8th MEETING of the ASSOCIATION of EUROPEAN GEOLOGICAL SOCIETIES

EXCURSION GUIDE

Field Trip C

Oil and gas, subsurface water, and geothermy in the Pannonian Basin

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Evolution of Intramontane Basins
on the Example
of the Pannonian Basin

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Oil and gas, subsurface water, and geothermy in the Pannonian Basin
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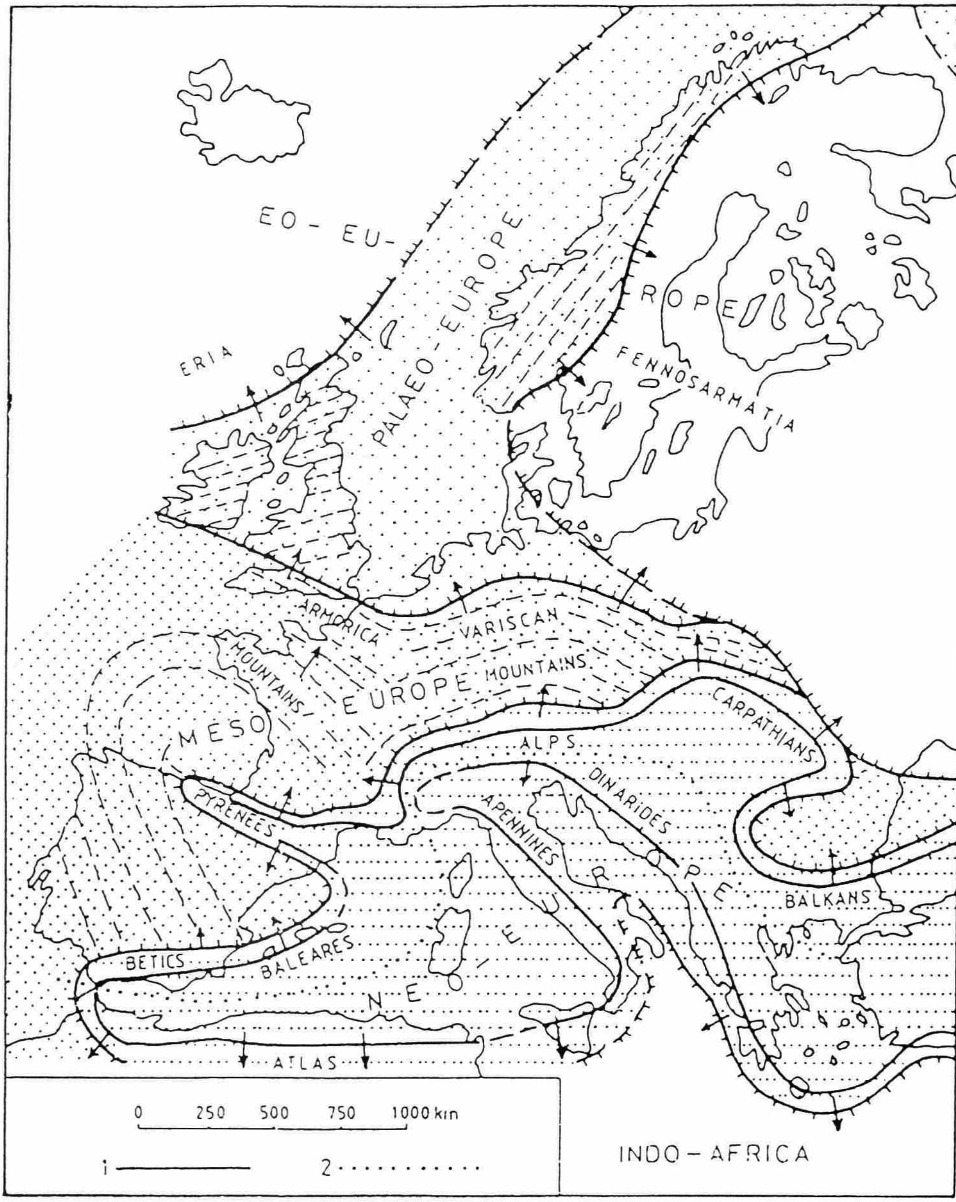
J. HAAS

Introduction

Fig. 1

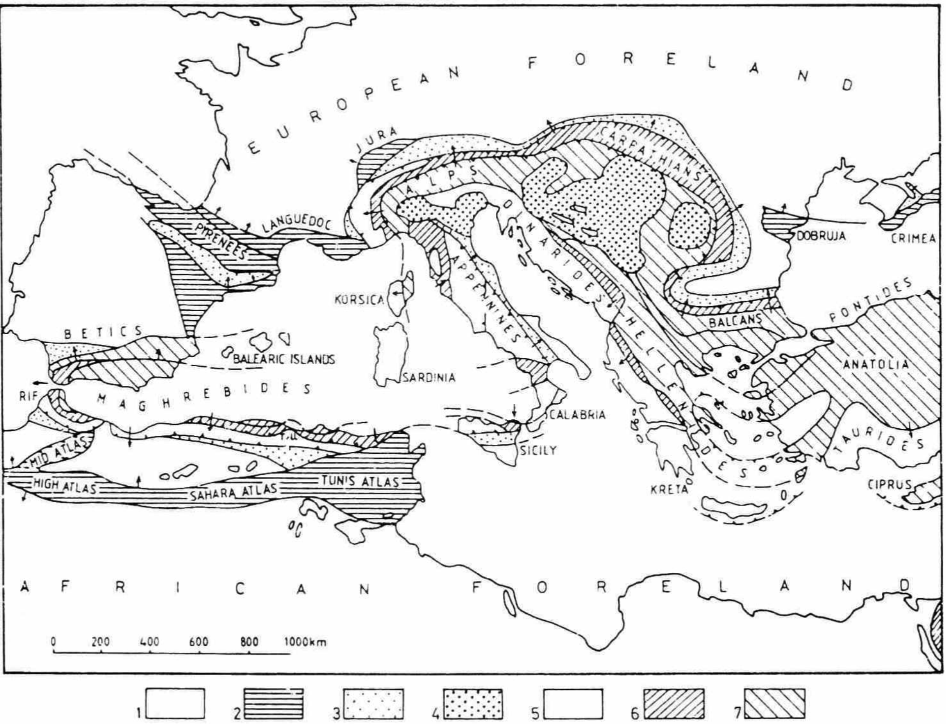


Megastructural subdivision of Europe (H. Stille 1924). 1: Strike of the Alpids. 2: Boundary of arctogenic and meridiogenic folding. To the Precambrian nucleus of Europe (Eo-Europe) three accretions have been added: Palaeo-Europe in the Caledonian phase, Meso-Europe in the Hercynian phase and Neo-Europe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

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

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.

Fig. 2

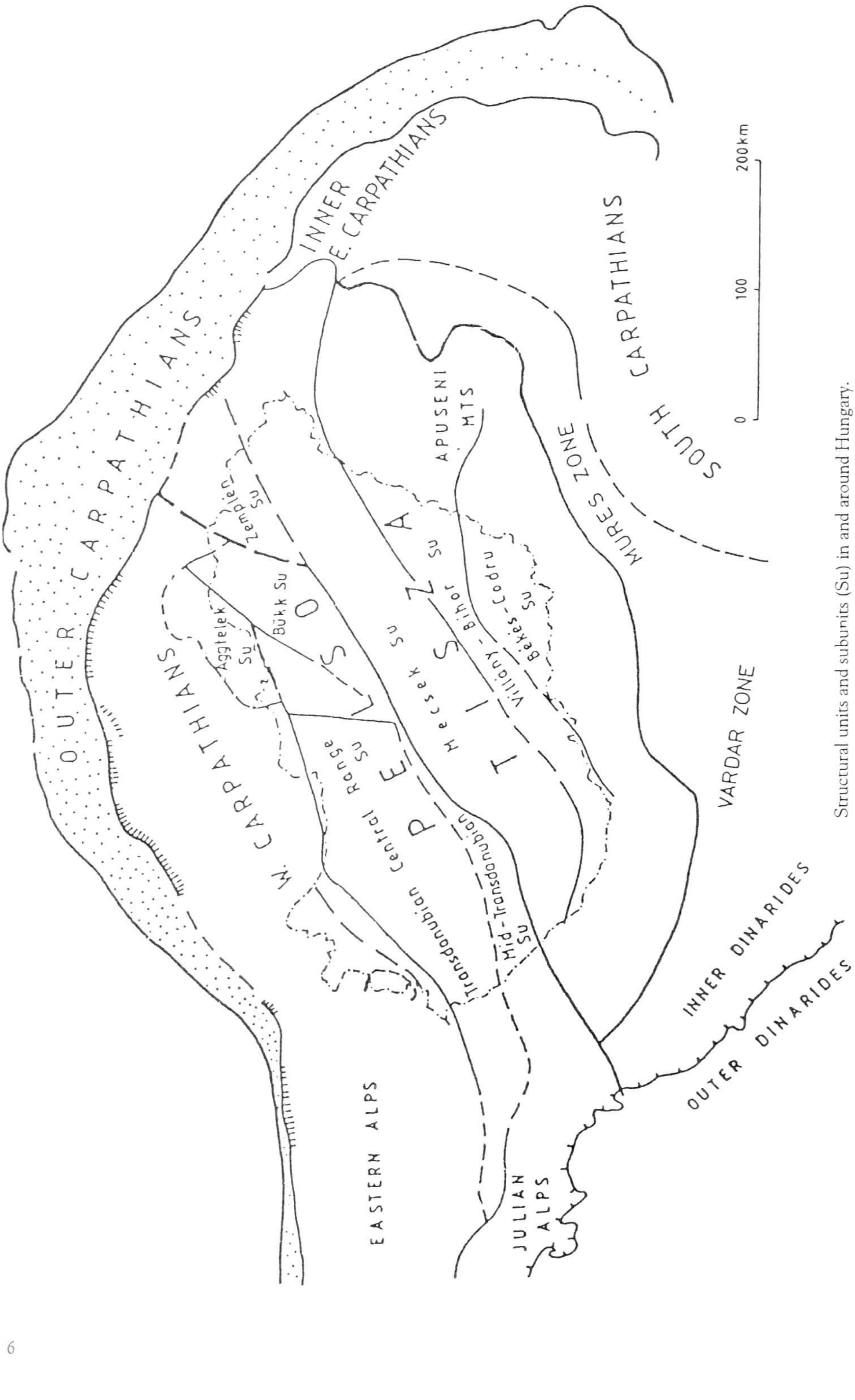


Alpine Europe (J. Aubouin - M. Durand-Delga 1971). 1: foreland, 2: intracratonic mountains, 3: molasse foredeep basins, 4: internal molasse basins, 5:external zone, 6: flysch nappes, 7: internal zone, 8: scale.

The 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 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.

Fig. 3



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

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 (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 1988c).

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,

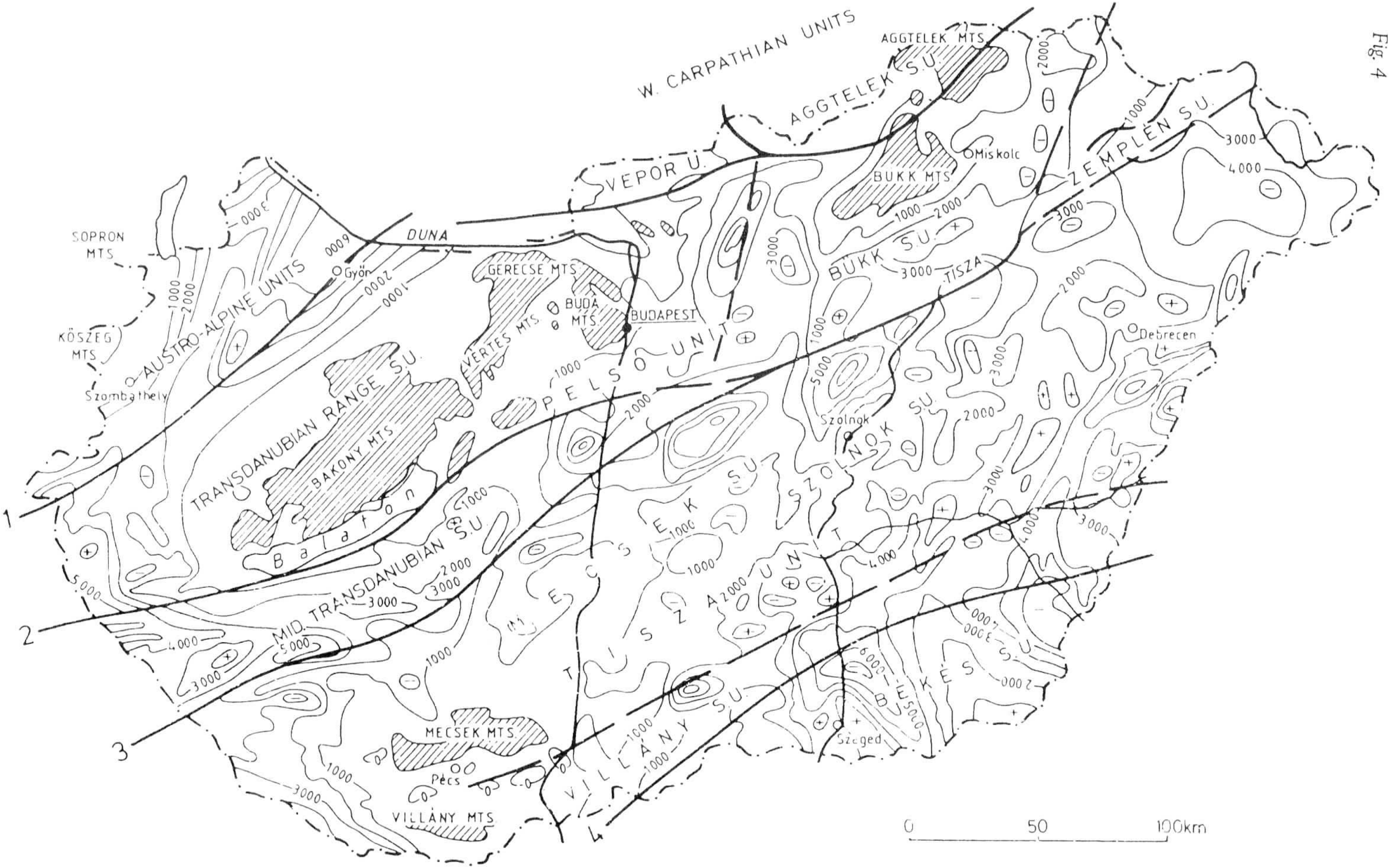
— the Alpine stage including the Late Paleozoic, Mesozoic and Paleogene evolution of the Tethys, with orogenic events (Eoalpine, Paleoalpine, Mesoalpine) manifested in napped-folded tectonism and large-scale strike-slip movements,

— 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.).

Fig. 4



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

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 similar 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

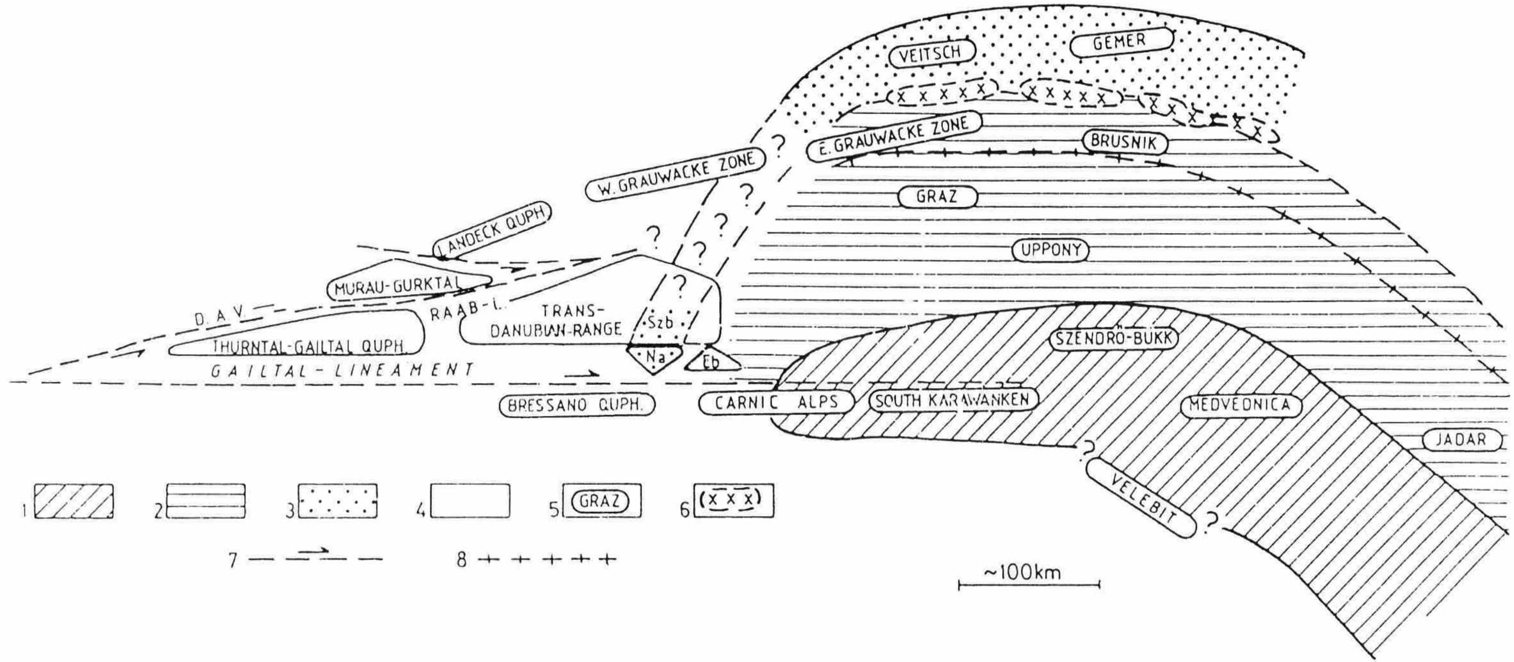
Interpretation of the Pre-Hercynian geohistory is particularly difficult due to the polyphase metamorphism and uncertain age determination.

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



Palaeogeographic situation of the NW and of the Alpine-Dinaric branch of Palaeo-Tethys in the Middle Carboniferous (schematik reconstruction by S. Kovács).
1: Flysch formation, 2: carbonate sedimentation on shallow shelf, 3: molasse sedimentation in pst-Cariscan 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.

Fig. 5

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.

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 disturbe the evolution trend in the carbonate ramp and subsequently the rimmed shelf sedimentation was continuous.

