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Comparison of the East Alpine and West Carpathian Flysch Zone - A Geochemical Approach

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4 Figures and 4 Tables

East Alps
West Carpathians
Flysch Zone
Klippen Zones
Geochemistry

Content

Abstract

Pelites in selected formations of the Eastern part of the Alpine Flysch zone (Lower Austria) were investigated with respect to their chemical and mineralogical compositions and compared with formations in the West Carpathians. The study is based on the determination of the main elements and 22 trace element concentrations. The close relationship between the Rhenodanubian Flysch in the Alps and the Magura group of nappes in the West Carpathians could once more be confirmed. There is a similarity between the Upper Cretaceous to Early Paleogene sediments of the Main Flysch Nappe and Greifenstein Nappe with the Northern part (Rača-unit) and the Laab Nappe with its Southern part (Bílé Karpaty = White Carpathian unit) of the Magura group of nappes. Sediments of the Lower and Mid-Cretaceous have similar features in all units and do not show such clear relationship. The results are discussed in detail.

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Vergleich der Flyschzone der Ostalpen und der Westkarpaten – ein geochemischer Versuch

Zusammenfassung

Pelite in ausgewählten Formationen des Ostteils der Alpinen Flyschzone (Niederösterreich) wurden geochemisch und mineralogisch untersucht und mit Formationen der Westkarpaten verglichen. Bestimmt wurden die Hauptelemente sowie 22 Spurenelemente. Die enge Beziehung zwischen dem Rhenodanubischen Flysch in den Alpen mit der Maguradecke in den Westkarpaten wurde erneut bestätigt. Es zeigt sich eine gute Übereinstimmung von Oberkreide-Alttertiärsedimenten der Flyschhauptdecke und der Greifensteiner Decke mit dem Nordteil der Magura-Deckengruppe (Raca-Einheit) und der Laaber Decke mit deren Südteil (Weißkarpatische Einheit). Sedimente der Unteren und Mittleren Kreide zeigen in allen Einheiten ähnliche Merkmale und keine so klare Beziehung. Die Ergebnisse werden diskutiert.

Srovnání Východních Alp a flyšové zóny Západních Karpat z hlediska geochemie

Abstrakt

Pelity vybraných souvrství východní části flyšové zóny (Dolní Rakousko) byly studovány z hlediska jejich chemického a minerálního složení a srovnávány se souvrstvími flyšové zóny Západních Karpat. Studium je založeno na stanovení minerálního složení, obsahu hlavních prvků a koncentracích 22 stopových prvků. Úzký vztah mezi Rhenodanubským flyšem Alp a magurským příkrovem Západních Karpat mohl být znovu potvrzen. Existuje podobnost mezi sedimenty svrchní křídy až spodního paleogénu hlavního flyšového příkrovu (Main Flysch nappe) a greifensteinského příkrovu se severní částí magurského příkrovu (račanská jednotka) a Laabského příkrovu s jeho jižní částí (belokarpatská jednotka). Sedimenty spodní a střední křídy neukazují takový jasný vztah. Získané výsledky jsou podrobně diskutovány.

1. Introduction

An extensive mineralogical-geochemical investigation of sediments in the Flysch Zone of the West Carpathians (Moravia and West Slovakia) was recently carried out.

Significant tectonic units of the Carpathian Flysch belt, Pouzdřany, Ždánice, Subsilesian, Silesian, Rača and Bile Karpaty units, were studied in detail with regard to their petrographic-mineralogical and geochemical properties. The work includes the determination of geochemical characteristics of the rocks, based on the study of major and trace element concentrations, their distribution, their correlation as well as the geochemical background values in rocks of individual formations of the particular tectonic units (ADAMOVÁ, 1983, 1986a, 1988a, b, 1989, 1991; ADAMOVÁ & STRÁNÍK, 1984).

The results of these investigations provided the basis on which the geochemical characteristics of the West Carpathian Flysch Zone could be determined.

A similar comprehensive study of the East Alpine Flysch zone has not yet been done. Geochemical and mainly mine-

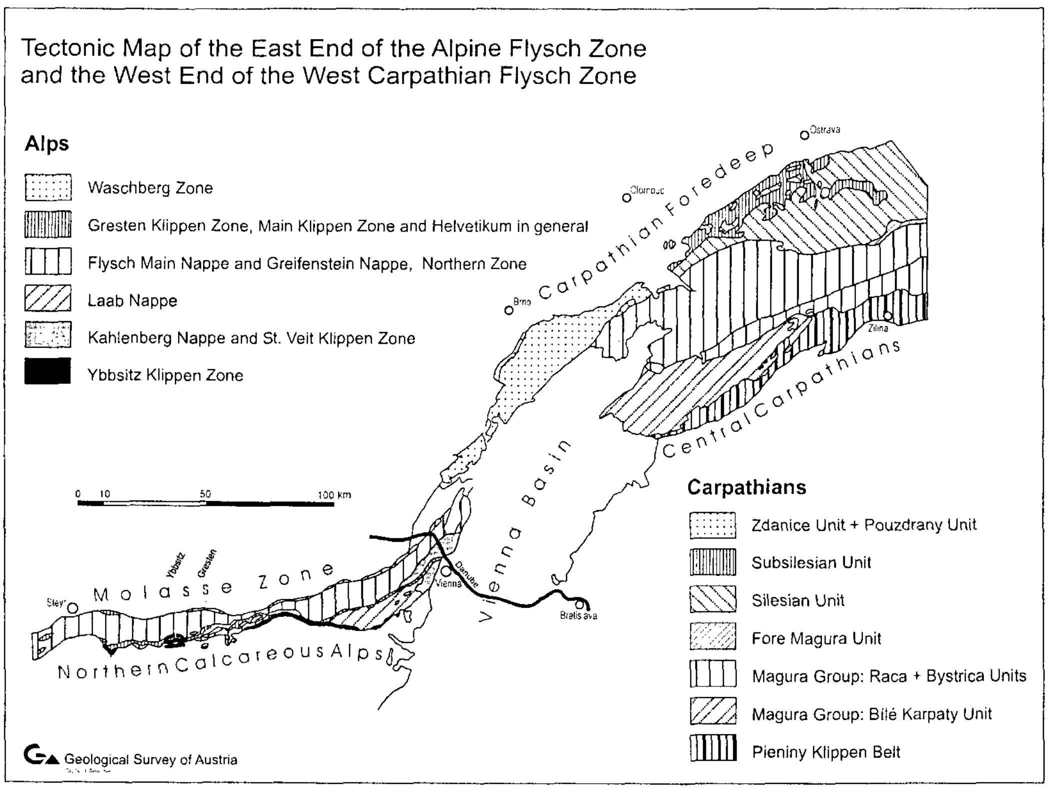


Fig. 1: Geological overview of the Flysch Zone of the East End of the Alps and the West End of the Carpathians.

ralogical data of this zone have been gathered during individual studies of certain formations and partly published in diverse literature (e. g. FAUPL, 1976, 1980), although a considerable part of the work was carried out within applied projects and as part of university theses and remained unpublished (e. g. HÖSCH, 1985).

In order to confirm the correlation of formations of the East Alpine Flysch zone with those of the Flysch belt of the Outer Carpathians, these comparative studies presented here were carried out in the Eastern sector of the Alpine Flysch Zone (Lower Austria). The application of the same geochemical methods to both sides of the Alpine and Carpathian Flysch belt should enable a better comparison.

The authors are aware that the limited number of analysis presented here can only give a preliminary indication of the geochemical relationship between the Alpine and Carpathian side of the Flysch Zone. It should stimulate further work.

This work is concentrated on the geochemical correlation of sediments of the Rača and Bile Karpaty units and the variegated beds in the Outer Carpathian Flysch belt (Moravia and Western Slovakia) with the Main Flysch Nappe, the Greifenstein and Laab Nappe and the variegated beds of the Klippen zones in the Eastern part of the Alps (Lower Austria).

