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EXCURSION GUIDE

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Marginal Facies of the Pannonian Basin

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Evolution of Intramontane Basins on the Example of the Pannonian Basin

19—26 September 1993

BUDAPEST, HUNGARY

Organized by the

Hungarian Geological Society

in cooperation with the

Association of Hungarian Geophysicists

under the auspices of the

Association of European Geological Societies

(AEGS)

Published by the Hungarian Geological Society
with the financial support
of
MOL Plc

Printed by the courtesy of the Hungarian Oil Company

BUDAPEST, 1993

Field Trip A
Marginal Facies of the Pannonian Basin
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JÁNOS HAAS

Introduction

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

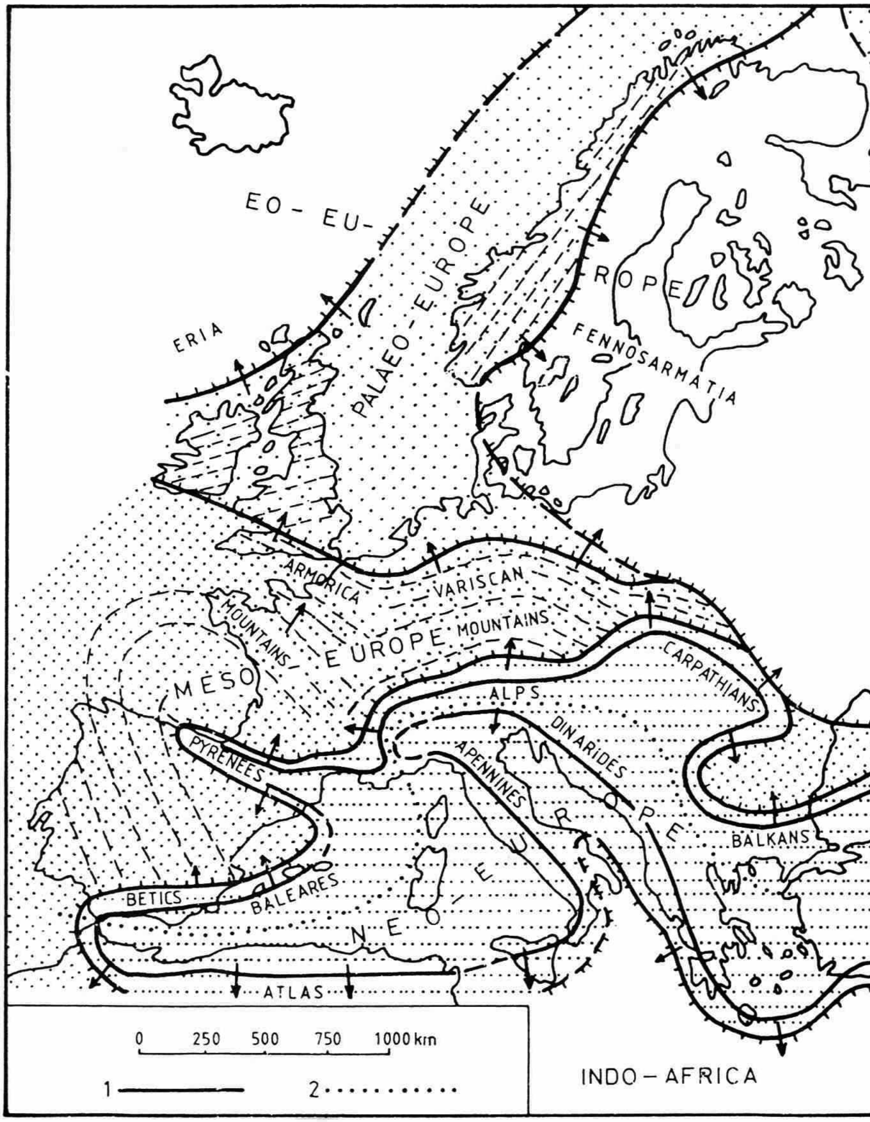


Fig. 1 Megastructural subdivision of Europe (H. Stille 1924). 1: Strike of the Alpids. 2: Boundary of arctogenic and meridiogenic folding. To the Precambrian nucleus of Europe (Eo-Europe) three accretions have been added: Palaeo-Europe in the Caledonian phase, Meso-Europe in the Hercynian phase and Neo-Europe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

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

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

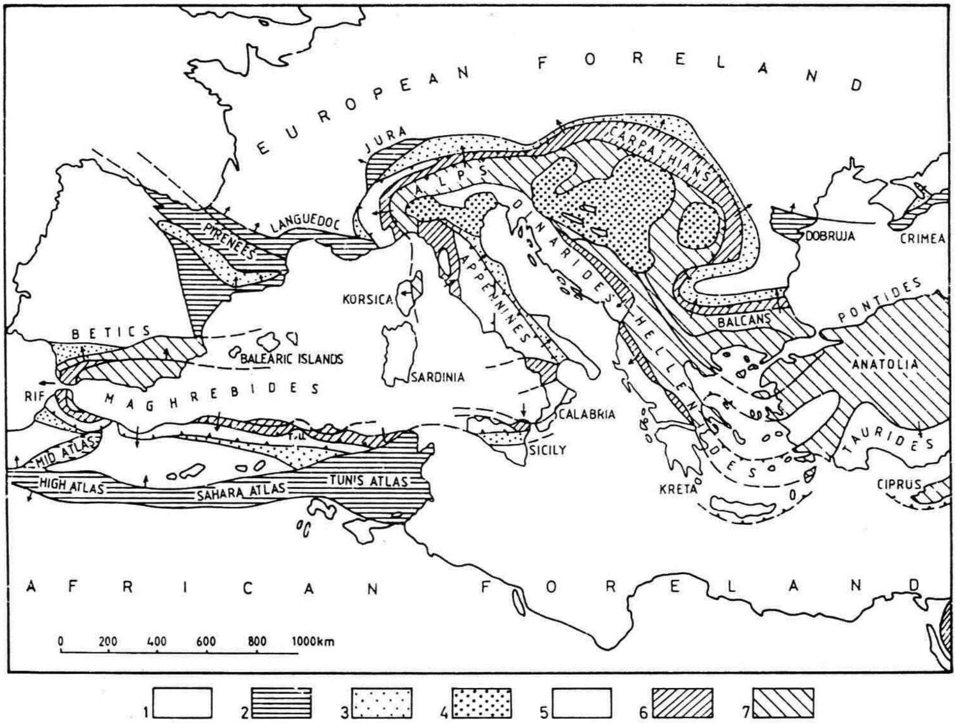


Fig. 2 Alpine Europe (J. Aubouin - M. Durand-Delga 1971). 1: foreland, 2: intracratonic mountains, 3: molasse foredeep basins, 4: internal molasse basins, 5: external zone, 6: flysch nappes, 7: internal zone, 8: scale.

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

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

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

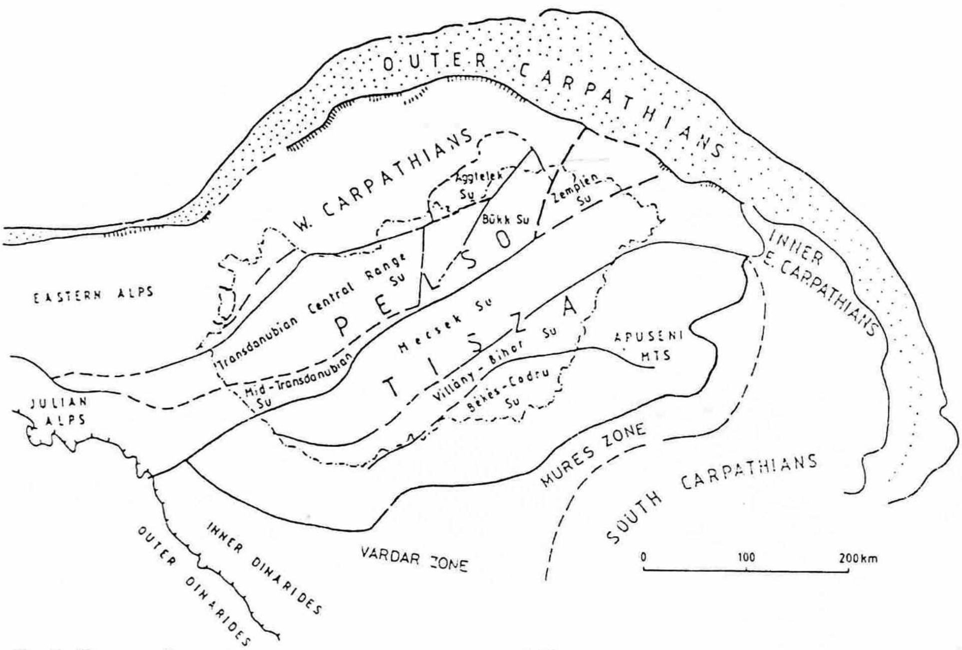


Fig. 3 Structural units and subunits (Su) in and around Hungary.

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

Megatectonic setting and structural units

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

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

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

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

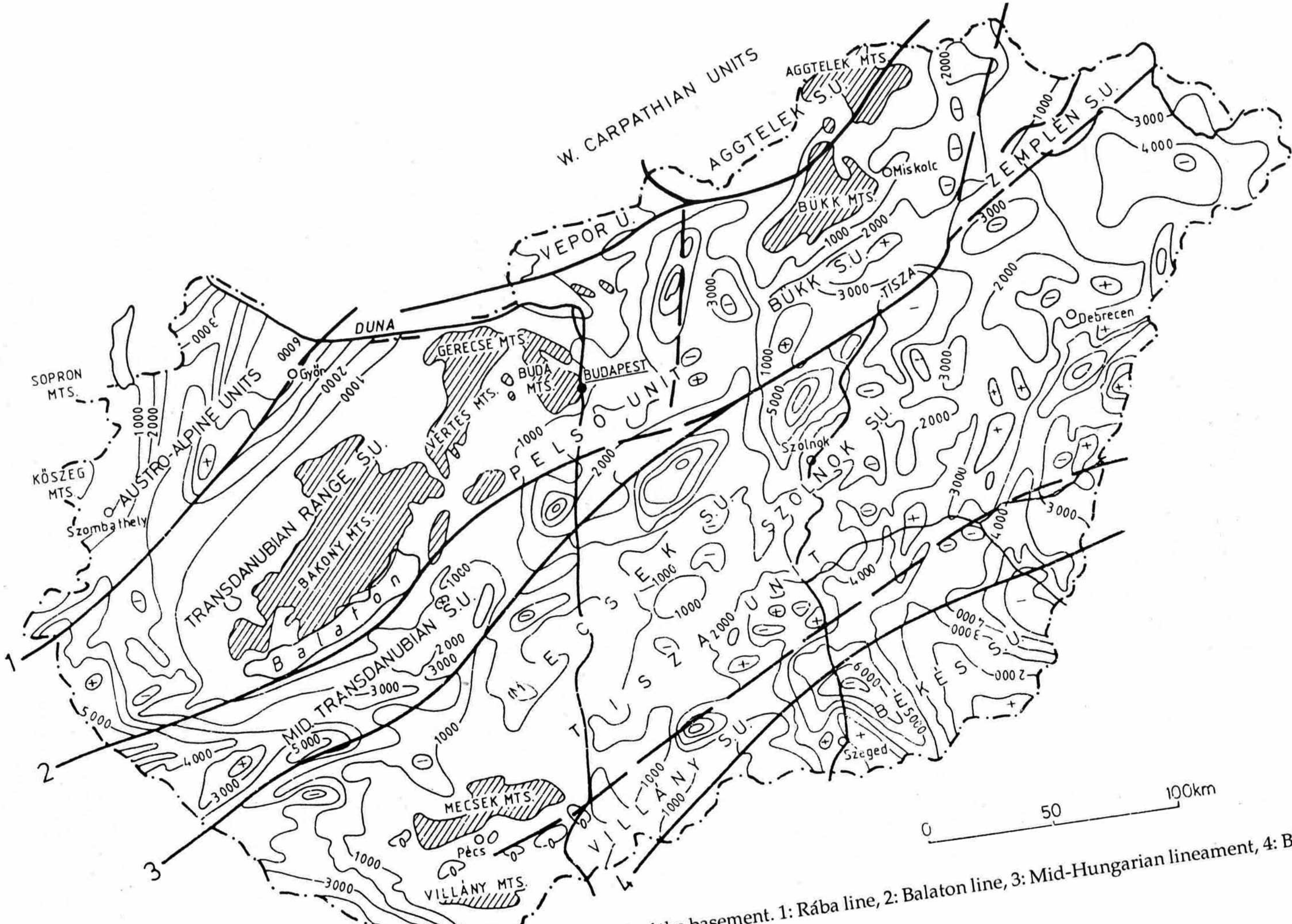


Fig. 4
Megastructural units and subunits (Su) of Hungary and depth (in m) of the basement. 1: Rába line, 2: Balaton line, 3: Mid-Hungarian lineament, 4: Békés line.

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

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

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

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

Structure evolution

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

Pre-Alpine phase

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

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

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

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

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

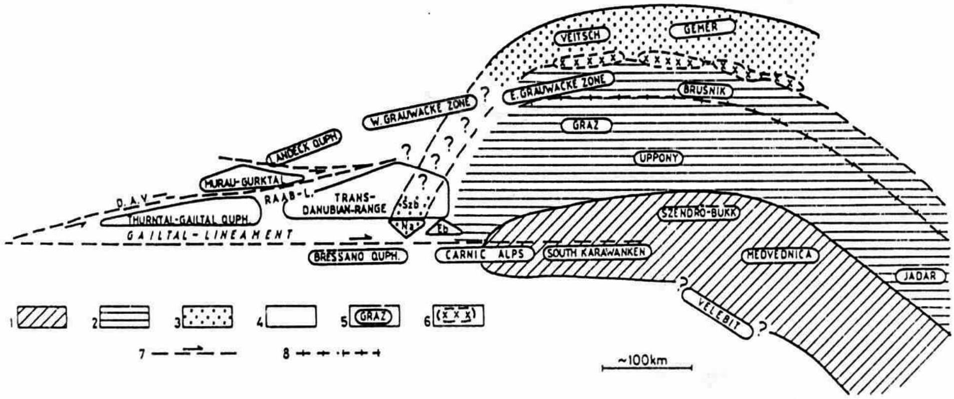


Fig. 5 Palaeogeographic situation of the NW and of the Alpine-Dinaric branch of Palaeo-Tethys in the Middle Carboniferous (schematic reconstruction by S. Kovács). 1: Flysch formation, 2: carbonate sedimentation on shallow shelf, 3: molasse sedimentation in post-Variscan basins, 4: continental areas (early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

Alpine phase

Within the Alpine phase the following stages can be distinguished.

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

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

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

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

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

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

In the Tisza Unit which was located in the external belt of the European shelf segmentation of the margin did not 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

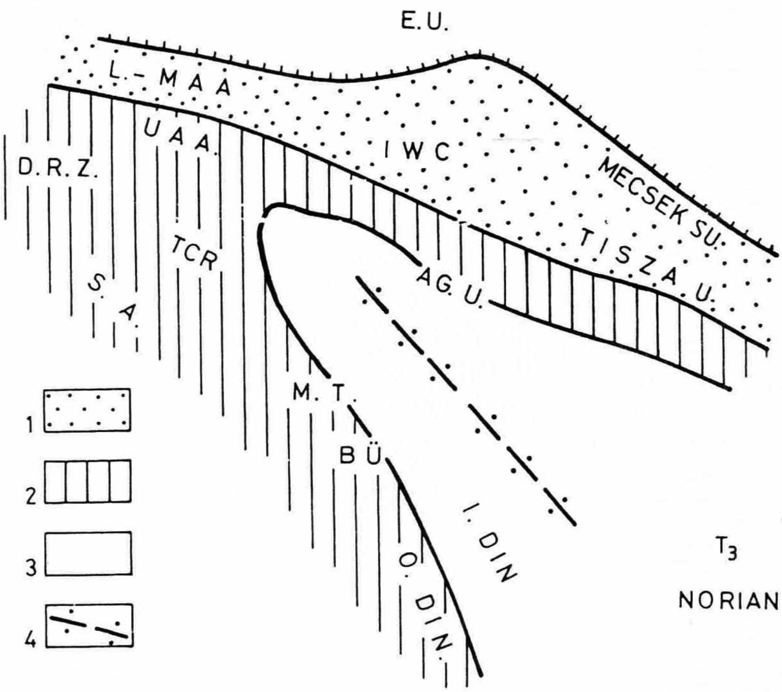


Fig. 6 Late Triassic (Norian) palaeogeographic position of the megastructural units of the basement of the Pannonian basin and the surrounding area (Haas and Kovács 1992). TCT: Transdanubian Central Range, AG. U. Aggtelek — Rudabánya Unit, E. U.: Stable Europe, L (M) E. ALP : Lower (Middle) Austroalpine,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

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

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

1.4 Opening of new oceanic branches in the Jurassic

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

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

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

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

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

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

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

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

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

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

The stages of the convergent phase are:

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

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

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

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

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

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

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

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

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

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

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

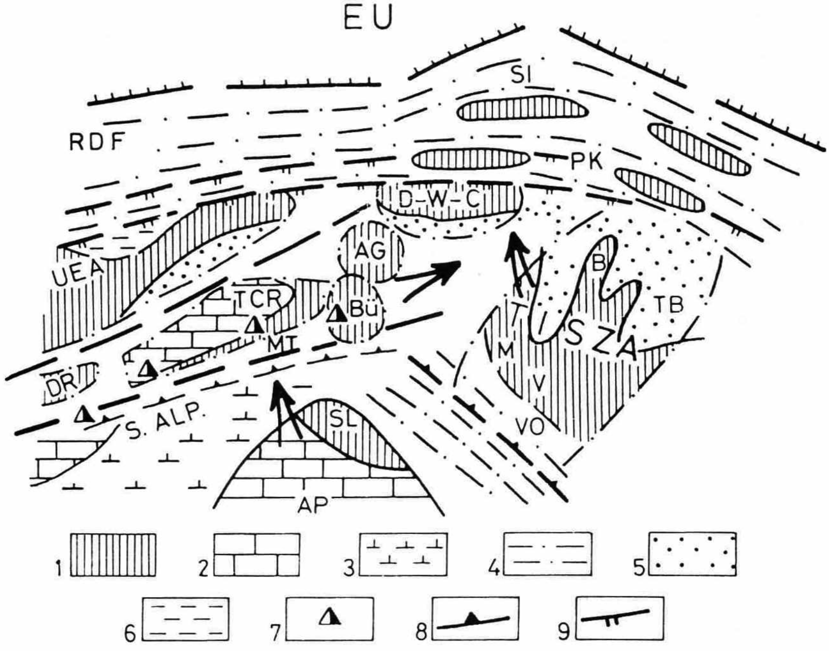


Fig. 7 Middle Eocene palaeogeography and directions of the Oligocene displacements. 1: elevated area, 2: carbonate platform, 3: pelagic sedimentation, 4: flysch sedimentation, 5: dominantly clastic sedimentation, 6: argillaceous sedimentation, 7: island-arc volcanism, 8: subduction zone, 9: overthrusting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

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

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

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

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

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

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

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

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

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

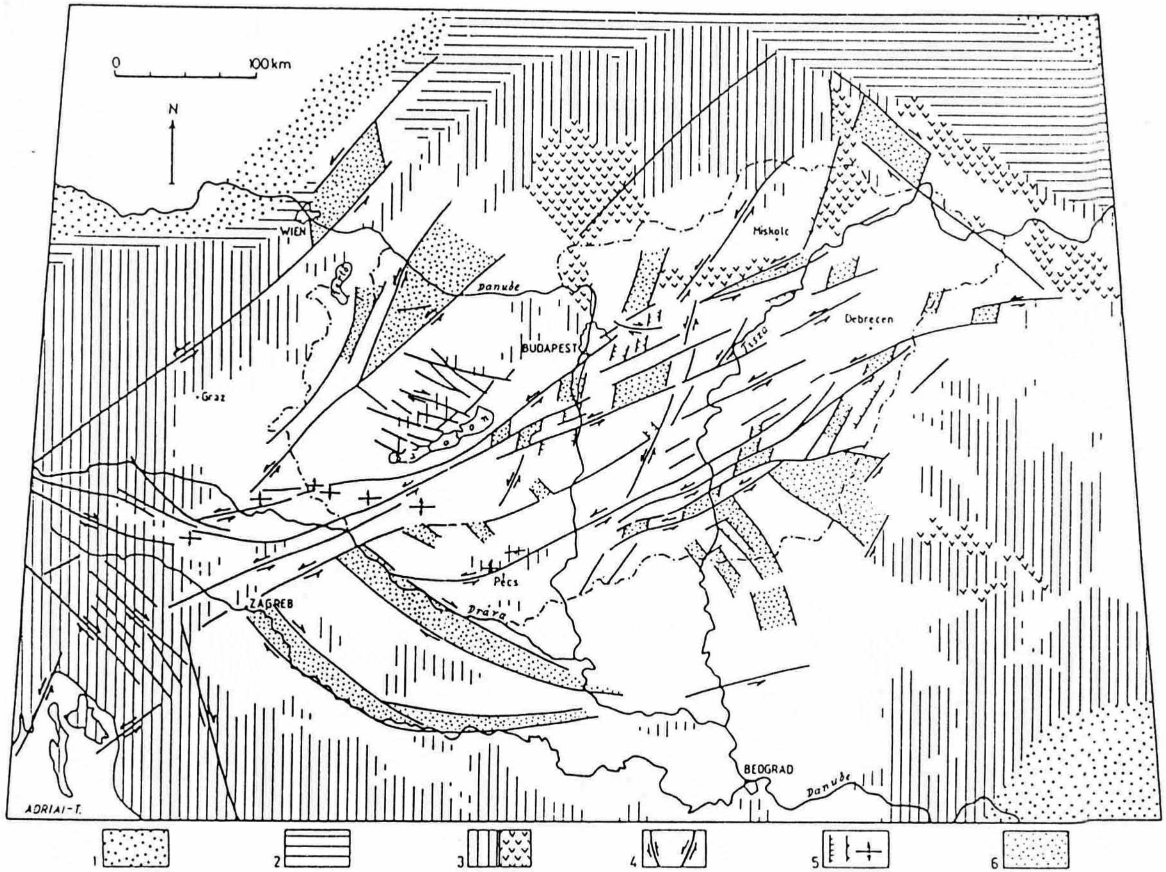


Fig.8
Neogene model of the Carpathian-Pannonian region (F. Horváth 1987). 1: molasse foredeep, 2: flysch belt, 3: Alpine, Carpathian and Dinaric Mountains, (a): Neogene volcanic area, 4: strike-slip fault, 5: normal fault, 6: deep depressions connected with faults.

