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PALEOGEOGRAPHICAL AND PALEOTECTONICAL OUTLINES OF SOME INTRACARPATHIAN PALEOGENE BASINS

(6 Figs.)

RCMNS

A b s t r a c t : The Paleogene sedimentary basins extending from Slovenia through Hungary to Czechoslovakia show no direct connections concerning their recent geographical position. Their boundaries are often of tectonical character. Several evidences support the theory, that the recent distribution of the Paleogene sedimentary basins is a consequence of the drifting of the Pelso unit from the SW toward NE along the first order transform fault – system of the Balaton and Mid Hungarian lines. Thus, one half of the Paleogene basin has been left behind in Slovenia, while the other part (N-Hungary and S-Slovenia) moved to its recent position. Second order lines, as the Buda, Darnó, etc. lineaments broke the Paleogene basin into more pieces. The NE movement of the Pelso block terminated in the Early Miocene, while the second order lines were active even in the Middle Miocene.

Р е з ю м е : Палеогенные осадочные бассейны простирающиеся от Словении через Венгрию до Чехословакии не показывают прямое соотношение с точки зрения их настоящей географической позиции. Их границы являются часто тектоническими. Несколько фактов подтверждает теорию что настоящее распределение палеогенных осадочных бассейнов является результатом дрифта единицы Пельсо с ЮЗ к СВ вдоль системы трансформных разломов первого порядка балатонской и средневенгерской линии.Это значит что половина палеогенного бассейна осталась в Словении и вторая часть (С. Венгрия и Ю. Словения) переместилась в ее настоящую позицию. Линии второго порядка, напр линеаменты Буды, Дарно и т. д., разделили палеогенный бассейн на несколько частей. СВ движение блока Пельсо окончилось в раннем миоцене, но линии второго порядка были активны еще в среднем миоцене.

Introduction

If one wants to outline the paleogeographic map of the Carpathian-realm, more exactly of the Pannonian subsidence in the Paleogene, that will find two main types of sedimentation. One is the „flysch-type“ sedimentary complex around the subsidence folded into the chains of the Carpathians, the other is the "epicontinental-type" sedimentation within the Intracarpathian area (Fig. 1.). The connection between the basins of the two sedimentation-types has been proved only at a few places, but this is a consequence of the dislocated character of the flysch. However, it is worth to mention, that no direct connection exists even among the Paleogene epicontinental basins in the Intracarpathian area, though the similarities in the sedimentary history and the uniform occurrence of some faunal elements make these former

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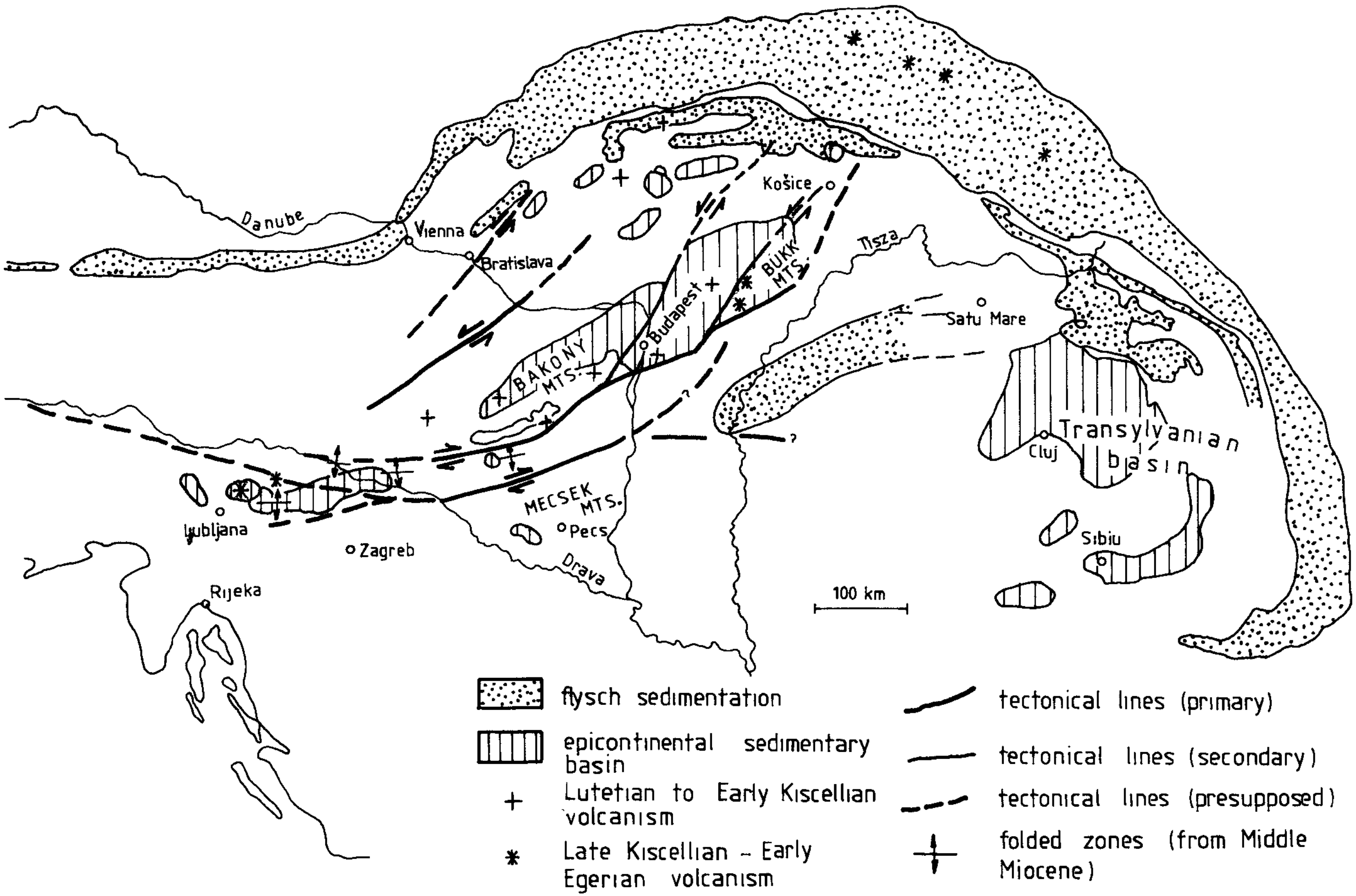


Fig. 1. Sketch of distribution of the Late Eocene–Oligocene sedimentation and volcanism in the Carpathian-Pannonian region (using materials: Gross – Váňová, 1976; Gross, 1979, 1986; Marschalko, 1978; Leško et al., 1959; Fusán 1985, etc.).

connections probable. Thus, for example it is highly uncertain, how the Slovenian-Croatian Paleogene basins might have a junction toward the Buda Paleogene basin or how a fauna exchange might exist between the Buda Paleogene basin and the Transylvanian Paleogene basin, located at a great distance from each-other. A special problem is to find the connection between the epicontinental-type sedimentary basins and the poorly known Szolnok-Maramures Flysch that can be found in the deep basement of the Great Hungarian Plain.

