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MESOZOIC EVOLUTION OF TATRIC UNITS IN THE MALÉ KARPATY AND POVAŽSKÝ INOVEC MTS.: IMPLICATIONS FOR THE POSITION OF THE KLAPE AND RELATED UNITS IN WESTERN SLOVAKIA

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Abstract: The Tatricum is a principal crustal superunit of the outer part of the Central Western Carpathians. It comprises pre-Alpine crystalline basement and its Late Paleozoic and Mesozoic sedimentary cover. The Mesozoic sedimentary and structural records indicate stable shelf conditions during the Triassic, Early Jurassic initial rifting event, Middle Jurassic to Early Cretaceous extensional tectonic regime and mid-Cretaceous flexural subsidence in front of the orogenic wedge prograding from the south. The extension created a passive margin along the north Tatric edge bordering the Vahic (South Penninic) oceanic domain. The passive margin was inverted to a convergent one as late as during the Early Senonian. The Vahic oceanic crust was then subducted southwards below the Tatricum. The final collision of the Centrocarpathian thrust stack with the Oravic (Pieniny Klippen Belt) ribbon continent during the latest Cretaceous resulted in transpression and transtension in this meso-Alpine suture zone. The tectonic scenario described is inconsistent with current views on the evolution of the Tatric-Oravic intervening zones; therefore an alternative model which considers some Klippen and Peri-Klippen Belt units to be derived from the Central Carpathians, specifically from the Fatric (Krížna) domain, is presented and discussed.

Key words: Western Carpathians, northern Tatricum, Mesozoic, paleotectonic evolution, tectonic implications.

Introduction

The Tatricum is an external upper crustal thrust sheet of the Central Western Carpathians (CWC), composed of pre-Alpine basement and its Late Paleozoic-Mesozoic cover with characteristic lithostratigraphic content. The Tatric superunit was individualized as a composite, fault-dissected domain with attenuated continental crust during the Early Jurassic rifting and inverted to an imbricated crustal thrust stack during Late Cretaceous shortening. The present northern edge of the Tatricum is one of the principal tectonic boundaries in the Western Carpathians and is analogous to the thrust faults separating Penninic and Lower Austroalpine units in the Alps. However, the north Tatric edge is usually hidden below superimposed cover nappes and Late Cretaceous to Tertiary postorogenic basin fills (Fig. 1). The paleotectonic evolution of this boundary zone must therefore be mainly reconstructed from circumstantial evidence.

There are several controversial views on the Mesozoic history of the northern Tatricum, particularly on its links with the more external zones north of it, i.e. the units of the Klippen and Peri-Klippen Belts (Fig. 2). The position of the Ultrapieniny (Andrusov) cordillera plays a key role in all models. This cryptic ridge is supposed to have been an elevated area during the late Early and Late Cretaceous, when it supplied enormous masses of Peri-Klippen Belt flysches with "exotic" pebble material. Later it completely disappeared due to underthrusting below the Tatricum. The "exotic" ridge has been reconstructed to be either an imbricated system of obducted oceanic elements, or a subduction mélange outcropping along the outer structural high of an accretionary paleoprism (see Mišík 1978; Mišík & Marschalko 1988; Birkenmajer 1988). As the "exotic" pebble material also contains calc-alkaline volcanics, granitoids and blueschists considered to be of Late Jurassic to Early Cretaceous age, the northern Tatric edge would have adjoined an active margin starting from Late Jurassic times. Nevertheless, this assumption does not appear to be supported by direct geological evidence in the Tatricum - neither petrological nor structural.

The aim of this contribution is to outline the paleotectonic evolution of the northern Tatricum largely on the basis of new results obtained in the Malé Karpaty and Považský Inovec Mts. (Fig. 1), and to formulate an alternative evolutionary model of the Late Cretaceous tectonism in the Outer/Central Carpathian junction zones.

Structure of the northern Tatricum in the Malé Karpaty and Považský Inovec Mts.

As a whole the Tatricum is a thick-skinned upper crustal sheet comprising pre-Alpine crystalline basement and its Upper Paleozoic to Mesozoic sedimentary cover. The basement consists of low to medium grade metamorphosed Lower Paleozoic volcano-sedimentary complexes and Variscan granitoid plutons. Pre-Variscan igneous and high grade metamorphic rocks are probably also present. Upper Carboniferous and Permian sedimentary and volcanic rocks form thick complexes only in the northern part of the Považský Inovec Mts. Elsewhere the Alpine cover begins with Lower Triassic transgressive clastics.

The frontal parts of the Tatric wedge are complicated by partial thrust nappes and recumbent folds. In the Malé Karpaty

