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PRE-TERTIARY BASEMENT CONTOUR MAP OF THE CARPATHIAN BASIN BENEATH AUSTRIA, CZECHOSLOVAKIA AND HUNGARY

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Within the cooperation between Bundesanstalt, Austria, Geofyzika n. p. Bratislava Branch, and ELGI, Budapest a unified basement contour map was constructed for that part of the Carpathian basin belonging to the three countries. The Carpathian basin can be divided into several basins, the largest of them being the Pannonian basin, which in turn can further be divided into sub-basins such as the Danube–Rába basin and the Békés basin just to mention the biggest ones. Wrench faulting is an important factor in the forming of these basins; the best-known pull-apart basins are the Vienna basin and the East Slovakian basin. Although the concept is unified as pre-Tertiary basement, both the geological model and the coverage by geophysical measurements are extremely heterogeneous. Four basic models can be assigned to the different sub-basins. The geophysical methods dominating in the map construction are governed by the geological model and the availability of geophysical data.

Keywords: Carpathian basin, Pannonian basin, Vienna basin, wrench faulting, pull-apart basins, pre-Tertiary basement, contour map

1. Introduction

In 1983–84 in the framework of preparing a Geological Atlas of Hungary, the geological map of the basement was constructed by a team of geologists and geophysicists — on a scale of 1:500,000 — and it was presented at the XXVII. International Geological Congress, Moscow, 1984. This map consists of two separate maps: the geological subcrop map and the depth contour map. As the contour map itself contains so much information, we thought it worthwhile to publish it separately. The map was published in Geophysical Transactions Vol. 35. No. 4. [KILÉNYI – RUMPLER 1984] on a scale of 1:1,000,000. In the Introduction it was written of the Pannonian Basin being divided into sub-basins:

> 'All these sub-basins are cut by political borders. Let this paper be an appeal to geologists and geophysicists of the neighbouring countries to join forces and construct a unified map of the whole of the Carpathian basin!'

The first step towards realizing this dream was the co-operation agreement between ELGI and Geofyzika n. p. Bratislava Branch, Czechoslovakia, in 1985.

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The existing basement contour map for Slovakia fitted well with the Hungarian one in the main features, though in detail there were quite a lot of problems to be solved. This work had just started when the annual co-operation discussions took place between representatives of Austrian and Hungarian geoscientists. The suggestion of ELGI for co-operation in unifying the basement contour maps met with the interest of the Austrian party and the topic was included in the co-operation programme.

The result of this trilateral co-operation is presented now (as an Enclosure) on a scale of 1:500,000.

2. Geological–geophysical characteristics

Although the concept is unified as pre-Tertiary basement, both the geological model and the coverage by geophysical measurements are extremely heterogeneous. Four basic models can be assigned to the different sub-basins:

A) Areas of crystalline or Mesozoic carbonate basement filled with Neogene sediments

This model is the most favourable for all geophysical methods: the basin floor forms a sharp physical discontinuity (*Fig. 1*). In such areas the accuracy of the contour map is determined by the density of the reflection seismic network, or by the proportion of direct depth defining methods in the applied geophysical ensemble.

B) Areas of non-carbonate Mesozoic or Palaeozoic basement

This model responds in different ways to different geophysical methods. For example, graphitic schists have low resistivity but high density and velocity. Thus the contradiction between two methods helps us to recognize this model, and the problem can only be solved with the help of an integrated interpretation of several geophysical methods.

C) Areas of inhomogeneous cover containing screening layers

This model is the most difficult and most ambiguous regarding depth determination. Areas of deep basins covered by sediments including Neogene (or Palaeogene) volcanics belong to this model. Tertiary volcanic formations, mostly of the Badenian to Sarmatian age, are a part of the basin fill. The

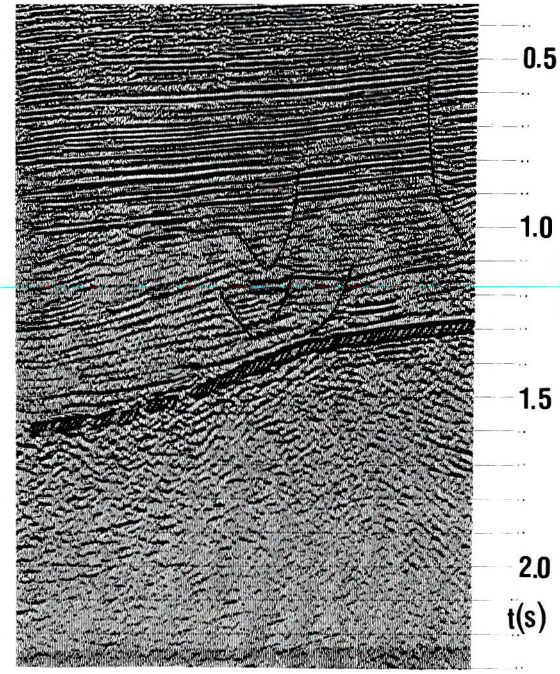


Fig. 1. Migrated time section from the Szeghalom area. Pre-Cambrian crystalline schists form the basin floor [after TAKÁCS E. 1990. Unpublished report of ELGI]

1. ábra. Migrált időszelvény Szeghalom környékéről. Prekambriumi kristályos palák képezik a neogén üledékösszlet aljzatát [TAKÁCS E. 1990 kéziratos jelentése, ELGI Adattár, nyomán]

Рис. 1. Временной разрез с миграцией из окрестностей г. Сегхалом. Фундамент неогеновых отложений сложен докембрийскими кристаллическими сланцами (по рукописному отчету Э. Такача [TAKÁCS E. 1990], фонды Венгерского Геофизического института)

evolution of volcanism exhibits a causality with the relief of the basement forming volcano-tectonic features in the relief (calderas, volcano-tectonic elevations and depressions (*Fig. 2*). Many volcanic formations are covered. On the surface they are most extensive in Central Slovakia.

Another type of area belonging to this class is where the cover contains high density, high velocity limestone layers (generally Eocene). In both cases (volcanics and limestones) the relative position of the screening layer basically affects the problem: if there is a thick enough layer of low resistivity and velocity between the screen and the basement, its depth can be determined by electromagnetic and seismic reflection methods. If, however, the screening layer is deposited directly on the basement, it cannot be separated by any geophysical method.

D) Flysch basins

The pre-Neogene basement of the Vienna Basin is partially formed by the flysch of the Vienna Forest and of the Magura group in the Externides, and the Senonian to Paleogene of the peri-Klippen zone (the Myjava formation) in the Internides (*Fig. 3*). The East Slovakian Basin — which extends partly into the Externides — probably includes the Palaeogene up to the Oligocene [GRECULA et al. 1981] in its basement (*Fig. 4*).

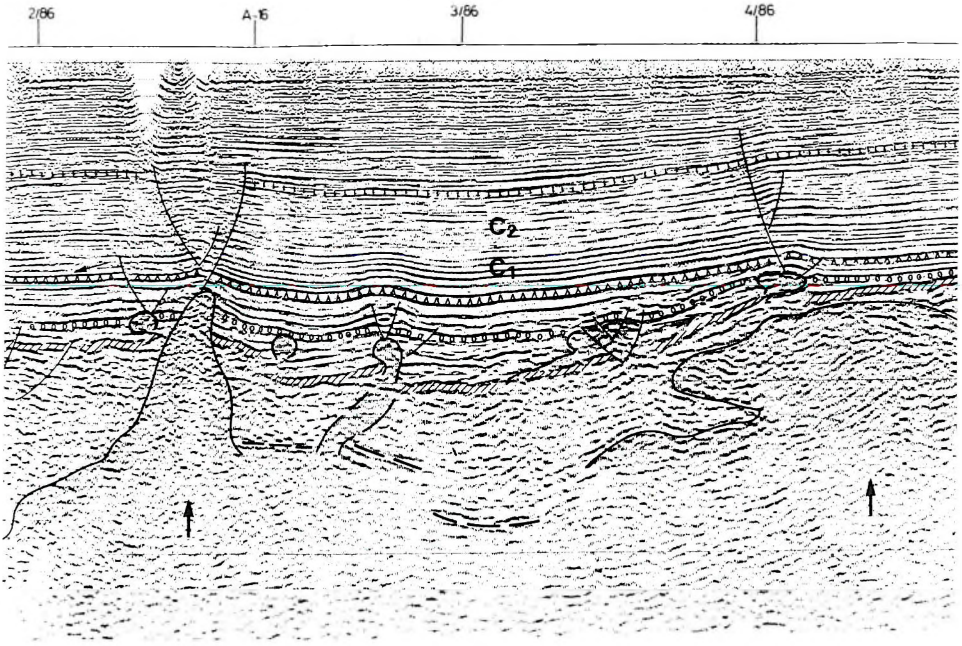


Fig. 2. Migrated time section from the Nyír area to illustrate the connection between volcanism and basement tectonics [after KILÉNYI et al. 1989]

2. ábra Migrált időszelvény a Nyírségből a vulkanizmus és aljzattektonika kapcsolatának szemléltetésére [KILÉNYI et al. 1989 nyomán]

Рис. 2. Временной разрез с миграцией из Ньирского района, приводимый для иллюстрации соотношений между вулканизмом и тектоникой фундамента (по Э. Киленьи и др. [KILÉNYI et al. 1989])

A special case of this model is the flysch zone of the Great Hungarian Plain. There the problem is not only a stratigraphic one. The northern border of the flysch zone is unknown: no borehole has penetrated the flysch below the thick Miocene volcanic series. Therefore geophysical data are the only sources for the map construction. But for gravity and geoelectric methods the flysch acts as young sediments; for seismic refraction the high velocity horizon is unambiguously the bottom of the flysch. On the other hand, with the seismic reflection method we can follow the surface of the flysch much more easily than its bottom, which can be identified only at the margin (*Fig. 5*). If we were to choose to map the top of the flysch starting from the southern border, we would be unable to connect it to the north, where — in the absence of seismic data — we had to base our map on gravity data, reflecting the older basement.