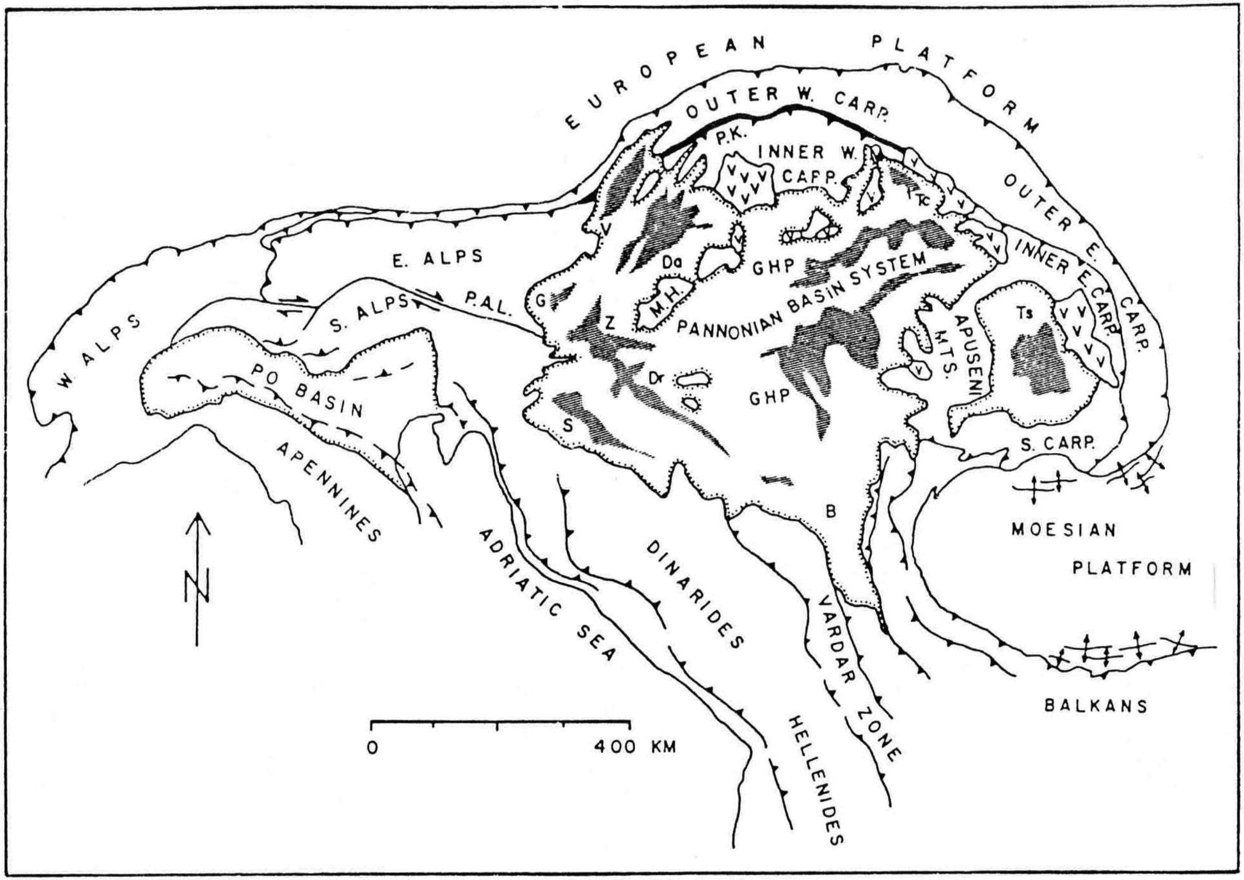


Fig. 9
Position of the Carpathian Mountains and the Pannonian Basin (Royden 1988). Strippled area indicates parts of the Pannonian Basin where the depth to base Miocene exceeds 3 km. Subbasins are: V: Vienna, Da: Danube, G: Graz, Z: Zala, Dr: Dráva, S: Sava, Tc: Transcarpathian, Ts: Transylvanian, GHP: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

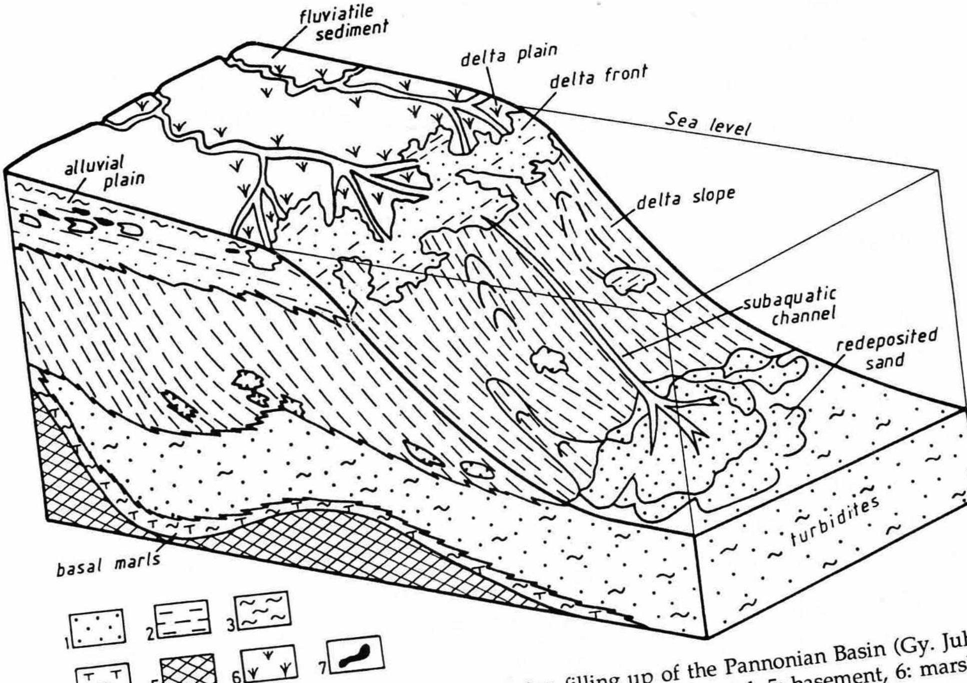


Fig. 10 Model of the fluviatile-deltaic sedimentation filling up of the Pannonian Basin (Gy. Juhász 1992). 1: sandstone, 2: silt(stone), 3: clay marl, 4: calcareous marl, 5: basement, 6: marsh, 7: peat (lignite).

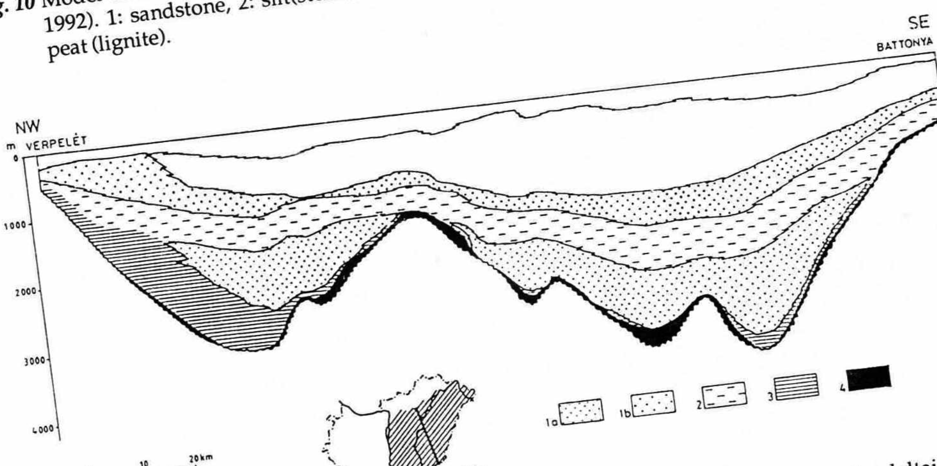


Fig. 11 NW-SE section accross the Great Hungarian Plain (Alföld), showing the fluviatile, deltaic and lacustrine upfilling of the Pannonian Basin (Gy. Juhász 1992). 1a., b.: sandstone, 2: silt(stone), 3: clay marl, 4: calcareous marl.

The Pannonian Basin

Pál MÜLLER

In 1924 Laskarev coined the name Paratethys to designate a Neogene aquatic bioprovince in Central and Eastern Europe. The biota of this province, or at least a part of it, is characterized by periods of endemism. The frequency and duration of these endemic events trend to increase from the early Oligocene to the late Neogene. This reflects an increasing trend of isolation of the basins closing the water bodies of the Paratethys not only from the oceans or from the Mediterranean, but from each other as well.

The middle part of the mentioned bioprovince, named Central Paratethys, was situated partly in the back arc basin system of the Carpathian mountain belt, partly in its foredeep, extending into some subbasins at the feet of the Eastern Alps and the northern Dinarides.

The Pannonian Basin is a back arc type basin system (Royden and Horváth 1988) which gave space to the bulk of the Central Paratethyan water bodies.

The early evolution and structure of the Pannonian Basin basement is characterized in the preceding chapter (Haas this volume). As the basement rocks outcrop only in very limited areas, and the number of drillings reaching it beneath the Neogene cover is also very low, the genesis and structure of the basement is interpreted in very diverging ways (Royden and Báldi 1988, Balla 1990).

The further Neogene history of the basin is much clearer, thanks to extensive drilling activity, geophysical research and seismic prospecting, aiming at hydrocarbons and water in the deeper parts, and various mineral reserves, as lignite, at the margins.

The convergent movements associated with the evolution of the Alpine mountain systems were diachronous (Royden 1988). In the Eastern Alps this type of deformation was mostly over by late Palaeogene time, while in the Carpathians the convergence and formation of nappes was still active during the early and middle Miocene, in the Eastern Carpathians even in the late Miocene.

Intimately associated with the convergence, the Pannonian Basin system came into existence in an area delimited by the arc of the Carpathians, by the Eastern Alps and the Dinaric Alps. Initially, during the early and middle Miocene, the basin was a complicated array of tectonic troughs, causing already an average crustal thinning. By late Miocene time a more regional and more uniform thermal subsidence prevailed. The transition to thermal subsidence was also diachronous in different parts of the basin. The final effect of these subsidences of different origin is a complicated pattern of basement depth with steep slopes, level differences of several kilometers in short distances, while the present surface might be completely flat or hilly.

The initial, early to middle Miocene basin system housed mainly marine water bodies, which repeatedly became isolated from the oceans, gained abnormal salinities and gave place to endemic evolution. The isolation became definitive near the middle/late Miocene transition, the inland sea became a lake and gave space to a most spectacular endemic evolution.

The often endemic character of the aquatic biota of the waters in the Central Paratethys and specifically in the Pannonian Basin system evoked many controversial proposals for the stratigraphy of their sediments. Such difficulties are still far from being entirely removed.

The repeatedly increasing endemism and the consequent difficulties of correlation with the global stratigraphic units lead to the development of a regional stratigraphic system for the Central Paratethys and partly for the Eastern Paratethys as well. Since the foundation of this system, continuous efforts have been made to clarify the stratigraphy of the realm. These efforts were coordinated and animated by the Regional Committee on Mediterranean Neogene Stratigraphy (RCMNS) of IUGS. The stratigraphic scheme pro-

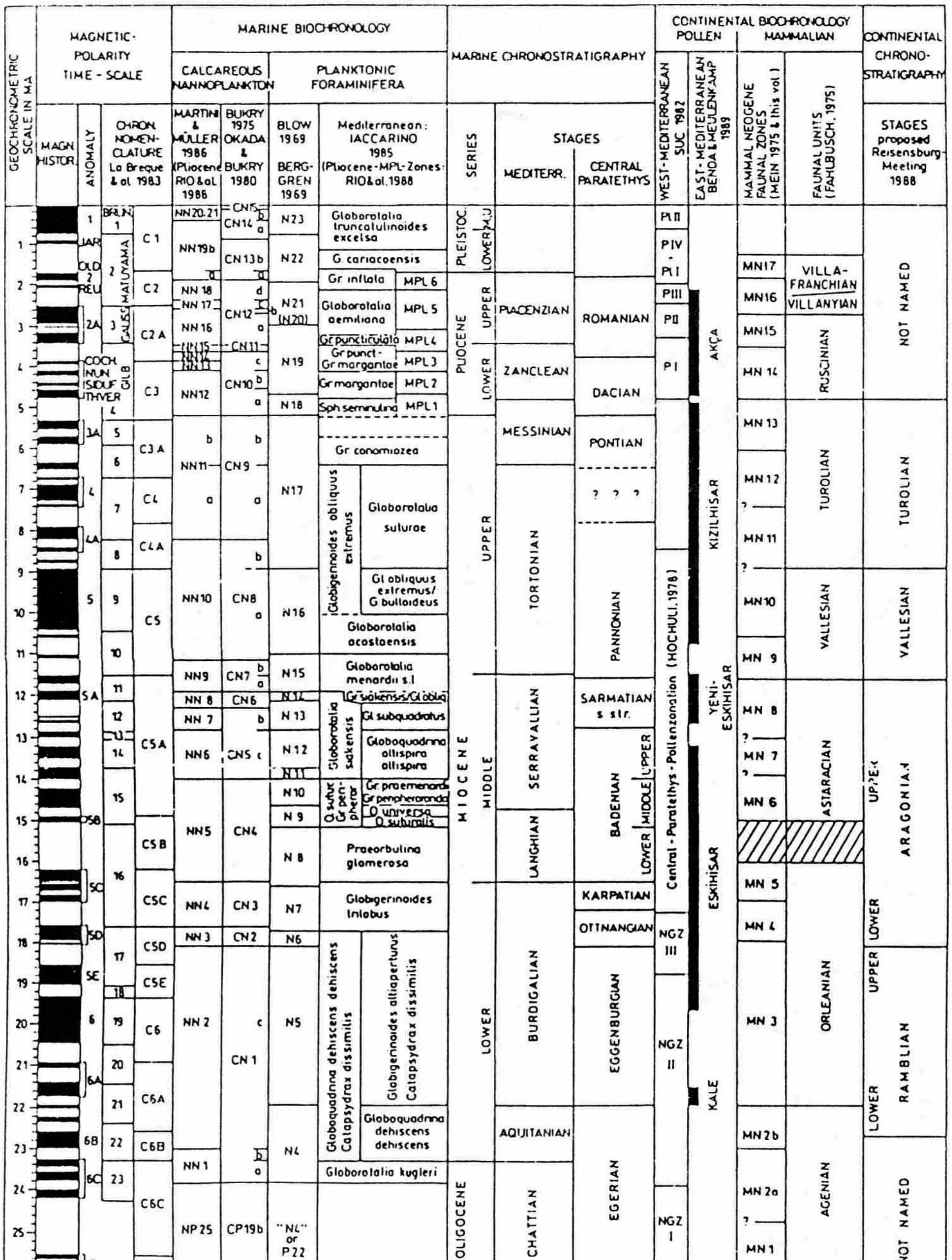


Fig. 12 Correlation chart for Neogene chronology of Europe (Steininger et al. 1990). Dotted lines between the stages Pannonian and Pontian refer to new results explained under title Stop 10 (Tihany).

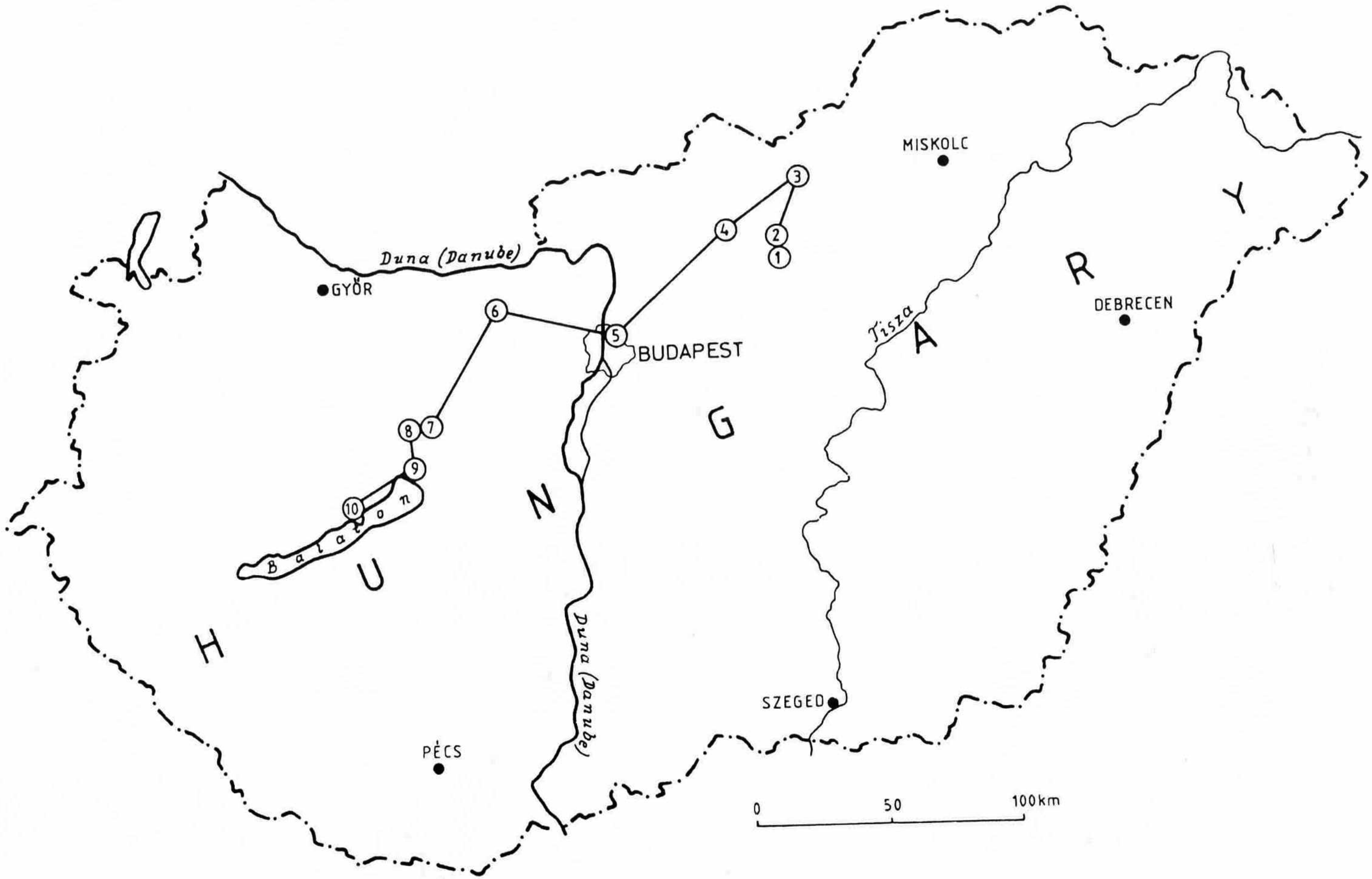


Fig. 13
Stops of the three excursions of the meeting. Circles: this excursion.

posed for the Central Paratethys as well as its correlation with global or Mediterranean stages is illustrated in Fig. 12, after Steininger et al. (1990), slightly modified. These correlations are based on different means, e.g. on planctonic forams, coccoliths for marine stages, mammal remnants recovered from marginal deposits, palynology and several methods of physical dating, of which magnetostratigraphy gave a welcome contribution in the last decade (Elston et al. 1990).

During this field trip we shall visit mainly outcrops of sedimentary rocks, both lacustrine and marine, but also volcanic rocks which constitute an important part of the Pannonian Basin Neogene (Fig. 13).

These outcrops are placed on the flanks of a mountain range, called the Hungarian Central Range, which cuts across the Pannonian Basin along a remarkably straight SWW-NEE line. In spite of the fact, that these mountains belong to different structural units, their arrangement and their uniform peak level (500-700 m on the western part, 900-1000 m on the eastern one), point to a remarkable uniformity in their, mainly Pliocene and Quaternary, elevation history, which can be attributed to the similarity of isostatic conditions along the range. The heights are built mainly of the uppermost erosion resistant rocks in the local sequences. These may be Palaeozoic-Mesozoic sandstones and carbonates, belonging to two very different structural units, middle Miocene intermediate volcanics, late Miocene lacustrine limestones or Pliocene basalts.

The field trip will demonstrate lower Miocene marine rocks (Stops 3 and 8), partly of strong Mediterranean affinities. These represent the Eggenburgian, Ottnangian and Karpatian regional stages, which are restricted to given narrow structures, and might be regarded as witnesses of the early evolution of the Pannonian Basin.

Middle Miocene, Badenian marine rocks will be shown at Stops 5 and 7. These show also Mediterranean affinities. The outcrop at Stop 5 include a transitional sequence toward a restricted marine stage, the Sarmatian, which is widespread in the Eastern and in the Central Paratethys, with a remarkable grade of endemism.

At Stop 2 middle Miocene intermediate volcanic rocks will be shown, at Stop 1O, Pliocene basalt agglomerates. Middle Miocene diatomites at Stop 4 are associated with coeval volcanic activities in the vicinity.

The rest of the Stops (Nos l, 6, 9 and partly No 10) deal with the most voluminous part of the Pannonian Basin fill, which are deposits of the so called Pannonian Lake, with an extreme high grade of endemism, including some endemic genera, and even subfamilies. Some of these are probable evolutionary sources of still living freshwater molluscs and fishes in Central and Eastern Europe.

The deposits of this lake were earlier ranged into one single stage, the Pannonian (Lőrenthey 1900), but later Stevanović (1951) proposed to remove the upper part of it to the Pontian stage with its stratotype in the Black Sea basin. Difficulties in the correlation of the stratotype Pontian with the upper part of the Pannonian Lake deposits led to the unfortunate situation that some scientists still use Lőrenthey's (1900) scheme, while others accepted the proposal of Stevanović (1951). Thus these upper parts are called either "Upper Pannonian s. l." or "Pontian".

STOP 1

Visonta, open cast lignite exploitation (Pontian, Upper Miocene)

György SZOKOLAI

Locality

The lignite open mine of Visonta is situated between the boundaries of Abasár, Visonta, Detk, Halmajugra and Aldebrő villages, at the foot of Mátra Mountains. The terrain is situated 125 to 145 metre above sea-level. It is a gently sloping pediment surface with approximately N to S running slades. The part of the open mine to be visited is the eastern cutting K-II (Fig. 14). After crossing the streamlet "Nyiget" and the industrial railway line we shall take a view of the K-II open mine from the look out point on the northern rim of the mine.

