*Slovak Geol. Mag., 6, 4(2000), 377–407*

# Palaeogeography of the East-Slovakian Basin

DIONÝZ VASS[1], MICHAL ELEČKO[2], JURAJ JANOČKO[3], STANISLAV KAROLI[3], MIROSLAV PERESZLENYI[4], JÁN SLÁVIK[4] & MICHAL KALIČIAK[2]

[1]Faculty of Forestry, Technical University of Zvolen, Masarykova 24, 960 53 Zvolen, Slovak Republic
[2]Geological Survey of Slovak Republic, Mlynská dolina 1, 817 04 Bratislava, Slovak Republic
[3]Geological Survey of Slovak Republic, Werferova 1, 040 11 Košice, Slovak Republic
[4]Slovak Gas Industry, VVNP – Research Oil Comp., Votrubova 11/a, Bratislava, Slovak Republik

*Abstract.* The East-Slovakian Basin is a basin with complex tectonic history determined by oblique subduction of an oceanic slab occurring between the North-European Platform and the ALCAPA plate. The basin represents an autonomous part of the Transcarpathian Basin. It extends mostly on the Slovak territory and is filled by the Neogene clastics, volcanics, caustobioliths and evaporites. Genetic type and spatial distribution of deposits varied during the basin evolution depending on tectonics, volcanic activity, sea level changes as well as sediment input. Spatial distribution of deposits and their sedimentary environments are displayed in maps expressing ten time slices through the Eggenburgian, Karpatian, Badenian, Sarmatian, Late Miocene and Pliocene.

*Key words:* Neogene palaeogeography, tectonics, sediments, volcanics, pull-apart basin, sea-level changes, sedimentary environment

## Introduction

The East-Slovakian Basin is an autonomous part of the Transcarpathian Basin with complex tectonic evolution and high variability in thickness and spatial distribution of sediments complicated by intrabasinal volcanics. Complex geologic evolution is a result of delicate interplay between intra- and extrabasinal processes such as tectonics, sediment input, depositional processes, climate and sea level fluctuation. They determined type of deposition, erosion and denudation, position of depocenters and basinal volcanism. Precise definition of basin fill stratigraphy, spatial distribution and type of deposits as well as type of tectonics comprise basis for unraveling basin history. This is the main role of palaeotectonic reconstructions which helps to understand the basin history.

The first palaeogeographic reconstruction of the East-Slovakian Basin was presented by Rudinec in 1978. The author updated this reconstruction in 1989 and in 1990 using also data from the Transcarpathian Ukraine. Recently, palaeogeography of the East-Slovakian Basin was presented by Kováč et al. (1996), Baráth et al. (1997) and Kováč & Zlínska (1998). The authors used a modern approach to analysis which is a contribution to the knowledge of the basin evolution. However, these reconstructions have often been schematic and lack more several important details.

Extensive and long-term research of the East-Slovakian Basin by the authors of this paper resulted in great amount of knowledge of sediments, tectonics, stratigraphy, palaeoclimate and palaeoecology. All these data provided sufficient database for a new palaeogeographic analysis of the basin. Maps showing ten time slices with thickness and spatial distribution of deposits, distribution of depocentres, erosional areas, volcano locations, character of volcanism and type of depositional environments during the Neogene are the main output of this analysis. The maps should serve not only for basic, but also for applied geological disciplines.

Initial data for the palaeogeographic reconstruction of ten time slices were obtained from deep boreholes. Based on this, sediment isopachs assigned to individual time slices were created. Borehole cores and drilling logs as well as surface outcrops provided information on lithology, facies types and sequences. This was complemented by analyses of reflection seismic profiles. Biostratigraphic subdivision of the basin fill has been based on foraminifera, nanoplankton, molluscs and ostracods.

Interpretation of the main structural elements – faults and overthrusts is based on the surface mapping and seismics. Fault characteristics were deducted from palaeostress fields which interpretation was based on the analysis of the brittle deformation. The sedimentation rate was interpreted on the base of the formation thicknesses. Sedimentological analyses were applied for definition of the geometry of sedimentary bodies and palaeoenvironmental analysis as well as for definition of the sediment input direction. All the data concerning the sediment input direction is related to present day coordinates. Radiometric ages of volcanics, which are barren on fossils, enabled their stratigraphic correlation with the biostratigraphically dated sediments. The palaeomagnetic data yielded basic information on the rotation of the lithospheric fragments underlying the basin fill.

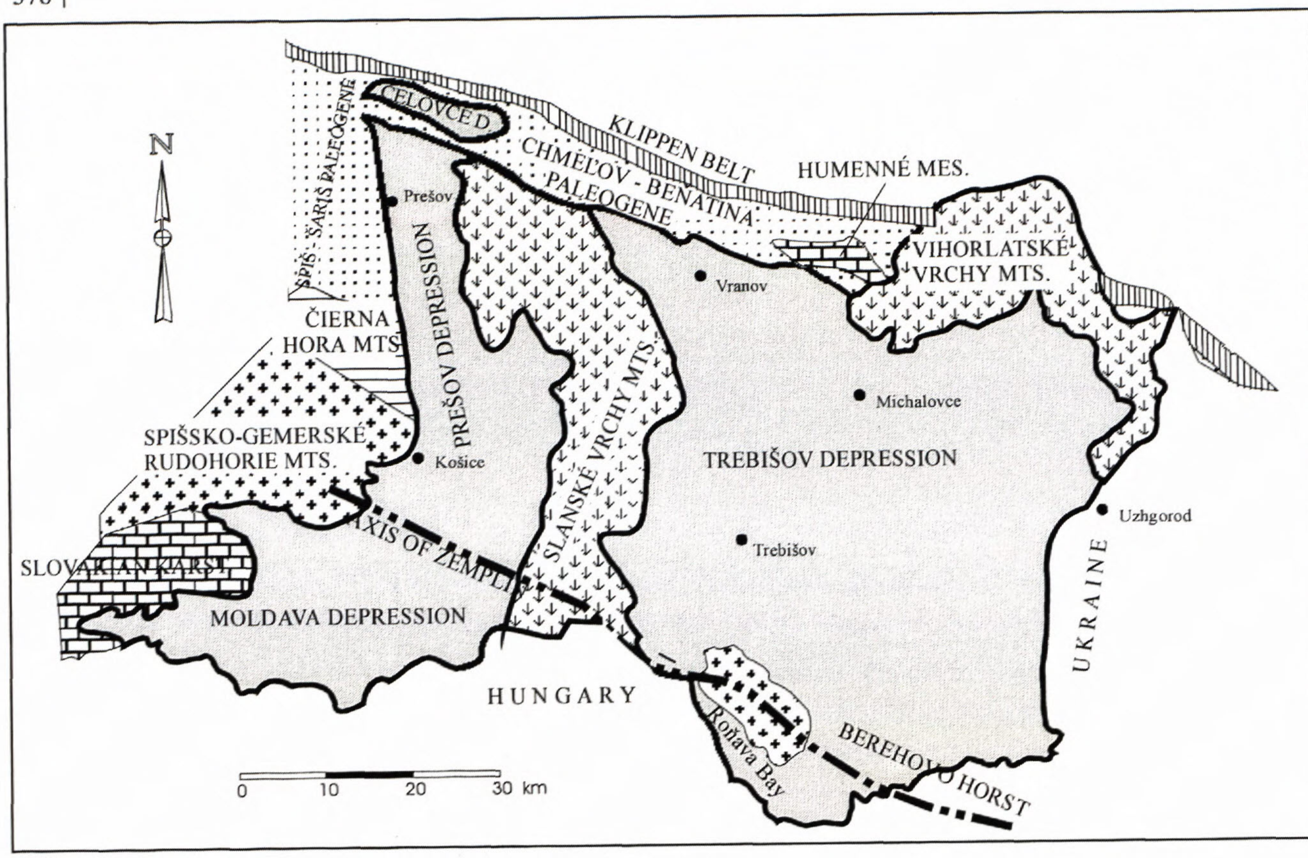



*Fig. 1: Regional subdivision of the East Slovakian Basin. The basin includes subunits of Prešov Depression, Slanské vrchy Mts., Trebišov Depression, Roňava "Bay" and Vihorlatské vrchy Mts. Surrounding units are also shown.*

## Geological setting of the East-Slovakian Basin

The East-Slovakian Neogene Basin comprises western and autonomous part of the Transcarpathian Basin extending from Košice and Prešov in the west to the Uzhgorod in the east (Fig. 1). The basin is fault-bounded to the Chmeľov-Beňatina Paleogene unit in the north and separated by system of faults from the Šariš - Paleogene unit and pre-Tertiary rocks of the Sľubica, Čierna Hora and Spišsko-Gemerské Rudohorie Mts. in the west. To the south it is restricted by the Zemplin-Beregovo Horst separating the basin from the Nyírség Basin of the Great Hungarian Plain. The eastern boundary of the basin is expressed by the buried Seredne transverse horst (Vass et al. 1988, Rudinec 1989).

Striking neovolcanic morphostructure of the Slanské vrchy Mts . divides the basin into two parts – the Prešov Depression in the west continuing into Moldava Depression in the south and the Trebišov Depression in the east with Roňava "Bay" in the southeast (Fig. 1). Both the Moldava Depression and Roňava "Bay" are formally assigned to the East-Slovakian Neogene Basin (Vass et al. 1988) although they genetically belong to the Pannonian back-arc depression to the Nyírség Basin.

The kinematic history of the basin is complex. The basin originated in transpressional regime which later changed to compressional and transtensional. The most important periods of the basin development are connected with a pull-appart regime (Vass et al. 1988). The basin lies on thinned, about 27 km thick crust thickening toward north and north-west where it reaches about 30 km (Šefara et al. 1987). The lithosphere thickness is 80 km (Babuška et al. 1986). Several gravity-magnetic anomalies occur in the basin, from which the most conspicuous are the Sečovce anomaly, anomaly nearby the village Zbudza and anomaly in the Moldava depression. All anomalies are probably induced by bodies of ultrabasic rocks although the opinion on their origin is still ambiguous (e.g. Hovorka et al. 1985, Vass et al. 1988, Gnojek et al. 1991, Šutora et al. 1990, Soták et al. 1993).

### *Pre-Neogene basement of the basin*

Pre-Neogene basement of the basin has a complicated structure composed of several units or superunits (Fig. 3). The complicated structure and its variability are related to the mechanism of the basin opening (pull-apart), when horizontal translations along basin generating faults („dismatch in basement,, of Christie-Blick & Biddle, 1985) resulted in convergence of different geologic units. Today's arrangment of the basement units located in the East-Slovakian Neogene Basin has a NW-SE trend consistent with the trend of the eastern part of the Western Carpathian belt (e.g. Fusán et al. 1972, 1987, Slávik 1974, Rudinec 1978, Ďurica 1982), but perpendicular to the structural trend of the adjacent regions of

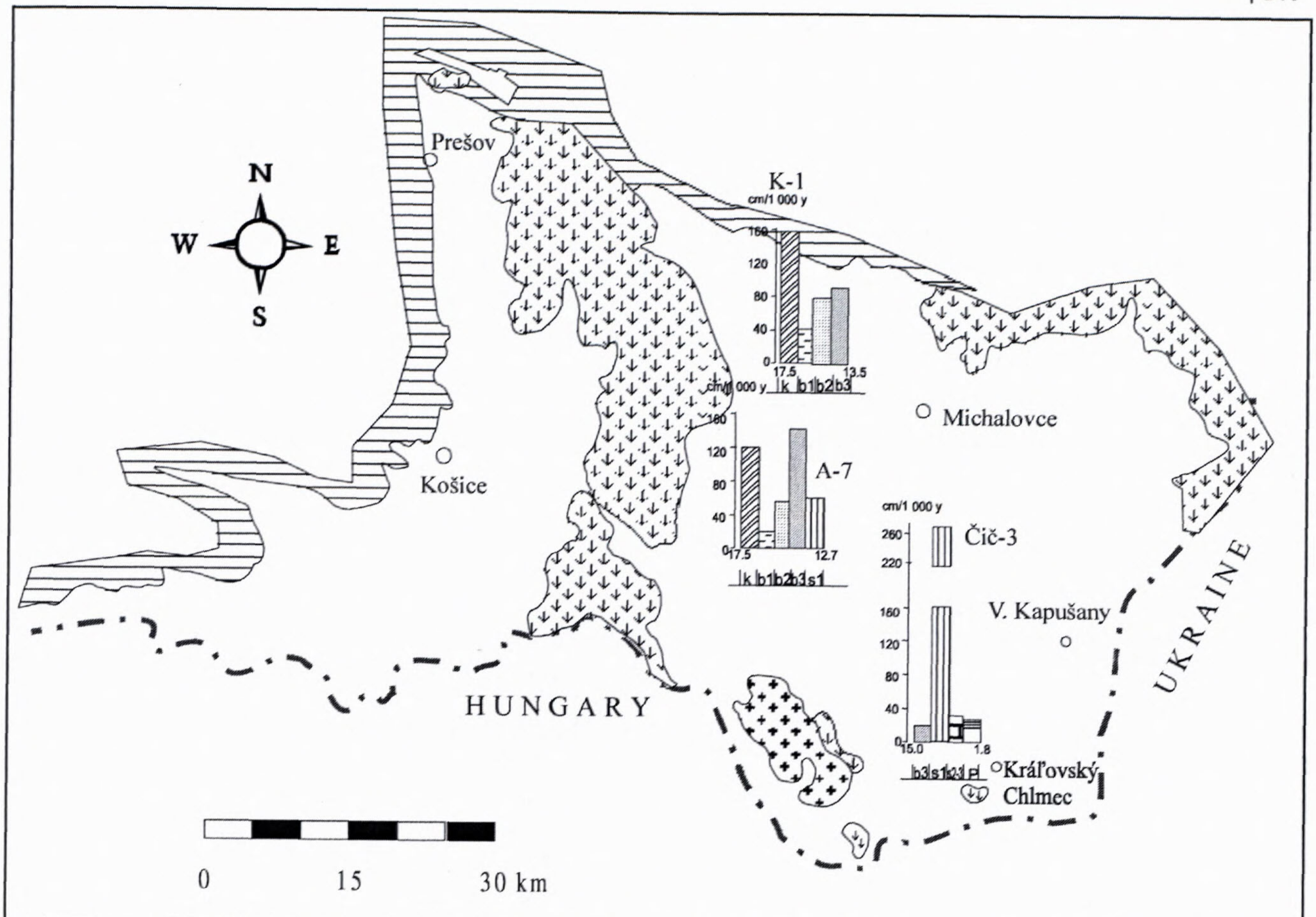



*Fig. 2: Migration of subsidence in the East Slovakian Basin. Maximum subsidence of Karpathian stage (k., NW part of the basin), Late Badenian ($b_3$ central part of the basin), Early Sarmatian ($s_1$, SE part of the basin). Sedimentary rates calculated according to the data taken from wells KD-1, A-7 and Čič-3. The sediment thickness is considered as decompacted. Abbrevation of chronostratigraphic Central Paratethys Neogene stages: k - Karpatian, $b_{1,2,3}$ - Lower, Middle and Upper Badenian, $s_1$ - Lower Sarmatian, $S_{2-3}$ - Middle and Upper Sarmatian, white field - Pannonian, Pontian and Pliocene.*

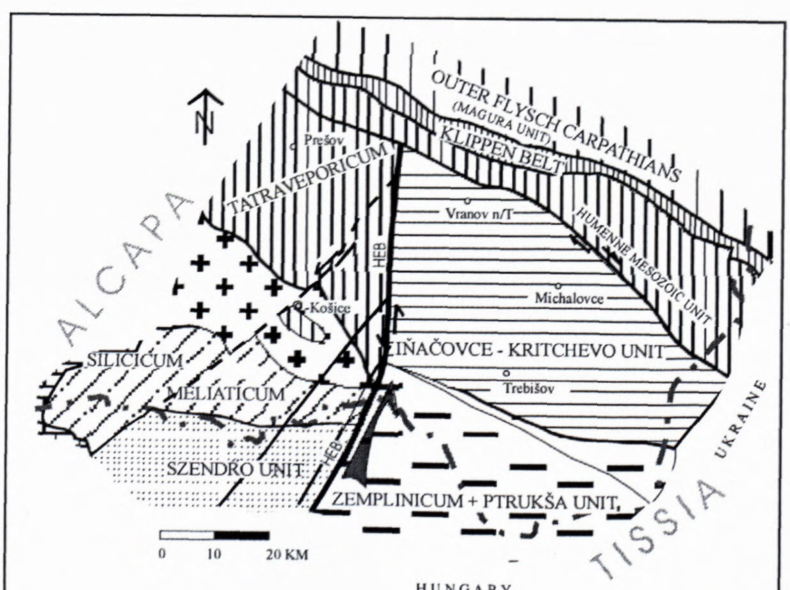



*Fig. 3: Pre-Tertiary units of the East-Slovakian basement and its surroundings. The contact between the ALCAPA and Tissia Units is interpreted along the Hornád Fault Belt (HFB)*

Hungary (Fülöp & Dank eds., 1987, Dank & Fülöp eds., 1990). This structural arrangement resulted from the Miocene CCW rotation.

The Magura Unit of the Outer Flysch Carpathians and Pieniny Klippen Belt are the northernmost units where the modern NE margin of the basin encroaches. To the south of the Pieniny Klippen Belt the Humenné Mesozoic Unit extends. The basement of the central and southern part of the basin is built by the Pozdišovce-Iňačovce Unit (Iňačovce - Kritchevo Unit), Zemplinicum and Ptrukša Units which belong by our opinion to Tissia. The Prešov Depression and a part of the Slanské vrchy Mts. are underlain by crystalline rocks and by the Mesozoic formations of the Čierna Hora Mts. On Fig. 3 both the Čierna Hora and Humenné Unit are lumped together in the Tatraveporicum. Some authors assume that the Choč Nappe underlies the northern part of the Prešov Depression (e.g.

Ďurica 1982). The Moldava Depression is underlain by the Paleozoic rocks of Gemericum and by the Mesozoic rocks of Meliaticum, Silicicum (Fig. 3) and eventually Turnaicum. We assigne all these units to the ALCAPA microplate (e.g. Kováč et al. 1999, Fig. 3). The Central-Carpathian Paleogene rocks, do not shown on Fig. 3, represent the youngest unit of the pre-Neogene basement. It underlies the northern part of the basin and it partly covers some of the before mentioned pre-Tertiary units.

*Neogene basin fill*

The East-Slovakian Basin is a basin with complex tectonic history. Vass (1998) considers the basin as a fore-arc and intra-arc one in relation to volcanic arc generated as the consequence of the North European Platform subduction beneath the ALCAPA Plate. Kováč et al. (1995) characterizes the basin as a back-arc basin. However, the clear evidence about the basin position in relation to volcanic arc is proved only from the Late Badenian when andesite volcanism directly related to the subduction appeared (Lexa & Konečný, 1998). We think that the basin tectonic evolution before the Late Badenian was related mainly to basin position behind the accretionary prism and oblique collision between the North European and ALCAPA plate.

The fill of the basin consists of sediments and volcanics stratigraphicaly ranging from the Eggenburgian to the Pliocene. The maximum thickness of the fill is up to 8 - 9 km. The depocenters migrated in time from NW to SE. In the NW part of the basin the subsidence culminated in the Karpatian stage, in the central part of the basin it culminated during the Late Badenian and finally, during the Early Sarmatian the highest amplitude of subsidence occurred in the SE part of the basin (Fig. 2). Prevailing deposits are composed of siliciclastics, caustobioliths (coal and lignite) and minor evaporite deposits. An important portion of the basin fill is composed of volcanic rocks (mainly volcaniclastics and effusive rocks). They are acid (absolutely prevailing from the Eggenburgian to the Early Badenian) and intermediate (from the Badenian to the Late Sarmatian and/or Pannonian) The volcanic activity culminated in the Badenian and Sarmatian (Tab. 1).

The basin fill is of horst-and-graben style which resulted from mainly syndepositional fault activity. The value of some fault system throws exceeds 1 000 m. Besides the fault structure, the basin fill is also slightly folded. On the N and S margin of the basin the beds dip toward the centre in angle from 30° to 50°. Overthrusts in older deposits are indicated on seismic sections (Keith et al. 1989, Magyar et al. 1997, Mořkovský et al. 1999) and occasionally also on surface (NE margin of the basin). We even found folded Pannonian deposits at some locations. Many listric faults of the basement originally represented thrust planes or reverse faults. Later, during the opening stage of the basin, they became normal faults.

