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

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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

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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 Mesoaalpine 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.


**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

Acta Geologica Hungarica 40, 1997
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

<table>
<thead>
<tr>
<th>Lower Cretaceous Alpes:</th>
<th>Bra</th>
<th>Branderfleck Fm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>gFas</td>
<td>Fasselfulan Fm.</td>
<td></td>
</tr>
<tr>
<td>gGlo</td>
<td>Globsbach Fm.</td>
<td></td>
</tr>
<tr>
<td>gHas</td>
<td>Haselgraben Fm.</td>
<td></td>
</tr>
<tr>
<td>Northern Calcareous Alpes:</td>
<td>gBra</td>
<td>Brunnbach Fm.</td>
</tr>
<tr>
<td>gHÖl</td>
<td>Höllgraben Fm.</td>
<td></td>
</tr>
<tr>
<td>gLSC</td>
<td>Lower Gosau Subgroup</td>
<td></td>
</tr>
<tr>
<td>gNIE</td>
<td>Nierenal Fm.</td>
<td></td>
</tr>
<tr>
<td>gRes</td>
<td>Ressen Fm.</td>
<td></td>
</tr>
<tr>
<td>gSpi</td>
<td>Spilzenbach Fm.</td>
<td></td>
</tr>
<tr>
<td>Drau Range (Lienzer Dolomiten):</td>
<td>Lalm</td>
<td>Lavant Fm. - Lower member</td>
</tr>
<tr>
<td>Laum</td>
<td>Lavant Fm. - Upper member</td>
<td></td>
</tr>
<tr>
<td>Central-Alpine Gosau occurrences:</td>
<td>g8</td>
<td>Gosau-&quot;Basisschichten&quot;</td>
</tr>
<tr>
<td>g8c</td>
<td>Gosau-&quot;Basalkonglomerat&quot;</td>
<td></td>
</tr>
<tr>
<td>g8l</td>
<td>Gosau-Bitumenmergeffolge</td>
<td></td>
</tr>
<tr>
<td>g8Hau</td>
<td>Gosau-Hauptbeckerfolge</td>
<td></td>
</tr>
</tbody>
</table>

Western Carpathians

<table>
<thead>
<tr>
<th>Pieniny Klippen Belt:</th>
<th>BrB</th>
<th>Brodná Beds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chm</td>
<td>Chmielowka Fm.</td>
<td></td>
</tr>
<tr>
<td>CzF</td>
<td>Czorsztyn Fm.</td>
<td></td>
</tr>
<tr>
<td>Dur</td>
<td>Dürsztn Fm.</td>
<td></td>
</tr>
<tr>
<td>Jar</td>
<td>Jarmuta Fm.</td>
<td></td>
</tr>
<tr>
<td>Jaw</td>
<td>Jaworki Fm.</td>
<td></td>
</tr>
<tr>
<td>Kap</td>
<td>Kapsynica Fm.</td>
<td></td>
</tr>
<tr>
<td>Lys</td>
<td>Lysa Fm.</td>
<td></td>
</tr>
<tr>
<td>PiF</td>
<td>Pieniny Fm.</td>
<td></td>
</tr>
<tr>
<td>Pom</td>
<td>Pommézd Fm.</td>
<td></td>
</tr>
<tr>
<td>Puh</td>
<td>Púchov Fm.</td>
<td></td>
</tr>
<tr>
<td>Sf</td>
<td>Šafranica Fm.</td>
<td></td>
</tr>
<tr>
<td>Sne</td>
<td>Snežnica Fm.</td>
<td></td>
</tr>
<tr>
<td>Stro</td>
<td>Stromowce Fm.</td>
<td></td>
</tr>
<tr>
<td>Tiss</td>
<td>Tissalo Beds</td>
<td></td>
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<tr>
<td>Uhř</td>
<td>Uhře Fm.</td>
<td></td>
</tr>
<tr>
<td>Upo</td>
<td>Upošlav Fm.</td>
<td></td>
</tr>
</tbody>
</table>

Manín Unit:

| But | Butkov Fm. |
| Hlk | Hlboček Fm. |
| Hrb | Hrabové Fm. |
| Kai | Kalisčo Fm. |
| Luk | Luckov Fm. |
| Noz | Nozdrowice Breccia |
| Pod | Podhorie Fm. |
| Pra | Pražnov Fm. |
| Zad | Žadorec Fm. |

*Acta Geologica Hungarica* 40, 1997
Belice Unit:
HBF Horné Belice Fm. Laz Lazy Fm.

