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Trenčianska kotlina and Ilavská kotlina basins – Remnants of an inverted Early Miocene wedge top basin (Western Carpathians, Slovakia)

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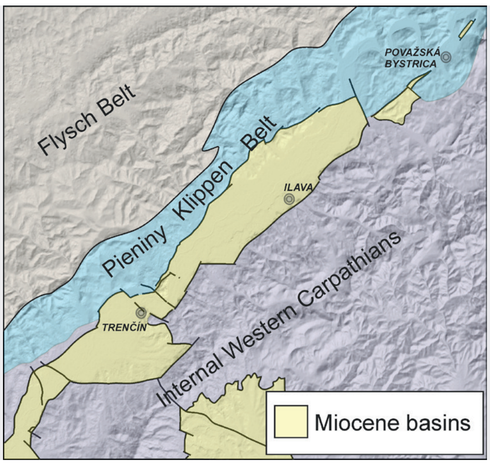
Abstract: The paper summarizes the latest knowledge about the Early Miocene Trenčianska kotlina and Ilavská kotlina basins, Slovakia. The studied basins are located at the boundary between the Internal and External Western Carpathians and overlie the Pieniny Klippen Belt and Internal Carpathian Mesozoic nappes (Tatricum, Fatricum and Hronicum). This research is based on the results of geological mapping in the northwestern Trenčianska kotlina Basin and westernmost part of the Ilavská kotlina Basin and summarizes all previous (bio)stratigraphic, sedimentological, geophysical and borehole (PB-1, HVJ-25) data. Sedimentary fill of the basins is represented by the transgressive Eggenburgian Čausa and Karpatian Závod formations. Sedimentary record is fragmentary since the Lower Miocene formations are reduced. Youngest sediments are represented by the Pliocene gravels and Quaternary fluvial and eolian deposits. Both Trenčianska kotlina and Ilavská kotlina basins formerly represented one Early Miocene wedge top basin connected with nearby Vienna Basin, Blatné depression, Bánovská kotlina, Hornonitrianska kotlina and Turčianska kotlina basins. The present shape of the Trenčianska kotlina and Ilavská kotlina basins is a result of inversion, rotation, and backthrusting occurring since the Karpatian-Badenian with additional inversion during Pliocene–Quaternary. There are no strong arguments for interpretation of the pull-apart nature of the basins as it was considered in the past.

Key words: Central Paratethys, Early Miocene, Middle Váh Valley, Pieniny Klippen Belt, Internal Western Carpathians

Graphical abstract



Highlights

- Trenčianska kotlina and Ilavská kotlina basins overlie the Pieniny Klippen Belt and Internal Western Carpathian units (Tatricum, Fatricum and Hronicum)
- Three tectonic phases can be recognized: (1) Wedge-top basin represented by Early Miocene (Eggenburgian to Ottnangian) sediments of the Čausa Fm.; (2) latest Early Miocene (Karpatian) to Middle Miocene extrusion, CCW rotation, backthrusting, and disintegration of pre-existing basin into horst and graben structure, during which the Závod Fm. (Karpatian) was deposited; (3) continuing tectonic inversion coeval with deposition of Pliocene fluvial gravels and Quaternary fluvial and eolian sediments

Introduction

The Western Carpathians represent the northern segment of the Alpine (Tethyan) collision zone formed by the Mesozoic to Paleogene northward-propagating nappe pile (Rakús et al., 1988; Vozár et al., 1999; Plašienka, 2018a; Schmid et al., 2020). The Carpathian nappes are traditionally divided into Outer (or External) and Inner (Internal) Carpathians (Uhlig, 1903; Mišík, 1997a; Lexa et al., 2000). The Outer Western Carpathians are represented by the Flysch Belt, composed of thin-skinned nappes (from north to south: Silesian-Krosno and Magura nappes) formed during the Cretaceous and Paleogene thrusting and Neogene collision (Poprawa & Nemčok, 1988; Ślączka et al., 2006). The Carpathian Flysch Belt is composed mainly of submarine mass wasting siliciclastic deposits alternating with pelagic claystones, the so-called "flysch". On contrary, the Internal Western Carpathians (IWECA) are represented by thick-skinned nappes including the pre-Alpine crystalline basement (from north to south Tatricum, Veporicum, and Gemericum) with mostly Mesozoic sedimentary cover and Mesozoic thin-skinned nappes (from north to south: Fatricum, Hronicum, Meliaticum, Turnaicum, and Silicicum, Hók et al., 2019). The dividing line between the External and Internal Western Carpathians is represented by the narrow Pieniny Klippen Belt (PKB), composed of "sub-autochthonous" Oravicum and overlying non-Oravic units, derived probably from the IWECA. The internal structure of the Pieniny Klippen Belt is very complicated and controversial. It is characterized by the presence of rigid Jurassic to Early Cretaceous limestone "klippen" surrounded by rheologically softer Late Cretaceous claystone and sandstone formations (Mišík, 1997b; Plašienka, 2018b).

The Late Cretaceous to Paleogene and Neogene to Quaternary sedimentary and volcanic formations in the IWECA are usually considered to post-date the nappe stacking. Especially the Late Cretaceous to Eocene Gosau type basins locally bear signs of post-depositional deformation, including folding and north-vergent thrusting, due to their wedge-top structural setting (Plašienka & Soták, 2015). The younger Eocene – Oligocene formations of the Central Carpathian Paleogene Basin, deposited between the Pieniny Klippen Belt and the outer edge of IWECA, are interpreted as forearc basin (Kováč et al., 1995; Soták et al., 2001; Plašienka & Soták, 2015; Kováč et al., 2016). The Early Miocene basins represented relic foreland and hinterland (retro-arc) basins. The Middle Miocene to Quaternary basins are largely connected to the back-arc Pannonian Basin system (Kováč, 2000; Vass, 2002, Kováč et al., 2017). The northwestern part of the Pannonian Basin is termed Danube Basin on the Slovak territory (or Kisalföld in Hungary). The Western Carpathian Middle Miocene volcanism is mostly calc-alkaline and related to the subduction rollback of the former basement of the Flysch Belt (Lexa & Konečný, 1998; Harangi & Lenkey, 2007).

The investigated Trenčianska kotlina and Ilavská kotlina basins (Fig. 1) are located within the outer edge of the IWECA and are partly overlying the Pieniny Klippen Belt units.

The Early Miocene (Eggenburgian to Karpatian; = late Aquitanian – Burdigalian according to the international time scale, e.g. Kováč et al., 2017, 2018), was a period of an ongoing collision in the western segment of the Carpathian Flysch Belt, where thrusting of the Waschberg-Ždánice (Silesian-Krosno nappe) units onto Carpathian foredeep occurred (Jiříček, 1979; Picha et al.; 2006, Stráník et al., 2007). The Lower Miocene sediments present in the IWECA are usually transgressively overlapping various Mesozoic and Paleogene tectonic units and formations (Kováč et al. 1988; Baráth & Kováč, 1989; Mello et al.,

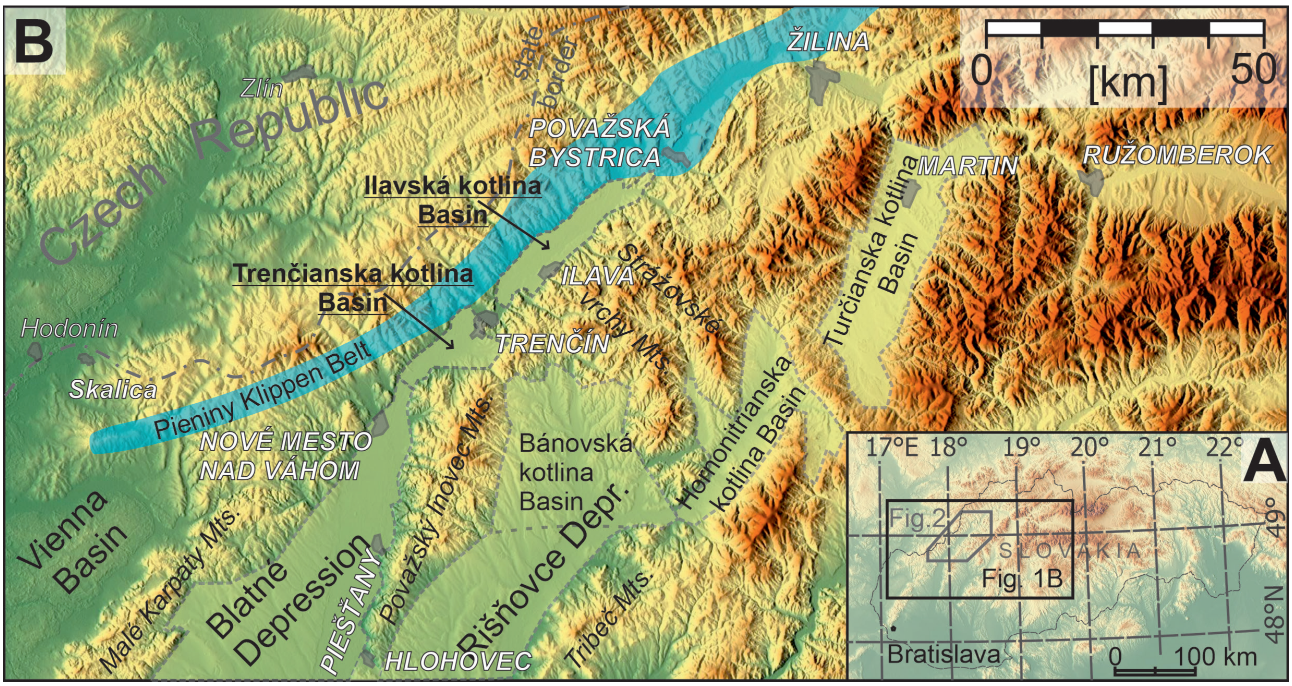


Fig. 1. Location of the studied area. A – Location within the Western Carpathians (Slovakia). B – Detailed view showing main basins/depressions and other important orographic features. Pieniny Klippen Belt marked in blue.

2005, 2011; Teťák, 2017). The Eggenburgian sediments in the western part of the Western Carpathians are particularly known only in the Turčianska kotlina Basin (Gašparik et al., 1993; Hók et al., 1998), Hornonitrianska kotlina Basin (Čechovič, 1959; Čechovič & Šinaly, 1962), Bánovská kotlina Basin (Fordinál et al., 2001a, 2001b), the northern part of Blatné Depression (Biela, 1978; Vrana et al., 2009), Trenčianska kotlina, Ilavská kotlina and Vienna basins – thus generally in the northern part of the Danube and Vienna basins and basins connected with Carpathian foredeep (Vass, 2002). The Eggenburgian sediments from the East Slovakian Basin have similar structural position, however, are present in laterally different segment of the thrust belt (Kováč et al., 1995). The Rožňava and Turňa basins (= South Slovakian Basin) have different paleogeographical provenance (Vass, 2002; Nagymarosy, 2013). Another type of Lower Miocene sediments is found in the Kremna Formation of the Carpathian Flysch Belt (Oszczypko-Clowes et al., 2018). The Kremna Formation represents more or less continuous sedimentation from the Oligocene and is located in clearly wedge-top setting between the thrust-sheets of the accretionary prism.

In the present shape, the Trenčianska kotlina and Ilavská kotlina basins represent relict or erosional remnants of larger Early Miocene basin system situated between the Vienna Basin and the northern margins of the Danube Basin (Blatné Depression, Bánovská kotlina Basin), and Hornonitrianska kotlina and Turčianska kotlina basins (Fig. 1). In today's form, however, both are modified by the Middle Miocene and Pliocene horst and graben structure and Pliocene-Quaternary erosion and deposition of the Váh River.

The Neogene sediments in the studied area were for the first time cartographically visualized on the Austrian-Hungarian geological map sheet Trentschin at scale 1 : 75,000 as "*Congerien Schichten*"). The presence of the Neogene sediments was shown as well in the other maps (Uhlig, 1903; Jahn & Beck, 1911; and Lóczy et al., 1922) and post-war general geological maps at scale 1 : 200,000 (sheets Gottwaldov and Žilina, Buday et al., 1963; Mahel' et al., 1964). Mapping was accompanied by biostratigraphic study of macro- and microfauna (Čtyroký, 1957, 1960; Seneš, 1960) and borehole PB-1 (Gabčo et al., 1963). Part of the sedimentary fill of the Trenčianska kotlina and Ilavská kotlina basins was partly incorrectly considered as Central Carpathian Paleogene sediments (a strip south of Trenčín castle ridge). The strip north of Trenčín castle ridge between the Trenčín, Skalka nad Váhom, and Visolaje was properly reported as lower Burdigalian (Mahel' et al., 1964). The fill of the Trenčianska kotlina and Ilavská kotlina basins was at this time mostly considered as Pontian (Late Miocene, Buday et al., 1963; Mahel' et al., 1964). This was later refined as Ruscinian (MN15) due to findings of mammalian macrofauna near Ivanovce (Fejfar & Heinrich, 1985; Fejfar & Sabol, 2004). Later maps of surrounding regions (Biele Karpaty Mts. and Strážovské vrchy Mts., Mahel' et al., 1982; Mahel', 1985; Began et al., 1993) at scale 1 : 50,000 paid only minor attention to the research of the Neogene fill of the Trenčianska kotlina and Ilavská kotlina basins. Latest partial knowledge about the Trenčianska kotlina and Ilavská kotlina basins was published in maps and explanatory notes of the Middle Váh Valley, Považský Inovec Mts. and Biele Karpaty Mts. geological maps (Mello et al., 2005, 2011; Ivanička et al., 2007, 2011; Pešková et al., 2020). Studied region includes auxiliary stratotype of the Eggenburgian near Sverepec (Steininger & Seneš, 1971).

Both Trenčianska kotlina and Ilavská kotlina basins are considered underexplored due to lack of deep boreholes penetrating the greater thickness of the Miocene sediments or reaching the pre-Cenozoic basement. Only a few boreholes are known, located on the opposite side of the investigated area (Fig. 2). In the northeastern tip of the Ilavská kotlina Basin, such a borehole is located near Sverepec (borehole PB-1, Gabčo et al., 1963). In the southwest Trenčianska kotlina Basin such boreholes/wells are represented by the HVJ-25 and 26 (Pospíšil et al., 1971). The thickness of Miocene sediments in the Trenčianska kotlina Basin was interpreted from vertical electric sounding (Zbořil et al., 1984) and seismic profiles (124, 6HR, Kadlečík et al., 1980; Vozár et al., 1999). In the Trenčianska kotlina Basin, it is reaching 1,000 m (Fig. 3) in the central part and in the Ilavská kotlina Basin approx. 250 m according to geophysical data (Kilény & Šefara, 1989). The pre-Cenozoic basement of Trenčianska kotlina and Ilavská kotlina basins is represented mainly by tectonic units of Pieniny Klippen Belt *sensu lato* (both Oravic and so-called Peri-Klippen or non-Oravic units) in the northwest and Mesozoic rocks of the IWECA units (Tatricum, Fatricum, and Hronicum) in the southeast (Fusán et al., 1987).

