2 METHODOLOGICAL AND INSTRUMENTAL INVESTIGATIONS

21 SEISMIC

The most important area of seismic reflexion methodological research in 1970 was unalterably the *Nyírség* area. The geological task was the exploration of eventual sedimentary formations under the volcanic complex and of their structure. The survey was carried out with stacking (CDP-method), with analog recording. The 1970 results point to the possibility to improve information-gathering even in the analog way. Especially much can be expected, however, from digital techniques. The interpretation results of waveform- and pressure investigations made in previous years will be published in our „Geophysical Transactions".

Reflexion measurements made on the margin of the *Transdanubian Central Range* can also be regarded partly as methodological research. Our aim has been here to obtain informations from under the Mesozoic basin-floor. The primary scope has been the separation of Cretaceous and Triassic formations, since their boundary is the main horizon of bauxite deposition. Its determination meets difficulties, if also the Cretaceous consists of limestones. The results obtained are discussed in connection with the geophysical exploration of the Transdanubian Central Range.

The *seismic crustal investigations* had, in 1970, a character of methodological-instrumental research. The measurements themselves were carried out with the digital field eqipment type SU-24, constructed for the Hungarian Academy of Sciences, and with a frequency-modulation equipment SM-24+6 of special sensitivity. With these measurements, the question was approached, whether it was possible to follow the excellent quality reflexion obtained at Hajdúszoboszló also with magnetic tape recording. In the first experiments, both shotpoint and spreads were located near Hajdúszoboszló. Also this time the reflexion pattern known from earlier recording was obtained. In the course of further recordings, shotpoint and spreads were arranged in such a way that the reflexions be recorded always from the same depth point (abt. from under Kaba village). Similarly to earlier experiments, the Moho-reflexion was found on the records in traces only. For the sake of orientation, some records made with the SU-24 equipment were processed on the computer MINSK-2. The computer succeeded in enhancing the Moho-reflexion from the background of disturbing waves (Fig. 32). Three characteristic seismograms were selected from the survey material according to the field playback. On record *A*, the reflexion from the Moho-discontinuity can be traced in full length, on record *C*, however, it is visible only on the half of the channels, on record *E* it cannot be picked at all. The two-dimensional filtering was applied with the following parameters:

velocity passed with an attenuation of 3 dB:

$$v_{min} = 8500 \text{ m/s},$$

3 dB points of the frequency characteristics:

$$f_{min} + 14 \text{ c/s}$$
$$f_{max} + 22 \text{ c/s}.$$

The filter-generator was of 9×41 points (on 9 channels in 41 time-instants).

On the filtered records *B*, *D*, *F*, the reflexions equivocally emerge from the noise level of the waves present on records *A*, *C*, *E* and can easily be picked.

Our intention is to carry out detailed processing of the data on the computer MINSK-32 of the Institute.

The methodological field exploration carried out in the Nyirség area, further the corresponding instrument development will be discussed in detail.

211 SEISMIC REFLEXION METHODOLOGICAL EXPLORATION IN THE NYIRSÉG AREA

The seismic deep structural exploration in NE-Hungary (Nyirség area) in 1970, contracted by the National Oil and Gas Trust (NOGT), had a double aim. Partly the reconnaissance reflexion survey of this geological unit continued, partly the seismic preparation of parameter-drilling, indispensable in the interests of geological-geophysical data-gathering, began. In 1970, only reflexion measurements were made, as mentioned before, exclusively with stacking in common depth-point systems. The seismic extended from the Kállósemjén–Nyirbátor, Nagyecsed line to the border. With these recent measurements, the existing base network has been broadened by profiles of a total length of 140 km (Fig. 33.).

The main location aspects of the profiles were as follows:
connecting the structural indications of Nyirlugos, resp. Aporliget (see Profile 8/b in the Annual Report for 1969);
closing up the network on W along the refraction profile BoR-14;
tying the structural indication at Nyirlugos to the borehole Nyirmártonfalva-1,
the exploration of a zone relatively free of magnetic anomalies in general for the preparation of the drilling, 3 extra profiles were measured to the E of Nagyecsed.

The methodological preparation of the measurements was made according to the experiences gathered in 1969: everything had to be done in the interest of a better signal-to-noise ratio and a deeper penetration. The number of GF-9B seismometers (made in Poland) was raised to 30 for each channel. Areal groups were formed from 3 parallel seismometer-„chains", each chain containing 10 seismometers. The seismometer interval was 5 m, the distance between two chains 3 m.

Fig. 34 shows a disturbing wave pattern, characteristic for the survey area. The apparent wave-length lies between 16 and 42 m. The disturbing waves were well attenuated by the 30-seismometer groups.

Beyond all these, importance was given to the investigation of the geometrical characteristics of stacking spreads. From the results obtained with the expanding spread system of *Dix and Musgrave* it can be stated that it is not advisable to plan the offset distance between shotpoint and the nearest seismometer of the spread solely according to literary data and to choose a too long spread in this way. It is well visible in Fig. 35 that the energy and correlation possibility of the seismic signal deteriorates beyond a distance of 1.2 km. An offset distance within 0–1.2 km shows the greatest advantage. This observation agrees with the results of analyses made concerning the efficiency of common depth point systems in other countries. Literary data emphasize the advantage of short spread systems: „Although long spreads are economical, it appears that the optimum length has already been exceeded. Shorter spreads of appropriate design can produce better results in all respects with appreciably lowered possibilities for inaccuracies. The only disadvantage of the shorter spreads is somewhat higher costs." (The common-reflexion-point method, Oil and Gas Journal 30. 9. 1968 p. 85–86.).

