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Comparison of Mesozoic Successions of the Central Eastern Alps and the Central Western Carpathians

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With 5 Text-Figures and 2 Tables

Österreich
Slowakei
Ostalpen
Westkarpaten
Mesozoikum
Fazieskorrelation
Paläogeographie
Vahikum

Contents

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Vergleich mesozoischer Schichtfolgen zwischen den zentralen Ostalpen und den zentralen Westkarpaten

Zusammenfassung

Im folgenden werden zentralalpine mesozoische Serien in Österreich mit zentralkarpatischen Serien der Slowakei verglichen. Der zentralalpine Querschnitt umfaßt Mittel-Pennin, Süd-Pennin, Unterostalpin und Mittelostalpin. Die zentralen westkarpatischen Serien gehören dem Tatrikum, der Krížna-Einheit (= Fatrikum) und dem Veporikum an.

1) Aufgrund sedimentologischer Belege müssen sowohl innerhalb der mittelpenninischen und unterostalpinen Jurafazies der Ostalpen als auch innerhalb der tatrischen Jurafazies und im Bereich des ab dem Jura aufsteigenden hypothetischen Ultrapienidischen Rückens (im Sinne A. TOLLMANNS) und dessen östlicher Fortsetzung („exotischer Rücken") Schwellenzonen mit Erosion oder Schichtlücken rekonstruiert werden.
   Der Vergleich der Jura-Faziesverteilung im Mittelpennin und Unterostalpin der Ostalpen zeigt aufgrund des lateralen Wechsels von Hochzonen und Becken große Ähnlichkeiten sowohl zu den Tatriden als auch zur Krížnafazies, ohne daß daraus allein schon eine Parallelisierung abgeleitet werden könnte.
2) Das Argument, daß nur die Krížna-Fazies wegen ihrer karpatischen Keuperfazies mit dem Semmering-Unterostalpin zu parallelisieren wäre, trifft nicht mehr zu, da Keuperablagerungen in der Tatrischen Fazies aber z. B. auch im Bajuvarikum westlich von Wien, bekannt sind.
3) Das Auftreten jurassischer Grobklastika in der Borinka-Einheit, der tektonisch tiefsten Schuppe und somit ehemals nördlichsten Fazieszone des westlichen Tatricums, wird als Schüttung von einer tatrischen Schwelle in einen Halbgraben nach Norden rekonstruiert. Dieser Bereich nimmt somit in der Frage der Korrelation ostalpiner mit westkarpatischen mesozoischen Serien eine Schlüsselposition ein.
   Läßt man rein hypothetische Gesichtspunkte anderer ehemaliger Schichtfolgen außer acht und beschränkt man sich bei den Serienvergleichen auf heutige Aufschlüsse, dann kann die Borinka-Einheit im Vergleich mit den Ostalpen sowohl aufgrund der Juraschichtfolge, der Schüttungsrichtung der Breccien als auch der im Laufe des Jura tiefergreifenden Erosion nur mit Bereichen des unterostalpinen Kontinentalrandes verglichen werden.

Das bedeutet einerseits eine unmittelbare Nachbarschaft des tatriden Kontinentalrandes zu einem nördlich parallel verlaufenden Becken (= ?Vahikum) und andererseits, daß sich in bezug auf die paläogeographische Position für das Ostalpine Mittelpennin in den Zentralen Westkarpaten kein Äquivalent mehr findet.

Als Konsequenz dieses Vergleiches zentralalpiner mesozoischer Fazieszonen der Ostalpen mit jenen der zentralen Westkarpaten wird wieder die Parallelisierung der in bezug auf das Mesozoikum teilweise sehr lückenhaft erhaltenen (ostalpinen) unterostalpinen Fazies mit der Tatrischen Fazies (Tatricum) u n d der Fatrischen Fazies (Vysoká und Zliechov) zur Diskussion gestellt.

Abstract

This paper compared Mesozoic facies in Austria with those in Slovakia. The Austrian section is comprised of the Lower Austroalpine, the South Penninic system, the cover units of the Zentralgneis-core (Middle Pennine) and the Middle Austroalpine. The Slovakian units are the cover units of the Tatrikum, the Krížna nappe group (Fatrikum) and the Veporikum.

1) Sedimentological evidence indicates that periods of erosion and non-deposition occurred on swell zones within the Middle Penninic and Lower Austroalpine Jurassic. Similiar sedimentary gaps are also present within Tatric Jurassic facies. The comparison of Jurassic facies of the Middle Pennine and the Lower Austroalpine of the Eastern Alps with the Tatrides and the Krížna facies, indicates great similiarities with respect to the general pattern of sedimentary swells and basins.
2) The argument that only Krížna facies with its Keuper beds can be parallelised with the Lower Austroalpine of the Semmering area is obsolete because since the Keuper formation occurs within the Tatric facies, and also for example within the Bajuvaricum west of Vienna.
3) The occurrence of Jurassic breccia beds within the Borinka unit, the lowermost tectonic slice and therefore northernmost facies zone of the western Tatrides, is interpreted as the deposit of coarse clastic material derived from a Tatric swell and deposited in a northern half graben. This newly studied Borinka area provides information of key importance in the correlation of central Austroalpine and western central Carpathian Jurassic series. The Borinka facies zone can only be compared with the facies of the Lower Austroalpine continental margin, with regard to the direction of breccia transport and the deepening of erosion during Jurassic time.

Since the reconstruction of a Tatric continental margin with its deposits in a halfgraben needs a northern foredeep (= ? Vahic basin), no paleogeographical equivalent of the Austroalpine Middle Pennine can be reconstructed in the Central Western Carpathians interpreting current geological data.

This comparison of central Austroalpine Mesozoic facies with central Western Carpathian facies leads to the conclusion that the Lower Austroalpine facies (with partly incomplete Mesozoic series in the Eastern Alps) can be correlated with the Tatric facies (of the Tatricum) a n d the Fatric facies (of Vysoká and Zliechov).

1. Introduction

The Eastern Alps and in particular the Northern Calcareous Alps of Austria are the classical areas of investigation of the Mesozoic Tethys-geology. Here lithostratigraphical terms were already established during the last century and then also applied in the Western Carpathians.

Based upon the generally accepted criteria of the parallelism of facies zones along the strike of tectonic units, (e.g. of the Alpine/Carpathian range) the correlation of the main tectonic zones (e.g. the Rhenodanubic flysch/Carpathian flysch zone or the Upper Austroalpine/Choč – Strazow – Gemeric) is well documented and accepted. Not so clear however seems to be the correlation of distinct Centroalpine and Centrocarpathian facies zones west and east of the Vienna basin. For example the question: "Do the Tatrides belong to the Lower Austroalpine or to the Penninic" posed by A. TOLLMANN (1965) acknowledged the controversial different points of view some decades ago (compare S. PREY, 1965, p. 102).

Initially the Wechsel was termed as (Middle-) Pennine by A. TOLLMANN, (1963, Pl. 3; with reservation). He later (1972, p. 200) parallelised the Wechsel dome with its "granitisch-granodioritischer Sockel mit der lückenhaften Hülle" with the Penninic Hochsteg swell and also with the Tatric swell. Following the results of W. VETTERS (1970) and P. FAUPL (1972), the former Penninic Wechsel window was redefined as the lowermost Lower Austroalpine tectonic unit by A. TOLLMANN (1978). It was therefore parallelised with the Krížna nappe. This example shows that a former important facies argument was replaced by a revised regional comparison of the tectonic position.

Nearly every scientist comparing the sequences of the Eastern Alps and the Western Carpathians presented arguments for different facies correlation and therefore different paleogeographic reconstructions. In contrast to A. TOLLMANN (1972, p. 188) S. PREY (1965, p. 100 ff.) compared the Frankenfels nappe with the Krížna nappe based on their formations of Cenomanian age and then used parallelism to equate the Lunz nappe with the Choč nappe. He argued (l.c., p. 102) that the Triassic of the Austroalpine Semmering area shows good correlation with the Triassic of the Krížna nappe but the Jurassic of the Krížna nappe is better compareable with the Jurassic of the Frankenfels nappe. Post-Triassic formations are generally missing in the Semmering area.

In a controversial paper concerning the Eastern Alps and Western Carpathians, W. FUCHS (1985) stated that the Lower and Middle Austroalpine of the Eastern Alps contained primarily post-Jurassic formations until Turonian age. He interprets the "Cenoman-Randschuppe" and the "Kieselkalkzone" to represent the tectonically displaced younger formations of the Lower Austroalpine. The Frankenfels nappe, in its present (bajuvaric) position on the northern rim of the Northern Calcareous Alps is interpreted as the tectonically displaced and consequently not metamorphosed primary cover of the Middle Austroalpine. The (Upper Austroalpine) Lunz nappe was believed to be the continuation of the Choč nappe by W. FUCHS. Based upon facies development, G. WESSELY (1975, p. 277; 1992, p. 352) also presented arguments for a possible correlation of Krížna nappe with the Frankenfels nappe.

Because of the various, fundamentally different pubished facies correlations between the Eastern Alps and the Western Carpathians (see also M. MAHEL', 1983) some of the problems concerning facies correlation are listed below. The following points have been considered important, by various authors concerned with palinspastic interpretation of tectonic units and their paleogeographic reconstruction:

* Tectonic position of a facies zone and its relation to other tectonic units within the orogenic belt (e.g. does the South Penninic Bündnerschiefer trough end east of Rechnitz?).
* Different palinspastic reconstructions of tectonic units and their facies zones, due to different interpretations of the main direction of thrusting (a-tectonics, b-tectonics; discussion L. RATSCHBACHER, 1987).
* Different possible assumptions for the geodynamic model (nappe thrusting combined with gravity gliding tectonics and/or strike-slip and/or dip-slip faulting).
* Different possible assumptions for the palinspastic reconstructions regarding the overall "geometry", the type of nappe tectonics (overthrust nappe/imbricate structure; basement nappe/stripped sheet) and regarding the temporal development of structures (pre-Gosau/post-Gosau) as a base for the paleogeographic reconstructions (mainly pre-gosauic thrusting in the Western Carpathians in contrast to the importance of pre-gosauic and post-gosauic thrusting in the Eastern Alps).
* Metamorphism of formations in different nappes and reconstruction of the primary sediments as a basis for their comparison (Bündner Schiefer/greywackes).
* Different definition of the tectonic organisation (e.g. Lower-, Middle- and Upper Austroalpine) in comparison or in contrast to facial zoning (e.g. is Upper Austroalpine facies restricted to Upper Austroalpine nappes?).
* Different assessment of the "characteristic facies" of sequences as a base for the assignment of tectonic units to paleogeographic facies zones (e.g. is the Liassic Hierlatz-limestone restricted to a certain nappe?).
* Different interpretations of missing sequences (at the base or at the top of a tectonic unit) as primary or as tectonic (e.g. were the younger formations of the Frankenfels nappe tectonically displaced from the Central Alps?).
* Different assumptions of the extent of a "characteristic facies" (local or regional; e.g. did the Hochstegen swell exist at a distance of some hundred kilometers?).
* Different estimations of the possible change of a facies along the strike of a tectonic unit ("multifacies nappe"; e.g. can a lateral facies change of local swells and troughs be reconstructed within the Lower Austroalpine of the Eastern Alps and the Tatric facies?).
* Different reconstruction of the paleogeographical (and paleotectonic) position of stratigraphic series from different tectonic units based only upon their nomenclatural association, which again implies a special facies zone (e.g. Jurassic swell zone of the Tatric = Hochstegenzone?).

If the comparison of facies is of fundamental importance for facies correlation and paleogeographical reconstructions, assumed geodynamic, palinspastic or paleogeographic models should not be imposed in the initial stage.

Nevertheless, recent achievments in a detailed lithostratigraphy and sedimentology of some post-Triassic successions of the Central Eastern Alps have been reported by H. HÄUSLER (1987; 1988) and in the Alpine-Carpathian junction area of the Malé Karpaty Mts. by J. MICHALÍK (1984), D. PLAŠIENKA (1987), M. MAHEL' (1987), D. PLAŠIENKA et al. (1991) and J. JABLONSKÝ et al. (in press).

The new knowledge on bio- and lithostratigraphy of Centrocarpathian Mesozoic complexes developed during the last decades by numerous authors (for review see M. MAHEL', 1986 and M. RAKÚS et al., 1990) allow a new insight into their paleogeographical development and paleotectonic settings.

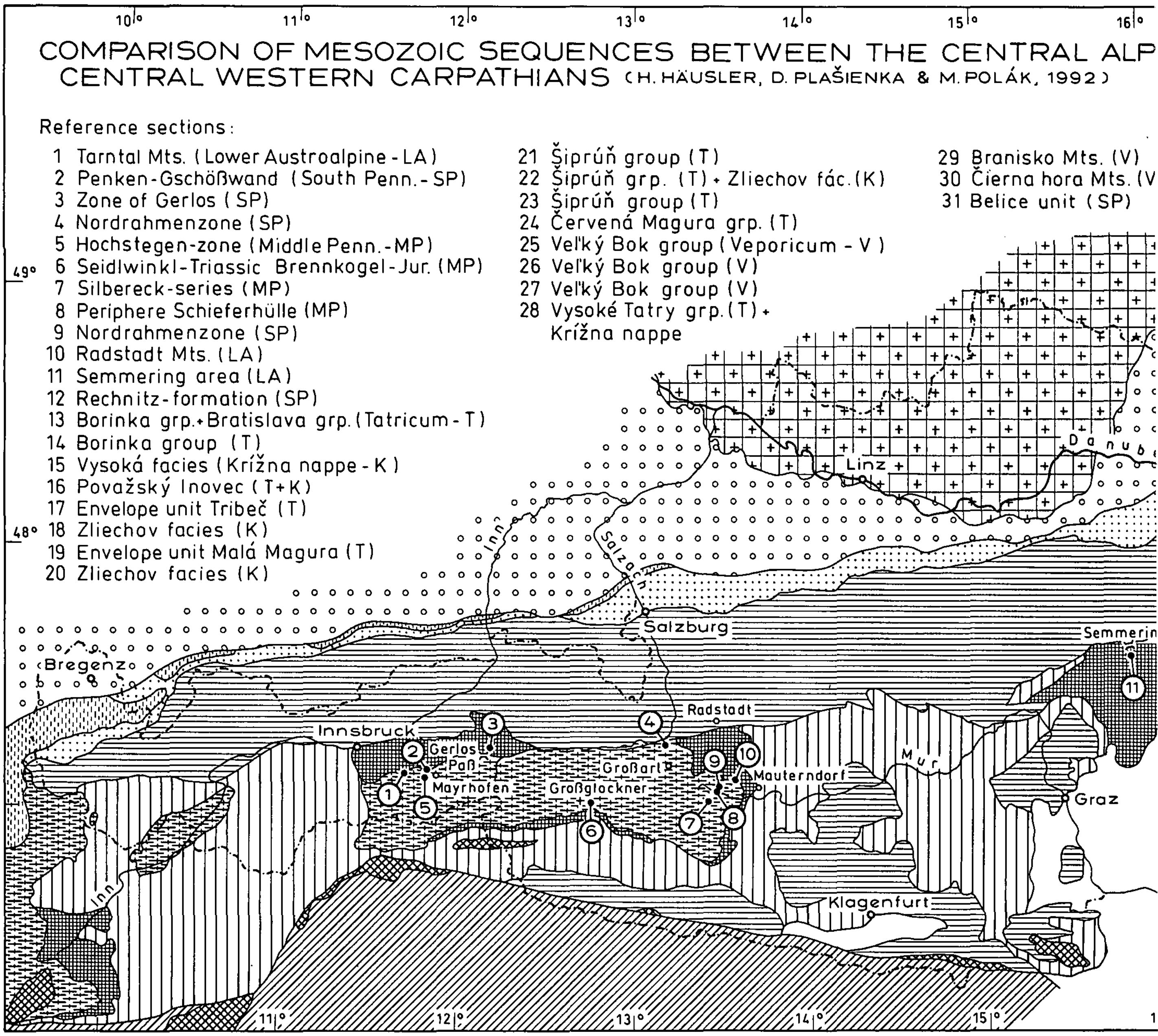
The aim of the present paper is to briefly summarize structural position, lithostratigraphy, sedimentology and paleogeography of some key Mesozoic units. The Central Austroalpine of the Tarntal Mts., Radstädter Tauern Mts. and Semmering area as well as South Penninic complexes of the Hohe Tauern Mts. and Rechnitz area and the cover of the Middle Penninic Zentralgneis-cores of the Tauern window will be discussed on the one hand and the Tatric cover successions and the Krížna nappe system of the Malé Karpaty, Považský Inovec and other Centrocarpathian "core mountains" on the other.