Miocene sedimentary fill in the northern part of nearby Blatné depression (so-called Beckov "gate") was drilled by the geothermal well GZV-1 Zelená voda (Fig. 2). Miocene sediments drilled by the well are represented by approx. 300 m of dark grey and sandy clays which directly overlap the pre-Cenozoic basement (Vrana et al., 2009). The core cuttings from the GZV-1, however, lack adequate biostratigraphic processing and are not entirely reliable, as the Karpatian age was gathered only from sediments at the depth 20–24 m. In the southern parts of the Blatné depression continuous Early Miocene sequence to the Pannonian can be observed (Biela, 1978; Rybár et al., 2015). The thickness of the Závod Fm. (Karpatian) in the borehole HVJ-25, located slightly northward, is only 70 m, and below it, 130 m thick Eggenburgian sandstones, claystones, and conglomerates of the Čausa Fm. are present directly above the pre-Cenozoic basement (Pospíšil et al., 1971).

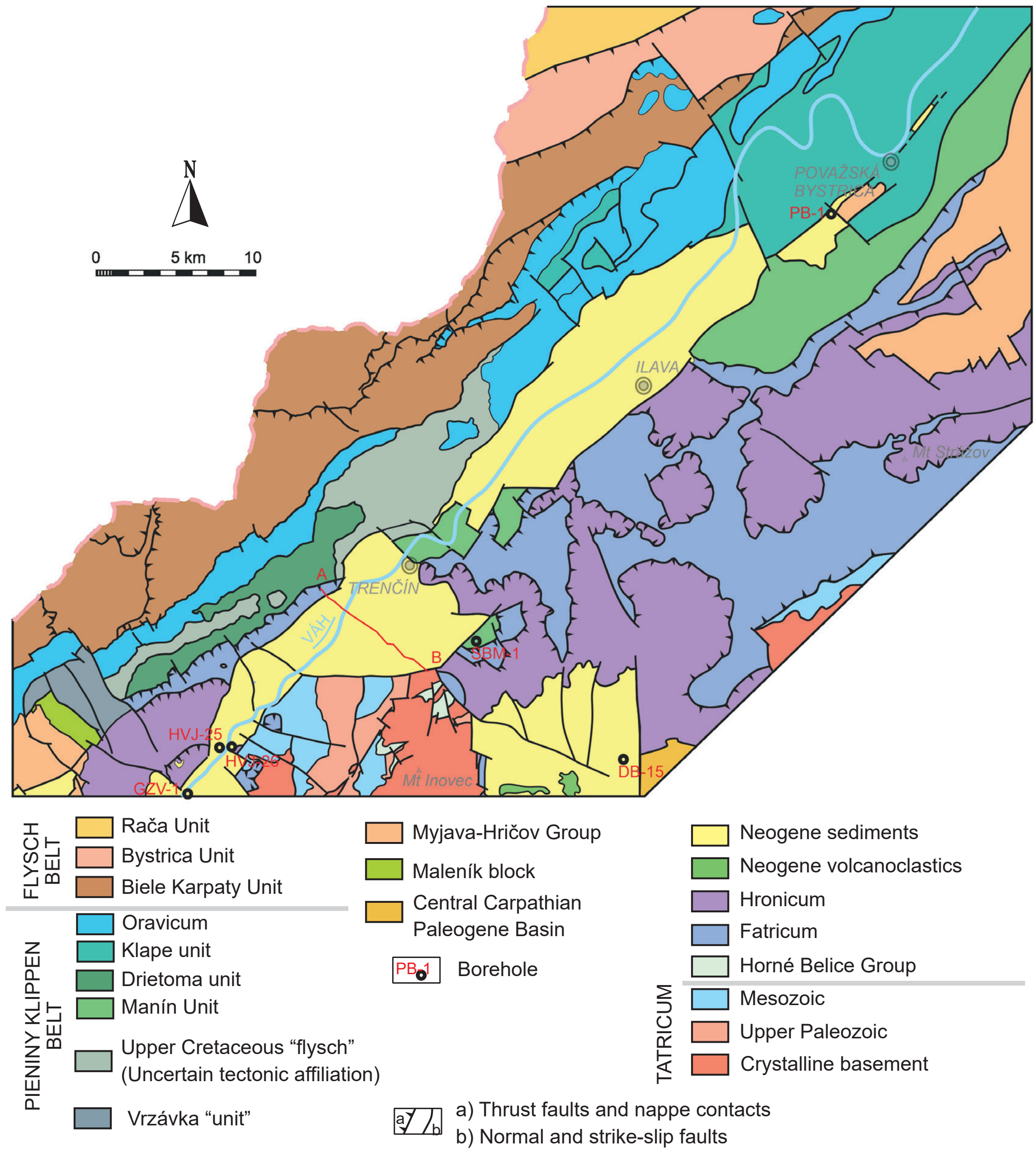


Fig. 2. Tectonic map of the wider region of the Trenčianska kotlina and Ilavská kotlina basins (compiled according to Maheľ et al., 1982; Mello et al., 2005; Ivanička et al., 2007; Bezák et al., 2008; Potfaj et al., 2014; Pešková et al., 2020). Cross-section A–B in Fig. 3.

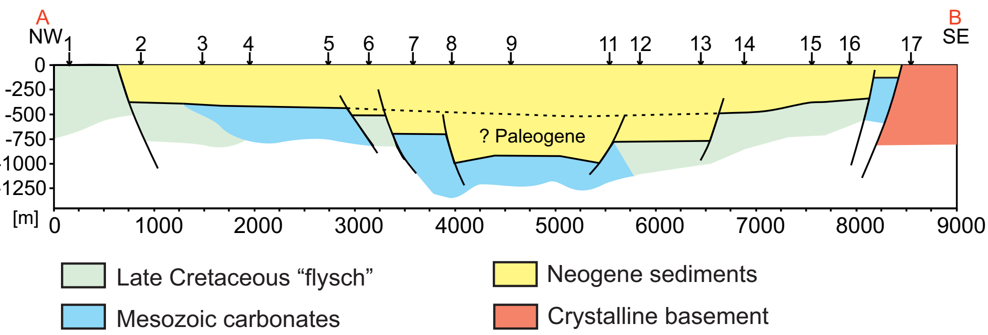


Fig. 3. Schematic cross-section A–B of the Trenčianska kotlina Basin based on vertical electric sounding data (Zbořil et al., 1984), partly modified according to recent knowledge of surface geology (Ivanička et al., 2007; Pešková et al., 2020).

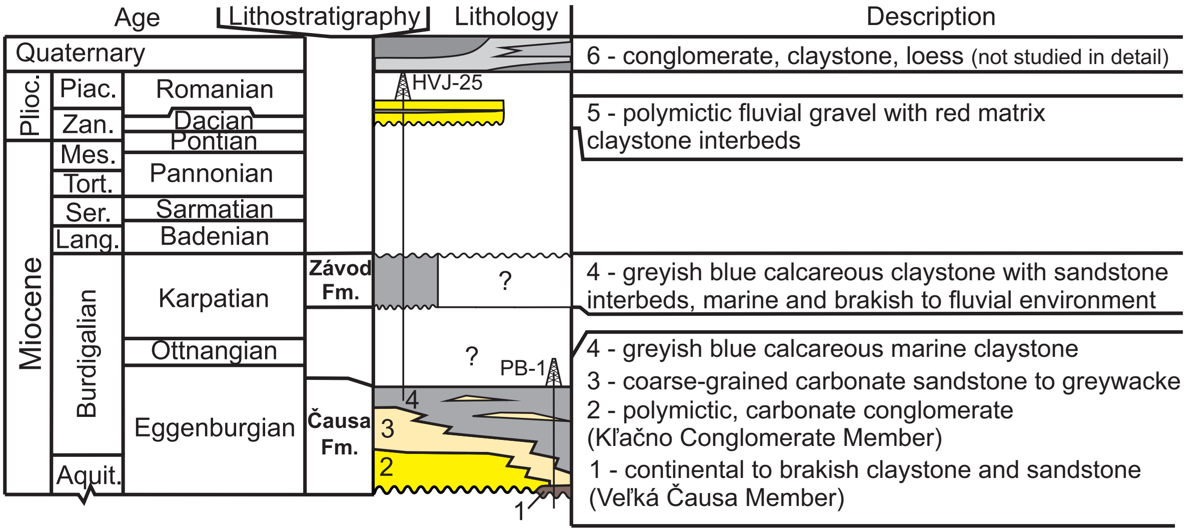


Fig. 4. Schematic lithostratigraphy of the Trenčianska kotlina and Ilavská kotlina basins. Mediterranean and Central Paratethys stages correlation according to Kováč et al. (2017).

Different depositional and tectonic history is seen from the borehole data in the nearby Bánovská kotlina Basin (Figs. 1 and 2). The whole basin contains Lower Miocene sediments (Čausa, Bánovce and Lakšárska formations), however, NE part was eroded and SW part subsided during Badenian (Brestenská et al., 1975; Fordinál et al., 2001a, 2001b).

Objectives and methods

The main aim of this paper is to summarize recent knowledge about geology and tectonics of the Early Miocene sedimentary fill of the Trenčianska kotlina and Ilavská kotlina basins, which are rather poorly covered in the present geological literature.

The research is largely based on the review and reinterpretation of the older sedimentological, structural, geophysical, and paleontological data. New field data were gathered during the geological mapping in the area of the Biele Karpaty Mts. in 2016–2019. Important studied sites and boreholes/wells are listed in Tab. 1. New results are supported by additional sedimentological and petrographic analyses as well as biostratigraphy (nannoplankton and foraminifera). Foraminifera and nannoplankton samples were treated with standard methods. Heavy minerals

Tab. 1
Table of important studied outcrops and boreholes/wells described in the text.

No.	Name	X (Long, E) °	Y (Lat., N) °	Lithology	Note	Reference
1	Soblahov	18.062132	48.867448	claystone, sandstone, conglomerate	material from well drilling (OP1TN/Ch1D)	
2	Trenčianska Turná, Hámre	18.037836	48.844728	claystone	Engineering geology borehole, depth 5 m (OP3TN)	
3	Chocholná-Velčice	17.946382	48.854646	claystone	Engineering geology borehole, depth 5m (OP556BKs)	
4	Skalka nad Váhom, Starý háj	18.061907	48.919941	sandstone, conglomerate	outcrop (OP397BKs)	
5	Skalka nad Váhom, Skalská Nová Ves	18.071691	48.929303	conglomerate	outcrop (OP492BKs)	
6	Kobela, Nové Mesto nad Váhom	17.831240	48.780534	conglomerate, calcarenite	outcrop (OP555BKs)	
7	Trenčín, Brezina	18.050383	48.879332	calcarenite, sandstone	outcrop (OP2TN)	
8	Ivanovská skalka	17.904632	48.824779	gravel	Railroad cut, caverns filled by gravel with mammal macrofauna	Fejfar & Heinrich (1985)
9	PB-1	17.857543	48.763418	-	Borehole	Gabčo et al. (1963)
10	HVJ-25	17.875758	48.788937	-	Borehole/Well	Pospíšil et al. (1971)
11	GZV-1	17.857543	48.763418	-	Well	Vrana et al. (2009)

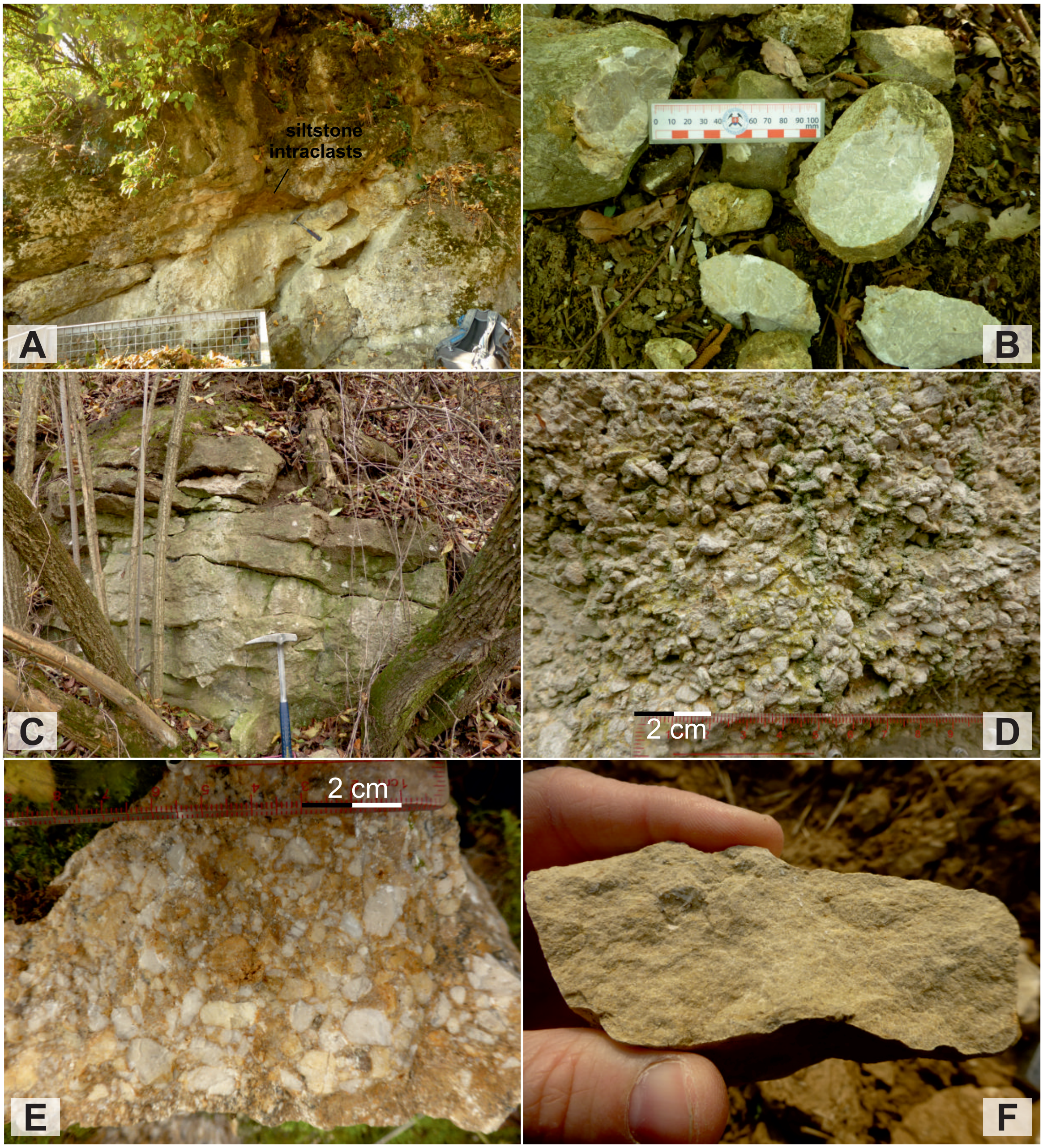


Fig. 5. A – Outcrop of thick-bedded conglomerates with siltstone intraclasts containing Cretaceous and Paleogene (redeposited) nanoplankton, Skalka nad Váhom, site 5. B – Boulders of the Wetterstein Limestone eroded from the conglomerates found in loose debris near the Skalka nad Váhom, site 4. C – Medium-bedded monomictic conglomerate, Kobela, N of Nové Mesto nad Váhom, site 6. D – Detail on the weathered surface from the previous figure. E – Fresh surface of monomictic conglomerate from the previous figure. F – Calcarenite with abundant echinoderm detritus, Kobela, N of Nové Mesto nad Váhom, site 6.

were studied by CAMECA SX 100 microprobe at the Department of special laboratories State geological institute of Dionýz Štúr.