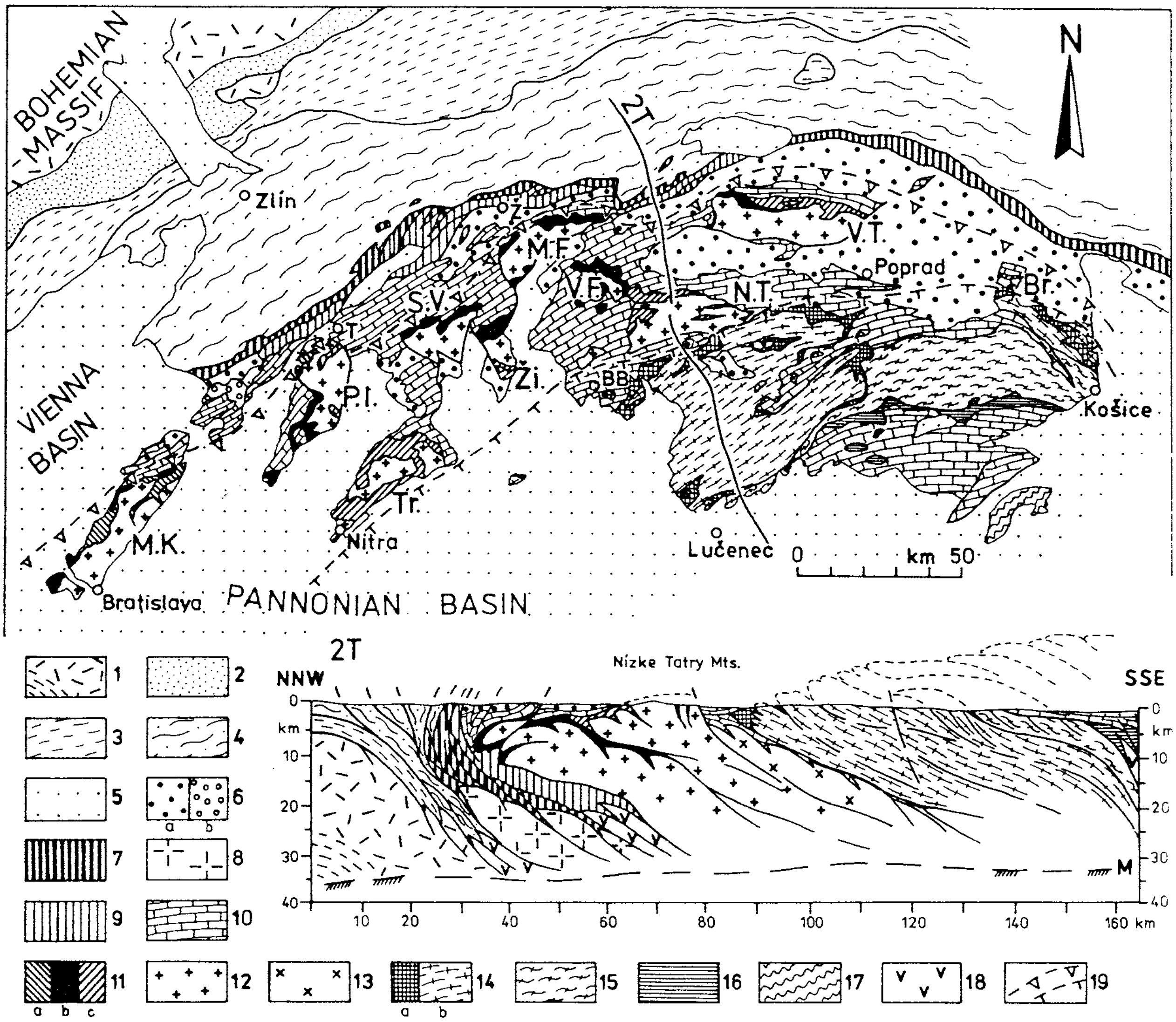


Fig. 1. Tectonic sketch-map of the Western Carpathians and position of the Tatricum (simplified after Mahel' 1986 and Marschalko 1986). The profile along the deep seismic line 2T adapted from Tomek et al. (1989), strongly modified in the Tatric - Klippen Belt area. Abbreviations of reference towns: **T** - Trenčín, **Ž** - Žilina, **BB** - Banská Bystrica. Core mountains: **M.K.** - Malé Karpaty, **P.I.** - Považský Inovec, **Tr.** - Tribeč, **Ži.** - Žiar, **S.V.** - Strážovské Vrchy, **M.F.** - Malá Fatra, **V.F.** - Veľká Fatra, **N.T.** - Nízke Tatry, **V.T.** - Vysoké Tatry, **Br.** - Branisko. **1** - North European Platform basement, **2** - Neogene molasse foredeep, **3** - Krosno (Silesian) flysch units, **4** - Magura flysch units, **5** - superimposed Neogene basins and volcanics, **6** - Centrocarpathian Senonian (a) and Paleogene (b) sediments, **7** - Pieniny Klippen Belt (Oravic units), **8** - inferred Oravic basement, **9** - Peri-Klippen Belt (Vahic and Fatric Units), **10** - Fatric - Hronic - Silicic system of cover nappes (Krížna, Choč and higher ones), **11** - Tatric cover (a - related to the North Tatric swell, b - related to the Šiprúň Basin, c - related to the South Tatric Ridge), **12** - Tatric pre-Alpine basement, **13** - inferred Fatric basement, **14** - Veporicum (a - Permomesozoic cover, b - pre-Alpine basement), **15** - Gemericum, **16** - Meliaticum, **17** - Paleozoic of the Szendrö Mts. (Bükkicum), **18** - remnants of oceanic crust, **19** - northern and southern demarcating lines of the Tatricum.

Mts., the large Bratislava basement-cover nappe overrode the subautochthonous infra-Tatric Borinka Unit, exhibiting some Penninic-related lithological features (Mahel' 1987; Plašienka 1987; Plašienka et al. 1991). Kinematic indicators point to a NW direction for nappe emplacement (with respect to present coordinates), generally perpendicular to the nappe fronts (Plašienka 1990; Putiš 1991).

In the Považský Inovec Mts. the Tatric Inovec Nappe overthrust the Belice Unit. Its lithostratigraphical content indicates an oceanic provenance essentially differing from the northern Tatric units (Soták et al. 1993; Plašienka et al. 1994). However, only scarce portions of the original nappe structure have been preserved, due to strong reworking by younger Alpine structural elements.

Latest Cretaceous to Early Tertiary dextral transpression and Late Tertiary sinistral transtension obliterated many of the primary nappe structures (for the review of post-nappe structural and paleostress history see Marko et al. 1995). The NW parts of the Malé Karpaty and Považský Inovec Mts. were also affected by the backthrust of cover nappes along the SE margin of a broad wrench corridor, which encompasses the northernmost Tatric elements, the NE prong of the Northern Calcareous Alps in the basement of the Vienna Basin and in the Brezovské Malé Karpaty Mts., the Peri-Klippen and Klippen Belts and the

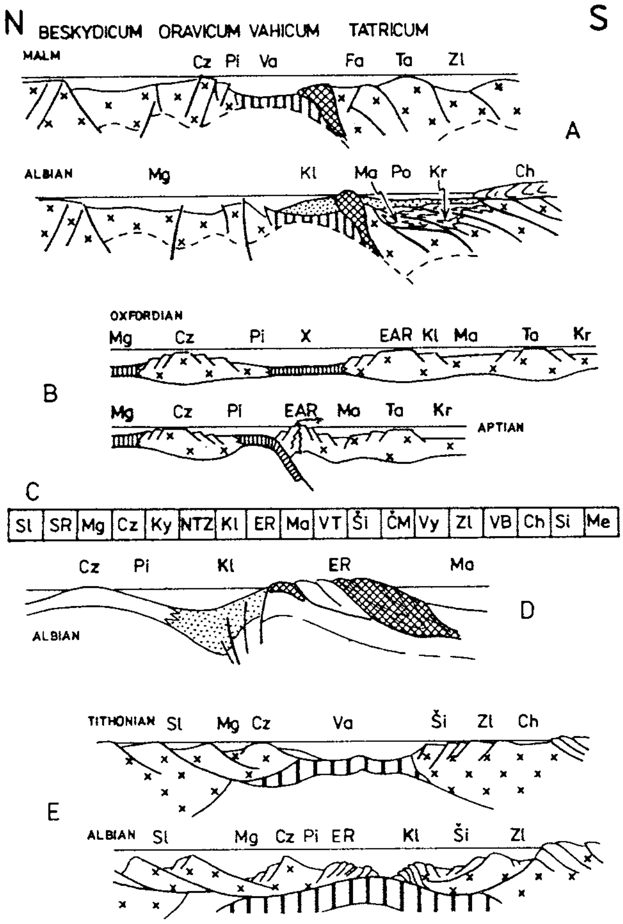


Fig. 2. Palinspastic position of the Tatricum and its relationships to more external units as suggested by different authors. **A** - after Mahel' (1989), **B** - after Birkenmajer (1988), **C** - after Rakús et al. (1990), **D** - after Mišík & Marschalko (1988), **E** - after Michalík & Soták (1990). **Sl** - Silesian Basin, **SR** - Silesian Ridge, **Mg** - Magura Basin, **Cz** - Czorsztyn Ridge, **Ky** and **Pi** - Kysuca and Pieniny Basins, **NTZ** - Northern Transform Zone, **Va** - Vahic Basin, **X** - Ultrapieniny basinal zone, **Kl** - Klape Basin, **ER**, **EAR** - Andrusov "Exotic" Ridge, **Ma** - Manín swell, **Fa** - Fatra Basin equiv. to **Ši** - Šiprúň Basin, **VT** - Vysoké Tatry Ridge and **ČM** - Červená Magura Ridge equiv. to **Ta** - Tatra swell, **Vy** - Vysoká swell, **Zl** - Zliechov Basin equiv. to **Kr** - Krížna, **Po** - Poruba Basin, **VB** - Veľký Bok swell, **Ch** - Choč Zone, **Si** - Silica Zone, **Me** - Meliata Zone. Dots - flysch sediments, cross hatching - oceanic mélange, crosses - continental crust, vertical ruling - oceanic crust.

Biele Karpaty Subunit of the Magura Unit of the Outer Carpathian Flysch Belt (cf. profile in Fig. 1; Plašienka et al. 1991).

Outline of the paleotectonic history

The evolution of the Mesozoic paleogeography and paleotectonics in the north Tatric zone is reconstructed from the almost continuous sedimentary record (Scythian-Maastrichtian) and from the structural record of large-scale processes. The whole story is partitioned into several stages, with changing tectonic regimes - generally longer periods of relative quiescence and shorter stages of increasing mobility recorded by sedimentary events and deformation.

Platform epeirogenesis (Triassic)

The Triassic stage is characterized by stable paleogeographic conditions. The Tatric domain was a part of the Northern Tethyan shelf, with restricted fault activity. Sedimentation was mainly controlled by eustatic sea-level changes (Michalík 1994).The principal lithofacies are Lower Triassic continental quartzose clastics, Middle Triassic carbonate platform sediments and Upper Triassic continental-lagoonal, partly hypersaline deposits (Carpathian Keuper Formation).