In conclusion, paleotectonic and paleogeographic implications are discussed and a preliminary attempt at a new paleogeographic correlation is presented.

2. Mesozoic Tectonic Evolution: An Outline

New geological data in the Eastern Alps and Western Carpathians confirm the similiar evolution of pre-Tertiary units of both mountain ranges previously proposed by numerous authors. The main points of the overall tectonic scenario are as follows:

* **Triassic**
  Continental and shallow carbonate platform sedimentation in northern domains (Pennine, Lower–Middle Austroalpine, Tatric, Fatric, Veporic) attached to the Northern European platform reveal normal continental crust. Local pelagic and slope facies in the south mainly during the Late Triassic (Bajuvaric and Tirolic nappes of the Northern Calcareous alps; Hronic–Silicic nappe system of the Western Carpathians) indicate thinned crust and proximity of a basinal domain rifted during the Middle Triassic (the Meliata–Hallstatt ocean sensu H. KOZUR, 1991; S. KOVÁČS 1982; A. TOLLMANN, 1990) underlain partly by a newly-formed oceanic crust.
* **Early Jurassic**
  Break up of the European shelf carbonate platform due to extensional tectonism caused by passive rifting, formation of deep-water furrows with strongly thinned continental crust (Lower Austroalpine, Tatric Šiprúň and Fatric Zliechov troughs; furrows also in Upper Austroalpine) or even newly formed oceanic domains (South Pennine and its eastern prolongation referred to as Vahicum – M. MAHEL', 1981). Rifting was partly transtensional, hence lozenge-shaped basinal domains formed, separated by continental ribbons characterized by ridge-type sedimentation. First manifestation of flysch sedimentation in the Meliatic basin.



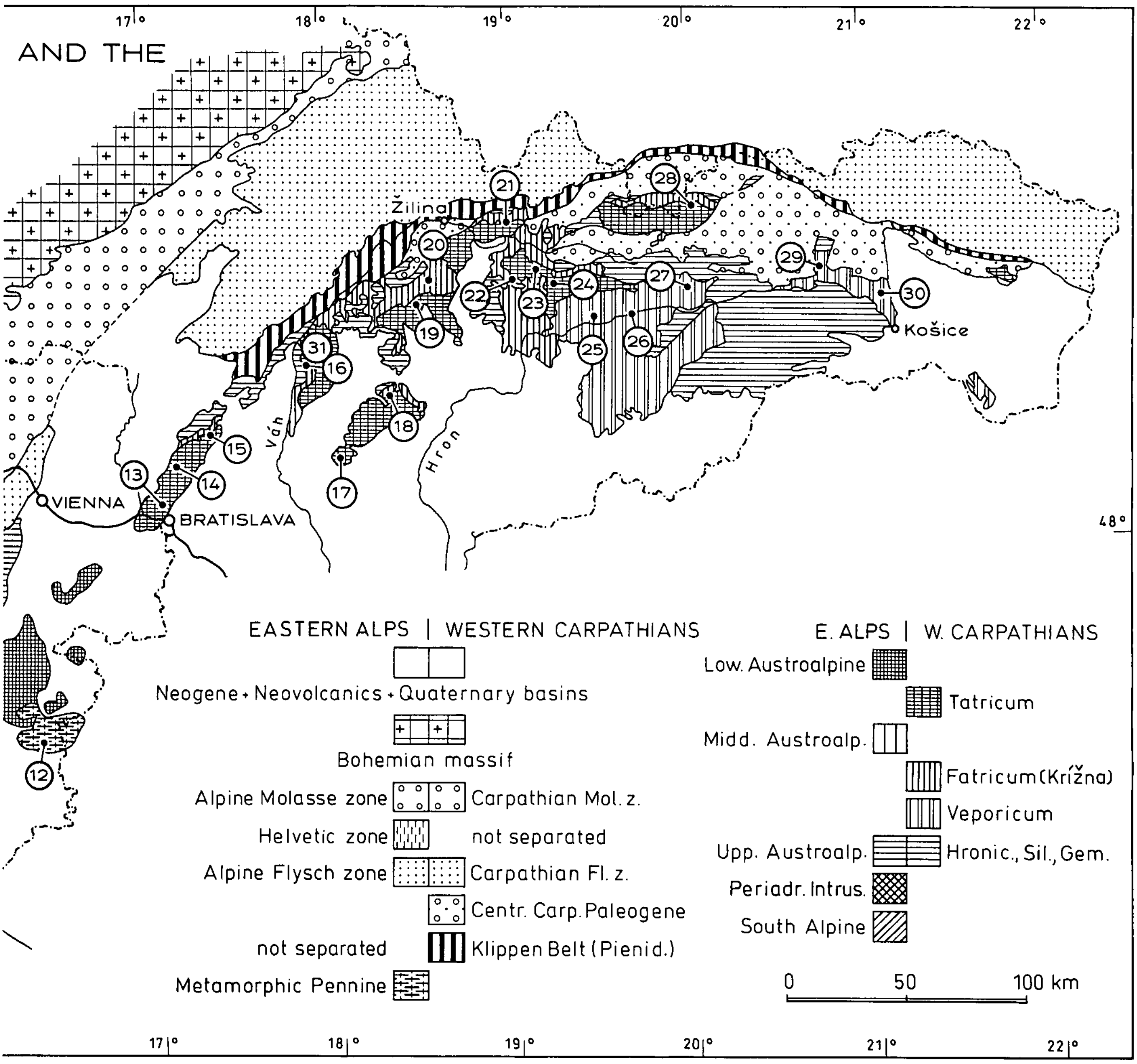
Text-Fig. 1.
Comparison of Mesozoic sequences of the central Eastern Alps and the central Western Carpathians.
Numbers indicate localities of reference-sections citied in text.

* **Middle–Late Jurassic**
Continuing extension in northern zones with culmination of subsidence during the Callovian–Oxfordian (radiolarites), southward subduction of the Meliatic oceanic bottom (wildflysch, olistolites, subduction melange) and its suturing during the Late Jurassic (H. KOZUR, 1991), gravity gliding in the Juvavic domain of the Northern Calcareous Alps (B. PLÖCHINGER, 1974; A. TOLLMANN, 1987a) – the Neocimmerian of "early-Alpine" shortening.

* **Early Cretaceous**
Continued compression northward, crustal stacking of the southern zones of later Centroalpine and Centrocarpathian domains (Gemeric over Veporic, basement shortening of the Middle Austroalpine indicated by some geochronological data – e.g. L. HOKE, 1990; H. FRITZ & M. KRALIK, 1987).

* **Middle Cretaceous (pre-Gosau)**
Formation of Austroalpine nappe stack, onset of southward Penninic subduction – the "eo-Alpine" paroxysm with HP-LT metamorphism in the Alps, shortening of the Fatric basin (flysch) and emplacement of the Krížna nappe system, Veporic basement overthrust over the Tatric, internal shortening of the Tatric basement – "paleo-Alpine" tectonism in the Western Carpathians.

* **Late Cretaceous**
Continuing Penninic subduction in the Alps, further Austroalpine shortening and emplacement of the Upper Austroalpine nappe pile, incorporation of the Gosau sediments into thrust tectonics (O. LEISS, 1988), underthrusting of the Vahic oceanic (?) substratum below the northern Tatric edge (flysch and wildflysch in the Periklippen zone).



The main differences in the paleotectonic history of the Eastern Alps and Western Carpathians started during the Early Tertiary. Oceanic areas of the outer Carpathians underwent continued subduction. Divergence became more pronounced during the Miocene, when eastward extrusion of the Carpathian domain accelerated (e.g. L. RATSCHBACHER et al., 1991) and deep pull-apart basins (Vienna basin, Little Hungarian Plain – Danube) were created in the Alpine-Carpathian junction area.

2.1. Central Eastern Alps

(H. HÄUSLER)

The tectonic architecture of the Central Eastern Alps is built up from bottom to top by

1) the metamorphic Pennine of the Tauern- and Rechnitz window (Middle- and South Pennine),
2) the Lower Austroalpine frame of the Tauern window (Tarntal Mts. and Radstadt Mts.) and the Semmering area and
3) the Middle Austroalpine.

Generally the alpine greenschist metamorphism decreases from south to north within the Penninic series of the Eastern Alps and also from the deeper (higher metamorph) to upper tectonic units (lower metamorph; cf. Ch. EXNER, 1983). The progressive metamorphism of Lower Austroalpine metasediments only gets up to low grade metamorphism (greenschist facies; illite-crystallinity between 2,5 and 3,8 after B. KUBLER; e.g.: Radstadt Mts., H. HÄUSLER, 1988, p. 30).

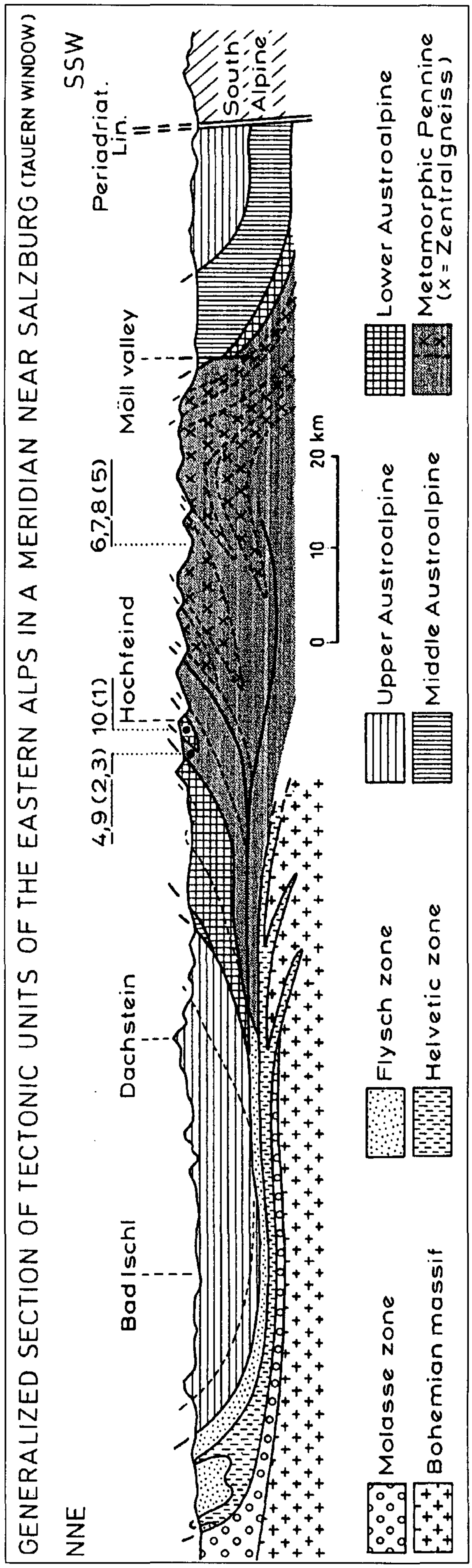
The age of the youngest metasediments of the Lower Austroalpine of the Radstadt Mts. has not yet been established (Schwarzeck formation: Upper Jurassic–? Lower Cretaceous). E. REITZ et al. (1990) found evidence indicating a Lower Cretaceous age for the Bündner Schiefer of the Nordrahmenzone. Overthrusting of the Tauern-window must have occurred later than middle-Cretaceous, about Albian/Cenomanian (after A. TOLLMANN, 1977, p. 34, p. 44; compare sedimentological, tectonic and geochronological models of P. FAUPL & A. TOLLMANN 1979; A. TOLLMANN 1987b; W. FRISCH 1984; W. FRISCH et al. 1987; W. FRANK et al. 1987; P. SLAPANSKY & W. FRANK 1987).

In contrast to the conventional idea of an early, generally meridional alpidic shortening, L. RATSCHBACHER (1987) argues for the interpretation of the alpidic east–west lineation as a primary a-lineation.

The term "Lower Austroalpine" is not only defined tectonically as a specific position between the Penninic nappes and the higher Austroalpine nappes, but is also used for a Mesozoic facies zone within the paleogeographic reconstruction of the central Alpine nappes.

The following areas of weakly metamorphosed Mesozoic outcrops were partially reinterpreted (Text-Fig. 2; numbers of sections referring to Text-Fig. 1):

1) Hippold-, Reckner- Quartzphyllite nappe; Tarntal Mts., (Lower Austroalpine)
2) Penken-Gschößwand west of Mayerhofen; Nordrahmenzone of the Tauern window (South Pennine)
3) Zone of Gerlos; Nordrahmenzone of the Tauern window (South Pennine)
4) South of Salzach-valley; Nordrahmenzone of the Tauern window (South Pennine)
5) Hochstegenzone; Mesozoic series of the Zentralgneis core (Middle Pennine)
6) Seidlwinkl Triassic and Brennkogel Jurassic; Mesozoic series of the Zentralgneis core (Middle Pennine)



Text-Fig. 2.
Generalized section of tectonic units of the Eastern Alps in a meridian near Salzburg (Tauern window; for reference sections see Text-Fig. 1 and Tab. 1; modified after A. TOLLMANN, 1986)

7) Silbereck series of Gastein nappe; Mesozoic series of the Zentralgneis core (Middle Pennine)
8) Periphere Schieferhülle south of Salzach valley; Mesozoic series of the Zentralgneis core (Middle Pennine)
9) South of Zederhaus valley; Nordrahmenzone of the Tauern window (South Pennine)
10) Pleisling-, Lantschfeld-, Hochfeind-, Quartzphyllite nappe; Radstadt Mts.; (Lower Austroalpine)
11) Grobgneis nappes; Stuhleck–Kirchberg nappe; Semmering area; (Lower Austroalpine)
12) Rechnitz-formation (South Pennine).

The association of facies zones with tectonic nappes is much easier in the Eastern Alps than in the Western Carpathians. This facilitates palinspastic and paleogeographical reconstructions.

2.2. Central Western Carpathians

(D. PLAŠIENKA)

The Central Western Carpathians encompass most of the area of the Slovakian Carpathians between the Pieniny Klippen belt in the north and the Meliata suture (M. MAHEL', 1985) in the south. They consists of several principal belts: the "core mountains", the Vepor belt and the Gemer belt.

The belt of the core mountains (Malé Karpaty, Považský Inovec, Tríbeč, Strážovské vrchy, Žiar, Malá Fatra, Tatry, Vel'ká Fatra, Nízke Tatry, Branisko, Humenské vrchy), which are Tertiary horst structures, comprises from bottom to top:

1) The Tatric pre-Alpine crystalline basement and its Late Paleozoic to Mesozoic sedimentary cover,
2) the Krížna Mesozoic cover nappe-system (Fatricum),
3) the Choč and higher nappes (Hronic–Silicic system) and
4) Upper Cretaceous and Tertiary post-nappe sedimentary and volcanic rocks.

Based on structural criteria, the originally flat-lying Cretaceous nappe pile, may be restored to the primary palinspastic position from north to south:

1) the Tatric area,
2) the Fatric (Krížna) area,
3) the Veporic–Gemeric area and
4) the Meliatic oceanic realm.