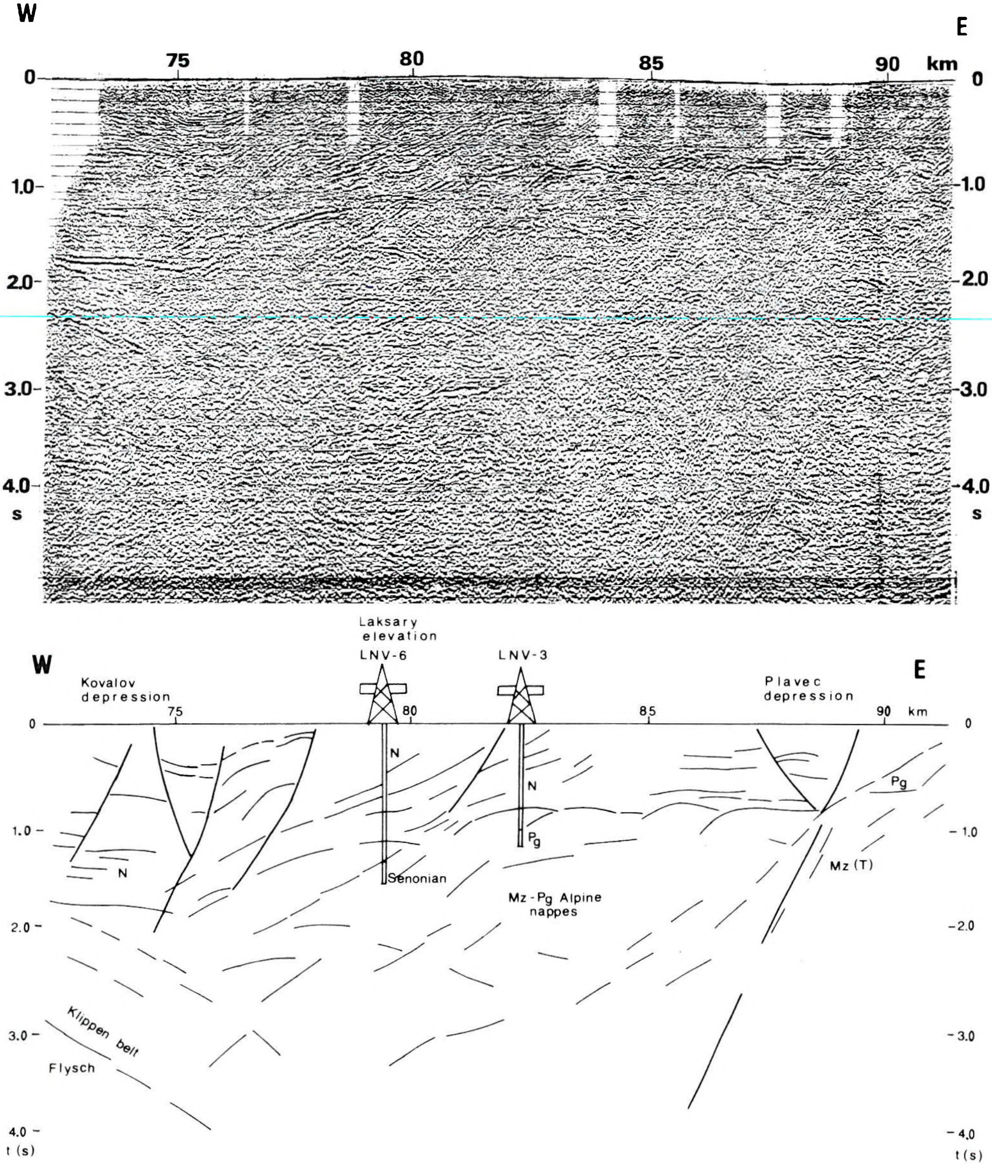


Fig. 3. Unmigrated time section with interpretation from the Vienna basin with Palaeogene (Oligocene) basement [after Tomek et al. 1989]

3. ábra. Migrálatlan időszelvény és értelmezése a Bécsi-medencéből paleogén (oligocén) aljzattal [Tomek et al. 1989 nyomán]

Рис. 3. Временной разрез без миграции и его интерпретация из Венской впадины с палеогеновым (олигоценовым) фундаментом (по данным Ч. Томека и др. [Tomek et al. 1989])

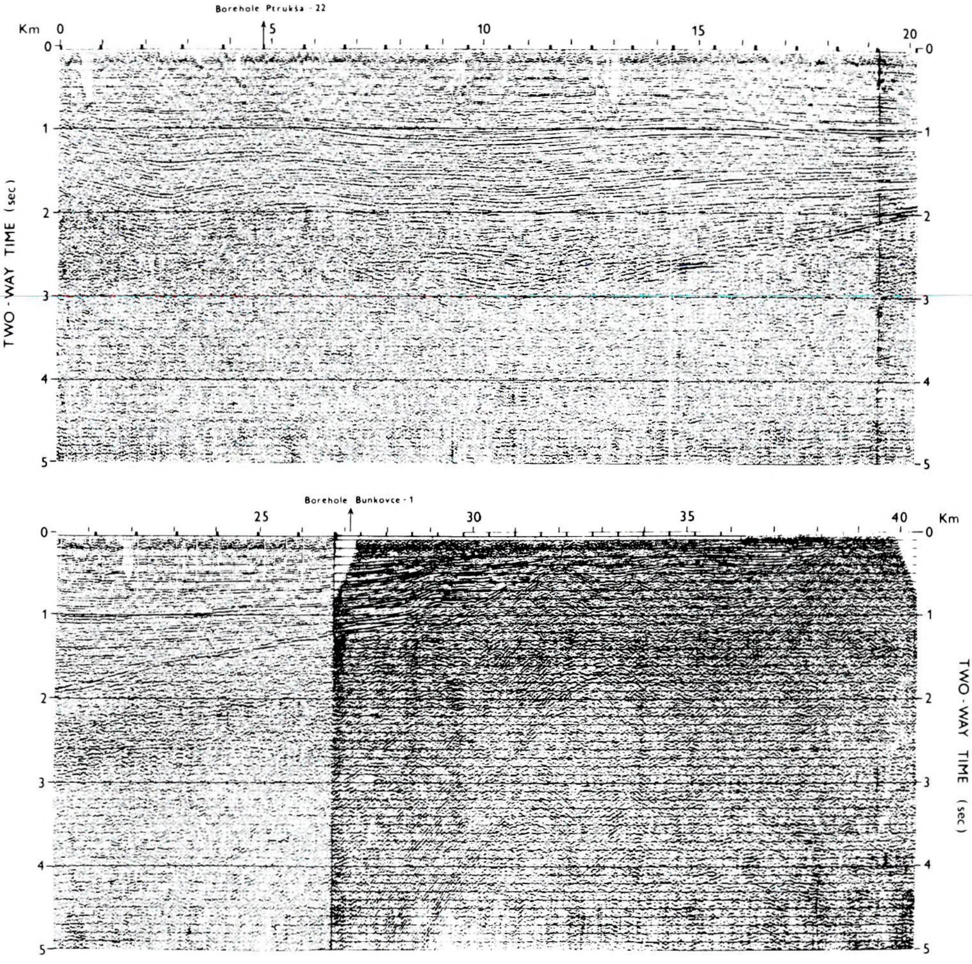
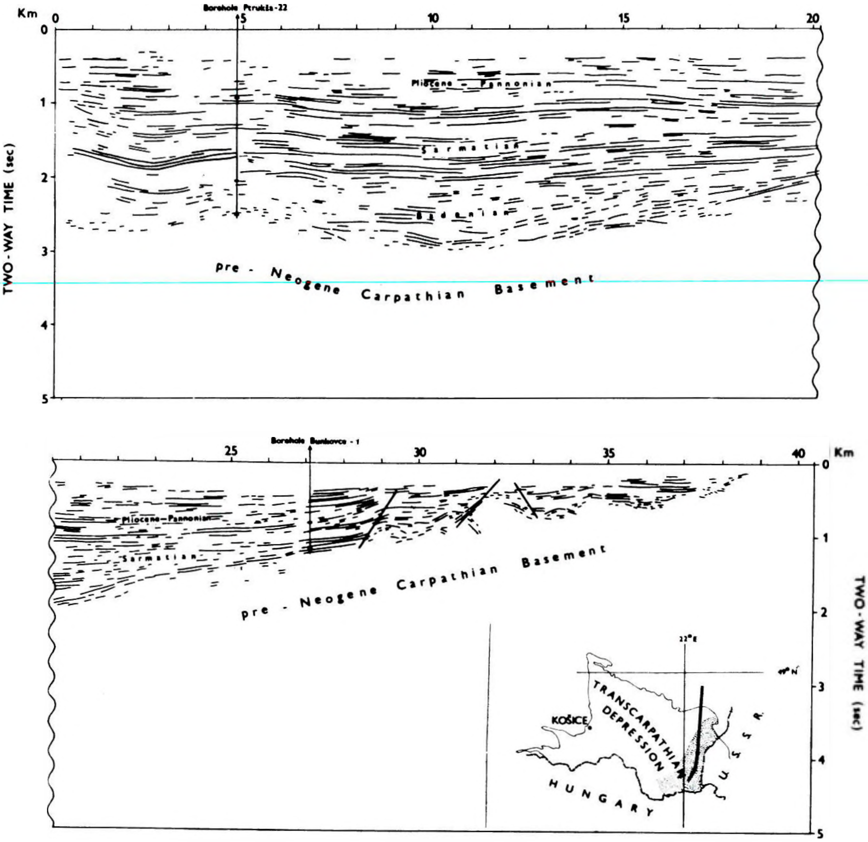