In 1970, recording was made in two different systems. On areas with unfavourable energy conditions, the offset distance did not exceed half a spread (15 m), while on deeper parts with good energy conditions it was 345 m long (half spread). The distance between channels was 30 m (within a spread of 690 m) everywhere, except the region of Nagyecsed, where it was increased to 40 m.

The shot systems were, with a minimum of exceptions, unidirectional; the coverage was $6 \times 100\%$ everywhere, except the No-3/70 profile with $12 \times 100\%$.

As generally known, the Nyírség survey area is poor in energy. For generating it 50 kg of Paxit-IV explosive was used in each 18–21 m deep boreholes. On account of very strict security-technical regulations, many difficulties arose in the field-work; therefore we tried to experiment also with other energy-generating procedures. Initial experiments were carried out with a special explosive, promising good results from literary examples, the exploding fuse (Geoflex). An exploding fuse fabricated in Hungary (NIPENTEX) was used. Its detonation velocity is over 6000 m/sec, its explosive-content is 11 g/m, fabrication length 100 m. With the aid of an agricultural plough we ploughed it 45 cm deep into the ground. Arrangements with various parameters were formed from the ploughed-in individual threads. On account of eventual acoustic wave effect, the distance between the shot and the nearest seismometer was chosen for 700 m. The resulting records are shown in Fig. 36. According to the results of the experiment, one has every hope for being able to use the Geoflex procedure as an effective energy-source in the Nyírség area.

The reflexion material recorded on megnetic tape was referred, by a static correction computed with indicatrix-type procedures, to a level of +100 m. a.s.l. Our experience in connection with the static correction has been that the goodness of correction is strongly dependent also on the shotpoint-distance of the channels. It is much more difficult to apply a good correction to the reflexion signals of distant channels, than to those of channels nearer the shotpoint. This phenomenon arises on account of the noise-sensitivity of the channels with lower energy.

The dynamical correction has been computed from velocity surveys and T_0—ΔT data. Average-velocity computations in the Dix-system yielded results comparatively near each other.

Velocities have been computed not only basing on special shooting systems, but also computations from the channels of common depth-point stacking systems began. Velocity computations on this principle are of high importance, since they can be carried out by computer directly on *routine records* with suitable programming, along one profile, with the required density. Fig. 37. shows the velocity spectrum cumputation results of six channels belonging to a common depth point, in a V_{RMS_i}—T_0 coordinate system with time-gates of 60 msec at every 30 milliseconds. By connecting the points of maximum energy, found by the program itself, the course of the time-weighted square mean velocity function (V_{RMS}) according to T_0 is obtained.

On the right side of the diagram, the temporal variations of the relative channel-energy are presented. The example shown originates from the neighbourhood of the point 8500 of the reflexion profile No-10/70. Even the deeper horizons display a good energy, contrary to the part of the area screened by magnetic anomalies.

An extended application of the method will furnish valuable data for our methodological research.

The reflexion records have been mostly processed on the analog center CS–621 of the NOGT; some of the material,—on the so-called "minicenter" SDC–1 of the Institute.

Some time-sections from the more interesting types of areas are shown in a few figures.

Fig. 38 shows a six-fold stacking section along profile No-15/70, traversing the nearly N-S directed magnetic anomaly at Nagyecsed. On both ends of the section, the presence of instrusions disturbing the even course of layers is clearly visible. A characteristic pattern within the range of the magnetic anomaly is shown by the double elevation with a quiet course of sedimentary beds between them, Over the magnetic anomalies, even the structural froms of the loose sediments are somewhat bent.

A similar part is shown also on Fig. 39, representing the Kállósemjén section of the sixfold stacking profile No-5/70, recorded with a short offset system. Until 1,1 second, arrivals from horizons with an excellent signal-to-noise ratio have been recorded. Under these, diffraction events referring to a fractured character occur.

The $3 \times 100\%$ variety of the stacking-section No-10/70, running parallel to the frontier, originates from one of the most interesting parts of the survey area. A horizon starts at abt. 1,2 sec, then it deepens first gradually, later steeply and reaches a depth of 2 sec around the point 700 of the profile (Fig. 40). This profile furnishes a good picture of the young sediment-deposition of considerable thickness of the area. This may be interesting from the point of view of prospecting for hydrocarbons. Its importance is raised by the fact that the screening effects, detectable by magnetic and complex electric survey and characterizing a great part of the Nyírség area, disappears in this part.

In connection with the development of the seismic digital field equipment, several contracts (in Hungary and with partners abroad) have been made, related to phases of different requirements of the research.

As for the Hungarian contract (with the Hungarian Academy of Sciences), the main purpose was a rapid construction of an experimental equipment with a comparatively broad dynamical range and computer processing possibility (SU-24), in order to utilize its favourable parameters mainly in crustal investigations and in prospecting as soon as possible.

In the finishing phase of the equipment SU-24, several units have been rebuilt, resp. improved for the sake of operational safety.

The pre-amplifiers have a symmetrical toroidal-transformer input of 1400 ohm, with a high-pass filter of a limiting frequency of 15 cps and of a slope of 24 dB/o, with a notch-filter of pole-frequencies of 49.4 and 50.6 and an attenuation of 40 dB, further with an antialiasing filter of an attenuation of 40 dB.

The noise calculated for the input of the amplifiers is, with filters off, 0.2 μV_{eff}. Their maximum voltage gain is 30 dB. Maximum operable signal level: 21 m V_{eff}.

