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# Airborne Geophysical Measurements in the Transdanubian Central Range (Hungary)

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With 10 Text-Figures and 1 Table

*Ungarn*
*Transdanubisches Mittelgebirge*
*Aerogeophysik*
*Aeroelektrische Prospektion*
*Messungen*

## Inhalt



## Aerogeophysikalische Messungen im Transdanubischen Mittelgebirge (Ungarn)

### Zusammenfassung

In den Jahren 1987–1991 wurden im Bereich des Transdanubischen Mittelgebirges in 10 Meßgebieten sehr detaillierte aerogeophysikalische Messungen (Elektromagnetik, Magnetik, Radiometrie) durchgeführt. Entsprechend den günstigen geologischen und geophysikalischen Bedingungen in den Untersuchungsgebieten konnten wichtige Informationen über verschiedene geologische Formationen und diverse petrophysikalische Bedingungen hergeleitet werden. Die Interpretation der Meßergebnisse beinhaltet sowohl eine regionale Bewertung der verschiedenen Parameterkarten als auch ein genaues Studium von Profildarstellungen zur Beurteilung von lokalen Strukturen.

## Légi geofizikiai mérések a Dunántúli-középhegységben

### Összefoglalás

A dolgozat a Dunántúli-középhegység tíz részterületén 1987-1991 közötti években végzett részletes légigeofizikai (elektromágneses, mágneses és radiometrikus) mérések eredményeit mutatja be. A kedvező geológiai-geofizikai modellnek köszönhetően nagyon fontos földtani információkat és különböző kőzetfizikai jellemzőket sikerült beszerezni. Az értelmezés kiterjedt a különböző paraméter térképek regionális értékelésére és az egyes szelvények szerkezeti kiértékelésére is.

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**Abstract**

Results of detailed airborne geophysical measurements (electromagnetics, magnetics, radiometrics) carried out during the years 1987–1991 over 10 areas of the Transdanubian Central Range are presented. Due to the favourable geological-geophysical model very useful information concerning geological formations as well as different petrophysical features was obtained. Interpretation includes regional evaluation of different parameter maps and studying individual profiles.

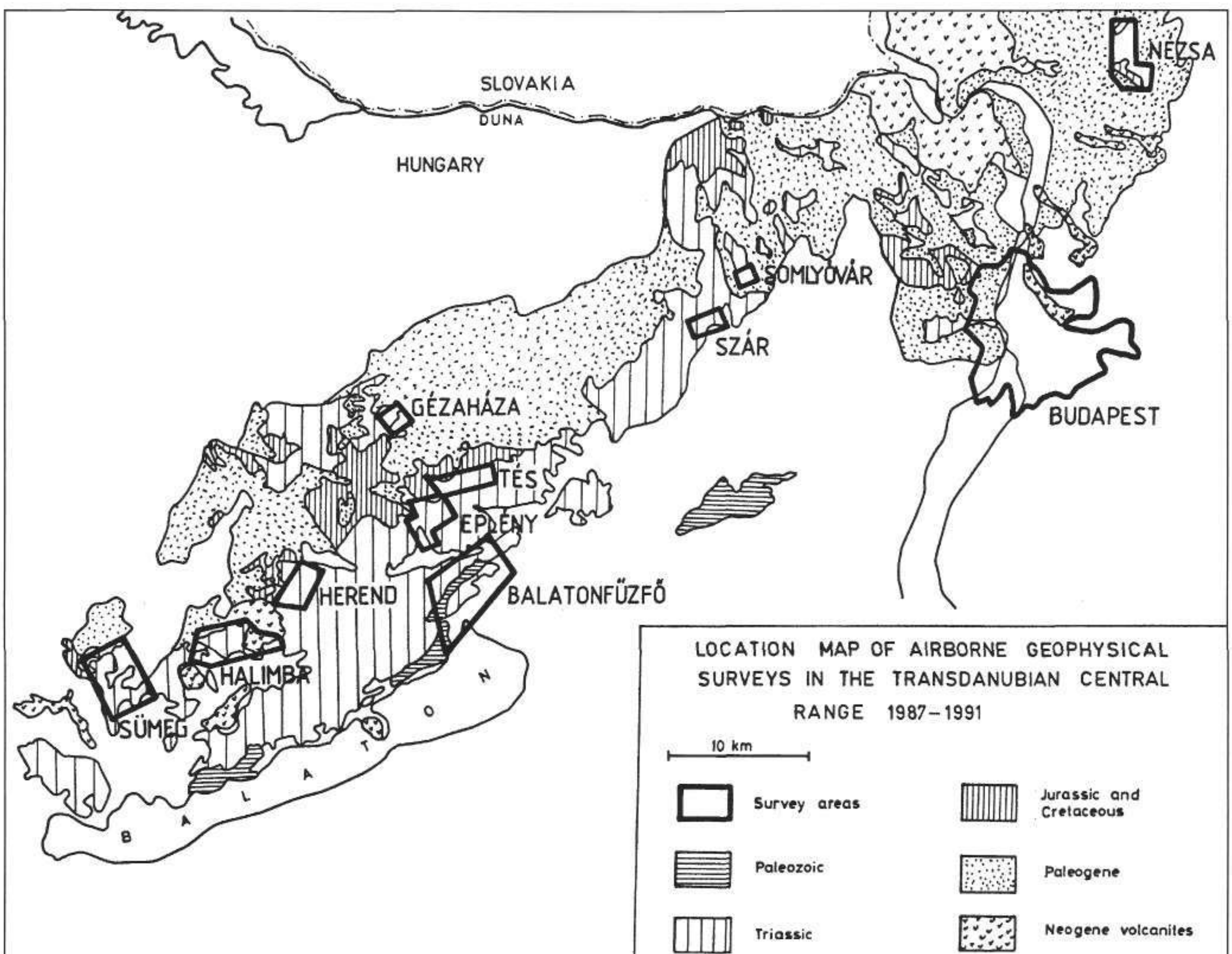
## 1. Introduction

In the course of the cooperation between the Geophysical Department of the Austrian Geological Survey and the Eötvös Loránd Geophysical Institute (ELGI) of Hungary helicopterborne geophysical measurements have been carried out in the Hungarian Transdanubian Central Range since 1987.

Over 10 areas (see Text-Fig. 1) approximately 6500 line kilometres were flown. The aim of the surveys in the areas of Sümeg (1989), Halimba (1989), Herend (1990), Eplény (1990), Tés (1990), Gézaháza (1987), Szár (1987) and Somlyóvár (1987) was a contributuion to the prospection for bauxite lenses located close to the surface. In the area of Nézsa (1991) the measurements were devoted to geological mapping purposes. The small lateral extension of the investigated structures required a dense line spacing which was generally 50 m. Covering the area of Balatonfüzfö by some individual profiles in 1991 served as a contribution to the current environmental studies of the Hungarian Geological Institute.

