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TRANSIENT ELECTROMAGNETIC SOUNDINGS—DEVELOPMENT OF INTERPRETATION METHODS AND APPLICATION TO BAUXITE EXPLORATION

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Under a cooperative program between the U.S. Geological Survey and the Eötvös Loránd Geophysical Institute, central loop and single loop time-domain electromagnetic (TDEM) soundings were made at a number of localities in Hungary. The primary objective was to test the usefulness of the method in exploration for bauxite. The results of the soundings were interpreted by use of a nonlinear least-squares computer algorithm which fits the data with one-dimensional models. Interpretation of the data was generally complicated by the fact that most of the soundings were distorted due to lateral changes in the conductance of the overburden or other causes. Direct evidence of known bauxite deposits was not found. However, the results indicate that TDEM soundings can provide structural information useful to locating bauxite deposits indirectly. In two areas, evidence of a deep conductor beneath a bauxite deposit was found. The central loop or single loop techniques were found to be rather slow for routine exploration where a dense set of soundings is needed. therefore, in the future, fixed source or large loop configuration will be tested in bauxite exploration.

There are two serious problems in interpretation of TDEM sounding curves by computer inversion; the required computer time is excessive for inversion of all the data acquired in a routine survey and satisfactory results cannot be obtained when the sounding curves are highly distorted by lateral changes in resistivity. Anomalous zones can readily be identified by plotting the data in the form of pseudosections with time along the vertical axis. To produce quantitative information on the variation of resistivity with depth or the depth to interfaces between layers, methods termed TSH and TRH are being developed. The TSH method is based on an approximation for the response of a thin conductive sheet in a resistive half space and it yields apparent conductance versus apparent depth curves. The TRH method is based on the rate of diffusion downward of the eddy currents in a half-space and it produces a resistivity versus depth curve.

Keywords: transient electromagnetic sounding, bauxite prospecting, Marquardt inversion, time-domain electromagnetics

1. Introduction

Many of the principles of transient electromagnetic depth sounding have been understood for more than 30 years. Until the past several years, transient or time-domain electromagnetic (TDEM) soundings were generally made with heavy equipment and large offsets between source and receiver to sound to depths of up to several kilometers. In the last few years, highly portable

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equipment, which was developed primarily for exploration for conductive mineral deposits, has been employed for sounding to shallower depths using short times and short offsets between the source and receiver. Time-domain methods have a number of advantages over other geoelectrical sounding methods. Generally, TDEM soundings are more sensitive to the presence of conductive layers than other geoelectrical measurements. Most TDEM techniques are relatively insensitive to topography and high precision in surveying is not required. Measurements made with short offset configurations are not as likely to be distorted by lateral variations in resistivity as measurements made with long offset configurations, and it is much easier to make high-resolution TDEM measurements than frequency-domain measurements using short offsets.

The development and application of TDEM methods for high-resolution sounding to depths of 0.5–1.0 km is of great interest to the Eötvös Loránd Geophysical Institute (ELGI) and the U.S. Geological Survey (USGS). Cooperative studies between these two organizations have included an evaluation of short offset TDEM methods in sounding and as applied to bauxite exploration in Hungary, the development of mathematical tools for computer inversion of data taken about large loops, and the development of rapid techniques for interpreting TDEM soundings.

2. Field studies

During November 1982, experimental TDEM measurements were made jointly by USGS and ELGI personnel at a number of locations in Hungary. The objectives were to test the usefulness of the method in bauxite exploration and in shallow sounding for other purposes. The basic equipment was a Mark II SIROTEM® desinged by CSIRO [Buselli–O'Neill 1977]. An auxiliary high power switcher developed by the USGS was used for some of the work. Most measurements were made using the central loop configuration in which a small vertical-axis, multi-turn loop is placed at the center of a much larger square transmitter loop. By means of an electronic switch at the input of the receiver the SIROTEM instrument can also be used with a single loop for both transmitting and receiving; a few such measurements were made. Transmitting loops with sides having dimensions at 50, 100, 200, and 400 meters were used. The system transmits a train of bipolar nearly-square pulses with an off-power interval between pulses. Measurements can be made at up to 32 times (channels) after the end of the current pulse. Results from a minimum of 512 and a maximum of 4096 pulses can be stacked. Typically the results from two or more individual runs, using 2048 stacks were averaged. The number of channels of useful information depended on the signal-to-noise ratio which, in turn, depended on the resistivity of the earth, the transmitter current, and cultural background noise, which in Hungary, was generally noise from 50 Hz mains. Av-

* Use of trade names does not constitute endorsement either by ELGI or USGS

eraged values of the transient voltage were transformed to apparent resistivity using microcomputer programs developed by Raab and Frischknecht [1983]. Apparent resistivity, as defined in their algorithm, is the resistivity of the homogeneous earth which would produce a response equal to the observed response. Apparent resistivity data were inverted using nonlinear least-squares programs developed by Anderson [1982/a, 1982/b], which fit data to one-dimensional models.

