

**OLIGOCENE—LOWER MIOCENE FORMATIONS  
OF THE TRANSDANUBIAN CENTRAL MOUNTAINS  
IN HUNGARY**



## INTRODUCTION

It is on the geological mapping of 1966/1976 done in the Central Mountains that our present lithostratigraphic treatise "Oligocene—Lower Miocene formations of the Transdanubian Central Mountains" compiled in the Central Mts Department of the Hungarian Geological Institute, is based. The author, as a field geologist, took part in the 1:25,000-scaled mapping from which a general geological understanding with detailed account of the Oligocene to Lower Miocene sequence of the Bakony Mountains has derived. In getting acquainted with the same formations so widely as the whole Central Mountains region, the logging of about 110 boreholes was instrumental. Field works, laboratory analyses and a comparative interpretation of latest and formerly collected data have been the foundation for our present summarizing evaluation. In accordance with the "Directives for stratigraphic classification, nomenclature and their application", published in 1975 by the Hungarian Commission on Stratigraphy, the mappable Oligocene—Lower Miocene formations have been defined.

A general description of these Formations is followed by other chapters concerned with the following subjects: sedimentary-geological features, facies and palaeogeographical conditions, evolution history, tectonics and, finally, the interpretation of data bearing on economic mineral deposits.

## RESEARCH HISTORY

The history of research concerning the involved Oligocene—Lower Miocene beds is considered to display a threefold division. These periods represent the following time spans:

- (1) From as early as the 1850s until the outbreak of World War One.
- (2) From the First World War till the end of World War Two.
- (3) From the end of World War II up to now.

*The first period* lasting from the 1850s up to the First World War is one that may be characterized by the introduction of a systematic geological mapping in line with the outset and development of brown coal explorations. The geological mapping on the scale of 1:144,000 and 1:75,000 extended as widely as covering the whole Central Mts region, and even, after the turn of the century, in some zones a geological mapping scaled to 1:25,000, could be organized. Among others, on these regional works fundamental to a stratigraphic deal, a threefold partition of the Oligocene—Lower Miocene succession was feasible.

Investigations carried out in the NE part of the Transdanubian Central Mountains have resulted in the setting up of a system of stratigraphic units (Kiscell Clay, by K. PETERS 1857; Hárshegy Sandstone and *Pectunculus obovatus* Sand, by K. HOFMANN 1871; Budafok Sandstone, by H. BÖCKH 1899). Parallely, and partly subsequently, the stratigraphic—palaeontological interpretation of the Oligocene to Lower Miocene beds of the Dorog Basin was done (M. HANTKEN 1861, 1865, 1867b, 1871). Likewise it was M. HANTKEN (1875, 1878) who examined the Foraminifera fauna of the Buda Marl and Kiscell Clay, together with the compilation of a regional overlook on the Oligocene to Lower Miocene browncoal-bearing zones (Szápár, Jásd, Vértessomló and Annavölgy). Properly speaking, M. HANTKEN was first (1868c) to recognize the presence of Oligocene—Lower Miocene formations in the Bakony Mountains (Szápár, Jásd). After the relevant statement made by J. BÖCKH (1878), in the geological literature of the Bakony Mts the surface-covering pebbles or conglomerates were considered to have developed as a “pebble formation of Mediterranean age”, for almost a century long.

Till the turn of the century, publications of A. KOCH (1871a, b, 1877 and 1899), J. SZABÓ (1879), B. WINKLER (1883), F. SCHAFARZIK (1884) and GY. HALAVÁTS (1892) are significant contributions to the knowledge of the Oligocene—Lower Miocene beds, including the makeup and areal extent of their stratigraphic units.

The first decade of our century brought about the 1:25,000 geological survey of the Northern Bakony, Vértes and Gerecse Mountains (A. LIFFA 1905, 1906, 1907, 1909 and 1910; H. TAEGER 1909 and 1911). In addition to a farther-reaching areal reconnaissance, this work has been found to deal with problems of stratigraphic division and correlation, too. A. LIFFA (1907) described Hárshegy Sandstone from Gerecse, and H. TAEGER (1911, 1914) made reference to the problem how to trace boundary between the *Clavulina*-bearing Kiscell Clay (now Middle to Upper Eocene foraminiferous argillaceous marl = Csabrendék Formation) found by M. HANTKEN (1868c) in the N Bakony and its overlying sterile “Mediterranean” conglomerate. Conglomerates with *Unio* sp. were assigned to the Pontian stage by the same author.

Z. SCHRÉTER (1909) evidenced the existence of transition from Hárshegy Sandstone to Kiscell Clay in the drilled section of Pilisborosjenő. Then it was K. TELEGDY ROTH (1912) who first let to know about the absence of the littoral facies of the Kiscell Clay, after having monitored the Oligocene in Northern Hungary.

L. LÓCZY SEN. (1913) complemented J. BÖCKH's (1878) observations with those of his own concerning pebbles relating to the “Neogene system”. He considered the Bakony Conglomerate to be of continental origin, assignable to the Lower Mediterranean or Sarmatian (=blanket pebbles) stages of Miocene time. LÓCZY designated for provenance of this conglomerate the regions of the present-day lowland in Fejér County and the Somogy County hilly land.

The end of this first period is marked by K. PAPP's (1915) publication making a concern of the iron ore and coal reserves found in the territory of the one-time Hungarian Kingdom.

During the *second period* lasting from the end of World War One up to the conclusion of World War Two, most geological efforts were dedicated to the prospecting and exploration of coal reserves in the Central Mountains. In the second half of the 1920s bauxite explorations and, in the late 1930s, a survey to

provide a basis for hydrocarbon explorations, were initiated in the Central Mts including their flanking zones too. For this purpose, previously prepared maps on different scales (1:144,000—1:75,000—1:25,000—1:10,000) were also used as key material. At this time, practically no systematic (detailed) or regional geological mapping aimed directly at the finding of mineral resources was being executed in the Central Mountains, however, most of the relevant reports were published with supplementary geological maps. In contrast with the previous period of investigations, a multiplication of papers dealing with Oligocene—Lower Miocene formations can be registered. Beside particularities, some regional or subject-summarizing geostudies were published at the time. Stratigraphic discussions were centred on the problem of the lower and upper boundaries of the Oligocene—Lower Miocene formations, with the involvement of their proper definition and application in stratigraphic classification (P. ROZLOZSNIK, Z. SCHRÉTER and K. TELEGDI ROTH 1922, G. TOBORFFY 1923, L. BOGSCH 1929, A. FÖLDVÁRI 1929 and 1933, H. HORUSITZKY 1933, F. HORUSITZKY 1934 and 1937, Gy. BOKOR 1939, S. JASKÓ 1939, Z. SCHRÉTER 1939, I. FERENCZI 1940, L. MAJZON 1942, J. NOSZKY SEN. 1943, S. VITÁLIS 1944).

Amongst the new recognitions, K. TELEGDI ROTH's statement on the infra-Oligocene denudation is quite outstanding (1927). Upon these observations of his, originally done in the Dorog Basin, TELEGDI ROTH made subsequent applications in the S Vértes and N Bakony Mts. As for these latter, he observed "unconformity surface" between the "Kiscell Clay" (=Middle and Upper Eocene foraminiferous claymarl) and the underlying Coal Measures Group. Thereafter L. MAJZON (1943) excelled in rectifying the stratigraphic assignment of the "Kiscell Clay" (dated as Eocene from that time on). Thereby the infra-Oligocene denudation surface has automatically been put into a higher stratigraphic position. Despite the fact that not much concern of this question is noticeable in geological literature, the recognition of the infra-Oligocene denudation is one of the most standing statements in the history of the Hungarian Tertiary stratigraphy. It is also particularly noteworthy the distinction of the Tard Clay Formation and the Foraminifera-based stratigraphic division of the Tard Clay and Kiscell Clay (L. MAJZON 1940, 1942 and 1943).

Data relating to the "Palaeogene volcanic chain" that had played an important part in the facial-palaeogeographical evolution of the Central Mountains' Oligocene to Lower Miocene formations, are attached to T. SZALAI's name (1937).

Repeated formulations have been made by F. HORUSITZKY (1939) and E. VADÁSZ (1940) with regard to the lack of an isochronous littoral facies of the Kiscell Clay Formation.

In order to eliminate the problem given by the fact that the Chattian sand deposit shows a regressive facies character accompanied with a transgressive mode of occurrence, F. HORUSITZKY (1939) proposed to introduce the term "Stampian stage" instead of Rupelian plus Chattian.

Summarizing studies by J. NOSZKY SEN. (1941) and F. HORUSITZKY (1941) written on the stratigraphy and palaeogeography of the Upper Oligocene and, respectively, Lower Miocene of the Carpathian Basin, are particularly remarkable. Among regional works, one of I. VITÁLIS (1939) entitled "Coal deposits of Hungary" and another written by H. TAEGER (1936) on "The regional geology of Bakony" are noteworthy. The Kiscell Clay was treated mineralogically and petrographically by A. VENDL (1932) and on a malacological basis by J.

NOSZKY SEN. (1939, 1940a). Moreover, an exploration-and-mining-historical deal with the Oligocene and Lower Miocene brown coal deposits (Szápár, Vértessomló) was published by J. TILES (1932 and 1934).

After the Second World War, the *third period* set out with a complex geological mapping plus mineral prospection activity multiplied in extension and intensity, as far as comparison is made with the previous period. Between 1948 and 1953, the 1:25,000-scale geological mapping and bauxite-geological survey embraced nearly all the zones with mineral potential in the Central Mountains. This was followed by a survey scaled to 1:10,000 in the Dorog Basin (1959—1967). Lastly, since 1960 a systematic geological mapping on the scale of 1:25,000 has been carried out in the mountainous regions Bakony, Vértes and Gerecse. Records from mapping and drilling were substantial enough to draw up a detailed and even minute picture of the geological makeup of the Central Mts. This holds true of the Oligocene—Lower Miocene sequences of the Transdanubian Central Mountains, as it can be proved when casting a glance at the almost three-times-increased number of publications issued during this period. The specialization of the researches has become manifold and deepened. Publications on Oligocene and Lower Miocene subjects mostly keep focusing on stratigraphic questions, however, with no lack of some important new recognitions e.g. the verification of the presence of Oligocene—Lower Miocene beds in the Northern Bakony (K. BERTALAN 1948, E. SZÓTS 1948, S. VÉGH 1960, L. ALFÖLDI 1963, P. BOHN and J. KNAUER 1964, T. BÁLDI 1966), not omitting to mention the demonstration of the genetic relations with correlable formations developed in NE Transdanubia (T. BÁLDI 1966, 1967 and 1969). The Bakony-wide detailed geological mapping from 1967 to 1977 was undertaken by G. BENCE, B. BERNHARDT, D. BIHARI, K. CSIMA, L. GYALOG, M. KAISER, J. KNAUER, G. KOPEK, L. KORPÁS, J. MÉSZÁROS, ZS. PEREGI, GY. RAINCSÁK and G. SOLTÍ. Thereby the areal extent of the fluvatile Oligocene—Lower Miocene formations has been determined and their genetic uniformity proved. Besides that, correlation in age and facies of the fluvatile rocks of the Bakony Mts and the fluvatile to marine and marine deposits of the NE Central Mountains has been re-interpreted (Á. JÁMBOR and L. KORPÁS 1971, Á. JÁMBOR, L. KORPÁS, M. KRETZOI, I. PÁLFALVY and L. RÁKOSI 1971, L. KORPÁS 1971b and 1975a).

Stratigraphically, the Oligocene—Lower Miocene boundary problem, the more accurate tracing of the stage boundaries and the correlation of the traditional stratigraphic units have been invariably enfocused. This involves 54 papers by 30 authors (marked with "o" in References). Summarizing works from the same period are attached to the names of E. VADÁSZ (1960), L. MAJZON (1957, 1966); K. BALOGH, F. HORUSITZKY, M. KRETZOI, J. NOSZKY, A. RÓNAI and F. SZENTES (1958), T. BÁLDI (1966, 1971, 1973) and K. BALOGH (1971).

Among regional generalizations, the following publications can be distinguished: M. PÉCSI, F. HORUSITZKY, B. MAURITZ, Z. SCHRÉTER and E. SZÓTS (1958), Z. SIPOSS (1959, 1965a, b), S. VÉGH (1960, 1962), F. SÓLYOM (1960), J. KÓKAY (1966), L. GIDAI, Á. JÁMBOR, L. ÓDOR and Z. SIPOSS (1967), Á. JÁMBOR and L. KORPÁS (1968), L. KORPÁS (1971).

Parallely and additionally, the following relevant subjects have got to be published: examination of the Hárshegy Sandstone (F. KASZANITZKY 1956) and of the Bakony conglomerates (S. VÉGH 1960, L. ALFÖLDI 1962); mineralogical and petrological (E. CSÁNK 1969), micropalaeontological (Á. NAGY-

GELLAI 1969, 1973), coal-petrological (I. IHAROS-LACZÓ) and palynological (L. RÁKOSI 1973) investigation of the Oligocene—Lower Miocene beds of the Dorog Basin. Maps (1:10,000 and 1:25,000) showing areal extent, mode of occurrence, thickness and facies types of the Oligocene—Lower Miocene sequences in the Dorog Basin were first prepared (Z. SÍPOSS 1965b). T. BÁLDI, M. HORVÁTH and A. NAGYMAROSI (1973, 1976) wrote a general evaluation on the Kiscell Clay and Hárshegy Sandstone. In 1975/1976, the first maps on the scale of 1:100,000 showing areal extent, depth, facies conditions and palaeogeography of the Oligocene—Lower Miocene formations of the Transdanubian Central Mountains, were produced (L. KORPÁS).

## LITHOSTRATIGRAPHIC UNITS

Before the characterization of the involved lithostratigraphic units, it is necessary to put down scientific and partly practical criteria of the marking out of the upper and lower stratigraphic boundaries delimiting the Oligocene—Lower Miocene strata in the Transdanubian Central Mountains.

As for this, no scientific or practical difficulties are dealt with. Lower boundaries are, with no exception, traceable upon field records and data from simple laboratory testing. Not the same is with the upper boundary. Faunal assemblages of biostratigraphic value have been found in a minor part of the area of study, thus the following fundamental lithological features should be taken into account:

- (i) The unity in material and genesis of the sedimentation.
- (ii) The appearance of the first pyroclastics during the process of deposition, representing an interpreted isochronous surface ("Lower Rhyolite Tuff").

On this approach, boundaries can be traced upon field recording to meet practical requirements too, and these limits are often verifiable also geophysically.

Accordingly, beds younger than Buda Marl and older than the Lower ("First") Rhyolite Tuff belong to the Oligocene—Lower Miocene sequence.

The Oligocene—Lower Miocene sequences in the Transdanubian Central Mountains are constituted by the following formations or formation groups:

### Csatka Pebble Formation

- Szápár Coal Measures Member
- Noszlop Coal Measures Member

### Mány Sand Formation

- Vértessomló Coal Measures Member
- Esztergom Coal Measures Member

### Hárshegy Sandstone Formation

### Tard Clay Formation

### Kiscell Clay Formation

### Törökbálint Sand Formation

### Budafok Sand Formation

## The Csátka Pebble Formation

### *Synonyms:*

Bakony conglomerate (J. BÖCKH 1878, L. LÓCZY 1913)

Pontian beds (H. TAEGER 1936)

Lime-cemented conglomerate complex of Városlőd (L. ALFÖLDI 1963)

Conglomerate of Szolimán-hegy (J. KÓKAY 1966)

Mór Formation (T. BÁLDI 1969)

Csátka complex (Á. JÁMBOR, L. KÖRPÁS, M. KRETZOI, I. PÁLFALVY and L. RÁKOSI 1971)

The typical sedimentary rocks of this Formation are widespreadly found in the Bakony Mountains and their flanking zones, as cropping out at the surface or hidden by younger sedimentary materials (Supplement 1). Their thickness varies between 0 m and 800 m. These beds overlie the older ones (Palaeozoic, Mesozoic, Eocene) with erosional and angular unconformity. On top of them, and also unconformably, Quaternary deposits rest (Bakonybél—Cseh-bánya Basin, Hárskút—Porva—Zirc—Dudar Basin, Olaszfalu—Eplény sag and the N and NE forelands to the Bakony Mts). In the N and NW foreland to the so-called High (or Pápa) Bakony, the cover is built up of unconformably lying Lower Pannonian beds. In the Nyirád—Devecser—Ajka region, towards the overlying (?) Ottnangian and Karpatian beds an unbroken succession of sedimentation is experienced. A gradual transition to (?) Ottnangian and Karpatian beds is observable also in the northern foreland to the Keszthely Mountains and in the Herend—Márkó Basin and Várpalota Basin.

By the Csátka Pebble Formation a fluvial cyclic sedimentation is exemplified. Its basal horizon consists of lacustrine to swamp deposits (Szápár Coal Measures Member), which also appear here and there in the higher parts of the section (Noszlop Coal Measures Member). The very constitution of these cycles is shown by a portion of the Csátka Ck-1 drilled section (Fig. 1). The formation is built up of alternating red—yellow—green-coloured (variegated) or greenish-grey clay, argillaceous marl, marl, silt and silty—argillaceous sand together with light grey sands, sandstones and conglomerates.

The pertinent *argillaceous rocks* generally show angular i.e. granular splitting, rarely weak lamination with traces of bedding destroyed or hardly preserved. Lime, siderite and limonite concretions, carbonized plant remains, freshwater or (sporadically) brackish water molluscs, moreover vertebrate bone fragments and teeth are contained frequently. Carbonate contents vary according to rock types but do not exceed 50 per cent. Compositional clay minerals are: illite, montmorillonite and their mixed-lattice types with subordinate kaolinite (examined by I. VICZIÁN).

*Sands—sandstones* are mostly grey-coloured, unevenly laminated. They are commonly bedded or cross-bedded showing sinuous, sinuous-crested, or diagonal patterns of cross-stratification. The matrix is carbonate (calcite or, seldom, dolomite) and clay. The presence of biotite, muscovite, chlorite is common, and along bedding or crossbedding surfaces "placer-like" 1-to-20-mm-thick concentrations of garnet or magnetite—ilmenite minerals occur. The grain-size constitution is varied, medium-or well-sorted. The rounded particles are derived from quartz, chert, phyllite (sericite schist), flint and feldspar. Bedding planes are covered with fragments of carbonized or silicified float-trees, plant remains, somewhere with fragments and casts or prints after molluscan shells. The average frequency of characteristic minerals is shown by Fig. 2 on the basis of 221 samples analysed (analysts: M. SALLAI, E. RADÓCZ, L. RAVASZ, É. TÓTH).

*Pebble accumulations and conglomerates* are embedded in unsorted coarse sand or, more rarely, in clay. They appear as genuine conglomerates when cemented with carbonate (calcite, seldom dolomite). The well-rounded pebbles have a mean size range of 2 to 3 cm, with a maximum of 30 cm. The pebbles are derived from white—grey—greenish—grey—red—black-coloured quartzite, black schist (or graphite schist), phyllite (chlorite and sericite schist), red and green sandstone-quartzite, grey and white biotitic muscovite gneiss, red and green muscovite-biotite gneiss, white muscovite granite, biotite granite, white tourmaline granite, granite gneiss, Permian red sandstone, red and grey quartz porphyry, jasper, black fine-grained limestone, grey dolomite, cherty dolomite, bituminous dolomite, bituminous limestone, yellowish-grey—greyish-brown—yellowish-brown fine-grained limestone, white Dachsteinkalk, reddish-brown and grey chert, radiolarite, Aptian crinoidal limestone, Requienia limestone, yellowish-grey limestone and calcareous marl, Eocene Alveolina-Nummulites limestone, greyish-green and red andesite and intraformational clay and silt. The position of the individual pebbles is frequently oriented according to dipping, and often their beds form lenses.

The petrological composition of pebble accumulations, well distinguishable upon field mapping methods, it was determined by thin-section analyses of about 400 selected samples (L. KÖRPÁS and T. SZILÁGYI). These data appear in Tables 1—11.

In total, 8500 samples collected from the surface or from boreholes in the vicinity of Csatka, Ácsteszér, Sur, Bakonycsérnye, Nagyveleg, Szápár, Csetény, Bakonybél, Szentgál, Városlőd, Ugod, Adásztevel, Gyepükaján and Bakonykoppány, were examined in details by D. BIHARI, L. KÖRPÁS and T. SZILÁGYI. Accordingly, the mean composition of accumulations containing larger pebbles than 30 cm has been determined as follows:

Granite and granite gneiss 0.1%, paragneiss 0.7%, quartzite 42.8%, black schist or graphite schist 0.7%, phyllite-chlorite schist (sericite schist) 8.1%, conglomerate of sandstone-quartzite 4.7%, quartz porphyry (liparite porphyry) 0.6%, Permian sandstone 1.0%, Palaeozoic and Mesozoic cherts and flints 1.4%, Eocene limestone 10.2% and Eocene andesite 2.2%.