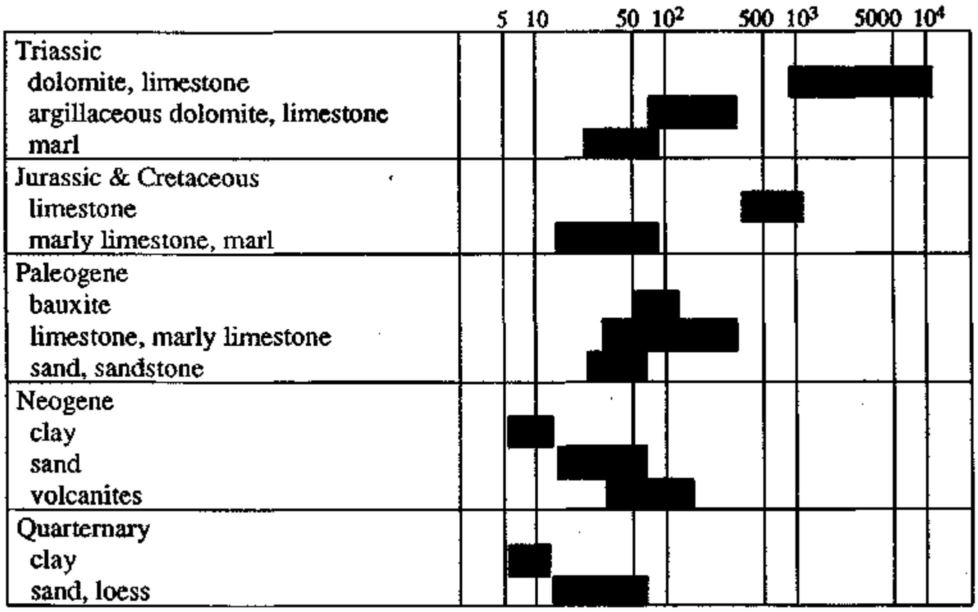
The project has been financed by the Hungarian Aluminium Trust and the Hungarian Geological Central Office. The instrumentation consisting of electromagnetic, magnetic and radiometric probes and a data acquisition system were installed in a MI-8 type helicopter of the Hungarian Army. For the purpose of special processing and interpretation an airborne geophysical research group was established in the ELGI. Results were partly published in the last years (CSATHÓ et al., 1990; GULYÁS et al., 1991, SZILÁGYI et al., 1991).

Due to the complexity of the surveys valuable information relating to the deliniation of the rock formations with different petrophysical parameters has been obtained. Tectonical features could also be determined. In some cases studying individual profiles provides more detailed




Text-Fig. 1.
Location map of airborne geophysical surveys in the Transdanubian Central Range 1987–1991.

Table 1.
Resistivity domains of the main rock types of the investigated areas [ohm·m].




information. Application of digital image processing softwares (construction of superimposed maps, classification and clustering of geophysical data) helped the interpretation of the obtained results.

## 2. Geological-Geophysical Model of the Transdanubian Central Range

The Central Transdanubian Range located north to the Lake Balaton is a syncline with a strike direction of SW–NE (see Text-Fig. 1) and is built up by sedimentary rocks of Paleozoic to Middle Cretaceous age. The syncline is covered by Upper Cretaceous and Cenozoic sedimentary and partly by volcanic sequences. Bauxite lenses are found in tectonically preformed karstic depressions of the Mesozoic carbonates.

The resistivity parameters of the rock types derived from field measurements rather than laboratory investigations are summarized in Table 1. The resistivity contrasts between the different formations make it possible to distinguish areas where the basement with high resistivity is found near the surface and areas of Paleogene and Neogene basins. Moreover, conductive elements of the Mesozoic (marl, marly limestone), can also be delineated if they are covered by thin Quaternary rocks.

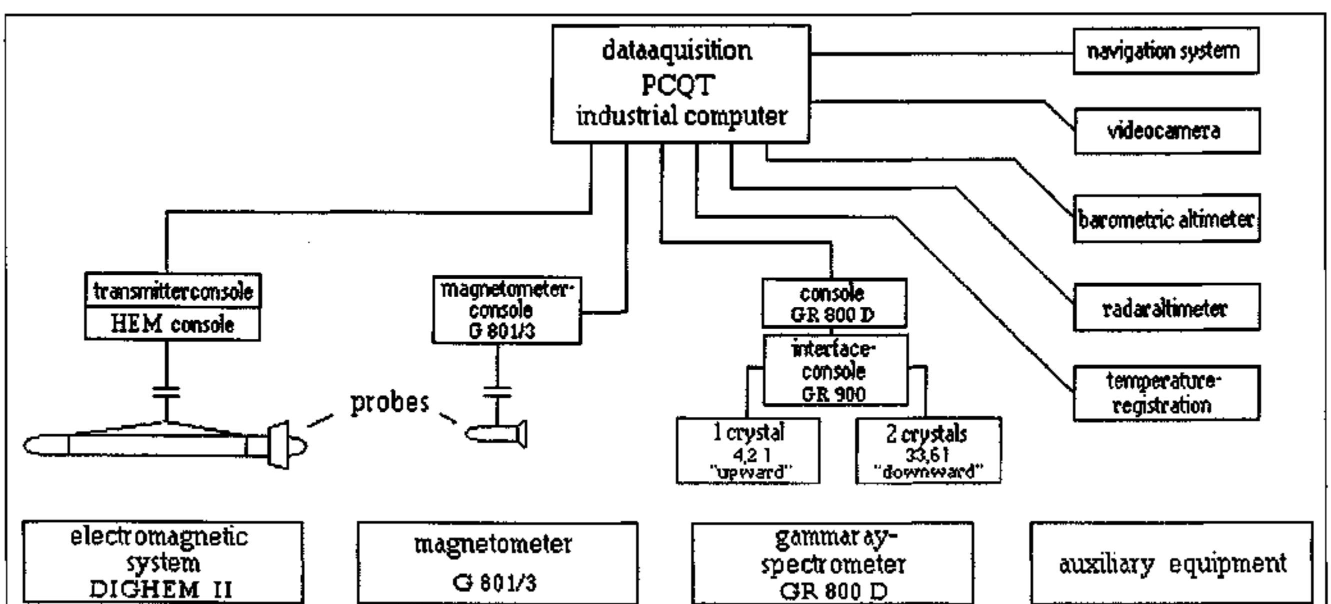
Volcanic bodies produced by the Late Pliocene basaltic volcanism can be detected by magnetic measurements.

Based on the high Thorium (Th) and low Potassium (K) contents of the Hungarian bauxites (Elek, 1984; Nyerges & Mindszenty, 1979) and the high K content of the basaltic rocks (Embey Isztin, 1981) gamma ray spectrometry could provide useful information for the detection of favourable mineralized areas.

## 3. Airborne Geophysical Survey

The aerogeophysical measuring-system used during the surveys in Hungary (a flow-diagram is shown in Text-Fig. 2), consisted of 3 major units:

- **Aeroelectromagnetic (AEM) unit**
  During the surveys in 1987 and 1989 a DIGHEM II AEM-unit consisting of a coplanar coil-system (3600 Hz) and a coaxial coil-system (900 Hz) was used. In 1990 a DIGHEM III unit (32.000 Hz coaxial, 7200 Hz




Text-Fig. 2.
Flow-diagram of the aerogeophysical measuring system.

coplanar, 900 Hz coplanar) was in operation. A similar unit was used during the survey in 1991, with the exception that the 32.000 Hz coil-configuration was also coplanar.
The sampling interval of the in- and outoff-component of the normalized secondary fields was 0,1 second. This means that due to an average surveying speed of 30 m/s, every 3 meters the AEM-data were sampled. This small sampling interval is necessary to recognize natural (e.g. sferics) as well as anthropogenic (e.g.: power lines, radio transmitters) noise in the data.