Age

The Visonta area is built up by molasse sediments that fill the Pannonian basin. The Bükkalja Lignite Formation, known in a 120 km long and 10 km wide zone along the northern margin of the Alföld basin, belongs to the Pontian stage.

History

On the basis of previous field observations exploration by drilling and mining began after World War I. Lignite prospects were summed up in unpublished reports by Gy. Vigh L. Szebenyi. Based on the favourable experience detained in Ecsed area a detailed exploration was started between Abasár and Visonta. The termal power station, designed originally to produce 400 MW, was expanded to 600 MW, then to 800 MW capacity. Exploration continued to the East (Detk, Tófalu, Kápolna), and to the South (Karácsond, Ludas, Nagyút, and Kál). Mining exploration in connection with the operation of the open mine is of the same volume as the preliminary and detailed exploration by drilling. The development of the dewatering method produces objects for well-logging and modern testing methods through a system of transmitting and monitoring wells.

Description of the sequence

The Pontian lignite bearing layers which can be examined on the territory of the open mine are shallow lacustrine formations (Jaskó 1973, Szokolai 1982). (Fig. 15).

The particulars that can be seen in the eastern open mine are:

— At the bottom of the open mine there is a barren sequence consisting of several incomplete cycles of mainly sand and silt. Its thickness is 12 to 18 m. (This "transmitting" layer, between Seam III and II, plays a key role in dewatering.)

— Seam II is 5 to 6 m thick in the southern part. It is multitracked with barren intercalations. The middle and upper banks bifurcate to the North. The two banks are separated here by intercalations of unstratified clay with dessication structures and lignite traces and by clayey silt and sand of organic colour.

— Seam I/a indicates that the transgression was not continuous. — Seams I and I/a are separated as a rule either by a clayey and silty member, deposited on the flood plane, or by a huminitic clay, deposited in a marsh or a lake. The thickness of this member is 2 to 5 m.

— In the mine K-II, Seam I is a rather uniformly developed formation of marsh forest facies.

— A sand formation, deposited in a delta front environment, was characteristic between Seams I and 0 in the K-I open mine, west of the K-II one. In the latter, and particularly in its northern part, this formation is often replaced by silty, clayey sediments of delta plain facies. Horizontal correlation of the interbedded sandy lenses is difficult or

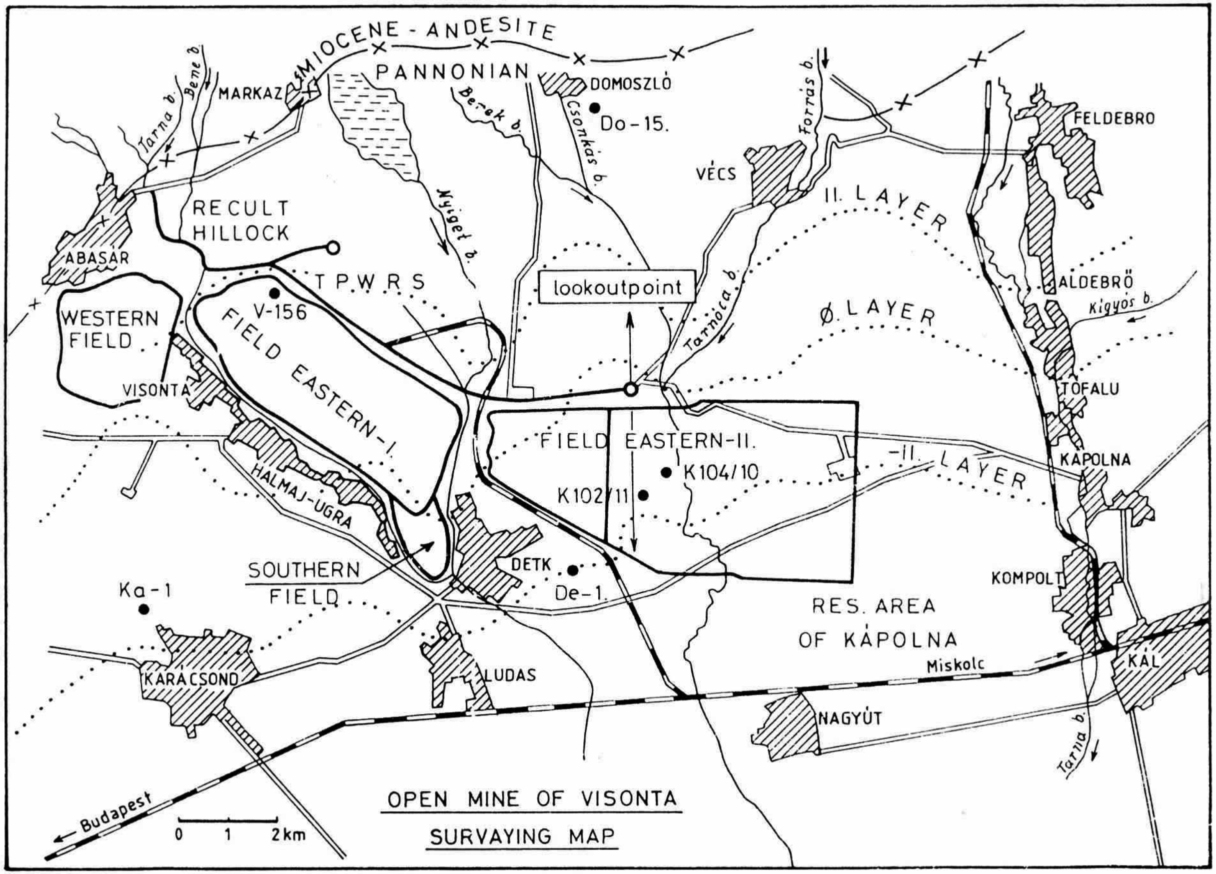


Fig. 14
Location of the Visonta lignite mine

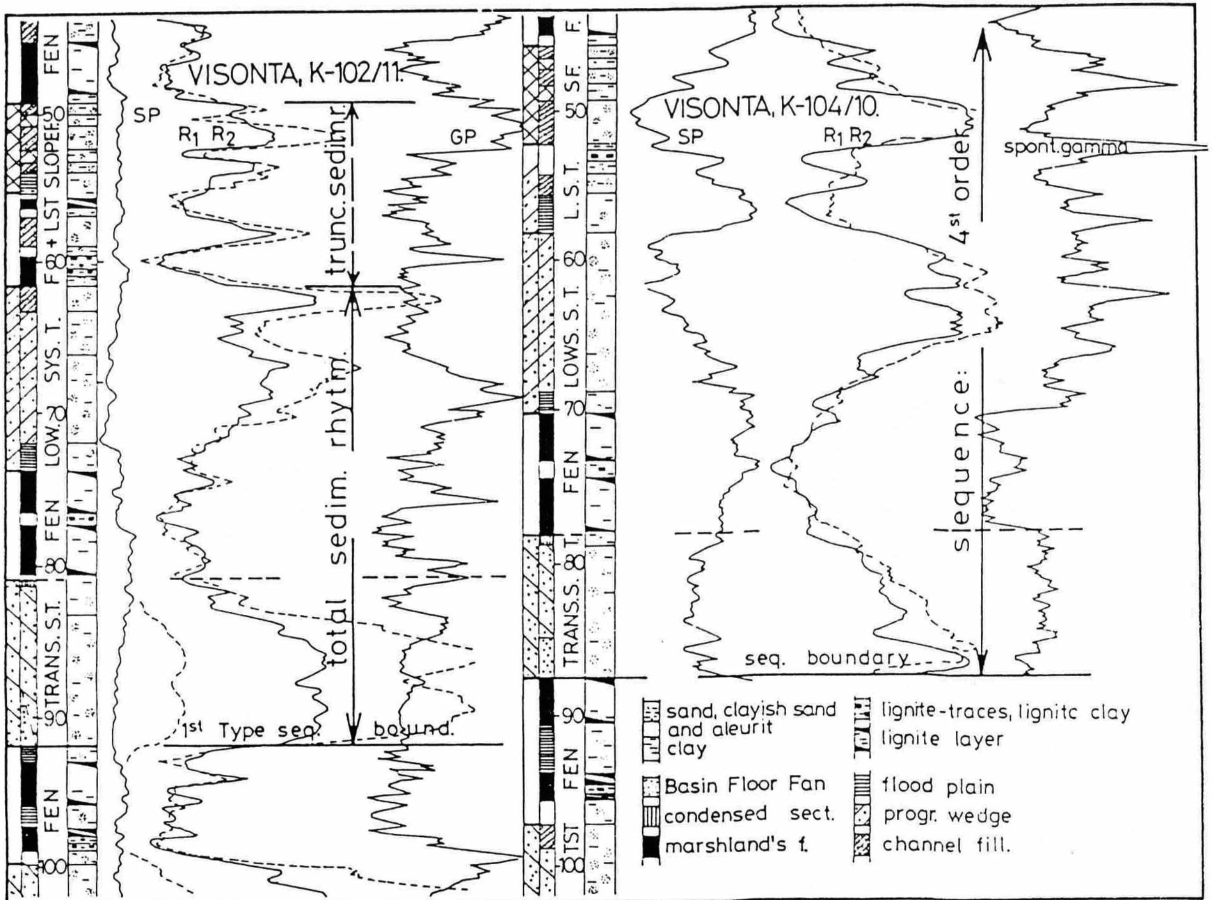


Fig. 15
Geological column of the Visonta sequence and its sequence stratigraphic interpretation

even impossible. They can be interpreted as distributary channel deposits. Especially the well-log shape of this sequence indicates a more symmetric structure than that of the corresponding complex in K-I.

— Seam I is 6 to 8 m thick, characteristically double-banked. The lower bank consists of marsh forest and shallow marsh deposits. The overlying formation was deposited in a lagoon or a shallow lake. It contains drying structures, lignite traces, lignite-detritus, and locally thin lignite stripes. This formation, however, displays a significant horizontal facies change. In the northwest, it is of flood plain facies, consisting of silt and fine-grained sand with lignite traces and plant remnants. In the southeast, the upper bank appears along an approximately SW-NE striking line.

— In Seam 0 the sediments of the different marsh zones rhytmically alternate. The different sections can be correlated only incompletely, and within a restricted area. At the same time, their macrostructure is similar, thus they provide useful information on the basin evolution.

— The best formation to study the sediments of a prograding wedge is the one covering Seam 0. The direct overlyer is a very thin, grey, stratified clay, usually overlain by an unsignificant lignite streak. The thickness of the rhythm is 0.3 to 1 m. (Seam I is overlain by a similar formation, too.) It still belongs to the deposits of a marsh-lake (or lagoon). Further upwards, first parallelly stratified silty clay with high montmorillonite content, then a coarsening-upward sand series are found. The thickness of the silty clay and that of the fine-grained sand are changing in a complementary way, and give a total thickness of 15 to 20 m. The silty clay, thickening towards the margin of the basin, marks the beginning of the transgression (backstepping parasequence). The rhythmicity of the prograding delta deposits is well expressed by the significant dip of the bedding-planes of the fine-grained layers. Therefore, the apparently homogeneous sequence in fact displays an extreme horizontal variability. In fresh exposition the stratification is enhanced by non removable residual water or by secondary carbonate-cemented sandstone lenses, formed between the silty clay and the sand layers.

— The Upper Pannonian sequence is terminated here with traces of a coal seam: bentonitic silt with detritus of fusite alternating with stratified silty clay containing leaf imprints. At the boundary of the formations limonitic-goethitic colours have been developed. On the top morphology of the Pannonian a level of carbonatic-limonitic concretions (sandstone?) can be found.

— The unconformly overlying Quaternary formations are not discussed in detail. They represent a Lower-Middle Pleistocene fanglomerate, the strongly weathered material of which has been transported by streamlets from the nearby volcanic mountains.

Water level fluctuations in the Pannonian lake

In large scale view (e.g. on a well-log of scale 1:1000) the whole of the Visonta succession, or the local verticum of the Bükkalja Lignite Formation is a second (or third?) order sedimentary sequence. Fig. 15 demonstrates how the higher-order sequences, caused by eustatic changes, can be recognized in a more detailed analysis. The local evolution can be described as follows:

— transgressive (ingressive) phase, deposition of well-stratified clay and silt in very shallow water, following seam formation;

— formation of a delta complex and immediate filling up during intensive subsidence;

— either stagnation of the lagoon in the topset (if permitted by the subsidence of the basin), or its repetitive filling (if the balance of subsidence was changed);

— effect of movements in farther parts of the basin is reflected by the rhythmicity of sedimentation and, in the seams, by the shift of the main marsh zones.

To sum up, higher and lower order sequences, examined in the open mine, consist of cyclic repetition of marsh deposits, developed in the equilibrium period, transgressive hanging wall formation, prograding delta complex, (terrestrial layers), and marsh deposits again. The whole process can be defined as an upfilling regression. It produced seam groups regrading towards the inner part of the basin. The whole sequence is a part of a higher order sequence, defined as the Bükkalja Lignite Formation.

STOP 2

Sástó, abandoned andesite quarry (Badenian, Middle Miocene)

Zuárd PUSKÁS

Locality

The Sástó abandoned andesite quarry is located on the southern slope of the Middle Mátra Mts between Mátraháza and Mátrafüred resorts, at about 600 m a.s.l. The quarry has been named after the small lake Sástó, which is situated 1 km southwestward, at about 510 m a.s.l. The area belongs to the southern, gently rolling slopes of mount Görgőbikk (693 m), and is characterized by modest relief energy.

Age

The rock material that used to be mined in the quarry is part of a thick pyroxene andesite lava flow of Middle Miocene (Early Badenian) age.

History

The first petrographical description of the Mátra Mts — inclusive the area under question — was a comprehensive account by Mauritz, B. (1909). The detailed petrological study of the area between Mátraháza and Mátrafüred has been carried out by Csillag-Teplánszky, E. (1964). Láng, S. (1955) treated in detail the physical geography of the whole Mátra Mts. The most comprehensive geological summary of the Mátra Mts as yet has been compiled by Varga et al. (1975). Balla and Havas (1982) dealt with the neotectonics of the Mátra Mts, while Jaskó (1986) with that of its broader surroundings (Mátra, Bükk and Tokaj Mts).

Miocene volcanism in Northern Hungary

There is a broad volcanic belt of Miocene age with a length of about 450 km in the SW-NE axis of the Carpathian Basin, from Muraköz in the SW to the Eperjes-Tokaj Mts in the NE. The western-southwestern part of the belt has been deeply buried under younger, mostly Miocene (Pannonian and Pontian) sediments, while its northern-northeastern segments crop out as the volcanic masses of the North Hungarian Range (Visegrád, Börzsöny, Cserhát, Mátra, Southern Bükk and Tokaj Mts). The thickness of the volcanics varies considerably, from some 100 to more than 1500 metres. On the basis of available borehole data the maximum is attained in the Western Mátra, in the southern forelands of the Mátra and Bükk Mts, as well as in the central region of the Tokaj Mts (Jaskó 1986). The buried southwestern wing of the belt is much less well known.

The Miocene volcanism in Northern Hungary was mainly intermediate. Andesite is the prevailing rock type. However, dacites and rhyolites are also important, locally even predominant. The basaltic andesites are subordinate. The distribution of these rock varieties in the individual members of the volcanic range differ significantly: biotite-amphibole andesites and dacites predominate in the Visegrád and Börzsöny Mts, more mafic pyroxene andesites are the most common in the volcanic complex of the Cserhát and Mátra Mts, almost exclusively rhyolitic and dacitic tuffs are found in the Southern Bükk Mts, while andesitic and rhyolitic volcanics are roughly balanced in the Tokaj Mts.

The Miocene volcanic mountains are of stratovolcanic superstructure with roughly equal proportion of lavas and pyroclastics. The only known exception is the Southern Bükk with its foreland, where acidic tuffs are almost exclusive.

The age of the volcanism shifted from Ottnangian in the West up to Lower Pannonian in the East. The volcanic activity in the Visegrád, Börzsöny, Cserhát and Mátra Mts was most intense in the Early Badenian, while in the Tokaj Mts in the Sarmatian (Gyarmati 1977). The recently significant height differences between the volcanic mountains and their buried prolongation are the consequence of Pannonian and even younger tectonic events (Kőrössy 1980).

Miocene volcanism in the Mátra Mts

The first volcanic products of Miocene age are early Ottnangian pumiceous rhyolitic tuffs (the so-called Lower Rhyolitic Tuff). They overlie relatively thin shallow-marine and terrestrial sediments of Eggenburgian age. Their thickness varies from some meters to some tens of metres. They are overlain by the Late Ottnangian coal-bearing transgressive sequence.

The major part of the Early Karpatian stage is represented by an up to 500 m thick marine marly siltstone series (so-called Schlier). In the upper part of the Karpatian the first appearance of andesitic volcanic products can be traced, mainly in the western part of the mountains. It was a submarine volcanism characterized by altered pyroclastics up to 100 m thick (Lower Andesite). The closing sequence in the Karpatian is a subaerial dacitic tuff (the so-called Middle Rhyolitic Tuff), which has a regional distribution of about 25-30 thousand sq km in Northern Hungary. Its explosion centres might have been in the southern foreland of the Bükk Mts. The thickness of the tuff in outcrops of the northern foothills in the Mátra Mts varies between 20 and 60 m. In boreholes of the south-eastern foreland it exceeds 100 m.

Miocene volcanism in the Mátra Mts reached its most intense phase in Early Badenian, producing a typical stratovolcanic sequence of andesitic character (Middle Andesite Formation). The proportion of lava rocks and pyroclastics is roughly balanced in the sequence. Total thickness decreases from more than a 1000 m in the west to about 500 m in the east. By far the most common rocks are different types of pyroxene andesites. Though the exact superposition of the various lava flows, agglomerates and tuffs can not exactly be deciphered any more, clear trends in the petrological character of the magmatism can be recognised on the basis of a number of outcrop sections as well as of borehole logs; According to Kubovics, I. (in: Kubovics and Pantó 1970) the first products were hypersthene andesites, from which the bronzitic augite andesites developed, representing the bulk of the volcanic superstructure. This variety was subsequently substituted by pigeonite-augite andesite that graded upwards to amafitic, and then to microandesites. Pyroxenes appear as porphyric constituents in the lower and middle level lava rocks, while in the amafitic andesites they are present in the groundmass only. Phenocrysts in the amafitic andesites are calcic plagioclase (labradorite, or even bytownite), while microandesites have practically no porphyric minerals at all, that is they are composed exclusively of groundmass. The disappearance of porphyric generations with the progress of magmatism is interpreted as a consequence of heating up the underlying crust by the volcanism itself.

There are compact, vesicular and amygdaloidal lava rocks of various grain size as well as pyroclastics in the Middle Andesite Formation. Intensive late and post-volcanic alterations are also common, mostly in the central and western parts of the mountains. Typical alteration processes include e.g. silicification, sericitization, argillization, chloritization, uralitization, carbonatization, pyritization, potassium metasomatism, hematitization-limonitization, and more rarely biotitization. The K_2O-content of potassium trachytes may attain up to 10-13 w% in places with an average being slightly over 8%. Vein type economic hydrothermal mineralization with galena, sphalerite and chalcopyrite as principal ore minerals developed in these heavily altered andesites.

The final products of the Middle Andesite Formation are geysirites and limnoquartzites deposited by hot springs, mainly in the south-southwestern parts of the mountains. After a temporary standstill the andesitic volcanism in the Mátra Mts was terminated by the formation of the so-called Overlying Andesite of still early Badenian age. This formation is up to 200 m thick, occupying the highest levels in the mountains, i.e. above 600-700 m. It consists mainly of fresh lava rocks with subordinate pyroclastics at their base. Petrographically they are pyroxene andesites with either hypersthene or augite being the main mafic constituent. Olivine also appears in the groundmass of some more mafic basaltic andesites. These rocks have not suffered any post-volcanic alteration.

There are two local occurrences of rhyolite in the Southern Mátra Mts overlying rocks of the Middle Andesite Formation. Having no direct relationship to the Overlying Andesite, their age relation is not quite clear. They are, however, most probably roughly synchronous products.

Following the termination of the Early Badenian volcanism, the higher levels of the Badenian and the whole Sarmatian are represented by various sedimentary deposits (diatomite, limestone, fine-grained and argillaceous sediments), mainly in marginal basins of the mountains. Rhyolite tuffs (the so-called Upper Rhyolitic Tuff) are interbedded in the Sarmatian marine and terrestrial layers, which are the last volcanic products of Miocene magmatism in the area. In places they can be redeposited.

The Sástó quarry

Pyroxene andesites of a thick lava flow belonging to the Middle Andesite Formation have been opened up in the quarry (Fig. 16). As a result of cooling vertical columnar jointing has developed.

No considerable evidence of alterations can be noticed by the unaided eye: the rock is uniformly dark grey and fresh. Porphyric plagioclase and less pyroxene in the size range of 1 to 2 mm can be recognised macroscopically. The lath- or square-shaped and generally zoned plagioclase phenocrysts have a rather high An-content, being labradoritic or even bytownitic in composition. A slight montmorillonitic alteration along edges, cracks and cleavage planes is common in most grains. Among the porphyric pyroxenes euhedral hypersthenes are more common than clinopyroxenes of pigeonitic composition. The orthorhombic pyroxene is fresh, however slight biotitization may occur along some grain edges. The pigeonite is totally fresh apart from some occasional resorption phenomena on their rims. The groundmass that amounts to about 60-70 v% of the rock consists of fine-grained lath-forming intermediate plagioclase, isometric clinopyroxene of augitic or pigeonitic composition as well as magnetite and subordinate biotite. Rarely zeolites in some 10 to 50 um patches have also been formed in the groundmass, evidencing some late volcanic fluid enrichment. The Sástó quarry has already been abandoned, the area belongs to the East Mátra Landscape-protection Area.

