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Cretaceous and Palaeogene sedimentary evolution in the Eastern Alps, Western Carpathians and the North Pannonian region: An overview

Peter Faupl
Institut für Geologie, Vienna

Géza Császár
Geological Institute of Hungary, Budapest

Milan Mišík
Department of Geology and Paleontology, Comenius University, Bratislava

with contributions by G. B. Árgyelán, R. Aubrecht, L. Fodor, A. Fogarasi, J. Haas, J. Jablonský, M. Kázmér, J. Michalík, H. Peresson, D. Reháková, J. Soták, O. Sztanó, M. Wagreich

On the basis of 44 sections exhibiting both the major facies and the trends in the terrigenous input, the sedimentary evolution of the Eastern Alps, Western Carpathians and the Transdanubian Range during the Cretaceous and Palaeogene is summarised. The three segments of the Alpine orogenic belt are characterised by a predominantly similar sedimentary history. It is demonstrated that two main sediment source terrains supplied the Austroalpine–Central Carpathian domain and the Transdanubian Range; one was situated along the northern active margin and the other was the intra-orogenic Tethys suture zone to the south. In spite of the fundamental similarity in the geological evolution, differences in both facies and time in the Upper Cretaceous and Palaeogene successions between the Central-Alpine domain of the Eastern Alps and the Transdanubian Range can be explained by an eastward shift of the latter unit along the Tethys suture zone.

Key words: Eastern Alps, Western Carpathians, Transdanubian Range, Cretaceous, Palaeogene, facies development

Introduction

The Eastern Alps, the Western Carpathians and the Pannonian region represent separate segments of the Alpine orogenic belt. Palaeogeographically, however, the entire sedimentary evolution belongs to the western Tethys realm and, therefore, the major events in its geodynamic history are the same in all three zones. Nevertheless, some problems arise in correlating the sedimentary sequences and tectonic units of these three regions, because Neogene and

Adresses: P. Faupl: Geozentrum, Althanstrasse 14, A-1090 Wien, Austria
G. Császár: H–1443 Budapest, Stefánia út 14, Hungary
M. Mišík: Mlynská dolina, SK-84215, Bratislava
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Quaternary sediments obscure various geological junctions. Furthermore, the circumstance that three different languages are used and that, for many decades, the political boundaries slowed down free scientific communication make the problems no easier to solve. As a result of this situation, a great variety of local formation names masks a considerable number of similarities in the facies and tectonic evolution of different sectors within the region. The purpose of this paper is, therefore, to give an overview of trends in the sedimentological character of these three neighbouring regions, which reflect their common Alpidic geodynamic evolution. The paper is especially focused on the Cretaceous and Palaeogene evolution because during these periods decisive orogenic events, such as the Eoalpine and Mesoalpine tectonic movements, occurred.

This overview is based on observations and discussions derived from eight field workshops of the Cretaceous–Palaeogene working group of the ALCAPA project, established by the Austrian, Hungarian and the Slovak Academies of Sciences. During the workshops, typical localities in the region of the eastern parts of the Eastern Alps (EA), the Western Carpathians (WCa) and the Transdanubian Range (TR), as shown in Fig. 1, were studied. Five to ten persons from each country contributed to the workshops. Details of the results will be published in separate papers. The sedimentary evolution is described by two kinds of sections: 1) stratigraphic sections exhibiting the major facies evolution and 2) sections which give information about the palaeogeographically significant terrigenous input. The numerous local formation names are listed in Table 1 and are also indicated as abbreviations on the right side of the stratigraphic columns.

For the Eastern Alps, the Cretaceous and Palaeogene sedimentary evolution is summarised as a whole or in parts by Oberhauser (1963, 1980, 1995), Tollmann (1976), Herm (1979, 1981), Flügel and Faupl (1987), Faupl and Wagreich (1992a, b, 1996), Wagreich and Faupl (1994) where further references are compiled. Overviews for the Western Carpathians (except for the Flysch zone not included in this study) have been published by Andrusov (1965a, b), Salaj and Samuel (1966), Samuel and Salaj (1968), Marschalko (1986), Birkenmajer (1977), Gross et al. (1980), Rakús et al. (1989, 1990), Gross et al. (1993) and Vašíček et al. (1994). For the Transdanubian Range summaries are given by Haas (1979, 1983, 1987), Korpás (1981), Császár (1984, 1986), Császár and Haas (1984), Báldi and Báldi-Beke (1985), Kázmér (1985b), Kázmér and Kovács (1985), Császár et al. (1987), Haas and Császár (1987), and Fodor et al. (1994).

Regional geologic setting

The Eastern Alps

The Eastern Alps (EA) are composed of three major tectonic units: the Helvetic, the Penninic and the Austroalpine nappe complexes. Northern units

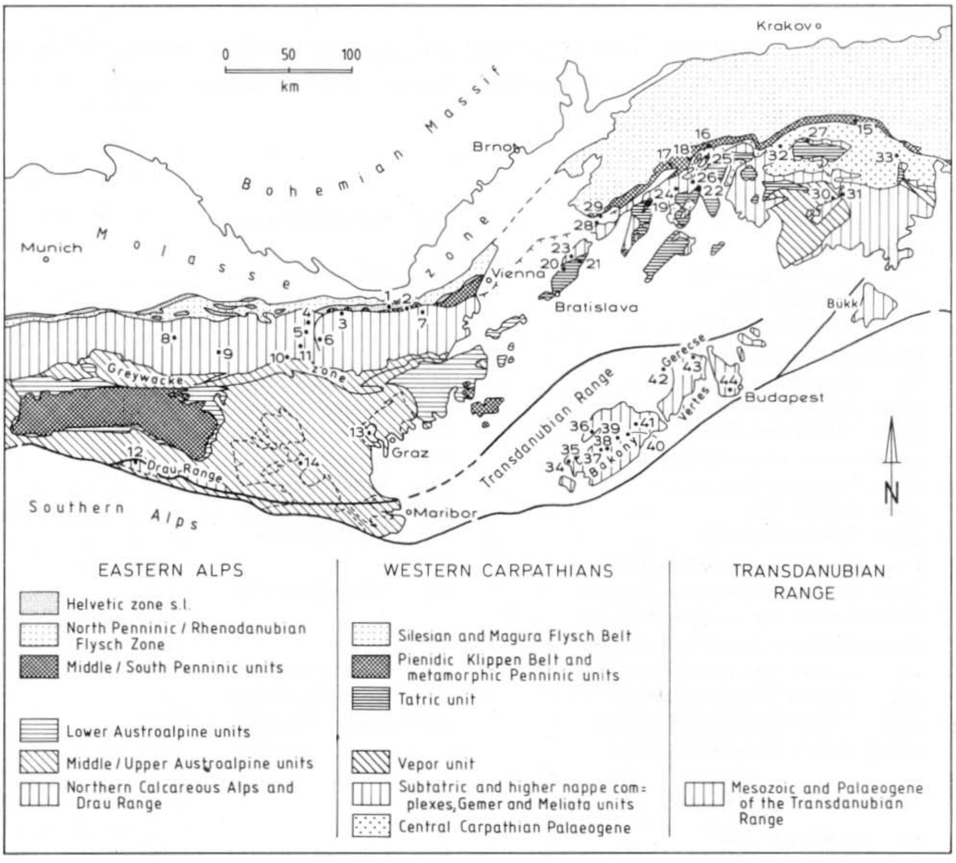


Fig. 1
Geologic map of the Eastern Alps, Western Carpathians and North Pannonian region. Numbers refer to the sections studied: *Eastern Alps:* 1. Gresten Klippen zone; 2. Ybbsitz zone; 3. Frankenfels/Ternberg nappe; 4. Reichraming nappe (Schneeberg Syncline); 5. Reichraming nappe (Ebenforst Syncline); 6. Lunz nappe (Weyerer Bögen); 7. Lunz nappe (Lilienfeld); 8. Tirolikum (Salzachtal); 9. Gosau Type Locality; 10. Gosau of Wörschach. 11. Gosau of Windischgarsten; 12. Drau Range (Lienzer Dolomiten); 13. Central-Alpine Gosau of Kainach; 14. Central-Alpine Krappfeld-Gosau. *Western Carpathians:* 15. Pieniny Klippen Belt (Czorsztyn zone); 16. Pieniny Klippen Belt (Kysuca-Pieniny zone); 17. Klape unit (Middle Váh Valley); 18. Manín unit (Manín Gorge region); 19. Belice unit (Považský Inovec Mts); 20. Tatricum (Malé Karpaty), Kuchyňa unit; 21. Tatricum (Malé Karpaty), Solírov and Orešany unit; 22. Tatricum (Malá Magura), Malá Fatra unit; 23. Krížna nappe (Vysoká unit); 24. Krížna nappe (Belá unit); 25. Krížna nappe (Zliechov unit, Polomec); 26. Krížna nappe (Zliechov unit, Strážovce); 27. Krížna nappe (Zliechov unit, Oravice); 28. Brezová Group (Bradlo facies), Brezovské Karpaty; 29. Brezová Group (Surovín facies), Brezovské Karpaty; 30. Šumiac; 31. Dobšinská Ladova jaskyňa; 32. Central-Carpathian Palaeogene (Orava area); 33. Central-Carpathian Palaeogene (Spiš region). *Transdanubian Range:* 34. Sümeg; 35. Darvastó; 36. Magyarpolány; 37. Ajka and *Padrag; 38. Úrkút; 39. Háskút; 40. Olaszfalu; 41. Bakonynána; 42. Tata; 43. Lábatlan (Gerecse);* 44. South Buda

Table 1
Formation names of the Cretaceous and Palaeogene of the Eastern Alps, Western Carpathians and the Transdanubian Range. Abbreviations used in the stratigraphic sections are given

Eastern Alps

Gresten Klippen Belt:

Bla	Blassenstein Fm.	Bun	Buntmergelserie

Ybbsitz zone:

Fas	Fasselgraben Fm.	Kah	Kahlenberg Fm.
Glo	Glosbach Fm.	Ybb	Ybbsitz Fm.
Has	Haselgraben Fm.		

Northern Calcareous Alps:

Bra	Branderfleck Fm.	gWör	Wörschachberg Fm.
gBru	Brunnbach Fm.	gZwi	Zwieselalm Fm.
gHöl	Höllgraben Fm.	Gra	Grabenwald Mb. of the Rossfeld Fm.
gLSG	Lower Gosau Subgroup	Los	Losenstein Fm.
gNie	Nierental Fm.	Ros	Rossfeld Fm.
gRes	Ressen Fm.	Schr	Schrambach Fm.
gSpi	Spitzenbach Fm.	Tan	Tannheim Fm.

Drau Range (Lienzer Dolomiten):

Lalm	Lavant Fm. - lower member	Schr	Schrambach Fm.
Laum	Lavant Fm. - upper member		

Central-Alpine Gosau occurrences:

gB	Gosau-"Basisschichten"	gTur	Gosau-"Turbiditfazies"
gBc	Gosau-"Basalkonglomerat"	Gut	Guttaring Group
gBit	Gosau-Bitumenmergelfolge	gZem	Gosau-Zementmergelfolge
gHau	Gosau-Hauptbeckenfolge		

Western Carpathians

Pieniny Klippen Belt:

BrB	Brodno Beds	Lys	Lysa Fm.
Chm	Chmielowa Fm.	PiF	Pieniny Fm.
CzF	Czorsztyn Fm.	Pom	Pomiedznik Fm.
Dur	Dursztyn Fm.	Puh	Púchov Fm.
Jar	Jarmuta Fm.	Sne	Snežnica Fm.
Jaw	Jaworki Fm.	Sor	Sromowce Fm.
Kap	Kapusnica Fm.	Spi	Spiš Fm.

Klape Unit:

Ihr	Ihrište Fm.	Sfr	Šafranica Fm.
Kap	Kapusnica Fm.	Sne	Snežnica Fm.
Kra	Kravárik Fm.	Sro	Sromowce Fm.
Nim	Nimnica Fm.	Stp	Štepnica Fm.
Orl	Orlové Fm.	Tiss	Tissalo Beds
Puh	Púchov Fm.	Uhr	Uhry Fm.
Pvb	Považská-Bystrica Fm.	Upo	Upohlav Fm.

Manín Unit:

But	Butkov Fm.	Luk	Luckov Fm.
Hlk	Hlboké Fm.	Noz	Nozdrovice Breccia
Hrb	Hrabové Fm.	Pod	Podhorie Fm.
Kal	Kalisčo Fm.	Pra	Praznov Fm.
		Zad	Žadorec Fm.

Belice Unit:

HBF Horné Belice Fm.
Laz Lazy Fm.

Tatricum:

Luc Lučivná Fm.
Oso Osobitá Fm.
Par Párnica Fm.
Por Poruba Fm.
Schr Schrambach Fm.
SoB Somár Breccia
Sol Solírov Fm.

Krížna Nappe:

Boh Bohatá Fm.
But Butkov Fm.
Hlb Hlboč Fm.
Kos Kosčieliska Fm.
Mra Mráznica Fm.
Osn Osnica Fm.
Par Párnica Fm.
PaV Padlá Voda Fm.
Pod Podhorie Fm.
Por Poruba Fm.
Schr Schrambach Fm.
Str Strážovce Fm.

"Post-tectonic" Senonian and Palaeogene; Brezová Group, "Gosau"-type deposits:

Bar Baranec Sandst. (Mb. of the Ostriez Fm.)
DeV Dedkov Vrch Fm.
DIc Dobšiná Ice Cave Conglomerate
DIm Dobšiná Ice Cave Marls
Hur Hurbanova Dolina Fm.
Jab Jablonka Fm.
Kos Košariská Fm.
Kra Kravárik Fm.
KrzB Kržlá Breccia
LuF Lubina Fm.
Men "Menilite" Fm.
Mos Mosnáčov Marl (Mb. of the Bradlo Fm.)
Ost Ostriež Fm.
Pbr Podbradlianska Fm.
Plf Podlipovec Flysch (Mb. of the Bradlo Fm.)
Pol Polianka Fm.
Pri Priepastné Fm.
PsV Pustá Ves Fm.
SBr Široké Bradlo Limestone (Mb. f the Bradlo Fm.)
Stv Štverník Marls (Mb. of the Ostriež Fm.)
Sum Šumiac Limestone
Val Valchov Conglomerate (Mb. of the Ostriež Fm.)