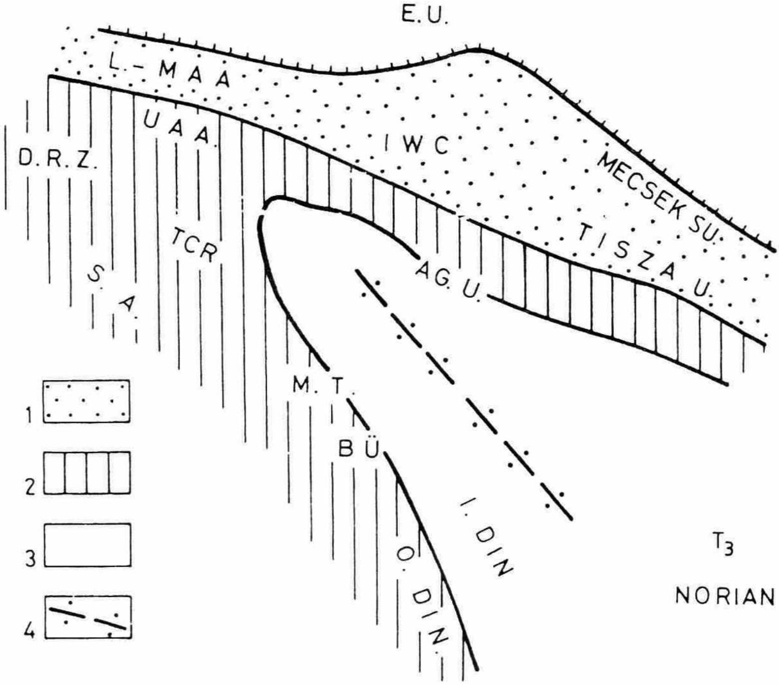
1.3 Stabilization of the passive margin in the Late Triassic.

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 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.



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.

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.

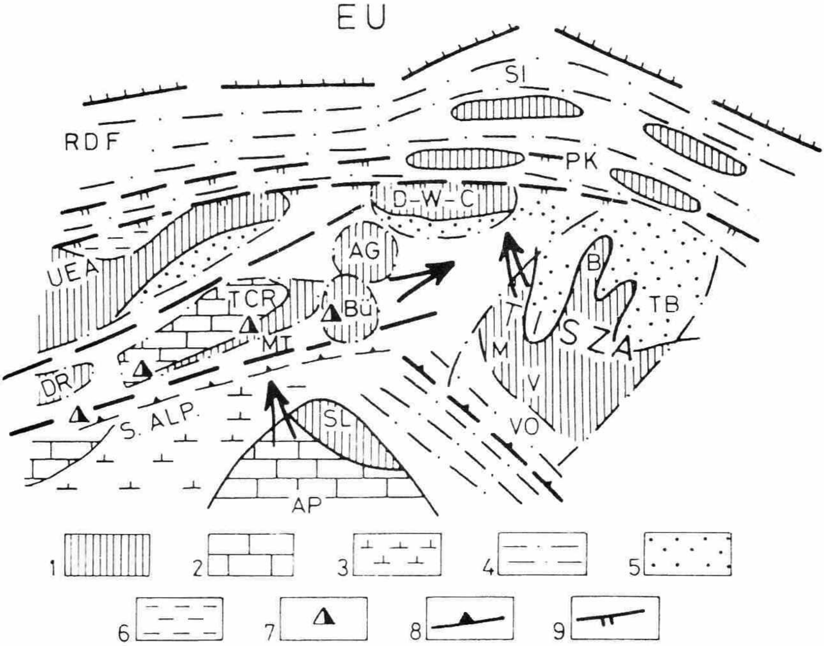
In the Apuseni Mts the main phase of the nappe formation may have been in the Early Senonian. This is probably true for the whole Tisza Unit. The orogenic phase (Sub-Hercynian) was followed by the Santonian-Campanian transgression-regression cycle, producing predominantly siliciclastic sediments.

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



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.

2.2. Partethys evolution and large scale displacements of the Pelso Unit in the Oligocene-Early Miocene (Fig. 7).

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 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 megaunits close to their present-day setting.

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

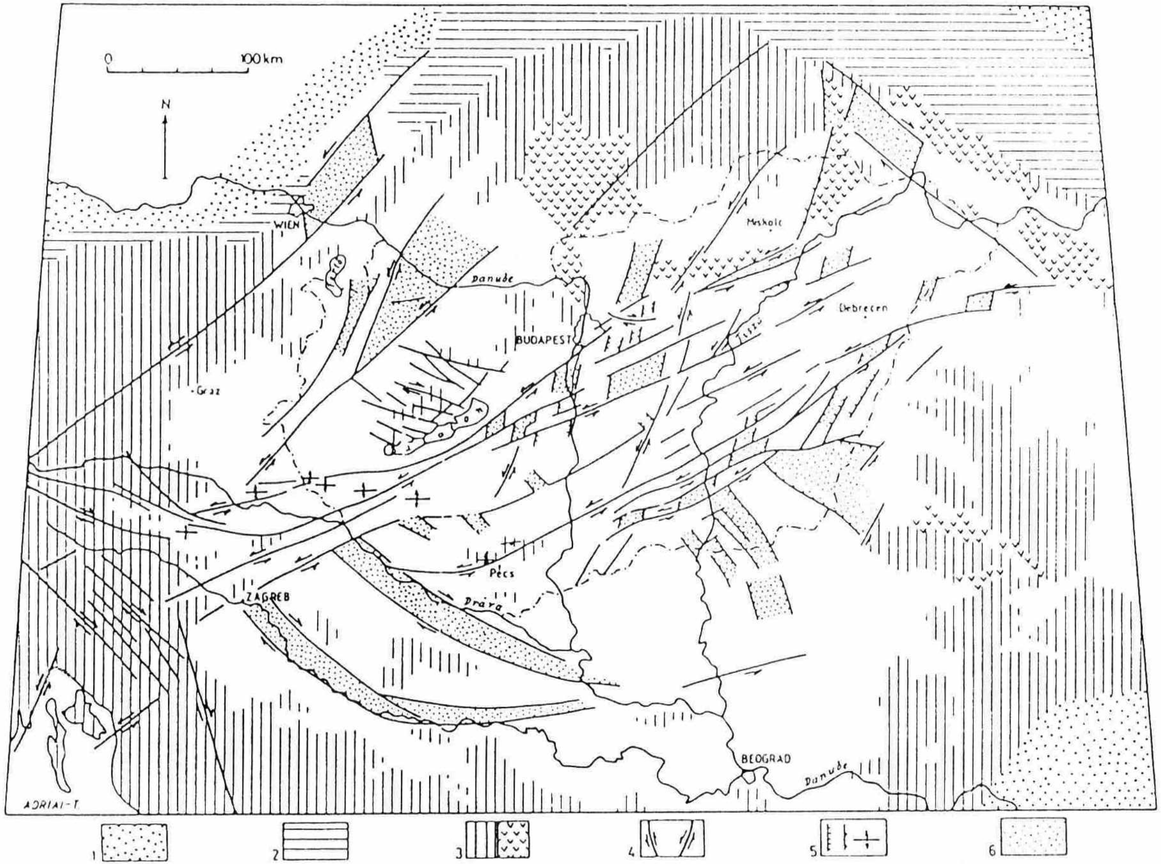
At the beginning of the Middle Miocene due to a significant orogenic event ("Styrian phase") a remarkable uplift occurred in the Alps and in the Carpathians. Coevally, in the southern foreland of the Alps and within the Carpathian arc deep grabens as well as basins came into being. The elongated grabens 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.

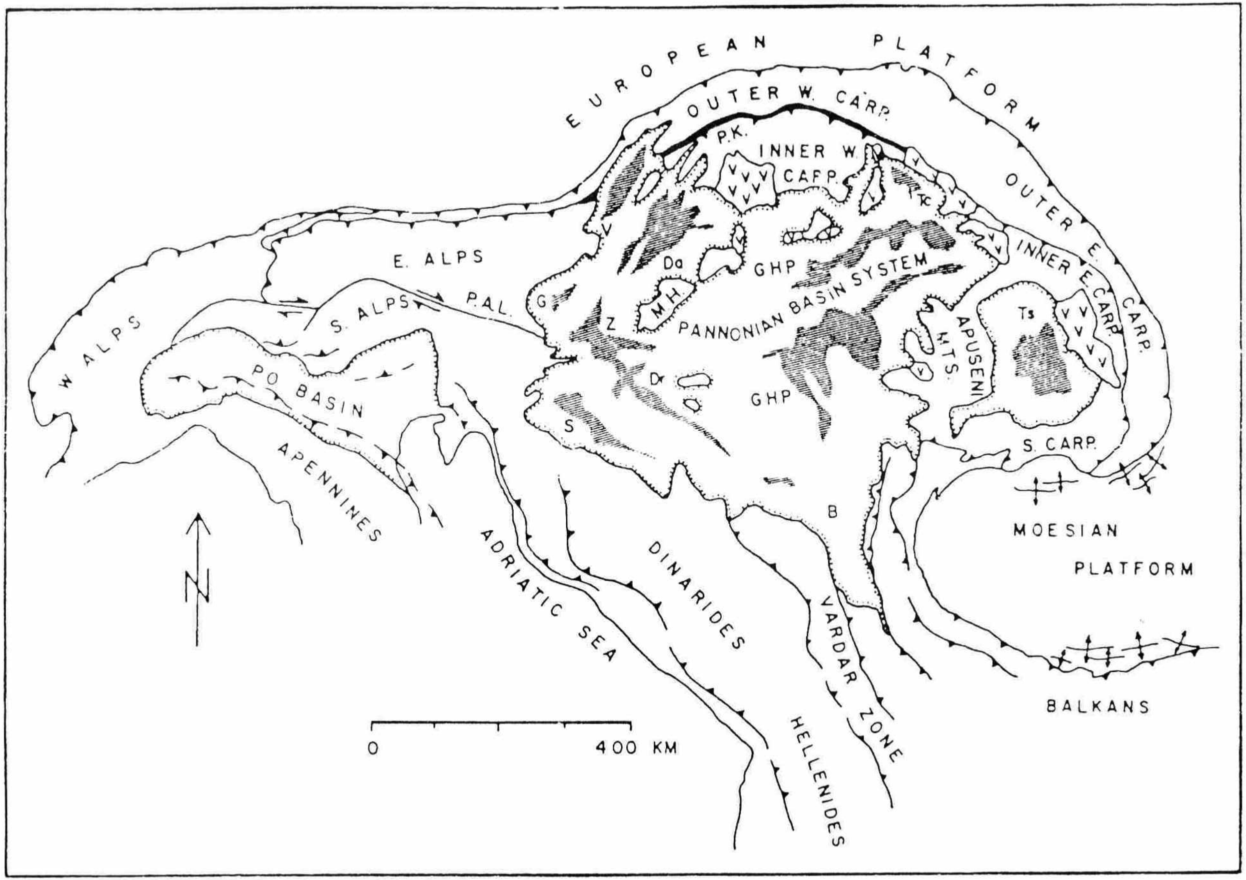
In the Late Miocene intense subsidence of areas of thinned crust started, a process which led to the genesis of the Pannonian Basins system. Coevally, the marine connection of the basins surrounded by the Alpine-Carpathian-Dinaride ranges came to an end.

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.



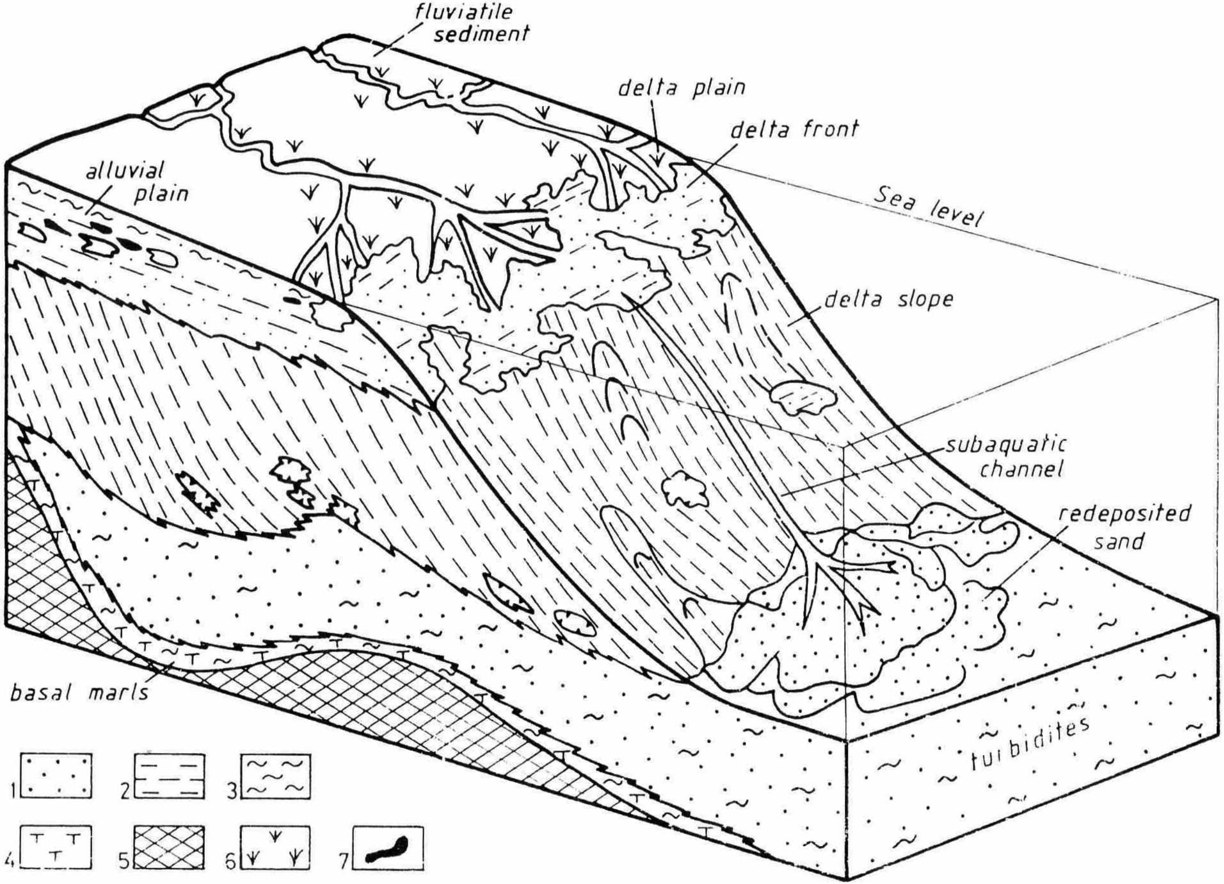
Neogene model of the Carpathian-Pannonian region (F. Horváth 1987). 1: molasse foredeep, 2: flysch belt, 3: Alpine, Carpathian and Dinaric Mountains, (a): Neogene volcanic area, 4: strike-slip fault, 5:normal fault, 6: deep depressions connected with faults.

Fig. 8



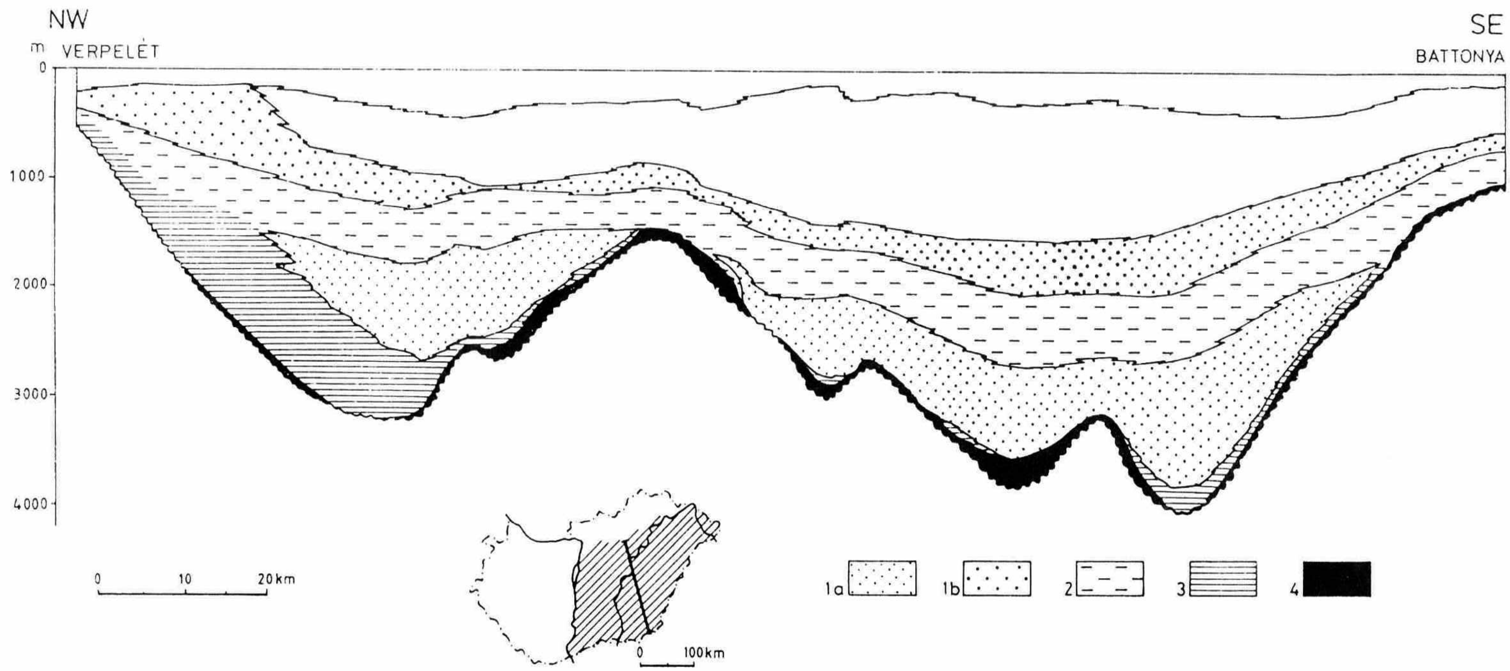
Position of the Carpathian Mountains and the Pannonian Basin (Royden 1988). Strippled area indicates parts of the Pannonian Basin where the depth to base Miocene exceeds 3 km. Subbasins are: V: Vienna, Da: Danube, G: Graz, Z: Zala, Dr: Dráva, S: Sava, Tc: Transcarpathian, Ts: Transylvanian, GHP: Great 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 Pan: onian Basin) (Gy. Juhász 1992). 1a., b.: standstone, 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 Creataceous 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 characterished 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 occurred, 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 de 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-fluival 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 unconformyty 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 rhytmic 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.) or immediately 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 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 restricted to the relative highs of the basement, the calcareous marl is widespread. Where the Pannonian is thin (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).

