8th MEETING of the ASSOCIATION of EUROPEAN GEOLOGICAL SOCIETIES

EXCURSION GUIDE

Field Trip B

Geology, agriculture, environment and urban engineering geology in the Pannonian Basin

BUDAPEST
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MAGYARHONI FÖLDTANI TÁRSULAT MENTE ET MALLEO 1848

MAEGS 8 EVOLUTION OF INTRAMONTANE BASINS

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Evolution of Intramontane Basins
on the Example
of the Pannonian Basin

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Field Trip B

Geology, agriculture, environment and urban engineering geology the Pannonian Basin

Excursion Guide

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PREFACE

The route of excursion B traverses the geographical regions of Gödöllő hilly area, Danube valley flatland, interfluve between the Danube and Tisza rivers, Mezőföld, and Lake Balaton basin.

The first three chapters offer an outline of these, areas in the frame of the Geat Hungarian Plain and Hungary, respectively.

The near surface portion of Quaternary aeolian loess, wind-blown sand, fluviatile deposits, and lacustrine Pliocene sedimentary sequences which have an overall thickness of about 1500—2000 m in the Pannonian Basin provide the substance of studies in soil science, agrogeology, engineering, and environmental geology and nature conservation in the Great Hungarian Plain.

G. Greschik
G. Szendrei

Megatectonic setting and geohistory of Hungary

JÁNOS HAAS

Introduction

Hungary lies in the central part of the Pannonian Basin surrounded by the Alps, the Carpathians and the Dinarides (Fig. 1, 2).

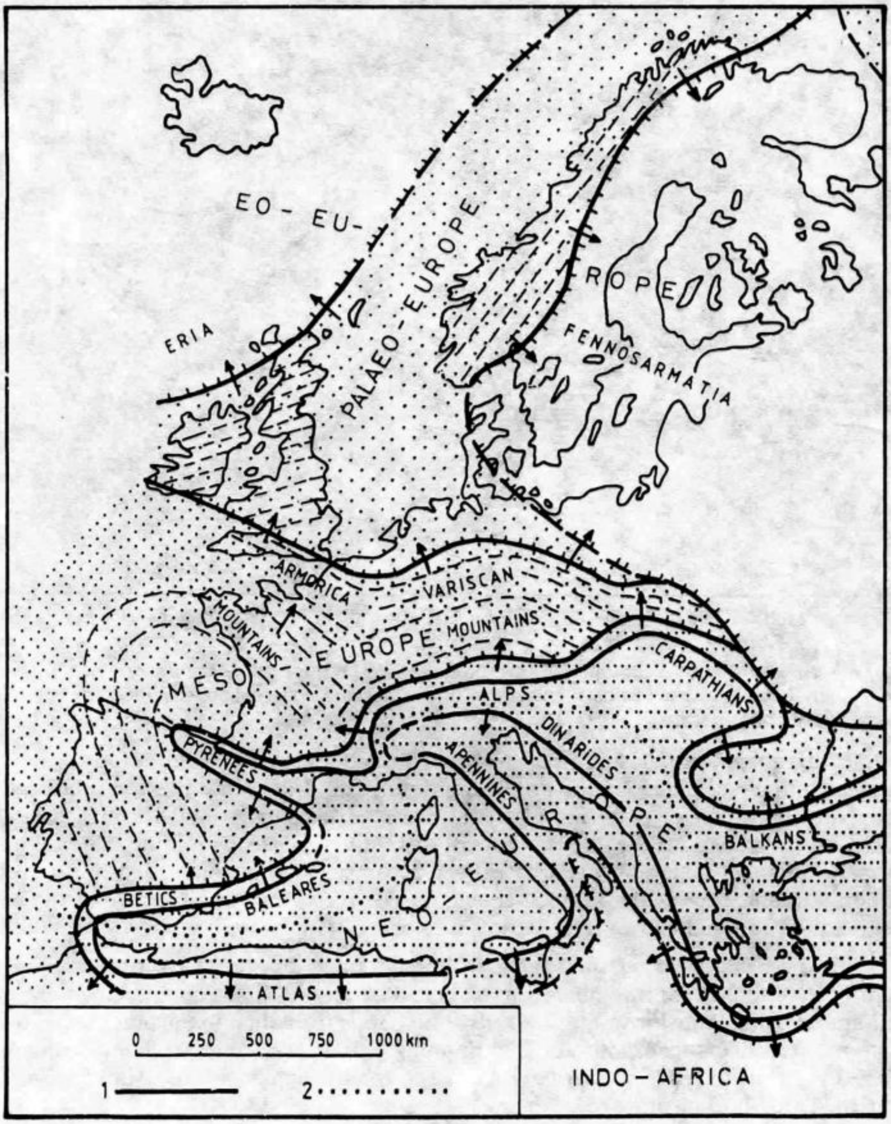


Fig. 1 Megastructural subdivision of Europe (H. Stille 1924). 1: Strike of the Alpids. 2: Boundary of arctogenic and meridiogenic folding. To the Precambrian nucleus of Europe (Eo-Europe) three accretions have been added: Palaeo-Europe in the Caledonian phase, Meso-Europe in the Hercynian phase and Neo-Europe in the Alpine phase.

Geological setting and structural features of this region are determined mainly by the Alpine structural evolution manifested in the opening and subsequent closing of the Mesozoic Tethys and by the Tertiary basin formation.

The Pannonian basin-system is an integral part of the Alpine realm. According to Stille's (1924) concept it belongs to Neo-Europe (Fig. 1, 2). The present-day geological setting is a result of a multi-stage, complex evolution. This is a consequence essentially of

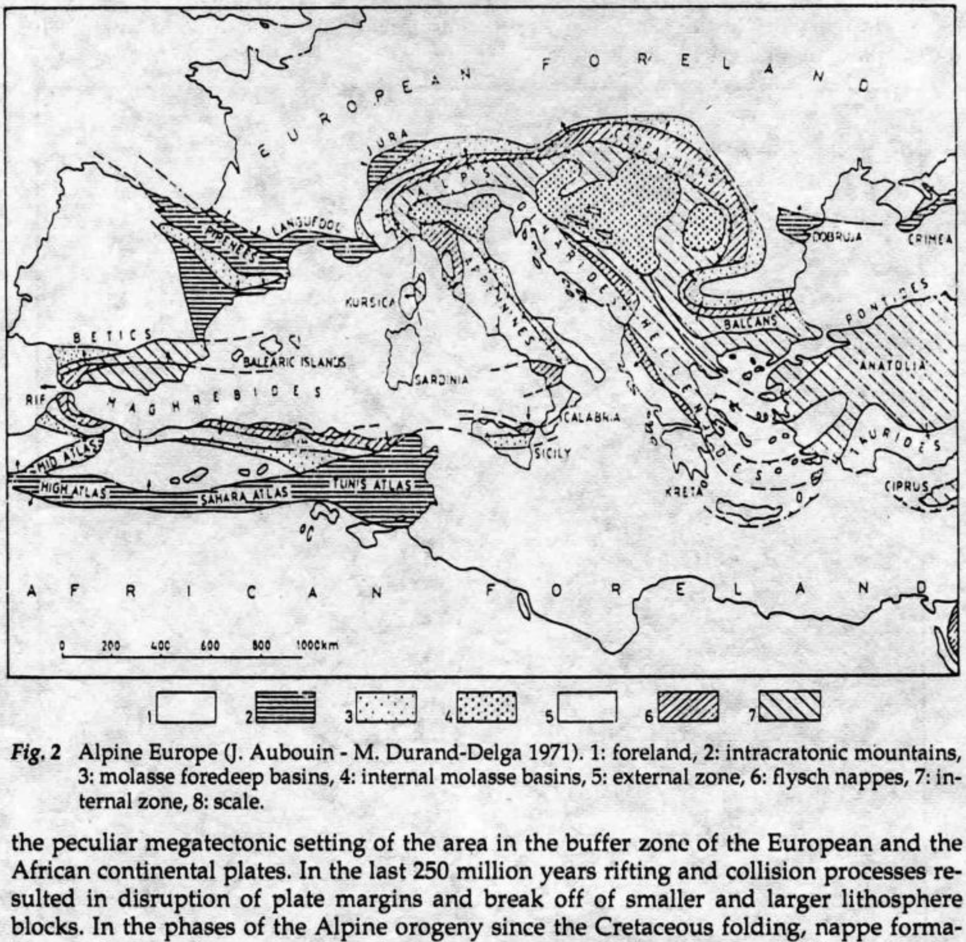


Fig. 2 Alpine Europe (J. Aubouin - M. Durand-Delga 1971). 1: foreland, 2: intracratonic mountains, 3: molasse foredeep basins, 4: internal molasse basins, 5: external zone, 6: flysch nappes, 7: internal zone, 8: scale.

the peculiar megatectonic setting of the area in the buffer zone of the European and the African continental plates. In the last 250 million years rifting and collision processes resulted in disruption of plate margins and break off of smaller and larger lithosphere blocks. In the phases of the Alpine orogeny since the Cretaceous folding, nappe formation, and regional metamorphism have been accompanied and succeeded by strike-slip motion and shearing of the lithosphere-chips. The recent mozaic-structure of the basement of the Pannonian Basin (Fig. 3) came into being in this way.

In the Neogene after their large-scale reorganization the eastward lateral movement of the lithosphere fragments was not blocked totally. Consequently deep grabens, pull-apart basins came into being coevally with nappe formation in the outer zones of the Eastern Carpathians. The extension and thinning of the crust led to accelerated sinking, a process which resulted in the formation of large and deep depressions (Alföld, Kisalföld) from the Late Miocene onward.

Our present-day concept on the structure and geohistory of the Pannonian Basin is the result of more than hundred years research activity which was carried out by a lot of workers. It was formed as well as modified as a result of debates and discussions always influenced by the actual tectonic hypotheses. Following Suess's nappe-concept Uhlig

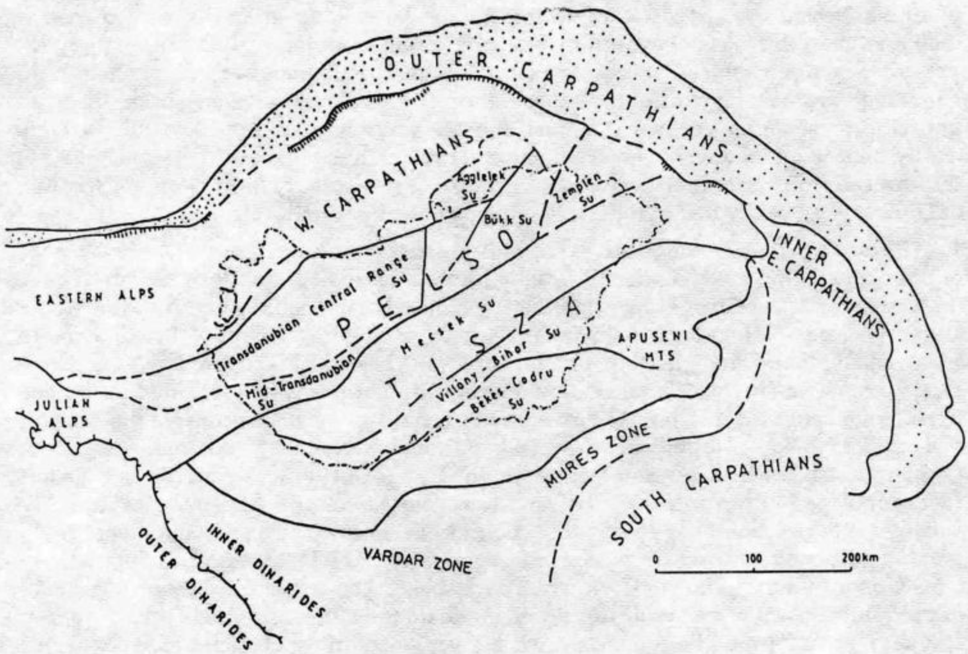


Fig. 3 Structural units and subunits (Su) in and around Hungary.

(1907) assumed that the basement of the Pannonian Basin was built up by huge detached nappes ("meganappes"). This idea provoked strong criticism of the Hungarian geologists since according to their observations the structure of the Pannonian Basin and the "island-mountains" within it significantly differed from the folded ranges of the Alps and Carpathians. Kober (1921), Lóczy sen. (1918) and a great number of their successors interpreted these differences by the so-called "median mass" concept. They assumed that the basement of the Pannonian Basin was built up basically of crystalline rocks covered by undeformed Mesozoic and Early Tertiary sequences deposited in the depressions of the basement. During the Alpine orogeny the surrounding mountain ranges were squeezed around this hard, cratonic core. Although the "median mass" hypothesis was criticized as early as in the 30-es its essential principles determined the tectonic conceptions till the 60-ies. Extensive geophysical measurements and drilling activity resulted in better understanding of the basement-structure as well as in progress of mobilistic thinking. The plate-tectonics brought a profound change in the tectonic concepts only in the 70-ies. Remarkably deformed and in the majority of the areas even nappe-structural nature of the "island-mountains" and the bedrocks of the basins became evidenced (Ádám et al. 1985, Balla 1983, Balogh et al. 1984, Csontos 1989). It has been revealed too that the basement is a mozaic of blocks of different build-up and geohistory (Wein 1969, 1978, Géczy 1973, Majoros 1980, Kovács 1983, Kázmér 1984, Fülöp et al. 1987, Balla 1988). Contemporaneously the concept that the Pannonian Basin is one of the types of the back-arc basins also emerged (Horváth and Stegena 1977, Horváth et al. 1981, Royden 1988) and became generally accepted.

Megatectonic setting and structural units

Three major geohistorical periods are reflected in Hungary's geology — a pre-Alpine evolutionary stage, difficult to reconstruct, connected with Central Europe's Precambrian-Paleozoic history, — the Alpine stage including the Late Paleozoic, Mesozoic and Paleogene evolution of the Tethys, with orogenic events (Eoalpine, Paleoalpine, Mesoalpine) manifested in napped-folded tectonism and large-scale strike-slip movements, — the Pannonian (Neoalpine) evolutionary stage lasting from the Early Miocene up to the present; a period characterized by formation of small pull-apart basins and then of the Pannonian Basin by high-amplitude subsidence. The young basins which basically determine the present-day geological setting and the physiography are filled up predominantly by fine-grained terrigenous sediments and locally by igneous rocks of significant thickness. According to the development patterns of pre-Tertiary formations, the territory of Hungary can be divided into the following megatectonic units (Fig.4).

Tisza Unit — To the South of the Mid-Hungarian lineament the Tisza Unit can be outlined, including the Mecsek and Villány Mountains and their subsurface extension in the basement of the Great Hungarian Plain (Alföld). It also includes the Apuseni Mountains (W Rumania) and the Slavonian "island mountains" (Papuk, Psunj, Krndija, Moslavnian Mts.). The high-grade polymetamorphic basement is covered by a Germano-type Permo-Triassic continental-shallow marine sequence. It is followed by Jurassic and Cretaceous series of different facies patterns enabling the distinction of the Mecsek, Villány and Békés Subunits. The Mecsek Subunit is characterized mainly by thick Gresten-type Liassic, deep-water facies from the Upper Dogger with a Mediterranean fossil assemblage and an intensive Lower Cretaceous submarine alkalic volcanism. The Villány (-Bihor) Subunit has a Jurassic sequence characterized by a great number of stratigraphic gaps, and a Lower Cretaceous of Urgon facies. The Békés (-Codru) Subunit contains Upper Jurassic to Lower Cretaceous dark shales. The Upper Cretaceous formations of predominantly marine clastic development lie on the older deformed rocks of various age with unconformity. Paleogene siliciclastic sequences of flysch facies are known only in the subsurface part of the Mecsek Subunit (Szolnok Flysch Zone). Based on development of the Paleozoic and early Mesozoic series the Zemplén Subunit in Northeastern Hungary is considered to belong to the Tisza Unit, too.

Pelso Unit — Situated between the Rába-Diósjenő Lines and the Mid-Hungarian Fault Zone, the Pelso Unit is characterized by very low-grade and low-grade metamorphic marine Early Paleozoic formations, and continental and marine Late Paleozoic sequences of South Alpine-Dinaric affinity. In the Mesozoic passive continental margin formations are characteristic, but in certain subunits remnants of the oceanic basement are known, too. The facies indicates Alpine-Dinaric relationship. Large-scale Eocene intermediary volcanism is an important and peculiar feature of the unit, what is unknown in the Tisza Unit. The Pelso Unit can be devided into the following subunits: The Transdanubian Central Range Subunit can be characterized by terrestrial-marine Upper Permian, multi-phase transgression from the Lower Triassic, intrashelf rifting accompanied by volcanism in the Middle Triassic, thick peritidal carbonate sequences in the Upper Triassic, intrashelf rifting with general trend of deepening in the Jurassic, tectonically forced trans-regressive cycles in the Middle and the Upper Cretaceous and in the Eocene. The Mid-Transdanubian Subunit consists of strongly tectonized heterogeneous blocks which are known only from boreholes. Marine Permian and Triassic carbonate platform formations show Dinaric affinity. Slightly metamorphic deep-water marine sedimentary and volcanic rocks were also found. The Bükk Subunit is constituted by a Late Paleozoic marine sequence from which the Lower Triassic evolved with no break in sedimentation, followed by a Middle and Upper Triassic of carbonate platform and intraplatform basin facies and volcanites, and by Jurassic formations of schistes lustres type deposited in deep-water slopes and basins as well as submarine basaltic volcanites. The Eocene and the Oligocene sedimentary and volcanic sequences were deposited after the nappe formation.

West-Carpathian Units — Aggtelek-Rudabánya (S.Gemer) Subunit: the upper nappe includes Triassic of carbonate platform facies and deeper water Jurassic showing North Alpine affinity. The lower nappes are composed of Middle and Upper Triassic of slightly metamorphosed deep-water facies and a Jurassic of schistes lustres character sim-

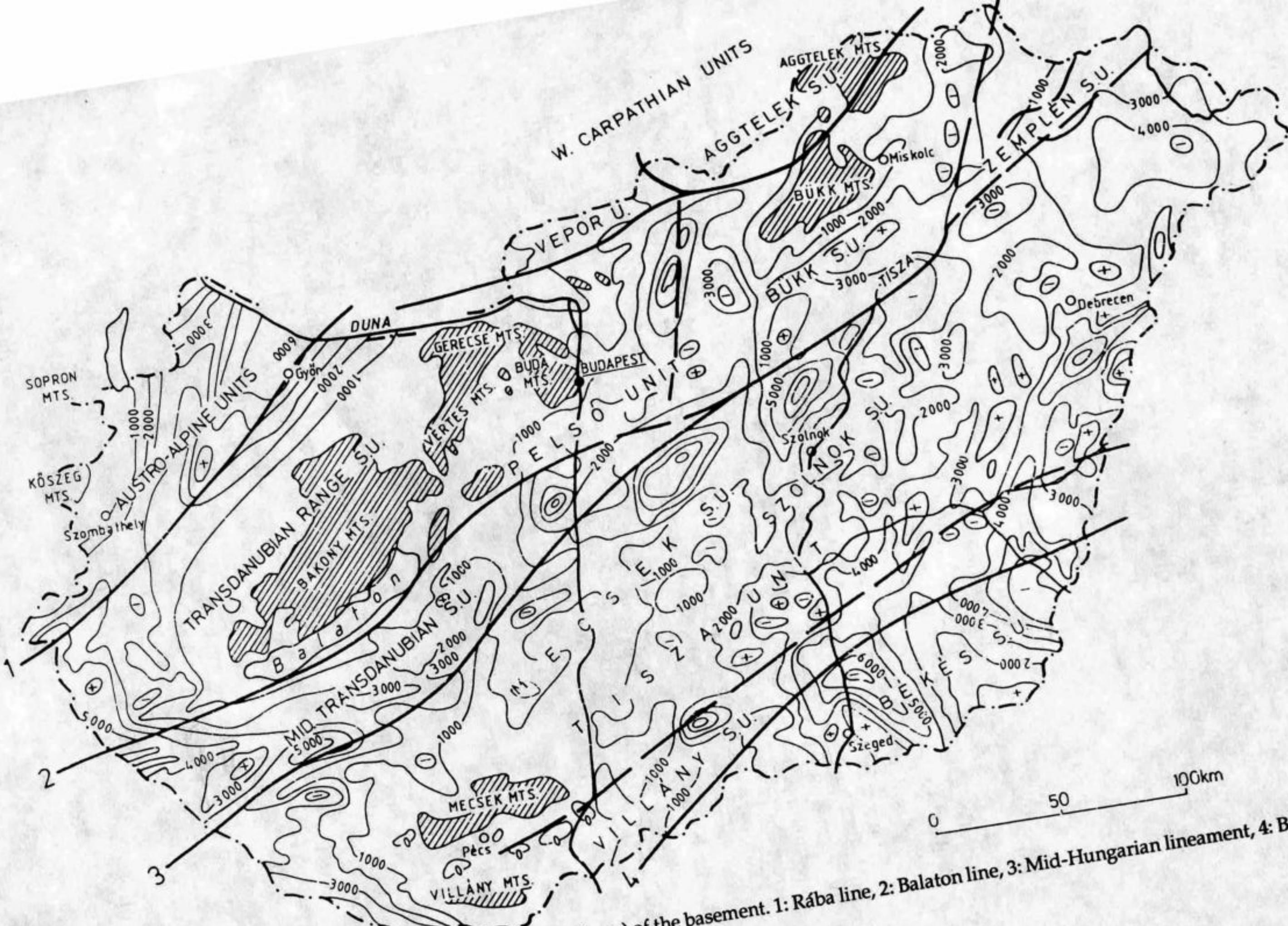


Fig. 4
Megastructural units and subunits (Su) of Hungary and depth (in m) of the basement. 1: Rába line, 2: Balaton line, 3: Mid-Hungarian lineament, 4: Békés line.

ilar to its counterpart in the Bükk Mts. North to the Diósjenő Line crystalline complex of the Vepor Unit extends into the country's territory. It is known only from deep drilling.

Austro-Alpine Units — *Penninic Unit*: Jurassic to Lower Cretaceous metamorphites of greenschist facies in the Hungarian part of the Rechnitz Window (Kőszeg Mts. and its subsurface extension in the basement of the Little Hungarian Plain [Kisalföld]).

Lower Austro-Alpine Unit: Paleozoic mesometamorphic formations known from the Sopron Mts.

Upper Austro-Alpine Unit: very low to low-grade metamorphites known from the basin substratum between the Répce and Rába rivers, representing an extension of the Graz Paleozoic series.

Structure evolution

The crucial points of the evolution-analysis of the Pannonian Basin are 1) the reconstruction of the original position and displacements of the structural units (terranes) and 2) the interpretation of the Neogene basin formations. Naturally due to lack of relevant data a lot of details of geohistory are not yet evidenced and a great number of significantly different hypotheses, interpretations are coexisting.

Pre-Alpine phase

Interpretation of the Pre-Hercynian geohistory is particularly difficult due to the polyphase metamorphism and uncertain age determination. Polymetamorphic series of the Tisza Unit were formed and metamorphosed first probably in the Cadomian or in the Caledonian phase but their meso- and ultrametamorphic transformation took place in the Hercynian phase. This metamorphic complex may have been situated on the margin of the European craton. It was a part of the Meso-European, Hercynian belt and this situation remained almost unchanged until the Alpine rifting and ocean opening period in the Mid-Jurassic.

Metamorphic Early Paleozoic rocks of the Pelso Unit and the Eastern Alpine Units should have been deposited in the "Paleotethys" basin in the foreland of the African plate. Early Paleozoic formations of the Lower-East Alpine nappes suffered metamorphic transformations perhaps in the Caledonian phase but most probably in the Hercynian. The Early Paleozoic sequences in the Transdanubian Central Range were slightly metamorphosed also in the Hercynian.

During the Hercynian orogenic phase as a result of the collision of the northern and the southern continents the joining of the Pangea was completed by the Middle-Late Carboniferous.

However, a comparatively narrow gulf survived between them. Here marine sedimentation was practically continuous in the Carboniferous-Permian interval. The Bükk Subunit (Bükk Mts. and Szendrő hills) may have belonged to this facies belt. It is characterized by flysch sedimentation in the Middle Carboniferous and shallow siliciclastic and carbonate accumulation in the Late Carboniferous. Development of the Uppony hills (Northeastern Hungary) may represent the shallow shelf around the deeper, central part of the bay, just like the Graz Paleozoic series. The clastic Upper Carboniferous rocks in the Transdanubian Central Range and the coal-bearing formations of similar age in the Villány Subunit were deposited probably in the external molasse basins (Fig. 5). In the Early Middle Permian both in the area of the Tisza Unit (in the southern belt of the European plate) and the territory of the Transdanubian Central Range (in the northern zone of the African plate) due to continental rifting deep, narrow grabens were formed and filled up by continental red beds and acidic volcanic rocks.

In the Bükk area which belonged to the axial zone of the Panthalassa Bay after a short term gap a new sedimentary cycle began to develop: a shallow marine siliciclastic — carbonatic — evaporitic complex, indicating the beginning of the Alpine evolution.

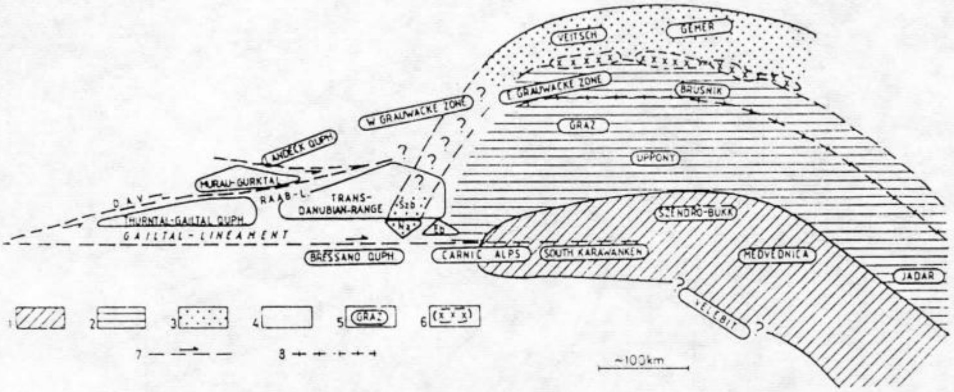


Fig. 5 Palaeogeographic situation of the NW and of the Alpine-Dinaric branch of Palaeo-Tethys in the Middle Carboniferous (schematic reconstruction by S. Kovács). 1: Flysch formation, 2: carbonate sedimentation on shallow shelf, 3: molasse sedimentation in post-Variscan basins, 4: continental areas (early Variscian mountains), 5: present day structural units, 6: mafic volcanism, 7: young shear zone, 8: strike of the Vardar zone, Szb: Szabadbattyán, No: Notsch, Eb: Ebriach, Quph: Quartz phyllite.

Alpine phase

Within the Alpine phase the following stages can be distinguished.

1. Divergent stage i.e. polyphase opening of the Tethys (branches) from the Late Permian to the Late Jurassic. The substages of the early evolution are enumerated below.

1.1 Pre-opening period from the Late Permian to the Middle Triassic.

The basement blocks were situated in various places of the large Panthalassa Bay existing in between the northern (European) and southern (African) parts of Pangea.

On the moderately subsiding substratum in the external, i.e. coastal zone fluviatile, lacustrine and deltaic sedimentation took place whereas in the bay on a shallow ramp siliciclastics and/or carbonates were accumulated. The Bükk Subunit belonged to the interval belt of the bay already at the beginning of this period. A significant part of the Transdanubian Central Range area was flooded only at the Permian-Triassic boundary, whereas the external Tisza Unit was occupied by the sea at the beginning of the Middle Triassic. By the middle part of the Anisian in every unit shallow carbonate platforms as well as ramps were formed all along the western margin of the Panthalassa Bay of fairly balanced topography.

1.2 Rifting and opening of the Vardar-Meliata oceanic branch in the Middle Triassic.

Disintegration of the platforms, formation of grabens and intraplatform basins and in the vicinity of the axis of the opening appearance of basic and ultrabasic magmatites characterize this substage. Tholeiitic rocks occur in the deeper nappes of the Aggtelek-Rudabanya Unit together with deep-sea sediments. Segmentation of the platforms as well as appearance of pelagic basin facies can be observed both in the uppermost nappe of the Aggtelek-Rudabánya Unit representing the European margin and the Transdanubian Central Range as well as the Bükk Mts. representing the African shelf (Fig. 6).

In the Tisza Unit which was located in the external belt of the European shelf segmentation of the margin did not disturb the evolution trend in the carbonate ramp and subsequently the rimmed shelf sedimentation was continuous.

1.3 Stabilization of the passive margin in the Late Triassic.

In the Carnian due to relief differentiation and a climatic change the terrigenous input significantly increased in the W Tethyan region. The change in the sedimentation is

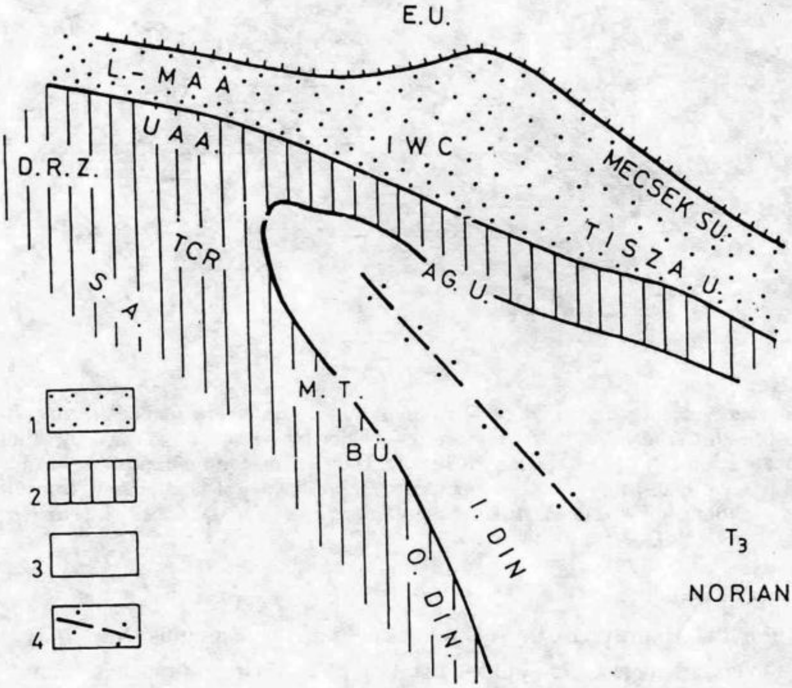


Fig. 6 Late Triassic (Norian) palaeogeographic position of the megastructural units of the basement of the Pannonian basin and the surrounding area (Haas and Kovács 1992). TCT: Transdanubian Central Range, AG. U. Aggtelek — Rudabánya Unit, E. U.: Stable Europe, L (M) E. ALP : Lower (Middle) Austroalpine, U. AA.: Upper Austroalpine, DRZ : Drauzug, S. A. : Southern Alps, IWC : Inner West Carpathians, M. T. : Mid-Transdanubian Unit, B.: Bükk Unit, O. Din. : Outer Dinarides, I. Din. : Inner Dinarides.

particularly conspicious in the most external zone of the Tisza Unit (Mecsek Subunit) where the predominantly siliciclastic sedimentation continued till the Early Jurassic. The increase of the terrigenous influx led to the upfilling of the intraplatform basins in the Transdanubian Central Range and to the accumulation of argillaceous sediments in the pelagic basins in the Aggtelek-Rudabánya and the Bükk Subunits.