The position of the Hronic–Silicic remains unresolved in this scheme.

The Vepor belt comprises:

1) the Veporic basement/cover thick-skinned sheet (pre-Alpine crystalline basement and Late Paleozoic-Mesozoic sedimentary, low-grade metamorphosed cover, namely the Vel'ký Bok and Foederata units),
2) unmetamorphosed nappes of the Hronic–Silicic system (Drienok, Muráň, Stratena, Vernar) and
3) Late Cretaceous–Tertiary cover rocks.

The Gemer belt includes

1) the Gemeric Paleozoic sheet,
2) Mesozoic rocks of the Jaklovce-Meliata metamorphic successions,
3) unmetamorphosed Radzim-Stratena Silica cover nappe group (the Silicicum) and
4) Late Cretaceous–Tertiary rocks.

In particular the spatial distribution and emplacement history of two principal units of northern zones, the Tatricum and the Krížna will be discussed (Text-Fig. 3).

The Tatricum is an extensive crustal sheet formed by the pre-Alpine crystalline basement and its Late Paleozoic (subordinate) – Mesozoic sedimentary cover. Its Mesozoic cover is devided into two facies units based on lithology, stratigraphy and paleogeographic considerations – the outer (northern) deep water Šiprúň zone (redefined as Fatra type by M. MAHEL' 1979) and the southern shallow-water Červená Magura–Vysoké Tatry zone (or Tatra type).

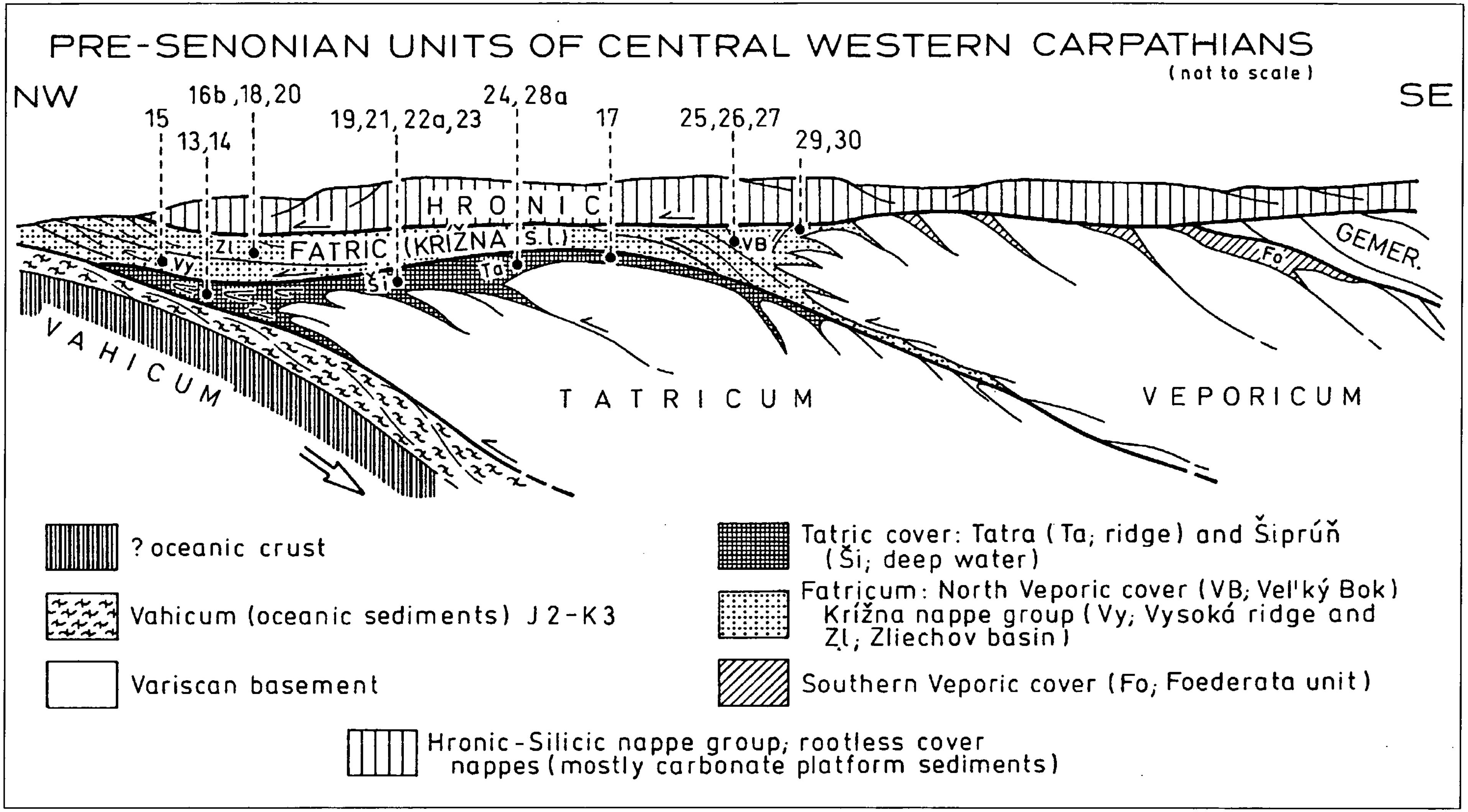
The Mesozoic complexes of the Šiprúň zone may be characterized structurally as flat-lying, autochthonous and/or parautochthonous with respect to their crystalline basement. However the marginal northern Tatric zones (Malé Karpaty, Považský Inovec and Malá Fatra Mts.) show important detachment of Mesozoic complexes and even large-scale recumbent folding of the basement/cover interface. The northernmost Tatric zone may be described as a system of short distance transported basement sheets or nappes which show significant shortening at the northern Tatric edge. Very low to low-grade metamorphic overprint in the cores of recumbent synclines and in subautochthonous footwall Mesozoic successions (e.g. Borinka unit of the Malé Karpaty Mts.) indicate stacking of some 5–7 km of tectonic load. Small-scale structural indicators as well as macroscopic fold architecture confirm a top-to-NW translation of thrust sheets (D. PLAŠIENKA et al., 1991).

Similarly, the Šiprúň/Tatra interconnecting zone is complicated by overthrusting and north trending recumbent folding in the Tatra basement and cover (Nízke and Vysoké Tatry Mts.). This means significant shortening between the Šiprúň and Tatra zones must be accounted for. There is however no doubt about the proximity of these two zones, not only in a present-day tectonic pattern, but in the original sedimentary area as well.

Shortening and thrusting inside the Tatric sheet is timed as Mid-Cretaceous, with the probable climax in the Upper Turonian, because of the youngest Tatric cover sediments being dated as Lower Turonian. Thrusting at the northern edge of the Tatricum continued into the Late Cretaceous however, as indicated by the involvement of Coniacian–Campanian sediments in the footwall of the Tatric overthrust fault (Považský Inovec Mts.) and by K/Ar dating of newly-formed micas in overthrust-related mylonites in the Tatric basement granitoids of the Malé Karpaty Mts. (about 75 Ma – M. PUTIŠ in M. KOVÁČ et al., 1991). The shortening and thrusting of the Tatric basement and cover utilized pre-existing crustal weaknesses inherited from the Mesozoic extensional period. Support for this is found in the Malé Karpaty Mts. Listric normal faults, forming asymmetric halfgrabens, inverted when suitably oriented to become overthrust faults (i.e. south-facing; D. PLAŠIENKA et al. 1991). In this way, the same fault plane has determined both the sedimentary content as well as the geometry of the thrust sheet itself.

The Krížna nappe group, or "stem nappe" (M. MAHEL', 1983), also called the Fatricum by D. ANDRUSOV et al. (1973), is a typical tectonic unit of the Central Western Carpathians. It overlies various Tatric units and is overlain by another important group of cover nappes – the Choč and the higher Hronic and Silicic units.

There are several major problems in the interpretation of the frontal parts of the Krížna nappe. Some authors (e.g. M. MAHEL', 1983, 1985 etc., J. MICHALÍK et al., 1987) consider the important Manín unit of the Periklippen belt (the zone between the northern edge of the Tatricum and the Klippen belt itself) as a partial, Vysoká-related unit of the Krížna nappe group. This is based on the resemblance or



Text-Fig. 3:
Hypothetical cross section of the principle units of the Central Western Carpathians in pre-Senonian time.
Numbers indicate assumed position of the studied localities cited in text (modified after D. ANDRUSOV, 1968 and after M. MAHEL', 1983).
The relationship of Vahic elements to the Central Carpathian units follows the interpretation of D. PLAŠIENKA (1992).

even correspondence of its Jurassic to Lower Cretaceous sequence to the Vysoká nappe. Most of the other authors (e.g.: D. ANDRUSOV, 1968; M. RAKÚS, 1977; R. MARSCHALKO, 1986; J. SALAJ, 1990) emphasize the continuation of the Middle to Upper Cretaceous succession and place the Manín unit paleogeographically north of the Tatricum.

If the Manín unit is in fact a constituent of the Krížna nappe group, one cannot exclude some other Periklippen units, such as Drietoma, Bosaca, Kostelec and even Klape as also belonging to it (at least their pre-Turonian formations). The inferred Upper Turonian timing of their thrusting however has not been identified in some stratigraphic sections which were deposited in deep-water facies.

The Krížna nappe is a relatively thin (1–3 km) overthrust sheet composed primarily of Lower Triassic–Middle Cretaceous carbonates. They were sheared off their original basement along shale and evaporite decollement horizons of Werfenian and Keuper age to form a widespread, completely allochthonous body. The nappe consists of numerous slices with recumbent folds and duplexes, but sections with relatively undisturbed stratigraphic successions are also present. From a lithostratigraphical point of view, the Krížna nappe is divided into two units – the Vysoká and Zliechov. The Vysoká unit contains shallow-water Jurassic successions similar to the Tatra, while the Zliechov is a corresponding deep-water succession. In Central Slovakia both units form independent nappe bodies, the Vysoká nappe being only tiny slices (Bela, Durcina, Havran) at the sole of the huge Zliechov nappe. At the western (Malé karpaty Mts.) and eastern (Branisko and Humenske vrchy Mts.) termination of the Tatricum, the Vysoká nappe becomes the main constituent of the Fatric and the Zliechov nappe gradually wedges out.

The southern extent of the Krížna nappe is limited by the northern edge of the Veporicum – another important crustal sheet of the Central Western Carpathians. It is not surprising that the boundary fault of the Tatricum and Veporicum – the Čertovica line is considered to be a suture, the "root zone" of the Krížna nappe. The sedimentary cover of the northern Veporic basement, the Vel'ký Bok unit has some similarities to the Krížna (Zliechov) type of successions, although its southernmost zones show clear shallowing during the Jurassic.

The Krížná-stem nappe and its associated partial nappes are far-travelled superficial gliding nappes, completely detached from their basement substratum. The basement-cover sheets and recumbent folds of the Lower Austroalpine, for example in the Radstädter Tauern Mts., closely resembles the nappe stack of the northernmost Tatric zones in the Malé Karpaty Mts. (D. PLAŠIENKA et al., 1991).

The evolution of the Krížna nappe can be explained using combined sedimentology and structural information found in the rock record. The architecture of the original Krížna basin can be reconstructed from the spatial distribution of shallow and deep-water successions.

In particular the central Zliechov trough was probably a lozenge-shaped domain some 50–100 km wide with fault-bounded halfgrabens on both its subequatorial flanks. The basin was formed by early Jurassic passive rifting and subsequent long-term extensional tectonics. The crustal extension was probably asymmetric with major low-angle crustal detachment faults inclined to the south.

Later on, attenuated crust could not support compressive stresses during the Mid-Cretaceous shortening. This resulted in extensive reduction through imbrication and underthrusting below the norhern Veporic crustal wedge. In front of the Veporic sheet, the Mesozoic infill of the Zliechov trough was detached from its basement and tegument (Permo–Triassic clastics). It accreted to the upper plate and formed a thick system of recumbent folds and imbrications. Southern Vel'ký Bok elements maintained their contact with the Veporic basement and formed large synmetamorphic recumbent folds.

The onset of compression at the southern flank of the Krížna basin is dated as Aptian–Lower Albian. At this time sedimentation in the Vel'ký Bok zone terminated and flysch deposition in the Zliechov through began.

Krížna basin substratum underwent shortening and underthrusting. Its sedimentary cover was detached and formed an accretionary prism with a trough in front of it where flysch sedimentation proceeded for about 20 Ma. In Lower Turonian the basin was filled in by sediments. Continuing convergence of the Tatric and Veporic zones allowed the Krížna thrust stack to overcome the southern counterslope of the Tatric frontal ramp and resulted in the development of high positive topography above the buoyant south Tatric continental ribbon.

It can be assumed, that this topographic high with basinal downslope foreland (Šiprúň trough) and continued push from the rear led to the northward gravity spreading and gliding of the Krížna pile to form a thin blanket covering the Tatric complexes. According to this interpretation, imbrications and recumbent folds of the Krížna nappe are not a result of their thrusting over the Tatricum but rather connected with shortening prior to gravity induced gliding.

Structural studies of the nappe sole reveal almost no influence of the Krížna nappe overthrust on the footwall structures. The overthrust mechanism probably was cataclastic flow within a thin layer with fluid overpressure at the overthrust plane interpreted as widespread hydrotectonic phenomena (W. JAROSZEWSKI, 1982).

Structural studies indicate the overthrust plane is often as a megastylolitic juncture, where considerable thickness of predominantly hanging wall carbonate rocks were removed by pressure solution during or immediately after thrusting. The original overthrust plane which is a zone of weakness has also been used during later tectonic events. In the case of extensional stress they form normal faults and under compression they form reverse and often back-thrust faults (conspicuously at the northern edge of the Centrocarpathic basement block – e.g. in the Malé Karpaty Mts.; J. MICHALÍK, 1984).

Similar hydrotectonic phenomena may have played a decisive role in the overthrust mechanism of overlying groups or superficial cover nappes, which are called either "the Choč and higher (sub-Tatra) nappes", or "the Hronic" – a term introduced by D. ANDRUSOV et al. (1973).

The timing of emplacement of Hronic nappes is quite precisly limited by the sediments of the Krížna nappe. The youngest sediments of the Krížná, below the overthrust plane, are of Cenomanian age (the lower limit) and the oldest post-nappe Gosau deposits on the top of the nappes are of Coniacian age (the upper limit). It can not be excluded however that younger sediments have been eroded or tectonically reduced.

The palinspastic reconstruction of the Hronic sedimentary area south of the Fatric is a problem. According to a common view, the Hronic nappes were pushed northward from the L'ubenik – Margecany cicatrix between the Veporic and Gemeric basement sheets. The basement shortening and nappe thrusting should have progressed through two stages – firstly, basement imbrication and low-grade metamorphism in thickened crustal domains and secondly, gravity gliding of superficial nappes overlying tectonically denuded areas (A. BIELY & O. FUSÁN, 1967). An alternative gravity spreading model of S. JACKO & T. SASVÁRI (1990) considers fluid push generated by subcrustal processes together with the externally driven basement shortening and telescoping effect of detached cover nappes to be the main overthrust mechanisms of the Western Carpathian nappes. The latter approach also requires piggy-back thrusting of a higher nappe during the activation of the lower overthrust plane. However, this can be only partly adopted for the outermost Centrocarpathic zones, where there is no structural and metamorphic gap between the individual constituents of the nappe stack (Tatric – Fatric – Hronic – Silicic).

