1 GEOPHYSICAL PROSPECTING

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The field work of ELGI for 1986 is presented in the map of *Fig. 1.*

From among the most important projects of the past years two programmes of northern Hungary have been completed (the ore exploration of the Mátra Mts and the regional structural investigation of the Aggtelek–Rudabánya hills), and the regional geophysical exploration of the Bükk Mts and surrounding areas commenced. The *reconnaissance bauxite exploration* has been extended to the area of the Villány hills. Here the task is to delineate the bauxite occurrence, known since the early 30s, and to make a prognosis for further bauxite deposits. In 1986, geophysical measurements were carried out in the southern and eastern foreground of the Szársomlyó hill. A gravity network of 9–10 station/km^2 was completed. The Bouguer anomaly map was constructed with $\sigma = 2.0$ g/cm^3 Bouguer correction. From the filtered anomaly maps the one with $\varkappa = 4$ is presented in *Fig. 2*. The depth to the Mesozoic basement known from boreholes correlates well with the residual anomalies. Exploratory boreholes were drilled on seismic profile Vá–2, but neither of the two holes reached bauxite. The time section of profile Vá–2 coloured according to amplitude strength is presented in *Fig. 3.* From the Hilbert transform variants the instantaneous amplitude section is shown in *Fig. 4.* In the central part of the profile the zone of low instantaneous amplitude and SSE dip is interpreted as the interface between Jurassic and Triassic limestone blocks.

Reconnaissance bauxite exploration was carried out in the following areas of the Transdanubian Central Range: Bakony-South, Tapolcafő, Gerecse-SE, Bajna–Epöl, Felsőgalla–Tornyó, Gyermely and Szomor. From these areas two case histories are presented. In the *Bakony-South area* the task was to determine the methodology for the reconnaissance survey. The experiments were carried out on four localities where, in 1986, 6 parameter drillings were executed by the Bauxite Exploration Enterprise. The locality of Diszel was used for carrying out potential mapping *(Fig. 5/a)* and Maxi-Probe frequency soundings *(Fig. 5/b)*. It was concluded that the conductance anomalies of the PM map are not caused by the changes in thickness of the overburden but by its resistivity variations. As a result of experimental measurements we could set up the geophysical model of the area and elaborate the exploration strategy.

Maxi-Probe sounding profiles were planned for the Gyermely locality using the results of the gravity survey of 100×100 m network of 1985. The task was to delineate the trough known from gravity data. In *Fig. 6*, above the Maxi-Probe electromagnetic section, the Δg and three different filtered profiles are plotted. The best correlation with the electromagnetic data is to be found in the case of $\varkappa=3$, therefore this map can be used to determine the strike of faults found in the e.m. sections.

In some areas of the Transdanubian Central Range, brown coal and bauxite are to be found at different levels. One of these areas in the Bajna–Epöl area for which a combined reconnaissance plan was prepared by the Hungarian Geological Survey and ELGI. In the first phase a gravity survey was carried out over a network of 100×100 m, to get an overview of the main structural directions. From the results the filtered anomaly map ($\varkappa=3$) is presented in *Fig. 7*. From the gravity maps (Bouguer and residual) an optimized depth to basement map was constructed by fitting their combination to borehole and depth determining geophysical data *(Fig. 8)*. The basic assumption for this operation is that the overburden is of constant density. In the present case this condition is not fulfilled since the steps in the basement topography are accompanied by pinch-outs and facies changes in the overburden. We have supposed that the difference between input and computed depth values—at the site of the input data—will reflect the density changes of the overburden. For example, the limestone facies of the Eocene, which is of great importance for both bauxite and coal exploration, should manifest itself by density increase. The difference map *(Fig. 9)*, however, does not show the expected correlation with the areal distribution of the calcareous Eocene—at least based on our present knowledge. Further experiments should help to solve the problem. A few parameter holes were drilled in the area, one finding good quality brown coal, and grey bauxite. *Fig. 10* presents the Maxi-Probe e.m. profile crossing this borehole. The dip of the coal seam is the same as that determined from cores (30°).

The *reconnaissance survey for Eocene brown coal in the Transdanubian Central Range* was continued in two areas in 1986. On the Mór-North area a gravity survey was carried out over a network of 200×200 m. Its residual anomaly map is presented in *Fig. 11*. On the Lencsehegy-South area—as boreholes had proved the presence of brown coal—the seismic reflection survey was continued *(Fig. 12)*. From the VIBROSEIS® profiles (of 14 sec long combisweeps), the one crossing the centre of the area is presented in *Fig. 13*. In the foreground of the main fault, we suppose—by analogy—the presence of the coal-bearing formation.