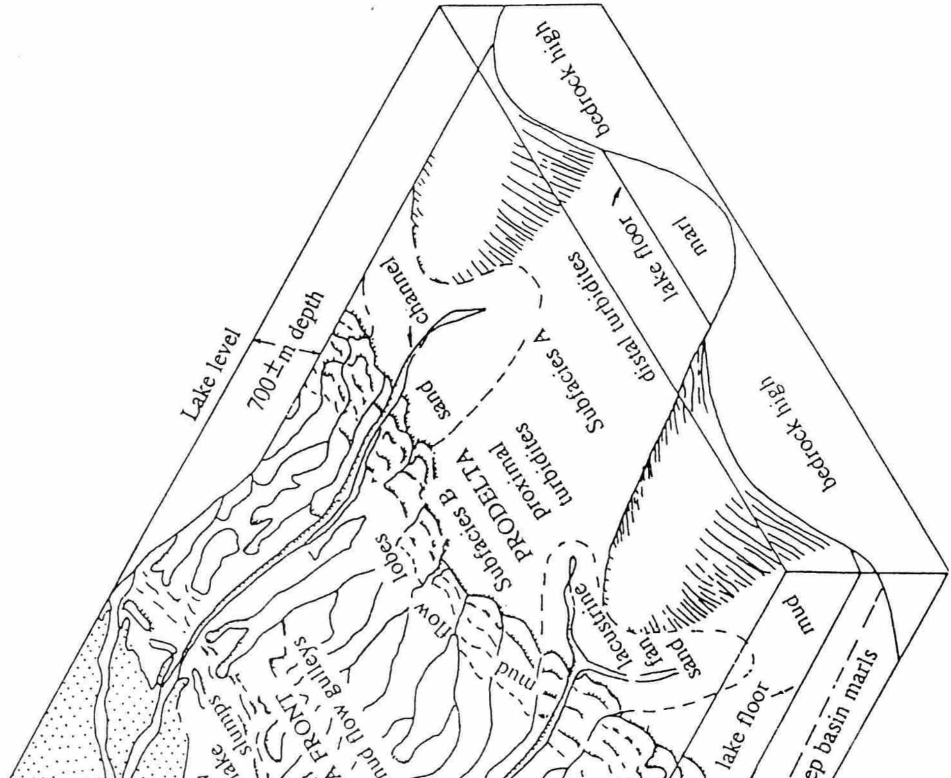
The turbidite unit comprises a sand-rich system with the sand content varying from about 30 to 90 percent. The upper members are more sandy. These sand-rich turbities in some places can be subdivided into several depositional systems on the basis of the characters of the vertical sedimentary sequences. 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 identified 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 overlines 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.

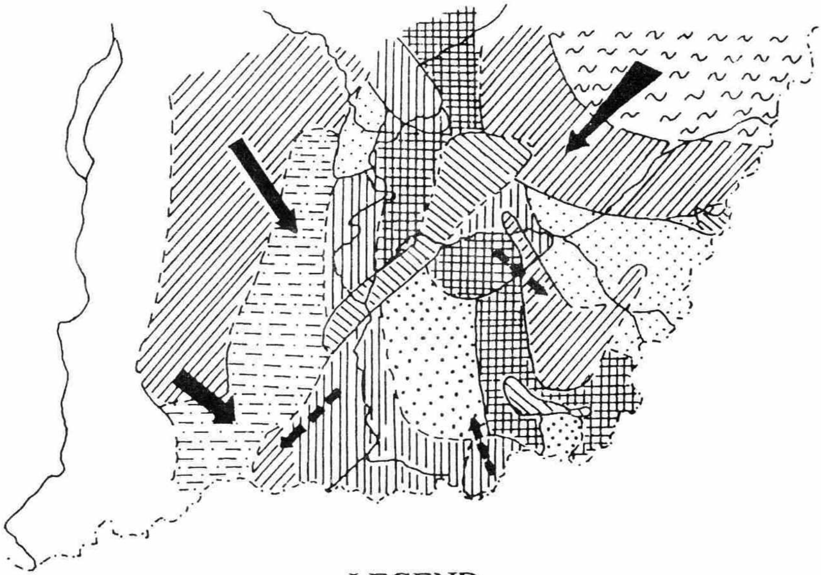
The Bouma sequences consist of Ta, Ta-e (over the 60 percent of the turbidies), Ta-b, Ta-b-e, and Ta-b-c. Complete Bouma division, that is, Ta to e and Ta-b-c-d is characteristic only in the basal part of the turbidites overlying the basal lobe deposits. Besides graded and massive sandstone, load structures, 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

Fig. 1



Lake level
700±m depth
DELTA PLAIN
Fluvial distributaries
Shoreline
Shallow lake
slumps
mouth bars
DELTA FRONT
mud flow gullies
Prograding lobate delta
slumps
distributary channel
channel
mud flow
lobes
Subfacies B
PRODELTA
proximal turbidites
sand
channel
Subfacies A
distal turbidites
lake floor
marl
bedrock high
bedrock high
lacustrine fan
sand
mud
mud
lake floor
Deep basin marls
Delta front facies
Prodelta
subfacies B
subfacies A

Fig. 2



LEGEND

ROCK BODIES

Connected with delta systems	Unconnected with delta systems
Upper fan	Upper fan morphology
Lower fan	Mid fan morphology
Not typical fan morphology	Coarse grained coastal formation
More typical fan morphology	Neogene basement

- Transport direction of the delta
- Transport direction of the deep water redeposition

sandstone containing argillaceous marl and siltstone clasts as well as laminated argillaceous marl and siltstone beds. Upward large-scale crosbedded sandstones and amalgamated turbidies overlie in turn the lower sandstone unit. This sequence may represent the basal part of a channel system.

Deformed turbidies as well 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.

Oil geology of the Great Plain sector of the Pannonian Basin

S. PAP

The Great Hungarian Plain constitutes the greatest part of Eastern Hungary and at the same time it is part of the Pannonian basin.

The Pannonian basin began to subside in Miocene time. The subsidence was accelerated at the beginning of the Pannonian. During subsidence the basin at some places became deeper than 7000 m (Fig.1). The Neogene basin of the Great Hungarian Plain is filled partly with Miocene volcanic and sedimentary rocks but mostly with Pannonian and younger sediments. The clastic material of the Pannonian sediments was carried by rivers to the sea. For this reason the salinity of the sea water decreased. Finally it became an inland lake. Farther from the shoreline neritic marls, clay-marls were deposited, overlain by prodeltaic sediments (distal and proximal turbidites), followed by sediments of delta slope, delta front and delta plain.

Fig. 1

Basement of the Neogene deposits in Eastern Hungary

Fluvial, lacustrine and palustrine sediments closed the sequence. The lithostratigraphic subdivision and facies of the Pannonian formations in the Great Hungarian Plain can be seen in Fig 2.

The average organic carbon content in the Neogene pelites is 8,6 mg/g. The clay-marl and siltite have an average organic carbon content of 5,0-7,0 mg/g. The calcareous marl contains more than 10 mg/g.

The average bitumen content in the Neogene pelite is 0,7 mg/g. This value is fair for the genesis of oil and gas. In the calcareous marl the average bitumen content is 1,21 mg/g, wich is favourable for oil and gas generation.

M. Hetényi published in 1992 the organic - geochemical data of some formations of the Pannonian s.l. in the Makó-3. well:

Formation	Number of Samples	TOC %	HC pot	— HI	Tmax C	Maturity stage
Great Hungarian Plain	20	6,08	6,00	68	421	
Zagyva and Törtel	61	21,98	31,32	132	417	diagenesis
Algyő	48	0,76	0,74	71	432	catagenesis
Szolnok	44	0,83	0,83	58	436	catagenesis

HC-pot: hydrocarbon potential (kgHC/ton of rock)
HI : hydrogen index (mgHC/gTOC)

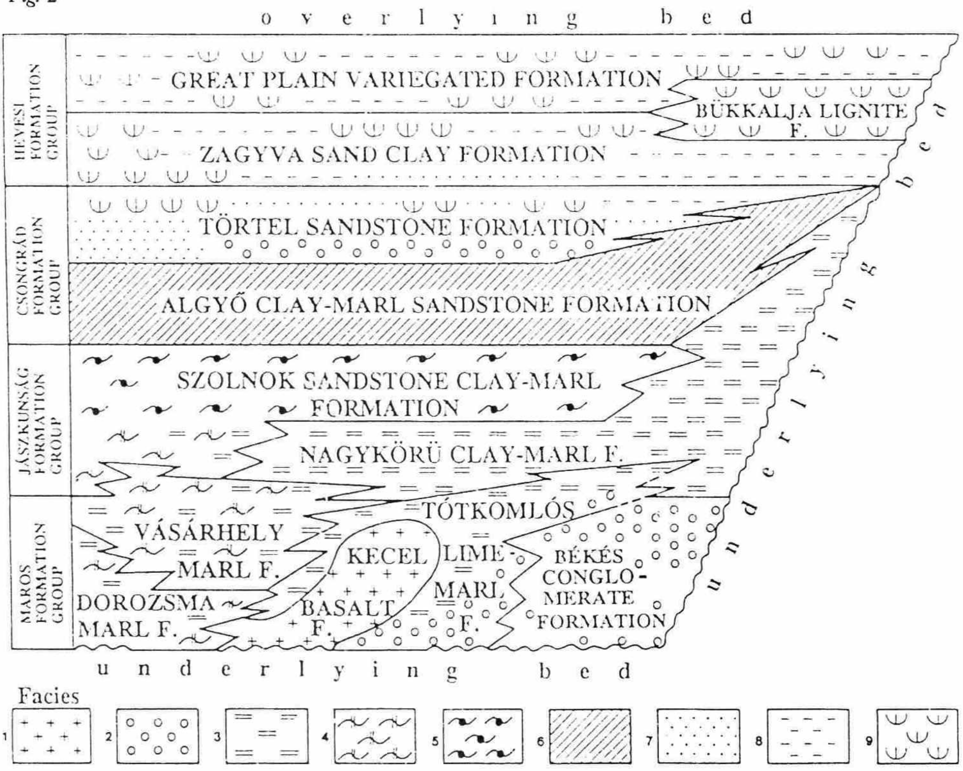
The high geothermal gradient (0,08-0,04 C/m) accelerated the maturation of the organic matter and thus the generation of oil and gas. The vitrinite reflection values characterise the maturity of the organic matter.

Depth (km)	Vitrinite average	reflection spread
2	0,5	0,06
2,5	0,64	0,09
3	0,82	0,14
3,5	1,07	0,22
4	1,30	0,33
4,5	1,82	0,63
5	2,48	0,85

On the basis of average vitrinite values the pelitic and carbonate rocks which are situated deeper than 2,5 km are effective source rocks.

The weathered, fractured, brecciated parts of Precambrian, Paleozoic and Mesozoic basement, the Miocene detrital rocks, the Pannonian basal conglomerate (Békés Conglomerate Formation) and the sandstone layers alternating with clay-marl layers are good water and hydrocarbon reservoirs.

Fig. 2

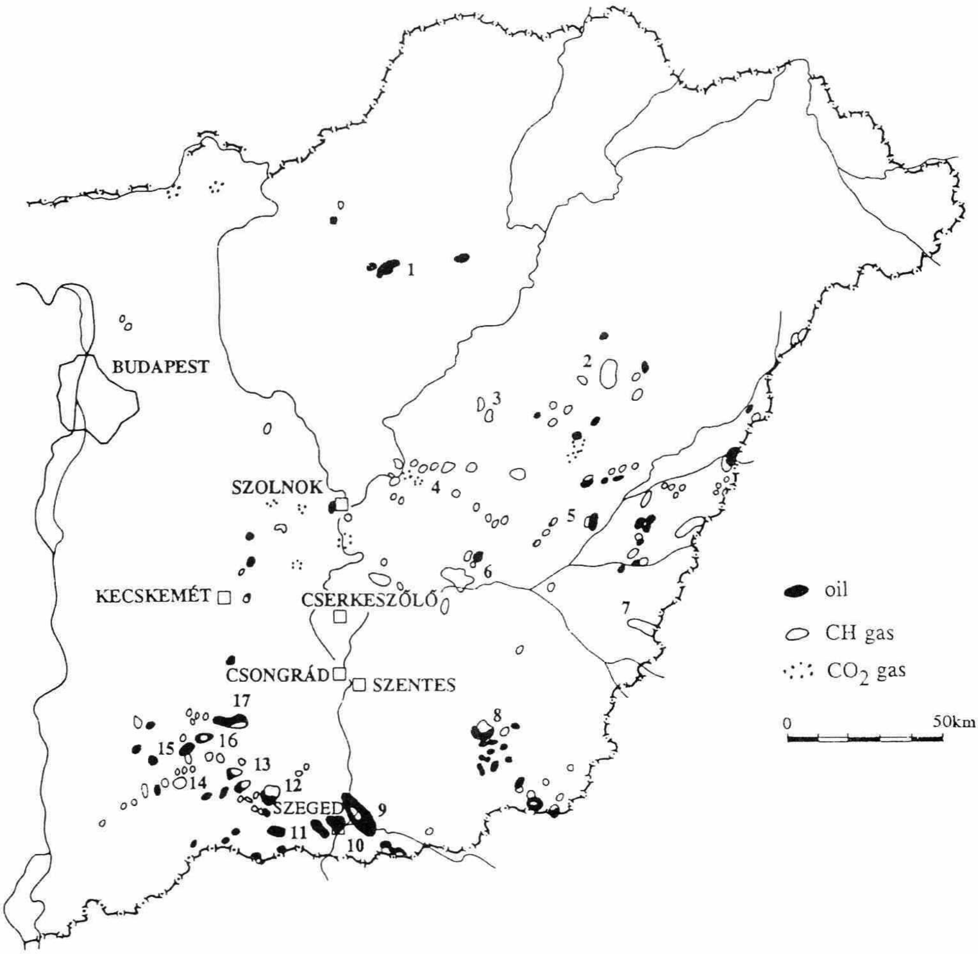


Lithostratigraphic subdivision of the Pannonian formations in the Hungarian Great Plain
1. Volcanic, 2. Shore shallow water, 3. Open-water, 4. Distal turbidites, 5. Proximal turbidites, 6. Delta-slope, 7. Delta plain, 8. Fluvio-lacustrine, 9. Palustrine

The first prospecting for hydrocarbons with the Eötvös torsion balance were performed in the Great Hungarian Plain in 1917. The place of the first exploratory drilling was already marked in 1918. However, most of the wells were dry. Only the wells drilled by MANAT in Tótkomlós and Kőrösszegapáti found oil and gas in 1941-1942. Some of the dry wells were transformed into thermal water wells. These wells resulted in the most known thermal and medicinal baths of the Great Hungarian Plain, namely in Hajdúszoboszló, Berekfürdő, and Cserkeszőlő.

After World War II. several oil and gas fields were discovered. The first important oil and gas field was Pusztaföldvár, discovered in 1958. The biggest oil and natural gas field of Hungary was found at Algyő in 1965. Until the present day nearly 150 oil and natural gas occurrences have been discovered in Eastern Hungary. The most important one is shown in Fig 3. These occurrences store 70% of the oil, 90% of the gas reserves of Hungary. The biggest and the best known occurrences (on the mape Fig.3. signed with numbers) are: Demjén (1), Hajdúszoboszló (2), Tatárülés-Kunmadaras (3), Nagykörü-Fegyvernek-Kisújszállás (4), Szeghalom (5), Endrőd-Szarvas (6), Sarkadkeresztúr (7), Pusztaföldvár (8), Algyő (9), Szeged (10), Kiskundorozsma (11), Üllés (12), Zsana-Zsana-észak (13), Kiskunhalas (14), Kiskunhalas-északkelet (15), Tázlár (16), Szank (17).

The oil and gas reservoir horizons in the various fields are different, depending on the geological setting. Between the rivers Duna and Tisza (occurrences No 10-17) only the Miocene rocks and the weathered-fractured, brecciated Precambrian - Paleozoic and



Oil and natural gas filds in Eastern Hungary

Mesozoic basement are reservoir. At Sarkadkeresztúr (7), Szeghalom (5) and their surroundings the weathered-fractured, brecciated Precambrian - Paleozoic metamorphites and the overlying Miocene detrital rocks of varying thickness are the main reservoirs.

At Demjén, the oil is stored in Oligocene sandstone. In the remaining parts of the listed fields the hydrocarbons are stored in the Pannonian s.l. formations. The greater part of the oil pools are in layers older than the Pannonian and in the Békés Conglomerate Formation of the Pannonian s.l. An exception is Algyő, where the oil is stored in the Törtel Formation. The majority of the oil and gas pools are in the depth range of 1500-2500 m. However smaller pools and oil shows are also known of 3500-4000 m (for example : at Sándorfalva, Makó, Kondoros, and Doboz).

The porosities of the brecciated, fractured metamorphic reservoirs are 2-8%. The average is about 5%:

Kiskundorozsma	(11) :	3,5%
Sarkadkeresztúr	(7) :	5%
Szeghalom	(5) :	5-7%

The porosity of the Mesozoic brecciated dolomite at Szeged (10) and Üllés (12) is 5-6 %. The porosity and the permeability are variable both in the metamorphic reservoirs and in the Mesozoic brecciated dolomite, just as the porosity of the Miocene reservoirs. Here are some Miocene examples:

Üllés	(12) :	8-10%
Kiskundorozsma	(11) :	7-8%
Szeghalom	(5) :	24%
Zsana	(13) :	13%
Szank	(17) :	25-33%

The porosity of the Békés Conglomerate Formation in the Pannonian s.l. is 17-25%. The porosity of the sandstone reservoirs in the different Pannonian formations is as follows:

Szolnok Sandstone - Clay marl Formation :	12-20%
Algyő Clay marl - Sandstone Formation :	12-20%
Törtel Sandstone Formation :	25-33%
Zagyva Sand - Clay Formation :	25-33%

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 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 sedimentary 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 water bearing sand units are connected with each other hydraulically in the vertical sense. The percentage of sandy 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 these 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 renge 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 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 .

The infiltrating water stemming from the former areas moved towards the deeper areas of the basin. Under the original condition 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 aquifers 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 Great Hungarian Plain. In addition, the bottom of the occurence 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 reachind 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 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 practicaly 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. 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 equalibrium 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.

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 mangitude 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 occus 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.

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 exploided 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 relased from the elastically compressed water and rock body. Nevertheless, 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/l (with the exception of waters which are intensivelly 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 flucial 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 western most 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-toess sequence affected considerably by redeposition resulting in the formation of sediments washed down from slopes as well as solifluctional deluvial depths. 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 of 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 (5-30 m) 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 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 4 m.

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, where as one of them becomes occassionally thicker, exceeding even 10 m.

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 alső 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 present. Wildely extended regions of the surface are affected by salinization, whereas large areas were covered by marshes and peat elsewhere. Unfortunatelly, the majoriti of the latter became the victim if 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 10-20 m, 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 Great 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 20-40 m 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 beinning 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 5-20 m depth.

In the range of depth between 10-30 m 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 presente of an unbroken sand horizon in the range of depth between 2-5 m 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.

STOP 1

Geology and Hydrogeology of Cserkeszőlő Area and Description of the 2311,5 m Deep Therapeutic Thermal Water Well Drilled within the Spa Area

E. FARKAS–ERDŐDI

The village of Cserkeszőlő is situated in the southern part of Szolnok county in a geographical district called "Tiszazug" ("Tisza corner"). This geomorphological region is bordered by the Tisza riwer in the west and by the Triple-Körös river in the east. The connecting line between the villages Martfű and Öcsöd marks the northern border. The average elevation of this tipically lowland area is about 85 to 95 m a.s.l.