In the Late Carnian as a consequence of upfilling of the intraplatform basins and then the acceleration of the subsidence of the shelves large carbonate platforms were formed and extremely thick peritidal-lagoonal carbonate sequences accumulated till the latest Triassic or even in the Early Jurassic, too.

1.4 Opening of new oceanic branches in the Jurassic

In the Jurassic the Penninic oceanic branch began to open from the West prograding eastward.

Metamagmatites of the West Hungarian Penninic Unit in the Kőszeg-Rechnitz window originated from this oceanic branch. They are typical oceanic basalts.

Mafic and ultramafic rocks in the Bükk Unit probably indicate the survival of spreading in the Vardar (-Meliata) ocean branch. Pelagic limestones, radiolarites and shales with lithoclasts partly of shallow platform origin represent the sedimentary sequence.

In the area of the Triassic carbonate platforms in originally neighbouring segments of the Southern Alps, the Transdanubian Central Range, the Northern Limestone Alps and the Inner West Carpathians the disintegration of the shelves commenced as early as the latest Triassic and was intensified in the Liassic. Uplifted blocks and deep grabens were formed by normal faulting. The extension is also indicated by neptunian dykes. On the elevated areas (submarine plateaus) condensed sedimentation with a great number of hardgrounds was characteristic.

In the Middle-Jurassic in the Transdanubian Central Range Unit pelagic deep-sea sedimentation prevailed just like in the Southern Alps or in the Northern Limestone Alps. Radiolarites are the most typical sediments. In the Late Jurassic the pelagic ammonitico rosso and the biancone (maiolica) facies are widespread. In the SW part of the Transdanubian Central Range (Bakony Mts) the formation of the maiolica facies continued in the Early Cretaceous, too.

Coevally, in the NE part of the Transdanubian Central Range (Gerecse Mts) a flysch-like redeposited siliciclastic series began to deposit. Minerals of ultrabasic origin in this series indicate obduction of the Vardar oceanic basement.

In the position of the Tisza Unit a significant change occured during the Jurassic. Lithologic features and fossil assamblages of the Lower Jurassic formations show definite European affinity. The sedimentation was characterized by intense terrigenous input. In the Middle Jurassic the terrigenous influx drastically decreased. Consequently in the Middle and Upper Jurassic formations the terrigenous component is practically missing — deep sea carbonates and cherts occur. Simultaneously in the biota the Mediterranean elements became predominant.

All these changes suggest the separation of the Tisza Unit from the European plate. The contemporenous beginning of continental rifting-type volcanism in the most external Mecsek Subunit was probably connected with this process. Paroxism of the volcanic activity in Early Cretaceous marks the main spreading period. In the more internal Villány facies zone the Upper Jurassic is represented by shallow carbonate facies. Above a gap at the base of the Cretaceous, Urgon-type carbonate platforms were formed in the Early Cretaceous.

2. Convergent phase — discontinuous collision from the Cretaceous to the Oligocene.

The closure of the Tethyan system which incorporated several smaller or larger subbasins and ocean branches was a long, multi-phase process. It resulted in a significant reorganization of terranes. By the end of the phase the position of the blocks may have been already similar to their present-day setting. The displacements were the result of nappe movements, large-scale lateral displacements and rotations.

The stages of the convergent phase are:

2.1. Collisions — orogenic phases in the Mid Cretaceous — Eocene interval.

Closure of the Vardar branch commenced as early as the earliest Cretaceous. The first major deformations in the Bükk and also in the Aggtelek-Rudabánya Subunit may be connected to this process.

The S-Penninic branch began to close later, at the end of the Lower Cretaceous and it resulted in the formation of large nappe systems in the Eastern Alps (Austrian orogeny). Regional metamorphism of the tholeiitic series and the sedimentary sequences in the W-Hungarian Penninic Unit took place in this phase.

In the Transdanubian Central Range Subunit, development of the characteristic synclinal structure and slight folding were the consequences of the Austrian orogeny. According to recent geophysical measurements nappe structure can also be assumed. If this is true the nappe formation should have taken place in the Mid-Cretaceous too.

In the Mecsek zone of the Tisza Unit the major change in the structure evolution at the end of the Early Cretaceous was probably manifested in the cessation of the rift-type basaltic volcanism.

In the Villány zone the appearence of flysch-like, redeposited sediments suggests the beginning of nappe formation in the Albian.

By the Late Cretaceous along the southern foreland of the European plate a more or less continuous flysch belt was formed in the subduction zone.

In the Apuşeni Mts the main phase of the nappe formation may have been in the Early Senonian. This is probably true for the whole Tisza Unit. The orogenic phase (Sub-Hercynian) was followed by the Santonian-Campanian transgression-regression cycle, producing predominantly siliciclastic sediments.

Coevally, the Transdanubian Central Range block began to separate from the Apulian microplate when deep peri-platform troughs evolved around the Apulian platform. Within the Transdanubian Central Range normal faulting characterizes the Sub-Hercynian phase, which was followed in the Santonian by a slow transgression with fluvial and lacustrine sedimentation, lignite accumulation and carbonate platform formation.

The Paleocene orogenic event resulted in uplifting of and disconformity in the Transdanubian Central Range and probably in the Bükk Subunit, too. Due to post-orogenic subsidence a new transgression-regression cycle commenced in the Early Eocene. Contemporaneously, island-arc-type volcanism began to evolve as a consequence of the subduction of the Apulian microplate. Traces of andesitic volcanism can be found in every member of the Pelso Unit indicating their actual position north the peri-Apulian troughs (Fig. 7).

2.2. Paratethys evolution and large scale displacements of the Pelso Unit in the Oligocene-Early Miocene. The collision of the African (Apulian) and the European plates resulted in the uplift of the Alps and Dinarides by the end of the Eocene. North of these

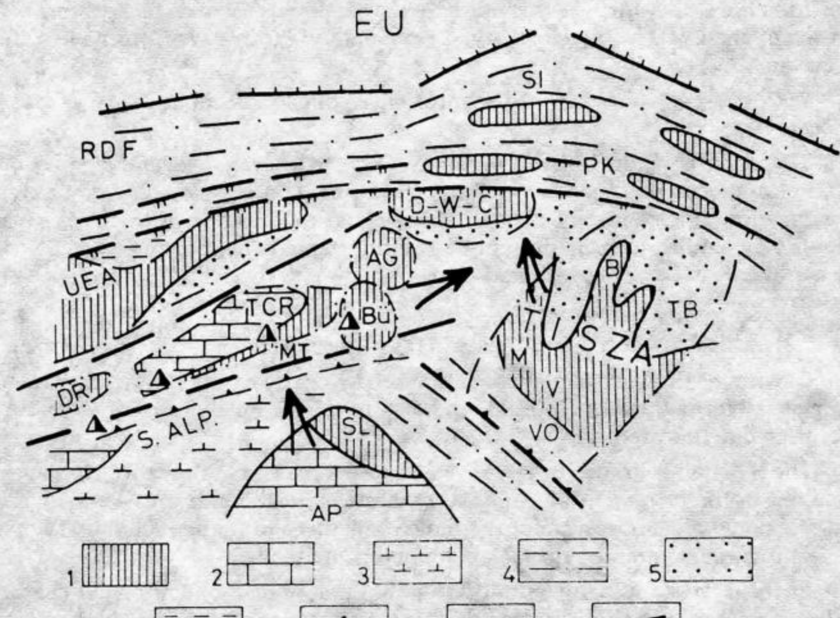


Fig. 7 Middle Eocene palaeogeography and directions of the Oligocene displacements. 1: elevated area, 2: carbonate platform, 3: pelagic sedimentation, 4: flysch sedimentation, 5: dominantly clastic sedimentation, 6: argillaceous sedimentation, 7: island-arc volcanism, 8: subduction zone, 9: overthrusting zone.

ranges a series of subbasins came into being in the latest Eocene-Early Oligocene — the Paratethys began to evolve. One of these subbasins is the North Hungarian Paleogene Basin, which was probably formed as a consequence of a large-scale eastwards displacement (escape) of the Pelso Unit (and perhaps the Western Carpathian Units, too) along the Mid-Hungarian Lineament due to the collision.

The North Hungarian Paleogene Basin was continuously deepening from the Late Eocene till the Middle Oligocene. After drawning of the Late Eocene shallow ramps anoxic shales and then argillaceous deep-sea sediments were deposited. The Late Oligocene regressive series is built up of shallow marine siliciclastics.

In the Mecsek Subunit of the Tisza Unit (in the "flysch zone") the accumulation of neritic argillaceous sediments continued till the end of the Oligocene. However, there is no evidence for direct connection between this basin and the North Hungarian Basin. The two large blocks, i.e. the Tisza and the Pelso Units, came into juxtaposed position probably in the Early Miocene. The collision of the blocks may be manifested in deformations (folding, imbrication, overthrusting) of the Paleogene formations in the "flysch zone" in the basement of the Great Hungarian Plain. The distribution and facies relations of the Ottnangian and Lower Badenian formations indicate a paleo-position of the two mega-units close to their present-day setting.

3. Pannonian Basin evolution from the Middle Miocene to the Quarternary (Fig. 8).

At the beginning of the Middle Miocene due to a significant orogenic event ("Styrian phase") a remarkable uplift occurred in the Alps and in the Carpathians. Coevally, in the southern foreland of the Alps and within the Carpathian arc deep grabens as well as basins came into being. The elongated grabens and pull-apart basins of predominantly NE-SW or perpendicular orientations were formed by eastward strike-slip motion of the basement blocks penecontemporaneously with the nappe-overthrusts in the Eastern Carpathians (Fig. 9).

Horizontal thrusting of the crust fragments, outstretching and thinning of the crust were accompanied by remarkable intermediate-acidic volcanism.

Throughs controlled by strike-slip faults or normal faults are filled by sedimentary or partly igneous sequences of 1-3 km thickness.

In the Late Miocene intense subsidence of areas of thinned crust started, a process which led to the genesis of the Pannonian Basins system. Coevally, the marine connection of the basins surrounded by the Alpine-Carpathian-Dinaride ranges came to an end.

A huge inner lake of step by step diluted water came into being. Its sedimentation was controlled first of all by upbuilding and progradation of deltas (Fig. 10). An all in all 3-6 km thick argillaceous — fine siliciclastic terrigenous complex was accumulated in the basins (Fig. 11). By gradual upfilling they were transformed into continental sedimentary basins of fluvial, lacustrine and palustrine facies.

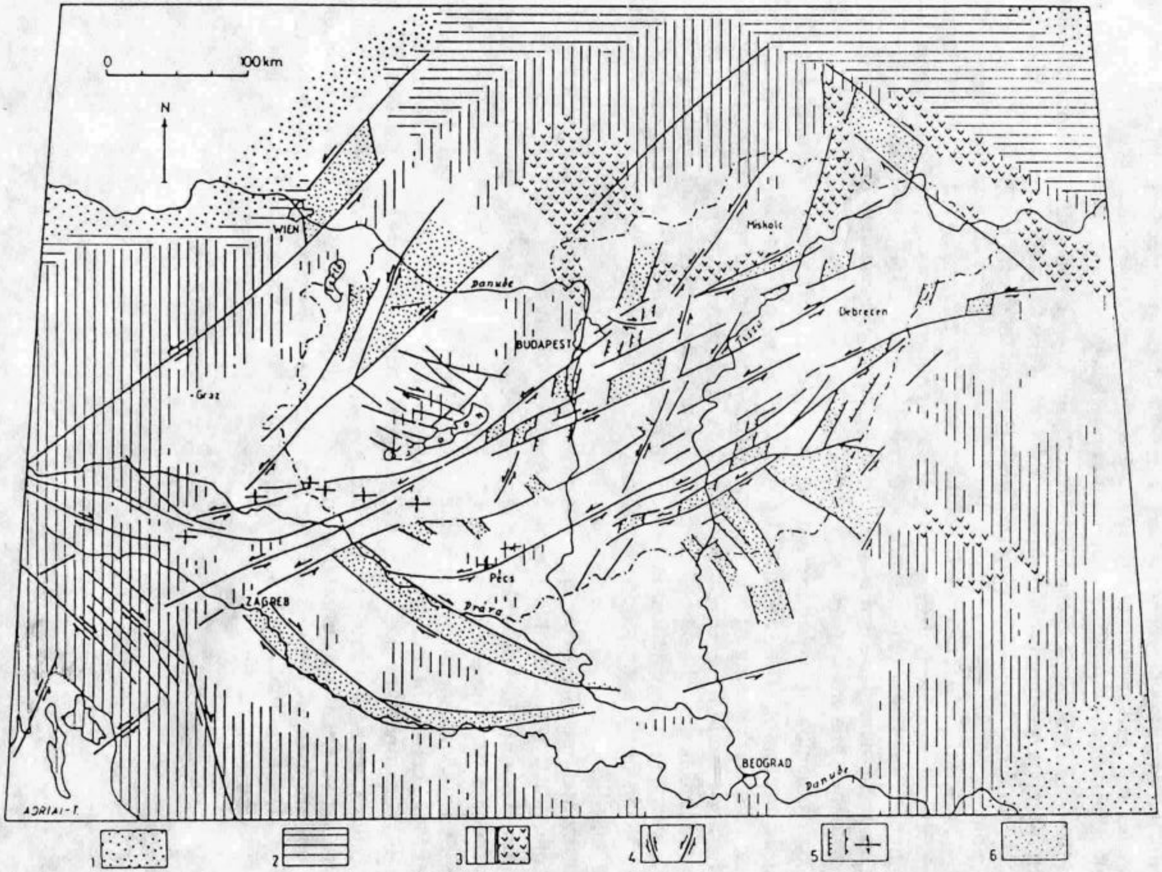


Fig. 8
Neogene model of the Carpathian-Pannonian region (F. Horváth 1987). 1: molasse foredeep, 2: flysch belt, 3: Alpine, Carpathian and Dinaric Mountains, (a): Neogene volcanic area, 4: strike-slip fault, 5: normal fault, 6: deep depressions connected with faults.

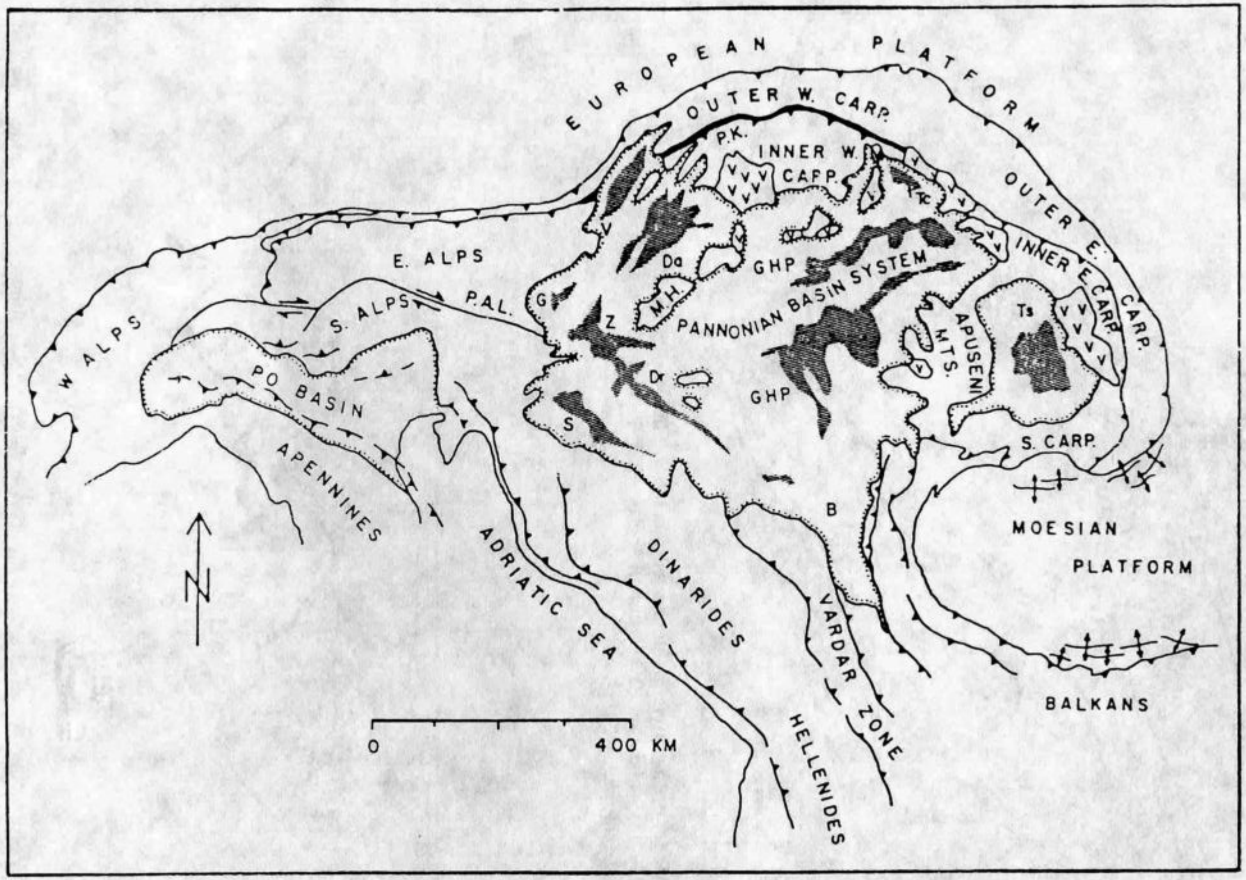


Fig. 9
Position of the Carpathian Mountains and the Pannonian Basin (Royden 1988). Strippled area indicates parts of the Pannonian Basin where the depth to base Miocene exceeds 3 km. Subbasins are: V: Vienna, Da: Danube, G: Graz, Z: Zala, Dr: Dráva, S: Sava, Tc: Transcarpathian, Ts: Transylvanian, GHP: Great Hungarian Plain, B: Banat. Other abbreviations : P. A. L. : Peri-Adriatic Line, P. K. : Pieniny Klippen Belt, M. H. : Hungarian Mid (or Central) Mountains.

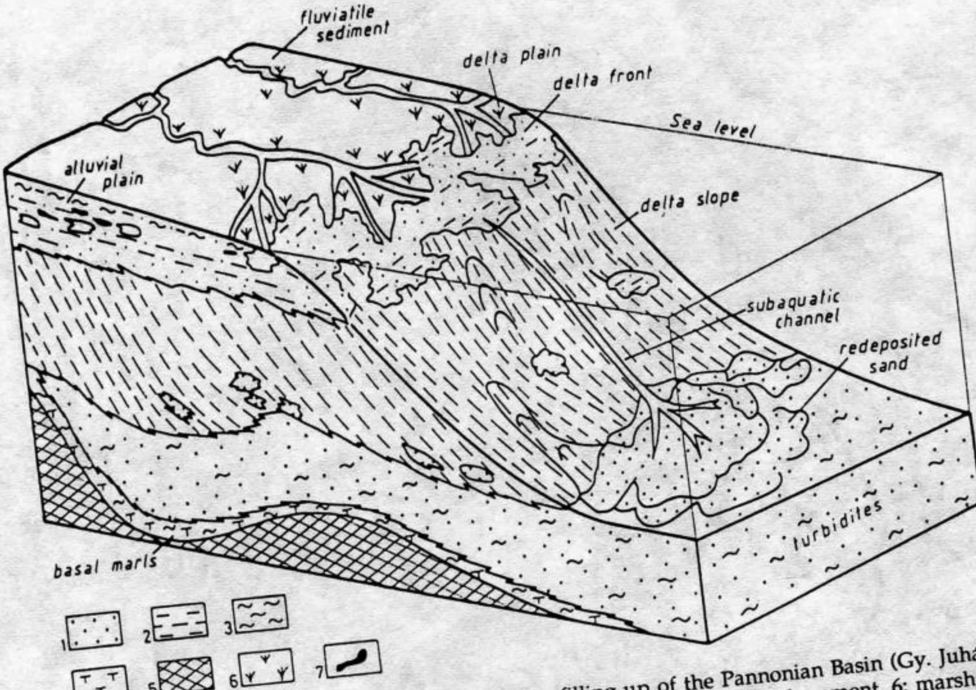


Fig. 10 Model of the fluviatile-deltaic sedimentation filling up of the Pannonian Basin (Gy. Juhász 1992). 1: sandstone, 2: silt(stone), 3: clay marl, 4: calcareous marl, 5: basement, 6: marsh, 7: peat (lignite).

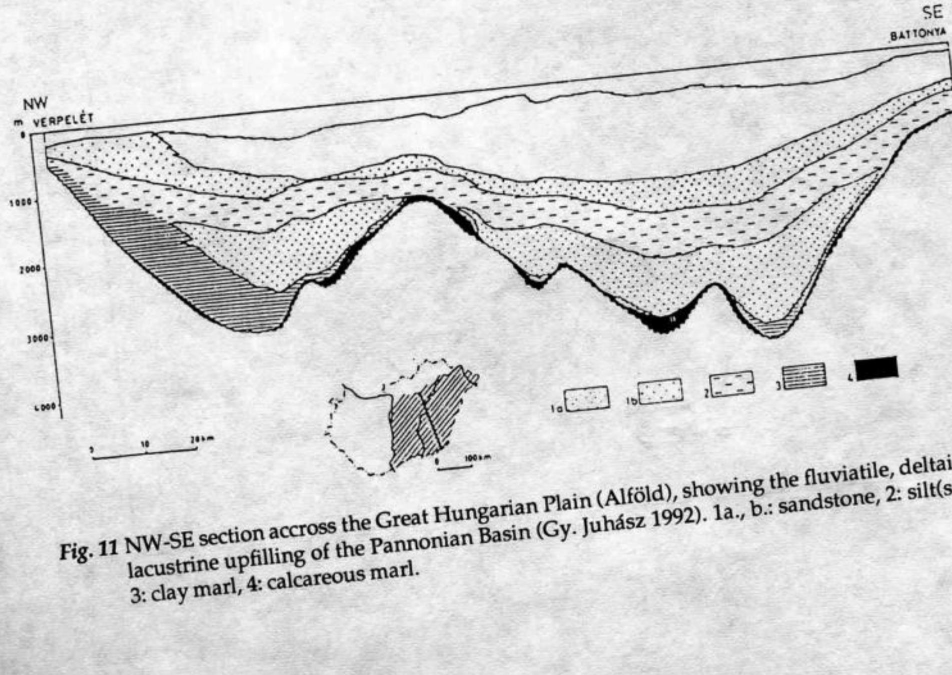


Fig. 11 NW-SE section accross the Great Hungarian Plain (Alföld), showing the fluviatile, deltaic and lacustrine upfilling of the Pannonian Basin (Gy. Juhász 1992). 1a., b.: sandstone, 2: silt(stone), 3: clay marl, 4: calcareous marl.

Stratigraphy and Evolution of the Great Hungarian Plain

K. SZENTGYÖRGYI, I. RÉVÉSZ

The Pannonian basin lies in the central part of the Carpathian Basin surrounded by the Alps, the Carpathians and the Dinarides.

Due to its complicated geological history, the geological setting of the Pannonian basin is unusually complex.

1. Pre-Neogene basement

The present position of the main structural units of the pre-Neogene basement developed before the formation of the Pannonian basin in Neogene time. Accordingly, in the basement the Mesozoic and Paleozoic formations of different origin can be found.

The characteristic features of the Mesozoic of the main structural units reflect the general evolution of the Tethys: rifting after the Hercynian orogeny, developing of a passive margin, spreading, then subduction, and finally a considerable horizontal displacement of the units.

In the pre-Tertiary basement two major megatectonic units can be distinguished: the Tisza Unit and the Pelso Unit, each consisting of several subunits.

The oldest formations of the Tisza Unit are pre-Alpine polymetamorphites. In the early-Alpine phase this unit belonged to the southern margin of the European continental plate. A considerable change occured in late Jurassic-early Cretaceous time. The Tisza unit became separated from the European plate and suffered a counter-clockwise rotation of 70 degrees.

In the Tisza unit, the post-Hercynian continental rifting is characterised by the formation of late Carboniferous molasse basin followed by the accumulation of Permian-early Triassic fluviolacustrine red beds and rift-type volcanics.

The development of a passive margin began by moderate subsidence and the deposition of clastic and carbonate sediments. In late Triassic and early Jurassic times some differences arose in the evolution of the individual subunits. In the Mecsek subunit a rapid subsidence and the accumulation of a thick terrigenous sequence occured, while in the Békés subunit the subsidence was moderate and in the late Triassic a Carpathian Keuper sequence, in the Liassic a shallow water marin carbonate sequence (punctuated by non-depositional epizodes) accumulated. In the southern subunit of the Tisza Unit carbonate ramp and platform sediments were deposited.

The Dogger-early Cretaceous is the period of rifting and closing of the Tethys. In the subunits of the Tisza Unit pelagic basin development and rift-type alkaline volcanism occurred with highrate subsidence; elsewhere deep pelagic basins were formed. Some subunits are characterized by the formation of a Malm carbonate ramp, a Tithonian — Valanginian uplift and the development of an Aptian carbonate platform.

In the basins, formed by fragmentation due to the Subhercynian phase, Gosau-type and pelagic formations were deposited in late Cretaceous time.

2. Paleogene formations

In the Pannonian basin Paleocene formations are unknown. There is no evidence of sedimentation between the upper Cretaceous and the Eocene.

For the time being in the eastern part of the Tisza Unit an Eocene-Oligocene flysch is known, confined to a narrow belt. In some places carbonate marginal facies were developed, too.

3. Neogene formations

Miocene to Pannonian sedimentary rocks locally attain a total thickness of 7000—8000 m. The thickness of the pre-Pannonian Miocene sequence varies from 1000 to 3000 m. In northern Hungary uninterrupted sedimentation can be observed between the Oligocene and the Miocene.

One full sedimentary cycle developed during Eggenburgian time. Savian folding and faulting resulted in a massive influx of terrigenous material into the Eggenburgian basins. The resulting formations consist of coarse-grained fluvial sediments and variegated clays. In N-Hungary a transgression came from the north or northwest. The littoral facies consist of conglomerates, standstones and limestones. Shallow marine glauconitic and schlieren were deposited in the central part of the basins, and lignite formation was started in the locally developed lagoons. At the top of the Eggenburgian the marine sequence is overlain by regressive deltaic-fluvial gravel, sand and variegated clay.

The geographic distribution of sedimentary rocks deposited during the Ottnangian sedimentary cycle is similar to that of the Eggenburgian sediments. Early Miocene (Savian) folding and faulting in southwestern Hungary produced a series of uplifted and subsided blocks. A rhyolite tuff series about 100-200 m thick was produced by the Ottnangian volcanic activity.

The oldest Ottnangian beds in the north Hungarian basin are terrigenous sandstones and shales with limnic and paralic lignite. In western Hungary the rhyolite tuff is overlain by a 500 m thick fining-upward sequence with fluvial beds. In southern Hungary coarse-grained clastic sediments with lignite seams are exposed.

As a rule, at the basin margins there is a well-defined unconformity at the Ottnangian-Karpatian boundary. In the basins the Ottnangian coarse-grained clastics are conformably overlain by Karpatian sediments.

The Karpatian sequence represents a transgressive-regressive cycle. As a result of the intense subsidence of the Dinaric foreland, a direct connection was established with the Mediterranean sea. The oldest beds of the Karpatian are of brackish water facies. In littoral environments, 300-400 m of sandstone and conglomerate were deposited. In the neritic zones, schlieren was deposited. Lagoonal environments developed mainly by the end of Karpatian time. The total thickness of the sequence is 600-1000 m.

In Transdanubia, the basal Karpatian is a transgressive coarse-grained series with intercalations of schlieren and variegated, brackish, lignitiferous, and fish scale-bearing lagoonal deposits.

In southern Hungary, Ottnangian sediments are overlain by onlapping clastic rocks deposited in brackish water. In the inner parts of the basin, Ottnangian sediments are overlain by rhythmic molassic beds with a gradual transition to schlieren in the central part of the basin.

The second phase of Miocene volcanic activity occured at the end of Karpatian time. Volcanogenic sediments as well as andesites, dacites and rhyodacites have the greatest areal extent.

The sedimentary formations of the early Badenian are the products of one transgressive-regressive cycle. Sedimentation was controlled by differential subsidence of the basement, reflected by considerable variation in facies. The „Leitha limestone", a sandy-gravely, biogenic limestone of littoral and shallow water facies, was deposited along the margins of the subsided area. The hemipelagic „Baden clay" is interfingering with the limestone toward the basin margin. The oldest part of the transgressive sequence is made up by conglomerates along the margin but by sandstone in the basin. Uplift of the basement resulted in the formation of brackish water lagoons where lignite accumulated along the basin margin.

