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NEOGENE EVOLUTION OF THE SOUTHEASTERN PART OF THE GREAT HUNGARIAN PLAIN ON THE BASIS OF SEDIMENTOLOGICAL INVESTIGATIONS

M. MUCSI AND I. RÉVÉSZ

ABSTRACT

The aspect and opinion of authors on the Neogene of the southeastern Great Plain were established as a result of the elaboration and sedimentological investigation of about 10 000 core samples. In addition to the structural and textural features of the rock samples the structural situation within the basin, as well as certain geochemical peculiarities and paleogeomorphological relations were also taken into consideration. The rhythmicity occurring in the Neogene sediment accumulations as well as the structural features of this rhythmicity were regarded significant factors. The study draws conclusions on the paleogeographic environment and modes of sedimentation.

INTRODUCTION

The area investigated lies in the southeastern part of Hungary. The majority of the detailed data published in this paper concerns the Pliocene sediments of the close vicinity of Szeged. In this part of the Neogene geosyncline of the Great Plain varied rock formations and facies were observed. Together with the sequence of 100 to 250 metres thickness which can be assigned to the Quaternary, the total thickness of the Neogene varies between 1000 and 6000 metres; in a smaller part of the area a value greater than 6000 metres can also be assumed.

Numerous geologists and paleontologists dealt with the filling up of the Carpathian Basin during the Neogene. Their statements can be comprehensively assigned to two directions. The first group of great number supposes erosion between the single stages and denies the continuous sedimentation. This direction was founded by M. HOERNESS [1853—1867] and KARRER [1877]. Others, the followers of HALAVÁTS [1882—1923] and LÓCZY [1913] assume continuous sedimentation.

The researchers of our days insist also on contradictory statements with compromises corresponding to the local features of the investigated basin part. On the basis of the borehole data it becomes ever conspicuous that the central formations of the basin cannot be or can be only conditionally identified with those of the marginal part or of central mountains type. The latter ones were several times studied both in superficial outcrops and in boreholes. The researchers assuming discordances start from these near-shore, thin strata and make generalization on the central part, too.

The most up-to-date and detailed investigations showed, however, the continuous sedimentation in relation with the marginal parts; in the strata sequence of concordant stratification tuff spreading indicates the boundary between Miocene and Pliocene [JÁMBOR, Á., 1971].

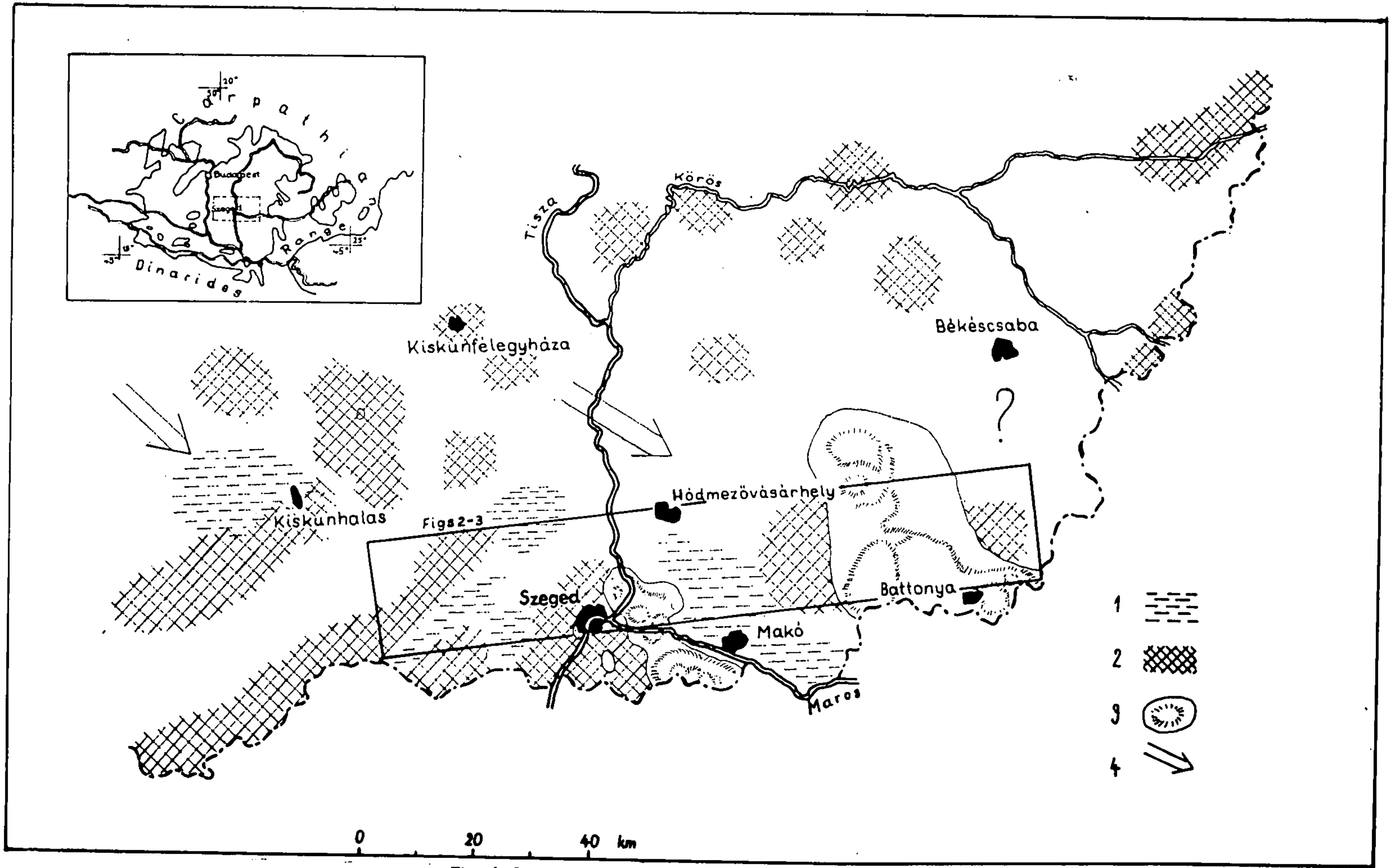


Fig. 1. Largest extension of Miocene sediments. Legend:
1) Miocene sediments accumulated at considerable water depth, in a reductive environment; *2)* Upper Miocene shallow water, saline or brackish water environment with islands of small area; *3)* Land em[illegible] iocene; *4)* Direction of transgression.

Basement

In the floor of the Neogene ("basement") sediments of varied facies are known [SZEPESHÁZY, K., 1973 and 1974]. On the basis of data obtained till now it can be assumed that among the basement formations the metamorphic schists and mesothermal gneisses, which can be assigned to the Precambrian, predominate. The rocks of Permian to Lower Cretaceous ages are also frequent, out of them the Triassic dolomites seem to be the most wide-spread ones. In the basement palingenic granites, granodiorites and quartzporphyres are also known; the latter one is hardly identified since the boreholes did not traverse volcanic sequence everywhere.

From the Upper Cretaceous to the Miocene, as well as in smaller spots to the Pliocene a long-lasting and intense erosion phase can be taken into account. The eroded sedimentary mass accumulated in the Carpathian flysch zones and in the Intra-Carpathian Paleogene troughs. Authors agree with the opinion that the recent spatial position of the rocks of different age and quality of the basement considerably differs from the original one, also in horizontal sense [SZEPESHÁZY, K. 1973].

Neogene sequence

The priority of chronostratigraphic classification was accepted as theoretical basis as against the biostratigraphic classification [HORUSITZKY, F., 1955 and 1971]. The Miocene, Pliocene and Quaternary strata of the investigated area belong to one structural stage. The temporal boundaries of the Neogene stages and parts of Hungary are recently only imagined isochronous surfaces. Errors are caused by the fact that limiting space of time has been attributed by researchers to lithological units and strata groups, or to certain fossils.

It is a fact that all the details of geological interpretation are interwoven by hypotheses. Some of the investigations are numeric and concrete but by the time one reaches the past by conclusions, i. e. from a past into another, from one field to the other it should be accepted that there is high probability of error. The ideal or required aim is to determine the formations of the geological past at a given moment. The geologists should be the geomorphologist, biologist and chemist of the past to realize this aim. The fact that the researchers of the earth sciences make bold to publish against of the aforementioned is due to their optimism and beside it that many hypotheses are proved by the ever increasing amount of industrial, mining experiences.

The mode, rate and environmental aspects of filling up as well as the paleobiocoenoses are known from several concepts but the dialectic aspect is missing in them.

Miocene

The Neogene sequence of strata of the South Great Plain shows continuous sedimentation and the unconformities caused by facies differences does not mean the interruption of continuity but indicates the spatial and temporal replacements of these facies [MUCSI, 1973].

As a result of the Styrian orogeny trench-like subsidences were originated also in the area of the South Great Plain. This phase shows a few and uncertain informations since the locations of the first Miocene transgressions fall also recently into

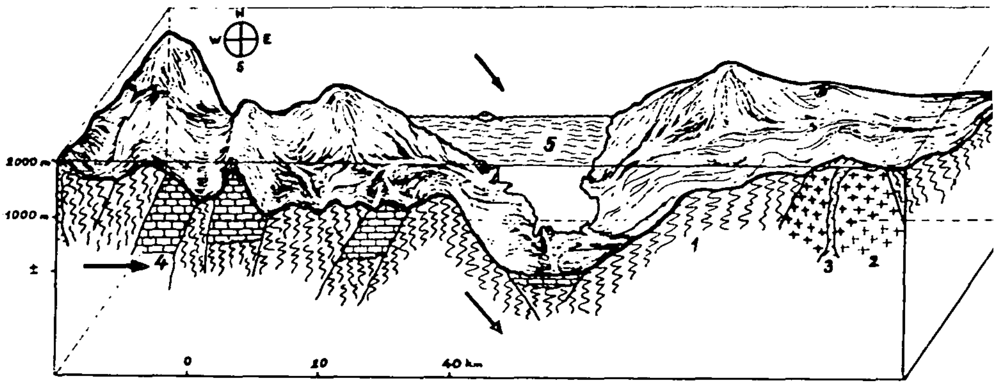


Fig. 2. Schematic block diagram showing the beginning of Miocene transgression. Basements: *1.* Metamorphic, *2.* Granitic, *3.* Quartz porphyric, *4.* Sedimentary, *5.* Sea

the structurally deep zones and these are hardly discovered by drills *(Fig. 2)*. Helvetian formations are known from the vicinity of Kiskunhalas, their presence, however, can be rendered probable also at other locations (*e. g.* the depression of Hódmező-vásárhely).