In Hungary, bauxite deposits typically occur in structural depressions or in sinkholes on the surface of high-resistivity Triassic carbonate rocks [Bárdossy 1982, 1984]. The bauxite is covered by Quaternary and Tertiary deposits of sand, clay, marl, and sometimes limestone of high resistivity. The other materials generally have resistivities ranging from about 5 to 100 Ωm. The resistivity of bauxite is generally similar or a little higher than that of the overburden, excluding the limestone. Thus, the bauxite does not constitute a good target for direct detection by electrical methods. However, it is often possible to detect depressions on the surface of the Triassic carbonates. Ideally one could detect such depressions using a series of central or single loop soundings. Apparent resistivity curves calculated for a hypothetical 3-layer model in which the thickness of the bauxite layer is varied are shown in *Figure 1*. The curves do not exhibit a pronounced feature characteristic of the bauxite layer, nevertheless, it should be possible to resolve these various cases in the

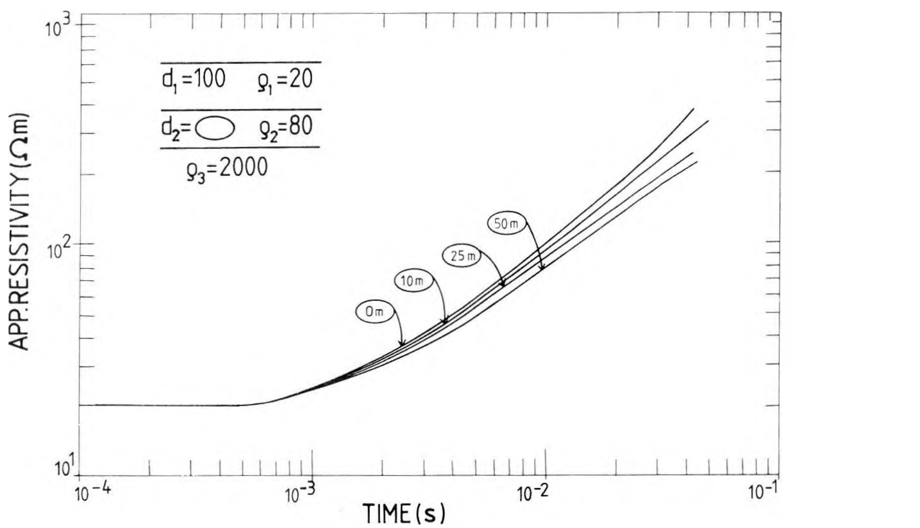


Fig. 1. Theoretical curves for a model containing a bauxite layer

1. ábra. Elméleti tranziens szondázási görbék bauxitréteget tartalmazó modell felett

Рис. 1. Теоретические кривые зондирования МПП над моделью, содержащей бокситовый слой field. Of course, the effect of an actual bauxite deposit would be somewhat smaller than indicated in Figure 1 because such a deposit has finite lateral dimension usually on the order of 50–200 m.

Measurements were made at one site where the earth was known to be rather uniformly conductive to a depth of several hundred meters, and at five sites where bauxite deposits exist. Single- and central-loop measurements were made between the Gerecse and Buda hills, SE of Zsámbék, where it is known from resistivity soundings that there is a thick section having a rather uniform resistivity. A good fit to the observed data was obtained with the model indicated in *Figure 2*. Parameters for the conductive layers are generally well resolved. Parameters for the thin upper layer and the depth to the resistive basement are not well resolved. The indicated depth in Figure 2 is less than the actual depth of about 550 meters. However, another, somewhat poorer fit to the data was obtained with a model in which the depth to basement is 600 meters. It is interesting to note that in this example, where a conductive overburden overlies a resistive basement, the effective depth of investigation was on the order of the loop dimensions (400 meters) using a current of about 2 amperes.

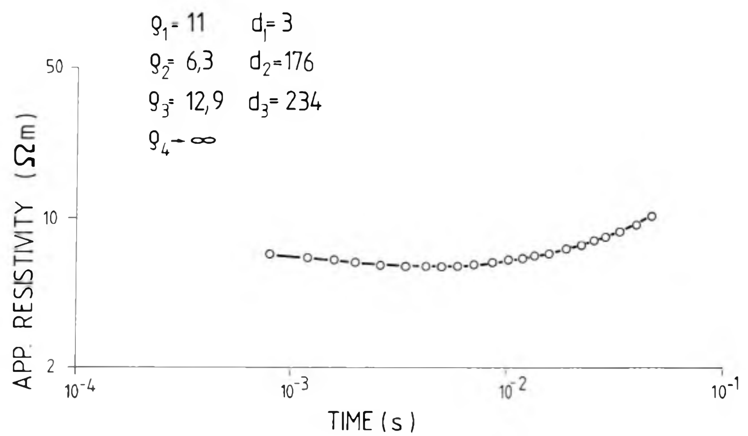


Fig. 2. Sounding curve and interpretation for nearly homogeneous half-space

2. ábra. Szondázási görbe és kiértékelése közel homogén féltér felett

Рис. 2. Кривая зондирования и ее интерпретация над полупространством, близком гомогенному

For the opposite case of an insulating layer over a conductive basement, the depth of investigation under the same conditions can be 3 or 4 times the loop dimension.