The late Badenian — Sarmatian sequence also represents one full sedimentary cycle. Acceleration of subsidence in the Pannonian basin resulted in the deposition of a transgressive sequence unconformaby overlying the lower Badenian beds at the margins of the basin. In the depression areas of a 300-500 m thick foraminifera-bearing argillaceous marl sequence was desposited containing upwardly increasing reef intercalations. This sedimentation pattern persisted in the early Sarmatian. A Sarmatian regression is suggested by the predominance of littoral facies. The characteristic sediment is a brackish water, oolitic limestone that shows a gradual transition to silty and shaly sediments in the areas of greater water depth. The maximum thickness of the Sarmatian sequence is 900 m. However, the thickness of Sarmatian sediments exceeds 300 m only in areas where the rate of subsidence was accelerated dramatically in late Badenian time. The Sarmatian regression was the final one in the Central Paratethys.

The youngest layers of Miocene volcanogenic sediments in Hungary are of late Badenian age. The thickness of the tuffaceous sediments in NE-Hungary, reaches more than 2 km. The related subsurface volcanic rocks of northern Hungary erupted along northeast- and northwest-trending fault zones.

In the Great Hungarian Plain basalt lavas and basaltic tuffs are present. Stratigraphically they belong to the lower Pannonian (s. l.) orimmediately underlie it.

The pannonian s. l. (that is the Pannonian s. str. and the Pontian) sequence represents the last megacycle of the evolutional history of the Pannonian basin. The earliest Pannonian s. str. series (i.e. the Lower Pannonian) has been deposited on Sarmatian or older formations. In the deepest subbasins the continuous sedimentation between the Sarmatian and Pannonian can only be inferred but cannot be proved unambiguously because of the extensive occurrence of turbidity flows.

The initial Lower Pannonian formations are partly coarse-grained and partly fine-grained clastic or chemical sediments. The coarse-grained detritus is connected with the islands of the Miocene inland sea. The other areas are characterized by argillaceous and calcareous marls. The latter two facies can be regarded as isochronous.

Within the study area the Pannonian basal conglomerate facies has been recognized in a number of wells. These rocks are essentially coarse-grained to medium-grained standstones with more or less gravel content. Locally fine-grained and medium-grained conglomerates and even boulders occur, too. These seemingly uniform sequences can be subdivided into subrhythms on the basis of fine-grained sandstone beds. In certain subrhythms the whole coarse-grained sequence shows a fining upward tendency. However, at some places the detected subrhythms consist of permeable and impermeable units. These latter are due to carbonate cementation. No significant orientation of the 1-40 percent gravel content can be observed. Stratification can be detected only in sandstones near the top of the sequences. The mainly non-stratified character and the grain-size composition suggest deposition in the abrasion zone. In the deeper structural positions the average grain size and the weight percentage of the pebbles in these sediments decrease. However, at some places the detected subrhythms consist of permeable and impermeable units. these latter are due to carbonate cementation. However vertically, approaching the top of the sequences the above-mentioned changes can be observed. (With increasing distance from the coast.)

In any structural position these coarse-grained sediments are overlain by calcareous marls containing pyritised plant remnants and/or bacteriopyrite nodules. The transitional zone between the lower coarse-grained stratum and these calcareous marls is characterized by some metres a interfingering of thick bedded fine-grained sandstones with carbonate matrix, siltstones and marls. Accordingly, the lithological transition is gradual and continuous. The sedimentation is also continuous upwards with the predominance of argillaceous marl beds. Here the marls and calcareous marls alternate with continuous transitions.

While the coarse-grained sedimentary sequence is restriced to the relative highs of the basement, the calcareous marl is widespread. Where the Pannonian is thain (e. g. Ásotthalom, Kelebia, Battonya) it is of bright-yellowish-grey colour and has been deposited presumably not very far from the coast. In the structurally deep regions, blackish-grey, bacteriopyritic and pyritic marls and calcareous marls with plant fragments belong to the lowermost Pannonian. They suggest a deep water, euxinic environment inherited from the Miocene.

The calcareous marls as chemical sediments are typical for shallow, medium deep and deep regions respectively and they were formed during a long-lasting period in the Early Pannonian. A reductive (that is euxinic) depositional environment is supposed to have existed in the medium-deep and deep zones at the time of the formation of calcareous marls.

This basal marl sequence is overlain by a thick series of deltaic sediments. The deltaic sequence is divided into prodelta turbidite, delta slope and delta plain units (Fig. 1).

The turbidite unit comprises a sand-rich system with the sand content varying from about 30 to 90 percent. The upper members are more sandy. These sand-rich turbidites in some places can be subdivided into several depositional systems on the basis of the characters of the vertical sedimentary sequences. In this way distal lobe deposits, amalgamated fans and channel sediments have been identified.

As the deltas advanced, coarse sediments were transported down the delta slope by slumping, in the form of density flows acting within the erosional gulleys and channels into the deep basin. Initially these flows were controlled by the bathymetric highs along the flanks and on the basin floor. Sediment transport pathways existed between these highs in the low regions until the delta advancement moved over them and filled these throughs. At least there deltaic progradational directions can be indentified in the Great Hungarian Plain. These are the NE, NW and the SW (Fig. 2).

The lobe sequence consists of repetitive bundles of upward-thickening sandstone beds containing thin marl laminations. This sequence rests on the basal marl. It is marl again that overlies the sandstone beds on the top of the deposit. The sandstones vary from fine to very fine in grain size. Sedimentary structures consist of graded beds containing Bouma sequences consisting mainly of Ta, Ta-e and Ta-b-e with rare Tc and Tc-e members. There are load structures, internal deformations, dish structures, mud drapped scours and thin sand laminae in marl form the remaining sedimentary structures. Overlying the basal lobe units and comprising the major part of the prodelta deposits are stacked beds of interbedded turbidities and marls. Depositional sequences are difficult to interpret due probably to the interfingering of multiple fan deposits derived from the advancing multiple deltas. However, repetitive upward thickening sequences which may represent interfingering lobe deposits are common. Amalgamated turbidites, shallow meandering channels, and possible deeper channel deposits are identified on cores.

The Bouma sequences consist of Ta, Ta-e (over the 60 percent of the turbidites), Ta-b, Ta-b-e, and Ta-b-c. Complete Bouma division, that is, Ta to e and Ta-b-c-d is characteristic only in the basal part of the turbidites overlying the basal lobe deposits. Besides graded and massive sandstone, load structures, flame structures, internal deformations, mud drapped scours, marl riping clasts and crossbeds, algamated sandstone beds and laminated sandstone and marl represent the sedimentary structures within this thick unit. The accretionary bank deposits consisting of planar to inclined alternating marl and sandstone composed of small-scale crossbeds suggest the existing of some meandering channels on top of the fan lobe systems. The accretionary bank deposits are overlain by sandstone containing argillaceous marl and siltstone clasts as well as laminated argillaceous marl and siltstone beds. Upward large-scale crosbedded sandstones and amalgamated turbidites overlie in turn the lower sandstone unit. This sequence may represent the basal part of a channel system.

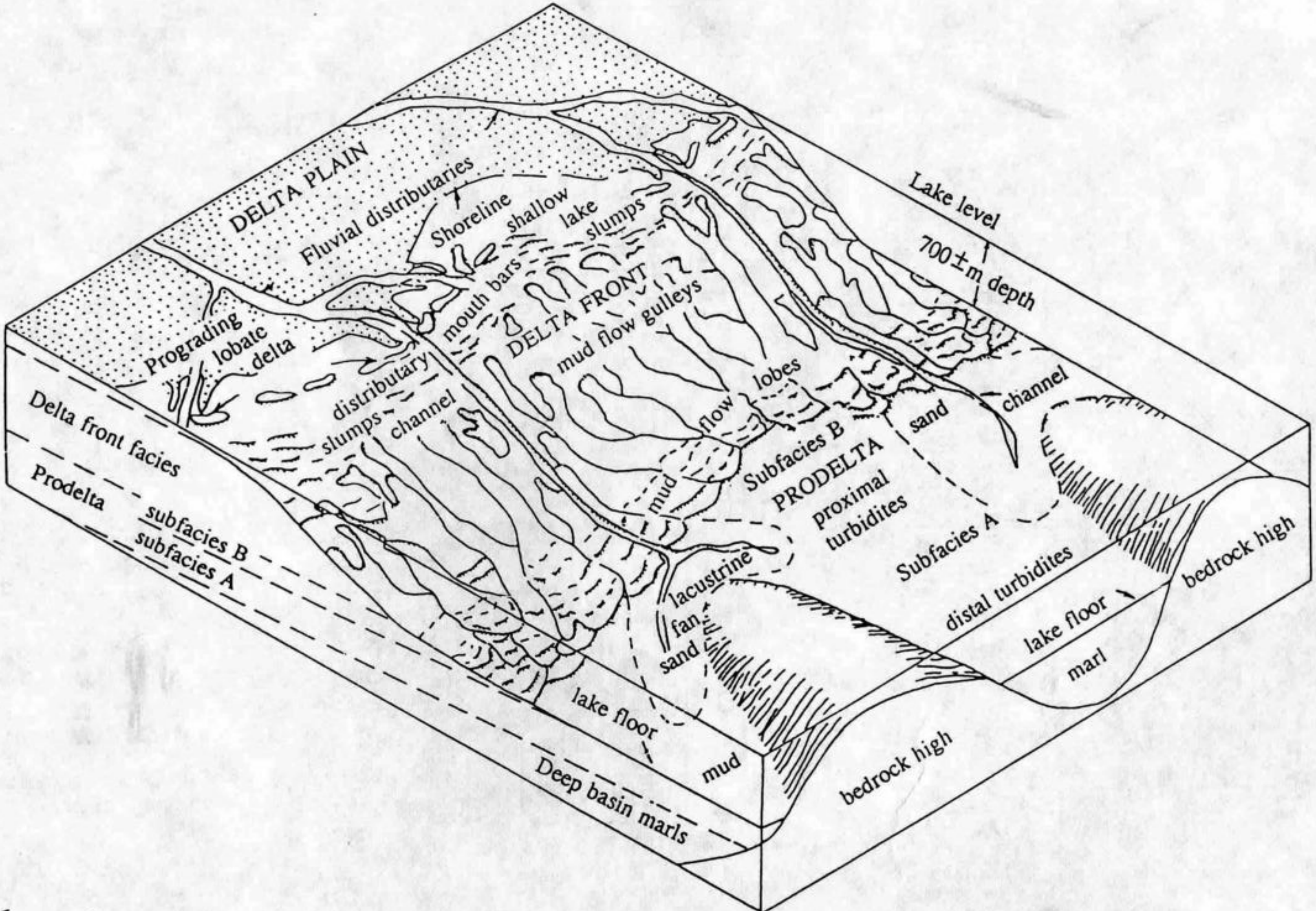


Fig. 1
Highly constructional fluvial-dominated delta system in the Makó—Hódmezővásárhely trough (after Phillips and Bérczi, 1985)

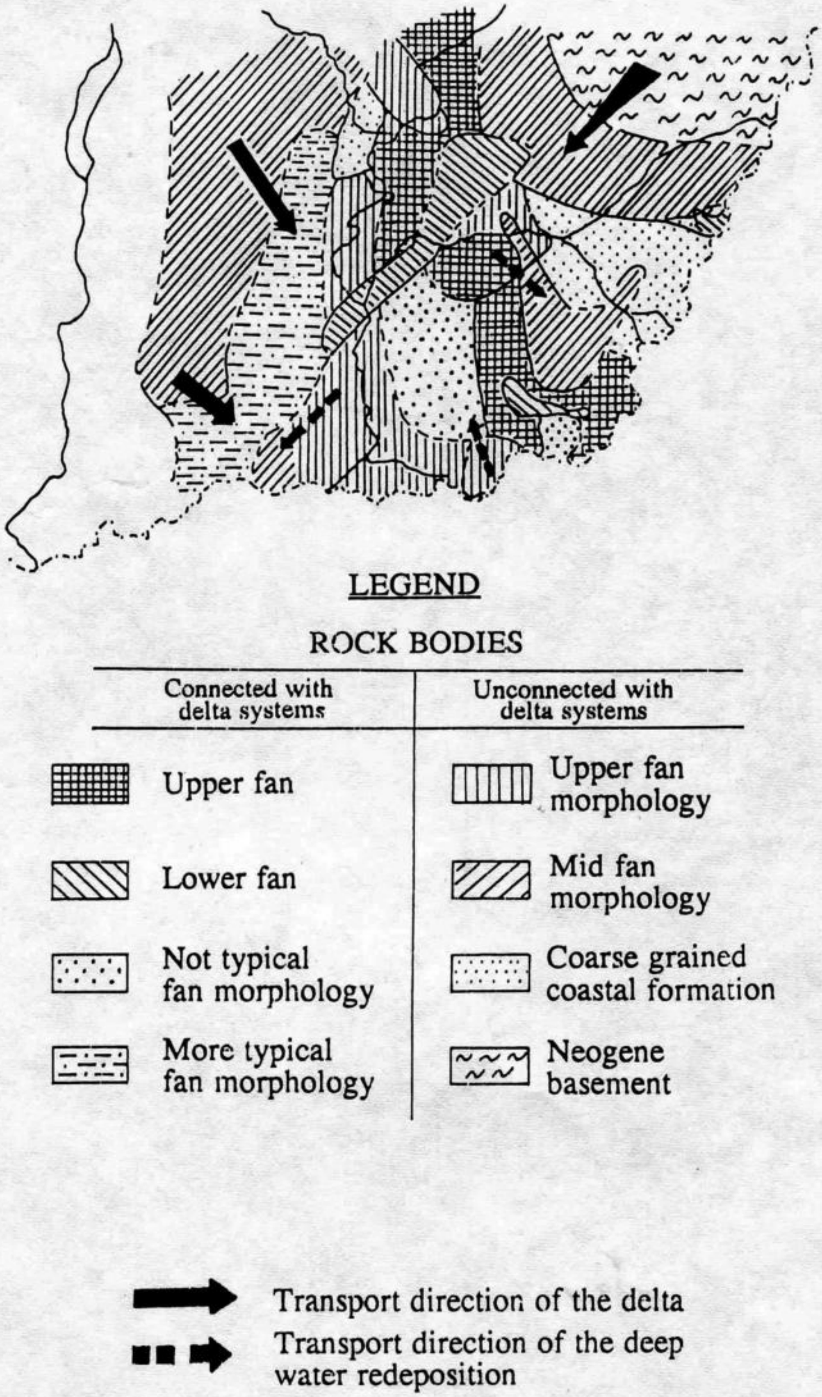


Fig. 2 Scetch map of the first prograding mega cycle (after Geiger—Révész, 1987)

Deformed turbidites as well as deformed laminated sandstones and marls representing slumped deposits can be found discontinuously in the upper part of the turbidite sequence and are rarely present at deeper depths. Overturned strata, vertical beds, abudant penecontemporaneous faulting or deformed strata form some of the depositional elements of these slump deposits. Horizontal bedded strata may bracket the deformed beds. Slumps developed from the prograding delta slope were carried into the prodelta region. This suggests that for the slumps to be carried into the basinal parts the deltas must have advanced over the bedrock highs surrounding them.

Turbidites in the upper part of the prodelta sequence exhibit increased sand content, contain abundant amalgamated sandstone beds and show increase in tractive currents as represented by crossbeds. The sandstone usually is of coarser grain size, ranging from medium to fine grained sand. Sedimentary structures include massive to graded turbidites containing Ta, Ta-e, Ta-c and Tc-e Bouma sequences, marl rip-up clasts, large- and small-scale crossbeds, dish structures, load structures and inclined or parallel bedded thin sand and marl laminations.

The overlying delta slope deposits record sedimentation controlled by gravity processes. These active processes range from downslope creep, traction currents, density currents, slumping and density gravity flows. Four main depositional sequences comprise the slope deposits: 1. alternating marl, siltstone and sandstone laminae interbedded with sandstone beds, 2. amalgameted turbidite sandstones, 3. deformed (slumped) beds of both types of strata found in 1 and 2, 4. channel deposits.

The main features the slope deposits are inclined strata with dips ranging from 3 up to 25 degrees, with most of the laminae and beds dipping between 3 and 8 degrees, however some beds appear to be horizontal or dipping at very low angles. Borehole recording indicates the abundant presence of well-developed silty marl laminae alternating with laminated sandstone, small to large scale down slope oriented cross-beds, amalgamated thin to thick massive sandstone beds or graded sandstone beds containing mainly Ta and Tb Bouma sequences with some beds containing Ta-b-c, Tb-c and Tc-d sequences, abundant rip-up clasts in sandstone beds, dewatering structures, abundant deformed strata, overturned beds, penecontemporaneous faults and distorted beds and scarce bioturbation represented by narrow vertical to horizontal burrows.

The delta plain sediments have been deposited with a facies change and angular unconformity on the sediments of the underlying delta-slope accumulations. This boundary can be seen on the electric logs by the sudden increase of sandstone content. The most important rocks are sandstones, siltstones and argillaceous marls. Hard sandstone with calcareous cementing material, marl, calcareous marl, coaly clay, lignite lenses and interbedding occur also frequently. Some scattered quartz gravel or gravel laminae are also present. The sequence consists of upward-coarsening distributary mouth bar sedimentary rhythms beginning with argillaceous marl or/and fine grained siltstone. Carbonized plant remants in vertical position, humic layers, leaf prints and layer sections with mica and carbonized plant remants laminae, small and large-scale crossbedding, distorted beds, horizontal bedding and lamination, inclined beds and laminae, frequent bioturbations are characteristic of this sequence of strata. The presence of quartz gravels in the fine-grained sediments indicates very contrary depositional energy.

The sandstone isopachous maps indicate channel-filling deposits. The sequence of strata above the deltaic sediments is composed of lacustrine-, fluvial-, flood plain-, marsh and finally eolic sediments as a result of the evolution until the present day.

Drinking water and thermal water-bearing formations of the Great Hungarian Plain

P. LIEBE

Quaternary and Upper Pannonian sand formations of the Great Hungarian Plain represent the extended, hydraulically connected drinking water- and thermal water-bearing formations in Hungary.

The good water-yielding sand beds — in deeper horizonts as sandstone beds — occur alternating with clay, marl and aleurit silt in the sedimentary sequence down to boundary between the Lower and the Upper Pannonian.

The greatest depth of this boundary in the southern part of the Great Hungarian Plain, that is, in the South-Tisza and Békés depression area reaches 2,5 km.

The Upper Pannonian sand-sandstone beds were deposited in an inland sea of gradually decreasing salinity. In the deeper horizons of the Upper Pannonian sedimentari sequence sand and sandstone beds are often embedding within clayey and marly formations in the form of lenses of various dimensions. The upper sediments are of fluviatile origin. The clay, marl and mud layers which separate the sand beds or form a no longer continuous impervious formation. This means that, the bearing sand units are connected with each other hydraulically in the vertical sense. The percentage of beds within the sedimentary sequence ranges from 10 to 60. The permeability of these porous beds ranges from 0.1 to 2.0 Darcy.

The Quaternary formations are of fluviatile origin. The sandy-gravely layers deposited by ancient rivers are also alternating with clayey-muddy beds, although the se do not form extended, impermeable beds. As a consequence, there are even, more effective vertical hydraulical connections in this horizon. The values of permeability within this coarse- and medium-grained sand formation of Quaternary age may range from 5 to 20 Darcy. In some very coarsegrained formations even higher permeabilites can be measured.

The original presure conditions of the Quaternary and Upper Pannonian sandy formations indicate according to certain studies that there is an underground flow system (Fig 1, 2) within the entire sedimentary basin. In the somewhat elevated areas covered by sand (that is, the Danube—Tisza interfluve area and the Nyírség in NE-Hungary) as well as along the northern border area of the Great Hungarian Plain the initial static water levels in the shallow, near-surface formations were higher by 30 to 40 m than in the deeper-lying regions of the basin. In these areas the static water levels were declining versus dept. This means that where vertical hydraulic conductivity allows it, an inflow, a downward migration can be taken place. According to hydraulic, radioactive and geothermal studies the downward water movement amounts about 20 to 40 mm/year in these areas (Fig. 3).

The infiltrating water stemming from the former areas moved towards the deeper areas of the basin. Under the original conditions some part of the groundwater flow ascended and contributed to streams and near-surface zones. The ascending motion was allowed by the higher static level of the deeper beds in comparison with that of the near-surface beds. In the depressed lowland areas the static water level of wells discharging from a few hundred meter deep aguifers was rising by more than 10 m above ground surface. However, this artesian overpressure and subsequent rising was stopped due to the decline in pressure.

The cooling and diluting effects of the above mentioned downflows can de observed most significantly in the subsidence area of the South-Tisza region where geothermal gradient is only of 40 to 50 °C/km in contrast to the characteristic value of 50 to 60 °C/km measured in the Geat Hungarian Plain. In addition, the bottom of the occurence

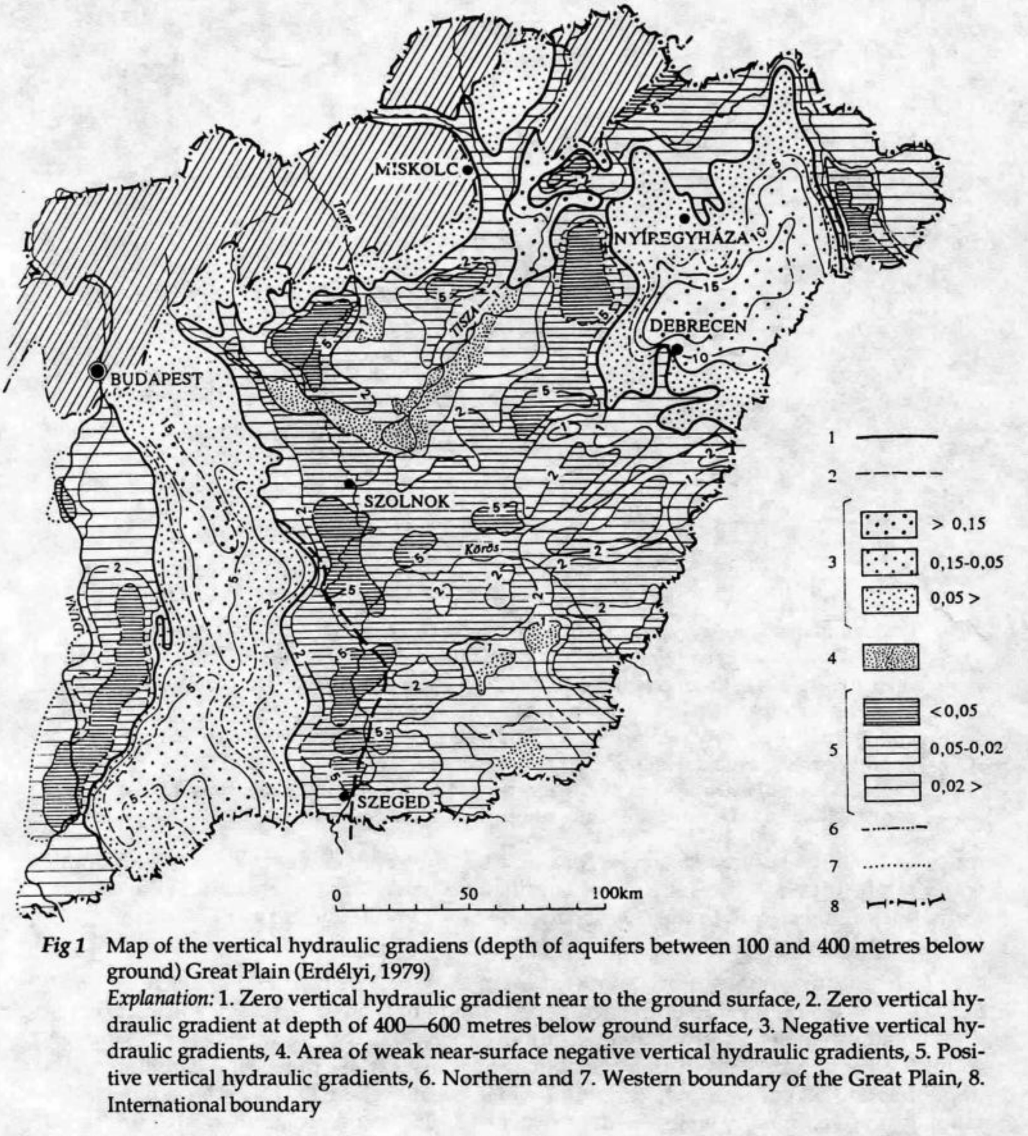


Fig 1 Map of the vertical hydraulic gradiens (depth of aquifers between 100 and 400 metres below ground) Great Plain (Erdélyi, 1979)
Explanation: 1. Zero vertical hydraulic gradient near to the ground surface, 2. Zero vertical hydraulic gradient at depth of 400—600 metres below ground surface, 3. Negative vertical hydraulic gradients, 4. Area of weak near-surface negative vertical hydraulic gradients, 5. Positive vertical hydraulic gradients, 6. Northern and 7. Western boundary of the Great Plain, 8. International boundary

of chloride-ion concentration less than 10 mg/l is about 500 m deeper than in other areas of the Great Hungarian Plain. The downflow is allowed here by the higherthan-average sand percentage within the sedimentary sequence which is characteristic of the Danube-type sedimentation. The region of Danube-type sedimentation is separated from that of the Tisza-type by a line of NW-SE direction connecting the villages of Tiszakécske and Makó. East of this line the percentage of coarse-grained sediments is less. The abovementioned downflow after reaching the thermal water-bearing horizon, was constrained to reserve at this boundary and the warmed-up waters began to ascend and provided heated zones as well as geothermal anomalies. Its most typical example is the Tiszakécske area where the geothermal gradient exceded the value of 70 °C/km (Fig. 6/a-b).

According to intensive studies the quantity of ground water flowing from the above mentioned elevated areas and from the border region of the northern basin towards the central parts of the Great Hungarian Plain under original conditions was

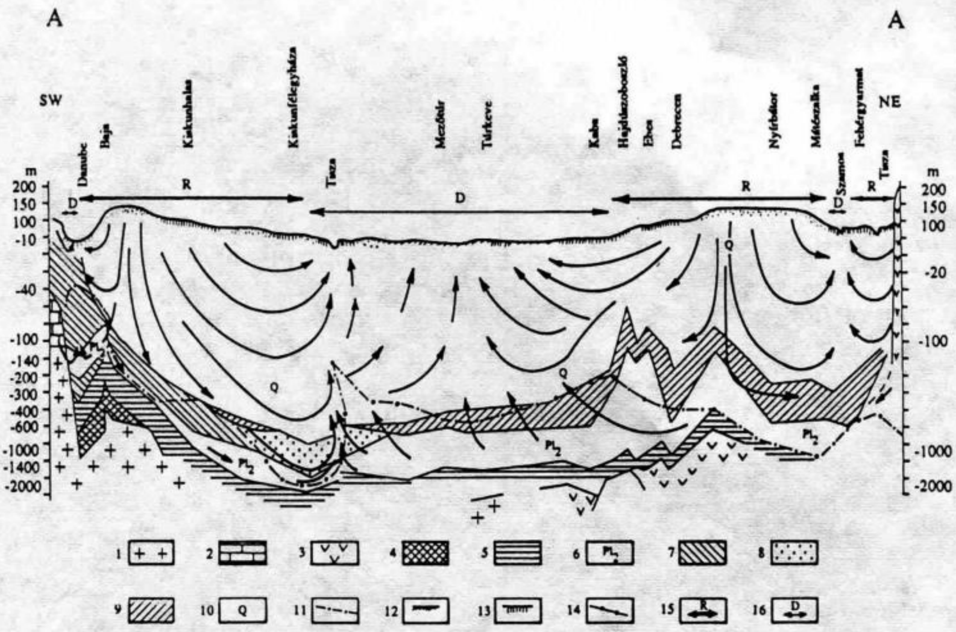


Fig. 2 Diagrammatic flow-pattern of the Great Hungarian Plain (Erdélyi, M. 1972, revised 1977)
Explanation: Lithology and stratigraphy: 1. Crystalline basement, 2. Mezozoic limestone, 3. Miocene volcanics, 4. Miocene sedimentary deposits, 5. Lower Pannonian (Pliocene), impermeable or poorly permeable, 6. Upper Pannonian (Pliocene), permeable, 7. Upper Pannonian, impermeable or poorly permeable, 8. Highly permeable Upper Pliocene, 9. Impermeable or poorly permeable top the Pliocene, 10. Quaternary.
Surface deposits: 11. Dune sand and loessy sand, 12. Impermeable alkali soils, 13. Moderately permeable soils, 14. Fresh-water and brine interface, 15. Recharge area, 16. Discharge area.

much as 1 million cubic/m/day. According to isotope studies a considerable part of this water can be found in the Tisza river. Originally it entered the river through the shallow formations connected with the river bed while nowadays it does so partly indirectly (waters extracted by wells).

The mean annual surface temperature in the Great Hungarian Plain is about of 10 to 12 °C. The average value of the geothermal gradient is 50 °C/km. This means that at a dept greater than 400 m groundwater of more than 30 °C can be found. Taking into account the cooling process in the wells the boundary can be practically considered at a dept of 450 to 500 m from where groundwater warmer than 30 °C can be exploited. (In Hungary conventionally wells yielding water of temperature higher than 30 °C are called thermal water wells).

For the purpose of development and exploitation of drinking water resources sand formations occurring in the sedimentary section between 50 m and 500 m can be taken into consideration. For the time being a groungwater quantity of about 1 million cu.m/days is extraced from this aquifer system. A greater part of this extracted ground water is recharged from the overlying shadow porous beds. The source of recharge is partly the increased infiltration in the original areas of inflow, partly the stop of earlier ascension of ground water onto the depressed areas. In the Danube — Tisza interfluve area the inflow might have been decreased under natural conditions due to the drought of the last decades. However, this decrease could not be followed due to the ground water exploration from the drinking water-bearing formations and due to the resulted drawdown. The low rate of infiltration derived from precipitation, the unchanged evaporation and the inflow affected regularly a regional decline of the phreatic water level (Fig. 4, 5).

