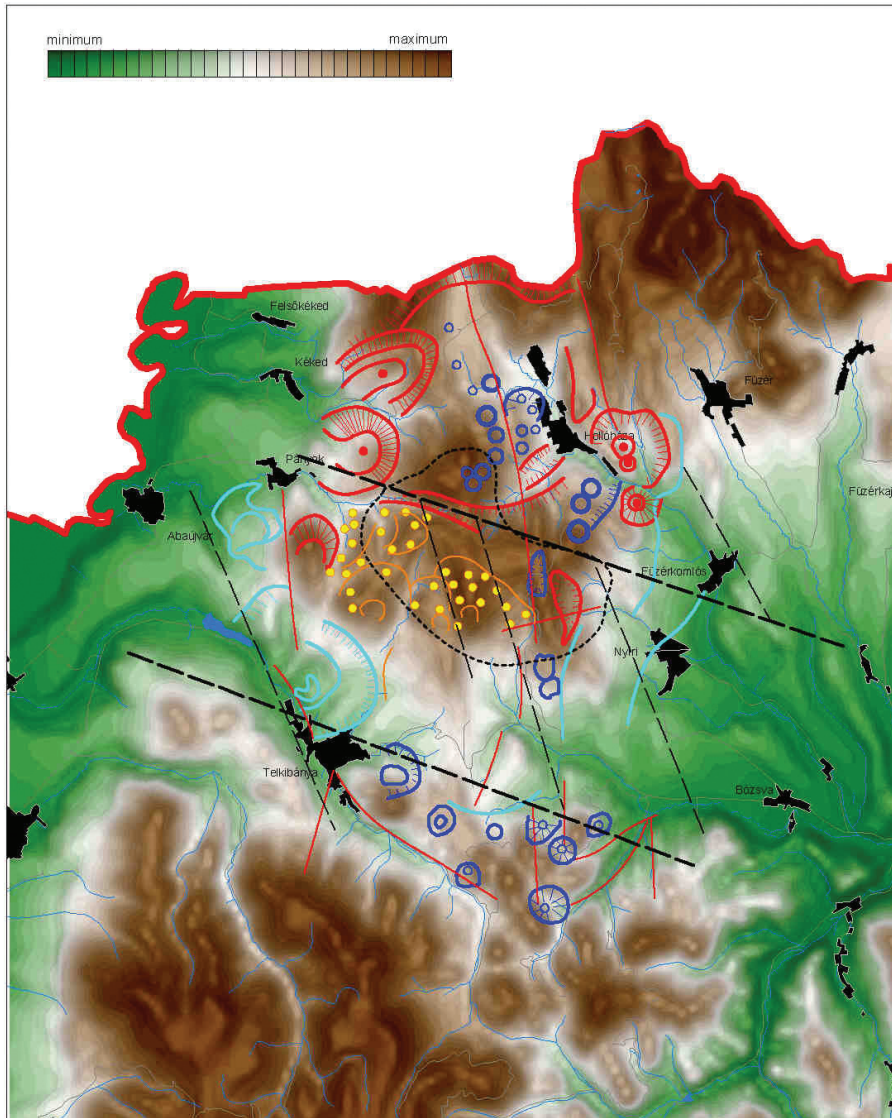


Fig. 9 Volcano-geological interpretation at Telkibánya (red curves: andesites, deep blue curves: rhyolites, light blue curves: tuffs of rhyolites, yellow dots and curves: K-metasomatic formations, red lines: tectonic lines, black lines: volcano-tectonic lines from airborne geophysics).

mafic volcanic rocks are rather typical on both, North and South side of this zone. This map is useful for the differentiation of acidic, intermediate and basic volcanic formations of the area.

Unfortunately the airborne measurements do not cover all of the area so the spreading of the volcanic formations can't be granted from airborne data.

3. GEOLOGICAL INTERPRETATIONAL SKETCH

In 1990 Fegyvári et al. have published a geological interpretational sketch of Telkibánya volcanic structures and formations based on the remote sensing and geological mapping data (it was reinterpreted in 1993 by Zelenka). The comparison of the interpretational sketch with the new geophysical results anyway may be interesting. There were no detailed results of new airborne measurements at the time of making this sketch. This volcano-geological interpretation sketch and the volcano-tectonic lines on the topography are presented on the next Figure (Fig. 9).

There is a good correlation with geophysical anomalies. The WNW–ESE direction volcano-tectonic lines may explain the spreading of different volcanic formations and the North limit of the K-metasomatic processes.

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