2. Geological setting (Fig. 1)

In this section a brief comment is given on those Alpine and West Carpathian external units which are either the concern of this paper or were examined in this study. For a more detailed overview and the literature concerning the Alpine and the Carpathian Flysch Zone and their correlation, readers are referred to ELIÁŠ, SCHNABEL & STRÁNÍK (1990) and SCHNABEL (1992).

The Flysch Zone of the East Alps and the Carpathians is the main external tectonic element of the Alpine-Carpathian orogenic system. Its dominating units are the Flysch nappes; it also includes remnants of the southernmost European Continental Margin (Eurasia), which are today represented by the tectonically lower systems of the Helvetikum and analogous units (Alps) and the Ždánice and Subsilesian nappes (West Carpathians). All these units are rootless nappes and widely overthrust over the Neogene molasse resting on the Southern stable European Platform.

Despite this relatively clear general situation, there are considerable differences between the Alpine and Carpathian domain for paleogeographical and tectonical reasons.

2.1. The Flysch Zone of the Eastern Alps

The Flysch Zone of the Eastern Alps is a narrow peripheral zone, widely overthrusted by the Northern Calcareous Alps during Neo-Alpine orogenic events (Oligocene to Early Neogene). Its main unit, the Rheno-Danubic Flysch, is for the most part represented by one nappe (Flysch Main Nappe, Late Lower Cretaceous – Early Eocene). A slice along its southern edge occurs in Western Lower Austria, the Ybbsitz Klippen Zone, with Lower Cretaceous to Campanian flysch and Middle to Upper Jurassic deep-sea sediments, along with serpentinites and picritic basalts. It very probably represents the substratum of these Ybbsitz flysch deposits and possibly give evidence of an oceanic or paraoceanic crust, at least in parts of the entire Rheno-Danubic Flysch.

Toward the Eastern edge however, in the Wienerwald area west of Vienna, the Flysch Zone becomes broader and tectonically more complex – it can be divided into three nappes, from N to S the Greifenstein-, Kahlenberg- and Laab nappes. The Greifenstein Nappe is the easterly prolongation of the Flysch Main Nappe, the others are clearly distinguished by facies and stratigraphic range. The Kahlenberg Nappe includes the St.Veit Klippen Zone with its "klippen" (Jurassic – Lower Cretaceous schists and cherty limestones) and the flysch-cover (Mid-Cretaceous – Maastrichtian). The Laab Nappe consists of flysch sequences of Upper Cretaceous to Middle Eocene age.

All these units are characterized by thick flysch formations and are widely considered as part of the Penninic system of the Alps. Due to the different geological settings, some authors assign the Greifenstein and Flysch Main nappes to the North Penninic, the Ybbsitz Klippen Zone, Kahlenberg and Laab nappes to the South Penninic (e. g. FAUPL & WAGREICH, 1992).

Other strings of klippen occur within these flysch units, as windows and slices of a lower tectonic system, representing the Helvetic system in the widest sense. These are the Gresten Klippen Zone to the West and the Main Klippen Zone in the Wienerwald area, containing Lower to Middle Jurassic shallow-water deposits, Upper Jurassic to Lower Cretaceous limestones and Upper Cretaceous to Middle Eocene variegated, hemipelagic calcareous clay, the so called "Buntmergelserie".

2.2. The Carpathian Flysch Belt

In contrast to the Flysch Zone of the Alps, the corresponding Flysch Belt of the Carpathians is much wider (some 60 km), tectonically less complex, but paleogeographically more individualised. It consists of several tectono-sedimentary nappes of Cretaceous to Early Miocene age, which can, in the West Carpathians, be divided into two groups. The Outer Group comprises several nappes, among which the Ždánice, Subsilesian and Silesian nappes are the most important. It also includes the Fore-Magura unit, remnant of an elevated zone (hypothetical "cordillera") between the Outer Group and the Magura group of nappes, the latter can be subdivided into the Rača, Bystrica and White Carpathian (Bílé Karpaty) units. More detailed facial and stratigraphical comments are given in chapter 4 of this study. The recently published "Geological Atlas of the Czech Republic, Stratigraphy", Sheet Nr. 7 (STRÁNÍK in KLOMINSKÝ, 1994) gives a splendid overview over the tectonic and facial units and lithostratigraphic formations treated in this paper.

The broad Flysch zone is bordered to the South by the narrow and very complex Pieniny Klippen Zone, which very probably had been its southern margin. The paleogeographical continuation further to the South is subject to intensive present-day discussions and will not be dealt here. The Central Carpathians, roughly corresponding to the Austroalpine domains, have not affected the Flysch zone during the Neo-Alpine orogeny like the Northern Calcareous Alps in the Alpine sector. This is one of the reasons why in the Carpathian Flysch belt the former arrangement of margins, basins and swells is much better displayed than in the Flysch zone of the Eastern Alps. But many questions remain open to discussion, there is for example no direct evidence of the character of the broad basin floors during the stages of their orogenic evolution.

2.3. The correlation

The Ždánice unit, which continues into the Waschberg Zone, is the only unit, where the junction between the Alps and the Carpathians can be traced on the surface. All the other units are covered by the Neogene fill of the Vienna Basin. This causes considerable difficulties in comparing particular units and formations. Even the large number of wells, which have penetrated the flysch units under the basin, do not give a clue to conclusive links, due to the numerous faults interrupting the continuity (HAMILTON, JIŘÍČEK, WESSELY, 1990; SAUER, SEIFERT, WESSELY, 1992; KRÖLL, A. et al., 1993).

The lithological and sedimentological similarities of the Maastrichtian and Early to Middle Paleogene of the Greifenstein Nappe with the Northern part of the Magura group of nappes (Rača unit, Luhačovice zone) is evident (ELIÁŠ, SCHNABEL, STRÁNÍK, 1992). Its congruency could be ascertained recently during joint investigations within the same project and should be published soon; geochemical results of which are the subject of this paper. It is emphasized that these correlatable formations become younger from W to E, displaying a diachronic shifting of the facial evolution in this direction.

The Helvetic system s.l. of the Alps is analogous with the Subsilesian unit of the Carpathians, as both originate from the former Southernmost European continental shelf or margin, which was affected by the alpine orogeny and today represents its lowermost nappes.

Other units do not have a definite equivalent in the East or West, such as the Kahlenberg Nappe with its St.Veit klippen basement in the Wienerwald and the Silesian and Fore-Magura units in the Carpathians; this is why no analyses were made in this study from sequences of the Kahlenberg Nappe.

In accordance with its N–S arrangement, the Laab Nappe in the Wienerwald should find its equivalent in the Bílé Karpaty (White Carpathians), the southernmost part of the Magura group of nappes. But closer examination shows that the relationship remains controversial (f. i. field observations, heavy mineral content). In order to make comparisons, additional regional mapping campaigns are necessary to resolve the tectonically complex situation in these very poorly exposed units.

An extension of certain units of the Pieniny Klippen Belt into the Alps is subject to intensive debate. For a long time the St. Veit Klippen Zone was considered to represent a comparable element, but this became improbable due to the different character of the Upper Cretaceous sediments ("Couche Rouge" facies of the Puchov marls in the Pieniny Klippen Belt, flysch in St. Veit). The essential question is if and how and where a Middle Penninic element in the Eastern Alps exists or does not exist. The Wienerwald area with several tectonic slices of questionable origin (e. g. Sulz Klippen Zone and variegated marlstones in front of the Kahlenberg Nappe, not shown in Fig.1) could help us out of this dilemma, but this cannot be dealt with here.