Palaeogene of the Central Western Carpathians:

BiP Biely Potok Fm.
Bor Borové Fm.
Hra Hrabník Fm.
Hut Huty Fm.
Hsm Šambron Conglomerate (Mb. of the Huty Fm.)
Puc Pucov Conglomerate
Zub Zuberec Fm.

Transdanubian Range

Ajk Ajka Coal Fm., $^{a}K_3$
BeM Bersek Marl Fm., $^{b}K_1$
BuM Buda Marl Fm., $^{b}E_3$-Ol_1
Csa Csatka Fm., $^{c}Ol_2$-Me or $^{c}Ol_2$
Cse Csehbánya Fm., $^{c}K_3$
Cso Csolnok Fm., $^{c}E_2$
Dar Darvastó Fm. $^{dt}E_2$
Dor Dorog Fm., $^{d}E_2$
Fel Felsővadács Breccia Mb. of the Bersek Marl Fm., $^{b}{}_{f}K_1$
Gan Gánt Bauxite Fm., $^{g}E_1$
JaM Jákó Marl Fm., $^{j}K_3$
KiC Kiscell Clay Fm., $^{k}Ol_1$
Kös Köszörűkőbánya Conglom. Mb., $^{l}{}_{k}K_{1-2}$
Lab Lábatlan Sandstone Fm., $^{l}K_{1-2}$
Man Mány Fm., $^{m}Ol_2$
MoL Mogyorósdomb Limestone Fm., $^{m}J_3$-K_1
PaM Padrag Marl Fm., $^{p}E_{2-3}$
PeM Pénzeskút Marl Fm., $^{p}K_2$
PoM Polány Marl Fm., $^{p}K_3$
SüM Sümeg Marl Fm., $^{s}K_1$
Sze Szentivánhegy Limestone Fm., $^{s}J_3$-K_1
SzL Szépvölgy Limestone Fm., $^{s}E_3$
SzöL Szőc Limestone Fm., ^{s}E
TaC Tard Clay Fm., $^{t}Ol_{12}$
TaL Tata Limestone Fm., $^{t}K_2$
Tes Tés Clay Fm., $^{t}K_2$
TöS Törökbálint Sandstone Fm., $^{t}Ol_2$
UgL Ugod Limestone Fm., $^{u}K_3$
VeS Vértessomló Siltstone Fm., $^{v}K_2$
ZiL Zirc Limestone Fm., $^{z}K_2$

of this nappe pile tectonically overlie the southern parts of the Molasse sediments which cover the southern Bohemian crystalline basement and autochthonous epicontinental Mesozoic successions. Sequences of the Helvetic zone *s. str.* are known only in the western and middle segment of the EA, up to the east of Salzburg. Further to the east, the Gresten Klippen belt has been assigned to the Ultrahelvetic zone. The Penninic realm as a metamorphic development appears in the Penninic windows, such as the Unterengadin Window, the Tauern Window and, at the easternmost border of the EA, the small windows of Rechnitz, Bernstein and Meltern as well as Kőszeg in Hungary. Beside these metamorphic series, non-metamorphic Penninic successions are confined to the Rhenodanubian Flysch zone named by Oberhauser (1968) and the Ybbsitz zone (Schnabel 1979; Decker 1990). The latter seems to be an equivalent to the Arosa zone in the boundary region of the Eastern and Central Alps. The Austroalpine domain can be subdivided into three major nappe systems; the Lower, the Middle and the Upper Austroalpine units. The distribution of the Middle and the Upper Austroalpine units, especially in the crystalline basement, is discussed in Tollmann (1987) and Frank (1987).

The sections studied in this paper are concentrated in the eastern parts of the EA and, especially, in the Upper Austroalpine units such as the Northern Calcareous Alps (NCA) and the Drau Range. External units are only documented by comparative sections of the Gresten Klippen belt and the Ybbsitz zone, the latter interpreted as having an oceanic origin within the South Penninic domain. In the Lower and Middle Austroalpine tectonic units of the eastern parts of the EA, neither Cretaceous nor Palaeogene sediments have been preserved, except for the so-called "Upper Eocene of Kirchberg/Wechsel", a small redeposited remnant of a former larger sedimentary cover.

The nappe pile of the NCA, a prominent sub-unit of the Upper Austroalpine tectonic system, comprises Upper Permian to Eocene formations. During the Cretaceous (Eoalpine) orogeny the sedimentary cover of the NCA was sheared off from its substratum and emplaced along the active northern margin of the Austroalpine microplate. This microplate was separated from the European continent by the Penninic ocean. In Late Eocene/Oligocene time, the NCA were affected by a further extensive deformational event (Mesoalpine orogeny). In a last great pulse of deformation the Alpine body was compressed and fractured during the Miocene (Ratschbacher et al. 1991; Decker et al. 1994).

The Western Carpathians

The external tectonic units of the Western Carpathians (WCa) comprise rocks of the Flysch belt (the Krosno or Silesian and Magura zones) and the Pieniny Klippen belt. Only the Ždanice unit, a Subsilesian element, and the Magura Flysch can be correlated directly with units of the EA (Waschbergzone and Rhenodanubian Flysch zone) (Eliáš et al. 1990). The Flysch belt is not included in this synthesis. To the south of the Peri-Pieniny Klippen zone lies the complex of the Central WCa, which is composed of the Tatricum and the Subtatric or Central WCa nappe complex (Krížna, Choč, Strážov units), the Veporicum and the Gemericum. This structurally complex nappe system of the Central WCa is assumed to belong to the Austroalpine realm *s. l.* The Manín unit is believed to be a tectonic element from the northern part of the Central WCa nappe system. The Czorsztyn facies of the Pieniny Klippen Belt was accumulated on a continental crust fragment situated within the mainly oceanic realm, which is believed to be the continuation of the Penninic domain. The Klape unit, represented by Cretaceous Flysch formations, contains the maximum concentration of conglomerates with exotic pebbles derived from the subducting clastic wedge of the oceanic domain (Ligurian–Penninic–Pieniny Ocean) situated between the Czorsztyn elevation and the northern margin of the Central WCa. According to Plašienka (1995), the Klape unit originated far to the south and was transported to the north as a nappe from an Ultraveporic position.

The metamorphic Upper Cretaceous successions of the Belice unit cropping out in a window in the Považské Inovec Mountains can be correlated with metamorphic Penninic units of the EA. Plašienka et al. (1994) assumed that this unit was situated palaeogeographically to the north of the Tatric units and thought it to be a unit similar to the Matrei zone from the southern border of the Tauern window in the EA. Metamorphosed Eocene sequences were only found in the boreholes beneath the Neogene sediments of the East Slovakian Basin (Soták et al. 1993). This Pozdišovce–Iňačovce unit probably belongs to the Eastern Carpathians.

Although the Tatricum of the Malé Karpaty shows similarities with the Lower Austroalpine units of the EA, the Tatricum of the Tatra and Fatra Mountains has been located at the northern edge of the Austroalpine microplate and contains specific Carpathian elements. The Krížna cover nappe system can be correlated with the tectonically lower nappes of the NCA, such as the "Cenoman-Randschuppe" and the Frankenfels nappe. The Choč and Strážov nappes can be correlated with tectonically higher units of the NCA. The Meliata unit of the southern parts of the WCa, with its Triassic oceanic facies elements (Kozur and Mock 1985), marks the Tethys suture zone and this extends westwards to the eastern segment of the EA (Kozur 1991; Kozur and Mostler 1992; Mandl and Ondrejičková 1991).

The Transdanubian Range

Within the Pannonian region, this paper is focused on the Cretaceous and Palaeogene development of the Transdanubian Range (TR). As the north-western part of the Pelso unit, the TR is situated along the southern border of the Austroalpine and Central WCa units, separated by major bounding faults (Rába Line – Scheffer and Kántás 1949; Rába and Diósjenő

Lines – Brezsnyánszky and Haas 1986). It is bounded to the south by the Balaton Line. The Central Hungarian Fault zone forms the fundamental tectonic contact between the Pelso and the Tisza units (Brezsnyánszky and Haas 1986). The Mesozoic stratigraphic successions of the TR comprise facies similar to the Northern and Southern Alps, with a closer relation to the latter (Kázmér and Kovács 1985; Császár and Dosztály 1993). Its formations are also dissimilar to the Alpine ones. Cretaceous formations of the TR crop out in the Bakony and Vértes Mountains, as well as in the Gerecse Mountains. Palaeogene deposits underlain by Middle Triassic to Upper Cretaceous formations are spread over a broad zone of the TR. Studied sections are situated in the Nyirád (Darvastó)–Padrag region (S-Bakony), the Gerecse Mountains and the Buda Hills (Kázmér 1985b; Fodor et al. 1994).

The separation of the TR began in the pre-Gosau tectonic phase. Its recent position was reached in the Early Miocene (Kázmér and Kovács, 1985). The distribution and changes in the stress field and tectonic phases were studied by Balla and Dudko (1989), Fodor et al. (1992, 1994) and Bada et al. (1996).

Facies distinguished in the sections

In the three Alpine regions, the facies development illustrated in the stratigraphic sections (Figs 2–5) is here reduced to nine major facies types. The *alluvial to fan-delta facies* comprises reddish alluvial successions, such as the basal conglomerates of the Gosau Group in Austria or the basal part of the Upper Cretaceous succession in the TR and WCa, and also including freshwater limestones and coal seams as well as transitional facies types. The occurrences of coal seams and freshwater limestones are indicated by separate symbols. In a few cases it appears necessary to infer a *lacustrine-paludal facies* as observed in the Tés Clay Fm. of the TR.

Grey shelf marls and neritic sandstone sequences are combined in the term *shallow-marine terrigenous facies*. Some sandstone successions are interpreted as storm-generated deposits. *Shallow-water limestones* comprise mainly the Urgonian-type platform carbonates of the Lower Cretaceous, the Upper Cretaceous rudistid limestones and the Eocene nummulite-bearing limestones as well. Further occurrences of rudist bioherms and nummulite beds are indicated separately.

The *deep-water limestones*, which occur frequently in the Lower Cretaceous successions, comprise pure Majolica-type limestones (Mogyorósdomb Fm. in the Bakony Mts.) as well as marly micritic limestones, typical of the upper parts of the Schrambach Fm. This latter type interfingers in several sections with thin turbiditic layers.

The *bathyal marl facies* is characterised by high proportions of planktonic foraminifera but also includes successions which exhibit transitional sediments deposited between outer shelf and slope deposits. Slump deposits occur frequently in this facies (Bersek Marl in Gerecse; Polány Marl in Bakony;

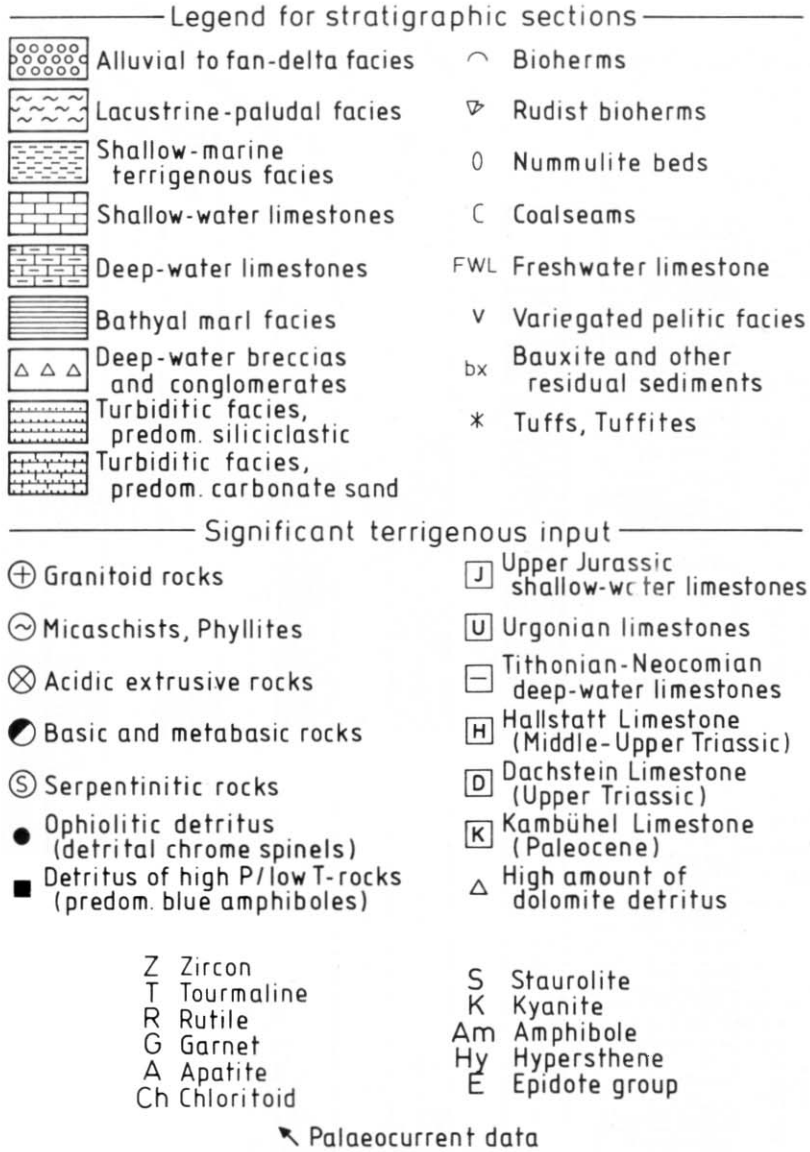


Fig. 2
Legend to the section on Figs 3–5

Nierental Fm. in the NCA). Reddish and variegated colours as well as dark grey series have been observed (Nierental Fm. in the NCA; Bersek Marl in Gerecse; Aptychenschichten in the North Karawanken; Košariská Fm. in the Brezovské Karpaty).