The subsurface geological setting of this area has been revealed by oil and gas prospecting in the 1940s as well as by lithologic logs of many boreholes drilled in the surroundings. At the same time, in recent years up-to-date geophysical surveying provided data about the thickness of the sedimentary sequence of the basin and about the depth of the basement.

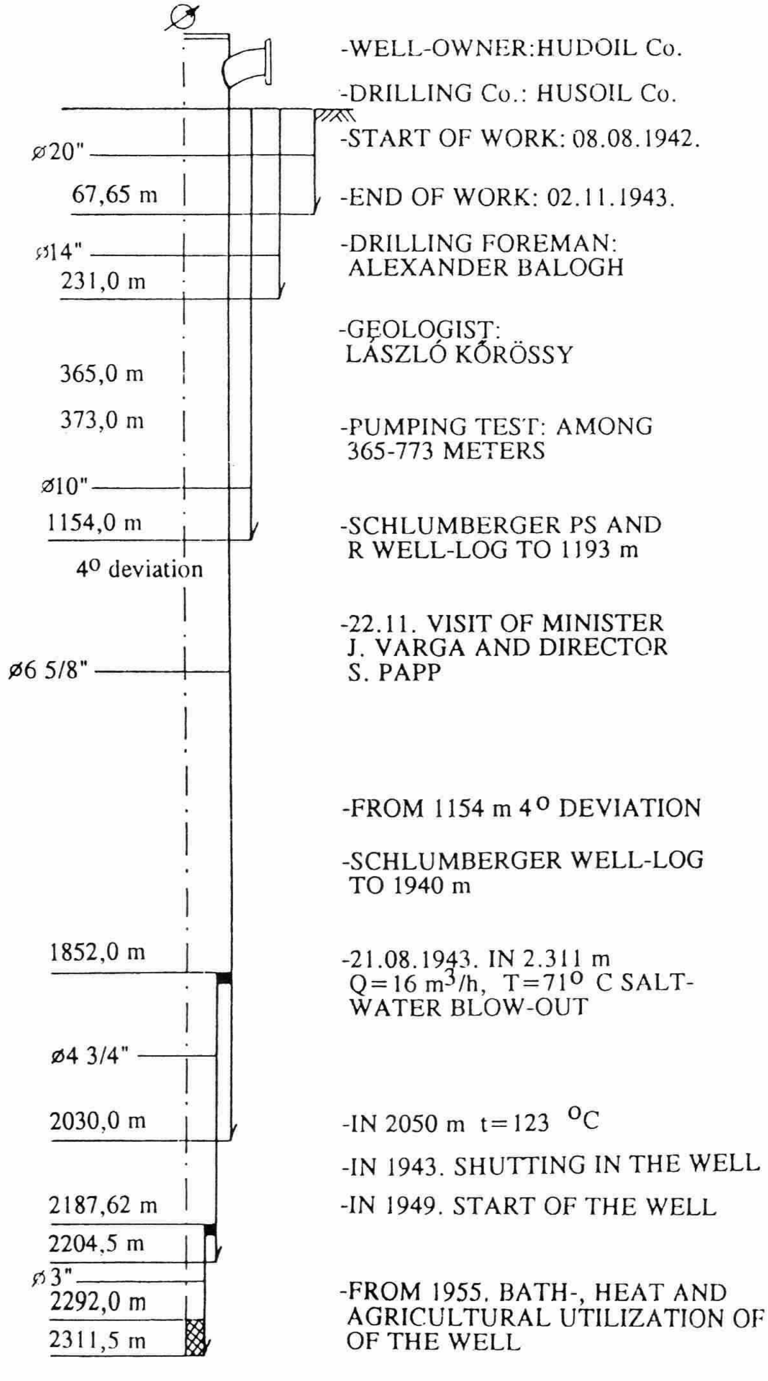
Within the Cserkeszőlő area in Kisasszonydűlő (earlier administratively linked to Tiszakürt) a hydrocarbon exploratory drillig was located on the gravity maximum of Tiszakürt (Tiszakürt well No.l.). Since it was a "dry" well, although it yielded flowing water of high temperature, it was shut-in at that time.

Table 1 **The Real Sequence From Manát co. Datas**

Epochs	Depths (M-M)	(Formation)
Pleistocene	0,0-166,0	Gray Sand, -Silt, Sandstone, Clay
Levantian	166-634	Clay, Gray Sand With Interbredded Layers of Lignite, C-Sand – S-Clay
Upper Pannonian	634-1226	Gray-, S. -Clay, -C-Sand, Sandstone
Lower Pannonian	1226-2259	Gray Clayer-Marl, Sandstone
Sarmatian or Tortonian	2259-2311,5	Marly Limestone, Conglomerate

The geological subdivision of this borehole was done correctly and is valid even today. However there are some unsettled sratigraphic problems. They thickness of the Quaternary sequence was established by some researchers as 300 m or 685 m, respectively. It is most likely that the best standpoint would be to admit that Pleistocene-Upper Pliocene boundary as an unresolved problem.

Fig. 1



Story of Hydrocarbon Exploratory Boring Tk-1

Within the upper 300 m section several fine to medium grained formations can be distinguished while in the lower section medium to coarse-grained water-bearing formations are known. In the lowest part of the sequence fine gravels were penetrated from 650 to 670 m by thermal water well No.2 of the spa. Silt and clay beds are embedded in the water-bearing formations.

The thick water-bearing sequence can be considered as originating from the paleo-Danube. The water-yielding capacity and pressure conditions of these aquifers are very favorable.

The first water well in Cserkeszőlő was completed 90 years ago in 1902. The total depth was 232 m. It yielded 400 l/minute artesian water with a water temperature of 27 °C. Up to now altogether 30 drinking water wells have been located on the sandy aquifers ranging from 130 to 160 m depth. All wells have yielded artesian water. The discharge of the modern well types amounts 1000 to 2500 l/minute tapping 10 to 30 m thick aquifers.

From the formation temperatures and well-head temperatures of these drinkin water wells a peculiar positive geothermal anomaly can be established within the Cserkeszőlő area which was observed already in 1902.

Temperature data of recently located weels also prove this anomaly, e.g, 250 m deep well made for the Waterworks had a water temperature of 32 °C along with a yield of 2400 l/m. This temperature exceeds even the very favorable average heat value of the Hungarian basin. The warming up of the aquifer system can be tributed to the geological setting. The reason of this phenomenon is that the rather homogeneous geological sequence of the Pleistocene - Pliocene formations is in connection through a stratigraphic window with the Upper Pannonian thermal water- bearing sand layers.

Table 2 **Some Waterchemical** *(Datas from 1943. To 1992)*

mg/l/ year	1943	1952	1965	1976*	1993
Anion+Kation	14.444	25.657	4.783	3.658	2.434
From: Na+K	5.016	8.984	1.517	1.110	653
Ca+Mg	196	396	44	22	13
Cl´	7.488	13.782	1.620	985	257
J´	2	7	1	1	1
HCO_3^-	1.122	1.224	1.370	1.342	1.482
H_2SiO_3	124	114	91	56	56
T °C	97	92	82	80	78

* Notice: (Medicinal Bath Authority)

The upper Pannonian sequence, in the 685 m to 1545 m interval consists of fine- to medium- and coarse-grained sand beds alternating with silt, shale and clay marl strata with lignite intercalations. Below 1100 m the sand beds grade into sandstones due to compaction.

The sand and sandstone formations in this thick sequence are suitable for water development and exploitation. A thermal water well (well No.2) was completed in 1976 within the spa area with a thermal water yield of 1500 l/minute and of 69 °C well-head temperature. Adepth interval from 945 to 1069 m was tapped where 4 separate aquifers occur.

Below the Upper Pannonian formations a rather uniform marl and marlstone sequence with sand lense intercalations was penetrated. This sequence has no economic importance since it does not contain any thermal water resources or oil and gas pools.

The Lower Pannonian sequence is underlay by Miocene (Sarmatian and Badenian) shallow marine marly limestones, unconsolidated limestones and gravel beds in a depth interval from 2259 to 2311,5 m. The water-yielding capacity is low, but its chemical composition and formation temperature are noteworthy.

STOP 2

Thermal Water Utilization in the Town of Szentes

F. NAGYISTÓK

1. Introduction

Drinking water and thermal water development and exploitation has more than 100 years old tradition in the area. At the beginning one of the deepest drinking water wells of a total depth of 313,8 m was drilled in Szentes in 1886. The deepest thermal water well of a total depth of 944 m was completed in Szeged in 1927.

The utilization of thermal water for energetic purposes was started in 1957 with a 1736 m deep thermal well located in the area of the municipal hospital in Szentes. Since 1963 many thermal water wells have been completed with state subsidies mainly for heating of greenhouses and animal husbandry facilities. In the immediate surroundings of Szentes more than 30 thermal water wells are operating for the time being (Fig.1). The main utilizer is the agriculture but nowadays heating also plays an important role. In the hospital and municipal indoor bath system as well as in the municipal out-door bath (swimming pool) an excellent example of the multi-purpose thermal water utilization has been produced.

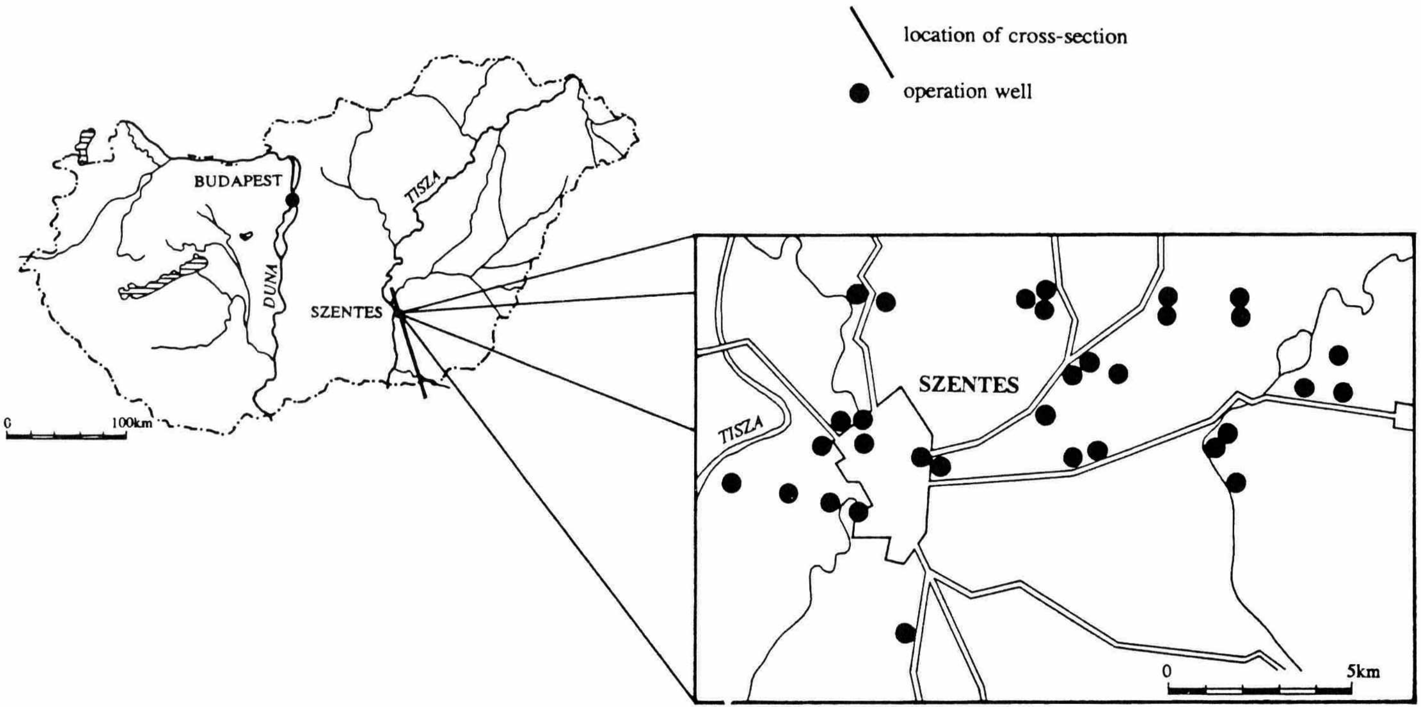
Thermal water wells are yielding about 30000 cu.m/d thermal water in the heating season. Used thermal water is collected in a storage basin of transitional type. Here in the suburb of Szentes there is one of the greatest artificial storage basins of Hungary. After the growing season the cooled water is pumped from the basin to the Tisza river. Most recently successful tests were carried out for reinjection of used water. A special form of this kind of disposal has been developed at one of heating centers of the town.

2. Hydrogeology

Oil and gas prospecting wells as well as drillings for the exploration of the structural features shed light on the subsurface geology of one of the deepest graben-type Neogene sedimentary basins of the Hungarian Great Plain.

The greatest thickness of the Neogene sequence is near to 6000 m. Along the axis of the graben (Fig.2) the sequence including sandstones, loose sands, sandy gravels of good permeability and transmissivity, and younger than Lower Pannonian, is 2.5 km thick. Within the 1 km thick Upper Pannonian sequence the ratio of productive sand formations amounts to 30-40 per cent. The upper part of Pliocene is a 500 m thick lacustrine-fluviable sequence. Its middle part ranging from 800 to 1000 m depth has good hydraulic conductivity with low total dissolved solid content which is favorable for supplying baths with regards to water quality and temperature. The covering Quaternary formations of 650 to 800 m thickness have very good hydraulic conductivity and the ratio of the productive sand beds is up to 50-60 per cent.

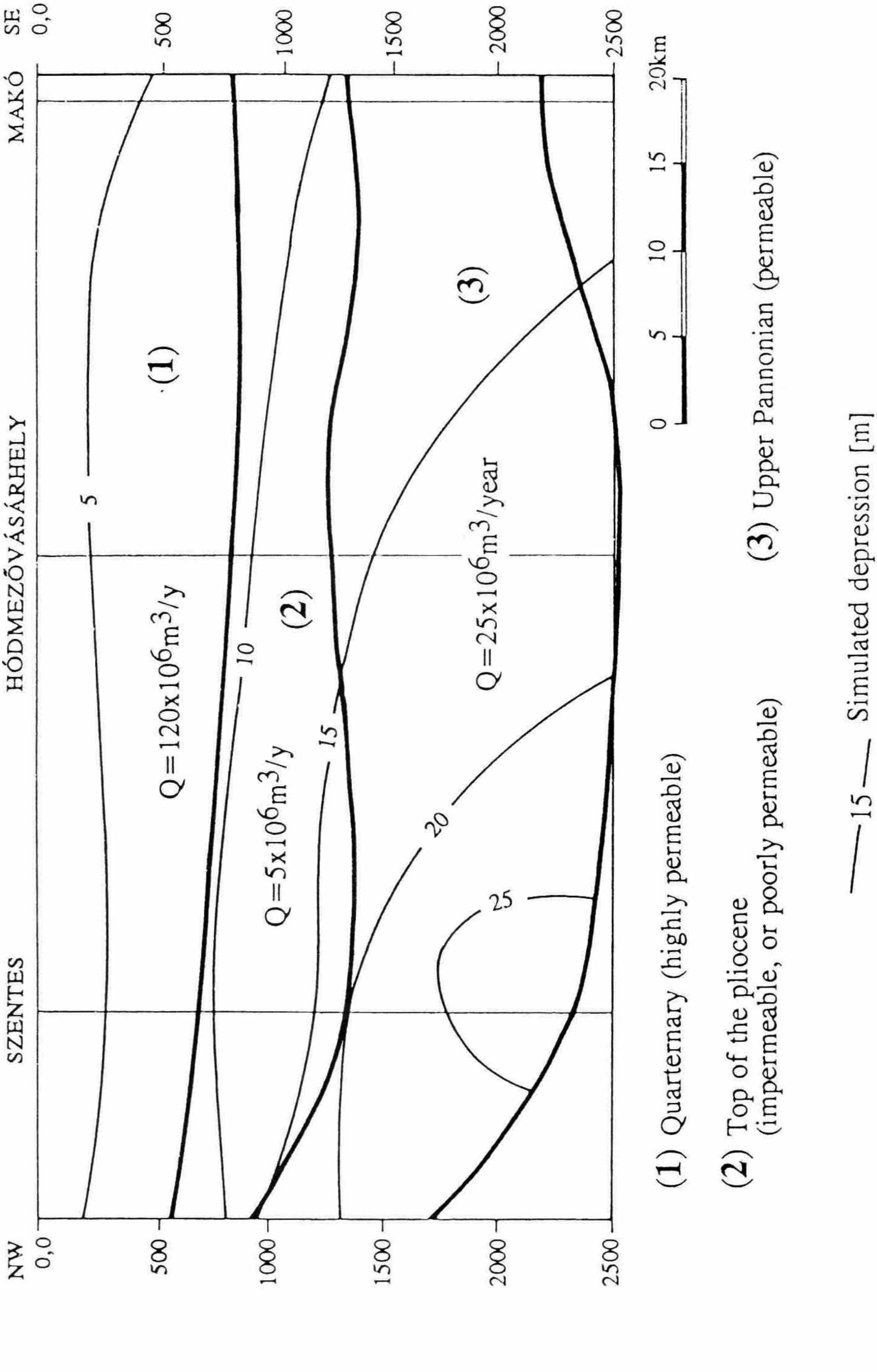
While the Quaternary sequence is affected by an intense, active hydrological cycle, the thermal water horizon has only a somewhat limited recharge. Originally before the groundwater withdrawal and exploitation period, hydrostatic conditions were prevailing (Fig.3). The mean value of the geothermal gradient in Szentes but also along the axis of the graben is 45 °C/km. As regards the water quality, the water is tipically alkaline bicarbonate with relatively low total dissolved solid content (1.5 to 2.5 g/cu.m) and with a relatively low gas content (0.1 to 0.2 cu.m/cu.m). Waters of higher salinity are liable to scaling. Permeability values of the beds are of 0.1 to 2.0 Darcy while the seepage coeffici-