Going further to the south, the structural and metamorphic disconformity between the footwall and hanging wall of the Choč and higher nappes increases. It represents at least 5 km of the rock column in the "root zone" of the Krížna nappe (metamorphosed Vel'ký Bok unit), 8–10 km in the southern Veporicum (parautochthonous Mesozoic Foederata unit vs. Muráň and Besnik nappes) and reaches up to 15–20 km between the HP-LT metamorphosed Meliata unit and the unmetamorphosed Silica nappe. These important rock masses should have been eroded before the inferred Turonian overthrust of the superficial cover nappes, i.e. during the Lower–Middle Cretaceous. It can therefore be assumed, that these missing rock volumes were important sources of the clastic material in the Mid-Cretaceous flysch deposits of the Krížná, Tatric and Periklippen belts.

A metamorphic and structural gap exists at the base of Hronic-Silicic nappes in southern parts of the Central Western Carpathians. This establishes long distance transport of these units to the Western Carpathians. These might be more probably placed southwestward of the present day Centrocarpathic domains. The search for an original palinspastic position of the Hronic–Silicic sedimentary area and the reconstruction of their structural evolution and emplacement history remains an important task of Alpine–Carpathian geology.

The following reference sections (see Text-Fig. 1) form the basis for the present discussion and paleogeographic reconstruction:

13) Borinka group + Bratislava group, Malé Karpaty (Tatricum)
14) Borinka group, Malé Karpaty (Tatricum)
15) Vysoká facies, Malé Karpaty near Smolenice (Krížna nappe)
16) Považský Inovec (Tatricum, 16a; Krížná nappe, 16b)
17) Envelope unit Tribec, NW Nitra (Tatricum)
18) Zliechov facies, near Partizanske (Krížna nappe)
19) Envelope unit Malá Magura, Strážovská hornatina Mts. (Tatricum)
20) Zliechov facies, Zliechov valley, Strážovská hornatina Mts. (Krížna nappe)
21) Šiprúň group, Vratna valley, Malá Fatra Mts. (Tatricum)
22) Šiprúň group (Tatricum, 22a) + Zliechov facies (Krížna nappe, 22b), Belianska valley, Vel'ká Fatra Mts.
23) Šiprúň, Lubochna valley, Vel'ká Fatra Mts. (Tatricum)
24) Červena Magura group (Tatricum)
25) Vel'ký Bok group, Hron Valley/Valaska (Veporicum)
26) Vel'ký Bok group, Hron Valley (Veporicum)
27) Vel'ký Bok group, Liptovska Teplicka (Veporicum)
28) Vysoké Tatry group (Tatricum, 28a) + Krížna nappe (28b; Belianske Tatry Mts., Zdiarska vidla).
29) Branisko Mts., Branisko saddle (Veporicum)
30) Čierna hora Mts., Ruzin barrage (Veporicum)
31) Belice unit (Vahicum ?)

3. Mesozoic Series of the Central Eastern Alps

(H. HÄUSLER)

Detailed mapping of the youngest sections of Lower Austroalpine and Penninic series of the Central Eastern Alps using microfossils has been done. Special emphasis was placed on examining the fine breccias and radiolarites. In spite of this more detailed investigation, biostratigraphic correlation was not possible.

The following areas of weakly metamorphosed Mesozoic outcrops of Lower Austroalpine, South- and Middle Penninic tectonic position were reinvestigated (numbers of sections referring to Text-Fig. 1). The most important characteristics of the following Mesozoic sequences are briefly described below in the Lower Austroalpine, the Nordrahmenzone, the Periphere Schieferhülle and from the Zentralgneis core.

3.1. The Lower Austroalpine

The best outcrops of Lower Austroalpine Mesozoic sequences are in the Tarntal Mountains (Tuxer Alps, Tyrol) and in the Radstadt Mountains (Niedere Tauern, Salzburg) at the corners of the Tauern window. The Mesozoic of the Semmering nappes (Lower Austria), along strike to the east, is the continuation of Lower Austroalpine nappes and leads to the Malé Karpaty Mts. (Little Carpathians) of Slovakia.

3.1.1. The Tarntal Mountains

Three main nappes, the Hippold nappe, the Reckner nappe and the overturned Quartzphyllite nappe in the highest position, can be distinguished from the Mieslkopf NE Matrei/Brenner up to the Tarntal Mts., SE of Innsbruck, overlying the Penninic Bündner Schiefer (H. HÄUSLER, 1988; see Text-Fig. 1, sec. 1).

The Hippold nappe consists of Paleozoic quartzphyllite, of Permoskythian quartzite and a Triassic section which has been mainly tectonically reduced. The Lower Jurassic changes rapidly vertically and laterally. It is about 300 m thick and contains the famous Tarntal breccia beds (with carbonate- and quartzite-clasts). In the paleogeographic reconstruction, it is proposed that coarse clastic material was derived from local scarps and deposited in a northern foredeep. The youngest Jurassic sediments are the manganese-bearing radiolarian schists.

The present sequence of the Reckner nappe consists only of Mesozoic rocks. They range from Anisian carbonates up to siliceous schists of the radiolarite niveau which are in contact with the serpentinite of the Lizumer and Naviser Reckner. The middle Triassic consists of Wetterstein-dolomite. The Upper Triassic contains thick carbonate rocks with Raibl beds, Hauptdolomit and fossiliferous Kössen beds. The Lower Jurassic is also rich in breccias (Tarntal breccia beds). The higher Jurassic contains the manganese bearing radiolarite schists, breccias, slaty schists and marble. These are in contact with the ophicarbonates of the Reckner serpentinite. For discussion of the nomenclature concerning the Lower Austroalpine ultramafics of the Reckner nappe see H. HÄUSLER (1988, p. 101).

3.1.2. The Radstadt Mountains

The Lower Austroalpine Mesozoic nappes of the Radstadt Mts. can be devided into three main nappes (including several slices). The lowermost Pleisling nappe is overlain by the Lantschfeld and the Hochfeind nappe. This sequence is again overlayn by the inverted Quartzphyllite nappe (H. HÄUSLER 1988; see Text-Fig. 1, sec. 10).

In the Hochfeind nappe, pre-Alpine crystalline basement (Tweng crystalline) is overlain by Alpine Verrucano and a basal quartzitic Triassic series (Lantschfeld quartzite). The Middle and Upper Triassic carbonates with Kössen beds grade into a carbonatic Jurassic sequence. Locally the Lower Jurassic contains some tens of meters of breccia beds (Türkenkogel breccia). A metaquartzite with lateral manganese bearing siliceous shales is interpreted to be a metaradiolarite of perhaps Lower Malmian age. The Upper Jurassic is represented by an enormous thickness of clastic (Schwarzeck breccia beds) which could extend up into the Lower Cretaceous.

The proposed great Jurassic rim between the Lower Austroalpine and the South Pennine as postulated by A. TOLLMANN ("Lungauer swell" of the Radstadt Mts.) has been revised by H. HÄUSLER (1988). The term "Lungau swell", however, is used in a new sense by D. PLAŠIENKA et al. (1991) as a hypothetical source area for the coarse clastic of the Somár breccia formation (Borinka group; Tatricum).

The stratigraphic sequence of the Lantschfeld nappe is not complete. The Tweng crystalline basement is overlain by the Lantschfeld quartzite, a Middle and Upper Triassic carbonate sequence and some slaty schists of Lower Jurassic age.

Like the Hochfeind nappe, the Triassic of the Pleisling nappe is underlain by Alpine Verrucano and Tweng crystalline basement. The Lower Triassic starts with Lantschfeld quartzite and is followed by Middle- and Upper Triassic carbonates. The Jurassic is rich in marble with some thin breccia beds and is exposed up to the radiolarite level.

The inverted Quartzphyllite nappe contains some crystalline of Tweng type, Paleozoic quartzphyllite, Lantschfeld quartzite and Middle Triassic carbonates.

3.1.3. Semmering Series

Similiar to the Radstadt Mts. the sedimentary cover of the crystalline basement (Grobgneiss) starts with Alpine Verrucano and a thick section of quartzite beds (Semmering quartzite). The development of the Middle Triassic is a carbonatic one. In Upper Triassic the Keuper facies dominates (compare G. WESSELY, 1975). Fossiliferous Rhäthian beds and Liassic spiculites are only known from boreholes in the Vienna basin (W. HAMILTON et al. 1990, Tab. 1).

The Permomesozoic of the Lower Austroalpine of the Eastern Alps can be summarized as follows: It generally overlies a crystalline basement. The Triassic is characterized by basal quartzites and well developed carbonates. The Upper Triassic changes from east to west, from Keuper to Hauptdolomit. The Dachstein limestone and Kössen beds occur in the Tarntal- and Radstadt Mts. Keuper beds indicate continental conditions in the Semmering area. The Jurassic section is varied and often includes breccia beds. Lower Cretaceous can be assumed but has not yet been proved.

The Hainburg mountains and the Little Carpathians (Malé Karpaty Mts.) were interpreted as the continuation of the Lower Austroalpine of the Semmering area by W. FUCHS & R. GRILL (1984). North of Bratislava, the post-Triassic series are well exposed from the early Jurassic (e.g. Borinka limestone – Ballensteiner Kalk; Marianka shales – Marienthaler Schichten) up to schists of Cenomanian/Albian age.

3.2. The South Penninic System

Low grade alpidic metamorphism and the rapid facies differentiation of Jurassic and Cretaceous formations of the "Nordrahmenzone", "Klammkalkzone" and the Rechnitz formation will be briefly described in order to form a base for comparison. In this paper, the term South Pennine in the Eastern Alps is used as defined by A. TOLLMANN (1977). Different points of view are evident in the nomenclature of the Lower Austrolapine/South Penninic facies area (see also discussion W. FUCHS, 1985). The same is true for the Triassic and Jurassic of the Ultrahelvetic/Middle Penninic facies zone (discussion W. FRISCH, 1975; reply A. TOLLMANN, 1987c; see also R. TRÜMPY, 1988, p. 102; Danubikum of the Eastern Carpathians: A. TOLLMANN, 1969, p. 1148). Some tectonic units, (e.g. Nordrahmenzone and Klammkalkzone) with a Triassic basement of the (former) Lower Austroalpine continental margin, are interpreted as South Pennine since Jurassic time. This is based on their present day tectonic position on the northern margin of the Tauern window as well as their special Jurassic–Cretaceous sediments (Bündner Schiefer). Since a biostratigraphic subdivision within the Penninic system is still lacking, paleogeographical reconstructions are proposed from a lithostratigraphic point of view (Tab. 1).

3.2.1. The Northern Frame of the Tauern Window ("Nordrahmenzone")

The northernmost formations of the Penninic Tauern window are termed "Nordrahmenzone". This northern casement of the Tauern window was effected only by low grade metamorphism and tectonically represents the highest Penninic zone. It is assumed to have been paleogeographically situated in the southernmost Penninic facies area. These South Penninic series are situated between the underlying "Periphere Schieferhülle" (Middle Pennine) and the higher Austroalpine nappes. They are well exposed in the Tarntal Mts. (Navis – Sägenhorst), the Penken-Gschößwand range and the Gerlos zone (Tyrol; W. FRISCH & F. POPP, 1981), south of Salzach valley (Salzburg, Ch. EXNER, 1979) and south of Zederhaus valley (Salzburg, Ch. EXNER, 1983).

The sequences generally include remnants of continental crust containing crystalline basement with Permomesozoic and Triassic cover. The Jurassic facies often contains beds of coarse clastic marine beds with carbonate olistholites of Lower Austroalpine origin. This indicates a paleogeographically close relation to the Lower Austroalpine continental margin for these South Penninic sediments.

Table 1.
Lithostratigraphic correlation of the Mesozoic of the Middle and South Penninic, Lower and Middle Austroalpine (mainly eastern Tauern window).

	MIDDLE PENNINE Ref. sec. 6	MIDDLE PENNINE 7 (5)	MIDDLE PENNINE 8	SOUTH PENNINE (12)	SOUTH PENNINE 2,3,4,9	LOW. AUSTROALPINE 10 (1)	LOW. AUSTROALPINE	MIDDLE AUSTROALP.	
	Rote Wand Nappe	GASTEINER N.	Periphere Sch.-H.	GLOCKNER N.	Nordrahmenzone	HOCHFEIND N.	PLEISLING N.	Rannach-, Thörl-,	
	Brennkogel fac.	SILBERECK SER.	(Marislwand slice)	Glockner fac.	'Klammkalk + Sdst.-Brecc.facies'	Hochfeind fac.	Pleisling fac.	Stubai Mesoz.	
CRETAC.	Jur. Brennkogel: Bündner Schiefer (+breccia beds)	Bündner Schiefer (+breccia beds)	Bündner Schiefer (+breccia beds)	Bündner Schiefer (+ophiolite)	Schiefer	?	?	calc. phyllite	CRET.
JURAS.	Bündner Schiefer (+breccia beds)	Bündner Schiefer (+breccia beds)	Bündner Schiefer (+breccia beds)	Bündner Schiefer (+ophiolite)	'Klammkalk' (+breccia beds)	Schwarzeck Ser. + brecc. beds / 'Radiolarite' / marble, shale + brecc. beds	shale + brecc. beds / Crin. marble	'Radiolarite' / calc. phyllite	JUR.
TRIASSIC UPPER	Triassic Seidlwinkl: Keupershales / Calcareous + Dolomitic marble	Calcareous + Dolomitic marble	Schrovin Group	primary missing	Keuper quartzite / Limestone + dolomitic marble	Kössen beds / Hauptdolomit	Hauptdolomit	Dolomite + limestone	TRIASSIC UPP.
MIDDLE	Calcareous + Dolomitic marble	Calcareous + Dolomitic marble	Schrovin Group	primary missing	Limestone + dolomitic marble	Dolom. + calc. marble, ± shales / Wetterstein Dolomite / Gutenstein limestone	Dolom. + calc. marble, ± shales / Wetterstein Dolomite / Gutenstein limestone	Dolomite + limestone	MID.
LOWER	Quartzite	Quartzite	Quartzite	primary missing	Quartzite	Lantschfeld quartzite	Lantschfeld quartzite	Quartzite	LOW.

Since Lower Cretaceous time this marginal facies area could have been involved in the sedimentation of the South Penninic ocean. Subduction and obduction processes can be postulated but no detailed proof has been found. The occurence of coarse clastic breccia beds with olistolithes could be of primary sedimentary origin (possible accretionary wedges) or the result of secondary tectonic thrusting. Use of these sections as a basis for a reliable reconstruction of post-Triassic facies development and of the sedimentary-tectonic processes is not yet possible because of the lack of microfossils.

3.2.1.1. The Penken – Gschößwand Range West of Mayrhofen/Zillertal (Tuxer Voralpen)

The Mesozoic of the Penken-Gschößwand range (Text-Fig. 1, sec. 2) is composed of Alpine Verrucano of Permian age, Lower Triassic quartzites, carbonatic Middle- to Upper Triassic and Lower Jurassic breccia beds (Penken breccia). Originally the Penken – Gschößwand range was thought to be Lower Austroalpine (E. KRISTAN-TOLLMANN, 1962). This unit has been reinterpreted by H. MILLER & B. VELS (1977) as an olistholit (of Lower Austroalpine origin) of the Bündner Schiefer and therefore appointed to the Penninic facies.

3.2.1.2. The Gerlos Zone

Previously termed as "Obere Schieferhülle", the Glockner nappe of the Gerlos zone (Text-Fig. 1, sec. 3) forms a plunging fold between the underlying Venediger nappe and the higher, inverted Quartzphyllite nappe.

Within the Glockner nappe, F. POPP (1984) discribed the following units: Wustkogel formation (Permotriassic), Middle Triassic dolomites, Keuper quartzite beds (Außerertens formation) and Bündner Schiefer of Jurassic to Lower Cretaceous age. Metamorphism is restricted to low grade metamorphism (low temperature greenschist facies).