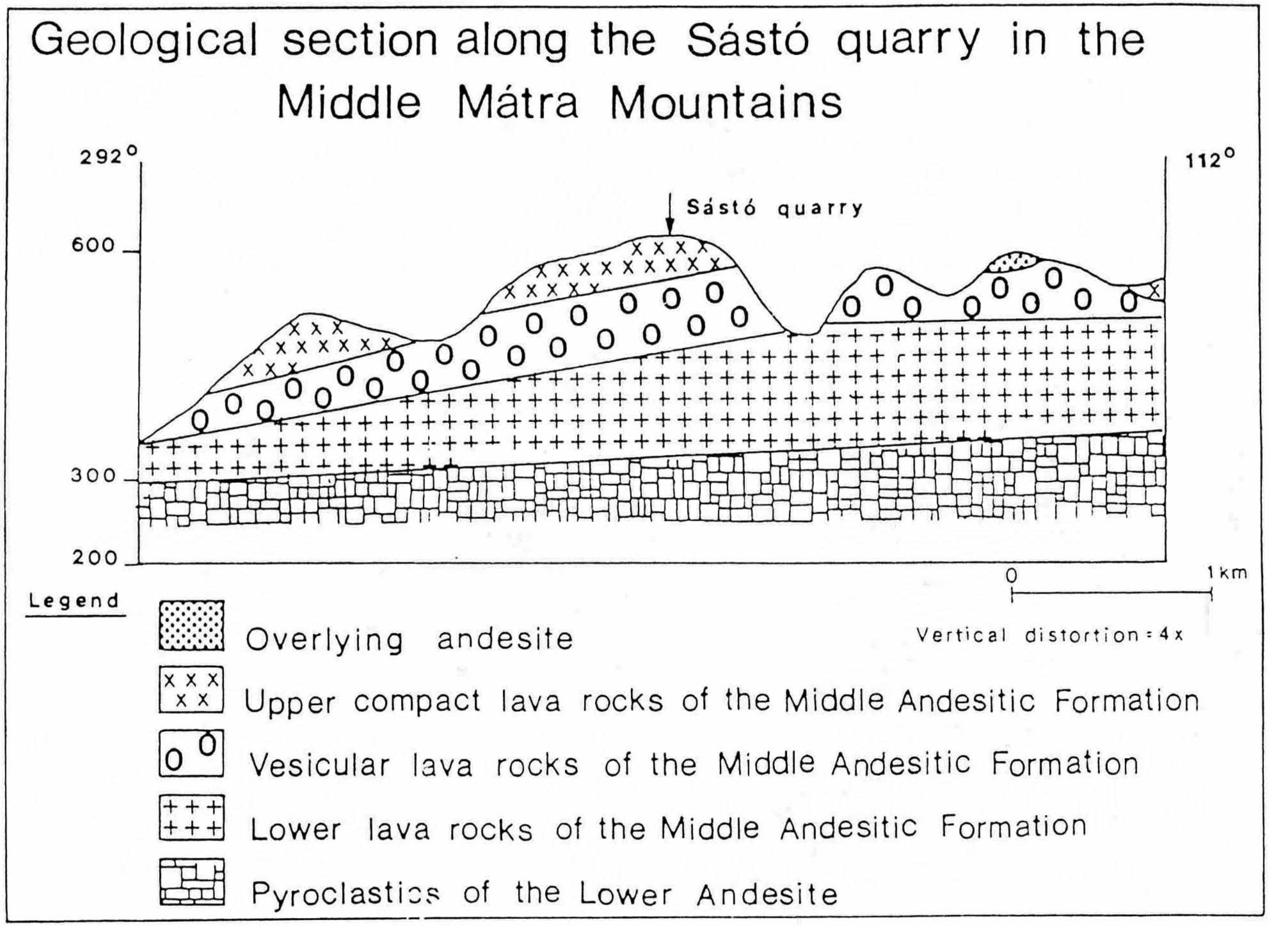

Geological section along the Sástó quarry in the Middle Mátra Mountains
292°
112°
Sástó quarry
600
300
200
0
1 km
Vertical distortion = 4x
Legend
Overlying andesite
Upper compact lava rocks of the Middle Andesitic Formation
Vesicular lava rocks of the Middle Andesitic Formation
Lower lava rocks of the Middle Andesitic Formation
Pyroclastics of the Lower Andesite

Fig. 16

STOP 3

"Noah's vineyard", Istenmezeje: transgressive surface of the Early Miocene

Orsolya SZTANÓ

Locality

The outcrop of the Pétervására Sandstone Formation called "Noah's vineyard" is situated at Istenmezeje in the Tarna valley, in northern Hungary (Fig. 17). It is a 500 m long, 60 m high outcrop of NW-SE strike. The bedrock has been exposed by erosion following intensive deforestation in the 16-17th century. The origin of the strange name is a legend about a wicked guard of the vineyard, who refused to give some grape to a tired strider. As a punishment the vineyard turned into stone. You may recognize the lines of sticks supporting the vine and the guard with his dog at the southern cliff.

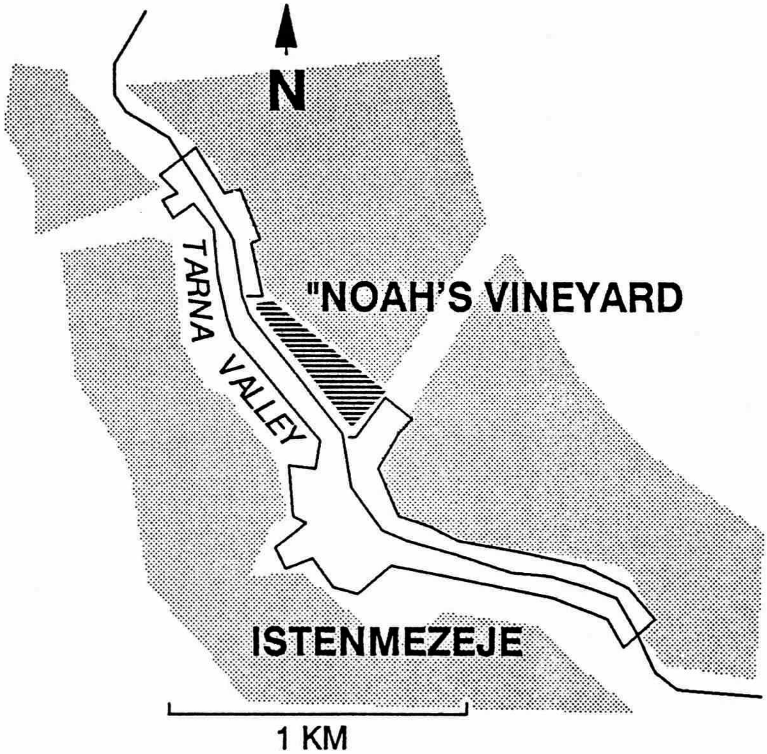


Fig. 17 Locality of "Noah's vineyard" in the village of Istenmezeje

Age

The age of the outcrop is Eggenburgian, Early Miocene regional stage (from latest Aquitanian to Early Burdigalian) in the Central Paratethys region (Steininger et al. 1990; Haq et al., 1987).

History

During the intensive geological research of northern Hungary the Pétervására Sandstone Formation was mapped as Chattian (Upper Oligocene) glauconitic sandstone

(Schréter 1929, 1940, 1948; Tomor, 1948; Bartkó, 1952; Hegedűs, 1952; Jaskó, 1952 and many others). The Istenmezeje area was throughly studied by Szentes (1943). Fossils are rare, therefore its age was debated for a long time. Stratigraphic works, however, determined Early Miocene (Late Egerian) age for the underlying siltstones (Szécsény Schlier, Báldi 1983, 1986 and references therein), confirming the Lower Miocene (Eggenburgian) position of the Pétervására Formation. Its depositional environment was studied recently (Sztanó, 1992; Sztanó and Tari, 1993). The formation is also known from South Slovakia as Fiľakovo Sandstone (Vass et al. 1989).

Biofacies

The Pétervására Sandstone is extremely poor in fossils, except for shark teeth and debris of mollusc shells accummulated in conglomeratic beds. The relatively high diversity mollusc community points to an Eggenburgian age. The Chlamys-Ostrea-Balanus assemblage is indicative of high energy, strongly agitated water (cf. Báldi 1983, 1986). In the visited outcrop, however, no fossil has been found.

Lithofacies

At "Noah's vineyard" three facies units of the Pétervására Sandstone can be studied (Figs. 18 and 19). Dominantly it is built up of medium- to coarse-grained sandstone with giant-scale crossbedding (C). It is covered by a very rapidly upward fining and thinning series of beds. A few sets of medium-scale crossbedding (B) is overlain by fine-grained sandstone with silty intercalations (A). The facies units A, B and C were formed in shore-parallel belts of decreasing water depth.

Facies unit A, with a wide range of sand/silt ratio, represents the transition towards siltstones (Szécsény Schlier), deposited in significantly deeper water then the Petervasara Sandstone. The lack of the typical "schlier biofacies", the higher amount of coarser grains and the abundance of current-induced sedimentary structures point to a higher-energy environment and shallower depositional depth for facies A, than for the adjacent Schlier.

Facies unit B is thin bedded fine- to medium-grained sandstone with 0.2-0.6 m thick sets of crossbedding. Foresets are covered by double mud drapes recording slackwater periods of successive ebb and flood events (Visser, 1980). Rippled silty bottomsets are common, as well as tiny trace fossils. Palaeotransport directions are dominantly towards the north. This unit is interpreted as a field of medium-scale dunes in a subtidal regime, driven by tidal currents.

Facies unit C. The dominant sedimentary structure is large-scale crossbedding developed in medium- to coarse-grained sandstones. Foreset morphology is tabular or tangential with an average set thickness of 2-3 m. Variations in shape, dip angle and grainsize of foresets suggest periodical changes of flow energy, which was correlated with spring-neap tidal cyclicity (Tari et al., 1989; Sztanó in prep.). Foresets uniformly dip to the north, indicating a highly asymmetrical tidal influence (ebb > flood). No structure infers to channelized deposition, rather a sheetlike morphology is supposed instead. These large bedforms are interpreted as northward migrating tidal sandwaves (in sensu Allen, 1980) in a depositional depth of 10-30 m (Allen, 1980).

Facies unit D, which does not appear in the visited outcrop, is built up of conglomerates. Beds of 4-10 m of thickness show normal gradation and weak crossbedding. This unit is interpreted as small coarse-grained deltaic lobes prograding from east to west, depositional slopes, however, are deviated to north by the strong tidal currents.

Sequence stratigraphy (Fig. 19)

The Pétervására Sandstone is underlain by the shallow bathyal-deep neritic Szecseny Schlier of NN1 age (Egerian), is interfingered with the Szécsény Schlier of NN2 age (Eggenburgian) and overlain by the terrestrial Zagyvapálfalva Clay. At the Egerian/Eggenburgian Paratethyan stage boundary depositional depth decreased dramatically, a smaller and shallower sea was formed (Nagymarosy and Müller, 1988). The deposition of

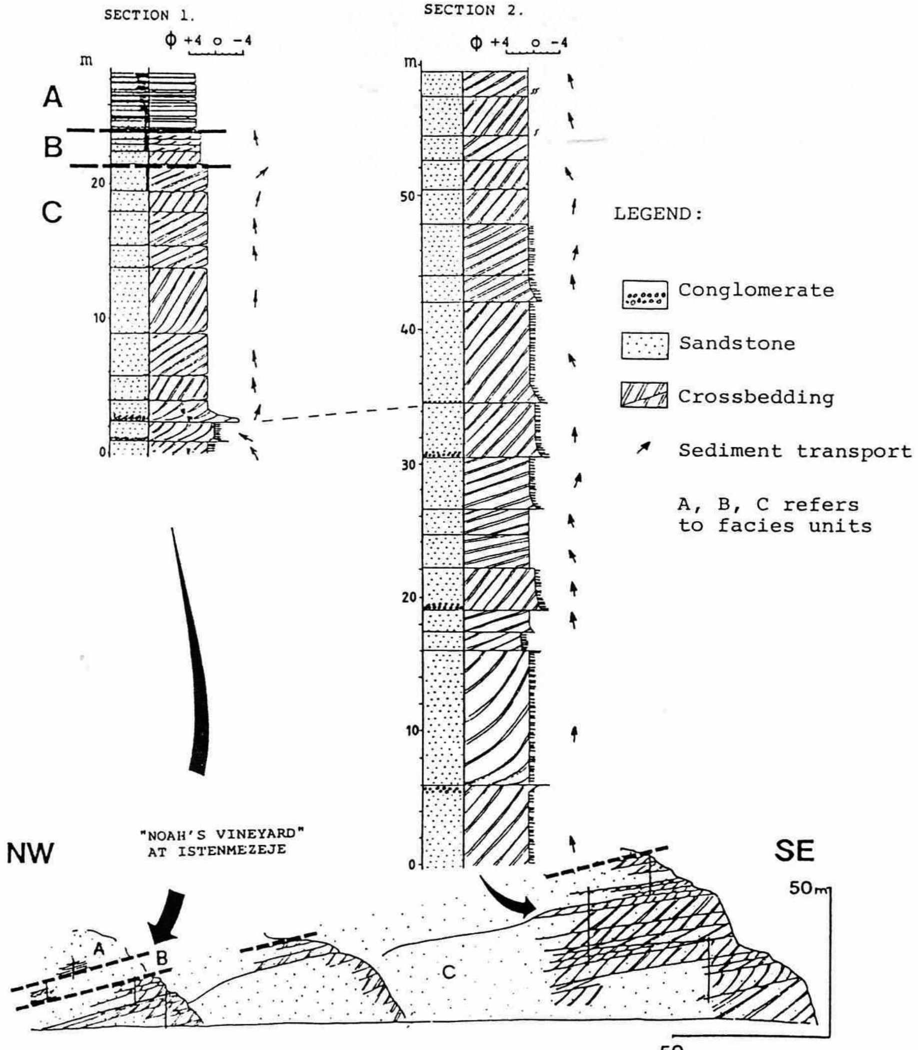


Fig. 18 Facies units of the Pétervására formation

Schlier continued only in the deepest, central part of the basin. In shallow marginal areas the tide-influenced Pétervására Sandstone prograded rapidly (regressive tidal deposits!). The corresponding relative drop of sea-level was rather of eustatic than tectonic origin (Sztanó and Tari, 1993), thus the demarcation of the Egerian Szécsény Schlier and the Eggenburgian Pétervására Sandstone is a sequence boundary. This surface can be followed in individual outcrops (not at Istenmezeje) and represents an approximately 20-30 km basinward shift of facies belts.

The rapid initial progradation was followed by the late lowstand, when facies belts built up vertically in aggradational units, indicating equilibrium between sediment accumulation and creation of accommodation space (Jervey, 1988; Posamentier et al, 1988). The topmost 60 m of vertically stacked sandwaves can be studied at Istenmezeje. Then the deposition of sandwaves (C) was stopped, a rapid landward shift of facies belts occurred, as shown by the appearance of silty sand (A). The increase of depositional depth

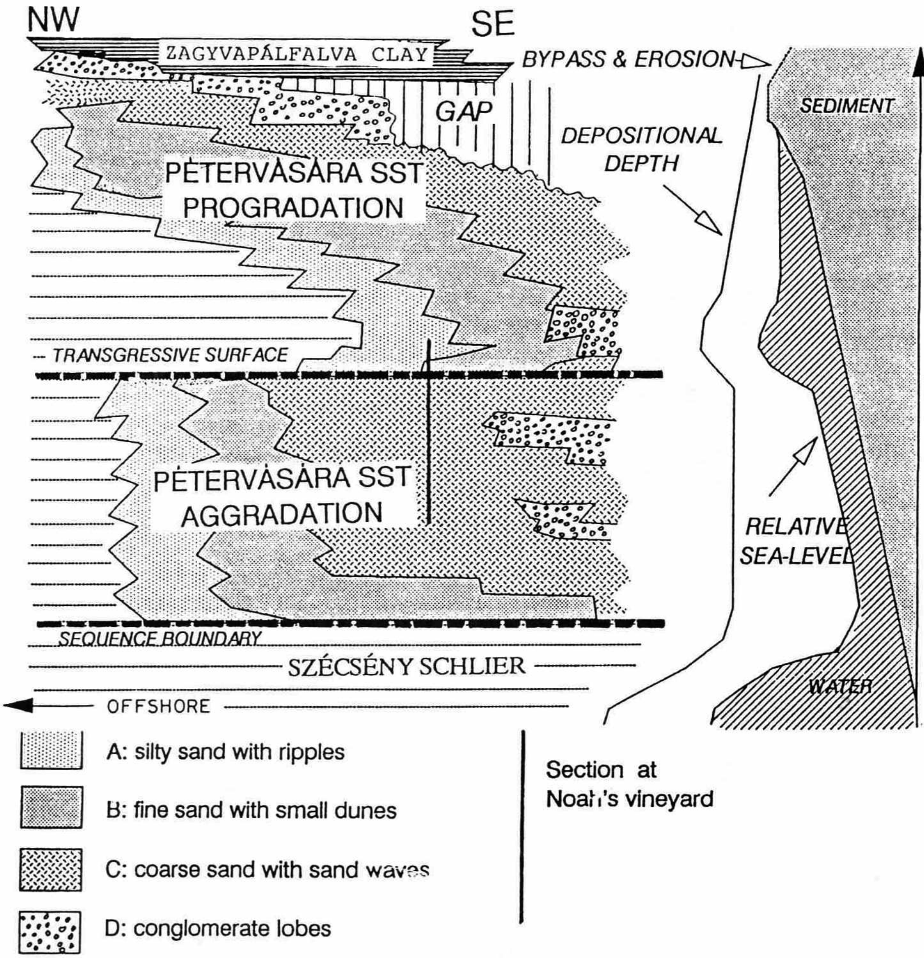


Fig. 19 Sequence stratigraphic interpretation of the Pétervására Sandstone Formation

is interpreted as a flooding event. At "Noah's vineyard" the transgressive surface is exposed. This rise of sea-level may correspond to the one which caused the "Burdigalian transgression" (cf. Homewood and Allen, 1981; Rögl and Steininger, 1983). The uppermost part of the Pétervására Sandstone is built up of coarsening upward sequences grading from small dunes (B) to large sandwaves (C) and to conglomerate lobes (D). This process was coupled with basinward shift of facies belts. The final progradation filled the basin up to sea-level and above (continental beds of Zagyvapálfalva Fm.). Although a rise of eustatic sea level is supposed (Haq et al, 1987; the same was reported from the Paratethys by Rögl and Steininger, 1983), the depositional depth decreased in this basin, inferring to a high sedimentation rate and/or slow tectonic uplift of the area (Sztanó and Tari, 1993).

STOP 4

Szurdokpüspöki, diatomite quarry

Márta HAJÓS

Locality

The diatomite quarry is located to the North of the town Hatvan, 4 kms to the Southeast of Szurdokpüspöki, on the western border of the andesite body of the Mátra Mts. (Fig. 20).

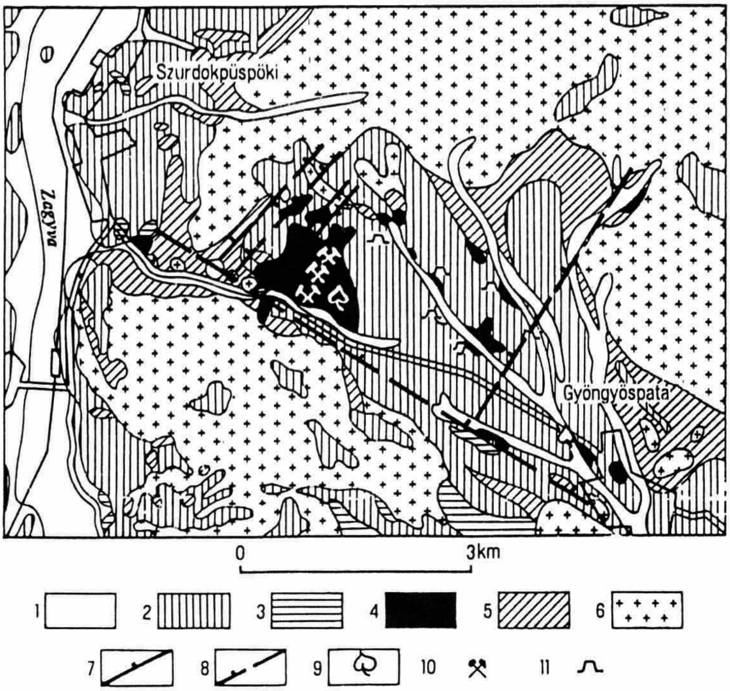


Fig. 20 Sketch-map of the Szurdokpüspöki diatomite region. 1: Holocene, 2: Pleistocene loess, 3: Upper Pannonian s.l. sand, clay, and marl, 4: Badenian diatomite sequence and rhyolitic tuff, 5: andesite tuffaceous agglomerate, 6: pyroxene andesite, 7: fault, 8: inferred faults, 9: locality of fossils, 10: quarry, 11: outcrop

Age

Middle Miocene, Badenian

History

The Szurdokpüspöki diatomite quarry is the most complete series of diatomaceous Badenian sequences in Hungary, amply documented with floristical and faunistical remains. Since the study of Pantocsek, published in 1889, it is well known all over the world. Pantocsek described 77 diatom taxa from two samples of Szurdokpüspöki, probably coming from the lowermost clayey-laminated beds of the recent quarry (Fig. 21, Bed 5).