Fig. 3a, b
Stratigraphic sections of the Eastern Alps

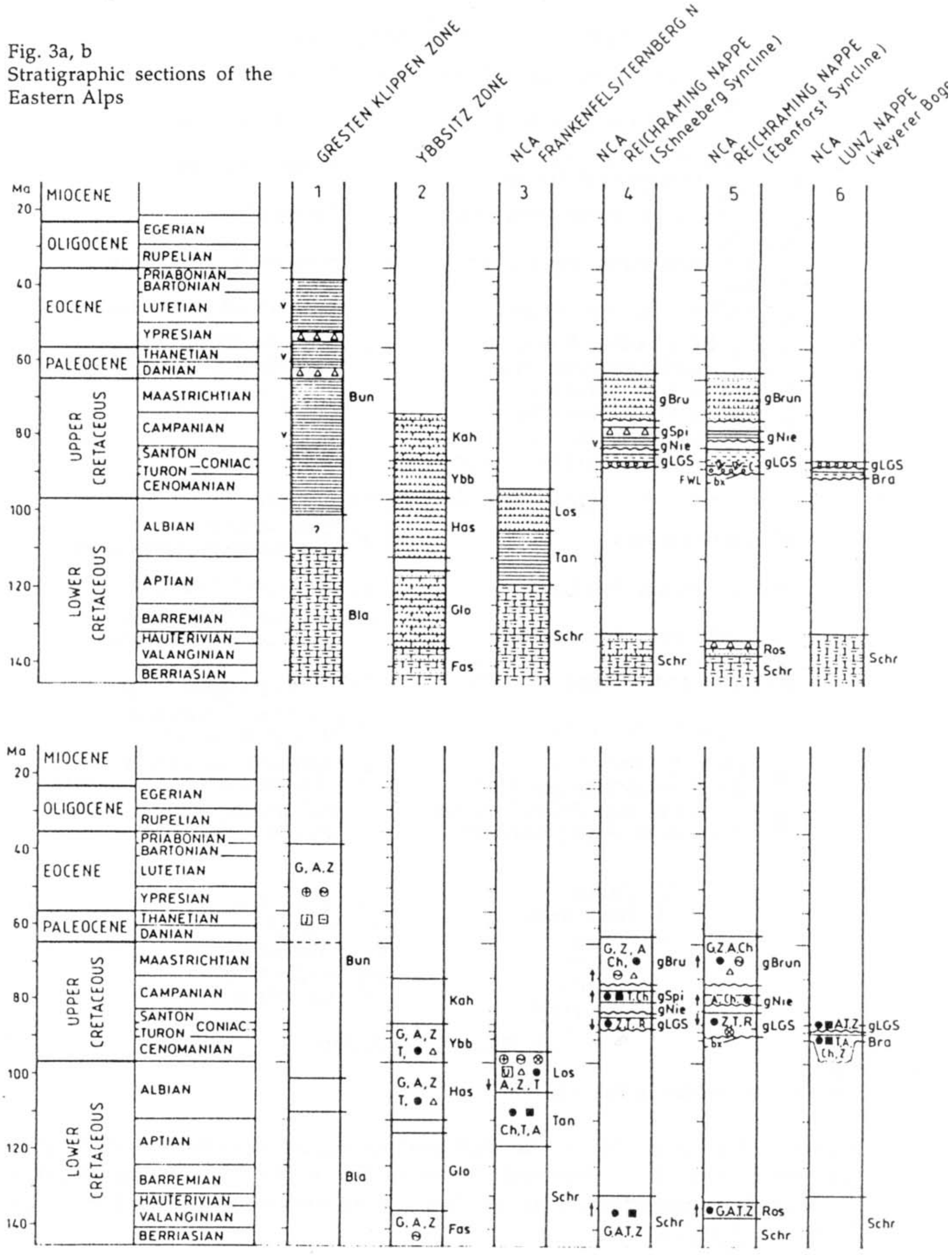
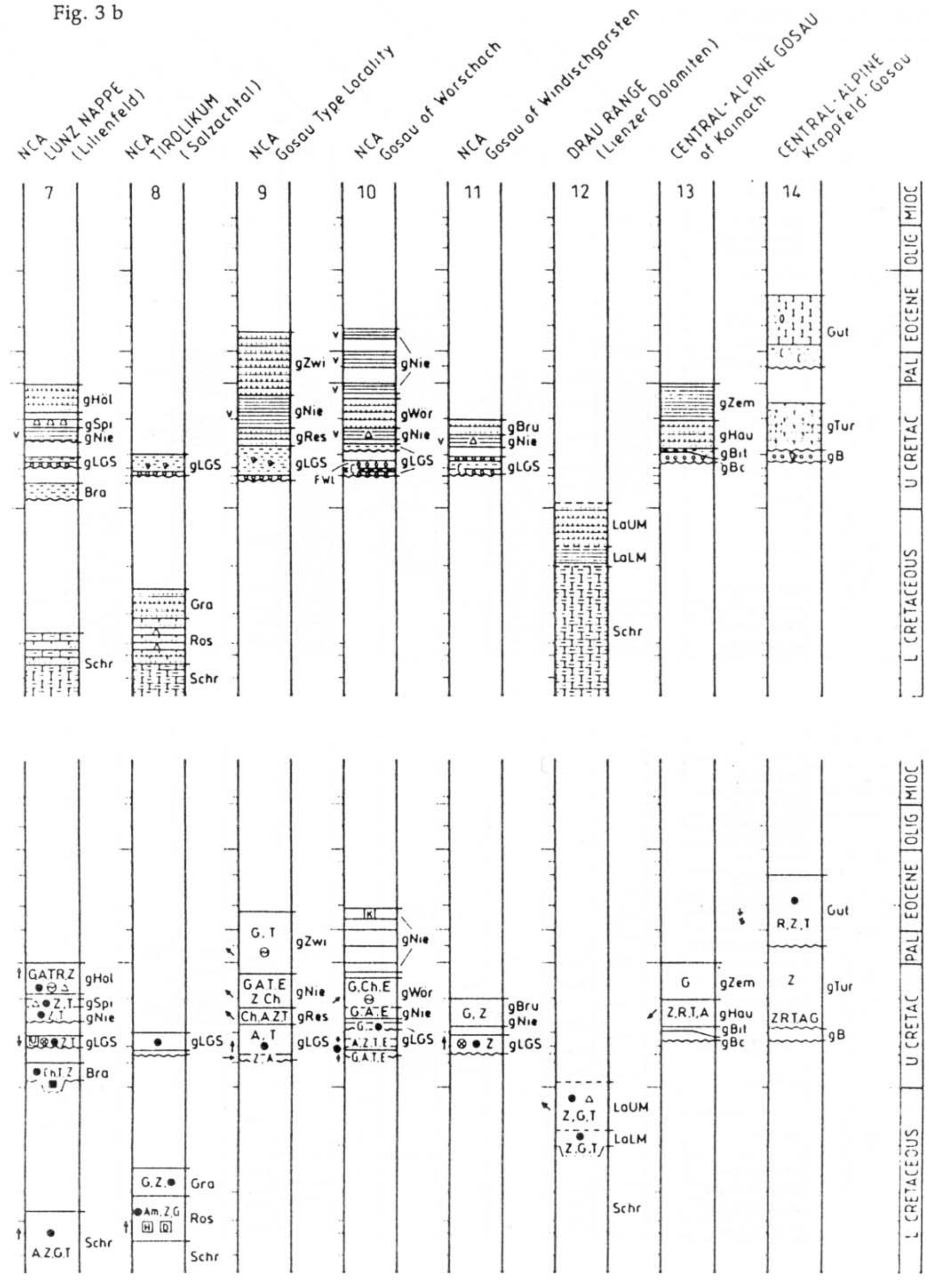


Fig. 3 b


NCA LUNZ NAPPE (Lilienfeld)
NCA TIROLIKUM (Salzachtal)
NCA Gosau Type Locality
NCA Gosau of Worschach
NCA Gosau of Windischgarsten
DRAU RANGE (Lienzer Dolomiten)
CENTRAL-ALPINE GOSAU of Kainach
CENTRAL-ALPINE Krappfeld-Gosau
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13
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MIOC
OLIG
EOCENE
PAL
U CRETAC
L CRETACEOUS
gHöl
gSpi
gNie
gLGS
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gZwi
gRes
Fwl
gWor
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GATRZ
A.Z.G.T
G.Z.
Am. Z.G
G.T
G.A.T.E
Z Ch
Ch.A.Z.T
A.T
Z A
G.Ch.E
G.A.E
A.Z.T.E
G.A.T.E
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Fig. 4a, b, c
Stratigraphic sections of the Western Carpathians

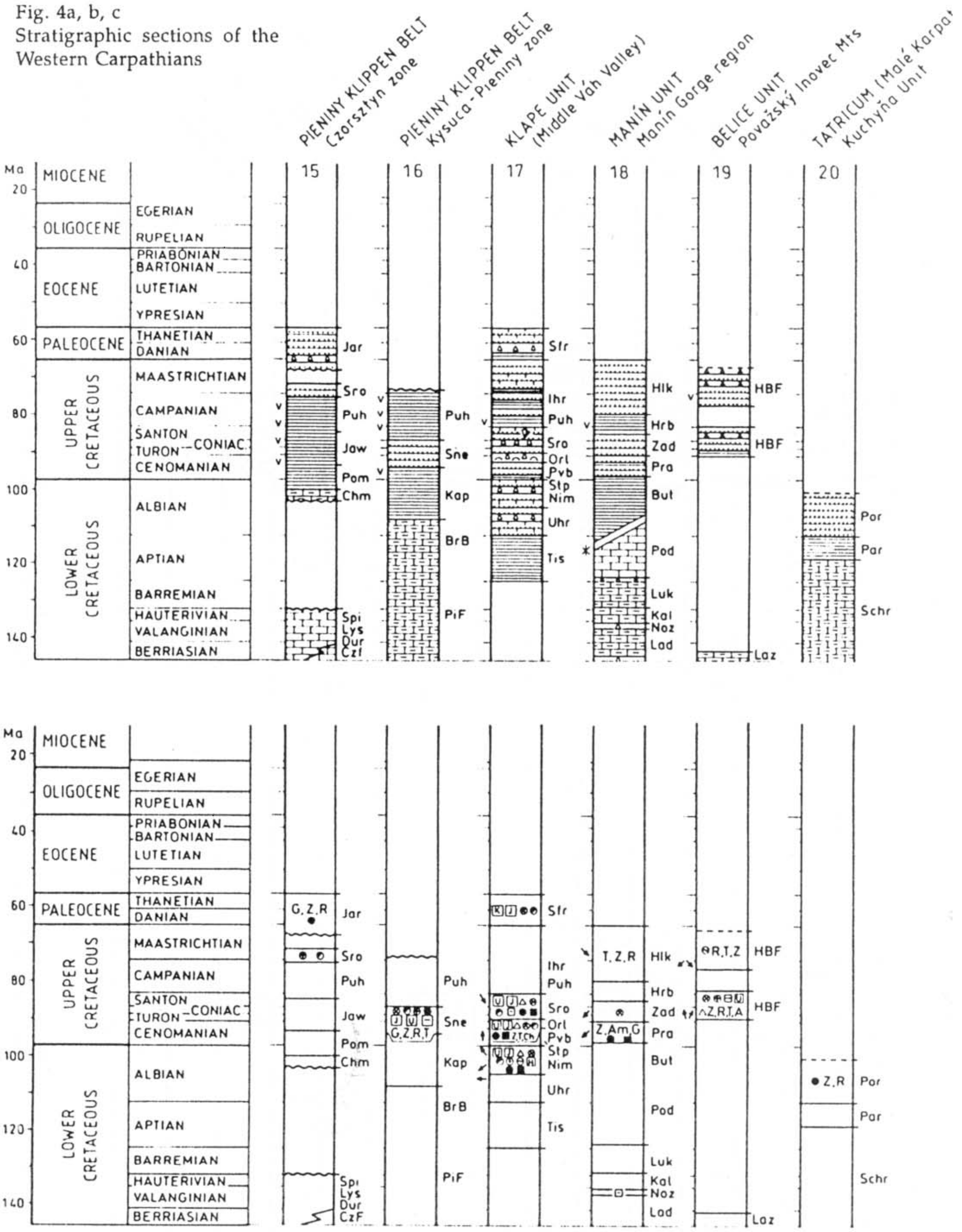
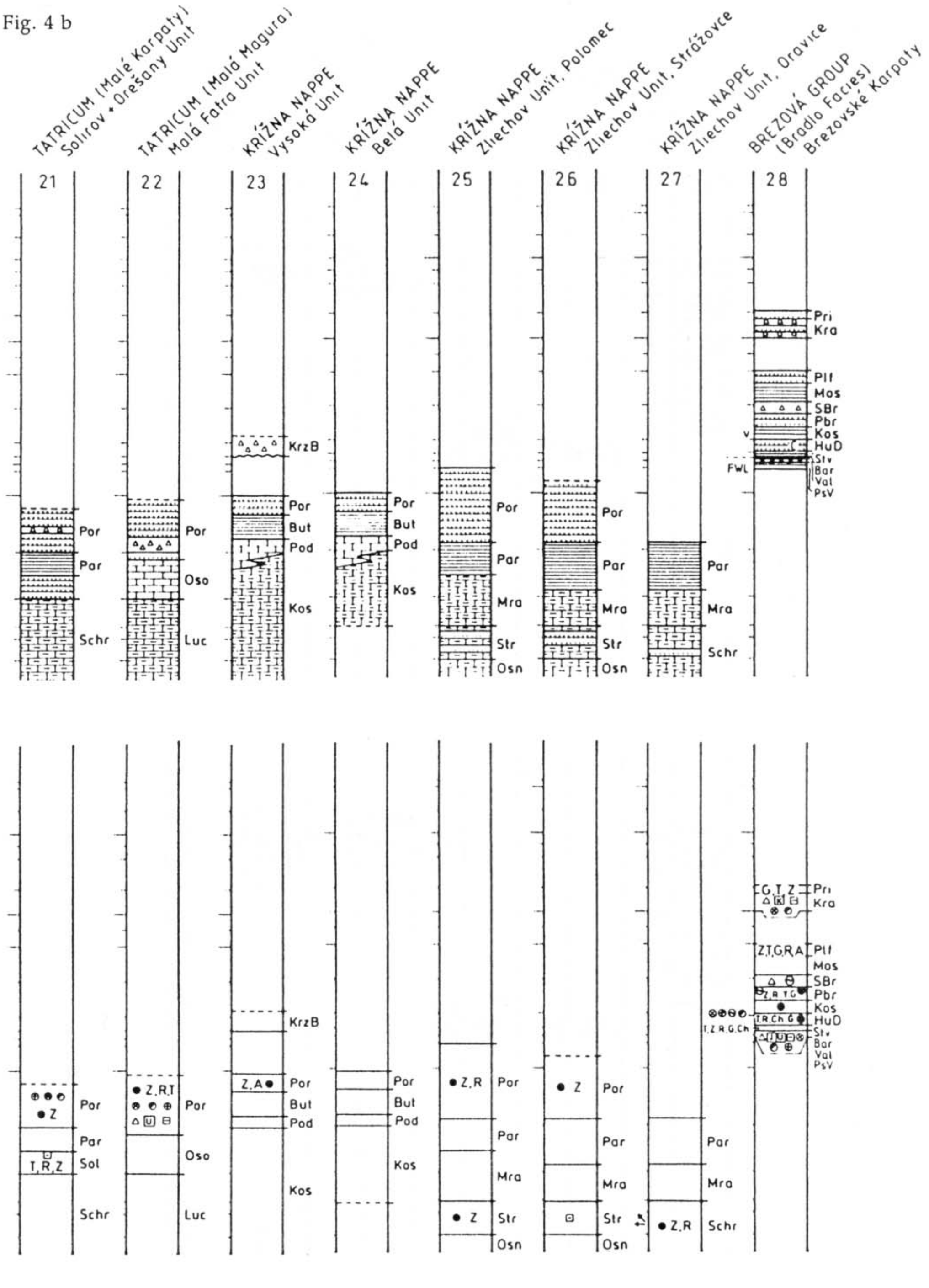