The problems above were explained by the earlier "fixist" geology as a result of erosional processes. Recently, in the era of the „mobil tectonic theories" they can be explained by great horizontal dislocations, by the moving of crustal plates or microcontinents along transform faults. The first "mobil" model of the tectonical evolution of the Carpathian-Pannonian region was published by Stegena–Géczy–Horváth (1975), and later by Wein (1978). These models were based mainly on the spatial restoration of Paleozoic and Mesozoic formations. In the eighties, Báldi (1983), Kázmér (1984), Kázmér–Kovács (1985) already suppose large-scale movements in the Tertiary, too. The papers of Balla (1984, 1987a, b) and Royden–Báldi (1988) give a modern synthesis of the Paleogene–Neogene evolution of this realm.

The uniform characteristic of all above-mentioned hypotheses is the fact, that they explain the forming of the Intracarpathian region by the juxta position of two crustal plates, which were located far from each other earlier. One unit is the Pelsonian, containing the Inner-Carpathians and the Pannonian "inselbergs", the other is the Tisza unit, i.e. the SE-part of the Pannonian basin (Brezsnyánszky–Haas, 1985). The Pelso unit, representing Alpian-Dinaric affinities and the Tisza unit, displaying a stable-Europe-type Paleozoic and Mezozoic are adjoining along a tectonical zone (mid-Hungarian line). The exact position of this line is quite uncertain, especially at its endings in the NE and SW.

While the experts agreed earlier that the above-mentioned process more or less has been finished by the beginning of the Cenozoic, the more recent studies in this topic have shown that this structural evolution greatly influenced the recent spatial distribution of the Paleogene and Early Neogene formations, i.e. the dislocation went on also in post-Paleogene times.

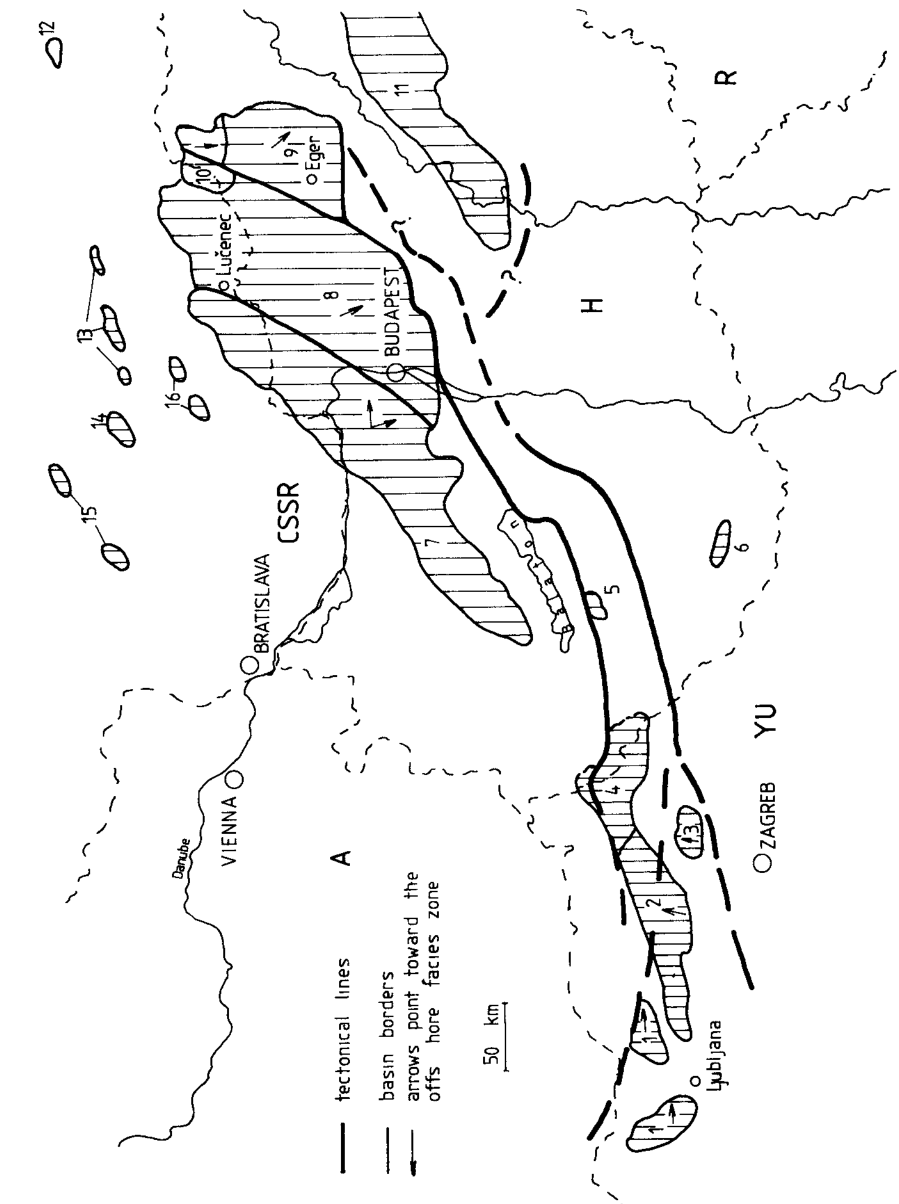
In the followings, we shall make an attempt to present some further evidences on the influence of this tectonical process on the former and recent distribution of the Paleogene rocks in the Carpathian region and try to give a simple sketch of the paleogeographical-tectonical position of the Intracarpathian area in the Oligocene and Early Miocene.