Fig. 4. Unmigrated seismic section from the East Slovakian basin [after Tomek and Thon 1988]
a) time section, b) interpretation with location map

4. ábra. Migrálatlan szeizmikus szelvény a kelet-szlovákiai medencéből
[Tomek és Thon 1988 nyomán]
a) időszelvény, b) értelmezés helyszínrajzzal

Рис. 4. Сейсмический разрез без миграции из Восточно-Словацкой впадины (по данным Томека и Тона (Tomek and Thon 1988])
a) Временной разрез
b) Интерпретация и план ситуации



We overcame the difficulty by means of a compromise: as our detailed reflection seismic survey only covers the southern border of the flysch zone (continuous brown line) we present the bottom of the flysch on the contour map and have marked the zone by dots. We must admit, however, that the Hungarian flysch zone represents the least reliable part of the whole map.

These four models are the basic ones; it would be possible to make several subdivisions but our aim is not exact classification, it is rather the presentation of the physical basis of the contour map and the justification for its not being uniform. It is therefore evident that the accuracy of the contour map depends not only on the level of geophysical survey but on the actual model too.

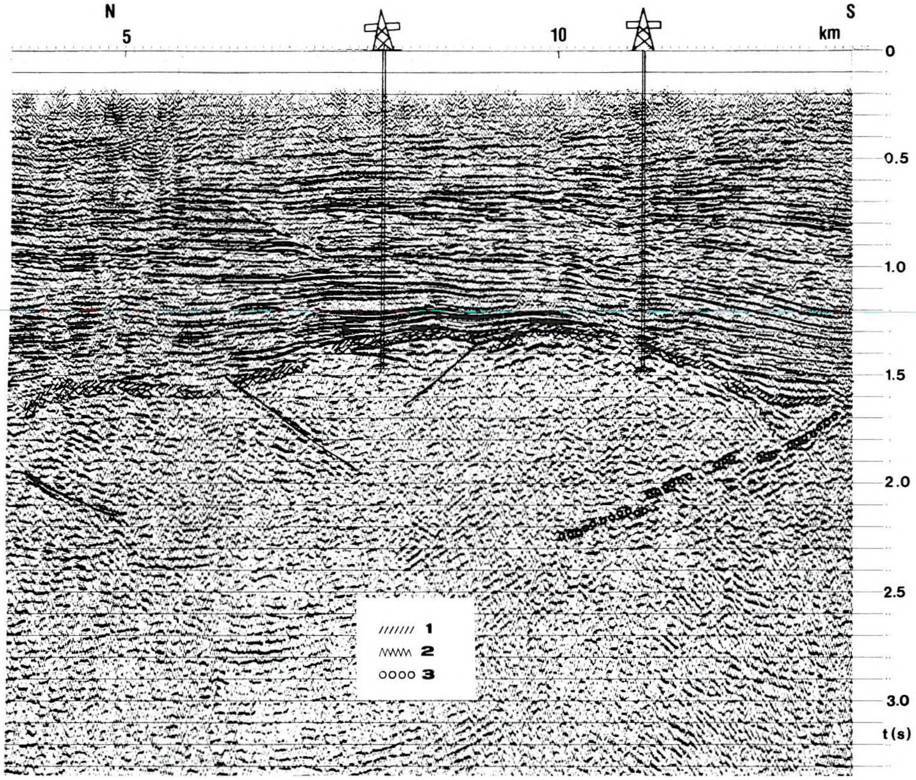


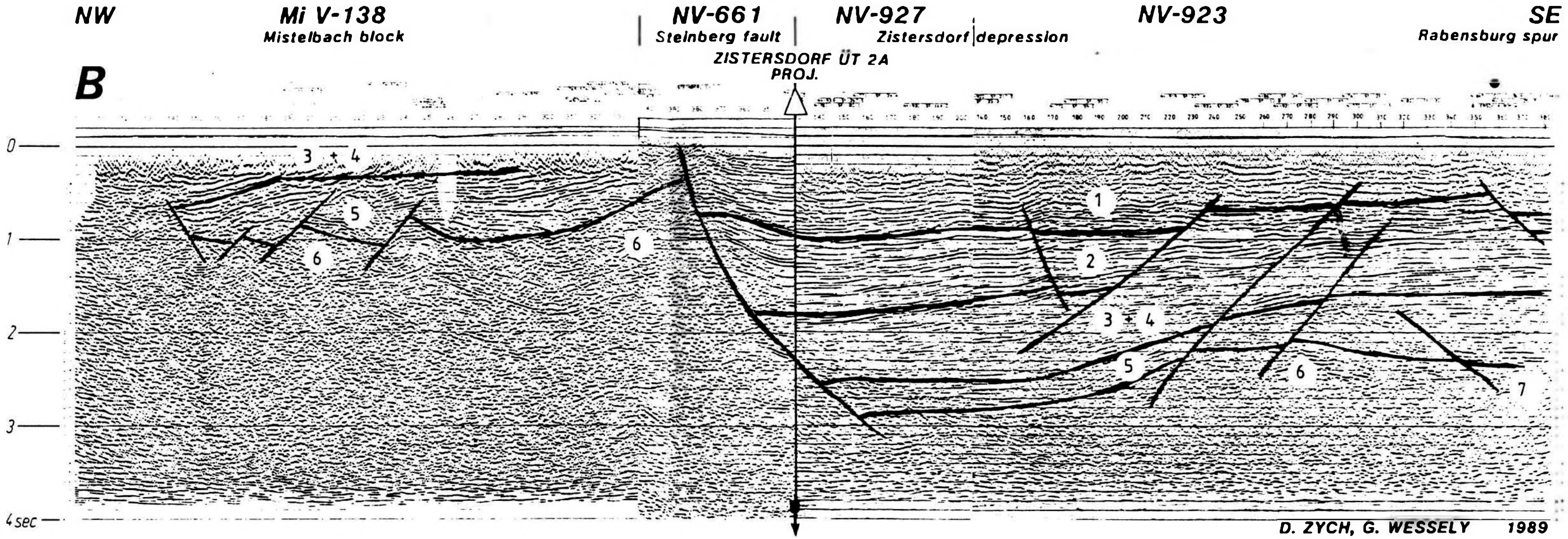
Fig. 5. Migrated time section from the Szolnok area with the southern boundary of the flysch zone [after Detzky-Lőrincz et al. 1989]
1 — base Pannonian; 2 — surface of flysch; 3 — overthrust plane of flysch

5. ábra. Migrált időszelvény Szolnok környékéről a flis zóna déli határával [Detzkyné Lőrincz K. et al. 1989 nyomán]
1 — pannon fekü, 2 — flis felszíne; 3 — a flis feltolódási síkja

Рис. 5. Временной разрез с миграцией из окрестностей г. Сольнок с южной границей флишевой зоны (по данным К. Децки-Лёринц и др. [Detzkyné Lőrincz K. et al. 1989])
1 — подошва паннона, 2 — поверхность флиша, 3 — плоскость надвигания флиша

3. Geological–geophysical data and the methodology of map construction

Boreholes which have penetrated the pre-Tertiary basement represent a fundamental information set. Their areal distribution is determined by exploration interests, mainly by those of oil, coal, and bauxite prospecting. The majority of boreholes which have reached the basement are located in the Vienna Basin, in the Drava–Mura region, in the SE part of the Great Hungarian Plain; few of them are located in marginal parts of the Rába–Danube Basin, in the northern part of the East Slovakian Basin, and in central Slovakian neovolcanites as well as in the coal-, bauxite-, and ore prospecting areas of the