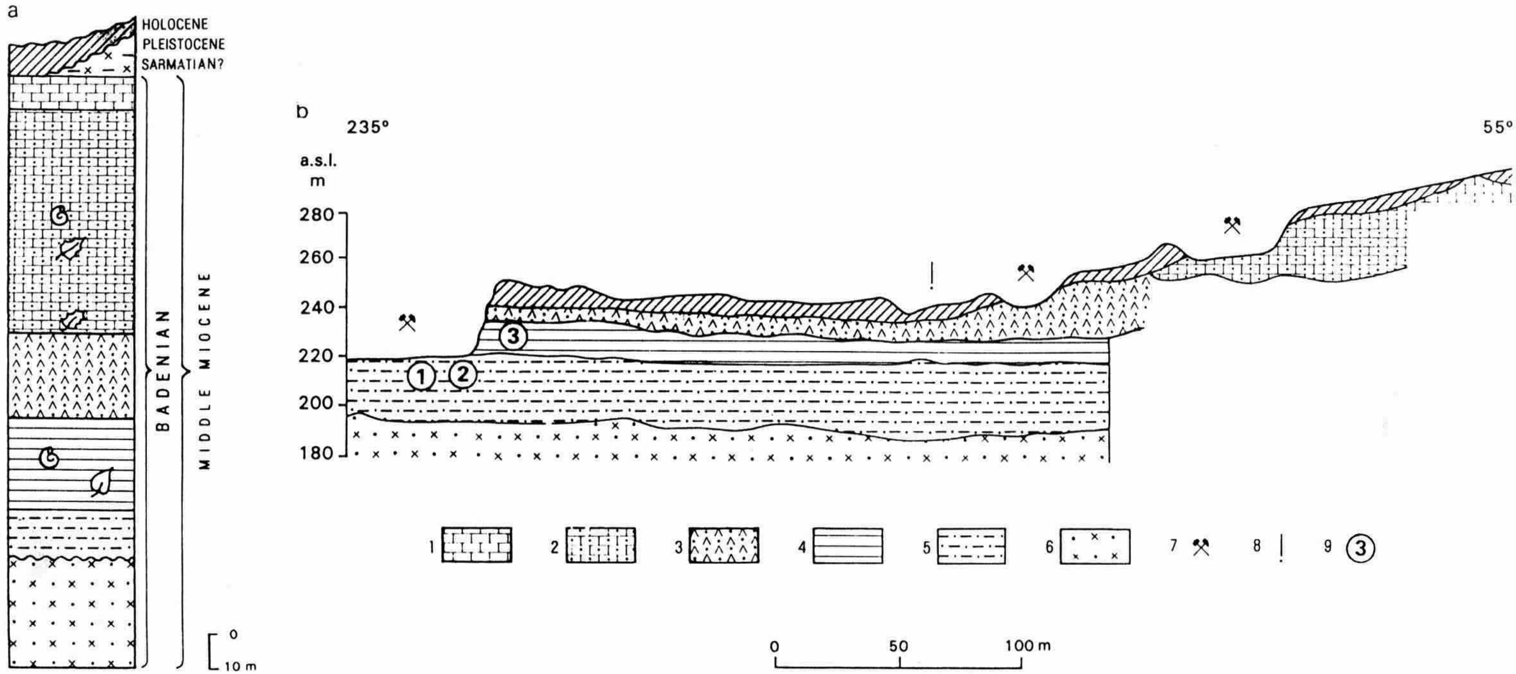


Fig. 21
The Szurdokpüspöki diatomaceous formations. (a: stratigraphical column, b: geological section) 1: Platy limestone "Leitha Limestone", 2: upper, marine diatomite beds, 3: rhyolitic tuff, 4: white diatomite, 5: grey, argillaceous diatomite (beds 4-5 are the freshwater-brackish water lower diatomite layers), 6: andesite tuff and agglomerate, 7: open cast quarry, 8: location of boreholes, 9: samples

Stratigraphy

The succession of formations is based on the sequence established for the immediate surroundings of the quarry. The underlying bed is a pyroxene-andesite tuffaceous agglomerate, the uneven surface of which is overlain by Badenian sediments mainly composed of skeletal remains of siliceous algae flourished around the contemporary postvolcanic siliceous springs.

Immediately overlying the uneven volcanic surface, there is the freshwater-limnobrackish water "Lower diatomaceous unit" (Fig. 21, Beds 4 and 5) in about 45 m of total thickness, the rhyolite tuff (25 m, Bed 3) and the marine "Upper diatomaceous earth" (15-60 m, Bed 2).

The uppermost beds of the "Lower diatomaceous earth" yielded remains of a new fossil turtle and Rhinocerotidarum gen. et sp. indet. (Kretzoi and Pálfalvy 1969).

The overlying bed is Leitha-type Badenian limestone, laminated, porose (Fig. 21, Bed. 1), overlain on its turn by Sarmatian and Pliocene-Pleistocene-Holocene strata (Fig. 21).

The Szurdokpüspöki quarry exposes the freshwater-limnobrackish- and marine diatomaceous earth beds.

Flora and fauna

a) Lower freshwater-limnobrackish-water diatomaceous earth unit (Fig. 22).

The organic matter content of the argillaceous, calcareous, finely-laminated sediment of the lower greyish-greenish grey layers (Fig. 21, Bed 5) is gradually decreasing upwards. The clayey and calcareous diatomaceous formations are characterized, apart from the presence of the limnobrackish Melosira, Stephanodiscus species, by assemblages of epiphytic and eutropheous species like Amphora, Cocconeis, Podosira and Surirella. The freshwater-oligohaline Navicula hungarica Grun. and N. cincta (Ehr.) Kutz. are pre-

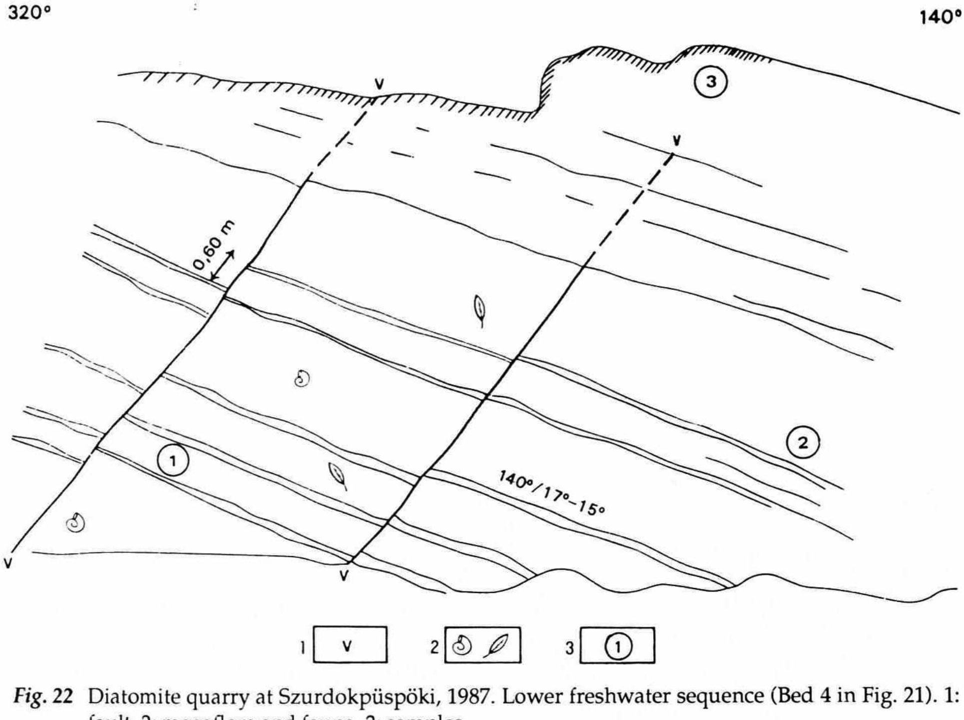


Fig. 22 Diatomite quarry at Szurdokpüspöki, 1987. Lower freshwater sequence (Bed 4 in Fig. 21). 1: fault, 2: megaflora and fauna, 3: samples

sent in great number indicating an almost completely freshwater environment. The presence of Pinnularia microstauron (E.) Cl. var. brebissonii (Kutz.) Hust. and P. viridis (Nitzsch) Ehr. denotes a shallow lake, poor in carbonate, and the presence of springs. Synedra pulchella (Ralfs) Kutz. and S. tabulata (Ag.) Kutz. are euryhaline forms, characteristic of sea-locked near-shore waters. Neidium dilatatum var. jacutica J. Kiss, Navicula halionata Pant., N. cincta (Ehr.) Kutz., Surirella costata Neup., Amphora sp. and Nitzschia sp. as well as their variants suggest a nearly fresh-water lagoon environment. On the basis of these, the shallow water of their environment was eutrophic, poorly aerated, its salt content could be around 0.3 %o, that is, oligohaline according to the terminology of Brockmann 1940 (Fig. 22, samples 1-2).

In the lower, clayey layers, accumulation of the brackish Surirella striatula Turp. and S. ovata var. crumena (Breb.) V. Heurck indicate gradual mudding as well as the fact that detritophil forms like Amphora, Fragilaria, Nitzschia, and Surirella become dominant.

The sporomorphs of the lower diatomite layers derive from a mixed, subtropical deciduous forest with many coastal elements: Taxodium, Podocarpus, Tricolpopollenites sibiricum (Lubomirova), Liquidambarpollenites sp., Caryapollenites simplex (R. Pot.) R. Pot., Myricipites myrocoides (Kremp) Nagy, Betulaepollenites betuloides (Pf.) Nagy, Laevigatosporites haardti (R. Pot. et Ven.) Th. et Pf., Polypodiisporites alienus (R. Pot.) Nagy, Leiotriletes maximus W. Kr., Polypodiaceoisporites hamulatus Nagy, Chenopodipollis multiplex (Weyl. et Pf.) W. Kr., Graminidites media (Cookson) R. Pot., etc. Tropical elements are rare: Sapotaceae, Engelhardtioidites, etc. (Nagy 1971).

The floral assemblage is dominated by laurel trees and bushes. Tropical elements are rare in the macroflora as well (Hajós and Pálfalvy 1961), completed by several evergreens and deciduous arboreal plants. These remains were transported by wind and currents into the sediments deposited in nearshore calm water.

The lower grey, clayey beds of the diatomaceous earth sequence are typically microlaminated. There are carbonized plant remains, prints of insects (Hymenopterae). Ostracoda (Candona sp., Cypris sp., Cytheridea perforata Roem.; Zalányi in Hajós 1968, p. 11) suggest an oligohaline environment. The shells of the mollusc species Hydrobia stagnalis Bast. occur, partly, dispersed in the layers, partly accumulated along the bedding planes to form a joint surface.

Overlying the grey, carbonaceous clayey layers there are yellowish white, then snow-white, light, loose, carbonate-free layers of diatomaceous earth in about 10-15 m thickness (Fig. 21, Bed 4). They contain no pollens or spores. The diatoms are small planctonic forms. Dominating species are the Stephanodiscus minutulus Pant., Melosira minima Hajós, M. menilitica Pant., M. bituminosa Pant., and Nitzschia frustulum Pant. and their variations. Epiphytic forms are rare. The water turned gradually clear, less carbonatic, and less saline. The eutrophic forms like Surirella and Campilodiscus disappeared, the representatives of the epiphytic genera Achnantes, Amphora, Cocconeis became subordinate (Fig. 22, sample 3).

From the upper, white diatomaceous earth layers of the sequence, remains of plants and fishes were recovered (Leiciscus sp., Clupea longimana Heck.; Bem in Hajos 1968 p. 11). Both genera are characteristic of freshwater or limnobrackish-water environment.

After the accumulation of the rhyolitic tuff this area subsided and became connected to the Badenian open sea.

The upper (marine) diatomaceous earth unit (45-60 m thick) was formed as a result of further postvolcanic activity (Fig. 21, Bed 2).

b) The upper diatomaceous earth unit is a marly formation containing remains of pelagic, planktonic unicellulars with siliceous skeletal elements. This unit is not satisfactorily exposed, therefore there is no chance for a detailed sampling. The most characteristic forms are: Coscinodiscus antiquus Grun., Liradiscus ovalis Grev., Actinoptychus splendens (Shadb.), Chaetoceras and Xanothiopyxis sp., Triceratium balearicum Cl. et Grun. cf. biquadrata (Jan.) Hust., Hemiaulus sp., Grammatophora sp., Plagiogramma sp., Mastogloia splendida (Greg.) Cl., Navicula lyra Ehr., Trachyneis aspera Cleve. All are pelagic forms, most of them are living in warm seas, in the Mediterranean. The relatively high number of Archeomonas cysts, Silicoflagellata species and Ebriids is also characteristic. The foraminifers of the formation are: Bulimina elongata d'Orb., Amphistegina sp., Nonion granosum (d'Orb.), N. boueanum (d'Orb.), Cibicides dutemplei (d'Orb.), Dentalina elegans d'Orb., Cassidulina subglobosa Brady, Orbulina universa d'Orb., Reusella spinulosa (Rss.), Rotalia papillosa Brady (determined by Korecz-Laky, Fig. 21, Bed 2).

The layers immediately overlying the marine diatomite formation are composed of platy limestone, the remains of which can be observed on the hillside. The loose part of this limestone yielded foraminifers: Rotalia beccarii (L.), Globigerina bulloides d'Orb., G. triloba (Rss.), Elphidium sp., E. cf. crispum L., Nonion sp., sponge spicules, gastropod internal casts and ostracods. These fossils represent Leitha type limestone of the Badenian.

STOP 5

Budapest, Rákos railway-cut: Badenian and Sarmatian limestones with rich marine fauna, coral reef

József KÓKAY and Pál MÜLLER

Locality

A low hilly area at and near the eastern suburbs of Budapest is built of Upper Oligocene and Miocene sediments. A part of this area is named after the creek Rákos-patak (literally: Crayfish-creek), flowing near a small hill which was cut across for a railway branching in the seventies of the last century. Later this cut was repeatedly deepened and widened easing the work of geologists (Figs. 23, 24).

Age

All layers exposed here are Badenian and Sarmatian (Middle Miocene).

History

József Szabó (1879), Professor of Geology and Mineralogy of the Budapest University, was the first to describe the Rákos section. He collected, among others, some decapods, which were soon described by Paul Brocchi (1883), Professor of Zoology of the Sorbonne University, Paris. These crabs were members of the first known diverse Neogene decapod fauna. Elemér Vadász (1906 and 1914) described the section in details and its echinoids. Imre Lőrenthey (in Lőrenthey and Beurlen 1929) dealt with many new decapod species collected in the Rákos exposure. The Badenian part of the section was chosen as the stratotype of the Rákos Limestone Formation (Kókay and Müller 1989), which corresponds to the Leithakalk, known from Austrian occurrences (Papp et al. 1978). Kókay (1985a) described the upper parts of the Badenian of the section, recognising its close Eastern Paratethyan affinities. Müller (1984) monographised the decapods of the Badenian stage; the best preserved, richest part of his material came from the Rákos area.

Description of the layers

The layers dip to SW at 6 to 7o. Thus the oldest layer crops out at the northeastern part of the cut. This is the uppermost part of a 30 to 50 m thick volcanoclastic deposit, the Tar Dacitic Tuff Formation. Its potassium-argon age is 15.6+-0.8 MY (Balogh in litt.), which indicates that it was deposited around the Karpatian-Badenian boundary. The marine sequence here is of Late Badenian age, beginning with a slight uncomformity, with a thin basal clastic layer (R I), containing reworked and bored blocks of the Tar Formation. This is covered by remnants of a patch reef, (layer RC), built mainly by Porites collegniana Michelin, preserved as moulds, often in vertical branches. Red algae and bryozoans contribute to the frame. In the matrix moulds of bivalves and snails are abundant, while decapod crustaceans are rarer, but frequently well preserved. The most abundant forms are: Chlorodiella mediterranea (Lőrenthey), Charybdis mathiasi Müller, Petrolisthes magnus Müller. These forms are bound to coral reefs.

A coeval, probably lagoonal sediment is exposed in another cut (layer R II), with moulds of brachyhaline molluscs, pointing to the restricted extent of the reef.

Coral reefs in the Badenian seem to be restricted to two distinct horizons, the lower one extending from the Lower Badenian to the lowermost part of the Middle Badenian. It is built of diverse (more than ten species) coral associations. The upper horizon is situated in the lower part of the Upper Badenian (Müller 1984). This upper one yielded only three or four species of corals. Although reef buildups are invariably restricted to small patches at least in the central and northern parts of the Paratethys, it seems that these reflect the two climatic peaks reported from the time interval represented by the Badenian stage

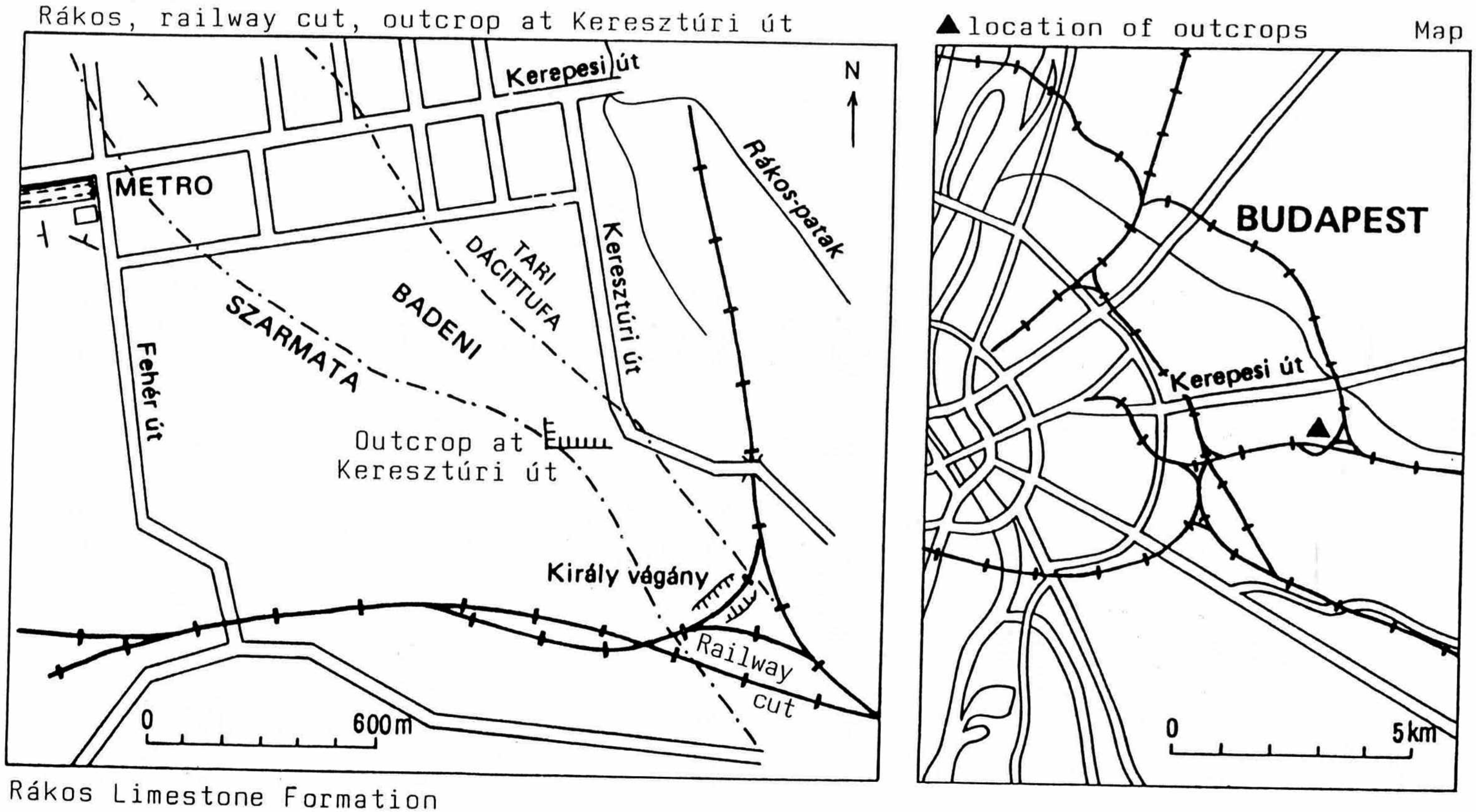


Fig. 23
Location of the "Rákos vasúti delta" outcrop in Budapest

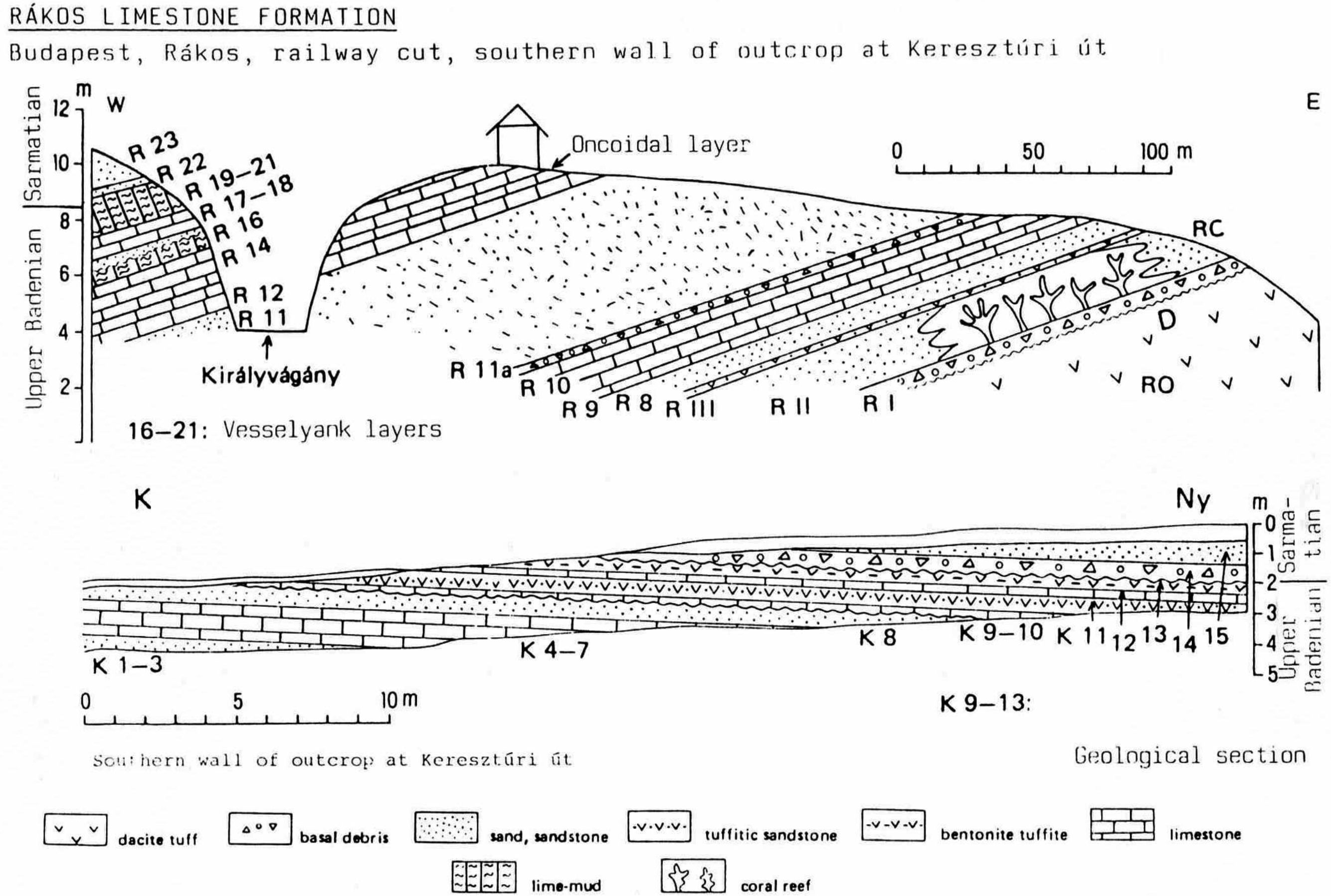


Fig. 24
Geological section across the "Rákos vasúti delta" outcrop

(Haq 1991, Nagy 1990), at about 13 and 15 Ma, respectively, B. P., representing the northernmost excursion of reefbuilding corals during Neogene times.