Results obtained from the SE Gerecse coal basin, NW of Zsámbék, are shown in *Figure 3*. Most of the parameters are fairly well resolved, although for the second layer the resistivity and thickness are not well resolved but its conductance. The resistivity of the basement is not well resolved and the depth to resistive basement is less than that given by a nearby borehole (380 m). The calculated TDEM apparent resistivity curve fails to rise as sharply as the observed curve at late times. It was not possible to find a layered earth model which would produce a suitable fit to this part of the observed curve; in fact, the results in Figure 3 were obtained by neglecting the last four points on the curve in the inversion process. Failure to find a 1-dimensional model which will

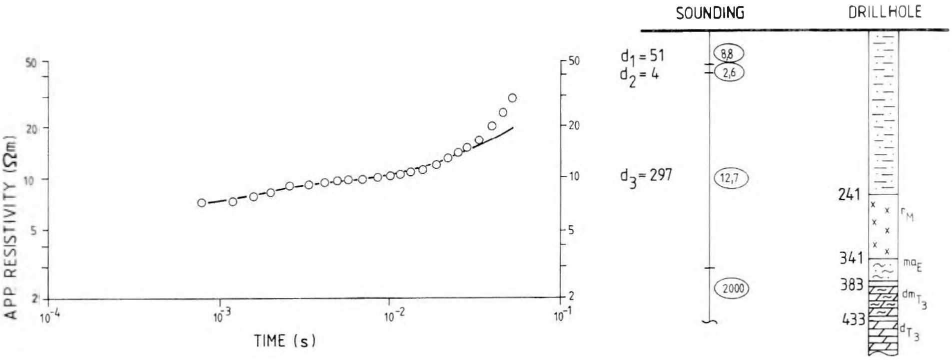


Fig. 3. Sounding curve and interpretation for the locality in the SE Gerecse coal basin
^{r}M = Miocene rhyolite tuff; ^{ma}E = Eocene marl with coal seams; $^{dm}T_3$ = Upper Triassic dolomitic marl; $^{d}T_3$ = Upper Triassic dolomite

3. ábra. Szondázási görbe és kiértékelésének összehasonlítása fúrási rétegsorral (Gerecse DK-i előtere)

Рис. 3. Кривая зондирования и сопоставление ее интерпретации с результатами бурения (ЮВ предгорье гор Герече)

^{r}M = риолитовый туф миоценового возраста; ^{ma}E = эоценовый мергель с углеродными слоями; $^{dm}T_3$ = верхне-триасовый доломитовый мергель; $^{d}T_3$ = верхне-триасовый доломит

fit the data indicates that the sounding curve is distorted by lateral variations in resistivity. In this case, abrupt thinning of the conductive layer in the vicinity of the sounding is the most likely cause of distortion and may account for the difference between the depths from the borehole and the sounding.

Three sounding curves obtained near Csabpuszta, the models obtained by computer inversion, and results from boreholes are shown in *Figure 4*. All three curves were fitted to a 5-layer model, although the presence of this many layers in not very obvious in sounding S–1. Good fits were found for *S*–1 and *S*–2. A layered earth model having a resistivity curve duplicating all of the details of *S*–3 was not found, indicating that *S*–3 is badly distorted by lateral variations in resistivity. This is not surprising considering the large differences observed between the three soundings. The values for the third and fifth layers, which have high resistivities, are not well resolved. The top of the third resistive layer coincides approximately with the top of middle Eocene sediments intersected by the boreholes. The top of the fourth conductive layer coincides rather closely