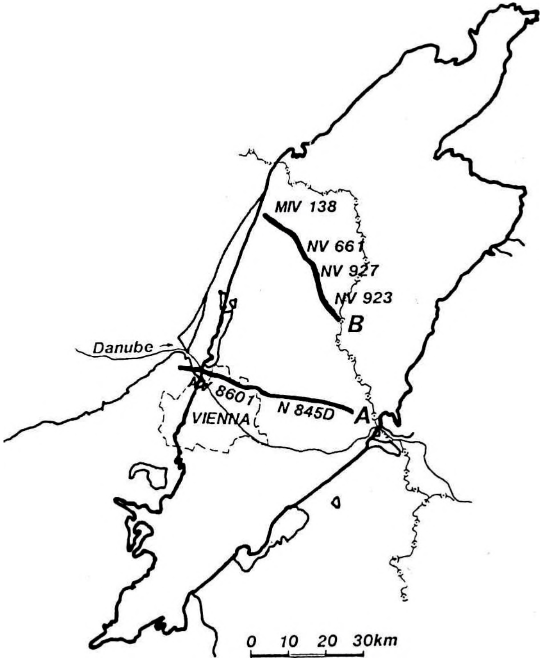


Fig. 6. Migrated time section crossing the Steinberg fault in the Vienna basin [after Wessely 1990]

1 — Pannonian (Pliocene); 2 — Sarmatian; 3 — Upper Badenian; 4 — Lower Badenian; 5 — Lower Miocene (Karpathian–Eggenburgian); 6 — Flysch belt; 7 — Klippen belt

6. ábra. A Bécsi-medencét átszelő Steinberg vetőt keresztező migrált szeizmikus időszelvény [Wessely 1990 nyomán]

1 — pannoniai; 2 — szarmata; 3 — felsőbádeni; 4 — alsóbádeni; 5 — alsómiocén (kárpáti–eggenburgi); 6 — flis öv; 7 — szirtöv

Рис. 6. Временной сейсмический разрез с миграцией вкрест Штейнбергскому сдвигу, рассекающему Венскую впадину (по данным Г. Вессели [Wessely 1990])

1 — паннон; 2 — сармат; 3 — верхний бадений; 4 — нижний бадений; 5 — нижний миоцен (карпат и эггенбург); 6 — флишевая зона; 7 — утесовая зона

Transdanubian Central Range and in the Mecsek Mountains. In nearly all regions there is a lack of drilling data from the deep parts of the basins. The greatest thickness of Neogene sediments (5842.5 m) has been penetrated by a borehole in the Makó depression. Of the other deep boreholes, the LNV–7 in the Czechoslovak part of the Vienna Basin drilled to a depth of 6405 m penetrated the basement already at a depth of 1564 m. In the Austrian part of the basin four wells were drilled to a depth over 6000 metres. The deepest hole is the Zistersdorf UeT2 with a total depth of 8553 metres. A thickness of 4884 metres of Neogene sediments cut by the big 'Steinberg' fault was explored by means of this well *(Fig. 6)*. Seismic data indicate that the greatest thickness of Neogene will be about 5800 metres. These wells have contributed considerably to our knowledge of the structure, stratigraphy and of the facies distribution.

The density of geophysical data is also irregular. The majority of geophysical data, mainly the seismic ones, come from areas promising for oil prospecting. In the neovolcanic regions of Slovakia, in the South Slovakian Basin, and in the interior depressions of the Inner West Carpathians there is coverage by less suitable methods (e.g. VES). In the Transdanubian Central Range and some other parts of Hungary electromagnetic methods play an important role in the ensemble of geophysical methods. Gravimetry is extremely important everywhere, especially in the Czechoslovak part of the West Carpathians (irregular grid, 3–6 points per square kilometre), and in the Vienna basin (up to 12 points per square kilometre).

Let us consider the reliability of the different geophysical methods in determining the depth to the basement. The mapping ability of *gravimetry* decreases with increasing depth to the basement. It has been shown by the data from approximately 200 boreholes in Slovakia [Husák 1986] and 88 boreholes in Hungary [Kilényi 1967] that sediment densities increase with depth, reaching values close to the densities of basements rocks *(Fig. 7)*. Gravity modelling, either 2-D or 3-D [e.g. Gerard and Debeglia 1975], needs a knowledge of both vertical and horizontal density distribution. Such studies were carried out in higher quantity in Slovakia [Grecula et al. 1981] and to a lesser extent in Hungary [Szabó et al. 1984]. It has been proved that ϱ–h curves may differ considerably therefore all gravity modelling should be based on the particular density situation deduced from local borehole data.

As both the basement rock and the sedimentary fill may have a varying density function, for gravity modelling a set of depth points is necessary. These depth points may come either from boreholes or from some depth determining geophysical methods. Unfortunately, most boreholes are located on structural highs leaving the deeper parts of the basin to seismic or geoelectric depth determination thus increasing the ambiguity of gravity modelling.

In some parts of the Pannonian basin Bouguer anomalies do not correlate with the basement topography. Among the causes there may be strong regional effects, special density conditions, etc. If these areas have no satisfactory seismic coverage, the only possibility of mapping the basement topography is to use

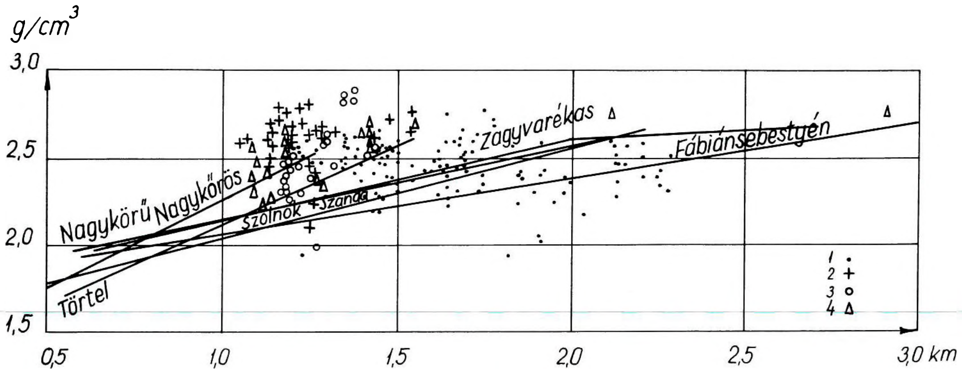


Fig. 7. Smoothed straight lines of the Pannonian density data and the densities of the different elements of the basin floor [after Kilényi 1967]
1 — Upper Cretaceous-Palaegoene; 2 — Triassic–Lower Cretaceous; 3 — Permian; 4 — pre-Cambrian

7. ábra. Medencealjzat képződmények sűrűségei az üledékösszlet kiegyenlítő sűrűség–mélység függvényeivel [Kilényi 1967 nyomán]
1 — felsőkréta–paleogén; 2 — triász–alsókréta; 3 — perm; 4 — ópaleozoós

Рис. 7. Плотности пород фундамента впадин и выравнивающие функции плотность–глубина для осадочных толщ (по данным Э. Куленьи [Kilényi 1967])
1 — верхний мел и палеоген; 2 — триас, юра и нижний мел; 3 — пермь; 4 — нижний палеозой

geoelectric methods. The reliability of different geoelectric methods depends on several factors. Similarly to gravity, the resistivity of both the basement and the sedimentary fill may have an areal variation but, in contrast to gravity, these variations affect data in a more complex way. The accuracy of depth determination depends on the type of geoelectric model, on the interpretation process and last but not least the geological structure with such effects as current channelling. And, on top of all these, we should not forget the phenomenon of equivalence.

The methodology of geoelectrics that proved to be the best in our mapping was the combination of telluric mapping with magnetotelluric (MT) soundings. The telluric isoarea map with the anisotropy ellipses *(Fig. 8)* reflects the main structural directions by the long axes being perpendicular to them, despite the map being distorted by the resistivity variations. MT soundings located on

8. ábra. Kisalföldi tellurikus izoarea térkép az anizotrópia ellipszisekkel [Dudás et al. 1987 nyomán]
1 — anizotrópia ellipszis; 2 — mélyfúrás; 3 — tellurikus bázis; 4 — magnetotellurikus szondázás

Рис. 8. Карта теллурических изоареалов по Малой Венгерской впадине с эллипсами анизотропии (по данным И. Дудаша и др. [Dudás et al. 1987])
1 — эллипс анизотропии; 2 — буровая скважина; 3 — пункт теллурических измерений; 4 — пункт магнитотеллурических зондирований