3. Methodology

3.1. Sampling (Tab. 4)

The study is concerned with pelites (mudstones); the material studied originates mostly from turbiditic deposits where two principle rock-types can be distinguished within the pelitic section: (a) the pelitic segment of the turbidite (BOUMA-division E or E[t]), which is the upper part of the turbiditic lithologies and a result of the upward decrease in grain-size and (b) the slowly deposited (hemi-) pelagite (BOUMA-division Ep or F). Distinction between hemipelagic and turbiditic mudstones are facilitated by the higher calcium carbonate content of the latter, sometimes also by a colour contrast (HESSE, 1975; HESSE & BUTT, 1976; FAUPL, 1976, 1980). Selective sampling of both of these divisions would have been desirable. However, in the field it appears that a distinction is very difficult, due to complex or uncompletely developed turbidites, poor outcrop conditions and other unfavourable circumstances and which also depend on the nature of the particular formation. In most cases the sampled material originates therefore from the upper part of the turbiditic pelite or from mixed layers.

3.2. Analytical methods

All the samples were analysed in the laboratories of the Ústřední ústav geologický Praha (now the Czech Geological Survey Praha). Besides a complete silicate analysis (major elements), a standard set of trace elements was determined by X-ray fluorescent spectral analysis and emission spectral analysis (Ing. SIXTA, Dr. M. PELIKÁNOVÁ, E. MRÁZOVÁ).

The mineral composition was determined by X-ray diffraction analysis and the result compared with those obtained by differential thermal analysis (Dr. J. ZOUBKOVÁ, I. HALADOVÁ).

Some samples of the Carpathian Flysch were analysed in detail by diffraction phase analysis (Ústřední ústav geologický Praha), which is based on the determination of the best correlation between measured diffraction data of a sample and theoretical diffractogram of the mixture (MORAVCOVÁ & FIALA, 1980).

3.3. Geochemical methods

The development of the chemical composition of flysch rocks is closely associated with the history of the geotectonic development of the sedimentary area. The chemical composition of the sediments was predominantly controlled by the tectonic regime, the composition of the source areas and the hydrodynamic regime of the basins. Complete recognition of the rock character requires the study of major chemical components of the rocks, as well as the study of concentrations, distributions and correlation relationship of trace elements, supplemented by the research of their mineral composition.

In addition to the study of major and trace element concentrations, geochemical characteristics of rocks requires also the comparison of ratios of selected pairs of elements studied and the observation of changes in average values of these ratios between lithostratigraphic members of a tectonic unit or between individual tectonic units. For example, a SiO_2/Al_2O_3 ratio in excess of 3 (KUKAL, 1962) indicates the share of clastic quartz or other SiO_2 forms of more than 25 %, whereas Al_2O_3/Na_2O ratio (PETTIJOHN, 1957) expresses chemical maturity of pelitic sediments (in chemically most mature sediments the ratio may reach 125). $Al_2O_3 + K_2O/Na_2O + MgO$, K_2O/Na_2O, Rb/K_2O ratios represent, according to TAYLOR (1965), BJÖRLIKKE (1974a, b) and DIPVIK (1977), other indices of pelitic sediment maturity.

Increased values of Ti//Zr, V/Zr, Ni/Co, Mn/V and V/Cu indicate, that mafic rocks were more significantly involved in the flysch sedimentation. On the other hand, prevailing high Ti/Cr, Cu/Ni, V/Cr, Zr/Ni and Zr/Cr values suggest, that also fragments of acid and intermediate rocks were deposited (AFANASJEVA, 1979; BHATIA, 1985; FAIRBRIDGE, 1972; FLOYD et al., 1987, 1990; KRAUSKOPF, 1967; ROSER & KORSCH, 1988; VINOGRADOV, 1962 and others).

The determination of the character of the sedimentary environment, particularly salinity, is significant not only for the paleogeographic studies but also as an indirect method of stratigraphic correlation. Geochemical methods make it possible to distinguish only substancial differences in the salinity of the sedimentary environment. Boron and so-called equivalent-Boron (REYNOLDS, 1965) and B/Ga and Th/U ratios (ADAMS & WEAVER, 1958) are especially suitable for the determination of the original salinity of a given environment; this also results from other researches on these problem (ERNST & WERNER, 1964; TOURTELOT, 1964; WALKER, 1968; CODY, 1970; REYNOLDS, 1965, 1972; BOUSKA, 1980; ADAMOVÁ, 1988b).

4. Fundamental mineralogic – geochemical characteristics of sediments of the Carpathian Flysch Belt

4.1. Magura group of nappes – Rača unit

The sediments of the Rača unit represent the Upper-Cretaceous and Paleogene sedimentation of the Northern subunit of the Magura group of nappes (PESL, 1968, 1971, 1987; PESL & HANZLIKOVÁ, 1963; ADAMOVÁ, 1989).

The ***Soláně Formation*** (Upper Cretaceous – Paleocene): Noncalcareous claystones are characterised by lower quartz-contents (15–21 %). Mica minerals dominate in the clay fraction (including minerals of the illite group) especially in the Lower Soláňe Member (=Ráztoka Member) and kaolinite (higher contents of the kaolinite in the Upper Soláně Member = Lukov Member). Chlorite occurs frequently (6–25 %), smectite rarely.

The ***Hostýn Member*** represents the Soláně Formation and the Beloveža Formation in the area of the Hostýn Mountains. Calcareous claystones contain quartz (30–35 %) and plagioclase, also kaolinite and mica minerals and smectite to a small amount.

The ***Upper part of the Beloveža Formation*** (Paleocene Middle Eocene): Noncalcareous up to very weakly calcareous claystones have a quartz-content of 18–23 % and considerable content of plagioclase. In the clay fraction, mica minerals, smectite and very often kaolinite are present in significant quantities. Chlorite was identified in a few samples.

The ***Luhačovice Member*** (Middle-Upper Eocene): Blue-green noncalcareous plastic claystones of the Lower Luhačovice Member have low contents in quartz and plagioclase and more kaolinite than mica minerals. Grey-green noncalcareous plastic claystones of the Upper Luhačovice Member contain 13–20 % quartz and plagioclase in trace quantities. Mica minerals dominate (41–53 %), the content of kaolinite is lower (30 %). Traces of siderite are identified in some samples.

The ***Rusava Member*** – stratigraphic equivalent of the Luhačovice Member in the Hostýn Mountains (Middle to Upper Eocene): Weakly calcareous and silicified claystones are characterised by a high content of quartz and a low content of plagioclase. In addition kaolinite and mica minerals are present.

The ***Zlín Formation*** (Middle Eocene – Early Oligocene). The formation with the highest quartz-content. It can be divided into the Vsetin and the Újezd Members.

– ***Vsetin Member:*** Claystones with differing carbonate contents (1–30 %), sometimes silicified, contain a high amount of quartz (30–35 %) and varying amounts of plagioclase. In all samples minerals of the smectite group are present (very often in sigificant quantities), together with mica minerals and in many samples kaolinite.

– ***Újezd Member***: It is represented by noncalcareous up to weakly calcareous claystones with quartz (30 %) and varying amounts of plagioclase. Mica minerals and kaolinite alternatively dominate in the clay fraction, smectite is present in lower amounts in many of the samples.

Claystones of Vsetín and Újezd Members differ from other claystones of the Rača unit by the presence of a significant portion of smectite and the absence of chlorite in the clay fraction. This points to a change in the source material and possibly to a lower erosion rate in the source area.

The claystones of the Luhačovice Member are distinctly different. Besides a relatively small amount of quartz, they contain only mica minerals and kaolinite. Additionally they are characterised by the highest ***degree of chemical and mineralogical maturity***. The claystones of the Upper Soláně (Lukov) and Variegated Beloveža Members have a medium degree of maturity in common. A very low maturity is characteristic for pelitic sediments of the Újezd, Upper Beloveža and Lower Soláně Members and Kaumberg Formation. Very low or no maturity is observed in the claystones of the Hostýn Member.

The sedimentary environment of the claystones of the Újezd Member and Beloveža Formation have a relatively higher oxidation compared with the sediments of the Hostýn, Soláně and Luhačovice Members. The sediments of the Vsetín Member point to a weak reduction (concentrations of Mn, V/Cr ratios).