In the Carpathian Basin the climax of Neogene transgression followed within the Tortonian (*Figs. 1* and *3*). The complete Tortonian strata sequences of greatest thickness are found also in the areas of relatively deeper structural position. The depression southwest of Kiskunhalas is an exception where as against the thickness of 2000 metres of the Miocene sequence, the Pliocene hardly surpasses the thickness of 1000 metres. The rock material is of varied quality and extends from the near-shore conglomerates to the pyritic pelites accumulated in reductive medium and to the carbonates, respectively. The flysch-type sediment of the formerly and recently deep-seated areas is also worthy of mention. The accumulation of the sediments of coarser grain size took probably place from turbidity currents. At their recent place these are "foreign rocks" and faciologically dissimilar. During the Tortonian the multiphase crustal movements, the related earthquakes and the inclination of the sea-floor generated these sediment "clouds". The intermediary period is characterized first of all by the change of pH, further by other changes, e. g. salinity etc. as a function of which clay-marl ($CaCO_3$: 10 to 40 per cent), marl ($CaCO_3$: 40 to 60 per cent), lime-marl ($CaCO_3$: more than 60 per cent) were formed.

During the Sarmatian — regarding its absolute space of time — continuous sedimentation is assumed in the area in question. The Tortonian — Sarmatian boundary, resp. the connection of the two stages could not be fixed. In the area of the Great Plain the assignment to Sarmatian is carried out on the basis of hydrocarbon exploring borings first of all by fauna impoverishment relating to limnification. Consequently, in the central part of the basin its space of time is the absolute time of the Tortonian-Pliocene freshening [Mucsi, M., 1973] which depends on the fundamentals of the localities.

The maps demonstrating the distribution of seas and continents within the Miocene [Hámor, G., Jámbor, Á., 1971; Jámbor, Á., 1971] show that the "assumed extension of the Sarmatian marine formations" was greater than the whole area of the "Tortonian pelagic and littoral" formations. Areal displacements are taken into account also by the authors mentioned above.

According to MERKLIN, R. L. [1959] the Sarmatian of Hungary corresponds to the Upper and partly to the Middle Lower Sarmatian known from the southern areas of the Soviet Union. The other parts of Miocene are represented in Hungary by Pannonian facies. JÁMBOR, Á. [1971] renders the Sarmatian time of Hungary between the Upper Badenian (Upper Tortonian) and the Lower Pannonian (about the Lower Pliocene) and fixes its stratigraphic boundaries by changes in the bio- and lithofacies.

As to our opinion the investigated area has continuously subsided with changing intensity and proved to be a geosyncline till the Recent getting a deeper position as compared to its environment. Relative "pseudo-uplift" resulted in by filling-up of local significance is possible. In the Carpathian Basin the rise of Central Mountains resulted in enviroments dissimilar of that of the South Great Plain. Thus, in the central part of the geosyncline the research of the litho- and biofacies corresponding to the classical, evaluated sequences of Central Mountain type becomes resultless. The statement that the lack of marginal facies means erosion periods and uplift is believed causeless. This is especially unacceptable since the lack of Sarmatian facies is apparent and these are supposed to be in the deep zones.

In the area of the South Great Plain hiatus, especially erosion, denudation cannot be evidenced at the Tortonian — Sarmatian — Pliocene boundaries on a stratigraphic basis (photos from the bores of Makó and Hódmezővásárhely, probably those of Forráskút, Sándorfalva). In Hungary the strating sediments of the Lower Pannonian (Lower Pliocene) are assigned to the Sarmatian interval without indicating the Miocene-Pliocene time horizon based on absolute age within this sequence. The Miocene-Pliocene boundary fixed earlier was dated by the appearance of *Limnocardium* and *Congeria* and by the disappearance of foraminifers. This is, however, only the change of biofacies and does not mean the change of the lithofacies, as well.

In the area of the South Great Plain the Miocene-Pliocene boundary is marked by the change in the chemical composition of the geosyncline's water which was manifested in a long-lasting freshening process. In several western, northern, eastern and southern units of the Carpathian Basin (*e. g.* Nógrád Basin, Sopron environs,

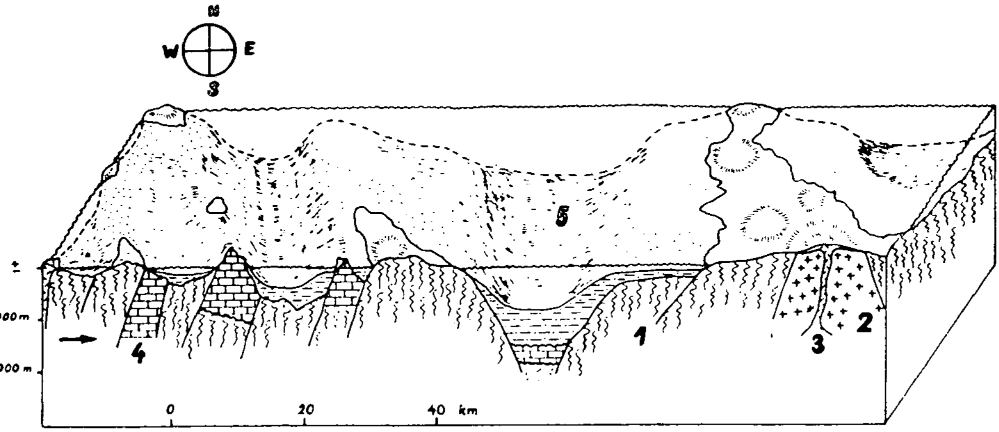


Fig. 3. Diagrammatic representation of the beginning of Lower Pannonian. Legend, see Fig. 2.

Transylvania, etc.) the Neogene cycle was completed by the Miocene. This regression process is reflected only by freshening in the investigated area. The islands, peninsulae shown in *Fig. 3* were inundated, consequently the Pliocene formations surpass here those of Miocene age, at the same time regarding the whole of the Carpathian Basin the regression filling-up mechanism becomes predominant. This phenomenon and high-grade change in the connection between the Carpathian and Pontian-Caspian basin are responsible for the differences of strata sequences and differences of time intervals of Hungary and of the neighbouring countries.

A further significant change is that with gradual rising of the Alps and Carpathians the drainage basin of the Pannonian Basin has considerably increased. Its water budget showed a positive trend as a result of these processes [JÁMBOR, 1971]. The inland sea transformed into an inland lake and its water surplus was drained towards the Rumanian Plain through channel-like ways.

As to our experiences the Miocene-Pliocene boundary can be marked by the disappearance of the gravel beds connected to turbidite currents in the internal and deep basin parts and by that of the only "gravel coats" at the boundary. The whole thickness of the Miocene sequence is characterized by the presence of conglomerate, sandstone, aleurolite, clay-marl, marl and lime-marl. Regarding their origin these rocks are developed partly in turbidite currents and partly in undisturbed water. The two genetic types form "half-rhythms" and the thickness of these is strongly changing. Generally and first of all at the end of Miocene the pelitic-calcareous phases predominate.

The thinning out resp. disappearance of the gravelly strata follows within a section of about 200 metres length *e. g.* in the Hódmezővásárhely depression; this section contains both foraminifers and *Limnocardium* (very small and only impressions). On the basis of *Limnocardium* this section is considered to be Pliocene.

Within the investigated basin part in the region of relative rises, occasionally islands and peninsulae the near-shore litho- and biofacies are characteristic. In many cases these are similar to the marginal formations.

Pliocene

Out of the oldest Pliocene formations the coarse clastics are connected to the islands of the Miocene inland sea. Depending on the facies the conglomerate, sandstone, aleurolite, clay-marl or carbonate sediments are known close to each other in space (Algyő, Sándorfalva, Forráskút, Szeged, Makó, Hódmezővásárhely, Fábiánsebestyén). Post-Miocene erosion should be taken into account at the places where formerly the sedimentation has not started.

In the investigated area numerous bores traversed the Pliocene "basal conglomerate". On the basis of its grain-size composition* this formation is mostly gravelly coarse-grained and medium-grained sandstone and reaches only rarely (the lowest several metres of the sequence) the conglomerate grain-size composition. Small quantity of very fine and fine grained sandstone also occurs in the sequence by means of which the apparently uniform rhythm can be divided into sub-rhythms. In the single sub-rhythms, but tendentiously in the whole "conglomerate" sequence the upward refinement of grain-size composition can be fixed. Classification becomes locally easier by means of the hard impermeable intercalations of calcareous cementing material. In the arrangement of the gravel substance of 1 to 40 weight per cent no orientation can be observed. The elements of stratification can be hardly observed, almost all the boundary surfaces are indistinct and gradual. This phenomenon is *considered one of the significant evidences of the accumulation in the* surf zone. In the bores located into the deeper structural position the refinement of grain-size composition as well as the decrease of the quantity of gravel fraction can be observed. When approaching the top of the horizon similar material change can be observed which proves the increase of distance from the shores of the accumulation and the changing conditions of the kinetic energy. The NaCl content of the waters deriving from this sequence changes between 10 and 15 mg/l. Lime-marl is the overlying layer and since it is tectonically undisturbed it can be assumed that this value is similar to the original salt concentration of the Lower Pannonian inland lake. When a dilution of small measure is accepted, the real value was certainly around the upper limit or slightly surpassed it.

The conglomerate is overlain by the "lime-marl horizon" containing pyritized plant remnants, bacteriopyrite and pyrite concretions and calciumcarbonate consisting of microcrystals in 60 to 95 per cent. The preceding clastic layer is separated by this phase of transitional material (fine sandstone, calcareous fine sandstone, limy aleurolite, marl) the thickness of which is mostly 1 to 2 metres. In the deepening parts of the basin, however, this transitional member may become thicker and there it can be divided into sub-rhythms of straight classification (their number does not exceed 10). The mode of deposition and the textural features relate to accumulation from turbidite currents. The formation of turbidite currents was resulted in by the floor relief though in this case only a displacement of several kilometres comes into question.

The clastic horizon occurs only in connection with the relative emergences of the basement, but the lime-marl is already a wide-spread sediment in the areas of the South Great Plain explored till now. Where the Neogene is of small thickness (Ásotthalom, Kelebia, Battonya, Mezőhegyes) it is not necessarily of open water and deep water facies, its color is virtually light-yellow. Regarding the whole investigated area its heteropic facies were observed only in several cases (Algyő, Ferencszállás). In the areas of deep structural position (Makó—Hódmezővásárhely trench, Békés-depression, Dorozsma—Kistelek trench) the marls and lime-marls with bacteriopyrite, pyritized plant remnants and of blackish-grey color are considered the oldest Lower Pannonian sediments. These were formed in deep water and euxinic environments. Summing up, the lime-marl is a chemical sediment both in the shallow, in the deep and in the medium areas but the reductive conditions can be assumed only in case of the two latter ones.