- **Aeroradiometric unit**
  Two large NaJ-crystal packages (total volume: 33 litres) were used to measure the energy of the gamma rays during the survey in 1987. The energy was recorded in five well selected windows. In the first and second window the energy from 0,2 to 3,0 MeV respectively over 3,0 MeV (cosmic counts) was recorded. In the other windows the energies from the natural radioactive elements Potassium ($^{40}$40), Uranium ($^{214}$Bi) and Thorium ($^{208}$Th) were registered.
  From 1989 onwards an upward-looking crystal (volume 4,2 Litres) was added to the crystal-packages mentioned above, in order to obtain the contribution of radon to the counts measured in the uranium window. Additionally, the spectrometer was improved to register not only the usual energy windows but also two energy spectra (256 channels each) from the downward- respectively upward-looking crystals.
  The sampling interval of all data was 1 second.
- **Aeromagnetic unit**
  To register the earth's magnetic field, a proton magnetometer was used during all surveys. It measured the total intensity of the magnetic field.
  The sampling-interval was 1 second.

In addition to the geophysical instruments a few auxiliary equipments were installed in the helicopter. The most important ones were a radar altimeter and an electronic navigation system.

Reliable geophysical parameter maps and profiles can only be obtained by using modern navigation systems. The detection of bauxite lenses which are economically still valuable in spite of their small lateral extension also requires high precision in positioning.

During the surveys in 1989 and 1990 a MICROFIX multimobile radiopositioning system was hired. The installation of the mobile stations was hampered by many difficulties. Especially the requirement of line of sight between the helicopter and the reference stations was a major problem. The effect of rough topography resulted in relatively high errors in the positioning of the helicopter.

In the most advanced Global Positioning System (GPS) satellites are used for positioning. In 1991 a GPS system (type M/XII, Astech Inc) was used for the first time in an airborne geophysical survey in Hungary. The receiver pair, the navigation computer and the software are suitable for static, pseudo/kinematic and kinematic positioning. A URH transceiver-system was added to provide real/time navigation.

## 4. Data Processing

- **Aeroelectromagnetics**
  From the recorded data and after the application of certain reduction procedures (e.g.: drift, artificial etc) the apparent resistivity and apparent depth is calculated using the homogeneous halfspace model. The former two parameters characterize the electrical conditions in the surveyed area. The apparent depth can be positive, negative or zero. In case of a less conducting layer lying on a good conductor, the apparent depth becomes positive and a very rough estimation of the thickness of the first layer is possible. In the opposite case the apparent depth is negative and represents only a qualitative indication for the conductivity distribution in the surveyed area. If the apparent depth is more or less zero, the homogeneous halfspace model is applicable to the data. Only in case of a homogeneous halfspace, the apparent resistivity corresponds with the true resistivity of the ground. Otherwise it will be only some average value depending on the thicknesses and the resistivities of the different layers of the ground.
- **Aeroradiometrics**
  After applying different corrections and reduction procedures (e.g.: compton scattering, height reduction etc) the corrected data are transformed into chemical equivalent values (eK %, eU ppm, eTh ppm) using sensistivity values, which were obtained from measurements over special calibration pads.
- **Aeromagnetics**
  To separate that part from the aeromagnetic data, which contains the geological information of the surveyed area, time-dependent variations (e.g.: daily variations, secular varation) and a suitable regional field have to be subtracted from the recorded data. The International Geomagnetic Reference Field (epoch 1977,7) was used for the regional correction. All corrected data are presented as maps (e.g.: isolines) as well as profiles.

The huge amount of data, not only obtained from the airborne measurements but also from geological mapping and ground geophysical surveys have to be handled together. Therefore it is necessary to establish a suitable data base and use data base management as well as processing and graphic program packages. In ELGI an airborne geophysical data base have been established on an IBM mainframe computer and on IBM PCs. By means of data base management programs developed in ELGI different types of user-specified selections are available. On the IBM PC not only interpolated parameter maps can be produced but also individual profiles can be studied.

Different graphical software systems and the ILWIS Geographical Information System are used for the representation of different types of data.

Electromagnetic and magnetic modelling programs support the interpretation. The development of two layer inversion programs for airborne EM measurements is going on.