The Lower Jurassic Bündner Schiefer contain carbonate-free black phyllites including breccia beds composed of carbonate and crystalline clasts and dolomitic olistholites (Richbergkogel zone; breccia type of Brennkogel facies). The basal black slates and calcischists of the Bündner Schiefer in the Krummbach valley NE of the village of Gerlos have been dated using *Echinoceras* sp. as Liassic Beta (determined by L. KRYSTYN; personal communication F. POPP, Vienna 1982). Some fragments of belemnites have also been identified (pers. comm. F. POPP) however no other fossils, and in particular microfossils, have been found.

There are also some sections of black phyllites within the Bündner Schiefer, which are intercalated by prasinites (Albit-Epidot-Chlorit-schists) and metadiabase, which can be interpreted as an indication of the "Glockner fazies"). This series of black phyllites is overlain by green stilpnomelan-bearing metaquartzite, which can be compared with the radiolarite niveau of the Lower Malmian. The overlying carbonates with some breccia influence can be compared lithologically to the bluish and greyish marble of the "Klammkalk" as well as to the "Hochstegenkalk".

The northern breccias of the Gerlos zone are called Richbergkogel zone after the moutain Richberg(kogel). The outcrops between Außerertens Alp and Isskogel show an intercalation of calcarous phyllites, slaty schists, black phyllites, matrix- and clast-supported breccia beds and greywackes. Rapid vertical facies variation and limited areal extent of the breccia beds indicates only local deposition. In some localities the coarse clastic sediments show a coarsening upward sequence (F. POPP, 1984; S. 251). Reconstruction of the eroded source area can be postulated from the following breccia clasts:

a) crystalline basement,
b) quartzites of Permoskythian age (including porphyr quartz),
c) carbonates of possibly Triassic age and
d) the direct base of the Bündner Schiefer, which contained slaty schists (clasts of black phyllites) and limestone (blue and grey marble clasts).

3.2.1.3. The "Nordrahmenzone" South of the Salzach River

The "Nordrahmenzone" of the Hohe Tauern is a term for the Penninic zone south of the Northern Calcareous Alps (south of Salzach river fault) and underlying the Grauwacken zone. Its main constituants are weakly metamorphosed Bündner Schiefer as e.g. black- and green phyllites, quartzites, marly schists, greenschists etc., and some tens of meters of calcareous marble ("Klammkalk"; Text-Fig. 1, sec. 4). Formerly the east–west striking zone between Fuscher and Rauris valley was termed the sandstone-breccia zone ("Sandstein-Breccienzone") and the zone containing the grey and blue marble of the "Klammpaß", as the Klammkalk zone.

These series have been remapped from a different point of view, based on a new idea of the age of these sediments. The east–west striking fine breccia beds and pebbly schists west of river Gasteiner Ache ("Permian" quartzite-breccia-porphyroid series; Ch. EXNER, 1979) have been parallelised with the breccia-bearing sericitic quartzitic schists of probably Cretaceous age of the range Gasteiner Höhe – Rainer Alp by H. PEER & W. ZIMMER (1980). In addition, these series resemble lithologically the green phyllites of Schwarzeck formation of the Radstädter Tauern (Hochfeind nappe).

As the tectonically strained breccia beds south of Gasteiner Höhe contain clasts of granitic gneiss, quartzite and carbonate rock as well as violet schists, a (? Middle Pennine) source area with crystalline basement, basal Triassic quartzite, Triassic carbonates and Keuper shales can be reconstructed. Possibly carbonates of Paleozoic age also existed. The huge carbonate blocks on the summits of Schuhflicker and Saukarkopf can be interpreted as olistholites within the clastic influenced chlorite-quartz-schists.

The folded metaquartzite on the summit of the Katzenkopf (south Anthaupten; "Post Triassic" after Ch. EXNER, 1979; section 4) can be lithologically compared with the varying metaquartzite of the Radstädter Tauern (Hochfeind nappe; Fuchslake area; metaradiolarite). It is a working hypothesis that the metaquartzite of the Nordrahmenzone could be an equivalent of the (? Lower Malmian) radiolarite (e.g. Schuhflicker area). The palynological proof of Lower Cretaceous age of the Bündner Schiefer surrounding the village Großarl (diploma field work by W. HUPAK und C. MEHLTRETTER) was published by E. REITZ et al. (1990). A more detailed reconstruction of the Jurassic and Cretaceous facies in the Southern Pennine and Lower Austroalpine facies is not yet possible due to the current lack of biostratigraphical data.

The recent attempts at biostratigraphical dating of the flysch-like sequences southwest of Embach (Rauris valley; J. ALBER, 1972), and Höferberg southwest of Taxenbach village (S. PREY, 1977) were not successful. The following working hypothesis for the stratigraphic correlation of the folded Klammkalk zone is postulated. A primary sequence of thin layered radiolarian metaquartzite (? of Lower Malmian age) below the Klammkalk can be postulated. The Klammkalk could laterally interfinger with a series of limestone, marly schist, phyllite and fine breccia beds and vertically change to breccia-bearing green phyllites of probably Lower Cretaceous age.

A. TOLLMANN (1977, p. 30) tectonically splits the northernmost part of the Nordrahmenzone, where the "Klammkalk" occurs. Therefore, he postulates its paleogeographic position as the southernmost Penninic facies area, the so called "Klammkalkfazies". The relationship of the Klammkalk zone to the sequence of dolomitic breccias and black phyllites north of Großarl (H. PEER & W. ZIMMER, 1980) and south of Embach (Anthaupten zone) remains an unsolved problem. It cannot be determined if this is a lateral facies change or due to tectonics, primarily because of a lack of biostratigraphic data.

3.2.1.4. The "Nordrahmenzone" South of the Zederhaus Valley

The position of the sequences between the Periphere Schieferhülle and the Lower Austroalpine of the Radstadt Mts. (Text-Fig. 1, sec. 9) is highly problematic. This zone is interpreted as a part of the so called Matreier zone by W. FRISCH et al. (1987, p. 60 f.). The Bündner Schiefer of the Nordrahmenzone contain blocks and complexes ranging from several meters to several kilometers thick which are of Lower Austroalpine origin (e.g. Rieding peak and Weißeck). They consist of Tweng crystalline, arkosic quartzite and Lantschfeld quartzite, Rauhwacke, dolomite and calcarous marble. The position of these boulders (olistholite versus tectonic slices) is not clear and Ch. EXNER (1983, p. 65) stated that in this zone it is impossible to distinguish between formations of the Nordrahmenzone and of the Lower Austroalpine.

3.2.2. The Glockner Nappe of the Hohe Tauern

Structure, stratigraphic sections and facies of the Glockner nappe were mapped by G. PESTAL (Geological Survey of Austria) in the Großglockner area (H.P. CORNELIUS & E. CLAR, 1935; 1939). Because of the well known problems of the differentiation of sedimentary and tectonic features, concerning breccia beds and ophiolitic rocks of the Bündner Schiefer, only a general outline is drawn here. According to A. TOLLMANN (1977, p. 42) the "Obere Schieferhüll-Decke" or Glockner nappe (in a newer sense) is characterized by the "Glockner facies", consisting mainly of calcareous micaschists and prasinites of post-Triassic age. These Bündner Schiefer are also rich in Jurassic breccias (containing primarily carbonate clasts). The Bündner Schiefer of the Glockner facies, situated paleogeographically south of the Brennkogel facies (Middle Pennine), are interpreted as the sedimentary cover of a newly generated oceanic crust.

3.2.3. The Rechnitz formation

East of the Tauern window no nappes are known which could be interpreted as an equivalent of the Zentralgneis-core, the nappes of the "old roof" or of the Schieferhüll nappe system. The Mesozoic of Rechnitz can be interpreted as being of South Penninic origin (Text-Fig. 1, sec. 12).

The easternmost outcrops of "Bündner Schiefer" in the Eastern Alps are in the Möltener-, Bernstein- and Rechnitz windows. The low grade metamorphosed Rechnitz formation (A. PAHR et al. 1984) contains quartzite of Lower Triassic age (Semmering quartzite), Rauhwacke, dolomitic and calcareous marble of Triassic age and Jurassic to Cretaceous phyllites including the conglomerate of Cák, calcischists, green-schists, metagabbro and serpentinites. The serpentinites, which occur at the top of the Rechnitz formation, were interpreted as tectonic slices by A. TOLLMANN (1977, p. 90). Recently these serpentinites have been reinterpreted as remnants of a nearly complete ophiolitic complex by F. KOLLER & A. PAHR (1980) with only pillow lavas missing.

H.P. SCHÖNLAUB (1973) established Cretaceous age for the limestones of the Rechnitz Bündner Schiefer. H. MOSTLER & A. PAHR (1981) found dolomite clasts of Middle Jurassic age in the Cák conglomerate. According to J. ORAVECZ (1979) the metamorphic Rechnitz formation of the Köszeg–Rechnitz area was not encountered by deep drilling in the Little Hungarian lowlands (e.g. bore hole Vat). The Cák conglomerate contains well rounded carbonate and gneiss pebbles as well as a dolomitic breccia with phyllitic matrix. This implies a source area with a crystalline basement and possibly Paleozoic and Mesozoic carbonates from which coarse clastic material was derived and episodically deposited in local areas (compare H. MOSTLER & A. PAHR, 1981, p. 89).

The synoptic interpretation of South Penninic sequences leads to the conclusion that before the opening of a South Penninic ocean in early Jurassic time, an area with remnants of continental crust existed, having a sedimentary cover of Paleozoic to Triassic age. The younger sedimentation (Bündner Schiefer) in the South Penninic ocean occurred mainly on newly generated oceanic crust. It shows some magmatic influence in a central part and locally coarse clastic influences from scarps of a more southern rim of the ocean. The coarse clastic deposits of Gerlos and Penken require individual scarps in Jurassic to Cretaceous time ("Klammkalk" facies area) north of the Lower Austroalpine (Hippold-) facies.

3.3. The Cover Units of the Zentralgneis Core (Middle Pennine)

The early Proterozoic (E. REITZ et al. 1989) and older Paleozoic basement (so called "old roof") which was penetrated by Paleozoic plutonites is discordantly overlain by sedimentary rocks of Permomesozoic age. The paleogeographic position of this (alpidic Zentralgneis-) zone is termed Middle Pennine by A. TOLLMANN (1990), as the eastern continuation of the Briançonnais. The Mesozoic sedimentary cover can be reconstructed using the outcrops of the Hochstegen zone, the Gastein nappe (Venediger nappe, Rote Wand nappe) etc. and of the "Periphere Schieferhülle".

At the Middle Penninic Jurassic swell facies type locality (Text-Fig. 1, sec. 5), at the village Hochsteg near Mayerhofen, the Zentralgneis is discordantly overlain by Hochsteg marble. The Bündner Schiefer group is characterized by breccias (so called "Brennkogel" facies comparable with the "Präpiemontais") within the Lower Schieferhüll nappe system (Rote Wand nappe) in the central and eastern parts of the Tauern window (e.g. Gastein nappe). In the western part of the Tauern window (e.g. Wolfendorn nappe and Venediger nappe), the Jurassic is characterized by limestone facies ("Hochstegen" facies) with overlying "Kaserer" series, which is also rich in breccias.

The composite stack of Middle Penninic origin consists of Middle Triassic dolomite, a few quartzite of probably Liassic age, up to 90 meters of Malmian Hochsteg (calcareous and dolomitic) marble and the thick Bündner Schiefer of Lower Cretaceous age (A. TOLLMANN, 1977, p. 26).

3.3.1. Seidlwinkl Triassic and Brennkogel Jurassic

The composite sequence of the so called "Brennkogel" facies (A. TOLLMANN, 1977, Tab. 2) of the Lower Schieferhüll nappe (Rote Wand nappe) starts with Alpine Verrucano. The well developed Triassic (= "Seidlwinkl Triassic") contains Lower Triassic quartzite, calcareous marble, dolomite and Upper Triassic Keuper shales (see Text-Fig. 1, sec. 6).

The thick "Bündner Schiefer"-development of Jurassic to Cretaceous age is characterized by the lack of ophiolites and extremely tectonically deformed breccia beds with dolomitic and quartzitic clasts (Brennkogel breccia beds; peak Brennkogel northwest of Hochtor, situated near the famous Glockner road).

3.3.2. Silbereck Series of the Gastein Nappe

Above the granitic gneiss of the Rotgülden gneiss core and a quartzite of Paleozoic age (pebbly quartzite of the Hafner Mts.) lies a Lower Triassic quartzite (Lantschfeld quartzite; Text-Fig. 1, sec. 7). The following carbonate sequences (dolomitic marble and calcareous marble; Silbereck marble) are assumed to be of Triassic age by Ch. EXNER (1983). The basal Bündner Schiefer contain breccia beds (dolomitic breccia of probably Liassic age) and are built up by an intercalation of green- and black-schists with calcareous marble. The clast-supported carbonate breccia of the basal Bündner Schiefer resembles the Türkenkogel breccia beds of the Hochfeind nappe lithológically. The matrix-supported breccia, with green phyllitic intercalations, resembles the Schwarzeck breccia of the Lower Austroalpine of the Radstädter Tauern. A calcareous quartzite with biotite (Ochsenkar-Sulzkopf-section north-east of the Silbereck peak) is interpreted as a Malmian radiolarian quartzite by Ch. EXNER (1983). The higher Bündner Schiefer are built up by black- and greenschists and ophicalcit.

To summarize, the Middle Pennine of the Tauern window is characterized by only a few remnants of Permomesozoic having primary sedimentary gaps and Triassic and Jurassic sequences which are extremly variable in an east–west direction (local swells: Hochsteg facies; local basins: Seidlwinkl Triassic and Brennkogel breccia beds; locally well developed Silbereck serie). As in the Rechnitz area, no Zentralgneis nappes with comparable Permomesozoic have been found, the continuation of the Middle Pennine east of the Tauern window is therefore very hypotetical (A. TOLLMANN 1986, section 1–3; see annotation).

3.3.3. The "Periphere Schieferhülle"

The "Periphere Schieferhülle" is defined as the tectonically truncated former cover series of the Zentralgneiscores. They are of Paleozoic to Mesozoic age and are now found as marginal sequences at the periphery of the Zentralgneis-domes. The peripheral coverschists of the Hafner Mts. (Text-Fig. 1, sec. 8) are divided into three internally folded sequences (Ch. EXNER, 1983):

a) Lower sequence: The Murtörl series (pass Murtörl) consisting mainly of blackschists of possible Paleozoic age.
b) Middle sequence: The sliced Schrovin series (Schrovin peak north of village Muhr) is composed of gneisses with Permotriadic cover sediments. The Permoskythian corresponds to the Wustkogel formation and the Triassic to the Seidlwinkel Triassic.
c) Upper sequence: The top of the complex is built up of sliced Bündner Schiefer.

The Middle Penninic cover of the eastern Tauern window containes Paleozoic (Murtörl serie), Triassic (Schrovin serie) and Bündner Schiefer. Whether the mentioned boulders of Lower Austroalpine facies within the Bündner Schiefer are tectonic remnants of alpidic time or Jurassic to Cretaceous olistholites, has not yet been solved.

3.4. Mesozoic of the Middle Austroalpine

Paleogeographically the Middle Austroalpine is bounded to the north by the Lower Austroalpine and to the south by the Upper Austroalpine.

According to A. TOLLMANN (1977, Tab. 9), the transgressive Permotriassic facies relationships can easily be reconstructed from outcrops in the Rottenmanner Tauern (Rannach series; Styria), the Thörl area (Styria), the Semmering area (Lower Austria) and the Stubai Alps (Tyrol).