The dynamic range of the binary amplifiers is 42 dB. Instead of the medium level A/D converter, a zero-level converter has been applied and the dynamic range increased to 72 dB (11 bits + sign). The overall dynamic range of the equipment is consequently 114 dB (1 : 500,000), its accuracy 72 dB (1 : 400). The maximum gain is 91 dB (1 : 30,000), thus the own noise of the amplifiers is sensed already by the A/D converter. In our first experimental digital equipment no higher binary gain was endeavoured, since it would be utilizable only when the aim were an operation of multiple (50–100-fold) stack. For large charges used in crustal surveys, no such aim has been set; such a requirement does not seem in place, in lack of suitable energy-source, even for other surveys with the digital field equipment.

Other reconstructions were made in the digital magnetic tape unit, in the control unit, in the playback and testing unit, further in the supply in order to increase the stability and to exploit earlier experiences.

With the equipment SU-24, systematic crustal investigations for a month around Hajdúszoboszló, further multiple stacking experiments similarly for a month in the Nyirség area were carried out.

213 SETTING THE GEOLOGICAL COMPUTER CENTER INTO OPERATION AND DEVELOPING PROCESSING UNITS

In 1970, the basic units of the computer MINSK-32 were purchased and their setting into operation began. For map- and diagram-drawing purposes, anincremental plotter Type 6011 of Computer Instrumentationca Ltd. was bought and a seismic section plotter built. Under the consideration of multiprogramming possibilities, a tape-puncher. Type Facit 4070 and 2 high-reliability magnetic-tape storage units Ampex TM-7 were acquired, and the matching of peripheries started.

During 1970, the minicenter was operated first in the continuous-profiling operation mode adjusted in 1969, with good section quality. Later in the year, also the improved variant of the new seismic, digital-controlled section plotter, containing also the necessary control, was ready and operated in routine.

Today multiple stacking sections are made only in digital way. For this purpose, the records of the frequency-modulation equipment SM-24+6 are transcribed into record with SDT-1 type recording. The transcriptor unit operates in the following modes:

analog-digital conversion,

digital-digital conversion,

mixing and playback for the minicenter SDC-1

control of the above-mentioned operation modes.

Also the control unit for plotting multiple-stack reflexion cross-sections has been built and tested on 300% and 600% stack profiles. The technical system of the unit is good; as to full reliability, especially to its sensitivity to external noise, further improvement is necessary.

214 DEVELOPMENT OF ENGINEERING-SEISMIC EQUIPMENTS

The optical system for UV-recording with the Pioneer-3 equipment has been built, in cooperation with the MOM, with a 75 W Xenon bulb as a light-source. The latter has the advantage against the mercury-vapour lamp, that it does not require pre-heating (and, on this account, a higher capacity current source).

The experiences gathered in this work have been utilized in the construction of the UV recorder of the digital field equipment. The recorder is driven by the synchro-motor of the Pioneer-1 type equipment, but the

500 cps generator unit can be synchronized with the digital magnetic tape equipment.

Plans for a shallow seismic field equipment with stacking system have been prepared with the aim of being able to carry out seismic surveys also in such places, where the single seismic signal does not emerge from the level of ground unrest.

215 SEISMIC THEORETICAL RESEARCH

Experimental seismic data processing began with the computer MINSK-32, using the first part of the six-fold stacking material from the profile No-69/8a measured in the Nyirség area. The main steps of processing are:

1. input of frequency-modulated records through an A/D converter, with control printing
2. static and dynamic corrections,
3. common depth-point channel-selection (TG),
4. stacking,
5. automatic improvement of static corrections,
6. digital frequency filtering,
7. two-dimensional (velocity-) filtering.

Also the program for true amplitude recovery (TAR) has been prepared in several varieties.

This first variety, giving informations also about seismic energy conditions, separates and individually investigates the factors causing energy changes: the course of the program, resp. of the BGC, spherical dispersion and absorption losses.

The second variety of the TAR is a digital modelling of the AGC functions.

The third variety compensates the decrease in average energy by sections, with linearly varying gain.

For theoretical work, a program system of the automatic processing of pressure-wave records, and a program for modelling of wave-propagation in inhomogeneous media were prepared. In the analysis of pressure-wave records, the mechanism of ghosting, the laws of signal-shape propagation and the effects of charge weight were studied.

With the wave-propagation modelling programs, propagation of ultrasonic waves in porous model media, generated with the Monte Carlo method, were studied, in order to examine the validity of porosity-velocity relations of ***Wyllie***, so important in acoustic interpretation.

Besides these, controlling punched tapes, interpretation nomograms and dominant-frequency finding programs were prepared for the correction unit of the minicenter.

22 GEOELECTRIC

221 GEOELECTRIC METHODOLOGICAL FIELD RESEARCH (NYÍRSÉG AREA)

The program of geoelectric deep-structural exploration of the ELGI for 1970 was determined, in the first place, by methodological problems arisen earlier in the Nyirség area. DE-soundings indicated in the sedimentary complex a high-resistivity horizon, the depth of which corresponds to that of the upper seismic refraction boundary with a velocity of 4200—4,300 m/s (Fig. 41). The geological identification of this boundary is not simple: it may be a compact lavatic member of the Miocene volcanic complex, or the Miocene-flysch boundary itself. The first MT soundings in 1968 indicated, however, that a good conducting complex and another high-resistivity horizon exist under this high-resistivity „screening" layer. A low-resistivity complex between two high-resistivity horizons may be important for oil-prospecting. It can be assumed, namely, that the Miocene volcanic rocks are not everywhere directly overlying the basin floor, but the latter is covered by clastic sedimentary reservoir rock series of varying thickness. Our methodological research continued therefore with the aim of gathering as many informations about this low-resistivity complex as possible.