Paleogene sedimentary basins in the Intracarpathian region

The borders of the younger Paleogene - i.e. Eocene–Oligocene - sedimentary basins are marked not always by nearshore sediments but very often by offshore ones. In some cases these borders coincide by well or poorly known tectonical zones. The main epicontinental Paleogene basins of the Intracarpathian region (Fig. 2.) are separated by the following tectonical zones (Figs. 1, 4, 5):

– The Slovenian epicontinental Paleogene basin is located south of the mid-Hungarian line or partly lays within the tectonical zone (areas 1–3.).

– The Szolnok-Maramures Flysch belt is situated near to the mid-Hungarian line (area 11.). It is not known, whether this tectonical zone is located north or south of the flysch belt. Though the flysch is bound by its genesis and affinities to the Pelso unit, however the magmatic and sedimentary rocks of the Mecsek zone Tisza unit were found in the drillings of the neighbourhood of the flysch. We suppose, that the momentary positon of the flysch is a consequence of its upthrusting onto the margin of the Tisza unit.


tectonical lines
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arrows point toward the offs hore facies zone
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Fig. 2.

– In the belt between the mid-Hungarian and Balaton lines only small patches of Paleogene are known from the boreholes at Buzsák and Táska (area 5.). The patches are "cut" by the Balaton line.

– North to the mid-Hungarian line the wedge-shaped Bükk Paleogene unit can be found (area 9.). Its northern boundary is the shore of the transgressive Oligocene sea, its western border coincides with the Darnó zone and its southern border is "cut" tectonically.

– The so called North- and South Buda Paleogene units extend north of the Balaton line (areas 7. and 8.). These are separated by the Buda line (Báldi–Nagymarosy, 1976). On the northern border of the units the marginal nearshore sediments of the Oligocene occur, though the sharp ending the North Buda unit in NW suggest a tectonical border. Both units are marked off by the Balaton line in the south. The Eocene of the 16. area (Štiavnica Mts.) and the Oligocene of the Hron valley (13. area, Fig. 2.) may have a junction toward the Buda Paleogene.

– The Transylvanian Paleogene basin is situated on the northern and eastern margin of the Tisza unit (Apuseni Mts.), SE from the Szolnok-Maramures Flysch belt.

Slovenia and N-Croatia (Fig. 3. column 1–2.) (after Drobne et al., 1985; Cimerman, 1979; Drobne, 1979; Šikić et al., 1979a, b; Rijavec, et al., 1979)

Eroded snatches of Middle and Upper Eocene limestones lay unconformly or tectonically upthrusted on the older rocks. The contact between the Eocene and Oligocene is also unconform. In Zagorje, the Oligocene series begins with fluviatile conglomerates. The overlying "Socka" beds consist of terrigenous rocks, coal seams and black fish-shale (NP 23 nannoplankton zone, Nagymarosy, unpublished data). The stratigraphic level of the shale coincides well with that of the Tard Clay in Hungary. The upper "Socka" beds were deposited in brackish lagoons and lacustric environment. North of Zagorje, as its lateral equivalent, the Gornji Grad beds were formed (2nd column), with fluviatile conglomerates on its base, and with large-foraminifera-bearing limestones and marls above it. Both series correspond to the NP 21-23 nannoplankton zones. The "Socka" and the Gornji Grad beds are uniformly overlain by the Kiscell Clay, which is very similar to the clay in the type-section, not only petrographically but also in its foraminifera-fauna and nannoplankton (NP 24 zone). The Smrekovec Andesite is interbedded into the upper portion of the Kiscell Clay. It is important to mention, that the transgression proceeded from the east to the west gradually (Kuščer, 1967), i.e. from the central part of the basin toward the margins.

The Upper Oligocene–Lower Miocene Govske beds usually lay unconformly on the older Oligocene beds. The Govske beds consist of marine terrigenous rocks with interbeddings of

Fig. 2. Paleogene basins and occurrences on the Pelso unit (NW part of the Carpathian realm). 1 – Upper Sava and Savinja valleys; 2 – Sava folds; 3 – South-Ivanšćica Mts., 4 – area between Drava and Mura; 5 – boreholes at Buzsák and Táska; 6 – continental sedimentation az Szigetvár (E_3 and O_2); 7 – North-Buda unit; 8 – South-Buda unit; 9 – Bükk unit area; 10 – Silica nappe region; 11 – Szolnok-Maramures flysch belt; 12 – East Slovakian Basin (M_1 near to Prešov); 13 – Hron river valley (Oligocene at Kordiky, Králiky, Závadka, Malachov); 14 – Nitra river valley (Lower Miocene at Velká Čausa); 15 – Váh river valley (Lower Miocene); 16 – buried Middle and Late Eocene at Ostrá Lúka and Banská Hodruša.