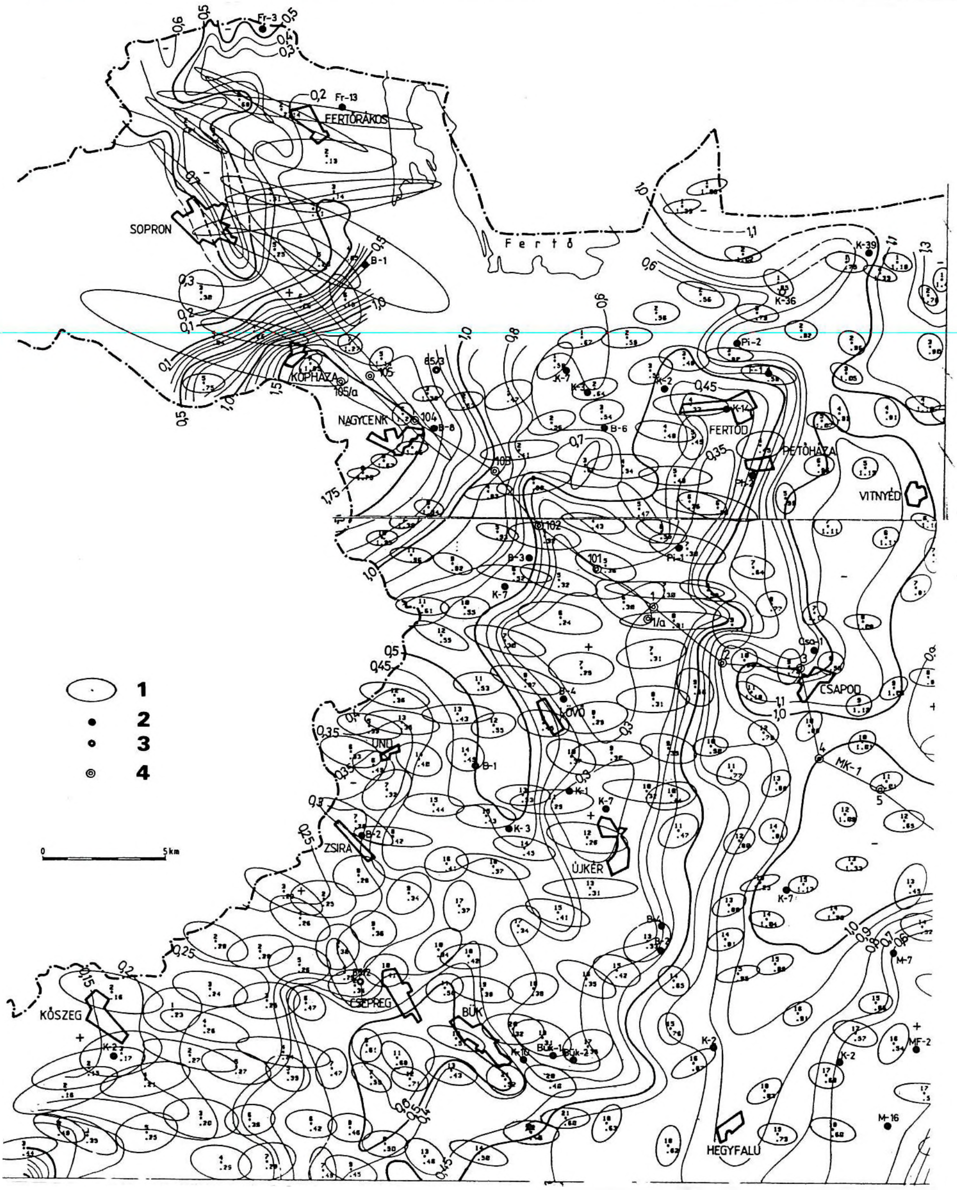


Fig. 8. Telluric isoarea map of the Danube—Rába basin with anisotropy ellipses [after DUDÁS et al. 1987]
1 — anisotropy ellipse; 2 — borehole; 3 — telluric basepoint; 4 — magnetotelluric sounding

characteristic anomalies and in directions parallel and perpendicular to the structural lines give information on the geoelectric model, the resistivity distribution and the depth to basement *(Fig. 9)*.

As far as *seismic methods* are concerned, the coverage is uneven and seismics — similarly to other methods — responds differently to different geological models. Although the velocity function has lost its position as the terror of the seismic reflection method, its effect on the unreliability of depth

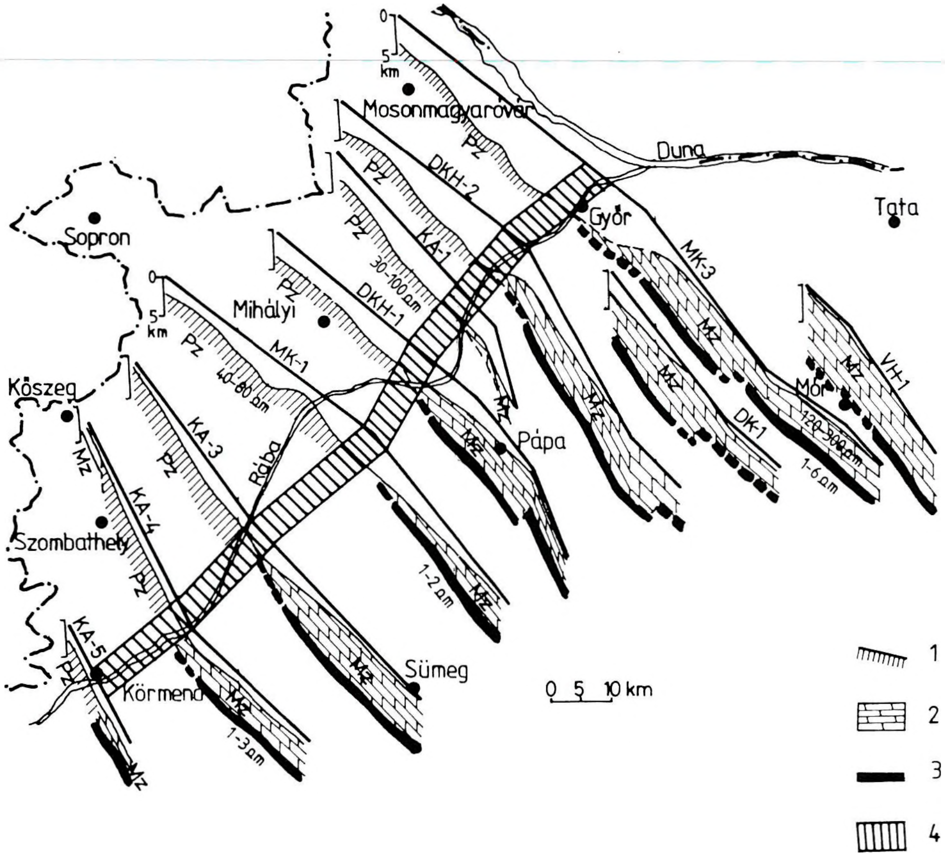


Fig. 9. Interpretation of MT profiles of the Danube–Rába basin [after Pápa et al. 1990]
1 — Alpine units; 2 — Transdanubian Central Range unit; 3 — conductive zone; 4 — zone of the Rába line

9. ábra. A kisalföldi MT szelvények értelmezése [Pápa et al. 1990 nyomán]
1 — Alpi egységek; 2 — Dunántúli-középhegység egység; 3 — jólvezető zóna; 4 — a Rába-vonal övezete

Рис. 9. Интерпретация магнитотеллурических разрезов по Малой Венгерской впадине (по данным А. Папы и др. [Pápa et al. 1990])
1 — альпийские единицы; 2 — единица Задунайского среднегорья; 3 — зона высокой электропроводимости; 4 — зона Рабской линии

determination may be as much as 20%. The ever improving quality of reflection seismics has contributed to the recognition of several geological features, the most spectacular of them being wrench-faulting. The finding of flower structures in Pannonian sediments revealed strike-slip movement in the centre of the Carpathian basin as young as 2 Ma *(Fig. 10)*. Similarly the link between wrench-faulting and elongated narrow trenches is a finding of the past few years. Thus topographical features of the basement may be indicators of tectonic movements. In the Vienna Basin a high coverage of good seismic data exists as well as some 3-D areas. Together with the well information these data are in good correlation with the geological reality. The depth determination is exact and depends primarily on the velocity distribution, relief and depth of the pre-Tertiary basement. Within the basin fill, conglomerates exist over wide areas with high velocity (4500–5400 m/sec). The variable thickness (50–400 m) and the time distance between the base of conglomerates and the base of Tertiary occasionally cause difficulties in the seismic correlation.