The programme dealing with the *regional exploration of the Danube–Rába* *lowland* continued according to plan. The progress that has been made in various geophysical surveys is shown in *Fig. 14*. From the results, comprising three depth ranges, two are reviewed. The structural analysis of the basement is the task of the combined telluric-magnetotelluric survey and of the seismic reflection profile spanning the whole basin. The isoarea map of the telluric survey, together with the anisotropy ellipses, is presented in *Fig. 15*. There is a good correlation between the telluric and the gravity maps on the whole area, except south of Kőszeg. It can be supposed that here the outcropping basement has a decreased resistivity whereas everywhere else the basement has high density and resistivity compared with the overburden. Magnetotelluric soundings follow the telluric survey by a few map sheets. Their results, together with those of former years, are presented in *Fig. 16*. The geoelectric basement seems to correlate with the surface of the Palaeozoic rocks, judging from the boreholes of Mihályi, Takácsi, Tét and Mosonszentjános. It can be supposed that resistivity values of 30–100 Ωm correspond to Palaeozoic in the deep basin too, while on the SE part of the profiles, resistivities higher than 100 Ωm refer to Mesozoic rocks. There, in the basement, appears the conductive layer of the Transdanubian Central Range.

As part of the structural analysis, a 70 km long seismic reflection profile was shot across the basin (for location see Fig. 14). On the western end of the profile the basement consists of the crystalline schists of the Sopron hills belonging to the lower East-Alpine nappe system *(Fig. 17)*. At picket 6 km, one can see the flattening continuation of the Mihályi elevation. Between pickets 20 and 23 km, at a depth of 6–6.5 km, we marked the possible causative body of the 220 nT magnetic anomaly of the Szigetköz. The greatest depth of the basin can be estimated as 8.5–9 km. Between pickets 42 and 50 km, there appears an extremely deep trough. Further SE the seismic character of the basement is quite different. The faults accompanying the southeastern margin of the trough form a typical flower structure, penetrating into the youngest sediments. We identify this zone as the Mesozoic–Palaeozoic contact, i.e. the Rába line. The magnetotelluric soundings yield depth data that correlate fairly well with the seismic. At two points at the SE end of the profile, the discrepancies refer to the appearance of the marls of the Bakony Mts in the basement. The seismic stratigraphic analysis of the sedimentary complexes enabled us to determine a scale analogous with that of the Great Hungarian Plain. In the axis of the basin the average sedimentation rate of the Pannonian sediments is estimated as 0.4 mm/year—compaction included.

Geophysical exploration of the medium depth range continued—following the methodology of former years. A typical geoelectric cross section is presented in *Fig. 18*. Variations of geoelectric characteristics of the area can be studied on the maps of average resistivity weighted by layer thickness. Here we present such a map of penetration depth of 100 m *(Fig. 19)*. Similar penetration is attained by IP sounding of AB=400 m *(Fig. 20)*. From the resistivity and polarizability maps, we have constructed lithologic sketches. The one that is valid for the depth range of 50–100 m, is presented in *Fig. 21*. This map divides the area into three parts, viz. the foregrounds of the Kőszeg and Sopron hills, where no hydrogeological interpretation can be made; the zones of coinciding anomalies of resistivity and polarizability—being partly present-day, partly ancient channel fills of rivers—forming the most favourable zones for water storage; and the areas above basement highs where Upper Pannonian sediments of small grain size are unfavourable for water yield.

The *geophysical exploration of the Balaton Highlands* is aimed at studying the possibility of different raw material occurrences. Regional gravity networks and seismic profiles enable us to determine the regional structural lines and structural units. Besides these tasks we can be of great help to geological mapping. In the Keszthely hills, for example, our task was to find small, near-surface karstic holes filled with kaolin. For this task the VLF method proved to be ideal. In *Fig. 22/a* the VLF resistivity map of the area is presented, where resistivity minima show locations of such sink-holes. Boreholes (A, B, C) proved that these holes are filled with good quality kaolin. The geophysical interpretation map *(Fig. 22/b)* shows further possible holes that are worth drilling.

At another locality of the Balaton Highlands the task was to determine the inner structure of the basement. Central loop transient sounding was found to be the most suitable method of solving the problem. The profile was measured in the dip direction *(Fig. 23/a)* and it clearly reflects the synclinal structure. Geological interpretation is presented in *Fig. 23/b*, where even the layers of different resistivity of the Sándorhegy marl formation could be separated (A, B, C).