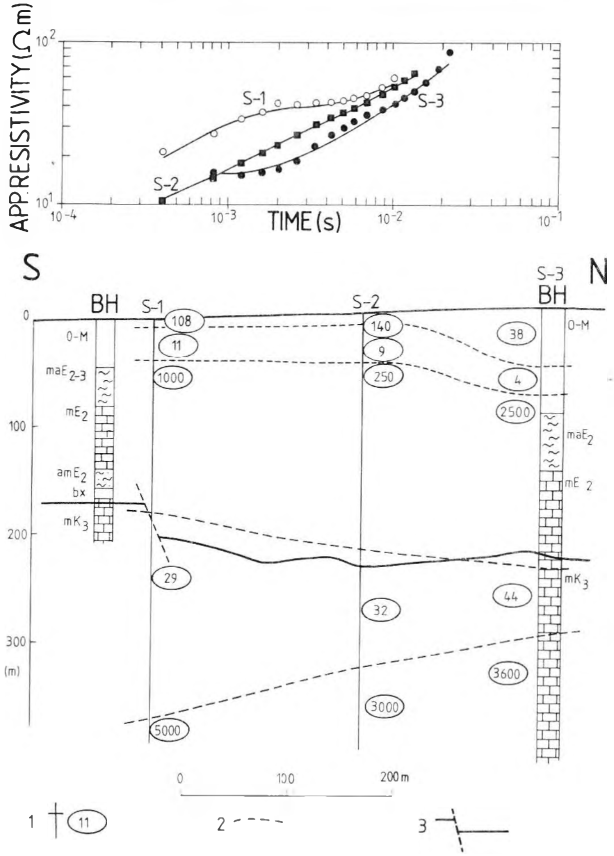


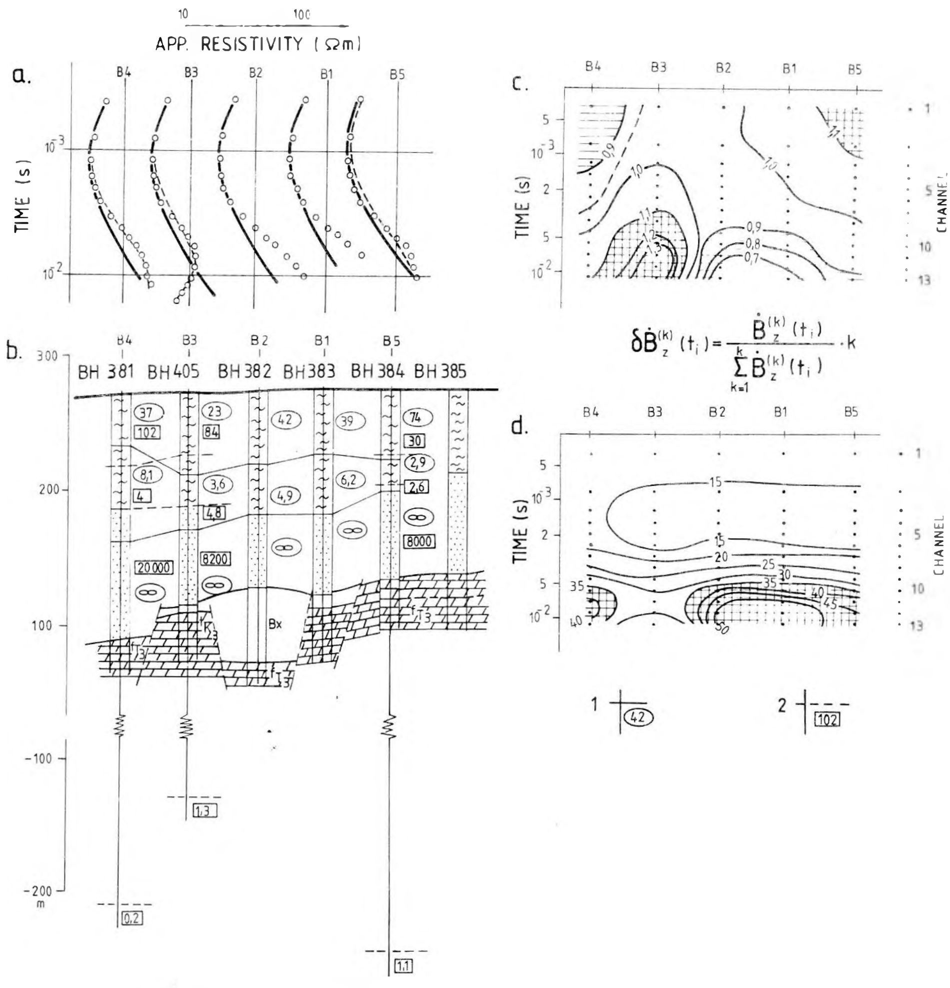
Fig. 4. Results of soundings for a locality near Csabpuszta
1 — layer resistivities and 2 — interface based on TDEM interpretation; 3 — surface of the Cretaceous limestone from drillholes, seismic measurements and multifrequency EM soundings; O – M = Oligocene – Miocene; $^{ma}E_2$ = Middle Eocene marl; $^{m}E_2$ = Middle Eocene limestone; $^{am}E_2$ = Middle Eocene argillaceous marl; bx = bauxite; $^{m}K_3$ = Upper Cretaceous limestone

4. ábra. A szondázások eredménye Csabpuszta környékén
1 — rétegellenállás és 2 — réteghatár a tranziens szondázások alapján; 3 — a felsőkréta mészkő (Ugodi Mészkő Formáció) felszíne fúrások, szeizmikus reflexiós és multifrekvenciás elektromágneses mérések alapján

Рис. 4. Результаты зондирования в окрестности Чабпуста
1 — сопротивление слоя и 2 — граница между слоями по данным МПП, 3 — поверхность известняков верхнемелового возраста (угодская свита известняков) по данным бурений, МОВ и частотного электромагнитного зондирования

O–M = олигоцен–миоцен; $^{ma}E_2$ = среднеэоценовый мергель; $^{m}E_2$ = среднеэоценовый известняк; $^{am}E_2$ = среднеэоценовый аргиллитовый мергель; bx = боксит
$^{m}K_3$ = верхнемеловый известняк

Рис. 5. Результаты МПП на месторождении бокситов Баконьослоп
a) Кривые зондирования МПП и их приближение трехслойной (сплошная линия) и четырехслойной (пунктирная линия) моделями
b) Геологический разрез с результатами зондирований МПП
1 — трехслойным, 2 — четырехслойным приближением
c) Остаточные величины кривой затухания в зависимости от времени (порядкового номера канала)
d) Кажущееся удельное сопротивление в зависимости от времени (порядкового номера канала)



$$\delta \dot{B}_z^{(k)}(t_i) = \frac{\dot{B}_z^{(k)}(t_i)}{\sum_{k=1}^{k} \dot{B}_z^{(k)}(t_i)} \cdot k$$

Fig. 5. Results of TDEM soundings from the Bakonyoszlop bauxite-prospecting area
a) TDEM sounding curves with 3-layer (solid line) and 4-layer (dashed line) model curves
b) Geologic section based on drillholes and electrical section interpreted from TDEM soundings
1 — result of 3-layer inversion; 2 — result of 4-layer inversion
c) Pseudosection of the residual decay curve as a function of the measurement time (channel number)
d) Pseudosection of the apparent resistivity as a function of the measurement time (channel number)

5. ábra. Tranziens eredmények, bakonyoszlopi bauxitelőfordulás
a) Tranziens szondázási görbék háromréteges (folytonos vonal) és négyréteges (szaggatott vonal) modellillesztéssel
b) Földtani szelvény a tranziens szondázások eredményeivel
1 — a háromréteges; 2 — a négyréteges közelítésből
c) Lecsengési görbe maradékértékei az idő (csatornaszám) függvényében
d) Látszólagos fajlagos ellenállás az idő (csatornaszám) függvényében

with the top of the Cretaceous sediments as found in the boreholes and by other geophysical measurements [Kakas 1983]. The fifth layer appears to dip to the north in disconformity with the other layers. We might expect this layer to represent the Triassic carbonate basement but the interpreted depth for resistive basement at S–3 is too shallow according to the borehole. Nonetheless, resistive layers could be present in the Cretaceous section of this sequence.