Over the reef, a gradual deepening is expressed by a sequence of medium-grained sandstone (R 8), an oyster-bearing limestone (R 10), and a fine-grained tuffitic sandstone (R 11). The faunae of these indicate an almost oceanic salinity (the foram Borelis melo, of which Rákos is the type locality, further molluscs as Flabellipecten leythaianus, Pecten aduncus, Ringicardium hians danubianum and many other big forms), and big-sized decapod crustaceans, as Calappa heberti, or the giant hermit crab, Petrochirus priscus. The extant relatives of this latter species live today in the Caribbean sea. In the sandstone coded R 11 there are numerous big callianassid burrows (Ophiomorpha), sometimes with callianassid chelae preserved within, probably belonging to their inhabitants. One of these, Callianassa munieri, was of remarklably big size.

Biotites separated from the layer R 11 gave a K/Ar age of 13.4+-0.6 Ma. This fits well to the presumed geological one, albeit a part of the biotites might be reworked from the underlying Tar Formation; but presumably the bulk of the volcanoclastic material was coeval with the deposition.

Similarly to other marine Badenian layers, those in the Rákos section, deposited under more or less normal salinity (R 2 to R 11), contain a lot of genera of different animal groups, today restricted to the Indo-west-Pacific realm. On this basis, several authors (Rögl and Steininger 1983, Bałuk and Radwański 1977, Hoffman 1977) suggested that a seaway from the Central Paratethys to the Indian Ocean was still open in the Late Miocene. Others (Müller 1984), pointing to the difficulties in the palaeogeographic reconstruction of such a seaway, think that such taxa may be merely descendants of a common Palaeogene-Early Miocene Tethyan-Indo-west-Pacific fauna, for which the tropical Indian and Pacific oceans offered a refuge. Thus many taxa survived the Late Neogene and Quaternary climatic deteriorations.

The overlying layers show a sudden drop in water depth and in the influx of terrigenic-tuffaceous material. This curiously contradicts the the observation, that regressions are generally accompanied by increased terrigenous influx. We tried to explain this apparent contradiction, suggesting that a climatic change toward a wet climate favorised the growth of forests on the surrounding flanks which might hindered erosion thus sediment influx into the sea (Müller 1984).

The lower part of this upper section (R 10) still contains an almost euhaline mollusc and crab fauna, but shows signs of a slightly changing salinity. An increasing trend in the reduction of salinity is clear in the overlying layers, accompanied by signs of further shallowing. This is the most obvious in the layer R 13 with big sized macroonchoids (Lelkes and Müller 1984), and in the overlying crossbedded, well sorted calcarenite (R 14), deposited on a beach.

The layers R 16 and R 17 were deposited in water of even more reduced salinity, than the underlying ones. Kókay (1985a) demonstrated that their fauna (e. g. "Cardium" praeplicatum, Modiolula bugloviensis, Ervilia trigonula), in contrast to that of the lower layers, show a clear Eastern Paratethyan affinity, namely with that of the Vesselyank (Upper Konka) substage. Using the hydrological regime of the extant Marmara-sea, a model was proposed (Kókay 1985a). According to this, an upper layer of the water column in the Central Paratethys, with low salinity, flowed in from the region outside of the Eastern Carpathians, while a counterflow of higher salinity was present at greater depth. Thus through the Central Paratethys the Mediterranean and Eastern Paratethyan waters were in exchange.

The benthic faunae of both layers reflect their salinity and origin: they have a predominantly Eastern Paratethyan character in the shallow parts, while a Mediterranean one in the deeper ones.

Layers R 19 to R 23 belong already to the Sarmatian stage. Their characteristic fauna is widespread, known from the Vienna basin and southern Poland to the Eastern Paratethys, namely to the Black sea and Caspian region and to the Aral sea (small sized molluscs: Mohrensternia forms, Mactra vitaliana, "Cardium" vindobonense). This fauna reflects a salinity probably significantly lower than that of the upper layers of the today Black Sea, at about 10 ppm. The grade of endemism on species and genus level is remarkable.

STOP 6

Tata, brickyard and Kálvária hill (Pannonian silt)

Margit KORPÁS-HÓDI and László GYALOG

Locality

The town of Tata is situated in the western foreland of Gerecse Mts (Fig. 25).

Age

Pannonian (s. l.) (see the interpretation of regional stages in chapter "The Pannonian basin").

History

The first data on the Pannonian (s. l.) of the Tata area were published in the second half of the last century. Geological and agrogeological mapping in the first decades of the

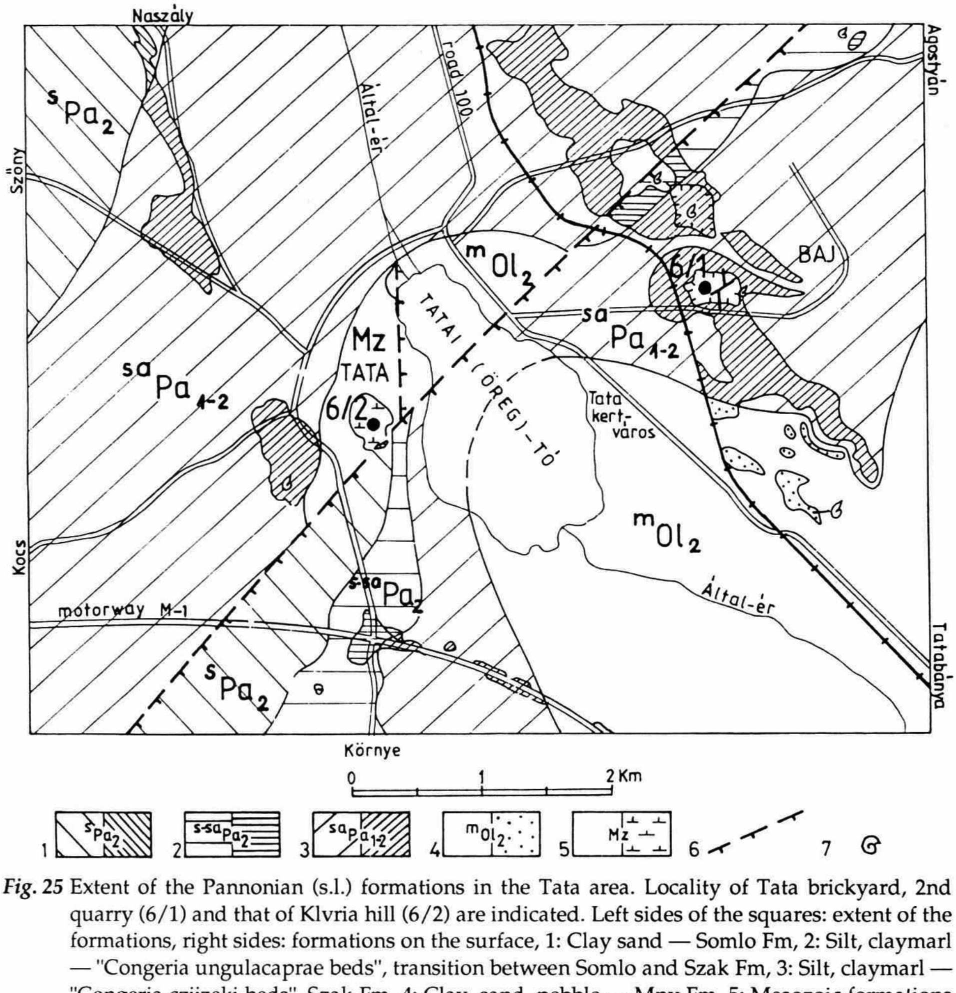
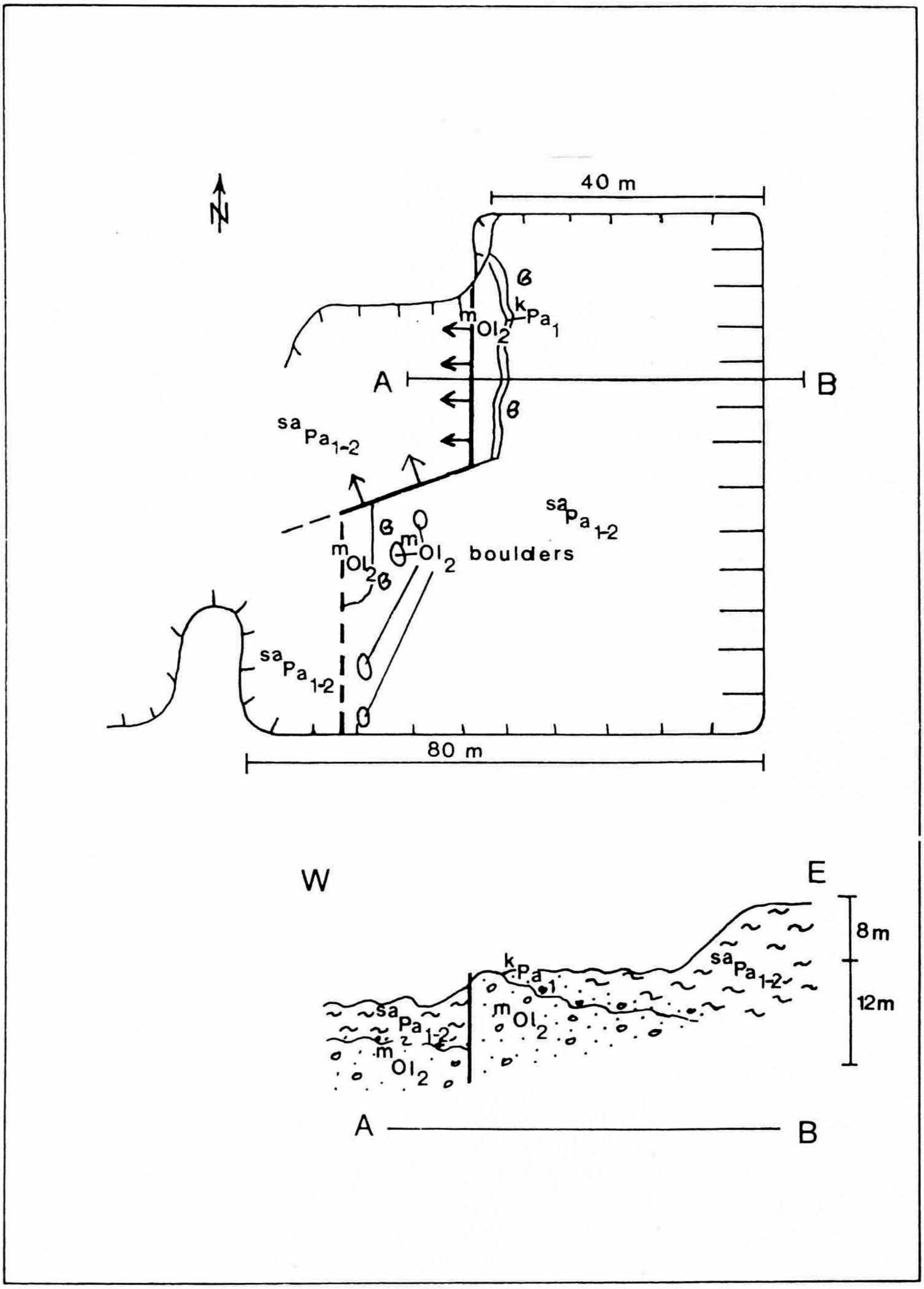


Fig. 25 Extent of the Pannonian (s.l.) formations in the Tata area. Locality of Tata brickyard, 2nd quarry (6/1) and that of Klvria hill (6/2) are indicated. Left sides of the squares: extent of the formations, right sides: formations on the surface, 1: Clay sand — Somlo Fm, 2: Silt, claymarl — "Congeria ungulacaprae beds", transition between Somlo and Szak Fm, 3: Silt, claymarl — "Congeria czijzeki beds", Szak Fm, 4: Clay, sand, pebble — Mny Fm, 5: Mesozoic formations



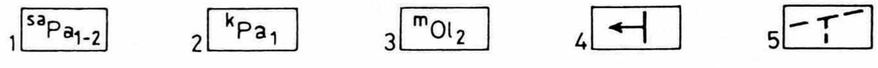


Fig. 26 Sketch and cross section of the Tata brickyard, 2nd quarry1: Szak Fm, silty claymarl, 2: Kisbér Fm, limonitic, gravelly siltite, 3: Many Fm, conglomerate, sandstone, 4: observed fault, 5: assumed fault

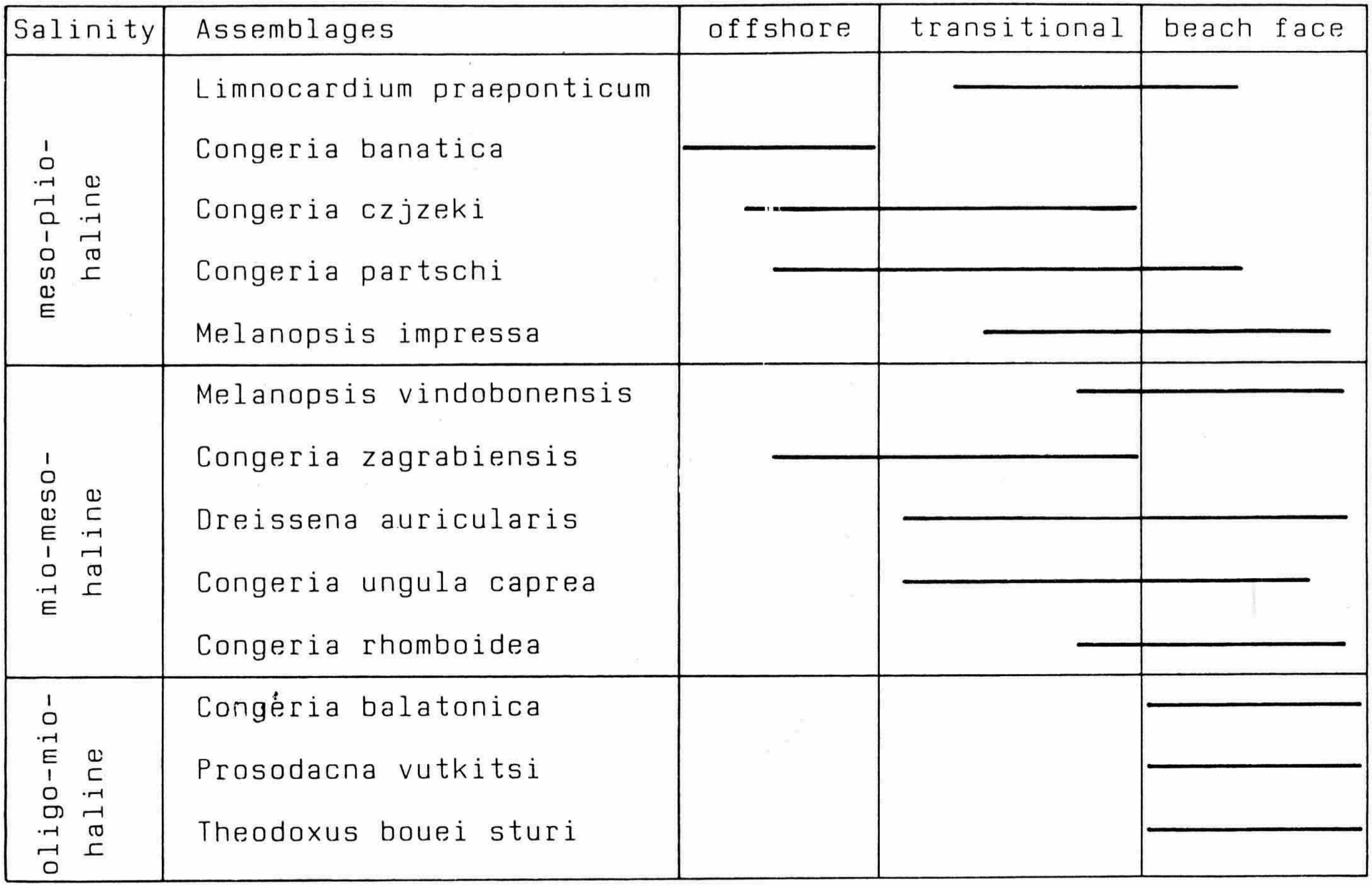


Fig. 27
Distribution of the most common Pannonian mollusc assemblages as a function of salinity and water depth

zone, in the middle of the quarry. It forms a limonitic crust above the Oligocene beds. The embedded molluscs, such as Congeria partschi, Congeria czjzeki, Lymnocardium pseudosuessi, Lymnocardium prionophorum, Lymnocardium zagrabiensis, Lymnocardium winkleri, Lymnocardium lorentheyi, Paradacna abichi, Gyraulus tenuistriatus, can be found in the overlying argillaceous marl as well, however, the frequency of the species is different. The basal layer is dominated by Congeria partschi, while the argillaceous marl by Congeria czjzeki. The molluscs of the basal layer are allochtonous.

The overlying formation is a blueish grey, silty argillaceous marl. Boulders of 5 to 50 cm diameter, originating from the underlying Oligocene-Lower Miocene formation, can be found in its lower part. The interbedded silt layers are horizontal. The mollusc fauna is paraautochtonous, and indicates a plio- to mesohaline, brackish-water environment in the offshore zone. The characteristic species are: Congeria czjzeki, Lymnocardium secans, Lymnocardium brunnense, Lymnocardium pseudosuessi, Lymnocardium rothi, Lymnocardium prionophorum, Lymnocardium triangulatocostatum, Valenciennesia reussi, Provalenciennesia arthaberi, Planorbis sp. The whole sequence is regarded as a transgressive unit.

Molluscan ecology of the Pannonian lake

In the absence of marine planctonic organisms, molluscs play an outstanding role in the biostratigraphy of the sediments of the Pannonian lake. The distribution of the assemblages was controlled by the nature of the substratum, salinity, water depth, nutrient quantity, and many other factors. The most important assemblages in the function of salinity and biotopes are illustrated in Fig. 27.

Tata, Kálvária hill, Pannonian cave filling

The Mesozoic block of Kálvária hill formed a stack in the Pannonian lake (Fülöp 1954). Abraded gravel was recovered by drillings in the base of the Pontian at the western margin of the Mesozoic block, studied by A. Jámbor and M. Korpás-Hódi. Formation of sea caves is probable in stack walls.

The E-W running wall of Kálvária hill, next to the water tower, exposes tectonic contact of Liassic and Dogger formations. A 2 m wide and 4 m high sea cave was formed in the Liassic beds by the wave action of the Pannonian lake. It communicates with the rock surface through a vertical chimney. The cave is filled with yellow and grey clayey silt, with white calcareous spots. The age of the cave filling is Pannonian (s. l.).

STOP 7

Várpalota, Szabó's sand pit with rich shallow-water marine fauna (Lower Badenian)

József KÓKAY

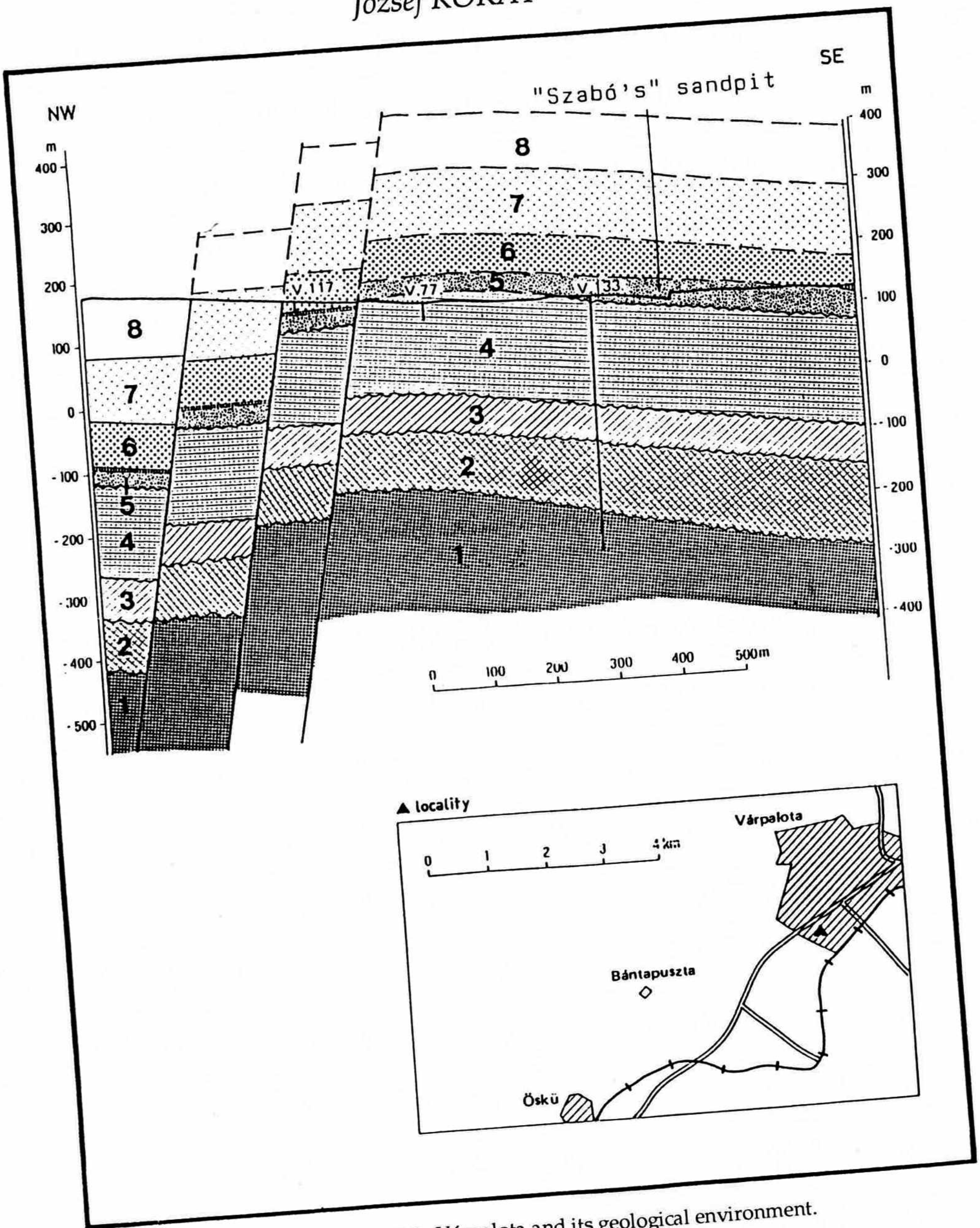


Fig. 28 Location of Szabó's sandpit in Várpalota and its geological environment.

Locality

The Miocene sand pit is located in the southwestern part of the town Várpalota, south of the highway No 8, inside the Rákóczi residential area (Fig. 28). It is a nature reserve and was fenced off. The key is obtenable from the keeper by presenting a permission from the KVI (Environmental and Water Directorate) in the town of Veszprém.

