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The origin and disappearance of Hungarian Paleogene Basins and short-term Lower Miocene Basins in Northern Hungary and Southern Slovakia

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Abstract: The Hungarian Paleogene basins generated in the area of the Western Carpathian - Northern Hungarian terranes before and during their tectonic escape from the Alpine domain as the consequence of the convergence of Afro-Arabian and Eurasian lithospheric plates. The basins disappeared after the main escape movements. Later on, two short-term basins - Fiľakovo/ Pétervására and Novohrad/Nógrád - replaced the previous ones with regional uplift in- between. Uplift was caused by initial lithospheric stretching as a result of astenosphere rise. The whole process of the tectonic escape finished by counterclockwise rotation (end of the Lower Miocene). The last pulse of the rotation was contemporaneous with the disappearance of the last Lower Miocene basin in the area studied.

Key words: tectonic escape, Hungarian Paleogene basins, Fiľakovo/Pétervására and Novohrad/Nógrád basins, strike slip movements, horizontal rotation, remanent paleomagnetic declination.

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During the Paleogene and Lower Miocene, the convergence of Afro-Arabia and Eurasia (ZIEGLER, 1988) provoked the collision of the Apulian promontory with the Bohemian Massif and subduction in the Outer Carpathians. The suction, or pull in front, caused by the subduction and push-behind exerted by the collision, led to tectonic extrusion, forcing the escape of the Western Carpathian - Northern Pannonian terranes from its home in Central Alps and Dinarides. The escape was driven to the east or north-east into the present Intra-Carpathian region (BALLA, 1984, KÁZMER and KOVÁCS, 1985, BÁLDI, 1986, NEUBAUER and GENSER, 1990, RATSCHBACHER et al., 1991a,b, CSONTOS, et al., 1992, and others) or, according to paleomagnetic evidences, to the Southeast (MÁRTON, 1933). The displacement was as large as 400 km (e.g. KÁZMER and KOVÁCS, 1985). The escape was in the Outer Carpathians compensated by the closing of Flysch troughs and by shortening of the space (i.e., by thrusting).

To the NE escaping Western Carpathian - North Pannonian terranes were confined in the south by a right-lateral shear zone with two important faults (Balaton and Mid-Hungarian lines) and in the north by the Peripieniny fault belt, with left-lateral shear (Fig. 1). Particular blocks between both limiting shear zones were confined by faults of wrench nature. The wrench faults caused opening of basins on both sides of the escaped terrane: the Hungarian Paleogene Basins (HPBs), North and South Buda units in sense of NAGYMAROSY (1990) (Fig. 3a) in south (Fig. 2) and Central-Carpathian Paleogene basin in north. Deposition centres of these basins migrated from west to east (GROSS et al., 1984, BÁLDI and BÁLDI-BÉKE, 1985, BÁLDI, 1986). The HPBs are recently interpreted as retroarc flexural foreland basins (TARI et al., 1992, TARI and SZTANÓ, 1993), but the main argument for such a model - evidence of back-thrusting of the Western Carpathians during the Paleogene, is missing yet.

The gently to the NW dipping reflectors in the pre-Tertiary basement of the Danube Basin (Slovakian part) interpreted as Alpine thrust planes reactivated during the Middle Miocene as low-angle normal faults (TOMEK and THON, 1987), are considered to be SE-vergent thrust planes by TARI et al. (1992). Those reflectors may be in fact thrust planes, but with by the Neogene uplifts overturned inclinations from SE to NW, as it is well visible everywhere on the northern flanks of the Central Western Carpathian "core" mountains (Vysoké and Nízke Tatry Mts., Veľká and Malá Fatra Mts., Tribeč Mts. etc.). The Hurbanovo-Diösjenö line is interpreted (Fig. 1) as to the NW steeply dipping and SE - vergent major thrust belt (TARI et al., 1992). More recent magnetoteluric measurements across the Hurbanovo line (VARGA in DŽUPPA et al., 1993) lead to the conclusion that the line is inclined more gently to the SE, so it can be a NW-vergent thrust fault (see also HORVÁTH, 1993).