## Palaeogeography

*Eggenburgian (23.0 - 19.0 Ma, Map 1)*

The first Neogene marine transgression into the area of the nowadays East-Slovakian Basin occurred during the Eggenburgian (23.0 – 19.0 Ma). The Eggenburgian deposits crop out in the narrow belt along the northern basin margin (Map 1). The belt continues in Zakarpatie (Transcarpathia) along the northern margin of the Zakarpatie (Transcarpathian) Depression (Burkalovo Formation; Vialov in Muratov & Neveskaja 1986, Rudinec

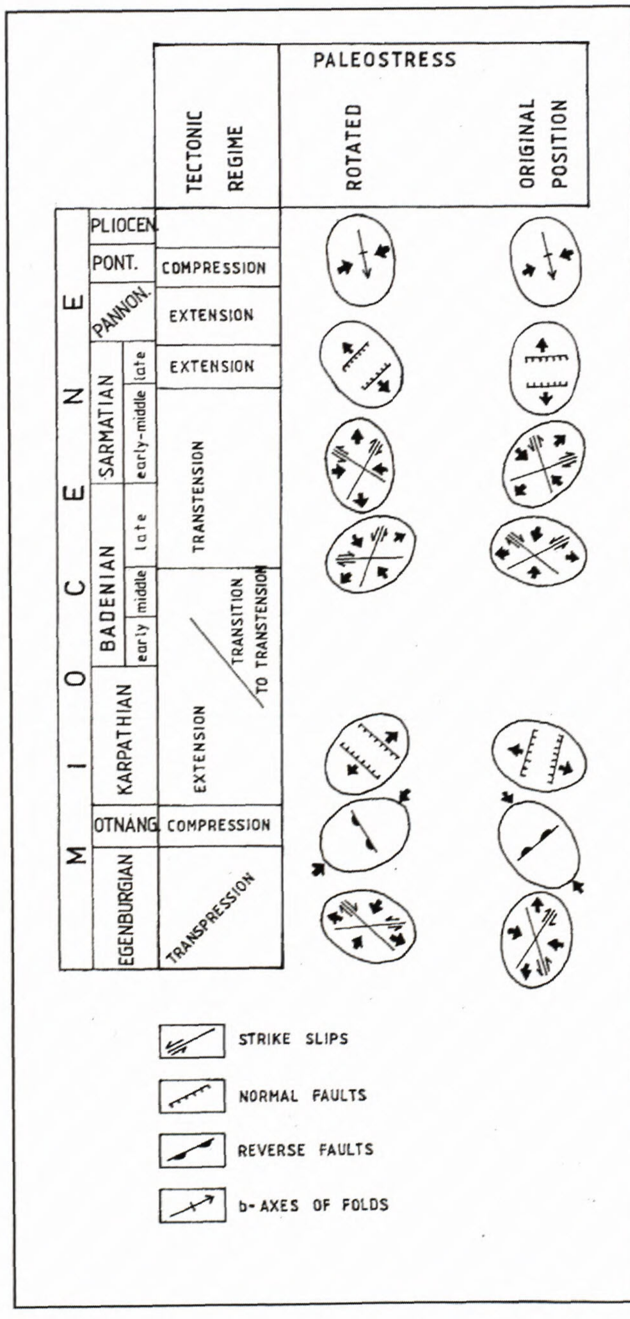



*Fig. 4: Tectonic regime and palaeostress fields during the basin evolution. Original and rotated positions of palaeostress fields are also shown.*

1989, Petraskiewicz & Lozinjak 1995, Andreyeva-Grigorevich et al. 1997).

The appearance of Eggenburgian deposits in a narrow belt was the principal reason to classify the Eggenburgian basin of East Slovakia as a wrench furrow (Vass, 1998). Recent study of the smectite expandability on the samples coming from the Central Carpathian Paleogene of the Northern Slovakia (Levočské vrchy Mts., region of Orava) enables to estimate the thickness of sediments removed by erosion from the area up to 3–4.6 km and the major part of missing deposits had to be Early Miocene in age (Uhlík, 1999). It seems, the Eggenburgian marine deposits in Northern and Eastern Slovakia were not bounded to a narrow belt, but they originated in a large intensively subsided basin of the fore-arc position.

The subsidence and/or opening of the Eggenburgian basin resulted from an oblique convergence in the subduction zone of the Outer Western Carpathians. Before or during the Eggenburgian culminated lateral escape of the Tissia partial units into the East-Slovakian area (Wein 1969, Grecula & Együd 1977). These units are represented by the Zemplinicum, Ptrukša Unit and Iňačovce-Kritchevo Unit. The escape occurred along sinistral strike-slip faults of the Hornád Fault System (Fig. 3).

Palaeostress interpreted from the brittle deformations would generate dextral and conjugate sinistral strike-slip faults. For the basin the dextral strike-slips played an important role (see Map 1 and Fig. 4). Some of them caused a lateral translation of the Humenné Mesozoic Unit as a partial unit of the Tatraveporicum to the east (see Fig. 3). A distinct seismic anisotropy and steep fault separating the Iňačovce-Kritchevo Unit and the Humenné Mesozoic rocks are well documented by the seismic line 612/88 (Fig. 7). The basin is also disturbed by NE - SW faults. They seem to be slightly younger, perhaps epigenetic normal faults (Map 1).

The opening and subsidence of the East-Slovakian wrench furrow ceased at the end of the Eggenburgian. It was gradually filled by progradational deltas.

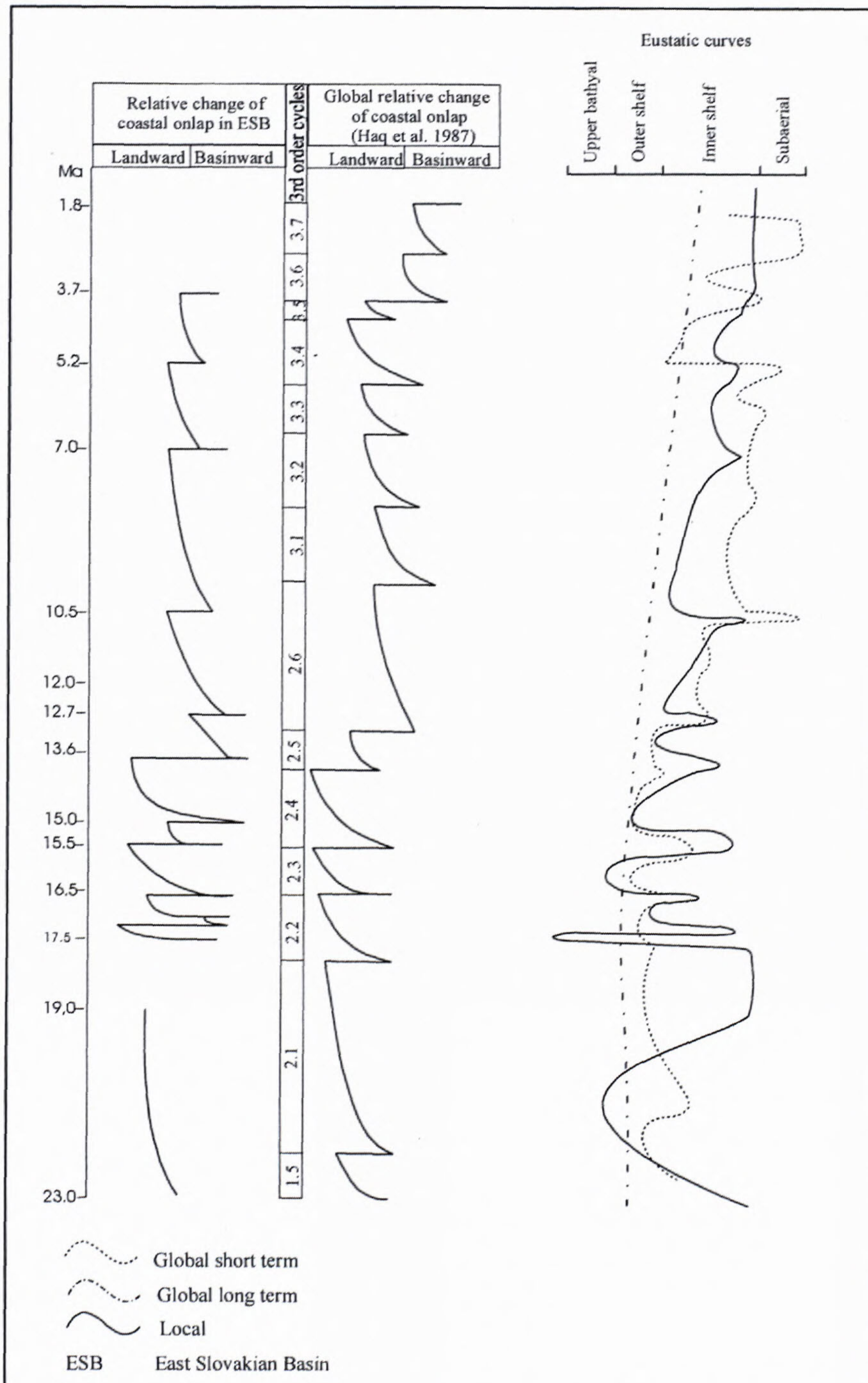



*Fig. 5: Correlation between local and global sea level fluctuations*

The Eggenburgian deposits of the East-Slovakian Basin have a transgressive character. The transgression is believed to be strengthened by the eustatic sea level rise (Fig. 5). The transgression occurred over the partially emerged Outer Flysch Carpathians e.g. over the Magura, Dukla, Silesian and Subsilesian Units. The Eggenburgian basin communicates over these units with both the Carpathian foredeep and original sedimentary areas of the Skole, Boryslav-Pokuty and Stebnik Units later incorporated into the frontal part of the Flysch Carpathians today.

The area of Eggenburgian sedimentation in East Slovakian Basin itself as it is shown on Map 1, was directly

VVNP Bratislava

# EAST SLOVAKIAN BASIN
## Legend

ŠTÁTNY GEOLOGICKÝ ÚSTAV DIONÝZA ŠTÚRA

### Areas of erosion and denudation

- Flat relief
- Sharp relief

### Areas of sedimentation

Continental

- Alluvial
- Lacustrine
- Swamp

Brackish

- Lagoon
- Delta
- Nearshore (Onshore)
- Offshore

Marine

- Inner shelf
- Outer shelf

Hypersaline

- b) Hypersaline sandwiched by marine

### Volcanics

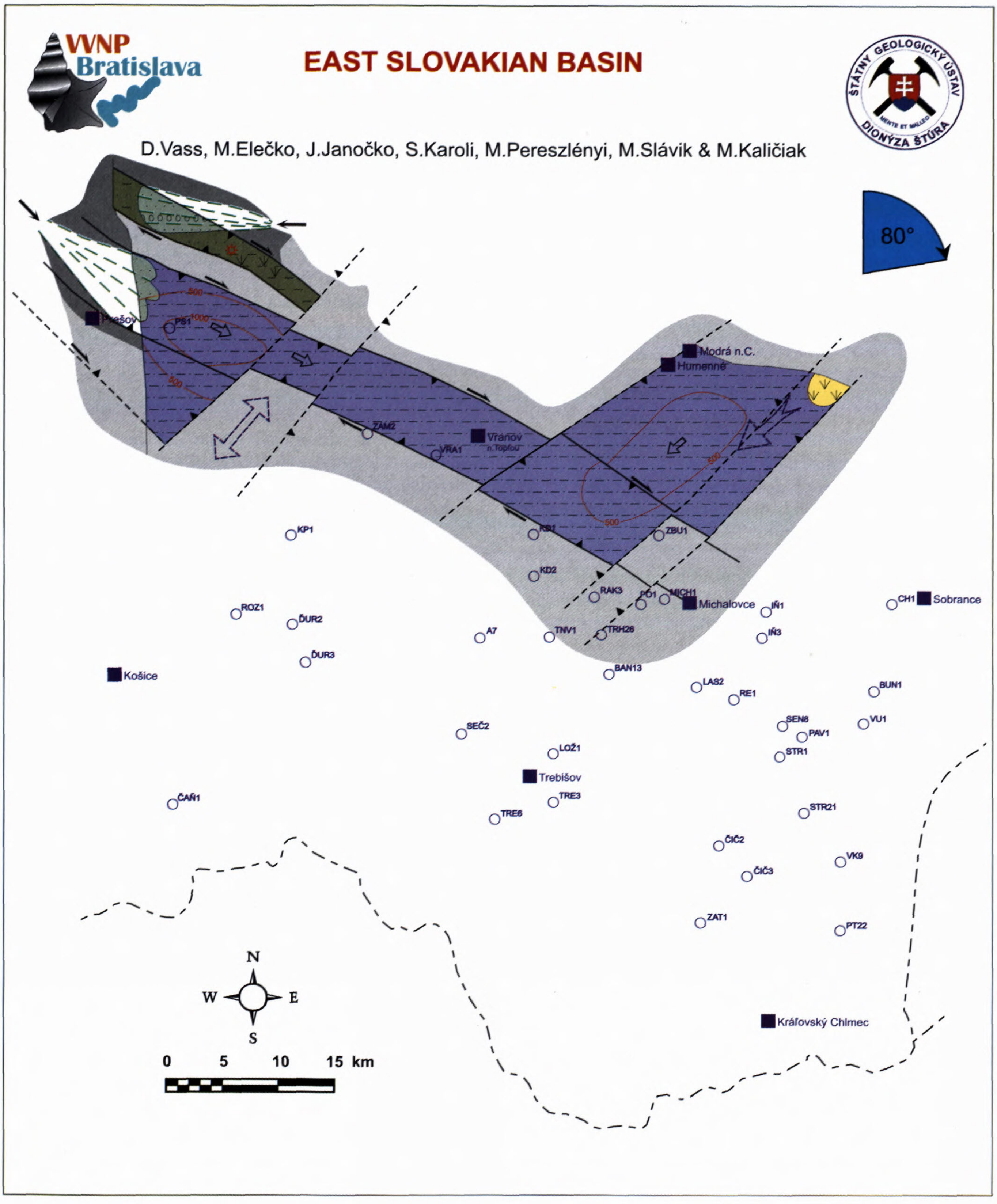
- Andesite, b) Volcanoclastics
- Rhyolite, Rhyodacite, b) Volcanoclastics
- Stratovolcano, b) Volcanic extrusion

### Lithotypes

- Conglomerate, gravel
- Sand, sandstone
- Silt, siltstone including schlier
- Clay, claystone
- Evaporite
- Coal and lignite
- Sand covered by clay
- Conglomerate and sandstone covered by
  a) claystone, mudstone
  b) and evaporite

### Other symbols

- Synsedimentary fault active during presented time period
- Other significant fault
- Strike slip
- 200 Recent thickness isoline
- Presumable direction of sediment input
- Presumable direction of sediment transport
- Sea way and/or direction of sea transgression (direction is not object of rotation !)
- Inlet and direction of hyposaline sea transgression (direction is not object of rotation !)
- Delta contour
- PS1 Important borehole
- 40° Direction and angle of rotation to original position


VVNP
Bratislava
EAST SLOVAKIAN BASIN
ŠTÁTNY GEOLOGICKÝ ÚSTAV
DIONÝZA ŠTÚRA
D.Vass, M.Elečko, J.Janočko, S.Karoli, M.Pereszlényi, M.Slávik & M.Kaličiak
80°
Prešov
PS1
1000
500
Modrá n.C.
Humenné
Vranov n.Topľou
ZAM2
VRA1
KP1
KD1
KD2
ZBU1
RAK3
PO1
MICH1
Michalovce
IŇ1
IŇ3
CH1
Sobrance
ROZ1
ĎUR2
ĎUR3
A7
TNV1
TRH26
Košice
BAN13
LAS2
RE1
BUN1
SEN8
PAV1
VU1
SEČ2
LOŽ1
STR1
Trebišov
TRE3
TRE6
ČAŇ1
STR21
ČIČ2
VK9
ČIČ3
ZAT1
PT22
Kráľovský Chlmec
N
W
E
S
0 5 10 15 km

connected with sedimentary areas of former Central-Carpathian Paleogene including the pre-Sarmatian Orava Basin (Czieszkowski, 1992).

The connection probably stretched further toward the W over the Inner Depressions of the West Carpathians where the Eggenburgian deposits are preserved (Turiec, Bánovce, Ilava, Trenčín Depressions) to the Vienna Basin and to the Carpathian Foredeep in the SW Moravia. This connection was already considered by Buday et al. (1967).

The basin was also opened to the SW where a sea communication with the Fiľakovo/Pétervásara Basin and/or a bay (Sztanó 1994, Halásová et al. 1996) existed.

The sedimentation during the Eggenburgian occurred mainly in the marine environment. The basal transgressive clastics are overlain by pelitic deposits which, in turn, are capped by regressive deltaic and lagoonal deposits.

The Eggenburgian deposits are composed of two formations:

**Prešov Formation** (Fig. 6) unconformably lies on the Eggerian and older Paleogene and pre-Tertiary rocks and crop out in the NW surroundings of Prešov. It was also penetrated by boreholes beneath younger rocks nearby Vranov. The maximum thickness of the formation is 1 000 m. It consists of basal medium- and coarse-grained polymic, mainly carbonate and quartz conglomerate probably originated in southeastward trending deltaic system (see Map 1). The conglomerate is overlain by gray, calcareous siltstones containing coal detritus and fine-grained calcareous, wacke sandstones (Karoli in Kaličiak et al. 1991) and fine grained conglomerates. The formation also contains tuff and redeposited tuff , which are mostly seladonized and bentonized. They probably originated during the first Early Miocene volcanic explosions in the Eastern Slovakia with center northward of Prešov (Kaličiak et al. 1991).

The Prešov Formation is rich in marine fauna with numerous molluscs (*Pitaria cf. lilacinoides, Cardium cf. moescheanum, Pecten cf. burdigalensis;* e.g. Švagrovský 1952) and relatively poor foraminifera assemblage with prevailing individuals of *Lenticulina* genus (*L. inornata, L. cultrata*, Cicha and Kheil 1962), *L. arcuatostriata*, and *Spiroplectinella carinata* as well as *Pappina bononiensis primiformis* (Zlinská, 1992).

**Čelovce Formation** (Fig. 6), occurring in the partial Čelovce Depression (Fig. 1), is composed of desintegrated, thick-bedded sandstone containing calcareous, variegated and dark coal clay and thin beds of brown glance coal. Coarse-grained, polymic and fine-grained, quartzite conglomerate intermittently forms small lenses in the formation. The maximum thickness of the formation is about 300 – 500 m. The lower part of the Čelovce depression fill prevailingly contains marine sublittoral and neritic microfauna (*Lenticulina meznericsae, Uvigerina hantkeni, Cibicides budayi, Planulina wuelerstorfi, Ammonia beccarii, Porosononion subgranosum* and others, Cicha and Kheil 1962). The brackish fauna is represented by assemblage of *Ostrea cf. cythula, Polymesoda brogniarti, Congeria basteroti, Pirenella hornensis* (Volfová 1959).

Nearby village of Modrá n/Cirochou E of Humenné a small erosive relic of the Eggenburgian deposits, overlying the Klippen belt and the Outer-Carpathian Flysch, occurs. It consists of gray and dark gray crumbled claystones and siltstones containing lenses and seams of coal (Vass and Elečko 1988). Besides allochthonous foraminifera they also contain autochthonous species *Tenuitellinota angustiumbilicata, Globoturborotalalia rotalita connecta , Globigerina lentiana, Almaea osnabrugensis, Cyclamina praecancelata* suggesting the Eggenburgian age of the deposits (Zlinská 1995). The autochthonous fauna reveals deteriorated conditions, most probably in the coastal lagoon with restricted communication with the open sea. The occurrence of coal seams suggests coastal swamp or marsh environment.

*Ottnangian (19.0 - 17.5 Ma)*

During the Ottnangian the change of palaeostress field resulted in emerging of the area of the future East-Slovakian Neogene Basin above sea level. The pressure generating shear was changed by a pure compression acting in the SW-NE direction resulting in uplift of the area and depositional hiatus (Janočko & Jacko 2 000). In such a palaeostress condition dextral translation along Periklippen Fault Belt (comp. Baráth et al. 1997) and along the faults separating Iňačovce-Kritchevo Unit and Humenné Mesozoic rocks would be active.

*Karpatian (17.5 – 16.5 Ma)*

At the beginning of the Karpatian stage a new depositional area opened in the region of the East-Slovakian Basin. During that time a marine transgression, corresponding to the cycle TB2.2 of the global eustatic sea level (Haq. et al. 1987) occurs in the area. The brittle deformations suggest extension in NE - SW direction (Fig. 4) and the basin was opened by normal faults parallel to the recent basin axis. The extension was most probably a result of the upheaval of the Pannonian asthenosphere (e.g. Vass 1995). The faults were often inherited from the older tectonic structure of the upper crust. The original thrust planes along which the Zemplinicum and the Ptrukša Units were overthrusted, were reactivated and changed to listric faults. Similarly, the thrust planes along which the Ptrukša Unit was overthrusted on the Iňačovce-Kričevo Unit, were reactivated (Fig. 8). The subsidence of blocks along these discontinuities resulted in extensional opening of the East-Slovakian Basin.

A marine transgression into the opening basin occurred mainly from the NE, i.e. from the basins occurring in the front of the Flysch Carpathians (from the original sedimentary basins of recent tectonic units of the Carpathian front: Skole, Stebnik and Boryslav-Pokuty units; Oszczypko 1997). Sea might also penetrate from the NW direction where Czieszkowski (1992) has suggested a marine basin in the area of Orava.