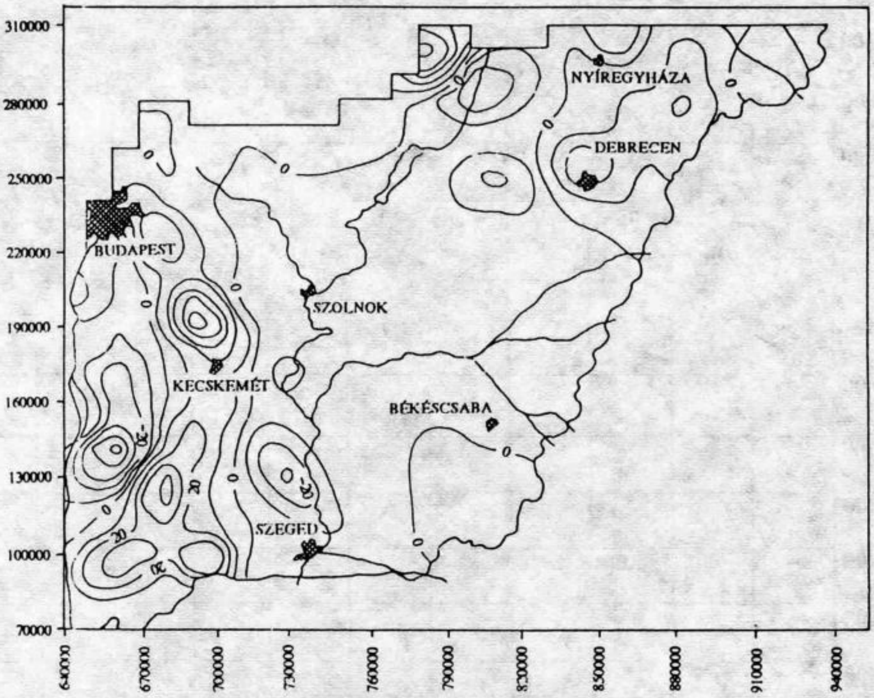


Fig. 3 Values of the natural recharge reaching the lower Pleistocene layers calculated by numerical modelling (mm/year) (VITUKI, 1991)

In those areas where evaporation from the phreatic water body is diminishing with alogh a decline of the phreatic water level, a new state of equilibrium can be formed after a low-scale decline of the phreatic water level. On the contrary, in such areas where phreatic water level was situated at a depth of a few meters and its decline could not be affected by evapotranspiration, the development of a new state of equlibrium might be exepected only after decline of the phreatic water level of several tens of meters. In these areas if draught will be continued the application of artifical recharge migh de required.

Tabl. 1

Groundwater production in the Great Hungarian Basin
(Million m^3/year)

Temperature range (°C)

Year	<30	30-50	50-60	60-70	70-80	80-90	90-100	>100
1950-1959	55,6	6,8	0,3	1,5	0,4	0,0	0,1	0,0
1960-1969	313,2	22,3	1,2	5,6	1,6	0,9	1,7	0,3
1970-1974	221,8	39,9	3,4	10,4	5,2	4,7	7,1	0,9
1975-1979	289,4	46,0	4,0	11,2	6,4	5,7	7,3	0,9
1980	334,3	43,3	3,9	10,7	6,2	6,5	8,1	0,7
1981	348,9	43,4	3,8	11,0	6,4	6,7	7,8	0,7
1982	363,8	45,6	3,7	11,0	6,8	6,7	7,8	0,7
1983	363,3	46,1	3,7	11,3	6,8	7,3	7,8	0,7
1984	365,7	46,3	3,7	11,2	6,8	7,8	9,2	0,7
1985	388,3	47,5	3,8	11,3	6,8	7,8	9,2	0,7
1986	401,6	49,7	4,1	12,0	7,1	7,8	10,2	0,7

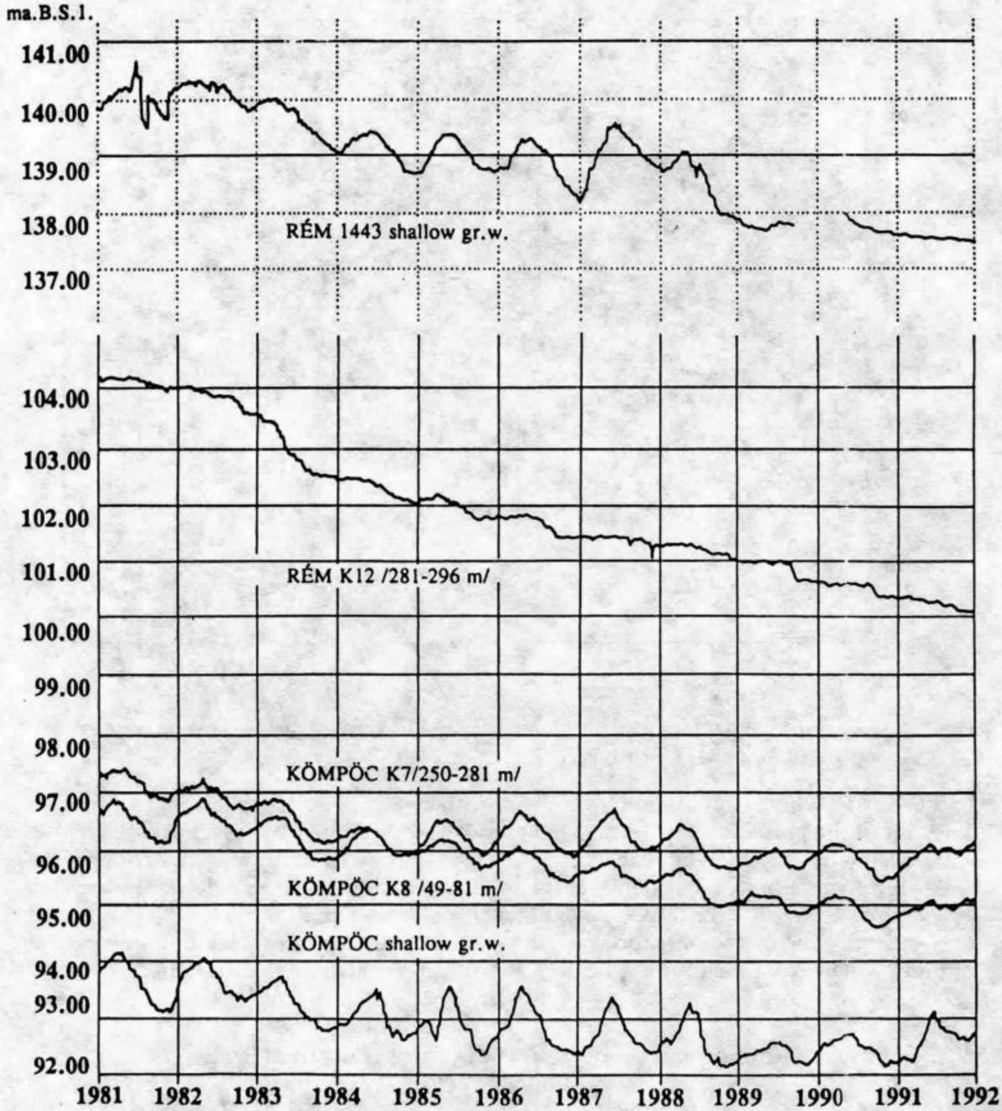


Fig. 4 Changes of the groundwater level in the south Danube-Tisza region

Under the influence of ground water exploitation until now from the drinking-water-bearing formations a decline in ground water level or in pressure of an order of magnitude of 10 m was followed which can be even of 20 m to 30 m around sites of concentrated ground water withdrawal. Nevertheless, ground water exploitation does not limit this drawdown since water-yielding formations occurs mostly at a depth of more than 100 m and as a consequence — with the exception of some shallow aquifers — there is no such a danger that water-yielding formations of the wells might be dried up. The limit of groundwater exploitation is marked rather by the effects and consequences of this drawdown, that is, the increase of the inflow and downflow derived from the phreatic water zone, the pollution transported by this downflow, as well as land subsidence at some places, due to compaction and consolidation caused by the drawdown.

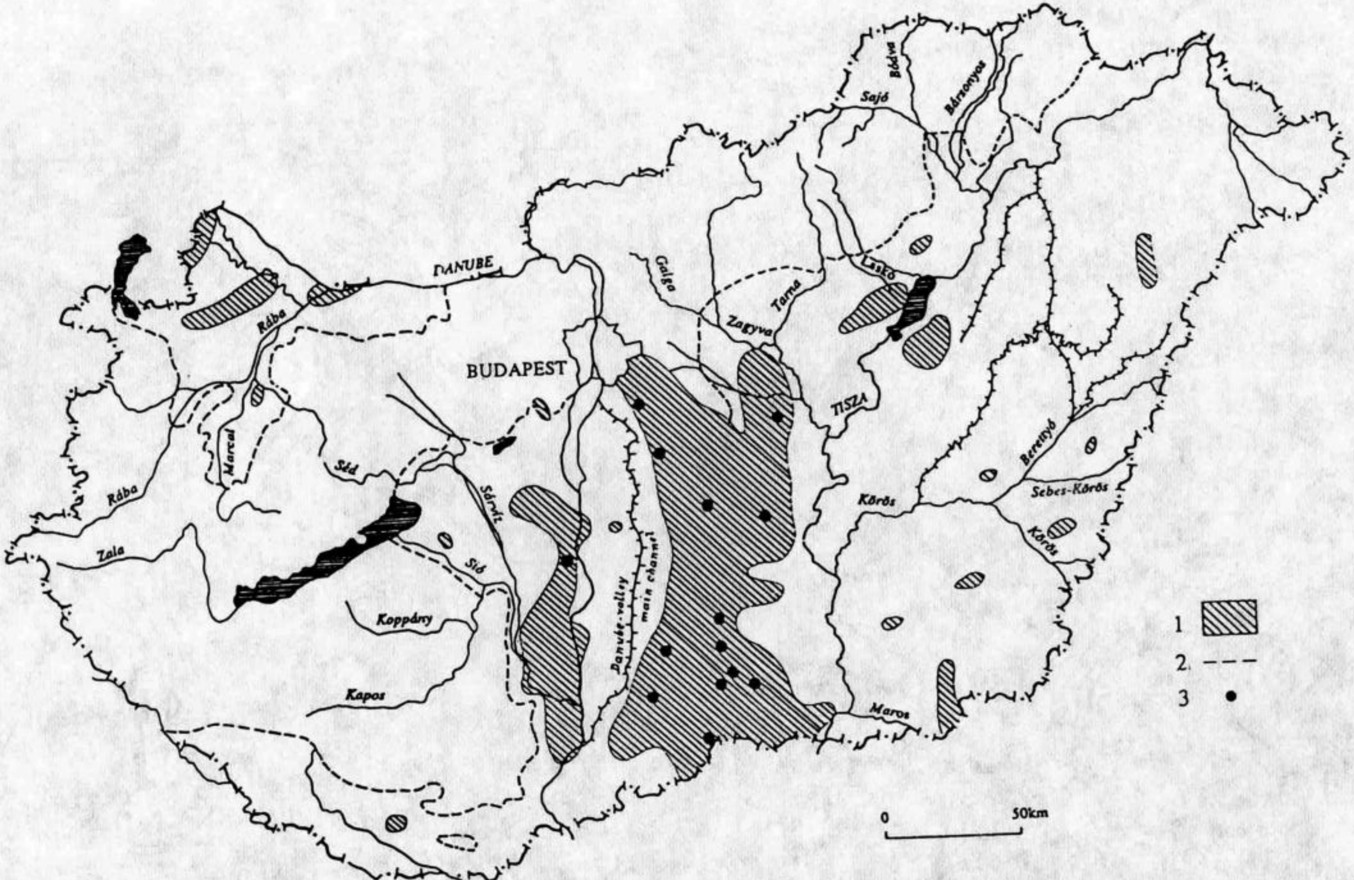
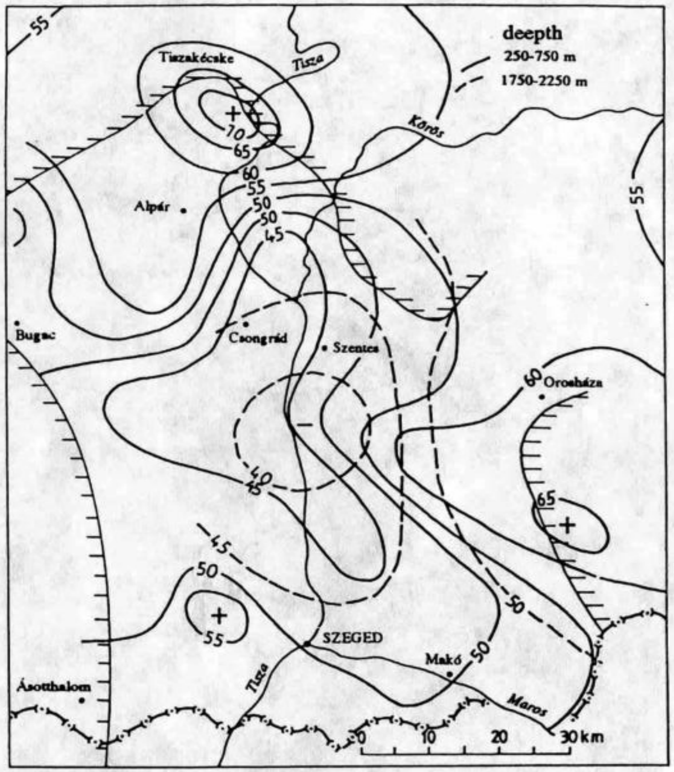
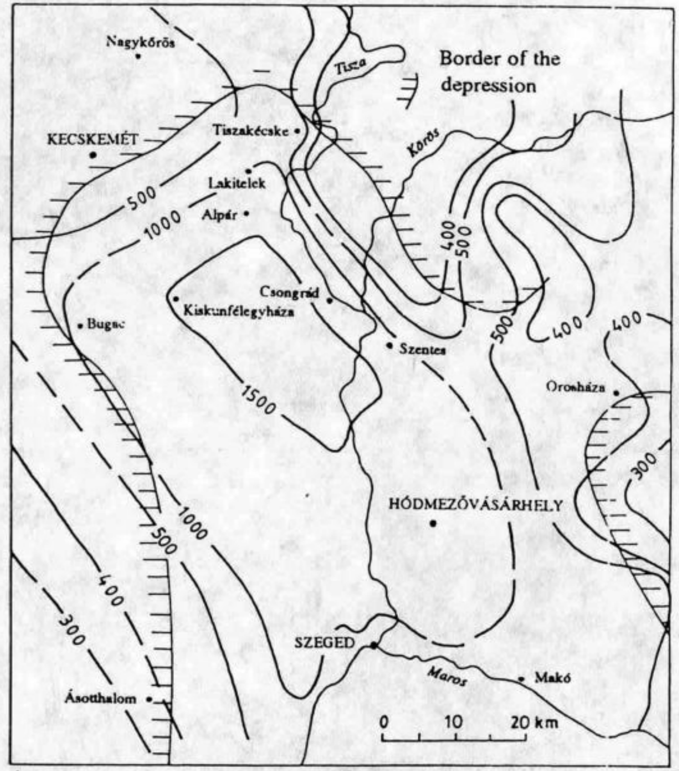


Fig. 5
Areas in Hungary with significant depression of water level in the shallow on groundwater horizon; 1. Areas with lower depression of water horizon in the shallow groundwater than 1 m between March-May 1956-60 and March-May 1990; 2. Border of low-land and hilly areas; 3. Shallow groundwater observation wells with water horizon depressions above 2 m.



a

Fig. 6/a
Geothermal gradient in the South-Tisza region (°C/km)
(Erdélyi, M. 1977)



b

Fig. 6/b
Bottom of the phreaticwater horizon in the South-Tisza region (m)
(Erdélyi, M. 1977)

Drinking water-yielding formations is the Great Hungarian Plain — with the exception of some shallow aquifers — can be considered as aquifer systems protected against contamination derived from the land's surface. The rate of inflow derived from the land's surface ranges from 0,1 to 1m/year. A part of the contamination will descend even slower than that of the water particles due to adsorption and chemical changes.

The danger of nitrate pollution of agricultural and communal origin may be diminished at many places by the considerable denitrification capacity of the near-surface layers.

A greater part of the quality problems of ground waters is of natural origin: arsenic, methane and humic acid exceeding the limit values and hardness than normal are responsible for these problems which exist mainly in the depressed areas of the Great Hungarian Plan where the role of recharge deriving from the border areas is lower even absent. The best quality water can be found in the coarse-grained formations which are replenished by „fres water" arriving from the border zones. In some aquifers of this kind, however, iron and manganese contents higher than the limit values may cause problems. In the middle part of the Greatest Hungarian Plain, in the upper few hundred meter sedimentary section occur formations of very low water-yielding capacity. For practical reasons, deeper aquifers containing thermal water should be developed and exploited for drinking water supply. The relative high temperature of this groundwater may cause secondary contamination problems within the drinking water distribution network.

The termal water exploitation in the Great Hungarian Plain amounts for the time being about 250 000 cu.m/day. The temperature of this extracted thermal water ranges from 30 to 100 °C. The most excessive thermal water withdraw is carried out in the southern part of the Great Hungarian Plain, in the surrounding of Szentes and Szeged. The extraction of enormus quantities of thermal water results in the decline of pressure by 1 to 2 bar on the average. Around sites of concentrated extraction pressure decline can exceed even 5 bar. In such areas due to the drop of pressure and where a vertical-hydraulical connection may exist an increased recharge can take place from the overlying formations and the extracted thermal water will originate from this zone. In the sandstone aquifers of definitely confined type occurring near the Lower- and Upper Pannonian boundary the ratio of the extracted water deriving from the storage is greater since it was released from the elastically compressed water and rock body. Nevertherless, thermal water extraction is limited by the recharge which is derived from the upper cold water-bearing formation, that is, from the shallow aquifers containing phreatic water. Where this kind of recharge is low, withdrawal is limited by the high decline of pressure.

The total solid content of thermal waters exceed generally the value of 2 g/1 (with the exception of waters which are intensively replenished from the overlying strata). As a consequence, the disposal of used thermal waters in special pits or pools on the surface has some problems. Consequently thermal water exploitation for heating purpose without water reinjection-repressuring system must not be allowed in the future, altrough recently performed reinjection tests have been not very successful.

The superficial formations of the Great Hungarian Plain

L. KUTI

The surface of the steadily sinking basin of the Great Hungarian Plain is covered by Upper Pleistocene and Holocene sediments. The framework of the superficial deposits is represented by fluvial and aeolian complexes of Pleistocene provenance making up the major part of these sequences. At a same time, some Holocene sediments can be observed in river valleys, on flood-plain areas, in flatlands between hills and sand dunes as well as in certain areas covered by aeolian sands.

Apart from bringing about a large number of different relief patterns, the uneven sinking of the Great Hungarian Plain going on up to the present day gives rise to a great variety of the processes of sedimentation together with the related sediments. As for the continuous action of the wind resulting either in erosion or in aggradation of the actual landscape, it forms a wide range of aeolian sedimentary complexes of different relief characteristics both in zones of accumulation and deflation by removing fluvial sands from their original localities and redepositing them in another environment.

In addition to the separation on a morphological and genetic basis, there is an opportunity of areal delineation of the fluival and aeolian sequences in the Great Hungarian Plain along with the remnants of fluvio-aeolian bodies preserved in areas affected by deflation and some lakes created between the lines of dunes and sandhills.

According to relief patterns as related superficial and near-surface sediments, the Great Hungarian Plain can subdivided on typical fluvial and aeolian land units from W to E.

Even though Mezőföld is situated W of the Danube river, it is considered geographycally as belonging to Alföld making up its westernmost intermediate land unit. Its superficial and near-surface sediments are constituted mainly by aeolian formations. The major part of the area is convered by a thick-loess sequence affected considerably by redeposition resulting in the formation of sediments washed down from slopes as well as solifluctional deluvial beds. With regard to aeolian sediments, windblown sand can be considered as the most typical formation of the S part of Mezőföld. It derives from sandy deposits od Upper Pleistocene fluvial terraces. At the same time, stream valleys dividing the area are made up of fluiviatile sediments.

The Danube valley representing the lowland between Pest and Mohács brought about by the gradually superimposed sediments of the Danube from the middle of the Pleistocene and affected later considerably by erosion. Gravels and sandy gravels of varying thicknesses (5-30m) constitute the oldest and deepest formations below the surface. They are overlain by sand showing equally variable thicknesses. According to some hill remnants observed in the Danube valley, this sand had once been substantially thicker, but its major part was blown away by prevailing winds at the end of the Pleistocene and, to a lesser extent, in the Holocene and redeposited successively on the range in the interfluve between the Danube and the Tisza rivers.

Except for the hills and some upland areas, fluvial sands are covered by silt and clayey silt affected by salinization in extensive areas in the N part of the Danube valley (approx. up to the line of Solt). The S sector the valley is described, in turn by the formation of peat and the presence of peaty patches. Occasionally, the thickness of peat in the Danube valley can exceed 4m.

Toward E the next land unit is represented by the range of the Danube-Tisza interfluve made up essentially of aeolian deposits described by NW-SE striking lines of aeolian sandhills as well as by loess ranges. These two typical aeolian formations alternate both laterally and vertically. Widely extended areas are characterized by the succession of sand and loess making up 2-4-m-thick horizons, whereas one of them becomes occassionally thicker, exceeding even 10m.

In flatlands between hills and dunes saline lakes and lakes with accumulation of carbonate mud as well as occasionally some peaty terrains can be observed. Sediments bearing carbonate mud or peat identified in near-surface position indicate the similarity between the Late Pleistocene and the present-day landscape.

The Tisza valley and the land unit E of the river Tisza is reffered to as a lowland made up of fluvial clayey, silty and sandy sediment deposited by the Tisza river and its tributaries. Fine-grained sediments prevail on the surface, whereas sandy patches occur also frequently. It should be noted, however, that according to mapping boreholes, the substantial part of this region can be described as a gradually fining upward sequence of fluvial deposits ranging from sand to clay. There are hardly any aeolian sediments by salinization, whereas large areas were covered by marshes and peat elsewhere. Unfortunately, the majority of the latter became the victim of man's activity.

Another aeolian unit follows toward E represented by Hajdúság and Nyírség in the NE part of the Great Hungarian Plain.

The former one is principally made up of loess of variable thicknesses ranging from some metres up 10-20m, frequently enriched in clay. Due to the action of water from rainfall accumulating in depressions of the surface as well as the surface wash from adjacent areas, silty and clayey sediments, occasionally several metres thick developed.

The surface of Nyírség is covered predominantly by wind-blown sand, subordinately by loess. As in the Danube-Tisza interfluve, the profile of this area is likewise made up of the alternation of 2-3-m-thick and loess horizonts. The principal difference observed between the sediments of these two land units is due to the that the formations of Nyírség are exempt of carbonates. Flat areas between the N-S striking hills are constituted here by finer-grained Holocene deluvial and limic sediments rich in organic matter.

The easternmost corner of the Geat Hungarian Plain bears a tiny lowland, called Szatmár Lowland built up of fluvial sediments. Superficial deposits of this land unit are equally represented by Upper Pleistocene and Holocene fluvial sequences. The base of this sedimentary series occasionally 20-40m thick is made up sporadically of gravel, but principally of sand overlain by variably thick silt or clay. Depressions of considerable extent facilitated the formation of peat here as well whose most typical example is provided by the Ecsed marshland. It has partially been destroyed at the beginning of this century by burning the peat of its surface with its rest burnt down some years ago.

Bodrogköz is a land unit clearly distinguished from the Szatmár Lowland and Nyírség. It has been developed by the combined effect of the rivers and the wind.

Drifting sand dues occur principally at Zemplénagárd, but some minor ones can also be located on the surface in the vicinity of Kenézlő. Considering the origin of its material, it can be identified as the wind-blown sand of Nyírség. It is not the one, however, covering the surface there but that buried in 5-20m depth.

In the range of depth between 10-30m below the surface fluvial sand, occassionally even sandy gravel prevail in Bodrogköz passing to sand, silt and clay upward the profile. Some spots of peat can equally be observed on the surface.

A typical feature of the whole area of Bodrogköz is the presence of an onbroken sand horizon in the range of depth between 2-5m below the surface as underlying the superficial almost uniform clayey, silty clay layer. The former has a determining role in the water management of the area.

An outlook of some problems of agrogeology, soil science, engineering- and environmental geology and nature conservation in the Great Hungarian Plain (Pannonian Basin)

G. Greschik[1], A. Iványosi-Szabó[2], L. Kuti[3], G. Raincsák[4] and K. Rajkai[5]

Introduction

The central part of the Pannonian Basin is mainly in the territory of Hungary. This deep basin if comparison to other intramontane basins is unique in many aspects, such as the geological setting, the relatively young age of the preTertiary basement, the reduced thickness of the crust the structure of the mighty sedimentary sequence.

The morphological and geological features control the environmental conditions of the Great Hungarian Plain and the particular tasks of agrogeology, soil science, engineering geology and hidrology, environmental protection and land use.

AGROGEOLOGY

The main objectives of agrogeological research include the elucidation of the interrelations in the complex system soil — parent rock — groundwater, the processes taking place therein as well as the factors influencing the system as a whole and its different entities.

The interrelations between agrogeological problems emerging in the Great Hungarian Plain are controlled by different features of the superficial and near-surface geological setting together with the behaviour and quality of ground-water stored and percolating in the related sediments. Consequently, different problems come up in various terrains bearing specific geological features like aeolian or fluvial sediments. The problems are markedly different in areas made up of sandy or clayey deposits or in regions affected by high ground-water level.

One of the principal adverse effects emerging in areas covered by sand is the risk of deflation associated with the granulometric composition and compactness of these sands, the degree of development of their humic layer as well as with the hydrostatic level of the related ground-water. The Nyírség area and the elevated region of the interfluve Danube-Tisza, both of them constituted by wind-blown sands, are mostly affected by deflation.

The phenomenon of soil acidification as well as inherent soil acidity are also related top sandy terrains. There is a difference between the two afore-mentioned typically aeolian land units in this respect. The $CaCO_3$ content of sands in the interfluve Danube-Tisza varies essentially between 10-20%. Grains of limestone and dolomite occur frequently between prevailing quarz granules. On the contrary, the sands of Nyírség are practically free of carbonates.

A certain disparity of agrogeological conditions can be observed between sandy areas characterized by a thick sand sequence exceeding occasionally the thickness of 10 m and those bearing only a 2-5 m thick sand on the surface underlain by some fine-grained sediments, such as loess, clay, etc., or by a fossil soil horizon. The latter bring about, namely, bening effects in the superficial sands considering the regime of nutrient elements and that of ground-water.

[1]Engineering geology, [2]nature conservation, [3]agrogeology, [4]introduction, environmental geology, [5]soil science.

Salinization and inundation by inland water can be referred to as the most serious factors provoking adverse effects in morphologically deeper situated areas made up of clay and silt. Both phenomena are associated with certain geological conditions.

Salinization is basically related to regions where ground-water flowing from various directions is accumulated and becomes stuck (for example in the Danube- and Tisza valley). These sites function like a trap. Ground-water stuck in these traps cannot flow away, it can only be discarded by evaporation resulting in the sanilization of the related surface by precipitating salts.

Permeability of the superficial and near-surface sediments along with the hydrostatic level of ground-water below the surface can be regarded as the crucial geological parameters controlling inundation hazard by inland water. Impermeability inhibits or slows down the infiltration of precipitation, while high ground-water level keeps this infiltrating water back which leads to the accumulation of precipitation on the surface. Three types of areas, namely river valleys, fluvial environments of the region beyond the Tisza river and small depressions between hills in aeolian terrains are particularly struck by this phenomenon.

We have been studying steadily the agrogeological aspects of the Great Hungarian Plain, like the ones discussed above and those which could not be handled within the framework of this paper. One of the basic tools for the elucidation of the basic geological features controlling pedological conditions and vegetation is the research of model areas. On the other hand, the agrogeological interpretation of data acquired during geological mapping also contributes to the solution of emerging problems. Maps compiled by means of these two procedures serve for featuring typical agrogeological aspects.

SOIL CONDITIONS

Main characteristics of natural conditions of the Pannonian Basin can be summarized in the continental climate, the potential vegetation of forest-step and hydrologically the extensive occurence of surface and shallow ground water reservoires.

Hydro-geographycally the Basin can be subd:vided into areas without and with ground water effect. On the territories without ground water effect, the zonal soils are the chernozem soils. Brown forest soils occure on the illuviated sand areas while different sandy soils are on the calcareous sand dunes of the Basin. There is no regular pattern in the occurence of the chernozem soils. The areal localization of the two (typical and lowland) subtypes of chernozem soils show similar distribution as it is in the parent material of the two subtypes; the coarse textured transdanubian loess and the more clayey lowland loess. The erosion takes the chernozem soils even more variable. On those territories where the effect of surface or subsurface waters appear in the soil formation solonetzic meadow and meadow, alluvial soils and their complexes occur.

Localization and extension of these soils types is determined by depth and chemical composition of the ground waters and intensity of the leaching. Under more expressed water effects peaty meadow soils are formed. The accumulation of organic materials are the main characteristic of this hydromorphic soils types. In some of the soil types (salt-affected and associated as well as sandy soils) of the Great Hungarian Plain the mineralogical compositions were deeply investigated and their relations to soil formation were found out. The maps of clay mineral associations in soils of Hungary were completed in the scale of 1:500 000. The data prepared for the map were evaluated to elucidate the role of clay minerals in soil formation, as well as in soil fertility. The micromorphology of salt-affected and associated hydromorphic soils as well as of chernozems of the Great Hungarian Plain were studied and the relations of the micromorphological features and formation processes were revealed.

ENGINEERING GEOLOGY

Engineering activity usually troubles strata consisting of Holocene, Pleistocene, and Pliocene sediments situated not deeper than some 10 to 20 m from the ground surface. The depth of the ground water table varies from less then 1 m through about 12 m.

Sand, peat, flood-plain mud and clay represent the Holocene.

Sandy-, silty- river sediments, silt, various types of loess and loess loam, slope clay exemplify the Pleistocene.