Our first interpretation tentatives for the determination of the thickness of the screening layer were made by assuming homogeneous, isotropic layers limited by horizontal planes.

As known, the screening of a high-resistivity layer imbedded in a conducting medium is determined not only by the thickness of the layer and the period of the electromagnetic wave, but also by the angle of incidence of the wave and by the dip angle and polarization of the layer. Consequently a thin but inclined high-resistivity layer may exert a screening effect in a comparatively broad frequency band. In such a case, dip-directed currents yield information about the complex down to the screening layer, while strike-directed currents reveal the total effect of the conducting complex.

Without going into details of the methods used, it can be stated that we succeeded, in certain areas, in determining the value of longitudinal conductivity (S) down to the top of the screening layer ($S_{1_{MT}}$), resp. to the basin-floor ($S_{2_{ME}}$) Fig. 41). By the way, the $S_{1_{MT}}$ values agree with the $S_{1_{MT}}$ values obtained from dipole-sounding. A control has been needed, however, also for the $S_{2_{MT}}$ values.

Since the BEMF-method (build-up of the electromagnetic field) can „transilluminate" not too thick screening layers, we introduced the BEMF-measurements in the Nyirség area in 1969 already, but we had to overcome numerous methodological and instrumental problems which were mostly solved in 1970. This has been supported also by the experiences gained over the horst at Biharnagybajom, well disclosed by drilling and geophysical exploration. Here, the S values obtained with BEMF agreed within error limits with the magnetotelluric $S_{2_{MT}}$ values.

Most of our 1970 survey points were placed along the seismic refraction profile NoR-1/69. The comparatively high ΔS values on the southern and middle part of the profile refer to a thickening of the lower good conducting complex. Between these two sections, however, only the S_a value was furnished by all measurements. This can be interpreted so that no conducting layer of considerable thickness exists here between the screening layer and the basin-floor. Since this section coincides with a magnetic Δ T maximum, the immediate surroundings of an effusion center seems to be in question. On the northern part of the profile, the Δ S values lie within the error limits, being therefore not interpretable.

222 COMPUTER PROCESSING OF GEOELECTRIC DATA

Our aims in computer processing of geoelectric survey data were laid down in the Annual Report for 1969. Since our capacity in this regard is moderate, we want to solve, as a first phase, data-processing for two methods, most important at present: resistivity measurements and magnetotelluric frequency-sounding.

In resistivity measurements, computation of theoretical curves of vertical electric sounding (VES) has become routine-work already, meeting always the requirements of the field survey. Programs for curves, resp, families of curves for any number of layers are available, automatic plotting and reproduction of these are also solved.

The procedure most favourable for field parties is briefly described as follows:

In a given area, first a few orientating soundings are made, in the knowledge of the geological pattern. With these, the geoelectric models valid for the area determined and a few corresponding characteristic curves concerning the geoelectric models are checked for correctness, then the list of families of curves to be computed handed over to the computer center.

A basic condition of such solution is, of course, to considerably lower computer and plotter costs, and to assure sending the families of curves to the field party within a few days after the demand was presented.

At present, families of curves are drawn by a Bryens-plotter controlled by a computer MINSK-2. These curves have an accuracy of ± 0.3 mm only, satisfying, however, field requirements. Plotting with an accuracy of ± 0.1 mm with Graphomat, further reproduction with Xerox or by printing is made only in case of frequently occuring families of curves.

One of the greatest problems of the interpretation of VES-curves is the equivalence of curves, i. e. that several different geoelectric sections may correspond to the same sounding curve. In this field, research work, started in the previous year, has continued, the equivalence-investigation of all H-type curves, besides H_∞ , has been solved and an interpretation procedure developed satisfying also practical requirements. Naturally this does not mean an automatic elimination of ambiguities due to the equivalence, but the possibility to decide, for a measured curve, what limits and what values may be taken by the parameters of the layers (thickness, resistivity).

For each basic type, the equivalent curves can be systematized in such a family of curves, where the resistivity of the third layer is given (i. e $\frac{\varrho_2}{\varrho_1}$ is known, the remaining parameters: m_1, m_2 and $\frac{\varrho_1}{\varrho_1}$, varying).

Fig. 42 represents family of equivalent curves of the type H_2. Equivalence nomogram (Fig. 43) belonging to this family of curves gives the possible thickness ratio $\lambda_2 = \frac{m_2}{m_1}$ for any curve, marked with a number on the curve, as a function of the resistivity ratio $\mu_2 = \frac{\varrho_2}{\varrho_1}$. The dotted line on the nomogram indicates the upper limit of the equivalence-range. The lower limit is $\mu_2 \rightarrow 0$.

If the curve measured in the field belongs to this basic type and is equivalent, it must coincide with one of the curves of the equivalence curve-family (resp. it can be interpolated between two curves). The field curve shown on the figure corresponds to the theoretical curve No. 6. With the aid of curve 6 of the equivalence-nomogram, $\mu_{2\max}$ and V_2, further μ_2 belonging to a given $_2$ can be determined (Fig. 42). On the lower part of the figure the value of correction factor b can be read off and the correct value of m_1 computed with its aid.

With the equivalence family of curves H_2 presented and with the nomogram, the evaluation of the curve for the upper and lower limit of the equivalence-range and for a given value ϱ_2 can be performed (in about 2 min).

The above-discussed families of curves and nomograms have been computed, up to now, for the basic types $H\infty$, H_5, H_2, H, H_1 $H_{0,5}$ $H_{0,25}$ further tentatively for the type $K_{0,25}$.