Results

The Eggenburgian sediments of the Trenčianska kotlina and Ilavská kotlina basins are represented by the Čausa Formation (originally defined in the Hornonitrianska kotlina Basin, see Samuel et al., 1988; Vass, 2002). The Čausa Formation is traditionally divided into (1) Basal continental, freshwater to brackish sandstones and claystones (the Veľká Čausa Member); (2) Upward-fining grey-brown to yellow alluvial to littoral conglomerates (the Kľačno Conglomerate Member) that pass into calcareous

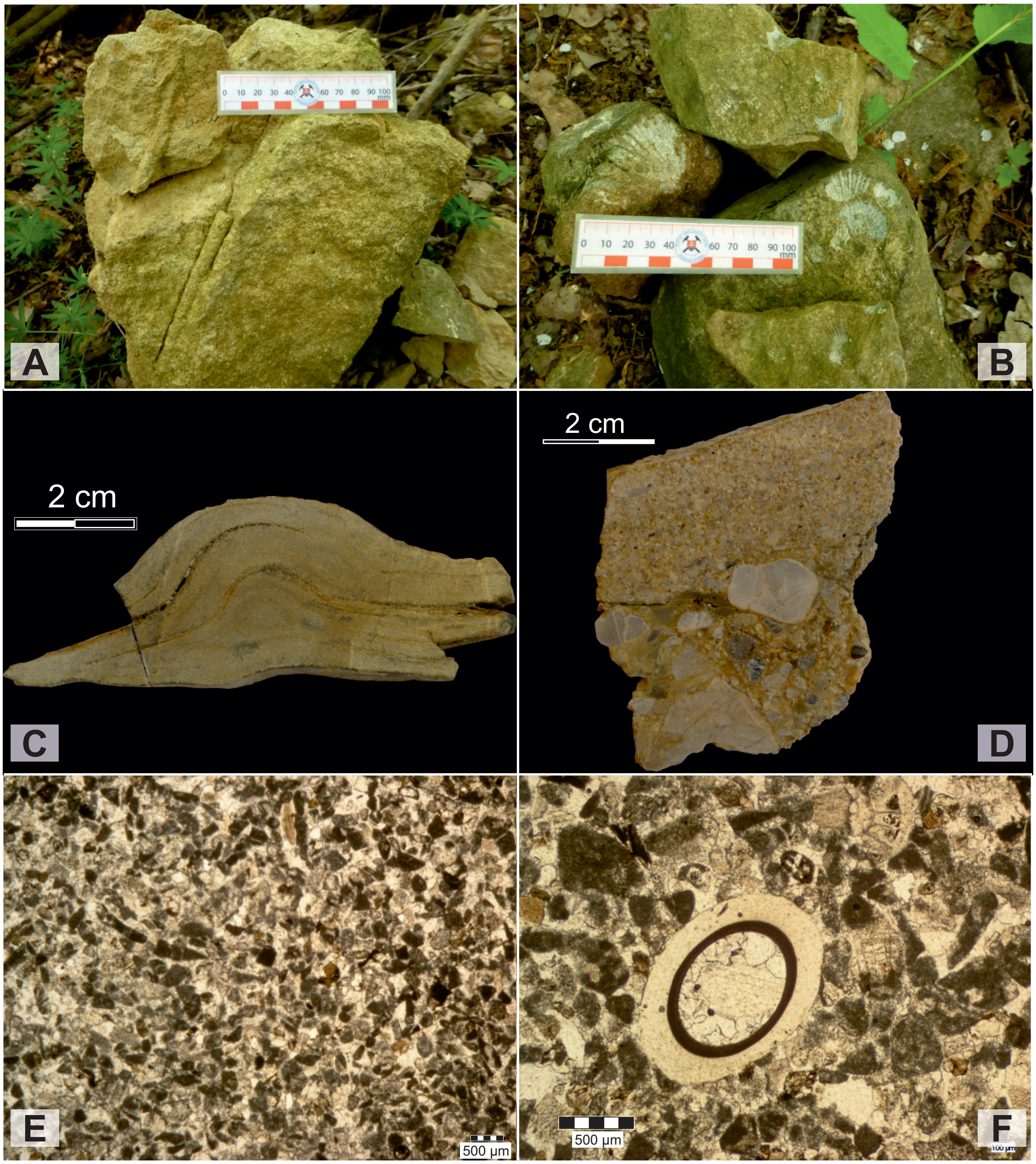


Fig. 6. A – Coarse-grained sandstones with *Ophiomorpha* burrows, site 4. B – Sandstones with fragments of thick-walled bivalvia, site 4. C – Slump fold from thin-bedded sandstones, site 1. D – Conglomerate interbed in the coarse-grained sandstone, site 6. E – Thin-section of calcarenite, site 6. F – Section of serpulid worm *Ditrupa cornea*, site 6.

littoral sandstones, calcarenites, or greywackes (3). The greyish calcareous sub-littoral to bathyal claystone ("schlier") sediments (4; Fig. 4) are traditionally included into the Čausa Formation (Mello et al., 2011; Ivanička et al., 2011). This lithofacies can be correlated with the lower part of the Lužice Formation (defined in Vienna Basin).

(1) Basal non-marine Eggenburgian sediments – so-called Veľká Čausa Member are described only from the PB-1 borehole (depth 80–60 m, Gabčo et al., 1963; Began et al., 1963). They are represented by the varicoloured sandstones and claystones lacking any faunistic remains and rich in siderite, probably of pedogenic origin. The sediments were deposited in continental or freshwater environment. The following 6 m thick dark grey sandy clays with sandy intercalations, probably of brackish, lagoonal origin, contain mollusc macrofauna of *Tympanotonus*

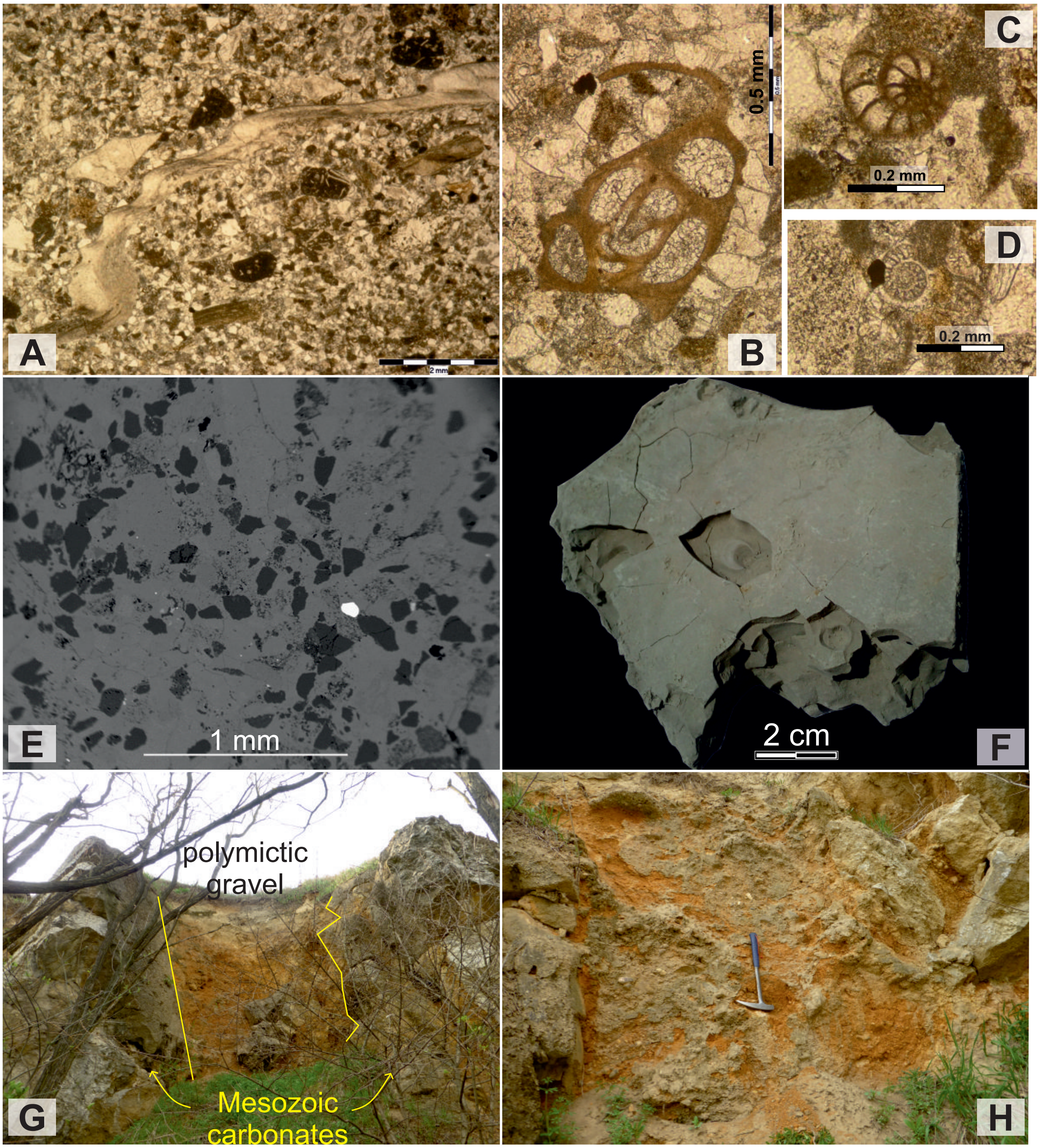


Fig. 7. A – Thin-section of sandstone with the thick-walled bivalve, site 1. B – Cross-section of *Quinqueloculina* cf. *buchiana* (d'Orbigny). C – Foraminifer *Ammonia* cf. *beccari* (Linnaeus). D – Foraminifer *Elphidium* sp. E – BSE image of sandstone, site 1. Dominating lithoclastic carbonate (pale grey) and angular clasts of quartz (dark grey) with homogenous grain size. Carbonate is present as well as cement. White mineral in the center, identified as monazite with marked oscillating zones, indicates its magmatic origin. F – Grey calcareous claystone representing typical pelitic lithofacies of the Čausa Fm. from the engineering borehole near Trenčianska Turná, site 2. G – Karst fillings with polymictic gravel of Pliocene age in the railroad cut near Ivanovce, site 8. H – Detail on the gravel from the previous image.

margaritaceus moniliformis (Grat.), *Tympanotonus margaritaceus grateloupi* (d'Orb.), *Melanopsis hantkeni* Hofm., *Clithon (Vittoclithon) pictus* Fér. and *Meretrix* sp.; foraminifera *Rotalia beccarii* (Linnaeus); sporadic radiolarians, *Characeae;* and pollen assemblage indicating humid subtropical climate (Began et al., 1963; Planderová, 1990). The overall thickness of the continental and brackish sediments is 40–50 m (Salaj, 1995).

(2) The conglomerate lithofacies, i.e. the Kľačno Conglomerate Member represents a continual transition

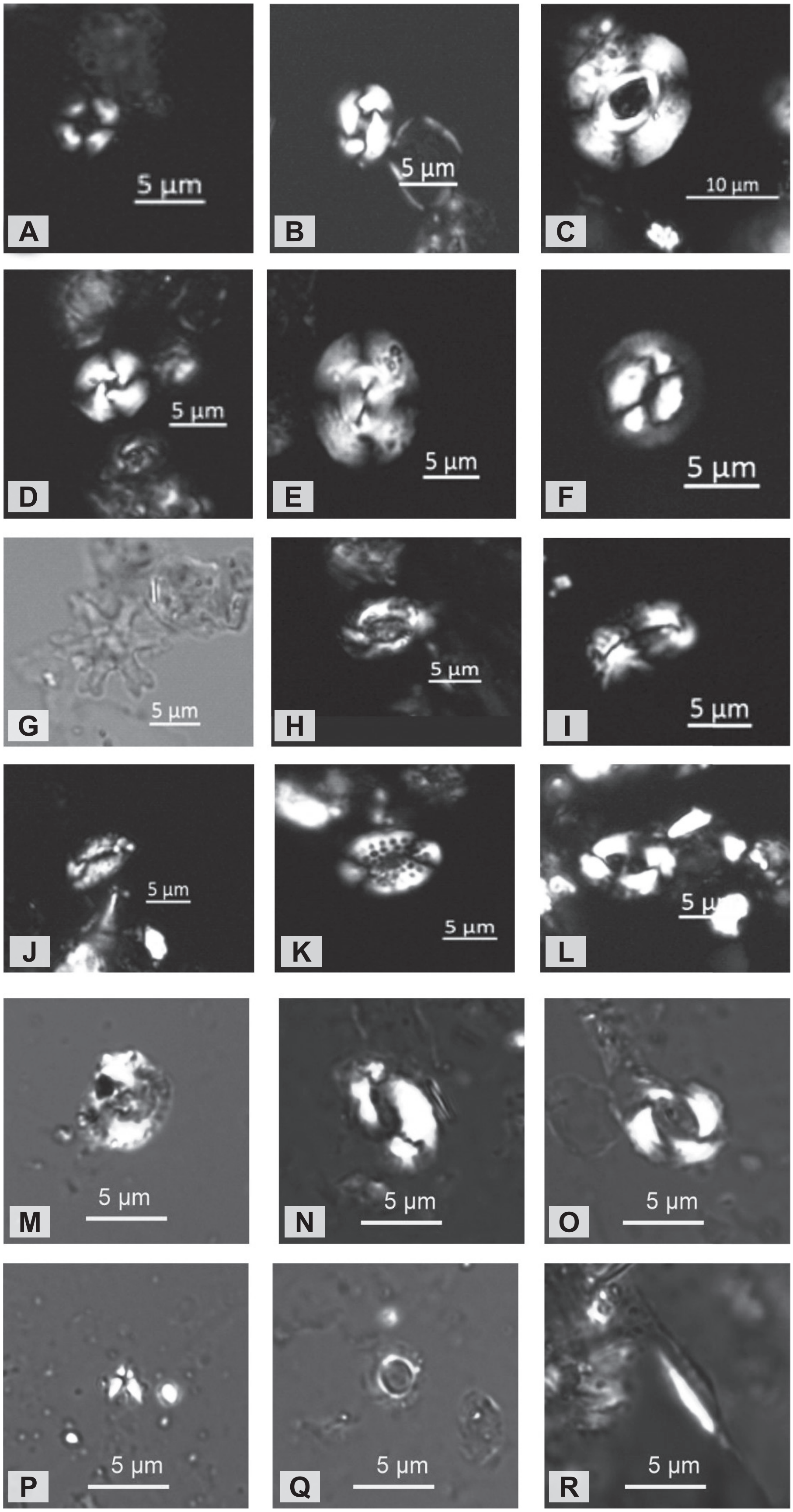


Fig. 8. Documented nannoplankton species (for location of samples see Tab. 1). A – *Reticulofenestra ornata* Müller, XN, site 1. B – *Reticulofenestra lockeri* Müller, XN, site 2. C – *Cyclicargolithus abisectus* (Muller) Wise, XN, site 2. D – *Cyclicargolithus floridanus* (Roth & Hay) Bukry, XN, site 2. E – *Reticulofenestra bisecta* (Hay, Mohler & Wade) Roth, XN, site 2. F – *Coccolithus pelagicus* (Wallich) Schiller, XN, site 2. G – *Discoster deflandrei* Bramlette & Riedel, XN, site 2. H – *Helicosphaera* cf. *ampliaperta* Bramlette & Wilcoxon, XN, site 2. I – *Helicosphaera scissura* Miller, XN, site 2. J – *Helicosphaera carteri* (Wallich) Kamptner, XN, site 1. K – *Pontosphaera multipora* (Kamptner) Roth, XN, site 2. L – *Helicosphaera recta* (Haq) Jafar & Martini, XN, site 2. M – *Calcidiscus leptoporus* (Murray & Blackman) Loeblich & Tappan, site 3. N – *Helicosphaera ampliaperta* Bramlette & Wilcoxon, site 3. O – *Reticulofenestra excavata* Lehotayová, site 3. P – *Sphenolithus* aff. *belemnos* Bramlette & Wilcoxon, site 3. Q – *Umbilicosphaera rotula* (Kamptner) Varol, site 3. R – *Triquetrorhabdulus carinatus* Martini, site 3.