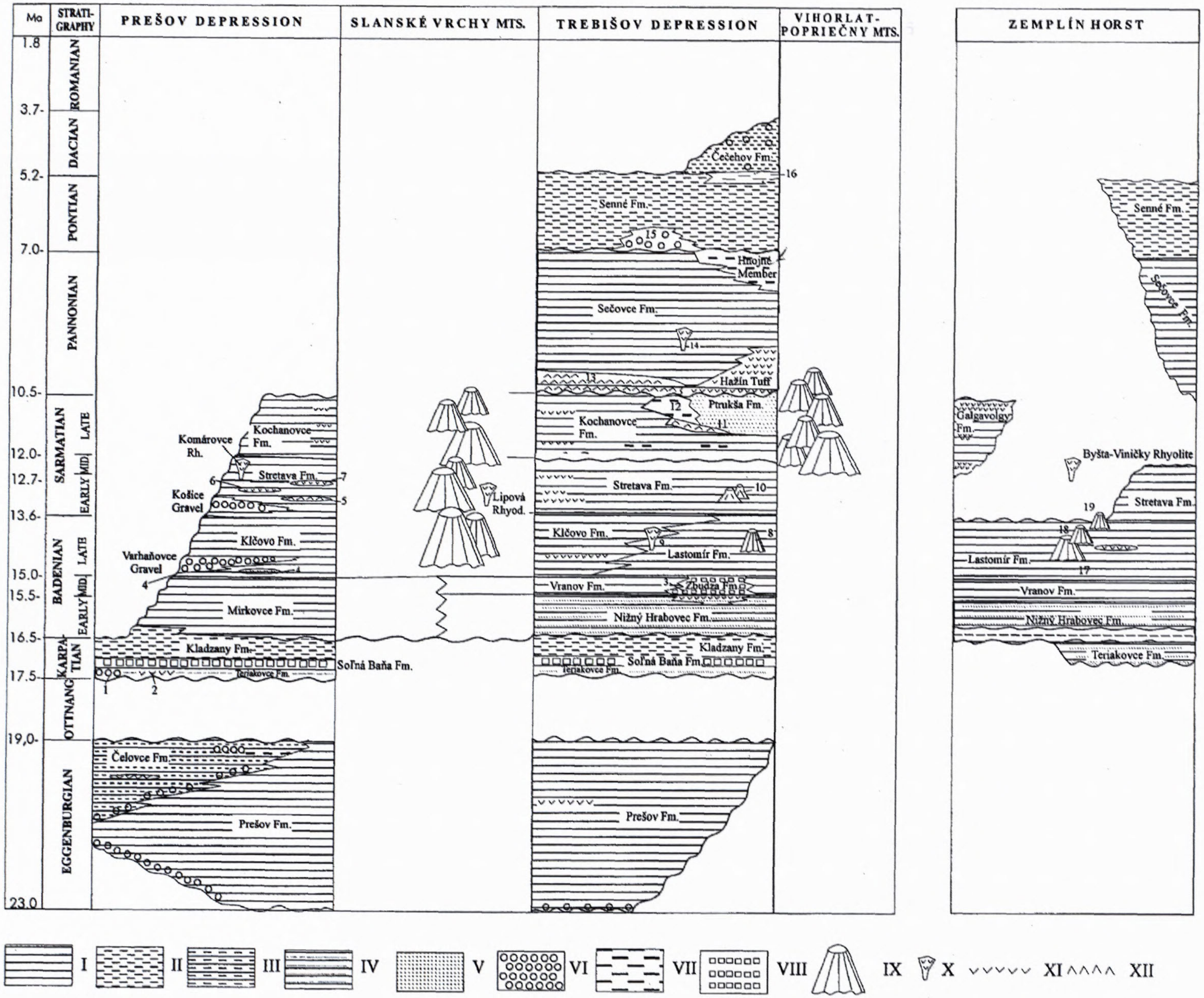



*Fig. 6 Lithostratigraphy of the East-Slovakian Basin fill*
*Explanation:*
*Legende numbers:*
*I – calcareous siltstone and claystone; II - multicolored clay/claystone; III – multicolored variagated and grey siltstone and claystone; IV – sandstone and siltstone; V – sand/sandstone; VI – conglomerate/gravel; VII – coal seams; VIII – evaporites; IX – stratovolcano (andesite); X – rhyolite and rhyodacite extrusive body; XI – rhyolite tuff; XII – andesite tuff*
*Lithostratigraphic units numbers: 1. Lemešany conglomerate, 2. Fintice tuff, 3. Hrabovec tuff, 4. Kráľovce tuff, 5. Olšava Mb., 6. Myšla Mb., 7. Rankovce tuff, 8. Zatin andesite, 9. Lesné rhyolite, 10. Malčice, Beša and Čičarovce stratovolcanos, 11. Lúčky volcaniclastics, 12. Závadka Mb., 13. Albinov tuff, 14. Michalovce rhyolite, 15. Pozdišovce gravel/conglomerate, 16. Iňačovce Mb., 17. Kráľovsky Chlmec stratovolcano, 18. Somotor stratovolcano, 19. Brehov stratovolcano*

The Karpatian deposits consist of three formations:

The basal, **Teriakovce Formationn** (Fig. 6), mostly consists of calcareous gray sandstone and claystone (flysch-like sequence) croping out in the NW part of the basin. Conglomer ate, occurring between Prešov and Ďurkov east of Košice (Map 2), comprises the lowermost part of the formation (Lemešany Conglomerate, Karoli in Kaličiak et al. 1991). Genetically the conglomerate represents a wide spectrum of depositional environments varying from fluvial through deltaic and shallow-marine conglomerates. The maximum thickness of the formation is about 250 – 400 m. The formation contains marine fauna *Uvigerina graciliformis, U. parkeri breviformis, U. bononiensis primiformis* (e.g. Kantorová in Kantor & Kantorová 1955, Cicha & Kheil 1962, Zapletalová 1970), *Brissopsis ottnangensis, Ammussium cristatum badense, Macoma elliptica, Lima cf. lebani*; (e.g. Seneš 1955). The calcareous nanoflora of the NN4 zone was also described in the surroundings of Hlinné (Lehotayová 1982). The foraminifera assemblage suggests outer shelf environment (Zlinská 1992, Kováč & Zlinská 1998).

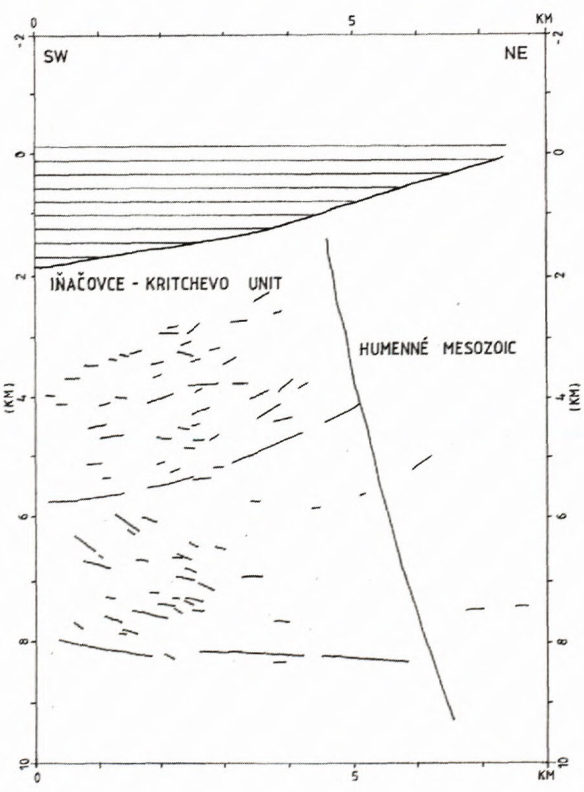


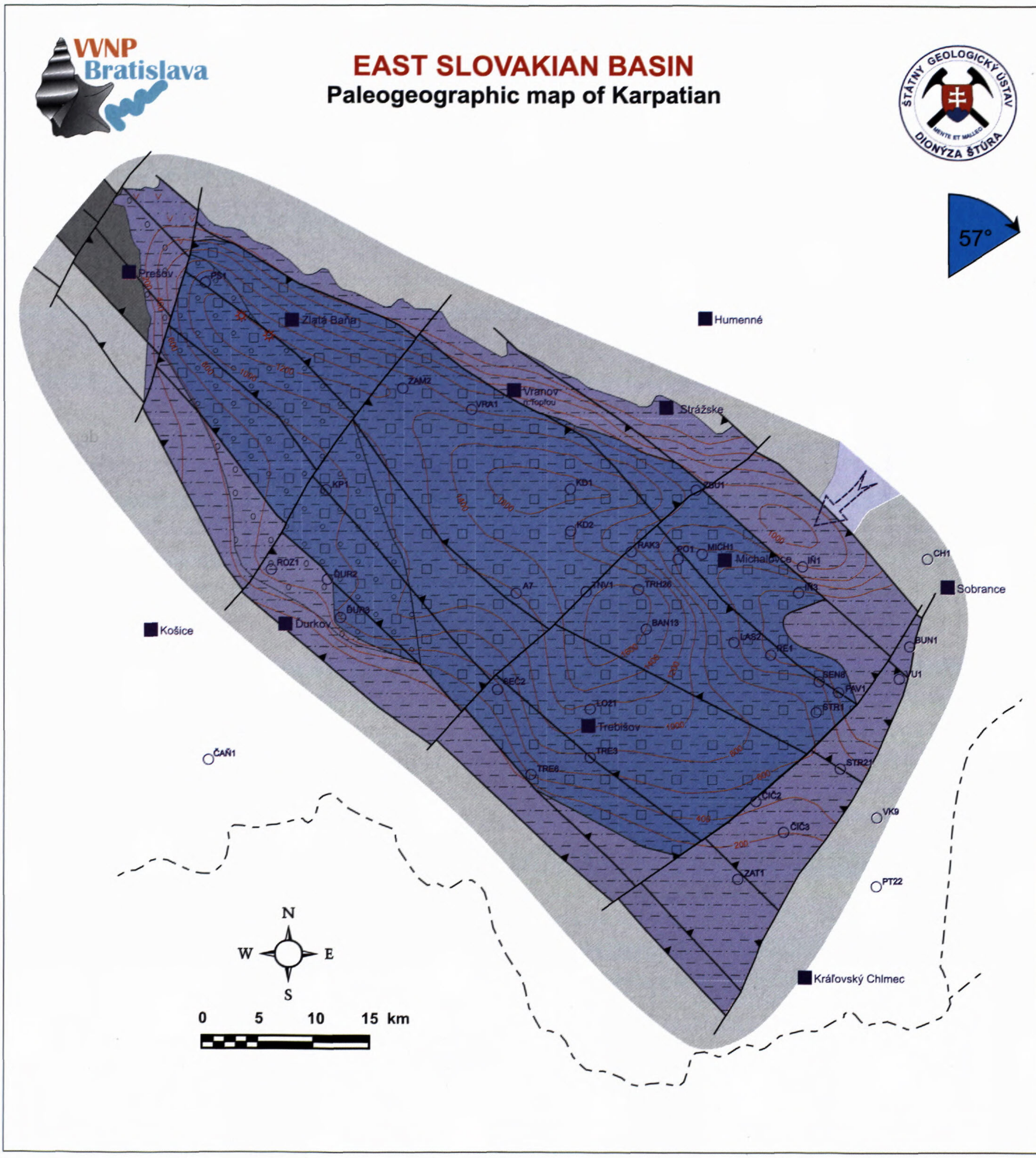

*Fig. 7: Deep seismic profile 612/88 showing distinct seismic anisotropy between the Iňačovce - Kritchevo Unit (strong reflections) and the Humenné Mesozoic (no reflection). After Tomek in Vozárová et al. 1993).*

**Soľná Baňa Formation** overlies Teriakovce Formation (Fig. 6). The decreasing of subsidence during that time resulted in semiclosed environment and prevailing deposition in hypersaline conditions. The formation consists of mudstone with gypsum laminae and sporadic nodular anhydrite at the base, which pass into salt breccia (mudstone and sandstone clasts floating in halite matrix). The uppermost part is again composed of prevailing mudstone deposits containing minor layers of salt breccia (Karoli 1998). The type of deposits and abrupt dissapearance of the foraminifera fauna suggest prevailing evaporite deposition in mud flat and salt pan environments. Maximum thickness of the deposits is 320 m. The formation crop out in the Prešov surroundings but it was were also documented in deep boreholes in the central part of the East Slovakian Basin (Map 2).

The occurrence of fauna in the formation is poor. Foraminifera assemblage composed of species *Florilus, Elphidium, Melonis*, is apparently influenced by hypersalinity of the environment. Typical Early Miocene species, e.g. *Uvigerina parkeri breviformis* and typical Karpathian species *U. graciliformis* (Kantorová 1954, Cicha & Kheil 1962) also occur sporadically.

The deposits of the Late Karpatian **Kladzany Formation** gradually evolved from the Soľná Baňa Formation, or they laterally pass into the Soľná Baňa Formation (Fig. 6). They consist of variegated calcareous claystone and clay with thin beds of sandstone. The structures of deposits together with the occurrence of anhydrite concretions, secondary fibrous anhydrite and fibrous halite filling fissures suggest shallow water deposition. The rocks crop out between Vranov and Strážske and in the Prešov Depression. The sediment almost lacks organic material. Occasionally marine foraminifera, including typical Karpatian species *Uvigerina graciliformis*, and *U. bononiensis compressa, U. acumianta, Bolivina hebes, Cibicides ungarianus*, (Danihelová 1954, Zapletalová 1974, Zlinská in Kaličiak et al. 1991, Holcová in Vass et al. 1996) were found. Foraminifera assemblages are not uniform and reflect local changes of coastal onlaps of the 4th and 5th order (Holcová in Vass et al. 1996, Fig. 9). According to the deep boreholes the formation, which max. thickness is about 1 300 m, occurs almost in the whole basin.

During the Late Karpatian a new tectonic regime appeared which was controlled by stress field formed by renewed activity in the subduction zone of the Carpathians (e.g. Kováč et al. 1994). There is no direct evidence on spatial orientation of the main direction of compression during the Late Karpatian but we asumme that the palaeostress recorded by brittle deformations of Early Badenian rocks (Kováč et al. 1994) was identical with the stress applied in the East Slovakian Basin during the Late Karpatian. The regime is suggested mainly by a very rapid, pull-apart type subsidence resulting in deposition of more than 1 000 m deposits of the Kladzany Formation in the NW corner of the basin (Fig. 2). In the palaeostress field with maximum compression in NW - SE direction the NW normal faults turn to dextral strike-slips and normal faults of NE direction were active as sinistral strike-slips. The dextral translation along Periklippen Fault Belt and faults separating the Humenné Mesozoic rocks and the Iňačovce-Kričevo Unit has been reactivated (see Fig. 4). These faults have been disturbed by sinistral strike-slips of NE - SW direction (Map 3).


VVNP
Bratislava
EAST SLOVAKIAN BASIN
Paleogeographic map of Karpatian
ŠTÁTNY GEOLOGICKÝ ÚSTAV DIONÝZA ŠTÚRA
MENTE ET MALLEO
57°
Prešov
Zlatá Baňa
Humenné
Vranov n/Topľou
Strážske
Michalovce
Sobrance
Košice
Ďurkov
Trebišov
Kráľovský Chlmec
N
W
E
S
0
5
10
15 km

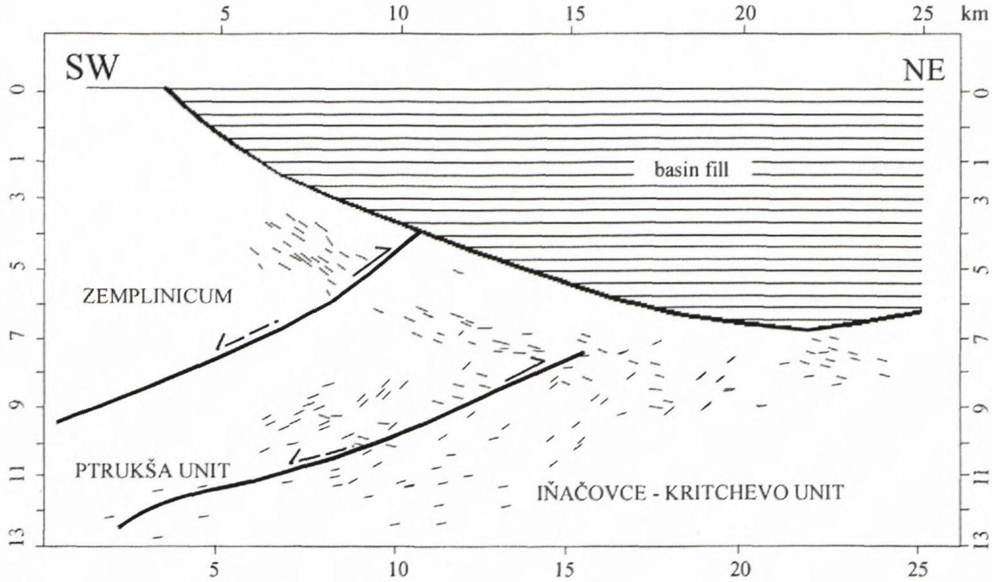



*Fig. 8: Deep seismic profiles 597 and 597A/86. As a result of crustal spreading, thrust planes turned into listric normal faults. After Tomek in Vozárová et al. (1993).*

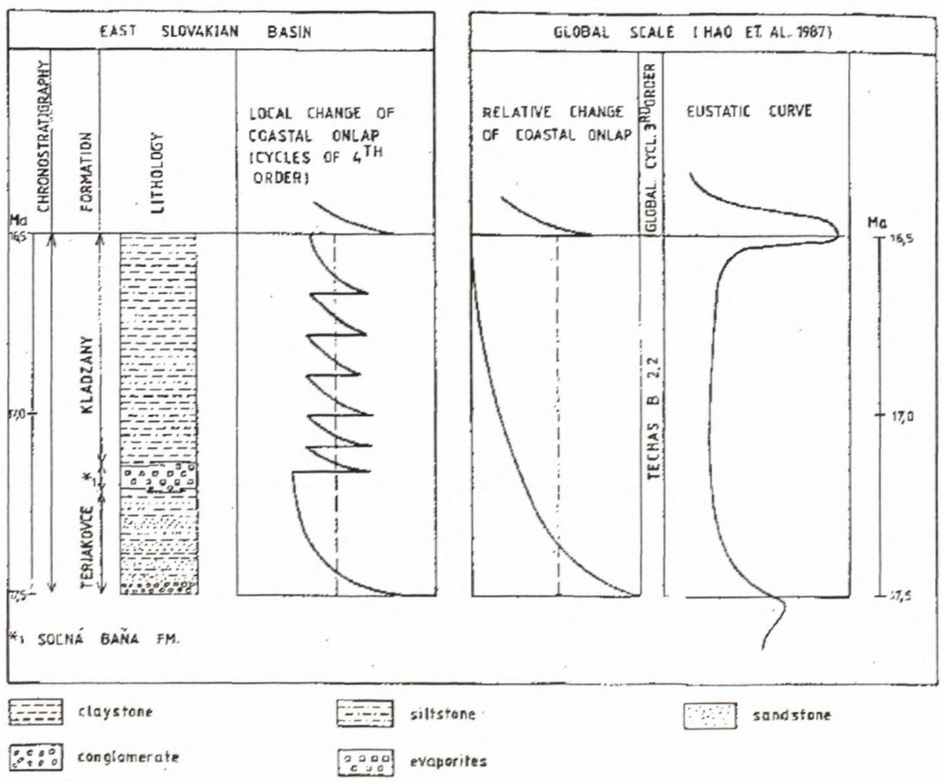



*Fig. 9: $4^{th}$ or $5^{th}$ order cycles of the sea level fluctuation in the East Slovakian Basin during deposition of the Kladzany Formation, Late Karpatian and comparison with the global scale of sea level fluctuation. After Holcová in Vass et a. 1996).*

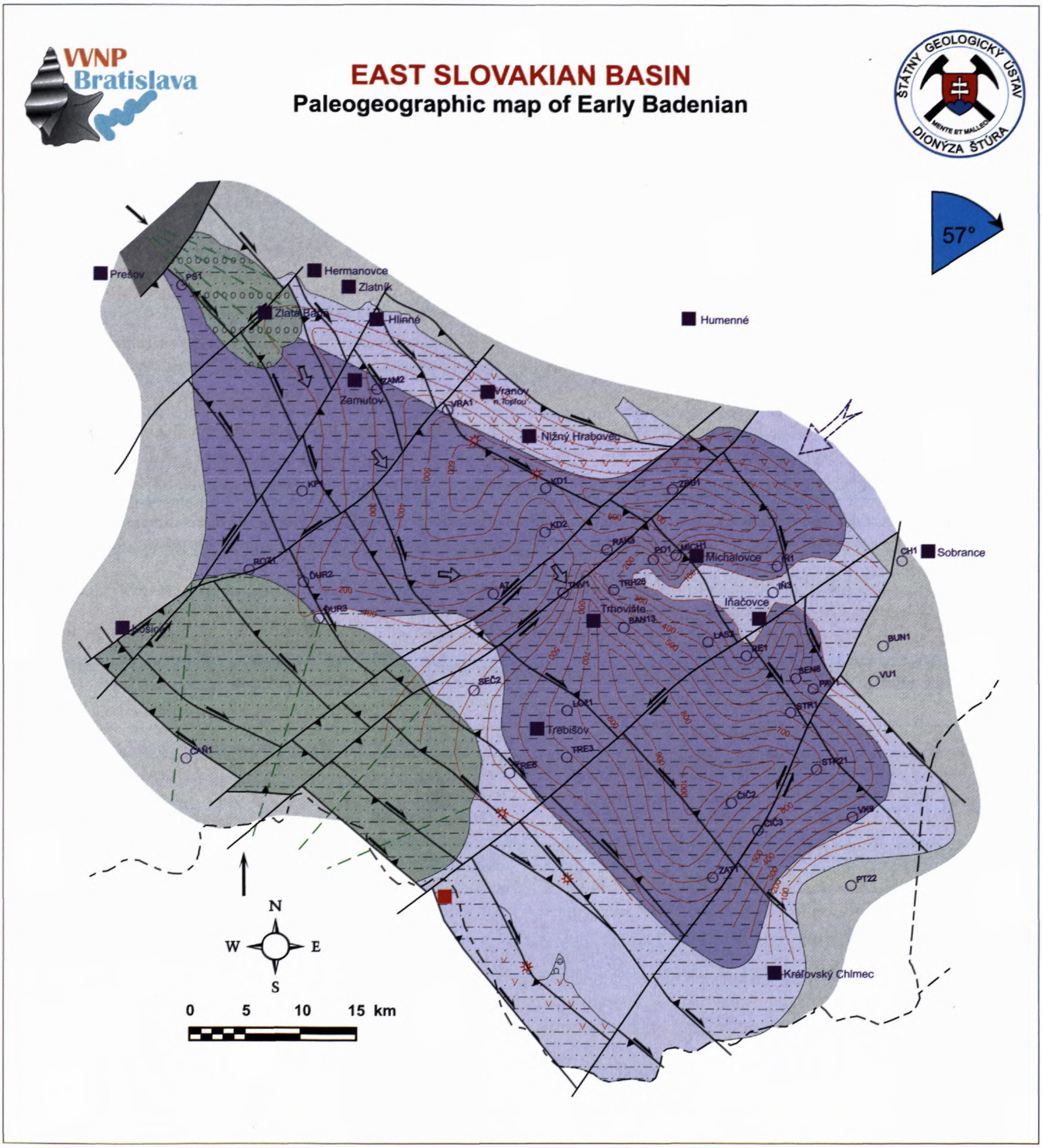
Cumulative thickness of the Karpatian deposits shows that the most intensive subsidence and the thickest deposits occurs S of Vranov, SW of Michalovce and SE of Prešov (Map 2). The thickest part of the deposits belongs to the Kladzany Formation.