As to the computer processing of magnetotelluric frequency-sounding data, we want to apply this to digital field records. In 1970, as a preliminary study, analog records were processed. Out of these, digitized sections were made with a converter type KAD-69, then the frequency desired was enhanced with mathematical filtering. Finally the impedance was determined with the method of least squares. Fig. 44 shows an original and two filtered records. It is observable that even this simple procedure permits to interprete such sections that are of no use on the original record.

223 DEVELOPMENT OF AUTOMATICALLY COMPUTING AC INSTRUMENTS

With the further development of automatically computing AC instruments, we wanted to solve two problems.

With the instrument type GE-50, it has been possible to attain, at a value of $\varrho_a = 10$ ohmm, an electrode-distance $AB_{max} = 800$ m.

Az $AB_{max} = 800$ m, the considerable error occurring so far (and depending on ϱ_a) was caused by mutual inductivity between measuring and supply-electrode lines, similar, as for wave-form distortion, to the skin-effect. In a first approximation, this error voltage is a function of the AB-MN distances only; consequently the error considerably increased at an arrangement AMNB ($\varrho_{max} = 10$ ohmm), but remained within the limit of error ($\Delta\varrho = \pm 3\,\%$) at a higher ϱ_a-value (around 50 ohmm) even at AB = 640 m. With shifting the MN-lines by 50 m perpendicularly to the original line, this induction effect practically ceased to exist, and the experiences of several field measurements resulted in the conclusion that the spread distance can be increased to AB = 800 even at $\varrho_a = 10$ ohmm (Fig. 45).

In the equipment GE-60 the input impedance in the highest sensitivity stage has been increased from the previous 10 kohm to 100 kohm.

By increasing the selectivity of the instrument, also the spread system could be simplified. It became possible, namely, to shorten the 50 m cable-offset used with the GE-50, to 25 m at a 100m MN distance and to 8 m at an 8 m MN distance (Fig. 46).

With the solution of these two problems, a very important experience has been gained for further development: the selective circuitry of the AC instrument must provide a minimum suppression of 60 dB not only on the industrial frequency, but even on the third harmonic of the square-wave supply current.

231 METHODOLOGICAL RESEARCH IN WELL-LOGGING

Investigation of a pulse-system borehole neutron-generator on a laboratory model

The Soviet-made borehole neutron generator IGN-4 has been adapted to the Hungarian well-logging equipments. Digital recording and data processing has been provided by a recording and control system developed in the Institute. Automatic normalization of measured data and the adjustment of the optimum width of time gates was realized by presetting the neutron-number. Previous to application in boreholes, stability and sensitivity indices have been determined under laboratory conditions for concentration variations of aqueous solutions of various chemicals.

In case of series consisting of a great number of recordings, stability is characterized by the scattering of observed values. The upper limit for measurements with the same duration, ± 11 μsec. Presetting the system to neutron pulses, the upper limit of scattering, using pairs of time gates, descended to ± 5 μsec. Optimum results are obtained when the five time gates at disposal cover nearly the entire decay period of the neutrons. Here, the maximum empirically determined scattering is ± 1 μsec.

Empirical data from investigations with various salt-solutions deviated, on account of the limited size of the model used, from the calculated (resp. literary) values, but the character of variations agreed with them (Fig. 47), making an estimate of expectable results possible. The neutron life-time of oil and salt-free water measured as 115 μsec/80.4% of the calculated, resp. literary value.

This is regarded as basic level and the formation waters with NaCl and boron content must be separated from this. The limit of characteristic separation of practical measurements, fixing it as a threefold of the upper value of the experimentally observed scattering, is assumed as the 0.5% NaCl content with a value of 109 μsec. According to our experimental measurements, a borax content of 0.018+ decreases the value of neutron life-time in a measure equal to a decrease caused by a 2+ solution. The separation of salt-water and oil is made more distinct by the boron content of formation waters in Hungary.

In 1970, the accuracy of the calibration techniques of two-detector gamma-gamma logging has been further increased.

For this purpose, the prototype of the radiometric equipment KRG-2-120-60 was developed. It is equally suitable for model and field measurements. The experimental measurements began in 1969; the equipment has been transformed in 1970 and made suitable for weight determinations under model and field conditions.

In the etalons different weights, built up at the model site, the optimum size of short and long sondes, the intensity and type of radiation source have been established, allowing the determination of the bulk-weight with the required accuracy (0.05 g/cm³). During the measurements, the sonde was pressed against the wall, and the radiation source shielded by lead towards the mud. From the final results of the experimental measurements, following measuring parameters are given here

1. sonde-lengths	$a_r + 20$ cm and $a_h + 50$ cm
2. distance of lead shield between source and detector	5 cm
distance between source and mud	4 cm
3. radiation source	7.28 mC Cs^{137}

From the calibration results obtained with short and long sondes, after dead-time correction, the calibration curve of the equipment has been constructed (Fig. 48). The straight line on the figure is the calibration diagram of the radiometric equipment, Type KRG-2-120-60, determined by the different volume weight values.

As to its character, the calibration diagram agrees with similar diagrams of the Schlumberger-type compensated systems. The gamma-gamma system elaborated by us permits to determine the volume-weight of rocks (at present for mud-cakes of small thickness: $t_{mc} \leqq 1$–1.5 cm).

With the radiometric equipment, calibrated for volume weight, several boreholes were logged. As an example, the gamma-gamma logs obtained in the borehole KF-9 at Gyöngyösvisonta (Fig. 49) and the corresponding volume-weight values calculated for a few beds are presented (Table I) For the sandy formations interbedded in the lignite-layers, porosity values have also been calculated; for the time being no comparative data are available.