Tatricum:
Luc Lučivná Fm. Schr Schrambach Fm.
Oso Osoľská Fm. Soš Somár Breccia
Par Párnica Fm. Sol Sollírov Fm.
Por Poruba Fm. E

Krížna Nappe:
Boh Bohatá Fm. Par Párnica Fm.
But Butkov Fm. PăV Pădilă Voda Fm.
Hbl Hlboč Fm. Pod Podhorie Fm.
Kos Kosčielska Fm. Por Poruba Fm.
Mra Mráznica Fm. Schr Schrambach Fm.
Osn Osnica Fm. Str Strážovce Fm.

"Post-tectonic" Senonian and Palaeogene: Brezová Group, "Gosau"-type deposits:
Bar Baranec Sandst. (Mb. of the Ostriež Fm.) Mos Mosnáčov Marl (Mb. of the Bradlo Fm.)
DeV Dedkov Vrch Fm. Ost Ostriež Fm.
Dlc Dobšiná Ice Cave Conglomerate Pbr Podbradlanská Fm.
Dlm Dobšiná Ice Cave Marls Příl Podlipovec Flysch (Mb. of the Bradlo Fm.)
Hun Hurbanova Dolina Fm. Pol Polianka Fm.
Jab Jablonka Fm. Pri Priepastné Fm.
Kos Košariška Fm. PšV Pustá Ves Fm.
Kra Kravár Fm. SBr Široké Bradlo Limestone
Krzb Kržlá Breccia Prf (Mb. of the Bradlo Fm.)
Luf Lubina Fm. Stv Štverník Marl (Mb. of the Ostriež Fm.)
Men "Menilite" Fm. Sum Sumiac Limestone

Palaeogene of the Central Western Carpathians:
BiP Biely Potok Fm. Val Valchov Conglomerate
Bor Borové Fm. (Mb. of the Huty Fm.)
Hra Hrabník Fm. Puc Pucov Conglomerate
Hut Huty Fm. Zub Zuberec Fm.

Transdanubian Range
Ajk Ajka Coal Fm., *K3 MoL Mogyorósdomb Limestone Fm., *J3-K1
BeM Bersek Marl Fm., *K1 PdM Pádrag Marl Fm., *E2-3
BuM Buda Marl Fm., *E3-0t1 PmP Pénzeskút Marl Fm., *K2
Csa Csata Fm., *Ol2-Me or *Ol2 PmP Polánky Marl Fm., *K3
Cse Csegbanya Fm., *K3 SúM Súmeg Marl Fm., *K3
Cso Csőkősk Fm., *E2 Sze Szentivánhegy Limestone Fm., *J3-K1
Dar Darvastó Fm., *E2 SzL Szépvölgy Limestone Fm., *E3
Dor Dorog Fm., *E2 SzOL Szőc Limestone Fm., *E
Fel Felsővádacs Breccia Mb. of the Bersek Tác Tárd Clay Fm., *Ol12
Mari Fm., *K1 TaL Tata Limestone Fm., *K2
Gal Gánt Bauxite Fm., *E1 TeS Tés Clay Fm., *K2
JaM Jáko Marl Fm., *K1 TÖS Törökbálint Sandstone Fm., *Ol2
KIC Kisicell Clay Fm., *Ol1 UgL Ugod Limestone Fm., *K3
Kös Köszőrűköbanya Conglom. Mb., *K1-2 VeS Vértessomló Siltstone Fm., *K2
Lab Lábatlan Sandstone Fm., *K1-2 ZIL Zirc Limestone Fm., *K2
Man Mány Fm., *Ol2

Acta Geologica Hungarica 40, 1997
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 (Mesoa Alpine 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 Ždâncz 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

Acta Geologica Hungarica 40, 1997
in this synthesis. To the south of the Peri-Pieniny Klippen zone lies the complex of the Central WCa, which is composed of the Taticum and the Subtatic or Central WCa nappe complex (Križna, 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 Ultradeep oceanic 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 paleogeographically to the north of the Taticum units and thought it to be a unit similar to the Matei 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–Išačovce unit probably belongs to the Eastern Carpathians.