Age

Lower Badenian (Middle Miocene)

Description of the site

The pit exposes a littoral sand sequence. The sand contains a rich mollusc fauna and falls into two distinct parts.

The lower part is homogeneous, this sand was deposited in relatively calm water, it is of light ochre colour, fine grained with just some clay content. It contains few fossils, some molluscs and more forams.

This part is overlain by a 4 to 5 m thick cross-bedded grey sand member. The cross-bedding suggests wave action. The sand is well-sorted, containing small and medium-sized grains. Some banks hold greenish-grey clay debris which has been washed into it from earlier pelitic sediments. Mollusc shells abound here ("lido-facies"), some of them yet show their original colours, most, however, are broken and abraded. Fragments of colnies of hermatypic corals occur also. The number of the moullusc species exceeds four hundred, these are described in various publications.

The most common molluscs are: Turritella aquitanensis, T. subtriplicata, T. Partschi, Protoma proto, Pirenella gamlitzensis, P. moravica, Bittium reticulatum, Cerithium europeum, Natica millepunctata tigrina, Rimella (Dientomochilus) decusata, Dorsanum nodosocostatum, Nassa hungarica, N. schoenni, Tudicla rusticula, Ancilla glandiformis conoidea, Drillia allioni, Genota ramosa elisae, Barbatia modioloides pseudobarbata, Arca noae, Anadara diluvii palotensis, Anomia ephippium, Ostrea gryphoides, Linga columbella, Acanthocardia paucicostata var., Cerastoderma edule arcella, Beguninea trapezia, Carditamera hippopea merignacensis, Venus (Circomphalus) subplicata, Pitar raulini, Solenocurtus candidus, Angulus planatus (Kecskemétiné-Körmendy 1962, Strausz 1955, 1966).

The sand (mainly the lower situated, yellow part) contains about hundred foraminifer species, almost exclusively benthic forms.

The stratigraphic position of the sand sequence in the Várpalota basin is clearly Lower Badenian. According to the RCMNS stratigraphy it belongs to the level M4b (to the "upper Lagenidae" zone, Kókay 1987, 1991). Based on numerous boreholes in this basin the lowest Badenian is characterized by denudation and terrestrial sedimentation (cf. Stop 8). The Lower Badenian marine sequence is made up by sands and clays, up to hundred m thick. The Szabó sand-pit belongs to the lowest part of this sequence.

The Miocene marine sand dips 8 t to 10 degrees to the southeast. It is overlain by 2 to 3 m of Quternary debris containing pebbles and clasts of Triassic dolostones, Pannonian freshwater limestones and Upper Pannonian mollusc specimens.

STOP 8

Várpalota, Bántapuszta: Sandy limestones with rich marine fauna (Ottnangian and Karpatian)

József KÓKAY

Locality

The section exposing the Miocene occurs near the northern front of the agricultural centre called Bántapuszta, W of the city Várpalota (Figs. 29, 30). The Miocene sequence can be studied in a number of outcrops at the foot of the Öreg-Futóné — Bér-hegy range of the Bakony mountains. Access to the site is possible by an access-road that issues from

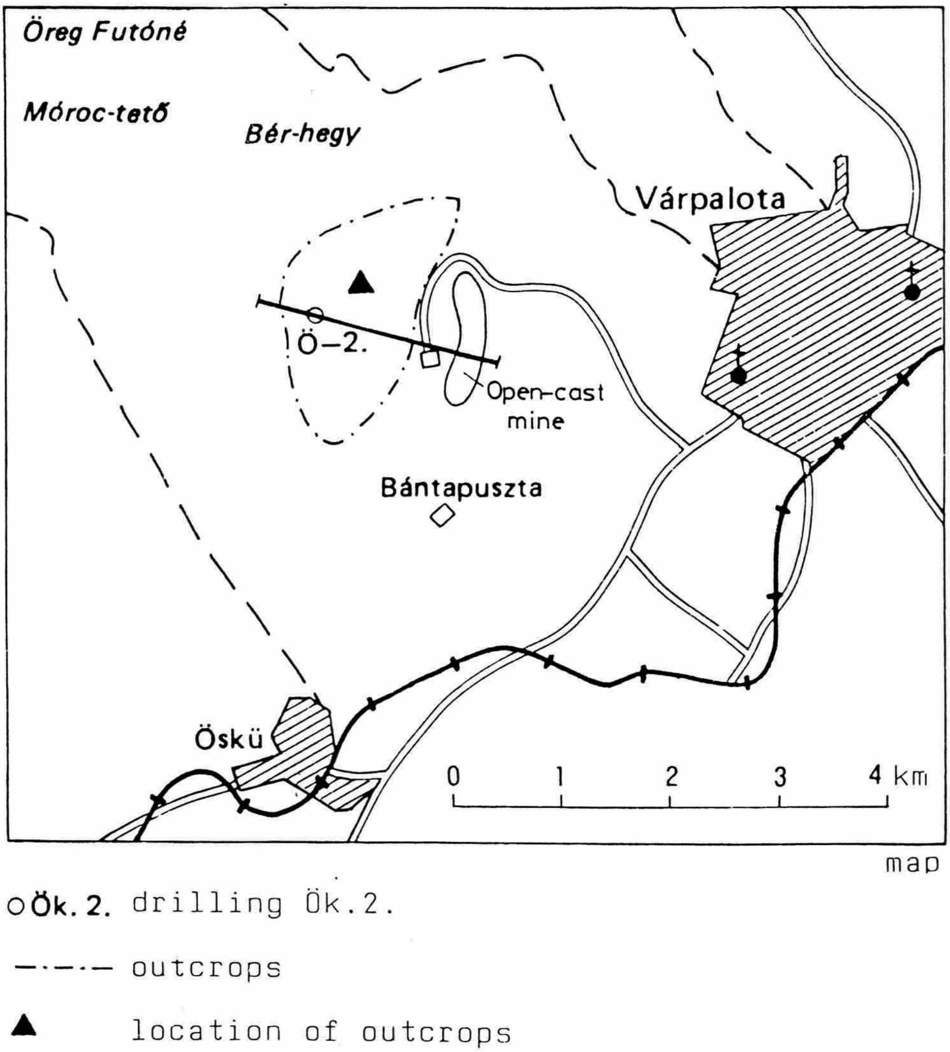


Fig. 29 Location of the Bántapuszta outcrop at Várpalota and its geological profile

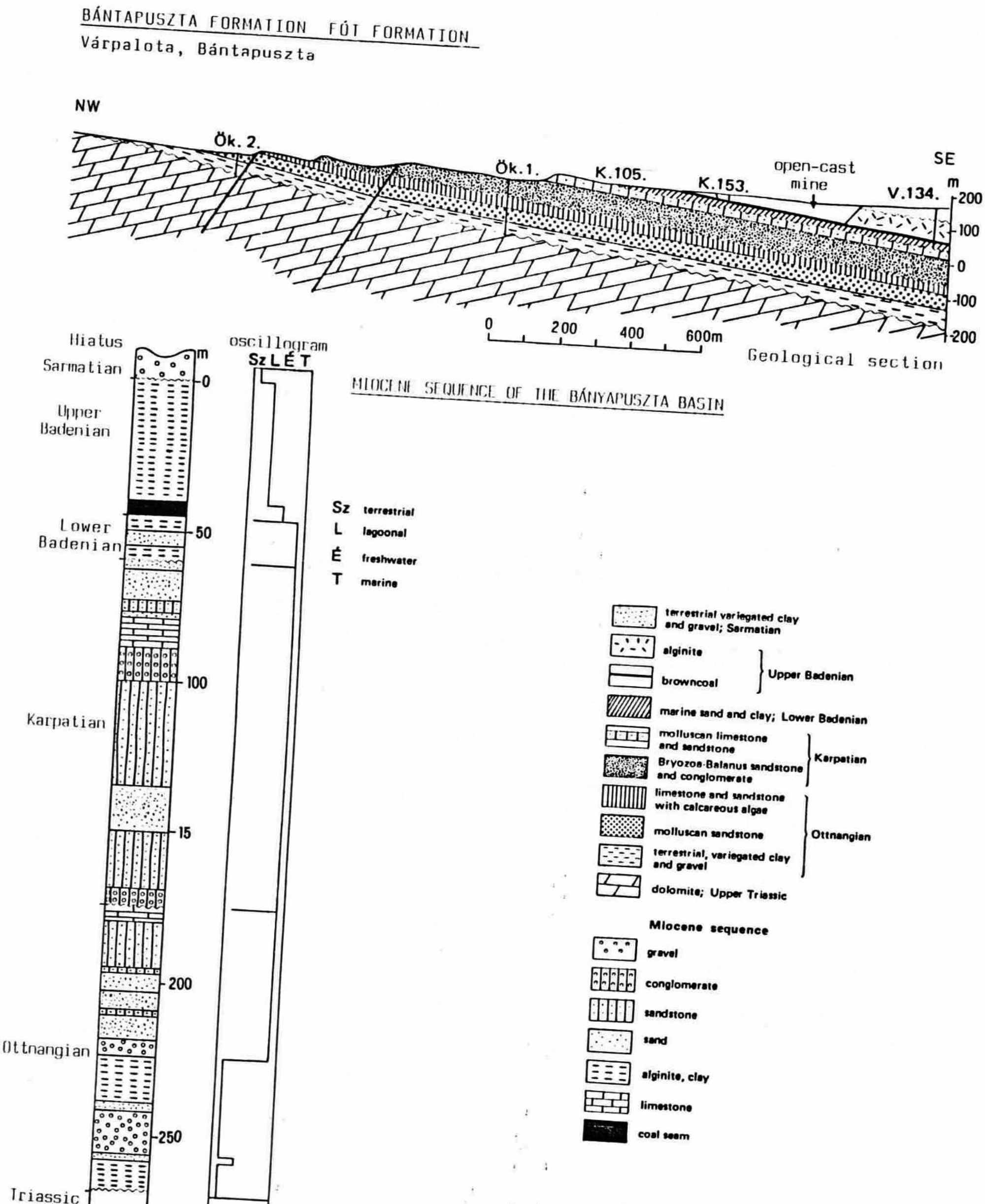


Fig. 30
The Miocene sequence of Bántapuszta area

Highway No 8 running in a westerly direction farther off the city and that leads to the collieries of Bantapuszta now already out of duty.

Age

Ottnangian and Karpatian (Lower Miocene)

Description of the site

The sequence has an overwhelmingly easterly dip of an angle of 8 to ten degrees. The oldest formations are exposed W of the mentioned access-road, near the edge of the forest. Assigned to the Ottnangian stage of the Lower Miocene, the sequence begins with a terrestrial series explored by a drillig (44 m thick, in borehole O-2). The Ottnangian beds overlying the former provide a section adopted as an international faciostratotype (Bántapuszta Formation, Papp et al. 1973). About the upper two-thirds of the marine Ottnangian sequence are exposed to daylight, whilst the lower third is penetrated by the borehole Osku-2. More recently, A. Nagymarosy has shown the presence in the lower third of the complete sequence the top of the microplancton zone NN3 (the total thickness being about 50 m). This stratigraphic horizon in the Várpalota basin is at the upper third of the marine Ottnangian sequence (Kókay 1991).

East of the edge of the forest there is an abandoned sand pit in front of which the afore-mentioned borehole O-2 was put down. The marine sand that used to be mined is about 6 m thick, containing just occasional traces of Ophiomorpha burrows. Next to follow is a hard calcareous sandstone layer with pectinids and thin-shelled sea urchins. The overlying beds are constituted by fossil-rich calcareous sandstone with casts of molluscs (Paphia benoisti praecedens, Discors spondyloides, Protoma rotifera, Turritella doubleri, etc.) and with pectinids. The thickness of the individual beds is varyingfrom 0.5 to 0.6 m. They grade into a red algal sequence of an average thickness of 20 m or so, growing thicker in southward direction. Its constituents include lime- and sandstone type bioclasts and unconsolidated red algalsands. Several decades of fossil-collecting from the Ottnangian sequence heve yielded an extremely rich pectinid assemblage (32 taxa), of which Pecten fotensis and Chlamys submalvinae are the most characteristic forms.

The Ottnangian formations are overlain with an erosional unconformity by the sedimentary sequence of the Karpatian sea (Kókay 1967). Attaining more than 100 m in total thickness, the Karpatian marine deposits are represented, in the lowermost few meters, by conglomerates of a varying grain size and a varying degree of cementation. Thick-walled oysters, and less frequently, large pectinids (Chlamys albina) can be found in them. The lower three-quarter of the complete Karpatian sequence is characterized by the abundance of sphaerical (Cellepora globularis), ramose and tongue-shaped bryozoans and balanids, occasionally by their massive presence in the calcareous and coarse clastic sediments (conglomerate, sandstone, limestone), the middle interval abounding with nodules of red algae. Locally not unfrequent in the sequence is the presence of Pecten expansior. This bryozoan-balanid bearing sequence resembles very much the formations of similar age and facies in the surroundings of Budapest (Fót Formation). The bryozoan-balanid sequence is overlain by about 10 m of echinoid-mollusc bearing limestone in which the representatives of Scutella (Scutella cf. guebhardti, Sc. lusitanica) are rather common. Next to follow are 2 m of foraminiferal (Amphistegina hauerina, Elphidium flexuosum subtypicum) sand which is exposed on the western slope of the above-mentioned roadcut. Superimposed on this is an "Anomia-mollusc" sandstone about 4 m thick. In addition to shells of Anomia ephippium, it abounds with mollusc casts (Arca noaea, Cardita crassa vindobonensis, Turritella vermicularis planulata) as well as Ostraea carpathica. Farther north there is an increase in the red algal content of the rock.

The foraminiferal sands and, at their top, the oyster-pectinid sands with which the Karpatian sequence ends, are not exposed. About one quarter of the Karpatian pectinid taxa recovered are forms in common with the Ottnangian and a similar number are forms in common with the Hungarian Badenian.

After the Kárpatian sequence had been deposited, tectonic movements led to tilting of the basin in an eastern direction, to its emergence and subsequent terrestrial denudation (Kókay 1985).

Newly ingressed into the erosional valleys formed in the preceding period, the Early Badenian sea (younger M4-b horizon) deposited a marine sequence of considerable thickness there. This is why its the thickness heavily varies in the Bántapuszta area: from 3 to 30 m. It is cropping out at the S tip of the first cut of the access-road skirting the abandoned open-air pit mine (oyster clay) on one hand, and, in form of "Turritella" clay, on the other, which has been exposed by a water-conduit at a distance of 20-30 m farther west, with a mollusc assemblage akin to the fauna of Szabó's sand-pit (see stop 7) at Varpalota.

In the Middle Badenian, there is a hiatus in the Bántapuszta area, while in the eastern and southern parts of the Várpalota basin terrestrial sediments belong here.

The next transgression started with the formation of the Upper Badenian coal seam (Hidas Formation) that has been mined for more than 100 years now (mainly conifers associated with swamps: Taxodium, Glyptostrobus). Its thickness in the E face of the openpit mine was about 5 m. In the S end of the access-road skirting the openwork, the seam suddendly pinched out in form of a 10 cm of carbonaceous clay. In the same place, a marginal calcareous facies (laminated to bedded calcareous marls) of an alginite (oil shale) forming the cover of the coal-seam was also exposed.

The Upper Badenian alginite can also be observed as exposed in some points of the openwork pit. Fish remains can often be found in it.

The terrestrial variegated clay and gravel sequence of Sarmatian age exposed on the SE side of the openwork (Gyulafirátót Formation) unconformably overlies the Badenian, whereas the sandy-gravelly deposits on the NE side of the openwork are Pannonian in age, the freshwater limestone (Nagyvázsony Formation) in turn has kept the record of the latest Pannonian geohistorical events.

STOP 9

Papvásári hill, sandpit (Pontian)

Mariann MAKÁDI and Imre MAGYAR

Locality

The sandpit is located east of Balatonfűzfő-Gyártelep, 3 km north of the northeastern embayment of the lake Balaton (Fig. 31).

Age

Upper Pannonian s. l., Pontian s. Stevanović. The facies of the sequence ("balatonica beds") corresponds to that of Tihany-Fehérpart, faciostratotype of the Portaferrian (Stevanović et al. 1990, p.427, Müller and Szónoky 1990). The Papvásári hill sequence, however, is somewhat older than the Tihany-Fehérpart layers.

History

Pannonian s. l. outcrops and molluscs of the Balatonfűzfő area were described by Halaváts (1903), Lőrenthey (1906), Vitális (1911), Strausz (1942), and Bartha (1959). Up to date lithostratigraphic and biostratigraphic subdivision of the Pannonian s. l. formations around the Transdanubian Central Range were established by Jámbor (1980) and Korpás-Hódi (1983), respectively. The sedimentological and palaeontological description of the Papvásári hill exposure is given by Makádi 1992a,b, and Makádi and Szónoky in press.

Sediments

The sandpit exposes shallow water, sandy beds of the Tihany Formation. The sequence is dominated by alternating beds of sand, silt, clayey silt, and huminitic silt. The thickness of the layers vary from 1 cm to 5 m.

Since the morphology of the sandpit is continuously changing due to working, here we describe a vertical section from the northeastern part of the exposure.

The basal layer of the sequence is light yellowish gray, well sorted, fine-grained, non-fossiliferous, carbonate-free sand (sample 30 in Fig. 32). It is overlain by a 0.9 m thick, clayey limestone (sample 29). The next layers are a thin, grey, limonitic, clayey, fine-grained silt, containing shall fragments of molluscs (sample 28), and a fine-grained sand (sample 27).

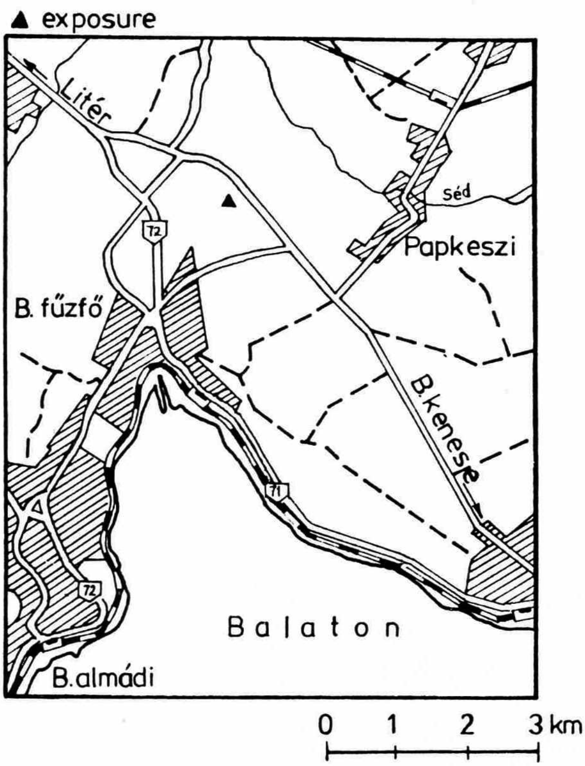


Fig. 31
Location of the Papvásári sandpit (with black triangle)

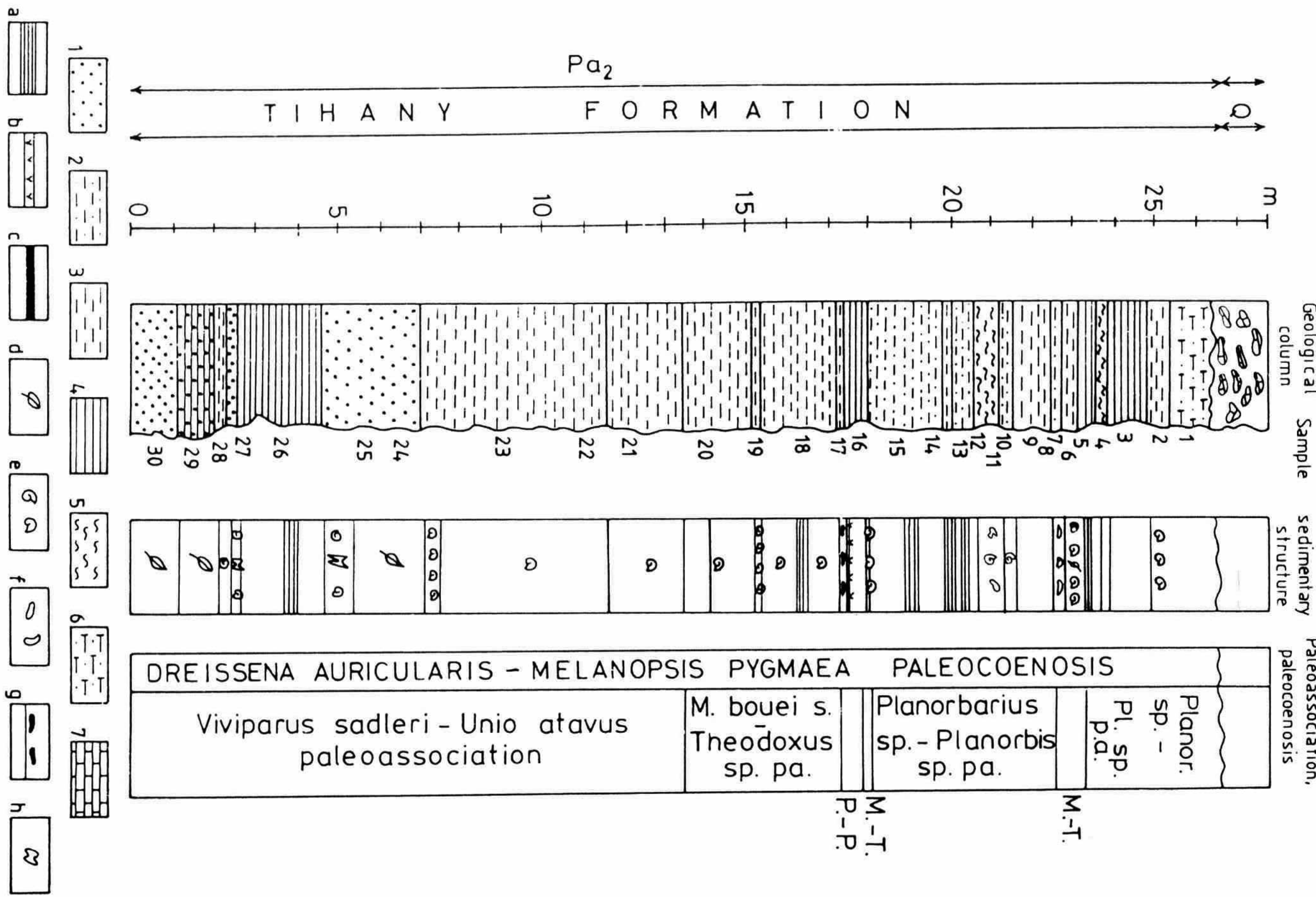


Fig. 32
Geological column of the Papvásári exposure. 1: Fine-grained sand, 2: Coarse-grained silt, 3: Fine-grained silt, 4: Clay, 5: Marl, 6: Limnic chalk, 7: Freshwater limestone; a: Microlamination, b: Marsh level, c: Lignite cord, d: Plant fossils, e: Enrichment of shells, f: Concretions, g: Limonitic crust, h: Fish tooth

The overlying, 2 m thick silty clay is non-fossiliferous (sample 26). The following fine-grained sand layer is 2.3 m thick. The quartz grains of the sand are angular, indicating only a short-distance transfer in a low-energy environment (samples 25 and 24). This layer contains numerous Unio and Viviparus shells.