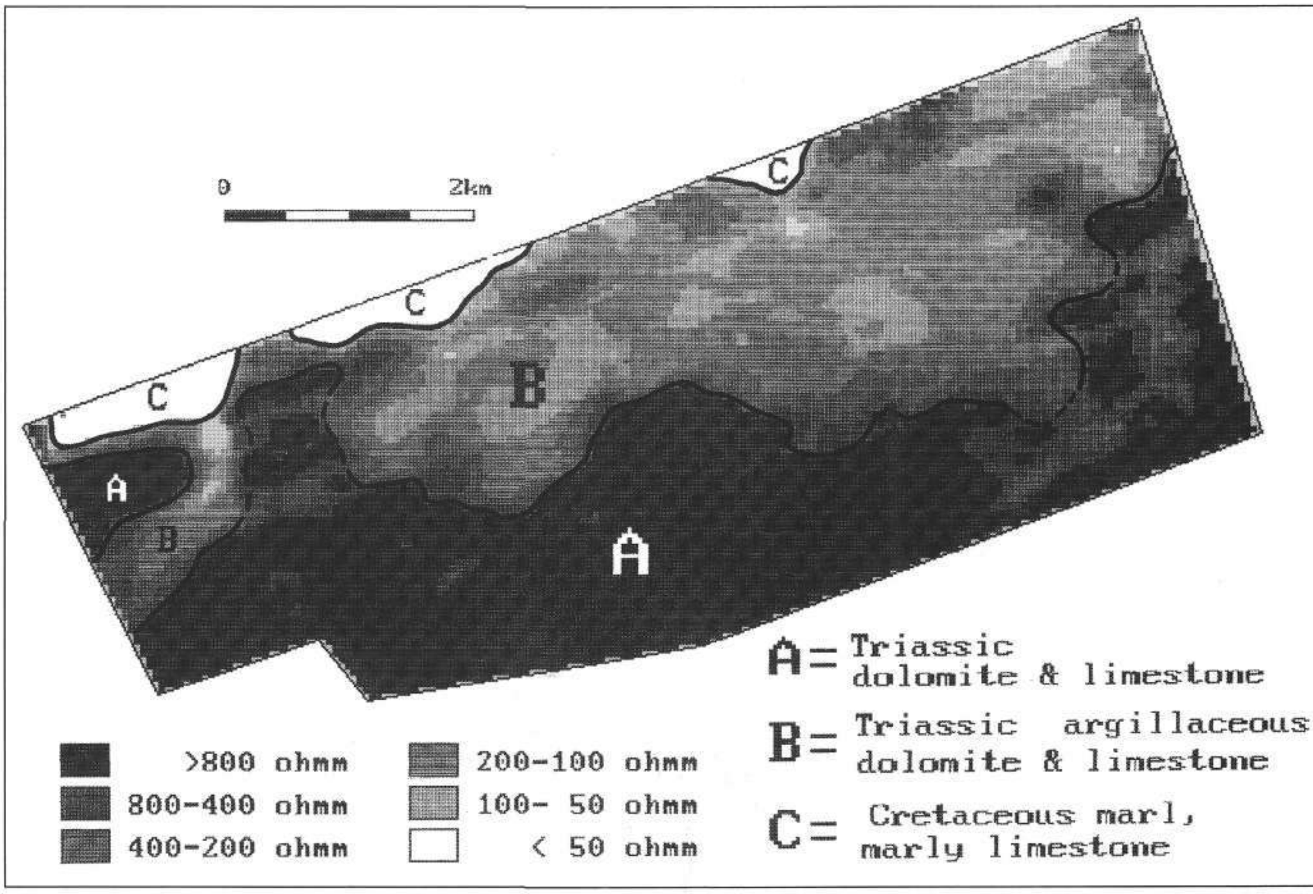
## 5. Results

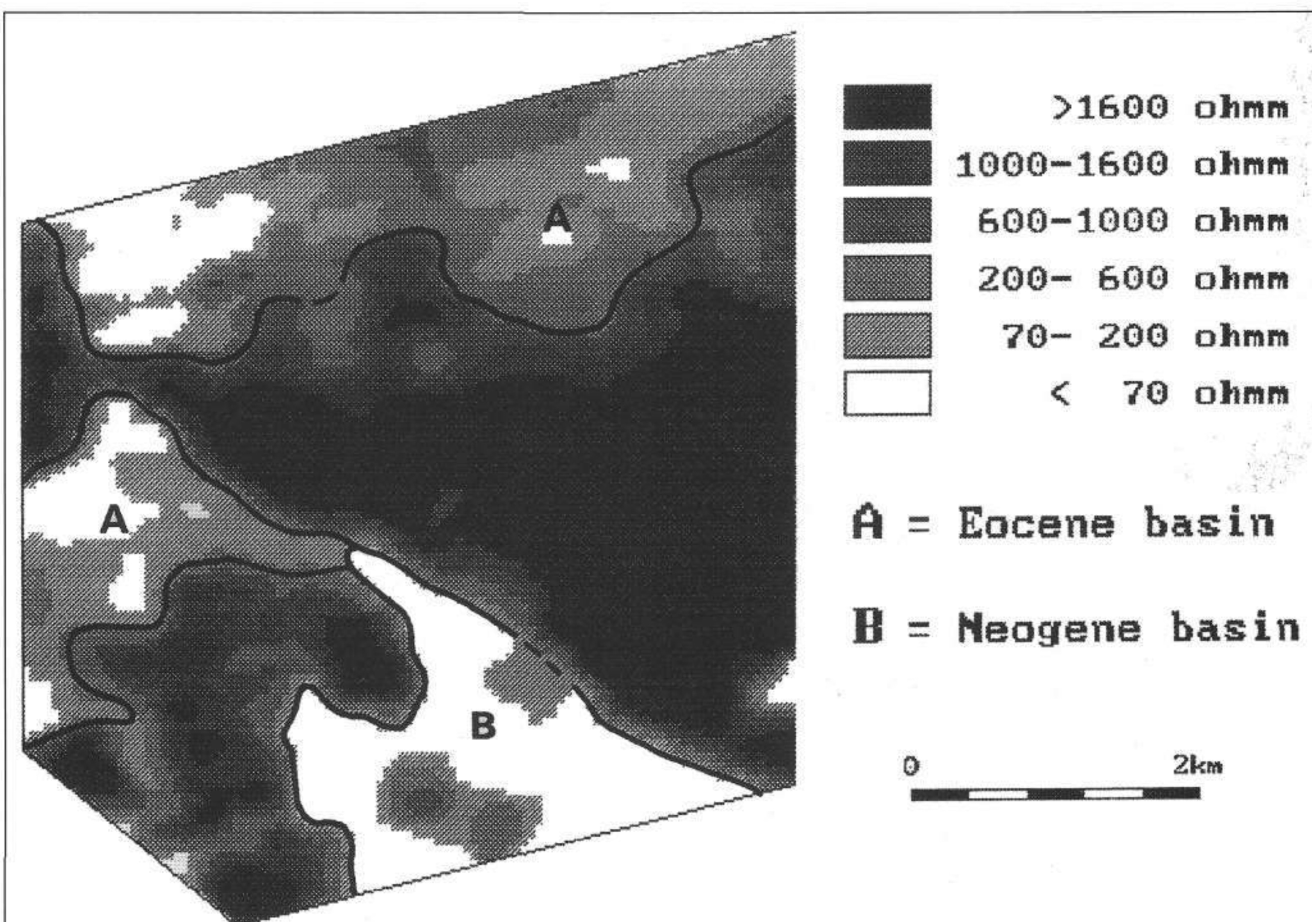
### 5.1. Electromagnetics

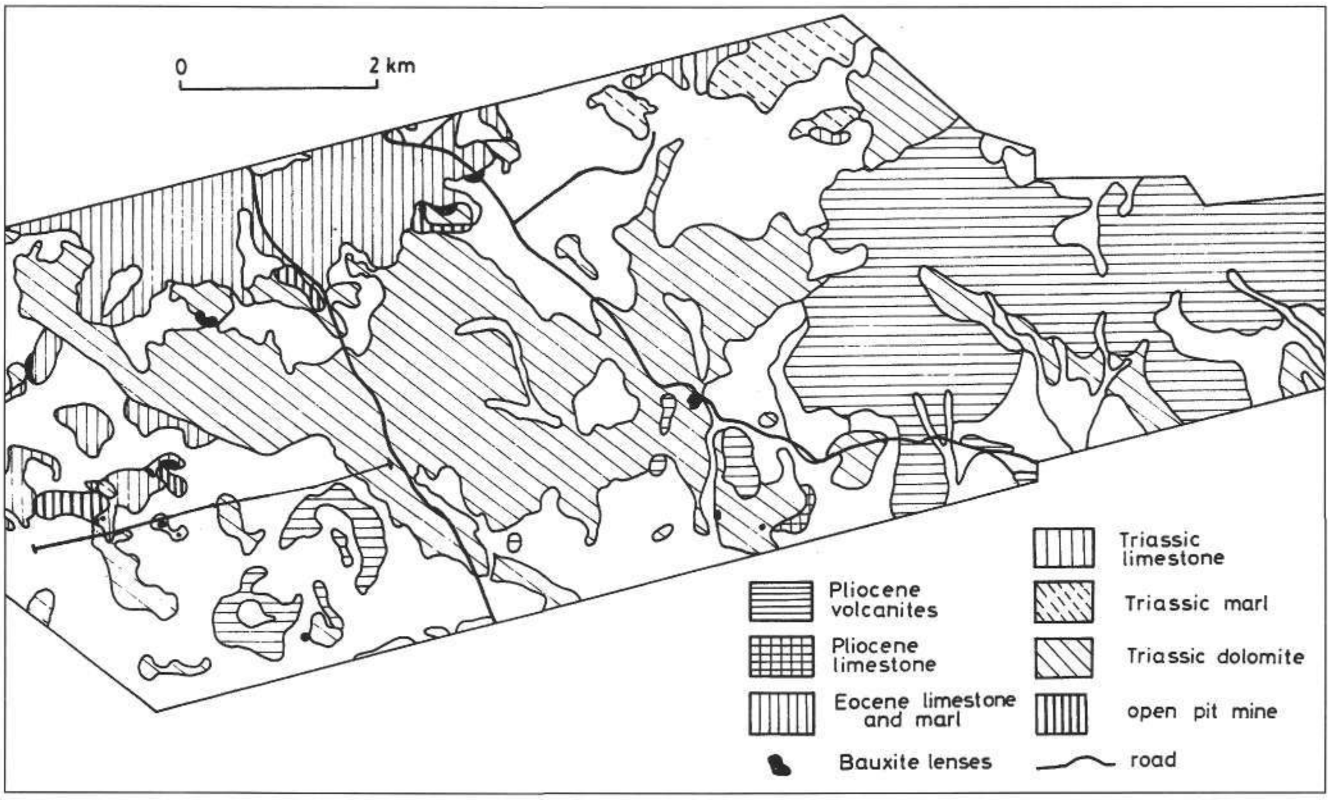
Apparent resistivity data derived from the measured components of the induced electromagnetic field provide

Text-Fig. 3. ⇛ ⇛ ⇛
Separation of Mesozoic Basement by means of airborne apparent resistivity mapping in the Halimba area.