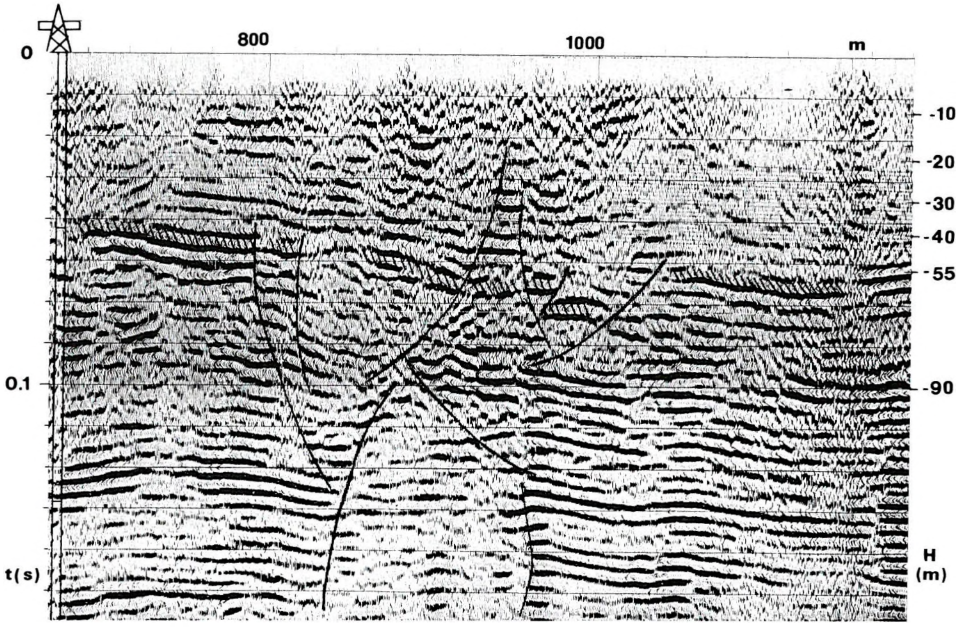
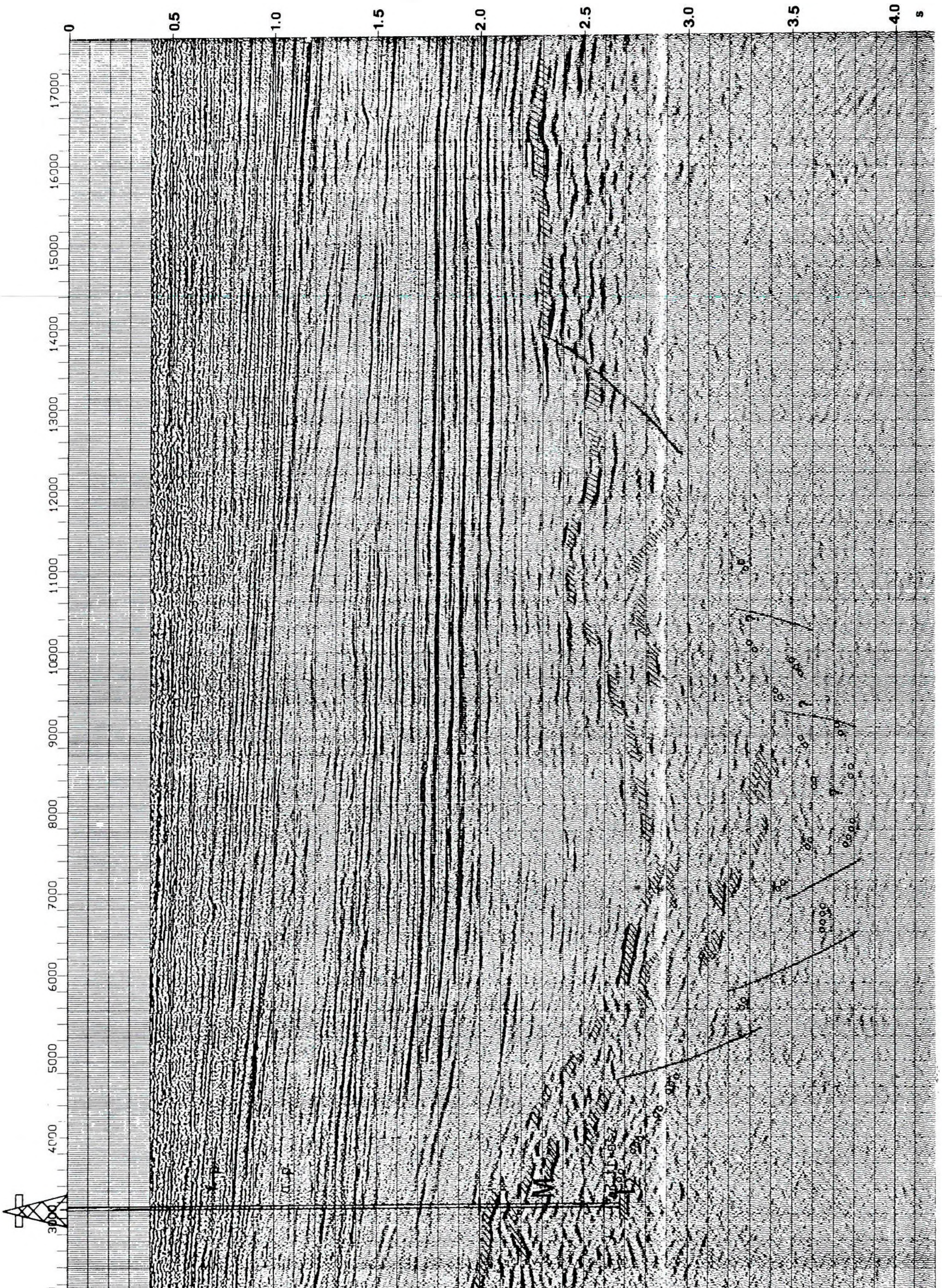


Fig. 10. Migrated shallow-seismic time section crossing the Mid-Hungarian megatectonic zone [after Guthy and Hegedüs 1989]. Correlated horizon: Pleistocene–Upper Pannonian contact

10. ábra. A középmagyarországi megatektonikai vonalat keresztező sekélyszeizmikus migrált időszelvény [Guthy és Hegedüs 1988 nyomán]
Korrelált felület: pleisztocén–felsőpannon határ

Рис. 10. Малоглубинный сейсмический временной разрез с миграцией вкрест Средневенгерской тектонической линии первого порядка (по данным Т. Гути и Э. Хегедюша [Guthy and Hegedüs 1988])
Скоррелированная поверхность — граница плейстоцена с верхним панноном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4. Geological interpretation

The question is: What contribution can be expected of a basement contour map (Enclosure) to the understanding of the geological evolution of the region? If we refer to the fact that investigation of the seafloor gave the clue to plate tectonics, the basement of the Carpathian basin, which should be regarded as the floor of the Miocene sea, may help us to delineate the tectonic units and to recognize the main movements.

Even though they are a unity in so far as their formation is connected to the Carpathian arch, the sub-basins of the Carpathian basin differ in many features: age, origin, geothermic conditions, etc. In the following some examples are presented to show this variability.

Valuable evidence on the time–space development of the basin is contained in the pre-Tertiary basement relief map. First of all we can mention the differences in shapes of basins. A basin filled with Palaeogene sediments was deformed during later stages. This kind of deformation took place in the Peri-Klippen zone in the form of overthrusting. Therefore the Neogene basins are the real indicators of basin evolution. They can be divided into graben type basins and subsidence basins with typical disk-like sinking. Of the latter type is the younger part of the Danube–Rába basin which is underlain by a basin with graben disintegration. This disintegration continues to the NE in enclaves which were also developed as graben-type basins synchronously with the Danube–Rába basin subsidence (after Sarmatian). It manifests itself by gravity tectonics revealed by geophysical modelling of their margins. The striking asymmetry of these graben-type basins can be regarded as a consequence of dynamic disintegration of the terrain with listric faults playing an active role. Similar asymmetry can be observed in South Slovakia where the basins perpendicular to the NW–SE trending graben-type ones (e.g. Trencin depression) prevail.

It has long been well known that structural units of different origin are juxtaposed in the basement of the Pannonian Basin [Vadász 1953]. In the latest subcrop map [Fülöp–Dank 1987] the line dividing Hungary into two — called the mid-Hungarian megatectonic line — is drawn along the Kapos line in Transdanubia, turns northward near the Danube then again takes a direction of NE–SW and terminates before the buried volcanic area of the Hajdú–Nyír

Fig. 11. North–south directed seismic time section through Kömlő–1 borehole to illustrate the trough [after Szeidovitz et al. 1988. Unpublished report of ELGI]

11. ábra. É–D irányú migrált időszelvény a Kömlő–1 mélyfúrástól D-re eső árok szemléltetésére [Szeidovitz Gyné et al. 1988 kéziratos jelentése, ELGI Adattár, nyomán]

Рис. 11. Меридиональный временной разрез с миграцией для иллюстрации строения грабена южнее скважины Кёмлё–1 (по рукописному отчету Сейдовицне и др. [Szeidovitz Gy-né et al. 1988], фонды Венгерского Геофизического инстута)