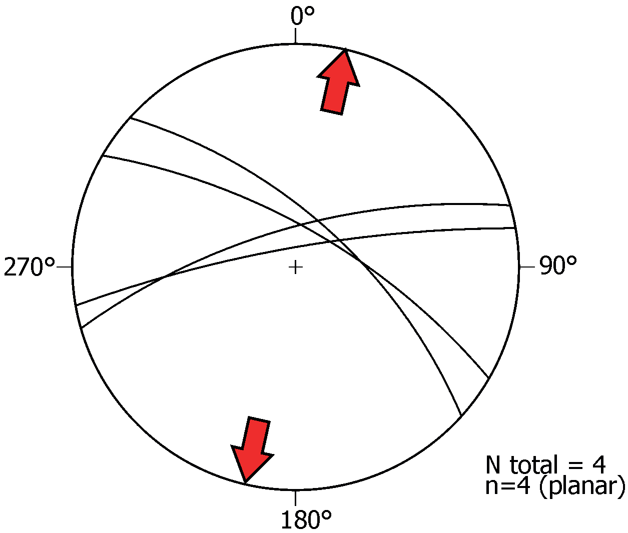


Fig. 9. Orientation of caverns in the Ivanovecká skalka elevation (site 8, for location see Tab. 1).

between the coarse-grained sandstone/fine-grained conglomerate to cobble conglomerate with clasts up to 10 cm in diameter (Fig. 6 A-B). The clasts are mostly represented by the Middle Triassic carbonates (Wetterstein limestone and dolomite), but also quartzites, radiolarites, sandstones, or siltstones, and clayey limestones with calpionellids. The conglomerates contain a mixed material, a large volume of which comes from the Hronicum and other Inner Carpathian nappes. Crystalline basement rocks were observed in negligible amount (for a more detailed analysis see Kováč et al., 1988; Baráth & Kováč, 1989). The matrix of conglomerates is calcareous and sandy. Since the conglomerates onlap the Pieniny Klippen Belt rocks as well, it can be assumed that deposition took place on the tectonically disintegrated basement, which, however, was not eroded up to the base of the Tatric sedimentary cover. Locally 5–10 cm beds of cross-bedded sandstones intercalate with conglomerates (Salaj, 1995). The overall thickness of the conglomerates is 80–100 m (Salaj, 1995).

The conglomerate and overlying calcarenites differ in the western tip of the Trenčianska kotlina Basin, north of Nové Mesto nad Váhom (site 6; Tab. 1), where the basal carbonate conglomerates are structurally immature (Figs. 5 C–E). Clasts – granules to small pebbles are poorly rounded, often angular, monomictic, mostly represented by Wetterstein Limestone and Wetterstein Dolomite, which are located in their basement. The conglomerates and calcarenites could possibly represent erosional remnant of the Planinka Formation (Ottnangian, Kováč et al., 1992). Due to the missing features which would allow precise stratigraphic assignment, we conditionally include the sediments into the Čausa Fm.

(3) The sandstone lithofacies is represented by the medium- to thick-bedded fine-grained to coarse-grained calcareous sandstone or calcarenites, locally with conglomerate interbeds, usually of greyish to yellow colour on weathered surfaces and grey-brown on a fresh surface (Figs. 5 F and 6 A–B). Apart from quartz and/or carbonate grains, also feldspars and muscovite are common. Matrix is mostly calcareous, however, silicification was locally observed as well. Sandstones are mostly structureless, however, may contain abundant fucoids (*Ophiomorpha*, Fig. 6 B) and fragments of thick-walled bivalves (Fig. 6 B). Locally, also minor slump folds were recorded (Fig. 6 C). Lithic detritus is mostly represented by clasts of carbonates. It is possible to identify clasts of calpionellid, radiolarian and Saccocoma limestones, clasts with thin-walled bivalves or rare *Globotruncanidae* fragments (Mesozoic redeposits). Heavy minerals from sandstones both from Trenčianska kotlina and Ilavská kotlina basins are characterized by the presence of apatite, leucoxene, zircon, rutile, garnet, tourmaline, epidote, spinel, staurolite, and monazite (Fig. 7 E). The chemical composition of 9 garnet grains analysed by electron microprobe in one thin section suggests presence of mixed populations, where composition (in mol %) varied as:

- almandine (59–46) – grossular (27–16) – pyrope (26–23) – spessartine (2–1)
- almandine (72–63) – grossular (26–3) – pyrope (11–7) – spessartine (25–2)
- almandine (64) – grossular (26) – pyrope (4) – spessartine (15)

The composition of analysed spinel grains (four grains per one thin section) responds to magnesiochromite and spinel, where Cr/(Cr+Al) = 0.28–0.55 and FeII/(FeII+Mg) = 0.3–0.47. Spinels and garnets chemically does not diverge from composition of samples from External Carpathian Flysch Belt sandstones.

Sandstones and calcarenites contain also *in situ* fossil remains. Apart of common fragments of thick-walled bivalves (Figs. 6 B and 7 A; described by Čtyroký, 1960), bryozoa, echinoderm spines, and foraminifers *Ammonia* cf. *beccarii* (Linnaeus), *Quinqueloculina* cf. *buchiana* (d'Orbigny), *Elphidium* sp. (Figs. 7 B-D) were identified from a thin section. Other foraminifers found in the sandstone are listed in Tab. 3. Eggenburgian age of the sandstones is based on the occurrence of the bivalves *Chlamys gigas* (Schlotheim) described from the Skalka nad Váhom (part Skala) and Horovce villages (Čtyroký, 1957; 1960). The yellow calcarenites occurring above the carbonate conglomerates north of the Nové Mesto nad Váhom are characterized by remains of serpulid *Ditrupa cornea* (Figs. 6 F). Similar as the underlying conglomerates they could possibly represent erosional remnant of the Planinka Fm. For now the calcarenites are included into the Čausa Fm.

The sandstones of the Čausa Formation pass gradually and laterally into siltstones, calcareous claystones, and

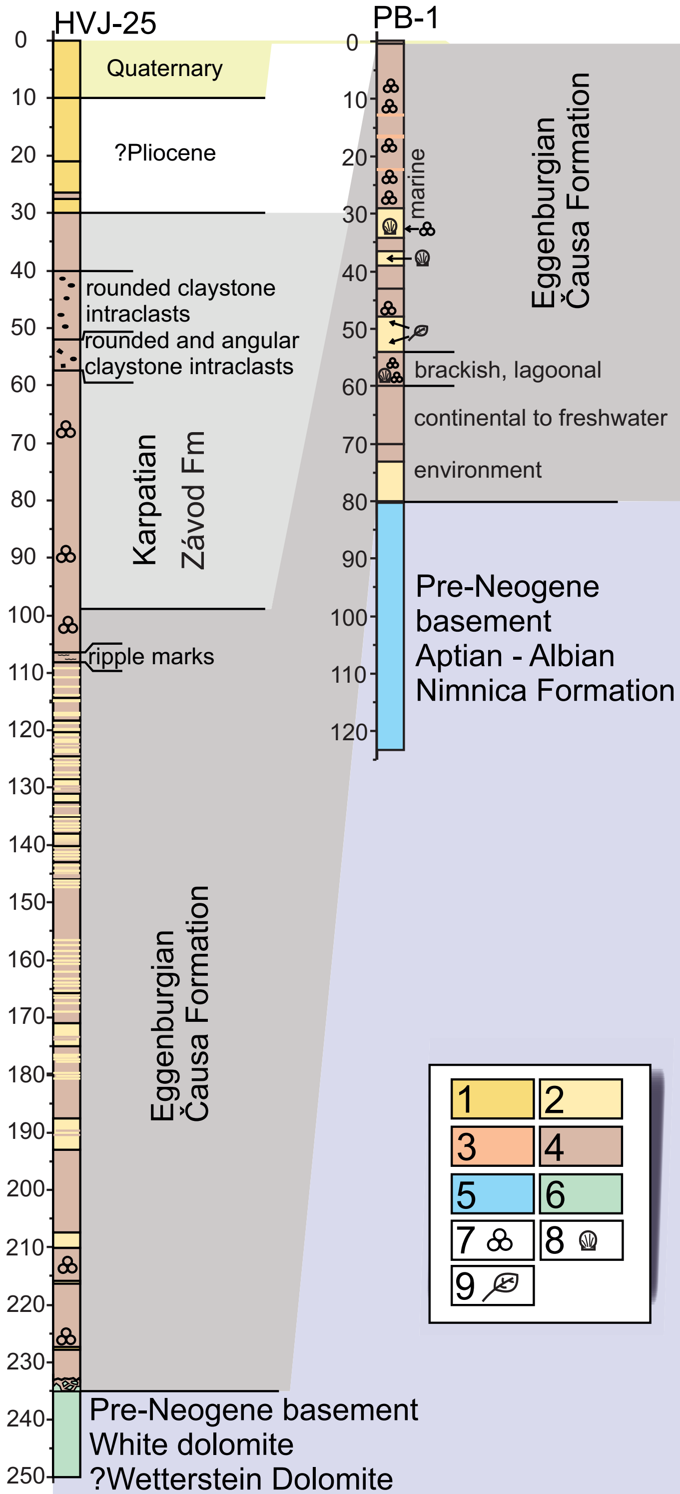


Fig. 10. Correlation profile across the boreholes HVJ-25 and PB-1 (based on Pospíšil et al., 1971; Gabčo et al., 1963). For the boreholes location see Fig. 3 and Tab. 1. 1 – conglomerate or gravel; 2 – sandstone; 3 – siltstone; 4 – claystone or clay; 5 – limestone; 6 – dolomite; 7 – microfauna; 8 – macrofauna; 9 – macroflora.

"schlier" sediments, that represent pelitic lithofacies. The overall thickness of the conglomerate and sandstone lithofacies is according to field observation maximum 80–150 m in the Trenčianska kotlina and Ilavská kotlina basins.

(4) Pelitic lithofacies is dominated by blueish, grey, and grey-green sandy calcareous claystones, siltstones, and "schlier" sediments (Fig. 7 F). Sediments are mostly massive, irregular lamination is usually observed only in the interbeds with higher sandy admixture. Fine-grained sediments form only sporadic outcrops and are mostly covered by Quaternary deposits. The wider occurrence of this facies in the larger area of Trenčianska kotlina Basin was confirmed by several shallow engineering geology boreholes, and hydrogeologic wells (Tab. 1; other localities are reported by Kysela, 1978).

Thickness of the pelagic claystones in the Trenčianska kotlina and Ilavská kotlina basins varies between 54 m in the borehole PB-1 (Sverepec) (Gabčo et al., 1963) and 136.5 m in the well HVJ-25 (Pospíšil et al., 1971). The borehole data for the region are, however, sparse. Outside the studied region, the DB-15 (Horňany) in the northern Bánovská kotlina Basin contains 204 m of the Eggenburgian pelagic claystones (Brestenská et al., 1975; Biela, 1978; Fordinál et al., 2001b). Not even such thickness would, however, explain the occurrence of pelagic claystones in various places under the Quaternary sediments in the central part of the Trenčianska kotlina Basin. The presence of the Ottnangian Bánovce Formation, possibly occurring above the Čausa Fm. could not be confirmed.

The age of the pelitic lithofacies was based on nannoplankton and foraminifers. Samples from pelagic claystones from sites 1 (Soblahov), 3 (Chocholná--Velčice), and 2 (Trenčianska Turná-Hámre) yielded Early Miocene nannoplankton assemblage of NN2 Zone based on the occurrence of *Helicosphaera scissura* Miller, *Helicosphaera recta* (Haq) Jafar & Martini, *Helicosphaera ampliaperta* Bramlette & Wilcoxon (Perch-Nielsen, 1985), and *Helicosphaera carteri* (Wallich) Kamptner (Figs. 8 A-R; Tab. 2). Studied foraminifera samples were poorer and did not contain index species (Tab. 3), however, planktonic zones N5 and N6 were described by previous research (Salaj & Zlinská, 1991).