Fig. 4 b


TATRICUM (Malé Karpaty) Solirov + Orešany Unit
TATRICUM (Malá Magura) Malá Fatra Unit
KRÍŽNA NAPPE Vysoká Unit
KRÍŽNA NAPPE Belá Unit
KRÍŽNA NAPPE Zliechov Unit, Polomec
KRÍŽNA NAPPE Zliechov Unit, Strážovce
KRÍŽNA NAPPE Zliechov Unit, Oravice
BREZOVÁ GROUP (Bradlo Facies) Brezovské Karpaty
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Por
Par
Sol
Schr
Oso
Luc
KrzB
But
Pod
Kos
Mra
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Kra
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SBr
Pbr
HuD
Stv
Bar
Val
PsV
FWL
T,R,Z
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T,Z,R,G,Ch

Fig. 4c

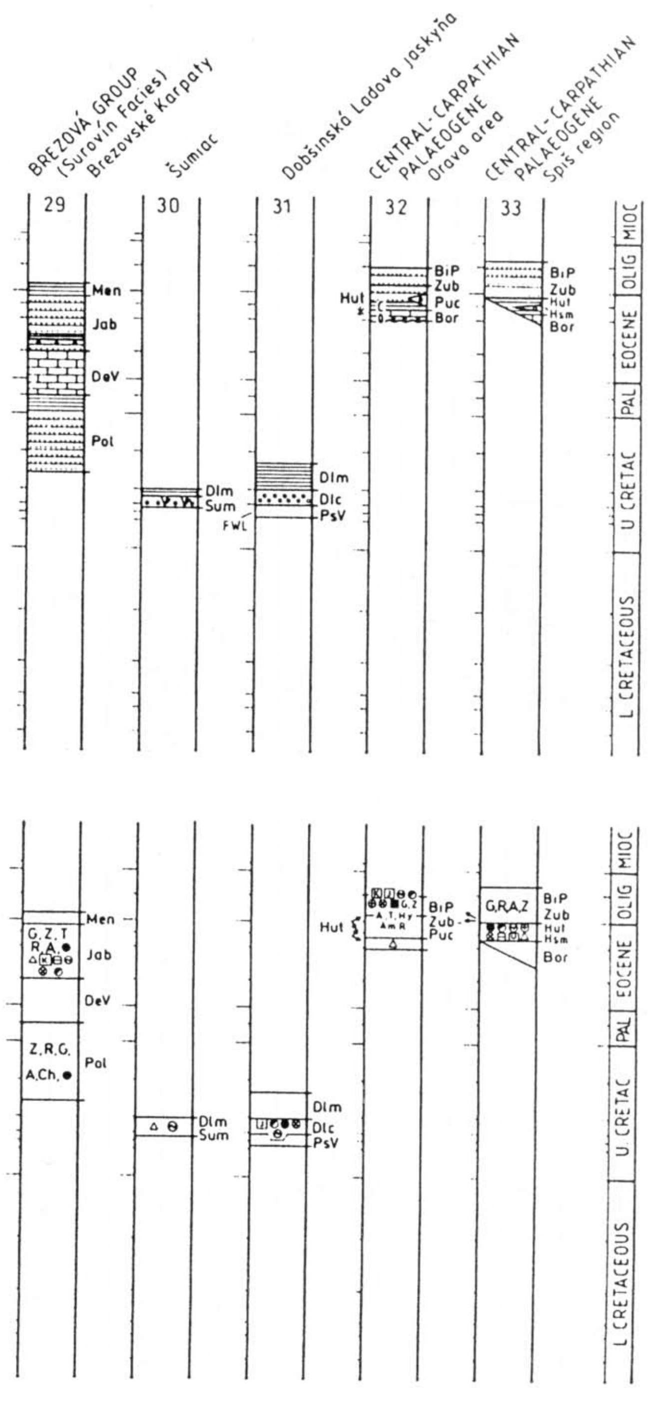
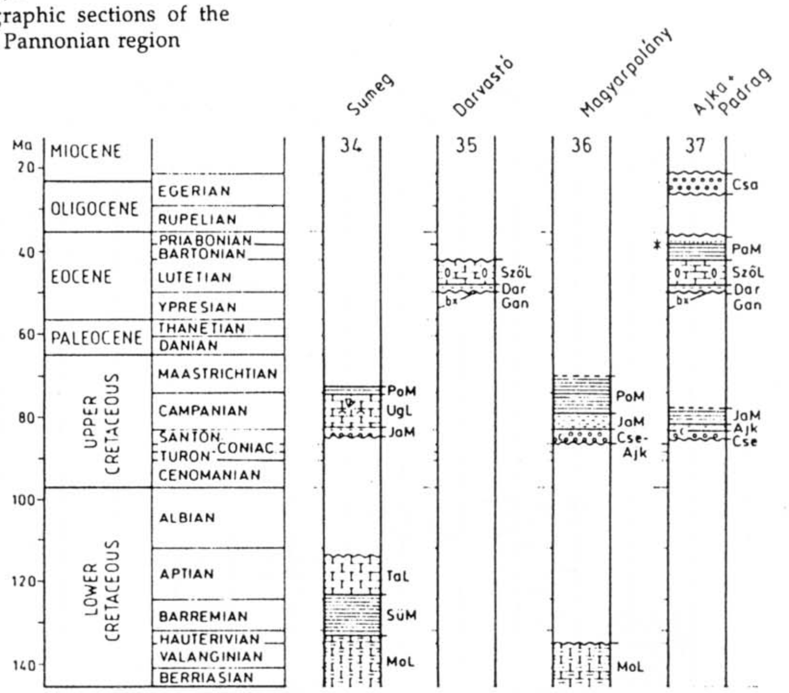

BREZOVÁ GROUP (Surovin Facies) Brezovské Karpaty
Šumiac
Dobšinská Ľadová jaskyňa
CENTRAL-CARPATHIAN PALAEOGENE Orava area
CENTRAL-CARPATHIAN PALAEOGENE Spiš region
29
30
31
32
33
Men
Jab
DeV
Pol
Dlm
Sum
Dlc
PsV
FWL
Hut
BiP
Zub
Puc
Bor
Hsm
MIOC
OLIG
EOCENE
PAL
U CRETAC
L CRETACEOUS
G, Z, T
R, A, ●
Z, R, G,
A, Ch, ●
G, R, A, Z

Fig. 5a, b
Stratigraphic sections of the North Pannonian region



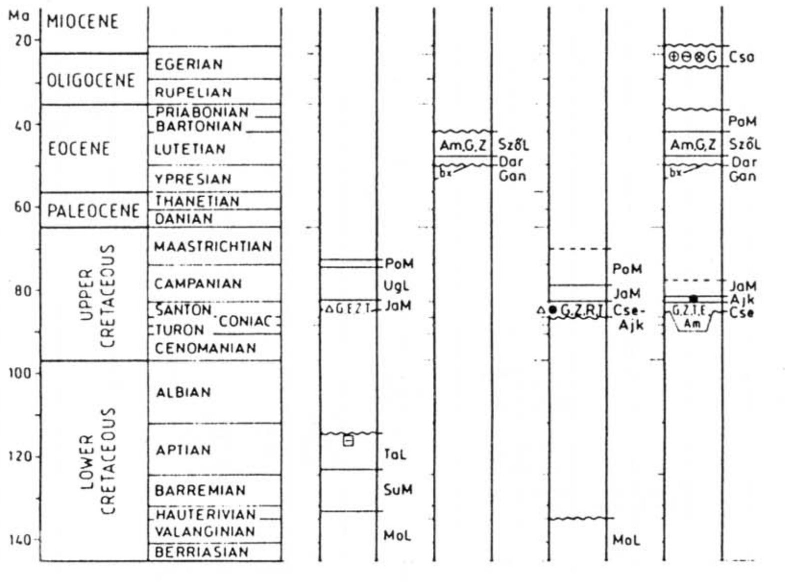
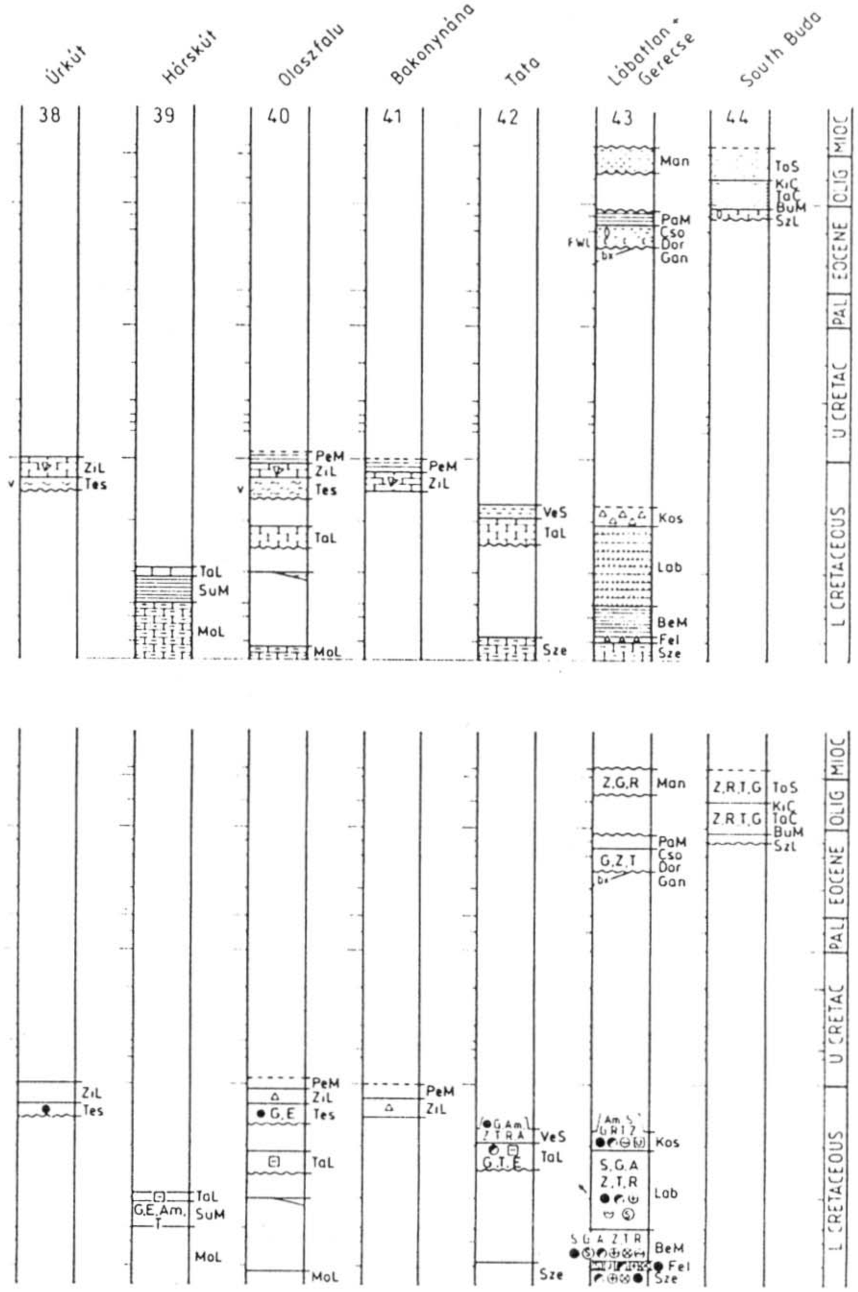


Fig. 5 b


Úrkút
Hárskút
Olaszfalu
Bakonynána
Tata
Lábatlan + Gerecse
South Buda
38
39
40
41
42
43
44
MIOC
OLIG
EOCENE
PAL
U CRETAC
L CRETACEOUS
ZiL
Tes
TaL
SuM
MoL
PeM
VeS
Sze
Man
PaM
Cso
Dor
Gan
FWL
Kos
Lab
BeM
Fel
ToS
KiC
TaC
BuM
SzL
Z,G,R
G,Z,T
Z,R,T,G
G,E
G,E,Am,
T
G,T,E
S,G,A
Z,T,R

The terrigenous deep-water development comprises coarse-grained facies of *deep-water breccias and conglomerates* (e.g. Spitzenbach Fm. in the NCA) and, mainly in sand grain size, the *turbiditic facies* (e.g. Rossfeld Fm., Brunnbach Fm in the NCA; Poruba Fm. in the WCa; Lábatlan Fm. in Gerecse). The latter facies is subdivided into *siliciclastic* and *carbonate-rich* turbidites on the basis of predominant clast material.