Ground magnetic surveys were carried out to delineate basalt occurrences. In the area of the Halagos hill *(Fig. 24/a)* we could distinguish between different types of basalts. The same was achieved near Tóti hill *(Fig. 24/b)*.

In northern Hungary, we started a regional project for *the structural exploration of the Bükk Mts and the surrounding areas* which is planned to be continued for 15 years. In 1986 the work started with the gravity, geoelectric and seismic surveys of the Szendrő hills. There has been considerable progress in the brown coal exploration project of Borsod county, where high resolution seismic profiles *(Fig. 25)* were successful in tracing thin coal seams deposited withing the Tertiary sedimentary complex. In the Lyukóbánya area special processing (to clarify the seismic image after Hilbert transformation a smoothing filter was applied designed by statistical analysis) helped to enhance the recogniction of changes in seismic characteristics *(Fig. 26)*. A 70–170 Hz frequency range and the respective 4 m resolution was achieved. The Sajókaza-W area raised another problem: the appropriate field technology had to be found for the gravelly surface and the shallow deposition of the coal. The result is a signal-rich, high-frequency (80–200 Hz) time section *(Fig. 27)*.

For the *structural analysis of the Mátra Mts and surrounding* areas geomagnetic *(Fig. 28)*, geological *(Fig. 29)*, and gravity maps *(Fig. 30)*, as well as contour maps constructed from refraction seismics *(Fig. 31)* were used. The measure of detail of the analysis can be regarded as 1:200,000 based on the available volcano-tectonic information *(Fig. 32)*. From the refraction seismic profile *(Fig. 33)* and geological mapping data, geological cross sections were constructed *(Fig. 34)* together with the stratigraphical column to be expected in the central part of the volcano *(Fig. 35)*. Using all these data, gravity model calculations were carried out *(Figs 36–39)* in order to find the best fitting solution (Fig. 38). The analysis was extended to the Eastern Mátra too *(Fig. 40)*. By integrating all the above-described information the following could be outlined for the structure and evolution process of the Mátra palaeovolcano.

The volcanic sequence of the Mátra consists of three members: the Lower Andesite (Upper Karpathian), developing progressively from the Oligocene–Miocene sediments; the Middle Rhyolite Tuff (on the boundary between the Karpathian and Badenien) deposited with erosional discordance on the Lower Andesite; and the Upper Andesite (Lower Badenian) developing with gradual lithological transition from the rhyolite tuff. The most frequently occurring formation is the Upper Andesite. The development of the palaeovolcano can be described as follows: (1) The ascending andesitic magma caused a flat dome of about 23–27 km diameter, before surface volcanic activity started. (2) In the course of the first phase of volcanic activity this dome collapsed forming a cauldron of 20–25 km diameter. The volcanoes of this phase appear on the rim of the cauldron (Nyikom, Óvár and others along the N–S crest of the Western Mátra. (3) Simultaneously or soon after the cauldron formed, from inside it, the volcano of Galya grew out, probably with its centre at Sár hill. (4) After some while, a dome of 16–20 km diameter was formed inside the cauldron as a result of newly ascending magma, probably without surface activity. (5) This dome collapsed, forming a new cauldron of 13–15 km diameter and, similarly to the first one, volcanoes developed around its rim. The volcano of Tippanos and the volcanic centre system around Gyöngyösoroszi mine were formed at that time. (6) It is possible that inside this cauldron a volcano grew out, that of Sári hill, but it is also possible that what we see now is a fragment of the Galya volcano, formed in stage (3).

The volcanic products below the Upper Andesite can be fitted into this picture in the following way: the Middle Rhyolite Tuff, against generally accepted opinion that its origin is outside the Mátra, may have originated from the earlier cauldron stage, since there are examples for rhyolitic eruptions connected with cauldrons in otherwise andesitic volcanic areas. The eruptive centre of the Lower Andesite can be tied to the outer basement elevation by its facies changes. In spite of considerable facies changes, the thickness of the complex is more or less constant (50–100 m). This signifies, maybe, erosion at the base of the Middle Rhyolite Tuff, with which the quick stratigraphic change is in harmony. Thus for the early cauldron (stage 2) three objects can be bound: the Lower Andesite, the Middle Rhyolite Tuff and the outer volcanoes of the Upper Andesite. The erosion between the two earlier events marks the discontinuous development of the caldera.