Sample 23 is from a thick layer of fine-grained silt. At the bottom of this silt smashed shells of Congeria, reworked by wave action, can be found in abundance. Otherwise the layer is dominated by the presence of Viviparus shells (sample 22). The overlying yellowish grey, well-sorted, fine-grained sand (sample 21) contains Congeria balatonica, Melanopsis, Lymnocardium.

The next layer is a 4 m thick, greyish yellow, fossil-rich, fine-grained silt (samples 20-18). It is overlain by black huminitic silt, containing freshwater molluscs (sample 17). The following alternation of grey, fine-grained and coarse-grained silt layers (samples 16 to 7) is interrupted by a 0.8 m thick calcareous marl layer (sample 12).

The upper part of the sequence is characterized by fossil-rich huminitic silt layers (samples 9, 7, 6). On the top of these, non-fossiliferous clay (samples 5 and 3) and limnic chalk (samples 4, 1) have been deposited.

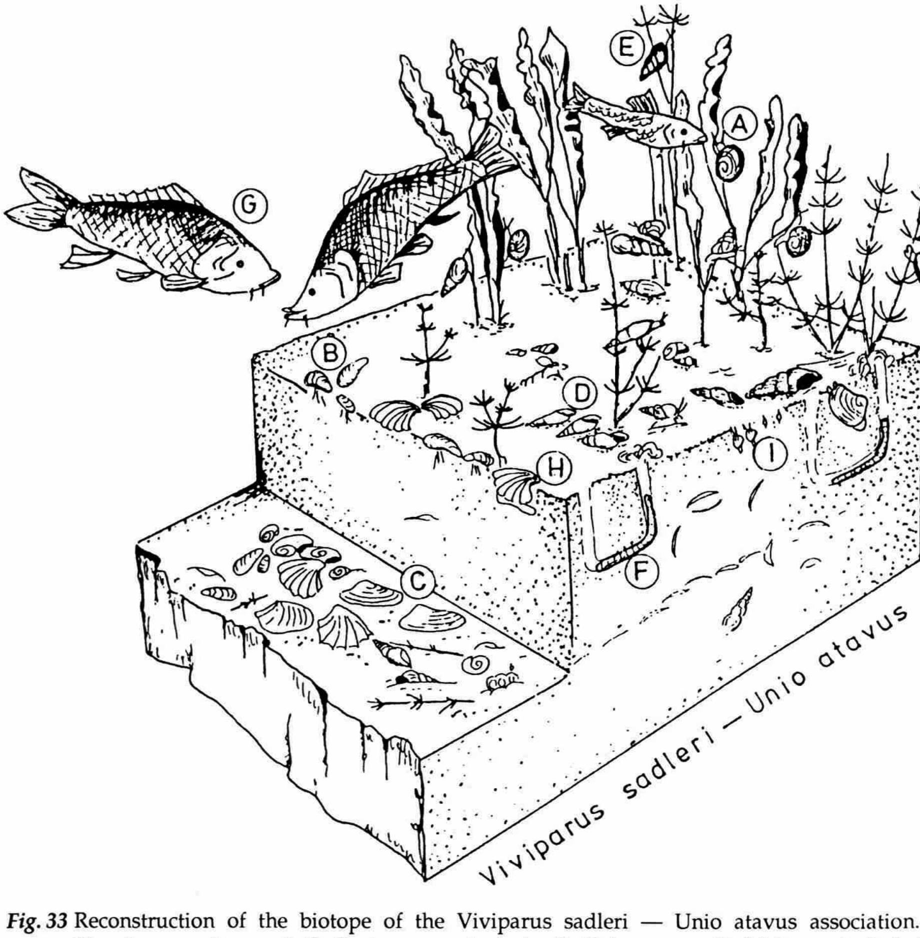


Fig. 33 Reconstruction of the biotope of the Viviparus sadleri — Unio atavus association. A: Theodoxus radmanesti, B: Dreissena auricularis, C: Unio atavus, D: Melanopsis fuchsi, E: Viviparus sadleri, F: Arenicola sp., G: Vegetable-feeding fish, H: Lymnocardium decorum, I: Pisidium sp.

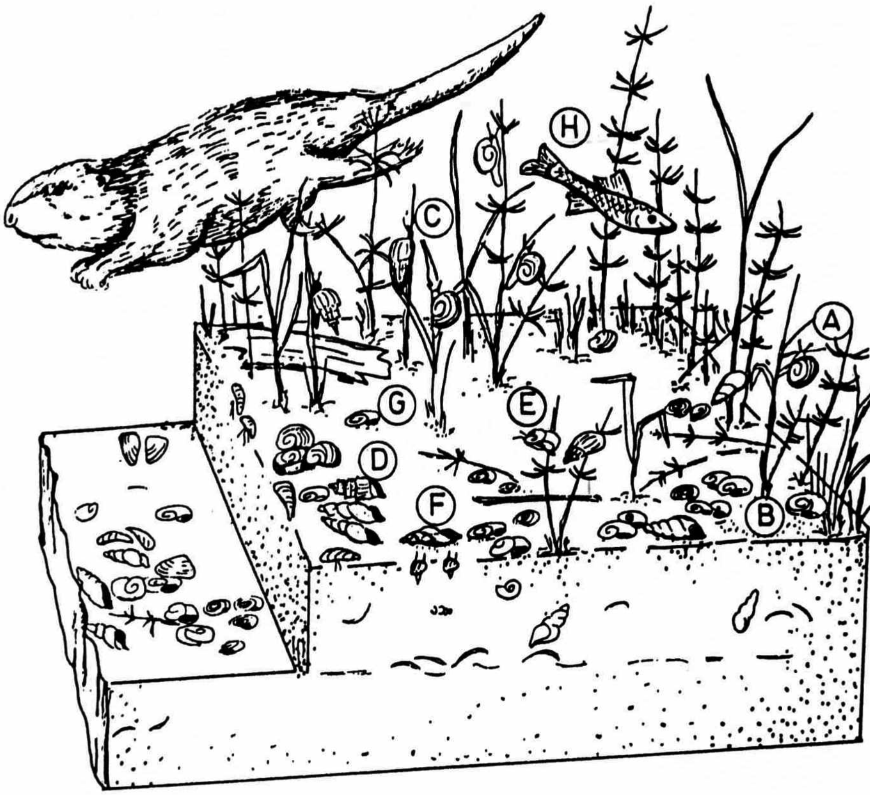


Fig. 34 Reconstruction of the biotope of the Melanopsis bouei sturi — Theodoxus radmanesti and Planorbarius sp. — Planorbis sp. associations. A: Theodoxus radmanesti, B: Planorbarius corneus, C: Melanopsis fuchsi, D: Melanopsis bouei sturi, E: Valvata minima, F: Lymnaea sp., G: Gyraulus sp., H: Vegetable-feeding fish

Yellowish brown, strongly weathered freshwater limestone of Pliocene-Pleistocene age covers the sequence with unconformity. The breccia-like appearance of the formation is probably due to periglacial weathering.

The sequence was formed in an extended littoral environment where shallow lacustrine, lagoonal, palustral, sandbar, and alluvial sediments occurred together. Since the drainage system of the Pannonian lake was endorheic, climatic fluctuations (annual and multiannual) often led to changes in the water level and to notable shifts in the shorelines especially on flat shores. The Papvásári sequence, with marsh deposits in its upper part, displays a shoaling trend.

Molluscs

The Pannonian Lake harboured one of the most diverse endemic lacustrine faunae ever known, including several hundreds of described molluscan species, dozens of endemic genera, and some endemic subfamilies.

In general, lacustrine faunae are mainly recruited from fluvial ones, but also from shallow standing waters such as marshes or oxbow ponds, and in rare cases from marginal marine habitats. Such migrations to lakes always involve profound changes in life conditions, accelerating the rate of evolution. The most characteristic forms of the Pannonian Lake (cardiids, dreisseniids, Melanopsis) come from marginal marine habitats. Molluscs of fluvial origin (Unio, Theodoxus, Viviparus, etc.) also developed endemic species. Some pulmonate molluscs originating from shallow standing waters may also profoundly change in their biology and morphology when they have to live in a lacustrine environment.

Representatives of the two latter groups play a dominant role in the Papvásári sequence. However, shells of Congeria, Lymnocardium, and Melanopsis are also abundant. The predominance of gastropods argues for a nutrient-rich, shallow water environment, overgrown by seaweeds. The fauna corresponds to the Dreissena auricularis-Melanopsis pygmaea ecozone of Korpás-Hódi (1983). The lower half of the sequence is characterized by the Viviparus sadleri-Unio atavus association (Fig. 33). Grazing Theodoxus species and small, spinose Melanopsis dominate the middle part of the sequence (Fig. 34). Pulmonate molluscs: Planorbis and Planorbarius become abundant in the upper third of the vertical section.

STOP 10

Tihany, Medieval monk's dwellings in basalt agglomerate covering lacustrine deposits of the Pannonian Lake (Late Miocene)

Pál MÜLLER

Locality

The exposures at "Barátlakások" (literally "monk's dwellings") are situated on the northeastern slopes of the Tihany Penisula (Fig. 35). This peninsula cuts Lake Balaton into two parts. The about hundred meter high flank is a result of erosion and abrasion, complicated by slumps resulting in an uneven, terraced slope.

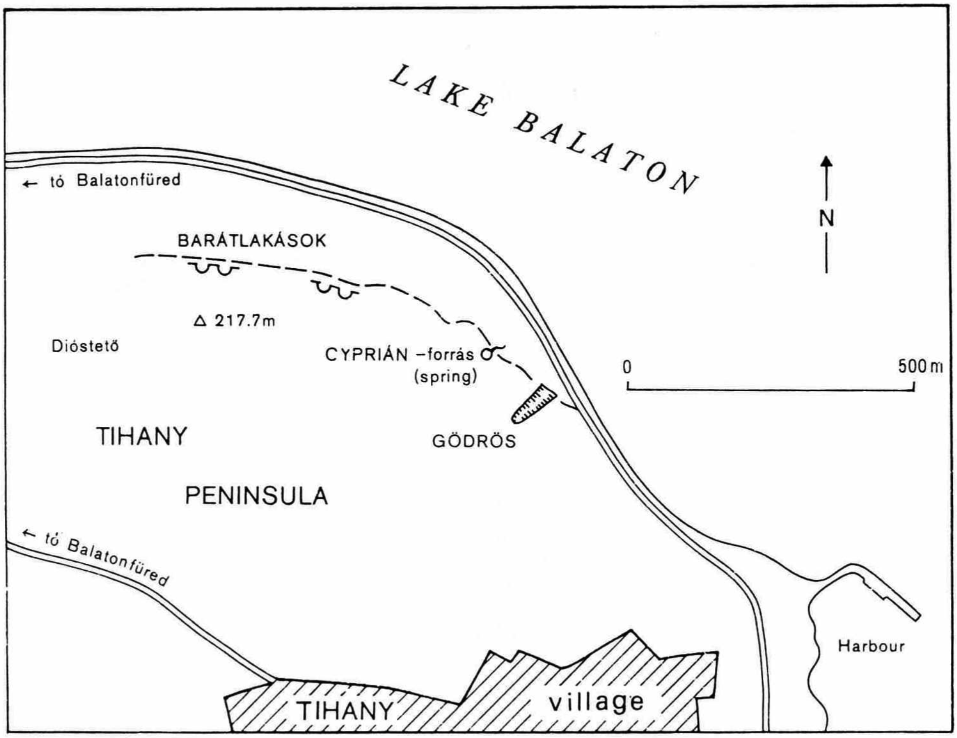


Fig. 35 Locality of exposures in Tihany peninsula

Age

All of the exposed rocks on this slope are of Pontian (sensu Stevanović 1951) age, late Miocene. The lower, lacustrine, 60-70 m of the sequence may be ranged into the Somló and Tihany Formations (Jámbor 1980), while the volcanoclastics capping the sedimentary layers may be regarded, with some reserve, as belonging to the Kabhegy Basalt Formation.

History

The cellars, cut into the volcanic rocks (basaltic tuffs and agglomerates) at "Barátlakások" were in fact dwelligs of orthodox monks coming from the grand duchesse of Kiev, invited by the Hungarian king András I, (ruled 1046-1060) whose wife, Anastazia, was daughter of Prince Yaroslav the Wise of Kiev. The spring between "Barátlakások" and "Gödrös", named "Cyprián-forrás" or "Oroszkút" ("Russian well") reflects also the memory of the Kiev monks.

King András I is buried in the crypt of the Abbey of Tihany. The crypt and the tomb are preserved in their original, simple, archaic form, as one of the oldest intactly remained architectural monuments in Hungary.

Remnants of the most characteristic fossil of the peninsula layers, Congeria ungulacaprae, were found abundantly removed in the Balaton alluvium and sold by children for tourists. These were named by the local inhabitants "Kecskeköröm" (literally translated "goat's hoof" or "Ziegenklauen"), inspiring fairy tales and puzzling scientists of the late 18th and early 19th century, until Partsch (1835) and Münster (1838) stated that these were abraded beaks of a bivalve, belonging to a yet unknown genus and species. This way it became the first named form of the perhaps most diverse endemic lacustrine fauna of the Earth's history, which populated the Late Miocene Pannonian Lake.

Description of the sequence

The Somló Formation (Fig. 36) extends upwards about twelve meters over the Balaton level. It consists mainly of blue silts and clays with sandy intercalations, deposited in open-lake nearshore areas of the Pannonian Lake, in depth from a few meters to about 20 or 30 m.

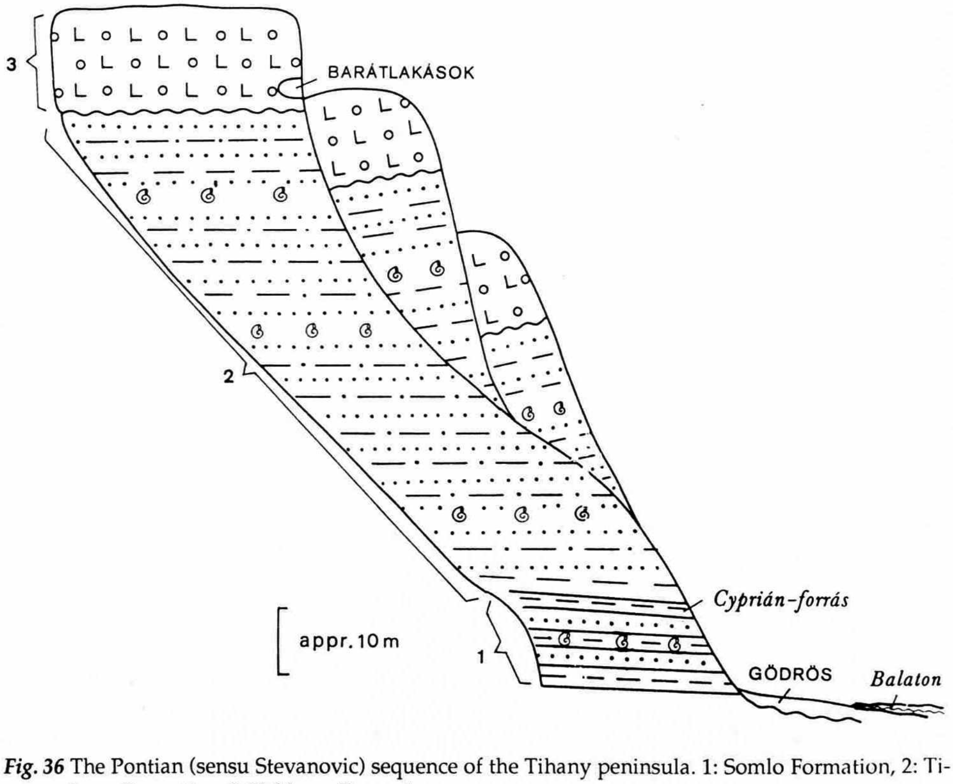


Fig. 36 The Pontian (sensu Stevanovic) sequence of the Tihany peninsula. 1: Somlo Formation, 2: Tihany Formation, 3: Kabhegy Formation

The overlying, 50-60 m thick Tihany Formation (Fig. 36) was deposited partly in nearshore areas of the lake, which were shallower than those where the Somló Formation was formed, but mainly in lagoons. These were periodically desiccated, but when covered with water, they were densely overgrown by seaweed. Thus the bulk of the layers consists of unlayered variegated silt with calcretes and rootprints, often palaeosol like, intercalated with dark huminitic layers, silts with pulmonates, Bithynia, Viviparus, mammal teeth. Another type of intercalation is sandy, formed on open shores and containing coquinas with a diverse lacustrine fauna. Congeria balatonica, or Unio mihanovici dominates these assotiations, with Theodoxus, Valvata, Melanopsis species (Müller and Szónoky 1990). The succession of the abovementioned formations reflect characteristic progradational processes, which shifted the facies in this area mainly southeastward.

A slightly eroded, already dry surface of the lacustrine Pontian layers was covered by a volcanoclastic material (Fig. 36), probably as a result of a short activity of one or few eruptive centres. The main eruption centre may be located in the Külső-tó ("External lake"). The volcanoclastic sequence includes several eruption units containing pyroclastic surge and pyroclastic fall layers. Mantle xenoliths occur subordinately in this suite, however, olivine megacrysts are common in the pyroclastic deposits as well as in the juvenile fragments. At the Barátlakások this basaltic agglomerates contain xenoliths derived from underlying sedimentary rocks, as Permian sandstones and fragments of Sarmatian fossils. The extend of the volcanic rocks roughly coincides with that of the peninsula.

On the top of the Tihany volcanic buildup several cone-like formations are scattered. The material of these is siliceous limestone. Some authors believe that these were geyser-cones, but certainly these are deposits of postvolcanic thermal water springs.

The potassium-argon age of bombs from "Barátlakások" and of material from a dyke at the nearby "Dióstető" hill was determined as 7.56 +- 0.50 and 7.35 +- 0.65 MY (Balogh et al. 1986).

The mentioned volcanic and postvolcanic rocks prevented the soft Pontian (sensu Stevanović 1951) sediments from being eroded. The Pontian lacustrine layers in all Tihany exposures are almost horizontal, disturbed only by slides at the steep slopes over Lake Balaton. Although slight volcanotectonic displacements may be presumed, their effects are probably hidden in the interior of the peninsula.

Correlation of the Pannonian basin Pontian with that in the Euxinian basin

The age of the Pannonian Lake deposits and their relation to the Pontian stage in the Dacian Black sea (i.e. stratotype) and Aegean regions remained a topic of debate for a long time. The strongly endemic character of practically all aquatic biota of the lake precluded attempts of correlation with marine Neogene sequences in the Mediterranean or elsewhere. Although there are several tens of mollusc species in common in the Pannonian respectively in the Dacian and Euxinian basins, due to the relative longevity of most of them, the temporal relation of the mentioned basins remained also ambiguous.

Mammal stratigraphic studies, radiometric dating and magnetostratigraphy recently gave starting points to the determination of the age of the Pannonian lake sediments. It is already a well established fact, that the Pontian as defined by Stevanović (1951), for the Pannonian Basin roughly coincides with the urolian mammal stage, i. e. with the MN 11 to MN 13 mammal zones (Müller and Magyar 1992a, 1992b), and the position of the Pannonian-Pontian boundary is at about 8.5 MY ago. The Pontian in its stratotype area, however, seems to be much shorter. Topatchewsky et al. (1987) found an MN 13 (or even higher) zone mammal fauna in the stratotype layer of the Lower Pontian in Odessa, suggesting that the stratotype Pontian corresponds only the upper part of the

Pontian in the Pannonian Basin as defined by Stevanović (1951), and comprising the formations present in the Tihany peninsula (Fig. 37).

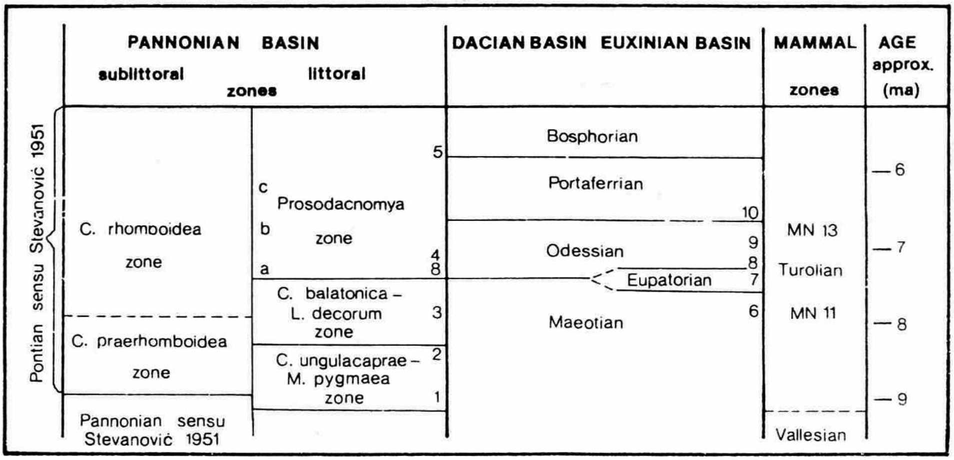


Fig. 37 Correlation chart of the Late Miocene of the Pannonian, Dacian and Euxinian basins (Müller and Magyar 1992b).

1: approximate position of end of magnetic anomaly 5
2: FA lacustrine Viviparus
3: MN 11 rodent
4: Tihany radiometric age 7.5-6.5 ma
5: Hatvan, Turolian (? MN 13) locality
6: MN 11, Early Turolian
7: FA Eupatorina
8: FA Prosodacnomya
9: MN 13, fide Topatchevsky et al. 1988
10: FA Congeria rhomboidea in Eastern Paratethys and Dacian basin

Subzones in the Balaton region:

a: Prosodacnomya carbonifera
b: Prosodacnomya dainelli-Viviparus kurdensis
c: Prosodacnomya vutskitsi-Viviparus balatonicus

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