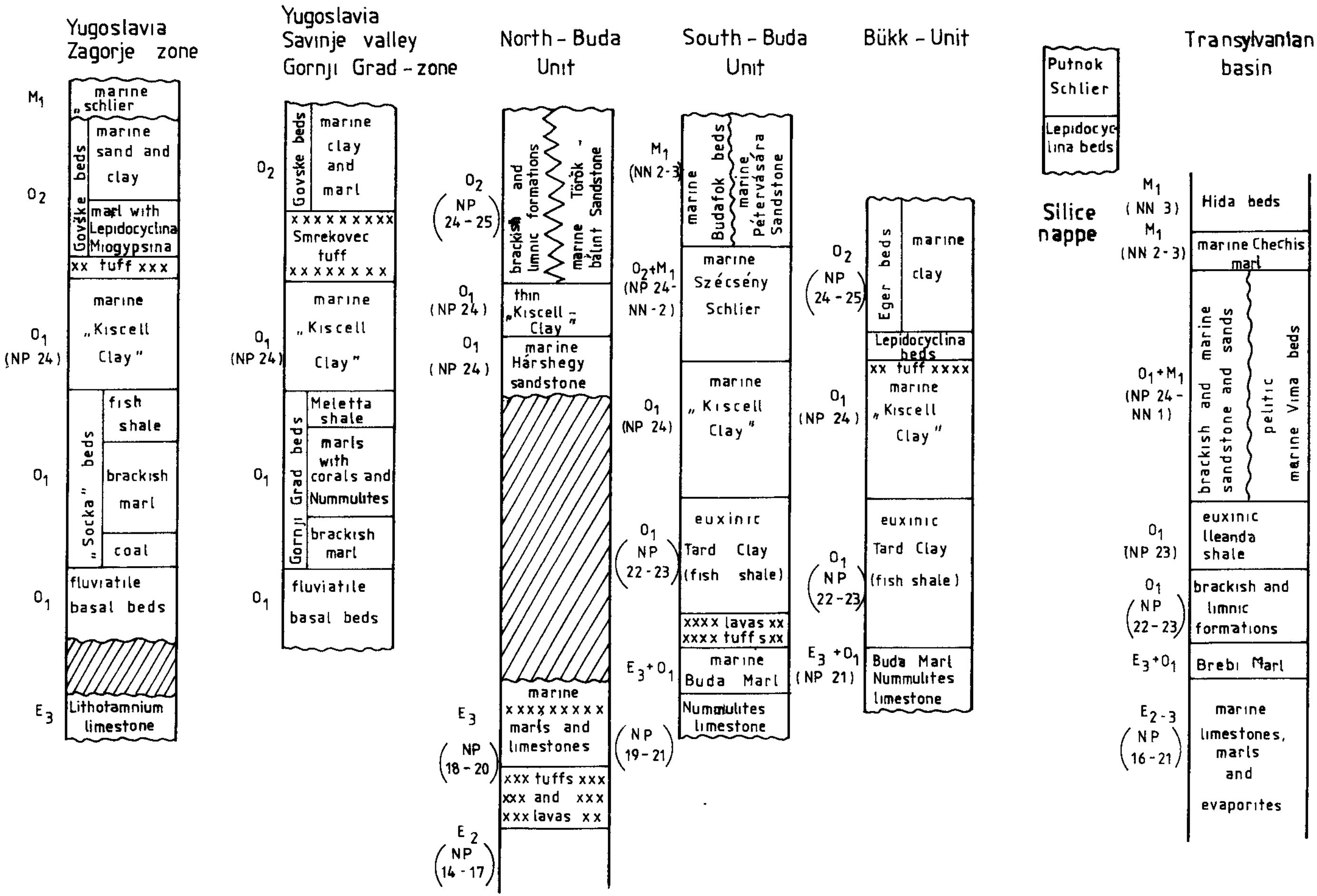

Fig. 3. Simplified stratigraphical columns of some Paleogene basins.

limestone, containing *Lepidocyclina* and *Miogypsina* formosensis (NP 25 zone, Nagymarosy, unpublished data). The series terminates with the brackish upper Govske beds.

The North-Buda Paleogene unit (Fig. 3, column 3) (Zala-basin, Bakony Mts., Gerecse Mts., NW-Buda Mts., S-Slovakian Paleogene W from Lučenec)

This type of sedimentation-area is separated from the S-Buda-type by the Buda line.

The formation of the N-Buda-type Paleogene series has begun in the Lutetian (nannoplankton zone NP 14, Báldi-Beke, 1984). The Eocene sea transgrading from the SW to the NE gradually, reached the NW-Buda Mts. in the NP 16 zone. There are conglomerates and paralic coal-seams on the base of the stratigraphic column, and these are overlain by a varied complex of carbonate rocks. The limestones transit into bathyal marls upwards, which show an additional deepening in the Upper Eocene. The andesite volcanism can be observed from the boundary of the Middle and Upper Eocene, its lavas and tuffs are widespread from the Zala basin until the Buda Mts. The Eocene sequence is finished by an erosional unconformity.

A new sedimentary cycle began in the younger part of the Early Oligocene (NP 23-24 nannoplankton zone-boundary). In the area of the NW-Buda Mts. and the Esztergom basin the coal-bearing Hárshegy Sandstone formation was deposited by the new transgression coming from the east. This formation is overlain by the thin Kiscell Clay. The transgressive Upper Oligocene sea moved further to the west until the S-Bakony Mts. In this sedimentary basin the heteropic formations of the limnic Csatka, the brackish Mány and the marine Törökbálint Sandstones were deposited. There is an erosional unconformity on the top of the Oligocene sequence.

The South-Buda Paleogene unit (Fig. 3, column 4) (SE-Buda Mts., E-Cserhát, Mátra Mts., S-Slovakian Paleogene E from Lučenec)

The Paleogene sedimentation begins in the stage Priabonian with nummulitic limestones and later by the deposition of the Buda Marl indicating the sudden deepening of the sedimentary basin (nannoplankton zone 19-21). The Buda Marl is overlain by the anoxic Tard Clay (NP 22-23) and this latter is covered by the extremely thick Kiscell Clay (800 m maximum thickness, NP 24 nannoplankton zone). The Szécsény Schlier lays conformly on the Kiscell Clay and this is followed by the several hundred meter thick Pétervására Glauconitic Sandstone. The schlier and the sandstone correspond to the stages Egerian and Eggenburgian. The sedimentary cycle was ending in the Ottnangian.

The earliest Paleogene volcanic activity of this area is known from the Priabonian–Early Kiscellian (Recsk, N-Mátra Mts.). Dacitic and andesitic tuffs and tuffites were observed in the upper part of the Buda Marl and in the whole Tard Clay (NP 21-23 zones). The volcanic activity was interrupted during the younger Oligocene and the Eggenburgian, and a new, large-scale volcanism occurred only in the stage Ottnagnian ("lower", Gyulakeszi Rhyolite Tuff).

The Bükk Paleogene unit (Fig. 3, column 5)

The sedimentation began in the Latest Priabonian, with nummulitic limestones and continued with the bathyal Buda Marl and the anoxic Tard Clay (NP 21-23 nannoplankton zones). This portion of the sedimentary column is very similar to that of the S-Buda unit.

Nevertheless, the thickness of the overlying Kiscell Clay is not so great as in the S-Buda area. Another distinction is, that there are volcanic interbeddings in the Bükk-type Kiscell Clay near to Fedémes, Bükkszék and Eger. Olistolith and turbidite interbeddings are very characteristic to the Kiscell Clay south of the Bükk Mts. The final part of the Oligocene sequence consists of the deep-sublittoral molluscan clay and the regressive brackish water beds of Egerian age.

A different kind of sedimentation is known on a small area north of the Bükk Mts.: thin snatches of Upper Eocene–Lower Miocene rocks are folded into the structures of the Rudabánya Mts. A thick sedimentary cycle began in the Earliest Miocene (NN 1 nannoplankton zone) on the margin of the Silice nappe. There is the *Lepidocyclina* and *Miogypsina* bearing Bretka Limestone on its base, and this is overlain by the marine Putnok Schlier in a thickness of 600 m. Also this sedimentary cycle was finished in the Ottnangian (Fig. 3, column 6).