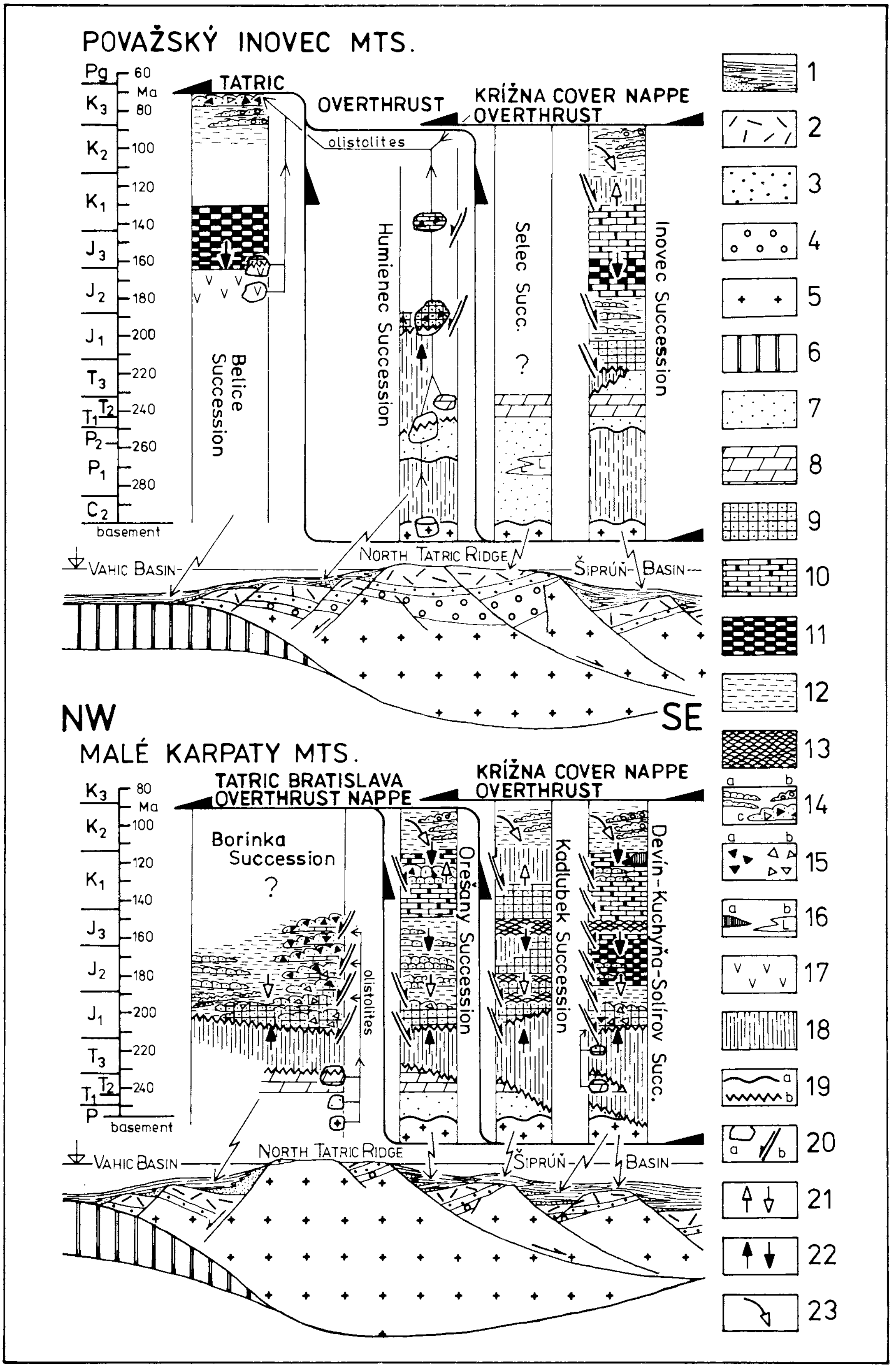
Initial rifting (Early Jurassic)

Uplift and deep erosion of Triassic sediments in the outermost Tatric zones preceded a strong rifting phase in the Early Liassic. Disintegration of the Triassic carbonate platform, passive rifting and differentiated extension, producing deep-water troughs and shallow swells, affected the whole CWC area. Ridge domains are marked by neptunic dykes, extraclastic carbonate breccias, sandy biodetritic limestones and sandstones (Sinemurian-Pliensbachian), while in the basinal domains (Šiprúň trough) the calciturbiditic Allgäu Formation (Fleckenmergel) started to be deposited already in the Sinemurian. At the same time the northern edge of the Tatric realm was formed. This is marked by steep north-dipping normal fault escarpments furnishing terrigenous material for resedimentation in peripheral halfgrabens (Fig. 3 - Borinka halfgraben, cf. Plašienka 1987).

Area extension (Toarcian - Aptian)

The Toarcian stage exhibits renewed extensional faulting activity, narrowing of ridge domains and beginning of extensive subsidence. The majority of terrigenous sources were flooded; only the northern edge of the North Tatric Ridge supplied the thick scarp breccias of the Borinka halfgraben until the Early Cretaceous (?). Several other intervals of normal fault activity, recorded by different types of resedimentation have been recognized in the Lower Dogger, Tithonian and mainly in the Barremian, when "Urgonian" carbonate buildups grew on elevated edges of tilted extensional halfgrabens, and occasionally fed slope debris resediments (Michalík & Soták 1990; Michalík et al. 1993, 1994; Jablonský et al. 1993; see Fig. 3). Basins reached their bathyal to abyssal depths during the Callovian-Oxfordian (radiolarites), and are probably due to thermal downwarping of the attenuated CWC lithosphere.

The final break-away of thinned crust occurred along the northern boundary of the Tatricum, probably during the Middle Jurassic and an oceanic domain called "Vahicum" (Mahel' 1981) was formed. However the Vahicum (other terminologies: "Northern Transform Zone" - Rakús et al. 1990; "X-zone", the hypothetical Ultrapieniny oceanic domain already opened during the Late Triassic - Birkenmajer 1988, or even in the Anisian - Birkenmajer et al. 1988), and appears to be a connection of the eastward propagating Southern Penninic and westward propagating Transylvanian oceanic rifts. The CWC domain, along with the Austroalpine realm, was consequently completely separated from the North European Platform and its passive margin facing the Penninic oceans was formed. Jurassic distension had a partly transtensional character, caused by a left-lateral movement of the Austroalpine - CWC domains with respect to the European margin. The area distribution of ridges (North and South Tatric) and basins (Šiprúň and Zliechov) in the CWC region probably had a


POVAŽSKÝ INOVEC MTS.
TATRIC
OVERTHRUST
KRÍŽNA COVER NAPPE OVERTHRUST
olistolites
Belice Succession
Humienec Succession
Selec Succ.
Inovec Succession
basement
VAHIC BASIN
NORTH TATRIC RIDGE
ŠIPRÚŇ BASIN
NW
SE
MALÉ KARPATY MTS.
TATRIC BRATISLAVA OVERTHRUST NAPPE
KRÍŽNA COVER NAPPE OVERTHRUST
Borinka Succession
olistolites
Orešany Succession
Kadlubek Succession
Devín-Kuchyňa-Solírov Succ.
basement
VAHIC BASIN
NORTH TATRIC RIDGE
ŠIPRÚŇ BASIN
Pg K3 K2 K1 J3 J2 J1 T3 T2 T1 P2 P1 C2 P
60 Ma 80 100 120 140 160 180 200 220 240 260 280
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

coulisse-like, lozenge-shaped pattern (Fig. 4). Extensional activity in the Tatric and Fatric zones culminated in small extrusions of submarine hyalobasanitic lavas of upper mantle origin (Hovorka & Spišiak 1988) which pierced the highly thinned CWC crust in Barremian-Early Albian times.