Volcanic activity during the Karpatian was represented by acid areal explosive volcanism with crustal origin of magma. The buried products of volcanism occur in the surroundings of Zlatá Baňa (SE of Prešov, Map 2) where also volcanic centers are asummed (Kaličiak et al. 1991) and they outrop NE of Prešov (Fintice Tuff).

At the end of the Karpatian the sea retreated from the larger part of the East Slovakian Basin as it is suggested by reflection-seismic sections from the area.

*Early Badenian (16.5 - 15.5 Ma; Map 3)*

New widespread marine transgression, corresponding to the TB 2.3 cycle of sea level fluctuation (Haq et al. 1987), occurred at the beginning of the Badenian. The main faults governing the opening of the basin, were dextral strike-slips active in the palaeostress field with maxi-


VVNP Bratislava
EAST SLOVAKIAN BASIN
Paleogeographic map of Early Badenian
ŠTÁTNY GEOLOGICKÝ ÚSTAV DIONÝZA ŠTÚRA
MENTE ET MALLEO
57°
Prešov
Hermanovce
Zlatník
Zlatá Baňa
Hlinné
Humenné
Zamutov
Vranov n. Topľou
Nižný Hrabovec
Michalovce
Sobrance
Trhovište
Iňačovce
Košice
Trebišov
Kráľovský Chlmec
N
W
E
S
0 5 10 15 km

mum compression in NNW - SSE direction. The sea transgression was from NE, i.e. from the basins located in the Outer Flysch zone or from the foredeep and from NW (from Orava marine basin). Occurrence of the Early Badenian deposits on the foothil of the Zemplínske vrchy Hills implies possible transgression also from the area of the Great Hungarian Plain or Nyírség Basin. The foraminifera assemblage analysed from the Early Badenian mudstones occurring close to the Zemplín Hills have a rich planktonic association (Lehotayová in Ivan 1962, Cicha in Čechovič et al. 1963) suggesting sedimentation in deeper, probably outer shelf environment. This, at least, implies seagates along the Zemplínske vrchy Hills suggesting marine communication from the south which, up till now, was first assumed in the Late Badenian. (Rudinec 1989a,b).

The deposits of Early Badenian (Moravian) **Nižný Hrabovec Formation** disconformably overlies the Kladzany Formation (Fig. 6). The only exception occurs in the Prešov Depression where a longitudinal horst trending from Zamutov to Zlatá Baňa determined preservation of shallow sea on the $CaSO_4$ saturation boundary and gradual transition from the Kladzany Formation. In this part the Early Badenian microfauna occurs in the upper part of variegated deposits of the Kladzany Formation (Zlínska & Karoli in Kaličiak et al. 1991). The communication with the sea was improved after a transverse deformation of the horst by faults of NE-SW direction. The Nižný Hrabovec Formation consists of grey calcareous siltstone and claystone interbedded by fine- to medium-grained massive sandstone up to 0.5 cm thick. The sandstone occurs more frequently in the NE margin of the basin where it comprises 0.3 – 3 m thick beds. Siltstone and claystone content increases basinward. In the central part of the basin calcareous clay/claystone prevails. The thickest (about 1 000 m) deposits occur east of Trebišov (Map 3). The deposits crops out on the N margin of the basin in the surroundings of Oblík and in a narrow strip between Hlinné and Nižný Hrabovec in the vicinity of Vranov. The occurrence of the formation in other parts of the basin is proved by deep boreholes. Lenses of fibrous gypsum with dimensions 50x30x7 m occur in dark grey claystone in the surroundings of the elevation point Oblík (Slávik 1967, Karoli in Kaličiak et al. 1991), and suggest lagoonal environment having intermittently oversaturated waters with $CaSO_4$ resulting in evaporitic deposition of sulphates. In the same area beds of polymic conglomerate and gravel associated by sandstone overlie interval consisting of claystone with gypsum. The conglomerate is coarse-grained and blocky. The clasts predominantly consist of flysch rocks and minor limestone and cherts. Similar conglomerate also occurs in the surroundings of Zlatník and Hermanovce SE of Prešov (Karoli in Kaličiak et al. 1991, Vass in Baňacký et al. 1987). The deposits probably originated in deltas entering the basin.

The base of Nižný Hrabovec Formation on the foothill of the Zemplín Hills is composed of polymic conglomerate consisting of local rocks. The conglomerate is overlain by grey sandy benthonitic clay and claystone containing sandstone beds, which is capped by pumice rhyolite tuff with clasts of rhyolite and sandstone composed of Carboniferous rocks fragments (Ivan 1962, Elečko & Vass in Baňacký et al. 1989). The stratigraphic profile of the Nižný Hrabovec Formation was revealed by the borehole Zat-1. The borehole was terminated after 600 m of drilling in the formation (Tereska 1969). The penetrated deposits consist of prevailingly dark grey, bituminous siltstone and claystone interbedded by calcareous sandstone, acid tuff, redeposited tuff and ryodacite which is often propilitized.

A typical member of the Nižný Hrabovec Formation is Hrabovec Tuff. It forms several meters to several tens of meters thick, light green layers. The volcanoclastic material is altered and zeolizated. The original rock was ryodacite or dacite tuff. NE of Sobrance nearby Podhoroď unaltered rhyolite tuffs represent equivalent of the Hrabovec Tuff.

Abundant marine fauna of the Nižný Hrabovec Formation suggests extensive transgression in the basin. The foraminifera assemblage contains for example index species of N8 zone *Orbulina suturalis* accompanied by planktonic forms *O. universa*, representants of species *Praeorbulina*, benthonic species including forms typical for Moravian (lagenids zones): *Lenticulina calcar, L. cultrata, L. auris* etc. (Lehotayová in Ivan 1962, Cicha & Kheil 1962, Cicha in Čechovič et al. 1963, Gašpariková & Slávik 1967 etc.). The calcareous nanoflora assemblage contains individuals typical for the zone NN 5 including index species *Sphenolithus heteromorphus* (Lehotayová 1982).

The Early and Middle Badenian deposits of the Prešov Depression are assigned to **Mirkovce Formation** (Fig. 6). Deposits of the formation crops out on the western foothil of the Slanské vrchy Mts. E and SE of Prešov. They are composed of monotonous, grey calcareous claystone rarely containing layers of fine-grained sandstone. Locally, montmorillonitic clay occurs in the lower part of the formation. In the area of the later stratovolcano Šťavica (SE of Prešov) the claystone was thermally altered by dioritic porphyres to contact chert having dish-like jointing. Maximum thickness of the formation is 630 m. It is underlain by rhyolitic pumice and lapilli tuff and volcaniclastic breccia beneath the Slanské Vrchy Mts. The fragments of breccia are composed of bounded rhyolit.

According to the bioecological and lithologic features several Early Badenian marine depositional environments may be distinguished in the basin (Map 3). In the central part of the basin, where the Nižný Hrabovec Formation has the greatest thickness and prevailingly consists of pelite, we assume relatively deepest depositional environment comparable to outer shelf. It is flanked by shallower environment from both northern and southern sides. This type of environment also occurs on the submarine elevation between Trhovište and Iňačovce having E-W direction. In the NW part of the Prešov Depression a delta, consisting of siltstone, sandstone and conglomerate, entered the basin. A greater delta also entered the basin from the SW. The western margin of the delta extended in to the Moldava or Košice Depression.

During the Early Badenian acid rhyolit-ryodacite crustal areal volcanism was active. The volcanic centers were mainly associated with the elongated fault system near the northern margin of the basin. The main product of this voclanic activity was Hrabovec Tuff representing equivalent of Novoe Selo Tuff in the Transcarpathian Ukraine and Dej Tuff in Romania. The rhyolite pumice, lapilly tuff and volcanic breccias containing fragments of bounded rhyolite, occurring in the centre of the later Zlatá Baňa stratovolcano, are probably also of the Early Badenian age.

*Middle Badenian (15.5 – 15.0 Ma; Maps 4 and 5)*

The evolution of the basin during the Middle Badenian continued in pull-apart regime similarly to the Late Karpatian and Early Badenian. We suppose any change in stress field and synsedimentary strike-slips occurred along the same faults like in the Late Karpatian and Early Badenian (Map 4). The basin opening continued along dextral strike-slip faults of NE - SW direction. Later, when salt-bearing Zbudza Formation was deposited, the strike-slip faults turned to be normal faults (Map 5).

The Middle Badenian (Wieliczkian), marine **Vranov Formation**, occurring east of the Slanské vrchy Mts. (Fig. 6) and upper part of **Mirkovce Formation,** located west of the Slanské vrchy Mts., suggest a continuation of marine transgression in the basin. The only difference was recorded in the area of the Zemplínske vrchy Hills where alternation of bathyal and littoral fauna (Lehotayová in Ivan, 1962, Kantorová in Baňacký et al. 1989) suggests oscillation of the sea level, most probably due to the tectonic activity of the Zemplín Horst. Main basin communication with open sea in the outer part of the Carpathians was still a seaway to the foredeep in NE. Another communication is assumed to the former marine Orava Basin in NW.

The deposits of Vranov Formation, croping out in Vranov and its surroundings, consist of gray calcareous claystone and siltstone alternating with sandstone. Sandstone and sand, suggesting a shallower environment, occur mainly on the NW margin of the basin in the surroundings of Ruská Nová Ves. Claystone prevails in the basin centre. In the surroundings of the Zemplínske vrchy Hills and nearby Trebišov redeposited vitroclastic tuffs and bentonized tuffaceous clays occur. Maximum subsidence occurred eastward of Trebišov and northward of Michalovce where the thickness of deposits is about 1 200 and 1 000 m, respectivelly. Both subsidence centers were separated by a submarine elevation between Trhovište and Iňačovce. The elevation also determined thickness and facial characteristics of deposits during the Early Badenian. Another depocentrum southward of Vranov was separated from above mentioned centres by a SW - NE trending submarine ridge between Slanec, Albinov and Dlhé Klčovo.

Foraminifera species of the formation correspond by their composition to assemblages of zone with *Spiroplectamina carinata (Valvulineria arcuata, V. marmaroschensis, Bulimina elongata intonsa, Uvigerina pygmoides, U. aculecta, U. hispida, U. aff. rugosa, U. aff. asperula, U. aff. costata* (Lehotayová in Ivan 1962, Zapletalová 1974, Kantorová in Baňacký et al. 1989, Zlinská, 1996).

The absence of coarse clastics suggests a flat relief surrounding the basin. Volcanic activity has not been recorded during the deposition of the Vranov and upper part of Mirkovce Formations.

The tectonic activity ceased during the Middle Badenian. Only normal faults with small throw amplitudes were active. The retreating sea determined development of hypersaline lagoons.

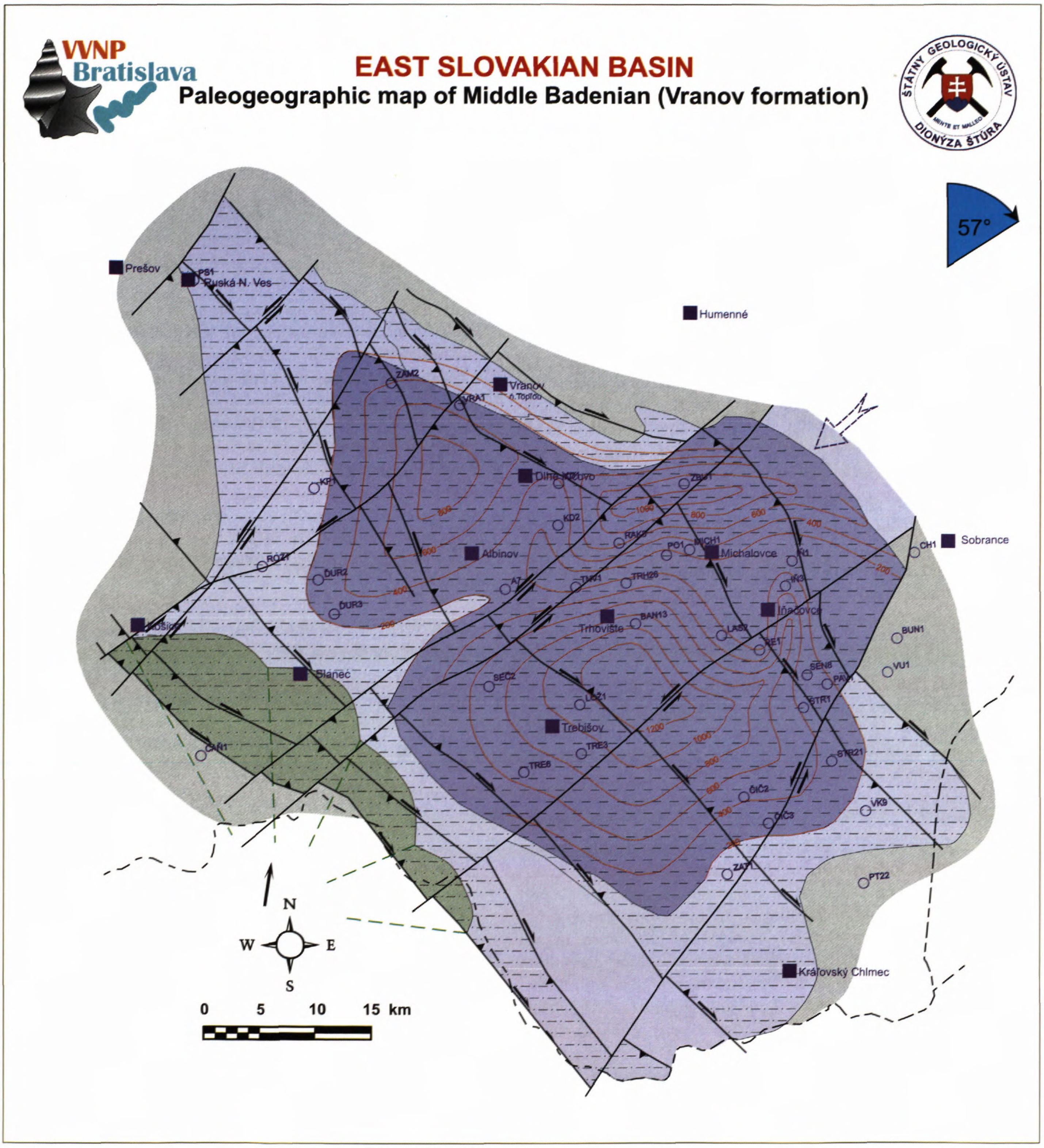
Evaporitic deposition, occurring in salt lagoons and shallow-marine environment, prevailed during deposition of **Zbudza Formation** extended in the central part of the basin (Fig. 6). It does not crop out and its occurrence was only documented by boreholes on the northern margin and in the central part of the basin (map 5). It attains maximum thickness of 300 m. The lower part of the formation consists of fine-grained clastics with chaotically dispersed or aggregated nodules of anhydrite. The clastics are overlain by lenticular, about 60 - 80 m thick and 3 km long, halite bodies. The whole succession is caped by beds consisting of clast-supported halite-rudite (Karoli 1998).

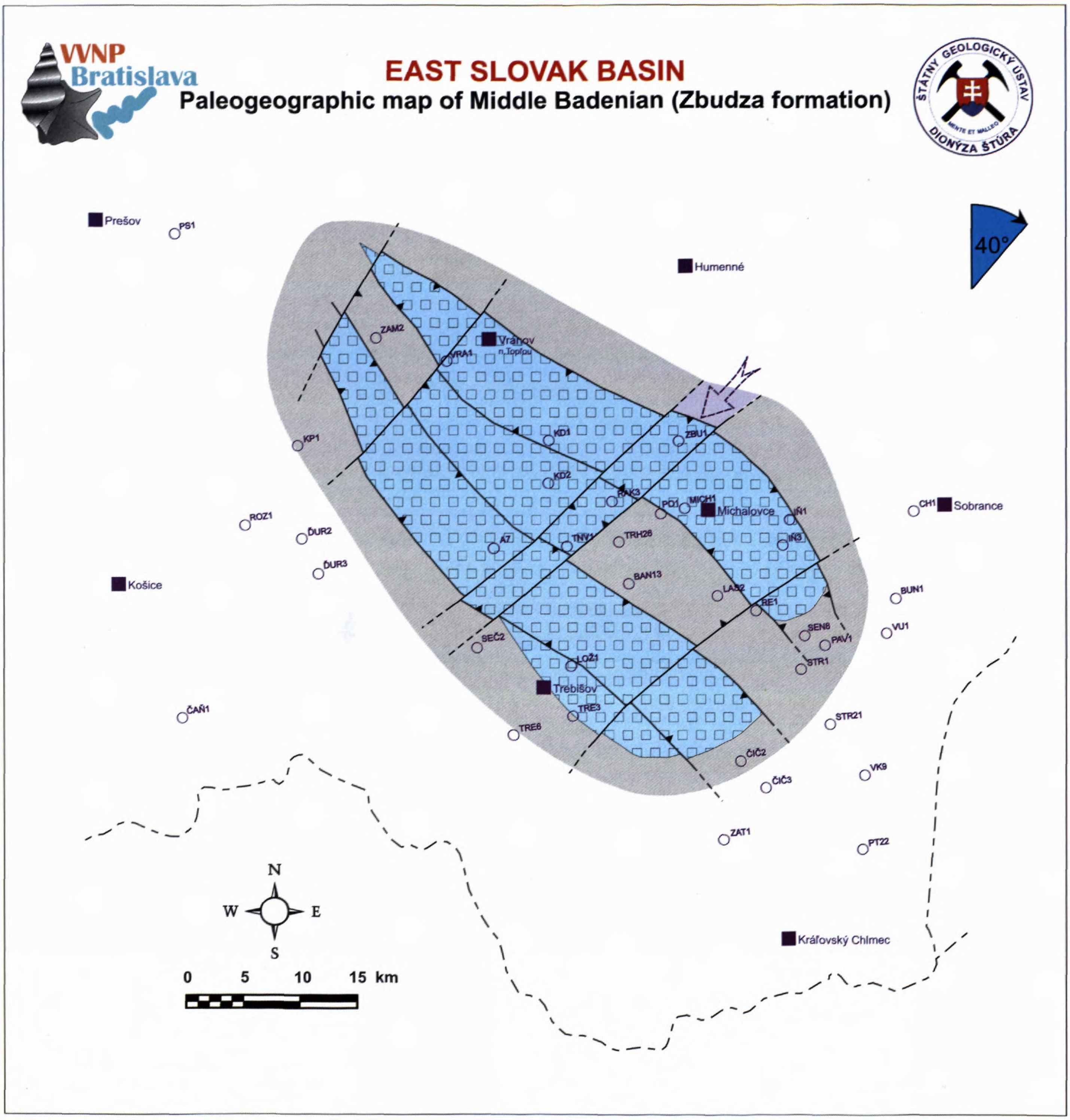
The Zbudza Formation originated during the regional salinity crisis in the Paratethys area. The massive halite originated not only in the East-Slovakian Neogene Basin but also in the Carpathian Foredeep (Wieliczka), in the Transcarpathian Ukraine and in the Romanian Transylvania. The formation contains a poor foraminifera assemblage: *Globigerina aff. bulloides, Globorotalia scitula, Globigerinoides trilobus, Uvigerina aculeata* (Gašpariková 1963).

*Late Badenian (15.0 – 13.6 Ma; Map 6)*

At the beginning of the Late Badenian (Kosivian), after salinity crisis, the tectonic activity of the basin increased resulting in revitalizing of pull-apart mechanism. The stress field had a maximum compression in E-W direction. The actual palaeostress was not found by measurements of brittle deformations of the Middle Badenian rocks (shortage of suitable outcrops), but on basis of data obtained from the Middle Sarmatian rocks (Kováč et al. 1994). We suppose those data is more reliable for the Late Badenian because palaeostress conditions of the Late Karpatian - Middle Badenian have been interrupted by the tectonic event enabling evaporitic sedimentation in the basin. The main role in a new basin opening played sinistral strike-slips of NW-SE direction and dextral strike slips of NE-SW direction. The faults of N - S direction were normal faults (Map 6 and Fig. 4).