Concerning the concentration and distribution of ***trace elements***, a significant change appears approximately during the Middle Eocene, during the sedimentation of the uppermost part of the Beloveža Formation and the Újezd Member. The Upper part of the Beloveža Formation is characterised by still higher concentration of Zr, but high contents of Cr and Ni and Co, mainly in the uppermost part. Typical of the Újezd Member are high concentrations of Cr and Ni and relatively higher contents of Co. The characteristics of the claystones of the Vsetín Member (probably only in the lower part) are concentrations of Cr and to a certain extent Ni, low contents in Be, Rb, Sn, Zr, Li and lower values in Ba, Ga and B.

The claystones of the Luhačovice Member (predominantly the upper part) have high concentrations of Be, Rb, Sn, Y, Zr, Ti, Li, Ba, B, Cr and V; Ni and Co are very low.

Average contents of B and in particular values of the equivalent B indicate a higher paleosalinity in the sedimentary basin of the Luhačovice and Rusava Members. Relatively lower paleosalinity can be concluded for the sedimentation period of the Újezd Member and Beloveža Formation.

Based on all the indicated data, it can be concluded that ***the material transported into the sedimentary basins*** of the Soláňe Formation (mainly the Upper Soláně Member), the Variegated Beloveža and the Luhačovice Members has essentially a higher acidity (meaning more granitoid material) compared with the source material of the Újezd and Vsetín Members (with a higher mafic component). The upper part of the Beloveža Formation has an intermediate position.

The chemical composition of the sandstones of all these formations correspond to a great extent to the chemical composition of the claystones. It shows a more basic nature of the source material of the Újezd and Vsetín Members. The sandstones of the Luhačovice Members (especially the Upper Luhačovice Member) have the highest content of the granitoid components compared with all other investigated sandstones.

4.2. Bílé Karpaty unit – Hluk development

The Hluk development of the Bílé Karpaty unit is composed of sediments of Lower Cretaceous up to Middle Eocene age. These sediments show great facies changes and are particularly developed in the flysch members of the Paleocene up to the Lower Eocene (STRÁNÍK et al., 1989).

At the end of the Albian the sedimentation of variegated claystones ***(Kaumberg Formation)*** starts in the Magura sedimentary area, continuing locally up to the Lower Paleocene (Gbely Formation has recently been declared as synonymous with the Kaumberg Formation – STRÁNÍK et al., 1995). The variegated sedimentation changed to a more mature flysch of the ***Svodnice Formation***. Tectonic activity in the basin is expressed by a lithofacially distinct differentiated sedimentation in the Paleocene. As a result there is a lateral substitution of the Svodnice Formation and ***Nivnice Formation*** and a higher contribution of a coarser clastic material during the sedimentary period of the ***Suchov lithofacies*** of the Svodnice Formation. ***The Kuželov Formation*** follows the Nivnice Formation at the Paleocene – Lower Eocene boundary.

Noncalcareous to calcareous claystones and marlstones of the ***Filipov lithofacies*** of the Svodnice Formation are characterised by a higher kaolinite content, the presence of mica minerals (including minerals of the illite group) and small amounts of smectite.

As a rule, mica minerals dominate over kaolinite in noncalcareous to intensively calcareous claystones and marlstones of the Suchov lithofacies (Svodnice Formation), smectite is present very often in lower up to medium amounts. Trace amounts of chlorite occur frequently in the Svodnice Formation.

The Nivnice Formation is represented by a prevalence of the noncalcareous up to intensively calcareous claystones of different colours. These claystones are characterised by a significant representation of mica minerals and smectite, sometimes kaolinite is present in a small amount only. Quartz-contents range between 23–30%. In contrast to the Svodnice Formation, the Nivnice claystones have a higher amount of plagioclase.

The claystones of the Kuželov Formation contain the highest quantities of plagioclase, among carbonates dolomite is evident, sometimes also siderite. In the clay fraction mica minerals prevail, chlorites are always present. At some localities kaolinite was found in significant quantities.

The Svodnice Formation has a higher degree of chemical and mineralogical maturity than the Nivnice and especially the Kuželov Formations. The Filipov lithofacies (Svodnice Formation) indicates a reducing environment (higher contents of organic matter and S) and a higher salinity – the average concentration of B-309 ppm and equivalent B-530. The claystones of this lithofacies contain higher concentrations of some trace elements (As, Co, Ni, V, Mo, Rb), which may reflect both a more reductive environment and a more basic nature of the source material, in contrast to the claystones of the Suchov lithofacies and mainly the claystones of the Nivnice and Kuželov Formations. The sediments of the Suchov lithofacies show a certain relationship to the Nivnice Formation.

The Nivnice Formation differs from the Kuželov Formation by both mineral and chemical composition. The claystones of the Nivnice Formation are characterised by a significant amount of smectite (the highest content of H_2O^-). The presence of chlorite and the highest contents in plagioclase are typical of the claystones of the Kuželov Formation. The lowest degree of the chemical and mineralogical maturity was found in the sediments of the Kuželov Formation. These sediments have the lowest concentrations of Cr, V and the highest contents of Ti. Zr-concentrations are equal to those in the Nivnice Formation; Ti-contents are lowest there.

The results of this investigation show that the source material of the Kuželov Formation has a more acid character compared with the Nivnice Formation and especially the Svodnice Formation. These results fully agree with the data on the composition of the sandstones of the Bílé Karpaty unit.

4.3. Variegated beds in the Flysch belt of the West Carpathians

Geochemical studies of variegated beds are based on the investigation of sediments in the Flysch belt of the West Carpathians in Moravia and West Slovakia (ADAMOVÁ, 1986a, b; ADAMOVÁ & STRÁNÍK, 1984). They focus on the comparison of mineralogical and chemical composition of sediments of variegated beds in all tectonic units of this area.

Variegated beds exist in the tectono-sedimentary units of the Outer Flysch Group (Subsilesian, Ždánice and Silesian units) and the Magura group of nappes (Fore-Magura unit inclusive). These red-brown, red and green noncalcareous and calcareous claystones are present in their lithological development as a component part of the distinct lithostratigraphic formations and members within the successions of strata of sandy flysch.

In the ***Subsilesian, Ždánice and Silesian units*** of the Outer Group of the nappes and the ***Fore-Magura*** unit, noncalcareous and calcareous claystones of variegated layers of uppermost Cretaceous, Paleocene to Middle Eocene age occur as a component part of the Submenilitic Formation. The lithologically distinct complex of the Variegated Member of the Godula Group of Cenomanian to Early Turonian age belongs to the Silesian unit.

In the ***Magura group of nappes*** this complex corresponds in age to the lithologically constant complex of the Kaumberg Formation (Lower Variegated Member) which belongs to the basal strata of the Rača unit. Stratigraphically younger variegated layers of the Rača unit – the variegated beds of the Beloveža Formation – are Paleocene to Middle Eocene in age. In the Bílé Karpaty, the variegated beds – Kaumberg Formation (Cenomanian – Campanian) – belong to the basal lithostratigraphic members in this succession of Late Cretaceous – Paleocene age.

Within the series of the ***Klippen zone and the Fore-Klippen development,*** superimposed by the Magura group of nappes at the tectonic contact, other variegated beds of Cretaceous age occur. These are the Puchov-marlstones (Cenomanian – Turonian, Upper Coniacian) and the Kaumberg Formation of the Fore-Klippen development (Cenomanian – Late Upper Cretaceous).

On the basis of ***mineral composition,*** a distinct similarity was ascertained between the variegated beds of the Submenilitic Formation of the Silesian unit and the variegated beds of the Beloveža Member of the Rača unit (mica minerals > kaolinite > smectite, occasionally chlorite minerals in small amounts). The claystones of the variegated beds of the Ždánce unit have a similar characteristic as the variegated beds of the Bílé Karpaty unit (mica minerals > smectile > kaolinite, chlorite in trace amounts). A very similar mineral association was found in the claystones of the Kaumberg Formation of the Rača unit and of the Fore-Klippen development (mica minerals > kaolinite; in the claystones mainly of Cenomanian – Turonian age chlorites are present, in the claystones of Campanian to Maastrichtian age a trace amount of smectite. A similar characteristic in the mineral composition is typical of the variegated beds of the Fore--Magura and Subsilesian units, kaolinite predominates in the clayey fraction.