Results of five soundings, made over a bauxite deposit in the Bakonyoszlop region are shown in *Figure 5*. The initial parts of all five soundings are very similar. The late time parts of soundings *B*1 and *B*2 rise too steeply to be fit with a layered earth model. Sounding *B*3 was fitted using a 4-layer model with a very conductive fourth layer and *B*4 and *B*5 were fitted approximately to a similar model. Since, with the possible exception of *B*3, the latter part of all of the soundings appears to be distorted, they were all fitted using 3-layer models and using only the first 6–8 points on the sounding curves. The results of this procedure are indicated by the solid lines and resistivity values shown on the cross section. The results obtained by fitting *B*3, *B*4, and *B*5 to 4-layer models are shown by dashed lines. Although the thicknesses and resistivities of the upper two layers are somewhat different for the two models, the conductances of the second layer are nearly the same suggesting that fitting only the first part of the sounding curves is a valid procedure. Values for the conductance of the second layer, as determined from the TDEM measurements, are a little higher than those obtained from interpretation of unpublished resistivity soundings made along the same profile. In a general way the 3 layers determined by TDEM measurements coincide with the lithology obtained from the borehole measurements. The conductive layers tend to correspond with sandstone and clay and the resistive layers with limestone and marl.

Data collected along a profile may be presented in a number of ways which emphasize qualitatively changes in the electrical section, such as those caused by faults or pinch-outs. To prepare the pseudosection shown in Figure 5/c, the difference between each decay curve and the average of all five curves were calculated, and the results were plotted and contoured with station position along the horizontal axis and time along the vertical axis. Since penetration depth increases with time, this pseudosection bears some resemblance to a true section. The principal anomaly coincides approximately with the known bauxite body. However, this simple procedure does not provide quantitative depth information and, with little doubt, the anomaly shown in Figure 5 is due to a conductive zone below the deposit rather than the bauxite deposit.

Similar pseudosections can be prepared by plotting and contouring apparent resistivity values as in Figure 5/d. In this pseudosection, a depression in the contours appears approximately beneath the bauxite deposit. Again let us emphasize that it is not the effect of the small bauxite deposit which is seen here, but rather a zone of low resistivity in the basement which has not been detected by other methods.

There is no independent evidence at this site to confirm the presence of a deep conductor as indicated by *B*3 or to suggest the cause of such a conductor.

Most likely, the conductive zone is a two- or three-dimensional feature rather than a layer and it may be displaced laterally from the profile. It is known from other localities in Hungary that fracture zones in dolomite, which are filled with water and sometimes clay, constitute conductors in the resistive basement. In fact, it has been suggested that structural depressions which may contain bauxite may sometimes be associated with such conductive zones in the basement.

The results for two soundings made near Bicske are shown in *Figure 6*. The soundings are very dissimilar, *C*–1 indicating the presence of 4 layers and *C*–2 indicating 3 layers. The conductances of the upper layer, as found from the two soundings, are quite similar and agree well with results of Slingram profiling.

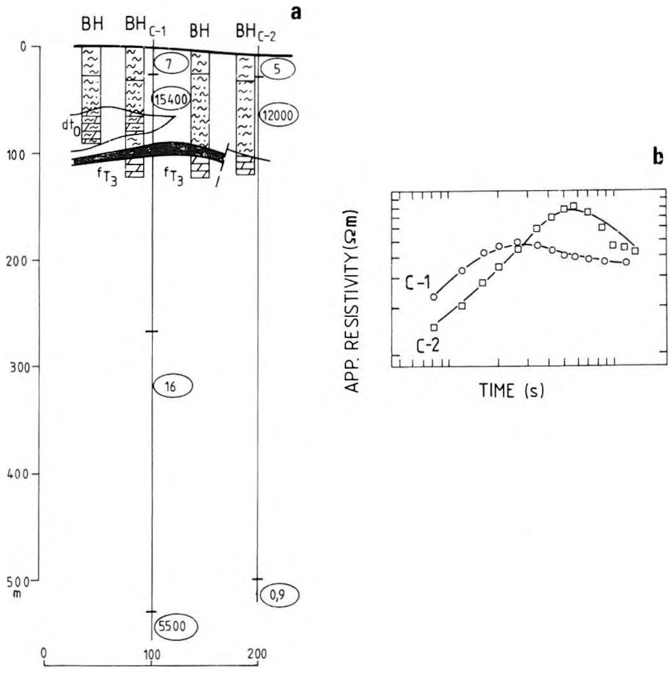


Fig. 6. Results of soundings from a locality near Bicske
a) Geological and electrical section
^{dt}O = Oligocene dolomite debris; ^{f}T$_3$ = Upper Triassic Hauptdolomit
b) Sounding curves with the best-fit inversions

6. ábra. A szondázások eredményei Bicske környékén
a) Földtani–geoelektromos szelvény
b) Szondázási görbék a legjobban illeszkedő megoldásokkal

Рис. 6. Результаты зондирований в окресности Бичке
a) Геолого-геоэлектрический разрез
^{dt}O = доломитовые обломки олигоценового возраста; ^{f}T$_3$ = верхнетриасовый основной доломит
b) Кривые зондирования и теоретические кривые, совместимые лучшим образом

The resistivities of the second layer are unrealistically high and are a result of fitting distorted curves. Other than the first layer, the models differ markedly from each other and do not correspond to known geologic features. Several attempts were made to fit the observed data with a model in which the upper layer was fixed to the depth to the Oligocene dolomite debris (*C*–1) or the depth to the Triassic basement (*C*–2); however satisfactory fits could not be obtained using these constraints. The resistivity for the deep conductor, as indicated by *C*–2, is unreasonably low. Likely, *C*–2 is badly distorted or contains some erroneous data points. However, the fact that *C*–1 indicates the presence of a conductive layer in the basement lends some support to the possibility of the existence of a conductor of unknown configuration in the basement.