Volume-weight values calculated from two-detector gamma-gamma logs of the borehole No. KF—9 at Gyöngyösvisonta

Table I.

No.	Rock	depth m	g/cm³	Porosity
1.	sand	10,0—11,5	1,82	31,60
2.	clay	11,5—19,0	1,68	—
3.	clayey sand	24,0—33,5	1,84	30,84
4.	lignite	33,5—36,6	1,44	—
5.	lignite	36,6—39,0	1,32	—
6.	sand	39,0—51,5	1,96	26,6
7.	lignite	51,5—55,0	1,32	—
8.	sand	55,0—60,5	1,84	30,84

Determination of hydrogen-porosity

Investigations for the determination of H-porosity were made on the H-model of the Institute with the neutron-sonde KRN-2-150-85 and with the scintillation probe SSD 1526-B.

The porosity was investigated within the range 5.2–40%. The probe-length varied by 5 cms in an interval of 35–90 cm. The relation between pulse rate and porosity was established. On the basis of the obtained results, considering also the mathematical derivations known from literature, optimum probe-lengths were chosen and optimum measuring conditions, valid for the given model-conditions were determined. A calibration diagram with a number of points, characteristic for the probe, has been drawn (Fig. 50), where the ratio of H-porosity and pulse rate related to water has been plotted for a model diameter of 159 mm. Theoretical calibration curves have been calculated for the same diameter (plus a characteristic oil well diameter, 216 mm). According to these, the slope of the measured curves is, for any of the proble-lengths, higher than that of the calculated ones. The reason lies in the difference of the initial conditions of calculation and modelling. It is out intention to find a closer relation between calculated and measured curves in the next year.

The computer program for the calculations permits to extend the calibration curves obtained to all borehole diameters occuring in practice.

The procedure includes methods for both single and double probe-lengths, and the family of curves involving hole-diameter effects can be used in both cases.

The factors influencing the measurement in the course of corrections were taken into consideration by means of families of deviation curves.

In 1970, work in this theme aimed at computer processing of well-log materials from oil wells.

Investigations siding the fulfilment of contracted tasks: analysis of the earlier prepared full program for interpreting acoustic logs, with special regard to the validity of geophysical bases used for constructing the program; realisation of the computer program serving to calculate equivalent formation water resistivity (R_{We}) and to process various logs; transformation of the earlier prepared boundary program.

For beds selected from the optimum laterolog curve, with the modified boundary program, the remaining part of the program calculates and prints out the following gophysical parameters, according to the arrangement, shown below:

Z_{H_1}	Z_{H_2}	h	
R_{We}	PS	nat. gamma	neutron gamma
	a_1	a_2	Hn-gamma
MO_{Rt}	Δa		

where:

where: Z_{H_1}: lower boundary of the bed in meters

Z_{H_2}: upper boundary of the bed in meters

h: thickness of the bed im m

Rop. lat.: resistivity of the bed in ohmm (from laterolog curve)

PS: SP value of the bed in mV (with correct sign)

nat. gamma: natural radioactivity of the bed in cpm

n-gamma: neutron-gamma level of the bed, corrected by natural gamma, in cpm

R_{we}: equivalent formation water resistivity of the bed in ohmm

a_1: clay-content of the bed, calculated from the SP curve

a_2: clay-content of the bed, calculated from the natural gamma curve

Hn-gamma: hydrogen-index of the bed, calculated from the neutron-gamma curve

MO_{Rt}: moving-oil index of the bed

Δa: differential clayeyness, characteristic for the bed

The entire computer program has been tested on several well-logs from Algyő. Experience showed that in most cases the layers to be investigated were correctly selected by the program; in certain cases, however, it appointed the lower boundary incorrectly (its cause will be cleared up after a great number of logs will have been processed by computers. Geophysical parameters computed for individual layers have been checked by manual computation.

Well-logging methodological field experiments

The selective gamma-gamma method has already been used for years to indicate ore-bearing layers. The unambiguous indication of ore-bearing sections was limited by rock density. Our task was to minimize the density effects. Our related methodological experiments partly aimed at modifying the proble-length. The new sonde-arrangement permits also to achieve very short sonde-lengths (4–10 cm source-detector distances). On the other hand, type and intensity of the radiation source and the quality of the tool case have been investigated.

Fig. 51 shows a selective gamma-gamma log recorded with two different sonde-lengths in siliceous andesite breccia. As constated, the log recoderd with the greater (25 cm) sonde-length is strongly affected by rock density variations, while the one recorded with the smaller length (10 cm) is less influenced, giving also a better resolution.

By choosing a source-detector distance of 8 cm, the density effect becomes still weaker and the resolution still better (Fig. 52). It can be seen that the selective gamma-gamma log is not sensitive to rock density variations, while the density log recorded with Co^{60} indicates rock density variations.

The method in its present form is also suitable for indicating the total metal content. The selective gamma-gamma log and the data obtained from core analysis show a good agreement (see corresponding figures). Certain deviations may be caused partly by an insufficient core recovery or by the lack of information about the accurate position of the core, partly by the presence of caverns affecting the logging itself.

Geological results of logging imply the indication of ore-bearing sections and the separation of improductive rocks within them; the elimination of uncertainties in sections with insufficient core recovery.

The selective gamma-gamma method has also been employed for determining ore-bearing sections in a hole drilled with the purpose of prospecting for manganese (Fig. 53). As it can be seen on the figure, the section containing manganese-ore can be reliably appointed on the selective gamma-gamma log only.