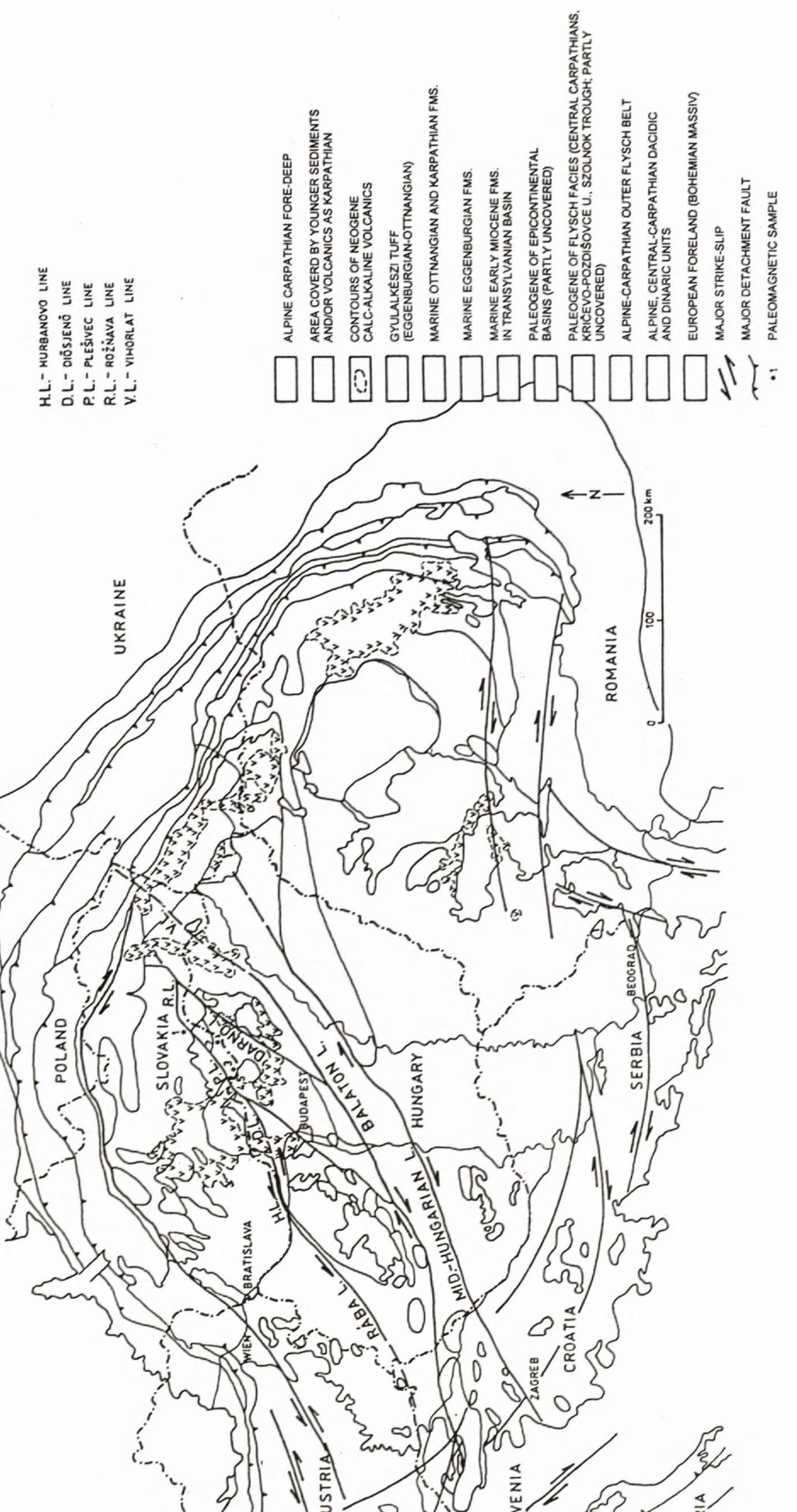

Fig. 1 Geological sketch map of the Carpatho-Pannonian region

The tectonic escape of the Western Carpathian - Northern Pannonian terranes had not only lateral movements, but also the escaping terrane was thrust above a unit equivalent to Penninicum in the Alpine domain. The thrusting is dated as Eocene, or post-Eocene, because the Krichevo-Iňačovce unit with the youngest sedimentary formation Eocene in age, considered an equivalent of Penninicum, is emerging from beneath the Western Carpathian pile of nappes at the floor of the East Slovakian Basin (SOTÁK et al.,1993).

The HPBs are of pull-apart origin (BÁLDI and BÁLDI, 1985, BÁLDI, 1986). Their development was not continuous. The onset of sedimentation was diachronous. Sea transgression was coming from the SW (DUDICH, 1977, DUDICH and KOPEK, 1980) after a long period of subaeral exposure, when karst-bauxite deposits were formed. The sedimentation started in the Carinthian Bay earlier (during the Cuisian) than in the Bakony bay inundated by a shallow sea during the Lutetian. The sea reached the Buda line (BÁLDI, 1986), or facial boundary (TARI et al.,1992). The transgressive progradational sequence started by coarse terrigenous clastics of the Darvastó Formation, graded upward into the neritic limestone of the Szöc Formation (Fig. 4). By the end of the Lutetian the sea became deeper (800–1200m) and bathyal marlstone of the Padrag Formation deposited, having in the upper part distal turbiditic intercalations (TARI et al.,1992).

During the Bartonian the sea transgression reached the NE part of the Bakony and NW part of the Buda (Fig. 4) units, starting with the thick paralic coal-bearing Dorog Formation indicating a humid climate. Later on, the Dorog Fm. was overlain by clastics of the Tokod Formation, neritic limestone of the Szépvölgy Formation and by the bathyal marlstone of the Piszke and/or Buda Formations respectively, with calciturbiditic intercalations. The Szépvölgy and Buda Formations spread further to the NE, covering the whole Buda and NW part of the Bükk units (TARI et al.,1992, for present position of the particular basement units see Fig.3).

During the Eocene the opening of the basins and their subsidence were controlled by a dynamically transforming paleostress field. FODOR (1992), based on brittle deformations study in the Central Hungarian Range (in Buda and Gerecse Hills), assumed the existence of a compressional paleostress field during the Eocene. In such a stress field there were generated antiforms, dextral strike-slips and normal faults. Still during the Eocene the paleostress field changed. Compression was replaced by extension (BERGERAT et al.,1984).

Paleogeographic evidence shows that during the Lutetian the Bakony unit was far away and well separated from the Carpathian Flysch, Central Carpathian or Podhale Flysch seas and Transylvanian sea. Lutetian fauna from Bakony is similar to fauna from Carinthia and both faunas have strong affinity to North Italian faunas, while the faunas of Podhale and Transylvania are rather different (BÁLDI, 1986 and KECSKEMÉTY, STRAUSZ, KÖRMENDI fide BÁLDI, 1986). The coal seams of Dorog Fm. (Bakony) and Carinthian coeval coals indicate humid climate, while the evaporites in the Lutetian of Transylvania indicate an arid one (BÁLDI, 1986). However, in the late Lutetian and early Priabonian the distance between the Bakony sea and Podhale sea shortened due to lateral translations inside the escaping terranes, the paleogeographic barriers, likewise, were suppressed and a sea strait via Krupina – Zvolen opened to connect both areas (VASS et al.,1979).

During the Oligocene the Bakony and partly Buda units were uplifted and underwent an "Infra-Oligocene denudation" (TELEGDI-ROTH, 1927). Meanwhile in the SE part of the Buda unit and NW part of the BÜKK unit an euxinic sea persisted during the early Kiscellian and a clay sequence of Tard Formation deposited there (BÁLDI, 1986).

During the late Kiscellian the sea rapidly invaded the Buda, Bükk and even Veporic and Gemeric units including Silicicum, Turnaicum and Meliaticum in the area of Ipeľ, Lučenec and Rimava depressions, S. Slovakia (Fig.3b). The sea transgression far to NE (in present day co-ordinates) was facilitated by lateral tectonic approach of the Bakony and Buda units to other above mentioned units. The transgression is marked by an extensive sheet of coarse clastics with coal seams (Harshegy Sandstone; Blh and Hostišovce members of the Číž Formation; BÁLDI 1986, VASS and ELEČKO, 1982) signalising again a humid climate. The southward wandering of boreal fauna indicates cooling (CAVELIER, 1979, fide BÁLDI, 1986). Coarse clastics grade into bathyal claystone/siltstone of the Kiscell Clay with turbiditic intercalations and Lenartovce member of the Číž Formation (HANTKEN, 1868, BÁLDI, 1986, VASS and ELEČKO et al.,1989,1992). At the end of the Kiscellian there was a regressive event marked by the basinward shift in facies and by prograding deltas (e.g. Rapovce delta in the Lučenec depression S. Slovakia, VASS and ELEČKO et al., in lit.).