The results given above indicate that the central-loop or single-loop TDEM methods can be used for sounding in the bauxite producing regions of western Hungary. However, the electrical sections there, which basically consist of conductive layers over a resistive basement, are not as easily resolved as in the opposite case when resistive rocks overlie conductive layers. Many of the sounding curves obtained are distorted; one of the primary causes is probably sharp lateral changes in the conductance of the conductive sediments. Previous experience with this method indicates that sounding curves taken near fairly pronounced lateral changes in resistivity can be fitted well to one-dimensional models even though the soundings are distorted [FRISCHKNECHT–RAAB 1984]. Thus, it is apparent that, lateral changes in resistivity in the localities studied in Hungary are very severe.

3. Fixed-source TDEM measurements

The central-loop and single-loop techniques are examples of moving-source methods in which the source is moved for each new station. Moving-source methods are very suitable for reconnaissance work where measurements are made at widely separated sites. They also have some advantages in that the geometrical relationship between source and receiver is constant. However, when a high density of stations along a profile is needed, the single- and central-loop techniques are very slow. Much higher rates of production can be achieved if the source loop is left in a fixed position for a series of measurements and the only receiver is moved for each new station. Besides being faster, fixed-source techniques offer an advantage over central- or single-loop techniques in that the horizontal component, as well as the vertical component of the field can be measured. While galvanic or "current gathering" effects are suppressed in the central or single loop techniques, they are enhanced at large source–receiver separations. The absence of galvanic effects simplifies interpretation but galvanic currents often identify the location of weak conductors that do not carry significant vortex currents due to direct induction. This phenomenon may be useful in bauxite exploration. Probably, the chief disadvantage of the fixed-source method for bauxite exploration is the changing geometry between source and receiver.

The USGS and ELGI have been working on interpretation techniques in anticipation of making TDEM soundings using the fixed-source method. ANDERSON [1984] has developed a very efficient computer program, using lagged convolution for computation of the horizontal and vertical frequency-domain fields inside and outside a large loop on a horizontally layered earth. A time-domain version of the same program is being evaluated. Following the general approach used by RAAB and FRISCHKNECHT [1983], Prácser has developed suitable expressions for calculation of apparent resistivity when a large loop is used. It appears that development of an inversion program for fixed-source soundings will not be a major task.

4. Development of other interpretation methods

Development of alternatives to interpretation by computer inversion is a major concern. In some areas, TDEM sounding curves can be interpreted easily but finding good fits to the data from the Csabpuszta, Bakonyoszlop and Bicske sites using four- and five-layer models required computation of many forward models for guidance, and many inversion runs using different starting parameters and constraints. The effort both in terms of personnel time and computer time was far too great to be practical in routine exploration. Furthermore, to achieve good results with the inversion technique used here, the sounding curves must not be seriously distorted by the presence of sharp lateral changes in the electrical section. Therefore, interpretative techniques which do not require large computer resources and which are stable and yield useful results when applied to distorted sounding curves are needed.

Pseudosections are useful in qualitative interpretation but they do not provide estimates of the depth to anomalous zones. A rapid means of making approximate depth estimates is needed for efficient conduct of field surveys as well as to provide final results when curve matching using one-dimensional models fails. What is needed is a simple and direct transform between time and depth; equivalent transforms exist for other methods such as magnetotellurics. The following two methods represent attempts to devise such transforms for time domain methods.

If a highly resistive half-space contains a thin, conductive layer, the transient response depends on an elementary algebraic expression [WAIT 1956]. For the case when the depth to that layer is of the order of the loop dimensions or greater WAIT's expression may be simplified to obtain a procedure for approximate inversion of sounding data. From the transient response we compute, at each time instant, the "apparent depth of investigation" and the total conductance of the section. The results of applying this procedure to a theoretical curve are plotted as a function of time *(Figure 7/a)*. In this diagram the effect of the conductive layer at 300 m is observed as a sharp feature at about 800 microsecs.

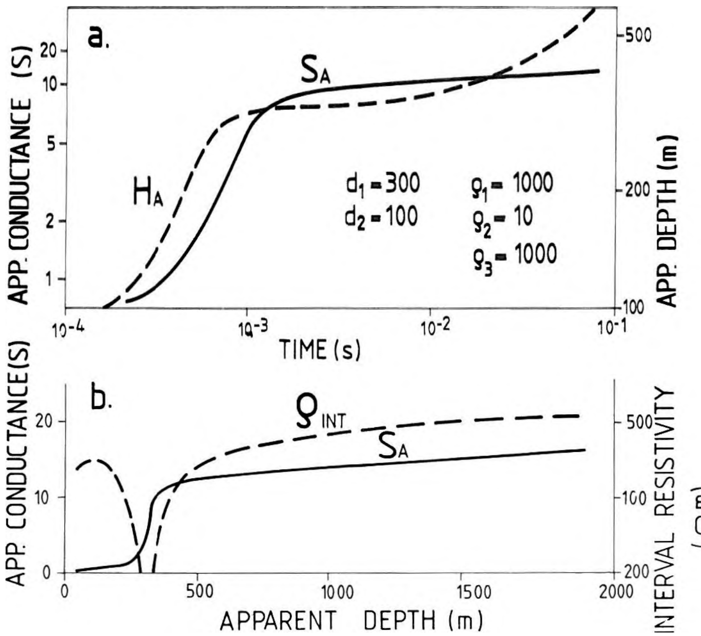


Fig. 7. Application of the TSH method for a theoretical model
a) Apparent conductance versus time and apparent depth versus time curves
b) Apparent conductance and interval resistivity versus apparent depth curves