The Late Badenian stage starts with marine transgression having about 0.5 Ma time lag against the global cycle


VVNP
Bratislava
EAST SLOVAKIAN BASIN
Paleogeographic map of Middle Badenian (Vranov formation)
ŠTÁTNY GEOLOGICKÝ ÚSTAV DIONÝZA ŠTÚRA
MENTE ET MALLEO
57°
Prešov
Ruská N. Ves
Humenné
Vranov n.Topľou
Dlhé Klčovo
Albinov
Michalovce
Sobrance
Iňačovce
Trhovište
Košice
Slanec
Trebišov
Kráľovský Chlmec
PS1
ZAM2
VRAT
KP1
KD2
ZBU1
RAK3
PO1
MICH1
R1
IŇ3
ROZ1
ĎUR2
ĎUR3
A7
TMH1
TRH26
BAN13
LAS2
RE1
SEN6
PAH
STR1
STR21
SEČ2
LOZ1
TRE3
TRE6
ČAN1
ČIČ2
ČIČ3
VK9
ZAT1
CH1
BUN1
VU1
PT22
1000
800
600
400
200
1200
N
W
E
S
0
5
10
15 km


VVNP
Bratislava
EAST SLOVAK BASIN
Paleogeographic map of Middle Badenian (Zbudza formation)
ŠTÁTNY GEOLOGICKÝ ÚSTAV
DIONÝZA ŠTÚRA
MENTE ET MALLEO
40°
Prešov
PS1
Humenné
ZAM2
Vranov n.Topľou
VRA1
KP1
KD1
ZBU1
KD2
RAK3
PD1
MICH1
Michalovce
IŇ1
IŇ3
CH1
Sobrance
ROZ1
ĎUR2
ĎUR3
AZ
TNV1
TRH26
Košice
BAN13
LAS2
RE1
BUN1
SEČ2
SEN8
PAV1
VU1
LOŽ1
STR1
Trebišov
TRE3
STR21
ČAŇ1
TRE6
ČIČ2
ČIČ3
VK9
ZAT1
PT22
N
W
E
S
0
5
10
15 km
Kráľovský Chlmec

TB 2.4 of the eustatic sea level fluctuation (Haq. et al. 1987), which was probably determined by local tectonics. Sea transgression came from NE from the Carpathian Foredeep (Fig. 5) in NE, and also from S and SW (Rudinec 1989).

The Late Badenian transgressive marine deposits are represented by the lower part of **Lastomír Formation**. The upper part of the formation interfingers with deposits of prograding delta assigned to the **Klčovo Formation** (Fig. 6). Deposits of the Lastomír formation are represented by calcareous, gray claystone containing beds of sandstone, acid tuff and redeposited tuff. Acid volcanoclastics occur on the N and NE margin of the Zemplínske vrchy Hills and on the foothills of the Slanské Vrchy Mts. (Map 6). Maximum thickness of the deposits, E of Trebišov, is 2 000 m. Shallow-marine facies of the formation marked as inner shelf occur in the southern and northern part of the basin. Toward the central and south-eastern part of the basin the facies pass into more deep-water facies of outer shelf. According to biofacial indicators the environment could represent a shallow bathyal zone.

Foraminifera assemblages containing species typical for Velapertine biozone (bulimina-bolivina zone) e.g. *Bulimina ex.gr.elongata, B. ex. gr. pupoides, B. ovata, Bolivina dilatata, B. antiqueformis, Uvigerina asperula, U. aff. semiornata, Valvulineria complanata, Cibicides boueanus, C. dutemplei* (Kudláčková et al., in Janáček, 1963, Jiříček 1972) suggest normal marine conditions.

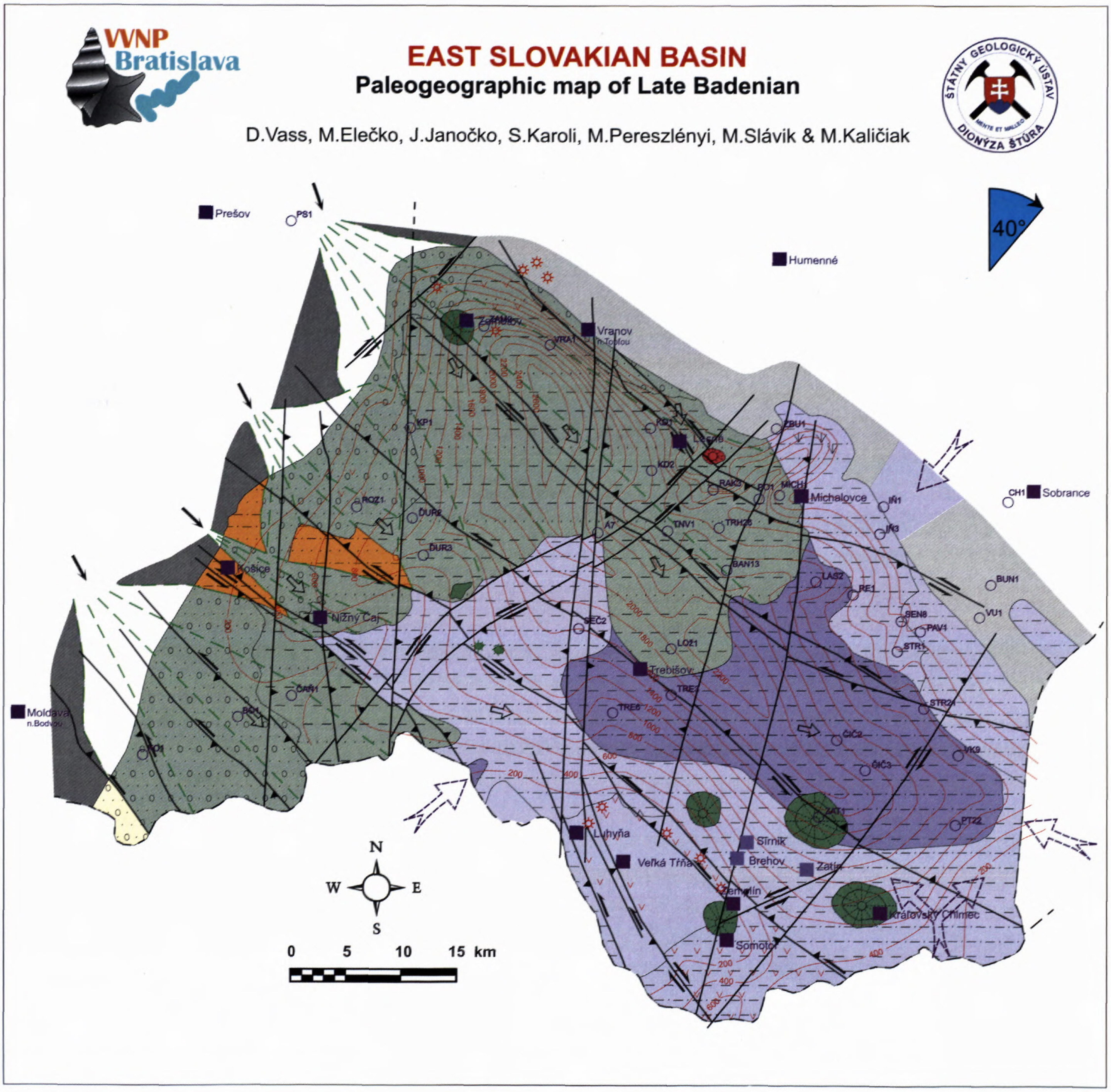
In the surroundings of Zatín the main part of the Late Badenian deposits consists of the Zatín volcanics having max. thickness about 1 400 m (borehole Za-1, Rudinec & Tereska 1972). The volcanics consist of lava flows composed of pyroxenic andesite associated by volcanoclastics and rhyolite. They are interlayered by bituminous clay/claystone and calcareous sandstone. Rarely marine fauna occurs (Jiříček in Tereska 1969). Radiometric ages of andesite and andesite tuff yielded 15.0-+2 Ma age (Slávik et al. 1976).

The Lastomír Formation laterally gradually passes into **Klčovo Formation**. This is proved by change of lithology and by change of some faunistic assemblages suggesting shallowing and hyposalinity of the environment as a result of the Klčovo delta progradations. The assemblages are depleted and they are represented by *Ammonia beccarii, Porosononion comunis, Elphidium sp., Virgulina schreibersi, Roussela spirulosa, Bulimina elongata, Ostrea digitalina, Cardium cff. andrusovi, C. turonicum, C. edule, Corbula gibba, Anomia ephipium , Ervilia dissita podolica, Clithon pictus, Hydrobia stagnalis* (Seneš 1955, Švagrovský 1959, Jiříček 1972). The Klčovo Formation as prograding deltas represents regressive part of the Late Badenian sedimentary cycle. The regression was accompanied by a uplift of the western basin margin which became the main source area delivering clastics into the basin. The deposits of the formation crop out in the Prešov Depression (Janočko 1990). Eastward of the Slanské vrchy Mts. (Fig. 5) it is mostly burried. In this part it was described by Jiříček (1972) and later defined on the base of seismic lines by Reřicha (1992). Its subsurface occurrence is as far as Trebišov and Michalovce. In the lower part of the formation poor brackish fauna assemblage was found (*Ammonia ex gr.beccarii, Porosononion subgranosum, Miliamina fusca, Egerella scabra*). Above this only ostracoda (*Candona strigulosa*) and terrestrial molluscs are autochtonous (Zapletalová unpubl., Jiříček 1972). Maximum thickness 2 800 m of the formation was found nearby Dlhé Klčovo southward of Vranov nad Topľou.

In the Prešov Depression the Klčovo Formation commences with Kráľovce Tuff which represents redeposited ryolite tuff containing pumice (up to 5 cm in diameter), lithoclasts of rhyolitic character and fragments of augit-hyperstenic andesite. The tuff is about 20 – 30 m thick (Kaličiak et al. 1991). The radiometric age of the tuff is about 13.9 +-0.3 Ma (Bagdasarjan et al. 1971). It is overlain by the Varhaňovce Gravel composed of polymic gravel having clasts from the Spišsko-Gemerské Rudohorie Mts. and Čierna Hora Mts. and greenish-gray, locally brownish-spotted calcareous clay. The clay contains layers of sand (up to 10 m of thickness), pebbles, redeposited tuff, coaly clay and rarely also lignite (Čverčko et al. 1968, Jiříček 1972, Janočko 1990, Reed et al. 1992). These sediments were mostly deposited in fan delta environments (Janočko 1990). They contain poor Badenian microfauna (Zlínska in Kaličiak et al. 1991).

Distal deltaic facies interfingering with shoreface deposits were described from the eastern part of the Moldava Depression in the borehole K-8 located nearby Nižný Čaj SE of Košice. They prevailingly consist of sandstone and siltstone, minor claystone and conglomerate. The lithology points to frequent lateral changes of distributary channels and interdistributary environments within the delta plain (Reed et al. 1992).

During the Late Badenian the basin deposition was accompanied by an important volcanic activity. It started by explosive ryodacite volcanism resulting in redeposited and pumice ryodacite tuff underlying andesites of the Kráľovský Chlmec stratovolcano. It was followed by andesite volcanism, products of which redeposited andesite tuff overlain by the lava flows of pyroxenic andesite. The stratovolcanoes occur in the surroundings of Zatín, Brehov, Sírnik and Somotor - see Map 6 (the assignement of these volcanics to the Late Badenian and not to the Sarmatian as it is on the map of Baňacký et al. 1989 is based on the radiometric ages of the Zatín andezite 15.0 ± 0.8Ma, Brehov andesite 14.0 ±1.4 Ma (Bagdassarjan et al. 1971) and mineralization accompanying older pre-Sarmatian volcanism). The extrusive ryodacite volcanism is today represented by individual bodies S and SE of Trebišov (Map 6). Ryodacite (rhyolite) occurring nearby villages Zemplín and Hrčeľ (Cejkov rhyodacite, see Fig. 6) are associated with silicified and adularized breccia. The radiometric age of the rhyolite at Hrčeľ is 13.5 ± 2.5 and 14.9 ± 2.8 Ma (Tsonj & Slávik, 1971). The character of alterations suggests submarine volcanism. The redeposited volcaniclastics are product of explosive-hydrothermal breccia in a submarine environment. The redeposited ryodacite tuff overlying the biostratigraphi-


VVNP
Bratislava
EAST SLOVAKIAN BASIN
Paleogeographic map of Late Badenian
D.Vass, M.Elečko, J.Janočko, S.Karoli, M.Pereszlényi, M.Slávik & M.Kaličiak
ŠTÁTNY GEOLOGICKÝ ÚSTAV
DIONÝZA ŠTÚRA
40°
Prešov
PS1
Humenné
Vranov
n.Topľou
Michalovce
Sobrance
CH1
Košice
Nižný Čaj
Trebišov
Moldava
n.Bodvou
Luhyňa
Veľká Tŕňa
Brehov
Zatín
Somotor
Kráľovský Chlmec
KP1
ROZ1
ĎUR2
ĎUR3
LAS2
RE1
SEN8
PAV1
STR1
STR2
BUN1
VU1
IŇ1
IŇ3
TNV1
A7
SEČ2
LOŽ1
TRE6
ČIČ2
ČIČ3
VK9
PT22
BAN13
KD2
RAK3
MICH1
ZBU1
VRA1
N
W
E
S
0
5
10
15 km

cally proved Late Badenian deposits, was found by drilling between Veľká Tŕňa and Luhyňa S of Trebišov. The pumice ryodacite tuff occurs S and SE of Trebišov (Kaličiak in Baňacký et al. 1989).

In the northern part of the East-Slovakian Basin a body having fluidal bounded structure was drilled in the area of the central zone of the younger Zlatá Baňa stratovolcano (Dubník located SE of Prešov). South of Soľ (NW of Vranov) a horizon of rhyolite tuff occurs which is associated with epiclastic rhyolite sandstone. The radiometric age of the tuff is 14.2 ± 0.7 Ma (Repčok in Kaličiak et al. 1991). Two bodies of rhyolite crop out at the village Lesné NW of Michalovce. The radiometric age of one of them is 15.2 Ma (Bagdassarjan et al. 1971).

South of Zamutov (W of Vranov) an extrusive ryodacite dome occurs. Its analogues found in the borehole Zam-2 were radiodated to 14.4 Ma (Bagdasarjan et al. 1971).

The evolution of the andesite stratovolcano Ošvárska (W of Vranov) commenced in the Late Badenian. It consists of autochthonous pyroclastics, pyroxenic andesite lava flows and andesite necks. The stratovolcano also was active during the Early Sarmatian.

*Early Sarmatian (13.6 – 12.7 Ma; Map 7)*

We assume that the main tectonic structure, of Early Sarmatian, is identical to the Late Badenian one. It is represented by NW sinistral, conjugate and NE dextral strike-slips as well as normal faults having N-S direction. The opening of the basin was intensive as it is proved by the highest sedimentation rate in the SE part of the basin (267.8 cm/1 000 years before decompaction and some 390.8 cm/1 000 years after decompaction; Vass & Čech 1989, Král et al. 1990, see Fig. 2).

During the Early Sarmatian the area of the central Paratethys, including the East-Slovakian Basin, began to be separated from the open sea. The Sarmatian epicontinental sea in the Paratethys was brackish with salinity around 20 – 25 ppm. In spite of the isolation, the transgression in the basin coincides with eustatic sea level fluctuation cycle TB2.5 (13.8 Ma , Haq et al. 1987; Fig. 5). The basin was connected with depositional areas in Hungary and the Transcarpathian Ukraine. The connection to the Carpathian Foredeep was terminated and the emerged Outer Flysch Carpathians became one of the main source area.

At the beginning of the Sarmatian the brackish sea incursed the basin from the south. It came round the Zemplin-Beregovo Horst and flooded area as far as Michalovce in the north, the Vranov nad Topľou in the northwest and Košice in the west (Map 7). It also overcame the Uzhgorod Horst and reached the Transcarpathian area. In the western and northern part of the basin sea was shallow and it was influenced by progradig deltas. A shallow sea also occurred in the area of the Zemplín – Beregovo Horst. In the southeastern part of the basin the brackish sea was relatively deeper. At these places the Early Sarmatian deposits attain the greatest thickness, up to 2 400 m.

The Early Sarmatian deposits comprise **Stretava Formation** (Fig. 6), which generally represents transgressive phase of Sarmatian periode. It consists of gray calcareous clay interbedded by layers of pale and variegated clay, sand, gravel and minor acid tuff. Tuff and reworked tuff occur in the Olšava and Myšľa Members (Švagrovský 1956, Rankovce Tuff, Seneš 1955). The intrusive ryodacite bodies or necks (ryodacite of Lipová), associated by swarm of dikes, crop out on the northern margin of the basin NW, of Vranov. Their radiometric age is 13.2 ± 3 and 13.3 ± 1.2 Ma (Repčok 1977, Merlič & Spitkovskaja 1974). Among Malčice – Beša – Čičárovce andesite stratovolcanos are interfingered with Stretava Formation (Ďurica 1965).

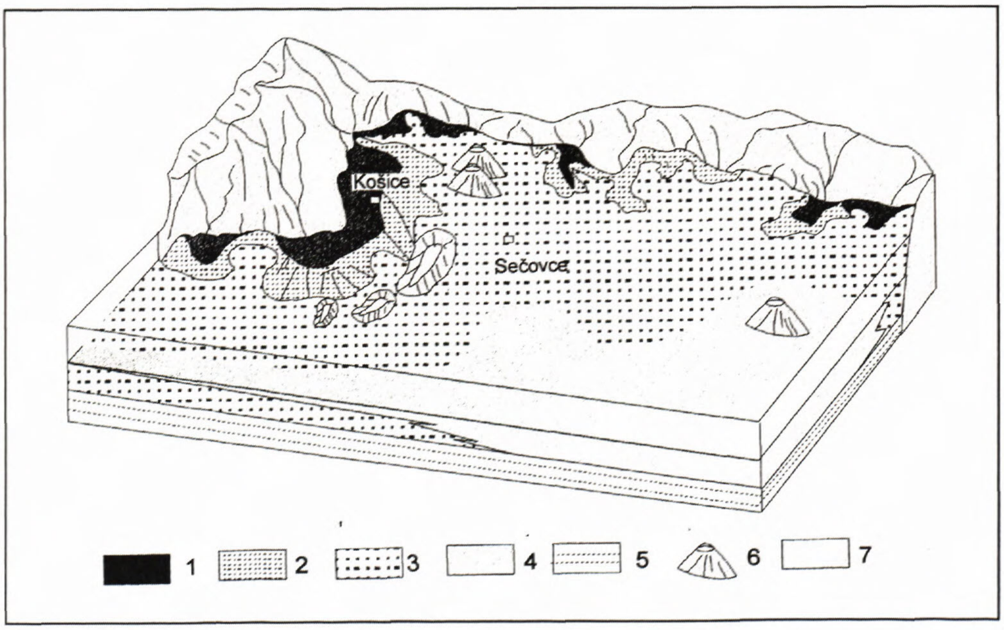
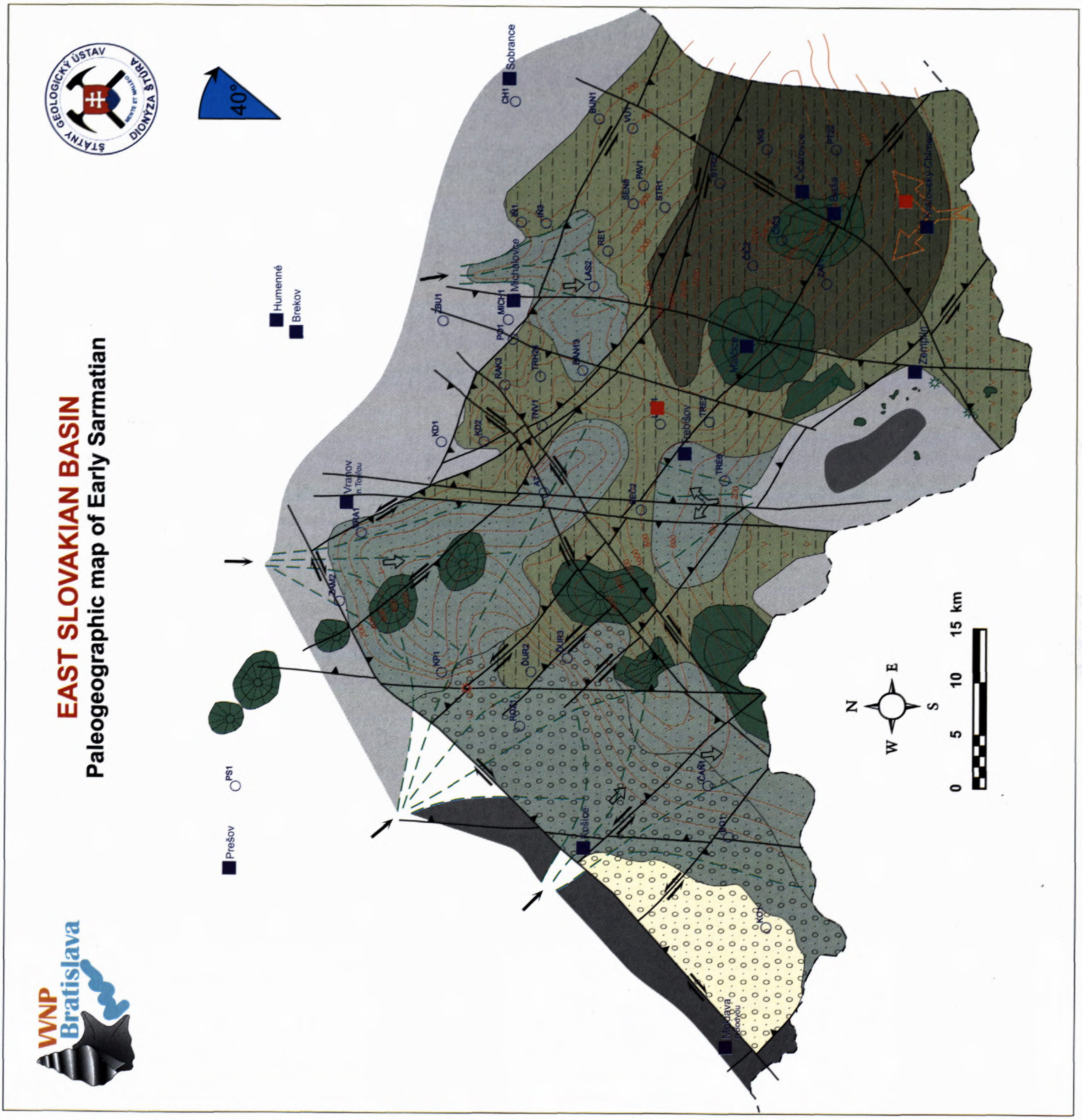



*Fig. 10: Blockdiagram showing assumed extension of the Early Sarmatian deltas in the East-Slovakian Basin. The extension of deltas in western part of Basin are limited by the contemporary stratovolcanos of Prešov – Tokaj Mts. Explanation: 1 – fan deltas, 2 – deltaic deposits, 3 – inner shelf, 4 – outer shelf, 5 – pre-Sarmatian deposits, 6 – volcanoes, 7 – pre-Neogene rocks*


EAST SLOVAKIAN BASIN
Paleogeographic map of Early Sarmatian
Prešov
Humenné
Brekov
Sobrance
Michalovce
Vranov n. Topľou
Trebišov
Košice
Zemplín
Čičarovce
Kráľovský Chlmec
40°
N
E
S
W
0
5
10
15 km

Slovak Geol. Mag., 6, 4(2000), 377–407

The formation contains brackish fauna assemblage: *Cardium politioanei politioanei, C. vindobonensis, Evilia dissita dissita, Tapes vitalinus, Mohrensternia sarmatica, Acteocina lajonkaireana lajonkaireana, Pirenella picta mitralis* (e.g. Čechovič 1940, Körössy 1940, Švagrovský 1952, 1956, 1960). Based on the foraminifera assemblage it is possible to subdivide the formation into two biozones: (Gašpariková, Cmuntová, Prokšová in Brodňan 1959, Lehotayová in Čechovič & Vass 1960, Brestenská & Priechodská 1959, Zlinská in Kaličiak et al. 1991, Zlinská, 1992).