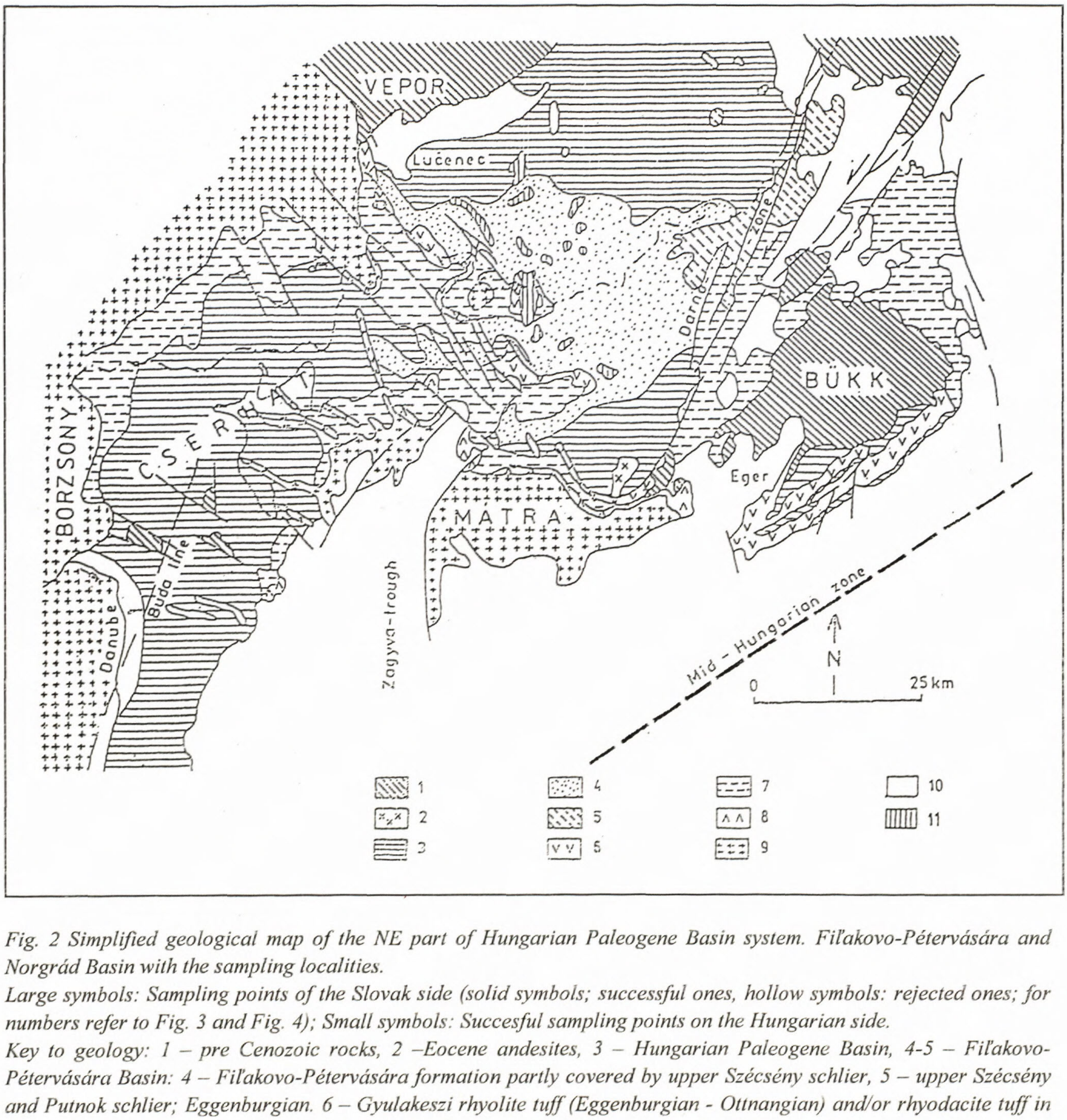

Fig. 2 Simplified geological map of the NE part of Hungarian Paleogene Basin system. Fiľakovo-Pétervására and Norgrád Basin with the sampling localities.

Large symbols: Sampling points of the Slovak side (solid symbols; successful ones, hollow symbols: rejected ones; for numbers refer to Fig. 3 and Fig. 4); Small symbols: Succesful sampling points on the Hungarian side.

Key to geology: 1 – pre Cenozoic rocks, 2 –Eocene andesites, 3 – Hungarian Paleogene Basin, 4-5 – Fiľakovo-Pétervására Basin: 4 – Fiľakovo-Pétervására formation partly covered by upper Szécsény schlier, 5 – upper Szécsény and Putnok schlier; Eggenburgian. 6 – Gyulakeszi rhyolite tuff (Eggenburgian - Ottnangian) and/or rhyodacite tuff in Bukovinka formation (Eggenburgian), 7 – Nógrád - Novohrad Basin. Ottnangian and Karpathian; 8 –" middle rhyolite tuff" and/or Tarr tuff; upper Karpathian - lower Badenian, 9 – Middle (and upper) Miocene vulcanics, 10 – Middle to upper Miocene sediments, 11 – Upper Miocene to Pleistocene basalts

The Egerian marine transgression did not enter the Bakony unit and an alluvial, continental sequence - Csatka (or Mór) Gravel (BÁLDI, 1969, see Fig.4) was deposited there. The marine transgression was directed to the NE (present-day co-ordinates), giving the largest extension of the HPBs to the NE. The transgression exceeded the northern margin of the Kiscell Clay/Číž Fms. Shallow marine clastics of the Panica member, Törökbálint and Eger Sand/Sandstones, (VASS and ELEČKO, 1982, BÁLDI, 1969) and organodetritic carbonatic rocks of the Budikovany member (VASS & ELEČKO, 1982) gradually and laterally pass into bathyal siltstone of the Szécsény Schlier (BÁLDI, 1971, HÁMOR, 1985). Some Miogypsinas and Mollusc taxa occurring in the already mentioned Budikovany member and in the Bretka limestone - a littoral facies of the Szácsény Schlier (SENEŠ in STEININGER et al., 1975) - indicate an increase of southern influence and warming of the climate, particularly during the early Egerian (BÁLDI, 1986). The end of the Egerian is marked again by a regression (BÁLDI, l.c.) with prograding deltas (e.g. Opatová delta in the Ipeľ depression, S. Slovakia, ŠUTOVSKÁ-HOLCOVÁ et al.,1993, Kováčov Sand in Štúrovo Paleogene, SENEŠ, 1958, BÁLDI, 1969). In this time the Bakony unit continued to be subaerally exposed with continental deposition (Csatka gravel). On the NW periphery of the HPBs a sebhka persisted during the Oligocene (Fig.5), indicating a drastic change of climate from humid (early Kiscellian) to arid (VASS et al.,1979). The sebhka deposits of the