The Závod Formation (Figs. 4 and 10) consists of grey sandy calcareous claystones, with yellow calcareous claystone and lignite interbeds containing brackish and freshwater microfauna of the Karpatian age. Sediments are not present on the surface in the Trenčianska kotlina and Ilavská kotlina basins,

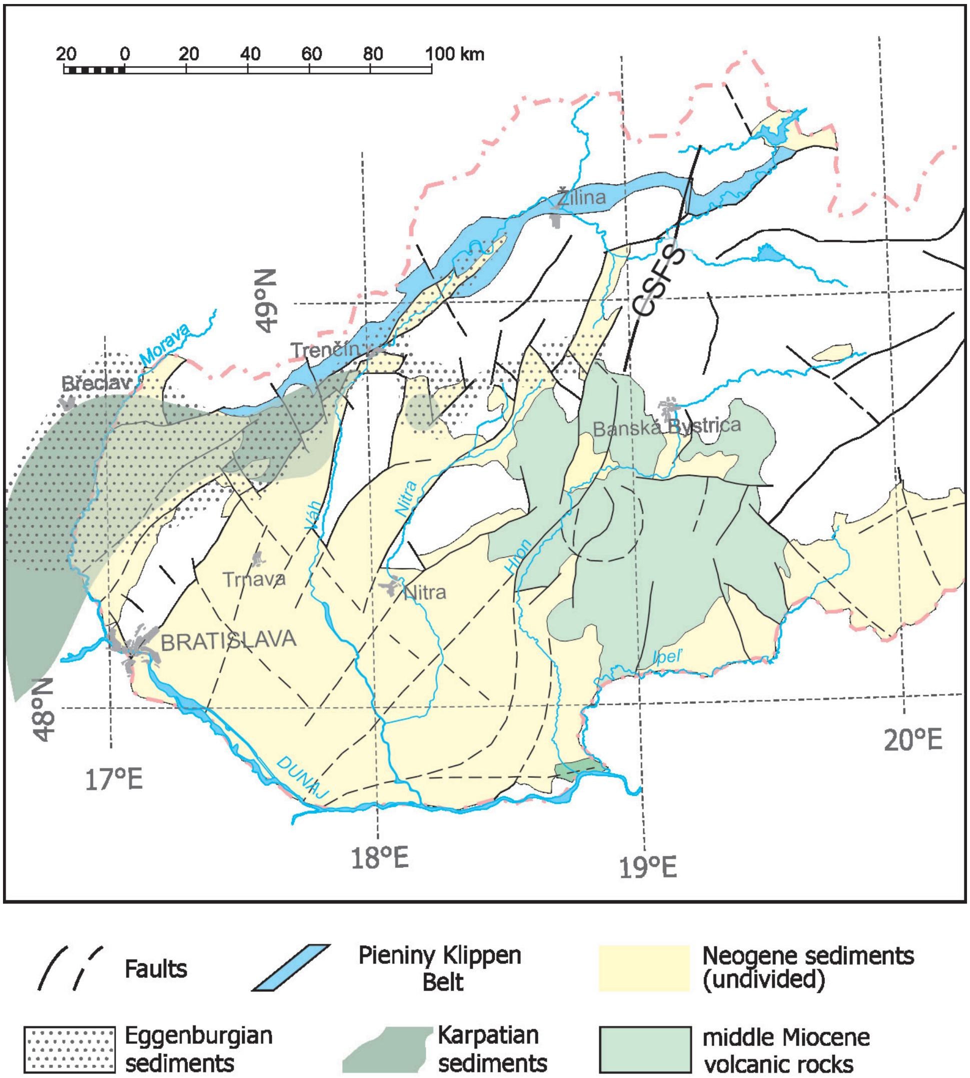


Fig. 11. Schematic map showing the distribution of Eggenburgian (dotted) and Karpatian (transparent grey-green) sediments in the Western Slovakia and surrounding regions (compiled according to Biela, 1978; Kováč et al., 1988; Kováč & Baráth, 1989; Gašparik et al., 1993; Pristaš et al., 2000; Ivanička et al., 2007; Potfaj et al., 2014; Pešková et al., 2020). Occurrences the Early Miocene sediments and in the South Slovakian Basin and the Flysch Belt are not shown. Background map based on Hók et al. (2019). CSFS = Central Slovak Fault System.

however, were revealed by the borehole HVJ-25 (Pospíšil et al., 1971). It overlies the basinal clays of the Čausa Formation and is characterized by sediments of similar lithology as the upper portion of the Čausa Formation. Their mutual contact suggests gradual transition; however, it includes hiatus and transgression that lacks basal clastics which are absent in the distal part of the basin. The Závod Formation was identified in the depth of 30–99 m in the HVJ-25 borehole (Pospíšil et al., 1971).

Sediments of the Pliocene age in the region are usually not sufficiently exposed, therefore most of the information came only from the boreholes. We include here medium-grained grey, yellow gravel with well-rounded quartzite and conglomerate pebbles reported from the upper portion of the borehole HVJ-25 (depth 10–37 m). Direct paleontological evidence is not given, however, possible redeposition of Karpatian microfauna in the clay interbed from depth 27.6–28.5 m was stated (Pospíšil et al., 1971). The post-Miocene sediments are represented as well by the red-brown fine- to medium-grained gravel observed in the railroad cut near Ivanovce village (site 8, Figs. 7 E–F). Mammal terrestrial macrofauna remains from this site indicate late Pliocene age (Ruscinian, MN15, Fejfar & Heinrich, 1985; Fejfar & Sabol, 2004). The gravel is present as cavern fill in the Mesozoic carbonates (Fatric Mraznica Fm.). The caverns have ESE-WNW and NW-SE strike and dip generally to the north (Fig. 9), suggesting NNW-SSE extension during the late Pliocene. Older reports also suggest the presence of greenish or brown clay interbeds considered as Pliocene in age (e.g. Salaj, 1988). The varicoloured gravel can be potentially correlated with the Kolárovo Formation.

Quaternary sediments of the Trenčianska kotlina and Ilavská kotlina basins were not studied in detail. The Quaternary fluvial terraces and alluvial fans of the wider area were studied for almost a hundred years (e.g. Hromádka, 1931; Andrusov, 1932), with some of the studies paying particular attention to the Trenčianska kotlina and/or Ilavská kotlina basins (e.g. Lukniš, 1946; Ložek & Tyráček, 1960; Mazúr & Kalaš, 1963a, b; Mazúrová, 1972; Beták, 2002). The Quaternary terraces and fans were also studied by mapping (e.g. Salaj, et al., 1989; Began et al., 1990; Potfaj, 2005; Ivanička et al., 2007, 2011; Mello et al., 2005, 2011; Pešková et al., 2020) and technical works (Zaťko et al., 1988; Mlynarčík, 1998; Šalagová et al., 1990). In the studied region, their overall thickness is usually 5–13 m, locally up to 20 m. The fluvial and alluvial accumulations (channel fill sand and gravel and floodplain clays) of the Váh River and alluvial fans of smaller tributary streams (notably Vlára and Drietomica) dominate NW part of the Trenčianska kotlina Basin and central part of Ilavská kotlina Basin. The eolian deposits are mostly grey and yellow loess and resedimented loess, often up to 10 m thick.

Several notable general patterns can be discerned in the Plio-Quaternary features of the Trenčianska kotlina and Ilavská kotlina basins. (1) The presence of NE–SW trend in both basins (albeit more pronounced in the Ilavská kotlina Basin) caused by the likewise-oriented faults. (2) Strong morphological contrasts between the flat and wide fluvial plains of the basins and the narrow, entrenched valleys, with steeper topography (so-called "gates") separating the basins. These are in all likelihood related to the faults running perpendicular to the basins. Differences between relative height in corresponding river terraces were observed between the basins and the "gates", implicating some degree of activity of these faults. (3) Gradual straightening of the Váh River channel, as well as narrowing of its alluvial plain during the Quaternary. The spatial distribution of terrace remnants demonstrates that the alluvial plain was much wider during the Pleistocene. Significantly greater river curvature in the entrenched "gates" presumably reflects the original watercourse preserved due to the more erosion-resistant bedrock. (4) Terrace and fan system dominated by the deposits of tributary streams. When compared to the upstream basins, the terrace remnants of the Váh River in the study area are characterized by a lesser extent, more fragmentary nature, and more material admixture from the tributary streams. The prevalence of the terraces diminishes further downstream, with little to almost none Váh River river terraces identified in the Trenčianska kotlina Basin. However, the increasing dominance of the tributary depositional landforms does not have an apparent effect on the erosive capability of the main river, as it laterally eroded distal parts of several fans. The older fans are dissected by their streams and, given enough space, basinward propagation of the younger fans can be observed within both basins, most prominently in the southeastern part of the Trenčianska kotlina Basin. The implications resulting from the presence of these features are debated in the discussion.

Interpretation and discussion

Despite the basic features of the Trenčianska kotlina and Ilavská kotlina basins sedimentary fill was already known since the 1960s, the information was fragmented, mostly available only in unpublished manuscripts and technical reports (Gabčo et al., 1963; Pospíšil et al., 1971; Kysela, 1978; Zbořil et al., 1984; Kováč et al., 1988), and later partly summarized in explanation notes to 3 different geological maps 1:50 000, covering various parts of the studied region (Mello et al., 2011; Ivanička et al., 2011; Pešková et al., 2020).

In the larger picture, the sedimentary fill of the Trenčianska kotlina and Ilavská kotlina basins (Figs. 1 and 2) was formerly an integral part of the larger Early Miocene sedimentary basin occurring on the outer margin of the IWECA, from the west located Vienna Basin to Blatné Depression and Bánovská kotlina, Hornonitrianska kotlina, and Turčianska kotlina basins in the eastern side (Fig. 11; Lexa et al., 2000; Kováč, 2000; Vass, 2002, Kováč et al., 2017). The deposition started in the early Eggenburgian with continental (limnic) and brackish clays and sands, locally also coarser clastics, known in the Brezovské Karpaty Mts. (Potfaj et al., 2014; Teťák et al., 2015), north-east located Ilavská kotlina Basin (borehole PB-1, Gabčo et al., 1963) and further south located Hornonitrianska kotlina Basin (Čechovič, 1959; Čechovič & Šinály, 1962). Much more widespread are the onshore (marginal) coarse clastics with different names and source areas in different basins – e.g. Chropov, Winterberg, Podbranč conglomerates in the Vienna Basin; Kľačno Conglomerate in Hornonitrianska kotlina, Bánovská kotlina, Trenčianska kotlina, and Ilavská kotlina basins, and Rakša and Slovany conglomerates in Turčianska kotlina Basin (Teťák, 2017; Ivanička et al., 2007; Pristaš et al., 2000; Mello et al., 2005; Gašparik et al., 1993; Vass, 2002). The coarse clastic sediments represent the onset of marine transgression affecting region along the western segment of the PKB – IWECA contact zone. The conglomerates were gradually replaced by finer clastics, mostly littoral sandstones, and finally, open marine calcareous claystones (Čechovič, 1959; Salaj & Zlinská, 1991), representing the maximum Early Miocene flooding. The Ottnangian Bánovce Formation was formerly described near the Soblahov village above the Eggenburgian Čausa Formation, however, without biostratigraphic verification (site 1, Tab. 1; see Maheľ et al., 1982; Ivanička et al., 2007). This study contradicts such interpretation, as the biostratigraphic analysis did not confirm the presence of Ottnangian sediments NW of Soblahov. The Ottnangian sediments among the western part of the Western Carpathian Neogene basins are represented by the Bánovce Fm. reported from the Bánovská kotlina Basin (Brestenská et al., 1975; Fordinál et al., 2001b) and the upper portion of the Lužice Fm. in the Vienna Basin. The absence of Ottnangian sediments is similar to the Hornonitrianska kotlina and Turčianska kotlina basins (Vass, 2002). It cannot be, however, excluded that the Ottnangian sediments were deposited and later eroded in the Trenčianska kotlina and Ilavská kotlina basins (as was stated by Salaj & Zlinská, 1991; Salaj, 1995). The more-or-less continuous marine sedimentation throughout the entire Early Miocene until the Karpatian was confirmed only in the Vienna Basin, northern Blatné Depression (e.g. borehole K-1 and possibly also GZV-1, Biela, 1978; Vrana et al., 2009), southwestern portion of the Trenčianska kotlina Basin (borehole HVJ-25, Pospíšil et al., 1971), and northern Bánovská kotlina Basin (Brestenská et al., 1975; Biela, 1978; Baráth & Kováč, 2000; Fordinál et al., 2001a, 2001b).

The Early Miocene stress regime was characterized by the NW-SE principal compressive stress (σ_1) in the Eggenburgian and was later accompanied by SW-NE tension (σ_3) in the Ottnangian and Karpatian in the western portion of the Western Carpathians (Hók et al., 1995; Nemcok et al., 1998; Fodor et al., 1999; Marko, 2012).

The following Middle Miocene rifting phase, starting in the Badenian, affected a large portion of the Pannonian Basin. Thick sequences of Badenian sediments accumulated in the northern Danube Basin, including Blatné and Rišňovce depressions (Biela, 1978; Baráth & Kováč, 2000; Hók et al., 2016). Simultaneously horst blocks of the Malé Karpaty, Považský Inovec, and Strážovské vrchy Mts. were elevated (Kováč et al., 1994; Danišík et al., 2004, Králiková et al., 2016; Marko et al., 2017), completely disrupting the existing Early Miocene basins configuration (Vass et al., 2002; Marko, 2012). The Badenian stress regime was characterized by the N-S to NNE-SSW principal compressive stress (σ_1) and E-W to ESE-WNW tension (σ_3) (Hók et al., 1995; Nemcok et al., 1998; Fodor et al., 1999; Marko, 2012)

Different mechanisms were proposed for the tectonic setting of the Early Miocene basins of the west portion of the IWECA. Formerly the model of strike-slip/wrench furrow basins was proposed (Vass et al., 1988; Kováč, 2000) and persists in the literature until today (Ivanička et al., 2011; Mello et al., 2011; Ludwiniak et al., 2019; Plašienka et al., 2020). The main arguments for a such model are: (1) the structural position on the outer margin of the IWECA at the contact with PKB which is usually interpreted as major oblique-slip plate boundary (Kováč & Hók, 1997); (2) elongate shape of the Ilavská kotlina Basin; and (3) signs of the compressional to strike-slip tectonic regime in the surrounding regions (Kováč & Hók, 1997; Šimonová & Plašienka, 2011). Such interpretation, however, lacks more solid arguments. The pull-apart nature of Trenčianska kotlina and Ilavská kotlina basins was never proved by structural (e.g. fault slip) or seismic data. There is lack of other strike-slip basin features including (Miall, 2000, p. 518): fault-flank conglomeratic wedges; strata with numerous facies changes; sediments with different stratigraphy; ample evidence of syndepositional tectonics (including intraformational folds and unconformities); offset of basin fill from their source area etc.

The Early Miocene basin was situated above the contact of the upper (continental) ALCAPA (IWECA) microplate and internally of accretionary prism represented by the Flysch Belt (EWECA). The basin represented continuous WSW-ENE oriented (in present coordinates) depositional area from the Vienna Basin, northern Blatné Depression and Bánovská kotlina, Trenčianska kotlina, Ilavská kotlina, Hornonitrianska kotlina, and Turčianska kotlina basins (approx. 100 km long and 40 km wide). It should be noted, that the Lower Miocene sediments are not present in the central part of Western Carpathians east of the Central Slovak fault system and west of the Hornád fault system. Their absence is probably the result of Ottnangian or later erosion (as was proposed in East Slovakian Basin, e.g. Kováč et al., 1995; Baráth & Kováč, 2000). The nature of microfauna and nannoplankton from the studied region confirms earlier assumptions of Salaj & Zlinská (1991) that the Trenčianska kotlina and Ilavská kotlina basins represented uniform open marine basin and not a restricted embayment during the late Eggenburgian. The tectonic classification of this basin is not entirely straightforward as the Lower Miocene sediments between the Vienna and Turčianska kotlina basins overlap various parts of the Western Carpathian orogenic wedge. The large-scale thrusting in the western segment of the Pieniny Klippen Belt gradually ceased during the Early Miocene. The Eggenburgian sediments seemingly seal and overlap the Pieniny Klippen Belt units without any signs of north-vergent thrusting in the studied region. However, the leading edge of the fore-thrusts propagated northward into the Waschberg-Ždánice units of the outer Silesian--Krosno nappes (Jiříček, 1979; Picha et al., 2006; Stráník et al., 2007). The basin was therefore still in the wedge top setting. The Early Miocene subsidence affecting relatively wide region was triggered by orogenic wedge collapse and had only minor strike-slip (transtensional) component. The fault deformation of the Lower Miocene sediments is not well documented, mostly due to poor outcrops, however, occurrences supporting such interpretation are known, e.g. near the Krásna Ves in the Bánovská kotlina Basin (Marko, 2012).