The Formation is very poor in fossils. Some remains may indicate facies conditions. The most important freshwater—oligohaline persistent forms have been described from borehole Csatka Ck-1 by T. BÁLDI (1973):

*Brotia escheri*, *Viviparus ventricosus*, *Pomatias antiquum*, *Archaeozonites* aff. *subangulosus*, *Unio inaequiradiatus*, *Sphaerium* aff. *normandi*, *Theodoxus crenulatus*, *Radix* sp., *Corethus* sp., *Caracollina* sp., *Melanopsis impressa hantkeni*, *Planorbis* sp., *Triptychia* aff. *antiqua*, *Helix* sp.

According to field survey and drilling records, some Polymesoda and Tympanotonus remains have been found in the zone of Bodajk and Balinka.

A few skeletons of microplanktonic organisms are usually present in argillaceous rocks. Examinations by F. BROKÉS, J. BÓNA and M. BÁLDI-BEKE (in P. BOHN 1979) of samples taken from bauxite-exploratory boreholes of Súr, Csehbánya and Iharkút, and others collected from kaolin-containing dolines in the Keszthely Mountains, show the presence of a poor nanoplanktonic assemblage, which is isochronous with the Formation and diagnostic of the biozone NP 21—25.

Vertebrata remains are very rare. Findings at some places such as Szápár (GY. ÉHÍK 1927), Ganna (M. KRETZOI 1956), Mór (D. JÁNOSSY), Súr and Csák-

berény (Á. JÁMBOR, L. KÖRPÁS, M. KRETZOI, I. PÁLFALVY and L. RÁKOSI 1971), are in favour of the faciological conclusions drawn from other kinds of evidence, however, the stratigraphic value of these vertebrate remains is not unanimously judged.

Plant remains (prints after leaves, squeezed branches, fragments of float trees, sporomorphs, Chara fruits, silicified tree remnants of *Magnolites* sp.) are badly preserved. The fossil flora of the Csátka Pebble Formation has not yet been dealt with in details.

Derived fossils (as well as Mesozoic to Eocene foraminifers, molluscs, algae, spores, pollens, planktonic remains) are present in some beds or horizons.

### The Szápár Coal Measures Member

#### *Synonym:*

Szápár brown coal deposit (M. HANTKEN 1868c)

Typical occurrences of this Member can be found in the Bakony Mountains and their N, NW and W adjacent zones. For areal distribution, see Supplement 3.

The thickness of this Member ranges from 0 to 120 m, and it rests on older rocks (Mesozoic, Eocene) with erosional or angular unconformity. In upward direction, a continuous transition into the fluvial beds of the Csátka Pebble Formation is observable.

This is lacustrine—swamp deposit made largely of argillaceous rocks (clay, silty clay, carbonaceous clay, argillaceous marl, silty-argillaceous marl, argillaceous silt) and, to a smaller extent, of carbonates (freshwater limestone, calcareous marl and dolomite) with coal (argillaceous brown coal and brown coal), see Supplement 5.

The *argillaceous rocks* are greyish-green, pale green, somewhere greyish-brown, brown-mottled or variegated, and they display uneven or conchoidal planes of parting. They are unbedded or weakly bedded, here and there laminated. Concretions of lime, siderite and limonite are frequently contained. The carbonaceous clays are generally of a brown to greyish-brown colour, bedded and laminated, and free of lime. The planes of stratification are often covered with fragments of carbonized plant remains. At places 1-to-2 mm-thick intercalated laminae of fusite, vitrite and pyrite grains are seen. The clayey rocks contain 25% carbonate on the average (and 50% as a maximum). According to I. VICZIÁN, the leading clay minerals are illite, montmorillonite and kaolinite.

*Freshwater limestone, calcareous marl and dolomite* occur rarely. They are formed by accumulations of greyish-white to yellowish-white, loose sedimentary material of nodular or granular structure, being not uncommonly concretions.

*Carbonaceous rocks* (meaning clayey or pure brown coal) are dark brown or black. They are laminated to foliated and, in stripes, finely banded. They represent an alternating succession of stripes made of carbonaceous clay, fusite and vitrite. Pyritic crust on bedding surfaces and parting planes is frequent. Brown coal seams have a thickness ranging from a few centimetres to 60 cm. Thicker seams (2,5 m) had been reported from the one-time production shafts of Szápár mine. According to contemporary mining documentation and published data (J. TILES 1934, I. VITÁLIS 1939 and E. VADÁSZ 1940), these seams

showed irregular changes of thickness within a few metres of distance. These papers report on a caloric value of 4,000—5,000 kilocalories and a high resin content (averaging 10%) of the brown coal of Szápár and Jásd. A fossil kind of resin called jásdite was also found here (I. VITÁLIS 1939). Though drilled elsewhere too in the Bakony Mountains, however, no further laboratory testing of these coal deposits was done because of their apparently low industrial grade of thickness and quality. No seam has been found as offering a better grade than that of Szápár, and even this latter has been proved uneconomic.

The pertinent rocks are poorly fossiliferous. Some molluscs have been found, which are persistent through all the Csatka Pebble Formation (T. BÁLDI 1973).

Vertebrata remains could be collected from these strata developed by Szápár (GY. ÉNIK 1927) and Bodajk (M. KRETZOI 1956).

The likewise poor fossil flora assemblage has not yet been treated. It consists largely of carbonized plant remains, Chara fruits and spore—pollen association which indicates a Taxodiaceae—Cupressaceae vegetation (L. RÁKOSI).

Derived fossils (such as Mesozoic and Eocene foraminifers, molluscs, algae, spores, pollens and planktonic forms) are frequently found in these beds.

### The Noszlop Coal Measures Member

#### *Synonym:*

Lignite-like brown coal of Noszlop (I. VITÁLIS 1939)

Sedimentary rocks assignable undoubtedly to this Member have been recognized in borehole Noszlop Not-8 only (Fig. 3). Data related to this deposit had been included in L. KOROMPAY'S mining report (1921). I. VITÁLIS (1939) also commemorated the former existence of mining.

Survey borehole Not-8 shows the beds of this Member to have been developed continuously from the fluvial beds of the Csatka Pebble Formation. Since an unbroken transition is experienced also upwardly, in proper terms we may speak of an intercalation drilled in a thickness of 43.5 m. Summarily, these are lacustrine to swamp-facies argillaceous materials (clay, silty clay, carbonaceous clay and argillaceous silt along with clayey brown coal and lignite) that form the Noszlop Coal Measures Member.

The *argillaceous rocks* are greyish-green, greenish-brown or variegated with brownish—reddish colours. They form beds displaying unevenly developed nodular to granular planes of parting, as being at the same time unbedded or weakly bedded. Lime, siderite or limonite concretions are often contained. Their everywhere-present constituent is given by small amounts of fine-grained and medium-sorted sand, making also mention of muscovite accumulated along banding planes. The typical rock is carbonaceous clay of greyish-brown and dark brown colour, which always shows a weak banding and nodular to conchoidal parting. Along planes, carbonized plant debris, fusite (some mm) and pyrite grains are also found.

*Carbonaceous deposits* (clayey brown coal and lignite) are mostly dark brown and they display a combined planar structure of parting planes along lamination and bedding. Along these planes pyritic crusts occur. The seam is

drilled in a thickness ranging from 0.3 m to 3.1 m. It is a low-quality coal (1200—3900 kilocalories).

These rocks drilled are practically unfossiliferous. A few molluscan shell fragments were only found. Any attempt to gain microfossils from these materials, has failed.

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In summary, the Csatka Pebble Formation is a separate lithostratigraphic unit, which is well-distinguishable upon surface and subsurface methods of geological investigation. Its generalized stratigraphic column is shown by Fig. 4.

At the base of this Formation, locally a lithostratigraphic subdivision, by beds of lacustrine—swamp facies called Szápár Coal Measures Member, appears. This grades upwardly into a fluvatile complex. On the petrological character of constitutional pebbles, a two-fold subdivision of this fluvatile complex is feasible where it has a total combined thickness of about 500 m, as it has been experienced in the region of Ácsteszer, Kisbér and Mór.

The pebble-composition of the lower horizon is heterogeneous [(quartzite, black schist—graphite schist, phyllite schist—chlorite schist/sericite schist), conglomerate of sandstone-quartzite, granite—granite gneiss, gneiss, quartz porphyry (liparite porphyry), Permian sandstone, Palaeozoic and Mesozoic carbonate rocks, flints, Eocene limestone and andesite)] and characterizable by a majority of rocks of metamorphic origin. Contrary to this, in the upper horizon Palaeozoic and Mesozoic limestone, dolomite and chert, moreover Eocene limestones prevail opposing metamorphic and Permian rock types. Granite—granite gneiss and eocene andesite are lacking. The Noszlop Coal Measures Member of lacustrine to swamp facies is only distinguishable in its type locality; no respective regional distribution can be given for the time being. Consequently, from among the lithostratigraphic units of the Csatka Pebble Formation (Fig. 4), in most cases, only the Szápár Coal Measures Member and the lower fluvatile complex are figurable in the one and the same section. In the section of zones unaffected by erosional wearing away (Ácsteszer—Kisbér—Mór), besides the Szápár Coal Measures Member and the lower fluvatile complex, the upper fluvatile sedimentary group can also be distinguished.

The per cent distribution of the rock types that are peculiar to this Formation, given on the basis of dealing with a total length of 6,700 m drilled by 29 boreholes, is shown in Fig. 5.

Laterally, the Csatka Pebble Formation is unbrokenly interfingering with the Mány Sand Formation towards the north-east (Fig. 6 and Supplement 4). The Csatka Ck-1 drilled section has been tested and proposed for stratotype (L. KÖRPÁS 1976b), see Supplement 5.

## The Mány Sand Formation

### *Synonyms:*

Pectunculus obovatus sand (K. HOFMANN 1871)

Cyrena clay (A. KOCH 1871b)

Potamides beds (L. MAJZON 1939)

Complex of mixed facies (S. VITÁLIS 1944)

Lower sand (Z. SPOSS 1965a)

Mány Formation (T. BÁLDI 1969)

The Mány Sand Formation is the most widespread lithostratigraphic unit of the NE Transdanubian Central Mountains. Its surface outcrops and subsurface ranges are widely known in the following regions: Dunazug Mountains, Buda Mountains (with basins of Nagykovácsi and Budakeszi), Solymár—Pilisvörösvár rift valley, Pilis Mountains, Dorog—Esztergom and Tatabánya—Csordakút—Nagyegyháza—Mány—Zsámbék. In the Vértes and Gerecse Mountains, these beds appear in some restricted areas of the surface, however, they can be widely detected as infillings in various inner basins (Vértessomló, Várgesztes, Vértestolna, Héreg—Tarján) and in the western foreland to the

Vértes and Gerecse Mts (Supplement 1). The farthest westward extent is marked by borehole Kocs-7.

The thickness of beds assignable to this Formation ranges from 0 m to >600 m and more. They rest with erosional and angular unconformity on Palaeozoic, Mesozoic and Eocene rocks. When being underlain by the Hárshegy Sandstone Formation, this Formation develops therefrom with a transition of alternating beds. The Formation is overlain unconformably (erosional, angular) by the following beds: Middle Miocene (Mány—Zsámbék, Dunazug Mts), Lower Pannonian (W foreland to the Vértes and Gerecse Mts), Upper Pannonian (Gerecse, Buda Mountains) and Quaternary.

The Formation is built up of facilogically very different rocks. In the Vértes and Gerecse Mountains and their W foreland, the fluvialite—deltaic deposits are predominant with subordinate brackish water to marine sediments. In zones like Tatabánya—Csordakút—Nagyegyháza—Mány—Zsámbék and Dorog—Esztergom, rock types of brackish water—marine facies prevail, and those of the fluvialite—deltaic facies are more subordinate. Finally, in the Pilis and Buda Mountains and their intermontane basins, moreover in the Dunazug Mountains, brackish water—marine sediments are nearly exclusive and fluvialite—deltaic beds are extremely rare.

As for facies development, a characteristically fluviomarine complex with cyclic sedimentation and basal limnic—paralic layers is treated here (Vértes-sómló Coal Measures Member, Esztergom Coal Measures Member). The constitution of its inner cycles is figured by a cut of the Etyek Csv-34 drilling section (Fig. 7).

The *argillaceous rocks* (clay, argillaceous marl and silt) are variegated by various colours such as grey, greyish-green, more subordinately yellowish-brown and brownish-red. Grey and greyish-green rocks generally display a bit limy and laminated character, here and there with conchoidal, nodular or granular planes of parting. The variegated and mottled rock types mostly have a nodular to granular parting; on the other hand they are unbedded and contain large amounts of concretions by lime, siderite or limonite. Small quantities of medium-to-well-sorted sands and of muscovite and biotite are often present showing an uneven distribution. Carbonized plant remains are fragmentary and of bad preservation. The molluscan fauna (freshwater, brackish water and marine) is seen in form of prints and shell debris, whereas intact shells are rare. Microfossils are usually contained in greyish-green and grey rocks. Sporadic Vertebrata remains (fragments of bone, teeth) are mostly attached to green-coloured and mottled—variegated rocks. Their mean carbonate content takes up 20% on an average, whereas the extremities are 0% and 50%. I. VICZIÁN has described illite, montmorillonite and their mixed-lattice types as constitutional clay minerals, however, at places the amount of kaolinite may also be substantial, and sericite together with chlorite are constant accessory components.

*Sands and sandstones* are grey, greyish-green, laminated and bedded, showing patterns of crested and diagonal cross-bedding. They are of a varied granulometric composition, medium-sorted or well-sorted, loose or cemented with clay or carbonate substances (calcite, not commonly dolomite). Along planes of bedding and cross-stratification, concentrations of biotite, chlorite, muscovite, garnet and magnetite (ilmenite) minerals are common. These last two may frequently constitute some-mm-thick enrichments. The chief mineral,

even observable with the unaided eye, is white and weathered feldspar. Uncommon glauconitic sand (stone) had already been described. It consists mostly of particles of metamorphic rocks (quartzite, chert, phyllite and sericite schist) with accessory grains derivable from flint and carbonate rocks. At many places, fossil plant fragments, somewhere pieces and prints of carbonized leaves, pieces of float-tree and silicified tree remains are included.

The freshwater—brackish water—marine molluscs are detectable in the form of accumulated shell fragments, shells, prints and casts. Microfossils are scanty in these rocks. In total 213 samples were examined micromineralogically (M. SALLAI, E. RADÓCZ and L. RAVASZ). Taking also into account some published data (E. CSÁNK 1969), the mean micromineralogical composition is given in Fig. 8.

Grey-coloured *pebble accumulations and conglomerates* form a few-metres-thick lenses. Pebbles are embedded in medium-to-coarse-grained and medium-sorted sand. Harder conglomerates are commonly cemented with calcite. The grade of sorting of the pebbles is average or good. The medium-rounded pebbles show a maximum diameter of 15 cm, averaging 1 cm. The pebbles are derived in 90% from metamorphic rocks (quartzite, chert, sandstone-quartzite, phyllite, sericite gneiss and gneiss), whereas the resting proportion by 10% is shared by Mesozoic limestone and dolomite, flint, radiolarite, Permian sandstone, quartz porphyry (liparite porphyry), Eocene limestone and andesite (in an order of decrease).

These rock types are generally poor in fossils. The scanty flora consists of carbonized plant debris, pieces of carbonized and silicified float trees, whereas the fauna is composed of washed-in molluscs and foraminifers of freshwater—brackish water—marine origin, displaying a mostly bad state of preservation. The latter are comparatively numerous, however, they represent a small number of species. Ostracods, moreover Echinodermata and Vertebrata remains occur subordinately.

The Mollusca fauna has been examined and described in very details by T. BÁLDI (1973). The significant palaeocoenoses with denominative taxions are as follows: lagoonal (Viviparus-Brotia, Polymesoda-Tympanotonus, Tympanotonus-Pirenella), shallow sub-littoral (Glycymeris, Pitar, Nucula-Angulus), shallow middle sub-littoral (Turritella).

From boreholes Etyek Csv-34 (1) and Szentendre Sze-II (2) the following molluscan fauna was collected (T. BÁLDI 1963b):

*Dentalium* cf. *fissura* (1), *D. simplex* (1), *Nucula mayeri* (1), *N. gracilis* (2), *Nuculana solymarensis* (1), *Anadara gümbeli* (1), *Pteria vogli* (2), *Chlamys deleta* (2), *Anomia ephippium* (1), *Isocardia subtransversa* (1, 2), *Coralliophaga cumeata* (2), *Thyasira vara* (2), *Laevicardium tenuisulcatum* (1), *L. cyprum* (2), *Pitar undata* (1), *P. polytropa* (1), *Macoma elliptica* (1), *Tellina* sp. (2), *Cultellus budensis* (1), *Corbula gibba* (1), *Trachia scabra* (2), *Pholadomya puschi* (2), *Theodoxus pictus* (1), *Turritella venus* (1), *T. beyrichi* (2), *Turritella* sp. (2), *Tympanotonus margaritaceus* (1), *Drepanocheilus* cf. *speciosus* (1), *Rostellaria hungarica* (2), *Polinices catena* (1), *Polinices* sp. (2), *Liomesus danicus* (2), *Phos pygmaeus* (2), *Hinia* sp. (1).

A summarizing evaluation on the Foraminifera fauna of the Dorog Basin was done by Á. NAGY-GELLAI (1973). A list of foraminifers collected from boreholes Etyek Csv-34 (1) and Szentendre Sze-II (2) is given here as follows:

*Rhabdammina abyssorum* (2), *Haplophragmoides* sp. (1), *Cyclammina cancellata* (2), *C.* cf. *precancellata* (1), *C. placenta* (2), *Cyclammina* sp. (2), *Haplophragmium* sp. (2),

*Spiroplectammia carinata* (2), *Vulvulina subflabelliformis* (2), *Textularia agglutinans* (2), *T. conica* (2), *T. globosa* (2), *Trochammia* sp. (2), *Karrerella siphonella* (2), *Spiroloculina tenuis* (2), *Spiroloculina* sp. (1, 2), *Quinqueloculina haveriana* (1), *Q. cf. julicana* (1), *Quinqueloculina* sp. (1, 2), *Triloculina consobrina* (1), *T. inflata* (1), *T. tricarinata* (1), *Triloculina* sp. (1), *Nodosaria bacillum* (2), *N. colomorpha* (2), *N. crassa* (1, 2), *N. scalaris* (1), *Nodosaria* sp. (2), *Dentalina* sp. (2), *Lagena sulcata* (2), *Lagena* sp. (1, 2), *Robulus arcuatostrata* (2), *R. cultratus* (2), *R. inornatus* (2), *R. limbosus* (2), *Robulus* sp. (1, 2), *Marginulina elegans* (2), *M. gladius* (2), *M. fragaria* (2), *Marginulina* sp. (1, 2), *Planularia kubinyii* (2), *P. nummulitica* (2), *Saracenaria hantkeni* (2), *Vaginulinopsis pseudodecorata* (1), *Globulina münsteri* (2), *Guttulina* sp. (2), *Polymorphina compressa* (2), *P. gibba* (2), *Polymorphina* sp. (2), *Pyrulina fusiformis* (1), *Sphaeroidina bulloides* (2), *Bolivina beyrichi* (1, 2), *B. elongata* (2), *B. beyrichi* var. *carinata* (1), *Bolivina* sp. (1, 2), *Bulimina buchiana* (2), *B. elongata* (2), *Bulimina* sp. (2), *Loxostomum digitale* (1), *Virgulina schreibersiana* (2), *Virgulina* sp. (1), *Uvigerina pygmaea* (2), *Baggina allomorphinoides* (2), *Rotalia beccarii* (2), *Rotalia* sp. (2), *Elphidium crispum* (1), *E. subnodosum* (1), *E. inflatum* (1), *E. minutum* (1), *Globigerina globulosa* (1), *G. bulloides* (2), *Globigerina* sp. (2), *Eponides teneris* (1), *Eponides* sp. (2), *Glandulina laevigata* (2), *Cibicides dutemplei* (1, 2), *C. lobatulus* (1, 2), *C. ungerianus* (2), *Cibicides* sp. (1, 2), *Cassidulina crassa* (2), *C. subglobosa* (2), *Nonion buxovillanum* (1), *N. cf. granosum* (1), *Nonion* sp. (1), *Pullenia* sp. (1), *Gyroidina soldanii* (1), *Gyroidina* sp. (2), *Anomalina cryptomphala* (2), *Almaena osnabrugensis* (1).

Sporadic remains of Ostracoda and Echinodermata have not yet been described. Nanoplankton examinations (M. BÁLDI-BEKE) have outlined an assemblage of fossils characteristic of the biozone NP 24—25.

Vertebrata remains could be collected at various places: Vértessomló (I. VITÁLIS 1939), Puzstavám (Á. JÁMBOR, L. KORPÁS, M. KRETZOI, I. PÁLFALVY and L. RÁKOSI 1971), Tata and Szend (M. KRETZOI). They have been evaluated likely to those found in the Csátka Pebble Formation.

The palaeobotanical investigation of the fossil plant assemblage contained in this Formation, till now has been based on the study of several outcrops i.e. sections (I. PÁLFALVY 1967, L. RÁKOSI 1966, L. HÁBLY 1976). On a preliminary megafloora—sporomorpha evaluation (Á. JÁMBOR, L. KORPÁS, M. KRETZOI, I. PÁLFALVY and L. RÁKOSI 1971) it can be said that the plant fossils of the Formation on the whole indicate uniformly a pre-existing mixed forest environment shared by swamp pine and cypress vegetation.