– a biozone containing *Elphidium reginum* with associated species *E. crispum, E. macellum, E. aculeatum*: the Early Sarmatian sensu Grill (1943) which deposits are showed in Map 7;

– a biozone containing *Elphidium hauerinum* with associated *species E. listeri, e. cf. aculeatum, E. cf. minutum, Porosononion bogdanoviczi* suggesting the Middle Sarmatian sensu Grill l.c. Deposits correlated with the biozone are included in Map 8.

In the western part of the basin the Stretava Formation contains coarse-grained deposits marked as Košice Gravel (Vass 1989, Janočko et al. 1991, 1998). The gravel is polymic and alternates with sand and gray and dark-gray clay containing sporomorphs assigned to the Early Sarmatian. The sedimentary succession originated in deltaic and shallow-marine environment. In the outcrops in the surroundings of Košice small cycles consisting of alternating deltaic, shoreface and offshore deposits occur. The change of deltaic to shoreface deposition was determined by allocyclic (sediment input and tetonics) and autocyclic (delta lobe switching) factors (Janočko 1998). The emerging volcanic range of the Slanské vrchy Mts. partly restricted the extension of the delta toward the east (Fig. 10). We also assume deltaic deposits at the NW foothill of the Zemplín Horst. Another deltas prograded into the basin from the north. The Laborec River palaeodelta entered the basin through the Brekov Gate and continues toward Michalovce. The Topľa River delta spread the deposits in the area S and SW of Vranov nad Topľou. Smaller deltas developed in the Moldava part of the basin and on the foothill of the forming Vihorlat and Popriečny Mts. (Map 7).

*Late Sarmatian (12.7 - 10.5 Ma; Map 8 )*

The palaeogeography expressed in Map 8 comprises the situation during the Middle and Late Sarmatian according to biostratigraphical subdivision (e.g. zone with Elphidium hauerinum and Porosonium subgramosum resp., Grill 1943). Decreasing sedimentation rate and prevailing extensional tectonic structures suggests change of the basin tectonic style from the pull-apart regime to simple extensional one. The direction of extension was NW-SE. Distribution of faults was similar to the Early Sarmatian system but former strike-slips changed to normal faults (both NW and NE trending systems) and the faults of N-S direction changed to dextral strike-slips (Map 8). The Late Sarmatian deposits represent a new sedimentary cycle (Fig. 5) consistent with T.2.6. cycle of Haq et al. (1987). The beginning of the cycle is well-defined in seismic profiles (Janočko in press).

In the western part of the basin the Middle and Late Sarmatian deposits are represented by **Kochanovce Formation** (Fig. 6). The formation is dominantly composed of light gray clay with scattered volcanic material, reworked tuff and pumice and pumice-lapilli andesitic tuff. Volcanic and volcanoclastic rocks often occur in the surroundings of the Slanské vrchy Mts. where andesite lava flows enter the formation (Kaličiak et al. 1991). Volcaniclasics are locally bentonised. Layers of lignite and coal clay occur in the formation too. The formation contains freshwater fauna (*Planorbis sp., Characeae, Candona II, Illiocypris* (Jiříček 1972, Holzknecht 1970 unpubl.). According to Planderová (fide Kaličiak et al. 1991) the sporomorpha assemblage represents the Late Sarmatian-Pannonian association.

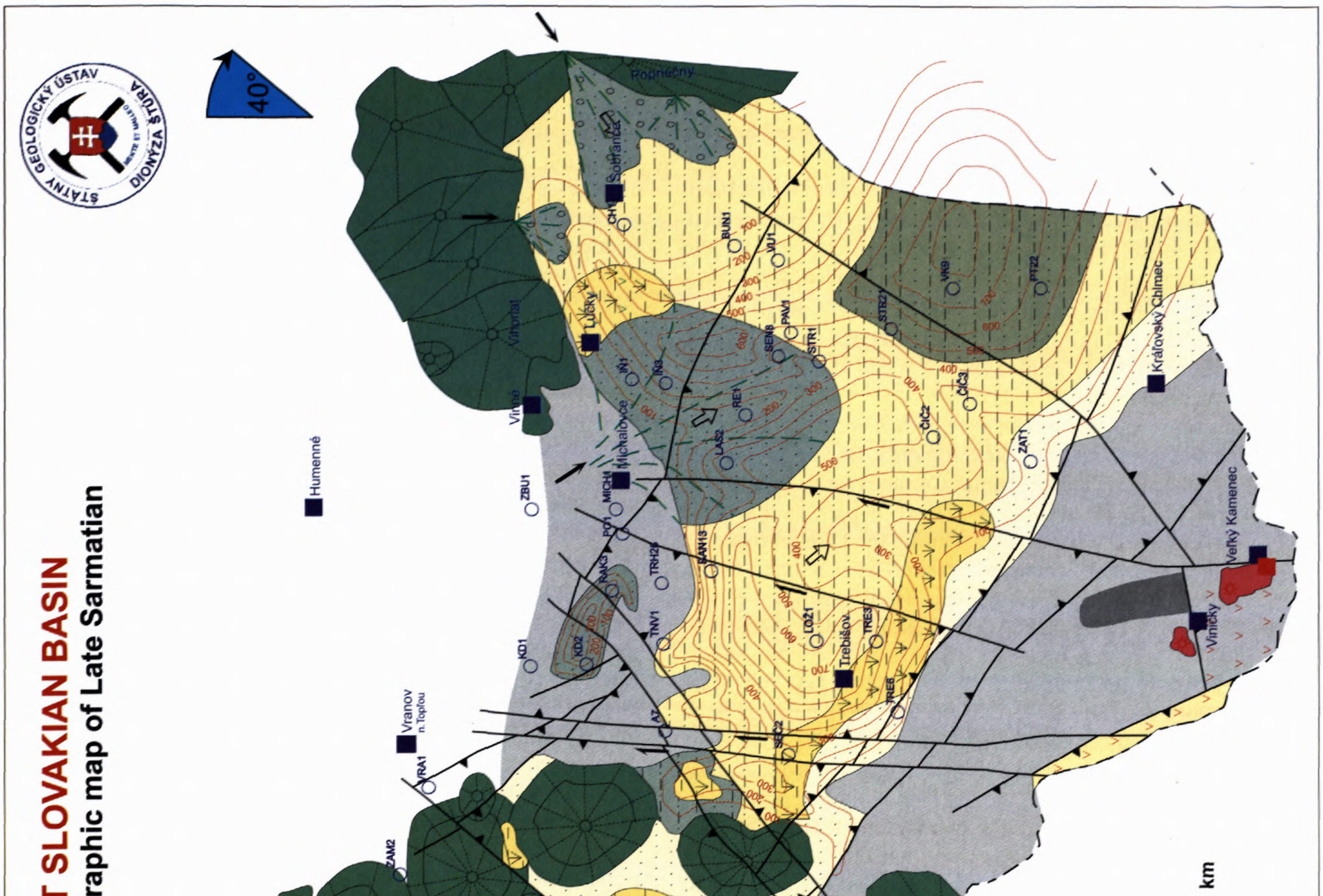
**Ptrukša Formation**, about 130-200 m thick, represents Late Sarmatian Formation in the eastern part of the basin. It consists of light gray calcareous sand and sandstone with layers of clay and reworked tuff. It contains fauna assigned to the Late Sarmatian biozone with *Porosononion subgranosum* sensu Grill (1943).

**Lučky Volcaniclastics** are equivalent of the upper part of the Kochanovce Formation and the lower part of the Ptrukša Formation (Fig. 6). They consist of andesite breccia, tuff, reworked tuff and autometamorphic lava of pyroxenic-amphibolic andesite. Tuffitic and silicious limestone occurs too. This member, which probably represents equivalent of the Vinné andesite, is about 50-80 m thick.

**Závadka Member** overlies the Lučky Volcaniclastics and passes into the Ptrukša Formation basinward. Závadka Member mainly consists of gray calcareous clay and claystone. Beds of sandstone, gravel and reworked tuff also occur. Coal seams grouped into four coal measures containing 13 seams are typical lithologies of the member. The seams are developed in lense forms and they attain thickness from a few cm to 5.9 m . Another typical characteristics of the formation is the occurrence of ironstone balls and layers (concretions and layers of pelosiderite). The Závadka Member contains the Late Sarmatian fauna.

**Galgavölgy Rhyolite tuff Formation** (formerly Tokaj Formation; Baňacký at al. 1989) is equivalent of the Kochanovce Formation in the Roňava „Bay“ (see Fig. 1 and Fig. 6). The formation mainly consists of rhyolite, rhyolite tuff, reworked tuff which are often bentonised. They are associated with lignite seams. Also rhyolite extrusive bodies S of T ebišov nearby the Slovak-Hungarian state border should be assigned to this formation (Vass, Elečko in Baňacký et al. 1998). The radiometric age of the rhyolite from Viničky is between 11.1 and 12.2 Ma (Vass et al. 1978).

The Sarmatian was a period of an eventful volcanic activity. Except above mentioned volcanics, which comprise a part of the basin fill (andesites and rhyolite tuffs), the main mass of volcanics forming the Slanské vrchy


EAST SLOVAKIAN BASIN
Paleogeographic map of Late Sarmatian
Prešov
Košice
Vranov n.Topľou
Humenné
Michalovce
Trebišov
Vinné
Lúčky
Kráľovský Chlmec
Veľký Kamenec
Viničky
N
W
E
S
0
5
10
15 km
40°

Slovak Geol. Mag., 6, 4(2000), 377–407

Mts. and Vihorlat Mts. was formed during the Sarmatian. The radiometric ages of the volcanic rocks from the Slanské vrchy Mts. vary from 10.0 to 13.6 Ma (Bagdasarjan et al. 1971, Slávik et al. 1976, Ďurica et al. 1978). The stratovolcano Ošvárska in the northern part of the mountains finished its activity during the Early Sarmatian. At that time also new and main andesitic stratovolcanoes started to form in the Slanské vrchy Mts. (see Fig. 6). Several isolated andesite and rhyolite bodies on the basin margin, rhyolite ignimbrite and perlite (at Viničky 11.1 and 11.4 Ma), including those penetrated by the borehole Ko-1 (12.1 ± 0.7 Ma) in the Moldava Depression also originated during the Sarmatian (Vass 1967, Bagdasarjan et al. 1968, 1971, Pulec and Vass 1969, Konečný, Lexa & Dublan in Baňacký et al. 1989).

According to the radiometric ages the Vihorlat and Popriečny volcanic mountains commenced to form during the Middle and mainly Late Sarmatian. During the Middle Sarmatian the andesite Vinné Complex originated. Ryodacite of the Beňatinská Voda are a part of the older structure of the Vihorlat Mts. During the Late Sarmatian a number of stratovolcanoes arose. Their activity terminated during the Pannonian (Bagdassarjan et al. 1971,Slávik et al. 1976, Ďurica et al. 1978, Žec et al. 1997).

Rhyolite and rhyodacite volcanoes Veľký and Malý Kamenec and Viničky (S of Trebišov) were formed on the Zemplín horst during the Late Sarmatian. They had short lava flows accompanied by various types of volcanoclastics and tuffs which form an important volume of the Galgavölgy Formation on the southern foothill of the Zemplín Hills. The explosions of „nuées ardentes„ type resulting in formation of above mentioned ignimbrite, tuff and perlite, also occurred in the Moldava Depression.

*Pannonian and Pontian (10.5 – 5.2 Ma; Map 9)*

Termination of the East-Slovakian Basin continued during the Late Miocene e.g. during the Pannonian and Pontian. During this stage of the basin evolution NE-SW and occasionally NW-SE normal faults prevailed (Map 9). During the Pontian the basin was subjected to stress resulting in a weak folding of the basin fill. This is indicated by seismic sections (Keith et al. 1989, Magyar et al. 1997, Mořkovský et al. 1999) and by small fold deformations found in the Teriakovce Formation of the Karpatian age. Another indications are steeply-inclined strata on the basin margin. The Pannonian deposits of Sečovce Formation are also slightly folded (Kováč et al. 1994) giving an important information for timing of the stress shock as post-Pannonian.

Beginning of the Pannonian is emphasized by onlaps on seismic profiles. The Pannonian deposits only extend in the middle and SE part of the Trebišov depression and in the Moldava Depression. They transgressively and unconformably overlie deposits of various biozones and lithostratigraphic units of the Sarmatian. The thickness of the Pannonian and Pontian deposits in the SE part of the basin is about 1 300 m. In the partial depression between Sečovce and Trebišov and E of the Zemplínske vrchy Hills the thickness of deposits is maximum 500 m.

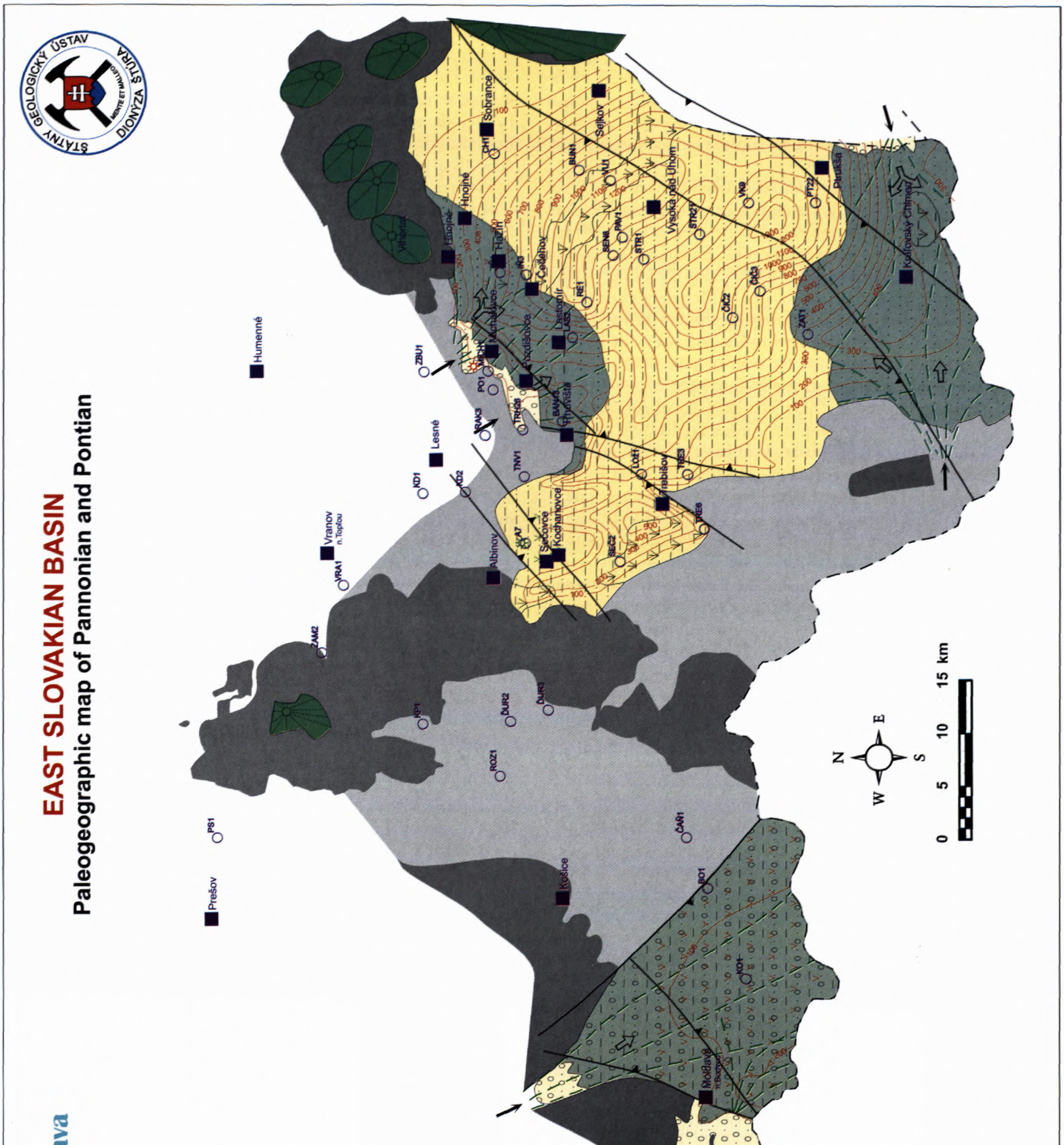
The whole Pannonian sedimentary cycle in the basin is represented by **Sečovce Formation** (Fig. 6). From the underlying deposits of the Kochanovce Formation it differs by variegated colour in the lower part of the sedimentary succession (Janáček 1959). In the upper part the formation consists of gray calcareous clay containing coal clay or seams and lenses of lignite with tuff and redeposited tuff layers. In the surroundings of Sečovce thick-bedded, coarse-grained Albinov Tuff (Albínovská Hôrka Tuff, Janáček 1959, 1963) of amphibolite-pyroxenic andesite occurs in the lower part of the formation. The thickness and grain size of deposits decrease toward the basin centre.

Jiříček (1972) described the „Pannonian type" fauna (*Ciprideis tuberculata, Bithynia aff. tentaculata*) from the Sečovce Formation in the Ptrukša surroundings. Ostracods (*Candona aff. sp.II., Cyprinotus salinus, Limnocytherae sp.*) and gastropods were found in the surroundings of Trebišov (e.g. Janáček 1963). The palynomorpha assemblage has Early Pannonian characteristics (Planderová in Baňacký et al. 1989).

Deposits of the Hažín Tuff and Hnojné Member, both of the Panonian age, occur at the Vihorlat foothill (E of Michalovce). **The Hažín Tuff**, 30 - 40 m thick, discordantly overlies the Závadka Member and Ptrukša Formation (Late Sarmatian, Fig. 6). It consists of pumice granatic grayish-green, palish-gray tuff and reworked tuff. Clasts of palish-gray pumice and rhyolite clasts are frequent. They are accompanied by tuffaceous clay, coal lenses and ironestone balls and layers. Jiříček (1972) reports ostracods and *diatomae Carychium minimum, Cyprinotus sp., Candoinella albicans, Darwinula stewensoni, Melosira arenaria* from deposits, which he considers as equivalent of the Hažín Tuff. He correlated them with the Early Pannonian „A" biozone.

**The Hnojné Member** overlies the Hažín Tuff. It mainly consists of gray and palish-gray clay containing seams and lenses of lignite. So called main coal seam measure has the largest areal extension. The coal seams in this member are 2.5 – 5m and occasionally up to 10 m thick. The main seam is divided by a layer of tuffitic limestone and spongodiatomic combustible shale into two beds in the eastern part of the Hnojné deposit. Higher up 10 – 15 seams having irregular thickness and development occur within clays. Reworked tuff, ironstone balles and thin layers also occur. The Hnojné Member contains fresh-water fauna from the family *Planorbidae*, diatomae of *Melosira* family and leaf imprints. From the beds considered as the equivalent of the Hnojné Member Jiříček reported ostracode assemblage of fresh-water fauna (*Carychium minimum, Bithynia tentaculata, Candoniella albicans, Ciprideis tuberculata, Pisidium sp.*) and he correlated this member with the Pannonian „B" biozone.

Lignite bearing beds nearby Sejkov are equivalent of the Hnojné Member (Rudinec & Čverčko 1970) and they are bounded to the NE slope of the depression between Lastomír and Vysoká nad Uhom (Map 9).