The present shape of Early Miocene basins is a result of disintegration and inversion during the Middle Miocene and later rearrangement of basins and changes in stress regime due to CCW rotation of ALCAPA (Márton et al., 2016). It is thought that the Middle Váh valley formed due to the activity of the NE-SW-striking faults, and was subsequently divided into an array of smaller basins by activity of perpendicular NW-SE-striking faults (e.g. Began et al., 1993; Mello et al., 2011; Ivanička et al., 2011; Pešková et al., 2020). The observed Pliocene–Quaternary features are consistent with the model, as they point out to the preexistence of a wide, NE-SW-trending basin bounded by the faults with the same orientation. The narrowing of the alluvial plain, as well as the increasing dominance of the tributary alluvial fans, and their progradation towards the basin axes, point to the diminishing activity of the marginal faults. Moreover, the subsequent activity of perpendicular faults with NW-SE orientation likely followed, which segmented the primary basin into an array of smaller basins. The perpendicular faults were likely active throughout the Quaternary, as indicated by the relative height perturbations of river terrace levels (Mazúr & Kalaš, 1963a, b; Began et al., 1993; Pešková et al., 2020) The neotectonic map of Maglay et al. (1999) interprets Trenčianska kotlina and Ilavská kotlina basins as Pliocene–Quaternary subsiding regions resulting from the ongoing orogenic collapse. Despite other models, e.g. the Quaternary strike-slip faulting (most recently by Ludwiniak et al., 2019) was proposed, there is no strong evidence to support such an interpretation. Although some streams at the basin margins could be interpreted as deflected or offset streams, no other geomorphological features associated with the strike-slip faults (such as fault-parallel linear throughs, benches, pressure ridges, shutter ridges, or alluvial fan offset) were observed. Also, the marginal faults lack distinct linearity that is typical for an active strike-slip fault. Moreover, the map of the Quaternary sediment thickness (Maglay et al., 2009) reveals a pattern that is not consistent with the typical depocentre distribution in the pull-apart basins. Therefore, in our opinion, there is insufficient evidence to warrant the interpretation of the Trenčianska kotlina and Ilavská kotlina basins as the Quaternary pull-apart basins. Despite some strike-slip component cannot be ruled out, the available evidence points out to the marginal faults with a predominant dip-slip component. In addition, the prevalence of the dissected and propagating alluvial fans, combined with the irregular nature of the basin margins, supports the notion of marginal faults with a diminishing degree of activity, that were later dissected by the younger perpendicular faults.

The problem and gap in our knowledge that persist are the absence of deeper (more than 300 m) borehole which would clarify the sedimentary fill nature of Trenčianska kotlina and Ilavská kotlina basins. Another difficulty that needs to be solved, is the abnormally thick Early Miocene sequence in the central part of the Trenčianska kotlina Basin indicated by the geophysical data (Fig. 4), which could be explained by the presence of Paleogene sediments or other kinds of low resistivity rocks.

Conclusions

The Neogene sedimentary fill of the Trenčianska kotlina and Ilavská kotlina basins is mostly represented by the following formations (Fig. 4): (a) The Eggenburgian Čausa Formation, divided into 4 lithofacies. (1) The locally preserved continental to brackish claystones and sandstones at the base of the formation. (2) Kľačno Conglomerate Member represented by the continental to littoral carbonate conglomerates with carbonate matrix. (3) Littoral calcareous sandstones to calcarenites often with thick-walled bivalves, *Ophiomorpha* burrows, and conglomerate and claystone interbeds. (4) Pelagic, open marine calcareous claystones with benthic and planktonic foraminiferal fauna and nannoplankton; (b) The Karpatian Závod Formation represented by the marine, brackish and fluvial calcareous silty claystones, present only in the southwest (borehole HVJ-25). (c) The varicoloured polymict gravel with mammal macrofauna indicating late Pliocene (MN15) age.

The Lower Miocene sediments seal the Pieniny Klippen Belt nappe structure. Northwestward thrusting was, however, still active in the Waschberg-Ždánice Unit of the Silesian-Krosno nappes. Minor horizontal and oblique slip deformation was still ongoing at the contact of ALCAPA (IWECA) with its foreland (EWECA) until the final docking with the Bohemian Massif at the Karpatian–early Badenian. The wedge-top basin model is proposed for the Early Miocene (Eggenburgian–Ottnangian) basin subsidence which was triggered by regional orogenic wedge collapse. The wedge top basin represented first evolution stage of the Trenčianska kotlina and Ilavská kotlina basins, which formed one continuous basin with nearby Blatné Depression, Vienna, Bánovská kotlina, Hornonitrianska kotlina and Turčianska kotlina basins.

The second stage is a result of block rotation, inversion, local backthrusting and exhumation of the Považský Inovec Mts., Strážovské vrchy Mts. and Čachtické Karpaty Mts. expressed as disintegration into horst and graben structure of the so-called Core mountains which occurred in multiple phases since the Middle Miocene (mainly Badenian and later). The final (third) stage of inversion occurred in the Pliocene to Quaternary and is responsible for modelling the Trenčianska kotlina and Ilavská kotlina basins in the present shape.

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References

Andrusov, D., 1932: O čtvrtohorních terasách Oravy a středního toku Váhu a několik poznámek o geomorfologii západních Karpát slovenských. *Věst. St. geol. Úst. Č. Republ., 8, 244–257.*

Baráth, I. & Kováč, M., 1989: Podmienky sedimentácie a zdrojové oblasti egenburských klastík v západnej časti Západných Karpát. *Miscel. micropaleont., IV., Knih. Zem. Plyn Nafta, 9, 55–86.*

Baráth, I. & Kováč, M., 2000: Miocene sequence stratigraphic key surfaces and depositional system tracts in the Western Carpathian basins (Central Paratethys, Slovakia). *Slovak Geol. Mag., 6, 2–3, 92–94.*

Began, A., Salaj, J., Hanáček, J., Rakús, M., Nemčok, J., Marschalko, R., Gabčo, R., Kalaš, L. & Kullman, E., 1963: Základný geologický výskum a mapovanie v M 1 : 25 000 a 1 : 50 000, spojený s edíciou máp v M – 1 : 50 000 List M-34-97-D Považská Bystrica. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 11454), 1–197.*

Began, A., Hanáček, J., Maglay, J. & Malík, P., 1990: Vysvetlivky ku geologickej mape list 35-142 (Beckov). *Manuscript. Bratislava, archive SGIDŠ (arch. no. 75296), 1–88.*

Began, A., Salaj, J., Horniš, J., Čechová, A. & Szalaiová, V., 1993: Vysvetlivky ku geologickej mape Bielych Karpát 1 : 50 000. Časť bradlové pásmo. Čiastková záverečná správa. Manuscript. *Bratislava, archive SGIDŠ (arch. no. 78506), 1–166.*

Beták, J., 2002: Geomorfologický výskum a mapovanie v oblasti k. ú. Trenčianska Turná. Diploma Thesis. *Manuscript. Bratislava, archive PriF UK.*

Bezák, V., Elečko, M., Fordinál, K., Ivanička, J., Kaličiak, M., Konečný, V., Kováčik, M., Maglay, J., Mello, J., Nagy, A., Polák, M. & Potfaj, M. (eds.), 2008: Prehľadná geologická mapa Slovenskej republiky 1 : 200 000. *Bratislava, Št. Geol. Úst. D. Štúra.*

Biela, A., 1978: Hlboké vrty v zakrytých oblastiach Vnútorných Západných Karpát. *Region. geol. Západ. Karpát, 11, 9–224.*

Buday, T. (ed.), Cicha, I., Paulík, J., Dornič, J., Dvořák, J., Kamenický, J., Maheľ, M., Matějka, A., Salaj, J., Scheibner, E. & Zelman, J., 1963: Geologická mapa ČSSR 1 : 200 000 M-33-XXX Gottwaldov. *Praha, Ústř. Úst. geol.*

Brestenská, E., Marková, M., Franko, O. & Kullmanová, A., 1975: Záverečná správa o vrte DB-15 Horňany v Bánovskej kotline. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 36027), 1–58.*

Čechovič, V., 1959: Geológia treťohorných vrstiev severného okraja Handlovskej uhoľnej panvy. *Geol. Práce, Zoš., 53, 5–58.*

Čechovič, V. & Šínaly, T., 1962: Paleogénne a spodnomiocénne vrstvy vo veľkobani Handlová. *Geol. Práce, Zpr., 25–26, 163–168.*

Čtyroký, P., 1957: Predbežné výsledky makropaleontologického výzkumu sp. miocénu v Považí. *Manuscript. Bratislava, archive SGIDŠ (arch. no. AP 2552), 1–30.*

Čtyroký, P., 1960: Fauna litorálních sedimentů spodního burdigalu z okolí Povážské Bystrice. *Geol. Práce, Zpr., 18, 141–152.*

Danišík, M., Dunkl, I., Putiš, M., Frisch, W. & Kráľ, J., 2004: Tertiary burial and exhumation history of basement highs along the NW margin of the Pannonian basin – an apatite fission track study. *Austrian J. Earth Sci., 95/96, 60–70.*

Fejfar, O. & Heinrich, W. D., 1985: Zur Bedeutung der Wirbeltierfundstätten von Ivanovce und Hajnáčka für die Säugetierpaläontologie in Pliozän und frühen Pleistozän in Europa: Kenntnisstand und Probleme. *Věst. Ústř. Úst. geol., 60, 213–224.*

Fejfar, O. & Sabol, M., 2004: Pliocene Carnivores (Carnivora, Mammalia) from Ivanovce and Hajnáčka (Slovakia). *Cour. Forsch.-Inst. Senckenberg, 246, 15–53.*

Fodor, L., Csontos, L., Bada, G., Györfi, I. & Benkovics, L., 1999: Tertiary tectonic evolution of the Pannonian Basin system and neighbouring orogens: A new synthesis of palaeostress data. In: Durand, B., Jolivet, L., Horváth, F. & Séranne, M. (eds): The Mediterranean Basins: Tertiary Extension within the Alpine Orogen. *London, Geol. Soc., Spec. Publ., 156, 295–334.*

Fordinál, K., Elečko, M., Šimon, L. & Holcová, K., 2001a: Bánovská kotlina Depression (northern part of the Danube Basin); Neogene stratigraphy and geological development. *Slovak Geol. Mag., 7, 3, 289–301.*

Fordinál, K., Šimon, L. & Elečko, M., 2001b: Regionálny geologický výskum neogénnej výplne a podložia Bánovskej kotliny. *Geol. Práce, Spr., 105, 29–37.*

Fusán, O., Biely, A., Ibrmajer, J., Plančár, J. & Rozložník, L., 1987: Podložie terciéru Vnútorných Západných Karpát. *Bratislava, Geol. Úst. D. Štúra, 1–123.*

Gabčo, R., Seneš, J., Lehotayová, R. & Planderová, E., 1963: Zpráva o geologickom mapovaní na liste mapy 1 : 50 000 Považská Bystrica v roku 1962. *Manuscript. Bratislava, archive SGIDŠ (arch. no. AP 4362), 14 p.*

Gašparik, J. (ed.), Halouzka, R., Bujnovský, A., Fojtík, I., Gorek, J., Haško, J., Lexa, J., Miko, O., Polák, M. & Rakús, M., 1993: Geologická mapa Turčianskej kotliny 1 : 50 000. *Bratislava, Geol. Úst. D. Štúra.*

Harangi, S. & Lenkey, L., 2007: Genesis of the Neogene to Quaternary volcanism in the Carpathian-Pannonian region:

Role of subduction, extension, and mantle plume. *Geol. Soc. Amer., 418, 67–90.*

Hók, J., Šimon, L., Kováč, P., Elečko, M., Vass, D., Halmo, J. & Verbich, F., 1995: Tectonics of the Hornonitrianska kotlina depresion in the Neogene. *Geol. Carpath., 46, 4, 191–196.*

Hók, J., Kováč, M., Rakús, M., Kováč, P., Nagy, A., Kováčová-Slamková, M., Sitár, V. & Šujan, M., 1998: Geologic and tectonic evolution of the Turiec depression in the Neogene. *Slovak Geol. Mag., 4, 3, 165–176.*

Hók, J., Kováč, M., Pelech, O., Pešková, I., Vojtko, R. & Králiková, S., 2016: The Alpine tectonic evolution of the Danube Basin and its northern periphery (southwestern Slovakia). *Geol. Carpath., 67, 5, 495–505.*

Hók, J., Pelech, O., Teťák, F., Németh, Z. & Nagy, A., 2019: Outline of the geology of Slovakia (W. Carpathians). *Miner. Slov., 51, 1, 31–60.*

Hromádka, J., 1931: Třídění povrchových tvarů Slovenska na podkladě jejich vývoje. *Sbor. prírodoved. Odb. Slov. vlastived. Muz. (Bratislava), 1924–1931, 4, 28–48.*

Ivanička, J., Havrila, M., Kohút, M. (eds.), Olšavský, M., Hók, J., Kováčik, M., Madarás, J., Polák, M., Rakús, M., Filo, I., Elečko, M., Fordinál, K., Maglay, J., Pristaš, J., Buček, S., Šimon, L., Kubeš, P., Scherer, S. & Zuberec, J., 2007: Geologická mapa Považského Inovca a jv. časti Trenčianskej kotliny, M 1 : 50 000. *Bratislava, Št. Geol. Úst. D. Štúra.*

Ivanička, J., Kohút, M. (eds.), Olšavský, M., Havrila, M., Hók, J., Kováčik, M., Madarás, J., Polák, M., Rakús, M., Filo, I., Elečko, M., Fordinál, K., Maglay, J., Pristaš, J., Buček, S., Šimon, L., Kubeš, P., Scherer, S. & Zuberec, J., 2011: Vysvetlivky ku geologickej mape regiónu Považský Inovec a jv. časť Trenčianskej kotliny, M = 1 : 50 000. *Bratislava, Št. Geol. Úst. D. Štúra, 1–389.*

Jahn, J. J. & Beck, H., 1911: Přehledná geologická a tektonická mapa Moravy a Slezska 1 : 300 000. 1. vyd. *Brno, Komise přírodovědověd. prozk. Moravy.*

Jiříček, R., 1979: Tektogenetický vývoj karpatského oblouku během oligocénu a neogénu. In: Maheľ, M. (ed.): Tektonické profily Západných Karpát. *Bratislava, Geol. Úst. D. Štúra, 203–213.*

Kadlečík, J., Roth, Z. & Stráník, Z., 1980: Hlubinná stavba v oblasti vnějších karpat na Moravě a Západním Slovensku. In: Maheľ, M. (ed.): Vážnejšie problémy geologického vývoja a stavby Českolsovenska. Kľúčové územia, metódy a riešenia. *Bratislava, Geol. Úst. D. Štúra, 65–77.*

Kilényi, E. & Šefara, J. (eds.), 1989: Pre-Tertiary basement contour map of the Carpathian Basin beneath Austria, Czechoslovakia and Hungary. *Budapest, ELGI.*

Kováč, M., 2000: Geodynamický, paleogeografický a štruktúrny vývoj karpatsko-panónskeho regiónu v miocéne: nový pohľad na neogénne panvy Slovenska. *Bratislava, Veda, 1–202.*