The two strata are called together Pliocene basal horizon though in the investi-

* Grain size limits used in this study:	Ø mm
conglomerate (gravel) in general	2—200
fine-grained conglomerate	2—5
sand, in general	0.06—2
coarse-grained sand	0.5 —2
medium-grained sand	0.2 —0.5
fine-grained sand	0.1 —0.2
very fine-grained sand	0.06 —0.1
aleurolite, in general	0.005—0.06
coarse-grained aleurolite	0.02 —0.06
fine-grained aleurolite	0.005—0.02
clay, in general	below 0.005
fine clay	below 0.002

gated area of 10 000 km² their joint occurrence can be observed only in special cases, i.e. in connection with the greater emergences of the basement. The totla thickness is strongly varying, it extends from several metres to hundred metres.

This Pannonian formations being considered the oldest ones is overlain by a Lower Pannonian sequence of 200 to 2 800 metres thickness. Coarser fractions do not occur (grain diameter of 1 mm only in case of micas). It rarely contains lime-marl and marl intercalations, their thickness amounts to 20 to 30 cm at most.

On the basis of the texture, structure and quality of the rock material the following types are distinguished:

"A" It is of clay-marl and fine aleurolite material, unstratified or hardly stratified. The "rolling" clay-marl is frequent. The rock consists mainly of clay minerals with considerable chlorite and dolomite content.

"B" It consists of the alternation of fine and coarse aleurolite containing less fine sandstone beds (max. of several 10 cm thickness) and wedging lenses. Stratified. The "rolling" clay-marl occurs. The sandy phases may be of coalified plant remnants. The rock consists of clay minerals, chlorite, dolomite and quartz.

"C" Its material is fine and very fine sandstone containing less aleurolite and clay-marl intercalations and wedging lenses; it is stratified and often of coalified plant remnants (first of all the thin-bedded, fine-sandy parts).

"D" It contains unstratified of hardly stratified phases consisting of fine and very fine sandstone.

In the "Szeged Basin" and in the area of the depressions of relatively deep structural position the thickness of any types does not exceed 20 metres. These are mostly of several metres thickness. The grain-size composition shows refinement tendency from the top downward, or from down upward. These subunits of the sequence of 20 to 40 metres thickness can be divided into sub-rhythms almost without exception. (Their thickness is of metre of order.) The base rhythm and especially the sub-rhythms are of asymmetric structure.

Within the Lower Pannonian sequence of a research field 30 to 50 rhythms can be distinguished in the areas of medium-deep and deep structural position. The single rhythms consist of the A, B, C, D sediment types classified above being of varied sequence and thickness, their structure is often incomplete.

The limits of rhythms are drawn always in type "A" since the lime-marl horizon is overlain by clay-marl. The frequent rhythms-types of the strata sequences are as follows:

A B C D C B / A. .	(occurs everywhere, one C or B may be absent)
A B C D / A. .	(rather in the upper part, out of B C D anyone may be absent, but A D A never occurs)
A D C B / A. .	(rather in the lower part, out of D C B anyone may be absent, but A D A never occurs)

To trace the spatial position of the rhythms is troublesome, their areal extension may amount to 100 km². The sandstones (D) are often wedging towards the relative emergences of the basment and become often clayey; it is probable that this occurs also towards the deeper parts. The ratio of the area of sandstones as compared to their thickness is very high, they seem to be of "sheet-type".

Within the types building up the rhythms on the basis of the changes of stratification and material quality further units, i.e. sub-rhythms can be distinguished. *E.g.* the type "A" is built up by the following variations:

"a_1" clay-marl, unstratified, rolling (in fresh air this decomposes wi:hin a few days to pieces of 0.5 to 2 cm diameter, of conchoidal-comminuted surface of elongated-flat shape; this fragmentation leads to the formation of pieces of millimetre diameter, apparently without any external influence);

"a_2" clay-marl, unstratified, banked structure;

"a_3" clay-marl of lamellar jointing (rare);

"a_4" rolling clay-marl with fine aleurolite intercalations;

"a_5" alternation of clay-marl and fine aleurolite, the clay-marl may be of rolling type, too;

"a_6" fine aleurolite with clay-marl intercalations, the clay-marl may be of rolling-type;

"a_7" fine aleurolite (often of lamellar jointing);

"a_8" fine aleurolite stratified with lamellae or lenses of millimetre thickness and of coarse aleurolite or fine sandstone material. These clastic sheets and lenses are always strongerly cemented.

The subdivision oi the types "B" and "C" is based on similar principles but the number of variants is greater. Type "D" may be built up by the following variations:

"d_1" fine and very fine sandstone, unstratified;

"d_2" fine and very fine sandstone, stratified occasionally by mica and coalified clastic plant remnants;

"d_3" unstratified layers of fine and very fine sandstone of 1 to 50 cm thickness, always thin-lamellated and of lamellar formation, dissected by coarse and fine aleurolite intercalations;

"d_4" stratified layers of fine and very fine sandstone with mica, occasionally with coalified clastic plant remnants, thickness is 1 to 50 cm, always thin-lamellated and of lamellar formation; dissected by coarse and fine aleurolite intercalations;

"d_5" fine sandstone, stratified, contains occasionally coalified plant clastics; alternates with the layers of aleurolite and clay-marl of 1 to 50 cm thickness; the quantity of sandstone and pelites is nearly the same.

The sediments of the Lower Pannonian inland lake got their accumulation place either in floated or in dissolved state. The material transport within the basin was carried out by changing flows of mainly low energy level. In the core samples the directions of flows cannot be determined. Out of the factors relating to the sedimentation conditions the structural features appearing on the rocks are of special importance. In case of the Lower Pannonian sediments the features being assigned to the terms internal and external stratification and deformation structures are found in a wide range. Out of the internal stratification types some photos are demonstrated. The most important internal stratifications types are as follows:

horizontal, parallel lamination; and

varied sub-types of the complex stratification (horizontal, inclined, flaser, complex undulatory, interconnected and interrupted lense-like stratification).

Disregarding the base level these may occur everywhere. Out of the external or surficial features the mechanoglyphes are represented by flow features, the traces of objects are infrequent. Bioglyphes are frequent only in the upper part of the sequence. Deformation structures occur only locally.

The $CaCO_3$ content of the sediments is independent of the grain size composition, its average quantity amounts to about 30 per cent, the deviation is negligible

(20 to 45 per cent; number of measurements is about 1000). A few per cent of the carbonates is clastic, the overwhelming majority, however, is of syn- and epigenic origin. On the basis of the investigations of Mezősi, J. [1975] all the three types contain calcite and dolomite, but sulphates are absent.

Several hundred rock-physical investigations were carried out on sand sediments. The results of bulk density, porosity and permeability are shown in *Fig. 4.* It can be stated that in the Lower Pannonian sequence the bulk density results in an average of 2.2 g/cm^3 but in the upper section the values are smaller. The average of porosity is about 10 per cent, the greater values are infrequent. Permeability is consecutively very low, the most frequent values appear between 0.1 and 50 md; in this case the increase of the values in the upper part is also valid. The investigation results of a core sample of Lower Pannonian age are demonstrated in *Fig. 4.*

The salinity of the inland lake can only be estimated. From down to the top the total salt content changes tendentiously between 8 and 3 g/l. On the basis of the sporadically occurring shell fauna found in the clay-marls of the sequence and of theoretical geochemical considerations (*Limnocardium* and *Congeria,* resp. osmosis and ionfiltration), the original salt content was higher. As to our ópinion this amounted to 15 to 20 g/l. As a result of investigations the quality of water is predominantly of NaCl.

It is problematic that in the South Great Plain the Lower Pannonian sequences of small thickness do not contain sandy intercalations but are built up practically without exception by clay-marl and fine aleurolite and only the sediments assigned to the type "A"/"a_8" represent the variety. On the contrary, in the parts of medium-deep and deep structural position only the rhythmic accumulation is characteristic, as described above. It seems to be the most simple explanation that these areas were ridges below the water table of the inland sea, probably in great distances from the shores, consequently from the flow zones of the deeper areas only the pelites and chemical sediments got these relative emergences. It is known that the flows on the bottom keep away from the relative emergences of the geosyncline's floor. The other reason may be the configuration of the water course network of the erosion area.

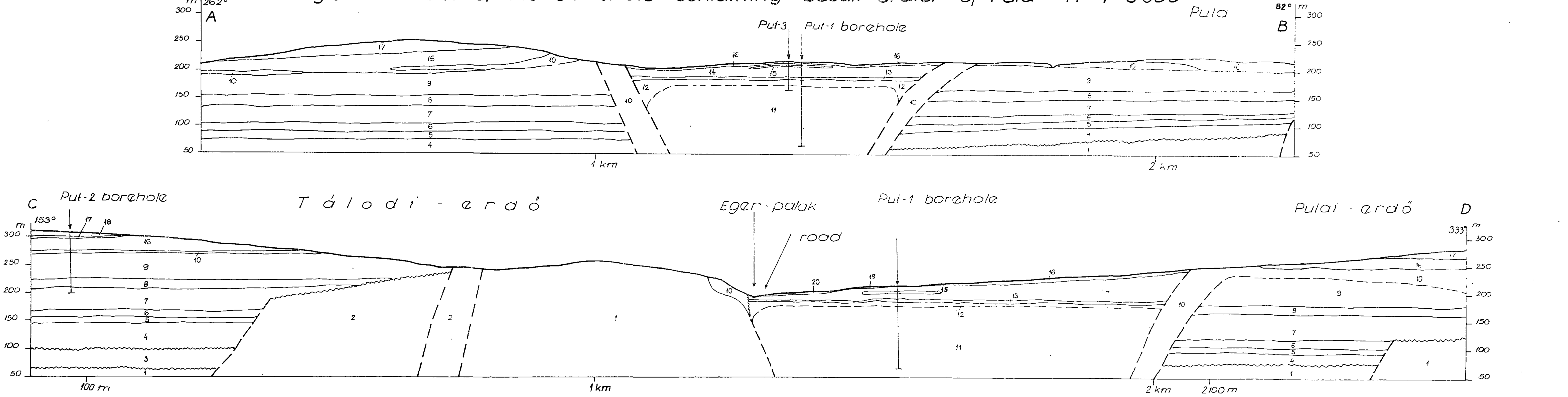
The investigation of the sedimentary features, the ratio of pelitic and psammitic sediments as well as of the vertical and horizontal connections of the core samples resulted in important paleogeographic conclusions.