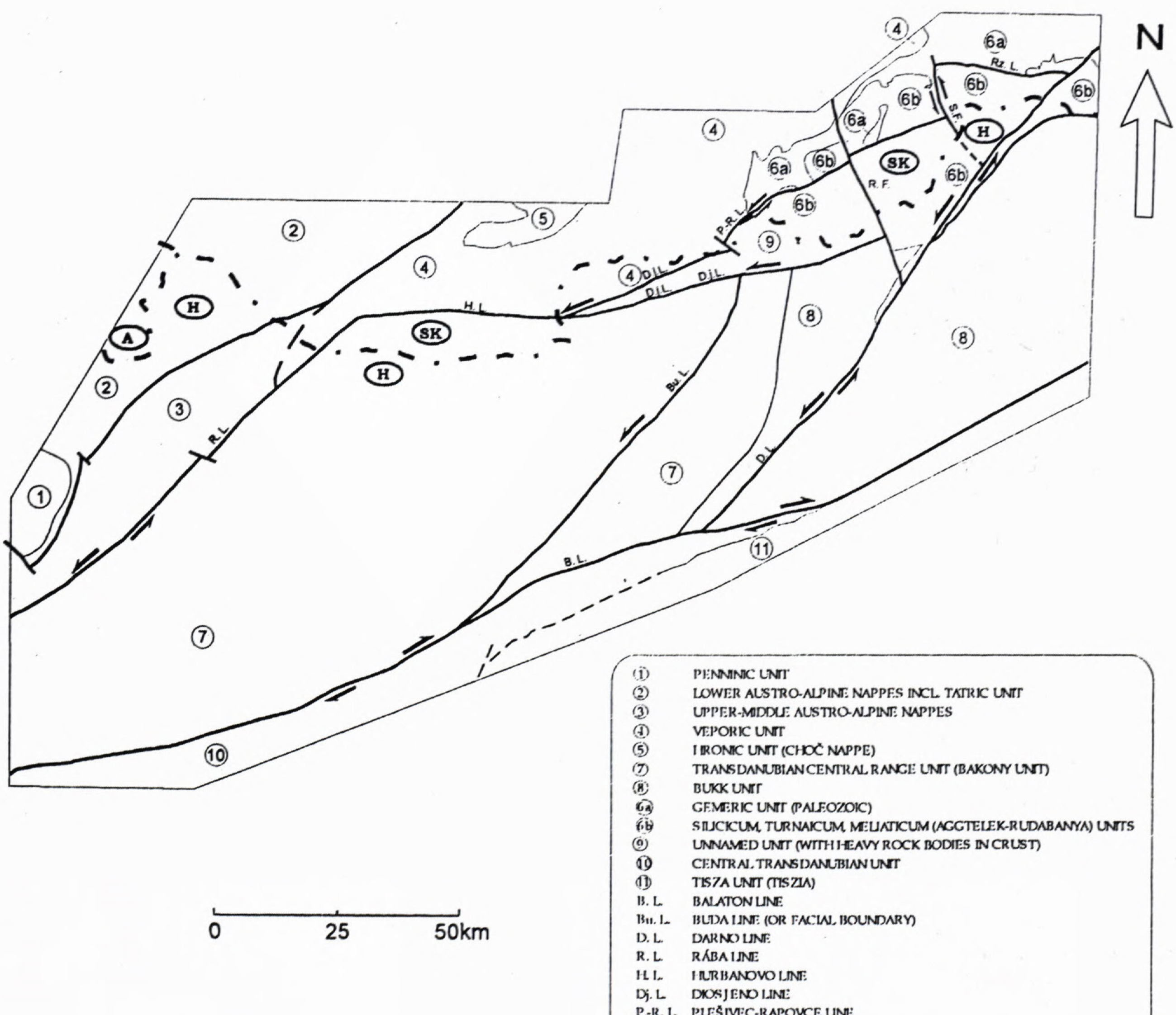

Fig. 3 Scheme of the Inner Western Carpathians (per partim) and Northern Pannonian terrane units built by pre-Tertiary rocks. Compiled by the author on the basis of FUSÁN et al.,1987, DANK and FŰLÖP et al.,1990

Krupina Formation are presently buried by sediments of the Lower Miocene and by Middle Neogene volcanics of Krupinská planina Plateau (Fig.3b). During the Egerian, the climate gradually deteriorated (cooling).

Concerning the paleostress field at the end of the Paleogene and very beginning of the Neogene, compression rotated from vertical to horizontal position. Such stress field produced or rejuvenated the normal faults controlling during the Kiscelian and Egerian the deposition in the partial South Slovakian depressions, particularly in the Rimava depression (VASS et al.,1993, VASS and ELEČKO et al.,1989). After the Egerian, the Plešivec - Rapovce fault belt (PLANČÁR et al.,1977, VASS and ELEČKO et al.,1992) with sinistral strike-slip movements was generated or revived (VASS et al.,1993). In South Slovakia these left-lateral motions caused the last tectonic approach of the Veporic unit to an unnamed unit having heavy rock bodies in the crust (VASS and ELEČKO et al., in lit., see Fig.3). On the surface these motions caused tectonic redistribu tion of Číž and Lučenec Formation along the Plešivec - Rapovce wrench fault (VASS et al.,1993).

On the southern margin of the escaped terranes, there is a well-documented right-lateral shear on the Balaton line, separating the Slovenian Basin and HPBs by approx. 300 km (NAGYMAROSY, 1990, CSONTOS, et al., 1992, see Fig.6). The shearing is dated as post-Egerian.

After the large lateral displacement the HPBs disappeared and from the beginning of the Eggenburgian they were replaced by the Fiľakovo/Pétervásara Basin (Fig.2) with a paleogeographic configuration of a bay (North Hungarian Bay, SZTANÓ, 1994). The mechanism of the basin opening was fairly similar to the HPBs, but the conditions changed essentially. The connection with the Mediterranean through the Slovenian strait (RÖGL and STEININGER, 1983, BÁLDI, 1986, HÁMOR et al.,1988) was closed and the lateral extension of the basin was reduced. The basin - bay opened by the sea ways to the NE (BÁLDI, 1986, SZTANÓ, 1994) and to the N, NNW (in present co-ordinates). On the margins of the basin deposited shallow-water clastics in the tide-dominated coastal environment of the Fiľakovo and/or Pétervásara Formations (SENEŠ in ANDRUSOV, 1965, HÁMOR, 1985)

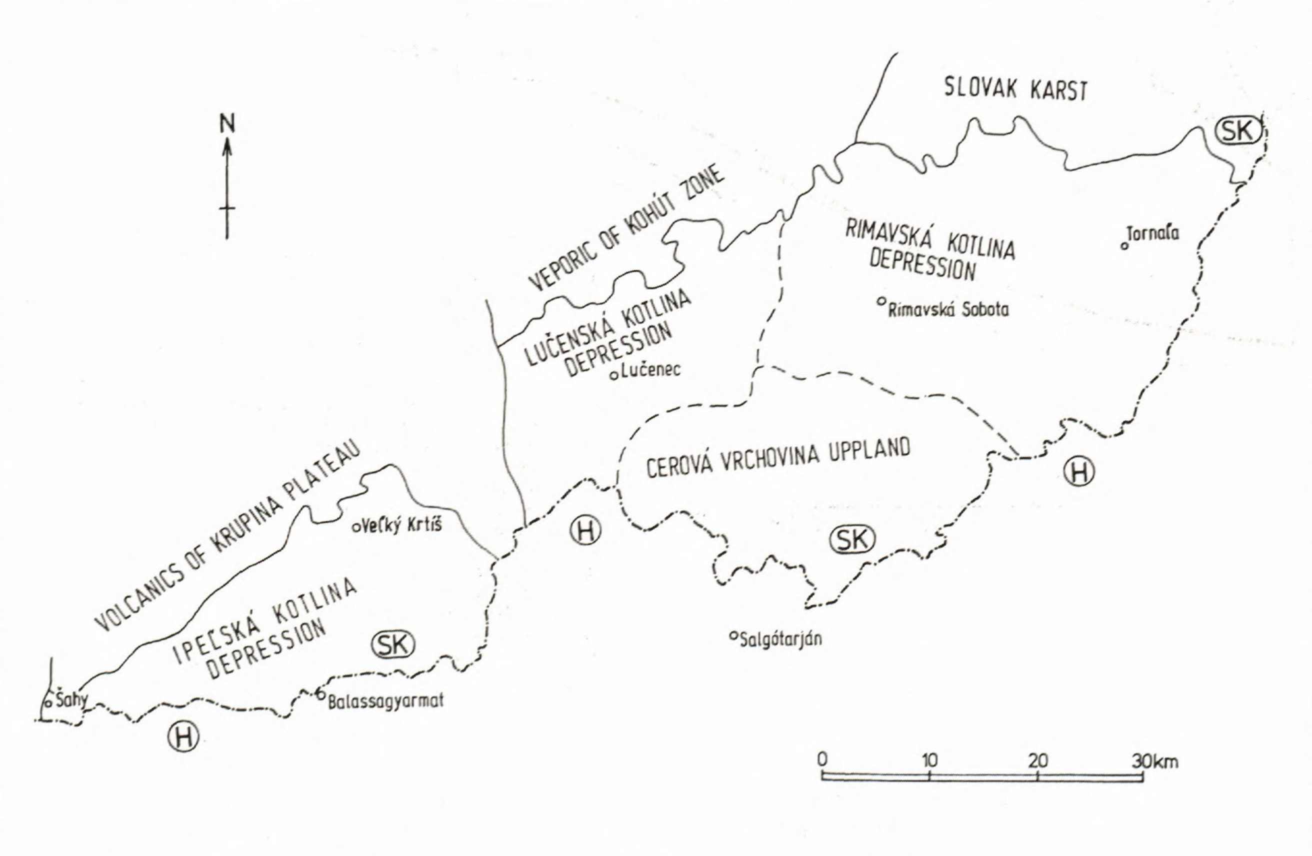

Fig. 3b Regional geological units of Southern Slovakia with respect to units mentioned in the paper