Derived fossils as well as foraminifers, spores, pollens and planktonic skeletons of Mesozoic to Eocene age, are peculiar to some rock types and horizons.

### The Vértessomló Coal Measures Member

#### *Synonym:*

Vértessomló—Gesztes coal deposit of Late Oligocene age (I. VITÁLIS 1939)

This Member is represented by the limnic—paralic basal beds to the Mány Sand Formation that is detectable in the Vértes Mountains including their western foreland. Its areal extent is shown by Supplement 3. The thickness of this Member varies between 0 m and 50 m. It rests on Mesozoic and Eocene rocks and is covered with Quaternary beds. Both boundaries testify to erosional and angular unconformity. Fluvial—brackish water—marine beds of the Formation concerned develop transitionally from this Member and even go beyond it. They are largely argillaceous rocks (clay, argillaceous marl) and, secondarily, carbonates (freshwater limestone) along with carbonaceous ma-

terials (clayey brown coal and brown coal) that form the sequence of the Vértes-somló Coal Measures Member.

The *argillaceous rocks* are generally grey, greyish-green or brownish-red variegated. They show parting along banding planes, which are characterizable by smooth, conchoidal or, more rarely, nodular and granular surfaces. The laminated types are usually also bedded, while the nodular to granular varieties are unbedded or weakly bedded. The rock types with pale grey colour and greasy lustre seem to be rich in kaolinite. Mainly calcite and siderite, less frequently pyrite and limonite are the materials that form concretions, which are very common here. The badly preserved fossils (fragmentary carbonized plants and freshwater to brackish water molluscs) are seen as fragments or prints.

The *freshwater limestone* consists largely of piles of lime concretions; they are greyish-white or yellowish-white. The bedded limestone is also laminated, whereas the unbedded variety shows granular planes of parting.

The *carbonaceous rocks* are laminated to foliated, with a planar structure built of alternating stripes of vitrite and fusite. Their colour is dark brown or black; pyritic crust on bedding planes is common. In the type locality of Vértes-somló, prior to the abandonment of mine, the following properties of the coal deposits had been registered (J. TILES 1932, I. VITÁLIS 1939 and E. VADÁSZ 1940): one to three lenticular seams of a thickness ranging from 0.5 to 3.5 m, with a caloric value of 4,200 kilocalories. The horizon of coal measures has been drilled by numerous boreholes set in the western margin and foreland to the Vértes Mts (Pusztavám, Oroszlány, Bokod and Környe). The thickness and quality of these coal seams is similar to those of Vértes-somló.

The Coal Measures Member as an autochthonous accumulation with originally local areal extent, can be derived from limnic—paralic swamp forest vegetation. Its facies relations are shown in Fig. 6 and Supplement 4.

### The Esztergom Coal Measures Member

#### *Synonyms:*

Esztergom coal measures group (M. HANTKEN 1868)

Sárisáp Oligocene coal formation (M. HANTKEN 1868)

Upper Oligocene coal deposit in the vicinity of Esztergom (I. VITÁLIS 1939)

The sedimentary rocks that have been assigned to this Member are the peculiar limnic—paralic basal sediments to the Mány Sand Formation occurring in a zone limited by Tatabánya, Csordakút, Nagyegyháza, Mány and Zsámbék. Their areal extent is shown in Supplement 3. They lie unconformably (erosional, angular) on Mesozoic to Eocene rocks with a thickness ranging from 0 m to 100 m. With likewise mostly erosional and angular unconformity, they are overlain by Quaternary beds. The proper overlying horizon, however, consists of fluvio-marine beds belonging to the Formation as higher division. This is a series of argillaceous rocks (clay, kaolinitic clay, argillaceous marl, carbonaceous clay, argillaceous silt) with subordinate carbonates (freshwater limestone, calcareous marl) or carbonaceous rocks (clayey brown coal and brown coal) that constitutes the Member concerned.

The *argillaceous rocks* are usually grey, greyish-green, seldom reddish-variegated. A structure of lamination, frequently conchoidal, less frequently

granular to nodular parting, moreover bedding or weakly developed bedding is seen. They are often kaolinitic; this reflects on a greasy lustre of parting planes. Concretions of lime, siderite, pyrite and limonite appear frequently. Dark grey to greyish-brown—coloured carbonaceous clays are laminated, bedded and free of lime. Along the planes of bedding and parting carbonized plant fragments are observable. The carbonate content averages 20% and amounts up to 50%. Clay minerals are kaolinite, montmorillonite and illite (E. CSÁNK 1969).

*Freshwater limestone and calcareous marl* are significant but comparatively rare. Colours such as greyish-white and yellowish-white prevail here. The rocks are bedded or weakly bedded, showing also nodular, granular or planar structures of parting. They consist of lime concretions and, to a smaller extent, of molluscan shells and shell fragments (*Bithynia* sp., *Planorbis* sp., *Brotia* sp.).

The *carbonaceous rocks* (clayey brown coal, brown coal) are dark brown to black ones. They are laminated, foliated and finely banded. This banding has been formed owing to lustrous (xilite—vitrite) and lustreless (fusite) stripes, moreover to the appearance of carbonaceous clay, kaolinitic clay, freshwater limestone and calcareous marl. Parallel to the planes of bedding and parting, strings and nests of resin and pyrite crusts are seen. There are operated coal mines there (Ebszónbánya, Mogyorósbánya) and also exhausted ones (Annayölgy, Csolnok, Tokod). The brown coal seams (1 to 3) have a thickness ranging from some cm to 2.0 m, with a caloric value of 4,000—5,000 kilocalories. The significant bitumen content averages 5%. Similarly developed coal deposits relating to this Member have been drilled by a lot of boreholes sunk in the regions Dorog—Esztergom and Tatabánya—Csordakút—Nagyegyháza—Mány—Zsámbék.

All the rocks described above are poor in fossils. Characteristic molluscan forms are assigned to the palaeocoenoses *Viviparus*—*Brotia*, *Polymesoda*—*Tympanotonus* and *Tympanotonus*—*Pirenella* (T. BÁLDI 1973). Among the scanty foraminifers agglutinate forms are prevailing (Á. NAGY-GELLAI 1973).

On the basis of the study of some localities and type sections (E. KRIVÁNHUTTER 1964a, b and L. RÁKOSI 1960, 1973), the flora is characterizable by a *Taxodium*—*Cupresaceae* vegetation.

The coal-deposit-bearing complex formed in various separated sub-basins, is an autochthonous sequence of limnic—paralic swamp forest facies (I. IHAROSLACZÓ 1964, 1973). Its facies relations are shown in Fig. 6 and Supplement 4.

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**S u m m a r y:** The Mány Sand Formation as a separate lithostratigraphic unit is mappable i.e. well-identifiable upon both surface and subsurface methods of geological investigation. Its division is figured by a generalized stratigraphic column (Fig. 9).

In some places, at the base of the Formation the Vértessomló and Esztergom Coal Measures of limnic—paralic facies appear as well-recognizable lithostratigraphic subdivisions. They pass into a transgressive fluvio-marine complex with continuous sedimentation. This latter may attain to a thickness of 100 m and more (in boreholes), involving the possibility of its further subdivision into two or three horizons, however, this is not generally feasible when mapping because of the small number of drilling data.

The per cent distribution of the Formation-building rock types (upon a sum of 6,200 m drilled by 29 boreholes) is shown in Fig. 10. The lateral facies relations of the Mány Sand Formation are presented in Fig. 6 and Supplement 4. The drilled section Etyek Csv-34 has been proposed for stratotype (Supplement 6).

## The Hárshegy Sandstone Formation

### *Synonyms:*

Hárshegy sandstone (K. HOFMANN 1871)

Quartzsandstone and conglomerate free of fossils (P. ROZLOZSNIK, Z. SCHRÉTER and K. TELEGDI ROTH 1922)

Hárshegy-type sandstone (A. LIFFA 1907)

Hárshegy Sandstone Formation (T. BÁLDI, M. BÁLDI-BEKE, M. HORVÁTH, T. KECSKEMÉTI, M. MONOSTORI and A. NAGYMAROSI 1976)

Additional names that have been used in field documentation and borehole logging: kaolinitic sand(stone), and grey quartzsand(stone).

In a typical form as having been described, this Formation is detectable in the following regions: Buda Mountains with intermontane basins (Nagykovácsi, Budakeszi), Solymár—Pilisvörösvár rift valley, Pilis Mountains and Esztergom Basin (see Supplement 1). Non-typical occurrences are found in the region of Tatabánya—Csordakút—Nagygyháza—Mány—Zsámbék. Upon testimonies by mapping records and drilling data, it can be said that the characteristic Hárshegy Sandstone Formation lies with erosional and angular unconformity on Mesozoic and Eocene beds. On its top the Neogene or Quaternary strata are likewise unconformable. The transition with alternating beds into the proper overlying (Mány Sand Formation and Kiscell Clay Formation) is gradual. The thickness is 0 m—30 m.

Practically, this Formation is characterizable by the presence of one or two grain-size composition cycles of the sand fraction. This makeup is shown by an extraction from geological drilling section Esztergom E-20 (Fig. 11).

A typical rock variety comes into focus by its dark brown, rust-brown or light grey colour and by its being bedded (10 to 50 cm) and impregnated with limonite. This is medium-to-fine-grained and well-sorted sandstone or conglomerate, with siliceous matrix, built largely of particles of quartzite and, less frequently, of chert, sericite schist, sandstone-quartzite and grey-coloured flint. Constant but sporadic components are feldspar and muscovite. The diameter of the well-rounded pebbles of a well-sorted accumulation comes to 5 cm, averaging about 0.5 cm. About 90% of the pebbles is derivable from grey, white and red quartzite. Beside this, pebbles of chert, graphite schist, sericite schist are present. In the immediate basal beds particles of Triassic limestone and dolomite of local origin are observable. These pebbles form generally some thin (maximum 20 cm) beds or strings, showing a poor stratification by sorting. In some places e. g. Szabadság-hegy, they are intersected by veins of white and red calcite, chalcedony and baryte. Below the land surface, the unweathered rocks generally contain aggregates of grey-coloured and non-oxidized pyrite crystals.

A detailed study of the silicified rock varieties (T. BÁLDI, M. HORVÁTH, A. NAGYMAROSI 1976) has shown them to be product of a hydrothermal process, as it had been stressed in earlier time. The decrepitation test of two baryte samples from Pilisborosjenő has shown an unusually high temperature of formation (310° C—320° C).

The non-typical variety of the Formation can be encountered in the region of Tatabánya—Csordakút—Nagygyháza—Mány—Zsámbék in the form of kaolinitic sand(stone) that appears at the base of the Mány Sand Formation. This is a greyish-white, medium-to-coarse-grained and well-sorted rock type,

which is mostly loose, bedded, at places cross-bedded. Its particles consist largely of white and grey quartz, weathered feldspar and, subordinately, of muscovite and chert. Pebbles are rarely contained. The well-sorted and well-rounded pebbles have a diameter of max. 3 cm, averaging about 0.5 cm. It is exclusively metamorphic material (quartzite, chert, sericite schist, sandstone-quartzite) that constitutes this pebble accumulation, without any pebble of local origin. Silicification is rarely seen and pyritization neglectable in comparison with the typical rock varieties.

The distribution of significant minerals of siliceous and kaolinitic rock types is shown in Figs. 12–14, according to the analyses of 9 samples and former descriptions (F. KASZANITZKY 1956).

The rocks of this Formation are extraordinarily poor in fossils. The molluscan fauna has usually been preserved as shell fragments brought together by water, along with casts and prints. The preservation of carbonized plant fossils is also poor. Float trees are generally carbonized here, and rarely silicified. Microfossils are sporadic, however, some kaolinitic clay or fireclay beds transitional towards the Mány Sand Formation and Kiscell Clay Formation, are abundant in foraminifers. Molluscs had been collected at 11 localities and then examined by T. BÁLDI et al. (1976) stating that mainly sub-littoral, subordinately brackish water—lagoonal palaeocoenoses can be indicated thereon.

A scanty Foraminifera fauna and elements of the flora were collected from single outcrops and sections. Their evaluation has not yet been carried out.

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**S u m m a r y:** Owing to the presence of included silicified and kaolinite-bearing rocks, the Hárshegy Sandstone Formation is generally well-identifiable as a separate lithostratigraphic unit. In spite of this, on invented or actual criteria taken into account during mapping and well-logging, some outcrops or beds of the coarsely grained Mány Sand Formation have been assigned to the Hárshegy Sandstone Formation. This can be explained by its small thickness and changing character, together with the transitions made of alternating beds. Consequently, it is only possible to roughly trace the boundaries in any vertical section of this Formation.

A generalized stratigraphic column (Fig. 15) and a representation of the lateral facies relations of the Hárshegy Sandstone (Fig. 6, Supplement 4) are given together with the distribution of its significant rock types (Fig. 16).

The Várerdő-hegy section of Sölymár (T. BÁLDI et al. 1976) has been proposed for stratotype of Formation.

## The Tard Clay Formation

### *Synonyms:*

Meletta-bearing slates of Gellérthegy (K. PETERS 1859)

Pteropoda marl (I. LŐRENTHEY 1903)

Meletta-bearing siliceous—slaty marl with plant remains (E. VADÁSZ 1910)

Tard beds (L. MAJZON 1940)

Andesite tuff-bearing laminated argillaceous marl (Á. JÁMBOR, L. KÖRPÁS, M. KRETZOI, I. PÁLFALVY and L. RÁKOSI 1971)

The areal (surface and subsurface) distribution of the Formation is restricted to the Buda Mountains (Pesthidegkút, Városmajor—Vérmező and Buda-keszi) and their immediate vicinity (the “edge plain” of Óbuda—Kiscell, the southern foreland to the Buda Mts). It develops from the Buda Marl Formation with an unbroken succession, and gets its proper covering by the Kiscell Clay

Formation. An overlying by unconformable Quaternary strata (erosional and angular unconformity) is also observable. The thickness of sequence ranges from 0 m to 100 m.

It consists mostly of laminated clay and argillaceous marl, which contain frequently andesite tuff and tuffite, and rarely sand intercalations. The Formation represents a cyclic buildup, the inner constitution of which is shown by an extract from the geological drilling section Budakeszi Bu-2 (Fig. 17).

*Clay and argillaceous marl* are dark grey and, on the surface, greyish-brown to brown, displaying foliation or laminaton (1—5 mm). In most cases, they are free of lime or weakly limy. Plenty of bacterial or crystalline pyrite concretion some tenth mm to 2 mm large is contained. Varieties abounding in pyrite are frequently silicified.

Along planes of stratification, accumulations of well-preserved plant remains (leaf, branch), fish remnants (scale, tooth and vertebra) and prints are found. Besides these, planktonic foraminifers, coccoliths, diatoms and sporomorphs are held in the rocks. The carbonate content averages 5% as varying from 0% to 10%. Characteristic clay minerals are kaolinite and illite. Organic matter content is abundant and even appreciable with the unaided eye. In Budapest, a borehole set on the Fillér street, penetrated at a depth of 38.0 m a kind of argillaceous silt that contains 0.87% organic carbon together with 0.07% bitumen extractable through a treatment with chloroform (I. VETŐ 1973).

Crystalloclastic *andesite tuff—tuffite* intercalations are light grey and stratified by bands or laminae 2 to 5 cm thick. These interbeddings are fine-to-medium-grained and well-sorted rocks that include porphyritic feldspars as large as 0.1 to 1.0 mm. Where bentonitized, they show a greyish-green colour and polyhedral parting. The parting planes are greasy-lustrous and a bit absorbent. A few pre-existing coloured minerals are unidentifiable because of limonitic decomposition.

Intercalations of *sand* are rarely found. They consist mostly of fine-to-small-grained and well-sorted particles that have been piled up into loose and finely banded sandbeds. Along these planes of stratification, accumulations of muscovite, biotite and chlorite can be seen megascopically. The distribution of characteristic minerals is given in Fig. 18.

In the fossil assemblage vertebrates (fishes) and plant remains prevail. Planktonic foraminifers, moreover Coccolithophora, Diatomacea forms and spore—pollen remnants are frequent and molluscs sporadic.

Most localities of the abundant fossil flora elements collected previously (M. STAUB 1886, K. RÁSKY 1943, G. ANDREÁNSZKY 1959), together with those of Vertebrata findings (W. WEILER 1933 and 1938, M. KRETZOI 1940, 1942) have turned to be unidentifiable in the course of time.

Most foraminifers collected from these rock sequences give no much support in the desired solution of the Eocene—Oligocene boundary problem. Thus, this is an ever-returning question in the stratigraphic literature of our Tertiary.

According to M. BÁLDI-BEKE (1976, 1977), this Formation is characterizable by the nanoplanktonic assemblage of biozone NP 21—23. No chronostratigraphic value is attributable to the sporadic molluscan fauna. Derived (mainly Eocene) nanoplanktonic forms are frequently contained in these rocks.

**S u m m a r y:** Upon its characteristic rock types, the Tard Clay Formation is a well-recognizable i.e. mappable lithostratigraphic unit. It can be separated from the Buda Marl Formation without exception, but not the same is with the Kiscell Clay Formation. In this respect, a successful separation is feasible when major and continuous rock sequences are to be dealt with. The setting of the concerned sedimentary rocks formed in a land-locked basin of euxinic-type conditions of sedimentation, is represented by a generalized geological columnar section (Fig. 19). The per cent distribution of the peculiar rock types as given in Fig. 20, it has been based on a 104-metre-long section drilled by a single borehole. Lateral facies relations are illustrated in Fig. 6 and Supplement 4.

The section of borehole Városmajor Vm-1 has been proposed for stratotype (Supplement 7).

## The Kiscell Clay Formation

### *Synonyms:*

Kiscell clay (K. PETERS 1859 and M. HANTKEN 1866a)

Foraminiferous argillaceous marl (P. ROZLOZSNIK, Z. SCHRÉTER and K. TELEGGI ROTH 1922)

Kiscell Clay Formation (T. BÁLDI, M. HORVÁTH and A. NAGYMAROSI 1973)

Rocks belonging to the above Formation are detectable in the following regions and zones: Buda Mountains (Budakeszi, Nagykovácsi, Pesthidegkút; Városmajor—Vérmező), their eastern and southern forezones (the Óbuda—Kiscell “edge plain” and the rift valley Solymár—Pilisvörösvár, respectively), Dunazug Mountains, moreover Dorog—Esztergom and Zsámbék—Perbál—Dág. Their presence between Vál and Gyúró is attested to by sporadic outcrops and drilling data (Supplement 1). The Formation develops from the underlying beds (Tard Clay, Hárshegy Sandstone and Mány Sand) with an unbroken deposition of alternating strata. It is overlain by the Törökbálint Sand Formation in a similar way. Erosional and angular unconformity is experienced when the overlying is constituted by Middle Miocene, Upper Pannonian or Quaternary deposits. The Kiscell Clay Formation has a thickness changing from 0 m to 500 m.

This is a series of mainly argillaceous rocks (silt, argillaceous marl and clay) that forms this marine Formation of cyclic makeup. Sand and sandstone are rarer and pebbles or conglomerates absent. The inner makeup of the characteristic cycle is represented by an extract from the geological section of borehole Esztergom E-20 (Fig. 21).

The *argillaceous rocks* are grey-coloured, laminated with conchoidal parting, moreover bedded and limy. They usually contain minor amounts of well-distributed, fine-grained and well-sorted sand, muscovite and biotite. There are no lime concretions but pyrite-and-limonite-composed ones accumulated along the planes of stratification.

In a similar position, badly preserved carbonized plant remains impregnated with pyrite and limonite, occur. Poor molluscan remnants are seldom well-preserved shells. On the other hand, these rocks are abounding in skeletons of planktonic and benthonic Foraminifera, Coccolithophora, together with spores and pollens. The mean carbonate content takes up 15%, with extremities by 0% and 50%. Clay minerals are mostly illite and, not so frequently, kaolinite and chlorite.

*Sands and sandstones* are grey, laminated, finely to small-grained, well-sorted, loose or cemented with carbonate (calcite). They are bedded, at places

cross-bedded showing a crested pattern. Characteristic minerals (biotite, muscovite, chlorite, garnet and magnetite) here also are accumulated along planar structures. A previously described sporadic variety is given by glauconitic sands and sandstones.

The above-described rocks are poor in fossils, and even frequently they are sterile. Carbonized plant fragments and molluscs and rare microfossils of a bad state of preservation have been brought together by water.

The mean mineral composition of the sand—sandstone group (Fig. 22) has been calculated upon the study of 48 samples taken from 6 boreholes, and published data (E. CSÁNK 1969) have also been taken into consideration.

The faunal assemblage of this Formation, abounding in specimens and species too, consists largely of planktonic and benthonic Foraminifera, Coccolithophora and Mollusca, in union of sporomorphs. Echinoids and ostracods cannot be seen systematically. Rarely, remains of corals, bryozoans, brachiopods and vertebrates may also be found.

The description of the Foraminifera fauna has been based on many exposures and boreholes. Some generalizations on foraminifers deal with descriptions (M. HANTKEN 1868a, 1875) and with regional or local zonation (L. MAJZON 1957, 1960, 1966 and Á. NAGY-GELLAI 1973, respectively).