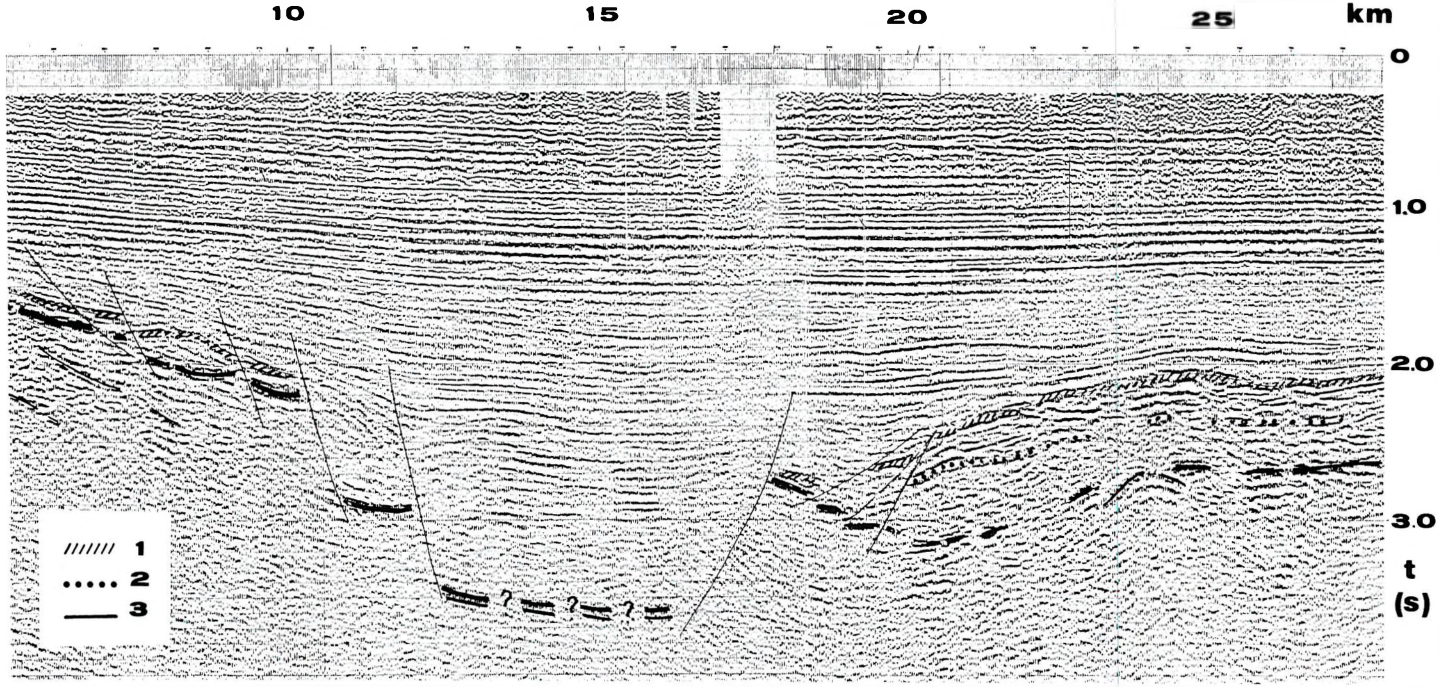


Fig. 12. North–south directed seismic time section near Tiszafüred to illustrate the eastern continuation of the trough system [after Kilényi et al. 1987]
1 — base Pannonian; 2 — surface of flysch; 3 — basement

12. ábra. Tiszafüred környéki, közel É–D irányú szelvény az árokrendszer K-i folytatásából [Kilényi et al. 1987 nyomán]
1 — pannon fekü; 2 — flis felszíne; 3 — aljzat

Рис. 12. Субмеридиональный разрез из окрестностей г. Тусафюред вкрест восточному продолжению системы грабенов (по данным Э. Киленьи и др. [Kilényi et al. 1987])
1 — подошва паннона, 2 — поверхность флиша, 3 — фундамент

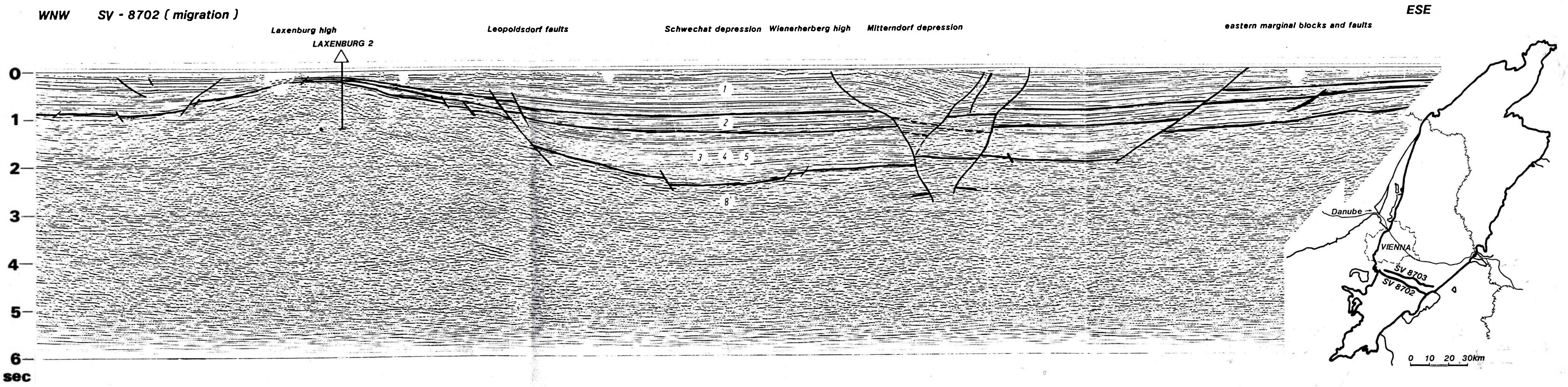


Fig. 13. Migrated time section from the Vienna basin [after HAMILTON et al. 1990]
1 — Pannonian (Pliocene); 2 — Sarmatian; 3 — Upper Badenian; 4 — Lower Badenian;
5 — Lower Miocene (Karpathian–Eggenburgian); 8 — internal Alpine–Carpathian units

13. ábra. Migrált időszelvény a Bécsi-medencéből [HAMILTON et al. 1990 nyomán]
1 — pannoniai; 2 — szarmata; 3 — felső bádeni;
4 — alsó bádeni; 5 — alsó miocén (Kárpáti-Eggenburgi); 8 — belső Alp-Kárpáti egységek

Рис. 13. Временной разрез с миграцией по Венской впадине (по данным Гамильтона и др. [HAMILTON et al. 1990])
1 — паннон (плиоцен); 2 — сармат; 3 — верхний баден;
4 — нижний баден; 5 — нижний миоцен (карпат — эггенбург); 6 — внутренние альпийско-карпатские единицы

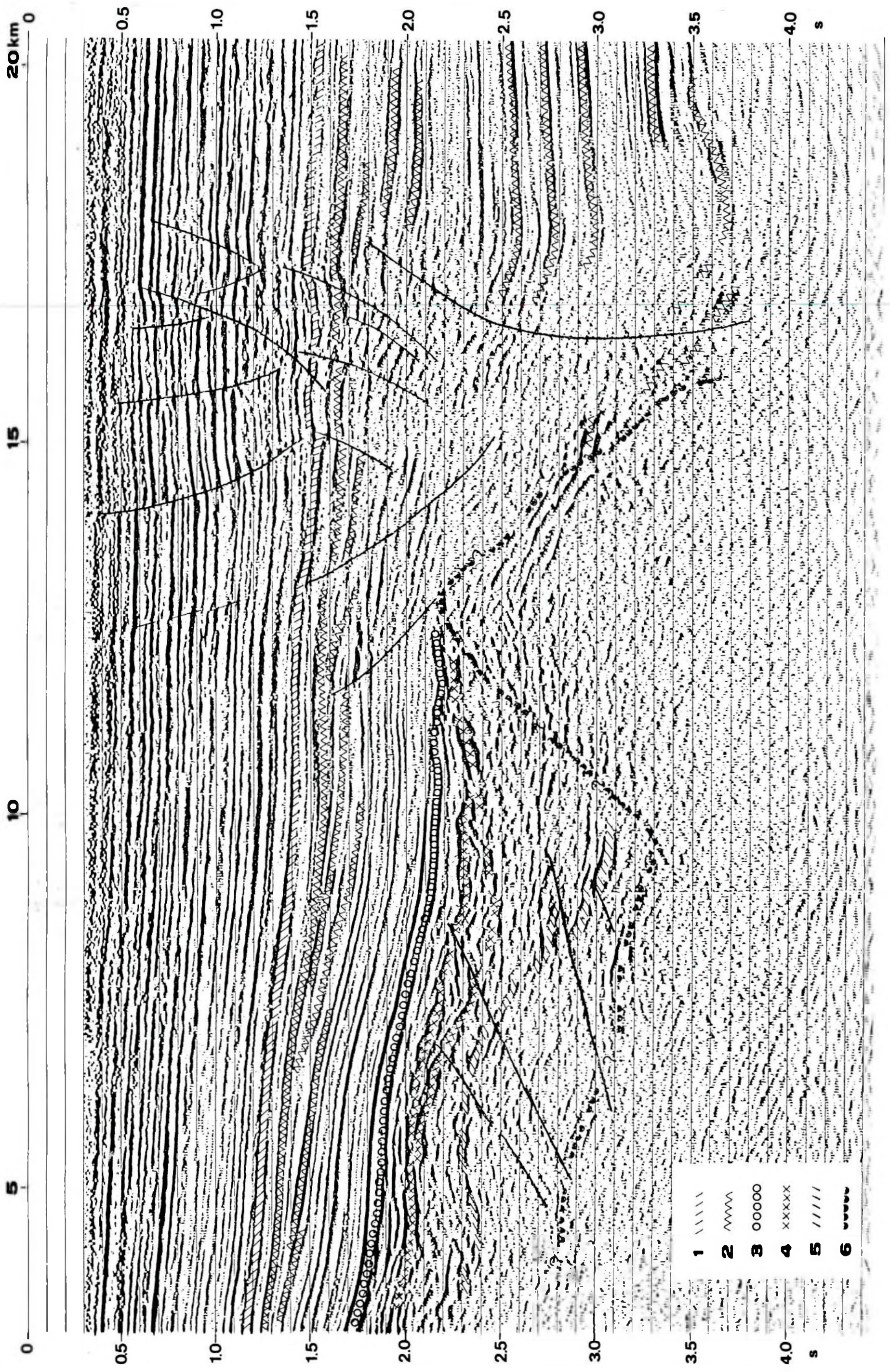
region. This termination indicates lack of information rather than real termination of the tectonic line. The line itself was drawn along strong features of the filtered gravity anomaly map [Szabó 1989]. As the contour map and the subcrop map were constructed simultaneously and fitted together at the last stage it was certain that the coincidence of the chain of deep grabens along the Mid-Hungarian megatectonic line was not the result of any subjective intention.