The sediments were accumulated in the more distant and internal part of the basin parallel with the gradually increasing depth of water and growing distance from the shores. Flow and flow-free sediment types are distinguished. The latter one predominates in the shallow areas. The flow-free type is built up by clay-marls and fine aleurolites ("A"). All the other sediment types of the Lower Pannonian are more or less bound to flows.

In the medium-deep and deep structural areas, on the basis of the sedimentary features a deep and a shallow water sequence can be separated overlying temporally each other. The sandstones of the deep-water and older sequence are characterized especially by "clay-marl pebbles". These sediments may form as a results of subaqueous avalanches. The avalanches are caused by the bottom relief and relate to contemporaneous shallow water environs. The steeper slopes are occasionally referred to by chaotically disturbed parts of the sequence. The differences of the bottom morphology being observable in the Lower Pannonian are partly inherited from the Miocene, and partly the results of the filling-up mechanism and gradual epirogenic subsidences renewing at the beginning of the Lower Pliocene. The considerable differences in depths of the geosyncline's bottom preserved also in the

Fig. 4.

Geological sections of the oil-shale containing basalt crater of Pula M = 1 : 5 000



Legend: 1. Upper Triassic, Hauptdolomit, 2. Carnian marl, limestone, 3. Middle Miocene, bauxitic clay, 4. Sarmatian limestone, marl, 5. Lower Pannonian marl, clay marl, 6. Upper Pannonian siltstone with Pectinidae, siltstone, quartz sand and freshwater limestone of Kapolcs, 7. Upper Pannonian clay marl, purple freshwater marl, coal-bearing clay, 8. Upper Pannonian clay, coal-bearing clay, 9. Upper Pannonian green clay, siltstone, 10. the 2nd basalt-tuff and bentonite, 11. the 2nd basalt, 12. Scoriaceous variant of the 2nd basalt, 13. Liminated siltstone, 14. Oil-shale member, 15. Calcareous dolomite, 16. „Freshwater limestone of Nagyvázsony" and marl', 17. the 3rd basalt-tuff, 18. the 3rd basalt, 19. Early Pleistocene terrace gravel, 20. Holocene terrace gravel, ~~~ Surface of unconformity / structural contour

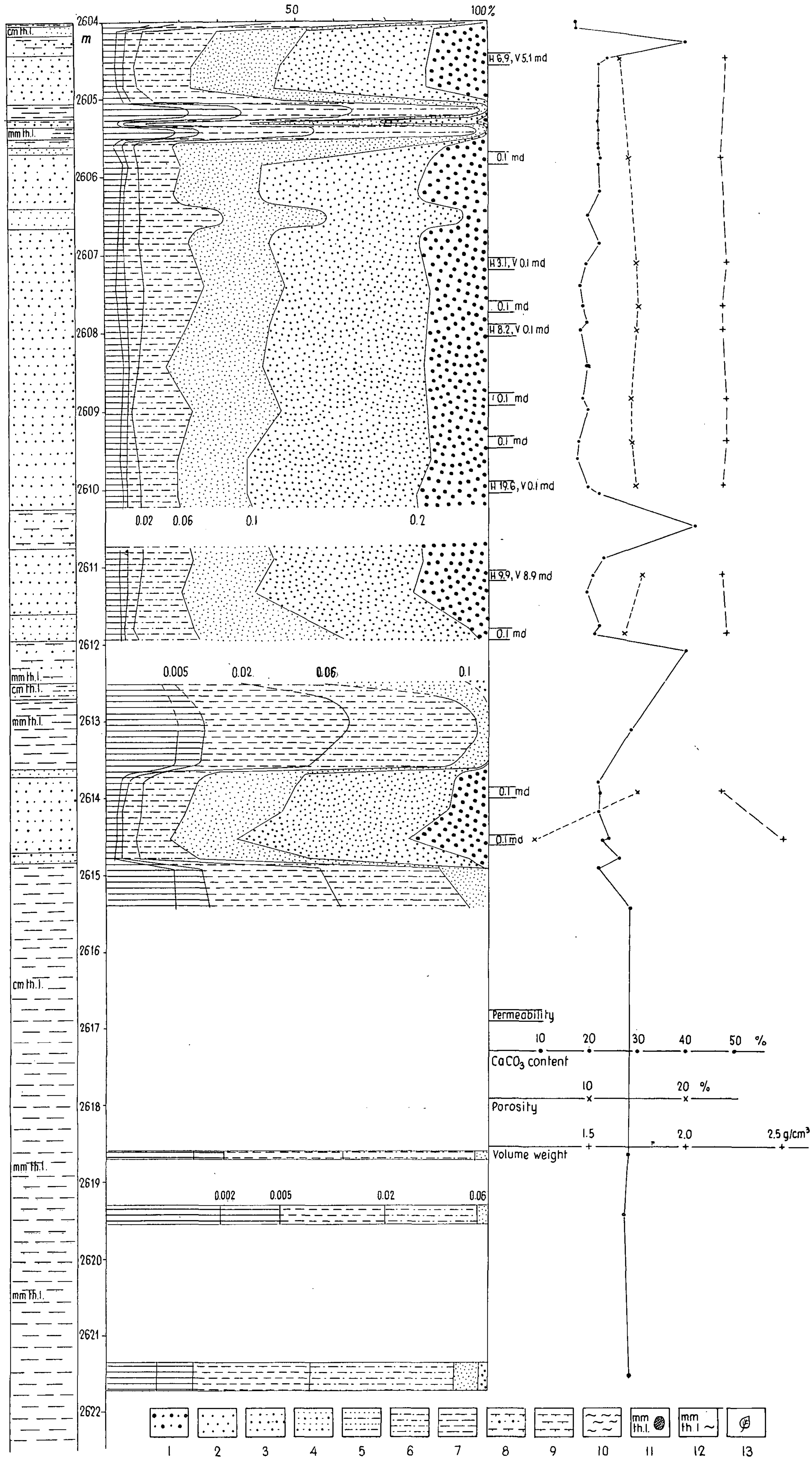


Fig. 4. Granulometric and petrophysical data of the core of borehole Algyő-248. *Lower Pannonian.* *1.* Fine-grained sandstone with medium-grained sand, *2.* Fine-grained sandstone, *3.* Very fine sandy fine-grained sandstone, *4.* Fine sandy very fine-grained sandstone, *5.* Aleurolitic fine-grained sandstone, *6.* Very fine sandy coarse-grained aleurolite, *7.* Coarse aleurolitic very fine-grained aleurolite, *8.* Calcareous sandstone, *9.* Clay-marl, *10.* Marl. Lime-marl, *11.* Finely laminated sediment with micaceous laminae of mm order in thickness, *12.* Finely laminated sediment with coalified vegetal detritus forming laminae of mm order in thickness, *13.* Coalified vegetal detritus

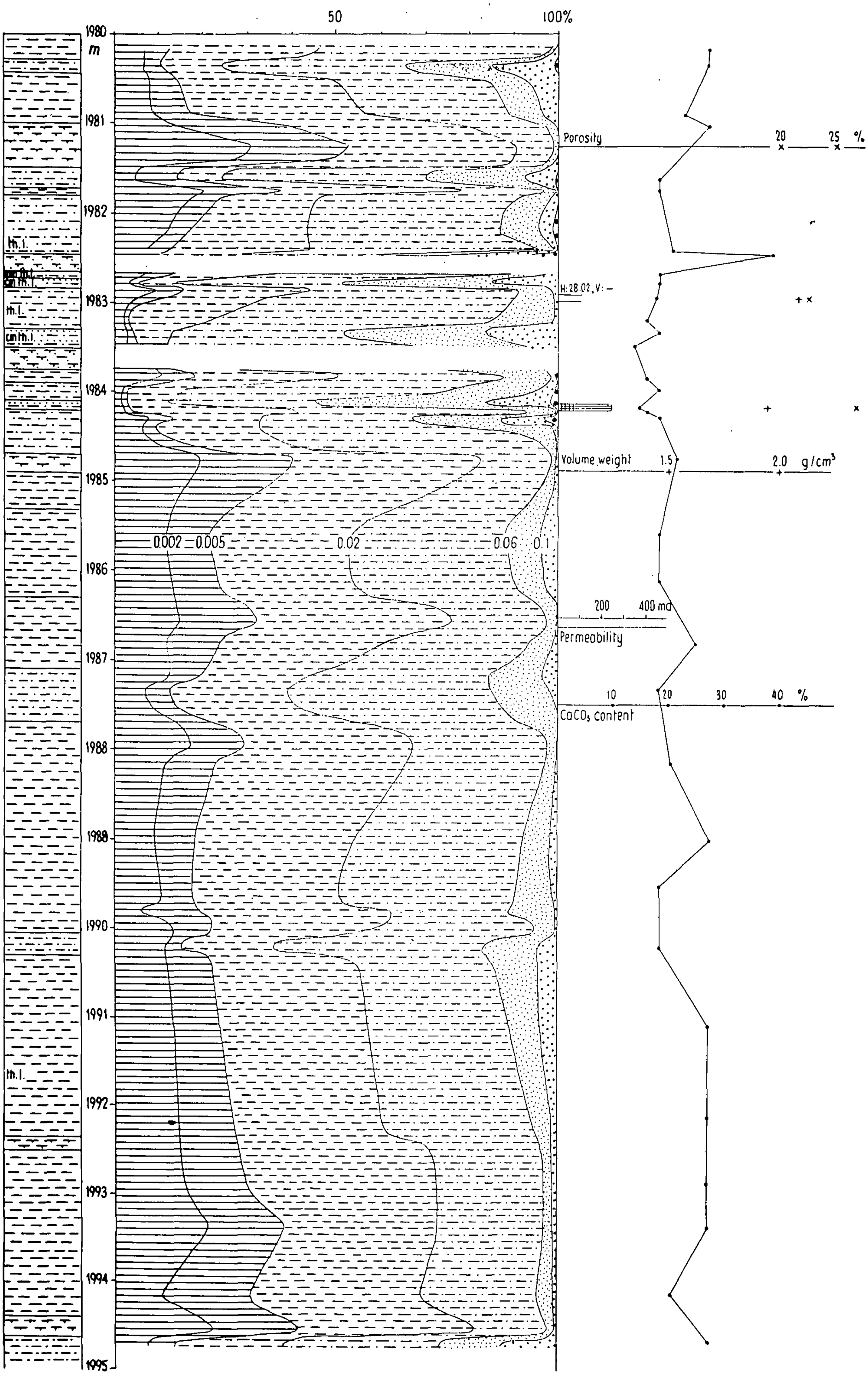


Fig. 5. Granulometric and petrophysical data of the core of borehole Algyő-254. *Upper Pannonian.* Legend, see Fig. 4.