Foraminifers of the drilled sections Szentendre II (1) and Budafok-2 (2) are as follows:

*Glomospira charoides* (2), *Haplophragmoides latidorsatus* (1, 2), *Cyclammina acutidorsata* (2), *C. cancellata* (1), *C. rotundidorsata* (2), *C. placenta* (1), *Cyclammina* sp. (1), *Haplophragmium glomeratus* (1), *H. latidorsatum* (1), *H. subglobosa* (1), *Haplophragmium* sp. (1), *Spiroplectammmina carinata* (1, 2), *S. deperdita* (2), *S. pectinata* (2), *Textularia agglutinans* (1, 2), *T. deperdita* (1), *T. subglabelliformis* (1), *T. sagittulina* (2), *T. globosa* (1), *T. globulosa* (1), *T. conica* (1), *T. tuberosa* (1), *Textularia* sp. (1), *Vulvulina pectinata* (1, 2), *V. subflabelliformis* (1), *Verneulina variabilis* (1), *Gaudryina rugosa* (2), *Karrerella siphonella* (1, 2), *K. reussi* (1), *Karrerella* sp. (1), *Martinottiella communis* (2), *Spiroloculina canaliculata* (2), *S. tenuissima* (2), *Spiroloculina* sp. (1), *Quinqueloculina akneriana* (2), *Q. agglutinans* (2), *Q. carinata* (2), *Q. ludwigi* (2), *Q. impressa* (2), *Q. juleana* (2), *Q. seminula* (2), *Quinqueloculina* sp. (1, 2), *Sigmoilina celeta* (2), *S. tenuis* (2), *Triloculina consobrina* (2), *T. gibba* (2), *T. tricarinata* (2), *T. trigonula* (2), *Nodosaria acuminata* (1, 2), *N. exilis* (2), *N. radícula* (2), *N. soluta* (2), *N. spinicosta* (2), *N. bacillum* (1), *N. coarctata* (1), *N. crassa* (1), *N. equisetiformis* (1), *N. irregularis* (1), *N. latejugata* (1), *Nodosaria* sp. (1), *Dentalina approximata* (1, 2), *D. acuta* (1), *D. adolphina* (2), *D. intermedia* (1), *D. elegans* (1, 2), *D. gümbeli* (1), *D. fiformis* (2), *D. fissicostata* (1), *D. inornata* (2), *D. hoernesii* (1), *D. pauperata* (1, 2), *D. eximus* (1), *D. pungens* (2), *Dentalina* sp. (1), *Fronndicularia budensis* (2), *F. tenuissima* (1), *Fronndicularia* sp. (1), *Lagena hispida* (2), *L. apiculata* (1), *L. sulcata* (1), *L. striata* (2), *Lagena* sp. (1), *Lenticulina arcuata* (2), *L. cultrata* (2), *L. gibba* (2), *L. inornata* (2), *L. limbosa* (2), *L. intermedia* (2), *L. simplex* (2), *L. vortex* (2), *Lenticulina* sp. (2), *Marginulina behmi* (1), *M. fragaria* (1, 2), *M. elegans* (1), *M. gladius* (1), *M. glabra* (1, 2), *M. minuta* (1), *M. hirsuta* (2), *M. recta* (1), *M. pediformis* (2), *M. subbullata* (1), *Marginulina* sp. (1, 2), *Planularia kubinyii* (1), *P. nummulitica* (1), *P. costata* (1), *Vaginulina* sp. (2), *Plectofronndicularia striata* (2), *Globulina gibba* (2), *G. münsteri* (1), *G. inaequalis* (2), *G. tuberculata* (2), *Guttulina problema deltoidea* (2), *G. acuta* (1), *G. problema* (1, 2), *Guttulina* sp. (1), *Pseudopolymorphina incerta* (2), *Polymorphina* sp. (1), *Pyrulina fusiformis* (2), *P. compressa* (1), *Pyrulina* sp. (2), *Glandulina discreta* (1), *G. aequata* (2), *G. hantkeni* (1), *G. laevigata* (1, 2), *Glandulina* sp. (1, 2), *Entosolenia orbignyana* (1), *Entosolenia* sp. (1), *Sphaeroidina bulloides* (2), *Bolivina beyrichi* (1, 2), *B. globosa* (1), *B. robusta* (1), *B. antiqua* (2), *B. elongata* (1), *B. scalprata* (1), *B. oligocaenica* (2), *B. punctata* (1), *B. semistriata* (1), *B. reticulata* (1, 2), *Bolivina* sp. (1), *Bulimina elongata* (1, 2), *B. buchiana* (1, 2), *B. ovata* (1, 2), *B. sculpilis* (2), *B. pyrula* (2), *Bulimina* sp. (1), *Nodogenerina spinicostata* (1), *Nodogenerina* sp. (1), *Virgulina schreibersiana* (2), *Uvigerina pygmaea* (1), *U. gallowayi* (2), *Uvigerina* sp. (2), *Hopkinsina* sp. (2), *Angulogenerina gracilis* (2), *A. gracilis tenuistriata* (2), *Angulogenerina* sp. (2), *Valvulineria* sp. (2), *Asterigerina planorbis* (2), *Rotalia canvi* (2), *R. umbilicata* (1), *R. propinqua* (2), *Rotalia* sp. (1), *Ammonia beccarii* (2), *Elphidium hiltermanni* (2), *E. minu-*

*tum* (2), *E. subnodosum* (2), *Elphidium* sp. (2), *Globigerina bulloides* (1), *G. triloba* (1), *Globigerina* sp. (1), *Eponides budensis* (2), *E. pygmaeus* (2), *E. schreibersii* (2), *E. umbonatus* (1, 2), *Eponides* sp. (1), *Planulina costata* (1, 2), *Planulina* sp. (1), *Planulinella osnabrugensis* (1), *Cibicides lobatulus* (1, 2), *C. propinquus* (1), *C. dutemplei* (1, 2), *C. ungerianus* (1, 2), *C. pseudoungerianus* (2), *Cibicides* sp. (1), *Cassidulina globosa* (1, 2), *C. vitalisi* (1), *C. crassa* (1), *C. subglobosa* (1), *Chilostomella cylindroides* (2), *Ch. ovoidea* (2), *Nonion affina* (2), *N. commune* (2), *N. granosum* (2), *Allomorphina trigona* (2), *Pullenia bulloides* (1, 2), *P. sphaeroides* (1), *Alabamina tangentialis* (2), *Gyroidina soldanii* (2), *G. girardana* (2), *Gyroidina* sp. (1), *Anomalina affinis* (1), *A. cryptophala* (1, 2), *A. granosa* (1), *Anomalina* sp. (1), *Hanzawaia boueana* (2), *Heterolepa costata* (2), *Almanea osnabrugensis* (2), *Ceratobulimina contrata* (1, 2), *C. haueri* (2), *Epistomina elegans* (2), *Robertina declivis* (2).

Nanoplanktonic and sporomorph assemblages of various sections (M. BÁLDI-BEKE 1977, J. BÓNA 1964, L. RÁKOSI 1966) are, according to a preliminary evaluation, indicative of the biozone NP 24 (M. BÁLDI-BEKE 1977).

The molluscan fauna was first described by K. HOFMANN (1873) and then by J. NOSZKY SEN. (1939, 1940a). Molluscs from exposures Budapest (Újlak and Pasarét) were reported by L. BOGSCH (1929).

Lamellibranchs and gastropods held in samples collected from boreholes Szentendre II (1) and Budafok 2 (2) are considered characteristic of the Formation concerned:

*Cadulus gracilina* (2), *Dentalium fissura* (2), *D. haerigense* (2), *D. haerigense densitexta* (1), *Dentalium* sp. (2), *Nucula deshajesiana* (2), *N. comta* (2), *N. comta praemissa* (2), *N. nucleus* (2), *Nucula* sp. (2), *Malletia degrangei* (1), *Tindaria* sp. (2), *Lembulus* sp. (2), *Yoldia raulini* (2), *Y. perovalis* (2), *Y. nitida raulini* (1), *Yoldia* sp. (2), *Limopsis retifera* (2), *Crenella deshajesiana* (2), *Pteria phalaenacea* (2), *Parvamussium bronni* (1, 2), *Variamussium* sp. (1), *Chlamys deleta* (1), *Thyasira vara* (1, 2), *Laevicardium cyprinum* (1, 2), *Macoma elliptica* (2), *Tellina* sp. (1), *Panopea menardi* (2), *Corbula gibba* (1), *C. subyarata* (1), *Sphaenia szalavi* (1), *Thracia ventricosa* (1), *Cuspidaria clava* (2), *Cuspidaria* sp. (2), *Solariella suturalis* (2), *Solariella* sp. (2), *Odontostoma arictum* (2), *Hydrobia acuta* (1), *Turritella beyrichi* (1), *Rostellaria hungarica* (1), *Polinices* sp. (1, 2), *Turris duchatelii* (2), *T. laticlavia* (2), *Cylichna* sp. (2), *Roxania burdigalensis* (2), *Spiratella* sp. (2), *Vaginella tenuistriata* (2).

No stratigraphic—ecological evaluation of the sporadic echinoids, ostracods, corals, bryozoans, brachiopods and vertebrates has been made till now.

Some rock types and horizons are characterizable by the presence of derived fossils (Mesozoic—Eocene spores, pollens, nanoplanktonic forms and foraminifers).

\* \* \*

**S u m m a r y:** The Kiscell Clay Formation is mostly well-recognizable and mappable as a lithostratigraphic unit. The geological makeup of this Formation, developed in a sub-littoral—neritic—shallow bathial environment of deposition, is shown by a generalized geological column (Fig. 23).

The per cent distribution of the peculiar rock types is given upon data gained from a 1,622-m-long section drilled by 12 boreholes (Fig. 24). Lateral facies relations are shown in Fig. 6 and Supplement 4.

The stratotype described by T. BÁLDI et al. (1973), is represented by borehole "Holzspach" R 8/7 in Budapest. The drilled section Szentendre Sze-II has been proposed for para-stratotype (Supplement 8).

## The Törökbálint Sand Formation

### *Synonyms:*

- Pomáz clay (K. PETERS 1857)
- Pectunculus obovatus sand (K. HOFMANN 1871)
- Cyrena beds (A. KOCH 1871)
- Cyrena clay (A. KOCH 1871)
- Potamides beds (L. MAJZON 1939)
- Upper sand (Z. SIPOSS 1965)
- Kovačov formation (T. BÁLDI 1969)
- Törökbálint sandstone (T. BÁLDI 1969)

The surface/subsurface areal extent of this Formation involves the following regions: Buda Mountains with their southern foreland, Pilis Mountains, Dorog—Esztergom Basin and Dunazug Mountains. It develops with gradual transition from the underlying Kiscell Clay Formation and, in upward direction, it passes with likewise continuous deposition into the overlying Budafok Sand Formation. On the other hand, the Formation is unconformably (erosional, angular) overlain by Quaternary beds. For the time being, its maximum thickness is taken for some 500 m (borehole Szentendre Sze-II).

The rocks that had originally been formed by a more marine less fluvio-marine cyclic sedimentation, show a variety of lithological properties which may be best studyable on the core samples taken from boreholes Budafok Bf-2, Dág D-14, Esztergom E-20, Szentendre Sze-II and Tököl I. The inner makeup of individual cycles is shown by an extract from the geological borehole section Szentendre Sze-II (Fig. 25).

The *argillaceous rocks* (clay, argillaceous marl, silt) making up the Formation are grey, subordinately greyish-green, yellowish-brown or reddish variegated, with nodular to granular planes of parting rather than being conchoidal-laminated. They are also weakly bedded or unbedded, and contain minor amounts of lime. The greyish-green and variegated rocks are often concretion-bearing (lime, siderite and limonite). Nearly all the included argillaceous rock types contain small quantities of fine-grained and well-sorted sand, muscovite, biotite and chlorite.

The plant fossils are carbonized and fragmentary. Freshwater—brackish water—marine molluscs appear here in the form of prints and shell fragments; intact shells are rare. Microfossils are found mainly in grey-to-greyish-green-coloured, laminated clays. The carbonate content is about 20% on an average. Clay minerals are illite and montmorillonite, along with their mixed-lattice types.

The *sandstones* are light grey, laminated, bedded and archedly cross-stratified. Their rock material is finely to coarsely grained, well-sorted, loose or cemented with carbonate (calcite, dolomite). Their peculiar minerals (biotite, chlorite, muscovite, garnet and magnetite) form "placer-like" concentrations up to some mm thick along bedding planes (garnet and magnetite). Some varieties are abounding in glauconite. The assemblage of fossils is generally poor. Fragments of molluscs brought together by water, moreover their impressions are commonest, whereas the presence of carbonized plant remains and prints, and of carbonized or silicified float-tree remnants is subordinate. Foraminifers are poor in number and species too. The distribution of characteristic minerals of the sand-sandstone beds is given according to the analyses of 81 samples taken from 5 boreholes, together with published data (E. CSÁNK 1969), see Fig. 26.

*Pebbles* of the grey-coloured conglomerate are embedded in unsorted, coarse-grained sand, which is argillaceous here and there. The cement is calcite, rarely dolomite. The pebbles are medium-rounded, and medium-to-well-sorted. Their maximum diameter is 20 cm, beside an average of about 1 cm. They are mostly derivable from metamorphic rocks (quartzite, chert, sandstone-quartzite, quartz phyllite, sericite schist and gneiss). In a certain rock types that are poor or even lacking in fauna, a scanty flora is found instead (carbonized plant fragments, carbonized and silicified float-tree remnants).

The faunal assemblage is represented by accumulated, badly preserved molluscs of mostly marine, secondarily freshwater—brackish water origin.

A detailed study was devoted to the molluscan fauna of this Formation (T. BÁLDI 1973). This fauna is characterizable by a majority of littoral to sub-littoral palaeocoenoses let known when treating the Mátyás Sand Formation, as being in sharp contrast with the inferior part played by the limnic—lagoonal palaeocoenoses. The most important forms collected from boreholes Szentendre II (1) and Budafok 2 (2) are as follows:

*Dentalium kickxi* (2), *Dentalium* sp. (2), *Nucula compta* (1), *N. laevigata* (2), *N. nucleus* (2), *Nucula* sp. (2), *Yoldia globerina varians* (2), *Y. raulini* (2), *Y. perovalis* (2), *Yoldia* sp. (2), *Arca diluvii* (1), *Arca* sp. (1), *Mytilus aquitanicus* (1), *Pteria phalaenacea* (2), *Chlamys incomparabilis* (2), *Chlamys* sp. (1), *Ostrea cyathula* (1), *Ostrea* sp. (1, 2), *Astarte gracilis degranii* (2), *Cyclocardium scalaris* (2), *Cyclocardium* sp. (2), *Polymesoda convexa* (1), *Batissa* sp. (1), *Isocardia* sp. (2), *Cyprina islandica* (2), *C. rotundata* (2), *Cyprina* sp. (2), *Congeria basteroti* (1), *Taras rotundatus* (1), *Thyasira vara* (1), *Lucinoma borealis* (2), *Laevicardium cyprinum* (2), *L. tenuisulcatum* (1, 2), *Cardium neglectum* (2), *C. bojourum* (1), *C. thiiense* (1), *Parvicardium praepapillosum* (2), *Ringicardium bükkianum* (1), *Pitar beyrichi* (1, 2), *P. polytropa* (1, 2), *Pirenella plicata* (1), *Venus* cf. *multiamella* (2), *Psammobia protracta* (1), *Macoma elliptica* (2), *Angulus nycti* (1, 2), *Angulus* sp. (2), *Panopea menardi* (1, 2), *Glycymeris latiradiata* (2), *Glycymeris* sp. (2), *Corbula gibba* (2), *C. cf. basteroti* (2), *Corbula* sp. (2), *Pholadomya puschi* (2), *Pholadomya* sp. (2), *Thracia pubescens bellardi* (2), *Th. ventricosa* (2), *Theodoxus pictus bükkensis* (1), *Neritina picta* (1), *Odontostoma* sp. (2), *Hydrobia acuta* (1), *Turritella beyrichi* (1), *T. venus* (1, 2), *Turritella* sp. (2), *Tympanotonus margaritaceus* (2), *Diastoma grateloupi turritoapenninica* (2), *D. grateloupi* (1), *Diastoma* sp. (2), *Calyptrea chimensis* (1), *Xenophora deshayesi* (2), *Drepanocheilus digitata* (1), *D. speciosus* (1), *Polinices catena* (2), *Polinices* sp. (2), *Hexaplex deshayesi* (1), *Lyria graniformis gárdonyi* (2), *Turris croxmontana* (2), *T. selysii* (2), *Turricula regularis* (1), *Gibbula affinis protumida* (1), *Archaeozonites ventricosus* (1), *Archaeogopsis discus* (1).

A summarizing evaluation of the Foraminifera fauna collected from this Formation in the Dórog Basin, was published by Á. NAGY-GELLAI (1973). A list of the foraminifers collected from boreholes Szentendre II (1) and Budafok 2 (2) can be given here:

*Cyclammina acutidorsata* (2), *Cyclammina* sp. (2), *Spiroplectammina carinata* (2), *S. pectinata* (2), *Textularia gramen* (2), *T. globosa* (1), *Trochammina* sp. (1), *Karreriella siphonella* (2), *Martinottiella communis* (2), *Spiroloculina canaliculata* (2), *S. tenuissima* (2), *Quinqueloculina carinata* (2), *Q. ludwigi* (2), *Q. juleana* (2), *Q. seminula* (2), *Quinqueloculina* sp. (2), *Sigmoilina celeta* (2), *Triloculina consobrina* (2), *T. tricarinata* (2), *Nodosaria exilis* (2), *N. semirugosa* (2), *Amphicorina angulosa* (2), *Dentalina approximata* (2), *D. adolphina* (2), *D. inornata* (2), *D. soluta* (2), *Dentalina* sp. (1), *Lagena hispida* (2), *L. globosa* (1), *L. striata* (2), *Lagena* sp. (1), *Lenticulina arcuatostrata* (2), *L. inornata* (2), *L. intermedia* (2), *L. simplex* (2), *L. pseudodecorata* (2), *Marginulina glabra* (2), *Marginulina* sp. (2), *Vaginulina* sp. (2), *Plectofrondicularia striata* (2), *Globulina gibba* (2), *G. granulosa* (2), *G. münsteri* (1), *G. inaequalis* (2), *Guttulina problema* (2), *Pseudopolymorphina incerta* (2), *Pyrullina cylindroides* (2), *P. fusiformis* (2), *Glandulina* sp. (1), *Sphaeroidina bulloides* (2), *Bolivina beyrichi* (2), *B. antiqua* (2), *B. dilatata* (2), *B. reticulata* (2), *Bolivina* sp. (1, 2), *Bulimina arnati* (2), *B. elongata* (1, 2), *B. pyrula* (2), *Reusella spinulosa* (2), *Uvigerina* sp. (2), *Angulogerina angulosa* (2), *Canaris turgidus* (2), *Hopkinsina* sp. (2), *Discorbis planorbis* (1), *D. resacaea*

(1), *Discorbis* sp. (1), *Siphonia reticulata* (2), *Asterigerina planorbis* (2), *Rotalia audouini* (2), *R. canui* (2), *R. propinqua* (2), *Rotalia* sp. (1), *Ammonia beccarii* (2), *Elphidium hiltermanni* (1, 2), *E. minutum* (2), *E. subnodosum* (2), *E. rugosum* (2), *Elphidium* sp. (1, 2), *Globigerina bulloides* (1), *Globigerina* sp. (1, 2), *Eponides schreibersii* (2), *E. umbonatus* (2), *Cibicides lobatulus* (2), *C. dutemplei* (1, 2), *C. ungerianus* (2), *C. pseudoungerianus* (2), *Cibicides* sp. (1, 2), *Virgulina schreibersiana* (2), *Loxostomum digitale* (2), *L. sinuosum* (2), *Cassidulina globosa* (2), *Chilostomella cylindroides* (2), *Nonion affine* (2), *N. boueanum* (2), *N. commune* (2), *N. granosum* (2), *N. pompilioides* (2), *N. tuberculatum* (2), *Nonion* sp. (2), *Pullenia bulloides* (2), *P. quinqueloba* (2), *Alabamina tangentialis* (2), *Gyroidina girardana* (2), *G. soldanii* (2), *Hanzawaia boueana* (2), *Anomalina cryptophala* (2), *Heterolepa* sp. (1), *Almanea osnabrugensis* (2), *A. osnabrugensis delmasi* (2), *A. osnabrugensis eccornesovensis* (2), *A. osnabrugensis hieroglyphica* (2), *Ceratobulimina contratia* (1).

The included Ostracoda and Echinodermata remains are sporadic and still undescribed. According to J. BÓNA (1964), the nanoplanktonic forms held by samples from borehole Szentendre II, are indicative of the biozone NP 24–25.

The palaeoflora has turned to be outlined upon surface collecting and by the examination of samples taken from borehole Szentendre II (L. RÁKOSI 1966). According to a preliminary evaluation of the remains (Á. JÁMBOR, L. KÖRPÁS, M. KRETZOI, I. PÁLFALVY and L. RÁKOSI 1971), this type of vegetation is identical with that of the Mány Sand Formation.