Slightly more consolidated, but still rather loose clayey, silty, sandy and loose calcareous sediments embody the upper part of the Pliocene.

A young sediment is generally an inconvenient ground (building) material.

The *loess* is a collapsible soil: the large pore volume, and the fragile calcareous cement between the grains result in large sudden settlements if the soil loaded by the weight of building becomes saturated.

The material of the *former sand dunes* is a poorly graded loose fine grained sand behaving as a quick, flowing mud when water is forced through by dewatering a working pit, or around a man-made embankment levée when retaining high water level of a river during a flood period:

Loose, saturated *soft clay and silt* results in long consolidation periods with large settlements when loaded by foundation.

The frost heave in the *clayey and silty* substrata may damage the road structure if the ground water table is in the proximity of the pavement. A long heavily cold winter period results in building up of frozen water lenses in the ground frost heave.

Peat is an unconvenient foundation ground.

ENVIRONMENTAL GEOLOGY

The already discussed branches of applied geology are closely collaborating with each other discipline for environment protection.

The Great Hungarian Plain is one of the most pollution-vulnerable landscape units in Hungary.

The most urgent tasks have to be faced in the fields of deposition and secondary utilization of industrial waste, as well as in the implementation of environment-friendly industrial and agricultural activities.

In the previous years, waste was simply deposited in depressions of the ground surface, without any geological expertise. This inadmissible practice must be changed. The waste disposal sites have to be established on the basis of geological studies. Geology has to contribute also to the complex monitoring system of the operated sites.

More and more local authorities request geological expertise for their planned waste disposal sites and pollution-hazardous waterworks.

Legal regulation of these problems will soon be issued in the framework of a Law on Environment Protection.

NATURE CONSERVATION

The lowland region of the Pannonian Basin is from a biogeographical point of view one of the 193 existent, independent biogeographical biomes of the Earth. It belonges to the Pannonian domain, wich is one of the most smallest ones. About 50% of this biom is to be found is Hungary. Therefore, it is not incidental that our counry's most important goals regarding nature conservation (and the most outstanding conservation values) are linked with this area.

The ultimate biogeographical features of the Pannonicum:

— the temperate-continental climate, which is an outcome of the geographical situation;

— the basin-effects designed by the Charpatian Mountains (as well as the Alps and the Dinarids) as the climate, the centripetal water-network, the persistence of the saline lakes and swamps;

— the frequent occurence of the transience determined by geofactors and the marginal range situations (the soil-development, the Western border of continental salinification, marginal areas of range of many plant- and animal species);

— it is a region of crucial importance in the bird-migration route crossing Central-Europe in N-S direction;

— as an outcome of the above mentioned facts, this area is the habitat of a great number of endemic plant- and animal species. The great number of communities typical only to this region is also worth attention.

The protection of the typical values of the area — beside the general aspects and prescriptions of the *species-protection* — are guaranteed by the Hungarian Nature Conservation in *national parks, landscape protection districts, nature conservation areas* and *natural monuments* (see Table 1. and Figure 1.)

Table 1

PROTECTED AREAS ON THE GREAT HUNGARIAN PLAIN

Denomination		Protected units	
		Number	area (thousand ha)
National park		2	89
from this	Hortobágy NP	1	53
	Kiskunság NP	1	36
Landscape protection district		17	145
Other areas under protection		350	60
Alltogether		**369**	**294**

The outstanding natural values of these protected areas are linked the following biotopes:

— large saline plains and their wet parts;

— the flood-plain and tite lands of the regulated rivers;

— freshwater swamps and bogs;

— sand-"pusta" (short-grassed lowlands) and sand-dunes of eolian origin.

From the lowland areas of our country, the two national parks as are *UNESCO Biosphere Reserves*. These and 8 other protected areas under the auspices of the *Ramsar Convention* (which aims the protection of wetlands of international importance) are linked with the nature protection programmes beyond national level.

RECOMMENDED LITERATURE

Agrogeology: Kuti 1981, 1986, Pécsi 1967, 1969, Rónai 1985.

Soil science: Darab—Gerei—Reményi— Szendrei 1971, Darab—Gerei 1978, Gerei—Szendrei 1974, Gerei— Darab—Reményi-Pártay 1966, Gerei 1978, Stefanovits 1963, 1985, Stefanovits—Dombovári 1985, 1986, Szabolcs 1965, Szendrei 1970, 1974, 1978, 1983, 1988, 1990 a, b, Szűcs 1970, Várallyay 1985, Zentay—Rischák 1983 a, b.

Engineering geology: Galli 1977, Greschik—Boromisza—Molnár 1975, Jámbor—Moldvay—Rónai 1966, Rónai 1967, Rónai—Szentes 1972.

Environmental geology: Kuti 1981, Raincsák et. al. 1988, Rónai et. al. 1963, 1969, 1981.

Nature conservation: Tóth A. 1988, Tóth K. 1979, 1985.

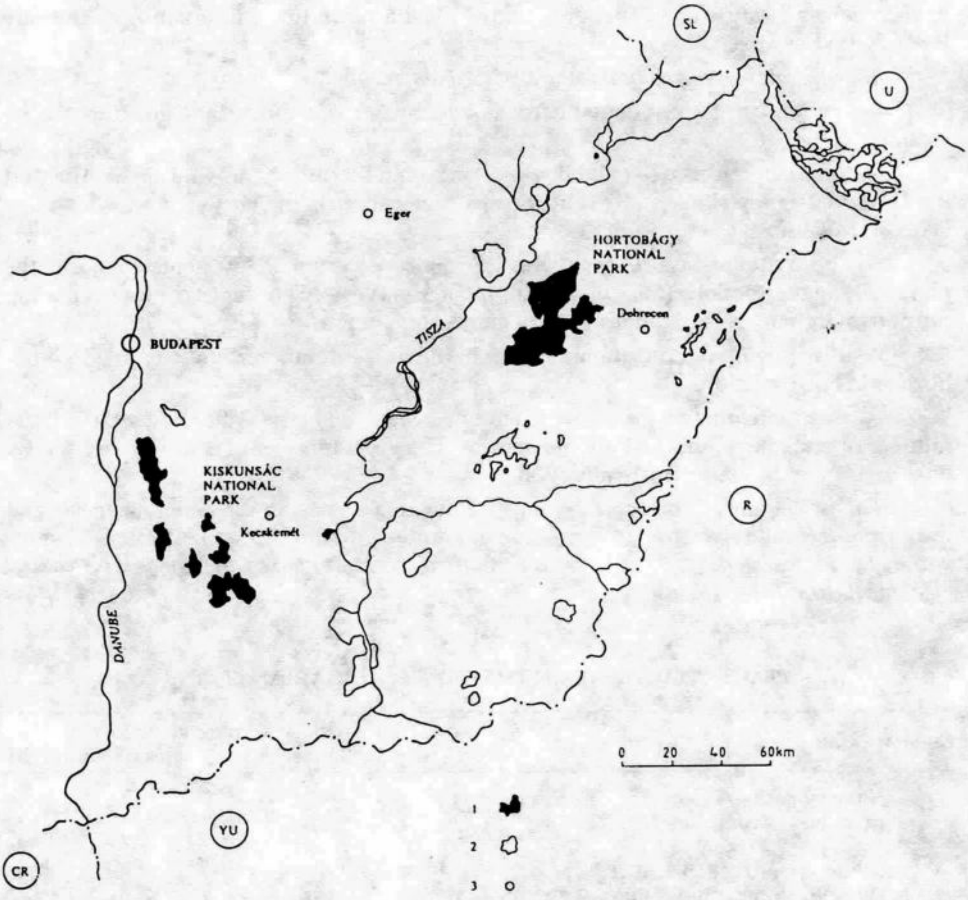


Fig. 1 Protected Areas of the Great Hungarian Plain; 1. National Park, 2. Landscape Protected District, 3. Headquaters

STOP 1

Geological Review of the Aszód—Galgamácsa Inorganic Hazardous Waste Disposal Site

PYRUS Ltd.

Location: Gödöllő hilly area. By road to Inorganic Hazardous Waste Disposal Site, N of the road from Aszód to Galgamácsa.

During the course of industrial production, inorganic waste arises in huge quantities. The handling, utilisation, temporary storage and the final and harmless disposal of those wastes, represent an extremely important environmental protection problem in every country.

Folowing the theorietical discussion of the theme in Hungary too, effective practical methods were formulated by the universities and colleges, the planning institutes and the professional authorities, within the framework of the programme prepared by the NEPO (National Environmental Protection Organisation) and the Hungarian Geological Survey and approved in 1982 by the Council of Ministers, entitled „*A National Hazardous Waste Network*''. Thus became possible to begin the search for sites suitable for the disposal of hazardous wastes, and prepare appropriate documentation for the site nomination procedures.

Of the sites proposed as suitable, the preparatory engineering geological investigations for the design of the site to be established in the western lateral valley of Aszód—Nagyvölgy were performed first (1982.).

A great part of the proposed area is an abandoned military proving ground, mainly overgrown pasture land with smaller areas of woodland and ploughland. The distance to the centre of the closest related populated area (Iklad) is 3 km. There is no holiday resort or nature protection area in the vicinity. The nearest public water supply base reservoir is 6—16 km away. The nearest surface water flows are the Galga brook 4 km away, and Breda Brook 2,5 km away. The 30 year area requirement of the final disposal site, including a band of woodland, is about 100 ha. For the establishment of the suitability of the selected area for the disposal of hazardous wastes, the preliminary field studies were performed by the following companies and institutions:

— the geological investigations were performed by the Budapest Regional Service of the Hungarian Geological Survey;

— the engineering geological examinations by the Geotechnika group;

— the engineering seismology examinations by the Geodesic and Geophysical Research Institute of the Hungarian Academy of Sciences;

— the examination of the physico-geographical relations and the effects upon the surrounding settlements by the Urban Construction Scientific and Projecting Institute;

The matters of hydrographical and water protection requirements were handled by the Water Design Company (VIZITERV) and the Civil Engineering Design Company (MÉLYÉPTERV);

— the construction and operator of the site is PYRUS Environmental Protection Service Company Ltd. (earlier name: FÖLDGÉP Environmental Protection Service Subsidiary, or FKSZV).

GEOLOGICAL SETTING

The area consists of upper Neogene deposits forming the transition area between the Neogene hills of the Cserhát and the younger Neogene Gödöllő sandstone hills. The

Triassic basement (limestone, dolomite) is at 1,500—2,000 m depth. It is overlain by an about 1,000 m thick lower and middle Oligocene sedimentary sequence. The lower member is made up of sandstone and clay strata, and the middle one is mainly clay and marl. These members, according to the evidence of hydro-carbon exploratory drilling contain

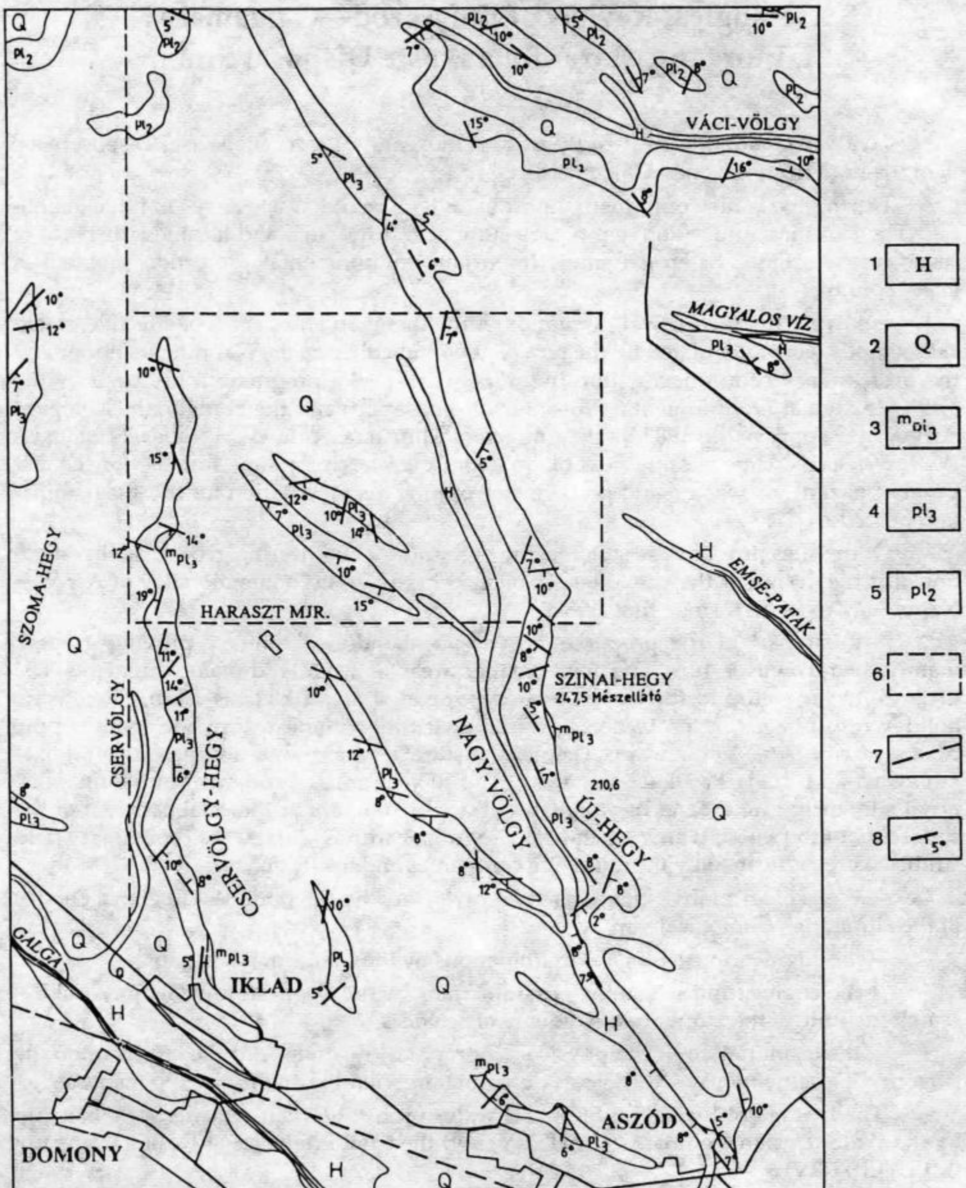


Fig. 1 Geological map of Aszód area (after Szentes, 1940); 1. Holocene valley infill, alluvium; 2. Quarternary loess, drifting sand; 3. „Levantine" freshwater limestone; 4. Upper Pannonian and "Levantine" clay, sand, sandstone; 5. Upper Pannonian Viviparus clay and sand; 6. Studied area; 7. Fault; 8. Incline

extraordinarily little water. On top of the previously described lies an about 500 m thick upper Oligocene sequence of sandy clay and clay marl with intercalations of fine and coarser-grained sandstone.

Upper miocene (Sarmatian) sediments can be found in the Galgagyörk area in minor surface distribution on both banks of the Galga brook. This is continental, mostly fluviatile series in which the lacustrine sediments are completely subordinate. That is why the sediment pattern is lenticular, cross-stratified, with repeated erosion surfaces. In accordance with this the clay, sand and silt content is variable, through in regard to the whole area, these three grain-size fractions are found in almost equal proportions in the sediment.

Part of the sand has been cemented to hard sandstone. On the flatter hilltops there are the remains of Pleistocene drifting sand dunes, which are slightly redeposited parts of Pannonian sands. A geological map of the area, including the vicinity of the waste disposal site established in the Nagyvölgy, can be seen in Fig. 1. There are no significant traces of loess on the surface, but the clayey silts close to the surface are partically of loess origin. On the bottom of the slightly inclining Nagyvölgy, a thin Holocene deposit is to be found, which consists of sand and silt washed down from the slopes, and to a lesser extent of marsh sediments. The outline plan of the site is shown in Fig. 2.

The formation examined in view of hazardous waste disposal is an Upper Pannonian or Pliocene lenticularly stratified clay, silt and series. It is underlain by the Upper Pannonian lacustrine Viviparus beds, a well stratified, only slightly lenticular, clay and sand series. The proportion of clay and sand strata is roughly similar to the surface formations, with the clay predominating at some places. The overlying sediments are Pleistocene eolian sand and loess.

Tectonics

The earlier mapping (1943) stressed the folded elements. The changes in clip may largely be attributed to cross-stratification, and to a lasser extent to block toppling. Geophysical research did not directly indicate faults in the lenticular series. Geomorphologically, however, the direction of the Nagyvölgy (NNW-SSE) must absolutely be regarded as controlled by fault.

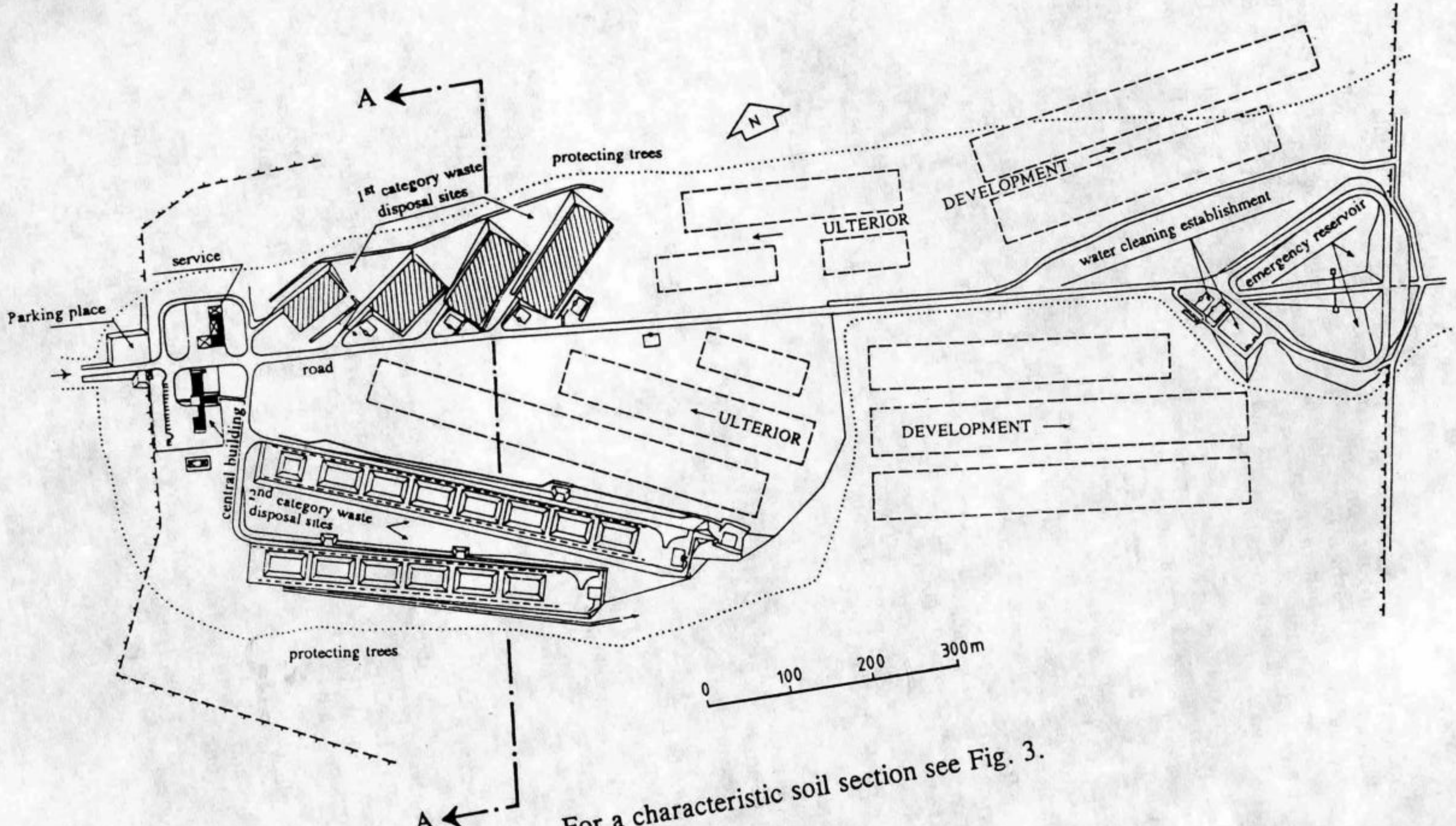
In summary, we may state that in the area the Pannonian formations are dislocated by a few metre high faults in a grid of a few hundred metres, though the faults can be indicated only geomorphologically. The structural characteristics of the waste disposal site, its upper 10 metres of stratification, and its topographic position, are shown in Fig. 3.

Hydrogeology

Impermeable formations of greater extension in the area may be expected only in the Lower Pannonian, at a dept of about 200m. The overlying upper Pannonian strata are lenticular. The water permeability of the series composed of 10^{-3} cm/sec. water permeability sands and 10^{-8}—10^{-9} cm/sec. water permeability clay approaches the value $p=10^{-7}$ cm/sec. Ground water is not to be found in the wells sunk on the site but stratum waters appear periodically.

Engineering geology

Mainly low and medium plasticity clays and silty sands occur in the construction area. Due to their lenticular sedimentation, their clip can not be unequivocally defined, in general it is less than 5 degress. The average thickness of the strata is 1-10m. The clays are consolidated. Consequently the probability of surface movements is very low.



For a characteristic soil section see Fig. 3.

Fig. 2 ... of the site established in 1989

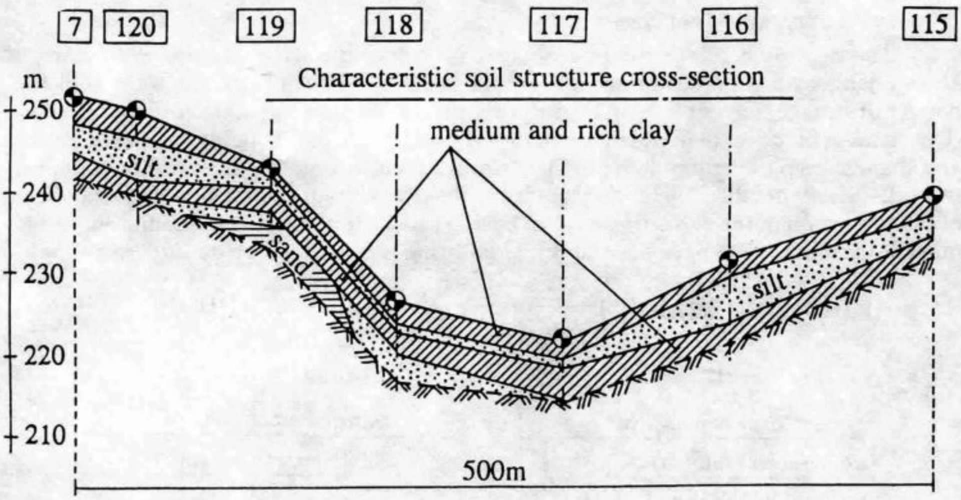


Fig. 3 Aszód—Galgamácsa hazardous waste disposal site

Basic requirements for site development

a) Protective distances

A protective distance of generally 1,000m/ from populated areas and 500m/ from independent occupied buildings must be ensured. The site must be surrounded by an 100m wide aforested security zone.

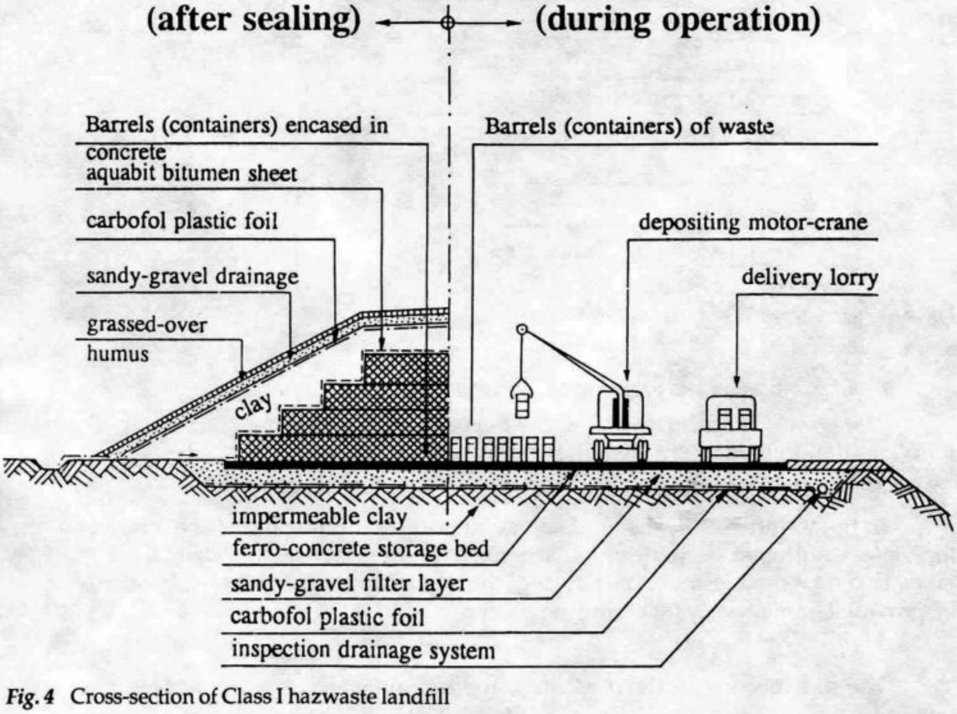


Fig. 4 Cross-section of Class I hazwaste landfill

b) Water protection requirements

The deposited waste must be isolated from the subsurface waters. With storage areas established in nontectonised geological formations free of ground water and the danger of surface movements, an engineering protection system satisfactory to the water closure must be provided. The mode of deposition of wastes belonging to hazard class I and II are shown in Figures 4 and 5. The rainwater falling onto the site must be collected in a satisfactory manner. Water may not leave the site without purification. In the interest of the protection of the sub-surface water base, a satisfactory number of monitoring wells must be established (15 have been sunk). Monitoring is performed by the authorities.

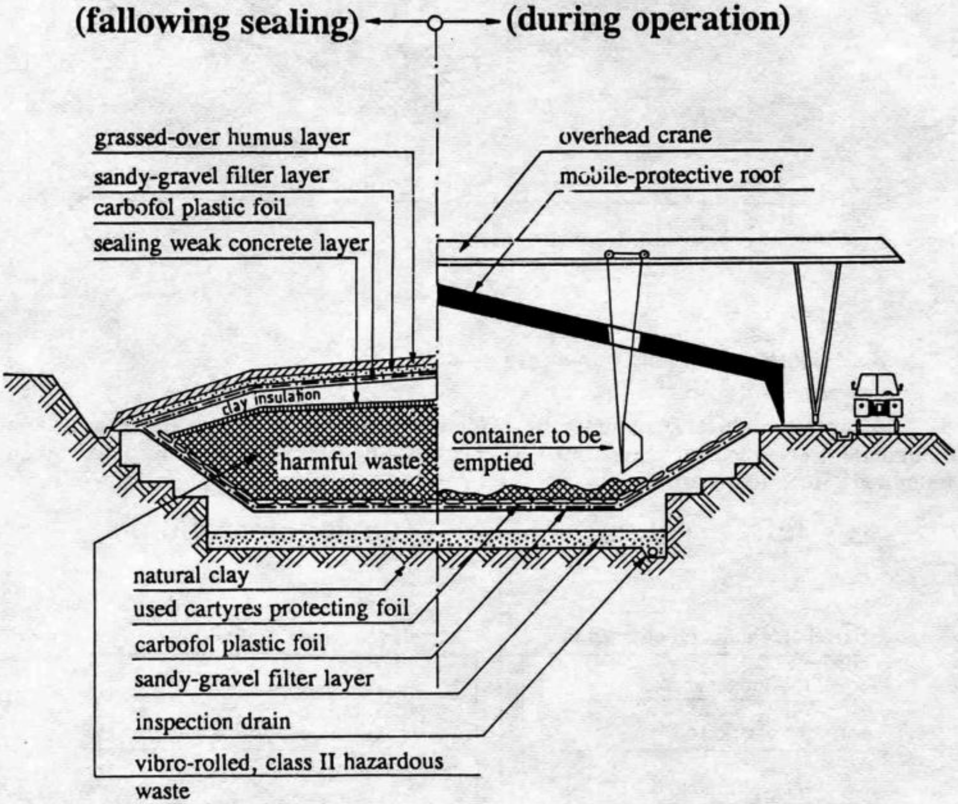


Fig. 5 Cross-section of Class II hazwaste landfill

c) Air purification and protection requirements

The wastes must be treated at the deposit site in a manner not causing air pollution. This requirement is ensured by authority inspection.

d) Protection of the food chain

In the vicinity of the disposal site periodical soil examinations and analyses of the local plant life must be performed, according to an established system. Care must be taken that dusting does not occur during, the deposition of the materials. Covering must be provided immediately following deposition

• • •

The site, meeting all the prescribed and recommended requirements began operation in 1989.

When planning and implementing the construction of the Aszód—Galgamácsa hazardous waste disposal site we utilised the following basic data and professional literature, and Ministry of Construction and Water Management Directive No.1/1968 ÉVM, Council of Ministers Directive No.56/1981 MT. and the planning guidelines OKTH No.9001/1982.

1. Preliminary environment geological opinion, HSGI Regional Department (1982)

2. For the compilation of the area utilisation documentation, the following information was provided by the Chemical and Explosives Materials Inspectorate (VRF): 1982.
   - The assessment and putting in order of hazardous industrial wastes. Final report (1982).
   - The quantity of hazardous waste that may be made harmless through depositing (1982).
   - Supplementary data for the completion of the authorising documentation of the hazardous waste disposal site to be established in the central planning zone (1983).
   - Supplementary data regarding the quantity of lime sludge generated in the environment of the central deposit site (1983)

2. The geological opinion of the Central Regional Service of the National Hungarian Institute of Geology (MÁFI) (1983).

4. Report on the geo-electrical, boring and absorption tests performed for the planning of the hazardous waste disposal site near Aszód, in Pest County. (Geotechnika, GMK, 1982).

5. Regional overview of the national network of hazardous waste disposal sites. Phase I. (Pest County) (VÁTI-OTK, 1982).

6. The engineering seismic examination of the hazardous waste disposal site planned in the outer territory of Aszód. (MTA/Hungarian Academy of Sciences/Geodesic and Geophysical Research Institute) (1983).