EAST SLOVAKIAN BASIN
Paleogeographic map of Pannonian and Pontian
ŠTÁTNY GEOLOGICKÝ ÚSTAV DIONÝZA ŠTÚRA
WNP Bratislava
Prešov
Košice
Humenné
Lesné
Vranov n. Topľou
Albinov
Sečovce
Kochanovce
Trebišov
Michalovce
Sobrance
Hnojné
Vysoká nad Uhom
Pavlovce
Lastomír
Moldava n. Bodvou
Kráľovský Chlmec
Vihorlat
N
E
S
W
0
5
10
15 km

Slovak Geol. Mag., 6, 4(2000), 377–407

Deltas entered the Pannonian and Pontian lake in the basin area. Two of them, obviously deltas of Laborec and Ondava palaoerivers, occurred on the northern margin of the lake. Lignite seams originated on the delta plain of the Laborec River delta. The delta, probably of the Latorica River, entered the basin from the east. A separate deltaic system developed in the Moldava Depression (e.g. Janočko & Šoltésová 1993).

During the Pannonian, the activity of the Slanské vrchy Mts. andesite volcanoes (about 10 Ma old, Slávik et al. 1976) as well as the activity of the most Vihorlat Mts. stratovolcanoes were ceasing. The youngest volcanics of the Vihorlat Mts. are about 9 Ma old (Slávik et al. 1976). The Pannonian radiometric ages (9 Ma) are reported from some andesite dikes occurring on the top of the Mount Vihorlat. Similar ages have dykes and necks of basaltic andesites and dacites at locality Dubník in the Slanské vrchy Mts. (Slávik et al. 1976, Kaličiak et al. 1991, 1996, Žec & Ďurkovičová 1993). The products of coeval explosive andesitic volcanism are represented by the Albínov Tuff northward of Sečovce. Acid volcanism was active on the southern periphery of the Vihorlat Mts. The rhyolite body of Hrádok Hill at the town of Michalovce seams to be Pannonian in age (Márton et al., 2000).

Opinions on the occurrence of the Pontian deposits in the basin vary. Janáček (1959) assigned to the Pontian the variegated formation which was later defined as **Senné Formation** by Vass & Čverčko (1985). It occurs in the middle and SE part of the basin, partly it also extends into the N part of the basin (Fig. 6). The maximum thickness of the formation is up to 600 m. It crops out on the Pozdišovce horst between Pozdišovce, Trhovište and Lesné. A member of the Senné Formation, the Pozdišovce Gravel consisting of gravel and interlayered variegated clay extends on the northern margin of the basin. It is interpreted as fluvial-deltaic deposit of palaeorivers Ondava and Laborec. The gravel beds are up to 30 – 40 cm thick and they almost exclusively consist of pebbles derived from the Outer Flysch - mainly sandstone, minor chert, occasionally Neogene rhyolite. The andesite clasts do not occur (Vass & Elečko 1977). Basinward the thickness of the Senné Fm. increases but the gravel pinches out. The main volume of the formation is composed of variagated clay.

Jiříček questioned the Pontian age of the Senné Formation and he assigned it to the Pannonian but later he admitted the correlation of the formation with the Pontian. Based on conception by Jiříček (1972) and proves by Slávik (1974), mainly emphasizing the absence of the andesite clasts in the Pozdišovce Gravel, Vass & Čverčko (1985) assigned the Senné Formation to the Pannonian. However, it is difficult to substantiate the basinwide hiatus during the Pontian. The deposits are also lithologically similar (especially variegated kaolinic clays) to the Poltár Formation extended in the Southern Slovakia and Moldava Depression, which age is well proved (Planderová 1986, Balogh et al. 1981). From this reason we prefer the Pontian age of the Senné Formation though there are not unambiguous biostratigraphic and other chronostratigraphic evidences.

A hiatus and erosion might be expected between the Sečovce and Senné Formations, especially in the marginal parts of their extension. The transgressive character of the Senné Formation is evidenced by its transgressive and disconformable position above the older Miocene formations in the northern part of the Trebišov depression. The tectonic events - slight folding of the Sečovce Formation deposits also suggest possibility of hiatus and discordance between the Sečovce and Senné Formations.

In partial Čečehov Depression (occurring from Michalovce to Vysoká n.Uhom) the upper part of the formation passes into the **Iňačovce Member**. It consists of gray clay with layers of coaly clay and lignite. Sporadically occurring gravel does not contain andesite clasts and it resembles Pozdišovce Gravel.

The Senné Formation contains poor fresh-water fossil assemblage of *Limax crassus, Valvata cf. variabilis, Candoniella albicans, Candoniella sp.III* (Jiříček 1972).

*Pliocene (5.2 – 1.8 Ma; Map 10)*

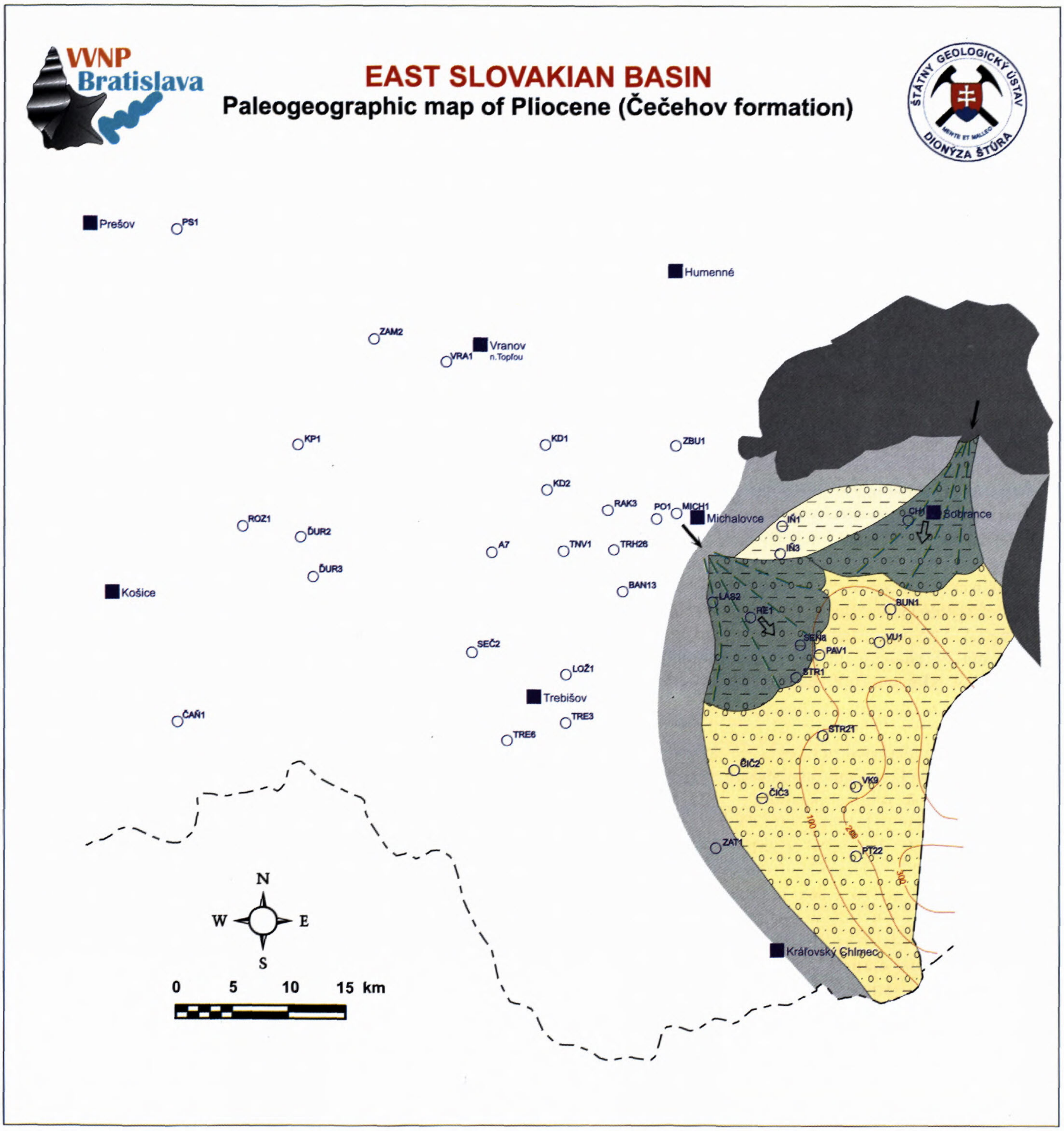
The basin markedly diminished in the Pliocene. Lacustrine deposits from this stage comprise **Čečehov Formation** discordantly overlying the Senné Formation (Fig. 6). The transgressive character is suggested by the position of the Čečehov Formation above the Hnojné Member of the Pannonian age in the Sub-Vihorlat Depression. The formation is about 120 – 200 m thick. It is composed of variageted clay containing layers of andesite gravel, sand and reworked tuff. Clastic andesite material was delivered to fresh-water lake by creeks draining the volcanic Vihorlat Mountains. Small deltas originated in the northern margin of the basin.

Fauna of the Čečehov Formation is very rare, the assemblages consist of fresh-water organisms rests (*Candoniella sp. III, Candona candida, Cyclocypria globosa, Cypria candonaeformis, c. tambovense, Planorbis sp.*) most probably Pliocene in age (Jiříček 1972). Pollen spectrum has a Pliocene in character too (Planderová in Baňacký et al. 1989).

## Discussion

Ideas on the structure of the East-Slovakian Basin pre-Neogene basement vary. Soták et al. (e.g. 1993) consider the Iňačovce - Kritchevo Unit as the Penninicum. They mainly reason by lithologic similarity, grade of metamorphosis and age. Vozár et al. (1993) correlates the same unit with the Szolnok - Maramures flysch (Tissia). This is based on its position at rear of the Carpathian units, heterogenity of metamorphic rocks, stratigraphy and lithology. We accept this opinion and we believe that the unit together with the Zemplinicum escaped from the Pannonian area into the Carpathians by a large sinistral strike-slip (Fig. 3) anticipating CCW rotation of blocks underlying the East-Slovakian Basin.

Vass et al. (1988) assume that the East-Slovakian Basin was opened principally by pull-apart mechanism. Based on brittle deformation analyses, Kováč et al.


VVNP Bratislava
EAST SLOVAKIAN BASIN
Paleogeographic map of Pliocene (Čečehov formation)
ŠTÁTNY GEOLOGICKÝ ÚSTAV DIONÝZA ŠTÚRA
Prešov
PS1
Humenné
ZAM2
Vranov n.Topľou
VRA1
KP1
KD1
ZBU1
KD2
RAK3
PO1
MICH1
Michalovce
ROZ1
ĎUR2
ĎUR3
A7
TNV1
TRH26
Košice
BAN13
Sobrance
IŇ1
IŇ3
LAS2
RE1
BUN1
SEN8
VU1
PAV1
SEČ2
LOŽ1
STR1
Trebišov
ČAŇ1
TRE3
TRE6
STR21
ČIČ2
VK9
ČIČ3
ZAT1
PT22
Kráľovský Chlmec
N
W
E
S
0 5 10 15 km

(1994) reason that at the beginnning of the Karpatian the opening of the basin resulted from heterogenous extension caused by astenosphere upheaval in the Pannonian domain. After deposition of the Soľná Baňa Formation the basin started to open by pull-apart mechanism. Kováč et al. (1995) define the basin as a back-arc basin. Later (Kováč et al. 1996) they assume that during the Karpatian and Early Badenian the basin was opened by a pull-apart mechanism, and later it became extensional back-arc basin although their figure 3 on page 13 suggests the intra-arc position of the basin.

Palaeomagnetic analyses performed on sediments and volcanics suggest their CCW rotation. Rotation occurred in several pulses while remanent magnetism of the oldest Neogene rocks indicates total rotation about 80° (Márton et al. 2000). According to several published data CCW rotation is preceded by sinistral strike slip and CW rotation is by dextral strike slip (Terres & Sylvester 1981, Sengor et al. 1985, fide Allen & Allen 1992). This is not consistent with Kováč & Márton (1998) relating dextral strike slip between the ALCAPA and Tissia - Dacia microplates to the CCW rotation. We presume that this rotation may be related to the sinistral strike slip between the Pelsó Unit and Central Western Carpathians and Eastern Alps along Raaba - Hurbanovo - Plešivec - Rožňava line. We assume that CCW rotation of blocks underlying the East-Slovakian Basin was preceded by sinistral strike slip along the Hornád Fault System enabling lateral escape of units belonging to the Tissia (Zemplinicum, Iňačovce - Kritchevo and Ptrukša Units) into the area of the East-Slovakian Basin (Fig. 3). We did not include rotation into our palaoegeographic maps due to small amount of analyses in the basin and northward of it (Pieniny Klippen Belt, Outer Flysch Zone). However, backward rotation of the basin into its original position may help to elucidate some palaeogeographic relation and therefore we depicted in maps 1 - 8 sphere sectors representing direction and magnitude of basin rotation according to its original position.

The present palaeomagnetic data suggest that the first rotation ca. 20°-25° CCW occurred in the Karpatian during stress relaxation causing extension (deposition of Teriakovce and Soľná Baňa Formations). The following rotation ca. 17°-20° CCW occurred in the Middle Badenian when salt-bearing Zbudza Formation was deposited. The third, Late Sarmatian rotation with magnitude about 40° CCW was terminated before the Pannonian. It is suggested by non-rotated Pannonian rhyolite extrusion the Hrádok Hill nearby Michalovce. The palaeomagnetic measurements do not support one-event, ca. 80° CCW basin rotation after or during the Ottnangian suggesting by some authors (e.g. Baráth et al. 1997).

## Conclusion

The East-Slovakian Basin represents an autonomous, eastern part of Transcarpathian Basin. It occurred behind the accretionary wedge rising due to convergency of the European Platform and ALCAPA microplate. Since the Late Badenian, when subduction-related volcanic arc evolved (Lexa & Konečný, 1998), the basin may be classified as an interarc basin. Due to oblique subduction the basin had complex tectonic history represented by extensional (Karpatian, Early Badenian, Late Sarmatian, Pannonian), transtensional (Middle and Late Badenian, Early Sarmatian), transpressional (Eggenburgian) and compressional (Otnangian, Pontian) regimes. The basin is mostly filled by Neogene, shallow-marine deposits containing caustobioliths and evaporites. Volcanics also comprise a significant portion of the basin fill. The spatial distribution of deposits, depositional palaeoenvironments and volcanism, depicted in maps representing ten time slices throughout the Neogene, were strongly determined by subsidence history, sea level fluctuation and sediment input.

For the basin opening, an important role played tectonic escape of the Tissia units by the left lateral motion along the Hornád Fault System into the area of the basin. Beside the basin opening the motion of the basin triggered the later CCW litosphere block rotations attaining a cumulative value 80°. Other tectonic phenomena taking part in the basin opening and evolution were strike-slip and normal, predominantly synsedimentary faults. This tectonic character determined prevailing pull-apart character of the basin. This interpretation is also suggested by thick basin fill (8 000 - 9 000 m) deposited in relatively short time period in depocenters shifting from NW to SE. Compressional shock at the end of the Miocene, recorded by slight folding of the fill, definitely terminated pull-apart character of the basin.

Volcanism significantly influenced the basin palaeogeography by both; large volume of volcanic rocks belonging to the basin fill and building a volcanic mountain chains playing a role of barrier for the transport of clastics in the basin. Eustatic and relative sea level changes as well as tectonic movements were responsible for opening and closing of the sea straits connecting the basin to the open sea.

Progressive decrease of salinity at the end of the Miocene determined hyposaline, and finally fresh-water conditions. In the Pliocene the history of the East Slovakian Basin was definitely achieved.

*Acknowledgement*

The work is a contribution to the project „Tectogenesis of sedimentary basins of the Western Carpathians„ financially supported by Ministry of Environment of Slovak Republic. Additional support was provided by Grant VEGA Project No. 1/52222/98.

## References

Allen, Ph. A. & Allen, J. R., 1992: Basin analysis, principles and applications. Blackwell Scient. Publ. London, 1- 451

Babuška V., Plomerová J., Šílený J. & Janathová Z., 1986: Struktúrni model hlboké stavby litosféry. Geofyzikální model litosféry, Brno - Praha, 245-254. (In Czech).

Bagdasarjan, G. P., Slávik, J. & Vass, D., 1971: Chronostratigrafický a biostratigrafický vek niektorých významných neovulkanitov východného Slovenska. Geol. Práce, Správy 65. Geol. Úst. D. Štúra, Bratislava, 87-96. (In Slovak, Engl. summary).

Bagdasarjan, G.P., Vass, D., & Konečný, V., 1968: Results of absolute age determination of Neogene rocks in Central and Eastern Slovakia. Geol. Zbor. 19/2, Bratislava, 419-425.

Baňacký, V., (edit.) 1988: Geologická mapa južnej časti Východoslovenskej nížiny a Zemplínskych vrchov 1 : 50 000. Geol. Úst. D. Štúra, Bratislava.

Baňacký, V., Elečko, M., Kaličiak, M., Straka, P., Škvarka, Ľ., Šucha, P., Vass, D., Vozárová, A. & Vozár, J., 1989: Vysvetlivky ku geologickej mape južnej časti Východoslovenskej nížiny a Zemplínskych vrchov 1: 50 000. Geol. Úst. D.Štúra, Bratislava, 1-143. (In Slovak, Engl. summary).

Baňacký, V., Vass, D., Kaličiak, M., Remšík, A. & Pospíšil, Ľ., 1987: Vysvetlivky ku geologickej mape severnej časti Východoslovenskej nížiny v mierke 1: 50 000. Geol. Úst.D.Štúra, Bratislava, 1-117. (In Slovak, Engl. summary).

Baráth, I., Kováč, M., Soták, J. & Landkreijer, A., 1997: Tertiary collision, metamorphism and basin forming processes in the Eastern Slovakia (Central Western Carpathians). In: Grecula, P., Hovorka, D. & Putiš, M. (eds.): Geological evolution of the Western Carpathians. Mineralia Slovaca, Monograph, 65-97.

Brestenská, E., & Priechodská, Z., 1960: Sedimentárno - petrografické a biostratigrafické vyhodnotenie oporného vrtu Bočiar-1. Geolog. práce, Zošit 59, Geol. Úst. D. Štúra, Bratislava, 243-249. (In Slovak, Germ. summary)

Brodňan, M., Dobra, E., Polášek, S., Prokšová, D., Račický, M. & Sýkorová, V., 1959: Geológia podvihorlatskej uhoľnej panvy, oblasť Hnojné. Geol. Práce, Zošit 52, Geol. Úst. D. Štúra, Bratislava, 1-69. (In Slovak, Germ. summary).

Buday T., (edit.) et al., 1967: Regionální geologie ČSSR, díl II. Západní Karpaty, zv. 2, Ústř. Úst. Geol., Academia, Praha, 1–651.

Ciezskovski M., 1992: Marine Miocene deposits near Novy Targ. Magura Nappe. Flysch Carpathians (South Poland) Geologica Carpathica 43, Bratislava, 339-346.

Cicha, J. & Kheil, J., 1960: Mikrobiostratigrafie miocénu východoslovenské neogénni oblasti. Sborník ÚÚG, sv. 27, odd. paleon- tologický, Praha, 315-348. (In Czech, Russ. summary).

Čechovič, V., 1940: Nález spodnosarmatskej fauny na východnom Slovensku. Technický obzor slovenský, IV/7, Bratislava. (In Slovak).

Čechovič, V., & Vass, D., 1960: Geológia južnej časti Košickej kotliny. Geol. práce, Zošit 59, Bratislava, 215-24.

Čechovič, V., et al., 1963: Vysvetlivky k prehľadnej geologickej mape 1:200 000 Trebišov. Geofond, redakcia Bratislava, 1-8.0

Čverčko, J., 1977: Zlomy vo východoslovenskej neogénnej oblasti a jej tektonický vývoj. Manuskript CSc Thesis, Archív ČND, Michalovce. (In Slovak).

Čverčko, J., Ďurica, D. & Rudinec, R., 1968: Příspěvek k hranici torton - sarmat ve východoslovenské neogénní panvi. Zprávy o geol. výzkumech v r.1967. Praha, 252-254. (In Czech).

Danihelová, R., 1954: Zpráva o mikropaleontologickom výskume východoslovenského neogénu. Geol. Zbor. 5/1-4, Slov. Akad. Vied, Bratislava, 420-427. (In Slovak, Germ. and Russ. summary).

Dank V. & Fülöp J. (eds.) et al., 1990: Magyarország szerkezet- földtani térképe. MAFI Budapest. (In Hungary).

Ďurica, D., 1965: Vulkanické štruktúry vo východoslovenskej neogénnej panve a ich význam. Geol. Práce, Správy 37, Geol. Úst. D. Štúra, Bratislava, 45–54. (In Slovak, Germ. summary).

Ďurica, D., 1982: Geológia Východoslovenskej nížiny. Mineralia slovaca. Monografia 1, Vydavateľstvo Alfa Bratislava, 7-60. (In Slovak, Engl. summary).

Ďurica, D., Kaličiak, M., Kreuzer, H., Müller, P., Slávik, J., Tözser, J. & Vass, D., 1978: Sequence of volcanic events in Eastern Slovakia in the light of recent radiometric age determination. Věst. Ústr. Úst. geol. 53, Praha, 75-88.

Fülöp, J. & Dank, V. (eds.), 1987: Magyarország földtani térképe a kainozoikum elhagyásával Magyar Allami Földtani Intézet. (In. Hung.).

Fusán, O. Ibrmajer, J., Plančár, J., Slávik, J. & Smíšek, M., 1971: Geologická stavba podložia zakrytých oblastí južnej časti vnútorných Západných Karpát. Západ. Karpaty 15, Geol. Úst. D.Štúra, Bratislava, 1-173. (In Slovak, Germ. Summary).