The Szolnok-Maramures Flysch

Though this sequence is not an epicontinental one, it is worth to mention here because of its key-position. These poorly-known, petrologically variegated formations (Nádudvar Group) today have no direct connection toward the Buda and Bükk Paleogene areas. Its connection toward the Maramures Flysch is only probable. The depositional time of the flysch corresponds to the NP 14-17 (Nagymarosy, unpublished data) and NP 18-25 (Báldi–Beke at al. 1981) nannoplankton zones.

The Transylvanian Paleogene unit (Fig. 3, column 7)

First of all the NW part of this sedimentary basin is well-studied, because it crops out to the surface. Some more recent drillings proved the occurrence of Paleogene rocks over the basement of the young subsidences, too.

The Middle Eocene sequence consists of neritic limestones, marls and evaporites (NP 16-21 zones). The overlying Breb Marl is overlapping the Eocene–Oligocene boundary. Brackish and limnic formations represent the deeper part of the Lower Oligocene on the margins of the basin, while more to the north, the anoxic Ileanda Shale was deposited in the offshore zone of the basin. This difference between the southern, nearshore and the northern, more pelagic formations is traceable also in the Upper Oligocene. The Lower Miocene transgression deposited the deep-sublittoral Chechis Formation, while the following regression deposited the Ottnangian Hida Beds.

There are several evidences on the connection between the Transylvanian Paleogene basin and the Maramures Flysch zone (Bombita, 1972).

Some small intramontan basins in the Carpathians had an evolution differing from the Transylvanian Paleogene basin during the Oligocene (e.g. Petrosani).

Comparing the sedimentation-history of the above-mentioned areas it is striking, that though each basin has an individual character, yet a number of similar events and formations appear in their history. The other important moment is, that the lines separating the Paleogene basins coincide with tectonical zones, with sharp changes in the facies and the formation-boundaries are marked off often by pelagic sediments.

Similarities and discontinuities in the Paleogene formations

Similarities

a) The Middle and Upper Eocene limestones with large foraminiferas seem to be very similar from North Italy through Slovenia and the Bakony Mts. until the Buda Mts. It means not only petrological similarities, but also a high percentage of common faunal elements and an almost full concordance of the large foraminifera zonations (Garavello et al., 1982; Kecskeméti, 1980). This may be the consequence of the free sea-ways, where the *Nummulits* and *Discocyclinids* might migrate in their favourable shelf-milieu without strong filters and barriers. These migrations would be unimaginable among the conditions of the recent geography of the Eocene basins. There is a greater difference between the foraminifera faunas of the Transylvanian Paleogene basin and the Buda unit, which may be due to their paleogeographic position. According to our theorie, the N-Buda Paleogene unit and Transylvania were separated by the Szolnok-Maramures Flysch belt and the deep-water conditions did not favour to the migration of the benthic large foraminiferas.

b) The Lower Oligocene Tard Clay is the product of an anoxic event, which occurred from the foredeep molasse of the Alps until the Aral Sea. This black shale is known from the Bükk and S-Buda Paleogene units, but its equivalents were described from Slovenia and from the drilling of Táska-4, S of the Balaton line (Fig. 4). A very similar formation is the Transylvanian Ileanda Shale, too. The age of the anoxic event is the same in all of the above-mentioned epicontinental basins, but it can be well correlated with the anoxic events in the Alpine foredeep molasse, the Carpathian Menilite Series and the black shales of the Majkopian Sea in the S-Soviet Union, too. An important evidence of a continuous "Tard Sea" is the occurrence of the endemic mollusc fauna *Cardium lipoldi,* that is known from the Slovenian, S-Buda, Bükk and Transylvanian Paleogene units and even from the Austrian molasse (Báldi, 1983, 1986, 1989). The monospecific nannoplankton floras, characteristic to the Tard Clay were found also in the Szolnok Flysch and in the Menilite and Majkop series. It proves, that rather free seaways existed in the Lower Oligocene among these, recently distant areas, and the same plankton assemblages could "conquer" the Forealpine, Carpathian and Majkopian basins.

c) The bathypelagic Kiscell Clay and its characteristic benthic foraminifera fauna is widespread in the Bükk, N- and S-Buda Paleogene units as well as in Slovenia (Kuščer 1967) or in the Croatian Ivanšćica Mts. (Šikić 1985).

d) The andesitic-dacitic volcanism having started about at the boundary of the Middle and Upper Eocene produced its lavas and tuffs along the Balaton line, from Zala through the Velence and Buda Mts. The Lower Oligocene beds of the S-Buda Paleogene units contain thin layers of tuffs, too. The Upper Eocene Recsk Volcanic Complex can be found at the western side of the Darnó line, which may be a lateral arm of the Balaton tectonical zone (Fig. 1).

e) The andesitic lavas and tuffs of the Smrekovec Volcanic Complex in Slovenia have the same stratigraphic position and age (Jelen et al., 1980; NP 24 nannoplankton zone) as the tuffs at the Kiscellian/Egerian boundary in the Bükk Paleogene unit (Eger, Bükkszék, Fedémes). Though they are not properly dated, however we have to correlate the volcanic complexes of Sári and Bugyi (SE to Budapest) with this Oligocene volcanism (Fig. 1).

Discontinuities along the tectonical zones

a) The Slovenian and N-Croatian Upper Eocene–Lower Miocene sedimentary basins extend south from the Mid-Hungarian line or they are located in its wider zone. The