Bauxites and other residual sediments (TR and NCA) as well as *tuffs* and *tuffites* are indicated in the sections by separate symbols.

Palaeogeographically significant terrigenous material

In the highly orogenic Cretaceous and Palaeogene period, essential information can be obtained about the position and composition of palaeogeographically important regions, such as suture zones, high-pressure belts and occurrences of ophiolitic rock assemblages by studying the terrigenous detritus (Fig. 2), much of which can be classified as exotic material. Thus, several significant rock types are exhibited in the stratigraphic sections (Figs 3–5), such as granitoid rocks, metapelitic rocks (micaschists, phyllites), acidic extrusive rocks, basic/metabasic rocks and ultrabasic rocks (mainly serpentinites). In addition to these silicate rocks, some carbonate clasts seem to be highly significant palaeogeographically, such as Upper Jurassic and Lower Cretaceous shallow-water limestones, Tithonian/Neocomian calpionellid-bearing deep-water limestones, Hallstatt Limestone (Middle to Upper Triassic), Dachstein Limestone (Norian–Rhaetian), and Kambühel Limestone (Palaeocene). Exceptionally high proportions of dolomitic detritus also occur in a few sections. In most cases, these clasts are gravel-sized, although serpentinite is mainly found in sand-size fragments.

Chrome spinel and blue amphiboles in detrital heavy mineral assemblages are important indicators of the occurrence of ophiolitic complexes and high pressure/low temperature-belts in the source area and are therefore indicated by separate symbols in the sections. Both clast types mostly occur in the sand-size fraction. Among the other heavy minerals, such as those of the stable group (zircon, tourmaline, rutile) as well as garnet, apatite, chloritoid, staurolite, amphibole, hypersthene, and epidote-group minerals, only the predominant ones or those which are of particular palaeogeographic interest are documented in the sections.

To enhance the palaeogeographic significance of the sections, the available information on palaeocurrents is shown at the left side of the columns.

Lower Cretaceous

The lower parts of the Lower Cretaceous successions of the EA are characterised by a widespread deep-water limestone facies, known as the Schrambach Fm. in the Upper Austroalpine units. For the frequent occurrence of aptychus shells the term "Aptychus beds" is commonly used in the EA. This limestone facies starts normally with relatively pure, calpionellid-bearing Majolica-type limestones and passes upwards into impure marly limestones. From the Valanginian on, turbiditic layers are intercalated with these deep-water limestones to a variable extent in the NCA (Vašíček and Faupl, in prep.). In the external units, such as in the Gresten Klippen belt, these limestones are termed Blassenstein Fm., whereas in the Ybbsitz zone they are named Fasselgraben Fm.

In the WCa, as in the EA, monotonous marly limestone successions of deep-water origin are also characteristic for the bottom parts of the Lower Cretaceous (Michalík and Vašíček 1989). An exception is seen in the section from the Czorsztyn zone of the Pieniny Klippen belt, where shallow-water limestones are developed. The deep-water facies of the WCa has been subdivided into more formations than in the EA. From the sections of the Krížna nappe, intercalations with turbiditic facies are also common (Strážovce Fm.). Thick deep-water breccias have been observed in the Manín zone, and are termed Nozdrovice Breccia. In the Manín and Krížna units there are numerous small occurrences of basic volcanics.

The deep-water radiolarian, Calpionella and Nannoconus limestone (Majolica-type) facies of the TR is termed Mogyorósdomb Limestone. A similar but shallower facies without radiolarian chert (Szentivánhegy Limestone) is developed in the north-eastern localities (Tata and the Gerecse Mountains), the uppermost part of which persists into the early stage of the Early Cretaceous (Fülöp 1975).

In the EA and parts of the WCa, the deep-water limestone facies passes upwards into a bathyal marl facies, followed by turbiditic facies developments enriched with exotic material (Rossfeld Fm., Tannheim–Losenstein Fm., Lavant Fm., Párnica Fm., Poruba Fm.). This trend can also be observed in the Gerecse Mts. of the TR, where the Szentivánhegy Fm. is overlain by the bathyal slope sediment of the Bersek Marl Fm. with a breccia at its base (Felsővadács Breccia) and intercalations of graded sandstones throughout (Császár and B. Árgyelán 1994; Császár 1995). The marls grade up into the prograding turbiditic succession of the Lábatlan Sandstone and the Köszörűkbőánya Conglomerate on the higher slope.

Contrary to this trend of increasing terrigenous influx in the deep-water formation, to the SW of Gerecse (Vértes Foreland and North-Bakony) a great variety of limestones from the Upper Triassic (Dachstein Limestone) to the lowermost Cretaceous (Mogyorósdomb or Szentvánhegy Limestone) are overlain by subtidal biodetrital limestones with extraclasts (Tata Limestone), restricted lagoonal marls (Vértessomló Siltstone) and shallow-water platform carbonates, the so-called Urgonian facies (Környe and Zirc Limestone) of Aptian and Albian age. The two Urgonian sequences, both with a retrograding trend, are separated from each other by a fluvial to marine clastic formation (Tés Clay – Császár 1995). The lower formation (Környe Limestone) is interfingered with the subtidal to shallow bathyal Vértessomló Siltstone and with the Tés Clay Fm.

The development of shallow-water carbonates is also preserved in some parts of the WCa, such as in the Manín zone (Podhorie Fm.), the High Tatric unit of the Tatricum (Osobitá Fm.) and in parts of the Krížna nappe (Muráň Limestone in the High Tatras; Belá unit; Podhorie Fm.). The shallow-water biodetritus is present in fluxoturbitites and calciturbidite intercalations (Mišík 1990).

In situ Urgonian facies has not been observed in the Austroalpine units of the EA, but redeposited Urgonian clasts have been repeatedly reported from Lower and Upper Cretaceous as well as Tertiary deposits (Gaupp 1980; Hagn 1982, 1983; Weidich 1984; Schlagintweit 1987; Wagreich and Schlagintweit 1990); it is thought therefore that such carbonate platform sediments also accumulated within or in the near vicinity of the Austroalpine realm and were later totally eroded. A thick Urgonian succession (Schrattenkalk) is developed and preserved only in the western part of the Helvetic zone of the EA (Heim and Baumberger 1933; Császár et al. 1994).

In some cases, from the Late Albian on the Urgonian platforms subsided rapidly (Császár 1995) and were overlain by bathyal marls and turbiditic formations, such as the Butkov Fm. and Poruba Fm. of the WCa and the Pénzeskút Marl Fm. of the TR. It is considered that this subsidence pulse was a direct response to the mid-Cretaceous tectonic movements (Austrian phase post-collisional subsidence).

The terrigenous material of the Lower Cretaceous deposits was derived from two major source areas (Faupl 1990; Faupl and Wagreich 1992). One was situated in front of the Austroalpine realm and the Tatricum, whilst the other corresponds to the Tethys suture zone located within the Austroalpine realm.

The northern provenance area was built up by an accretionary wedge consisting of rocks of continental origin derived from the deforming Austroalpine margin and related units as well as from oceanic complexes. The oceanic series originated from obducted bodies of the Penninic–Ligurian Ocean associated with a subduction phase during the Early Cretaceous. Ophiolitic detritus is mainly represented by chrome spinel (Pober and Faupl 1988). The existence of high pressure/low temperature rocks within this accretionary wedge is proved by the occurrence of blueschist fragments in the Klape and Manín units of the WCa, in the Albian Poruba Fm. of the Humenné Mts. and also those redeposited in the Palaeogene sequence of Orava (Zoubek 1931; Mišík 1979; Mišík and Sýkora 1981; Mišík and Marschalko 1988; Ivan and Sýkora, 1993; Dal Piaz et al. 1995) and by detrital blue amphiboles and a few discoveries of lawsonite in the northernmost tectonic units of the NCA (Woletz 1970; Winkler and Bernoulli 1986; Faupl and Wagreich 1992). The Urgonian platform, which is preserved in several Tatric units, also seems to have served as a source area, but pebbles of Urgonian limestone with ophiolitic detritus are of exotic origin (Mišík 1990). From redeposited pebbles in the Losenstein

Fm. of the EA, it is known that such shallow-water carbonates occurred on the accretionary wedge (Wagreich and Schlagintweit 1990).

The existence of an intra-Austroalpine suture zone situated to the south of the NCA and acting as a source terrain during the Cretaceous and Palaeogene can also be deduced from Early Cretaceous clastic material. Within the NCA, the Rossfeld Fm. contains high amounts of detrital chrome spinel, accompanied by metamorphic heavy mineral associations derived from this suture zone (Faupl and Tollmann 1979; Decker et al. 1987). An analysis of Upper Cretaceous conglomerates in the NCA demonstrates that Urgonian carbonate successions were also deposited in parts of the NCA, but were later totally eroded. Pebbles of Urgonian-type limestones bear extremely high amounts of chrome spinel with relatively high Cr-contents, and it is believed that they were also derived from this intra-Austroalpine suture zone (Wagreich et al. 1995). Comparable chrome spinel-bearing pebbles have also been reported from the WCa by Mišík (1979), Mišík et al. (1980) and Mišík and Sýkora (1981). In the TR, the ophiolitic detritus of the Gerecse Mountains, which is also accompanied by metamorphic heavy minerals, points to the same source area. There the massive occurrence of ultrabasic and basic rock fragments (also associated with high-Cr-bearing spinel in the heavy mineral fractions – Császár and B. Árgyelán 1994) can be explained by a more proximal position of the Gerecse basin (Sztanó 1990) to this suture zone than the Rossfeld Fm of the NCA. The chemistry of detrital chrome spinels from the Rossfeld Fm. (Faupl and Pober 1991) and from the Gerecse section (Árgyelán 1996) are highly comparable. Detritus of the Urgonian-type limestones in the Gerecse Mountains was derived from the margin of the Tethys-Vardar Ocean (Császár and B.Árgyelán 1994; Császár 1995). The Tethys suture zone probably also supplied ophiolitic detritus to the Lower Cretaceous deposits of the WCa, as found in several units of the Krížna and Choč nappes (Mišík et al. 1980; Jablonský 1992), although no clear indications are available from palaeocurrent data.

Upper Cretaceous

In some parts of the tectonically lower nappe system of the NCA (Frankenfels and Ternberg nappe) the turbiditic facies of the Losenstein Fm. persisted into the Cenomanian. An analogous trend can be observed in parts of the Krížna nappe of the WCa, where the turbiditic Poruba Fm., with a comparable facies, also continued into the Cenomanian. A similar situation is known from the TR, where the carbonate platform was drowned in the Late Albian, with silty marls deposited in the Late Albian to Early Cenomanian and sandstones in the Middle Cenomanian. The Lábatlan Sandstone in the Gerecse Mountains is also supposed to extend into the Cenomanian, in the same palaeoenvironment (Császár 1995). The sequence of the Pénzeskút Marl spread over the Zirc Limestone in the Bakony Mountains in the Late Albian and the deposition of the coarsening-upward argillaceous-siliciclastic sedimentation continued at least until the Middle Cenomanian.

The sedimentary development of the Branderfleck Fm. of the NCA, resting unconformably upon external parts of the Lunz–Reichraming–Lechtal nappe system (Gaupp 1980, 1982; Weidich 1984, Faupl and Wagreich 1992) has no equivalent in the WCa or in the TR. While the Branderfleck Fm. of the western NCA represents a clastic deep-water facies, it is developed as a grey terrigenous shelf facies rich in ammonites (Summesberger 1992), inoceramids, and orbitolinid foraminifera in the middle and eastern parts.

In a particular way, the clastic mid-Cretaceous deep-water facies reflects the geodynamic activities of the Eoalpine stage. In the entire Austroalpine realm, including both the central WCa tectonic units and the TR, sedimentation was interrupted during the mid-Cretaceous as a result of Eoalpine folding and nappe stacking. Only in the "Cenoman-Randschuppe" of the western NCA did the deep-water sedimentation continue without interruption up to the Santonian/Campanian (Weidich 1984).

In the external units of the EA such as the Helvetic–Penninic domains (e.g. Gresten Klippen belt, Ybbsitz zone), and in the Manín and Klape units of the WCa as well as in the Pieniny Klippen belt, bathyal or turbiditic sedimentation passed continuously from the Early into the Late Cretaceous without major gaps. In the Klape unit an exception has been described, where oyster bioherms are embedded within a clastic deep-water sequence (Marschalko and Kysela 1980).

In the Turonian, a new sedimentary succession termed Gosau Group in the NCA (e.g. Wagreich and Faupl 1994) accumulated unconformably upon the deformed pre-Turonian successions. In the equivalent Brezová Group in the WCa sedimentation began in the Senonian (Samuel et al. 1980; Salaj and Began 1983). The Brezová Group is subdivided into the Bradlo and Surovín facies. The basal part of all these deposits consists of an alluvial to fan-delta facies (Kreuzgraben and Streiteck Fm., Valchov Conglomerate). In some places, freshwater limestones (e.g. Pustá Ves Fm.) and small bauxite deposits have been observed at the base and coal seams have been found within the transitional facies of alluvial to fan-delta environment. The alluvial to fan-delta facies passed into a shallow-marine terrigenous facies which also includes thin beds of rudist bioherms and related sediments. This shallow-marine development is overlain by a mostly reddish bathyal marl facies (e.g. Nierental Fm., Košariská Fm.) or grey marls such as the Štverník Marls, Mosnáčov Marls associated with deep-water breccias (Spitzenbach Fm., Široké Bradlo Limestone) and by a turbiditic facies (e.g. Ressen Fm., Brunnbach Fm., Höllgraben Fm., Zwieselalm Fm., Podbradlianska Fm., Podlipovec Flysch, Polianka Fm.), both deep-water developments demonstrating the rapid deepening of the basin. In many localities of the NCA, a conspicuous unconfomity developed between the Lower Gosau Subgroup, comprising the terrestrial to shallow-marine deposits, and the deep-water sediments of the

Upper Gosau Subgroup. This unconformity does not appear to occur in the Brezová Group of the WCa.