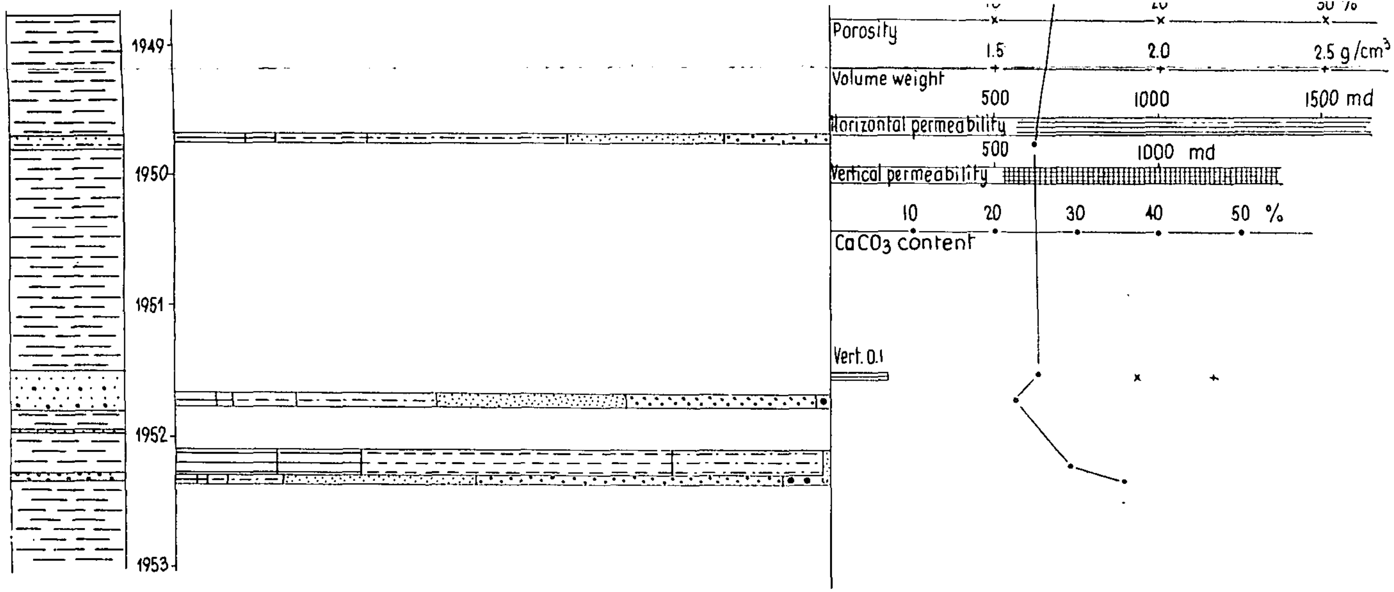
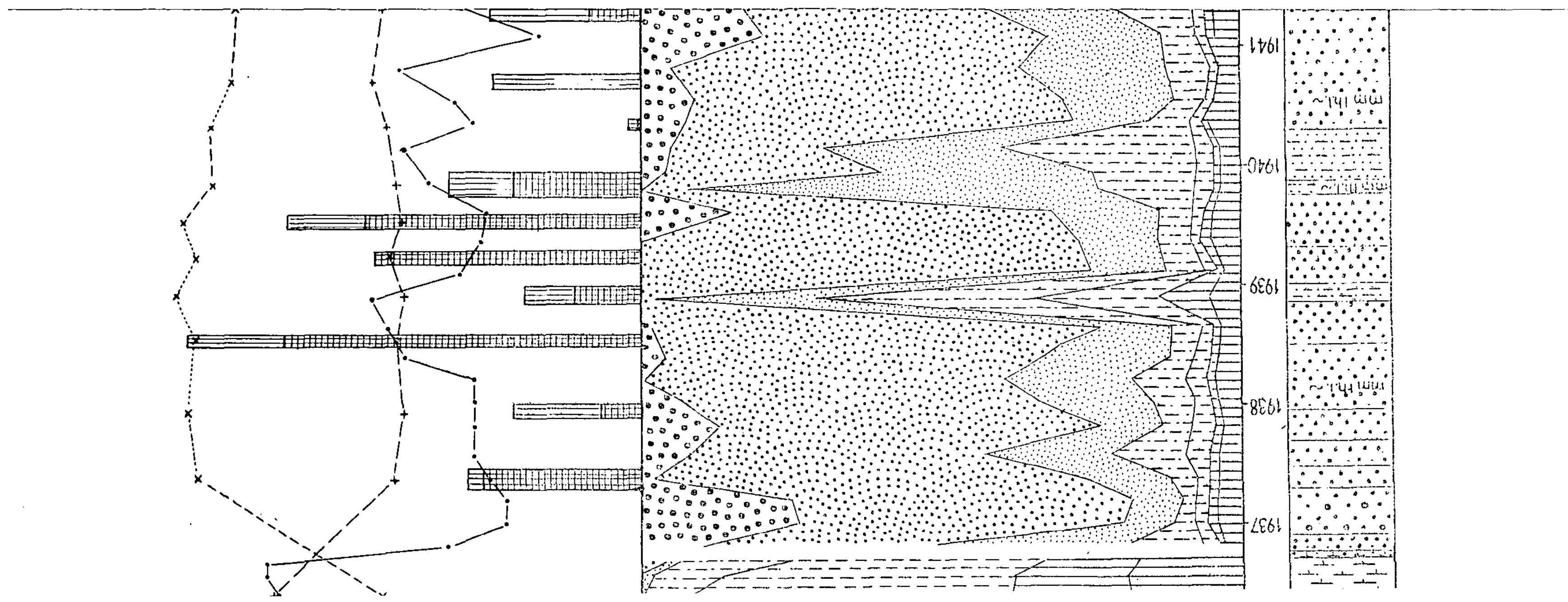
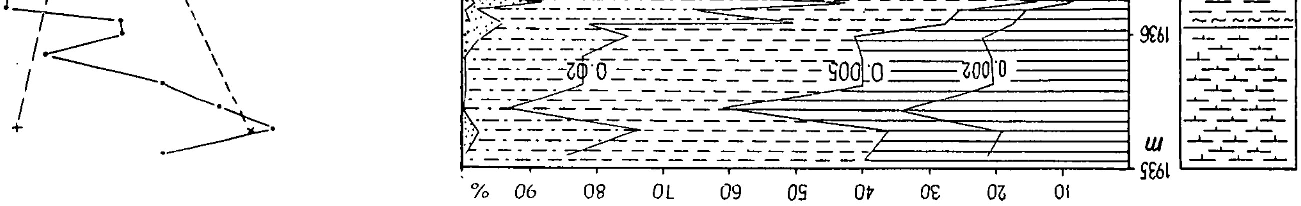


Fig. 6. Granulometric and petrophysical data of the core of borehole Algyő-198. *Upper Pannonian.*
Legend, see Fig. 4.