The Triassic contains quartzite (Semmering type), middle Triassic limestone (e.g. white Thörler limestone, greyish dolomite – Anisian) and dolomite (Ladinian). Locally Keuper gypsum or Raibl beds occur. The Triassic and Jurassic can be composited by the Stangalm-Mesozoic below the Gurktal nappe and by the Stubai Mesozoic. Referring to A. TOLLMANN (1977, Tab. 13) the Upper Triassic carbonates of the Stangalm-Mesozoic contain limestones and dolomites. Siliceous calcareous schists, manganese bearing red radiolarites and calcareous phyllites represent the Jurassic. The Jurassic of the Brenner (= Stubai) Mesozoic also contains some breccia beds (l.c., Tab. 15). Occasionally when Mesozoic sedimentation continued into the Jurassic, Upper Triassic may still be missing due to either primary (Piz Lischana, Engadin) or tectonic reasons (Norian of Stangalp).

4. Mesozoic Complexes of the Northern Zones of the Central Western Carpathians

(D. PLAŠIENKA & M. POLÁK)

The northern zones of the Central Western Carpathians comprise the Tatricum, the Krížna nappe group and the Veporicum.

The Tatricum comprises the so-called core mountains, with a crystalline basement and its autochthonous to parautochthonous, sedimentary Late Paleozoic to Mesozoic cover. In this paper the Malé Karpaty Mts. (Little Carpathians), the Považský Inovec Mts., the Šiprúň-, Červená Magura and Vysoké Tatry groups are type localities for the Mesozoic cover units of the Tatricum. The Mesozoic facies of the allochthonous Krížna nappe system is named Fatricum. Krížna nappe type of the Vysoká facies represents shallow water sedimentation during the Jurassic. Krížna nappe type of Zliechov facies is characterized by Jurassic deep water sedimentation. The Mesozoic facies of the northern part of the Veporic crystalline basement (with its parautochthonous Late Paleozoic–Mesozoic cover) in the Nízke Tatry Mts. and Braninsko and Čierna Hora Mts. is called Vel'ký Bok-succession.

All these units exhibit similiar paleohistoric trends and are closely related by mutual interconnections, e.g. the Krížna cover nappe by its basal digitations with the underlying Tatric successions and by its structures with the Vel'ký Bok unit confined to the Veporic basement. The similiar paleogeographic evolution of these zones is based on the presence of some characteristic lithostratigraphic units and in common paleotectonic events. The Bajuvaricum, as represented by the Frankenfels–Lunz nappe west of Vienna, also displays these characteristics, which are listed below.

1) Lower Triassic quartzose sandstones (Lužna formation).
2) Middle Triassic shelf carbonates (mostly Gutenstein and Wetterstein formations).
3) Thin intercalations of the Lunz beds in the Krížna and Vel'ký Bok units.
4) Hauptdolomite and distinctive Carpathian Keuper formation in the Upper Triassic.
5) Early Jurassic break-up of the Triassic paleogeography was expressed by deposition of alternating zones characterized by a deep-marine, mostly pelagic sedimentation (Šiprúň and Zliechov troughs) and by a shallow-water or pelagic ridge sedimentation (Tatra high).
6) Maximum subsidence during the Oxfordian (Radiolarites).
7) Pelagic biancone type limestones during the Neocomian.
8) Uniform sedimentary conditions at the end of Early Cretaceous and terminal siliciclastic flysch deposition (Poruba formation, except the Vel'ký Bok unit) during the Albian and Cenomanian, as late as Lower Turonian in the northern Tatric zones.
9) Basement shortening and emplacement of cover nappes advancing from the south, starting in the Albian (Vel'ký Bok unit) and terminating during the Upper Turonian to Lower Senonian.

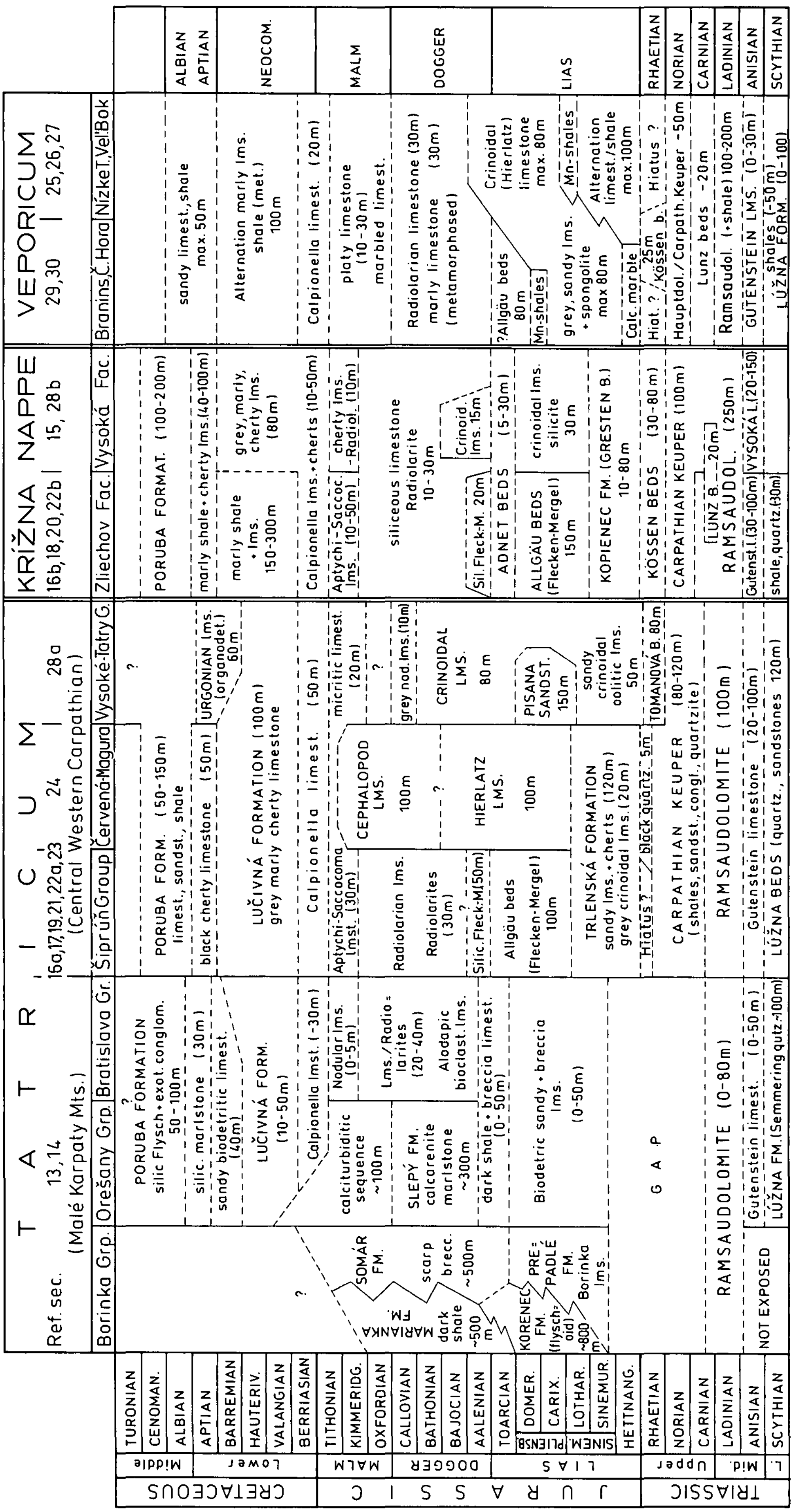
The Tatricum and Krížna nappe are classical terrains of Carpathian Mesozoic stratigraphy, especially Jurassic to Lower Cretaceous. This is in contrast to the Vel'ký Bok unit, which has been studied from a structural point of view due to its low-grade metamorphism and strong deformation.

The main criteria for the association of Mesozoic successions to the Tatricum or to the Fatricum (Krížna) are their tectonic position and basement relation. The Tatric successions are generally confined to the pre-Alpine basement, whereas Krížna successions are stripped off along the Werfenian shale horizon. Krížna nappes tectonically overly Tatric rocks in the whole area.

4.1. The Cover Units of the Tatricum

Mesozoic complexes of the Tatricum (= cover units = envelope units) are exposed in the "core mountains" of the Central Western Carpathians. They form a sedimentary cover of the pre-Alpine crystalline basement which is

Table 2.
Lithostratigraphic correlation of the Mesozoic of the Tatricum, Krížna nappe and North Veporic of the Western Carpathians



composed of biotitic paragneisses with subordinate amphibolite bodies, several types of migmatites and numerous granitoid massifs. Most of the metasedimentary rocks are probably of Early Paleozoic age, with medium- to high-grade metamorphism and with granitoid plutonism during the Variscan orogeny (about 420–280 Ma).

The lithostratigraphic content of the Tatric cover includes scarse Upper Permian terrestrial clastics (exceptionally thick Late Paleozoic sediments are preserved in the outermost Tatric zones of Považský Inovec and Malá Fatra Mts.), Lower Triassic clastics, Middle Triassic carbonate platform sediments, Upper Triassic continental-lagoonal and shallow-marine sediments, several lithofacial types of mostly carbonate Jurassic to Lower Cretaceous formations and Middle Cretaceous (up to the Lower Turonian) flysch sequence (Tab. 2).

In the present paper, we subdivide the Tatric realm into three subparallel longitudinal zones with characteristic lithostratigraphic contents. These are as follows:

❶ the northern (or rather the north-western) Malé Karpaty – Považský Inovec zone as a dissected, partly shallow-water domain (Text-Fig. 1, sec. 13, 14, 16),

❷ the broad Šiprúň deep water basin in the centre

❸ the southern Červena Magura – Vysoké Tatry shallow water swell (Text-Fig. 1, sec. 28a).

4.1.1. The Borinka-, Orešany- and Bratislava Group of the Malé Karpaty Mountains (Little Carpathians)

The Malé Karpaty Mts., an isolated island amidst Tertiary flatlying sediments, represent an important link between the Alps and Carpathians. The Tatric Mesozoic successions have been divided into three major tectonic units (D. PLAŠIENKA, 1987; D. PLAŠIENKA et al., 1991), the Borinka unit, the Orešany unit and the Bratislava unit (Text-Fig. 1, sec. 13, 14), which is an extensive allochthonous basement sheet overlying the Borinka and Orešany units.

The Borinka unit is a subautochthonous element (tectonic window) and consists mostly of Jurassic rocks. These overlie Middle Triassic carbonate rocks. The Upper Triassic rocks are interpreted as missing due to erosion during Early Jurassic rifting processes. Lower Triassic rocks probably exist, but do not crop out.

The reconstruction of the Mesozoic paleogeography (D. PLAŠIENKA et al., 1991, Fig. 3) shows the Borinka Halfgraben (Borinka group) in the north and the Oresany group in the south of an erosional swell in Jurassic time. Farther to the south the Mesozoic graben- and horst structures of the Bratislava unit are devided (from west to east) into the Devín- and Kuchyňa basin, the Kadlubek high and the Solírov basin. The most important Jurassic formations of these three units (Borinka-, Orešany- and Bratislava group; Tab. 2) are briefly described:

1) The Jurassic Borinka group is the only surface representative of the subautochthonous Borinka unit, a probable Infratatric basement-cover sheet. The lithostratigraphic content of the Borinka group differs considerably from other Tatric successions due to the prevalence of coarse clastic sediments. The Borinka group consists of the Prepadlé formation, the Koronec formation, the Marianka formation and the Somár formation.
   The Prepadlé formation is represented by up to 200 m of extraclastic mud-supported breccia limestones (Borinka or Ballenstein limestone) with some bioclastic lenses, marly shales and quartzose sandstones. It is of Lower Jurassic (Sinemurian) age and occasionally contains olistolites of the immediately underlying Triassic carbonates. Towards the NW, the Prepadlé formation interfingers with the Korenec formation, which is made up of 800 m of siliciclastic marly turbidites. It is overlain by the Marianka formation consisting of 200 m of dark anoxic marly shales with some Mn-bearing intercalations (Toarcian). This formation cannot be compared with the primary Bündner Schiefer facies of the Eastern Alps because no greywackes or volcanic layers occur within the Marianka shales. The conspicuous Somár breccia formation is developed in a proximal position above the Prepadlé fm. It is up to 500 m thick and is composed of several 50–100 m thick bodies of unsorted clast-supported (mixtitic) breccias containing primarily clasts of crystalline basement, as well as olistolites (up to 200 m in diameter) of Triassic quartzites and carbonates. Breccia bodies are separated by lenses of quartzose sandstones and limestones yielding Middle–Upper Jurassic microfauna. It cannot be excluded, that Somar breccias may pass up to the Lower Cretaceous.
2) The Orešany group is a Jurassic–Middle Cretaceous sequence of another subautochthonous Tatric unit of the Malé Karpaty Mts. – the Orešany unit. It is made up of pre-Alpine basement, some Permian arkoses, Lower Triassic quartzites and scattered remnants of deeply eroded Middle Triassic carbonates. The base of the Orešany group consists of lenses of pale bioclastic sandy limestones (?Sinemurian–Pliensbachian, 0–20 m), then dark shales and extraclastic breccia limestones (?Toarcian, 0–50 m) followed by up to 300 m of turbiditic calcarenites and marlstones (Slepý formation, Middle Jurassic). It is often deposited directly on Lower Triassic quartzite. The calciturbiditic Slepý formation (200 m, ?Aalenian–Bajocian) is overlain by a body of sandy bioclastic limestones (Barremian Solírov formation), some 30 m of silicified marls and bodies of hyalobasanitic lavas (?Aptian–Lower Albian) and final the Poruba formation – up to 100 m of siliciclastic flysch with lenses of conglomerates from exotic sources.
3) Beside the pre-Alpine basement the Bratislava group contains several Mesozoic successions with differring lithostratigraphic content, especially in the Jurassic interval. All are juxtaposed with respect each other. Pre-Jurassic formations were largely eroded prior to the Jurassic transgression and rarely preserved. The Bratislava group consists of the Devín-, Kuchyňa- and Kadlubek succession.

The Devín succession is composed of the Permian Devín formation (A. VOZÁROVÁ & J. VOZÁR, 1988), Lower Triassic quartzites, Middle Triassic limestones and dolomites with fissures and cavities filled and overlain by breccia limestones of Lower Jurassic age. They are followed by siliceous limestones and radiolarites (Oxfordian), nodular limestones (Kimmeridgian), thick-bedded Calpionella limestones (Tithonian–Berriasian), thin-bedded cherty limestones (Neocomian) and grey shales (?Aptian–Albian).

Lower Jurassic breccias and sandy limestones of the Kuchyňa succession were often deposited directly on crystalline basement. Dark marly and spongolitic shales (20 m) probably represent the Toarcian ingression. Middle–Late Jurassic evolution is recorded by a siliceous sequence with some turbiditic bioclastic limestone intercalations (20–40 m). The Tithonian–Neocomian is represented by the Calpionella limestone (30 m) and grey cherty limestone (Lučivná formation – 50 m). The Barremian–Aptian sequence contains dark siliceous and marly shales with allodapic bioclastic layers and relatively large hyalobasanitic lava flows. The Poruba formation (Albian–Cenomanian flysch) attains only 20–50 m.

The Kuchyňa succession passes laterally into the Kadlubek succession, marked only by several tens of meters of Jurassic–Lower Cretaceous shallow-water variegated limestones and is overlying Lower Triassic quartzites. The Lower Jurassic is represented by yellowish and pink crinoidal limestones. The Toarcian is represented by hematitized red nodular limestones. The Middle–Upper Jurassic to Lower Cretaceous has massive bioclastic, often intraclastic breccia limestones with features of condensed sedimentation, erosion, neptunic dykes etc. These are also overlain by the Poruba formation.

The Solírov succession is almost identical to the Kuchyňa. Differences occur in its detachment at the base of the Jurassic sequence and the characteristic presence of Barremian Solírov formation (J. JABLONSKÝ et al., 1991) – fluxoturbiditic sandy bioclastic limestones up to 50 m thick. The Solírov succession tectonically overlies the Orešany group at the NE corner of the Malé Karpaty Mts.