Kováč, M., Baráth, I. & Holický, I., 1988: Stratigrafická a paleogeografická korelácia vývoja egenburských sedimentov SV časti Malých Karpát, Trnavskej tabule a Považia. Tektonogenéza a paleogeografia Západných Karpát a ich vzťah k ostatným jednotkám. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 69775), 1–227.*

Kováč, M., Šutovská, K., Baráth, I. & Fordinál, K., 1992: Planinské súvrstvie – sedimenty otnansko-spodnokarpatského veku v severnej časti Malých Karpát. *Geol. Práce, Spr., 96, 47–50.*

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., Kráľ, J., Márton, E., Plašienka, D. & Uher, P., 1994: Alpine uplift history of the Central Western Carpathians: geochronological, paleomagnetic, sedimentary and structural data. *Geol. Carpath., 45, 2, 83–96.*

Kováč, M., Plašienka, D., Soták, J., Vojtko, R., Oszczypko, N., Less, G., Ćosović, V., Fügenschuh, B. & Králiková, S., 2016: Paleogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. *Glob. Planet. Change, 140, 9–27.*

Kováč, M., Márton, E., Oszczypko, N., Vojtko, R., Hók, J., Králiková, S., Plašienka, D., Klučiar, T., Hudáčková, N. & Oszczypko-Clowes, M., 2017: Neogene palaeogeography and basin evolution of the Western Carpathians, Northern Pannonian domain and adjoining areas. *Glob. Planet. Change, 155, 133–154.*

Kováč, M., Halásová, E., Hudáčková, N., Holcová, K., Hyžný, M., Jamrich, M. & Ruman, A., 2018: Towards better correlation of the Central Paratethys regional time scale with the standard geological time scale of the Miocene Epoch. *Geol. Carpath., 69, 283–300.*

Kováč, P. & Hók, J., 1996: Tertiary development of the western part of Klippen Belt. *Slovak Geol. Mag., 1, 2, 137–149.*

Králiková, S., Vojtko, R., Hók, J., Fügenschuh, B. & Kováč, M., 2016: Low-temperature constraints on the Alpine thermal evolution of the Western Carpathian basement rock complexes. *J. struct. Geol., 91, 144–160.*

Kysela, J., 1978: Základná inžinierskogeologická mapa 1 : 25 000 list Trenčín. Manuscript. *Bratislava, archive SGIDŠ (arch. no. 41512), 1–55.*

Lexa, J. & Konečný, V., 1998: Geodynamic aspects of the Neogene to Quaternary volcanism. In: Rakús M. (ed.): Geodynamic development of the Western Carpathians. *Bratislava, GS SR, 219–240.*

Lexa, J., Bezák, V., Elečko, M., Mello, J., Polák, M., Potfaj, M. & Vozár, J. (eds.), 2000: Geological map of the Western Carpathians and adjacent areas 1 : 500 000. *Bratislava, Ministry Environ. Slovak Republic, Geol. Surv. Slovak Republic.*

Lóczy, L., Papp, K. & Teleki, P. (eds.), 1922: Geological map of the Hungarian Empire and the adjacent countries. Map, scale: M = 1 : 900 000. *Budapest, Hung. Geograph. Soc.*

Ložek, V. & Tyráček, J., 1960: Příspevek k poznání vývoje údolí Váhu medzi Trenčínem a Piešťany. *Sbor. Čs. Společ. zeměp., 61, 1, 6–14.*

Ludwiniak, M., Śmigielski, M., Kowalczyk, S., Łoziński, M., Czarniecka, U. & Lewińska, L., 2019: The intramontane Orava Basin – evidence of large-scale Miocene to Quaternary sinistral wrenching in the Alpine-Carpathian-Pannonian area. *Acta geol. pol., 69, 339–386.*

Lukniš, M., 1946: Poznámky ku geomorfológii Beckovskej brány a priľahlých území. *Práce Št. geol. Úst., Soš., 15, 5–32.*

Maglay, J. (ed.), Halouzka, R., Baňacký, V., Pristaš, J. & Janočko, J., 1999: Neotektonická mapa Slovenska. *Bratislava, MŽP SR, GS SR.*

Maglay, J., Pristaš, J., Kučera, M. & Ábelová, M., 2009: Geologická mapa kvartéru Slovenska. *Bratislava, Geol. Úst. D. Štúra.*

Maheľ, M., 1985: Geologická stavba Strážovských vrchov. *Bratislava, Geol. Úst. D. Štúra, 1–221.*

Maheľ, M. (ed.), Andrusov, D., Čechovič, V., Kamenický, L., Kuthan, M. & Matějka, A., 1964: Geologická mapa ČSSR 1 : 200 000, M-34-XXV Žilina. *Praha, Ústř. Úst. geol.*

Maheľ, M. (ed.), Kahan, Š., Gross, P., Vaškovský, I. & Salaj, J., 1982: Geologická mapa Strážovských vrchov 1 : 50 000. *Bratislava, Geol. Úst. D. Štúra.*

Marko, F., 2012: Kenozoické napäťové pole a zlomová aktivita severného okraja Dunajskej panvy (Západné Karpaty, Slovensko). *Miner. Slov., 44, 3, 213–230.*

Marko, F., Andriessen, P. A. M., Tomek, Č., Bezák, V., Fojtíková, L., Bošanský, M., Piovarči, M. & Reichwalder, P., 2017: Carpathian Shear Corridor – a strike-slip boundary of an extruded crustal segment. *Tectonophysics, 703–704, 119–134.*

Márton, E., Grabowski, J., Tokarski, A. K. & Túnyi, I., 2016: Palaeomagnetic results from the fold and thrust belt of the Western Carpathians: an overview. In: Pueyo, E. L., Cifelli, F., Sussman, A. J. & Oliva-Urcia, B. (eds.): Palaeomagnetism in Fold and Thrust Belts: New Perspectives. *London, Geol. Soc., Spec. Pub., 425, 7–36.*

Mazúr, E. & Kalaš, L., 1963a: Metódy kvartérnych výskumov na príklade stredného Považia. *Geol. Práce, Zoš., 64, 35–40.*

Mazúr, E. & Kalaš, L., 1963b: Vývoj doliny stredného Váhu v mladom pleistocéne. *Geogr. Čas., 2, 115–131.*

Mazúrová, V., 1972: Príspevok k poznaniu vývoja doliny stredného Váhu v kvartéri. *Geogr. Čas., 24, 1, 31–38.*

Mello, J., Potfaj, M., Teťák, F., Havrila, M., Rakús, M., Buček, S., Filo, I., Nagy, A., Salaj, J., Maglay, J., Pristaš, J. & Fordinál, K., 2005: Geologická mapa Stredného Považia 1 : 50 000. *Bratislava, Št. Geol. Úst. D. Štúra.*

Mello, J. (ed.), Boorová, D., Buček, S., Filo, I., Fordinál, K., Havrila, M., Iglárová, Ľ., Kubeš, P., Liščák, P., Maglay, J., Marcin, D., Nagy, A., Potfaj, M., Rakús, M., Rapant, S., Remšík, A., Salaj, J., Siráňová, Z., Teťák, F., Zuberec, J., Zlinská, A. & Žecová, K., 2011: Vysvetlivky ku geologickej mape Stredného Považia 1 : 50 000. *Bratislava, Št. Geol. Úst. D. Štúra,* 1–378.

Miall, A. D., 2000: Principles of sedimentary basin analysis. 3rd ed. *Berlin – Heidelberg, Springer, 616 p.*

Mišík, M., 1997a: Slovakia. In: Moores, E. M. & Fairbridge, R. W. (eds.): Encyclopedia of European and Asian Regional Geology. *Dodrecht, Springer, 656–664.*

Mišík, M., 1997b: The Slovak part of the Pieniny Klippen Belt after the pioneering works of D. Andrusov. *Geol. Carpath., 48, 4, 209–220.*

Mlynarčík, M., 1998: Kvartér Trenčianskej kotliny a priľahlé mezozoikum, Q-M 038. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 83132), 171 p.*

Nagymarosy, A., 2013: Accretion of ALCAPA Mega-Unit. In: Haas, J. (ed.): Geology of Hungary, Regional Geology Reviews. *Heidelberg, Springer Verlag, 81–102.*

Nemcok, M., Hok, J., Kovac, P., Marko, F., Coward, M. P., Madaras, J., Houghton, J. J. & Bezak, V., 1998: Tertiary extension development and extension / compression interplay in the West Carpathian mountain belt. *Tectonophysics, 290, 137–167.*

Oszczypko-Clowes, M., Oszczypko, N., Piecuch, A., Sotak, J. & Boratyn, J., 2018: The Early Miocene residual flysch basin at the front of the Central Western Carpathians and its palaeogeographic implications (Magura Nappe, Poland). *Geol. Quart., 62, 3, 597–619.*

Pešková, I., Teťák, F., Pelech, O., Sentpetery, M., Olšavský, M., Kováčik, M. & Vlačiky, M., 2020: Geologická mapa regiónu Biele Karpaty – sever v mierke 1 : 50 000. *Manuscript. Bratislava, archive SGIDŠ.*

Picha, F. J., Stráník, Z. & Krejčí, O., 2006: Geology and hydrocarbon resources of the Outer Western Carpathians and their foreland, Czech Republic. In: Golonka, J. & Picha, F. J. (eds.): The Carpathians and their foreland: Geology and hydrocarbon resources. *Tulsa, Amer. Assoc. Petrol. Geol. Mem., 84, 49–175.*

Planderová, E., 1990: Miocene microflora of Slovak Central Paratethys and its biostratigraphical significance. *Bratislava, Geol. Úst. D. Štúra, 1–137.*

Plašienka, D., 2018a: Continuity and episodicity in the early Alpine tectonic evolution of the Western Carpathians: How large-scale processes are expressed by the orogenic architecture and rock record data. *Tectonics, 37, 7, 2029–2079.*

Plašienka, D., 2018b: The Carpathian Klippen Belt and types of its klippen – an attempt at a genetic classification. *Miner. Slov., 50, 1, 1–24.*

Plašienka, D. & Soták, J., 2015: Evolution of Late Cretaceous--Palaeogene synorogenic basins in the Pieniny Klippen Belt and adjacent zones (Western Carpathians, Slovakia): Tectonic controls over a growing orogenic wedge. *Ann. Soc. geol. Pol., 85, 43–76.*

Plašienka, D., Bučová, J. & Šimonová, V., 2020: Variable structural styles and tectonic evolution of an ancient backstop boundary: the Pieniny Klippen Belt of the Western Carpathians. *Int. J. Earth Sci. (Geol. Rdsch.), 109, 1355–1376.*

Poprawa, D. & Nemčok, J. (eds.), 1988: Geological atlas of the Western Carpathians and their foreland 1 : 500,000. *Warszawa, Panstw. Inst. Geol., 9 p.*

Pospíšil, Z., Chrobok, J., Loupanec, M., Mašek, F., Novák, P. & Plesník, K., 1971: Zpráva o výpočte zásob podzemných vôd kvartéru stredného toku Váhu. Manuscript. *Bratislava, archive SGIDŠ (arch. no. 25459),1–184.*

Potfaj, M., 2005: Textové vysvetlivky k účelovej geologickej mape. Súbor regionálnych máp geologických faktorov životného prostredia regiónu Myjavská pahorkatina a Biele Karpaty. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 86620), 1–35.*

Potfaj, M., Teťák, F. (eds.), Havrila, M., Filo, I., Pešková, I., Olšavský, M. & Vlačiky, M., 2014: Geologická mapa Bielych Karpát (južná časť) a Myjavskej pahorkatiny v mierke 1 : 50 000. *Bratislava, Št. Geol. Úst. D. Štúra.*

Pristaš, J. (ed.), Elečko, M., Maglay, J., Fordinál, K., Šimon, L., Gross, P., Polák, M., Havrila, M., Ivanička, J., Határ, J., Vozár, J., Mello, J. & Nagy, A., 2000: Geologická mapa Podunajskej nížiny – Nitrianskej pahorkatiny 1 : 50 000. *Bratislava, Št. Geol. Úst. D. Štúra.*

Rakús, M., Mišík, M., Michalík, J., Mock, R., Ďurkovič, T., Koráb, T., Marschalko, R., Mello, J., Polák, M. & Jablonský, J., 1988: Paleogeographic Development of the West Carpathians: Anisian to Oligocene. In: Rakús, M., Dercourt, J. & Nairn, A. E. M. (eds.): Evolution of the Northern Margin of Tethys, Vol. III. *Mém. Soc. géol. France (Paris), Nouv. Ser., 154, 11, 39–62.*

Rybár, S., Halásová, E., Hudáčková, N., Kováč, M., Kováčová, M., Šarinová, K. & Šujan, M., 2015: Biostratigraphy, sedimentology and paleoenvironments of the northern Danube Basin: Ratkovce 1 well case study. *Geol. Carpath.,* 66, 51–67.

Salaj, J., 1988: Geologická štúdia širšieho okolia Považskej Bystrice. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 66756), 1–51.*

Salaj, J., Began, A., Horniš, J., Nagy, A., Modlitba, I., Iglárová, Ľ., Remšík, A. & Vozárová, A., 1989: Vysvetlivky ku geologickej mape 24-441 (Považská Bystica). *Manuscript. Bratislava, archive SGIDŠ (arch. no. 70510), 1–112.*

Salaj, J. & Zlinská, A., 1991: Spodnomiocénne sedimenty slienitej fácie od Považskej Teplej. *Miner. Slov., 23, 2, 173–178.*

Salaj, J., 1995: Geológia Stredného Považia. Bradlové a pribradlové pásmo so súľovským paleogénom a mezozoikom severnej časti Strážovských vrchov – 2. časť. *Zem. Plyn Nafta, 39, 4, 297–395.*

Samuel, O. (ed.), Biely, A., Eliáš, M., Fusán, O., Jablonský, J., Ložek, V. & Michalík, J., 1988: Stratigrafických slovník Západných Karpát 3. *Bratislava, Geol. Úst. D. Štúra, 1–292.*

Schmid, S. M., Fügenschuh, B., Kounov, A., Matenco, L., Nievergelt, P., Oberhänsli R., Pleuger, J., Schefer, S., Schuster, R., Tomljenović, B., Ustaszewski, K. & van Hinsbergen, D. J. J., 2020: Tectonic units of the Alpine collision zone between Eastern Alps and western Turkey. *Gond. Res., 78, 308 – 374.*

Seneš, J., 1960: Burdigalská fauna v slienitých sedimentoch Považia. *Geol. Práce, Zpr., 17, 105–114.*

Soták, J., Pereszlenyi, M., Marschalko, R., Milička, J. & Starek, D., 2001: Sedimentology and hydrocarbon habitat of the submarine-fan deposits of the Central Carpathian Paleogene Basin (NE Slovakia). *Mar. Petrol. Geol., 18, 87–114.*

Steininger, F. F. & Seneš, J., 1971: M1 – Eggenburgien. Chronostratigraphie und Neostratotypen. *Bratislava, Veda, 827 p.*

Stráník, Z., Hrouda, F., Otava, J., Gilíková, H. & Švábenická, L., 2007: The Upper Oligocene – Lower Miocene Krosno lithofacies in the Carpathian Flysch Belt (Czech Republic): sedimentology, provenance and magnetic fabrics. *Geol. Carpath., 58, 4, 321–332.*