An independent position is typical of the claystones of the variegated beds of the Godula Group of the Silesian unit, significant is the lack of kaolinite (eventually very small trace amount). Mica minerals > smectite (and I-M mixture minerals) > chlorite are typical of these claystones. The Puchov marlstone has an analogous composition to the highly calcareous claystones of the Kaumberg Formation of the Fore-Klippen development of Cenomanian – Turonian age (mica minerals > kaolinite > chlorite).

Distinctly different from other sediments are the variegated sediments of the Fore-Klippen development and of the Bílé Karpaty unit because of their higher content of. MgO, MnO and by higher MgO/Al_2O_3 ratios. The highest amounts of alkalies are present in the Kaumberg Formation of the Bílé Karpaty and the Rača units. There is a certain enrichement of alkalies, compared to Al, deduced from K_2O+Na_2O/Al_2O_3 ratios of the sediments of Cretaceous age.

The highest concentration of iron was found in the variegated sediments of the Magura group of nappes, the lowest in the variegated Godula Member. From the point of view of ***chemical maturity*** of the sediments, the claystones of the variegated beds of the Beloveža Formation and of the Submenilitic Formation of the Fore-Magura and Silesian units appear to be the most mature. The sediments of the Fore-Klippen development are the least mature.

Regarding the concentrations of the ***trace elements*** in noncalcareus claystones, it is found that the highest concentrations of most of these are in the variegated beds of the Beloveža Formation and in the variegated beds of the Submenilitic Formation of the Silesian unit. Some elements are characteristic of a certain age (e. g. B, Zr), others of certain tectonic units or eventually of a group of tectonic units (e. g. Ni, Co, V, Mo, Be). In Cretaceous sediments of all tectonic units there are significantly higher (nearly double) B-concentrations than in the Paleocene sediments (they most probably indicate a higher salinity of the sedimentary environment at the time of the deposition of Cretaceous sediments). On the contrary, the concentrations of Zr in Cretaceous variegated claystones are considerably lower than in the sediments of Paleogene age, which may be due to a more mafic composition of the source material transported into the Cretaceous basin. The sediments of the Magura group of nappes (the Rača and Bílé Karpaty units and the variegated sediments of the Fore-Klippen development) are characterised by higher concentrations of Ni and to some degree of Co compared with the sediments of the Outer Group of nappes (Silesian, Subsilesian and Ždánice units). The V-contents are in a reverse relationship. Mo was detected only in variegated beds of the Silesian and Bílé Karpaty units and in the Fore-Klippen development. Variegated sediments of the Silesian unit are typical of the highest concentrations of Ga and Be, variegated claystones of the Fore-Klippen development and Bílé Karpaty unit of the highest Y-concentrations.

On the basis of trace elements contents and the ratios of selected pairs of trace elements (WEDEPOHL, 1968; AFANASJEVA, 1979; FAIRBRIDGE, 1972; TAYLOR & MCLENNAN, 1984) there is marked similarity between the variegated claystones of the Fore-Klippen development and of the Bílé Karpaty units. The variegated sediments of the Magura group of nappes and of the Fore-Klippen development also have similar values in many of the ratios determined. The increased Zr/Ni values are characteristic of Paleogene sediments, whereas the Cretaceous sediments have typically higher B/Ga values.

The similar characteristics of their chemical composition was determined in the claystones of the Submenilitic Formation of the Fore-Magura and Subsilesian units. In contrast to the Subsilesian unit, the variegated sediments of the Fore-Magura unit have higher concentrations of REE (rare earth elements), Th, Cs, and Hf and considerably lower values of K/Rb, K/Cs and Th/Yb ratios.

The highest concentration of ***rare earth elements (REE)*** occurs in the variegated noncalcareous claystones of the Magura group of nappes, mainly of the Rača unit, and it is somewhat lower in the Silesian unit. Overall the Kaumberg Formation of the Rača unit has higher concentrations of REE, Th, Sc, Rb and Cs. The lowest concentrations of Hf were found in sediments of the Bílé Karpaty unit and of the Fore-Klippen development.

5. Mineralogical-geochemical comparison of the sequences of the East Alpine Flysch zone with those of the Carpathian Flysch belt

5.1. General remarks

Based on the mineral and chemical compositions of the samples from the Alpine Flysch zone (Tab. 1, 3), the following relationships of the individual lithostratigraphic units in the Carpathian Flysch belt to the Alpine Flysch zone are deduced.

Some general differences in the geochemical and mineralogical characters between both sides have to be stressed. These are:

– the material of the Alpine Flysch zone is considerably much more carbonatic than that of the West Carpathian Flysch belt.

– a higher mineralogical maturity, meaning more clay minerals and less feldspar, is characteristic of the Carpathian Flysch belt compared to the Alpine.

5.2. Main Flysch nappe

Variegated shales (Sample 30: red-brown calcareous claystone of the Seisenburg Formation – "Upper variegated shales", Coniacian – Santonian; sample 31: red-brown claystone of the Perneck Formation – "Uppermost variegated shales", Campanian/Maastrichtian boundary): The mineral composition of both red claystones agrees with the Kaumberg Formation of the Rača unit and the Fore-Klippen Zone. Mineralogical and chemical maturities, the contents of alkali and trace elements and the paleosalinity of the sedimentary environment (Tab. 1–3) also have the closest resemblance to the Kaumberg Formation, especially of the Fore-Klippen Zone, both samples are very similar in this respect. The non-calcareous red claystone of sample 31 contains higher amounts of Fe and Ti, in contrast to the calcareous one of sample 30, which contains the highest concentration of B and the equ.B value, higher contents of Cr, Ni, Co and a lower content of Ti (which means a closer relationship to the claystones of the Fore-Klippen Zone).

Altlengbach Formation – lower part (Maastrichtian) – grey claystone (sample 21): Judged by its mineral composition, major elements, mineralogical and geochemical maturities and trace element concentrations (mainly B, Rb, Ti, V, Cr, Nb; Ti/Zr, V/Zr and Ti/Cr ratios Tab. 1b, 2; Fig. 2a), this sample shows the highest degree of resemblance with the Lower Soláně Member (Rača unit). It is very similar to sample 16. In contrast to the Soláně Formation, both of these samples have a lower concentration of Zr.

– upper part (Early Paleocene) – grey claystone (sample 16): Mineral and chemical compositions of this sample corresponds to sediments of the Soláně Formation, particularly the Lower Soláňe Member; Zr/Cr and Zr/Ni ratios correspond to the Upper part of the Beloveža Formation (Rača unit). It is more mature and has a more basic character compared with sample 15.