7. ábra. A TSH kiértékelés vizsgálata elméleti görbéken
a) Látszólagos vezetőképesség–idő és látszólagos mélység–idő görbe
b) Látszólagos vezetőképesség- és intervallum-ellenállás–látszólagos mélység görbe

Рис. 7. Анализ интерпретации "TSH" на теоретических кривых
a) Кривые кажущейся проводимости–времени и кажущейся глубины–времени
b) Кривые кажущейся проводимости–кажущейся глубины и интервального сопротивления–кажущейся глубины

We can produce a more descriptive and clear display if we plot the total conductance as a function of the apparent depth *(Figure 7/b)*. From this plot the layers can be identified and the depths of the layer boundaries can be estimated. We have plotted also what we term the "interval-resistivity curve"; it is computed from differences in the apparent conductances and depth. This plot is also useful in preliminary interpretation. This method might be called the TSH method because we established a transformation between the time, T, and depth, H, using the conductance, S.

The second method is based on the velocity with which transient eddy currents move downward and outward from the transmitter loop in a homogeneous half-space [NABIGHIAN 1979]. The effective depth of the currents, or "smoke ring", is a function of time and half-space resistivity. For the central-loop configuration a short formula can be used to transform the apparent resistivity versus time function to apparent resistivity versus apparent depth function. We can call this technique a TRH method because it is a transformation between the time, *T*, and depth, *H*, using the resistivity, *R*. We are testing this technique on theoretical and field results. In this simplest form it seems to work well for a conductive layer over an insulator, but not for the opposite case. Work is continuing to try to find a suitable modification which will make the technique more useful. The TSH and TRH methods require little computer time and can also be applied to distorted sounding curves, but improvements must be made before these techniques will be useful in routine work.

Efficient application of TDEM soundings in a large exploration program requires an integrated program of data acquisition and interpretation. A block diagram illustrating proposed relationships between data acquisition, rapid methods of interpretation, and interpretation based on curve fitting is shown in *Figure 8*.

5. Conclusions

Direct evidence of the bauxite deposits at two of the locations (Bakonyoszlop and Bicske) where transient field measurements were made cannot be discerned from the data. This is not surprising considering the size and resistivity of the deposits and the complexity of the electrical section of these sites. It appears that such deposits can be detected only indirectly by mapping their structural settings. The central-loop time-domain method can provide needed structural information in areas where lateral changes in resistivity are gradual, but sounding curves which are badly distorted by sharp lateral changes in resistivity cannot be fully interpreted using existing techniques. If the central-loop configuration is applied in areas similar to the sites at Csabpuszta and Bicske, we recommend using a station spacing of one-half or possibly one-quarter of the side of the loop to help cope with lateral variations. We also recommend making measurements at earlier times to define better the near-surface part of the electrical section. To increase productivity, we suggest use of large-loop TDEM techniques.

Existing inversion or curve fitting techniques using one-dimensional models are too slow and too sensitive to distortions in the data to be adequate for routine interpretation of data, such as would be acquired in bauxite exploration. Some success was achieved in developing more rapid and robust methods of interpretation but substantial improvements must be made before these methods will be useful in routine interpretation.