More details see Csomor-Kiss (1962), Kiss—Csomor—Simon (1968), Noszky (1940), Papp—Vitális (1967), Réthly (1952), Szentes (1940).

STOP 2

Agrogeology. The Apajpuszta model area

L. KUTI

Location: Danube valley region. Approx. 50 m of the road from Kiskunlacháza to Kunszentmiklós at 14 km Approx 200 m S of riding-shool "Apajpuszta".

The research of the ca. 100 km^2 large area, east of Apajpuszta village has been aimed essentially to studying agrogeological aspects of the fluvial sedimentary sequence, in particular the interrelation of geological factors initiating salinization.

Some 96, 5-6 m deep boreholes have been drilled in the area. This depth was needed for hitting the gravels which constitute the base of superficial sediments.

The gravel is overlain medium-grained then fine sand followed by clayey silt and silty clay further up in the profile. The latter has been affected by salinization of different degree all over the area.

Some sand-hills shaped by the wind can be observed in the NE corner of the area. According to the results of geological and geophyisical investigations, they are suggested to be the remnants of the one-time sand mantle covering once the whole area. The sand in between has been removed by the wind.

With regard to our research in this model area, the factor promoting salinization can be interpreted as its rather low morphological position along the central line of the Danube valley as compared to both the interfluve Danube-Tisza and the stripe along the Danube. That is why the lowest hydrostatic levels of ground-water have been recorded in this particular sector of the region. Consequently, it functions as a collector of ground-water throughout its surroundings. Water becomes stuck in the resulting trap. Lacking the ability to be evacuated it is reduced only by evaporation. The first constituent precipitating from the evaporating water is $CaCO_3$ followed by sodium-hydrogencarbonate. The first gives rise to the formation of a subsurface horizon characterized by lime accumulation, whereas the latter initiates the development of a superficial salt-affected layer.

More details see Kuti (1986), Rónai (1985), Pécsi (1967).

When planning and implementing the construction of the Aszód—Galgamácsa hazardous waste disposal site we utilised the following basic data and professional literature, and Ministry of Construction and Water Management Directive No.1/1968 ÉVM, Council of Ministers Directive No.56/1981 MT. and the planning guidelines OKTH No.9001/1982.

1. Preliminary environment geological opinion, HSGI Regional Department (1982)

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   - The assessment and putting in order of hazardous industrial wastes. Final report (1982).
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More details see Csomor-Kiss (1962), Kiss—Csomor—Simon (1968), Noszky (1940), Papp—Vitális (1967), Réthly (1952), Szentes (1940).

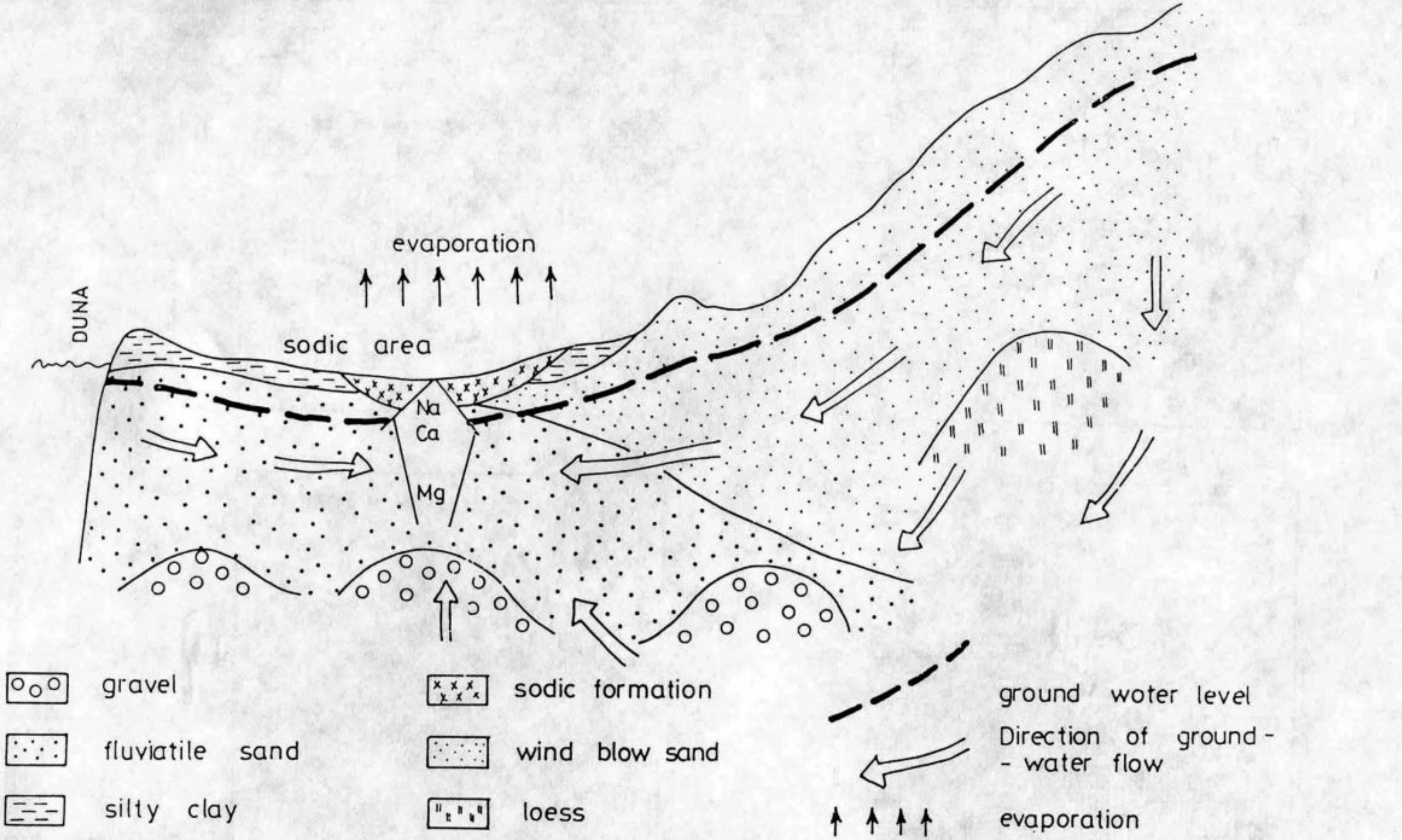

Fig. 1
Apajpuszta. The sodification modell of Duna—Tisza interfluve

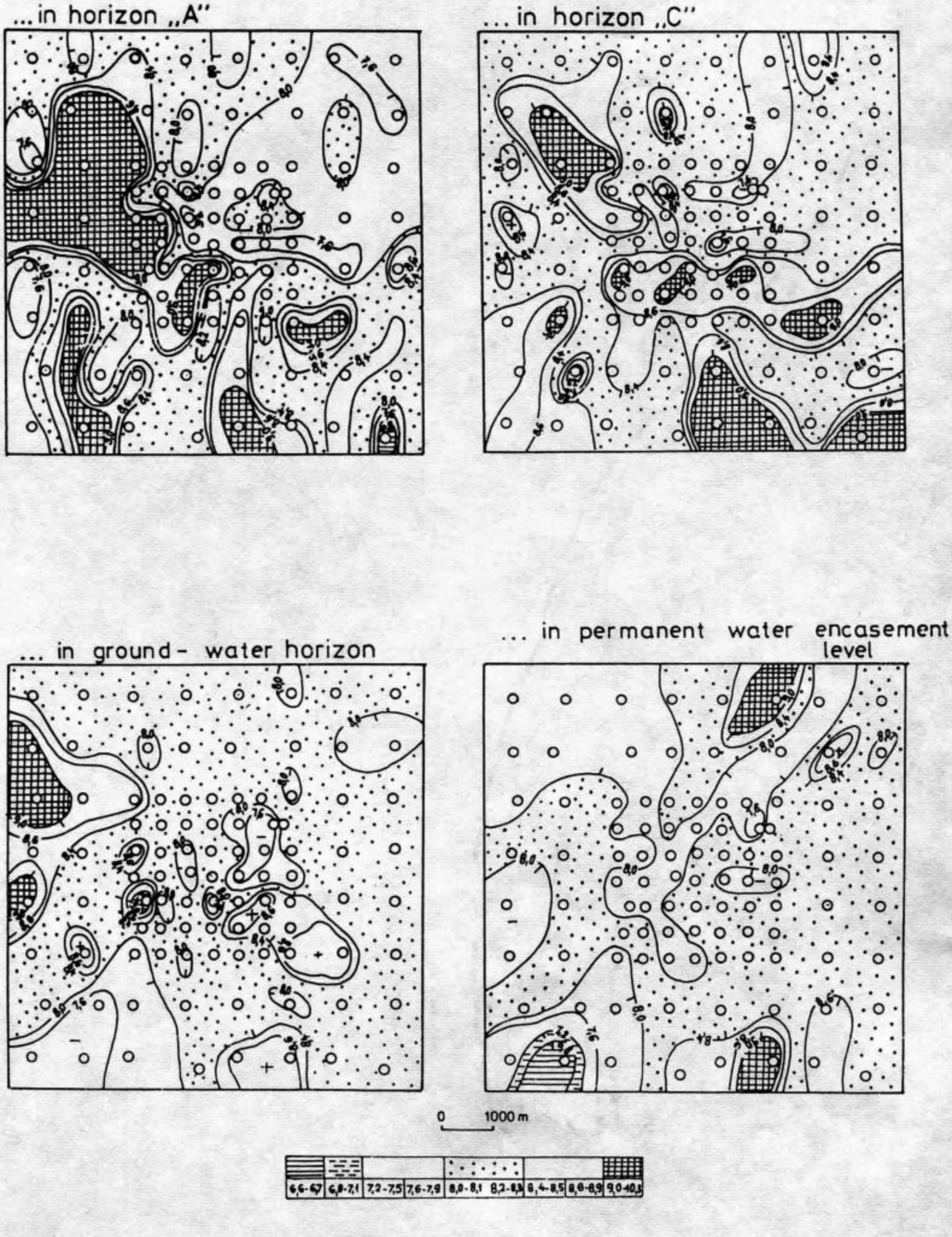

Fig. 2 Apajpuszta. The pH of the formations

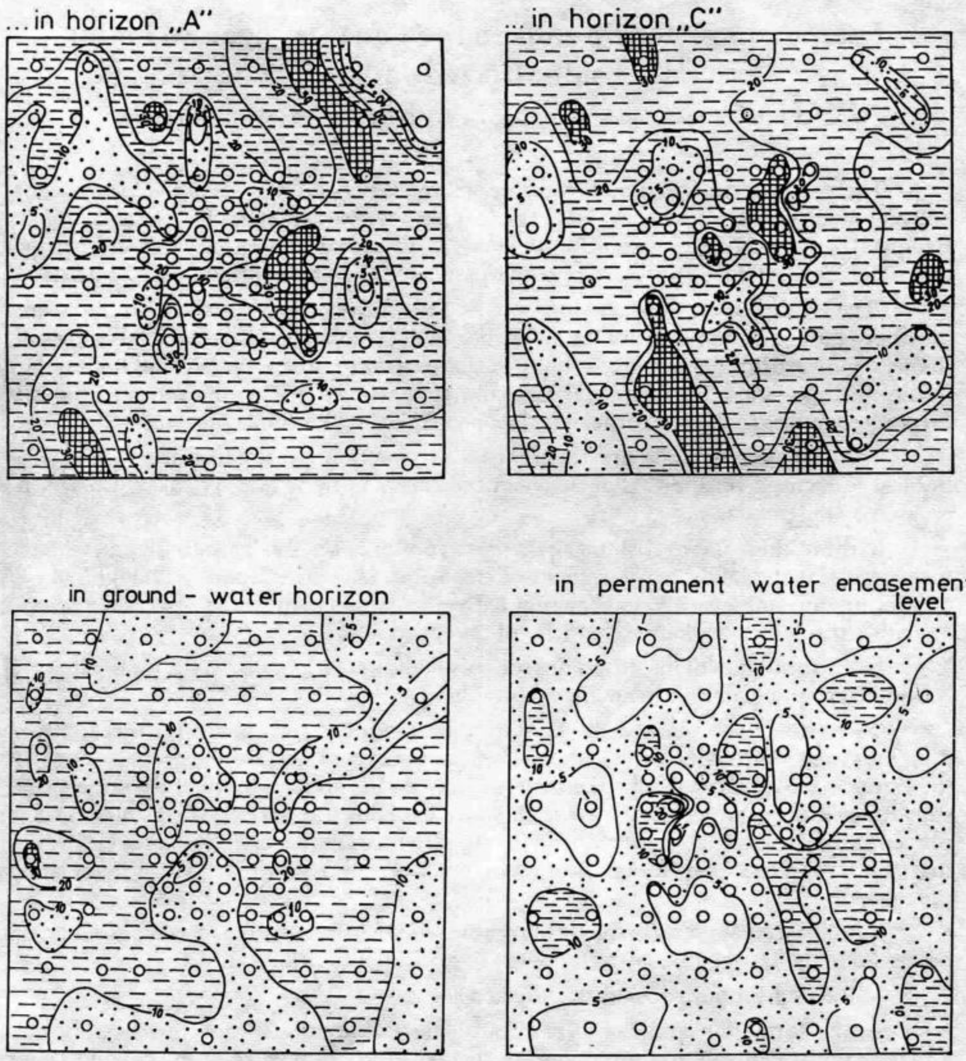

Fig. 3 Apajpuszta. The $CaCO_3$ content

STOP 3

Extended low fertile soils in the Great Hungarian Plain: salt-affected soils

K. RAJKAI with the contribution of G. SZENDREI (soil mineralogy and micromorphology)

There are several different low fertile soil types of alkaline soils in the lowland area between the rivers Danube and Tisza. These types are characteristics for separate smaller regions. The types of alkaline soils found in this relatively small area vary to such an extent that in this respect the territory is almost unparalleled even by international standards.

The two main types of alkaline soils in the north-northwestern region of the area (northern part of Kiskunság) are the solonchak and the solonchak-solonetz. Alkaline soils in this region are limited to the low-lying localities, while in the elevated sites the soils are fertile meadow-lands. The deeper layers of the latter are also rich in salts, but since the salts do not find access to the supperficial layers, no alkaline soil profile will result.

The salt-affected soils are frequent in all over the Great Hungarian Plain. Our interest is focused on the region between the rivers Danube and Tisza, which will be crossed by the excursion.

In the middle part of Kiskunság there is a combination of salt accumulation with the formation of marshlands. In this region solonchaks and marshland soils with high salt and organic matter content are equally common. Drying of the soil in this region certainly leads to a more pronounced alkaline character of the soils.

In the formation of the different types of alkaline soils in the area the high salinity of the underground water plays an important role.

Várallyay (1967) pointed the Tertiary volcanic rocks and their remnants surrounding the Great Plain as the primary source of salt being washed into the ground waters of the Danube Valley. That is why the main source of salts is the salinity of the surface and subsurface ground waters in the area. This idea explains the fact that the Danube waters concentrated during evaporation do not result salt accumulation after the flood. He proved that surface waters play a significant but not decisive role in the salt accumulation processes.

Várallyay (1968) proves the primary role of subsurface waters in salt accumulation processes in the Danube Valley as follows:

— the high amount of salts the affected soils,

— the formation and the dynamics of the salt accumulation processes: the soil horizons with high salt accumulation are related to the dynamics of the ground water depth of the soils:

— the characteristic layering of the salts in the soil profiles in the order of their increasing solubility (from down in upward direction $CaCO_3$, $MgCO_3$, $NaHCO_3$. NaCl). The salt accumulation processes can be explained by the net sum of the water balance of the soil profile in which rain water and ground are the main sources. When net upward water movement occurs from the salty ground water table salt accumulation is the result. However, the yearly water and salt balance is a function of ground water depth. The intensity of salt accumulation and the location of the salt maximum in the soil profile is determined by the ground water table depth. The ground water table depth above which salt accumulation occurs in the overlaying soil profile is called the 'critical depth'. The amelioration of the salt affected soils maintain the ground water table below the 'critical depth' and increases the leaching of the soil profile.

When the Na^+ is dominating in the water soluble salts in the salt affected soils of the Danube Valley the hydrophysical properties of these soils are highly unfavorable. This results in low water capacity and water conductivity and high water holding capacity. Altogether low fertility is the main feature.

Finally, one can conclude that salt-affected soils in the Danube Valley have been formed where the ground water is strongly alkaline, containing $NaHCO_3$ type salts and where the conditions for the concentration of soil solution in the upper part of the soil profile are suitable. The formation of salt affected soils is associated with the formation of non-salty hydromorphic soils as meadow, peaty meadow and alluvial soils.

In the salt-affected area the high variability of the soil and vegetation is characteristic. This is due to the variable soil layering and ground water table depth, which result in different depth and intensity of salt accumulation. In case of solonetz soil the thickness of the horizon A is of great importance. The thicker the horizon A, the better the physical properties and fertility of the solonetz soils. In the Danube Valley there are solonetz soils completely lacking a horizon A. In the cases, the crusty or columnar horizon B is on the surface. The solonetz soils of the Danube Valley are calcareous and sodic. Among the salt affected soils of the Danube Valley the richest in salts and sodium carbonate are the solonchak and solonchak-solonetz soils. As a rule, their salt and sodium carbonate maximum can be found in the surface layer. These two soil types are always calcareous and sodic in Hungary, and the ground water table is near (< 1 m) to their surface.

In the relative concentration of Na^+ among the cations of the soil solution is higher then a threshold limit (15 S%) the physical conditions of the soil show salt affected characteristics. However, the development of salt affected marks in the soil profile occurs together with accumulation of Na salts in the soil profile.

The common salt affected soil types in the Danube Valley are the solonchak-solonetz or in smaller extent the solonchak and solonchak like meadow solonetz soils. More details see Szabolcs (1965), Szabolcs—Jassó (1961), Várallyay (1967a,b, 1968). The main charateristics of a solonchak-solonetz soil are given as follows (from the area of Apaj):

ANALYSIS RESULTS (1978):

	Na meq/100 g soil	ESP[1] %	pH	$CaCO_3$ %	Salt %	H[2] %
0— 5 cm	4.9	14.3	7.7	29.8	0.12	2.7
15—25 cm	13.6	55.0	9.2	27.3	0.37	2.2
33—45 cm	12.9	48.9	9.8	33.5	0.70	1.2
58—68 cm	10.2	46.5	9.9	54.5	0.50	—

[1]Exchange Sodium Percentage; [2]Humus content

Description of the soil profile:

Surrounding: wet meadow

Topography: flat

Vegetation: Puccinellia limosa, Artemisia monogyna

Effervescence: to the surface

Phenolphtalein reaction: down to 5 cm

Ground water table depth: 160 cm

Depth of humus layer: 45 cm

Depth of profile: 114 cm

Genetic horizons:

A 0—5 cm Brownish-black, moist, sticky, densely rooted, grumble structured, slightly compacted sandy loam. Abrupt transition.

B1 5—33 cm Brownish-black, densely rooted, columnar structure, compacted, fresh clay-loam. The surface of structural elements have wax shine. Transition is gradual.

B2 33—45 cm Greyish-black, compacted, fresh, blocky structured loamy clay. In lower part of the horizon $CaCO_3$ accumulation is noticeable. Transition is abrupt in color.

B_{Ca} 45—80 cm White-yellowish-grey, fresh, compacted $CaCO_3$ accumulation horizon in clay-loam texture. There are many fine $CaCO_3$ concentrations and reduction mottles. Transition is gradual.

BC 80—115 cm Greyish-reddish-yellow, moist, compact loam. On the surface of structural elements there are reddish and black coatings. Transition in color and texture is abrupt.

C 115— cm Brownish-grey, loose, structureless sand.

Soil type: Crusty meadow-solonetz.

Soil mineralogy

In the salt-affected and associated soils of the Danube Valley mainly quartz, mica, feldspars, calcite and dolomite occur (Darab, Gerei, Reményi and Szendrei, 1971; Szendrei 1977). Among the rare minerals (composition of heavy mineral assemblage) garnets, amphiboles, pyroxenes, rutile, turmaline, epidote, cirkon, andalusite, sillimanite, staurolite, cyanite and magnetite were reported (Szendrei, 1970).

In the clay fractions of these soils besides the dominating illite quartz, chlorite and feldspars occur. In salt-affected soils, especially their B horizons smectite and smectite-illite interstratification were determined, consequently the occurrence of these minerals is related to alkalinization process (Gerei, 1978).

Soil micromorphology

Pedofeatures will be discussed, wich can be interpreted from the aspect of soil formation. In the given area salt affected (solonchak, solonchak-solonetz, meadow solonetz) and associated soils (alluvial meadows soil) were investigated. These soils are calcareous mainly from surface. In these soils carbonate skeletons, nodules and crystallic b-fabric were observed. Among ferruginous pedofeatures indicating hydromorphic influence only grain coatings can be found. The occurrence of clay coatings differs in the various soil types. In alluvial meadow soil clay coatings are absent, however in meadow solonetz soil, especially in horizons B they are characteristics, in solonchak soil they cannot be found again. In meadow alluvial soil due to the low ESP and in solonchak as a consequence of high water soluble salt content clay particles are not mobilized, whereas in meadow solonetz soil in the consequence of high ESP clay is illuviated. In deeper horizons the changes in coarse/fine (particles) related distribution are due to layering (Szendrei, 1978).

In the continuous yearly water deficit in the last decade in Hungary lowered the average ground water table level in the Great Plain, which shifts the solonchak and solonchak-solonetz soils into solonetz or solonetzic-meadow soils. The effecs of this tendency are noticeable in the Apaj region as well.

STOP 4

Bugac
(Nature Protection in the Great Hungarian Plain)

A. IVÁNYOSI SZABÓ

The *lowland* features of the Hungarian nature conservation are discussed in the summary of the Field Trip Guidebook. The nature conservation tasks of the values enumerated there are undertaken by the *National Authority for Nature Conservation*, supervised by the *Ministry for Environment and Regional Policy;* respectively by its *regional organisations.* One of these is the Directorate of the *Kiskunság National Park,* based *in the town of Kecskemét,* which manages the natural values of the Danube-Tisza Interfluve region and the Lower Tisza-flow area.

The most outstanding values of the Southern Great Plain region can be found in the *Kiskunság National Park* (Fig. 1).

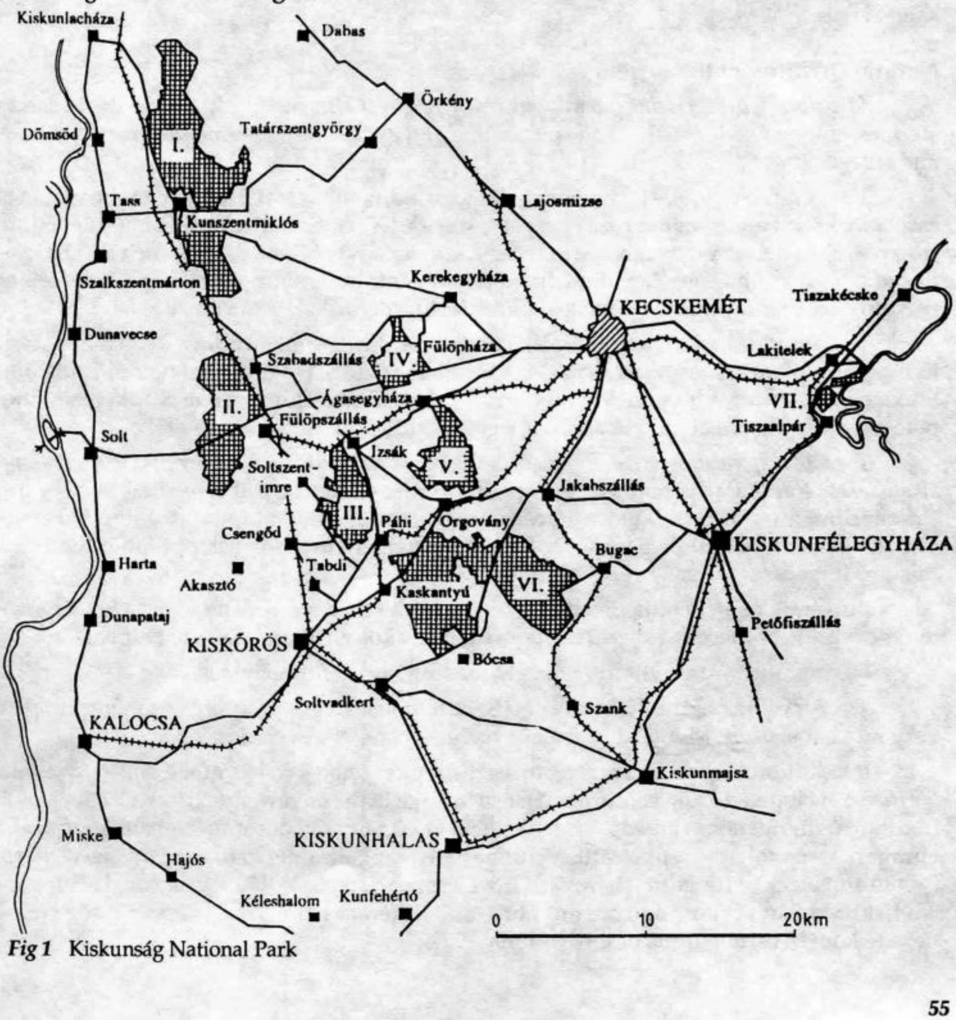

Fig 1 Kiskunság National Park

Geographical situation

The Kiskunság National Park, the fourth largest reserve in Hungary was founded in 1975. The area of the National Park amounts to 36.000 hectares. It is a complex of 7 individual units (Table 1).

The Units of the Kiskunság National Park ***Table 1***

Territories	Area in ha
Alkali steppe of Upper Kiskunság	11.061
Saline and alkali lakes of Upper Kiskunság	3.905
Kolon lake near Izsák	2.962
Dune region of Fülöpháza	1.992
Region of Orgovány	3.753
Dune region and sand steppes of Bócsa—Bugac	11.488
Back-water of the Tisza river at "Szikra" ans the meadows of Alpár	698
ALTOGETHER	35.859

In 1979 two thirds of the National Park was designated as a *Biosphere Reserve* within the framework of UNESCO's "Man and Biosphere" Programme. The *"Ramsar" Convention* which serves for the increased protection of waterfowls applies to the Upper Kiskunság saline lakes.

Natural Qualities of the Region

The park region *retains typical features of the Great Hungarian Plain* sand-drifts, sandy steppes, solonetz-solonchak alkali soils, saline and alkali lakes, moors, salt marshes, reed-and-tide-lands.

The sedimentological, geomorphological and pedological diversity of the region is associated with an immense *variety of plant species*. Of particular scientific importance are the specific endemic phytocenoses of the calcareous sand and alkali soils such as: Lepidio-Puccinellietum limosae, Lepidio-Champhorosmentum annuae, Artemisio-Festucetum pseudovinae, Festucetum vaginatae danubiale, Junipero-Poluletum albae.

The flood-lands, marshes and swamps display a great variety of plant species. Remarkable plant associations are: Salicetum albae-fragilis, Fraxino pannonicae-Ulmetum, Fraxino pannonicae-Alnetum, Molinetum coeruleae, Festucetum pratensis, Salicetum cinereae ass. caricetosum elatae subass., Caricetum acutiformi ripariae.

The most typical animal communities of the National Park evolved around the *saline and alkali lakes*. Particularly noteworthy are the birds. Characteristic breeding species are Charadrius alexandrinus, Limosa limosa, Tringa totanus, Himantopus himantopus, Recurvirostra avosetta, Glareola pratincola, Sterna hirundo. In the broad steppe lands the Great Bustard (Otis tarda) is still breeding.

Burhinus oedicnemus breeds regularly in the *sand steppes and dune fields*. Characteristic reptilia of these regions are Vipera ursinii rakosiensis and Lacerta taurica.

Herons and water-rails are typical breeding birds of the *swamps*.

The *back-water* of the Tisza river at "Szikra" houses a great variety of singing birds. A very rare bat species, Myotis dasycneme, has also been discovered this place.

In addition to these natural features the region retains relicts of the *typical farmstead life from* developed during centuries of close linkage to the environment, as well as pastoral traditions. Indigenous breeds of live-stock are maintained for gene-bank purposes. Hungarian podolian steppe-cattle, Hungarian mangalica-pig, Hungarian racka-sheep (white and black), Hungarian barnyard fowl, Hungarian goose, Hungarian duck, Hungarian halfbred (bay, yellow and cream) horse and different Hungarian sheperd's dog varieties are kept in certain units of the National Park.

The Bugac area

It is the largest area of the Kiskunság National Park, which hosts extremely various values. Its geological features are presented in the description by Professor *Dr. B. Molnár*, Head of the Geology Department at the University of Szeged.

In this area *two NW-SE wind-blown sand dune lines*, those of Bócsa and Bugac, respectively, can be found here, and the protected area follow their direction.

Its geomorphologically highest part, 131 m a.s.l. is in the axis of the dunes, while the lowest parts at the feet of the dunes are 108 m a.s.l. or lower. 10-15 m difference in level is general within a few 10 distances (Fig. 2). Among the dune lines sodic depressions can be observed.