Text-Fig. 4. ⇛ ⇛ ⇛
Separation of Eocene and Neogene Basins by means of airborne apparent resistivity mapping in the Halimba area.

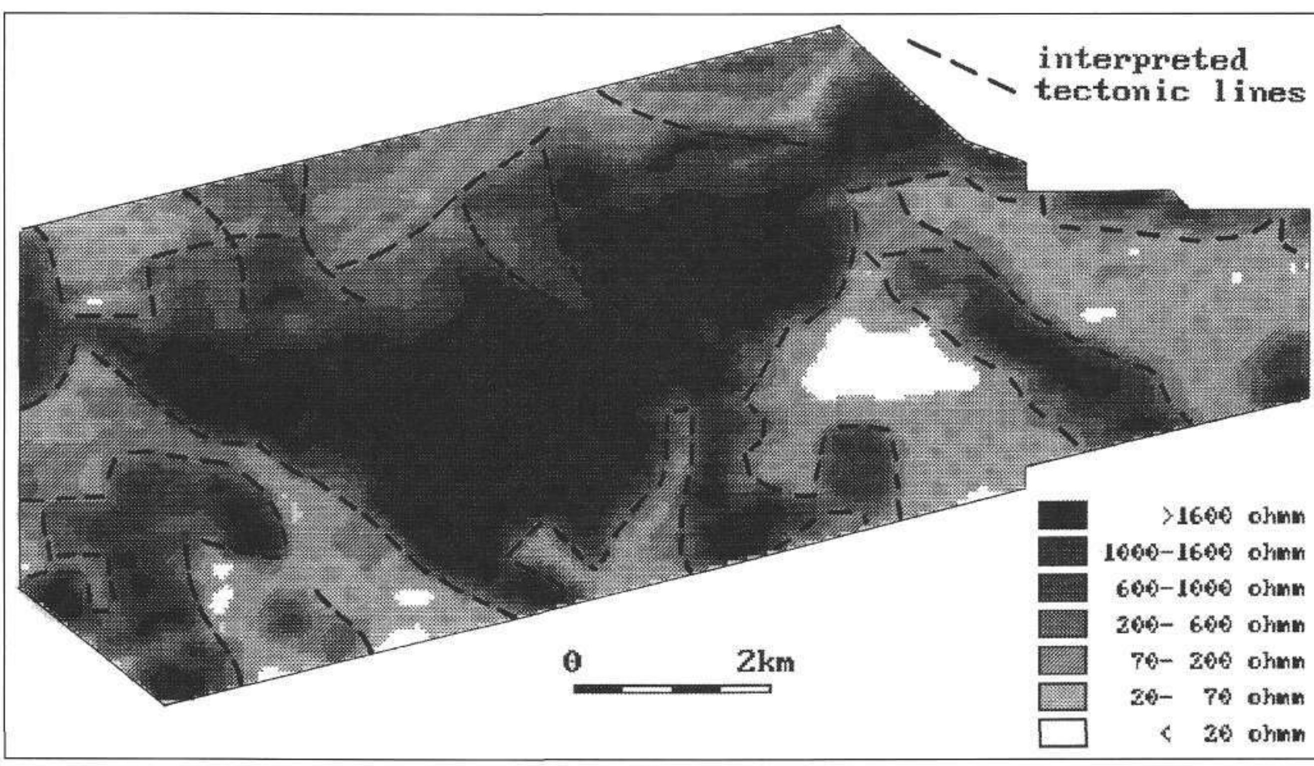

0
2km
C
C
C
B
A
B
A
A = Triassic dolomite & limestone
B = Triassic argillaceous dolomite & limestone
C = Cretaceous marl, marly limestone
>800 ohmm
800-400 ohmm
400-200 ohmm
200-100 ohmm
100- 50 ohmm
< 50 ohmm


A
A
B
>1600 ohmm
1000-1600 ohmm
600-1000 ohmm
200- 600 ohmm
70- 200 ohmm
< 70 ohmm
A = Eocene basin
B = Neogene basin
0
2km




Text-Fig. 5.
Geological map of the Halimba area.

qualitative information about the geological features of the areas. If the geological sequence can be considered as uniform above the investigation depth, the apparent resistivity transformation corresponds to the real resistivity distribution of the formation below the surface. If the geological sequence consists of at least two layers with different resistivities, the values of the apparent resistivity depends on the resistivities and thicknesses of the layers located above the investigation depth. Considering the geological model (generally: Cenozoic series overlying a Mesozoic basement) and the resistivity values of the rock formations (Table 1) it is obvious that the decrease of the




Text-Fig. 6.
Tectonical evaluation of apparent resistivity map of the Halimba area.

apparent resistivity can be correlated with a decrease of the resistivity of the Mesozoic basement and/or to an increase of the thickness of the conductive Cenozoic cover.

When the rock formations of the Mesozoic basement with different resisitivities are covered by thin Cenozoic sediments, which are not significantly varying in their thickness and resistivity, the delineation of former units can be obtained by means of electromagnetic mapping. In the area of Tes it is known from the results of previous geological mapping and the data of boreholes (Text-Fig. 1) it is known that Quaternary loess overlies the Triassic complex, which consists of dolomite, argillaceous dolomite-limestone, limestone beds and Cretaceous marl or marly limestone.

Considering the resistivity domains (see Table 1) of these formations, zones of the apparent resistivity map (Text-Fig. 3) characterized by high ("A"), medium ("B") and low ("C") values can be interpreted as Triassic dolomite, argillaceous dolomite-limestone, and Cretaceous marl, marly limestone respectively. Determination of the rock types building up the basement has a great importance in respect of bauxite prospecting. The possibility of karstification is decreasing with the increase of clay content. That is why zone "A", where high apparent resisitivity indicates dolomite, the basement can be qualified as the most promising area for finding primary bauxite bodies. Local resistivity minimums and embayments at the border of the zone might refer to structures containing the ore. Naturally resedimented bauxite can also occur over the less advantegeous basement but their detection is more difficult.

In case of a homogenous basement with high resistivity, apparent resistivity changes are caused by the lateral inhomogeneities both in thickness and conductivity of the cover. In the western part of the area Halimba (Text-Fig. 1) Eocene limestone-marly limestone as well as Neogene clastic series (clay, sand and gravel) overlie the Triassic dolomite basement (Text-Fig. 5). Studying the apparent resistivity map of the area (Text-Fig. 4) – due to the resistivity contrast between the Eocene and Neogene sequences (see Table 1) – the Eocene and Neogene basins can be distinguished. In the interior of the basins where the series are assumed to be electrically homogenous, zones with high resistivity can be interpreted as regions where the Triassic dolomite is covered by thin rock formations.