Fusán, O., Biely, A., Ibrmajer, J., Plančár, J. & Rozložník, L., 1987: Podložie terciéru vnútorných Západných Karpát. Bratislava, Geol. Úst. D. Štúra, 5–123. (In Slovak, Engl. summary).

Gašpariková, V., 1963: Mikrobiostratigrafické pomery okolia ložiska Zbudza. Geol. Práce, Správy 29. Geol. Úst.D.Štúra, Bratislava, 105-110. (In Slovak, Ger. summary).

Gašpariková, V. & Slávik, J., 1967: Spodný tortón s.l. v seve- rovýchodnej časti Vihorlatu. Geol. Práce, Zprávy 43, Geol. Úst. D. Štúra, Bratislava, 119-124. (In Slovak, Germ. summary).

Gnojek, I., Hovorka, D. & Pospíšil, L., 1991: Source of magnetic anomalies in the pre-Tertiary basement of Eastern Slovakia. Geol. Carpathica, 42/3, Bratislava, 169-180.

Grecula, P. & Együd, 1977: Pozícia zemplínskeho ostrova v tek- tonickom pláne Karpát. Mineralia slovaca, 9/6, Bratislava, 449-462. (In Slovak, German summary).

Grill, R., 1943: Über mikropaleontologishe gliederungemöglichkeiten im Miozän des Wiener Beckens. Mitt. Reichsamts Bodenforsch, Wien, 33-34.

Halásová, E., Hudáčková, N., Holcová, K., Vass, D., Elečko, M. & Pereszlény, M., 1996: Sea ways connecting the Fiľakovo/ Petervásara Basin with the Eggenburgian/ Burdigalian open sea. Slovak. Geological Mag. 2/96, Bratislava, 123-136.

Haq, B.U., Hardenbol, J. & Vail, P.R., 1987: Chronology and fluctuating sea levels since the Triassic. Science, v. 235, 1156–1167.

Hovorka, D. et al.,1985: Ultramafic rocks of the Western Carpathians, Czechoslovakia., Bratislava, Geol. Úst. D. Štúra, 1–258.

Christie-Blick, M., and Biddle, K. T., 1985: Deformation and basin formation along strike-slip faults, in Biddle, K. T., and Christie-Blick, M., eds., Strike-slip Deformation, Basin Formations, and Sedimentation: Society of Economic Paleontologists and Mineralogists Sp. Publ. 37, 1-34.

Ivan, Ľ., 1962: Ročná správa z listu Borša. Úkol 02-A-8. Manuskript, Archív Geol.Úst.D.Štúra, Bratislava. (In Slovak).

Janáček, J., 1959: Stratigrafie, tektonika a paleogeografie neogénu východního Slovenska. Geol. Práce, Správy 52, Geol. Úst. D. Štúra, Bratislava, 73-182. (In Slovak, Germ. Summary).

Janáček, J., 1963: Vysvětlivky geologické mapy 1:50 000 list Trebišov (M-34-128-A). Sedimentární neogén. Manuskript, Archív Geol. Úst. D. Štúra, Bratislava. (In Slovak).

Janočko J., 1990: Sedimentečné prostredie hrubých detritov vrchného bádenu v severnej časti Košickej kotliny. Mineralia slovaca 22, Bratislava, 539-546. (In Slovak, Engl. summary).

Janočko, J. 1998: Early Sarmatian deltaic and shallow-water deposits in the East-Slovakian Neogene Basin. Sedimentology, in press.

Janočko, J.,1996: Sediment and facies of small deltas in the Eastern Slovakian Basin. Geol. Práce, Správy 101, 25.

Janočko, J. & Jacko, D., in press: Architecture of a steep delta fan front, Eastern Slovakia. Palaeogeography, Palaeoclimatology, Palaeocology.

Janočko, J., & Šoltésová, E. 1993: Deltaic and alluvial fan sedimentation of Stretava Formation, southern part of Košice Basin. Mineralia Slovaca, 28, 36-42.

Jiříček, J., 1972: Problém hranice sarmat-panón ve vídeňské, podunajské a východoslovenské pánvě. Mineralia slovaca,14/1, Bratislava, 39-81. (In Czech).

Kaličiak, M., Baňacký, V., Jacko, S., Janočko, J., Karoli, S., Molnár, J., Petro, Ľ., Priechodská, Z., Sečev,V., Škvarka, L., Vozár, J., Zlinská, A. & Žec, B., 1991: Vysvetlivky ku geologickej mape severnej časti Slanských vrchov a Košickej kotliny v mierke 1:50 000. Geol.Úst.D.Štúra, Bratislava, 1-231.

Kaličiak, M. (edit.), 1996: Vysvetlivky ku geologickej mape Slanských vrchov a Košickej kotliny - južná časť 1:50 000. Vydav. D. Štúra, Bratislava, 1-206. (In Slovak, Engl. summary).

Kantorová, V., 1954: Mikropaleontologický výskum prešovského solonosného miocénu. Geol. práce, Zpr. 1, Geol. Úst. D. Štúra, Bratislava, 91-93. (In Slovak).

Karoli, S., 1998: Genéza a sedimentačné prostredie evaporitov permotriasu a neogénu Slovenska. Manuskript, CSc Thesis, SAV, Bratislava. (In Slovak, Engl. summary).

Keith, J., F., jr., Vass, D., Stephens, L., H., Elečko, M., Kanes, W., H., Král, M., & Reed, J., K., 1989: Sedimentary basins of Slovakia, Part. 1, ESRI Technical report 89-0018, University of S. Carolina, 1-213.

Kőrössy, L., 1940: Az Abauj - Torna vármegye Hornádsadány környékének földtani leírása. Földt. Közl. 70, Budapest. (In Humg.)

Kováč, M., Bielik, M., Lexa, J., Pereszlényi, M., Šefara, J., Túnyi, I. & Vass, D., 1997: The Western Carpathian intramountane basins. In:

Grecula, p., Hovorka, D. & Putiš, M., (eds.): Geological evolution of the Western Carpathians. Mineralia Slovaca – Monograph, Bratislava, 43-64.

Kováč, M., Hudačková, N., Rudinec, R. & Landkreijer, A., 1996: Basin evolution in the foreland and hinterland of the Carpathian accretionary prism during the Neogene: evidence from the Western to Eastern Carpathians junction. Anales Tectonicae 10/1-2, Firenze, 3-19.

Kováč, M., Kováč, P., Marko, F., Karoli, S. & Janočko, J., 1995: The East Slovakian Basin – a complex back arc basin. Tectonophysics 252, 453-466.

Kováč, M., Krystek, I. & Vass, D., 1989: Vznik, zánik a migrácia sedimentačných priestorov Západných Karpát v neogéne. Geol. Práce, Spr. 88, Geol. Úst.D.Štúra, Bratislava, 45-58. (In Slovak, Engl. summary).

Kováč, M., & Zlinská, A., 1998: Changes of paleoenvironment as a result of interaction of tectonic events and sea level oscillation in the East Slovakian Basin. Przeglad Geol. 46/5, Warszawa, 403-409.

Kováč, P., Vass, D., Janočko, J., Karoli, S., Kaličiak, M., 1994: Tectonic history of the East Slovakian Basin during the Neogene. ESRI Occasional Publication New Series No.11 A-B, South Carolina, U.S.A.,1-15.

Král, M., Pereszlényi, M. & Vass, D., 1990: Vzťah rýchlosti akumulácie sedimentov ku genéze východoslovenskej neogénnej panvy a k ložiskám uhľovodíkov. 50 rokov výuky geol. a paleont. na Slovensku. Sedim. problémy Záp. Karpát. Konf., symp., sem. Geol. Úst. D. Štúra, Bratislava, 107-114. (In Slovak, Engl. summary).

Lehotayová, R., 1982: Miocenne nannoplankton zones in West Carpathians. - Západné Karpaty, sér. Paleontológia 8, Geol. Úst. D. Štúra, Bratislava, 91-110.

Lexa, J. & Konečný, V., 1998: Geodynamic aspects of the Neogene to Quaternary volcanism. In: Rakús, M. (Eds.): Geodynamic development of the Western Carpathians. Dionýz Štúra Publ., Geol. Surw. SR, Bratislava, 219-240.

Magyar, J., Rudinec, R. & Mořkovský, M., 1997: The latest tectonic in eastern part of Neogene East Slovakian Basin EAPG 59th Conference and Technical Exhibition – Geneva. Extended Abstracts, Vol. 2, p. 509.

Márton, E., Vass, D. & Túnyi, I., 2000: Counterclocwise rotations in the East Slovakian Basin. Geologica carpathica 51/3, Bratislava, 159–168.

Merlich, B., & Spitkovskaja, S., M., 1974: Glubinnye razlomy, neogenovyj magmatism i orudnenje Zakarpatja. Lwov State University, Lvov, 1-175. (In Russ.).

Mořkovský, M., Magyar, J., Rudinec, R., Jung, F. & Soták, J., 1999: Distinctive strike-slip and vertical movements along the NE marginal faults of the East Slovakian Basin and their, consequences. Geologica Carpathica 50, Spec. issue, Bratislava, 158-161.

Muratov M.V. & Neveskaja L.A., (eds.) 1986: Stratigrafia SSSR neogenovaja sistema 1-2, Nedra, Moskva, 1-417. (In Russ.).

Oszczypko, N., 1997: The Early - Middle Miocene Carpathian peripheral foreland basin (W.Carpathians, Poland). Przeglad Geol. 45/10, Warszawa, 1054-1063,

Petraskiewicz, M. & Lozinjak, P., 1995: Litologo-paleogeografischne karty neogena Zakarpatskeho progiba. Manuscript UKRDIGRI, Lvov. (In Russ.).

Planderová, E., 1986: Biostratigrafické zhodnotenie sedimentov poltárskeho súvrstvia. Geol. Práce, Spr. 84, Geol. Úst. D. Štúra, Bratislava, 113-118. (In Slovak, Engl. summary).

Plašienka, D., Grecula, P., Putiš, M., Hovorka, D., & Kováč, M., 1997: Evolution and structure of the Western Carpathians: an overview. In Geological evolution of the West Carpathians (Grecula, P., Hovorka, D., & Putiš, M.,eds.) Mineralia Slovaca Monograph, Bratislava, 1-24 i.

Plašienka, D., Soták, J. & Prokešová, R., 1998: Structural profiles across the Šambron – Kamenica Periklippen Zone of the Central Carpathian Paleogene Basin in NE Slovakia. Mineralia Slovaca 30/3, Bratislava, 173-184.

Pulec, M. & Vass, D., 1969: Les textures et les structures des tufs soudés du Néogene superieur de la Slovaquie orientale. Geologica Carpathica, 20, Bratislava, 65-80.

Reed, K. J., Janočko, J., Vass, D., & Gibson, M. jr., 1992: A sedimentological and petrographic investigation of the Nižný Čaj K-8 well. Mineralia slovaca, 24, Bratislava, 219-226.

Repčok, I., 1977: Stopy delenia uránu a možnosti ich využitia pre datovanie na príklade vulkanických skiel. Západné Karpaty, sér. mineral., petrogr. geochem., ložiská 3, Bratislava, 175-196. (In Slovak, Engl. summary).

Rudinec, R., 1978: Paleogeographical, lithofacial and tectogenetic development of the East Slovakian Basin and its relation to volcanism and deep tectonics: Geol. Zb., Geologica Carpathica, 29, Bratislava, 225-240.

Rudinec, R., 1989: Nový pohľad na paleogeografický vývoj transkarpatskej depresie. Mineralia slovaca, 21/1, Bratislava, 27-42. (In Slovak, Engl. summary).

Rudinec, R., 1990: Vertikálna distribúcia neogénnych sedimentov v transkarpatskej depresii. Mineralia slovaca, 22/5, Bratislava, 393-397. (In Slovak, Engl. summary).

Rudinec, R. & Čverčko, J., 1970: Výsledky štruktúrneho a čiastočne pionierského prieskumu v podvihorlatskej oblasti so zreteľom na prieskum živíc. Manuskript, Geofond, Bratislava. (In Slovak).

Rudinec, R. & Tereska, C., 1972: Nafto-plynonádejnosť vulka- nických štruktúr vo východoslovenskom neogéne. Mineralia slovaca, 4, 4, Bratislava, 23-28. (In Slovak).

Řeřicha, M., 1992: Vrchnobádenská delta vo Východoslovenskej neogénnej panve. Mineralia slovaca, 24, Bratislava, 63-68.

Seneš, J., 1955: Stratigrafický a biofaciálny výskum niektorých neogénnych sedimentov východného Slovenska na základe makro- fauny. Geol. Práce, Zošit 40, Geol.Úst.D.Štúra, Bratislava, 1-171.

Slávik, J., 1967: Gips und Anhydrit aus den Salz führende Formationen des Miocens der Ostslovakei. Geol. Zborník 18/1, Bratislava, 65-77. (In Slovak).

Slávik, J., 1974: Vulkanizmus, tektonika a nerastné suroviny neogénu východného Slovenska a pozícia tejto oblasti v Neoerope. Manuskript DrSc Thesis, Geofond, Bratislava, 1-341.

Slávik, J., Bagdasarjan, G.P., Kaličiak, M., Tözsér, J., Orlický, O. & Vass, D., 1976: Radiometricheskije vozrasty vulkanicheskich porod Vigorlata i Slanskich gor. Mineralia slovaca, 8,4, Bratislava, 319-334. (In Russ., Engl. summary)

Slávik, J., Čverčko, J., & Rudinec, R., 1968: Geology of Neogene volcanism in East Slovakia. Geol. Práce, Správy 44-45, Bratislava, 215-239.

Soták J., Rudinec R. & Spišiak J.,1993: The Penninic "pull-apart" dome in the pre-Neogene basement of the Transcarpathian Depression (Eastern Slovakia). Geologica carpathica 44,Bratislava, 11-16.

Sztanó, O., 1994: The Tide-influenced Pétervására Sandstone, Early Miocene, Northern Hungary: sedimentology, palaeogeography and basin development. Geologica ultraiectina. Universiteit Utrecht, 120, 1-155.

Šefara J., et al.,1987: Štruktúrno-tektonická mapa vnútorných Západných Karpát pre účely prognózovania ložísk. Manuskript – archív Geofyziky, Bratislava. (In Slovak).

Šutora, A., Leško, B., Čverčko,J. & Šrámek, J., 1990: Príspevok geofyzikálnych dát k riešeniu geologickej stavby a roponádejnosti juhovýchodného Slovenska. Mineralia slovaca 22, 3, Bratislava, 193-212. (In Slovak, Engl. summary).

Švagrovský, J., 1952: Geologické pomery a fauna severnej časti Košickej kotliny. Geolog. sborník 3/3-4, Bratislava, 259-292. (In Slovak, Germ. summary).

Švagrovský, J., 1956: Neogén širšieho okolia Košíc. Geol. Práce Zpr. 9, Geol. Úst. D. Štúra, Bratislava, 84-102. (In Slovak, Germ. sum.).

Švagrovský, J., 1959: Asociácie mäkkýšov brakických uložením vrchného tortónu a spodného sarmatu východného Slovenska. - Geol. Práce, Zošit 55, Geol. Úst. D. Štúra, Bratislava, 215-254. (In Slovak).

Švagrovský, J., 1960: Biostratigrafia miocénu a ekológia makrofauny oporného vrtu Sečovce-1. Práce, Výzk. Úst. Čs. naft. dolů 15, Praha, 53-93. (In Slovak).

Tari G., Horváth F. &Rumpler J., 1992: Styles of extension in the Pannonian Basin. Tectonophysics, 208, 203-219.

Tereska, C., 1969: Geologická stavba južnej časti Potisskej nížiny, so zreteľom k problematickému výskytu živíc. Manuskritp, RNDr Thesis, Archív, Nafta Michalovce.

Tsonj, O.V. & Slávik, J., 1971: Vek ryolitov zemplínskeho ostrova. Geol. Práce, Spr. 55, Bratislava, 215-216. (In Slovak).

Uhlik, P., 1999: Vývoj častíc illit- smektitu počas diagenézy PhD theses. Comenius University, Bratislava. (In Slovak, Engl. summary).

Vass, D., 1967: Vek a petrografické zloženie neogénnej výplne komárovskej depresie. Zbor. Východoslov. múz. sér. A 7 Košice, 87-95.

Vass, D., 1989: Lithostratigraphy of West Carpathians Neogene, meeting of KBGA Comission on Stratigraphy, Paleogeography and Paleontology. Liptovský Ján 1989, Unpublished.

Vass, D., 1995: Odraz globálnych zmien morskej hladiny na severnom okraji maďarského paleogénu, vo fiľakovskej a v novohradskej panve (juž. Slovensko). Mineralia slovaca, 27, 3, Bratislava, 193–206. (In Slovak, Engl. summary).

Vass, D., 1998: Neogene geodynamic development of the Carpathian arc and associated basins. In Rakús, M. edit.: Geodynamic development of the Western Carpathians. Geol. Survey of S.R., Bratislava, 115-188.

Vass, D., Began, A., Kahan, Š., Köhler, E., Krystek, I., Lexa J. & Nemčok, J., 1988: Regionálne geologické členenie Západných Karpát a sev. výbežkov Panónskej panvy na území ČSSR. Geol.Ústav D.Štúra Bratislava, Geofond Bratislava, Vojenský kartografický ústav Harmanec. (In Slovak, Engl. summary).

Vass, D. & Čech, F., 1983: Sedimentation rates in molasse basins of the West Carpathians. Geol.. Zbor. Geologica carpathica 34/4, Bratislava, 411-422.

Vass, D. & Čech, F., 1989: Evaluation of sedimentation rates in Alpine molasse basins of the West Carpathians. Z. geol. Wiss. 17/9, Berlin, 869-878.

Vass, D., & Čverčko, J., 1985: Litostratigrafické jednotky neogénu východoslovenskej nížiny. Geol. Práce, Spr. 82, Bratislava, 111-126. (In Slovak, Engl. summary).

Vass, D. & Elečko, M., 1977: Tvar valúnov a genéza pozdišovskej štrkovej formácie. Mineralia slovaca, 9/1, Bratislava, 43-66. (In Slovak, Engl. summary).

Vass, D. & Elečko, M., 1988: Prvotná dokumentácia vrtov MCV-1 a MCV-2 (Modrá nad Cirochou). Manuskript, Archív Geol. služba SR, Bratislava. (In Slovak).

Vass, D., Holcová, K., Karoli, S. & Suballyová, D., 1996: Príspevok k poznaniu vývoja kladzianskeho súvrstvia (mladší karpat) vo východoslovenskej panve. Geol. Práce Spr. 102, Geol. Úst. D. Štúra, Bratislava, 71-78. (In Slovak, Engl. summary).

Vass, D., Töszér, J., Bagdasarjan, G. P., Kaličiak, M., Orlický, O. & Ďurica, D., 1978: Chronológia vulkanických udalostí na východnom Slovensku vo svetle izotopických a paleomagnetických výskumov. Geol. Práce, Spr. 71, Geol. Úst. D. Štúra, Bratislava, 77-88. (In Slovak, Engl. summary).

Volfová, J., 1959: Zpráva o makropaleontologickom zhodnocení vrtu Čelovce-1. Manuskript, Geofond, Bratislava, 1-45. (In Slovak).

Vozár, J., Tomek, Č. & Vozárová, A., 1993: Reinterpretácia predneogénneho podložia východoslovenskej panvy. Mineralia Slovaca, 25/6, Bratislava, Geovestník, 1-2. (In Slovak).

Vozárová A., Vozár J., Tomek C., Rakús M. &Kováč P., 1993: Reinterpretácia podložia Východoslovenskej panvy a jej korelácia s jednotkami Karpát. Ms. Archív Geol. Úst. D. Štúra, Bratislava. (In Slovak).

Wein, Gy., 1969: Tectonic review of the Neogene – coverd areas of Hungary. Acta Geol. Acad. Sc. Hungaricae, 13 Budapest, 399-436

Wernicke B., 1993: Evidence for large scale simple shear of the continental lithosphere during extension: Geological Society of America Abstract 15, 310-311.

Zapletalová, I., 1970: Mikropaleontologické vyhodnotenie vrtov v okolí Vranova. Manuskript, Archív MND, Michalovce. (In Slovak).

Zapletalová, I., 1974: Mikropaleontologické a fyzikálne rozbory vrtov Uránového prieskumu. Manuskript, Archív MND, Michalovce. (In Slovak).

Zlinská, A., 1992: Zur biostratigraphischen Gliederung des Neogens des ostslovakischen Beckens. Geol. Práce, Spr. 96, Bratislava, 51-57.

Zlinská, A., 1995: Biostratigrafické štúdium miocénnych sedimentov z Modry nad Cirochou na základe foraminifer. Geol. práce, Správy 100, Geol. Úst. D. Štúra, Bratislava, 53-56. (In Slovak, Engl. sum.).

Zlinska, A., 1996: Mikrofauna vranovského súvrstvia z vrtu BB-1 (Byšta, Východoslovenská nížina). Geol. Práce, Spr. 102, Bratislava, 37-40. (In Slovak, Germ. summary).

Žec, B. & Ďurkovičová, J., 1993: Chronostratigrafické zaradenie vybraných vulkanických formácií južnej časti Slanských vrchov. Mineralia slovaca 25/2, Bratislava, 109-116. (In Slovak, Engl. summary).

Žec, B., Kaličiak, M., Lexa, J., Konečný, V., Baňacký, V., Rakús, M., Potfaj, M., Karoli, S. & Zlinská, A., 1997: Vysvetlivky ku geologickej mape Vihorlatských a Humenských vrchov, 1 : 50 000. Geol. služba SR, Bratislava, 1-254. (In Slovak, Engl. summary).