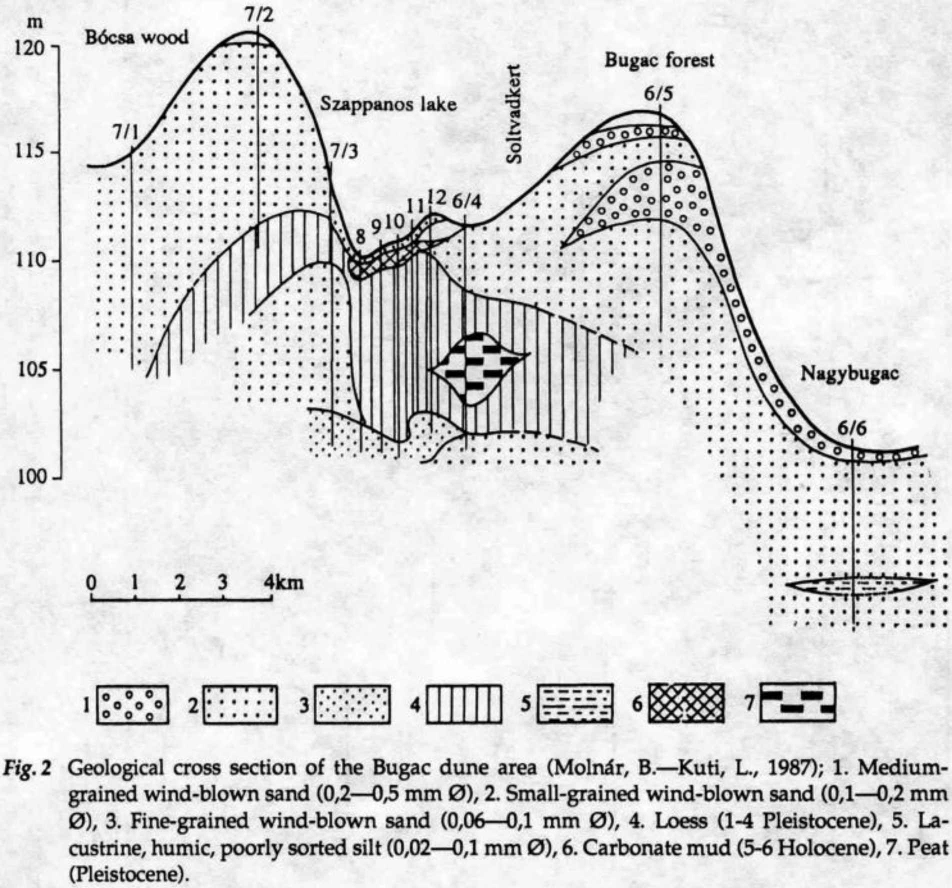

Fig. 2 Geological cross section of the Bugac dune area (Molnár, B.—Kuti, L., 1987); 1. Medium-grained wind-blown sand (0,2—0,5 mm Ø), 2. Small-grained wind-blown sand (0,1—0,2 mm Ø), 3. Fine-grained wind-blown sand (0,06—0,1 mm Ø), 4. Loess (1-4 Pleistocene), 5. Lacustrine, humic, poorly sorted silt (0,02—0,1 mm Ø), 6. Carbonate mud (5-6 Holocene), 7. Peat (Pleistocene).

Wind-blown sand is of the greatest extension on the surface followed by *carbonate mud* as the second. This latter always appears filling in the depressions of NW-SE direction. *Fine sandy loess* is deposited in the W part of the protected area. Loess is subcropping in the W part of the protected area. Under the surface the loess is also extending eastward and it is more important than its surface extension (Fig. 3). Loess plays an important role here in the hydrogeology of the area since it's less permeable than the wind-blown sand. In the morphologically deeper areas together with the carbonate appearance (if it is impermeable) in more humide periods it facilitates the formation of natron lakes.

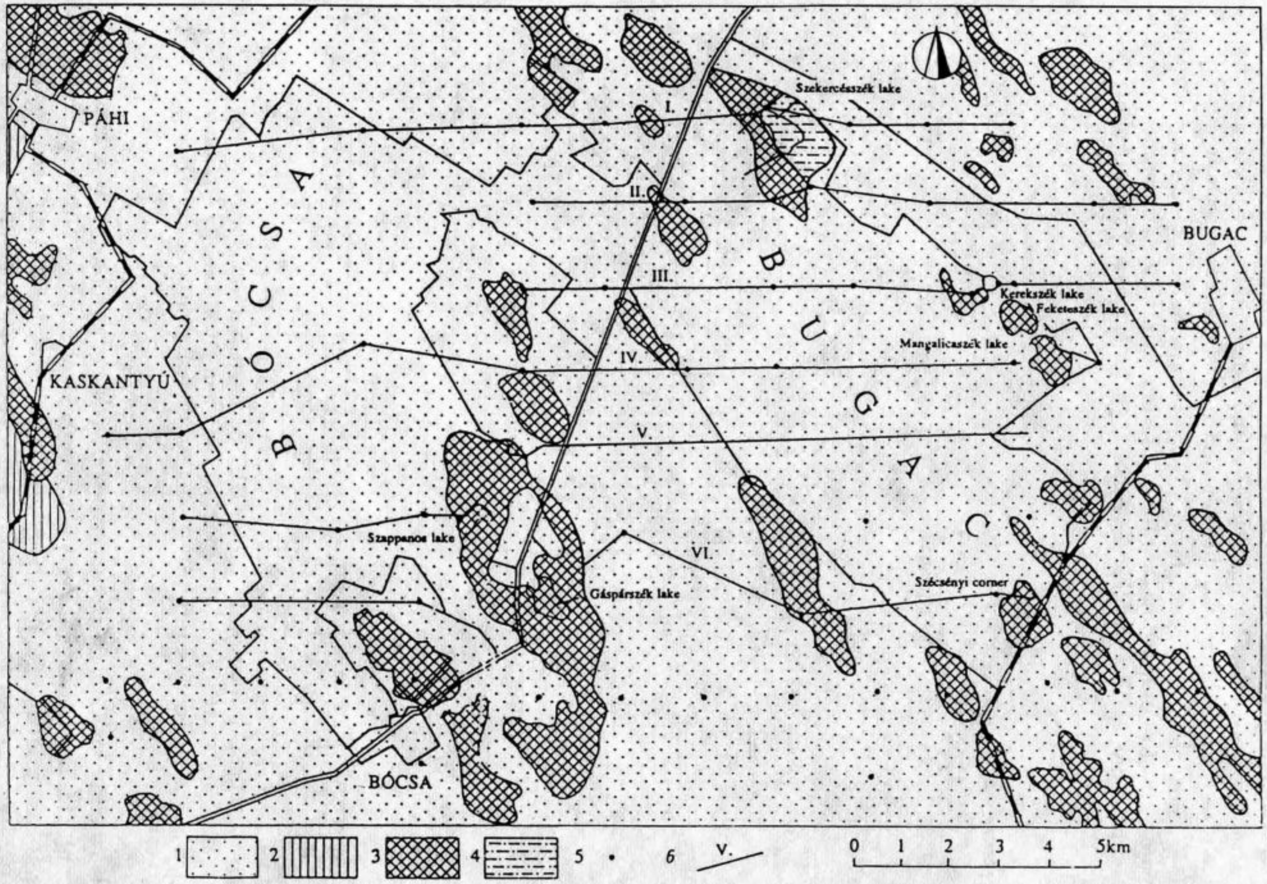

Fig. 3
Surface geology of the Bócsa—Bugac area and its surroundings, with location of the profiles (after Molnár, B.—Kuti, L., 1987); 1. Wind-blown sand, 2. Loess (1-2 Pleistocene), 3. Carbonate mud, 4. Lacustrine humic, poorly sorted silt (3-4 Holocene), 5. Borehole, 6. Geological section line, 7. I-IV Number of geological section

Groundwater is also migrating towards these local depressions. In the development of the area the prevailing microenvironment is of great importance. The morphological differences of the one-time surface often resulted the development of different sedimentary environments.

Eolian and lacustrine sedimentation was alternating within the same area.

In the chemistry of groundwater, a very considerable salinity is characteristic for the lakes, it is max. 20842 mg/l, while at more distant areas it is reduced to 625 mg/l. In the water, among the cations Na^{+} Ca^{++} and Mg^{++} are predominating, while among the anions the *hydrogen carbonate*, and in smaller quantities the sulfate and chloride.

Among the carbonate minerals, beside the calcite and dolomite the Mg-bearing calcite, Fe-bearing dolomite and magnesite play role. Magnesite is present only at the deepest parts, where the water coverage lasted for the longest period, and the Mg/Ca ratio of the lake was extremely high, due to evaporation.

According to the fossil content of the geological formations of the region the rich gastropod fauna of the *loess* indicates cold climate and locally humid biotope.

The *windblown sand* is poor in fauna, and the existing species refer to warm and frequently dry climate periods. This sediment belongs already to the Holocene. The carbonate mud of calcitic composition contains a small number of speciments but a relatively large number of species that are thermophylous, and also species of great ecological tolerance (Table 2). If the carbonate mud is of dolomitic or magnesitic, the contemporary lake water was of very high salinity and pH value, that, already could not provide the essential life conditions for the molluscs.

More details see Dömsödi (1977), Fényes (1983), Fényes-Kuti (1987), Geiger-Révész (1987), Krolopp (1964), Molnár (1970 a, b, 1980, 1983, 1985 a, b, 1988), Molnár-Kuti (1983, 1987), Molnár-Murvai (1975), Molnár-Szónoky (1976), Molnár-Iványosi-Szabó-Fényes (1979), Molnár-Mucsi-Magyar (1971), Molnár-Murvai-Hegyi-Pakó J. (1976), Molnár-Szónoky-Kovács (1980), Tóth-Molnár (1987), Várallyay (1967).

Table 2

Mollusc fauna and ecological groups of the fauna from the core samples of Lake Bócsa-Bugac and of its environs, Kiskunság National Park

Á. Tóth—B. Molnár (1987)

I. AQUATIC SPECIES	
Ecological demand	Species belonging to the ecological group
V1 Thermophylous species requiring constant coverage by water	Planorbis planorbis (L) Limnaea stagnalis (L) Limnaea palustris (O. F. MÜLL) Planorbarius corneus (L) Gyraulus albus (SHEP) Bythynia leachi (SHEP)
V2 Species tolerant to periodical water coverage	Valvata cristata O. F. Armiger crista (L) Gyraulus riparius (WEST) Pisidium sp Bathyomphalus contortus (L) Segmentina nitida (O. F. MÜLL) Valvata pulchella STUD. Physa fontinalis (L) Anisus spirorbis (L) Anisus septemgyratus (ROSS) Anisus leucostoma (MILLET) Anisus vortex (L) Aplexa hypnorum (L) Galba truncatula (O. F. MÜLL) Radix peregra (O. F. MÜLL)
II. TERRESTRIAL SPECIES	
Ecological demand	Species belonging to the ecological group
SZ1 Species of shore requiring humidity	Succinea elegans RISSO Succinea oblonga DRAP Carychlum minimum (O. F. MÜLL) Succinea putris (L)
SZ2 Species requiring less humidity	Zonitoides nitidus (O. F. MÜLL) Euconulus fulvus (O. F. MÜLL) Cochlicopa lubrica (O. F. MÜLL) Limax sp. Vitrea crystallina (O. F. MÜLL)
SZ3 Thermophylous terrestrial species	Vallonia enniensis (GRED) Vallonia pulchella (O. F. MÜLL) Vertigo antivertigo (DRAP) Vertigo anggustior (JEFFR) Monachoides rubiginosa (A. SCHMIDT) Nesovitrea hammonis (STRÖM)
SZ4 Species of high ecological tolerance	Pupilla muscorum (L) Vallonia costata (O. F. MÜLL) Vertigo pygmaea (DRAP) Punctum pygmaeum (DRAP) Clausilia sp.
SZ5 Xerothermal species	Abida frumentum (DRAP) Chondrula tridens (O. F. MÜLL)
III. LOESS SPECIES	
L1 Species tolerant to humidity and cold	Trichia hispida (L) Vertigo substriata (JEFFR)
L2 Species tolerant to drought and cold	Columella columella (G. MARTENS) Columella edentula (DRAP) Vertigo pracedentata (A. BRAUN) Discuc ruderatus (FERUSS)

STOP 5

Agrogeology. The Bugac model area

L. KUTI

Location: Danube-Tisza interfluve region. At 22 km of road No-54 (Kecskemét-Baja) turn to NE After approx. 10 kilometers turn to SW. The last distance is approx. 3 km

It is situated westwards from Bugac village and extends to the E slopes of the Ősborókás-hills as well as on flat areas further eatswards. The major objective of the study was the investigation of agrogeological conditions of the aeolian sedimentary formations and related depressions between sand-hills. Particular attention has been devoted to the processes of acidification and salinization.

Some 89, 10 m deep boreholes have been deepened in this ca. 100 km^2 large model area.

Apart from the bottom of recently dried-up lakes, the surface is covered by sand all over the area. On the contrary, lake bottoms bear clayey silt, or silty clay. These lacustrine sediments have been affected by salinization and calcification resulting frequently in the formation of a thin layer of calcareous mud on or below the surface.

The superficial sand rests in NE and SW on loess appearing in different depths (2-6 m), whereas 10 m deep drilling carried out in the central 2-4 km wide belt traversed profiles comprising unanimously windblown sand indicating thus the presence of a more than 10 m thick sand sequence.

Appart from the above-mentioned central belt, the profile can be described by the alternation of 2-5 m thick layers of sand and loess. Below the surface aeolian beds are occasionally substituted by lacustrine sediments.

The hydrostatic level of ground-water below the surface varies as a function of the characteristics of the area. Below flat regions and lakes, in sand complexes and in the SW part of the area it is around 1-2 m, below 4 m and below 10 m, respectively.

The mechanism of salinization is quite similar to that of the Danube valley, the only difference being that the affected spots in the Bugac sector are smallers. Flat areas between sand-hills give rise otherwise to the same mechanism of trapping ground-water streaming in from all over its surroundings.

Considering the process of acidification, three types of soil profiles have to be distinguished: complexes with inherent acidity all along the profile, soil series devoid of acidity, and sequences with only their superficial or basal part being affected by acidification. The notion of acidification refers, namely, solely to areas free of inherent acidity.

Consequently, some external effects have been responsible for triggering the process of acidification. This mechanism can be suggested to function in regions described by acid superficial deposits — presumably, they became acid with time —, while the underlying formations have so far been spared by this phenomenon.

More details see Kuti (1981), Pécsi (1967, 1969), Rónai (1985).

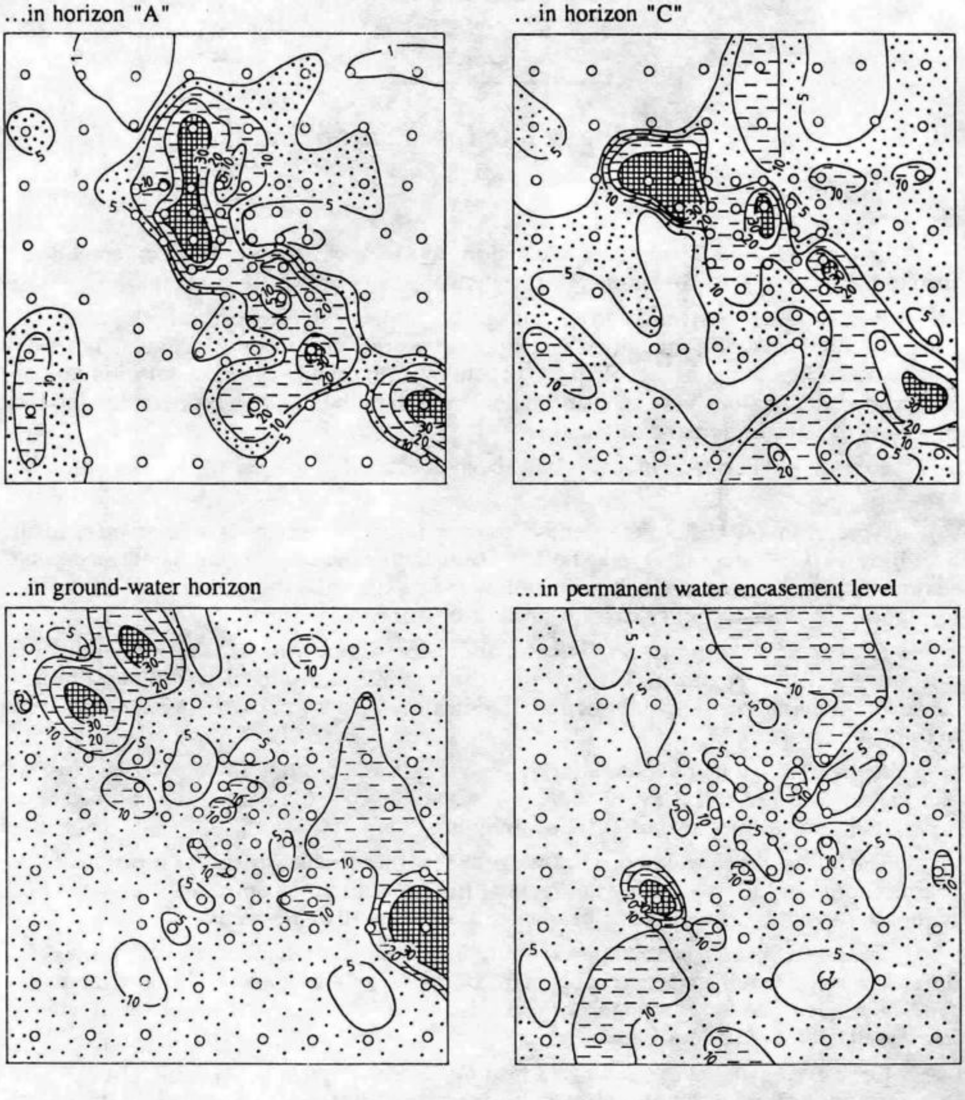

Fig. 1 Bugac. The $CaCO_3$ content

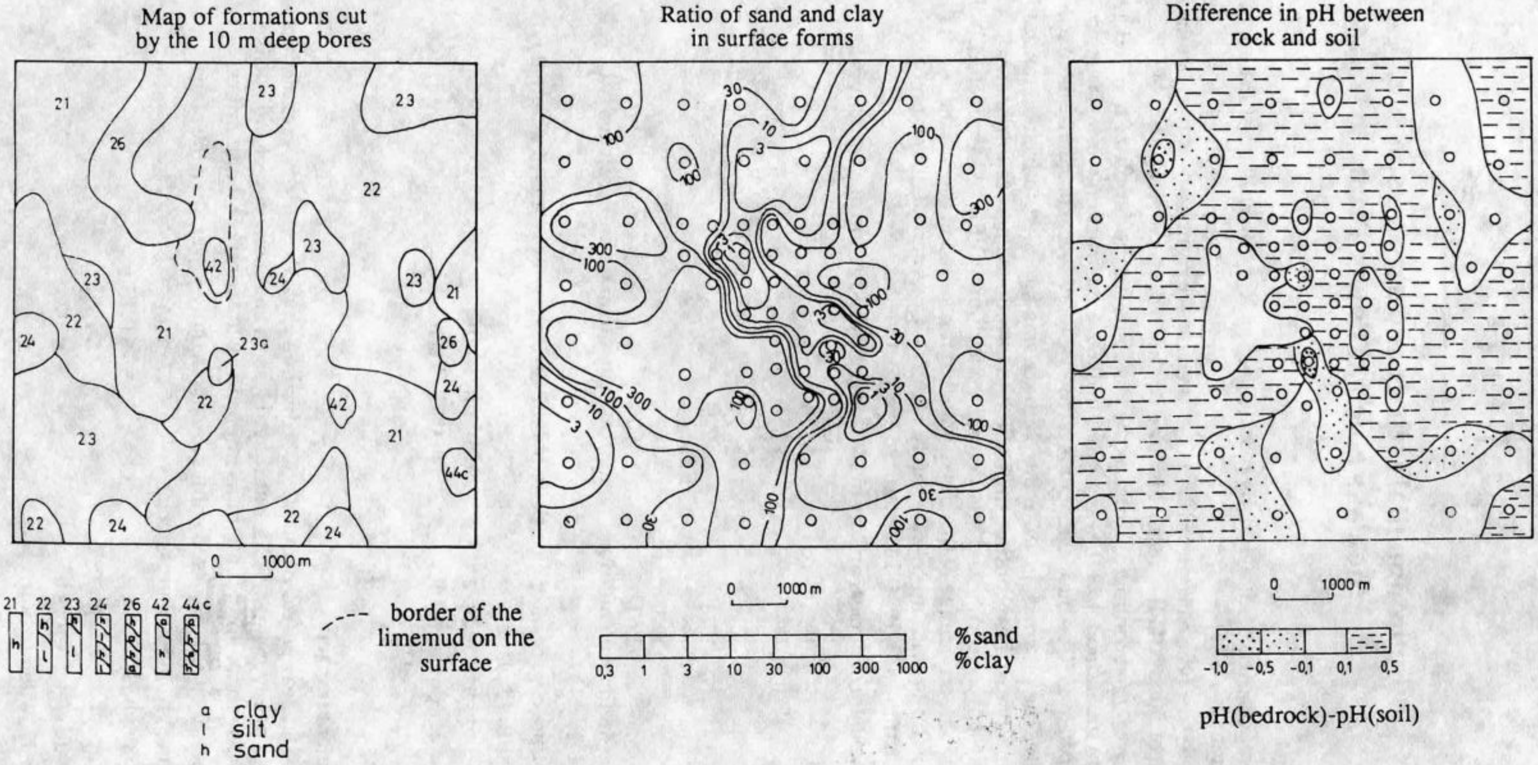

Fig. 2
Bugac. Soil composition shetch maps

The individual dose assessed from the released radioactivity of the plant is very low, about 0.0004 mSv/y in the 3-5 km distance from the NPP. This value is about 1000-times less than the authorized annual limit (0.44 mSv). An average individual in Hungary recieves about 0.0003 mSv/hour from natural sources.

Safety Features of VVER 440 Models 213 and 230 Compared.

In the second generation design (model 213) engineered systems are providede that ensure safety in accidents involving sudden rupture of the main cooling pipeline of 500 mm interior diameter. The primary cooling circuit equipment and its components are housed in a leak-tight containment to cope with 0.15 MPa overpressure. The plant is equipped with core flooding accumulators, emergency core cooling systems and sprinklers, as well as a bubbling condenser-vacuum system designed to limit overpressure in the containment during a loss of cooland accident (LOCA) by condensing steam and retaining noncondensing gases. The following table summarizes the distinctive features of models 230 and 213, most of them relating to safety systems.

Characteristics	*Model 230*	*Model 213*
Date of design	1960s	1970s
Startup date	1972-1982	1980-1987
Units in operation	10	14
Units shut down	6	-
Planned units	-	4
Cancelled units	-	6
Design basic accident	LOCA (100 mm)	LOCA (100 mm)
Containment	No	Yes
Emergency core cool. system	2x100%	3x100%
Main circulating pumps	hermetic design no inertia	shaft seal, high inertia
In-core instrumentation	only temperature	temperature and SPD on-line monitoring
Diagnostics	rudimentary	comprehensive
Core monitoring	without computer	plant computer

The safety systems of model 213 do not differ very much from those of other PWR designs. The only exceptions are the containment system and the bubbling condenser-vacuum system. Analogous features can be found in the CANDU design.

It should be stressed that nuclear safety is not a static concept, but has to evolve over time to reflect more stringent regulatory requirements, the results of safety research and operating experience. For this reason, a long-term design upgrading programme was initiated at Paks early in the lifetime of the plant. Over time new items are added and completed measures are deleted.

Operational Safety

The safety performance of the nuclear plant depends not only on the safety of the desing, but also on the safe operational practice.

The key factors of safe operation in our opinion are:

* training;
* use of simulators;
* organisation of work;
* documentation;
* feedback of experience;
* periodic independent supervision;

More details see Bajsz—Vámos (1991), Fehér (1992). More details will be demonstrated on the spot.

STOP 7

Neotectonic phenomena in the area of Paks

A. KÓKAI

Location: Approx. 5 km W of Paks, N of the road to Nagydorog, in the NW periphery of Földes-puszta, in a small valley.

Indentification: Földes-puszta

Geological age: Upper Pleistocene

Revelation history: In compliance with the instructions elaborated by the International Atomic Energy Agency, the previously foreseen extension of the Paks nuclear power plant necessitated an assessment of earthquake hazard in its surroundings accompanied by the investigation of geological and neotectonic conditions. The first phase of this study concerned a preliminary geological mapping of a 15-km-wide area around the plant conducted by the South-Transdanubian Department of the Hungarian Geological Survey. During this examination some NNE-SSW striking displacements with a dip of 75°-80° attaining a 1 dm dimension have been revealed in the exposure concerned. Unfortunately, a detailed documentation has been omitted. A geological mapping coupled with a neotectonic study has been carried out in 1989 in the area between the Tengelic-Szőlőhegy and Pusztavecse followed by a similar investigation in the 30-km-wide surroundings of the power plant in 1992. This study resulted in the revelation of quite a number of joints in the exposure and in its vicinity.

Lithostratigraphy: According to the guide-lines laid down in the "Lithostratigraphic units in Hungary" published in 1983, the geological sequences of this area correspond to the upper part of the Marcal Sand and the Paks Loess Formations.

The lower part of the profile is represented by yellow sand comprising some brighter stripes and patches. It is intermediately sorted and made up of fine and medium grained fractions. It contains some coarse sand and small-grained gravel as well, forming some-cm-thick layers and lentils. It is intermediately consolidated. Its grains are constituted by quartz, muscovite and rubble. It reveals occasionally some slightly developed cross-bedded features. The majority of shell fragments observed in this formation are intensively eroded. The rugged surface of this unit is overlain by yellow, greyish-yellow, well sorted coarse silt principally made up of quartz and subordinately of muscovite. It does not reveal any stratification but bears a fauna represented by sporadically distributed shell fragments. It might be reffered to as a uniform loessial fauna of the Upper Würm glacial period. In the NW part of the exposure a 130/88° dipping fault plane resulting in a some cm displacement as well as some joints with characteristics of 128/88° and 80/88°, respectively, have been located.

STOP 8

Zonal fertile soils in the Mezőföld Region of the Great Hungarian Plain: pseudomiceliar chernozems

K. RAJKAI *with the contribution of* G. SZENDREI *(soli mineralogy and micromorphology)*

Location: Mezőföld region. Approx. 50 m W of road No. 6. (Budapest-Pécs), at 97,5 km, S of Dunaföldvár.

The Mezőföld region geographically belongs to the Great Hungarian Plain. Its climate is transitional between the Transdanubian Hilly Region and the Great Plain east of the Danube. The area is covered dominantly by loess, however in many places the Pannonian alluvial sediments appear at the surface showing that it has not sunk as deep as it did in other parts of the Great Plain. The hydrological conditions are also different from the great Plain, because its flat table joins the Danube with a high terrace giving high energy to the surface waters which create deep erosional gullies.

The surface of the Mezőföld Region is sectioned into pieces with different altitudes and their expositions slope alone the NW-SE direction of fissures.

In the depressions there are swamps and stagnant waters. Beside the flood area of ancient rivers there are eolian sand deposits which were resulted by wind blowing activity in the dry periods (at Dunaföldvár and Paks). In the Mezőföld Region the soil cover is dominated by chernozem soils.

Formerly in the northern part of the region brown forest soils were developed (mostly on loess) which is reflected in the occurrence of spots of chernozem-brown forest soils and chernozem soils with sings of an earlier forest effect within extended pseudomiceliar chernozems. In the southern part, chernozem-brown forest soils, which have passed through a forest soil formation, can be found on sandy parent material in the presence of a relatively high water table. The parent material of the different chernozem soils in the Mezőföld area consists mainly of typical loess, sandy loess and loessic sand. In some places, Pannonian sand, sandy clay, clay, etc. come up to the surface or to the surface layers. On the Dunaföldvár sand area mostly chernozem-brown forest soils occur, but on lower altitude places, on loess materials pseudomiceliar chernozems are found.

At Bölcske this chernozem soil is demonstrated.

The main characteristics of the profile are as follows:

Surroundings: arable land

Topography: flat plateau

Effervescence: to the surface

Depth of humus layer: 85 cm

Depth of profile: 150 cm

Genetic horizons:

Aplough	0-35 cm	Dark brown, dusty, weak granular structured loam. Many fine roots. Clear transition in compactness.
A	35-69 cm	Dark blackish-brown, fine granular structured loam. Pseudomiceliar coating on the surface of structural elements. Few roots. Transition is gradual.
B	69-85 cm	Reddish, brown, dry fine granular loam. Few roots. Pseudomiceliar coating on the surface of the structural elements.

BC	80-100 cm	Pale yellowish brown crumbling granular loamy-loess. Pseudomiceliar coating is weakly developed. Transition is clear.
C	100- cm	Dry, pale yellowish brown loess with $CaCO_3$ fissures. In the loess sandy inter layering is noticeable.

Soil type: Pseudomiceliar chernozem soil.

Analysis data:

	pH (H_2O)	$CaCO_3$ %	Plasticity index (KA)	OM %	$Ca_{Exc.}$ S%	$Mg_{Exc.}$ S%
A_{plough}	7.82	8	41	2.8	60	10
A	8.12	27	43	1.2	70	15
B	8.15	28	40	0.8	75	15
C	8.35	26	41	—	65	20

Analysis data are from Szűcs L. (1970) and Register of the Authory for Land Evaluation (1983).

The data show that the calcium is dominating among the exchangeable cations (70-90%) while Mg is within 10-15% and K and Na are insignificant.

The region separated from the northern part of Mezőföld according to recent physico-geographical landscape-classification, must be regarded, from the viewpoint of soil geography, as a part of Mezőföld because the described soil forming factors have similar effects both in the southern and in the northern part of the area.

The only difference between the two parts of the mentioned area is that the surface of the northern part is exposed to significant soil erosion in consequence of the higher relief energy, while this phenomenon is much less intensive in the southern part because of the gentle slopes and the broader table-land relief formation.

The physiogeographical changes in the Mezőföld area resulted in some modifications of the main soil-forming processes, consequently further types and subtypes of chernozem soils developed.

The effect of such environmental factors can be observed in the Upper Pleistocene subsided regions near to Polgárdi and in the flat lowland area, without any outlet, of the Pannonian ridges, where calcareous lowland chernozems and meadow chernozems with hydromorphic characteristics in their profile, have been formed.

On the basis of our knowledge about the soil geographical regularities and of a detailed soil survey, it has been determined that in Mezőföld the following chernozem soils have been formed:

1. chernozem-brown forest soil
2. chernozem soil with sings of an earlier forest effect
3. calcareous chernozem
4. calcareous lowland chernozem
5. meadow chernozem.

In Mezőföld besides the above mentioned wide-spread calcareous chernozems, the formation of other chernozem types is also significant.