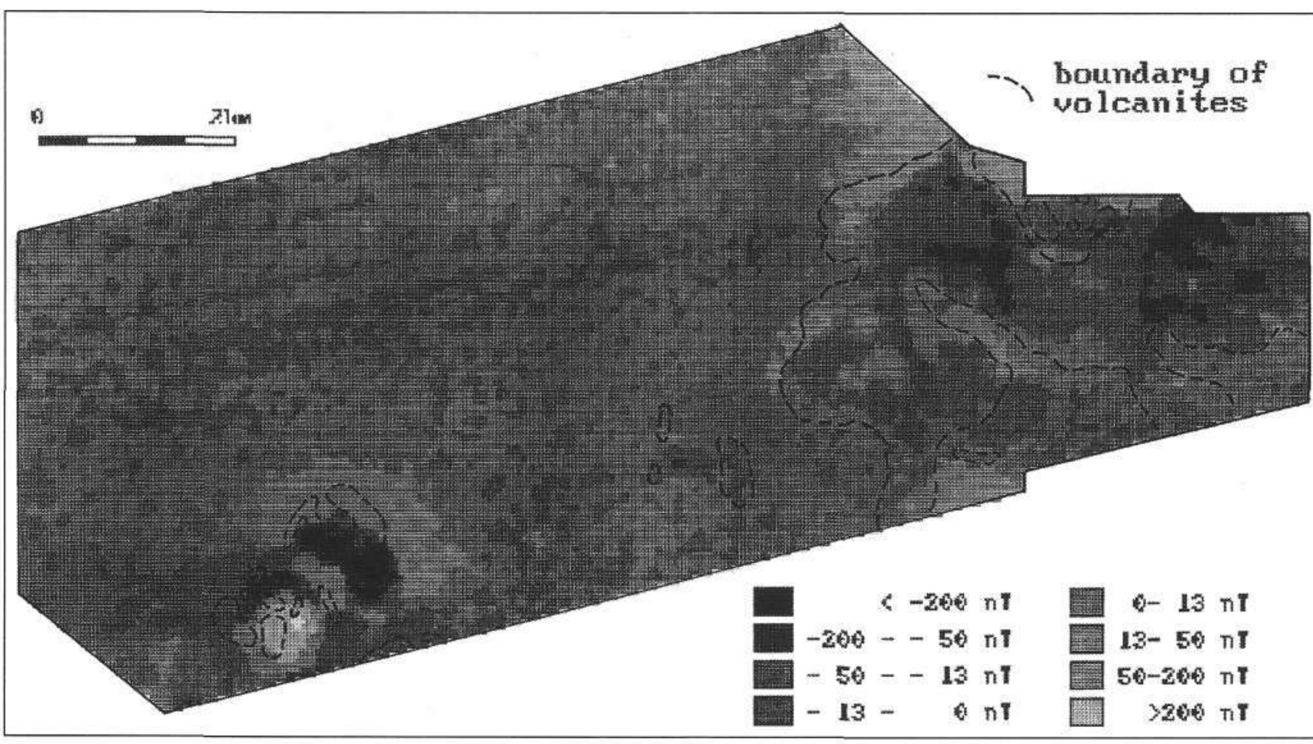
The apparent resistivity maps can also be used for tectonical evaluation. Abrupt changes of the apparent resistivity in the parameter map mark significant tectonic lines of the area separating formations with conductivity contrasts. A tectonical interpretation of the apparent resistivity map of the Halimba area is presented in the Text-Fig. 6.

### 5.2. Magnetics

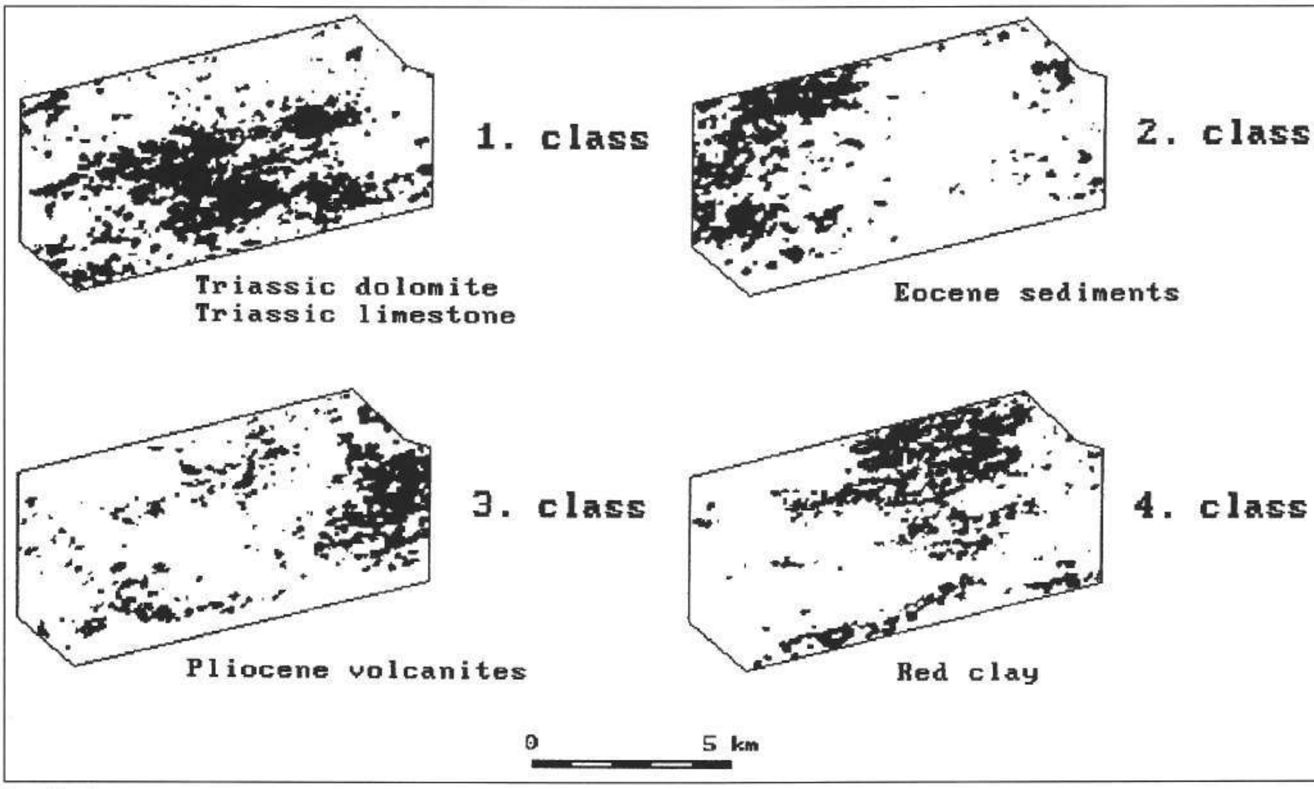
Changes of the total magnetic field data caused by the presence of formations with high magnetic susceptibility can be detected by magnetic surveys. In the southern part of the Halimba area (Text-Fig. 1) Neogene series embody Upper Pliocene volcanites with high susceptibilities. The total magnetic field map of the area can be seen in the Text-Fig. 7. Considerable magnetic effects were only detected in the south-west and in the east, where Pliocene basaltic rocks are located. The anomalies in the southwest indicate at least two parts of almost isometric magnetic bodies. The results of magnetic survey suggests that the basalt eruption occured within two phases of polarity. In the eastern part of the area the low intensity anomaly with large horizontal extent can be interpreted as an effect of a basaltic layer.