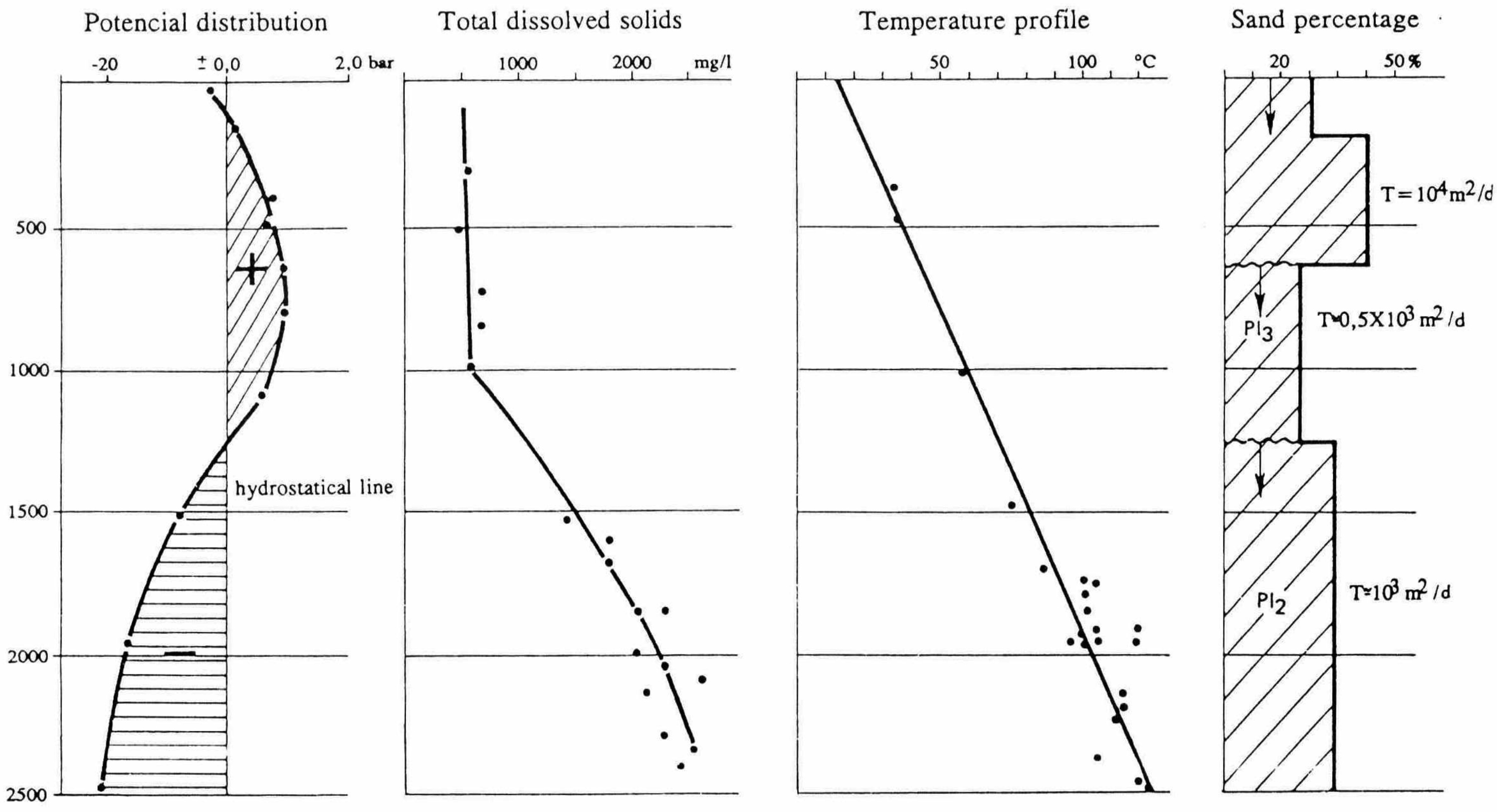
Location of the area

Fig. 1

Fig. 2



Typical cross-section



Main hydrogeological elements in the typical cross-section

Fig.3

ent ranges from 0.1 to 1.0 m/d. The perforated sections of the wells may range from 80 to 120 m and the water-yielding capacity is 1400 to 2800 cu.m/d. The productive beds are opened by yet perforation. In order to form a more favorable free influx surface, frequently a preperforated screen-device is installed.

3. Water Production Experience

In spite of the nearly hydrostatical pressure level and the low gas content, it is the high well and formation temperature - about 120 °C at a depth of 2500 m - which allows an out-flowing thermal water production in the form of heat-lift. With the growing number of the wells interference loss was increasing and in addition, a depression was superimposed due to the limited recharge. At the end of the 1970s, it was obvious that the out flowing production can not be maintained without the renewal of the formation energy. Nowadays, within the areas of concentrated water withdrawal, an increase of depression is nearly of 30 m. This is somewhat less than the initially forecasted value which can be attributed to the well beeing in operation as a rule only in the heating season in function of the heat demand.

At the beginning, air-lifting production was also taken into account. Howewer, its low efficiency, scalling and other oxidation products badly affected this production method, consequently it was only temporary solution.

The introduction of pumping was rather complicated since the casing string was so small diameter (that is, of 177 mm) and pumps can not be installed. Consequently, this part of casing had to be cut and pulled out, at least the upper 100 to 150 m string.

It was an advantage that within the annular space of the casings of 244 mm diameter and of 177 mm diameter the top of the cement column was at a depth of about 100 m. In some cases, the pulling out of these casing string attached to the cement column was less successful and very expensive.

Another problem are due to the lack of heat-resistant submersible pumps which could have been applied in thermal waters of 80 to 95 °C. Such submersible pumps are manufactured by KSB and GRUNDFOS. Nowadays pumps with long axis and submersible pumps are commercially sold. Unfortunately, the casing of 244 mm diameter impedas many kinds of pump to be installed. There is no way to use the original well capacity without further change of the upper well structure.

Problems caused by scaling can be solved by adding organic polyphosphate. This practice was preceded by long, tiresome experiments in the field. The chemicals are pumped into the well below the sucker opening by some few meters.

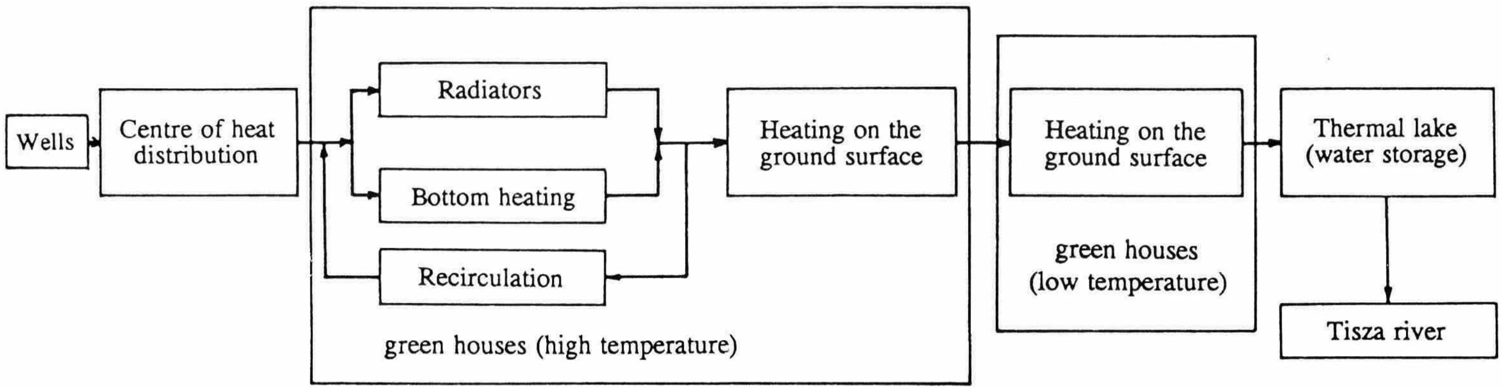
Thermal water wells are generally characterized by great cooling loss due to the high heat-extraction of the Quaternary sequence involving intense waterflow. As a rule this heat-extraction amounts 15 to 25 °C. Recently, this loss was moderated in some new wells by subsequent lining of the casing along its upper 500 to 600 m section.

4. Utilization in the Cooperative "Árpád"

This is a leading agricuitural organization in the field of thermal water utilization in quantitative as well as in the qualitative sense. It has 12 productive wells which supply 4 heat centers. Each heat center distributes thermal water into greenhouses, animal husbandry facilities, into bureaus and social buildings. The total heated surface exceeds 30 hectares which is remarkable even on the world scale. Tomato, paprika and cucumber are growen in the greenhouses. The greatest and mostupto-date heat center is connected with 7 operating thermal wells. These productive wells in the form of well-pairs and triple-wells are tapping the thermal water reservoir along its entire thickness.

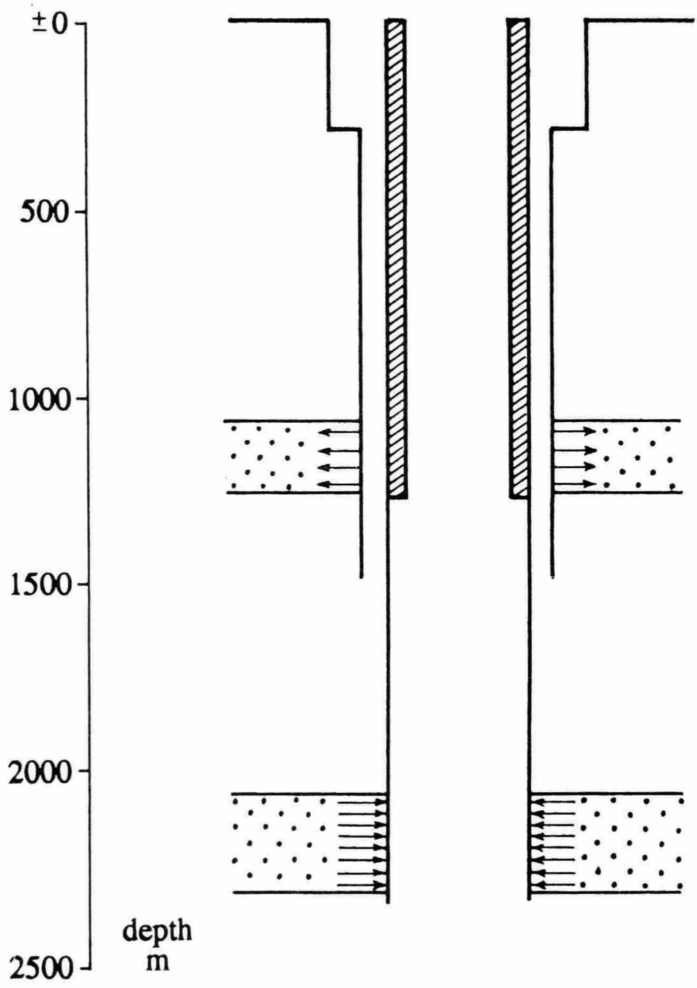
Well-operation, heat-distribution and production, and heatdemand coordination are dipatched by a computer system. Heat-extraction is carried out in cascades by airspa-

Fig. 4



The way of thermal waters in the heat using system of Árpád co-operative

Fig. 5



Structure of double well

ce, soil and soil surface heating (Fig.4). The primary water of 80 to 90 °C temperature after utilization becomes as an effluent or secondary water of about 30 °C and it flows into a special storage pond. Recently, some tests were carried out to form a fish-lake and to develop fishery. Unfortunately, this is hampered by the taste and odour substances /e.g. phenol/.

The heating season ranges from mid-October to mid-April. In between all wells will be shut-in.

5. Utilization in Heating Centers

A special solution was developed when a productive section and an injection one were completed within a single well (Fig.5). The water entering in the lower section into the well is flowing to the surface through a tubing which is lined by a special material. After heat-exchange it is pumped and reinjected at a few bar presure through the annular space of the safety casing string and the tubing into the injection section. The lining was made of a special bakelite in order to minimize heat-transfer.

This solution allows a reinjection by minimum energy since the thermal water-yielding section is of considerable thickness, and its upper part is less compact and of higher permeability.

The costs are favorable. It is disadvantageous, however that the needed well-servicing and special workover jobs are somewhat difficult.

6. Summary

Due to favorable hydrogeological conditions, the utilization of geothermal energy in the surroundings of Szentes started 35 years ago. The initially wasting thermal water management was recently changed to a genial and conscious management accompanied by increasing utilization, more experience and complying with the growing environmental requirements.

As we are facing a limited renewal capacity of the thermal water resources, a further increase of water withdrawal will result in a deterioration of thermal water production. This trend can be improved by reinjection of the used water after heat-utilization. The initial steps have been made not so long ago, even if it is getting somewhat late.

STOP 3

The Observation Well-Group of the Hungarian Geological Institute in Csongrád

A compilation made under the guidance of

A. RÓNAI

From 1964 on a new geological surveying was initiated in the Great Hungarian Plain by the Hungarian Geological Institute. Its objective was to study the size, dimension, situation, occurence, rock materials and ground water budget of the Quaternary and Tertiary water-bearing formations.

The study of the subsurface water-yielding formations (aquifers) was performed by means of geological key-boreholes. Along sections of two (N-S and W-E) directions a total of 37 key-boreholes were drilled. Beside these, a total of 74 wells on 25 sites were built till the end of 1980 (Fig.1).

In these completed wells observation was started by weekly manual measurements. The ground water levels situated below the ground surface were measured in shafts and in open ended tubes and pipes while water level rising above the ground surface were observed at the well-head also in free tubes and pipes. Later on continous recording devices allowed the observation of water movement and fluctuation of different origin and type with rather great accuracy (in mm).

In this way fluctuations of 1 to 2 cm magnitude by 6 hours period caused by earth tide; atmospheric pressure affected water- level fluctuations of 1 to 2 dm magnitude and of about 1 to 2 weeks duration; fluctuation of annual water mowement (many meters); amplitude of fluctuation of many meters due to the multiannual water movement and fluctuation of few decimeters affected by extraordinary processes (e.g. flood earthquake) can be recorded and registered.

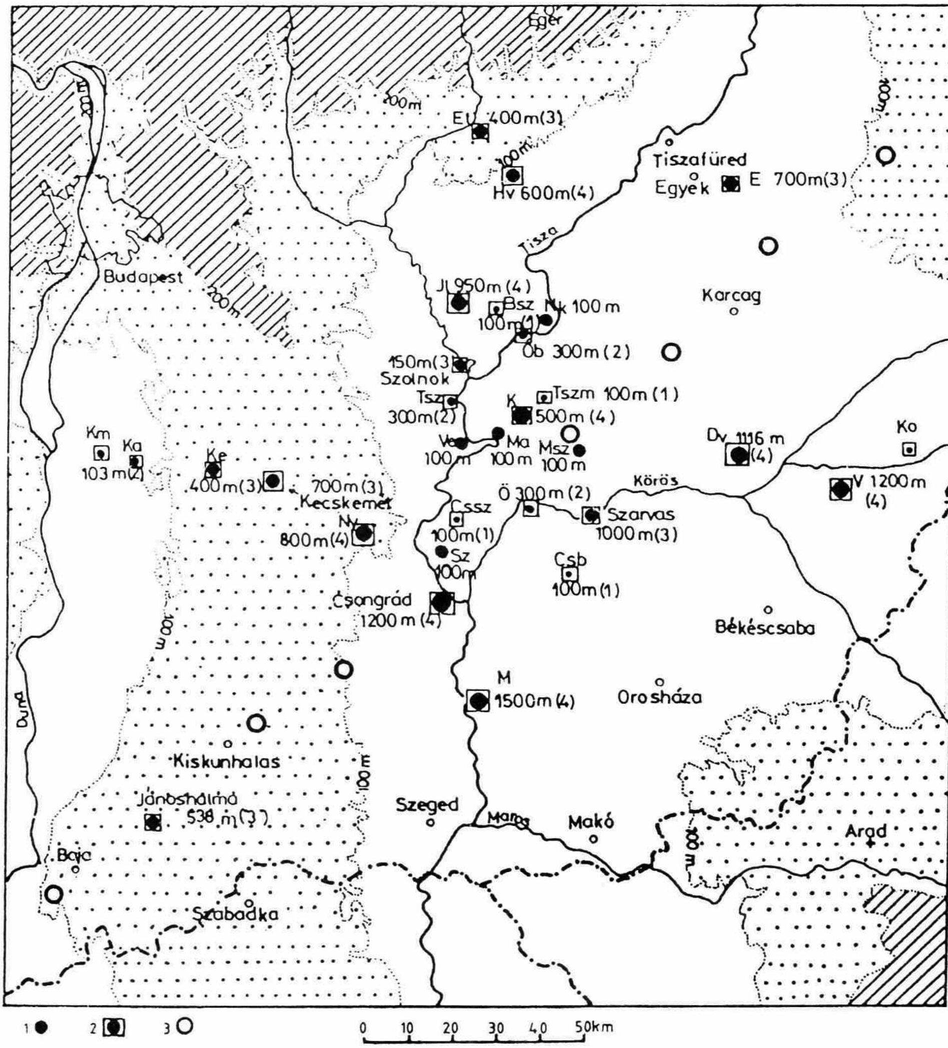
The 4 observation wells in Csongrád within an area characterized by positive pressure conditions clearly show the relation of water-level fluctuation with depth (Table 1).

In the water movement fluctuation curve of the 1056 m deep well one can see fluctuations of a magnitude of 8 to 15 mm by 6 hours period affected by earth tide on the last four days of time-series from 9th to 22th october 1980. The risie and fall of the water level is taking place in two wawes after the drop in atmospheric pressure (Fig.2). Within two weeks this movement had a magnitude of 105 mm. At the same site in the 655 m deep well the curve of water fluctuation coincides exactly with that of the deeper well, however, with somewhat lesser amplitude (85 mm). Within the third, 445 m deep well the same water movement was recorded but the descending limb of the water level on the 19th October indicated a half-day delay in comparison with the start of decline in the water level in the 655 mm deep well.

The amplitude of fluctuation is again smaller than in the deeper well (80 mm). The fluctuation is the same in the 241 m deep well and the descending limb of the second wave shows further delay of 10 hours compared to the 445 m deep well. The entire amplitude of the two week long fluctuation is again smaller (56 mm).

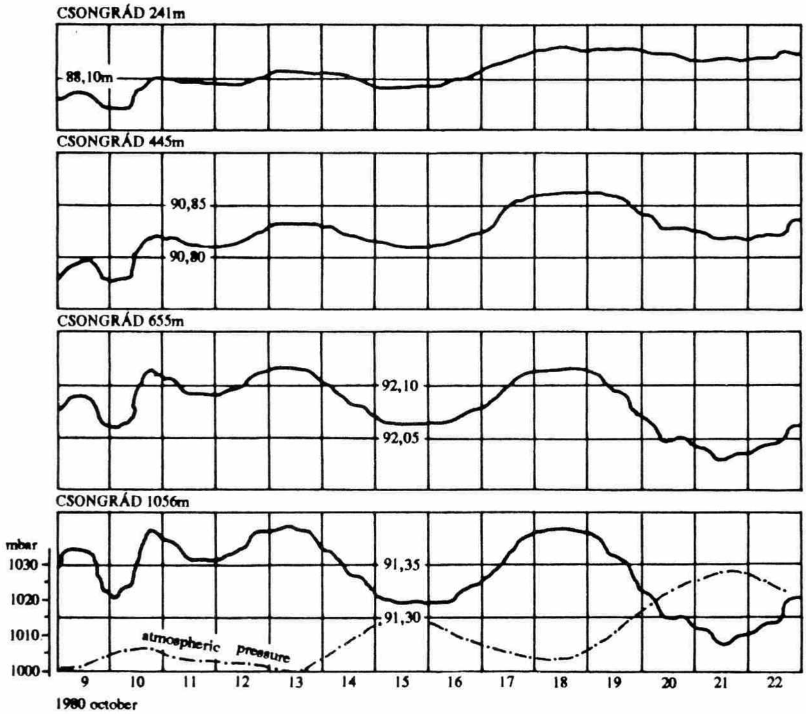
It is remarkable that the low fluctuations of the earth tide can be indicated on each curve of the wells in Csongrád, although with decreasing amplitudes upwards.