Flexural subsidence (Albian–Cenomanian)

Cretaceous shortening, crustal stacking and nappe emplacement show a marked northward polarity as is postulated in the CWC by numerous authors (e.g. Andrusov 1968; Biely & Fusán 1967; Maheľ 1974; Plašienka 1991). During the Aptian, the compressional orogenic front reached the southern margin of the Krížna (Zliechov) Basin at its zone bordering with the Veporic domain, where sedimentation ceased (Veľký Bok Unit) and where an underthrusting zone of the attenuated Zliechov basement substratum below the north Veporic edge originated (Plašienka 1983). The foreland of the underthrusting zone - the Fatric (Krížna) and Tatric realms gradually subsided and became a place of pre-orogenic flysch sedimentation (Albian-Cenomanian Poruba Flysch Basin - Fig. 4). This period reflects a crucial paleogeographic change - instead of a differentiated submarine topography with numerous highs, slopes and depressions rimmed by mostly carbonatic clastic resediments derived from local sources, a wide flysch trough supplied by extrabasinal, partly exotic sources, appeared. This phenomenon can be attributed both to thermal subsidence after the latest Barremian-Aptian rifting event, as well as to the flexural downbending of the CWC lithosphere due to a topographic load, produced by the orogenic crustal wedge prograding from the hinterland. During the Turonian, shortening also affected the Tatric domain which was accreted to the tip of the overriding orogenic wedge. This process brought about a termination of previously continuous Mesozoic sedimentation and a beginning of mostly structural recording of orogenic processes.

Shortening and thrusting (Turonian–Senonian)

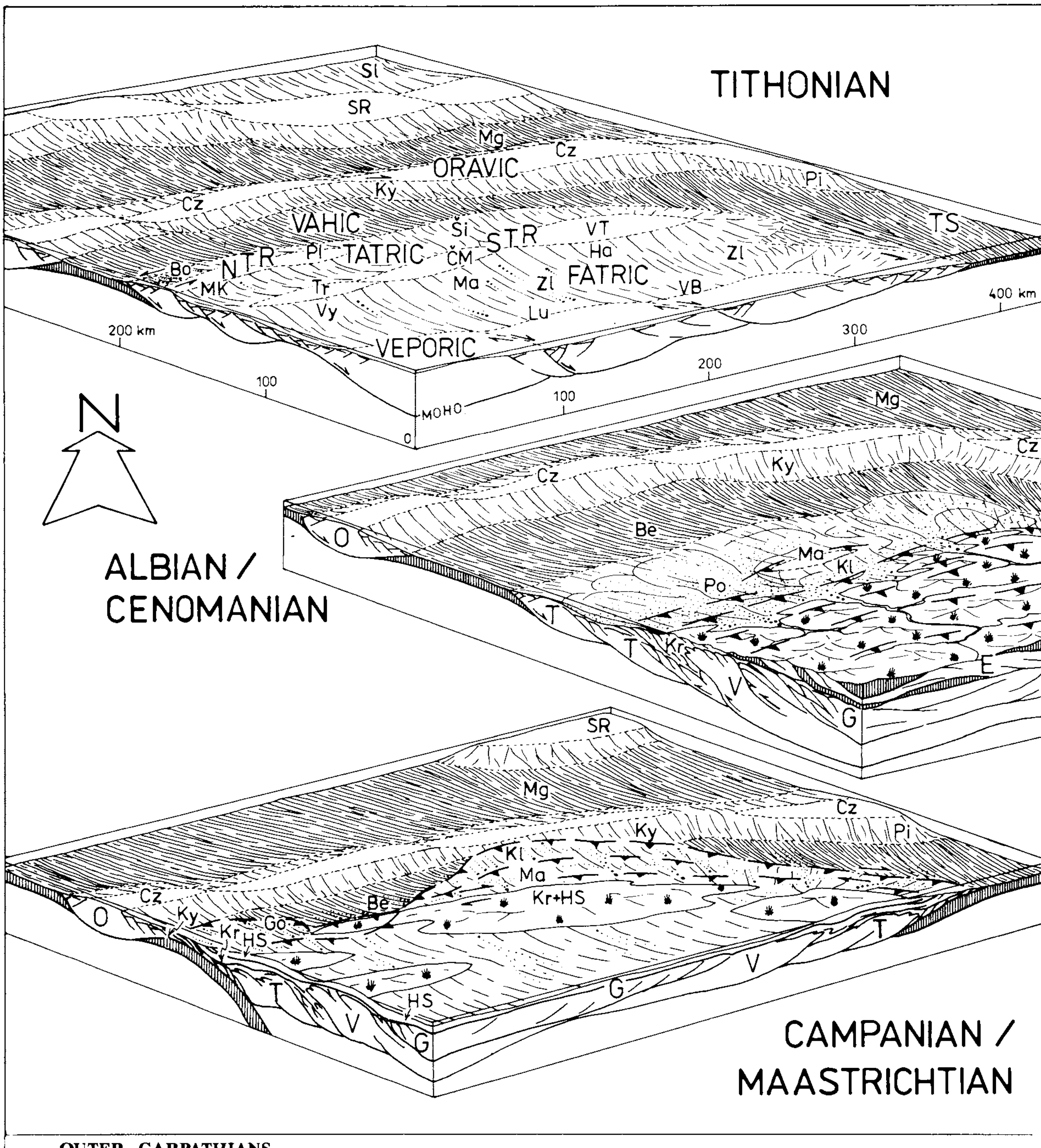
The reactivation of extensional normal fault systems as frontal ramps was the main shortening mechanism of the strongly thinned Tatric crust. Basement-cover recumbent folds and imbricated thrust nappe sheets originated (Plašienka 1991). However, a substantial part of Tatric complexes has been covered by the superficial Fatric - Hronic - Silicic Nappe System (Krížna, Choč and higher nappes) and by superimposed Tertiary deposits. Consequently, the relationships of the outermost Tatric units to the more external zones is mostly obliterated, with the exception of the northern part of the Považský Inovec Mts. There, Jurassic and Cretaceous rocks of the Belice Succession crop out from below the Tatric basement and its Late Paleozoic-Mesozoic cover (Soták et al. 1993; Plašienka et al. 1994). The Belice Succession consists of probably Middle Jurassic basaltic (oceanic?) basement, Late Jurassic cherts, Middle Cretaceous variegated marls and Senonian flysches including conglomerates and olistolite bearing mixtitic breccias with mainly Tatric material (Figs. 3, 5). The succession is highly dismembered tectonically into numerous slices and resembles a tectono-sedimentary mélange, similar to the East Alpine Matrei Zone at the contact of the Penninicum and Austroalpinicum (Frisch et al. 1987). Plašienka et al. (1994) regard the Belice Succession to be a part of the Vahic Superunit which records a gradual convergence of the Tatric continental and Vahic oceanic domains, subduction of the latter below the former and an inversion of the Middle Jurassic-Middle Cretaceous passive margin into an active one in Late Cretaceous times. All the principal units of the northern part of the CWC became sources of the Upper Cretaceous terrigenous clastic sequences, heralding the closing period of the Vahic ocean (Fig. 5). Kullmanová & Gašparíková (1982), who first determined the Senonian age of the Belice Flysch Formation, attributed it to the Klape Unit. However, the Klape Unit is considerably different with respect to its lithostratigraphy, sources of the terrigenous material, thickness and structural position (Plašienka et al. 1994).

Implications for the position of the Andrusov "Exotic" Ridge

Several attempts at reconstructing the palinspastic arrangement of the areas under discussion are outlined in Fig. 2. The following N-S succession of principal isofacial zones is at present widely accepted: Oravic (i.e. the Pieniny Klippen Belt s.s., incl. Czorsztyn and Kysuca-Pieniny Zones) - Vahic as the oceanic realm (equiv. to the Southern Penninic, Northern Transform Zone, partly also X-zone) - Klape Zone with Middle Cretaceous "exotic" flysch (incl. Drietoma, Bošáca and some other Peri-Klippen Belt units) - "exotic" cryptic ridge (syn. Ultrapienidic cordillera, Andrusov "Exotic" Ridge) - Manín Zone - Tatric (incl. the Červená Magura-Vysoké Tatry swell and Šiprúň Basin) - Fatric (the Krížna Zone, incl. Vysoká, Havran and Zliechov) - Veporic (incl. the Veľký Bok Zone). An alternative arrangement is proposed in Fig. 4: Oravic (Czorsztyn Ridge and Kysuca Basin) - Vahic (incl. the Belice Unit) - Tatric (incl. the Borinka margin, North Tatric Ridge, Šiprúň Basin, South Tatric Ridge) - Fatric (incl. the Manín, Vysoká, Havran, Klape and Zliechov) - Veporic. The principal difference of this model, compared with the others is that the Klape Unit is placed inside the CWC realm to the Fatric domain and, consequently, the "exotic" ridge should have been located even further to the south, in the present Veporic or more southern areas. This opinion is based on some facts, which cast doubt on the existence of a Late Jurassic-Early Cretaceous active margin along the Vahic/Tatric interface, at least in the territory of western Slovakia, and consequently on the presence of a subduction-related "exotic" ridge in this position. Objections are based on a number of contradictions:

1 - The "exotic" ridge is considered to be a mélange-bearing compressional structure, but there are no signs of compression in the zones adjacent to the inner side of the ridge (Tatric, event. Manín) until the Cenomanian-Turonian; instead, an extensional

Fig. 3. Mesozoic paleotectonic evolution of units at the north Tatric margin. **1** - Jurassic to Cretaceous proximal and distal sediments (syn- and post-rift); **2** - Middle to Upper Triassic carbonate platform pre-rift sediments; **3** - Lower Triassic sandstones; **4** - Late Paleozoic clastics; **5** - Variscan basement; **6** - inferred oceanic crust; **7** - continental and deltaic deposits; **8** - carbonate platform sediments; **9** - shallow-marine bioclastic sandy limestones; **10** - pelagic cherty limestones; **11** - silicites; **12** - hemipelagic shales and marls, partly anoxic; **13** - nodular limestones and condensed horizons; **14** - resediments: a - sandy calciclastic and siliciclastic, b - "exotic" conglomerates, c - mixtitic breccias with local material; **15** - extraclastic material: a - polymict, b - carbonate; **16** - volcanism: a - alkaline basalts, b - rhyolites; **17** - oceanic basalts; **18** - sedimentary gaps and eroded formations; **19** - unconformities: a - post-Variscan, b - Early Liassic uplift and erosion; **20** a - olistolites, b - extensional faulting; **21** - tectonic uplift and subsidence; **22** - thermal uplift and subsidence; **23** - flexural subsidence.



	OUTER CARPATHIANS							
		ORAVIC		*VAHIC*				
Sl	*Silesian Basin*	**Cz**	*Czorsztyn Ridge*	**Be**	*Belice Unit*		**TS**	*Transylvanian ocean*
SR	*Silesian Ridge*	**Ky**	*Kysuca Basin*					
Mg	*Magura Basin*	**Pi**	*Pieniny Basin*					
	CENTRAL WESTERN CARPATHIANS							
Go	*Gosau basins*							
T	*TATRIC*			*FATRIC*			**V**	*VEPORIC*
Po	*Poruba Flysch Basin*					**Kr**	**Lu**	*Lučatín Unit*
Bo	*Borinka margin*	**STR**	*South Tatric Ridge*	**Kl**	*Klape Flysch Basin*		**VB**	*Veľký Bok Unit*
NTR	*North Tatric Ridge*	**Tr**	*Tribeč domain*	**Vy**	*Vysoká Unit*	*Kríž-*	**G**	*GEMERIC*
MK	*Malé Karpaty domain*	**ČM**	*Červená Magura Zone*	**Ma**	*Manín Unit*	*na*	**E**	*"EXOTIC" UNITS*
PI	*Považský Inovec Zone*	**VT**	*Vysoké Tatry Zone*	**Ha**	*Havran Basin*	*Nap-*	**HS**	*HRONIC - SILICIC*
Ši	*Šiprúň Basin*			**Zl**	*Zliechov Basin*	*pe*		*NAPPE SYSTEM*

Fig. 4. Block-diagrams depicting the Jurassic - Cretaceous history of the Tatric and adjacent domains of the Western Carpathians. Vertical shading indicates oceanic crust; continental crust and sediments are shown in blank.

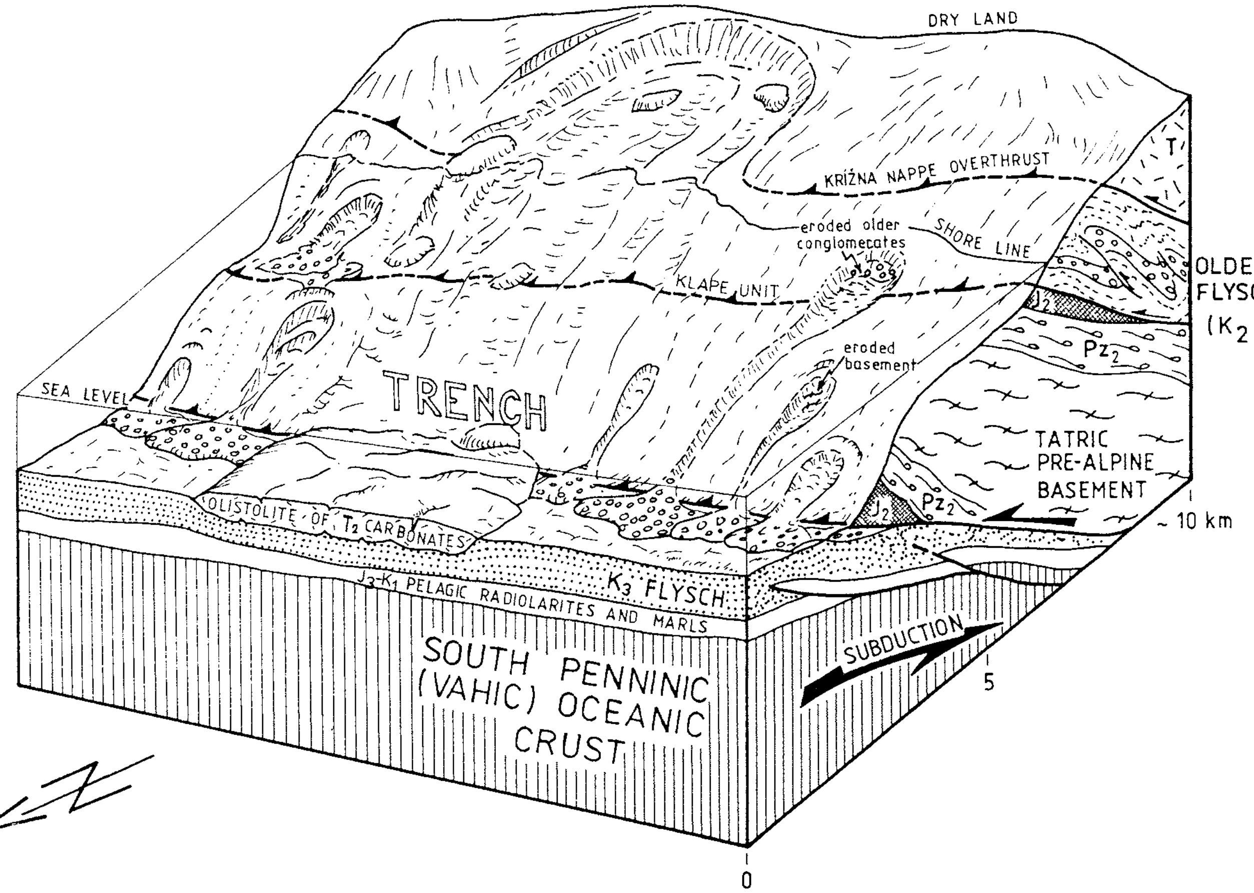


Fig. 5. Schematic block-diagram showing supposed clastic sources and the position of the Senonian flysch of the Belice Unit in the Považský Inovec Mts.

tectonic regime is recorded for ca. 100 Ma (Lower Jurassic - Lower Albian). If a back-arc extension in the Tatric and Fatric domains is assumed (Birkenmajer 1988), the cryptic zone should have been tens of km wide, and then the absence of any remnants of this sialic zone in the present Carpathian edifice is curious. Moreover, the initial evidence of the supposed back-arc extension should have occurred at the onset of calc-alkaline volcanism in the "exotic" ridge (Late Jurassic). However, this was a relatively quiet period in the Tatric-Fatric realm, much later than several rifting events.