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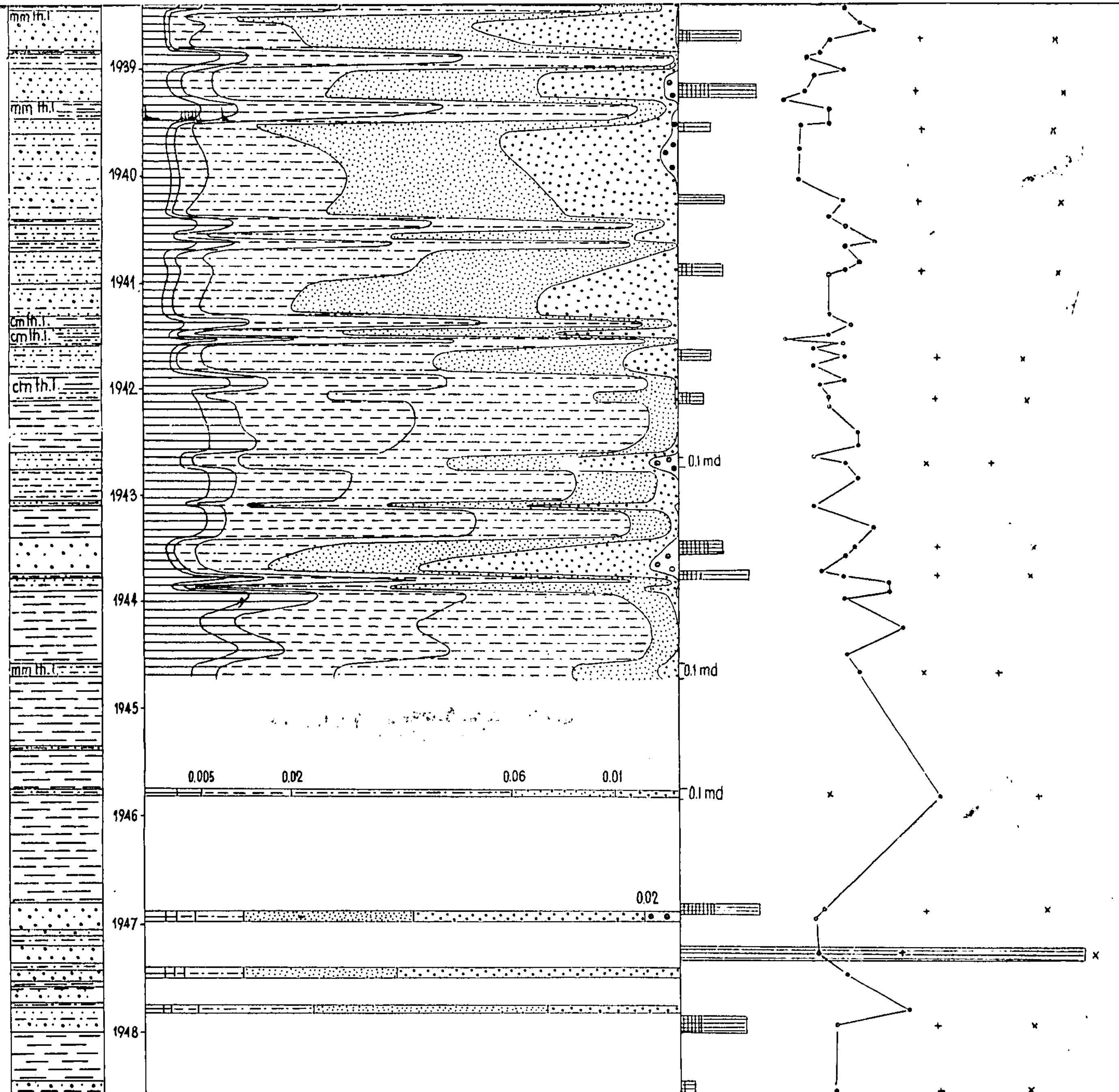
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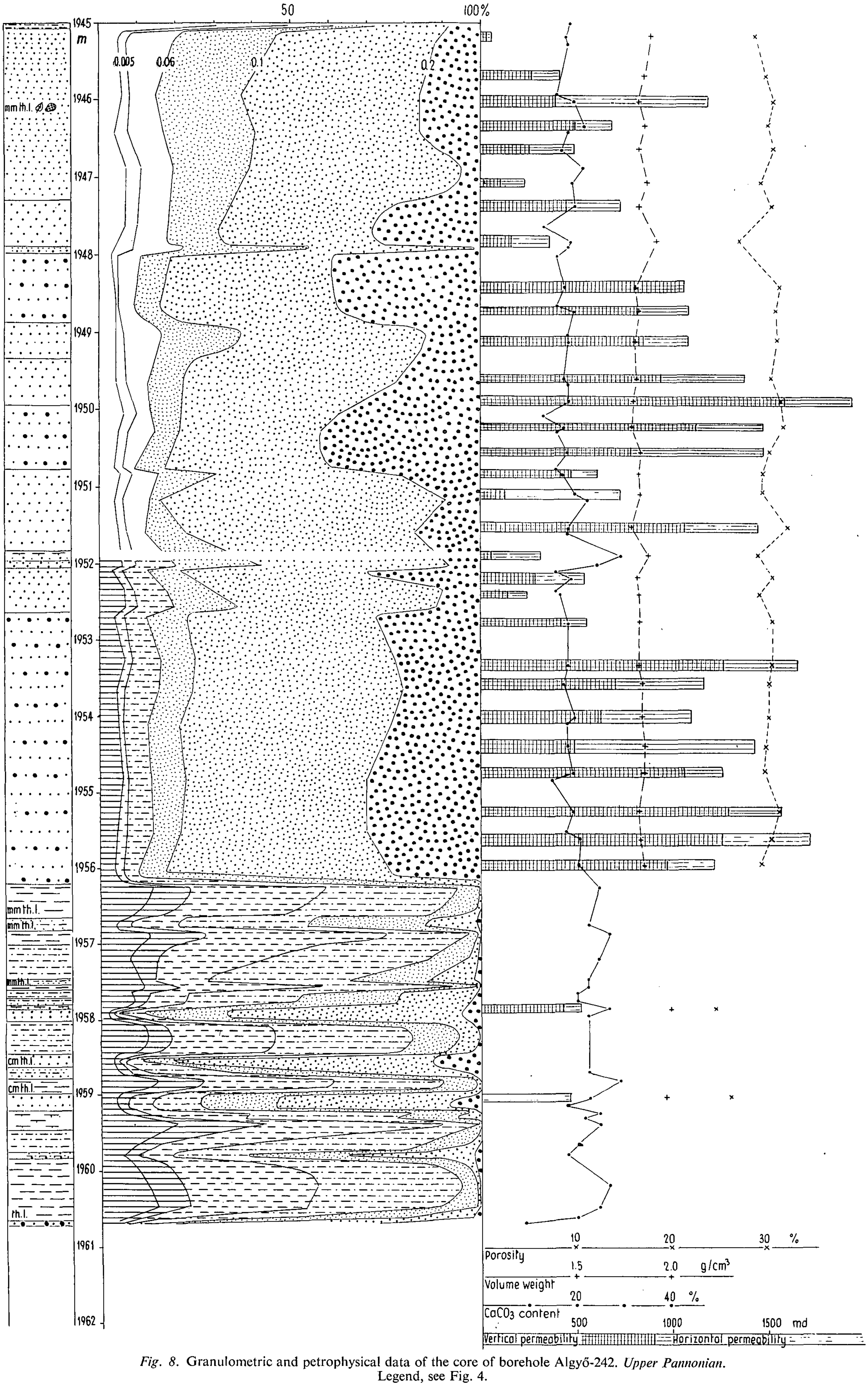


Fig. 8. Granulometric and petrophysical data of the core of borehole Algyő-242. *Upper Pannonian.* Legend, see Fig. 4.

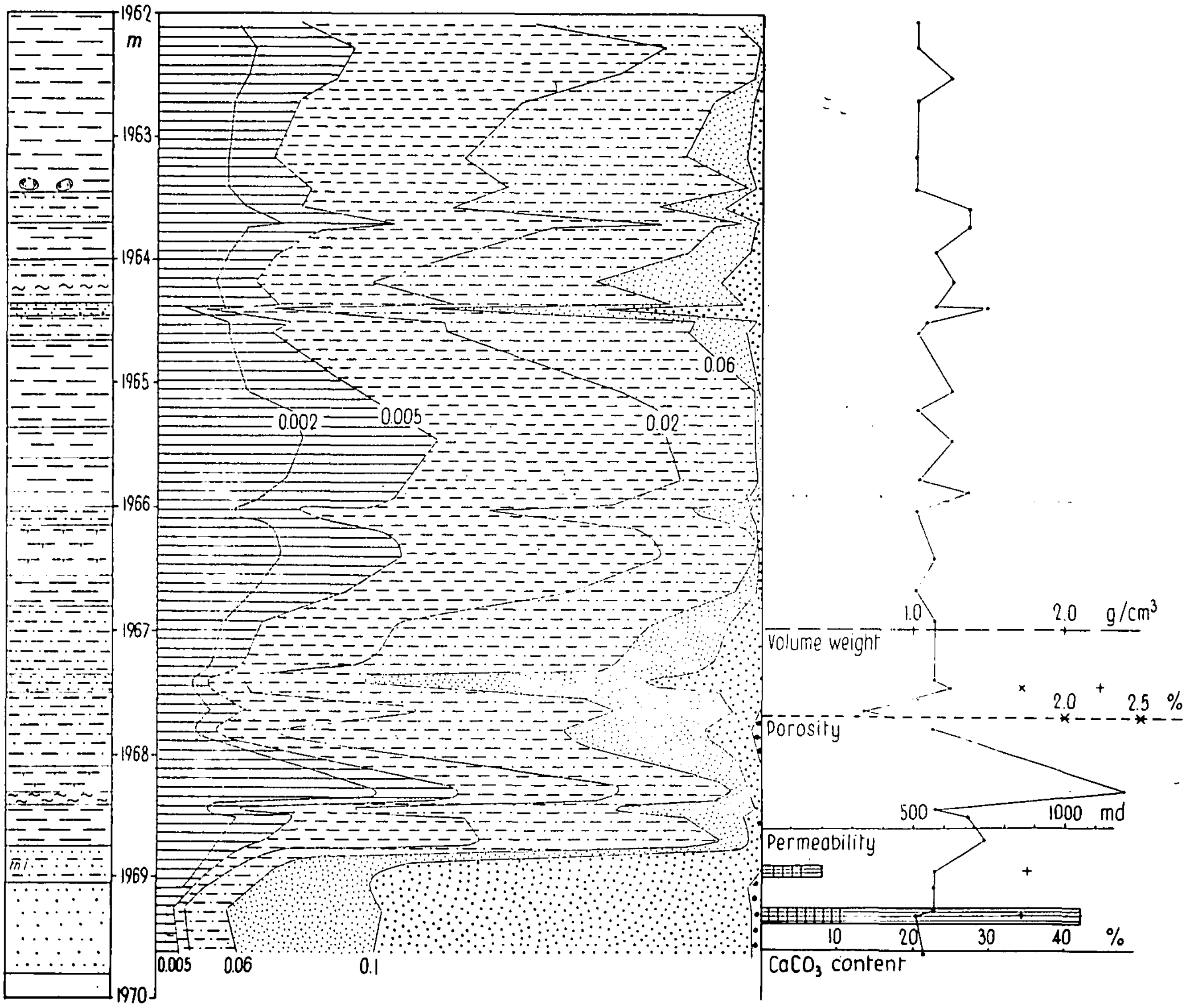


Fig. 9. Granulometric and petrophysical data of the core of borehole Algyő-242. *Upper Pannonian.*
Legend, see Fig. 4.

younger phases of the Lower Pannonian and this is proved also by the deposition of the strata assigned to this period. The presence of the shallower type is further evidenced by the frequency of the double-sheet structure built up by coalified plant detritus and other rocks. Locally, the bores traversed also coal sheet of centimetres thickness. Regarding their origin these are allochtonous. The shallowing of water, the greater trequency of the rhythms built up by A B C D / A... types in the upper part, as well as the change of the sedimentary features indicate the filling up of the basin, i.e. the advance of shore line.

Taking the whole of the investigated area the thickness of the Upper Pannonian sediments changes between 500 and 1700 metres. The thinner formations, similarly to those mentioned above, are found above the basement of relatively uplifted structural position. The sediments are also of rhythmic structure. These are separated from the Lower Pannonian sediments by hardly observable angular unconformity. The angular unconformity was caused by the change of facies.

The sediments of this period are varied: in addition to the predominant types, *i.e.* fine sandstone, very fine sandstone, coarse aleurolite, fine aleurolite, less clay-marl, other types, *e.g.* gravelly sandstone, medium-grained sandstone, marl, lime-marl, woody brown-coal, coaly clay and humic rocks also occur.

Based on about 3 000 data the value of the part dissolving in cold hydrochloric acid proved to be 23 per cent, the extreme values were 0 and 85 per cent. As compared to the values of the Lower Pannonian the bulk density decreased (1.7 to 1.9 g/cm^3), the values of porosity and permeability increased and this is demonstrated in *Figs. 5—10.* It is to be noted that in case of the less compacted samples found next the surface (which are neglected in this study) the investigation results changed in accordance with the data of literature.