The sedimentation of the Lower Gosau Group appears to have been tectonically controlled by the oblique subduction of the Penninic–Ligurian Ocean below the Austroalpine margin. Deposition took place in a transtensional crustal regime behind the accretionary wedge, a palaeogeographic feature mentioned previously, lying in the frontal part of the Austroalpine domain since the mid-Cretaceous. The diachronous onset of the deep-water sedimentation of the Upper Gosau Group began in the north-western parts of the NCA and migrated towards the south-east. It is presumed that the new subsidence pulse of the Upper Gosau Group was triggered by a collisional event causing subcrustal tectonic erosion, during which the accretionary wedge was removed. In the sedimentary column this event is documented by deformation and erosion of parts of the Lower Gosau Group and by the discontinuous onset of deep-water sediments.

The so-called Central-Alpine Gosau deposits of the EA, resting unconformably upon Upper Austroalpine units such as the Palaeozoic of Graz (Kainach Gosau) and the Gurktal Nappe (Krappfeld Gosau, Gosau of St. Paul/Lavanttal), have an equivalent development in the western parts of the TR (Bakony Mts). In both cases, sedimentation commenced in the Santonian and comprises a terrestrial to shallow-marine lower part and an upper part of deep-water sediments. In the Central-Alpine Gosau of the Krappfeld the lower series, including extensive deposits of rudist limestones, were widely eroded and redeposited into the deep-water environment. In contrast, in the TR, fluvial-paludal (Csehbánya Fm. – Jocha-Edelényi 1988) and pit-bog facies (Ajka Coal Fm. – Haas et al. 1986; Császár et al. 1993) deposits are preserved to a much greater extent, where they developed in troughs. At the base of the Hungarian successions bauxites locally accumulated in karst depressions (Halimba Bauxite Fm.), not only in the troughs but also high on the slope. The non-marine succession is overlain by a shallow-marine marl (Jákó Marl Fm.), while the topographic highs separating the troughs are covered directly by Campanian rudistid platform carbonates (Ugod Limestone Fm.), replaced laterally and upward by shallow bathyal marls (Polány Marl Fm.). The lithoclastic (debrite) bodies (Jákóhegy Breccia Mb.) interfingering with the Polány Marl were derived from the carbonate platform and moved onto the slope a few kilometres away from the source (Haas 1979, 1983). The upper part of the Polány Marl turns into a coarsening-upward siliciclastic marl, resembling the Pénzeskút Marl Fm. Locally (Tapolcafő), the carbonate platform was raised above sea-level and karstified just prior to the drowning of the platform. There the Polány Marl shows an coarsening-upward trend starting with red clays.

A comparable development of Upper Cretaceous deposits appears to be missing in the WCa, although the successions of Šumiac and Dobšinska Ladova

Jaskyna could be interpreted as small remnants of the lower parts of the successions described from the EA and the TR.

One of the major differences between the Hungarian Senonian and the Central-Alpine Gosau of the EA is found in the rock and mineral composition of the terrigenous material. Whereas the Hungarian deposits are characterised by the occurrence of chrome spinel in the heavy mineral associations (B. Árgyelán, personal communication), this ophiolitic detritus is totally missing in Upper Cretaceous successions of the Central-Alpine Gosau. Furthermore, the facies development of the Central-Alpine Gosau and the Senonian of the TR differs considerably from those of the Gosau in the NCA and Brezová Group in the WCa (Oberhauser 1963).

The terrigenous material in the Upper Cretaceous formations was derived from the same two major source terrains as recorded in the Lower Cretaceous: the intra-orogenic Tethys suture zone to the south and the accretionary wedge in front of the Austroalpine domain to the north. The material from the accretionary wedge which supplied the Klape and the Manín units of the WCa is characterised by high proportions of ophiolitic detritus and high-pressure rock fragments, as well as by manifold suites of carbonate clasts such as Upper Jurassic and Lower Cretaceous (Urgonian) shallow-water limestones and Tithonian/Neocomian deep-water limestones. This accretionary wedge was also active in supplying chrome spinel-rich detritus and exotic pebbles to the Lower Gosau Group of the NCA (Wagreich and Faupl 1994), the Brezová Group (Wagreich and Marschalko 1995) and the unit joining them covered by Neogene sediments in the Slovakian sector of the Vienna Basin (Mišík 1994).

With the onset of subcrustal tectonic erosion which removed the accretionary wedge, intra-orogenic source areas including the Tethys suture zone began to play a more important role. As a consequence, ophiolitic detritus decreased considerably in the WCa and EA and only a local supply of chrome spinel from the Tethys suture zone can be observed. In the Gosau Group of the NCA, rock fragments, especially light micas derived from the Eoalpine metamorphosed Austroalpine crystalline basement, were deposited from Late Campanian time on (Pober 1984). The ophiolitic detritus of the Upper Cretaceous of the TR was supplied exclusively from the Tethys suture zone.

Palaeogene

In the Gosau Group of the EA, the deposition of bathyal marls and turbidites continued from the Upper Cretaceous to the Eocene. The same trend has been observed in the Gosau-type Brezová Group of the WCa. However, the shallow-water limestone facies of the Dedkov Vrch Fm. (Paleocene/Eocene) in the Surovín facies of the WCa, which forms an intercalation within the deep-water development, is an exception. This formation possibly represents redeposited shallow-water material in a proximal deep-water environment, as also suggested for the Kambühel Limestone (Lower Paleocene) at the type locality in Lower Austria. The entire succession of the Surovín facies persists up to the Rupelian. In these facies the occurrence of detrital chrome spinel is reported from the turbiditic Polianka Fm. (Maastrichtian) as well as from the deep-water deposits of the Jablonka Fm. (Eocene). Similar occurrences of ophiolitic detritus have also been reported from several turbiditic formations of the Upper Gosau Group of the NCA (e.g. Gießhübel Fm. – Sauer 1980; Brunnbach Fm. – Faupl 1983) which proves that the Tethys Suture zone was active as a source terrain during this late stage of sedimentation.

In the external tectonic units of the EA, described in this paper, a deep-water development is characteristic for Paleocene–Eocene times, such as in the Gresten Klippen belt of the EA (Buntmergelserie with deep-water conglomerates) as well as in the Pieniny Klippen belt and Klape unit of the WCa.

In the Krappfeld area of the EA, a succession of shallow-marine terrigenous facies with coal-bearing beds at its base lies unconformably on Central-Alpine Upper Cretaceous Gosau deposits (Wilkens 1989). These terrigenous formations pass up into a highly fossiliferous shallow-marine limestone facies with nummulite beds. This transgressive sequence as a whole forms a new sedimentary cycle and is here summarised under the stratigraphic term "Guttaring Group", which has been subdivided into three formations and several members by Wilkens (1991). Contrary to the comparable Hungarian deposits, which are free of detrital chrome spinel, ophiolitic detritus has been observed in sandstones of the Guttaring Group.

A very small occurrence of shallow-water limestones (Priabonian) from Kirchberg/Wechsel, resting upon the crystalline basement complex of the Lower Austroalpine unit, is not presented among the sections of the EA. It appears to be similar to the Szépvölgy Limestone in the Buda Hills of Hungary (Kázmér 1985a). The Upper Eocene–Oligocene successions of the "Unterinntal-Tertiär" (NCA) are not discussed in this paper.

In the TR, a comparable transgressive development of shallow-marine deposits commenced in the Middle Eocene, or later than in the EA. At the base, well-known large bauxite deposits (Gánt Bauxite Fm.) are widely distributed. In western parts of the TR (Darvastó at Nyirád and Padrag) the shallow-marine terrigenous facies is associated with coal seams and passes into nummulitic limestones (Szőc Limestone Fm.). The entire succession shows a deepening-upward trend with a bathyal facies at the top (Padrag Marl Fm.). In the troughs between the North Bakony and the Dorog Basin, with a varied morphology similar to the Upper Cretaceous one, sedimentation began with terrestrial sediments, including thick coal measures, followed by marls and siltstones. The topographic highs were covered directly by nummulitic and biodetrital limestone (Szőc Limestone Fm.) of Late Lutetian age. To the east, in the South Buda Hills, the transgression started later (in the Priabonian) with the Szépvölgy Limestone Fm. which also passed into a bathyal facies at the end of the Eocene. The Oligocene to the east of Buda developed continuously from the bathyal Buda Marl Fm. and is represented by fine-grained siliciclastics (Fodor et al. 1994). As far as to the west of Buda it forms a new sedimentary cycle, which began with variegated alluvial fan deposits (Korpás 1981). The Egerian transgression occurred with a shallow-marine terrigenous facies (Mány Fm.) towards the east and variegated fluvial sediments to the west (Csatka Fm.). In the South Buda Hills, the Törökbálint Sandstone Fm. directly overlies the bathyal facies of the Kiscell Clay Fm. (Rupelian) without any unconformity.

In the WCa, the transgression from the region of the Flysch Belt into the Peri-Klippen Belt area, which contains blocks of the biohermal Kambühel Limestone, had already begun in the Paleocene. In the eastern part of the Pieniny Klippen Belt, the Paleocene Proc Conglomerates include almost the same inventory of exotic rocks as the Cretaceous conglomerates of the western part of the Klippen and Peri-Klippen zones. These exotic components could not have been redeposited from the Cretaceous conglomerates because such a facies is totally absent in the eastern sector.

The transgression of the "Central-Carpathian Palaeogene" (Gross et al. 1993) commenced in the Middle Eocene, starting with the shallow-water deposits of the Borové Fm. These deposits pass rapidly via a bathyal marl facies (Huty Fm.) into the thick Central-Carpathian Flysch sequences of the Zuberec and Biely Potok Fms. The palaeocurrents show various directions, but besides local currents a general trend towards the east is characteristic for the central and eastern parts of this basin (Gross et al. 1993). From the Spiš region, ophiolitic detritus has been reported in these formations (intercalation of the "serpentinite sandstone" within the Šambron zone – Soták and Bebej 1996). In the Orava area, the occurrence of glaucophane-bearing pebbles, probably redeposited from the Cretaceous conglomerates of the Klippen Belt, is of special interest. The rapid subsidence of the Central-Carpathian Flysch basin is interpreted to have been caused by subcrustal tectonic erosion which seems to continue in the WCa for a longer period than in the EA.

Conclusions

The sedimentary history of the three segments of the Alpine orogenic belt, the Eastern Alps, the Western Carpathians and the Transdanubian Range, is predominantly similar. This similarity can be summarised as follows:

1) In the Early Cretaceous, deep-water pelagic limestones with turbiditic intercalations in them are typical for almost the entire area concerned: Blassenstein Fm. (Gresten Klippen Zone), Fasselgraben Fm. (Ybbsitz Zone), Schrambach Fm. (NCA), "Calpionellenkalk" (N Karawanken, not in the presented sections), Nozdrovice Fm. (Manín unit), Strážovce Fm. (Krížna nappe) and Szentivánhegy Limestone–Bersek Marl Fm. with the Felsővadács Breccia Mb. (TR).

2) In the Valanginian the pelagic limestones were replaced first by turbiditic marl deposits (lower part of the Rossfeld Fm. (NCA) and Bersek Marl Fm. (TR)) and then by coarser grained clastics (upper part of the Rossfeld Fm. (NCA), intercalations in the Stražovce Fm. (loc. Oravice) and Lábatlan Sandstone Fm., Köszörűkőbánya Conglomerate (TR)). The coarsening-upward tendency is conspicuous in all three regions.

3) In some zones the sedimentation of bathyal marls continued or only began in the Aptian and/or Albian: Tannheim Fm. in the NCA, lower member of the Lavant Fm. (Drau Range), Párnica Fm., Butkov Fm., Tissalo Beds and Kapusnica Fm. in the WCa, and Vértessomló Siltstone Fm. in the TR. In the EA and WCa, this bathyal marl facies marks the onset of further synorogenic clastic deep-water sedimentation (e.g. Losenstein–Branderfleck Fm., Lavant Fm., Poruba Fm.).

4) Due to the overall tectonic activity, or as a consequence of a shallowing-upward trend, in some areas platform carbonates of Urgonian facies developed: In the WCa the Podhorie Fm. (Manín unit, Krížna nappe) and the Osobitá Fm. (Tatricum, High Tatras); in the TR the Zirc and Környe Limestones (Vértes Foreland, not in the presented sections). These platforms are mainly prograding. In the EA Urgonian carbonate successions are only preserved in the western parts of the Helvetic zone *s. str.* (e.g. Schrattenkalk, not in the presented sections). However, exotic Urgonian pebbles from the EA and WCa are evidence for the existence of carbonate platforms to the north on the accretionary wedge forming the leading edge of the Austroalpine–Central Carpathian margin, as well as to the south at the active margin of the Tethys-Vardar Ocean. Urgonian-type olistoliths, found in the Köszörűkőbánya Conglomerate Mb. (Gerecse Mts.), were supplied from this southern source terrain.

5) The accretionary wedge at the northern active margin of the Austroalpine–Central Carpathian complex and the Tethys suture zone in the south seem to have been the two major sources of exotic clasts, including ophiolitic detritus from the Cretaceous up to the Palaeogene.

6) The carbonate platforms were drowned in the (Late) Albian as evidenced by the Butkov and Poruba Fm. (WCa) and the Pénzeskút Marl Fm. (TR).