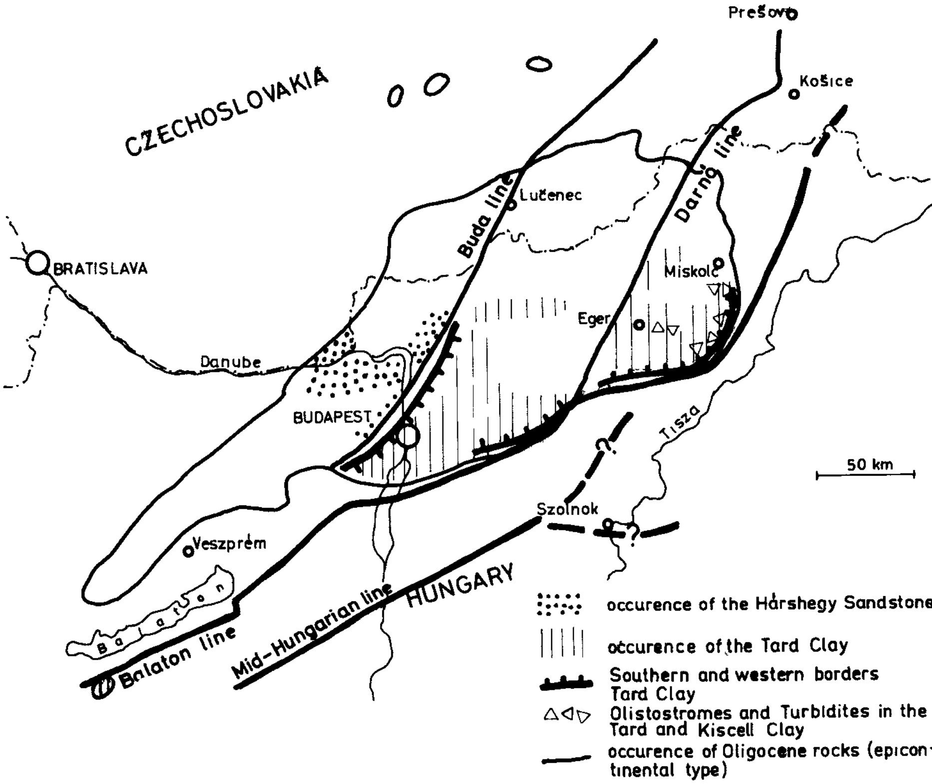

Fig. 4. Occurrence of some Lower Oligocene formations in the Bükk, North and South-Buda Paleogene units.

documentation of the geological maps shows that the Upper Eocene–Lower Oligocene formations are confined only South of this zone.

b) The Balaton line cuts from north the Upper Oligocene–Lower Miocene sedimentary basins of the Drava and Mura valleys (Figs. 1, 2).

c) The Bükk, N- and S-Buda Paleogene units are bordered in the south by the Balaton line. The bathyal Tard and Kiscell Clays and the deep-sublittoral Szécsény Schlier and Eger Clay have an abrupt ending along this line, without nearshore sediments. One has the impression that the Oligocene-sea "had no shore" southward (Figs. 4, 5).

d) Several discontinuites are bound to the Buda line. The Transdanubian Middle Eocene formations extend only until this tectonical zone. The Upper Eocene formations can be found in both sides of the line already. In the western side of the Buda line there was no sedimentation during the early Lower Oligocene. Some hundreds of meters from the line to the east, the 100 m thick anoxic, bathyal Tard Clay occurs which does not contain significant amount of terrigenous debris or sand (Fig. 4). The Hárshegy Sandstone was deposited at the beginning of the Upper Kiscellian transgression in the western side of the Buda line (Fig. 4). This has a sharp boundary along the line with the bathyal Kiscell Clay corresponding in age to the Hárshegy Sandstone. The thickness of the Kiscell Clay in the eastern side of the Buda line is 8–10 times so much as that of on the western side of the line.

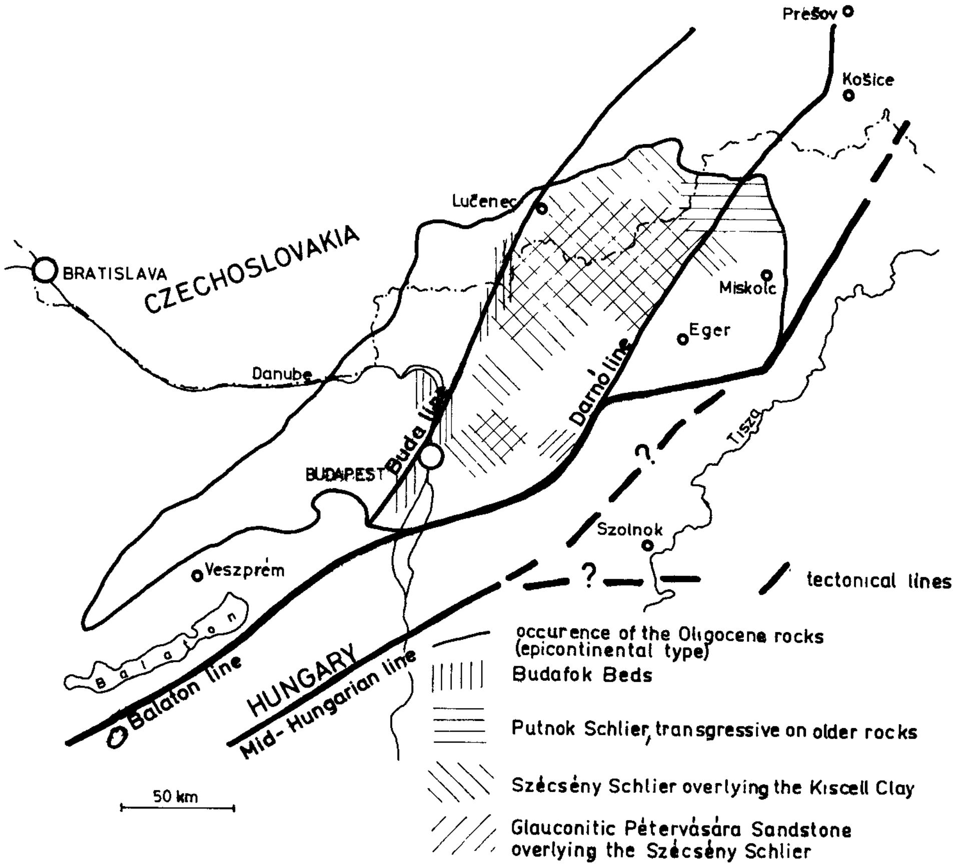

Fig. 5. Occurrence of some Upper Oligocene and Lower Miocene formations in the Bükk, North and South-Buda Paleogene units.

e) The Upper Oligocene marine, littoral Törökbálint Sandstone and the marine and brackisch Kovačov Formation do not cross the Buda line. The Eggenburgian Budafok beds with large *Pectinids* occur exclusively only in the zone of the Buda line. Its occurrences in Buda and in the Cserhát Mts. suggest, that these were separated from each-other and transported to their recent position by a 30–40 km long transform fault (Fig. 5).

f) The silicification of the Hárshegy Sandstone was observed only along the Buda line, presumably due to postvolcanic activity (Báldi–Nagymarosy, 1976).

g) There are sharp changes in the facies also on both sides of the Darnó line. The anoxic Tard Clay of the eastern side is unknown on the western side of the line (Fig. 4). It is substituted in Recsk by tuffs and volcano-sediments. The Upper Oligocene–Lower Miocene is represented on the western side of the line by the Szécsény Schlier and Pétervására Sandstone, while on the eastern side there is a hiatus, or more to the north, the Lower Miocene, pelitic, deep-sublittoral Putnok Schlier occurs. The narrow Darnó zone itself differs from both previous areas, where the full Paleogene sequence is missing, and the thin coarse-grained Darnó Conglomerate was deposited in the stage Eggenburgian. By the way, the Pétervására Sandstone does not "step over" the Darnó line (Fig. 5). The coal-bearing Ottnangian beds of the eastern side are not known on the western side of the line. Only the Badenian formations cross the Darnó zone.