2 - There is no evidence of subduction-related magmatism, even in the most external Tatric zones - no subvolcanic dyke systems, no pyroclastic admixture in sediments. Barremian-Lower Albian alkaline basalts are genetically related rather to extension than to compression.

3 - An older argument is that some "exotic" pebbles, e.g. Triassic pelagic limestones, Tithonian-Neocomian shallow-water limestones, Urgonian limestones with chrome spinel and glaucophane clasts, are missing in the autochthonous position in the Tatric and Fatric zones. The Barremian Solírov Formation of the Tatric in the Malé Karpaty Mts. consists of calciturbiditic resediments full of terrigenous material of local provenance, but not one chrome spinel grain has been observed by Jablonský et al. (1993).

4 - Several possibilities of large-scale left-lateral strike-slip movements of the CWC block along the north Tatric edge juxtaposing originally very distant units and separating "exotic" flysches from their sources have been discussed and rejected by Mišík & Marschalko (1988). We may add that there is a lack of structural evidence for any such movements during mid-Cretaceous times.

5 - The "exotic" ridge should have originated as an elevated volcanic belt during the Late Jurassic, but it started to provide coarse clastic material, as late as in the Albian, to both its sides at the same time towards the north to the thick marginal apron of the Klape Unit and towards the south to the relatively thin deposits of the Poruba Flysch Basin. There is no explanation for this time delay.

6 - As was previously mentioned, rocks of the Klape, "exotic" ridge and Manín zones are missing at the discrete Vahic/Tatric interface in the northern Inovec Mts. This implies that Jurassic and Cretaceous sedimentary sequences of the Klape and Manín Units were entirely detached from their subducted (?) substratum and piled up in front of the Tatricum, while the wide and elevated "exotic" ridge was totally subducted - an improbable solution. Moreover, the Senonian flysch of the Vahic Belice Unit contains, among others, also clasts derived undoubtedly from the Tatric basement of the nearby Inovec Unit. Accordingly, the Klape, Manín and related units may have not been located between Vahic and Tatric domains at that critical time.

In our opinion, placing of the Klape, Manín and related units into the Fatric paleogeographic realm, i.e. to the Krížna Nappe System, is supported by following arguments:

1 - Typical Peri-Klippen Belt units, such as the Klape, Manín, Drietoma, Bošáca and others follow the paleogeographical trend similar to that of the Tatric and Fatric Units. This is valid mainly for the more or less identical Jurassic-Lower Cretaceous sequences, which have led e.g. Andrusov (1938) to assign the Klape klippe to the Krížna Unit. Later Mahel' (1978, 1985, 1986) and Michalík et al. (1987) attributed Manín to the Krížna Unit, while Borza et al. (1980) assigned the Bošáca Unit to the Krížna Unit. The onset of flysch sedimentation during the Early to Middle Albian is also contemporaneous, while in the supposed adjacent Klippen Belt s.s. units (Kysuca) is mainly the Late Turonian and in the newly defined Vahic Belice Unit as late as the Coniacian.

2 - Flysch sedimentation in the Klape and Tatric-Fatric Poruba Basins covered a considerable time span (Middle Albian-Middle Cenomanian, approx. 15 Ma) dated, however, by only scarce biostratigraphical determinations. The calculated sedimentation rate attained 7.5-15 cm per 1,000 years (Marschalko 1986), in some time intervals even 90 cm per 1,000 years (Salaj 1991) in the more than 1 km thick proximal complexes of the Klape Unit. The sedimentation rate for the Poruba Formation, normally not more than 100 m thick, in some cases up to a maximum of 400 m, was considerably lower. The Poruba flysch is even missing in some units (Fig. 6). Despite this, the Klape and Poruba flysches show analogical sources which are often "exotic". There is probably no principal sedimentological objection to the assumption that the Klape and Poruba Basins were once spatially closely related.

3 - The tectonic model for the origin of the Krížna Nappe (Plašienka 1983, 1991) presumes gradual southward underthrusting of the Krížna basement below the north Veporic wedge during the Albian - Cenomanian, contemporaneous detachment of the Mesozoic cover complexes and their piling up in a system of recumbent folds, imbrications and duplexes by a "push from the rear" mechanism. The final gravity spreading and gliding towards the Tatric foreland occurred during the Late Turonian. A purely geometrical approach to the modelling of shortening (Fig. 7) indicates a foreland migration of stacking of imbricates and of the flysch sedimentary trough axis with coeval detachment of unlithified flysch complexes from their underlying, predominantly carbonate lithologies. The thickest flysch prisms developed in the trench depression in front of the overriding Krížna (Zliechov) thrust wedge and to the rear of the frontal south Tatric elevation, including the Manín Unit, which lacks Middle Cretaceous flysch sequences. The final overstepping of the Tatric frontal ramp induced gradual shallowing of the Klape Succession (Salaj 1991; Marschalko 1986) during the Cenomanian and final deposition of several hundred meter of thick oyster-bearing littoral Orlové sandstones (Middle Cenomanian-Lower Turonian). A rapid, but gradual thrusting of frontal elements of the Krížna thrust stack over the south Tatric swell resulted in sequentional detachment of individual tectonic units and their independent gravitational gliding towards the external parts of the Tatric foreland. The first detachment attacked thick dorsal flysch complexes (Klape Unit), the second the frontal Manín and related units, and the final one moved the main body of the Krížna Nappe - huge masses of the Zliechov basinal sequences with restricted ridge-type Vysoká partial nappes at their front and base. From this point of view the Klape, Manín and related units represent early diverticulated gliding nappes, detached from the frontal and dorsal parts of the Krížna thrust stack and becoming part of the fore-Tatric zones as late as during the Late Turonian. The overthrusting event may have been of a very short-term, catastrophic nature and need not necessarily be recorded by a sedimentary gap or an erosional surface. The overthrust of the Krížna Nappe System was immediately followed by gliding of Choč and higher superficial nappes (Hronic - Silicic system).

The model presented above is capable of contributing to the solution of certain controversial problems in the search for source areas of "exotic" pebbles in mid-Cretaceous flysch conglomerates (for a review see Marschalko 1986; Mišík & Marschalko 1988; Mišík 1990 and Birkenmajer et al. 1990). If there were not objections with reference to the size distribution of pebbles (largest in the Klape, not in Tatric-Fatric) and some of their composition (cf. Mišík & Marschalko 1988), most of the "exotic" pebbles could also have had their sources in the southernmost units of the Western Carpathians. Concerning the distribution of proximal facies and the largest block-sized clasts, the placing of Klape sedimentary area in the Fatric (Krížna) realm would provide an alternative solution. The lack of the Urgonian limestones with orbitolinids in the southern zones may be explained by a complete erosion of some higher units originally overlying the present-day units exposed south of the northern Veporic, i.e. the Gemericum, Meliaticum and probably also Bükkicum, eventually also some cover units analogous to the Mesozoic sequence of the Gerecse Mts. in Hungary, where Urgonian limestones, also with chrome spinel grains, are present. These units were emplaced during the Late Jurassic-Early Cretaceous and were eroded mainly during the mid-Cretaceous before the Turonian, as is shown by a marked metamorphic and structural gap (e.g. Vrána 1966; Plašienka 1993) between the basement units and superficial cover nappes of the Hronic-Silicic system emplaced during the Late Turonian-Early Senonian. This gap represents at least 10 km of missing crustal section in the southern Veporicum (Foederata Unit vs. Muráň Nappe - Plašienka 1993) and approximately 15-20 km in areas south of the Gemericum (glaucophanites of the Meliata Unit vs. the Silica Nappe, cf. Reichwalder 1982). The radiometric cooling ages from the Veporic basement-cover complexes (see review by Kováč et al. 1994) indicate a fairly rapid uplift during the time span between 100 and 85 Ma (Late Albian-Early Senonian). The uplift was accomodated partly by structural unroofing of core complexes and partly by erosion. The erosional products might have supplied the Klape and Poruba Flysch Basins in the foreland of this uplifting domain.