### 5.3. Radiometrics

By processing the natural $\gamma$-ray energies measured at the proper energy windows equivalent K, U and Th con-




Text-Fig. 7.
Total magnetic field map of the Hlimba area.




Text-Fig. 8
Classification result from the Halimba area using the radiometric parameters (eU, eTh, K).

centration maps can be obtained. Considering the fact that the method provides information from the uppermost 10–20 cm of the soil it may only be used indirectly for geological interpretation. The thickness of the soil cover (due to weathering processes) usually varies from 10 to 100 cm. If it was not eroded or resedimented, the measured $\gamma$-ray values may correspond to the content of radioactive elements of the host rock.

Thorium is one of the most important trace elements of rocks. As Thorium may be incorporated in the crystal lattice of some heavy minerals, placer deposits can be characterized by higher thorium counting-rates. During the allitic weathering processes producing bauxites the relatively immobile Thorium can be concentrated in bauxite lenses. In the direct prospecting of the Hungarian bauxites the relative increase of the thorium can be qualified as a reference to the location of the ore. The relation between the Th-content and the quality of the Hungarian bauxites was examined by NYERGES et. al. (1979). Nevertheless general conclusions studying just this parameter map can not be drawn.

The equivalent Thorium map of the Eplény area (Text-Fig. 1) is depicted in Text-Fig. 9. The Th-maximum "A" is related to known outcrops of bauxitic material. The Th-maximum "C" is associated with the bauxite mine Alsópere. Other Th-maxima (eg "B") were controlled by insitu radiometric measurements, and some of them have been suggested for drilling.

For interpretation the results of geological mapping and borehole data were also considered. Cenozoic basins are clearly marked by apparent resistivity minima. Lower values over the Pliocene basin ("A") were detected than over Eocene sequences ("B"). Because of the relatively low resistivity contrast between the Eocene limestone and the Triassic dolomite (see Table 1) in Eocene basins the resistivity profiles do not reflect the topography of the basement sufficiently. The fault zone separating Pliocene and Triassic formations (I) caused an abrupt decrease in the apparent resistivity curves, whereas the delineation of fault zone II – located between Eocene and Triassic units – is more difficult because of the facts mentioned above. Local apparent resistivity minima within high resistivity environments ("a", "b") may be associated with shallow depressions of the Triassic basement located near the surface.

Relative increases of the Th- concentration are caused by the bauxitic sediments derived from an open pit mine. High potassium concentrations at the same site may suggest significant clay-contents of the bauxite lenses. The potassium high can also be explained by human effects (fertilizers).

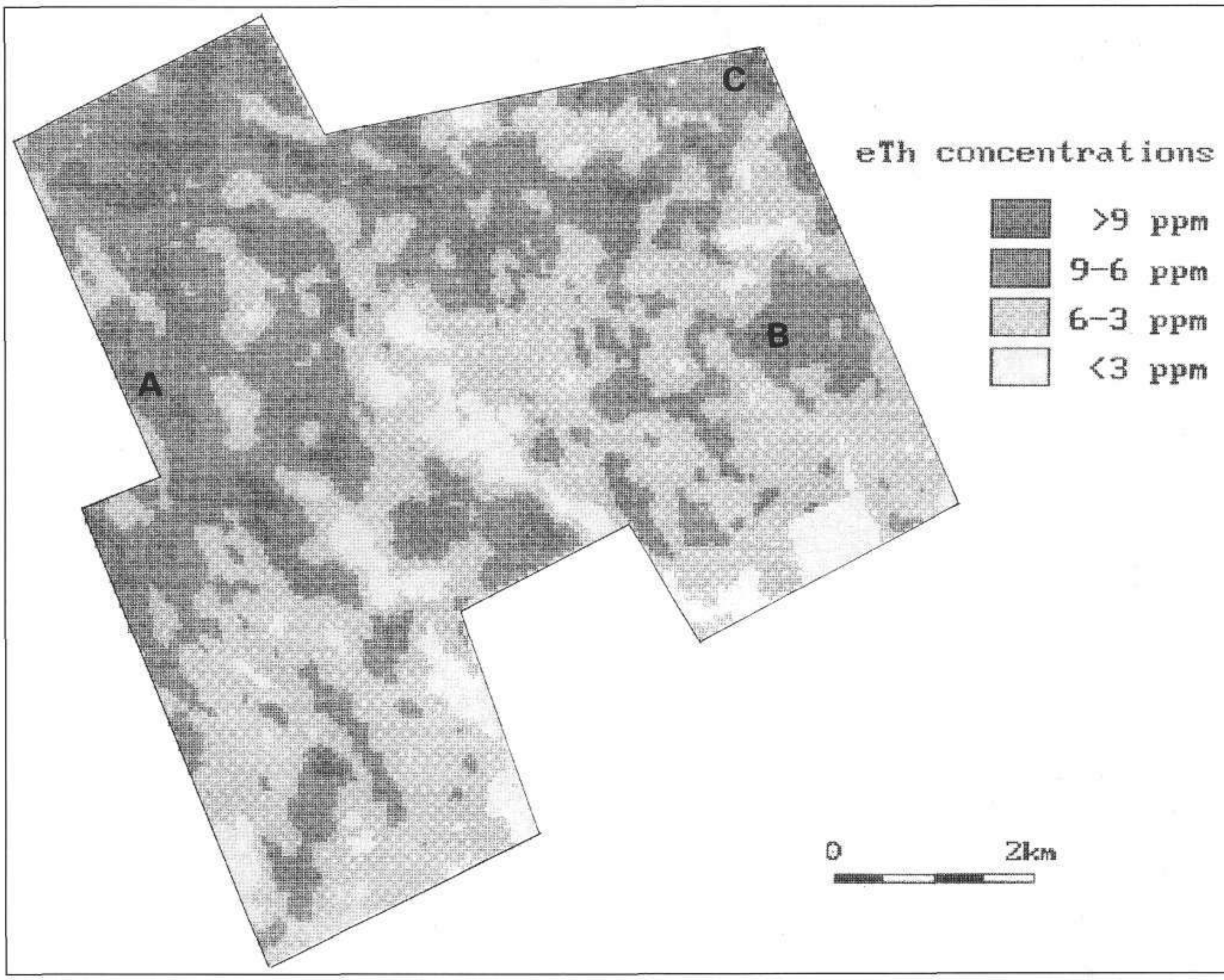
The correlation of the maxima of the total magnetic field and the Potassium concentration curves in the east can be associated with the presence of basaltic volcanites in the vicinity.

## 5.4. Cross sections

By studying individual cross sections more detailed interpretations are possible. An example is shown in Text-Fig. 10. The location of this cross section can be seen in the geological map of the Halimba area (Text-Fig. 5).

## 5.5. Digital Image Analysis

The application of image processing in the analysis of data sets obtained with non image systems, especially with different geophysical and geochemical methods has expanded rapidly in the last few years. At ELGI the first image processing experiments were made on airborne geophysical data (GULYÁS et al., 1991).



Text-Fig. 9.
Equivalent Thorium concentration map of the Epleny area.