Although the Taticum of the Malé Karpaty shows similarities with the Lower Austroalpine units of the EA, the Taticum of the Tatra and Fatra Mountains has been located at the northern edge of the Austroalpine microplate and contains specific Carpathian elements. The Križna 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 Ondrejíčková 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 Pélos 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 1964).
Lines – Brezsnýánszky 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 (Brezsnýánszky 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 Dòsztály 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 Nyirág (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;
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

Acta Geologica Hungarica 40, 1997
Fig. 3 b

Cretaceous and Paleogene sedimentary evolution 283

Acta Geologica Hungarica 40, 1997
Fig. 4a, b, c
Stratigraphic sections of the Western Carpathians

Acta Geologica Hungarica 40, 1997
Fig. 4b

Cretaceous and Paleogene sedimentary evolution

Acta Geologica Hungarica 40, 1997
Fig. 5a, b
Stratigraphic sections of the North Pannonian region
Fig. 5 b
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 Nanoconus 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 (Fülop 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 Lábátlan Sandstone and the Köszörükőbánya Conglomerate on the higher slope.

Contrary to this trend of increasing terrigenous influx in the deep-water formation, to the SW of Gerecse (Vértess 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 bidetrital 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 (Tőcs Clay – Császár 1995). The lower formation (Környe Limestone) is interfingered.

*Acta Geologica Hungarica* 40, 1997
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 fluxoturbidites 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 Klapa and Manín units of the WCa, in the Alban 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

*Acta Geologica Hungarica* 40, 1997
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 Mišik
(1979), Mišik et al. (1980) and Mišik 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 (Sztánó 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
Križna and Choč nappes (Mišik 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 Križna
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

*Acta Geologica Hungarica 40, 1997*
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–Lechtaß nappe system (Gauß 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 Klappe 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 Klappe 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 (Kreuzgrabern 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., Košárská 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., Podbradianska Fm., Podlipovec Flysch, Polianka Fm.), both deep-water developments demonstrating the rapid deepening of the basin. In many localities of the NCA, a conspicuous unconformity developed between the Lower Gosau Subgroup, comprising the terrestrial to shallow-marine deposits, and the deep-water sediments of the

Acta Geologica Hungarica 40, 1997
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 (debrice) bodies (jákóhegy Breccia Mb.) interfingerling 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 (Tapolcaő), 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

*Acta Geologica Hungarica* 40, 1997
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. Argyelán, 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 (Milišík 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 Surovin 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. Gießhäuser 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 WCg.

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 (Wilkins 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 Wilkins (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 "Unterinttal-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 Nýirád 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 (Mánya 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 Kissell 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 biothermal 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 glauconphane-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), Nozdrovce 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., Köszörükóbánya Conglomerate (TR)). The coarsening-upward tendency is conspicuous in all three regions.

3) In some zones the sedimentation of benthal 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 benthal 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 Kőrnye 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 Köszörükóbánya 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, Ybbssitz zone, "Cenoman Randschuppe", Klapo 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 benthal facies (e.g. Nierenthal Fm., NCA; Štverník Marl etc., WCa; Zementmargelfolge,
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 Klapo 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 (Pádrag 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


Acta Geologica Hungarica 40, 1997


Marschalko, R., J. Kysela 1980: Geology and sedimentology of Klippen Belt and Marín Unit between Zilina and Považská Bystrica. – Západné Karpaty, sér. geol., 6, pp. 7–79, Bratislava.

*Acta Geologica Hungarica* 40, 1997


Mišk, M. 1990: Urgonian facies in the West Carpathians. – Knihovnicky Zemlinho plynua a nafny, 9a, pp. 25-54, Hodonín.


Acta Geologica Hungarica 40, 1997


Wagreich, M., R. Marschak 1995: Late Cretaceous to Early Tertiary palaeoecography of the Western Carpathians (Slovakia) and the Eastern Alps (Austria): Implications from heavy mineral data. – Geol. Rundschau, 84, pp. 187–199.


Acta Geologica Hungarica 40, 1997