and littoral sandstone rich in fauna (Budafok and Lipovany Sandstone, BÁLDI, 1973, VASS and ELEČKO et al.,1992). In these clastics there are layers, or intercalations, of acidic tuff, in places bentonised. The radiometric age of the tuff is 20,5±0,5 Ma (REPČOK, in VASS and ELEČKO et al.,1992), confirming the Eggenburgian age (according to the radiometric time scale of the Central Paratethys, VASS et al.,1987). Basin facies is represented by siltstone apparently continuing from the Egerian Szécseny Schlier (Čakanovce member of the Fiľakovo Formation, VASS and ELEČKO et al.,1992).

The short life of the Fiľakovo/Pétervásara basin ended by regional uplift in the whole area of the present day Pannonian Basin and the sea receded from the territory. Tectonic escape of a large amount of crustal mass provoked an instability in the astenosphere. Activated astenosphere started to rise and a thermal mantle plume formed. Heat flux out of the rising astenosphere was large enough to cause rapid thinning of the continental lithosphere and isostatic uplift. It seems that the uplift or doming preceded the rifting, because signals of tectonic subsidence caused by rifting appeared during the Karpathian (TARI et al.,1992, P.KOVÁČ et al.,1994) approx. 2-3 Ma after the strong manifestation of the uplift in the area. In this order, when the isostatic uplift precedes the rifting or the lithospheric rifting stretching can be classified as active one (KEEN, 1985 and others). Heating of lithosphere besides the uplift caused mobilisation and rise of crustal sialic magmas, supporting the isostatic uplift. Sialic magmas gave origin to extensive areal volcanic activity of rhyodacite/rhyolite nature as it is shown in Fig. 2 (PANTÓ et al.,1966, SZABÓ et al.,1992, LEXA et al., 1993).

At that time the sea completely receded from Southern Slovakia and from the area of present Pannonian Basin, where fluviatile sedimentation took place (Bukovinka and/or Zagyvapálfalva Fms. of S. Slovakia and N. Hungary, Sásvár Fm. of the Mecsek and surroundings, areas of the basins Zala and Drava, Madaras Fm. of the Alföld, Brenberg Fm. of the Soprony area, Fig.7, VASS and ELEČKO, 1982, HÁMOR et al.,1978, KOVÁCS, 1975, VENDL, 1929,1930).

Radiometric age of tuff coming from the Bukovinka Fm. (S. Slovakia) is 19,8 ± 0,2 and 20,1 ± 0,3 Ma (KANTOR et al., and REPČOK in VASS and ELEČKO et al.,1992). The tuff or ignimbrite - "Lower tuff" and/or Gyulakézsi rhyolite tuff (HÁMOR et al.,1979) spreading in N. Hungary and in S. Bükk area originated in a larger time interval, because their radiometric ages are 19–17Ma (HÁMOR et al.,1979). Thus, at least a part of the tuff layers may be younger than Eggenburgian.

Later, during the Ottnangian, the whole region subsided again and a new Novohrad/Nógrád Basin was generated (Ottnangian-Karpathian in age) (Fig.2). Normal faults were responsible for the opening of the basin. These faults were generated or reactivated in the lasting process of rifting. The rifting in the area studied took place in a paleostress field with extension in NW-SE direction (recent coordinates, VASS et al.,1993). The sea penetrated slowly into newly formed grabens, as the Dačov Lom graben in the Ipeľ depression (S. Slovakia, VASS et al.,1979). The sea came into the Pannonian-Carpathian realm through the intradinaric sea way, forming marine deposits in the Bantapuszta area (BAKONY, KÓKAY in PAPP et al.,1973)). Further to the north, sea transgression was preceded by sedimentation in rivers, swamps and lakes, which gave rise to the Salgótarján Formation (NOSEKY, 1930, HÁMOR in PAPP et al.,1973), invaded occasionally by sea (VASS et al.,1987, ŠKVARKA et al.,1991). In Borsód area sea conditions even predominated, which is documented by paralic coal seams (BOHN-HAVAS, 1985) and by the presence of marine calcareous nannoflora (BÁLDI-BÉKE and NAGYMAROSY, 1979, BOHN-HAVAS and NAGYMAROSY, 1985).

From paleomagnetic investigations realised in the North Hungarian Central Range and in South Slovakia it follows that important counterclockwise rotational displacement occurred during the Late Ottnangian (MÁRTON and MÁRTON in lit.). It was the first phase of a rotation as large as 40–50°. Uniform size and direction of the paleomagnetic declination rotation in a large area - between the Ipeľ depression, the Salgótarján region and South Bükk region - suggests rotation of the whole Western Carpathian – Northern Pannonian terranes and/or Pelsó megaunit (DANK and FÜLÖP, 1990); (Fig. 8). However, from the dynamic, physical and spatial point of view - more probable seem individual but uniform and unidirectional rotations of a set of small blocks. Horizontal rotation of the blocks is a tectonic feature associated with pull-apart basins and/or lateral strike-slips. The sense of the rotation depends on the sense of lateral strike-slip (TERRES and SYLVESTER, 1981). The counterclockwise rotation must have been associated with the left lateral