Fig. 1



Observation wells in Csongrád county
1. Geological key borehole with depth, 2. Observation wells, 3. Planned wells

Fig. 2



Earth tide and athmospheric pressure affected water-level fluctuation in the wells of the Hungarian Geological Institute in Csongrád

Observation wells of Csongrád

Location and Number of Well			Csongrád 1.	Csongrád 2.	Csongrád 3.	Csongrád 4.
Year of Drilling			1970-71	1970	1973	1973
Total Depth of (Core) Drilling			1200,0 m	700,0 m	458,5 m	254,0 m
Bottom-Hole Temperature			61 °C 1194 m	37 °C 700 m	28 °C 458,0 m	27 °C 254,0 m
Stratigraphic Boundaries			$Q\text{-}Pl_3=672$ m, $Pl_3\text{-}Pl_2=1076$	ad 1. well	ad 1. well	ad 1. well
Total Depth of Well			1130,0 m	700,0 m	458,1 m	253,6 m
Size and Depth of Screens			JET 1029-1046, 1048-1056	642,02-655,3 m	427,9-445,5 m	204-217, 232-241 m
WELL DEVELOP	Stativ Water Level		+ 15,97 m	+ 13,96 m	+ 10,6 m	+ 6,25 m
	Water-Yield	Flowing	750 l/min + 0,98 m	1340 l/min	500 l/min + 1,75 m	650 l/min + 1,02 m
		Max. Oper.	1500 l/min -1,0 m	1500 l/min	730 l/min	1080 l/min
		Specif.Yield	88,4 l/min/m	100,3 l/min/m	40,4 l/min/m	115,5 l/min/m
	Water-Temp.	Flowing	43 °C	30 °C	24 °C	19 °C
		Bottom-Hole				
Start of Observation			1971	1971	1974	1974
Method of Observation			Steremat	Steremat	Steremat	Steremat
Elevation A. S.L.			83,1	83,1	83,1	83,1
Elevation A. S.L. of Measurement			99,2	99,2	99,2	99,2
Elevation of Measurement from Ground Surface			+ 16,0 m	+ 16,0 m	+ 16,0 m	+ 16,0 m

STOP 4/a

Algyő, the Most Important Hungarian Oil Field

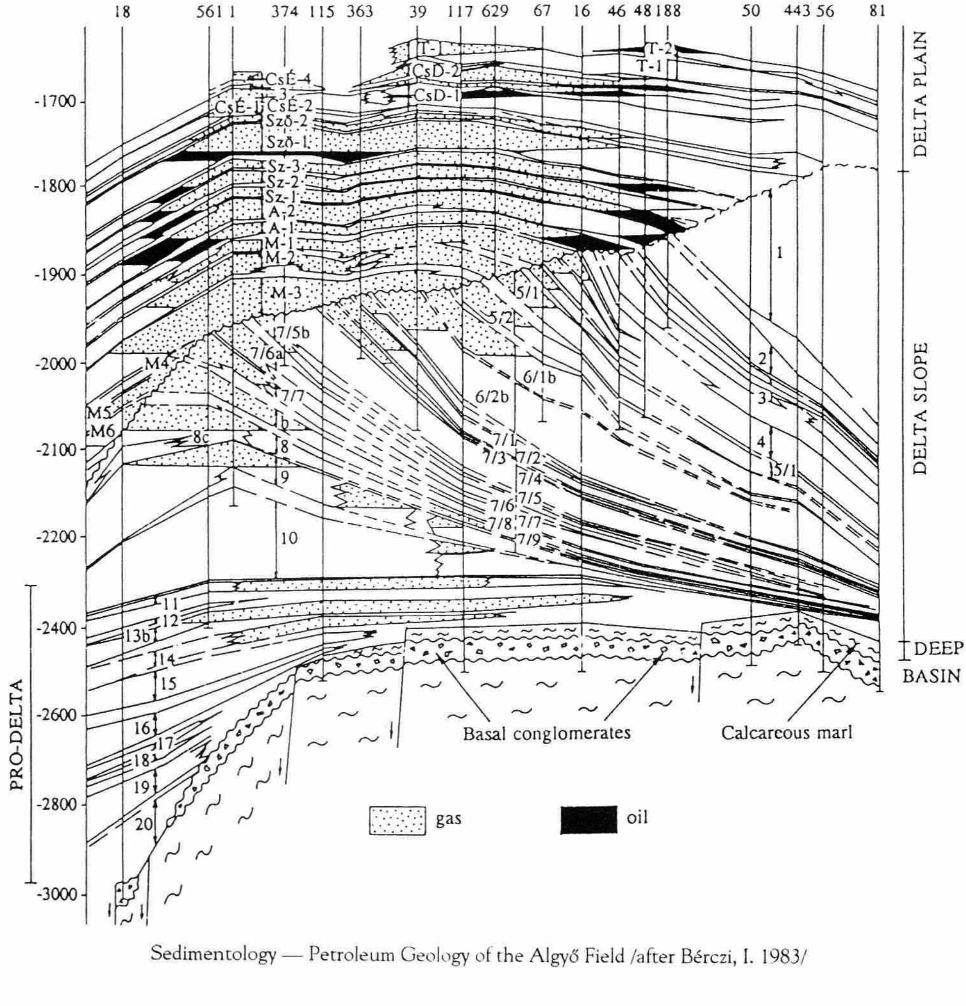
A. HARMATH - L. MAGYAR

The Algyő structure is a NW-SE striking anticline.

The basement is built up of Precambrian metamorphic rocks (mica schist, gneiss, mica quartzite, chlorite schist, etc.) in a depth range of about 2500-3000 m, and in the NW part (in deeper position, in a little area) by Middle Triassic dolomite, as proved by two wells.

Thick Neogene and Ouaternary sediments overlie the basement. The structure is a "saddle" over a relative bulge of the basement compact Only in some, mostly marginal

Fig. 1



Sedimentology — Petroleum Geology of the Algyő Field /after Bérczi, I. 1983/

boreholes (15), the Pannonian s.l. sediments overlie directly the basement. The Pannonian s.l. sediments are the most significant in the area. Their thickness amounts to 1800-2800 m. The thickness of the Pannonian s. str. sediments is 500-1500 m. Within the Pannonian s. str. from the bottom upwards the following formations can be distingnished:

1. Basal conglomerate. It lies transgressively on the basement. It mostly gravely sandstone and conglomerate. Its thickness is 0-79 m.

2. A basal marle sequence. It overlies the previous one or directly the basement, with on an average thickness of 20-30 m.

3. Argillaceous marl sequence. It consists of a Clay rnarl and argillaceous series 10-100 m thick.

4. Sandstone sequence. It is built up of an alternation of clay marl, siltite and sandstone strata. The pelit esare predominating. Its lower part is a pro-delta turbidite, while the upper one is a delta-slope sediment (Fig.1).

The so-called "Upper Pannonian" sediments cover the Pannonian s. str. with a facies unconformity in the 750-2000 m depth range. The most important sediment types are clay marl, siltite and sandstone. The percentage of sandstones increases up to 40%. In thinner (10-100 cm) lenses of calcareous marl, carbonatic sandstone, lignite, and coal-bearing clay occur too. Between the surface and 750 m there are Quaternary sediments.

Petroleum geology

Geophysical prospecting was started in this area at the beginning of the century. It took a major impulse in the years 50-60. The Algyő-1 well was drilled in 1965. Since then 960 wells have been drilled, 110 of which reached the basement. The vast majority of wells (about 750) have about 2000 m bottom depth.

The Pannonian s.l. layers are in depths between 1700 and 2500 m (Fig.1) (67 layer). There are sandstone reservoirs which are closed in most cases. The most important reservoirs, the so- called base reservoirs (Algyő-1, Algyő-2, Szeged- 1) are here. At the bottom of the Pannonian s.l. coarse clastic rocks and the upper part of the Precambrian metamorphic rocks constitute a gas reservoir (Deszk layer).

STOP 4/b

Problems and Techniques of Hydrocarbon Production in the Szeged Region

J. POZSGAI

The Szeged Branch of the MOL Rt (Hungarian Oil Company) is situated in the southern part of the Great Hungarian Plain. It co-ordinates the CH production within Csongrád County.

There are 14 oil-gas and gas fields in this region. In addition, propane, iso- and normal butane, iso-and normal pentane, isohexane, and gasoline are also produced by this branch.

Algyő is the biggest Hungarian oil and gas field penetrated by about one thousand wells. The reservoir layers are exploited by water injection method from both sides of the oil body. The amount of watercut is nearly 85%. Beside this standard method, several other manners of exploitation are used, for instance ethane-rich gas injection and other pilot plant chemical methods.

The domestic importance of the Üllés gas field is given by the winter gas-supply.

The Móraváros oil sool has been revealed under (the centre of) Szeged mainly by deviated wells.

The Dorozsma field is famous for the first Hungarian horizontal well of Do-7. The horizontal section of this well is 120 m long.

Beside the CH production activities outlined above the Szeged Branch is also involved in other investments in the fields of oil and gas transportation and maintenance.

Thermal energy utilization seems to be another profitable business. Since the past few years some wells, withdrawn from the CH-production system, have been started to be prepared for the utilization of the thermal capacity of the subsurface strata.

The use of high technology equipment in the production guarantees the absolute safe provision of the sufficent energy to satisfy almost the whole the domestic demand. Our gas products match the highest quality requirements.

The Szeged Branch is paying particular attention to environment protection. The surface water is absolutely prevented from CH pollution. The water which has been previously separated from the oil is streamed back to the subsurface strata in closed circulation.

STOP 5/a

Oil beneath Szeged-Móraváros

L. MAGYAR - A. HARMATH

The exploration of the area started in 1971 with drilling the Szeged-1 well. The purpose of this well was to check the summit of the gravity anomaly between the Algyő and the Dorozsma areas. The well disclosed a 126 m thick oil reservoir in Middle Triassic formations, proving the existence of the Mezozoic basement near the town of Szeged for the first time.

During the first phase of exploration (to November 1973) ten, in the course of the second, detailed phase (to October 1975) five wells were drilled (Szeged-1-15).

The producing wells were started in June 1976 with borehole Szeged-27. Until June 1980, eleven producing wells (Szeged-20-30) were drilled. Later two more producing wells were drilled and examined (Szeged-31-32). The testing of the last well was completed on 14 November 1988.

On the whole 15 exploratory wells and 13 producing wells have been drilled.

Because of the special geological setting and the urban settlement concerned most of the wells (17 out of 28) had to be drilled as controlled inclined wells. The biggest inclined and the biggest horizontally deviated wells of Hungary (Szeged-4,-14,-15) can be found here.

By the wells a 7 km^2 reservoir of 180 m separate height has been explored. It is saturated, but it has gascapped oil layer. The initial depth of the oil-water boundary was: -2630 m. There the original pressure was 339.6 att, the temperature: 145 °C (Fig.1).

The Móraváros reservoir consists of rocks of different age and facies wich constitute a direct integrated hydrodinamic system.

The metamorphic basement is built up of Precambrian metamorphic rocks (mica schist, mica quartzite, gneiss) and/or Paleozoic metamorphic breccia. In most cases they can not be separated from each other. They can serve as reservoirs depending on theis structural position, but their rock-physical parameters are very unfavourable. The metamorphic rocks have a porosity of one volume %.

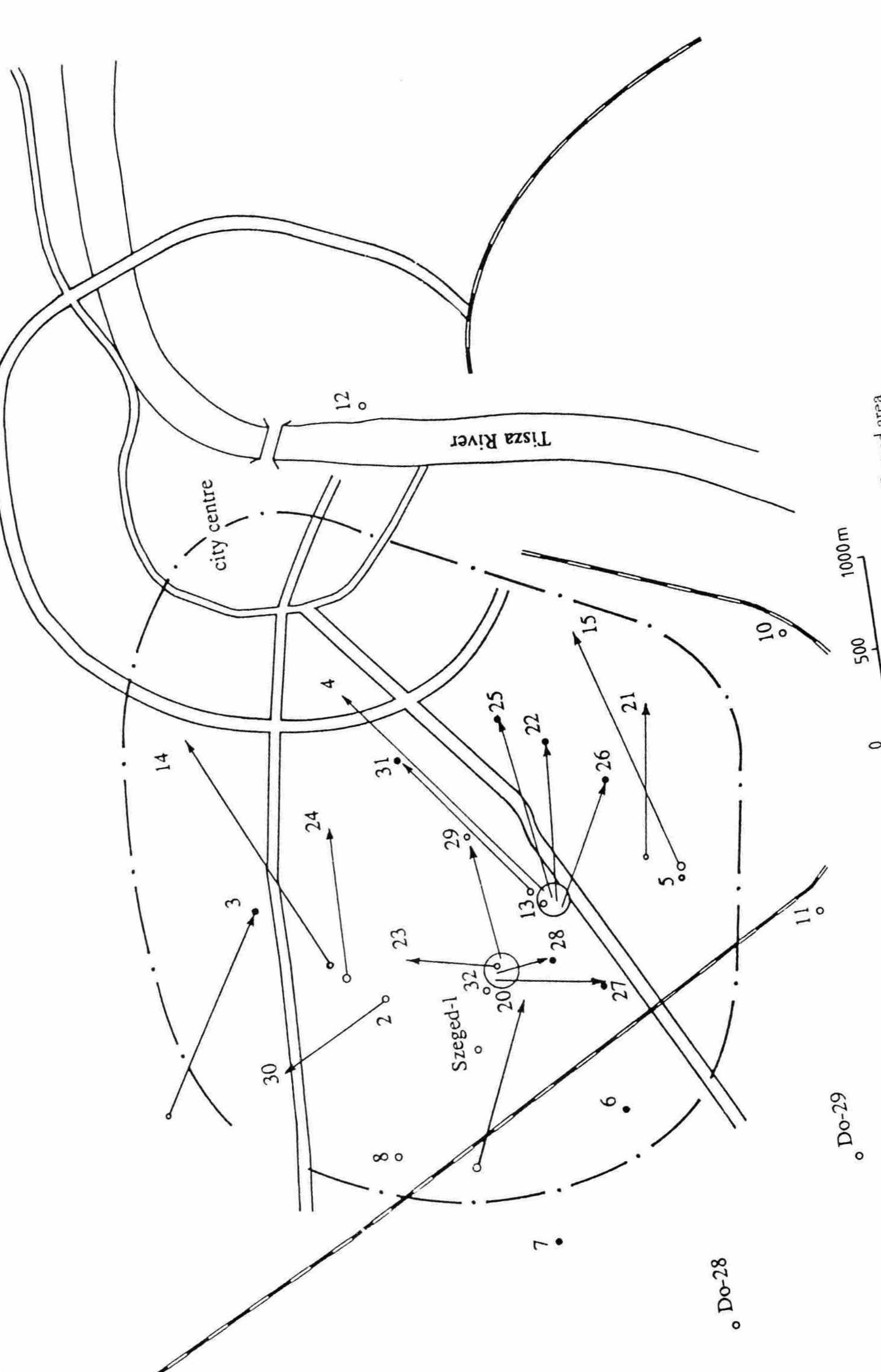
The metamorphic basement is overlain by Lower Triassic clay schist, dolomarl and quartz- sandstone. The quartz sandstone may serve reservoir at some places, but its rock-physical parameters are bad (just as there of the metamorphic reservoir rocks).

A very significant reservoir rock is the Middle Triassic fissured, authigenic, brecciated dolomite. It is the second best reservoir rock in this area. The Triassic rocks have a porosity of 38 volume %.

The Miocene conglomerate is the best reservoir rock. It is characterized by a porosity of 61 volume %.

The Pannonian s.l. and Quaternary sequence of 2500 m thickness overly the Miocene. They are of similar composition as the Miocene sediments, just like in the Algyő area.

Fig. 1



Location sherch of the horizontally deviated wells in Szeged area

STOP 5/b

Thermal Water Development Potential and Thermal Water Utilization in the Town of Szeged

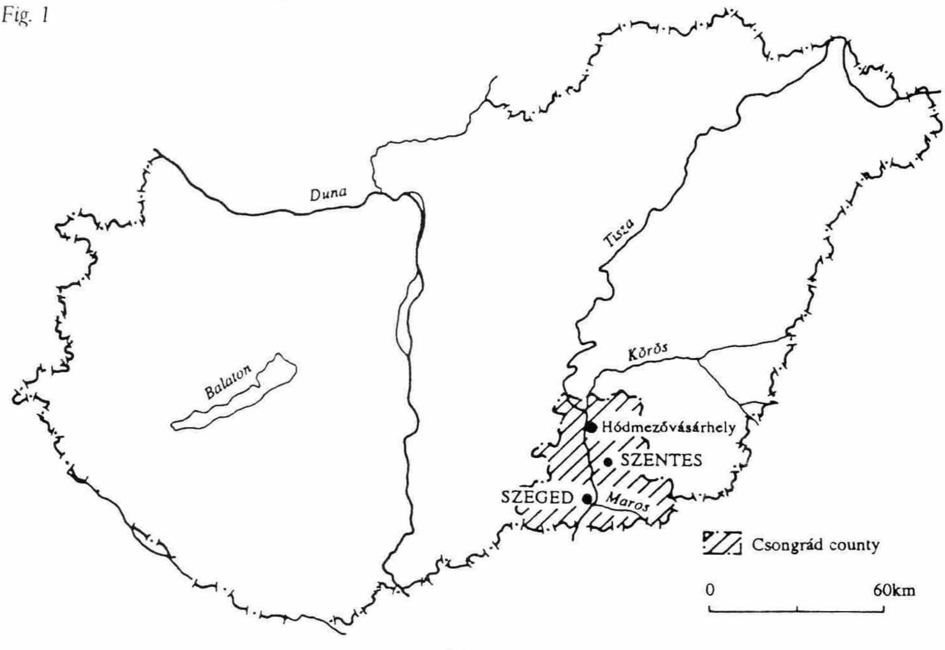
J. TÖRÖK

The territory of Csongrád county is the richest thermal water province in Hungary, The abundant thermal water resources are stored in a Neogene marine sediment sequence which fills the basin of the Great Hungarian Plain. The most productive water- yielding formations are Upper Pannonian sand and sandstone beds forming Multi-storey, multi-unit thermal water reservoir system. This sediment sequence of about 1000 to 1600 m thickness is situated in the depth interval from 600 to 2000 m. However in some depressious (e.g. in the graben between Hódmezővásárhely and Makó) it is at depths from 800 to 2400 m.

In Szeged the sandstone formation below 1800 m is oil- and gasbearing. As a consequence, thermal water exploitation can not take place below this level. The upper boundary of the thermal water-bearing sequence is at a depth of 550 to 600 m coinciding with the transition zone of Pleistocene-Pliocene sediments.

(1) The first thermal water-yielding horizon is the about 400 to 500 m thick Upper Pliocene (Levantinian) sequence. It yields an outflowing water of 40 to 60 °C temperature along with a maximum discharge of 1000 to 1500 l/minute/well. The chemical composition of this water is alkaline biocarbonate with low total dissolved solid content (e.g. in the case of Anna-well : 855 mg/l.