Soil mineralogy

The clay mineral associations are illite-chlorite, illite-chlorite-kaolinite and illite-chlorite–kaolinite–smectite in the soils of the area according the map of clay mineral associations in the soils of Hungary (Stefanovits and Dombovári, 1985). The amount of illite increases, the quantity of smectite decreases in the upper horizons of pseudomiceliar chernozems compared to deeper horizons. This distribution can be interpreted by smectite→illite transformation (illitization). (Stefanovits-Dombovári, 1986; Varju-Stefanovits, 1979).

Soil micromorphology

The presence or absence of different micromorphological features in pseudomiceliar chernozem indicates the absence of clay illuviation (clay coatings do not occur) and of hydromorphic influence (ferrouginous and manganiferous nodules cannot be found) and an intensive carbonate dynamics. The latter is proved by the variety of different carbonate features i.e. acicular carbonate coatings, carbonate nodules, crystallic b-fabric (Szendrei, 1990). The various forms of carbonates are characteristic for the chernozems of the forest step zone (Poljakov, 1989).

STOP 9

Neotectonic phenomena in the area of Paks

A. KÓKAI

Location: SSW of Dunaföldvár, approx. 500 m of the road to Bölcske at N edge of Nagy-hegy, in an abandoned sand pit.

Identification: Dunaföldvár, Nagy-hegy.

Geological age: Middle and Upper Pleistocene.

Revelation history: In the framework of the earthquake hazard assessment at the site of the Paks nuclear power plant in 1989-90 a study was carried out by the Geological and Geophysical Departments of the Eötvös Loránd University led by Dr. Ferenc Horváth. It was the merit of László Csontos to draw attention to this exposure with the structural phenomena observed there. The profile described during the geological mapping of the 30-km-wide surroundings of the power plant in 1992 can be outlined as follows:

The exposure represented by this pit is divided on for parts by three unconformities.

Eastern face — I.

The lower part of the sequence is made up of yellow, intermediatelly rounded qartz sand, bearing occasionally limonite, with quite a number of opaque grains. The grain size varies in a considerable range — the fine-grained sand badly sorted while the small-grained gravel layers of the coarse fraction are arranged in lentils. A slight, but not characteristic oblique stratification can also be observed in an approx. 2 m interval.

This sequence is overlain by a 1,5-m-thick fossil soil horizon overlain in turn by silt and the soil cover.

II.

Its base is similar to that of the first unit, it is namely represented by an approx, 2-m-thick sand with the coarse fraction also arranged in lentils.

It is overlain by a uniform horizon constituted by pale-yellow, unstratified sandy silt and silt.

As compared to the first block, this one has been displaced downwards, the absence of the fossil soil horizon is due to some palaeogeographical or geochemical phenomena.

III.

It is made up of medium-grained and coarse sand. It can be considered as the horizon presenting the best stratification. The coarse fraction is virtually absent. Parallel beds and fine laminae are characteristic. It bears the shell fragments of Molluscs. It passes upwards to sandy silt (loess) with a continuous transition.

IV.

It is represented by medium-grained and coarse sand with small-grained gravel. The oblique stratification is very clearly manifested. The small-grained gravels are arranged in lentils. It contains few micas. It presents also a continuous transition in the overlying sandy silt and silt horizons thinner as in the case of the previous block.

The plane of the first fault can be described by 234/64°, it seems to be straight.

The plane of the second fault can be described by 86/56°, it is straight.

The third fault is curved with the characteristics of 92/57°.

A number of fissures and several planes of collapse can be observed parallely with the plane of the wall as well as a fissure described by 220/57°.

During the geological mapping made in 1992 we measured 1379 joints in the surroudings of the nuclear power plant. On the basis of their statistical evaluation it has been found that the main part of the joints are parallel to the "Kapos-line"-parallel structures could have been active in the Pleistocene. From this point of view, the "Paks-line" — proved in the Pliocene sediments near the power plant — can not be a favoured zone. Although the intersection of the structural lines which are parallel to the "Kapos-line" and the "Mór-graben", respectively, is very important from the view of seismotectonical security, its existence has not been proved.

More details see Ádám-Marosi-Szilárd (1959), Balla (1988a,b,c, 1991), Chikán et al. (1986, 1987a,b, 1992), Chikán-Kókai (1989), Erdélyi-Chikán-Kókai (1985), Jaskó-Krolopp (1991), Jámbor et al. (1982), Kókai (1988), Marosi (1953), Marosi-Schweitzer (1991), Némedi-Varga (1977, 1986), Pécsi (1959), Pogácsás (1990), Pogácsás et al. (1988), Rónai (1964).

STOP 10

Slope stability problems of the Pannonian outcrops along the eastern shore of Lake Balaton

T. BOROMISZA

Introduction

Location: road No 71, NW of Balatonakarattya railway station. Turn to SW up to Kisfaludy street. Approx, 100 m NW on the street.

Balatonaliga-Balatonakarattya-Balatonvilágos are three neighboring resort places on the east coast of Lake Balaton. Moving East from the coast, the flat pediment along the coastline turns into a high rise steeple. The free face accommodates strata of the elevated Pannonian sequence named "Balaton Plateau". That plateau is covered by loess. It is about 100 m above Lake Balaton. Its is surrounded by the Polgárdi blocks from the North, and by the Middle and the West Plateaus of the Mezőföld from the East and South.

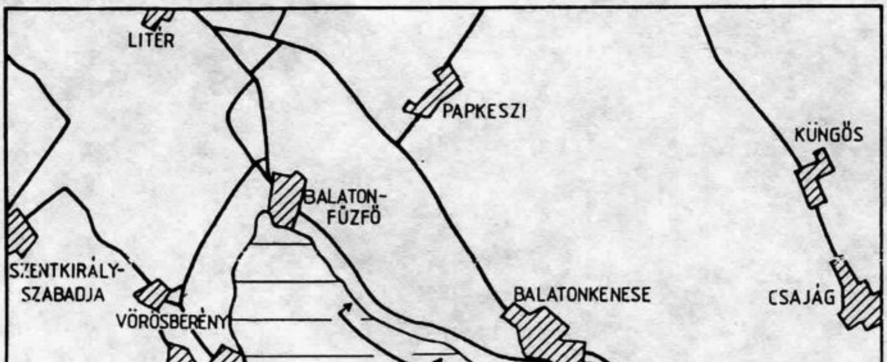

Fig. 1 The north-eastern shore of Lake Balaton. Number 11: place of the excursion

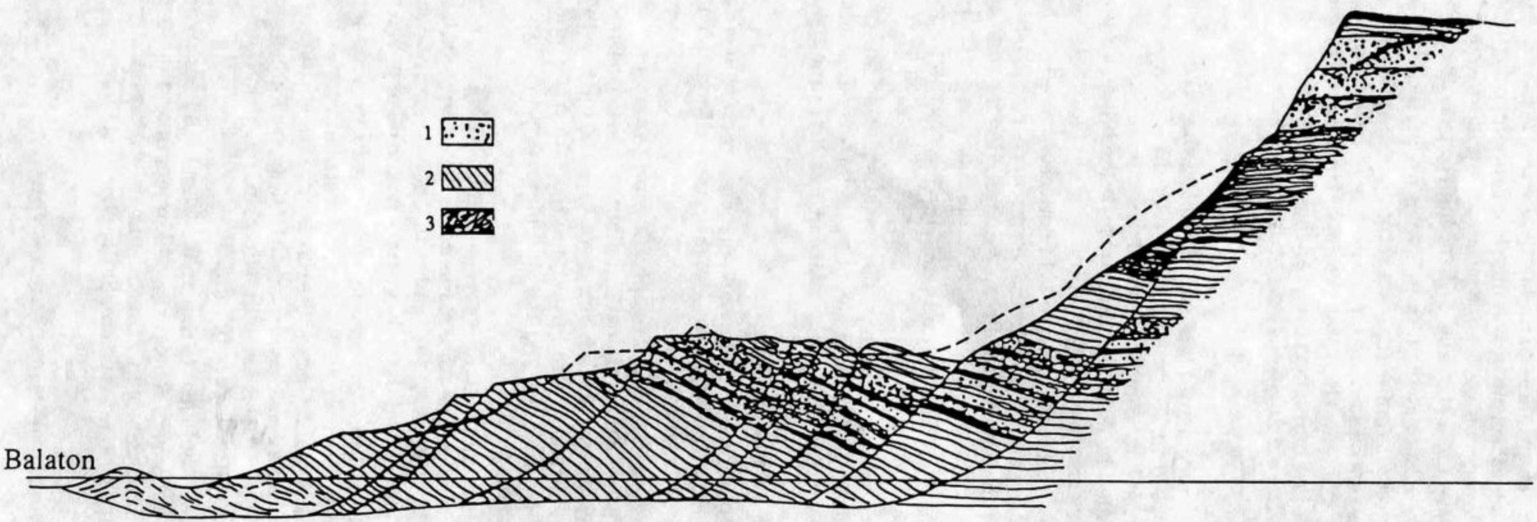

Fig. 2
Cross section at Akarattya after landslide in 1908; 1. Sand, 2. Silt, 3. Clay.

The north-eastern shore of the lake is adjacent to the loess-covered Mezőföld (Fig. 1). The typical geological set-up of this area is a Pannonian sequence, consisting of sand, silt and clay. The layers can be seen well along the north-eastern shore, where the level difference between the water table and the high coast is about 70 m.

Behind the coast line the terrain level is lower, therefore rainwater can accumulate and infiltrate into the ground. It passes through the sand layers and breaks out in springs. One part of these springs are under the bottom of Lake Balaton, others make wet the clay layers of the escarpment. This is the reason of landslides. The danger of these movements increased in the last times, because the villages are not canalised, but they have a drink water network. The old dug wells are out of use, consequently the ground water table rose.

Akarattya area

The first movement dates back to 1869 when the lower part of Csittény hill at Akarattya collapsed in 250 m length. In 1908 during the railway construction an other landslide occurred between the 336-343 hm sections (Fig. 2). The axis of the railway trace had to be relocated by 30 m distance towards the hill and a tunnel of 95,5 m length was built, functioning as a retaining pillar.

New movements occurred in 1914 between the 340-360 hm sections under Csittény hill. To prevent the damages, a drainage system was established and shore strengthening was executed with stone blocks. Because of mudding the drainage system was renewed in 1958 (Fig. 3) and in the sixties the shore of the lake was filled up in 50 m width.

The slope of Csittény hill was unloaded in 1987-88 by removing 170 000 m^3 earth. Drains and ditches were built.

Another typical endangered spot was the eastern side of the escarpment where the earth moved down in 1936 and swept away the dressing cabins of the beach. Here the beach was relocated by filling up the lake in a width of about 40 m.

Balatonkenese-Balatonfűzfő area

The first observation of the movement of Fancsér hill is dated from 1875. During the railway construction in 1908 because of the repeated landslide the railway axis ought to be relocated towards Lake Balaton.

After putting the railway in operation, on 11 May 1914 at noon, in consequence of a disastrous landslide, a mass about 0,5 million m^3 of earth rushed down on the trace, moved it and a train which was just passing there, towards the lake by 40 m. The locomotive and two passanger-carriages were turned into the lake. The engine driver, seeing the movement, stopped the train, he and the staff jumped out at right time. Fortunately, no passangers were in the train.

After this event the trace was relocated towards Lake Balaton along 800 m length in a width of about 60 m. The embankment was based on stone blocks. The movements were repeated in 1936, 1937, 1941, 1942 and 1946. The earth movement lifted up the highway Nr. 71. Both the highway and the railway trace had to be removed several times.

The reason of this movements is the rise of the piezometric water level. A typical cross section is to be seen in Fig. 4. The water infiltrates into the sand layers causing hydrostatic pressure and wetting the clay layers. The slip occurs on the surface between the pervious and impervious layers, as the shear strength decreases. The shear strength measured on core samples along the slip plan is 40-45 kN/m^2. Calculating with this value, the angle of the stable slope is 10° (Fig. 5).

Because it is hopeless to dry up the 60 m high Pannonian outcrop, both the railway and the road trace were relocated in 3 km length and in 70-120 m width towards Lake Balaton in the fifties. Since that time no movement has occurred on this section. Nevertheless the drainage system is systematically observed (Fig. 6).

More details see Eartl (1967), Dörre-Virág (1963), Virág-Csutkay (1959).

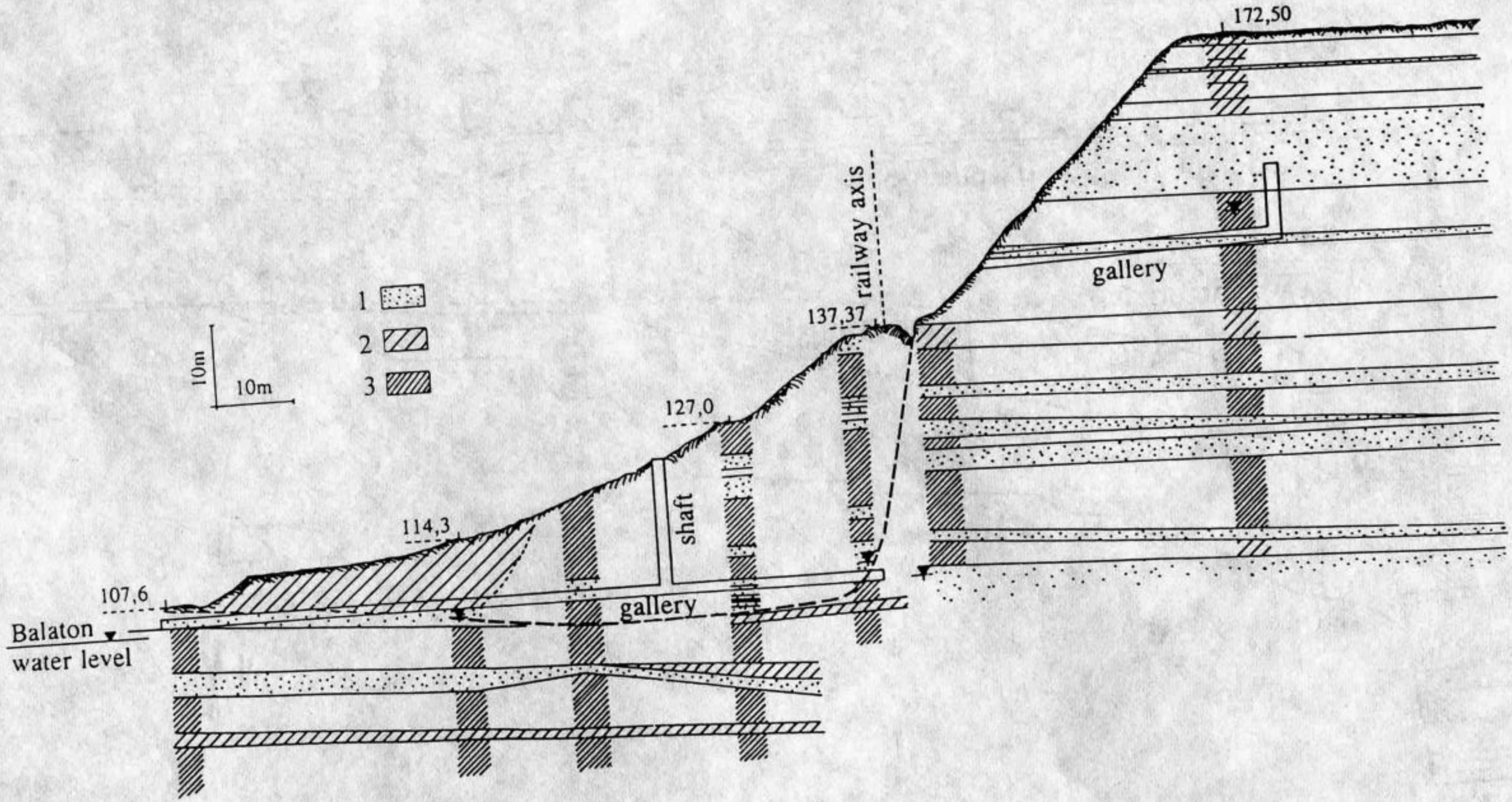

Fig. 3
Cross section at Akarattya after landslide in 1958; 1. Sand, 2. Silt, 3. Clay.

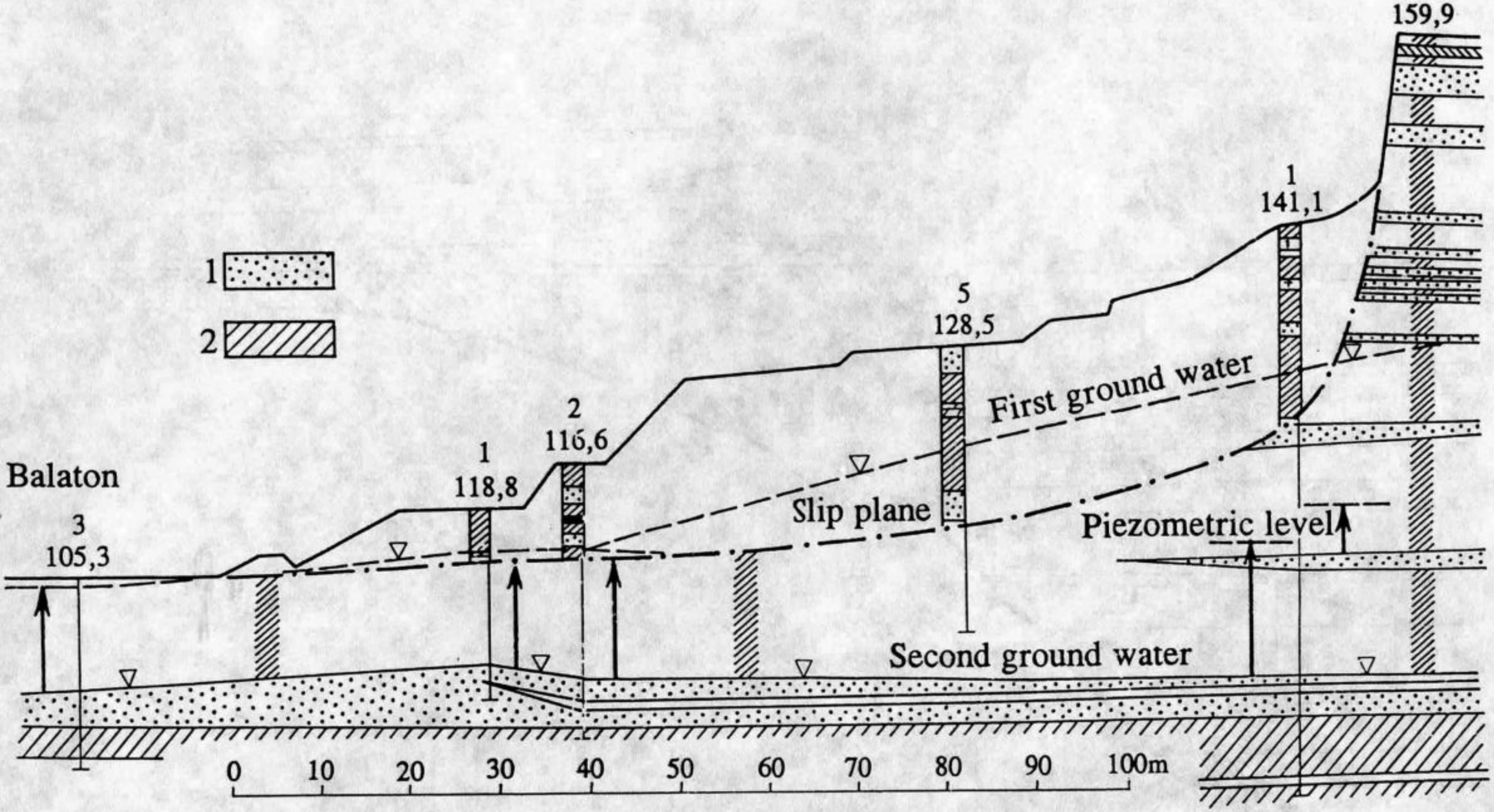

Fig. 4
Cross section between Balatonkenese and Balatonfűzfő; 1. Sand, 2. Silt.

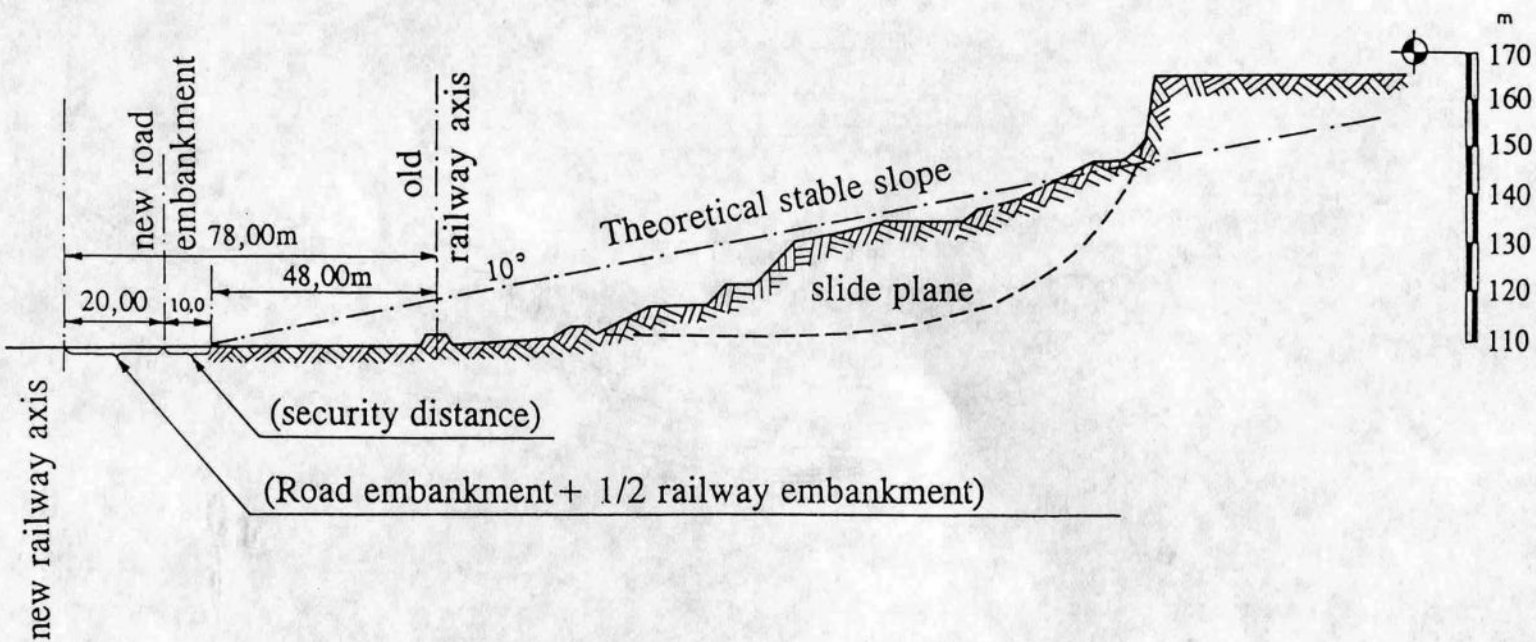

Fig. 5
The theoretical stable slope angle between Balatonkenese and Balatonfűzfő

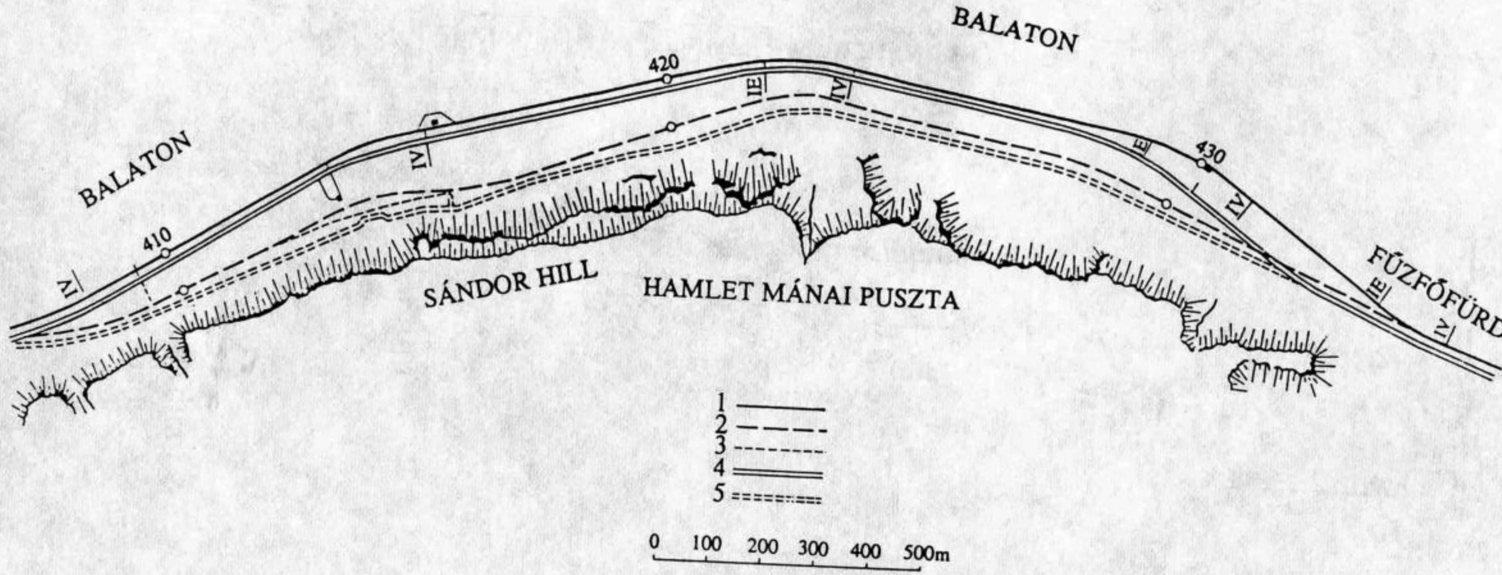

Fig. 6
Trace relocation between Balatonkenese and Balatonfűzfő; 1. New railway, 2. Old railway, 3. Old trace relocating, 4. New road nr. 71, 5. Old road nr. 71.

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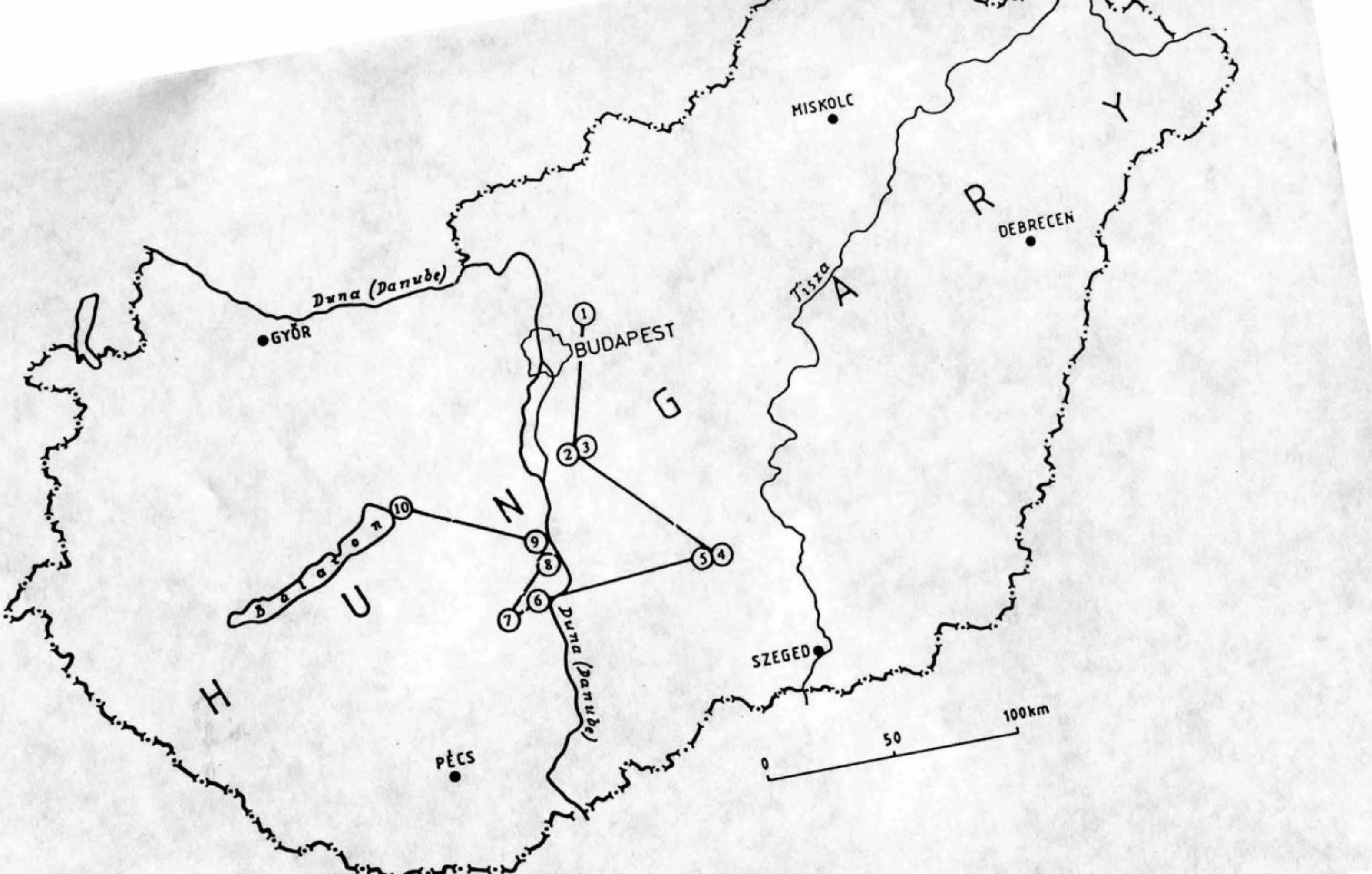

Route of the field trip and locations of the stops

5543-93. MOL Rt. • Nyomda, Szolnok