– upper part (Middle Paleocene) – grey claystone (sample 15): A strongly calcareous claystone (ca. 31 % $CaCO_3$), which appears to have very low mineralogical and geoche-

Tab. 1a: Contents of major element oxides and minor elements (in %) in pelites of the East Alpine Flysch and Klippen Zones (RF: Rheno-Danubic Flysch)

Tab.1a		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Geological unit	samp. nr.	SiO_2	TiO_2	Al_2O_3	FeO	Fe tot	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	CO_2	S	F	C-Org	H_2O+	H_2O-	Li_2O
RF.: Main Nappe																			
Altlengbach-Fm.																			
Eocene	18	19,59	0,31	5,91	0,57	2,23	0,190	0,72	36,31	0,40	1,22	0,157	28,38	0,03	0,050	0,27	2,18	1,26	0,004
-"-	20	51,92	0,68	13,93	0,64	4,84	0,078	1,29	10,91	0,51	2,23	0,070	7,46	0,06	0,120	0,20	4,51	1,43	0,013
Paleocene	15	41,49	0,48	9,98	0,71	3,86	0,120	1,22	19,21	0,58	2,12	0,090	14,36	0,03	0,065	0,58	3,92	2,45	0,007
-"-	16	53,99	0,96	20,37	3,11	6,35	0,036	2,28	0,91	0,80	4,10	0,040	0,08	0,28	0,095	0,83	6,43	2,91	0,022
Maastrichtian	21	57,24	0,86	18,65	1,58	5,70	0,031	2,35	0,91	0,65	5,58	0,076	0,16	0,06	0,070	0,25	5,71	1,96	0,013
Uppermost variegated beds	31	57,84	0,65	16,08	1,89	8,70	0,021	2,11	2,02	0,79	3,34	0,060	0,98	0,02	0,110	0,12	4,84	1,90	0,014
Upper variegated beds	30	54,60	0,54	15,34	0,71	5,70	0,098	2,40	6,08	0,80	3,24	0,090	4,31	0,02	0,110	0,08	4,35	1,85	0,015
RF.: Greifenstein Nappe																			
Gablitz-Fm.	12	44,39	0,72	12,15	1,73	5,40	0,150	1,40	15,42	1,12	2,49	0,098	11,65	0,03	0,060	0,30	3,73	1,77	0,012
Irenental-Fm.	24	54,14	0,87	21,10	0,44	6,59	0,100	1,63	0,95	0,22	2,42	0,080	0,06	0,04	0,100	0,30	7,44	3,70	0,023
-"-	9	59,94	0,95	19,05	2,17	5,39	0,033	1,88	0,59	0,51	3,01	0,070	0,14	0,09	0,070	0,13	6,53	2,14	0,021
Greifenstein-Fm.: varieg. shales	10	50,17	1,09	16,40	0,20	11,68	0,450	1,54	2,81	0,57	2,98	0,220	1,39	0,05	0,185	0,11	6,30	3,90	0,018
-"-	11	49,77	1,27	18,96	0,49	13,48	0,090	1,64	0,46	0,58	3,29	0,174	0,02	0,04	0,070	0,08	7,11	3,69	0,018
Greifenstein-Fm.: sandst. facies	22	69,06	0,91	14,08	1,06	3,87	0,010	0,95	0,20	0,50	3,08	0,067	0,02	0,53	0,040	0,19	5,54	1,40	0,013
RF.:Laab Nappe																			
Laab-Fm.: Agsbach-Sfm.	8	70,08	0,54	10,46	2,38	4,60	0,027	1,23	3,42	0,33	2,21	0,050	1,49	0,15	0,040	0,74	4,09	1,50	0,008
-"-	7	52,69	0,75	15,59	5,04	6,35	0,096	2,27	7,64	1,13	2,84	0,096	5,58	0,29	0,050	0,10	4,91	0,88	0,013
-"-	26	53,15	0,76	17,92	2,08	6,53	0,075	1,81	4,43	0,66	3,32	0,110	2,97	0,03	0,100	0,34	5,50	1,82	0,018
Laab-Fm.: Hois-Sfm.	23	56,26	0,94	20,57	1,33	5,31	0,020	2,11	0,62	0,28	6,41	0,100	0,04	0,04	0,120	1,08	5,07	1,41	0,011
-"-	3	43,45	0,64	14,91	1,55	4,34	0,052	1,68	13,85	0,50	4,39	0,088	10,40	0,04	0,090	0,63	4,11	0,78	0,007
transitional serie: calcareous	6	34,92	0,49	11,62	1,51	3,61	0,079	1,30	22,46	0,54	3,02	0,155	17,14	0,06	0,070	0,87	3,29	0,88	0,006
-"- :dark claystone	5	63,46	0,63	12,90	3,25	4,37	0,081	1,71	2,04	0,68	2,73	0,156	1,54	1,11	0,050	3,16	4,14	1,08	0,014
Kaumberg-Fm.	4	55,36	0,88	19,12	1,86	7,13	0,047	1,96	2,14	1,19	4,56	0,138	1,32	0,05	0,090	0,08	4,70	1,39	0,011
-"-	25	56,56	0,81	19,51	1,65	7,70	0,020	2,07	0,76	0,98	4,38	0,070	0,24	0,03	0,090	0,13	4,70	1,44	0,016
-"-	1	60,50	0,74	16,12	2,19	4,02	0,033	1,64	3,55	1,03	3,77	0,086	2,58	0,06	0,090	0,19	4,25	0,93	0,015
-"-	2	58,98	0,78	16,84	2,75	7,26	0,035	1,90	2,41	1,47	3,59	0,101	1,61	0,05	0,070	0,09	4,44	0,71	0,014
Ybbsitz Klippen Zone																			
Ybbsitz-Fm.: santonian	19	55,17	0,72	14,47	1,73	5,14	0,110	4,34	4,09	1,08	3,44	0,095	5,58	0,04	0,150	0,16	4,37	1,06	0,016
-"-	28	56,67	0,64	16,48	1,42	6,47	0,072	3,95	2,29	1,57	4,09	0,130	2,48	0,02	0,100	0,08	4,07	0,84	0,016
-"- :aptian-albian	17	51,52	0,65	15,06	2,45	5,90	0,070	3,73	6,74	1,72	3,53	0,100	6,05	0,04	0,080	0,14	4,19	0,36	0,014
Gresten Klippen Zone																			
Buntmergelserie	13	34,98	0,58	12,63	2,91	4,45	0,100	1,24	21,87	0,78	1,70	0,090	16,83	0,10	0,060	0,14	4,09	1,08	0,017
-"-	14	29,73	0,44	10,08	1,25	3,74	0,130	1,09	27,07	1,08	2,19	0,063	20,73	0,03	0,060	0,22	2,90	0,73	0,009
-"-	29	57,61	0,66	18,43	1,17	6,99	0,045	2,61	0,73	0,45	3,26	0,080	-0,01	0,02	0,120	0,07	5,80	2,51	0,016
-"-	27	61,52	0,65	16,77	1,21	6,96	0,012	2,16	0,58	0,56	3,28	0,100	0,04	0,02	0,130	0,11	4,80	1,78	(0,001)

Tab. 1b: Contents of trace elements (in ppm) in pelites of the East Alpine Flysch and Klippen Zones. Values in brackets are below detection limit. (RF: Rheno-Danubic Flysch)