Deep erosion of the Triassic carbonate platform during the Lowermost Jurassic was followed by development of the deep-water domains which were separated by a (possibly) subaerial high during the entire Jurassic. All clastic sequences were supplied with terrigeneous material from local sources until the Barremian, when widespread Mid-Cretaceous subsidence occured. Local topographic difference diminished with the onset of flysch sedimentation and a more uniform paleotectonic evolution resulted. Some of the crustal fault structures developed by Jurassic rifting and extension were utilized during Upper Cretaceous shortening and were inverted into low-angle thrust faults (D. PLAŠIENKA et al., 1991).

4.1.2. The Tatricum of the Považský Inovec Mountains

Other important "core mountains" of the Central Western Carpathians are the Považský Inovec Mts. (Text-Fig. 1, sec. 16a). The Tatric Mesozoic series is underlayn by slices which are probably of Vahic origin (sec. 31) and overlain by the Mesozoic of the Krížna nappe (Zliechov fac., sec. 16b). They are NE of the Malé Karpaty Mts. and separated by the Tertiary filling of the Piešt'any embayment of the Danube (Kisalföld) basin.

Central areas are made up of the Tatric basement and its Šiprúň-type Mesozoic cover, but in the northern part, important infratatric sequences crop out. The Tatric complexes form a system of large-scale recumbent folds truncated by high-angle out-of-sequence thrusts. This creates an antiformal thrust stack, where footwall sediments below the Tatric overthrusting plane are squeezed between basement imbrications. They reach the surface only in the Western Carpathians and although only a small and poorly preserved succession is present, it provides an unique opportunity to gain an insight into the structure and evolution of the outermost Tatric elements.

The rudimentary Infratatric succession (Belice unit; Text-Fig. 1, sec. 31) consists of tiny slices. Upper Jurassic is represented by deep-water siliceous shales and radiolarites (M. PETERČÁKOVÁ, pers. comm.). They are followed by variegated pelagic marlstones of the couches rouges-type (Turonian – J. SOTÁK, pers. comm.) and siliciclastic flysch sequence of the Senonian (Coniacian–Maastrichtian? – A. KULLMANOVÁ & V. GÁŠPARÍKOVÁ, 1982; J. SOTÁK, pers. comm.). This flysch includes bodies of polymict conglomerates and mixtitic breccias containing olistholites of Tatric crystalline basement, Permian rocks, Triassic carbonates, Lower to Middle Jurassic sandy limestones and mafic volcanics of unknown provenance. This whole succession resembles a strongly imbricated melange (without ophiolite development however), in the footwall of the Tatric overthrust. This can hardly be compared with other successions forming the Klippen and Periklippen Belts in front of the Tatric sheet. Consequently, we presuppose a South Penninic (Vahic) appertenance of the Belice succession, which was detached.

4.1.3. The Šiprúň-, Červená Magura- and Vysoké Tatry Groups

Three groups of Mesozoic rocks from the Central Western Carpathians are described, the Šiprúň group (Text-Fig. 1, sec. 17, 19, 21, 22a, 23), of the Červená Magura group (sec. 24) and the Vysoké Tatry group (sec. 28a).

Triassic sedimentation began in all regions with deposition of the transgressive detritic Lužna Formation (O. FEJDIOVÁ, 1980). It is Lower Liassic age and composed of light coloured middle to fine-grained quartzose sandstones and sandstones with conglomerate layers in basal parts. In the upper part of the formation, pelitic sediments (claystones) are more abundant than sandstones. The thickness of Lužna Fm. varies from 30 to 100 m. Sedimentary environment can be interpreted as shallow water, beach and/or continental fluvial (braided river environment).

Platform carbonate sedimentation started in Middle Triassic. In basal parts dark-grey to black bedded Gutenstein limestones of Anisian age predominate and represent the deeper part of basin. The Ramsau dolomite of Anisian to Ladinian age is grey to dark-grey, mostly fine-crystalline and occasionally containing Dasycladaceae. The thickness of Gutenstein limestones is 50–150 m. The Ramsau dolomite attains locally up to 200 m. In the Tríbeč Mts. both rock types are often weakly metamorphosed. Intercalations and layers of black bituminous shales occur within the dolomites which in some cases could correspond to Lunz beds. A substantial part of Carnian however, probably represents a stratigraphical hiatus.

In Upper Triassic (Norian) Carpathian Keuper as a continental facies points to a regressive period. In the Tatric envelope units it is mainly detritic, consisting mostly of variegated material (quartzsandstones). The upper part is composed of variegated coarse and medium-grained sandstones. Total thickness does not exceed 120 m. The uppermost Triassic (Rhaetian) represents a depositional hiatus in the envelope units of the Central West Carpathians. A small amount can be found in the western part of the Western Carpathians (Považský Inovec Mts., Tríbeč Mts. and Strážovské vrchy Mts.). In the Vysoké Tatry Mts. Rhaetian is represented by the continental sedimentation of the Tomanová formation (J. MICHALÍK et al., 1976).

The Jurassic sedimentary cycle in the Tatric envelope sequences starts with an easily identifiable transgression. The base is usually composed of dark-grey, sandy and sandy-crinoidal limestones, which vertically change to crinoidal and fine-grained, locally organogenic limestones. They often contain nodules and layers of dark and black chert – Trlenská Formation (A. BUJNOVSKÝ et al. 1979a). The age of this transgressive sequence is Hettangian–Sinemurian, and it varies from 50–150 m in thickness.

Stable conditions gave way to basin deepening during the Lotharingian. Euxinic conditions resulted in the deposition of up to 100 m of dark-grey to black shales with marly limestone intercalations called the Allgäu beds (Fleckenmergel). These conditions persisted until the Toarcian. This stratigraphic interval is represented by the Hierlatz formation in the Červená Magura sequence. In the Vysoké Tatry sequence it is represented by Pisana sandstones (Sinemurian–Domerian) and crinoidal limestones containing a large amount of detrital material (up to Bathonian). Subsidence of the Carpathian sedimentary area continued and the depth reached a maximum in the Dogger with only 20 m of silicified radiolarian limestones and radiolarites in the Šiprúň facies area.

In contrast, the Cephalopod limestones were deposited in the Červená Magura sequence and in the Tatric envelope sequence of the Vysoké Tatry Mts. grey nodular limestones of Bathonian to Callovian age are found. The overlying lithostratigraphic unit is represented by thin-bedded Aptychi-Saccocoma limestones, which only occasionally develop nodules. The age of the basal Aptychi limestones is determined by microfauna as Kimmeridgian. They do not exceed 25 m in the envelope sequences and change vertically into bedded grey marly Calpionella limestones of Tithonian age. In the Vysoké Tatry sequence, limburgites and their tuffs are also found in the Tithonian.

The overlying Lúčivná Formation (Berriasian–Lower Aptian) contains bedded, grey marly limestones with nodules of dark-grey to black silicites and attains a maximum thickness of 150 m. In the Vysoké Tatry Mts., the Barremian–Aptian interval is composed of Urgonian limestones with a maximum thickness of 60 m. The Aptian of the Šiprúň and Červená Magura sequences is up to 50 m and represented by dark-grey to black, marly to cherty limestones with intercalations of marly shales. This sequence of variable limestones and marly shales grades into the overlying Poruba Formation. It is characterized by an increasing supply of clastic material and the appearance of sandy components in the limestones. It is transitional to the characteristic flysch type sedimentation, with an alteration of sandstone and claystone. The age of Poruba Fm. is Albian to Lower Turonian (Vysoké Tatry Mts.) and the thickness of the sequence does not exceed 150 m.

4.2. The Krížna Nappe group (Fatricum)

The Krížna nappe group is an extensive tectonic unit which is very well developed in the Western Carpathians (Text-Fig. 1, sec. 15, 16, 18, 20, partly 22 and 28). It represents the basic nappe element of the Fatricum (D. ANDRUSOV et al., 1973) which is made up of numerous small nappes or slices (e.g. Vysoká-, Bela-, Durcina- and Havran nappes).

The Krížna nappe is characterized by deep water Zliechov facies sedimentation (M. MAHEL', 1967). This is in contrast to the Vysoká facies of the Vysoká and Bela nappes which show predominantly shallow water sedimentation in the Jurassic. The stratigraphic interval of the Krížna nappe is Lower Triassic to Cenomanian, with only minor stratigraphic breaks.

The sedimentation of the Fatricum began with the Lower Triassic Lúžna Formation, which has a maximum thickness of 20 m. It is poorly preserved due to tectonic shearing as the principal detachment plane of the Krížna nappe lies above the Lúžna quarzites in the Werfenian shales. Lithologically it is very similiar to the Lúžna fm. in the Tatricum.

The Middle Triassic is characterized by shallow-water, carbonate platform sediments, the lower part being the Anisian Gutenstein limestones. In the Malé Karpaty Mts. the Vysoké limestones occur as an equivalent, with a maximum thickness of 100 m. The massive Ramsau dolomit of Anisian to Ladinian age attains a maximum thickness of 200 m. In the Tríbeč Mts. thick layers of light-grey, bedded, weakly metamorphosed crystalline limestones are common in the Middle Triassic. The lower part of the Upper Triassic (Julian) is characterized by typical Lunz beds with a maximum thickness of 20 m. The upper part of Carnian consists of 50–80 m of dolomite. The Norian is represented by up to 100 m of Carpathian Keuper, which is lagoonal and shallow-water deposits. Lithologically it is composed of variegated shales, primary dolomites and only a few sandstone beds. The Raetian is represented by Kössen beds – Fatra formation of dark organodetritic and often organogene (coral) limestones with intercalations of dark marly shales. The Fatra Fm. does not exceed 80 m. The predominance of shales and dolomite in the Carpathian Keuper and Kössen beds in the Fatricum (Krížna nappe) is the main difference compared to the Tatric envelope units, where sandstone Keuper is abundant.

The Jurassic sedimentary cycle of Zliechov facies starts with up to 80 m of transgressive Kopienec formation (Hettangian to Sinemurian). The sediments consist of psammitic material, dark crinoidal limestones, shales, organodetritic limestones and sometimes spongolites. The depositional environment was well aerated, strongly agitated and with a significant amount of clastic material. The upper part of Liassic (Lotharingian–Domerian) in Zliechov facies contains 100 m of euxinic Allgäu beds (Fleckenmergel) which consist of alternating dark, marly, spotty limestones and shales. Very often the uppermost Liassic (Toarcian) is represented by 15–20 m of locally deposited red nodular limestones (Adnet beds).

Sedimentation of the Vysoká facies also consisted of crinoidal limestones and red nodular limestones of Upper Liassic age. In the deepest sedimentary environment of the Carpathian geosyncline belt, 30–50 m of radiolarian limestones and radiolarites of Dogger–Oxfordian age found.

In the Zliechov facies up to 30 m of Aptychi-Saccocoma limestones gradually developed from the underlying radiolarian sequence and show variegated, grey, often nodular limestones of Kimmeridgian age.

In the Vysoká facies, 30 m of red nodular (Czorsztyn) limestones of Kimmeridgian–Tithonian age are described. The Upper Berriasian–Barremian (Neocomian) is represented by marly limestones, shales and marles of about 300 m thickness. The up to 50 m of Padla Voda Formation (Aptian) consists of massive black, organodetritic shallow-water limestones and marly limestones with siliceous cherts.

The Mesozoic sedimentary cycle of the Zliechov facies ends with the deposition of 200 m of Poruba Formation, represented by flysch sedimentation of Albian–Cenomanian age.

The Mesozoic lithostratigraphy of the Tatricum and the Fatricum (Krížna) is very similar (Tab. 2). The main differences between these units are: Lunz beds are only known from Krížna, Carpathian Keuper contains more sandstone in the Tatric and more dolomite in the Krížna. Rhaetian rocks are rarely preserved in the Tatric (continental facies), while Kössen beds are found in the Krížna. The Lower Jurassic (sometimes even Upper Liassic) is transgressive in the Tatric, while the Krížna sequence is complete. Jurassic to Lower Cretaceous basinal and ridge facies occasionally differ in both units. Poruba flysch fm. ends in the Middle Cenomanian in the Krížna and in the Late Turonian in the Tatric.

4.3. Veporikum – The Mesozoic of the Vel'ký Bok Group (Nízke Tatry Mts., Branisko, Čierna Hora Mts.)

The Veporicum consits of a crystalline basement with two Mesozoic units, the Vel'ký bok series and the

Foederata series. In the Nízke Tatry Mts. and Branisko-Čierna hora, Mesozoic outcrops displaying dynamic metamorphism are found (Vel'ký Bok sequence). They are in parautochtonous positions on the crystalline complexes of the Veporicum. Their distinct common feature is the weak grade of metamorphism with a strong dynamic component (Text-Fig. 1, sec. 25–27, 29–30).

The basal complexes are formed by the Lower Triassic Lúžna formation, made up of variegated quartzites and shales. The Middle Triassic is of characteristic carbonate development. The Anisian Gutenstein Limestone attains a maximum thickness of 50 m. The main rock type is the Anisian to Ladinian Ramsau dolomite, containing intercalations of dark shales in the upper parts. Generally, the dolomites are strongly recrystallized. The Lower Carnian is represented by Carpathian Keuper, consisting of a complex of variegated shales, dolomites and quartzites. Claystones are distinctly dynamically metamorphosed as shown by the linear distribution of fabric components. The Rhaetian (Kössen beds) was deposited only in the Čierna hora Mts.

Distinct differentiation of the simple Triassic sedimentation began in early Liassic and is reflected in the facies variety of Jurassic sediments. Lower Liassic sedimentation in the Branisko Mts. is characterized by cordillera facies – black crinoidal cherty limestones. In the lower part of the Vel'ký Bok sequence, black marly shales with intercalations of crinoidal limestones occur. These limestones are more common in the upper part (of the Vel'ký bok sequence) where indications of manganese mineralization were found. Metamorphic influences are distinctly manifested in the linear alignment of fabric components and the growing of new minerals (chlorite, sericite, feldspars, prehnite?).

The Upper Liassic is represented by Allgäu beds. Already in the Dogger, variegated radiolarian limestones and radiolarites are known. In Branisko, these rocks are intensively folded. Above are light grey, pinkish thin-bedded marly to shaly limestones. In the Vel'ký Bok sequence, relatively weakly metamorphosed Kimmeridgian Saccocoma limestones are found, whereas in Branisko and Čierna hora Mts. the major part of the whole Mesozoic succession is distinctly metamorphosed.

Younger lithostratigraphic units are only found in the Vel'ký Bok sequence. Light-grey, weakly marly Calpionella limestones correspond to the Tithonian. The overlying sequence of grey, marly limestones, marls and shales is of Berriasian-Lower Aptian age. It is intensively folded and distinctly phyllitized.

5. Main Aspects of the Comparison of the Central Eastern Alps and the Central Western Carpathians

(H. HÄUSLER, D. PLAŠIENKA & M. POLÁK)

The Eastern Alps and Western Carpathians have many similiarities as well as significant differences. This study has compared their structure and metamorphism as well as the lithology and facies development of their Mesozoic sequences. New stratigraphic and facies investigations of the last decade have provided data which allows strong arguments to be made for a new east–west correlation.

The tectonic architecture of the Central Eastern Alps and the Central Western Carpathians is distinctly different. The Cretaceous orogeny in the Eastern Alps is marked by the total overthrusting of the Lower–Middle and Upper Austroalpine over the Middle and South Pennine (low grade metamorphism and locally eclogite facies, respectivly). The tectonic units of the Tatricum and Veporicum are generally fold nappes and only the Krížna nappe (s. l.) was squeezed out and thrusted to the north. The Middle Penninic Periphere Schieferhülle and the Upper Austroalpine as well as the "Fatric (Krížna)-Hronic-Silicic" can be described as stripped sheet nappes which were partly or totally sheared off from their former crystalline basement. The Tatricum, Veporicum, Gemericum, and Lower Austroalpine can be characterized to some extent as composite nappes with respect to the crystalline basement and the Paleozoic to Mesozoic sequences. As a typical Carpathian feature in the Eastern Central Alps, A. TOLLMANN (1972, p. 201) described the disintegration of a unique lateral doming of the Central zone, into many local domes, which also represent tectonic windows.