Fig. 1



Location of the Szeged area

(2) The second thermal water-yielding horizon is the Upper Pannonian formation below 1000-1100 m forming a total productive thickness of 200 to 300 m. The ratio of sand beds is 30 per cent. They are storing thermal water of 55 to 70 °C temperature. Their water-yielding capacity and the chemical composit are similar to those of the first horizon with the exception that the total dissolved solid content is higher (i.e., 1000 to 1500 mg/l).

(3) The third thermal water-bearing horizon is the lower section of the Upper Pannonian sequence, with sandstone formations. The most productive water-yielding beds are in the depth interval from 1700 to 2000 m where thermal water of 70 to 95 °C temperature can be tapped. The maximum water-yield ranges from 1000 to 2000 l/minute with a total dissolved solid content of 2000 to 3000 mg/l.

The geothermal gradient is about 50 to 60 °C/km while the terrestrial heat flow has a value of 70 to 80 mW/m^2.

The original pressure values of the thermal water reservoir can not be easily reconstructed due to the lack of reliable measurements. At that time, there was no essential geothermal waterlevel differences among the thermal water-yielding horizons: the static water level was 20 to 30 m above the ground-surface. The gas-water ratio (GWR) of thermal waters amounts 0.2 to 0.7 cu.m/cu.m. Scaling process causing production troubles and utilization problems occur only in the deepest part of the third thermal water yielding horizon. The upper horizons are not liable to scaling.

Since the drilling of the first thermal well (Anna-well, 1927) altogether 30 wells have been drilled and completed in Szeged /Fig.2/.

Due to the fastly inreasing thermal water production, the formation pressure of the thermal water reservoir was decreasing (0.1 to 0.2 bar/year). In the 1980s most of thermal wells become negative, that is, thermal water level was dropped below the ground surface and water production had to be carried out by pump. The utilization of thermal waters follows two directions. One is the extraction of geothermal energy, the other is the proper use of water.

The oldest form of utilization is district and space heating as well as comunal use (indoor and outdoor baths, swimming pools for balneological and for therapeutical purposes, in hospitals and domestic and sanitary water supply).

The industrial utilization of thermal water includes heating and technological branches. In the oil industry thermal water is applied for secondary recovery when thermal water is reinjected into the peripherical wells of the Algyő oil-field.

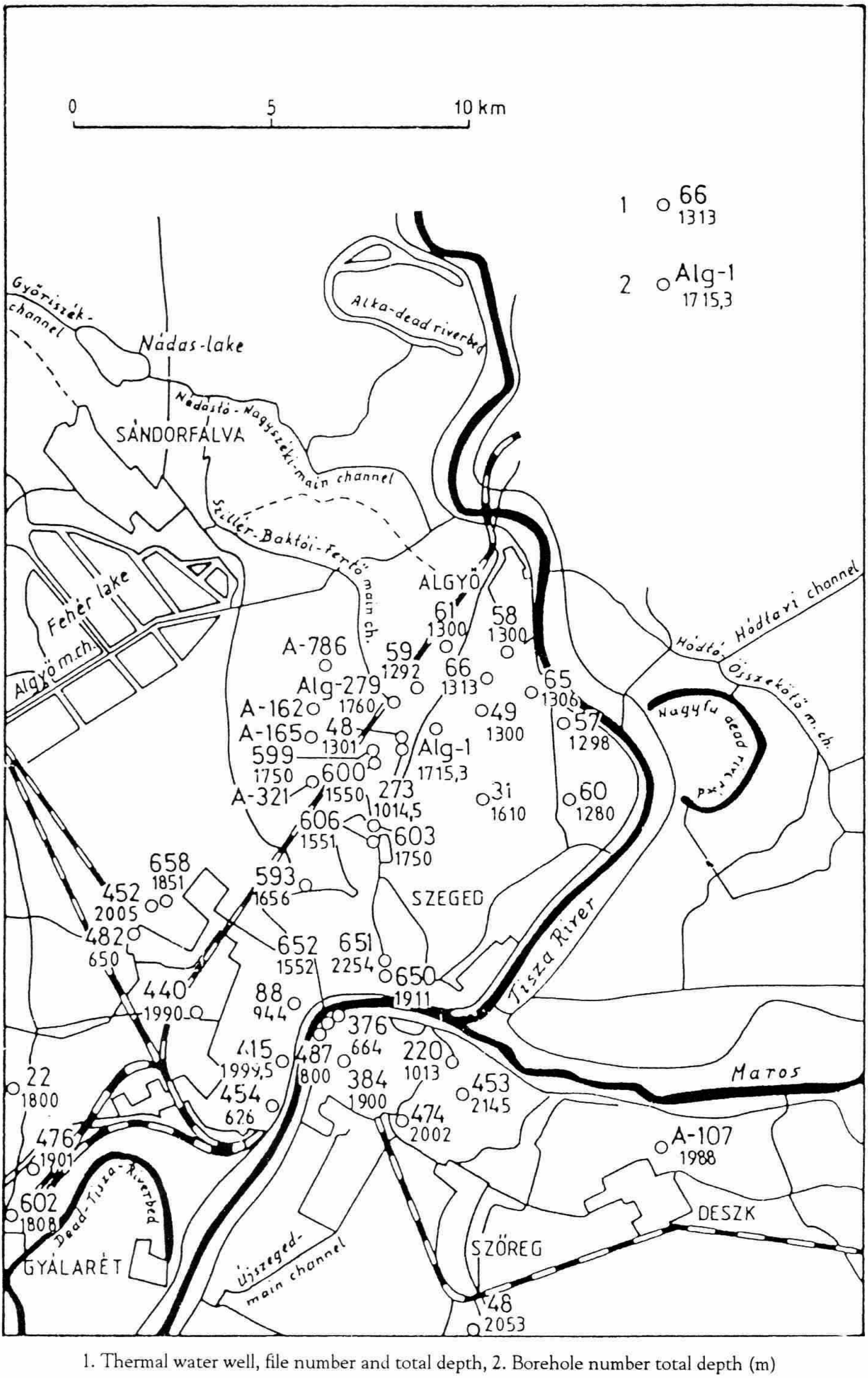
The most important branch of thermal water utilization is the agricultural and horticultural use. Thermal waters of high temperature are widely used in greenhouses, plastic tents and tunnels as well as in animal husbandry facilities.

All these branches of utilization can be found in Szeged and in its surroundings. The cooled water after utilization - with the exception of the oil industry - is introduced into the public canals and drainage canals transmittingit into the Tisza river.

The target sites of the excursion are three places of thermal water utilization. One (and the oldest) is the "Steambath" founded in 1896.

An other is the "Anna-well". It was drilled and completed in 1927 and had a total depth of 944 m with a water-yielding capacity of 420 l/minute and of 50 °C temperature. The water has been declared medicinal water. Patients are treated in mud baths, in baths using extensor weight equipment and by complex physicotherapy and inhalation.

An outstanding example of district heating project carried out by geothermal energy is the so called Odessza district in Szeged where a 1900 m deep thermal well drilled in 1962 yielded 1500 l/minute water of 89 °C has been utilized for apartement and space heating as well as for domestic water supply. Meanwhile a pump was installed since



1. Thermal water well, file number and total depth, 2. Borehole number total depth (m)

water-yield had dropped to 720 l/minute. The geothermal heating is basically operating even today, however a gas boiler system is connected for complementary heating.

A remarkable experimental solution is a double well completed in 1985 with directional drilling in Szeged-Felsőváros. The side by side located boreholes were vertical to a depth of 600 m and from this level a directional drilling was applied to a depth of 1900 m. In sucn a manner, bottomhole distance exceeds 900 m. After repeated tests (the latest was carried out in October 1992) a 40 to 60 cu.m/h thermal water of 70 to 80 °C temperature yielded by the production well was reinjected onto the disposal well after minimum utilization.

The test as an example of the environment-friendly geothermal utilization has many technical and economic problems. Final execution of the utilization project may be expectea by the assistance of PHARE.

STOP 6

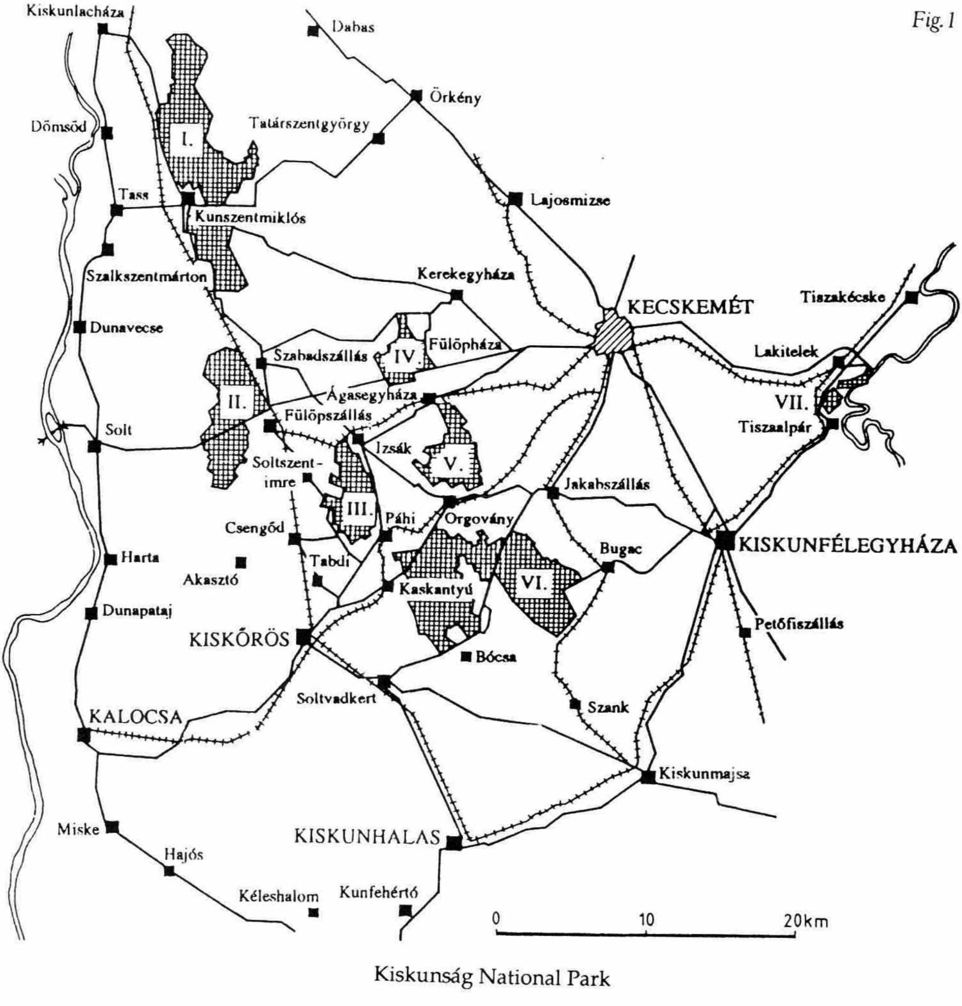
Bugac (Nature Protection in the Great Hungarian Plain)

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.

Geographical Situation

Fig. 1



Kiskunság National Park

The Kiskunság National Park, the foureth largest reverse 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

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" and 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 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, Flestucetum pratensis, Salicetum cinereae ass, caricetosum elatae subass., Caricetum acutiformiripariae.

The most typical animal communities of the National Park evolved around the saline and alkali lakes. Particularly noteworthy are the brids. 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 form 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 step-cattle, Hungarian mangalica-pig, Hungarian racka-sheep (white and black), Hungarian branyard fowl, Hungarian goose, Hungarian duck, Hungarian halfbred (bay, yellow and cream) horse and different Hungarian sheperd's dog varietes are kept in certain units of the National Park.

The Bugac Area

It is the largest area of the Kiskunság National Park, wich hosts extremely various values. Its geological features are presented in the description by Proffessor 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.

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 s 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 importand 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

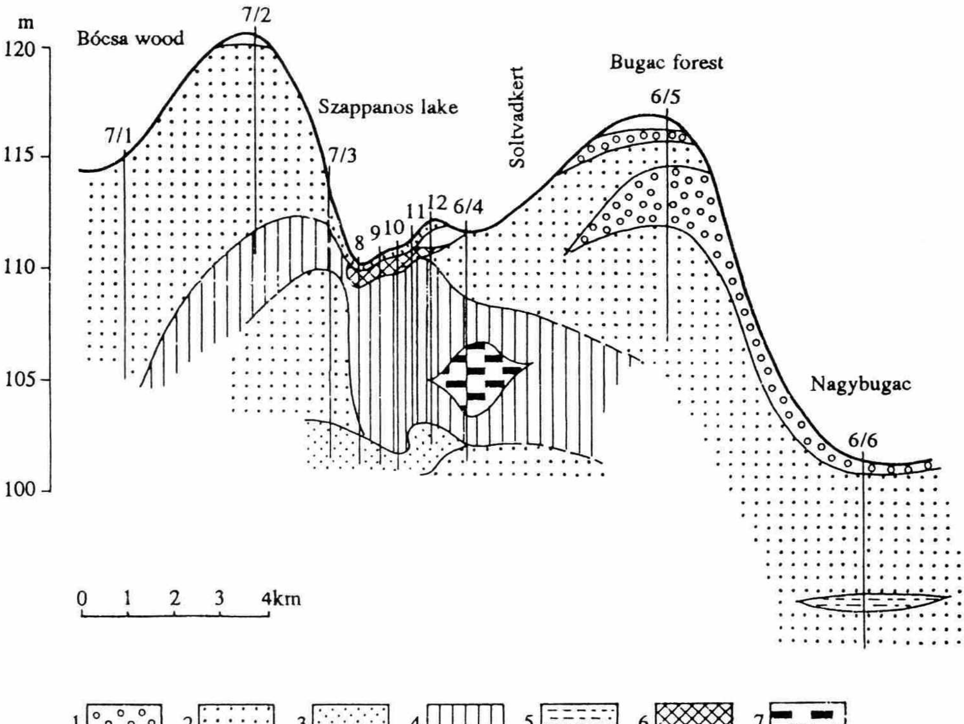
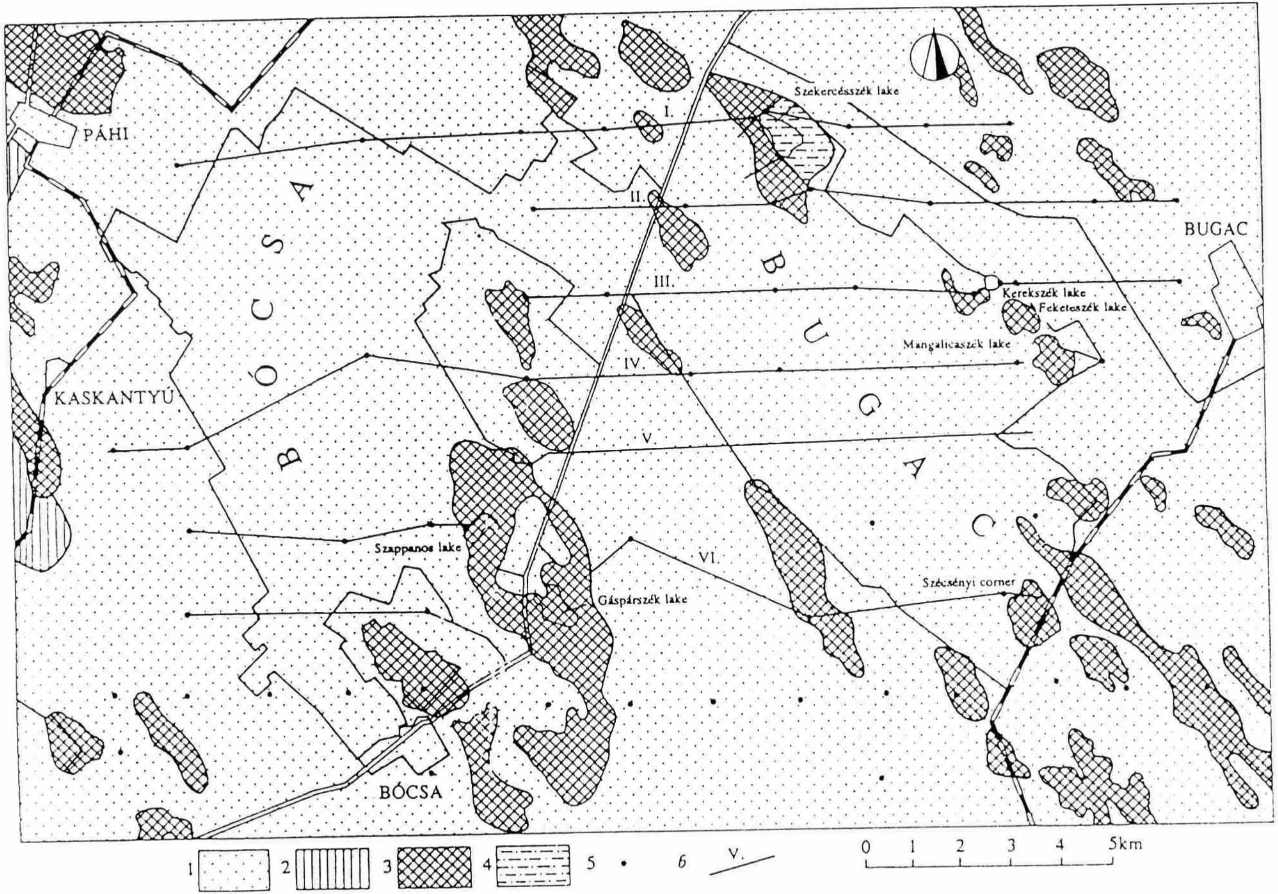


Fig. 2 Geological cross section of the Bugac dune area (Molnár, B.—Kuti, L., 1987); 1. Medium-grained wind-blown sand (0,2—0,5 mm Ø), 2. Small-grained wind-blown sand (0,1—0,2 mm Ø), 3. Fine-grained wind-blown sand (0,06—0,1 mm Ø), 4. Loess (1-4 Pleistocene), 5. Lacustrine, humic, poorly sorted silt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

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 the morphologically deeper areas together with the carbonate appearance (if it is impermeable) in more humide periods it facilitates the formation of natron lakes.

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-bearign calcite, Fe-bearing dolomite and magnesite play tole. Magnesite is present only at teh deepert parts, where the water coverage lasted for the longest period, and the Mg/Ca ratio of the lake was extremely high, due to evaporation.

Mollusc fauna and ecological groups of the faune 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 grouup
V 1 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)
V 2 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)

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 specimens 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 and Kuti (1983, 1987), Molnár and Murvai (1975), Molnár and Szónoky (1976), Molnár, Iványosi-Szabó, and Fényes (1979), Molnár, Mucsi and Magyar (1971), Molnár, Murvai and Hegyi-Pakó J. (1976), Molnár, Szónoky and Kovács (1980), Tóth and Molnár (1987) Várallyay (1967).