7) Except in external tectonic units (Gresten Klippen zone, Ybbsitz zone, "Cenoman Randschuppe", Klape and Manín units), sedimentation was interrupted in the entire Austroalpine realm in mid-Cretaceous time, followed by an extensive erosion prior to or during the Turonian.

8) The Upper Cretaceous sedimentary cycle began with alluvial and fan-delta facies in the NCA and the WCa in the Turonian and in the central parts of the EA and the TR in the Santonian: Kreuzgraben and Streiteck Fm. (NCA), a part of the Valchov Conglomerate (WCa) and Csehbánya Fm. (TR). It was followed first by shallow-marine successions (e.g. Grabenbach and Hochmoos Fm., NCA; Baranec Sandstone, WCa; Jákó Marl Fm., Bakony Mts.) and then by bathyal facies (e.g. Nierental Fm., NCA; Štvernik Marl etc., WCa; Zementmergelfolge,

Central Alps; Polány Marl, Bakony Mts.). These marls represent predominantly deep bathyal facies with turbiditic intercalations in the NCA and WCa, whereas in the Central-Alpine Gosau and in the TR a more shallow bathyal facies with slope breccias is developed.

9) Late Cretaceous rudistid bioherms are distributed in a northern zone (NCA and WCa) while platform carbonates were formed in central parts of the EA and the TR. Its continuation is supposed to be developed in the Dobšiná area of the WCa (loc. Šumiac).

10) Continuous deep-water sedimentation up to the Palaeogene is reported from the Helvetic zone *s. l.* (Gresten Klippen zone), the Pieniny Klippen Belt and the Klape unit as well as from the Gosau and Brezová Group. A gap is documented in the Central-Alpine domain and in the TR. The terrigenous coal-bearing sedimentation in the Krappfeld area commenced in the Early Eocene and in the TR and the Central-Carpathian Palaeogene in the Middle Eocene. In all these places the succession continued either with shallow-marine nummulitic limestones (Szőc Limestone, TR; Borové Fm., WCa) or directly with pelagic marls (Padrag Marl Fm., TR). Clastic sedimentation continued with shallow bathyal facies east of Buda and as flysch in the Central-Carpathian Palaeogene.

In spite of local and temporal differences, the main events of the Cretaceous–Palaeogene history of the study area basically correlate with each other, especially within the NCA and the WCa as well as in the TR and the Central-Alpine part of the EA. However, the facies and time differences of the Upper Cretaceous and Palaeogene sequences between the Central-Alpine domain of the EA and the TR are clear evidence that the shift of the TR towards the east, away from its Permian to Early Cretaceous position, began in the mid-Cretaceous and lasted until the Late Cretaceous and Palaeogene.

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References

Andrusov, D. 1965a: Geologie der Tschechoslovakischen Karpaten. – II, Berlin (Akademie Verlag) – Bratislava (SAV), 443 p.

Andrusov, D. 1965b: Geology of the Czechslovak Carpathians. – III. Slov Akad. Vied, pp. 1–392, Bratislava, (in Slovak with a German summary).

Árgyelán, G.B. 1996: Geochemical investigations of detrital chrome spinels as a tool to detect an ophiolitic source area (Gerecse Mountains, Hungary). – Acta Geol. Hung., 39, 4, pp. 341–368.

Bada, G., L. Fodor, G. Székely, G. Tímár 1996: Tertiary brittle faulting and field evolution in the Gerecse Mts., Hungary. – Tectonophysics, 255, pp. 269–290.

Balla, Z., A. Dudko 1989: Large-scale Tertiary strike-slip displacements recorded in the structure of the Transdanubian Range. – Geophysical Transactions, 35, pp. 3–63, Budapest.

Báldi, T., M. Báldi-Beke 1985: The evaluation of the Hungarian Paleogene basins. – Acta Geol. Hung., 28, pp. 5–28.

Birkenmajer, K. 1977: Jurassic and Cretaceous lithostratigraphic units of the Pieniny Klippen Belt, Carpathians, Poland. – Studia Geol. Polon., 45, 158 p., Warszawa.

Brezsnyánszky, K., J. Haas 1986: Main features of the pre-Tertiary basement of Hungary. – Geol. Zbor. Geol. Carpath., 37, pp. 297–303.

Császár, G. 1984: Middle Cretaceous paleogeography and evolutionary history sketch of the Transdanubian Central Range in the light of key and reference sections. – Schriftenreihe Erdwiss. Kommission, Österr. Akad. Wiss., 7, pp. 173–192.

Császár, G. 1986: Middle Cretaceous Formations of the Transdanubian Central Range: stratigraphy and connection with bauxite genesis. – Geol. Hungarica, ser. Geol., 23, pp. 149–207.

Császár, G. 1995: An overview of the Cretaceous research in the Gerecse Mountains and Vértes Foreland. – Általános Földtani Szemle, 27, pp. 133–152, Budapest. (In Hungarian with an English summary)

Császár, G., G.B. Árgyelán 1994: Stratigraphic and micromineralogic investigations on Cretaceous formations of the Gerecse Mountains, Hungary and their palaeogeographic implications. – Cretaceous Research, 15, pp. 417–434.

Császár, G., I. Bodrogi, L. Czabalay, A. Horváth, M. Juhász, M. Monostori 1987: Facies and ecology of the Albian-Cenomanian Pénzeskút Marl Formation in the light of the fossil record. – MÁFI Évi Jel. 1985-ről, pp. 381–403. (In Hungarian with an English summary).

Császár, G., L. Dosztály 1993: Lower and Middle Cretaceous formations of the Transdanubian Range. – Cretaceous and Paleogene paleogeography and geodynamics of the Alcapa region, July 5–8th, 1993, Budapest, Field guide, pp. 1–52.

Császár, G., J. Haas 1984: The Cretaceous in Hungary: a review. – Acta Geol. Hung., 27, pp. 417–428.

Császár, G., D. Mehl, R. Oberhauser, H. Lobitzer 1994: Comparative study of the Urgonian facies in Vorarlberg (Austria), in Allgäu (Germany) and in the Villány Mountains (Hungary). – In: Lobitzer, H., G. Császár, A. Daurer (Eds): Jubiläumsschrift 20 Jahre Zusammenarbeit Österreich – Ungarn, Teil 2, pp. 145–207, Wien.

Császár, G., E. Jocha-Edelényi, J. Knauer, K. Szentgyörgyi 1993: Terrestrial and shallow-marine Cretaceous clastics of Hungary. – Cretaceous Research, 14, pp. 307–335.

Dal Piaz, G.V., S. Martin, J.M. Villa, G. Gosso, R. Marschalko 1995: Late Jurassic blueschist pebbles from the Western Carpathian orogenic wedge and paleostructural implications for the Western Tethys evolution. – Tectonics, 14, pp. 874–885.

Decker, K. 1990: Plate tectonic and pelagic facies: Late Jurassic to Early Cretaceous deep-sea sediments of the Ybbsitz ophiolite unit (Eastern Alps, Austria). – Sedimentary Geol., 67, pp. 85–99.

Decker, K., P. Faupl, A. Müller 1987: Synorogenic sedimentation on the Northern Calcareous Alps during the Early Cretaceous. – In: Flügel, H. W., P. Faupl (Eds): Geodynamics of the Eastern Alps, Deuticke, Vienna pp. 126–141.

Decker, K., H. Peresson, P. Faupl 1994: Die miozäne Tektonik der östlichen Kalkalpen: Kinematik, Paläospannungen und Deformationsaufteilung während der "lateralen Extrusion" der Zentralalpen. – Jb. Geol. B.-A., 137, pp. 5–18, Wien.

Eliás, M., W. Schnabel, Z. Stráník 1990: Comparison of the Flysch Zone of the Eastern Alps and Western Carpathians based on recent observations. – In: Minaríková, D., H. Lobitzer (Eds): Thirty years of geological cooperation between Austria and Czechoslovakia, Federal Geological Survey Vienna, Geological Survey Prague, ÚÚG, Prague, pp. 37–46.

Faupl, P. 1983: Die Flyschfazies der Gosau der Weyerer Bögen (Oberkreide, Nördliche Kalkalpen, Österreich). – Jb. Geol. B.-A., 126, pp. 219–244, Wien.

Faupl, P. 1990: Eoalpine collisional events of the Eastern Alps in the light of heavy mineral detritus. – 13th Int. Sed. Congr., Abstracts, pp. 76–77, Nottingham.
Faupl, P., E. Pober 1991: Zur Bedeutung detritischer Chromspinelle in den Ostalpen: Ophiolithischer Detritus aus der Vardarsutur. – In: Lobitzer, H., G. Császár (Eds): Jubiläumsschr. 20 Jahre Geologische Zusammenarbeit Österreich – Ungarn, Teil 1, pp. 133–143, Wien.
Faupl, P., A. Tollmann 1979: Die Roßfeldschichten: Ein Beispiel für Sedimentation im Bereich einer tektonisch aktiven Tiefseerinne aus der kalkalpinen Unterkreide. – Geol. Rundsch., 68, pp. 93–120.
Faupl, P., M. Wagreich 1992a: Transgressive Gosau (Coniac) auf Branderfleckschichten (Turon) in den Weyerer Bögen (Nördliche Kalkalpen, Oberösterreich). – Jb. Geol. B.-A., 135, pp. 481–491, Wien.
Faupl, P., M. Wagreich 1992b: Cretaceous flysch and pelagic sequences of the Eastern Alps: correlation, heavy minerals, and palaeogeographic implications. – Cretaceous Research, 13, pp. 387–403.
Faupl, P., M. Wagreich 1996: Basin analysis of the Gosau Group of the Northern Calcareous Alps (Turonian–Eocene, Eastern Alps). –In: Wesswly, G., W. Liebl (Eds): Oil and gas in Alpidic thrustbelts and basins of Central and Eastern Europe, EAGE Spec. Pub., 5, pp. 127–135.
Flügel, H. W., P. Faupl (Eds) 1987: Geodynamics of the Eastern Alps. – Deuticke, Vienna, 418 p.
Fodor, L., Á. Magyari, A. Fogarasi, K. Palotás 1994: Tertiary tectonics and Late Paleogene sedimentation in the Buda Hills, Hungary. A new interpretation of the Buda Line. – Földtani Közlöny, 124, pp. 240–305, Budapest.
Fodor, L., Á. Magyari, M. Kázmér, A. Fogarasi 1992: Gravity-flow dominated sedimentation on the Buda paleoslope (Hungary). Record of Late Eocene continental escape of the Bakony unit. – Geol. Rundschau, 81, pp. 695–716.
Frank, W. 1987: Evolution of the Austroalpine elements in the Cretaceous. – In: Flügel, H.W., P. Faupl (Eds), Geodynamics of the Eastern Alps, Deuticke, Vienna, pp. 379–406.
Fülöp, J. 1975: The Mesozoic Basement Horst Blocks of Tata. – Geol. Hungarica, ser. Geol., 16, pp. 1–228.
Gaupp, R. H. 1980: Sedimentpetrographische und stratigraphische Untersuchungen in den oberostalpinen Mittelkreide-Serien des Westteiles der nördlichen Kalkalpen. – Diss. Techn. Univ. München, 282 S., München.
Gaupp, R. 1982: Sedimentationsgeschichte und Paläotektonik der kalkalpinen Mittelkreide (Allgäu, Tirol, Vorarlberg). – Zitteliana, 8, pp. 33–72, München.
Gross, P., E. Köhler 1980: Geology of Liptovská kotlina (Liptov Depression). – Geol. Úst. D. Stúra, pp. 1–242, Bratislava, (in Slovak with an English summary).
Gross, P., E. Köhler, J. Mello, J. Hasko, R. Halouzka, A. Nagy 1993: Geology of the southern and eastern part of Orava. – Geol. Ústav D. Stúra, Bratislava, 319 p (in Slovak with an English summary).
Haas, J. 1979: The Ugod Limestone Formation (Senonian Rudist Limestone) in the Bakony Mountains.— Földt. Int. Évkönyve, 61, pp. 121–144, Budapest.
Haas, J. 1983: Senonian cycle in the Transdanubian Central Range. – Acta Geol. Hung., 26, pp. 21–40, Budapest.
Haas, J. 1987: Position of the Transdanubian Central Range structural unit in the Alpine evolution phase. – Acta Geol. Hung., 30, pp. 243–256.
Haas, J., G. Császár 1987: Cretaceous of Hungary: Paleogeographic implications. – Rend. Soc. Geol. Italiana, 9, pp. 203–208, Roma.
Haas, J., E. Jocha-Edelényi, Császár, Z. Partényi 1986: Genetic circumstances of the Senonian coal measures of the Bakony. – MÁFI Évi Jel. 1984-ről, pp. 343–353, Budapest. (In Hungarian with an English summary.)