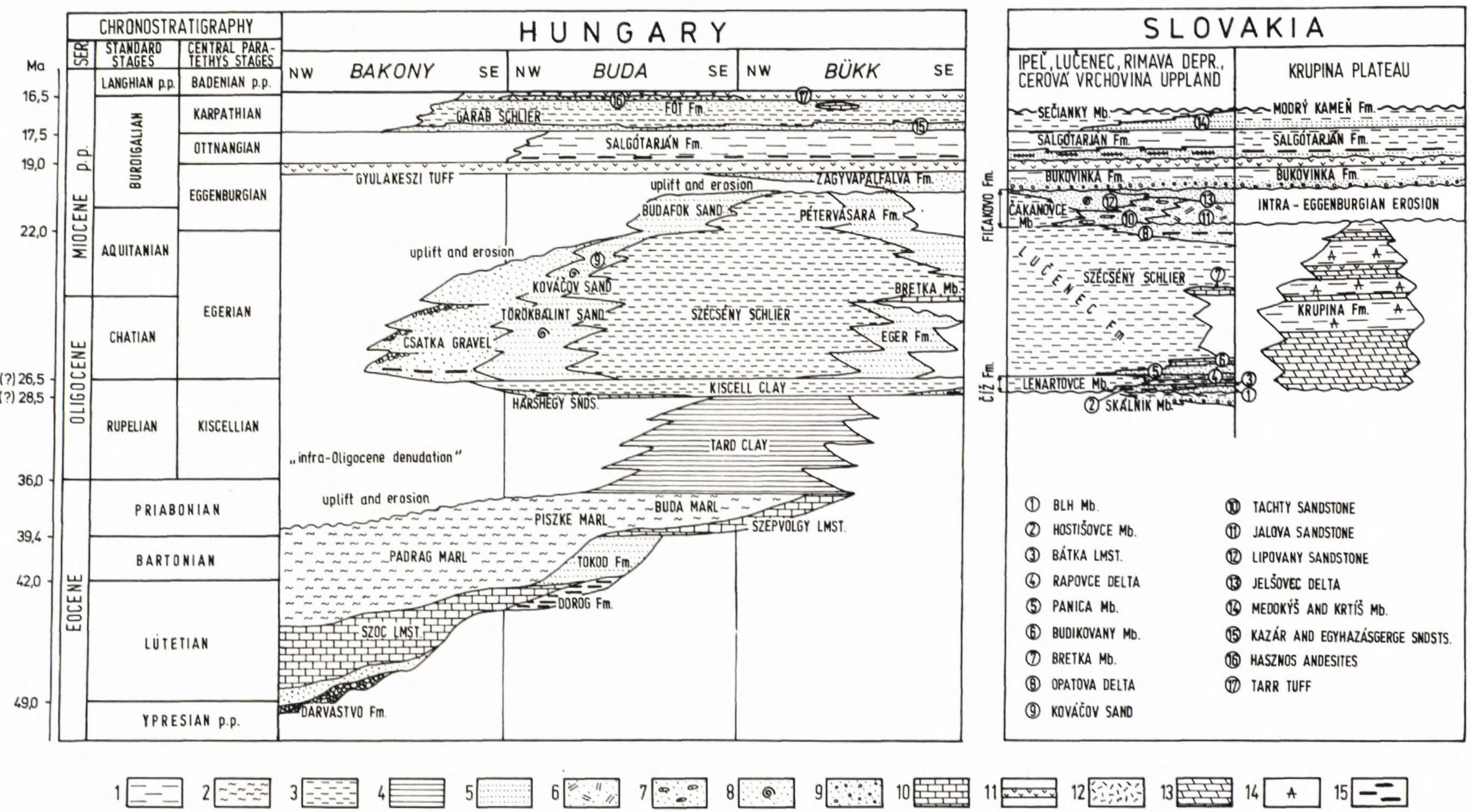

Fig. 4 Simplified litho- and chronostratigraphy of the Hungarian Paleogene Basins, Fiľakovo/Pétervására and Novohrad/Nógrád Basins.
1 - clay, 2 - marlstone, 3 - calcareous siltstone/claystone (schlier), 4 - euxinic clay/claystone, 5 - sand/sandstone, 6 - cross bedded sandstone, 7 - sandstone with hard banks/concretions, 8 - sandstone rich in mollusc fauna, 9 - gravel/conglomerate and sand, 10 - limestone, 11 - rhyodacite/rhyolite tuff, 12 - andesite volcanoclastics, 13 - evaporitic dolomite, 14 - evaporitic sulfates, 15 - coal seam

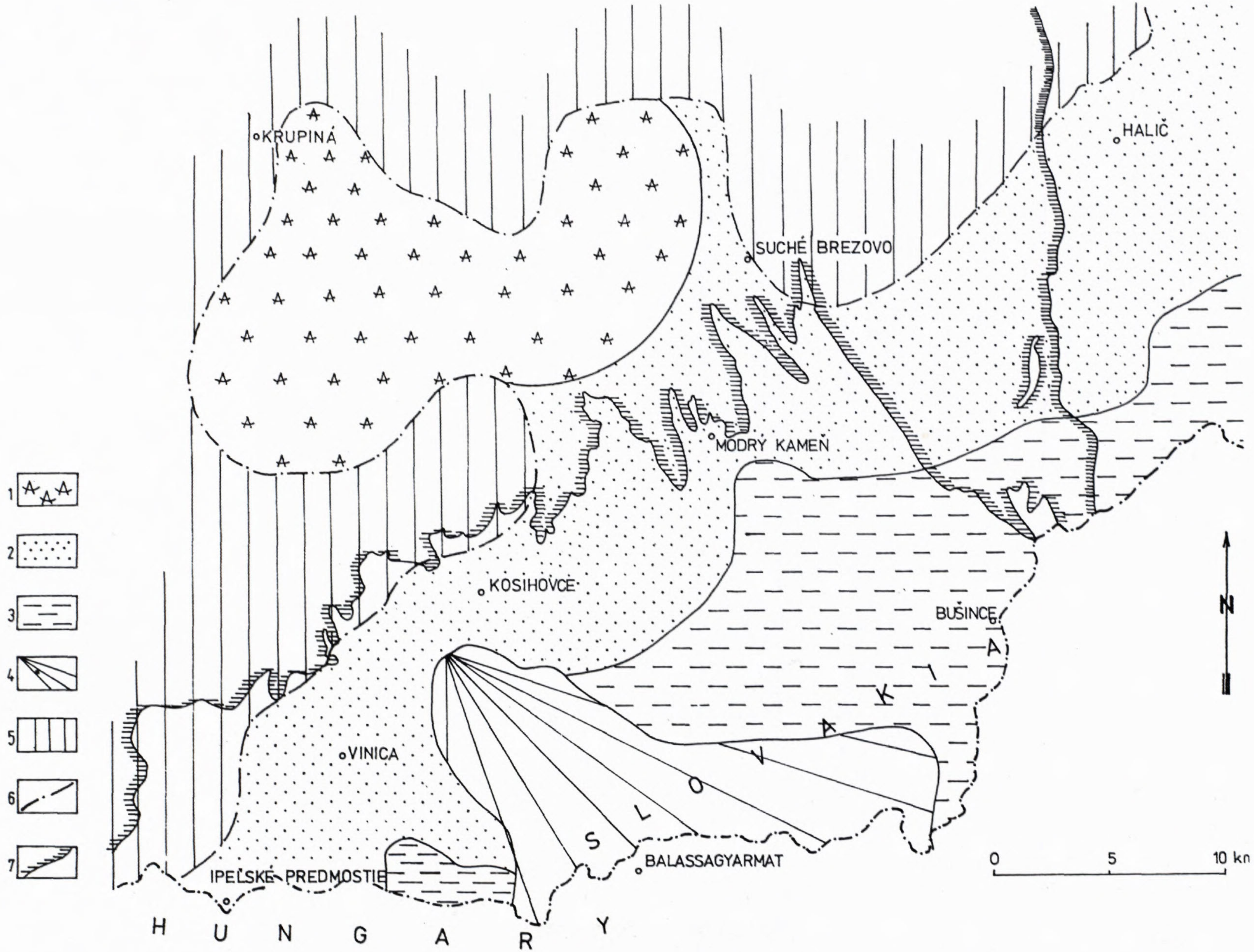

Fig. 5 Section from paleogeographical map of the Egerian in the Ipeľská kotlina depression showing the position of the Krupina Fm with evaporites, buried by Lower Miocene deposits and by neovolcanics of Krupinská planina Plateau (according to VASS et al., 1979).