The eoalpine events were probably very similiar in the Alpine–Carpathian belt. The difference in tectonic architecture of the Centrocarpathians and the Central Alps is mainly due to post-Cretaceous events which affected only the Alps. The Western Carpathians remained more or less in the eoalpine stage of Upper Cretaceous tectonic development. The front of the Krížna nappe system shows northward plunging digitation, which can be compared with the style of the Semmering nappe system. Choč-, Strazow- and Šturec nappes, as well as Muráň nappe, represent downsliding from former southern positions, which is tectonically similiar to the Upper Austroalpine.

According to the nappe stack in the Eastern Alps, the Mesozoic series were affected by progressively increasing greenschist metamorphism. Metamorphism reached a higher degree in the more southern area of the Tauern window and in the Wechsel unit (P. FAUPL 1972; A. PAHR 1991). Features of very low to low grade metamorphism in the Tatric successions are confined to lower structural units, as is also the case in the Veporic Vel'ký Bok unit. This is in contrast to low grade metamorphism (indicated as LT-HP by C. MAZZOLI et al., 1992) of the South Veporic Foederata cover unit which required a considerable tectonic load. Since the degree of metamorphism can change in the lateral prolongation of a mountain range, the tectonic position and the primary facies development are better arguments for the parallelisation of Mesozoic facies belts than the similiarity of metamorphism.

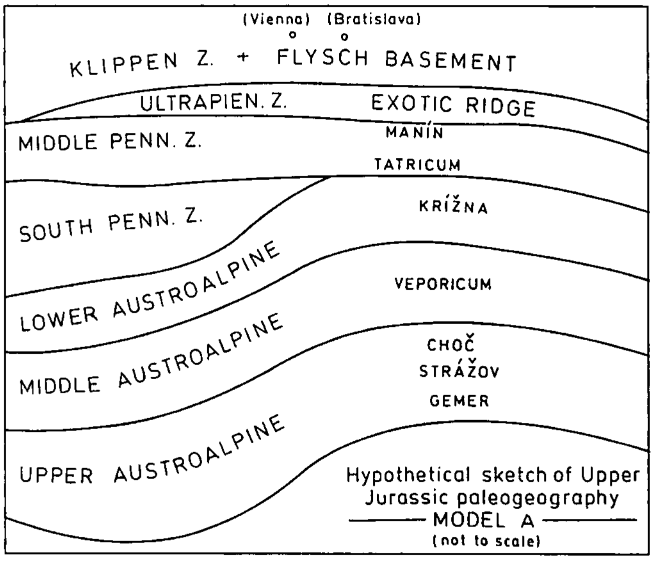
The Pennine and Lower Austroalpine Jurassic (and possibly Cretaceous) of the Eastern Alps contain very few fossils. This is likely due to the relatively high metamorphism and deformation. This is in contrast to the detailed stratigraphic and facies zonations which have been established in the Central Western Carpathians based on the widespread presence of micro and macrofossils.

The stratigraphy and depositional facies of the Triassic in the Western Carpathians (A. BUJNOVSKÝ et al., 1979b) display many strong similiarities to the Semmering Mesozoic (where higher Jurassic–Cenomanian is missing), the Tatric facies and – with reservation – the Krížna facies as well.

The facies development of Middle Penninic Mesozoic sequences of the Eastern Alps, in particular the Jurassic, can easily be compared with the Tatrides. Shallow water deposition, with lateral facies changes due to local swells (with erosion or incomplete sedimentation) and troughs (e.g. Šiprúň trough) in the Tatric facies area seem very similiar to the variation of local swells (e.g. Hochsteg zone) and basins (e.g. Silbereck series) of the Middle Pennine in the Eastern Alps. Correlating these rapidly changing facies zones only with the well known Briançonnais no longer seems appropriate.

Most of the Tatricum is composed of the Šiprúň facies which is a complete Mesozoic deep water succession. The early facies comparisons between the Tatrides and the Briançonnais by E. PASSENDORFER (1938, p. 271), Z. KOTAŃSKI (1959a; 1959b, p. 139) or J. DEBELMAS (1960, p. 113) emphasised the old-Cimmerian tectonic unconformities of the High Tatra in the Polish Tatra mountains. They did not compare the facies distribution of the Tatricum as a whole. It is therefore very questionable that unconformities of the Hochsteg zone and of the Tatrides, in particular of the High Tatra, are equivalent, because the main paleotectonic process in the Eastern Alps and Western Carpathians in Jurassic time is extension.

Recent studies of the Jurassic of the Tatricum and in particular of the Borinka unit, north of Bratislava by D. PLAŠIENKA (1987), now indicate that the Mesozoic of that region was complete. On local swells, however, Liassic Borinka limestone infills local fissures.



Text-Fig. 4:
Hypothetical sketch of Upper Jurassic paleogeography of the Alpine-Carpathian passage: Model A (modified after A. TOLLMANN, 1990)

6. Paleogeographic Reconstruction

(H. HÄUSLER, D. PLAŠIENKA & M. POLÁK)

Since Lower Jurassic time, the continental crust of Zentralgneis-complexes and adjacent areas in the Western and Eastern Alps is thought to have been separated by rifting. This also corresponds to the break-up of the so called South Penninic ocean including the development of oceanic crust. From this time, the Lower Austroalpine Jurassic facies is assumed to have been seperated from the Middle Penninic ("Hochstegen"-zone) area, by the Bündner Schiefer-trough of the South Pennine. Based on the tectonic nappe piling and the general meridional palinspastic reconstruction, the following Upper Jurassic facies distribution is proposed for further paleogeographic considerations:

- ✰ **Eastern Alps:**
  Middle Pennine – South Pennine – Lower Austroalpine – Middle Austroalpine
- ✰ **Western Carpathians**
  (Vahicum) – Tatricum – Krížna – Veporicum

A major difficulty lies in the lateral parallelization of individual facial belts between the Central Alps and the Central Carpathians. Is an individual facies restricted to a certain tectonic unit, or does one tectonic nappe system contain changing facies conditions in the sense of a multifacies nappe?

Two possible reconstruction models are proposed based on different initial points of view:

a) The South Penninic ocean wedges out east of Rechnitz. The Lower Austroalpine facies is correlated to the Fatric facies (Krížna). Therefore the Middle Penninic (Hochsteg) belt is equivalent to the Tatricum, specifically the High Tatra- and Manín zone (cf. A. TOLLMANN, 1965, 1968, 1989, 1990). See Text-Fig. 4: Hypothetical sketch of Upper Jurassic paleogeography – model A.

b) The South Pennine possibly extended north of the Tatricum. The Tatricum is, together with the Fatricum and Veporicum, the continuation of the Lower–Middle Austroalpine system. The Middle Pennine is therefore correlated to the Pieniny Klippen Belt (Czorsztyn ridge) – e.g. D. ANDRUSOV (1968), D. ANDRUSOV et al. (1973), M. MAHEL' (1978, 1983, 1986), J. MICHALÍK & M. KOVÁČ (1982), J. DERCOURT et al. (1990, Pl. 5), M. RAKÚS et al. (1990). See Text-Fig. 5: Hypothetical sketch of Upper Jurassic paleogeography – model B.

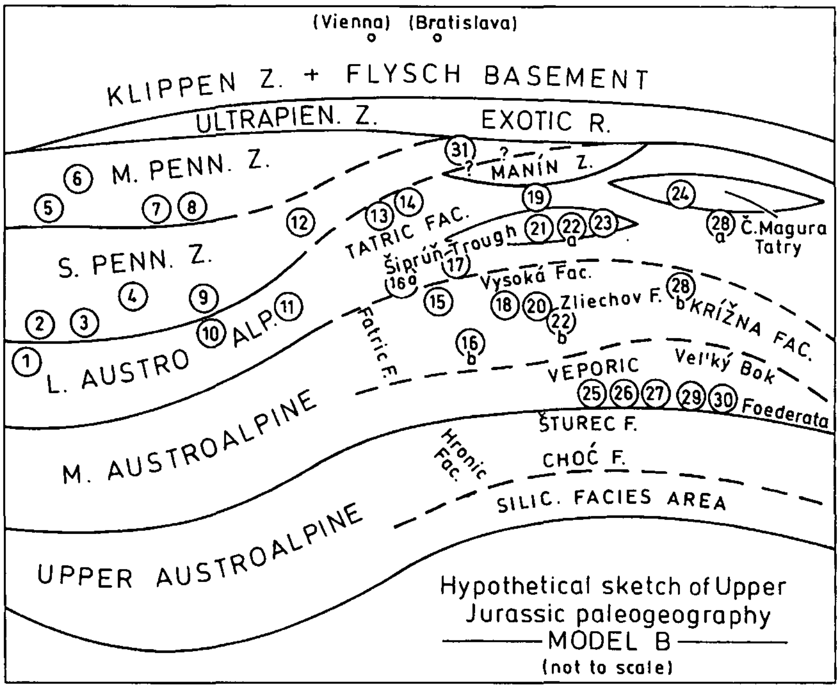
Lateral wedging out of several basinal units of the Central Carpathians (Zliechov, Šiprúň) points to the lens-like, or more probably rhomboidal shape of their original sedimentary basins, which infers the transtensional, not orthogonal extensional nature of their origin.

Hence the whole Austroalpine–Carpathian realm, including the Tatricum, may be considered (concerning Jurassic–Lower Cretaceous paleogeography) as an intricate system of basin and ridge domains, generated by heterogeneous stretching of normal epi-Variscan continental crust. Lower Jurassic passive rifting created lozenge-shaped basinal areas with attenuated crust and ribbons with thicker continental crust which extended finally to the South Penninic ocean basins on the outer periphery of the Austroalpine realm (Text-Fig. 5).

Shortening of basinal and ridge domains produced anastomosing tectonic units, although most of them contain coherent stratigraphic successions of independent paleogeographical domains following the inversion theory. The coulisse pattern of basement tectonic units of the Centroalpine–Centrocarpathian realm is therefore a natural product of shortening of previously heterogeneous, "en echelon"-like thinned Austroalpine crust.

The central zones of the Eastern Alps and Western Carpathians show many common evolutionary features. Of these, the best correlation is possible in their Mesozoic paleogeography and the timing of principal paleotectonic events. The main points for the comparison and correlation of their facies are:

a) **Uniform Triassic evolution**
Lower Triassic characterized by quartzose clastics (Lantschfeld and Semmering quartzite of the Eastern Alps, Lúžna Formation in the Western Carpathians).
Middle Triassic comprised of carbonate platform sediments (mostly Gutenstein, Ramsau- and Wetterstein Formation).



Text-Fig. 5:
Hypothetical sketch of Upper Jurassic paleogeography of the Alpine-Carpathian passage: Model B (modified after D. ANDRUSOV, J. BYSTRICKY & O. FUSAN, 1973)

Upper Triassic having fluviatile-lagoonal facies in external zones (Carpathian Keuper group), passing to the Hauptdolomit facies in more internal zones of the Central Alps, followed by fossiliferous Kössen beds in both mountain ranges.

b) **Early Jurassic rifting**
Break up of the Triassic carbonate platform and differentiation of the sedimentary area into several subparallel belts. These belts consist of shallow-water or ridge settings and deep furrows with calciturbiditic sedimentation (Allgäu Fm. or "Fleckenmergel").

c) **Middle to Late Jurassic subsidence**
Pelagic sedimentation, even below CCD, in troughs during the Oxfordian (Ruhpolding Fm.). Condensed sedimentation on ridges. Coarse clastics were deposited in the South Penninic–Lower Austroalpine and Tatric boundary (Tarntal-, Türkenkogel-, Schwarzeck- and Somár scarp breccia formations).

d) **Early to Middle Cretaceous**
events are not correlateable, because of the lack of relevant biostratigraphic data in the Central Eastern Alps.

It should be noted that these developments also correspond to Upper Austroalpine features (G. WESSELY, 1975; 1992) in many cases.

TOLLMANN's concept of the Hochsteg – Tatra – Manín continuation is based on their position with respect to the ultra-Pieniny exotic cordillera as well as from analogies with ridge-type Jurassic facies of Hochsteg and Tatra zones. There are however important objections to this interpretation.

Most authors (except e.g. M. MAHEL') terminated the Jurassic South Penninic ocean east of Rechnitz. This is due to the fact that no equivalent fine to coarse grained clastic, or volcanic influenced deposits similiar to the Bündner Schiefer are known in the Central Carpathians, below for example the High Tatra unit or the Vysoká and Križna nappe.

The coarse clastic deposits of Lower Cretaceous age (M. MISIK & M. SYKORA, 1981) in the Klippenbelt and Manín unit contain continental, as well as oceanic derived sediments. The reconstructed source area of these sediments is the Pieniny "exotic ridge". The clasts derived from a continental platform include both shallow water and pelagic facies of Jurassic age. Those from an oceanic basin include ultramafic clasts (serpentinite; chromian spinel) deposited during Barremian to Alban time. Remnants of volcanics and high pressure metamorphic rocks of Jurassic to Cretaceous age are also found.

Regarding the eoalpine high pressure metamorphic event, postulated by F. KOLLER (1985) for the ophiolites of the Rechnitz series, equivalent rocks could have been obducted and then eroded from an exotic ridge of the Pieniny cordillera and deposited in sediments of Albian to Maastrichtian time in the Kysuca-, Klape- and Manín unit.

This paleogeographic reconstruction, of an ocean basin including oceanic crust, could be interpreted as the eastern continuation of the South Penninic facies in the Western Carpathians (= Vahicum, sensu M. MAHEL').

The Fatric (Vysoká and Krížna) facies realm could not have had a direct connection to the South Pennine–Lower Austroalpine transition. There is a complete lack of Bündner Schiefer-like (greywacke) sediments, scarp breccias and ophiolitic rocks or other rock units typical for this Alpine belt. This is even the case in the Zliechov trough, which in spite of deep-water facies (radiolarites, biancone limestones) was underlain by continental, although strongly attenuated crust. Moreover, in the Malé Karpaty Mts. some 100 km NE of the last Penninic windows of the Rechnitz area, the Zliechov unit thins and the Fatricum is composed almost entirely of the Vysoká unit. Its ridge-type Jurassic to Lower Cretaceous sequences have little in common with the Lower Austroalpine or Penninic, either in lithostratigraphy, or in structure.

As a plate-tectonic working hypothesis, a system of strike-slip faults, especially transform faults, could have connected the South Penninic basin of the "Eastern Alps" and the "Vahic" with the Vardar ocean (compare R. TRÜMPY, 1988).

The hypothetical Ultrapienidic ridge (compare A. TOLLMANN, 1990) could be an element, or possibly the eastern continuation, of the interrupted Zentralgneis zone in Jurassic time. This is based on its Middle Penninic position which can be assumed, while the separation of the Ultrahelvetic margin from the North Penninic ocean took place.

In our opinion, the concept of a combined Lower and Middle Austroalpine to Tatric–Krížna–Veporic connection is the more plausible concept. This is also supported by analogies in the lithostratigraphy and structure of the Lower Austroalpine and Lower Tatric units (see previous chapters) and taking into consideration the existance of multifacies nappes. The Lower Austroalpine therefore can be parallelised with the Tatrides, contrary to the earlier interpretations of for example E. KRISTAN & A. TOLLMANN (1957) and A. TOLLMANN (1958; 1965–1990). Text-Fig. 5 summarizes the proposed new correlations of the Central Eastern Alps and the Central Western Carpathians which have been presented in the current discussion.

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