The presence of derived fossils (Mesozoic to Eocene spores, pollens, nanoplanktonic forms and foraminifers) is characteristic of various rock types and horizons of the Törökbálint Sand Formation.

\* \* \*

**S u m m a r y:** The Törökbálint Sand Formation as a separate lithostratigraphic unit is recognizable and mappable in its surface and also subsurface position. In consequence of its being very similar to the Mány Sand Formation, the farthest extent in westward direction of the Törökbálint Sand Formation cannot be given. In those sections where the underlying consists of Kiscell Clay, no problem of distinction exists. Contrary to this, in faciological transitional zones represented by the Mány Sand Formation (Tatabánya—Csordakút—Nagyegyháza—Mány—Zsámbék, Dorog Basin) or in other places where the Kiscell Clay Formation had not developed or had turned to be eroded off prior to the deposition of the Törökbálint Sands, it may be difficult to check up the stratigraphic position of the latter. The geological make-up is shown by the generalized stratigraphic column of Fig. 27.

The per cent distribution of the peculiar rock types is shown in Fig. 28, according to the analysis of a 1,624-m-long section drilled by five boreholes.

In lateral direction, the Törökbálint Sand Formation joins with no break the Mány Sand Formation (Fig. 6, Supplement 4). A section drilled by borehole Budafok 2 examined as paratype of the Egerian (T. BÁLDI 1973), has now been proposed for stratotype of the Formation concerned here.

## The Budafok Sand Formation

### Synonyms:

- Bryozoa beds (M. HANTKEN 1861)
- Anomien-Sand (G. STACHE 1866)
- Budafok sandstone (H. BÖCKH 1899)
- Aequipecten-bearing beds (F. HORUSITZKY 1937)
- Budafok Formation (T. BÁLDI 1969)
- Anomia-and-larger-Pecten-bearing sand of Budafok (T. BÁLDI 1973)

Deposits belonging to this Formation can be detected in both surface and subsurface distribution in the southern foreland to the Buda Mountains and

in the Dunazug Mountains. The Budafok Sand Formation is conformably underlain by the Törökbálint Sand formation and it is overlain with erosional and angular unconformity by Quaternary beds. In our area of study, its relation to overlying Middle Miocene strata is fairly unclear. In the Dunazug Mountains, a sharp upper boundary of heterolithic unconformity is given by the appearance of cycle-beginning pyroclastics of the Mid-Miocene volcanic activity. Despite the variety of lithofacies types that have developed in the southern foreland to the Buda Mountains, no erosional or angular unconformity is observable in the southward-dipping monoclinical beds of the Formation, which terminates by the Lower ("First") Rhyolite Tuff in the Tétény Plain area. Its presumable maximum thickness is 250 m. The cyclic sedimentary series that consists largely of marine and partly fluvio-marine rocks with characteristic lithological properties, is presented in this very quality in the geological facies sections of the beds drilled by boreholes Budafok Bf-2 and Tököl-1 (Supplement 9). The inner makeup of its individual cycles is shown by an extract from the geological section of borehole Budafok 2 (Fig. 29).

The *argillaceous rocks*, sandstones and conglomerates of the Formation are practically identifiable with their equivalents in the Törökbálint Sand Formation. Essential lithological differences are given only by the petrological character, size and roundness of the pebbles. In the Dunazug Mountains and in the southern foreland to the Buda Mountains, there are mostly littoral pebbles with maximum and minimum diameters of 20 cm and 1 cm, respectively. These pebbles are medium-rounded and medium-to-well-sorted. In their composition, metamorphic rocks (quartzite, chert, sandstone-quartzite and sericite schist) prevail. Accessory pebbles of Mesozoic limestone, dolomite, flint and radiolarite, and even minor amounts of quartz porphyry, andesite and granite are observable.

The mineral composition of sands and sandstones, identical with those of the Törökbálint Sand Formation, has been established upon analyses of 10 samples taken from 2 boreholes (Fig. 30).

Most fossils are found in the southern foreland to the Buda Mountains, whereas their presence is sporadic in the Dunazug Mountains region. In the vicinity of Budafok there are some classical localities with abundant molluscs that were studied in details and more times than one. This faunal assemblage can be characterized by predominant littoral to sub-littoral palaeocoenoses and subordinate limnic—lagoonal ones (H. BÖCKH 1899, F. HORUSITZKY 1926, 1937, A. FÖLDVÁRI 1929, I. CSEPREGHY-MEZNERICS 1956, T. BÁLDI 1959, 1964, 1969 and T. BÁLDI in F. STEININGER—J. SENEŠ 1971).

The most important forms are listed here as collected from borehole Budafok 2:

*Dentalium kickxi*, *Nucula nucleus*, *N. notabilis virgata*, *Nucula* sp., *Mytilus* sp., *Pecten* sp., *Chlamys opercularis miotransversa*, *Chlamys* sp., *Flexopecten palmata crestensis*, *Anomia ephippium*, *Ostrea* sp., *Cardita* sp., *Cyclocardia scalaris*, *Laevicardium* cf. *spondyloloides*, *L. tenuisulcatum*, *Laevicardium* sp., *Cardium* sp., *Acanthocardia moeschani*, *Pitar* cf. *erycinoides*, *Pitar* sp., *Venus* cf. *multilamella*, *Glycymeris* sp., *Corbula gibba*, *Corbula* sp., *Gibbula* sp., *Diloma* sp., *Turritella venus*, *T. terebralis subgradata*, *Turritella* sp., *Protoma cathedralis quadricincta*, *Terebrata praedentata*, *Polinices catena*, *Babylonia eburnoides*, *Olivella clavula vindobonensis*, *Cylichna* sp.

Fauna collecting from exposures and core samples has led to the description of foraminifers relating to this Formation (M. HORVÁTH and Á. TÓTH-MAKK 1974).

The characteristic forms of the section drilled by borehole Budafok 2 are as follows:

*Nodosaria oblonga*, *Asterigerina planorbis*, *Globulina gibba*, *G. granulosa*, *G. inaequalis*, *Pseudopolymorphina incerta*, *Reusella spinulosa*, *Rotalia audouini*, *Ammonia beccarii*, *Elphidium crispum*, *E. hiltermanni*, *E. minutum*, *Lepidocyclina* sp., *Nonion boueanum*, *N. commune*, *N. granosum*, *N. tuberculatum*, *Alabamina tangentialis*.

Skeletons of Ostracoda and Echinodermata are sporadic and undescribed. It is the same with the scanty fossil plant remains.

\* \* \*

**S u m m a r y:** In respect with distinctions to be made on the surface or in borehole logging, the Budafok Sand Formation is considered generally distinguishable upon its characteristic pebbles in the first place and, less reliably, by the molluscan fauna. Together with this, however, it remains a hardly mappable lithostratigraphic unit. When fossils or pebbles are absent, no separation from the Törökbálint Sand Formation is feasible. Its geological makeup is shown by the stratigraphic column of Fig. 31.

The per cent distribution of the peculiar rock types is shown in Fig. 32, on the basis of analysing a 183.5-metre-long drilled section put together by two boreholes.

As the described stratotype of this Formation, the Pacsirta-hegy exposure at Budafok can be referred to (T. BÁLDI 1969). Additionally, the Eggenburgian part of the sequence drilled by borehole Budafok 2 upon a proposal made by T. BÁLDI (1974), has been chosen as para-stratotype (Supplement 9).

## SEDIMENTARY-GEOLOGICAL FEATURES OF THE LITHOSTRATIGRAPHIC UNITS

On the description of each lithostratigraphic unit, an overall generalization on the relevant sedimentary features can be dealt with here. This is a summary of experiences gained during geological mapping and borehole logging, which might be instrumental in the identification, genetic and faciological monitoring and correlation of the Formations, viewing them together or separately. The below-summarized evaluation of sedimentological phenomena corresponds to the order seen in Table 12.

An essential feature is given by *cyclic sedimentation*. This term can well be applied to the sequences of Csatka Pebble, Mány Sand, Hárshegy Sandstone, Törökbálint Sand and Budafok Sand, with no exception made for the otherwise seemingly homogeneous Tard Clay and Kiscell Clay formations. In building up these formations, the cyclic units are as large as 10 m to 15 m in thickness. In full sequences, a number of 15 to 20 units take part, however, their correlation has not yet been solved.

Pale and "oily" colours prevail. Rocks lying on the surface or along bed boundaries display characteristic colours attributable to weathering crusts. Colour is an important tool e.g. in identifying some underlying (e.g. Eocene) or overlying (e.g. Pannonian) rocks. Rocks being variegated, green or grey are equally peculiar to the Csatka Pebble, Mány Sand, Törökbálint Sand and Budafok Sand formations; the proportion of variegated colour decreases in the above order (Figs. 5, 10, 28 and 32). Unweathered rocks of the Hárshegy Sandstone, Tard Clay and Kiscell Clay formations are grey, whereas variegated or green colours are almost completely missing (Figs. 16, 20 and 24).

*Bedding* is one of the most significant features of this group of formations. Parallel bedding is quite widespread. Stratification by sorting is observable in the following formations: Csatka Pebble, Mány Sand, Hárshegy Sandstone, Kiscell Clay, Törökbálint Sand and Budafok Sand; this is a feature that deserves more attention in the future. Arched, crested and diagonal patterns of cross-bedding are often observable in the Csatka Pebble, Mány Sand, Hárshegy Sandstone, Törökbálint Sand and Budafok Sand formations, whereas the Kiscell Clay Formation displays rarely such a kind of stratification.

As for *sorting*, medium-to-well-sorted sedimentary rocks, coarser than 0.2 mm in grain-size, are widely spread. This is true for the Csatka Pebble, Mány Sand, Törökbálint Sand and Budafok Sand formations. Subordinately, poorly sorted or unsorted rocks also occur. The rock materials that form the Tard Clay or Kiscell Clay, are well-sorted without exception.

*Washout surfaces* are peculiar to some formations (Csatka Pebble, Mány Sand, Hárshegy Sandstone, Törökbálint Sand, Budafok Sand). This sedimentary

structure is bound to cycle-beginning coarsely grained rocks (sand, sandstone, pebble, conglomerate). Conspicuous examples, even observable in the field, are given by intraformational clays, argillaceous marls and brown coal pebbles. In the coal-bearing members, moreover in the case of the Kiscell Clay and Tard Clay formations, this phenomenon has not been observed.

*Mineral concentrations* are seen in the Csatka Pebble and Mány—Török-bálint—Budafok Sand formations, moreover, much less commonly, in the Hárshegy Sandstone and Kiscell Clay formations. This "placer-like" accumulations consist mostly of garnet, magnetite and ilmenite, together with biotite, muscovite, chlorite, somewhere glauconite "float" minerals that form very thin layers along planes of bedding or cross-bedding.

*Pebbles* are characteristic of the Csatka Pebble, Mány Sand, Hárshegy Sandstone, Törökbalint Sand and Budafok Sand formations, whereas in the Coal Measures members, moreover in the Tard Clay and Kiscell Clay formations they are missing (see Figs. 4, 9, 15, 19, 23, 27 and 31). The lithostratigraphic assignment of beds is the most important tool in the genetic—faciological evaluation and correlation of these formations. To this, a reliable grounding may be given by taking into account characteristics such as petrological composition, sorting, roundness, matrix or cement, superimposed modifications, encrustation and leaching phenomena to be observed systematically during field work. On the basis of the properties mentioned above, the relationship in material and genesis of the pebble formations can be recognized even if the size or rock material of pebbles is different.

The *carbonate content* is also characteristic of the rocks building up every formation in concern. Its distribution, form and material is, however, multivariate, regarding not only the formations but their compositional rock types too. Matrix and cement of calcite or dolomite in carbonate bound are common in all formations. On the other hand, carbonate concretions which are indicative of the one-time level of vegetation, are found in the Csatka Pebble, Mány Sand, Törökbalint Sand and Budafok Sand formations only. Intercalations of carbonate rocks (freshwater limestone, dolomite) are present merely in the coal-bearing members (Figs. 4 and 9).

*Organic matters* consist mainly of huminite and, less frequently, bituminite (Figs. 4, 9, 15, 19, 23, 27 and 31). The presence of huminites is particularly peculiar to the coal-bearing members. Nevertheless, these rocks contain systematically bituminite too, except for the Noszlop Coal Measures Member. In the Tard Clay Formation, a predominance of bituminite is accompanied with minor amounts of huminite.

*Kaolinite* is found by rock-forming quantities in the Hárshegy Sandstone Formation. Its smaller proportions are detectable also in the Mány Sand Formation including the pertinent Coal Measures Member. In the field, all types of kaolinitic clay and sand are well identifiable.

*Silicification* is only important in the Hárshegy Sandstone Formation and Tard Clay Formation, being attested to by a few rock types.

*Pyritization* is sporadic but widely spread involving all formations. Similarly to silicification, more significant pyrite accumulations are bound exclusively to the formations of Hárshegy Sandstone and Tard Clay.

*Products of pyroclastic volcanic fallout* (synsedimentary pyroclastics) have been detected in the Hárshegy Sandstone and Tard Clay Formation only. Traces of pyroclastic material have been evidenced in various rocks of the Szápár

Coal Measures Member (in borehole Bakonycsérnye Bcs-11). Records of borehole-logging speak frequently of these materials in terms of "tuffite, tuffite-bearing sand, tuffaceous sand, biotite-bearing sand" etc. These records require more evidence for the presence of isochronous volcanic interbeddings.

*Fossils* (flora, fauna) are generally significant, however, their number and state of preservation is extraordinarily varied.

*Silicified plant remains* (pieces of tree-trunks) are peculiar in the Csatka Pebble Formation and also in the Mány, Törökbálint and Budafok Sand formations, whereas in the Hárshégy Sandstone they occur only sporadically. The coal-bearing members, moreover the Tard Clay and Kiscell Clay formations do not contain silicified plant remnant.

*Carbonized plant fossils* are characteristic of all the formations concerned here. Their state of preservation (fragment, print or intact specimen) depends on the lithofacial character of the including rock. The best-preserved specimens are found in the Tard Clay and Kiscell Clay formations.

*Derived plant remains* (spore, pollen) can be collected from every formation, with the exception of the Noszlop Coal Measures Member and the Hárshégy Sandstone Formation. Spores and pollens of (mostly) late Cretaceous, (subordinately) Eocene and (sporadically) Triassic age are accumulated in certain rocks and horizons of the formations on the whole.

*Fossils brought together by water* and the respective formations are of the same age. This assemblage which consists largely of molluscs with sporadic mammals, is peculiar only to the Csatka Pebble, Mány Sand, Hárshégy Sandstone, Törökbálint Sand and Budafok Sand formations, whereas these faunal elements rarely occur in certain rocks of the Kiscell Clay Formation. The molluscan remains consist of fragments, shells, casts and impressions. Fossil mammals are represented by bone fragments and teeth. Intact skulls or mandibles are rare.

*Autochthonous faunal elements* are present in each formation, however, they are fundamentally peculiar to the coal-bearing members, moreover to the Tard Clay and Kiscell Clay formations. The molluscan fauna is predominant with well-preserved shells, impressions or, rarely, casts. Vertebrate fossils appear sporadically as bone fragments, teeth and impressions, sometimes intact specimens.

*Derived faunal assemblages* are widespreadly characteristic but uneven in distribution. In the Csatka Pebble, Mány Sand, Hárshégy Sandstone, Törökbálint Sand and Budafok Sand formations both benthonic (foraminifers, algae) and planktonic (foraminifers, coccoliths) derived specimens are frequent. Benthonic forms are derived mainly from Eocene or (rarely) Upper Cretaceous rocks, whereas planktonic remains originate mostly from Eocene and Upper Cretaceous, subordinately from Triassic beds. The exclusively planktonic fossils (Foraminifera, Coccolithophora assemblages) of the Tard Clay and Kiscell Clay formations are mostly derivable from Eocene and Upper Cretaceous deposits. Likely to the reworked spores and pollens, the derived planktonic association is persistent through all formations.

## FACIES AND PALAEOGEOGRAPHIC CONDITIONS

On the basis of the relevant properties of the individual lithostratigraphic units, we are able to draw due conclusions from their composition and areal extent.

*Characteristic facies.* All the formations are characterizable by the predominant lithofacies. To establish criteria for determining a lithofacies, the lithological and palaeontological data are proved to be helpful. Taking these criteria into account, we find that the Csatka Pebble Formation is fluvial, and the Szápár and Noszlop Coal Measures members are limnic (lacustrine—marshy) in facies. Consequently, the southern boundary in areal extent of the channel facies can be traced (the line of Csabrendek—Nagytárkány—Halimba—Ajka—Városlőd—Herend—Márkó). Along this line, surface exposures and borehole sections alike show that the Csatka Pebble Formation is largely built of pebbles and conglomerates with peculiar boulders as large as 10–30 cm in diameter. Towards the north-east, the proportion of the pebbly beds and the particle size gradually decreases, though the channel facies cannot be delimited. The varied rocks of the fluvial facies were deposited in water a few cm to 10 m deep. The minimum depth of water has been determined on a basis of lithological properties of the argillaceous beds (variegated colour, granular—nodular—brecciated texture types indicative of desiccation phenomena, root-level-marking carbonate concretions) and their fossils (flora, moreover vertebrate and molluscan remains). The maximum depth of water has been verified by taking into account the presence of channel-facies-indicating rocks (pebble, conglomerate, sand and sandstone), moreover types of their stratification, and also upon modern analogies.

The Máty Sand Formation is of fluvio-marine (fluvial—deltaic—marine) origin, whereas the Vértessomló and Esztergom Coal Measures were deposited in a limnic—paralic swamp facies. This Formation on the whole is characterizable by the presence of marine beds which get to be predominant in E—NE direction. The depositional depth of the fluvial sediments is likely extending from some cm to 10 m. On a palaeontological interpretation, we find that the pertinent lagoonal, littoral and sub-littoral fluvio-marine—marine rocks may have deposited in a maximum 60-m-deep water.

In the Hárshegy Sandstone Formation, marine, littoral to sub-littoral rocks prevail. As for their depth of deposition, we mean upon lithological observations (cross-bedding) and palaeontological records (fauna) that it did not exceed 30 m. The average particle size of its coarse clastic rocks decreases towards SSW. Thus, this earlier recognition holds true of the NE region of the Transdanubian Central Mountains, too.

Laminated rocks of the Tard Clay Formation are of lagoonal—euxinic facies indicative of a pre-existing constant water inundation with a maximum depth ranging from 20 m to 30 m. This latter assumption may be supported by observing the colour of the argillaceous rocks together with their texture and stratification types. As for the water depth, the presence of numerous and well-preserved leaf prints may be diagnostic.

Marine beds pertaining to the Kiscell Clay Formation recall the depositional conditions of a sub-littoral—neritic—shallow bathyal region. The fossil assemblage seems testifying to a water depth ranging from 30 m to 300 m.

The Törökbálint Sand and Budafok Sand formations consist mostly of marine and, subordinately, of fluvio-marine deposits. The involved fluviatile, lagoonal, littoral and sub-littoral rocks must have been formed in water as deep as some cm to 60 m.

*Distribution of the formations.* The areal extent of these formations is shown in Supplements 1 and 3, according to our present knowledge. The originally transitional boundaries apparently have varied due to erosional wearing away so that they may represent, in reality, zones 1 to 2 km wide. Accordingly, the boundaries of the Csátka Pebble Formation, traced upon drilling records in the line of Nagyigmánd—Kisbér—Tét—Vaszar—Takácsi—Vinár—Celldömölk villages, might well have been extended farther towards the west. Its transitional ranges towards the Mány Sand Formation have already been drilled by many boreholes in the western foreland to the Vértes and Gerecse Mountains. These two formations have been separated upon the farthest known existence in northward direction of the freshwater—brackish water interbeddings (borehole Kocs-7).

The areal extent of the Mány Sand Formation can easily be determined. On the other hand, this time its transition into the Hárshegy Sandstone cannot yet be recorded on a map. Nevertheless, there are boreholes (Máriaalom M-3, Piliscsaba Pcsb-2 and -3) which have drilled the pertaining zones of lateral grading into the Kiscell Clay Formation in the western and southern parts of the Dorog—Esztergom Basin and along a line marked by the villages of Nagysáp, Sárísáp, Dág, Tinnye, Perbál, Herceghalom and Etyek.

In recording geological boundaries, the areal distribution of the Hárshegy Sandstone Formation and its transitional beds into the Mány Sand and Kiscell Clay formations cannot be indicated accurately.

The western boundaries of the Tard Clay Formation (Szentendre—Pomáz—Üröm—Pesthidegkút—Budakeszi) is well-recordable as coincident with original facies boundaries.

The westwardly farthest extent of the Kiscell Clay Formation is marked by original boundaries. Its boundary with the Törökbálint Sand Formation is identifiable, in essentials, with that of the Mány Sand Formation.

For the time being, the areal extent of the Törökbálint Sand Formation and its transition into the Mány Sand and Kiscell Clay formations cannot be determined on the basis of the available geological map prepared on any scale.

The same problem is confronted when dealing with the Budafok Sand Formation.