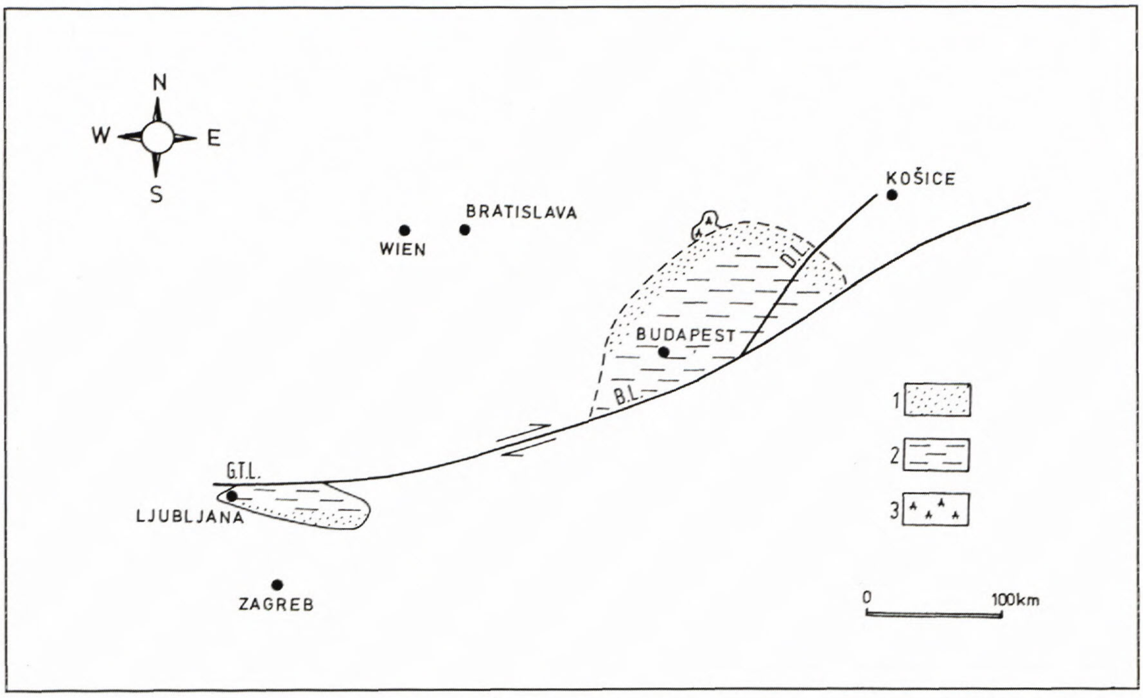

Fig. 6 Lateral displacement of the Slovenian and Hungarian Paleogene Basins after the Egerian (according to CSONTOS *et al.,1992).*

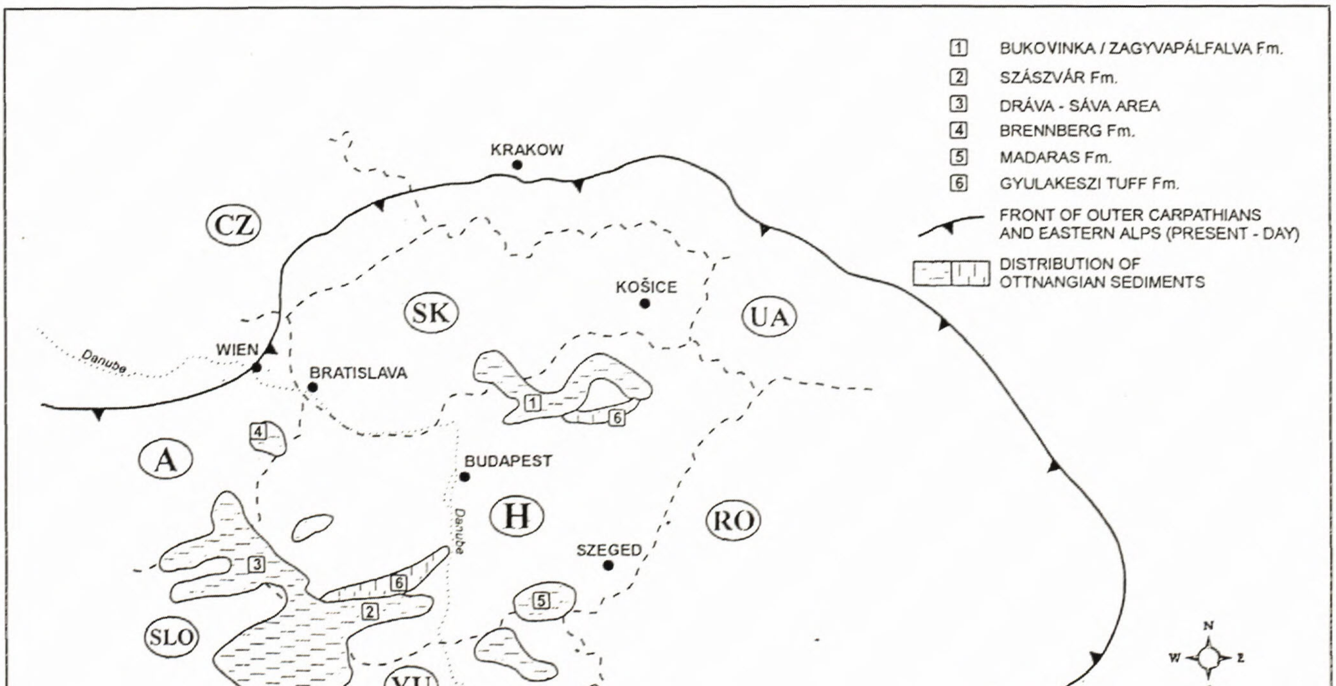

Fig. 7 Continental formations late Eggenburgian early Ottnangian in age, distributed in the "Pannonian" area. Areas in-between are assumed to have been exposed to erosion. The picture clearly documents the regional uplift in the whole area of present-day Pannonian Basin (according to HÁMOR *et al., 1988, modified and completed by the author) .*