In 1970, the solution of problems of the national oil industry stood in the foreground. As our main task the development of high-temperature logging tools has been regarded. The tool of type KRG-2-250-70 contains two gamma-photon-sensitive detector groups, i.e. it belongs to the two parameter gamma-tools. Its maximum operation temperature is 250° C (with this tool, radiometric logging was made in the deep drilling at Makó). Two similar tools (of a diameter of 86 mm), with corresponding surface units type KRF-2-12B-220, have been built for the Hungarian oil industry.

In cooperation with our oil-industrial partners, efforts have been made in order to raise the temperature limit to 270° C (occasionally to 300° C), and the sonde-head, packing and case for the tool type KRG-2-300-86 have been built. The electronic parts of the tool have been tested under laboratory conditions.

For the National Oil and Gas Trust, a small-diameter (43 mm), high-temperature (180° C) logging tool (type KRNG-2-200-43) has been built, which is suitable for detecting oil-, water- and gas-bearing layers behind multiple iron and concrete casing in producing oil wells.

In order to maintain a good layer-resolution with this small-diameter tool, a proportional tube filled with Texlium 9339 type He^3 gas up to 10 atm and 20 Geiger–Müller tubes type SzBM-14 in four successive packets have been built in the former as a neutron detector and the latter as a device for transferring gamma-rays. With these detectors, a comparatively high ray-sensitivity has been obtained even with small dimensions.

The electronic parts of the tool are all transistorized. They are mounted in a steel case of high pressure-resistance, fitted with O-rings. The case can be coupled to a 5000 m long single core sheathed steel cable.

In the past year, two such equipments were built and laboratory-tested. Field tests will follow in the next year.

Apart from these, a logging tool of the type KRN-2-150-86 and a surface unit of the type KRF-2-12 have been built for the Well-logging Methodological Department of the ELGI. Both the sonde and the surface unit are all transistorized. As a neutron-detector, a proportional tube of the type BF_3 has been used. The full electronic design of the experimental sonde has been published in the Annual Report for 1968. Fig. 54 shows a log recorded with this tool.

Other units built: a linear ratemeter type LR-63-50, a universal supply unit type TPS-4-50 and a complete downhole electronic system type KRG-2-250-70.

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As to the scintillation radiometric equipments, the program for the past year included the introduction of nuclear tools with scintillation detector system of types SSD-1015 (single-channel, 60 mm diameter, 100° C temperature-resistance) and SDD-1526 (two-channel, 85 mm diameter, 150° C temperature-resistance).

We changed the electronic design and constructional techniques in order to ensure the stability of the tool in routine work, too. The energy-resolution of energy-selective tools has been increased by a more up-to-date and better quality photo-electron-multiplier and crystal. Within the Soviet–Hungarian cooperation, the borehole-tool SVGS has been built. In this work we utilized our experiences concerning the application of the Soviet-made metal-case Dewar bottles. In this way we succeeded in raising the maximum operation temperature of scintillation tools to 200° C.

233 ELECTRONIC WELL-LOGGING

The experimental development of the resistivity-logging spectrum-frequency basic circuits of the medium-depth (3000 m) well-logging equipment has begun, with 4+1 channel (two-frequency-channel) measuring circuits and two square wave current generators. These units provide matched connections to the digital magnetic-tape recording system. Its analog photorecorder contains 9 galvanometers. Basing on the circuitry solutions developed for the spectrum-frequency well-logging system, about 50% of the laboratory models of the experimental circuits are finished already.

A null-series of three spectrum-frequency moderate-depth well-logging trucks was delivered for our Czechoslovakian partner. Against earlier equipments of the same type, it contains a digital voltage output, an inclinometer surface unit and an induced potential surface unit, too. According to the wishes of the Czechoslovakian partner, the equipments have been provided with special complex resistivity-logging and directed-field borehole tools.

The SSP-SPP and capacitance methods have been studied and laboratory investigations were made for the specification of the instrument. Steps have been taken for patenting it in Swedish, French and Canadian relations.

Laboratory measurements, temperature-characteristics investigations and field measurements were made in order the develop the induction calibration system, resp. to test the individual borehole-tool types and surface units. The temperature-resistant type of the calibrating switch was longperiod-tested in laboratory up to 240° C. The investigation of the outer system, resp. characteristics of our induction tools was carried out in co-operation with the metholological group. It has been constated that the six-coil system is properly compensated up to a mud resistivity of 0.2 ohm. The Soviet-made temperature-resistant constructions, calibration and modelling materials were studied. Under consideration of these and of our own experimental results, plans for the production technology have been prepared and circuitry experiments carried out in order to be able to develop a great-depth type of the induction tools for 210° C and 1000 atm in 1971. Two six-coil borehole-tools have been designed; their main coil systems have been constructed, according to the need of the oil industry, with 40 cm and 1 m intervals, providing information with different penetrations. The case of the tool is finished, the stability and sensitivity tests in laboratory have been carried out. The zero stability is better than 20 mS.

Experimental field measurements were made with the induction system designed for the oil industry. On the latter's request, the surface unit has been constructed in the system of the deep electronic logging equipment, with a 4500 m long cable and with a coil-system of a main-coil distance of 1 m for the sake of greater penetration required. The calibrating switch system has three positions: for two calibrating voltages and one operation switching. Its sensitivity is about 20 mV/100 mS. Three successful loggings were made anyway in logging depths smaller than 2000 m.