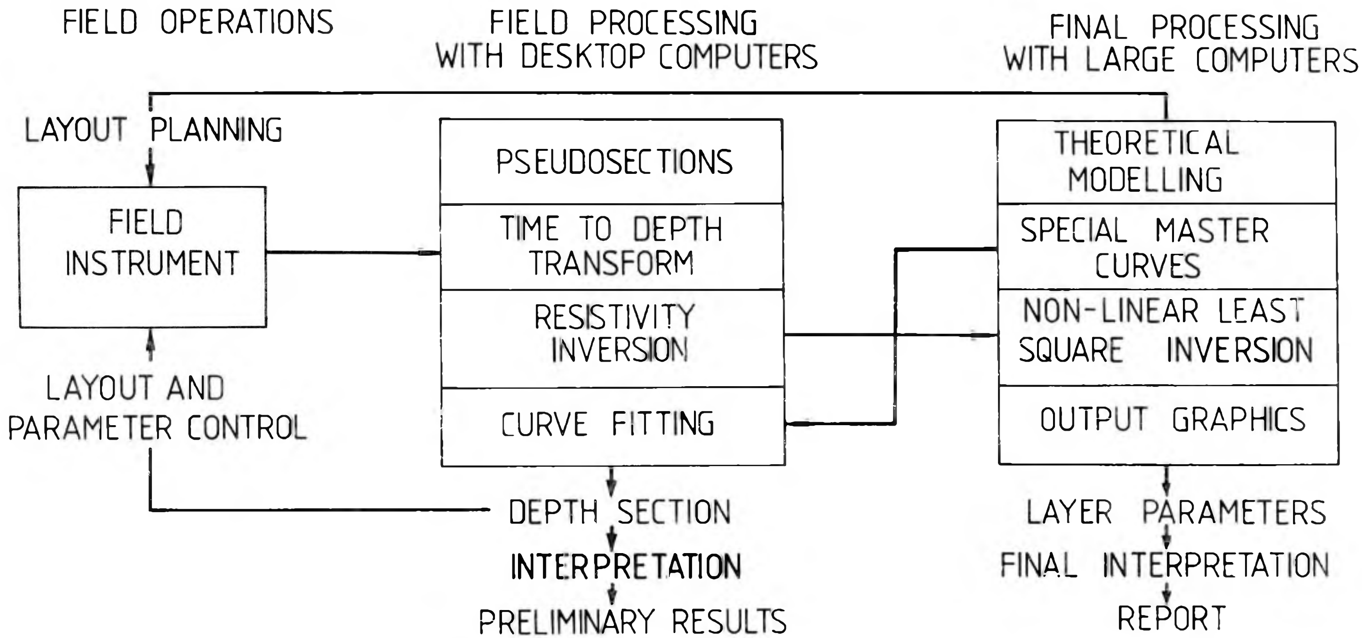


Fig. 8. Block diagram for acquisition and interpretation procedure of TDEM data

8. ábra. A tranziens mérések adatgyűjtési és kiértékelési rendszerének vázlata

Рис. 8. Блок схема системы сбора данных и интерпретации МПП

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A TRANZIENS ELEKTROMÁGNESES SZONDÁZÁSOK KIÉRTÉKELÉSI MÓDSZEREINEK FEJLESZTÉSE ÉS A SZONDÁZÁSOK ALKALMAZÁSA A BAUXITKUTATÁSBAN

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Az USGS és az ELGI együttműködésének keretében kísérleti tranziens szondázásokat végeztünk több bauxittároló szerkezet felett a Dunántúli-középhegységben. A szondázásokat egydimenziós Marquardt-inverzióval értékeltük ki. A kiértékelést megnehezítette, hogy a szondázások nagy része (főleg a fedőellenállás inhomogenitása miatt) torzult volt. Bár a bauxittelepeket közvetlenül nem lehetett kimutatni, az eredmények azt mutatják, hogy a tranziens szondázásokból kapott szerkezeti kép a bauxittestek indirekt detektálására alkalmas. Két bauxitelőforduláson a bauxittest alatt jólvezető mélyzóna volt kimutatható. Nagy területek hálózatos felmérésére akár a középponti vevőtekercses, akár az egyhurkos elrendezés alkalmazása lassú, ezért gazdaságtalan; erre a TURAM (nagykeretes) elrendezést tervezzük használni.

A számítógépes inverziós kiértékelésnek komoly hátránya egyrészt, hogy sok számítógépidőt igényel, másrészt, hogy torz görbék kiértékelésére nem alkalmas. Kvalitatív kiértékeléshez (anomális zónák kijelöléséhez) az adatokat pszeudoszelvények formájában, az idő függvényében ábrázolhatjuk. Az ellenállás–mélység függvény, vagy a határfelületek mélységének kvantitatív meghatározásához a TSH és a TRH eljárást kívánjuk alkalmazni. A TSH eljárás a nagyellenállású féltérben települő vékony vezető réteg feltételezésén alapul, és vezetőképesség–mélység függvényt eredményez. A TRH eljárás a szondázási görbe mélységtranszformációját végzi el, az örvényáramok maximumának mélység–idő összefüggése alapján.

РАЗВИТИЕ СПОСОБОВ ИНТЕРПРЕТАЦИИ ДАННЫХ ЭЛЕКТРОМАГНИТНЫХ ЗОНДИРОВАНИЙ ПО МЕТОДУ ПЕРЕХОДНЫХ ПРОЦЕССОВ И ПРИМЕНЕНИЕ ЗОНДИРОВАНИЙ ДЛЯ РАЗВЕДКИ БОКСИТОВ

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В рамках сотрудничества между Геологической службой США и ЭЛГИ были проведены экспериментальные зондирования по методу переходных процессов под некоторыми бокситоносными структурами в районе Задунайского среднегорья. Зондирования были обработаны одномерной инверсией Маркарта. Интерпретация данных была затруднена искажением большой части кривых (главным образом из-за неоднородности сопротивлений в покрове). Хотя нельзя было прямо выявить бокситовые залежи, результаты указывают на то, что полученная в результате зондирования по методу переходных процессов структурная картина позволяет выделять бокситовые тела косвенным путем. На двух месторождениях боксита в подошве бокситового тела была выделена хорошо проводящая глубинная зона.

Для съемки обширных районов по сети применение установок как со средней приемной катушкой, так и с одной петлой оказывается медленным, и поэтому неэкономичным способом; для такой цели предусматривается применине установки ТУРАМ (с большой рамой).

Серьезным недостатком инверсионной интерпретации на ЭВМ является высокая потребность в машинном времени, с одной стороны, и негодность ее для интерпретации искаженных кривых с другой. Для качественной интерпретации (выделения аномальных зон) данные могут изображаться в виде псевдо-разрезов в зависимости от времени. Для определений зависимости сопротивления от глубины, или для количественного определения глубины залегания разрезов в настоящее время разрабатываются способы TSH и TRH.

Способ TSH основан на предположении наличия тонкого проводящего слоя в высокоомном полупространстве и в результате дает функцию зависимости проводимости от глубины. Способ TRH выполняет преобразование кривой зондирования по глубине на основании зависимости глубины максимума вихревых токов от времени.