Tab.1b		ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Geological unit	samp. nr.	Be	Ag	As	Cr	Cu	Mo	Nb	Ni	Pb	Rb	Sn	Sr	Y	Zn	V	U	Ti	Zr	Ga	Ba	Co	B
RF.: Main Nappe																							
Altlengbach-Fm.																							
Eocene	18	(1,0)	(0,05)	7	48	27	1,0	8	27	14	70	(1,0)	641	18	34	48	(10)	1020	33	9,3	160	8	(10)
-"-	20	1,8	0,15	17	89	59	1,8	14	55	21	104	5,8	225	25	84	124	(10)	3420	108	18,0	390	10	11
Paleocene	15	1,0	0,10	13	110	29	1,0	15	34	23	106	2,6	417	21	83	93	(10)	2338	112	13,0	220	12	110
-"-	16	3,8	0,14	14	112	53	1,6	25	62	31	216	9,0	117	28	118	171	(10)	5456	137	38,0	440	19	240
Maastrichtian	21	2,1	0,08	5	106	41	1,0	20	48	28	263	6,4	97	17	101	160	(10)	4676	135	26,0	400	11	290
Uppermost variegated beds	31	1,0	(0,30)	16	91	21	1,0	15	61	5	132	5,0	116	26	124	132	(10)	4197	118	20,0	318	11	155
Upper variegated beds	30	1,0	(0,30)	14	112	44	1,0	13	77	16	137	4,0	201	32	97	134	(10)	3537	133	16,0	272	18	251
RF.: Greifenstein Nappe																							
Gablitz-Fm.	12	1,5	0,05	8	75	72	1,0	14	57	24	101	2,2	312	23	89	113	(10)	3420	114	11,0	370	18	84
Irenental-Fm.	24	3,0	(0,30)	7	116	68	2,0	19	58	49	121	7,0	88	40	146	172	(10)	5600	150	26,0	378	15	58
-"-	9	2,5	0,10	8	129	74	2,0	24	48	22	139	8,6	93	32	99	155	(10)	5815	246	24,0	420	10	120
Greifenstein-Fm.: varieg. shales	10	2,5	0,09	8	93	61	1,3	21	62	23	127	5,7	113	58	135	164	(10)	6954	263	23,0	720	23	73
-"-	11	3,3	0,08	8	99	115	1,6	23	62	27	129	6,5	59	34	136	196	(10)	8153	223	28,0	520	22	64
Greifenstein-Fm.: sandst. facies	22	1,5	0,15	8	142	31	1,8	21	21	27	175	7,3	65	33	60	155	(10)	5695	489	16,0	420	5	94
RF.:Laab Nappe																							
Laab-Fm.: Agsbach-Sfm.	8	1,5	0,25	12	86	49	2,4	11	45	21	107	10,0	138	18	71	97	(10)	2938	99	16,0	340	9	88
-"-	7	1,7	0,12	7	121	56	1,0	18	60	20	133	5,4	195	25	100	149	(10)	3897	117	24,0	380	15	150
-"-	26	2,0	(0,30)	14	155	70	1,0	18	81	15	150	6,0	140	31	114	193	(10)	4676	139	27,0	437	19	107
Laab-Fm.: Hois-Sfm.	23	3,0	0,30	23	135	68	4,0	19	40	27	248	8,0	110	42	134	214	(10)	5456	208	26,0	467	13	280
-"-	3	1,6	(0,05)	16	87	39	1,0	16	36	17	215	5,1	444	25	77	142	(10)	3237	116	15,0	320	10	150
transitional serie: calcareous	6	1,3	(0,05)	15	70	30	1,0	13	33	20	149	1,6	500	14	71	107	(10)	2218	68	6,6	280	9	90
-"- :dark claystone	5	2,5	0,39	25	75	54	2,8	15	87	20	115	6,6	92	30	113	103	(10)	3597	128	18,0	320	11	93
Kaumberg-Fm.	4	2,2	(0,05)	10	105	32	1,0	17	51	20	193	6,1	102	31	104	139	(10)	5336	277	30,0	390	13	270
-"-	25	2,0	(0,30)	16	111	37	1,0	17	47	14	193	6,0	112	37	100	167	(10)	5012	165	20,0	409	11	115
-"-	1	2,3	0,11	20	95	54	1,0	16	47	23	166	6,2	110	24	98	134	(10)	4257	161	22,0	330	14	190
-"-	2	3,5	(0,05)	10	84	48	1,0	17	55	17	158	5,1	108	24	117	109	(10)	4736	189	25,0	380	16	200
Ybbsitz Klippen Zone																							
Ybbsitz-Fm.: santonian	19	1,3	(0,05)	9	103	52	1,0	15	70	27	138	4,7	124	29	96	124	(10)	3897	176	18,0	290	15	180
-"-	28	2,0	1,66	11	109	26	1,0	13	96	15	146	4,0	72	39	113	140	(10)	4316	176	20,0	347	17	218
-"- :aptian-albian	17	2,2	(0,05)	12	114	24	1,0	16	66	18	147	5,1	96	31	89	131	(10)	3837	174	20,0	340	13	160
Gresten Klippen Zone																							
Buntmergelserie	13	1,3	0,06	6	67	36	1,0	12	36	16	94	2,1	483	17	81	91	(10)	2698	100	10,0	760	11	90
-"-	14	1,5	(0,05)	6	58	24	1,0	10	34	20	102	1,7	414	22	66	89	(10)	1978	82	10,0	235	12	77
-"-	29	2,0	(0,30)	9	78	77	1,0	14	60	22	130	7,0	89	39	128	105	(10)	3656	120	23,0	360	14	170
-"-	27	2,0	(0,30)	10	87	47	1,0	11	37	27	132	4,0	77	33	87	120	(10)	4047	131	17,0	275	11	201

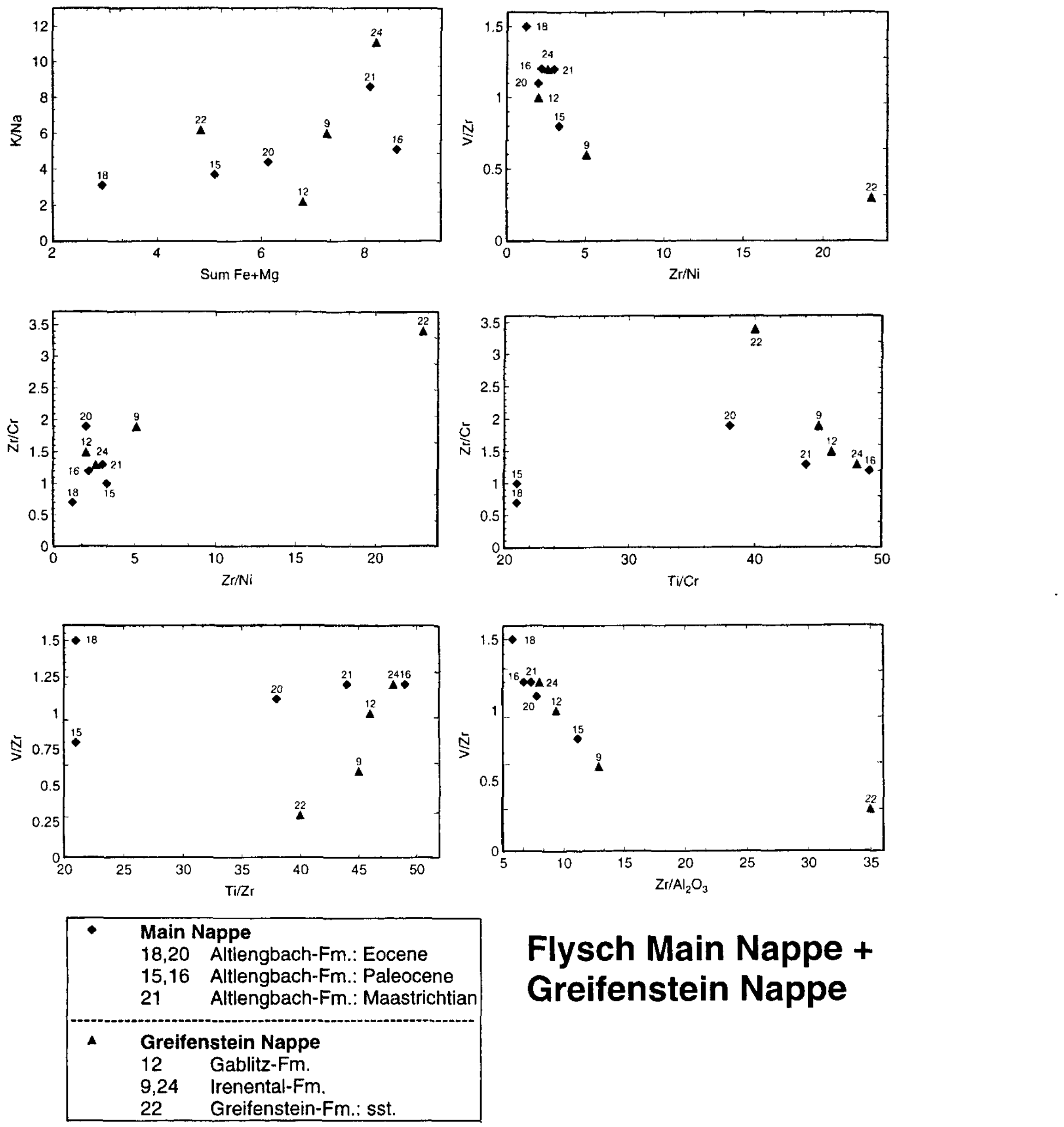


Fig. 2a: Diagrams of ratios of selected major and trace elements in the East Alpine Flysch: Flysch Main Nappe and Greifenstein Nappe.

mical maturities such as the claystones of the Hostýn Member. According to its mineralogical composition and the concentrations of the trace elements, this claystone has a close relationship to the Soláňe Formation, especially to the Lower Soláně Member (except the carbonate content), possibly also to the Hostýn Member. The sumFe+Mg value shows similarity to the Lower Luhačovice Member.