II. Terrestrial species	
ecological demand	species belonging to the ecological group
SZ 1 species of shore requiring humidity	Succinea elegans RISSO Succinea oblonga DRAP Carychlum minimum (O. F. MÜLL) Succinea putris (L)
SZ 2 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)
SZ 3 thermophylous terrestrial species	Vallonia enniensis (GRED) Vallonia pulchella (O. F. MÜLL) Vertigo antivertigo (DRAP) Vertigo anggustior (JEFFR) Monachoides rubiginosa (A. SCHMIDT) Nesovitrea hammonis (STRÖM)
SZ 4 species of high ecological tolerance	Pupilla muscorum (L) Vallonia costata (O. F. MÜLL) Vertigo pygmeae (DRAP) Punctum pygmaeum (DRAP) Clausilia sp.
SZ 5 xerothermal species	Abida frumentum (DRAP) Chondrula tridens (O. F. MÜLL)

III. Loess species	
L 1 species tolerant to humidity and cold	Trichhia hispida (L) Vertigo substriata (JEFFR)
L 2 species tolerant to drought and cold	Columella columella (G. MARTENS) Columella edentula (DRAP) Vertigo pracedentata (A. BRAUN) Discuc ruderatus (FERUSS)

STOP 7

Hydrogeological Development of Waterworks no.2 in Kecskemét

M. MISBRENNER - A. SÁRKÁNY

The waterworks of Kecskemét consist of two separate units. Waterworks No.1 is lying west of the town between the roads heading for Izsák and Kunszentmiklós. Waterworks No. 2 is located southeast of the town along the Csukás-ér main canal (Fig .1). The upper section of the Pleistocene-Holocene formations represents the water supplying horizon located at 400 m depth. The development of waterworks No.2 (along the Csongrádi út) was started in 1962 to 1964 with the location of 6 wells.

These reached depths of 190 to 273 m. An enlargement was carried out by the location of additional 4 wells. Further development was done by the completion of 10 new wells to depths from 200 to 450 m. The last stage of development occurred in 1982 and 1983 by the completion of 6 additional wells. For the time being, Waterworks No.2 consists of 26 wells (in fact of 13 well-pairs).

In the study area, wells No. 6/b and No.8/a of Waterworks No.2 were chosen.

Basic Data

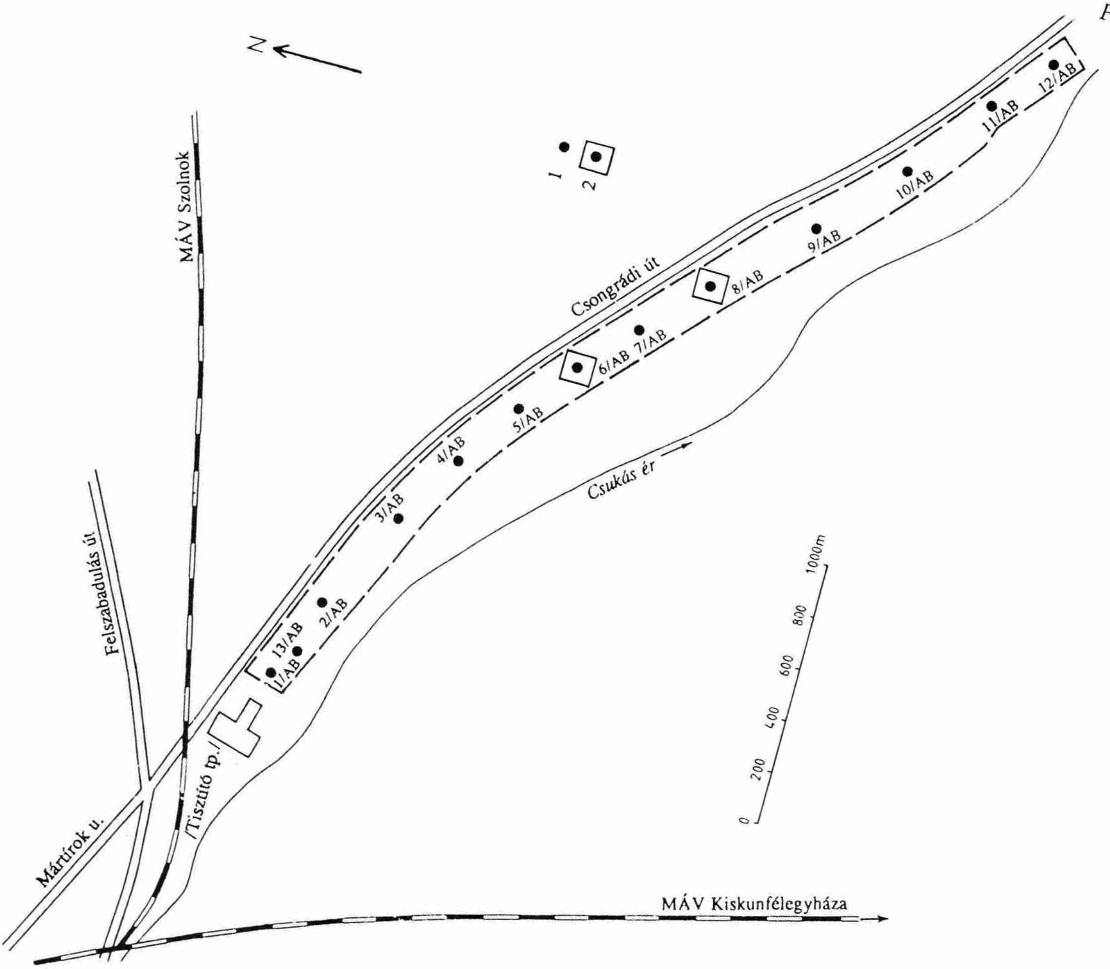
Well sites are plotted on the layout plan of Waterworks No. within the protective area.

Location of well No. 6/b with coordinates:

x = 171.105,84	y = 703.854,13
File or cadastre number:	K - 839
Total depth;	190 m

Lithologic log

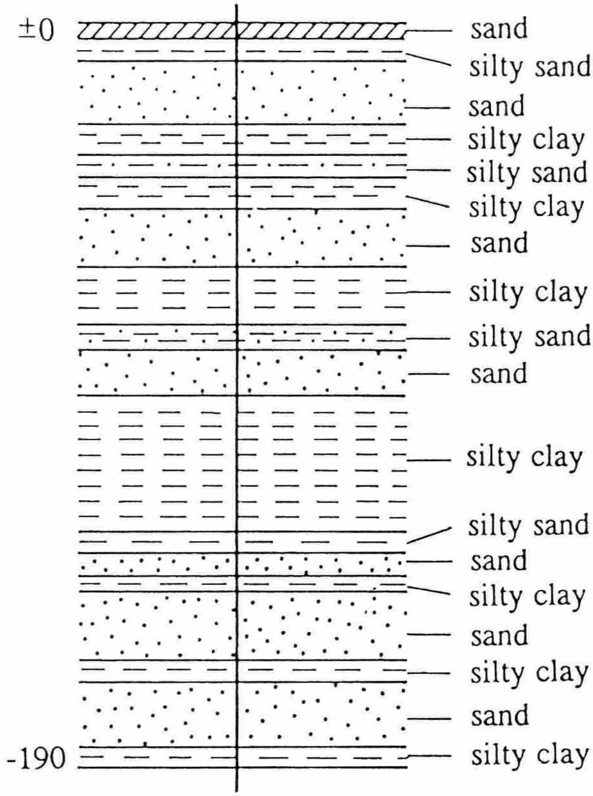
0,0	1,0 m	sand (greyish yellow, loose, quartzose)
1,0	5,0 m	silty sand (yellowish grey, loose, limy, medium-grained)
5,0	25,0 m	sand (greyish yellow, loose)
25,0	35,0 m	silty sand (light greyish yellow, loose fine-grained)
35,0	45,0 m	silty clay (bronish grey, fairly cohesive, very limy)
45,0	60,0 m	sand (yellowish grey, loose, quartz, muscovite)
60,0	75,0 m	silty clay (grey, fairly cohesive)
75,0	80,0 m	silty sand (greyish yellow, loose, slighty cohesive, quartz)
80,0	90,0 m	sand (light, yellow, loose, very limy)
90,0	129,0 m	silty clay (greyish yellow, fairly cohesive, very limy)
129,0	134,3 m	silty sand (greyish yellow, loose)
134,3	139,0 m	sand (light greyish yellow, loose, well worn, coarse-grained, quartz)
139,0	142,6 m	silty clay
142,6	165,0 m	sand (light greyish yellow, loose, well worn, medium- and coarse-grained, quartz)



Kecskemét, Waterworks No, 2. Layont plan
1. Wells of Waterworks with numbering, 2. Well

65,0	167,3 m	
67,3	185,0 m	silty clay
,0	190,0 m	sand (light greyish yellow, loose, well worn, quartz with some muscovit fragments)
y		silty clay (yellowish grey, fairly cohesive, very limy)
to	1,0 m	Holocene
to	190,0 m	Pleistocene

Fig. 2



6/B

well log

Kecskemét, Waterworks No. 2

Formations tested for water:

128,8	to	142,1 m
148,3	to	183,7 m

Location of well No.8/a

x = 67.498,88 y = 54.927,42

File or cadastre number: K - 861

Total depth: 450,0 m

Lithologic log

0,0	0,8 m	topsoil (dark greyish brown, humic, loose, porous)
0,8	5,0 m	sand (light brown, very loose, limy, fine-grained)
5,0	25,0 m	clayey sand (light grey with brownish tint, loose, fine grained)
25,0	59,0 m	sand (cohesive clayey sand with thin clay laminae)
59,0	123,5 m	clayey sand (light brownish grey, loose, wery limy, fine-grained)

123,5	140,0 m	sand (light brownish grey, loose, with thin clay laminae)
140,0	143,5 m	sandy clay
143,5	186,0 m	sand (light grey, brownish, loose, limy)
186,0	197,0 m	clay and sandy clay
197,0	214,0 m	sand (light grey, loose, limy)
214,0	218,5 m	clay and sandy clay
218,5	248,0 m	sand (light grey, loose, porous, limy)
248,0	252,5 m	clay and sandy clay
252,5	268,0 m	sand (light grey, limy)
268,0	274,0 m	clay
274,0	279,0 m	sand (light grey, loose)
279,0	280,5 m	clay
280,5	331,5 m	sand (light grey, loose, porous, limy)
331,5	333,0 m	clay
333,0	425,5 m	sand (grey, loose, coarse-grained)
425,5	427,0 m	clay
427,0	430,0 m	clayey sand
430,0	450,0 m	clay and sandy clay

Stratigraphy

0,0	to	0,8 m	Holocene
0,8	to	425,5 m	Pleistocene
425,5	to	450,0 m	Upper Pannonian

Formation tests for water production:

360,6	to	403,8 m
413,2	to	424,7 m

(Fig. 3.).

Hydrogeology

The developed area belongs to the Great Plain. The Great Plain is the surface of a young basin filled by marine and fluvial sediments. The basement consists mainly of Paleozoic granite which was struck by drillings deeper than 1000 m. The basement is tilted to south - southeastern direction. It is overlaid by Miocene marls, limestones and sandstones (the Kiskunhalas Formation) as a result of scdimentary products of the ever shallower sea. There are covered by Lower Pannonian clayey marly and fine-grained sand formations (Jászkunsag Formation group). At some places the Miocene formations might be missing and the Lower Pannonian strata can overlie directli the basement.

The Upper Pannonian sequence consists of alternating clayey marl, clay, sandy clay, unconsolidated sandstone and sand beds. The porous formations of the Upper Pannonian sequence are water- bearing. These Upper Pannonian aquifers are supplying with water the thermal baths. The thermal water well is 1000 m deep tapping the water-bearing porous formations in the 823-959 m interval. The temperatura of the thermal water is 46 °C at the well head.

The Lower Pannonian sequence contains no thermal water resources of economic importance.

The marine Upper Pannonian sequence is overlaied by Upper Pliocene red clays (the Great Plain red clay formation). There sediments are covered by fluvial gravelly sand and coarse sand formations of Late Pliocene and Early Pleistocene age. These sediments were laid down by the Paleo-Danube and by some other riwers within the Danube catchment area.

The Danube river was flowing through several branches in the depression. Its bed later shifted progressively westwards, and finally it reached its recent present-day north-south flow direction.

The good water-bearing formation is thicken south- souteastwards while it is pinching out northwards and westwards. Its total thickness is 500 m. This sequence is generally porous and semipermeable. Clayey and silty beds occur only locally and do not block the communication between porous horizons. The static level of the groundwater is below the surface and it is going downwards below the piezometric pressure level. The specific water yield of wells located on this formation is favorable, that is, 100 to 200 litres/meter/minute while the safe-yield is about 1000 litres/minute. It is of drinking water quality, although, its relatively high iron content requires some treatment.

The water contains calcium, magnesium and bicarbonate. The total dissolved solid content is low, medium hardness, and some corrosive effect has been stated.

The water is used for the Waterworks of the town as watersupply stemming from the wells screened in the depth interval from 150 to 400 m.

The upper hundred meters section of the Pleistocene sequence is fine-grained: silty clay, silty sand and fine-grained sand beds are alternating. The cover of this sequence consists of eolian beds, loess and wind-blown sands. The fine-grained pattern of these upper formations allows, however, only local, small-scale water development.

More than 1000 drilled water wells of Kecskemét were located on the Pleistocene sequence. Their specific water-yielding capacity is of 10 to 20 litres/minute/meter.

Chemical Analysis

A total of 13 well-pairs are operating in the waterworks. Wells "A" are deeper than wells "B". Both well categories tap Pleistocene aquifers. All well waters have similar chemical composition. As to their chemical character, they contain calcium and magnesium cations, hydrocarbonate anions. The total dissolved solid content is low (from 316 to 340 mg/1) and the hardness is medium (15.51 to 15.86 grade).

The chloride-ion concentration is low (9 to 11 mg/1); the sulphate-ion content is very low.

The water is not polluted (Values of NO_3, NO_2 and oxigen consumption are zero).

The calcium sodium ion ratio is nearly the same, approximately 2,5 to l. Free carbon dioxid concentratíon (32 to 43 mg/1) and pH values (7,3 to 7,4) have some corrosive effect on steel structures.

Due to its aggressive HCl content (13 to 20 mg/1) it belongs to the category "weekly aggressive". Manganese ion concentration: 0.10 to 0.30 mg/l. Iron content: 0,16 to 0,30 mg/1.

Hydrobiological Analysis

The water is biologically adequate. There are no pathogenic organisms present, only iron-manganese bacteria (Gallionella) occur causing no problem.

The quality of water is biologically suitable for human consumption in spite of its relative high iron-manganese and organic content.

Biological (microscopical) Test

Iron - manganise bacteria: 950 indiv./litre

Gaillonellag ferruginea
Crenothrix polyspera
Crenothrix fusca
Leptothrix ochracea
Leptothrix ferruginea

Animal organisms: 9 indiv./litre

Alternating amoeba	1 indiv./litre
Framed amoeba	2 indiv./litre
Colorless Flagellaeata	2 indiv./litre
Ciliate	1 indiv./litre
Rotaria	2 indiv./litre
Nematoda	1 indiv./litre

Suspended matter: 3.12 mg/1

Humine matter: 1.05 mg/1

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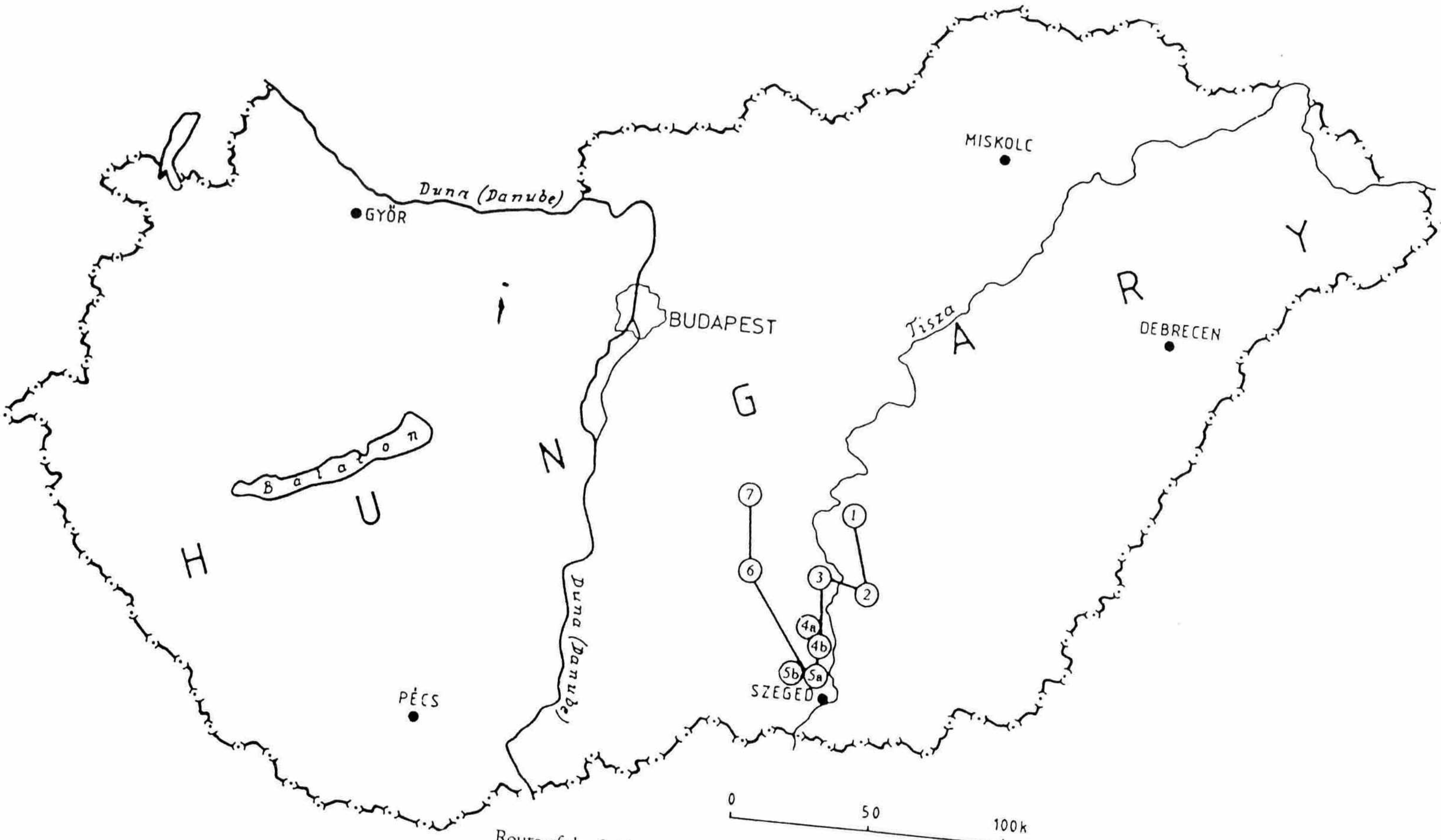

Route of the field trip and locations of the stops