Implications for the structure of the Peri-Klippen Belt

The concept presented above implies other important consequences for the evolution and structure of the fore-Tatric areas, the so-called Peri-Klippen Belt. This belt shows a complex imbricated structure, a close spacing of subvertical tectonic contacts of different units dominated by Cretaceous, particularly Upper Cretaceous formations and extensive shortening, probably in an accretionary prism setting of the "Laramian" tectonism. The belt includes:

1 - Elements of the Centrocarpathian Hronic-Silicic superficial nappe system (Veterlín, Havranica, Jablonica, Nedzov Nappes in the northern part of the Malé Karpaty Mts., where this belt appears to be a prolongation of the Northern Calcareous Alps from the basement of the Neogene Vienna Basin - Fig. 1) and their Senonian Gosau-type cover;

2 - In our view also Central Carpathian Fatric elements (Manín, Klape, Drietoma, Bošáca and related units) and their Senonian cover;

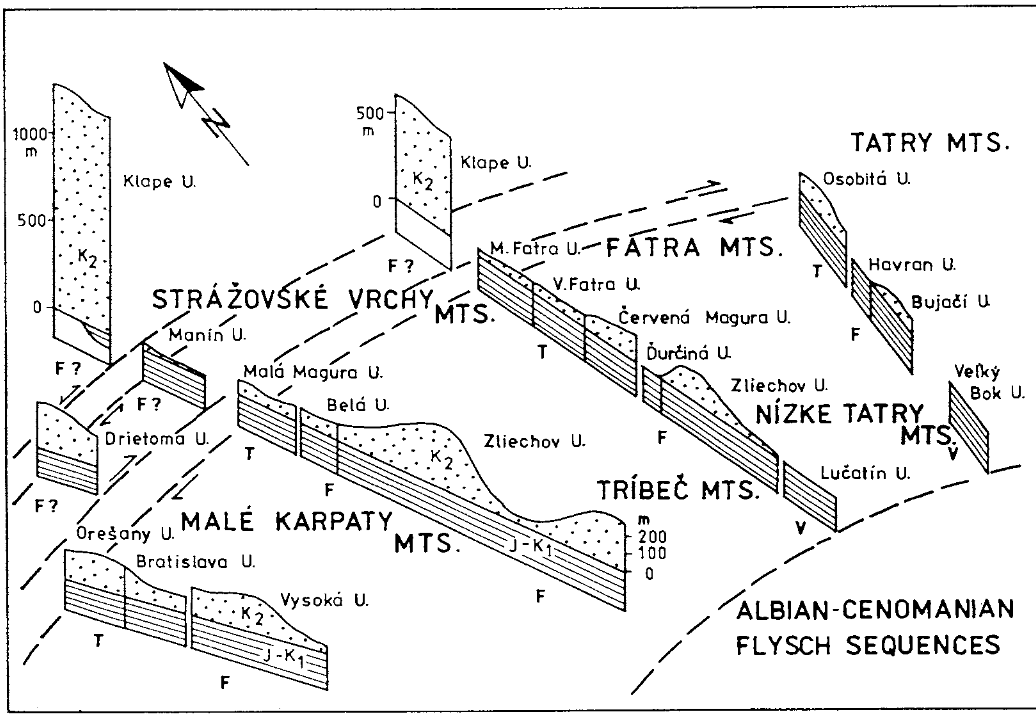


Fig. 6. Distribution of Albian - Cenomanian flysch sequences in the Peri-Klippen, Tatric and Fatric Units. The widely accepted position of their source area, the Ultrapieniny "exotic" ridge, should be between Drietoma-Klape and Manín-Tatric domains. Dots - flysch complexes, horizontal shading - Jurassic to Lower Cretaceous formations. Abbreviations: **F?** - Peri-Klippen, inferred Fatric Units, **T** - Tatric, **F** - Fatric, V - Veporic Units.

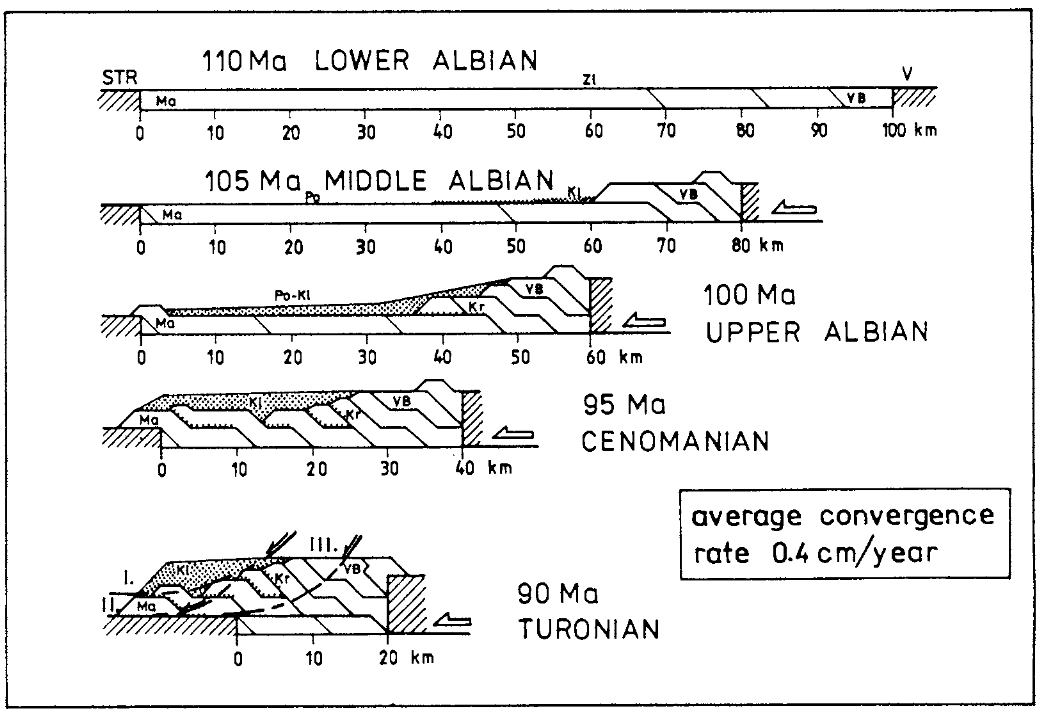


Fig. 7. Geometrical model of shortening of the Fatric domain. Flexural downbending and erosion of uplifted units are omitted. **STR** - South Tatric Ridge, a frontal ramp, **V** - Veporic rigid buttress, **Ma** - Manín Unit, **Zl** - Zliechov Basin, **VB** - Veľký Bok Unit, **Po** - Poruba Flysch Basin, **Kl** - Klape Flysch Basin, **Kr** - Krížna Unit. Dotts - proximal flysch sediments. **I.** - first diverticulation, the Klape gliding nappe, **II.** - second diverticulation, the Manín gliding nappe, **III.** - third diverticulation, the Krížna gliding nappe.