The contour maps of the bottom of oceans and seas reveal linear features (ridges or grabens) along major plate movements. Seismic examples of present-day active wrench faults [Bally 1983] exhibit narrow deep grabens. Thus we think the coincidence of the chain of grabens and the Mid-Hungarian megatectonic line means a strict causative connection.

In the northeastern part where the filtered gravity map lost its strong features because of the great depth to basement, some seismic lines crossed this zone and revealed the characteristics of grabens. Unfortunately the river Tisza flows, for a long stretch, along the tectonic line — not without causative contact. The river hinders seismic surveys, the break of the regular system and cross shooting result in poor quality. Even so, the graben can be seen unambiguously. *Fig. 11* shows the graben near borehole Kömlő–1, *Fig. 12* shows the same or another graben further to the east. The origin of this chain of grabens is connected with the strike-slip movement between the two main structural units: the Alpine type Pelso unit and the southern Tisza unit.

Further, but less direct evidence has been obtained about wrench fault systems in the Little Carpathians–Váh system accompanied by shallow earthquakes (focal depth about 7 km) up to the Žilina area [Schenková et al. 1979, Gutdeutsch and Aric 1988]. Besides geological evidence [Buday et al. 1986] a horizontal component of movement was proved [Pospíšil et al. 1985, Vass et al. 1988] by study of the earthquake mechanism. Moreover Fusán et al. [1987] presume that in the area near the Little Carpathians the Northern Limestone Alps structures terminate evidently extending into the basement of the Vienna Basin in the form of strike-slip movement.

Among the sub-basins, several have the features characteristic of pull-apart basins. The two big ones — the Vienna basin and the East Slovakian basin — are topics of several past and, most probably, future publications. Some of these papers are included as examples in the list of references [Čekan et al. 1990, Granser et al. 1990, Hamilton et al. 1990, Jiřiček and Tomek 1981, Kröll and Wessely 1973, Ladwein 1988, Meurers and Steinhauser 1985, Royden 1985, Wessely 1988, Wessely 1990]. However, some remarks about the Vienna basin are pertinent here. This basin represents an area of major subsidence along the NW-edge of the Alpine–Carpathian internal basin system. The Neogene fill of the basin was deposited on an allochthonous stack of nappes during and after their thrusting over the autochthonous basement (Bohemian massif) covered by Jurassic, Upper Cretaceous and older Tertiary Molasse sediments. The evolution of the basin is closely connected with the Alpine–Carpathian geodynamics. The basin played a specific role within the large Pannonian basin system because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of its position within the thrust belt. The relatively shallow sub-Alpine–Carpathian basement controlled the mechanism of basin-forming tectonics to a certain extent. The basin has an elongated shape and is filled by Neogene clastic sediments in a very active tectonic environment. Several generations of synsedimentary faults — the most important of them being of Middle and Late Miocene and Pliocene age — created substantial thickness, varying from area to area in the same sedimentary unit *(Figs.* 6 and *13)*. The internal structure is characterized by a large number of faults, fault blocks, and structural ridges. The faults are mostly synsedimentary normal faults, some with a displacement of 4000 to 6000 metres. There are many phenomena which are common in pull-apart basins. The assumption of a pull apart mechanism generating the Vienna basin was documented by Royden [1985]. Although at present this mechanism seems to be more complex its feasibility is increased by regarding the summation of lateral movements along the main Alpine–Carpathian thrust planes. A number of normal faults seem to be restricted to the allochthonous thrust complex, but the autochthonous basement must have controlled the strike of the Alpine–Carpathian thrust front and late Miocene faulting.

Separated from the Vienna basin, about 150 km to the SW, a smaller basin — the Styrian basin — exists with the same geological sequence but with a basin floor formed by crystalline allochthonous Palaeozoic and, to a lesser extent, by Cretaceous. This basin is situated south of the Central-Alpine ridge as a zone of asymmetric subsidence to the SE and is bounded in the east by a SW–NE striking fault system in combination with a high zone (South Burgenland Rise) formed by Palaeozoic and crystalline rocks. This ridge separates the Styrian Basin from the wide Pannonian Basin. The former reaches a maximum depth of 3000 metres and is filled by Neogene sediments including — in some areas — hundreds of metres of volcanics. This fact causes some uncertainties in the interpretation of geophysical data and, consequently, in the determination of depth to the pre-Tertiary basement.

In addition to the large basins we would mention two smaller ones: the Turiec basin in Western Slovakia, where extensive gravity slides and steep marginal fault zones extend into the basement, and the Derecske basin in East Hungary, where the movement involves even Upper Pannonian sediments *(Fig. 14)*.

Fig. 14. Migrated time section crossing the Derecske pull-apart basin. The strike-slip movement causes listric faults even in the Upper Pannonian sediments [after Horváth and Rumpler 1988]
1 — Upper–Lower Pannonian contact; 2 — Lower Pannonian layers; 3 — Miocene sedimentary and 4 — volcanic series; 5 — Palaeogene flysch; 6 — Mesozoic and crystalline basement

14. ábra. A Derecskei árkot keresztező migrált időszelvény. Az oldaleltolódás még a felsőpannóniai üledékekben is okoz lisztrikus vetőket [Horváth és Rumpler 1988 nyomán]
1 — alsó–felsőpannon határ; 2 — alsópannoniai rétegek; 3 — miocén üledékes és 4 — vulkáni összlet; 5 — paleogén flis; 6 — mezozoos és kristályos aljzat

Рис. 14. Временной разрез с миграцией вкрест Деречкейскому грабену. Листрические сбросы вызываются сдвигом даже в верхнепаннонских отложениях (по данным Ф. Хорвата и Я. Румплера [Horváth and Rumpler 1988])
1 — граница нижнего и верхнего паннона; 2 — нижнепаннонские отложения; 3 — миоценовые отложения; 4 — миоценовые вулканиты; 5 — палеогеновый флиш; 6 — мезозойский и палеозойский фундамент

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A HARMADKORI MEDENCE ALJZATÁNAK SZINTVONALAS MÉLYSÉGTÉRKÉPE A KÁRPÁT-MEDENCE AUSZTRIAI, CSEHSZLOVÁKIAI ÉS MAGYARORSZÁGI RÉSZÉRE

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és Godfrid WESSELY

Az ausztriai Bundesanstalt, a csehszlovakiai Geofyzika n. p. Braatislava és az ELGI együttműködése keretében e három országra megszerkesztettük a harmadkori medence aljzatának mélységtérképét. A Kárpát-medence számos medencére osztható, melyek közül a legnagyobb a Pannon-medence, amely viszont tovább osztható részmedencékre, mint a Kisalföldi- és a Békési-medence, csak hogy a legnagyobbakat említsük. A medencék kialakulásában az oldaleltolódásoknak fontos szerepe volt; a legismertebb széthúzási (pull-apart) medencék a Bécsi-medence és a kelet-szlovákiai-medence. Bár a medencealjzat fogalom egységes, mint a harmadkorinál idősebb kőzetek felszíne, mind a földtani modell, mind a geofizikai felmértség rendkívül heterogén. Négy alapmodellt rendelhetünk a különböző rész-medencékhez. A térképszerkesztésben domináló geofizikai módszereket részben a földtani modell, részben a geofizikai adatok léte és hozzáférhetősége határozta meg.

КАРТА ГЛУБИН ФУНДАМЕНТА ТРЕТИЧНЫХ ВПАДИН В ИЗОЛИНИЯХ ПО АВСТРИЙСКОЙ, ЧЕХО-СЛОВАЦКОЙ И ВЕНГЕРСКОЙ ЧАСТЯМ ВНУТРИКАРПАТСКОЙ ДЕПРЕССИИ

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Ян ШЕФАРА, Петер ШТЕИНГАУЗЕР, Золтан САБО,
Годфрид ВЕССЕЛИ

В рамках сотрудничества между Геологическим институтом Австрии, предприятием »Геофизика« в Братиславе и Венгерским Геофизическим институтом составлена карта глубин фундамента третичных впадин по этим трем странам. Внутрикарпатская депрессия может быть подразделена на ряд бассейнов, наиболее крупным из которых является Паннонский, в котором в свою очередь могут быть выделены частные впадины, как например Малая Венгерская или Бекешская, чтоб упоминать лишь наиболее крупные. В формировании впадин большую роль играли сдвиги, наиболее известными врадинами этого (pull-apart) типа являются Венская и Восточно-Словацкая. Хотя понятие »фундамент впадин« единообразно в качестве поверхности дотретичных образований, как геологическое строение, так и геофизическая изученность варьируют в широких пределах. Различные частные впадины относятся к четырем основным типам. Набор геофизических методов, игравших определяющую роль в составлении карты, определялся отчасти геологическим строением, отчасти наличием и доступностью геофизических данных.