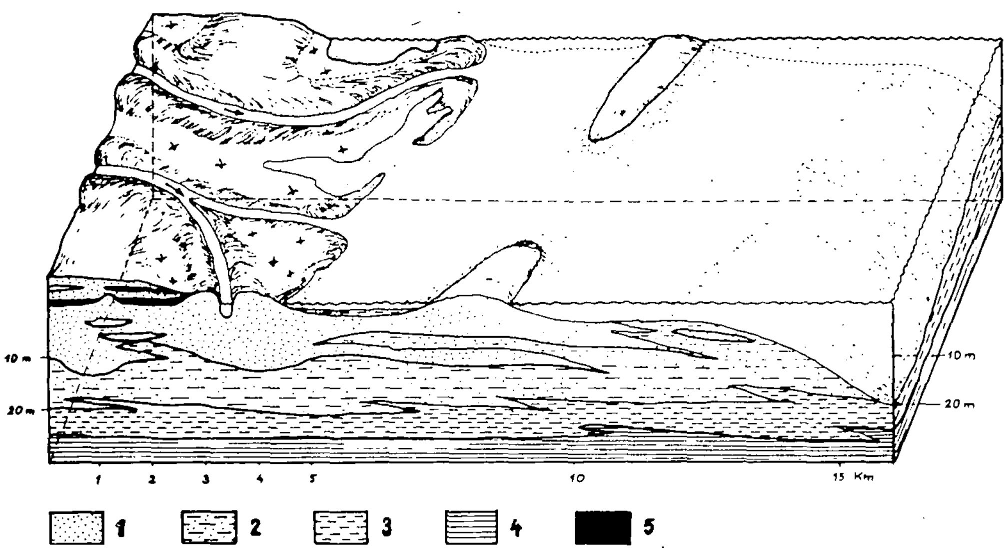


Fig. 10. Schematic block diagram illustrating the sedimentary environments at the beginning of the Upper Pannonian.

1. Sandstone, *2.* Sandstone and aleurolite, *3.* Aleurolite, *4.* Clay-marl, *5.* Coal

The statistic parametres computed from the great number of grain size distribution of the sandstones and of certain areas, evidenced that in the course of accumulation the energy states have considerably changed both in space beside each other and in time above one another.

Several researchers dealt with the classification of the Upper Pannonian sequence but there are considerable differences between the statements [Bartha, F., 1971 and 1974; Jámbor, Á., Korpás, L., Hódi, M., 1971; Jaskó, S. 1974; Kőrössy, L. 1968—1973, and Strausz, L. 1971]. As to our opinion the divergences of views are based upon the fact that in case of the classifications based either on paleontology or on lithofacies they simplified the mechanism of filling up of the Carpathian Basin and of its part-basins and drew generalizing conclusions from the thin strata sequences of the surficial outcrops.

Our investigations detailed have discovered phenomena which cannot be build-in into the previous imaginations. First of all the Algyő-Szeged area explored in details by bores (about 500 bores) made possible to draw the conclusions. *E.g.* the core samples contained occasionally one or two rounded quartz pebbles and gravel band imbedded in sandstone and aleurolite groundmass, further they contained lime concretions which from here upward show a systematic appearance! The intercalations of autochtonous coaly-clay — woody brown coal — coaly clay of max. 1 m thickness are frequent. Their arrangement within one rhythm shows areally and vertically regular development. The coalified plant remnants of vertical position occur also in connection with the area and with horizon within the rhythm. Imprints of leaves of deciduous trees of good preservation and from the middle part of the Lower Pannonian Equisetum remnants are frequent. In about the lower third of the Upper Pannonian sequence the grain size composition becomes tendentiously coarser upward within one rhythm so, that in the few metres closing the rhythm it suddenly transforms into the clay-marl separating the single rhythms. In the areas containing woody brown coal bands the strata of this re-transformation is marked by coal bands. The areal changes of grain size composition of the rhythms are also tendentiously directed (refinement to NW-SE). In the rhythms overlying each other the areas of coarser grain size composition and the coaly intercalations are displaced also to the SE. On the basis of the sandstone thicknesses accumulations of "channel-filling" could be fixed within one rhythms.

Similarly to the Lower Pannonian the boundaries of rhythms were delineated in clay-marls. From these *Limnocardium, Congeria* and *Valenciennesia* fauna was found which were poor in species. Only one species, the *Limnocardium* (Paradacna) *abichi* R. H. var. appears in predominance, on the other side bound to coaly strata the fresh-water forms, e.g. *Psilunio, Unio, Viviparus, Planorbis,* etc. appear in small number. Fauna was found only sporadically in other rhythm members. Palynological investigations relate to the neighbourhood of gallery forest along watercourses and morass environments.

The stratification types and the other sedimentary features are in accordance, resp., can be explained with the features listed above.

These data evidence the presence of delta sedimentation and its environments in the lower third of the Upper Pannonian investigated in details.

From other research areas of the South Great Plain similar sediments were collected relating to the common extension of the fluvio-lacustrine environments. The apparent contradiction, i.e. "everywhere delta at the same time" at the beginning of the Upper Pannonian was resulted in by the fact that the separation from the Lower Pannonian was based on the change of lithofacies and this was considered the time-boundary. As to our opinion, the Great Hungarian Plain is considered a uniform geosyncline and the filling up of the basin from the margins started already in major part of the Lower Pannonian, i.e. the formation of the Upper Pannonian environments has begun. In addition to the features of delta accumulations, the periodic epirogenic subsidence of the basin is responsible for the rhythms overlying each other. In addition to these two most important factors other reasons can also be mentioned, *e.g.* the extension of the erosion area, the working capacity of rivers, the system of redepositing-levelling factors within the geosyncline, etc. According to our hypothesis this transgressing "Upper Pannonian" environment replaced the Lower Pannonian inland lake in the whole of the area within a greater time interval, consequently no isochronism can be attributed to the petrological and paleontological (molluscs) delineation, either. To fix recently the time horizon can be carried out only relatively by smaller units. In our case, in the South Great Plain, *e.g.* in Algyő the sandy sequence put into the lower part of the Upper Pannonian is contemporaneous with the completing sediments assigned to the Lower Pannonian and lying southeast and east of it. Taking into account the megaunits, the buried block-range of Battonya with its related deep-zones was filled-up from the Bihar Mountains which follows from its structural and geographical location.

In the following periods of the Upper Pannonian the spatially neighbouring Upper Pannonian sediments accumulated in a shallow fresh-water lake-systems and in their close neighbourhood from the rivers filling up the lakes themselves. Temporally, above one another a similar system can be observed. In a given smaller part-unit and in definite time the predominating regime is determined by the relation of the measure of filling-up and of the epirogenic subsidence (compaction), since block-like irregular subsidence is evidenced by the differences of thicknesses.

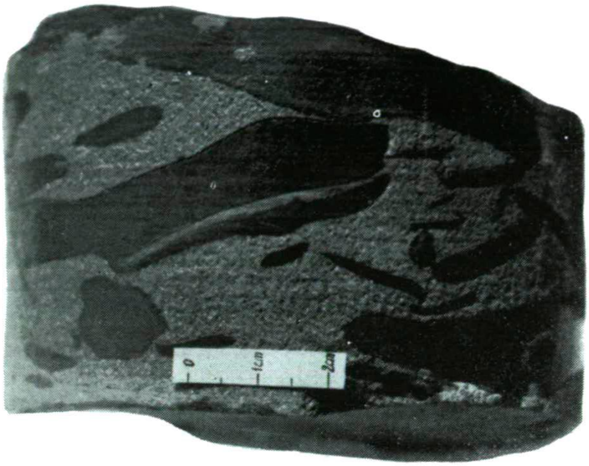
From the medium third part of the sequence the change is apparent, *i.e.* the the sediments hardly diagenized, the clay-marl disappear. In this phase the aleurolite with plant remnants and concretions predominates. The upper third is of sand formation again and the coaly intercalations are more frequent, as well.

From the Upper Pliocene up to the Holocene the sedimentary environments mentioned above are replaced tendentiously by the predominance of the terrestrial facies.

In the course of making this study authors used the results of several geologists of the OKGT, i.e. of ÁKOS LELKES, LÁSZLÓ MAGYAR and JÁNOS TANÁCS. Special acknowledgement is given for the valuable advices of DR. JÓZSEF MEZŐSI.

SUMMARY AND CONCLUSIONS

On the basis of the core sample processing of several years, authors state that the detailed sedimentological investigation of the rock material of core samples is a successful possibility to know the Neogene sequence. The studying of the horizontal and vertical connections of the paleogeographic "snapshots" obtained in this way in details makes possible the research of the temporal and spatial changes of geological evolution of an area explored by numerous bores, and taking always into consideration the limited possibilities of geological cognition.



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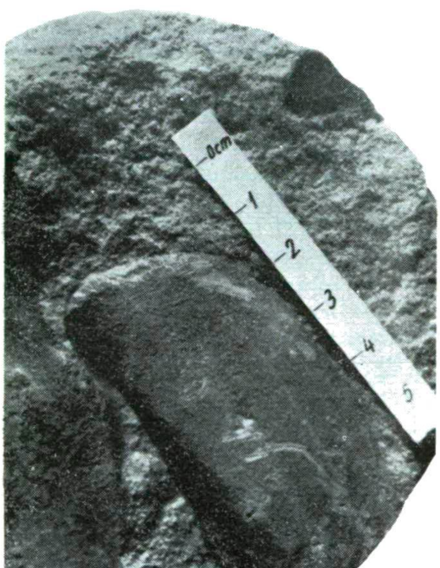

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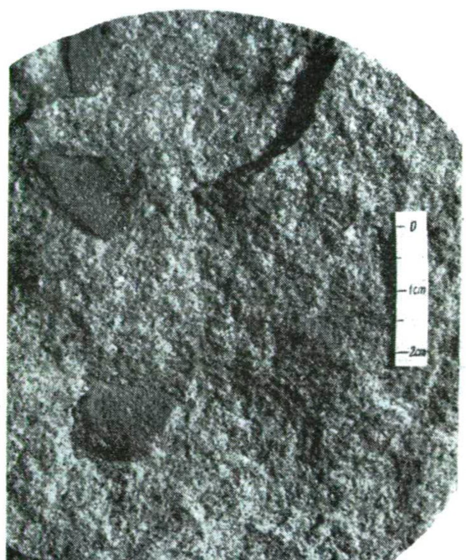