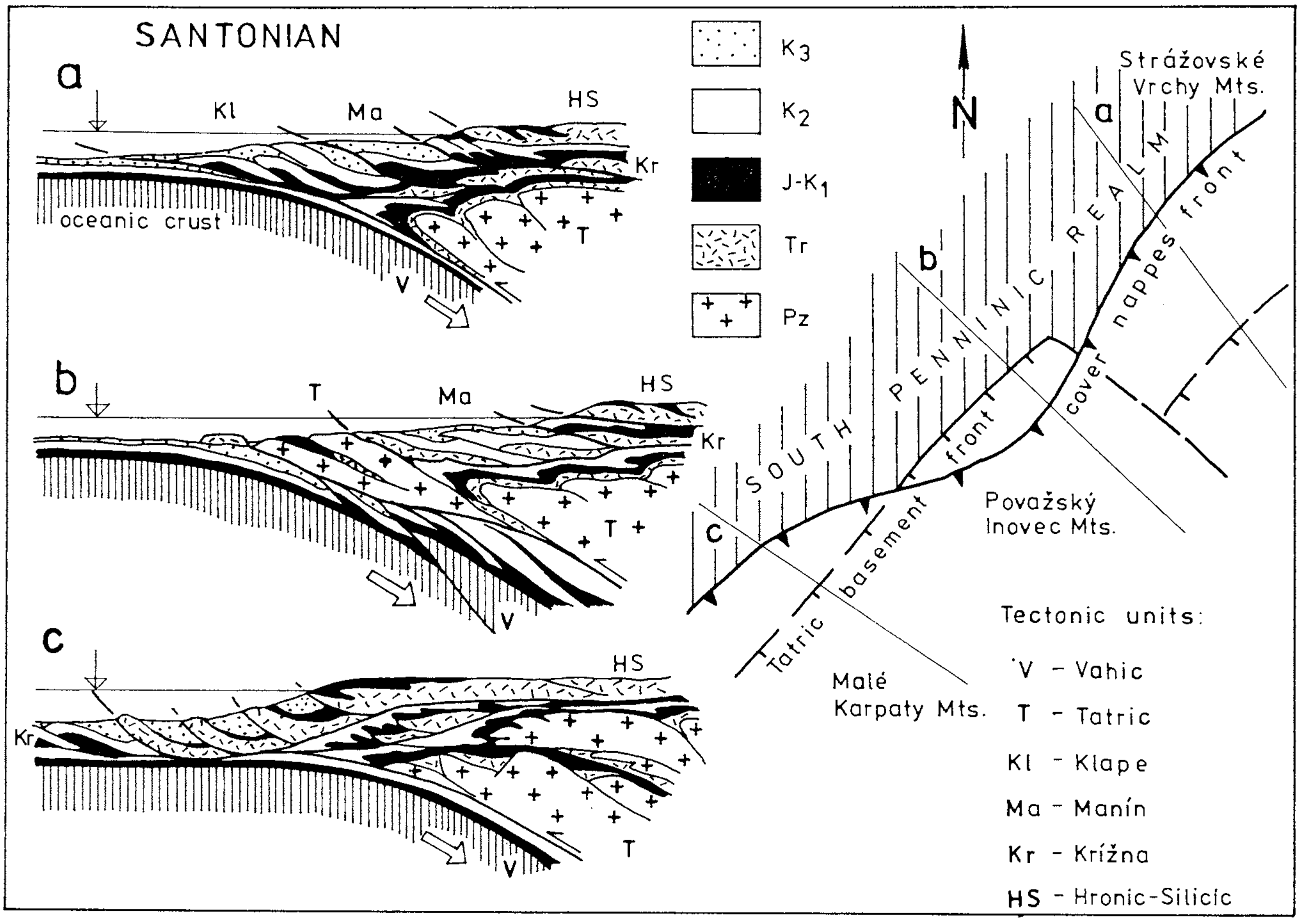


Fig. 8. Schematic presentation of the Late Cretaceous convergence at the north Tatric active margin. Centrocarpathian gliding nappes occupied a position of the fold-and-thrust belt in front of the overriding Tatric sheet.

3 - Rare fragments of the oceanic Vahic Superunit (Belice Unit perhaps the Surovín Unit and probably also some other highly disintegrated slices almost unrecognizable in the recent structure).

Generally, the Vahicum was almost completely subducted below the Tatricum. All these units, allochthonous as well as paraautochthonous, were additionally shortened and strongly imbricated in front of the overriding Tatric crustal thrust sheets, i.e. in the position of an accretionary wedge during Senonian times. The Alpine Gosau sediments were probably deposited in piggy-back compressional basins between secondary thrust sheets (Leiss 1988, 1992), and/or in transtensional pull-aparts behind the frontal accretionary wedge (Wagreich 1988; Faupl & Wagreich 1993), or the Gosau basins subsided due to the subcrustal tectonic erosion (Wagreich 1993). The Senonian complexes overlying the Fatric elements show a similar position, and from this point of view they may be also regarded as constituents of the Gosau group. All of the Senonian basins in the Peri-Klippen area follow a comparable lithostratigraphical trend: Santonian flysch, Campanian pelagic "couches rouges" marls, Maastrichtian flysch. Basins situated on top of the Upper Austroalpine and Hronic-Silicic cover nappe system started during the Early Coniacian with fluvial conglomerates, but subsided during the Late Coniacian (neritic marls). However, most of the Eastern Alpine Lower Gosau Group remained under shallow-water conditions of deposition until the Early Campanian (Faupl et al. 1987). The Campanian "lull" appears to be an expression of the maximum eustatic sea-level rise (+200 m, Haq et al. 1987) flooding the terrigenous sources.

The composition of the clastic material in flysch deposits sometimes abruptly differs in individual, narrow longitudinal basins dependent on the composition of local elevated structures (sometimes with small reefs, see Salaj 1990) feeding adjacent basins (Fig. 8). Vahic cover complexes were rarely scraped off their oceanic substratum, but locally basement imbricates also provided olistolites (Belice Succession - Fig. 3; Soták et al. 1993; Plašienka et al. 1994) in front of the overriding Tatric basement (Fig. 5, 8b). All of the Senonian formations point to a mobile enviroment with features of fast shallowing and deepening (Salaj 1991), clastic material was derived from unstable, mostly carbonate shelf sources in proximal settings; it also includes conglomerates containing "exotic" pebbles. These latter may have been recycled from older Middle Cretaceous "exotic" conglomerates of the Klape Unit (cf. also Birkenmajer 1988 and Salaj 1990), although Marschalko's analysis (1986) seems not to support this possibility.

The sedimentation in the Peri-Klippen zone terminated, or rather was interrupted during the latest Cretaceous-earliest Paleocene, when the Peri-Klippen accretionary prism collided with the Oravic Czorsztyn Ridge - an extensional continental ribbon (Fig. 4). The collision resulted in dextral transpression (Plašienka 1990) of the Peri-Klippen and Klippen Belt units north of the Tatric edge. Transpression continued the complication of the structure of these belts through formation of transpressional duplexes. Each duplex may comprise a coherent lithostratigraphy differing from the adjacent unit, and units of distant provenances (Oravic, Vahic, Tatric, Fatric, Hronic) may be mixed in an intricate pattern. The Paleocene tectonism is poorly recorded by the sediments, except for blocks of coral and algal reefs present in the Lower Eocene conglomerates in the Peri-Klippen area (Köhler et al. 1993). The inner zones, on the northern edge of the CWC block, thick aprons of monomict carbonate breccias (Súľov conglomerates) covered the dorsal Hronic - Silicic units in a very deep, seismotectonically controlled basin (Marschalko & Samuel 1993), after a period of emergence and lateritic weathering.

Conclusion

The sedimentary, magmatic and structural rock record in the Mesozoic successions along the north Tatric margin reveals the following paleotectonic history:

1 - Triassic pre-rift platform stage with stable shelf conditions;

2 - Lowermost Jurassic uplift and initial rifting phase, establishment of zones with localized extension, where syn-rift terrigenous sequences began to be deposited in tilted halfgrabens;

3 - Late Liassic to Aptian extensional tectonism with several renewed rifting events (Toarcian, Tithonian, Barremian) and general thermal subsidence indicated by widespread eupelagic sediments (Late Jurassic-Early Cretaceous), followed by restricted submarine alkaline basaltic volcanism (Barremian-Early Albian);

4 - Mid-Cretaceous flexural subsidence in front of the orogenic wedge prograding from the hinterland, recorded by overall flysch sediments with "exotic" conglomerates which buried the previous rugged morphology of the basin bottom;

5 - Late Turonian nappe thrusting and additional shortening, dextral transpression and backthrusting during the Senonian. The north Tatric divergent margin facing the Vahic (Southern Penninic) oceanic realm was inverted to a convergent one as late as during the earliest Senonian, and the Vahic oceanic crust was consumed there up to the earliest Tertiary.

This tectonic scenario partly contradicts the generally accepted opinions about Mesozoic evolution and the palinspastic pattern of zones between the Tatric and Oravic domains. These usually consider the presence of an active margin starting from the Late Jurassic and an uplift of a mid-Cretaceous "exotic" ridge along the north Tatric edge, based on the position of the Klape Unit. To explain these inconsistencies the Fatric, i.e. Central Carpathian provenance of the Klape and related units is suggested and supported by several arguments. However, the relevance of this working hypothesis must be further tested and made more precise by new stratigraphical, structural and sedimentological data.

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