Hagn, H. 1982: Neue Beobachtungen in der Unterkreide der nördlichen Kalkalpen (Thierseer Mulde SE Landl, Kalkalpine Randschuppe, SW Bad Wiessee). – Mitt. Bayer. Staatsslg. Paläont. hist. Geol., 22, pp. 117–135, München.
Hagn, H. 1983: Die Kreide- und Alttertiär-Gerölle des Wachtberg-Schotters (Ottnang, Subalpine Molassezone) N Salzburg. – Mitt. Bayer. Staatsslg. Paläont. hist. Geol., 23, pp. 125–150, München.
Heim, A., E. Baumberger 1933: Jura und Unterkreide in den helvetischen Alpen beiderseits des Rheins (Vorarlberg und Ostschweiz). – Denkschr. schweiz. naturforsch. Ges., 68, pp. 155–220.
Herm, D. 1979: Die süddeutsche Kreide – Ein Überblick. – Aspekte der Kreide Europas, IUGS Series A, 6, pp. 85–106, Stuttgart.
Herm, D. 1981: Höhere Oberkreide. – Geologica Bavarica, 82, pp. 22–26, München.
Ivan, P., M. Sykora 1993: Finding of glaucophane-bearing rocks in the Cretaceous conglomerates from Jasenov (Krízna nappe, Eastern Slovakia). – Mineralia Slov., 25, pp. 29–33, Bratislava, (in Slovak with an English summary).
Jablonský, J. 1992: Rossfeld Formation in Krízna and Choc nappes, Western Carpathians. – Terra Abstract, 4, 2, p. 34, Oxford.
Jocha-Edelényi, E. 1988: History of evolution of the Upper Cretaceous basin in Bakony Mts. at the time of formation of the terrestrial Csehbánya Formation. – Acta Geol. Hung., 31, pp. 19–32.
Kázmér, M. 1985a: Microfacies pattern of the Upper Eocene limestones at Budapest. – Ann. Univ. Sci. Budapest, Sec. Geol., 25, pp. 139–151.
Kázmér, M. 1985b: Continuous and discontinuous Upper Eocene sequences in the Buda Hills and their tectonic implications. – Őslénytani Viták, 31, pp. 65–69, Budapest. (In Hungarian with an English summary.)
Kázmér, M., S. Kovács 1985: Permian–Paleogene paleogeography along the eastern part of the Insubric–Periadriadic lineament system: evidence for continental escape of the Bakony–Drauzug unit. – Acta Geol. Hung., 28,pp. 71–84.
Korpás, L. 1981: Oligocene–Lower Miocene formations of the Transdanubian Central Mountains in Hungary. – Földt. Int. Évkönyve, 64, pp. 83–126, Budapest.
Kozur, H. 1991: The evolution of the Meliata–Hallstatt ocean and its significance for the early evolution of the Eastern Alps and Western Carpathians. – Palaeogeogr., Palaeoclim., Palaeoecol., 87, pp. 109–135.
Kozur, H., R. Mock 1985: Erster Nachweis von Jura in der Meliata–Einheit der südlichen Westkarpaten. – Geol. Paläont. Mitt. Innsbruck, 13, pp. 223–238.
Kozur, H., H. Mostler 1992: Erster paläontologischer Nachweis von Meliaticum und Süd-Rudabányaicum in den Nördlichen Kalkalpen (Österreich) und ihre Beziehungen zu den Abfolgen in den Westkarpaten. – Geol. Paläont. Mitt. Innsbruck, 18, pp. 87–129.
Lesko, B., O. Samuel 1968: The geology of the East Slovakian Flysch. – Geol. Úst. D. Stúra., Bratislava, 245 p., (in Slovak with an English summary).
Mandl, G. W., A. Ondrejičková 1991: Über eine triadische Tiefwasserfazies (Radiolarite, Tonschiefer) in den Nördlichen Kalkalpen – ein Vorbericht. – Jb. Geol. B.-A., 134, pp. 309–319, Wien.
Marschalko, R. 1986: Evolution and geotectonic significance of the Klippen Belt Cretaceous Flysch in the Carpathian megastructure. – Veda, 137 p, Bratislava, (in Slovak with an English summary).
Marschalko, R. 1986: Vyvoj a geotektonicky vyznam kriedového flysu bradlového pásma. – Veda, Bratislava, 137 p, (in Slovak with an English summary).
Marschalko, R., J. Kysela 1980: Geology and sedimentology of Klippen Belt and Manín Unit between Zilina and Povazska Bystrica. – Západné Karpaty, sér. geol., 6, pp. 7–79, Bratislava.
Michalík, J. 1994: Notes on the palaeogeography and palaeotectonics of the Western Carpathian area during the Mesozoic. – Mitt. Österr. Geol. Ges., 86, pp. 101–110, Wien.

Michalík, J. 1995: Lower Cretaceous stratigraphy, facies, faunas and Tethyan/Boreal influences in the Western Carpathians. – Cretaceous Research, 16, pp. 299–310.
Michalík, J., D. Reháková, Z. Vašíček 1995: Early Cretaceous sedimentary changes in the West-Carpathian area. – Geol. Carpathica, 46, pp. 285–296, Bratislava.
Michalík, J., Z. Vašíček 1989: Lower Cretaceous stratigraphy and paleogeography of the Czechoslovakian Western Carpathians. – In: Wiedmann, J. (Ed.): Cretaceous of the Western Tethys, Schweizerbart, Stuttgart, pp. 505–523.
Mišík, M. 1979: Pieniny Klippen Belt and the global tectonics model. – In: Mahel, M., P. Reichwalder (Eds): Czechoslovak geology and global tectonics, Veda, Bratislava, pp. 89–101.
Mišík, M. 1990: Urgonian facies in the West Carpathians. – Knihovnicka Zemního plynu a nafty, 9a, pp. 25–54, Hodonín.
Mišík, M. 1994: Senonian continental sediments with marine intercalations (Gosau complex) in the basement of the Slovakian part of the Vienna basin (borehole Gajary Ga-125). – Mineralia Slov., 26, pp. 297–310, Bratislava.
Mišík, M., J. Jablonský, P. Fejdi, M. Sýkora 1980: Chromian and ferrian spinels from Cretaceous sediments of the West Carpathians. – Mineralia Slovaca, 12, pp. 209–228, Bratislava.
Mišík, M., R. Marschalko 1988: Exotic conglomerates in flysch sequences: examples from the West Carpathians. – Mém. Soc. Géol. France, N.S., 154, pp. 95–113.
Mišík, M., M. Sýkora 1981: Pieninsky exoticky chrbát rekonštruovany z valúnov karbonátovych hornín kriedovych zlepencov bradlového pásma a manínskej jednotky. – Západné Karpaty, sér. geol., 7, pp. 7–111, Bratislava.
Mišík, M., M. Sýkora, R. Mock, J. Jablonský 1991: Paleogene Proč conglomerates of the Klippen Belt in the West Carpathians, material from the Neopieninic exotic ridge. – Acta geol. et geogr. Univ. Comenianae, Geologica, 46, pp. 9–101, Bratislava.
Oberhauser, R. 1963: Die Kreide im Ostalpenraum Österreichs in mikropaläontologischer Sicht. – Jb. Geol. B.-A., 106, pp. 1–88, Wien.
Oberhauser, R. 1968: Beiträge zur Kenntnis der Tektonik und der Paläogeographie während der Oberkreide und dem Paläogen im Ostalpenraum. – Jb. Geol. B.-A., 111, pp. 115–145, Wien.
Oberhauser, R. (Hg.) 1980: Der geologische Aufbau Österreichs. – Springer Verl., Wien – New York, 701 p.
Oberhauser, R. 1995: Zur Kenntnis der Tektonik und der Paläogeographie des Ostalpenraumes zur Kreide-, Paleozän- und Eozänzeit. – Jb. Geol. B.-A., 138, pp. 369–432, Wien.
Plašienka, D. 1995: Mesozoic evolution of Tatric units in the Malé Karpaty and Povazsky Inovec Mts.: implications of the Klape and related units in Western Slovakia. – Geol. Carpathica, 46, pp. 101–112, Bratislava.
Plašienka, D., R. Marschalko, J. Soták, M. Petercákova, P. Uher 1994: Origin and structural position of Upper Cretaceous sediments in the northern part of the Povazsky Inovec Mts. (Central Western Carpathians). Part 1: Lithostratigraphy and sedimentology. – Mineralia Slov., 26, pp. 311–334, Bratislava, (in Slovak with an English summary).
Pober, E. 1984: Stratigraphische und sedimentologische Untersuchungen in der Gosau von Wörschach (Steiermark). – Unveröff. Diss. Formal- u. Naturwiss. Fak. Univ. Wien, 149 S.
Pober, E., P. Faupl 1988: The chemistry of detrital chromian spinels and its implications for the geodynamic evolution of the Eastern Alps. – Geol. Rundsch., 77, pp. 641–670.
Rakús, M. and National Working Groups 1989: Stratigraphic sections. Czechoslovakia. – In: Rakús, M., J. Dercourt, A.E.M. Nairn (Eds): Evolution of the northern margin of the Tethys, vol. II, Mém. Soc. Géol. France, N.S. No. 154 (II), pp. 161–181.
Rakús, M., M. Mišík, J. Michalík, R. Mock, T. Durkovič, T. Koráb, R. Marschalko, J. Mello, M. Polák, J. Jablonsky 1990: Paleogeographic development of the West Carpathians: Anisian to Oligocene. – In: Rakús, M., J. Dercourt, A.E.M. Nairn (Eds): Evolution of the northern margin of the Tethys, vol. III, Mém. Soc. Géol. France, N.S. No. 154 (III, Pt. 1), pp. 39–62.
Ratschbacher, L., W. Frisch, H.-G. Linzer 1991: Lateral extrusion in the eastern Alps, part II: structural analysis. – Tectonics, 10, pp. 257–271.

Salaj, J., A. Began 1983: Senonian and Paleogene paleogeographic and tectonic development of the Myjavská Pahorkatina Upland (West Carpathians, Czechoslovakian). – Zitteliana, 10, pp. 173–181, München.
Salaj, J., O. Samuel 1966: Foraminifera der Westkarpaten-Kreide. – GÚDŠ, Bratislava, 291 p.
Samuel, O., J. Salaj 1968: Microbiostratigraphy and foraminifera of the Slovak Carpathian Paleogene. – GÚDŠ, Bratislava, 232 p.
Samuel, O., J. Salaj, A. Began 1980: Lithostratigraphical classification of Upper Cretaceous and Paleogene sedimentary rocks of the Myjavská pahorkatina. – Západné Karpaty., sér. geol., 6, pp. 81–111, Bratislava.
Sauer, R. 1980: Zur Stratigraphie und Sedimentologie der Gießhübler Schichten im Bereich der Gießhübler Gosaumulde (Nördliche Kalkalpen). – Unveröff. Diss. Formal- u. Naturwiss. Fak. Univ. Wien, 181 p., Wien.
Scheffer, V., K. Kántás 1949: Die regionale Geophysik Transdanubiens. – Földtani Közlöny, 79, pp. 327–360, Budapest. (In Hungarian with a German summary.)
Schlagintweit, F. 1987: Allochthone Urgon-Kalke aus Konglomeraten der basalen Gosau (Coniac) von Oberwössen (Chiemgau/Nördliche Kalkalpen). – Mitt. Bayer. Staatssslg. Paläont. hist. Geol., 27, pp. 145–158, München.
Schnabel, W. 1979: Geologie der Flyschzone einschließlich der Klippenzone. – Arbeitstagung Geol. B.-A. 1979, pp. 17–42, Wien.
Soták, J., R. Rudinec, J. Spišiak 1993: The Penninic "pull-apart" dome in the pre-Neogene basement of the Transcarpathian depression (Eastern Slovakia). – Geol. carpathica, 44, pp. 11–16, Bratislava.
Soták, J., J. Bebej 1996: Serpentinitic sandstones from the Šambron-Kamenica Zone in Eastern Slovakia: evidence for the deposition in Tertiary collisional belt. – Geol. carpathica, 47, pp. 227–238.
Summesberger, H. 1992: Ammoniten aus dem Turon (Oberkreide) der Nördlichen Kalkalpen (Österreich). – Ann. Naturhist. Mus. Wien, 94, pp. 103–133.
Sztanó, O. 1990: Submarine fan-channel conglomerate of Lower Cretaceous, Gerecse Mts., Hungary. – N. Jb. Geol. Paläont. Mh., 1990, pp. 431–446.
Tollmann, A. 1976: Analyse des klassischen nordalpinen Mesozoikums. – Deuticke, Wien, 580 p.
Tollmann, A. 1987: Geodynamic concept of the evolution of the Eastern Alps. – In: Flügel, H.W., P. Faupl (Eds), Geodynamics of the Eastern Alps, Deuticke, Vienna, pp. 361–378.
Vaš ícek, Z., J. Michalík, D. Reháková 1994: Early Cretaceous stratigraphy, paleogeography and life in Western Carpathians. – Beringeria, 10, pp. 1–17, Würzburg.
Wagreich, M., P. Faupl 1994: Palaeogeography and geodynamic evolution of the Gosau Group of the Northern Calcareous Alps (Late Cretaceous, Eastern Alps, Austria). – Palaeogeogr. Palaeoclim. Palaeoecol., 110, pp. 235–254.
Wagreich, M., R. Marschalko 1995: Late Cretaceous to Early Tertiary palaeogeography of the Western Carpathians (Slovakia) and the Eastern Alps (Austria): implications from heavy mineral data. – Geol. Rundschau, 84, pp. 187–199.
Wagreich, M., F. Schlagintweit 1990: Urgonkalkgerölle aus den Konglomeraten der Lilienfelder Gosau (Oberkreide; N.Ö. Kalkvoralpen). – Mitt. Ges. Geol. Bergbaustud. Österr., 36, pp. 147–167, Wien.
Weidich, K. F. 1984: Über die Beziehungen des "Cenomans" zur Gosau in den Nördlichen Kalkalpen und ihre Auswirkungen auf die paläogeographischen und tektonischen Vorstellungen. – Geol. Rundsch., 73, pp. 517–566.
Wilkens, E. 1989: Paläogene Sedimente des Krappfeldes und seiner Umgebung. – Arbeitstagung Geol. B.-A., 1989, pp. 89–99, Wien.
Wilkens, E. 1991: Das zentralalpine Paläogen der Ostalpen: Stratigraphie, Sedimentologie und Mikrofazies Großforaminiferen-reicher Sedimente. – Unveröff. Diss. Fachbereich Geowiss. Univ. Hamburg, 227 S., Hamburg.

Winkler, W., D. Bernoulli 1986: Detrital high-pressure/low-temperature minerals in a late Turonian flysch sequence of the Eastern Alps (western Austria): implications for early Alpine tectonics. – Geology, 14, pp. 598–601, Tulsa.

Woletz, G. 1970: Zur Differenzierung der kalkalpinen Unterkreide mit Hilfe der Schwermineralanalyse. – Verh. Geol. B.-A., 1970, A80–A81, Wien.

Zoubek, V. 1931: Caractéristique de quelques roches cristallophyllienes et éruptives des galets éxotiques des conglomérats sénoniens et palógènes des Carpathes Occidentales. – Knihovna Stát. Geol. Úst., 13, pp. 353–358, Prague.