In *oil and gas prospecting* ELGI participated, as in former years, in the form of a contract with the National Oil and Gas Trust. In the surrounding *area of Kiskunfélegyháza*, a total of 750 km seismic profiles were shot between 1983 and 1985 *(Enclosure 1)*. Processing and interpretation of the material of the 200 km profile length shot in 1985 were completed in 1986; we report here on this work. The geomagnetic and the gravity residual anomaly maps of the area—used for interpretation—were published in the Annual Report for 1985 (Figs. 33, 34). From the 1985 profiles six time sections are presented *(Figs. 41–46)*. For marking, we used the same colours as last year, with some modification. Two of the maps are presented: the time contour map of the Pannonian basin floor *(Enclosure 2)* and that of the pre-Austrian basement *(Enclosure 3)*. The Pannonian basin floor is the most certain horizon in the whole area. The pre-Austrian basement is extremely heterogeneous both in time and lithology. To it belong Lower Cretaceous volcanites, Lower Cretaceous and older Mesozoic sedimentary rocks and pre-Cambrian metamorphic rocks. Where this last could be separated from the Mesozoic, it was coloured pink. We traced the pinch-out zone of the Upper Cretaceous in the profiles and marked this zone on the map of the pre-Austrian basement.

In the seventies all of ELGI's efforts in CH prospecting were directed to the *Nyír region*. There, the most serious obstacle to geophysical exploration is the varied distribution of the Miocene stratovolcanic complex, whose thickness may reach several thousand metres. In the last few years the Nyír region has again come into the focus of interest. ELGI is taking part in the geophysical activity by gravity, geoelectric and seismic surveys. Here we report on the results of the geoelectric measurements. We used a new methodology by combining the measurements of the natural and artificial fields in the wave zone (5 Hz> f> 0.1 Hz). The primary task of the geoelectric measurements was to map the pre-Austrian basement. In the given geological build-up the resolution power of the magnetotelluric soundings is hindered not only intrinsically but by the fact that in the frequency range of 5 Hz> > f> 0.1 Hz, which is important for reaching the layers below the screening volcanic complex, there is the energy minimum of the natural electromagnetic field. In *Fig. 47* one can see that the error of the magnetotelluric soundings increases in the range of the multifrequency electromagnetic soundings. Thus by combining the two measurements, the signal-to-noise ratio could be increased. The new methodology resulted in the profile of *Fig. 48*. The most intriguing results are the those in points 1 and 2; in the central part of the volcanic activity of the Nyír region the pre-Austrian basement could be determined.

The programme of *geophysical measurements along geological base lines* has continued for several years with the aim of investigating Hungary from the tectonic viewpoint. As one of its results, the conductive zone was found at an anomalous shallow depth in the Transdanubian Central Range (2.5–3.5 km). To check these results a further 20 magnetotelluric soundings were carried out in the area of this anomaly. *Fig. 49* presents all the curves in a map-like illustration; *Fig. 50* illustrates the depth to the conductive zone as computed by one-dimensional interpretation of the $\varrho_{\max}$ and $\varrho_{\min}$ curves. The direction of the $\varrho_{\max}$ curves is also plotted. The characteristics of the curves are practically the same for the whole area: all curves reflect the effect of the conductive zone in the basement. The anisotropy, however, on the right-hand side of the curves, may surpass two orders of magnitude. Depths from such extreme values may be as different as 3–15 km. We had to conclude that, in the area, one-dimensional approximation cannot be accepted. The results of numerical model calculations, presented in *Fig. 51*, may be regarded as a first approximation of two-dimensional interpretation.

For several years, in ELGI it has been under progress to develop a new method of structural analysis—kinematic modelling. A new model was formed for the development of the Carpathian–Pannonian region in the Miocene, and it was fitted into the broader scope of the Central Mediterranean. After that we started to check the implications of this model in smaller units and to extend the modelling to earlier times. As a result, we outlined a tectonic evolutional process that formed the present structural features of Hungary in the Oligocene and the Miocene. In the course of checking the overall model we subjected the *structural reconstruction of the Transdanubian Central Range* to a detailed study. The well-known syncline of the Bakony and Vértes Mts was followed in the Gerecse, Pilis and Buda hills where its axis gradually turns to the south-east. It was worked out that this structural bend was formed during the Albian–Turonian time span, together with the folding and nappe forming. We have separated four stages in the Oligocene–Quaternary evolutionary process *(Fig. 52):* (1) dextral shear of the south-eastern rim in the Oligocene which caused the formerly isometric bodies to become elongated towards the west. This stretching formed the strips of the Velence–Balaton granite zone and that of the Buda–Seregélyes–Buzsák Mesozoic zone. (2) The compression of the south-eastern margin (Early and Middle Miocene) bending the strips into an S-shape and turning, counter-clockwise, the Vértes hills relative to the Bakony Mts. (3) Sinistral shear (Middle and Late Miocene) manifesting itself in the translational movement terminating the Buda hills and appearing similarly in the northern rim of the Velence hills too, and in the sinistral faults of the Gerecse–Pilis region. (4) Block movements in connection with new N–S faults (Late Miocene–Quaternary) which formed the present structure and topography of the area east of the Vértes. The modelling has, up till now, revealed general relations, and has proved its capability in practical tasks. These tasks may be divided into two groups: (i) determining the present structure with higher accuracy thereby creating a sound bsis for any kind of exploration task or engineering problem, and (ii) by reconstructing palaeogeographical situations, serving as a basis for coal-, bauxite-, etc. prognosis. Obviously the scale of the study is always limited by the quantity of information at our disposal.