*Unbroken and broken successions of deposition.* A continuous sedimentary transition is observable between the underlying Eocene Buda Marl Formation and the Tard Clay Formation. The areal extent of this type of geological development is marked by that of the Tard Clay Formation (Szentendre—Pomáz—

Üröm—Pesthidegkút—Budakeszi). Types deposited continuously to this effect, are found east and south of the line mentioned above, whereas areas lying toward the west are characterizable by broken depositional succession.

*Main zones of sedimentation and original outpinching of beds.* To furnish criteria for making judgement on these conditions of geological development, the variation in thickness and the presence of various key horizons (e.g. Lower or "First" Rhyolite Tuff) in the continuously developed overlying sequence should be taken into account. Accordingly, a south-eastward—directed and southerly pinching out of the Mány Sand Formation is verifiable. Data of thickness of the formation assemblage show the NE Bakony Mts, the W foreland to Vértes and Gerecse and the Drog—Esztergom Basin to be the main zones of the contemporaneous deposition.

*Zones without deposition* (see formation boundaries in Supplements 1 and 3) can be outlined upon the knowledge of boundaries and of the trends treated above. As resting on Mesozoic and Eocene rocks of the Transdanubian Central Mountains, the erosional remnants of the concerned formations can well be identified and delimited. Referring to Supplement 1, we may find conspicuous that on the Mesozoic-rock-built plateaus of the Keszthely and Bakony Mountains or in the SE foreland of the Vértes Mts, no remnants of the Csatka Pebble or Mány Sand formations have been detected by mapping and drilling, whereas the key horizons (Lower or "First" Rhyolite Tuff) of the sequence overlying the Csatka Pebble Formation are found, at some places, as resting immediately on Mesozoic bedrocks (Bánd, Szentgál). Thereupon it can be indirectly evidenced that no deposition took place during Oligocene and early Miocene times in the regions of Mesozoic plateaus of the Keszthely and Bakony Mountains or in the south-eastern foreland zone to the Vértes Mountains.

*A former extent of the formations.* The original extent and transitional zones of the individual formations (i.e. main facies types) are shown in Supplement 3 and by the generalized stratigraphic column of Fig. 6, respectively. These boundaries and lateral transitions are interpreted as stretching identically or likely to the actually known ones.

*Areas of unbroken sedimentation* are considered to have been formed farther towards SSW, between Lake Balaton, Lake Velence and the Danube River (testimonies by boreholes Csepel-I and II, Tököl-I and Buzsák Bu-8, -13), however, they cannot be delimited even if approximately. Another zones are characterized by discontinuous sedimentation.

Into the main zones of deposition, besides those mentioned above, the Nyirád—Devecser—Ajka zone, moreover the whole northern Bakony and Gerecse may be classified. The region situated between the Balaton—Velence lakes and the Danube River must have yielded to a significant marine sedimentation (Supplement 3), despite the fact that the relevant evidences are not too numerous for the time being.

*Areas originally free of deposition* (Supplement 3) had once been areas of provenance supplying sediments for the building up of the actual formations. The study of grain-size distribution and roundness of pebbles belonging to the Csatka Pebble and Mány Sand formations has resulted in the verification of a pre-existing provenance area whose SW part must have been a mid-mountainous region of rugged morphology. Its presumable geological setting is sketched up in Fig. 33.

The mean height and surface-morphological pattern of these mid-mountains referred to must have shown a N—E tending gradual decrease i.e. smoothing down concerning the zones situated between the present-day Vértes—Velence Mountains, and some foreland zone NE, E and SE of the Velence Mts. Then the NE part of the provenance area formed a ridge of flat to moderate terrain. No coarse detritus derivable from the characteristic rocks of that zone is now observable in the basal beds or higher horizons of the Mány Sand Formation. Accordingly, in the line of Lake Balaton—Lake Velence, it must have existed a barrier (the Balaton—Velence Palaeogene ridge) that separated the fluvial to fluvio-marine sedimentary region from that of purely marine sedimentation. On modern analogies it may be said that detritus originating from the breakdown of rocks of the south-western part of barrier was transported by at the most 30-km-long mountain brooks and finally heaped up into piles of large boulders in their actual zone of accumulation (Csabrendek—Nagytárkány—Halimba—Ajka—Városlőd—Herend—Márkó). These detritus-carrying brooks must have met a river flowing from SW towards NE in this zone. Farther on, the detritus transportation must have continued in a similar direction, as it has been evidenced upon data bearing on the north-easterly tending decrease in the amount (Figs. 5 and 10) and mean particle size of pebbles.

Published opinions consider the compositional detrital material of the Hárshegy Sandstone Formation to be derivable from a NNE direction. This observation is supported by the frequency analysis of the rock types contained in the pertaining pebbles and conglomerates, and also by the fact that the grain-size and kaolinite contents of the kaolinitic sands and sandstones tend to be smaller i.e. poorer, respectively, in SSW direction. Evidences gained from sections drilled in the Dorog—Esztergom Basin and in the Tatabánya—Csordakút—Nagygyháza—Mány—Zsámbék region, are affirmative in this respect. The assumption of a pre-existing "Vepor-type" provenance area (F. KASZANITZKY 1956) is widely accepted.

Detritus accumulated in various occurrences of the Törökbálint Sand Formation in the Dorog—Esztergom Basin, Pilis and Dunazug Mountains, is identical with that of the Mány Sand Formation. Consequently, a SW direction of wearing away is verifiable. In the Tétény Plateau, the pebbly constitution of the Budafok Sand Formation, which develops from the Törökbálint Sand Formation with continuous sedimentation, is essentially changed. With regard to the larger size and poorer roundness of these pebbles along with their heterogeneous composition, here a different area of source is to be presumed. An efficient monitoring of this provenance is not feasible in the Transdanubian Central Mountains region.

*Stratigraphic questions.* The fourfold division (Lattorfian, Rupelian, Chatian = Egerian and Burdigalian = Eggenburgian, see Fig. 34) of the Oligocene—Lower Miocene sequence in the Transdanubian Central Mountains has essentially been based on biostratigraphic considerations, as having been set up by early stratigraphers and accepted widely till our days. In the light of published data, the chronostratigraphic boundaries were being changed from time to time according to the varying standpoints of different authors. In connection with stratigraphic classification and correlation, doubts have been raised (K. TELEGI ROTH 1912, F. HORUSITZKY 1939, E. VADÁSZ 1940, T. BÁLDI 1965, L. MAJZON 1966) as relating, among others, to the missing isochronous littoral facies

of the Kiscell Clay Formation, or to the problematic interpretation of the transgressive mode of occurrence of the Chattian regressive sand deposit.

Fig. 6 shows the lithostratigraphic division and correlation of the formations in concern. This has been based on the described lithological properties and sedimentological phenomena observable in the field, together with the results of comparative petrological and mineralogical analyses (Figs. 2, 7, 8, 10, 22, 24, 26, 28, 30 and 32) and palaeontological examinations. For correlation, a regional evaluation of the assemblage of fossils, moreover the most important data of local findings have been taken into consideration. Radiometric dating of a few rock samples from the Kiscell Clay Formation (Pilisborosjenő Brickyard) and from its underlying glauconitic sandbeds (borehole Budajenő Bó-2) was also carried out. Dates by K—Ar method have shown an age of  $33.5 \pm 2.4$  million years for the Pilisborosjenő sample (T. BÁLDI, M. BÁLDI-BEKE, M. HORVÁTH, A. NAGYMAROSI, K. BALOGH and E. SÓS 1975). As for three glauconite-bearing processed specimens of samples taken from a depth interval ranging from 522.8 m to 523.9 m in the borehole section of Budajenő, their respective dates are  $39.5 \pm 2.5$ ,  $44.7 \pm 2.7$  and  $61.0 \pm 3.5$  million years (K. BALOGH and E. ÁRVAI 1976). The available lithostratigraphic, biostratigraphic and chronostratigraphic data do not enable to draw securely chronostratigraphic boundaries inside the assemblage of formations.

Instead of the lithostratigraphic nomenclature used in former chapters, the evolution history and tectonic setting is here described in chronostratigraphic terms. Besides that, the observations made on the basis of a geostructure recording are invariably first-mentioned. It is on these observations together with data relating to facies and palaeogeography that the characterization of the Oligocene—Lower Miocene geostructural cycle of the present-day Transdanubian Central Mountains region, is based. A closing part of this chapter is given by dealing with infra-Oligocene denudation and with the tectonic and facies pattern to be drawn up for the Oligocene—Lower Miocene formations in Hungary.

*Mode of occurrence, contacts and basal beds.* The formations are generally seen in undisturbed lying. The dip averages  $5^{\circ}$  and it rarely can be read with higher angle than  $10^{\circ}$ . In a basin-marginal position, dips at  $20^{\circ}$  to  $30^{\circ}$  are observable. Sharply higher grade of dipping ( $30^{\circ}$ — $90^{\circ}$ ) which may be indicative of contraction-type tectonic disturbances in the Central Mountains, have not yet been reported or published from mapping or drilling. Nevertheless, it is known that an Oligocene sequence drilled closely to Buzsák is made of nearly vertical beds. Their lower and upper boundaries are marked partly with erosional and angular unconformity, and partly with continuous transitions. The youngest beds overlain by unconformable Oligocene—Lower Miocene ones, are of Late Eocene age. In the case of a continuous transition (Tard Clay Formation), the underlying is likewise Upper Eocene (Buda Marl Formation). The youngest beds developing therefrom transitionally are (?) Ottnangian—Karpatian, and those of lying with erosional and angular unconformity are assigned to the (?) Lower Badenian. The structural features are almost invisible on the surface, thus fault surfaces can be seen in mining shafts or on core samples of drilling. As for the latter, these planes represent normal faulting. It is noteworthy that dips with angles of  $20^{\circ}$  to  $30^{\circ}$  are measured in narrow zones of tectonic disturbances so that they change into  $5^{\circ}$ — $10^{\circ}$  within a distance as short as some metres. Data indicating indirectly the existence of bed repetition or folding, have been recorded from borehole Zsámbék 10 only.

Basal beds to these formations are seldom thicker than 1 m. Even in coarsely clastic basal beds, rock pieces originating from the nearby underlying rocks, are hardly seen (Hárshegy Sandstone Formation). Basal pebbles are extraneous, as far as their rock material is concerned. Argillaceous basal rocks are frequent; here the detritus of local origin is concentrated in the lowermost stripe 10 to 20 cm thick, consisting of angular fragments up to a diameter of 3 cm, derived from limestone and dolomite. These basal materials are mostly filling

substance accumulated in the fissures and caverns of the carbonate underlying rocks. Among various theories about their origin, the one called "mud infilling" is most probable.

*Intraformational structure elements.* In a term applied to structural features, there are a few intraformational phenomena by fracture and slumping. Displacements provoked thereby come to some cm only (e.g. cut by road No. 8 at Bakonygyepes). Despite the frequent washout phenomena, it can be stated that no particular diagnostic features (angular unconformity, weathering crust and basal bed) of a regional or local unconformity to break the continuity of the Oligocene—Lower Miocene succession, are observable.

*Volcanic phenomena.* Products of a synsedimentary volcanic activity are found in the Tard Clay Formation and presumable in the Szápár Coal Measures Member. The presence of dacite tuff has been described by GY. WEIN (1977, pp. 31—32, fig. 16) to be interbedded in the Hárshegy Sandstone Formation. By the way, these formations lack in synsedimentary pyroclastics, and the rebirth of volcanic activity is marked only by the appearance of the overlying Lower or "First" Rhyolite Tuff. As far as the volcanics of disputed age of the Drog Basin are concerned, we accept the standpoint of I. MUNTYÁN et al. (1971) considering them to be formed in Neogene time. The lack of lapilli and volcanic bombs together with the exclusive presence of crystals smaller than 1 mm in the crystalloclastic andesite tuff and tuffite of the Tard Clay Formation, may indicate a distant centre of volcanic eruption.

*The Oligocene—Lower Miocene tectonic cycle.* For the better understanding of this structure-geological cycle, it is necessary to draw up a regional-wide picture of the areal distribution of the earlier-deposited Eocene beds. Fig. 35 shows that the epicontinental terrigenous—carbonate unit of the N and NW forezones to the Transdanubian Central Mountains was well separated from the likewise epicontinental terrigenous—carbonate-bearing—effusive one during Eocene time. This partition was secured by the Lake Balaton—Lake Velence-striking Palaeogene ridge, toward which both units, mentioned above, show a gradual outpinching. The facies types and their areal distribution, as given for the Oligocene—Lower Miocene sequence, are by far different (Fig. 36). For the Central Mountains and their NW foreland, the formation of continental—epicontinental terrigenous beds took place parallel with the epicontinental—terrigenous sedimentation characteristic of the SE foreland, meanwhile the Lake Balaton—Lake Velence Palaeogene ridge continued to exist. Some particular cycles, involved by the Oligocene—Early Miocene structure-geological megacycle expressed by an order of regression—transgression—regression, are well distinguished. These individual cycles are presented by the geological sections of Supplement 4.

The Tard Clay Formation may be designated to represent the regressive first cycle that was formed in zones of epicontinental—marine unbroken sedimentation (Buda Marl Formation, Tard Clay Formation). Transgression (the second cycle) is marked by the Hárshegy Sandstone, Mány Sand and Kiscell Clay formations, whereas the fluvatile—deltaic lower beds of the Csátka Pebble Formation represent a continental sedimentation. The transgression culminated in the (westwardly farthest) appearance of the fluvio-marine Mány Sand Formation with brackish water to marine faunal assemblage. Lastly, a regressive (third) cycle is given by the fluvio-marine Mány Sand Formation, marine and fluvio-marine Törökbálint Sand and Budafok Sand formations in the epiconti-

mental zones and by the upper fluvial sequence of the Csátka Pebble Formation developed in continental zones. This regressive cycle, and thereby the whole Oligocene—Lower Miocene structure-geological megacycle terminates by the appearance of Middle Miocene transgressive beds shown in Fig. 37. Making a comparison between this map and those showing Eocene and Oligocene—Lower Miocene formations, the extraordinarily significant changes become obvious.

*The infra-Oligocene denudation* as recognized by K. TELEGI ROTH (1927) turned out to be observable in all sections of the zones with erosional gaps. It is true, however, that the frequently rigid interpretation in space and time of this otherwise widely accepted fact has led to a one-sided or negative judgement on the predictable mineral potential (Eocene brown coal, bauxite) of the underlying formations. It is widely meant that the absence of brown coal and bauxite deposits in some zones is "attributable to the infra-Oligocene denudation". Supplement 3 and Fig. 36 show unambiguously the area that may have been attacked by the infra-Oligocene denudation. The correlation of formations (Fig. 6) and the illustration of the spatial distribution of sedimentary cycles (Supplement 4) are evidencing a much reduced area and time of action of this denudation. Thereupon it is demanded that the investigations devoted to the verification of an original presence or absence of raw materials shall be taken more seriously in deciding the perspective of mineral potential of the underlying rocks.

*The tectonic—facies pattern of the Oligocene—Lower Miocene formations* in Hungary is shown in Fig. 38. Accordingly, the Oligocene—Lower Miocene formations of the Hungarian territory can be classified into the following tectonic—facies units corresponding to their SW—NE-striking known areal extent:

- (i) Molasse areas of Transdanubia.
- (ii) Area of the Palaeogene volcanic belt.
- (iii) Epicontinental marine areas.
- (iiii) Flysch-type marine areas.

(i) The "Transdanubian molasse areas" constitute a structural—facial unit with questionable boundaries in the north and west, owing to the lack of drilling data. The term is used here to describe sedimentary rocks of mostly fluvial, subordinately fluvio-marine origin, produced by cyclic sedimentation. Terrigenous type formations are the Csátka Pebble and Máty Sand. Its lateral relation to the epicontinental marine zones is well-marked.

(ii) The "Palaeogene volcanic belt area" is likewise a verified structural—facial unit. Its SW and SE boundaries are traced approximately. Rocks of this unit are formed mostly by neutral and acid volcanics, along with volcano-sedimentary products. A terrigenous—effusive type formation cannot be identified for the time being. Facial relationships are detectable mainly towards epicontinental marine zones.

(iii) The "Epicontinental\* marine area" is a verified structural—facial unit whose SE boundary is now untraceable. Mostly littoral—neritic sequence of cyclic constitution is claimed to belong to this unit. Terrigenous type formations are the Hárshegy Sandstone, Kiscell Clay, Törökbálint Sand, Budafok Sand,

\* „Epicontinental" means here the shelf region at any time (the author's note)

moreover the Szécsény, Eger, Parád, Putnok formations, whereas the Tard Clay Formation is qualified as a terrigenous—effusive type formation. Its facies relations to the Transdanubian molasse are well-defined, but those towards the volcanic and volcano-sedimentary rocks of the Palaeogene volcanic belt are just outlined.

(iii) The “Flysch-type marine areas” name covers a presumable structural—facial unit whose existence may be extended to flysch zones of the Danube—Tisza Interfluvium and the Trans-Tisza region. It is presumed to exist upon facts such as the position of the structural—facial units mentioned above, or rare palaeontological dates, with no exception made for the knowledge of Oligocene—Lower Miocene flysch formations of the Carpathian—Dinaric system and the defectiveness of the written Palaeogene stratigraphy of the Great Hungarian Plain’s flysch formations.

## MINERAL RAW MATERIALS

The Oligocene—Lower Miocene formations of the Transdanubian Central Mountains are poor in economic mineral resources. These are mentionable in the following order of value: energy-bearing materials, metallic minerals, construction materials and non-metallic minerals, and water.

*Energy-bearing materials.* Provable deposits or indications of hydrocarbons, stored in or derivable from the Oligocene—Lower Miocene beds, cannot be detected in the Transdanubian Central Mountains. Formations of the zones with erosional gaps can be left out of consideration as potential native rock or reservoir for hydrocarbons. In the zones with continuous sedimentation, the sapropelic ("oil shale") facies of the Tard Clay Formation is considered potential native rock. In the same zones, we may reckon with sands and sandstones belonging to the Kiscell Clay and Törökbálint Sand formations as potential reservoir rocks. Their mean porosity is 20%. Hydrocarbon accumulations derivable from the Oligocene—Lower Miocene formations may be invariably expectable in the zones of unbroken sedimentary succession of the south-eastern foreland to the Transdanubian Central Mountains, as it has been confirmed by practice. Their significance, however, is very reduced as compared with the hydrocarbon resources of the Neogene sequences in Hungary.

As far as oil shale is concerned, its proved (borehole Buzsák-8) and probable plus possible occurrences are related to the Tard Clay Formation developed in the zones of continuous sedimentation. Surface or near-surface deposits are restricted to a few zones of the Buda Mountains (the surroundings of Pesthidegkút and Budakeszi, Városmajor—Vérmező in Budapest) and adjacent zones such as the Óbuda—Kiscell (Old Buda) "edge plain" and the southern foreland. A regional prospecting carried out on oil shale deposits of the Transdanubian Central Mountains by the Central Mountains Department of the Hungarian Geological Institute, has resulted in the statement that no additional research of the Tard Clay Formation is worth doing in this respect.

Localities of brown coal deposits relating to the Coal Measures members of the Oligocene—Lower Miocene formations are shown in Supplement 3. Beside exploited and abandoned mines (Noszlop, Szápár, Vértessomló, Anna-völgy, Csolnok and Tokod) and partly operated ones (Ebszönybánya, Mogyorósbánya) brown coal has been drilled by many boreholes in the following zones: intermontane basins and NW foreland to the mountains Bakony, Vértes and Gerecse, and the Tatabánya—Csordakút—Nagyegyháza—Mány—Zsámbék zone. The number of seams is 1 to 3; according to mining documentation, the thickness of these lenticular seams comes to a maximum of 3.5 m. Their calorific value is 4,000—5,000 kilocalories with a bituminite content of 5% to 10%. The

mines of Ebszónybánya and Mogyorósbánya are still operated because of the presence of parallelly exploitable Eocene brown coal reserves; if not so, the brown coal deposits are uneconomic. None of the brown coal seams found in the area of study is worth mining.

*Metallic minerals.* Here only the "ore indications" of the Hárshegy Sandstone are mentionable. These characteristic limonite concentrations are cropping out at the surface in many places of the Buda and Pilis Mountains. Pyrite- and limonite-bearing types were drilled in the Dorog—Esztergom Basin and in the zone of Tatabánya—Csordakút—Nagyegyháza—Mány—Zsámbék. Samples taken from outcrops in the Central Mountains were duly analysed. Samples of pyritiferous rock were collected from borehole Bajna Bnt-3 and tested for concentrations of *Au* and *Ag*, without positive result. These occurrences of ore have no economic significance.

*Construction materials and non-metallic minerals.* The most important industrial deposit of the Oligocene—Lower Miocene sequence is clay for making brick and roof tile. There are various abandoned localities of extraction [Óbuda (Old Buda), Budaújlak, Csillaghegy and Békésmegyer] and operating brickyards (Solymár, Pilisborosjenő, Pilisvörösvár, Keszölc, Esztergom, Nyergesújfalu and Törökbálint). Additional clay reserves are supposed to exist in adjacent zones to the active brickyards [S foreland of the Buda Mts, Óbuda (Old Buda)—Kiscell "edge plain", the Solymár—Pilisvörösvár rift valley and Dorog—Esztergom Basin].