The relatively straight southern boundary of the Paleogene formations in the South-Buda Paleogene unit has a break in the Jászberény-Nagykáta-Kerecsend line and it is continuing more to the North toward its original direction. According to our interpretation this shape of the southern boundary is due to a 30–40 km lateral displacement along the sinistral Darnó fault (Figs. 4, 5).

Restoration of the Oligocene paleogeography – timing

To get the Oligocene paleogeographical map of the Carpathian region one must make a number of re-arrangements of tectonical units.

1) By the re-folding of the outer Carpathian nappes the whole rigid Intracarpathian block (Tatrids, Gemerids, Veporids, the Hungarian "inselbergs") must be pulled back into a southwestern direction. Thus, a wide belt of the flysch-seas (or "oceans") will extend from the Alpine molasse zone through the Carpathians until the Getic and Bucovinian units.

2) The Adria plate and the front of the Dinaric nappes have to be re-rotated into a western direction.

3) The Transdanubian range (Bakony etc.), the Bükk, the Western Carpathians need a clockwise rerotation, while the Eastern Austroalpian nappes need a slight and the Tisza unit (Mecsek Mts., S-Pannonia) a significant re-rotation into counter-clockwise direction. We have no reliable Tertiary paleomagnetic data from the S-Alps. All these rotational transformations are explained in details by Balla (1984) and Mauritsch et al. (1987).

Báldi (1983) proposed first for the pre-Egerien times to push back the Bükk unit to the Slovenian Paleogene basins along the Balaton line. Kázmér (1984) and Kázmér – Kovács (1985) supposed, that the whole Bakony + Bükk unit was in the neighbourhood of the Karavanken and the Julian Alps. This theory fits the best also to our paleogeographical conception. (To this transformation a number of evidences were enumerated in the previous chapters.) The necessary space to this rearrangement can be delivered by the pushing back of the Adria plate.

The Fig. 6 shows that two kinds of tectonical lines are supposed in the Late Paleogene in the southern part of the Intracarpathian block.

There are two lines of *primary significance:* The Balaton and the mid-Hungarian lines, both dextral. These transcurrent faults caused the large-scale wandering of the North-Buda (Bakony Mts.), South-Buda and Bükk Paleogene units and maybe even of other parts of the large Intracarpathian block. The start of the fault activity must have been in the Late Eocene, when the first deep-subsidences were formed along the Balaton fault-zone. If our evidences seem to be convincing and we replace the Bükk Paleogene unit into the neighbourhood of the Gornji Grad zone, then the dimension of the movement is between 2–300 kms. We cannot estimate the dimension of the movement along the mid-Hungarian line exactly, but if we suppose, that the Buzsák Paleogene is a snatch detached from the Slovenian Paleogene, than the northeastward movement of this zone is about half as much as that of the Balaton line. The rather narrow appearance of the belt between the two primary faults may be due to a Middle (or Late) Miocene folding having caused the spatial shortening of this zone (Sava folds and its continuation in the Drava and Zala depressions). As we pointed out, the beginning of the primary fault activity can be put as early as the Late Eocene, but the significant part of the dislocation happened after the Egerian or even after the Eggenburgian. This is supported by two facts:

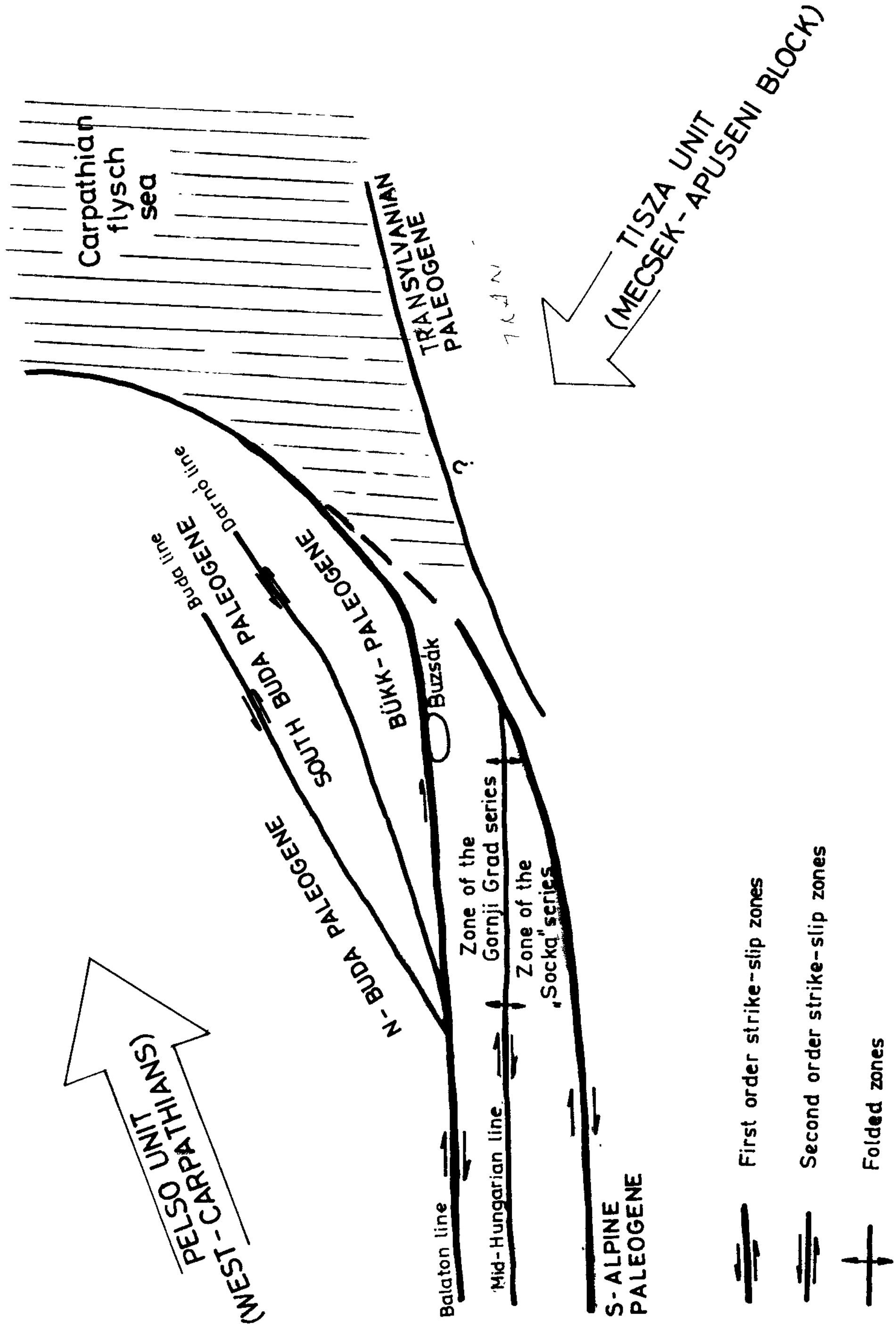

Fig. 6. Sketch of the reconstruction of Paleogene sedimentary basins in their position in the Early Oligocene.

a) The highly similar events in the Kiscellian (anoxic event in the Lower and transgressive event in the Upper Kiscellian) created so similar formations in all Paleogene units, that these might not be too far from each other in the moment of their genesis.

b) The Egerien (and sometimes also the Eggenburgian) occurrences are cut by the Balaton line: from the south in N-Hungary and from the north in Slovenia.

The Buda and Darnó lines may be a type of tectonical zones of *secondary importance*. Their common features are:

a) The small-scale dimension of the movements along the fault-system. As it was estimated in chapter 3, the distance of the movement might have been about 30–40 kms sinistral.

b) The parallel angle and shape.

c) Both have sharp changes in the facies of the Paleogene on their opposite sites. (In contrary of this, there is no facies-change on the opposite sides of the primary tectonical lines: opposite of the Paleogene there is usually no Paleogene.)

However, the Buda and Darnó lines have different features, too:

a) There is a strong post-Oligocene compression along the Darnó line. At Bükkszék, Permian–Triassic rocks have been upthrusted onto the Oligocene sequence. At the Rudabánya Mts. some slight compression occurs as late as the Pannonian (Late Miocene). In the zone of the Buda line no strong compressional processes were detected so far.

b) The construction of the Buda line is relatively "simple", comparing to that of the Darnó zone. The rocks of the Darnó zone are more complex in their facies and their age (from the Paleozoic to the Tertiary).

c) The age of the tectonic acitivity in the Buda line-zone is not younger, than Ottnangian. The Karpatian facies zones already cross the Buda line. In the Darnó zone only the Latest Karpatian–Early Badenian formations are similar on both sides of the Darnó line. As Balla suggested, the Darnó movements have left their marks on the Middle Miocene Mátra-volcano too.

d) No Paleogene volcanic acitivity is known along the Buda line, but in contrary of this, a significant volcanic complex is located in Recsek, on the eastern side of the Darnó zone. This situation suggests, that the Darnó zone may be a continuation (lateral branch?) of the Balaton line, rich in Paleogene volcanoes.

Our general impression is, that while the Buda line existed only through a rather short periode, until the complexity and long-term acitivity of the Darnó line admits to suppose, that the beginning of the movement along the Darnó line might have started earlier, than it was previously thought and the dimension of the movement might be greater. In this case, on the Fig. 6 the wedge-shaped Bükk unit ought to be placed more to the southwest, i.e. nearer to the Dinaric-South Alpine belts. The Darnó would be a part of the Balaton line during the Paleogene and the virtual displacement of the fault (30–40 km) would be caused only by the post-Egerian faulting (Figs. 4, 5).

Trying to put the elements of this Paleogene jig-saw puzzle on their original place we concluded to the following paleogeographical pattern:

The Paleogene basins of the Intracarpathian area might be a lateral epicontinental extension of the large flysch-sea. Exchange of plankton-rich water masses and even of benthic faunal elements was possible through this sea, toward the Majkop Sea (in the Early Kiscellian) and toward the Rhine graben – North Sea (Late Kiscellian). This row of epicontinental basins might have a junction also toward the Mediterranean Tethys during the Middle and Late Eocene permanently. The Mediterranean connection was stopped for the Early Kiscellian and was renewed only in the Late Kiscellian. We suppose, that this connection has stopped again after the Early Ottnangian.

The position of the Paleogene basins might have been from the north to the south as follows (Fig. 6):

– North-Buda unit with a maximum deepening and sediment accumulation in the Eocene. It has a marginal position in the Oligocene (hiatuses!).

– South-Buda unit with a maximum deepening in the Kiscellian (almost complete sequence during the Late Eocene–Early Miocene).

– Bükk unit with a maximum deepening in the Kiscellian and Egerian. The resedimented olistostroms and turbidites show, that this was the deepest belt of the epicontinental sea (almost complete sequence during the Oligocene–Early Miocene).

– Gornji Grad zone with a rather complete Oligocene–Early Miocene sequence. It shows a shallower character than the Bükk unit.

– Zone of the "Socka" series, more marginal than the Gornji Grad zone (hiatuses).

– Brackisch-marine Egerian south from the Ivanšćica Mts.

The Transylvanian Paleogene basin is supposed to be located on the southern margin of the flysch-sea, at such a distance, which made the faunal exchange possible.

Among these paleogeographical conditions the acitivity of the long transform faults started in the Late Eocene. Along the two fault systems a row of deep basins developed in the Kiscellian stage. A northeastward progression of the subsidences can be observed (Báldi, 1986): The maximums ot the Eocene sediment accumulation (Zala-basin) wandered in space and time and reached the northern margins of the S-Buda and Bükk units and also the Mura-Drava region by the Early Miocene. The maximum of the fault-displacement might have taken place in the Late Egerian and Eggenburgian. The process might have stopped in the Ottnangian or in the Karpatian. The Buda and Darnó tectonical zones had their maximum acitivity after the Eggenburgian. They break the contours of the Balaton line, thus proving their younger age.

The northeastward moving of the Pelso unit resulted in a compressional zone at its contact with the Tisza unit. A long belt of the Szolnok Flysch has been pinched in and upthrusted onto the Tisza unit. The youngest nannoplankton datum from the flysch is NP 25, Upper Oligocene, so the process must have taken place in the Lower Miocene, as the earliest.

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