For the *central part of Transdanubia (Fig. 53)* a series of geological cross sections was constructed *(Fig. 57)* from the stratigraphic columns of boreholes *(Figs. 54–56)* and by using the gravity residual anomaly map *(Enclosure 4)*, the geomagnetic map *(Enclosure 5)* and the results of integrated geophysical interpretation *(Fig. 58)*. Isopach maps were constructed for the Sarmatian–Pannonian sequence *(Enclosure 6)* and for the pre-Sarmatian Miocene *(Enclosure 7)*. Having integrated all these data, a map of Oligocene–Miocene structural features was constructed *(Enclosure 8)*. All these enabled us to draw the tectonic evolution of the region as follows. The striped pattern of the basement was formed in the Oligocene by the shear accompanying the about 500 km horizontal displacement of the Bakony unit. The boundary between the sheared and undeformed areas follows the axes of the Balaton and Velence lakes, cutting through basement strips. The central deep zone in the basement was formed only in the Miocene. During collision in the Early to Middle Miocene these strips were bent into S shapes in the area between the Balaton and the Danube. The compressional features connected with the collision need to be proved by further investigation of the deeper zones of the basin. In the Badenian, a compressional zone was formed cutting through the basement strips at an acute angle. This can be followed from Buzsák to Bugyi. The northern depressions of the central deep zone were formed simultaneously with the compression, after the termination of the volcanic activity at Nagyszokoly. We were unable to determine the age of the southern depressions in a precise manner although their Miocene age can be accepted, though this was probably after the termination of the volcanic activity. It is also likely that the elevations of Igal and Tolnanémedi are products of the same compression since their location and shape seem to be in connection with the structure and appearance of the northern overthrust zone. Younger Miocene movements followed the basement strips only on a large scale, but the details are of different directions. Therefore gravity maps reflecting basement topography cannot be used directly to delineate basement strips.

The *engineering geophysical investigation of the Balaton recreation area* continued with the method of four-parameter engineering geophysical sounding. The loose Tertiary and Quaternary cover, which can be studied by that method, consists of Pleistocene loess in most parts, overlying directly the Triassic limestones of the Bakony Mts. On the rim of the mountains and in its basins Pannonian shallow-lake, marsh, and shore-line sediments of varied composition and physical parameters were deposited. These were studied in detail in the Tapolca basin *(Fig. 59)*.

The most important task in the *exploration for ground water* was that of studying the alluvium of the rivers Mura and Kerka. The project started in 1984, with the aim of exploring the underground water potential—on a reconnaissance scale—both in the vertical and horizontal sense. The methods that were utilized were: engineering geophysical sounding and combined resistivity -IP measurements. In the Lenti basin, our geophysical activities were completed with the following results: we defined the general geophysical model of the area *(Fig. 60);* we proved that the thickness of the Holocene cover is not enough to provide protection against surface pollution. Thus the near-surface Pleistocene clastics, whose thickness *(Fig. 61)* and porosity would be satisfactory, cannot be counted on as a regional water base. The Upper Pannonian appears in two different geoelectric types in the area: a two-layer model (Fig. 60, 3a and 3b), and a one-layer model (Fig. 60, 4). The lower layer of the two-layer model seems to indicate that there may well be suitable drinking water in the necessary quantity. Its depositional depth--where it occurs--is presented in *Fig. 62*. In the area of the one-layer model resistivity maxima *(Fig. 63)* mark out the localities where the percentage of the higher porosity component increases i.e. those sites suggested for water production. The resistivity log recorded in a borehole *(Fig. 64)* drilled in the area of the two-layer model, proves the existence of the lower high-resistivity layer. Furthermore, a pumping test from the filtered 80–100 m zone produced water at a rate of 2000 l/min, although this depth zone represents just the beginning of the lower high-resistivity layer.