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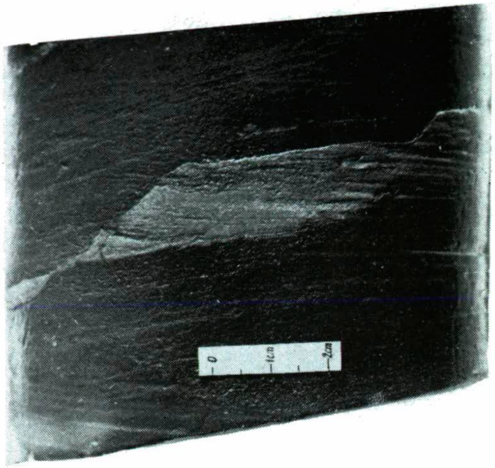

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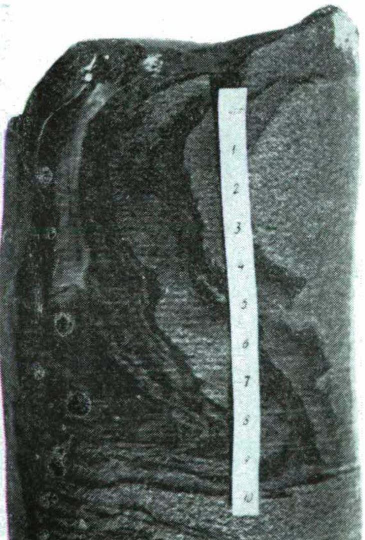

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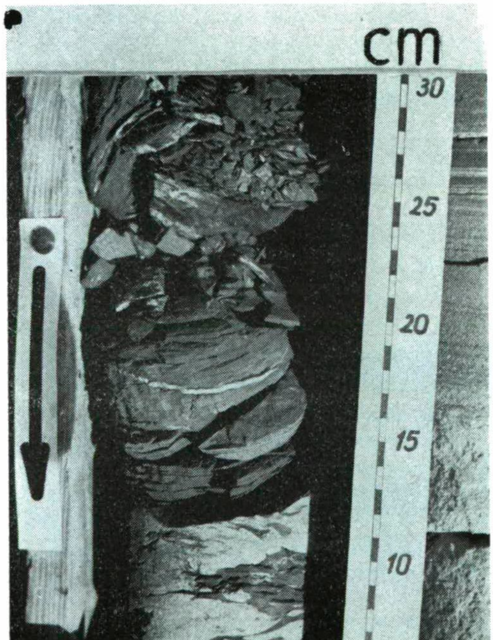

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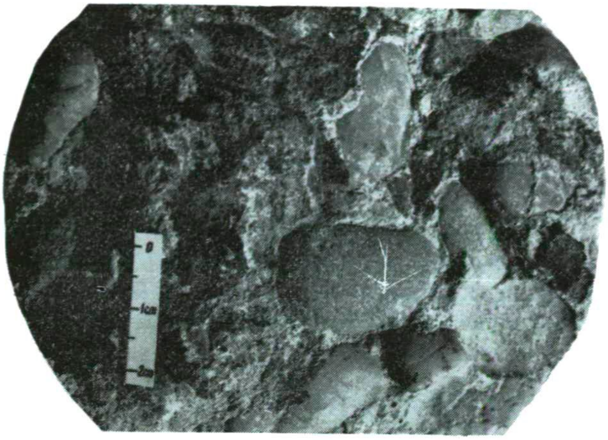

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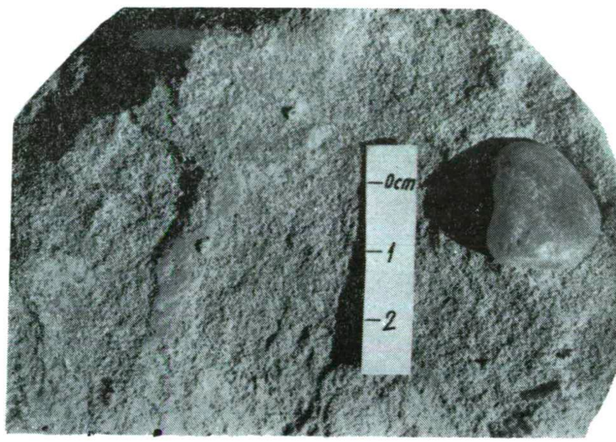

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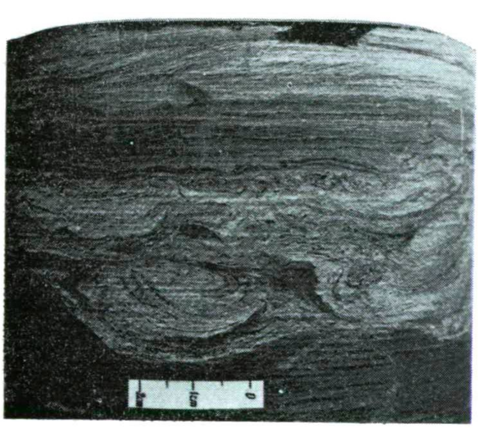

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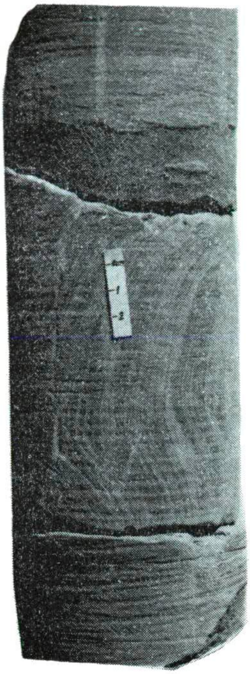

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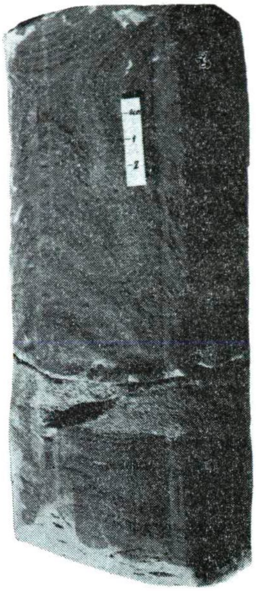

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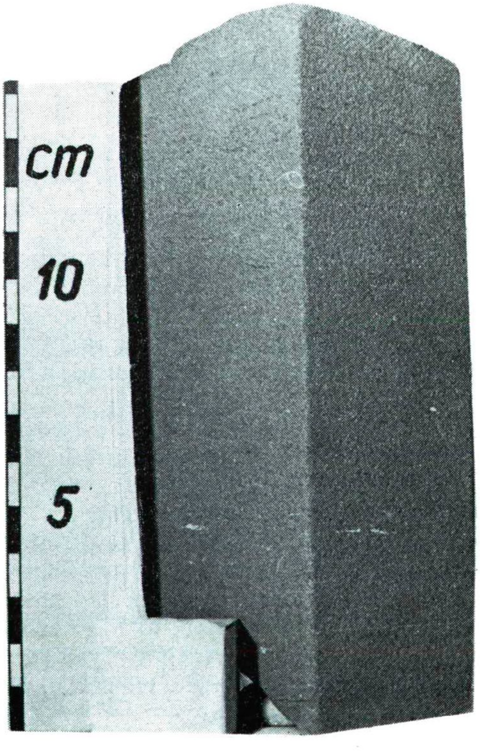

3

EXPLANATION OF PLATES

PLATE I

1 and 2 Sandstone containing clay-marl pebbles. Lower Pannonian. — Borehole Algyő-248 2600,62—2601,05 m

3 Sandstone with plant debris and fine-grained aleurolite pebbles. Lower Pannonian — Borehole Algyő-92 2468,40 m

PLATE II

1 Fine-grained aleurolite holding very fine-grained sandstone lens. Micro-fault was formed by the effect of compaction. Lower Pannonian. — Borehole Algyő-86 2421 m

2 Sandstone and aleurolite having folded bedding. Lower Pannonian. — Borehole Algyő-264 2414,05—2414,23 m

3 "Rolling" clay-marl and fine-grained sandstone. Lower Pannonian. — Borehole Ferencszállás-13 2385—2395 m

PLATE III

1 Gravel band with coaly plant debris in sandstone. Upper Pannonian. — Borehole Algyő-19 2107-60 m

2 In sandstone there is a rounded quartz pebble. Upper Pannonian. — Borehole Algyő-230 1956,4 m

3 Convolution of sand waves sunken by differential load into the under lying siltstone. Upper Pannonian. — Borehole Algyő-242 1965,4 m

PLATE IV

1 and 2 Sandstone characterized by grain size change having horizontal and chaotic laminated parts with erosive surface aleurolit pebble. Upper Pannonian. — Borehole Algyő-241 2017,30—2017,58 m

3 Fine-grained sandstone without interbedding. Upper Pannonian. — Borehole Algyő-194 1937,0—1937,5 m

The most important conclusions are as follows:

1. In the investigated area the last sedimentary cycle (From the Helvetian up to the Holocene) is uniform and free of intermediary greater regressions; its accumulation had been continuous at a given place.

2. In the Carpathian Basin the "climax" of the marine facies can be put at the Tortonian though the local increase of inundation may occur in addition of the slow regression of the whole basin.

3. The oldest formation of the Neogene is for the most part of clastic formation, in single parts of areas or in single bores its age may be Helvetian, Tortonian, Sarmatian and Lower Pannonian; but when accumulation has started the cycle had been continuous up to the Recent.

4. Since the Upper Miocene the brackish environment is replaced gradually by fresh-water environments and the individual evolution of the geosyncline being independent of the Pontian-Caspian Basin strated.

5. During the Miocene and Lower Pannonian there are considerable differences within the geosyncline (depth of water, salinity, bottom-relief, transportation and movement directions of the sediments, rock facies) and the environment is euxinic.

6. In the Upper Pannonian a fluvio-lacustrine system has developed which had been ceased by the human intervention in the Holocene.

7. The limitation of the Lower and Upper Pannonian by the quantitative increase and fauna content of the sand sediments is conventional and this does not mean a uniform time-demarcation of the whole of the area.

8. The sandstones assigned to the Lower Pannonian are coat-sands accumulated under uniform inundation of water while those of the Upper Pannonian are connected to delta sedimentation and shallow-water environments.

9. Upward from the boundary of the Lower and Upper Pannonian autochtonous coal-bed bearing sections are found in several horizons being of thin, *i.e.* of several cm (up to 1 m) thickness; these are the regular occurrences of the morassic environments.

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DR. MIHÁLY MUCSI

Institute of Mineralogy, Geochemistry
and Petrography, Attila József University,
H-6722 Szeged, Egyetem u. 2—6, Hungary

ISTVÁN RÉVÉSZ

OGIL,

H-6701 Szeged, Pf. 30,
Hungary