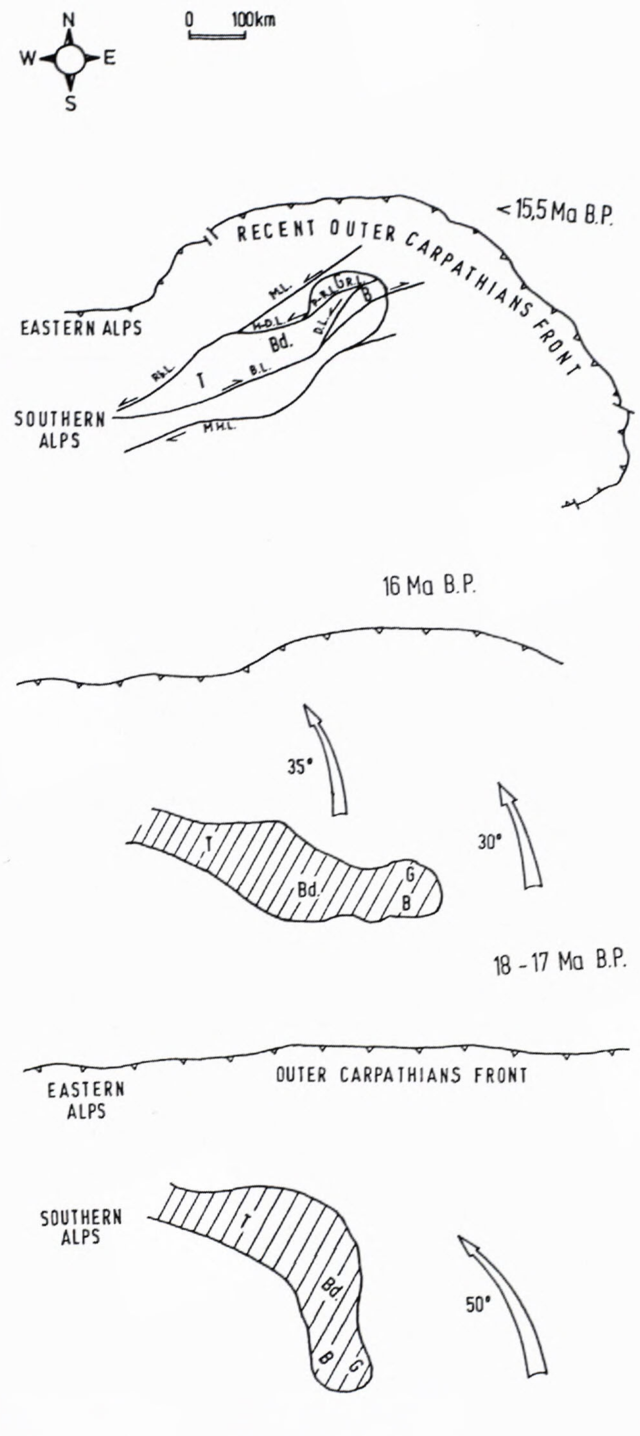

Fig.8 Model of the Lower Miocene counter-clockwise rotation in the area of Southern Slovakia and North Hungarian Central Range.

strike-slip. It is obvious that the area with counterclockwise rotation in the time, when rotation took place, was in a stress field with compression causing left-lateral strike slip movements on the principal faults and fault belts trending in NE-SW direction of present co-ordinates (Fig. 8).Thus, at the end of the Ottnangian the compression rotated from vertical to horizontal position with NNE–SWS direction.

With the beginning of the Karpathian, conditions of sedimentation changed progressively through lagoonal (Medokýš Mb) and littoral (Krtíš Mb) into pure marine, basinal (Sečianky Mb). The marine deposits in Southern Slovakia compose the Modrý Kameň Formation (VASS et al.,1983). In the North Hungarian Central Range the lagoonal Kazár Sandstone and the marine transgressive Egyházgerge Sandstone graded into basinal Garab Schlier, followed by Fót Formation topped by Hasznos Andesites and by products of a new acidic volcanic activity (TarrTuff) appearing on the Karpathian/Badenian boundary (HÁMOR, 1985). The Fót Formation is generally a regressive one. In Etes Trough (Nógrád-Cserhát area, N Hungary) the Fót Formation seems to be a delta: sandy deposits with brackish, oligo-miohaline and freshwater fauna and with fossil soil horizons (HÁMOR, 1985).

By the end of the Karpathian the area studied rose and the Novohrad/Nógrád Basin disappeared. The erosion removed a significant portion of Lower Miocene deposits. After this upheaval event, during the Early Badenian, the subsidence was rejuvenated but only for a very short time. Subsidence occurred in a paleostress field with compression in NNW–SSE direction and sedimentation controlled the NNW–NW trending faults (present day co-ordinates, Vass et al.,1993). Subsidence was followed by a volcanic paroxysm, when magma came from deeper-seated chambers giving rise to calc-alkaline andesites at least partly related to the subducting European plate and/or Pannonian astenolith (Vass et al.,1988), and the sea receded from the area. At that time the second additional counterclockwise rotation as large as 30° took place (MÁRTON and MÁRTON in lit., MÁRTON and FODOR, 1995).

The counterclockwise rotation was accomplished after the Early Badenian. Badenian intrusive bodies of the Šiator – Karancs andesite with garnet (radiometric age is of 15,1 Ma, BALOGH, 1984 e.g. Middle Badenian after VASS et al.,1987) intruded after the rotation, because their remanent magnetisation has Badenian orientation, which is close to recent one. Similar remanent magnetisation have also the host rocks - sandstones of the Fiľakovo Formation, Eggenbrugian in age, which underwent contact metamorphism with temperature of around

550–570 °C (HOJSTRIČOVÁ et al., 1995.). The Curie point was exceeded and the sandstones lost their original remanent magnetisation, which would have been affected by counterclockwise rotation, as proved by paleomagnetic investigation in Southern Slovakia (ORLICKÝ et al., in lit.). Paleomagnetic measurements realised by MÁRTON and MÁRTON (in lit.) on rocks younger as early Badenian in in the area studied have shown no rotation.

Conclusions

The HPBs originated on the Western Carpathian – Northern Pannonian terranes, when the terranes, as the consequence of tectonic extrusion, escaped from the Alpine and Dinaric domain. The tectonic extrusion had been provoked by the convergence of Afro-Arabia and Eurasia, namely by the collision of the Apulian promontory with the Bohemian Massif and by the roll-back effect of the subduction in the Outer Carpathians.

The escaping terranes were confined in south by a right-lateral shear zone – the Balaton and Mid-Hungarian lines and in north by the left-lateral Peripieniny fault belt. Blocks between both limiting shear zones were disturbed by faults of wrench nature causing opening of the HPBs, as well as the Central-Carpathian Paleogene basin.

The marine transgression entered into the newly opened HPBs from the SW. The transgression as well as the basin opening prograded to the NE (in present day co-ordinates) through the Bakony unit, reaching in the end the Bükk, Vepor, Gemer. Silicicum, Turnaicum and Meliaticum units.

After the Egerian a large lateral displacement of the tectonic escape took place and HPBs were closed. After that, two short-term basins were created in the area studied: Fiľakovo/Pétervásara Basin of the early Eggenburgian and Novohrad/Nógrád Basin lasting from the late Ottnangian to the end of the Karpathian. In-between, the whole Pannonian area was uplifted as a result of astenosphere rise and lithosphere stretching. The sea completely receded from the area and rhyodacite-rhyolite areal volcanism was active in this time.

Later, during the Ottnangian, the Novohrad/Nógrád Basin opening was caused by rejuvenation of strike-slip movements accompanied by the first pulse of a counterclockwise rotation (50°). At the end of the Karpathian, due to strong compression, the area was uplifted again. and erosion removed a significant portion of the Lower Miocene deposits.

The last sea invasion into area of South Slovakia occurred at the beginning of the Badenian as result of areal subsidence supported by fault tectonics. Then the second pulse of counterclockwise rotation took place (30°). Shortly after strong calc-alkaline volcanism and a new upheaval, the sea was forced out, and never more entered the area of Southern Slovakia as well as a significant part of the North Hungarian Central Range.

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