Also the tests with the induction surface unit of the moderate-depth logging equipment were finished. This equipment will be presented, in co-operation with NIKEX, in the GDR. Its six-coil system is properly compensated up to a mud resistivity of 0.2. The coil system is built on a solid plastic body, the downhole electronic units specified for 150° C and 600 atm. Main coil distance: 40 cm; sensitivity: 20 mV/100mS; the zero stability better than 1 mV. Its calibrating switch system contains two electric calibrating marks (0.5 and 5 ohm) and an operation position.

For ore-logging purposes, a small-diameter (60 mm) four-coil induction borehole-tool has been designed. Its construction is a task for 1971.

The experimental field borehole electronic unit for 210° C is finished in 50%. Its resin cover, with its basic material of glass-fibre-reinforced eporosite, obtains a heat-treatment on 240° C. Its design-, modelling-and log-material is included in the detailed report of the Institute *(Archives)*.

At present, a common feature of the various digital logging procedures and equipments, known in well-logging practice, is, that all of them are suitable for processing very slow signals only and they sample the individual information channels in the function of depth or time in such a way that each sampling furnishes a single numerical data. The equipments used at present are suitable for recording only one-variable functions by channels, not satisfying the future technical and economical requirements, not even exploiting the possibilities at disposal.

Beyond the digital recording of continuous one-variable (e.g. resistivity) functions, the complex digital well-logging equipment permits a simultaneous digital recording, on several channels, of rapidly varying functions or function-pairs with two or more variables (e.g. acoustic wave-pattern, decaying signal form of induced polarization measurements, proton-precession measurements), further of multivariable functions, resp. function-pairs comprising statistical elementary events (e.g. energy-selective measurement of natural and gamma spectra, created by elastic scattering of neutrons or radiation capture, measurement of neutron-lifespan, etc.). Data arriving from the individual information channels are processed in a time-multiplex system, with a multi-programmed solution arranged in a priority sequence.

At present the equipment is being constructed, in co-operation with the National Oil and Gas Trust, with six priority levels and eight different programs. The individual programs can be operated also in suitable combinations, with such a restriction for the time being, that each sampling may result in a data block consisting of a maximum of 256 words. The concept of sampling has been generalized in the equipment so that each sampling represents the total of all the informations required from a single depth-point (interval). The depth value, i.e. the address-like information, is contained in two words by every block; apart from this, e.g. it may contain the data obtained from six one-variable continuous function and a single energy-selective spectrum (eventually gated in time, too) from two gamma-detectors.

The construction of the equipment permits connection to the borehole-tools, surface units and adapters used in present logging practice, not excluding the borehole-converter solution either. The equipment is built up according to the most up-to-date design and constructional principles, mostly of integrated circuits.

Further details of the equipment and the possible application fields have been discussed in a separate paper (Magyar Geofizika, XII. 1., 1971).

In 1970, the technical plans of the system and circuitry of the experimental equipment were completed. The construction work advanced to about 70% of the laboratory phase.

The main outlines of the specification set as an aim for the experimental type:

1. simultaneous six-channel recording with a power of resolution of 1% for slowly varying one-variable functions (e.g. resistivity, SP);
2. recording of the upper 2×121 channels of a simultaneous digital analysis of 128 channels of each of two nuclear detectors;
3. recording of the energy-window data of further four single-channel digital energy-analyzer placeable in arbitrary grouping on any of the two detectors, with an accuracy and resolution determined by the 128-channel analyzer;
4. recording of the decaying signal form of induced potential measurerement simultaneously on seven channels, with the recording of 121 points of each channel with an accuracy of 2%. The sampling rate is 100 μs or 1m^{s}.
5. Digital recording of the wave-pattern of acoustic measurements, for a system with two transmitters and one erceiver; recording of 242 data of each wave-package one by one, with an accuracy of 2%; with a sampling rate of 5 μsec.
6. sampling rates (taking the concept of sampling in the earlier, generalized sense) are: 5 cm, 10 cm, 20 cm or 50 cm;
7. The equipment yields the observed depth of the address data of the blocks formed of the individual samples in a system permitting the automatic depth correction for the computer program.

The experimental type of the equipment consists of two main units: the digital field recording equipment and the digital playback unit operating at the field base.

The experimental field recorder is built up of a data input unit, a data sorter and arithmetic unit, a digital magnetic-tape data storage unit and a display unit. Apart from these, it includes the central control unit providing for multi-programming the above mentioned units and for maintaining the priority sequence, as well as for time-dependent measurements. In time-dependent measurements, sampling, starting and stopping of the measurement is made not in the function of depth but of time. The data input unit contains also the converter and multiplexer. The data sorter and arithmetic unit contains also a ferrit-memory of 256 words (with 16 bits in each word). The display unit provides the driving of the visual galvanometer-recorder and contains an oscilloscope unit for visual presentation of spectra, wave-patterns and signal forms.

The functions of the *digital playback unit* on the basis are:

1. section-wise drawing of logs from field digital records, according to wish, but from a material sampled at a rate equal to that used during recording; at most, scale, calibration and starting point can be schosen by the interpreter;
   in a single step, the log or logs can be plotted from 1024 data.
2. Drawing, resp. oscilloscope display of spectra and wave patterns (on the oscilloscope, also the log sections to be drawn can be displayed).
3. Partial data reduction and processing, preceding the plotting of logs (e.g. of various radiometric energy-logs).
4. Data are received by the equipment from magnetic tape or punched-tape and presents data, beyond those mentioned above also on punched tape or printer.

The construction of both the field recorder and the playback units will follow the laboratory and field measurements to be made in 1971. The main tasks, in this regard, will be represented by design and construction work necessary partly for the final construction of the field equipment, partly for the realization of such operation modes which are still missing in the experimental type (e.g. pulsed neutron-generator measurements).