Pebbles, conglomerates, sands and sandstones of the Csatka Pebble, Mány Sand and Hárshegy Sandstone formations have been subjected to a widely spread free quarrying marked by a lot of open pits abandoned or still operated. The quality of these materials does not meet the industrial requirements.

High quality clays (fireclay, kaolinitic clay) appear on the surface and in a subcrop position too, as allied to the Esztergom Coal Measures Member and the Hárshegy Sandstone Formation. Besides some abandoned mining localities, in a few pits clays are seasonally worked. Most important occurrences are found near Sárísáp, Pilisvörösvár and Solymár.

*Water.* The Oligocene—Lower Miocene formations as reservoirs have a little share in the subsurface water budget of the Central Mountains. Their hydrogeological role is mainly constituted by the fact how they compare with their underlying or overlying rocks. Water stored in them are of calcium-magnesium hydrogen carbonate type and, subordinately, sulphatic. No connate waters are present in these formations which are, on the other hand, separate hydrogeological units.

Dependently on its underlying (Palaeozoic shale, Permian—Lower Triassic sandstone, Upper Triassic marl, Middle Cretaceous Muniera-bearing argillaceous marl, Turrilites marl, Upper Cretaceous Gryphaea—Inoceramus marl, Eocene foraminiferous argillaceous marl), the Csatka Pebble Formation may store more significant amounts of water in its pebbly and conglomerate-built basal beds. Other important aquifers are detectable in the zones of Nyirád—Devecser—Ajka, Bakonybél—Csehbánya—Herend—Márkó and Hárskút, in both surface and subsurface position. This group of pebble, conglomerate and sand-sandstone may attain to a combined thickness of 200 m, and miners consider it a "separate water horizon" (hanging water) whose relation to the karst water reservoir system needs more clarification. Among the unconformably

overlying beds, in the first place the Lower Badenian, moreover Lower and Upper Pannonian pearl-like pebbles and sandbeds are likely storing comparatively much water, whereas no mentionable water accumulates in the Quaternary covering.

The basic hydrogeological features of the Mány Sand Formation are largely similar to those of the Csatka Pebble Formation. The hydrogeological importance of the Mány Sand Formation is, however, essentially determined by its lateral interfingering-type access to the Kiscell Clay Formation (Fig. 6). Thus, subsurface water stored in the lower part of the complex cut to two by the Kiscell Clay Formation, is immediately connected with the karst water system, whereas the hydrogeological characteristics of its overlying complex are mostly identical with those of the Törökbálint Sand and Budafok Sand formations. The amount of water of hydrogen carbonate type storable separately, is insignificant. Water percolated into the overlying unconformable Neogene or Quaternary sequence is also stored in this unit.

The hydrogeological role of the Hárshegy Sandstone is also highly influenced by its geological position. Accordingly, it belongs directly to the karst water aquifer system when underlain by Mesozoic carbonate rocks. Resting on Eocene beds, it is a separate aquifer owing to its porosity and limiting lower boundary. Nevertheless, no much water is stored therein. The pyritic—limonitic kinds of aquifer give way to the rise of sulphatic aggressive waters.

The Kiscell Clay and Tard Clay formations are the chief impervious horizons in both horizontal and vertical direction. Stratigraphically and also hydrogeologically, they cut to two the whole Oligocene—Lower Miocene succession. This horizon separates its underlying or isochronous water-bearing beds belonging to the karst-water aquiferous system from waters stored in the overlying Mány Sand and Hárshegy Sandstone formations. From its impervious top upwardly, water originating from the Törökbálint Sand Formation or from the unconformable Neogene and Quaternary beds, accumulates. Where the Tard Clay Formation is situated below the actual karst water level or is contacting at least partially the sites of karst water inflow, one may count with the increased sulphate content resulting in the emergence of aggressive water. It is the same with the top of the argillaceous rocks of the Tard Clay Formation when percolated subsurface water is accumulated thereon.

The Törökbálint Sand and Budafok Sand formations are united into the one and the same separate hydrogeological unit. From deeper-stored subsurface waters, this unit is separated by impervious Kiscell Clay. Hydrogen carbonate-type ground-waters appear in few quantities expectable, in the first place, on the top surface of the underlying Kiscell Clay Formation. On top of the unit in concern, in the Neogene and Quaternary beds percolation waters are accumulating, however, quantifiable water yields therefrom have been recorded only in the southern foreland to the Buda Mountains.

\* \* \*

On the facies and palaeogeographic conditions, evolution history and tectonic setting described above, it is possible to make some statements that may influence indirectly the present-day practice of explorations for brown coal and bauxite deposits, and support a forthcoming prospecting for potential non-ferrous mineral deposits in the region of the "Palaeogene volcanic belt".

The re-interpretation of the "infra-Oligocene denudation" problem enable to say that in zones characterizable by erosional gap the lack of sediment is reduced i.e. this erosional vacuity represents a short time interval. According to the small amount or even lack of reworked rock material accumulated in the basal beds, the work criterion stating that the absence of bauxite or Eocene brown coal is attributable exclusively to the infra-Oligocene denudation, has no solid foundation. Upon the new considerations about the character of this denudation, it is demanded that the reconnaissance of the original existence or non-existence of the bauxite and Eocene brown coal deposits in this region be taken more seriously in the future.

Among the andesite pebbles of the Csatka Pebble Formation, few but generally observable rock varieties with traces of dissemination sulphide ore (pyrite—chalkopyrite) are present. The "large boulders" of andesite are derivable from inside the "Palaeogene volcanic belt" area situated S—SW of these occurrences of pebble (Csabrendek, Nyirád). The presumable distance between the two sites does not exceed some 30 km. Taking into account this and also some possible horizontal tectonic movements to take place after the boulders had been transported to their present-day site, the source area seems localizable in the Palaeogene volcanic belt outlined by drilling and geophysical means. On the basis of the ore traces found in andesite pebbles, the provenance may hide an endomagmatic sulphide ore formation. Some "placer-like" concentrations of magnetite (ilmenite) and garnet minerals in the Csatka Pebble Formation are interpreted to have been formed as products of the partial destruction and wearing away of this endomagmatic formation.



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 F. K. = Földtani Közlöny (Budapest)  
 F. Kut. = Földtani Kutatás (Budapest)  
 F. Sz. = Földtani Szemle (Budapest)  
 G. H. S. P. = Geologica Hungarica. Series Palaeontologica (Budapest)  
 G. H. S. G. = Geologica Hungarica. Series Geologica (Budapest)  
 H. K. = Hidrológiai Közlöny (Budapest)  
 J. G. R. A. = Jahrbuch der k. u. k. Geologischen Reichsanstalt (Wien)  
 MÁFI-AD. = Magyar Állami Földtani Intézet Adattára (Budapest)  
 M. F. T. M. = Magyarhoni Földtani Társulat Munkálatai (Budapest)  
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 Ó. V. = Óslénytani Viták (Budapest)  
 R. A. I. G. D. = Relationes Annuae Instituti Geologici Publici Hungarici. B. Disputationes, i.e. Beszámoló a m. kir. Földtani Intézet Vitaüléseinek Munkálatairól (Budapest)  
 V. G. R. A. = Verhandlungen der Geologischen Reichsanstalt (Wien)  
 Zb. M. = Zentralblatt für Mineralogie, Geologie und Paläontologie (Stuttgart)

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# A DUNÁNTÚLI-KÖZÉPHEGYSÉG OLIGOCÉN-ALSÓ-MIOCÉN KÉPZŐDMÉNYEI

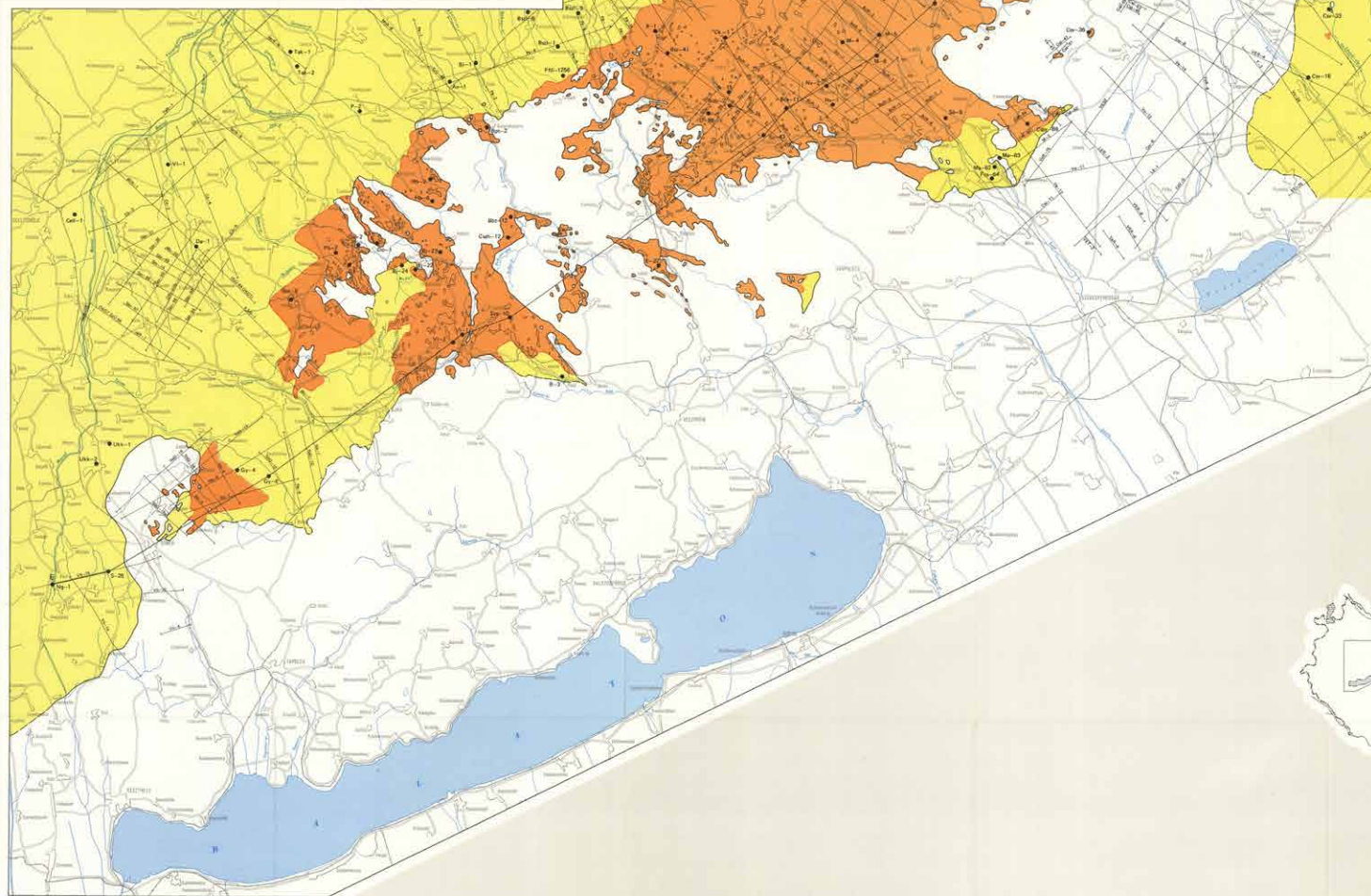
## 1 FEDETLEN FÖLDTANI TÉRKÉP

Szerkesztette: Dr. Korpás László (1976)

OLIGOCENE–LOWER MIOCENE FORMATIONS OF THE TRANSDANUBIAN  
CENTRAL MOUNTAINS  
SUBSURFACE GEOLOGICAL MAP

0 10 20 km

-  A felsőképződmények elterjedési határa  
Areal extent of underlying rocks
-  Az oligocén–alsó-miocén képződmények felszíni kibontásai  
Oligocene–Lower Miocene rocks cropping out at the surface
-  A felülben települő neogén képződmények elterjedési határa  
Areal extent of the overlying Neogene rocks
-  Főbb kőzetek  
Significant rock types
-  A földtani vágány irányja  
Orientation of geological section
-  A geotektonikus és szisztemikus szerkezeti nyomvonalak  
Geotectonic and tectonic traces



A TÉRKÉP FÖLDRAJZI HELYZETE



KIADJA A MAGYAR ÁLLAMI FÖLDTANI INTÉZET, 1981

KÉSZÜLT A DUNÁNTÚLI-KÖZÉPHEGYSÉG 1:100 000 MÉRÉTBARÁNYÚ FEDETLEN FÖLDTANI TÉRKÉPE (MÁF), VALAMINT AZ 1:100 000 MÉRÉTBARÁNYÚ MENDÉCELJZAT TÉRKÉPE (MELC) ÉS A MELYFURASOK ADATAINAK FELHASZNÁLÁSÁVAL.

Lektor: Dr. Márta Tóth  
Szerkesztés: Dr. Deák Magdolna 1980  
Jólábrós és M. Áll. Földrajzi Intézet  
Tudománytörténeti Kiadóosztály

Földrajzi kiadó: Dr. Hózer Gábor igazgató  
Tudománytörténeti Kiadóosztály  
Sokszorosított Képgrafikai Vállalat  
Földrajzi kiadó: Dr. Péter György igazgató

Kiadás: B/1 és B/2, 1000 példányban  
Engedélyszám: 03 280/1981/ 1980. 982 és 2786 7 CM

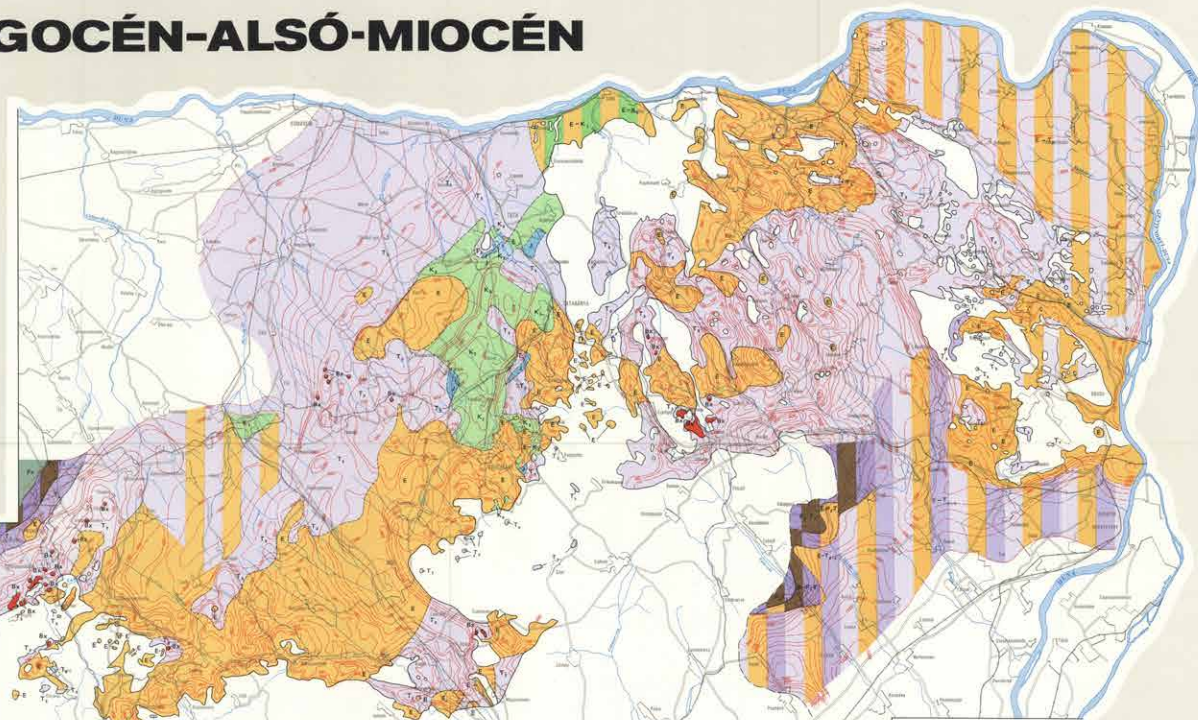
# A DUNÁNTÚLI-KÖZÉPHEGYSÉG OLIGOCÉN-ALSÓ-MIOCÉN KÉPZŐDMÉNYEI

2

## TELEPÜLÉSI MÉLYSÉG- ÉS FEKÜTÉRKÉP (tengerszintre vonatkoztatott helyzet)

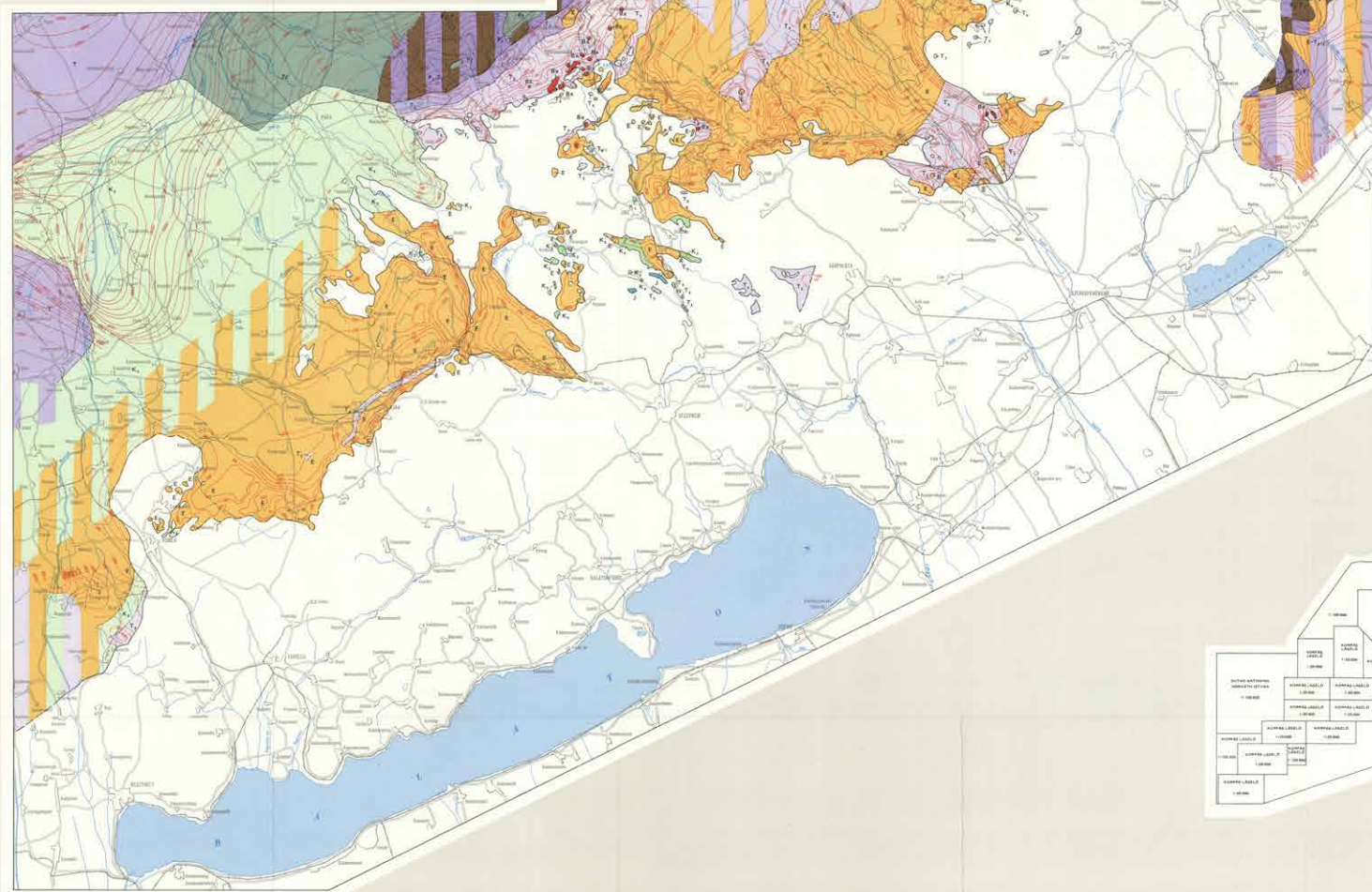
Szerkesztette: Dr. Korpás László és Muntyán Istvánné 1975–1976

OLIGOCENE–LOWER MIOCENE FORMATIONS OF THE TRANSDANUBIAN  
CENTRAL MOUNTAINS  
SUBSURFACE MAP WITH DEPTHS  
RELATED TO THE SEA LEVEL



0 10 20 km

- Eocén általában  
Eocene in general
- Bazalt, bazaltos agyag  
Basalt, basaltic clay
- Felső-kriéta  
Upper Cretaceous
- Középső-kriéta  
Middle Cretaceous
- Alsó-kriéta  
Lower Cretaceous
- Jura általában  
Jurassic in general
- Felső-triász  
Upper Triassic
- Középső-triász  
Middle Triassic
- Alsó-triász  
Lower Triassic
- Triász általában  
Triassic in general
- Felső-perm  
Upper Permian
- Paleozóikum  
Paleozoic
- Az oligocén–alsó-miocén tektonikumok  
átjáróinak helye  
Areal extent of rocks underlying  
the Oligocene–Lower Miocene sequences
- Az oligocén településeknek megállított és  
feltételezett mélysége  
Measured and inferred depth above sea  
level of the Oligocene–Lower Miocene sequences



KIADJA A MAGYAR ÁLLAMI FÖLDTANI INTÉZET, 1981  
KÉSZÜLT A MÁFI, MÁELGI, OKGT PUBLIKÁLT ÉS KÉZIRATOS TÉRKÉPEINEK,  
VALAMINT A MELYFURÁSOK ADATAINAK FELHASZNÁLÁSÁVAL.