Šalagová, V., Tyleček, B. & Drahoš, M., 1990: Ilavská kotlina – kvartér a neogén. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 87965), 1–118.*

Ślączka, A., Krugłov, S., Golonka, J., Oszczypko, N. & Popadyuk, I., 2006: Geology and hydrocarbon resources of the Outer Carpathians, Poland, Slovakia, and Ukraine: General geology. In: Golonka, J. & Picha, F. J. (eds.): The Carpathians and their foreland: Geology and hydrocarbon resources. *Tulsa, Amer. Assoc. Petrol. Geol. Mem., 84, 221–258.*

Šimonová, V. & Plašienka, D., 2011: Kinematická a paleonapäťová analýza zlomov v butkovskom lome (manínska jednotka, Západné Karpaty). *Acta Geol. Slov., 3, 1, 21–31.*

Teťák, F. & Potfaj (eds.), M., Havrila, M., Filo, I., Pešková, I., Boorová, D., Žecová, K., Laurinc, D., Olšavský, M., Siráňová, Z., Buček, S., Kucharič, Ľ., Gluch, A., Šoltés, S., Pažická, A., Iglárová, Ľ., Liščák, P., Malík, P., Fordinál, K., Vlačiky, M. & Köhler, E., 2015: Vysvetlivky ku geologickej mape Bielych Karpát (južná časť) a Myjavskej pahorkatiny v mierke 1 : 50 000. *Bratislava, Št. Geol. Úst. D. Štúra, 1–306.*

Teťák, F., 2017: Neogene sediments between Podbranč and Hradište pod Vrátnom, Vienna Basin. *Acta Geol. Slov., 9, 1, 1–14.*

Uhlig, V., 1903: Bau und Bild der Karpaten. In: Diener, K., Hoernes, R., Suess, F. E. & Uhlig, V. (eds.): Bau und Bild der Österreichs. *Wien – Leipzig, Verlag F. Tempsky, Verlag G. Greytag, 651–911.*

Vass, D., 2002: Litostratigrafia Západných Karpát: neogén a budínsky paleogén. *Bratislava, Št. Geol. Úst. D. Štúra, 1–202.*

Vass, D., Kováč, M., Konečný, V. & Lexa, J., 1988: Molasse basins and volcanic activity in West Carpathian Neogene: Its evolution and geodynamic character. *Geol. Zbor. Geol. carpath., 39, 5, 539–561.*

Vass, D., Elečko, M. & Fordinál, K., 2002: Závada – Bielice Rise – a buried elevation between Bánovce and Rišňovce Depressions in the Danube Basin. *Slovak Geol. Mag., 8, 1, 13–20.*

Vozár, J., Šantavý, J. (eds.), Potfaj, M., Szalaiová, V., Scholtz, P., Tomek, Č., Šefara, J., Machková, N., Gnojek, I., Šály, B., Pereszlényi, M., Hrušecký, I., Hlavatý, I., Jureňa, V., Rudinec, R., Magyar, J. & Slávik, M., 1999: Atlas hlbinných reflexných seizmických profilov Západných Karpát a ich interpretácia. *Bratislava, GS SR, 1–76.*

Vrana, K., Fendek, M., Panáček, A., Drexler, V., Szalaiová, V. & Reháková, D., 2009: Geotermálny vrt GZV-1 Nové Mesto nad Váhom – Zelená voda. Záverečná správa geologickej úlohy. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 89661), 1–90.*

Zaťko, M., Mičian, Ľ., Škvarček, A., Zatkalík, F., Minár, J., Brnka, K., Machová, Z. & Krajčovičová, Ľ., 1988: Svahové deformácie a geomorfologické pomery v časti Bielych Karpát a Trenčianskej kotliny v oblasti Bošáca – Záblatie. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 75451_19), 1–123.*

Zbořil, L., Halmešová, S., Nromec, J., Král, M., Kurkin, M., Puchnerová, M., Stránska, M. & Hladík, P., 1984: Trenčianska kotlina – Piešťanská priehlbeň. *Manuscript. Bratislava, archive SGIDŠ (arch. no. 59631), 1–54.*

Tab. 2
Nannoplankton alphabetical faunal list. For sample localization see Tab. 1.

	Locality		
Species	**1**	**2**	**3**
Arkhangelskiella cymbiformis Vekshina	x		x
Biscutum constans (Górka) Black in Black & Barnes			x
Broinsonia sp. Bukry		x	
Calcidiscus leptoporus (Murray & Blackman) Loeblich & Tappan			x
Calcidiscus sp. Kamptner			x
Calculites obscurus (Deflandre) Prins & Sissingh in Sissingh			x
Clausicoccus fenestratus (Deflandre & Fert) Prins			x
Coccolithus formosus (Kamptner) Wise		x	x
Coccolithus eopelagicus (Bramlette & Riedel) Hay, Mohler & Wade		x	
Coccolithus pelagicus (Wallich) Schiller	x	x	x
Coronocyclus nitescens (Kamptner) Bramlette & Wilcoxon			x
Cribrosphaerella ehrenbergii (Arkhangelsky) Deflandre in Piveteau		x	x
Cyclagelosphaera margereliii Noël			x
Cyclicargolithus abisectus (Muller) Wise		x	x
Cyclicargolithus floridanus (Roth & Hay, in Hay et al.) Bukry	x	x	x
Discoaster sp. Tan	x		x
Discoster deflandrei Bramlette & Riedel		x	
Discoaster lodoensis Bramlette & Riedel		x	
Discoaster multiradiatus Bramlette & Riedel		x	
Discoaster nodifer (Bramlette & Riedel) Bukry		x	
Eiffellithus eximius (Stover) Perch-Nielsen			
Eiffellithus turriseiffelii (Deflandre in Deflandre & Fert) Reinhardt			x
Ellipsolithus distichus (Bramlette & Sullivan) Sullivan			x
Ellipsolithus macellus (Bramlette & Sullivan) Sullivan			x
Fasciculithus sp. Bramlette & Sullivan			x
Fasciculithus tympaniformis Hay & Mohler in Hay et al.		x	
Helicolithus trabeculatus (Górka) Verbeek			x
Helicosphaera sp. Kamptner	x		
Helicosphaera ampliaperta Bramlette & Wilcoxon		x	x
Helicosphaera cf. *ampliaperta* Bramlette & Wilcoxon	x		
Helicosphaera bramlettei (Müller) Jafar & Martini		x	
Helicosphaera carteri (Wallich) Kamptner	x		x
Helicosphaera compacta Bramlette & Wilcoxon	x	x	
Helicosphaera recta (Haq) Jafar & Martini		x	
Helicosphaera cf. *scissura* Miller	x		
Helicosphaera scissura Miller		x	
Helicosphaera seminulum Bramlette & Sullivan	x	x	
Holodiscolithus macroporus (Deflandre, in Deflandre & Fert) Roth			x
Chiasmolithus sp. Hay et al.			x
Lucianorhabdus maleformis Reinhardt	x		
Lanternithus minutus Stradner			x
Manivitella pemmatoidea (Deflandre in Manivit) Thierstein			x
Markalius inversus (Deflandre) Bramlette & Martini	x	x	
Micrantholithus sp. Deflandre in Deflandre & Fert			x
Micula staurophora (Gardet) Stradner	x		x
Neochiastozygus sp. Perch-Nielsen			x
Neococcolithes dubius (Deflandre) Black		x	
Owenia hillii Crux			x
Pemma sp. Klumpp			x
Pontosphaera sp. Lohmann			x
Pontosphaera alta Roth		x	
Pontosphaera duocava (Bramlette & Sullivan) Romein		x	x
Pontosphaera enormis (Locker) Perch-Nielsen			
Pontosphaera latelliptica (Báldi-Beke, in Báldi-Beke & Báldi) Perch-Nielsen			x
Pontosphaera latoculata (Bukry & Percival) Perch-Nielsen	x	x	
Pontosphaera multipora (Kamptner ex Deflandre in Deflandre & Fert) Roth		x	x
Pontosphaera pulcheroides (Sullivan) Romein			x
Pontosphaera pulchripora (Reinhardt) Aubry			
Pontosphaera punctosa (Bramlette & Sullivan) Perch-Nielsen	x		

Tab. 2 – continuation

	Locality		
Species	**1**	**2**	**3**
Prediscosphaera cretacea (Arkhangelsky) Gartner		x	x
Prinsius sp. Hay & Mohler	x		
Retecapsa sp. Black	x		
Retecapsa crenulata (Bramlette & Martini) Grün in Grün & Allemann		x	x
Retecapsa ficula (Stover) Burnet		x	
Reticulofenestra sp. Hay, Mohler & Wade	x		x
Reticulofenestra bisecta (Hay, Mohler & Wade) Roth	x	x	x
Reticulofenestra daviesii (Haq) Haq	x	x	
Reticulofenestra dictyoda (Deflandre) Stradner	x	x	
Reticulofenestra excavata Lehotayová			x
Reticulofenestra haqii Backman			x
Reticulofenestra lockeri Müller	x	x	x
Reticulofenestra minuta Roth			x
Reticulofenestra ornata Müller	x	x	x
Reticulofenestra reticulata (Gartner & Smith) Roth & Thierstein		x	x
Reticulofenestra stavensis (Levin & Joerger) Varol		x	x
Reticulofenestra umbilicus (Levin) Martini & Ritzkowski	x	x	x
Reticulofenestra wadae Bown		x	
Rhagodiscus sp. Reinhardt			x
Sphenolithus belemnos Bramlette & Wilcoxon			x
Sphenolithus moriformis (Bronnimann & Stradner) Bramlette & Wilcoxon		x	x
Syracosphaera sp. Lohmann			x
Thoracosphaera sp. Kamptner			x
Toweius sp. Hay & Mohler			x
Toweius crassus Bramlette & Sullivan		x	
Toweius gammation (Bramlette & Sullivan) Romein			x
Tranolithus minimus (Bukry) Perch-Nielsen			x
Tribrachiatus orthostylus Shamrai		x	x
Triquetrorhabdulus carinatus Martini			x
Umbilicosphaera rotula (Kamptner) Varol			x
Watznaueria barnesiae (Black in Black & Barnes) Perch-Nielsen	x	x	x
Watznaueria britannica (Stradner) Reinhardt	x		
Zeugrhabdotus sp. Reinhardt		x	x
Zeugrhabdotus bicrescenticus (Stover) Burnet	x		
Zeugrhabdotus embergeri (Noël) Perch-Nielsen	x		x
Zygrhablithus bijugatus (Deflandre in Deflandre & Fert) Deflandre		x	x

Tab. 3
Foraminifers alphabetical faunal list. For sample localization see Tab. 1. (*) marks thin section samples.

	Locality			
Species	**1**	**3**	**4***	**6***
Ammonia cf. beccari (Linne)			x	
Bolivina hebes Macfad.	x			
Bulimina schischkinskaye (Samoilova)		x		
Cibicidoides sp.		x	x	
Cibicidoides ungerianus (Orb.)	x			
Globigerina sp.		x		
Globigerina ciperoensis Bolli	x	x		
Globigerina ottnangiensis Roegl	x			
Globigerina praebulloides Blow	x			
Globigerinoides trilobus (Rss.)		x		
Globoturborotalita ouachitaensis (Howe & Wallace)		x		
Hanzawaia boueana (Orb.)	x			
Heterolepa dutemplei (Orb.)		x		
Lenticulina melvilli (Cush. & Renz)		x		
Melonis pompilioides (Fichtel & Moll)		x		
Pullenia bulloides (Orb.)	x	x		
Quinqueloculina sp.			x	

Tab. 3 – continuation

Species	Locality			
	1	3	4*	6*
Semivulvulina sp.				x
Stilostomella sp.		x		
Tenuitellinata angustiumbilicata (Bolli)	x			
Textularia sp.				x
Textularia gramen Orb.		x		
Turborotalita quinqueloba (Natland)		x		
Uvigerina cf. *vicksburgensis* Cush. & Ellisor		x		
Valvulineria complanata (Orb.)		x		
* Thin-section samples				

Trenčianska kotlina a Ilavská kotlina – zvyšky invertovanej nesenej spodnomiocénnej panvy

Trenčianska kotlina a Ilavská kotlina predstavujú erózne relikty spodnomiocénnej panvy nachádzajúcej sa na rozhraní Vonkajších Západných Karpát a Vnútorných Západaných Karpát (sensu Hók et al., 2019; obr. 1 a 2) a prekrývajú celky karpatského bradlového pásma a vnútrokarpatských mezozoických príkrovov (tatrikum, fatrikum a hronikum). Výskum sa opiera o výsledky geologického mapovania v severozápadnej časti Trenčianskej kotliny a najzápadnejšej časti Ilavskej kotliny a sumarizuje doterajšie (bio)stratigrafické, sedimentologické, geofyzikálne a vrtné údaje (vrty PB-1 a HVJ-25; obr. 4 a 10) zo širšieho regiónu. Sedimentárna výplň paniev pozostáva z egenburských klastík čausianskeho, karpatského a závodského súvrstvia a mladších pliocénnych a kvartérnych fluviálnych a eolických uložením (obr. 4). Sedimenty pelitickej litofácie čausianskeho súvrstvia vystupujú priamo pod kvartérnymi sedimentmi na viacerých miestach. Ide o šíromorské sedimenty, čo dokladá prítomnosť nanoplanktónu (obr. 8, tab. 2) a foraminifer (tab. 3; Salaj a Zlinská, 1991). Spodnomiocénne sedimenty transgresívne a diskordantne prekrývajú staršiu príkrovovú stavbu bradlového pásma. Prítomnosť sedimentov otnanského veku sa nepodarilo uspokojivo potvrdiť. Je pravdepodobné, že v panve pôvodne mohli byť prítomné, ale dnes sú odstránené eróziou (napr. Salaj a Zlinská, 1991). Celková hrúbka miocénnej výplne Trenčianskej kotliny dosahuje v jej centrálnej časti asi 1 000 m (obr. 3), v Ilavskej kotline sa pohybuje okolo 250 m (Kilény a Šefara, 1989). Presné poznatky o ich najhlbších častiach a predkenozoickom podloží nie sú známe pre chýbajúce vrty v ich centrálnych depresiách. Výsledky výskumu naznačujú, že Trenčianska kotlina a Ilavská kotlina pôvodne tvorili súčasť väčšieho spodnomiocénneho sedimentačného bazénu typu nadklinovej panvy, ktorá siahala zo severu Viedenskej panvy cez blatniansku priehlbinu do Bánovskej kotliny, Hornonitrianskej kotliny a Turčianskej kotliny. Pôvodná stavba bola dezintegrovaná inverziou, rotáciou blokov, spätným nasúvaním a výzdvihom okolitých pohorí (Kováč et al., 1994; Danišík et al., 2004; Marko et al., 2017), ktoré prebiehali v karpate až strednom miocéne. Inverzia v pliocéne až kvartéri mala za následok modelovanie kotlín do dnešnej podoby. Neexistujú žiadne presvedčivé argumenty na interpretáciu týchto kotlín ako paniev typu pull-apart, ako sa uvažovalo v minulosti, i keď šikmá (transtenzia) až horizontálna deformácia mohla v malej miere ich vývoj ovplyvniť.

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