After encouraging results ELGI has bought an ILWIS program package. It is a useful tool for the integration of different types of gridded data (remote sensing, geophysical etc) and the image processing of them. In addition ILWIS is an up-to-date Geographical Information System.

Using image processing methods the quality of the airborne geophysical maps can be improved; different types of geophysical parameter maps can be handled together and can be transformed to easily interpretable integrated maps (colour composites, cluster maps etc).

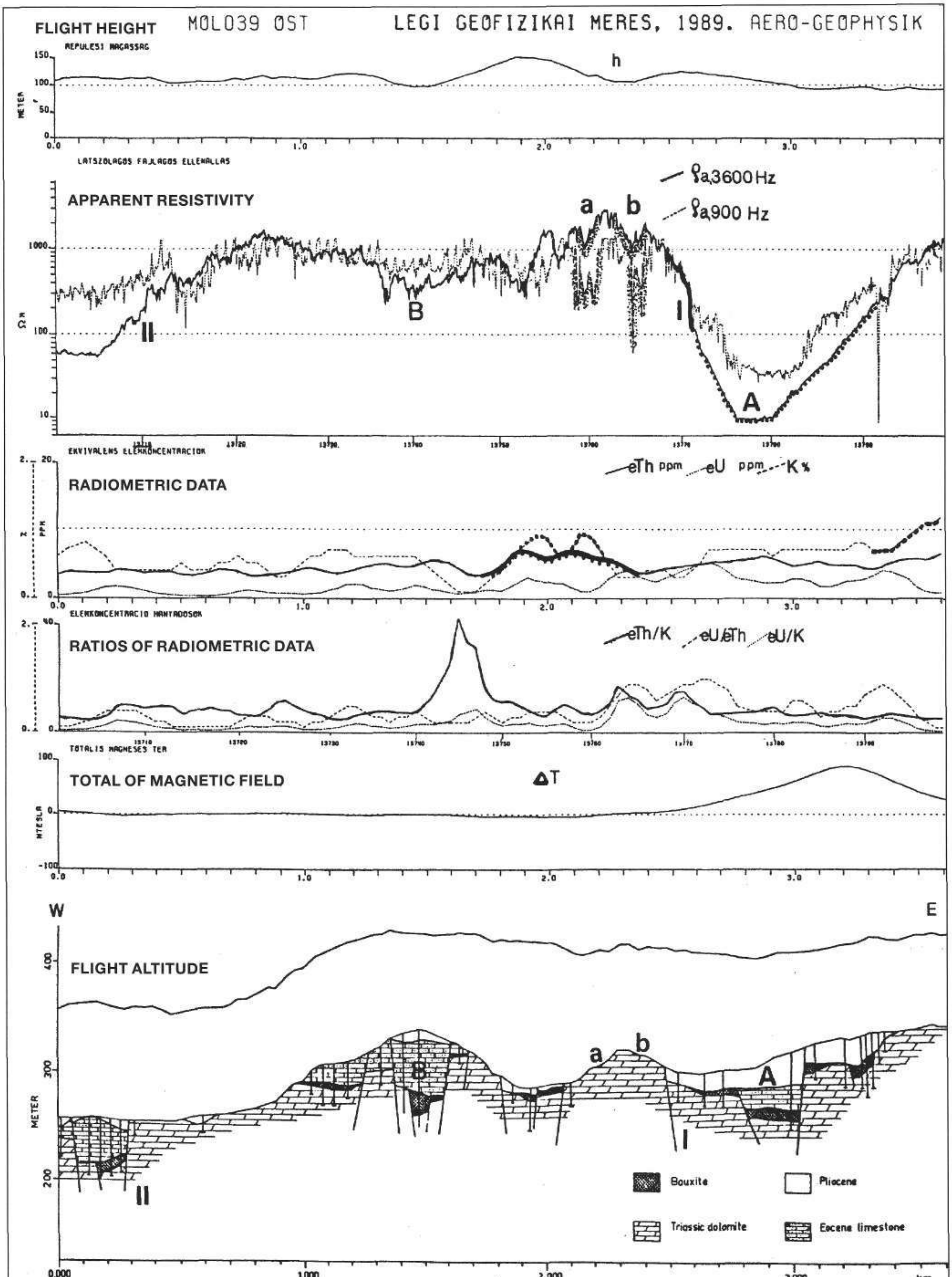
The effectiveness of these methods is illustrated by the result of a supervised classification using the radiometric parameters (eU, eTh, K) from the Halimba area. The representative study areas were chosen on the geological map of the area (Text-Fig. 5). Based on these four classes were distinguished in the studying areas: Triassic dolomite and limestone (1. class), Eocene sediments (2. class), Pliocene volcanites (3. class) and red clay and bauxitic material (4. class) – see Text-Fig. 8.

Comparing the results with the geological map, the DTM (digital terrain model), airial photos, satellite images and borehole data the following conclusions can be drawn: In areas where the different rock formations are outcropping, the result of classification shows good coincidence with geological evidences. The areas with thin Quarternary cover were classified into different classes according to the bedrock type. Misinterpretations occured mainly in the case of the 3. class, because both alcalic basalts and fertilized agricultural areas are characterized by a high Potassium content.

As the individual channels of radiometric parameters are not suitable for geological interpretation the image processing has a great importance in handling those data.

## 6. Conclusions

Contour maps obtained by airborne geophysical measurements can be successfully applied both for regional geological mapping and bauxite prospecting. Qualitative interpretation of the parameter maps has been achieved at the present stage of the project. Quantitative information is expected from the comparison of the results of the detailed airborne survey stored in a data base and the data of the some thousand boreholes of the surveyed areas. Interpretation of the airborne geophysical profiles by interactive EM and magnetic modelling methods is also in progress. The result of these activities supported by field and laboratory measurements can improve the methodology of the airborne measurements and yield new ideas for the interpretation of the aerogeophysical data.




Text-Fig. 10.
Interpretation of profile data.

## Acknowledgments

The results described above were obtained by a group of Hungarian and Austrian scientists.

Many of our colleagues have been involved in field measurements, data processing and interpretation. We thank all of them especially Ms. Márilla BODROGI – the leader of the Halimba and the Eplény surveys – for their considerable effort within this project.

## References

CSATHÓ, B. et al. (1990): Application of airborne measurements for bauxite prospecting in a sedimentary environment in Hungary. – Paper presented in 52nd EAEG Annual Meeting, Copenhagen, Denmark.

ELEK, I. (1984): Contributions aux recherches radiogeochimiques des bauxites hongroises. – Bulletin Hungarian Geological Society, **114**, No.3, 321–334, Budapest.

EMBEY ISZTIN, A. (1981): Statistical analysis of major element patterns in basic rocks of Hungary: An approach to determine their tectonic settings. – Bulletin Hungarian Geological Society, **111**, No.1, 43–58, Budapest.

GULYÁS, A. et al. (1991): Interpretation of airborne geophysical measurements in sedimentary environment by image processing. – Paper presented in 53rd EAEG Annual Meeting, Florence, Italy.

NYERGES, L. & MINDSZENTY, A. (1979): Investigation of characterictics of bauxite beddings by means of geophysical measurements and their importance for industrial bauxite exploration. – Magyar Geofizika, **20**, No.5, 161–167, Budapest.

SZILÁGYI, I. et al. (1991): New results of airborne measurements for bauxite prospecting in Hungary. – Paper presented in the Third Mining Symposium, Isfahan, Iran.