Lektor: Dr. Balcz Tünde  
Bárczavarró: Dr. Deák Margit 1980  
Jelölés: Dr. Á. Á. Péterfy István  
Földrajzi neve: Dr. Hózer Géza igazgató  
Technikai szerkesztő: Szirmai Zoltán  
Szerkesztés: Kertész György  
Földrajzi neve: Dr. Nagy Gyula igazgató

Képlet: B1-es form. 1:000 példányszám  
Engedélyszám: 53 200/1981 ISBN 962 01 2706 7 CM

# A DUNÁNTÚLI-KÖZÉPHEGYSÉG OLIGOCÉN-ALSÓ-MIOCÉN KÉPZŐDMÉNYEI



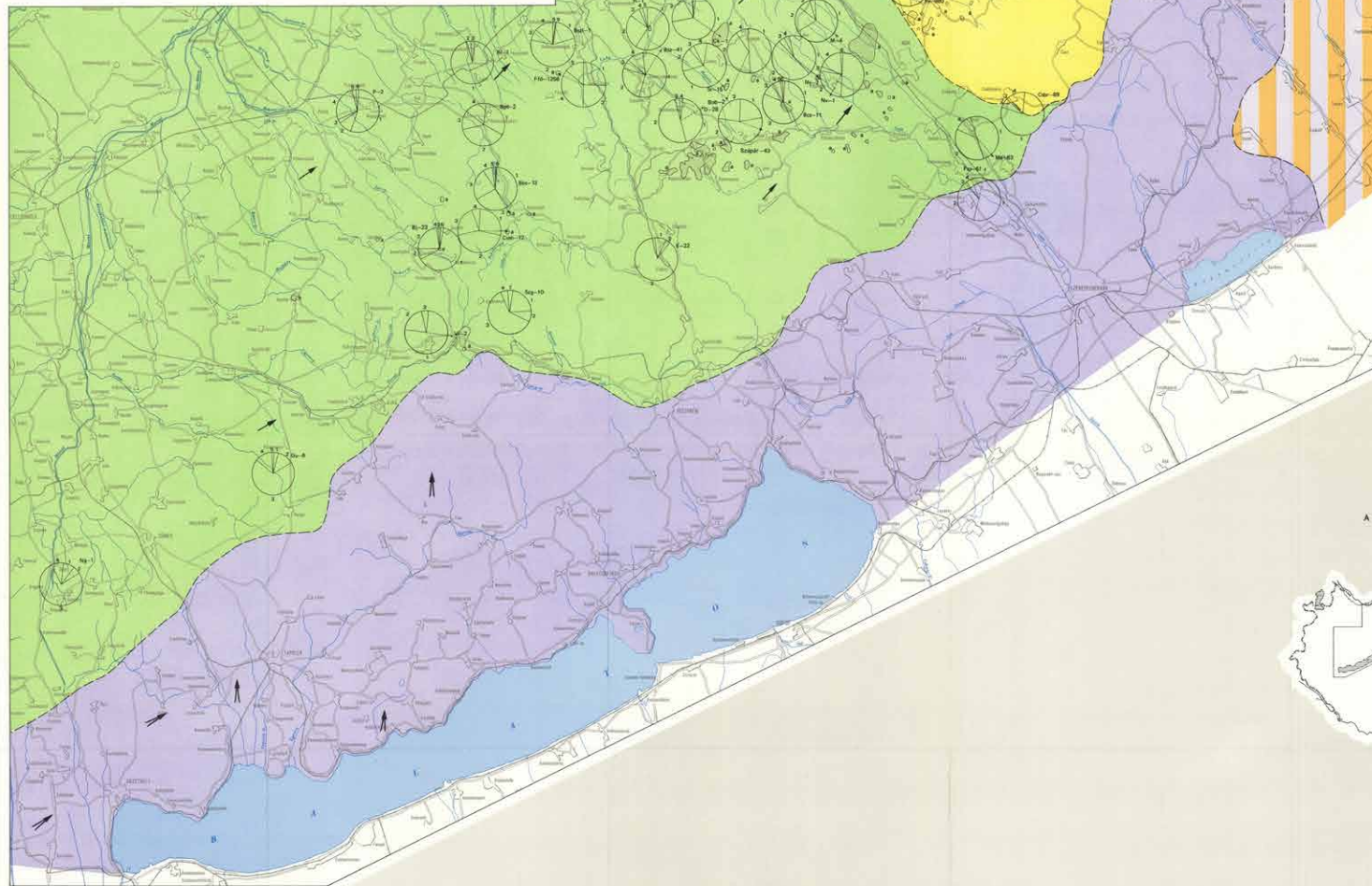
## VÁZLATOS FÁCIÉS ÉS ŐSFÖLDRAJZI TÉRKÉP

Szerkesztette: Horváth István (1967) és dr. Siposs Zoltán (1965) adatainak felhasználásával dr. Korpás László (1976)

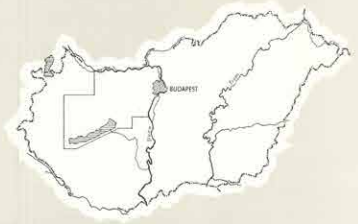
OLIGOCENE-LOWER MIOCENE FORMATIONS OF THE TRANSDANUBIAN CENTRAL MOUNTAINS  
SCHEMATIC MAP SHOWING FACIES AND PALAEOGEOGRAPHICAL CONDITIONS

0 10 20 km

- Csútkai Kékes Formáció  
Csútkai Kékes Formation
  - Szigeti Sótörzsen 7 Tagozat  
Szigeti Coal Measures Member
  - Nővelői Sótörzsen Tagozat  
Nővelői Coal Measures Member
  - Mányi Homok Formáció  
Mányi Sand Formation
  - Vénrosnyói Sótörzsen Tagozat  
Vénrosnyói Coal Measures Member
  - Esztergomi Sótörzsen Tagozat  
Esztergomi Coal Measures Member
  - Kiscelli Agyag Formáció  
Kiscelli Clay Formation
  - Törökbalinai Homok Formáció  
Törökbalinai Sand Formation
  - Üledék nélküli területek  
Areas with no sedimentation
  - Feltételezett határ  
Estimated
  - Határozott határ  
Factual boundary
  - Az üledékfelrakás és az üledékeltávolítás határa  
Boundaries of the zones of unconsolidated sedimentation
  - A lefordulás 10 irányja  
Main direction of the leaning away of rock
  - Az anyagelmozdítás 10 irányja  
Main direction of the displacement of sediment
  - Fontosabb kőzetfajta-összetétel diagramja  
Diagram showing proportions of rock types in more important lithological sections
1. Agyag, agyagmész, márga, slisz; 2. homok, homokkő; 3. kavics, konglomerátum; 4. tarka agyag; 5. barnaköcsök, csomós agyag; 6. dolomitos és mészkő törmelék; 7. basaltos agyag, kalcinos agyag; 8. dácit törmelék; 9. adremit márvány
1. Clay, argillaceous marl, marl and silt; 2. sand and sandstone; 3. pebbles, conglomerate, conglomeration; 4. variegated clay; 5. brown coal, carbonaceous clay; 6. dolomitic and limestone debris; 7. basaltic clay, calcareous clay; 8. dacite fragments; 9. freshwater limestone



A TEREKLEP FÖLDRAJZI HELYZETE



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# A DUNÁNTÚLI-KÖZÉPHEGYSÉG OLIGOCÉN-ALSÓ-MIOCÉN KÉPZŐDMÉNYEI

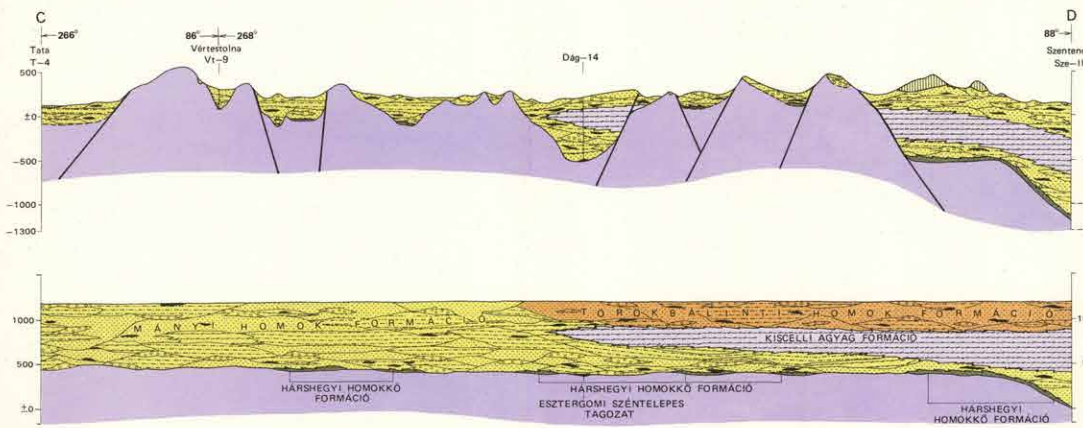
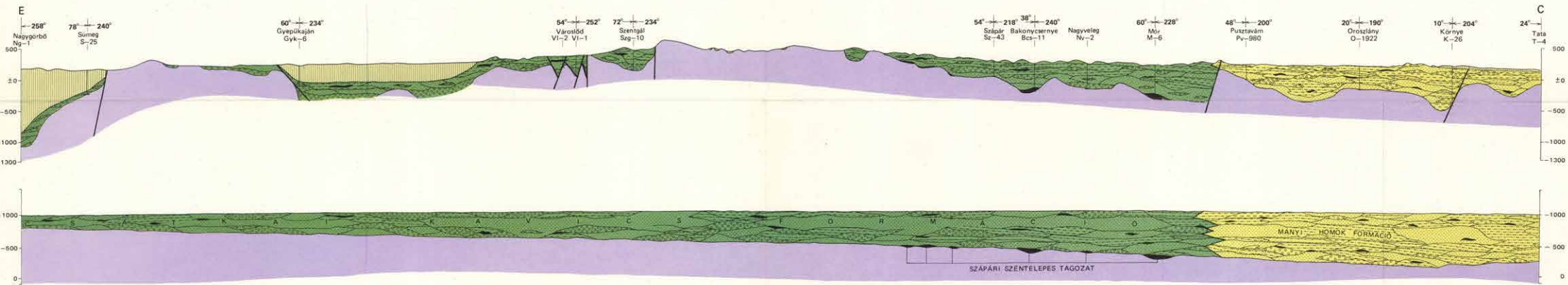
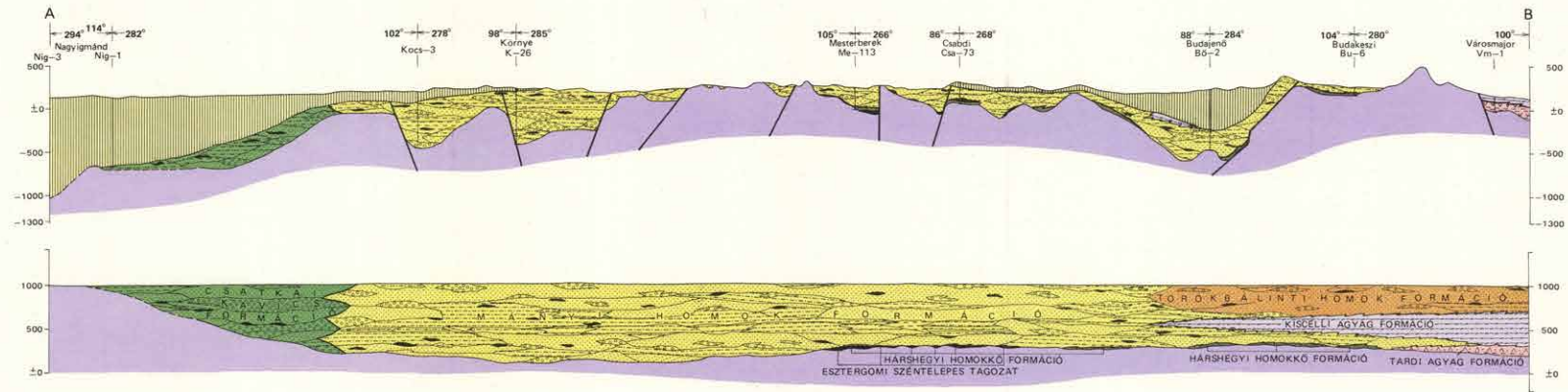


## FÖLDTANI SZELVÉNYEK

Szerkesztette: Dr. Korpás László (1977)

0 10 20 km

OLIGOCENE-LOWER MIOCENE FORMATIONS OF THE TRANSDANUBIAN CENTRAL MOUNTAINS GEOLOGICAL SECTIONS



- |  |   |
|--|---|
| Csatka Kavic Formáció<br><i>Csatka Pebble Formation</i>                          | Agyag<br><i>Clay</i>  |
| Szápari Széntelepes Tagozat<br><i>Szápar Coal Measures Member</i>                | Agyamárga<br><i>Argillaceous marl</i>                       |
| Mányi Homok Formáció<br><i>Mány Sand Formation</i>                               | Aleurit<br><i>Silt</i>                                      |
| Esztergomi Széntelepes Tagozat<br><i>Esztergom Coal Measures Member</i>          | Homok, homokkő<br><i>Sand, sandstone</i>                    |
| Hárshegyi Homokkő Formáció<br><i>Hárshegy Sandstone Formation</i>                | Kavic, konglomerátum<br><i>Pebbles, conglomerate</i>        |
| Tardi Agyag Formáció<br><i>Tard Clay Formation</i>                               | Barnaköszén<br><i>Brown coal</i>                            |
| Kiscelli Agyag Formáció<br><i>Kiscell Clay Formation</i>                         | Andezittufa<br><i>Andesite tuff</i>                         |
| Törökbalinti Homok Formáció<br><i>Törökbalint Sand Formation</i>                 |   |
| Mezozoos-eocén képződmények általában<br><i>Mesozoic-eocene rocks in general</i> |   |
| Neogén képződmények általában<br><i>Neogene rocks in general</i>                 |   |
|  | Fűrés jele és száma<br><i>Symbol and number of borehole</i> |
|  | Vető<br><i>Fault</i>  |

KIADJA A MAGYAR ÁLLAMI FÖLDTANI INTÉZET, 1981

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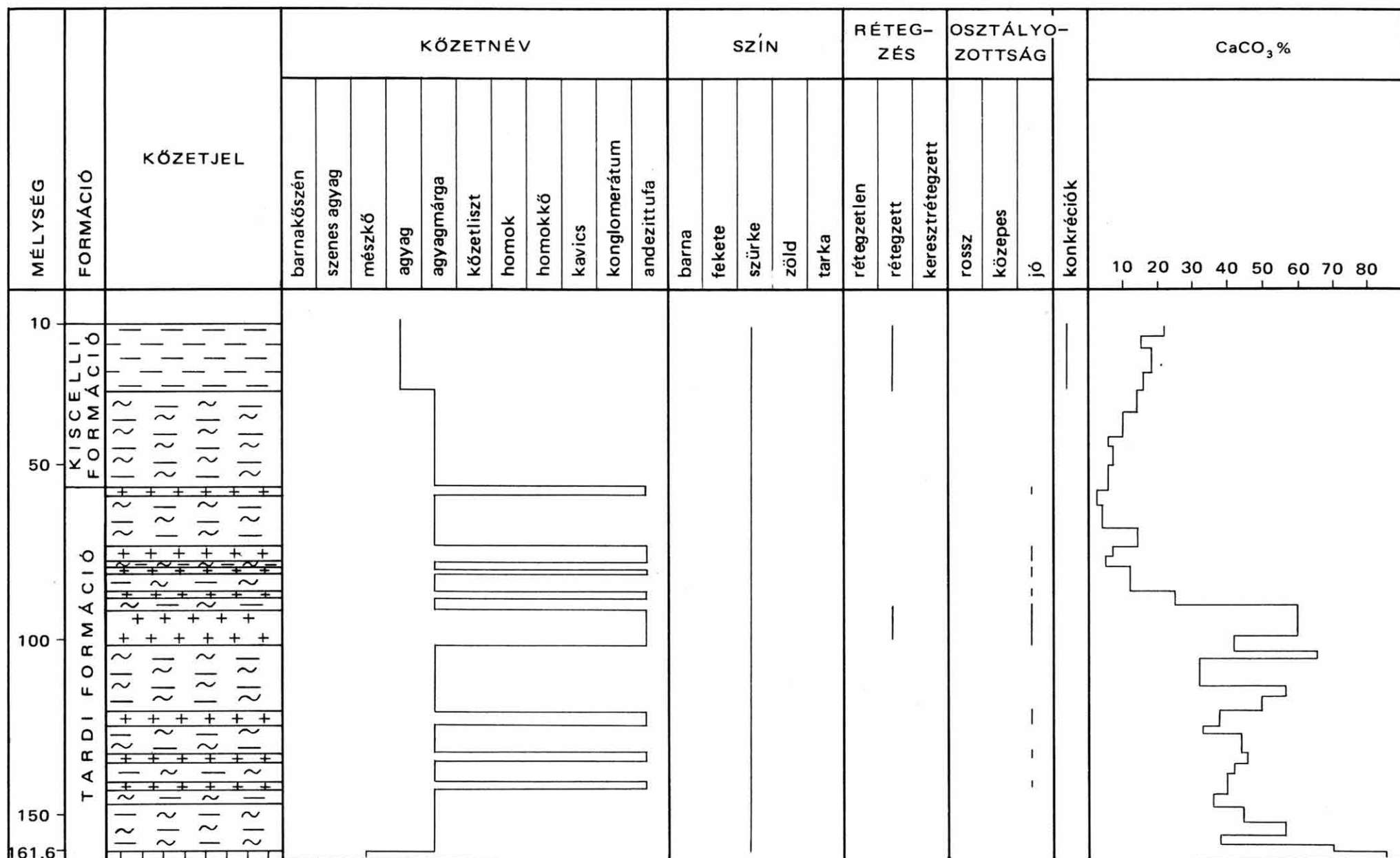
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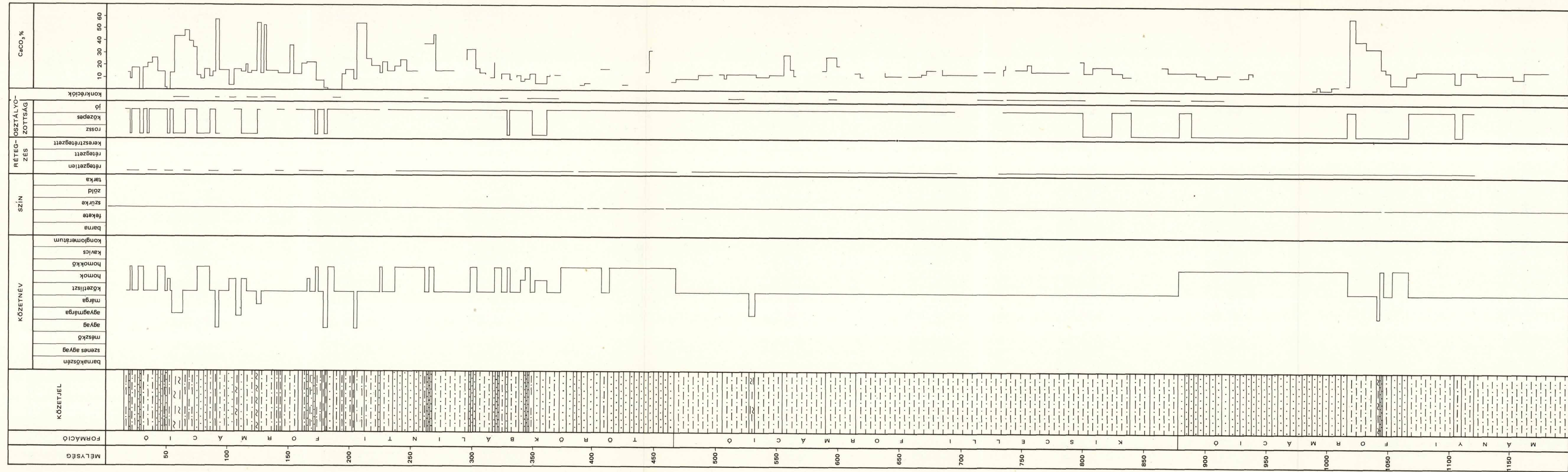
**A VÁROSMAJORI VM-1 JELŰ FŰRÁS FÖLDTANI-FÁCIÉS SZELVÉNYE**  
**DIAGRAMMATIC REPRESENTATION OF GEOLOGICAL FACIES CONDITIONS UPON**  
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 DIAGRAMMATIC REPRESENTATION OF GEOLOGICAL FACIES CONDITIONS UPON  
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