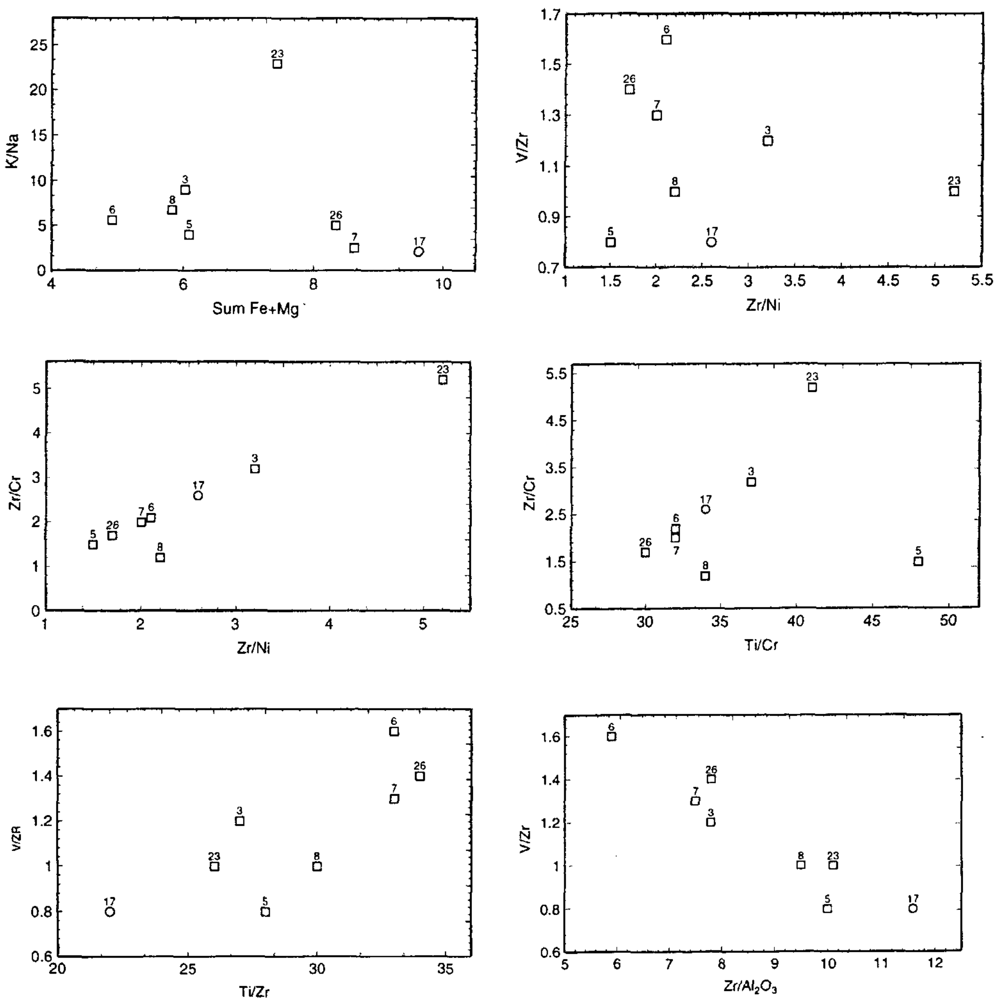
– uppermost part (Early Eocene) – grey claystone (sample 20): This sample is correlatable with the Vsetín Member of the Rača unit, especially with dark grey-brown claystones (major elements, mineralogical and chemical maturities, B, V, Rb; V/Zr, Ti/Zr, Zr/Cr, Ti/Cr ratios etc.). The source material is more acidic than that of sample 18.

– uppermost part (Early Eocene) – grey-brown claystone (sample 18): The mineral composition of this claystone is most similar to the Zlín Formation, especially to the Vsetín Member. Trace element concentrations show undoubtedly a resemblance with the Újezd Member (mineralogical and geochemical maturities, Zr/Cr, Zr/Ni, Zr/Ti and Nb/Y ratios) possibly to the Vsetín Member (low sumFe+Mg; Al/Si ratio).

5.3. Greifenstein nappe

Greifenstein Formation, Lower Greifenstein Formation (Late Paleocene) – blue-green claystone between thick turbidites (sample 22): The mineral and chemical composition agrees very well with the Rusava Member, possibly the Upper Soláně member (except a lower paleosalinity). This sediment reflects the most acidic source material of all the samples from the Flysch Main nappe and the Greifenstein nappe.

– variegated shales (Paleocene/Eocene boundary) – red claystones (samples 10, 11): Mineral and chemical compositions (mainly the high concentration of Fe, the lower alkali element contents, Rb, Mg, the higher contents of Ti, Zr and Cu), mineralogical maturity and paleosalinity of the sedimentary environment agree with the sediments of the variegated beds of the Beloveža Formation (Rača unit). The chemical maturity is lower and corresponds rather to the Kaumberg Formation (Bílé Karpaty unit). The source material of these red claystones is distinctly more acidic than the red claysto-



□	**Laab Nappe**	
	7,8,26	Laab-Fm.: Agsbach-Sfm.
	3,23	Laab-Fm.: Hois-Sfm.
	6	Laab-Fm.: transitional serie: calc.
	5	Laab-Fm.: dark claystone
○	**Ybbsitz Klippen Zone**	
	17	Ybbsitz-Fm.: aptian-albian

Laab Nappe + Ybbsitz Klippen Zone

Fig. 2b: Diagrams of ratios of selected major and trace elements in the East Alpine Flysch: Laab Nappe and Ybbsitz Klippen Zone.

nes of Upper Cretaceous age of the Main Nappe (samples 30 and 31).

Irenental Formation (Early Eocene, NP12-13) – blue-green claystone (sample 9): The mineral composition, mineralogical and geochemical maturities, trace element concentrations (As, Cr, Cu, Nb, Ni, V, Rb and especially Ti, Co, Zr and Li) and the Zr/Ni, Ti/Zr, V/Ni and Cr/Ni ratios (Tab 2; Fig. 2a) correspond to the Luhačovice Member, possibly also to the Rusava Member. The values of B, equ.B and B/Ga, the content of sumFe+Mg and Si/Al, K/Na and K+Na/Al ratios show a certain relationship to the Vsetín Member, especially to its dark grey-brown claystones. The source material is more acidic than that of sample 24.

– grey claystone (sample 24): From the viewpoint of mineralogical and geochemical maturities, there is a distinct similarity to the Upper Luhačovice Member. Mineral composition, paleosalinity and trace element concentrations (B, Zr, Ti, Cr, V, Zn, Co, As; Zr/Ni, V/Zr, Ti/Cr, Zr/Cr, Ti/Zr ratios) indicate the highest degree of similarity to the Zlín Formation (Újezd and paricularly Vsetín Members).

Gablitz Formation (Early Eocene, NP11) – greenish-grey claystone (sample 12): This is a claystone representing a highly immature sediment. Mineralogical and chemical maturity and alkali elements concentration are identical to the Hostýn Member. The mineral composition shows similarity to sediments of the Zlín Formation (the plagioclase content points to the Újezd Member, the carbonate content to the Vsetín Member). Trace elements concentration and selected ratios best agree with claystones of the Vsetín Member.

5.4. Laab nappe

Kaumberg Formation (Senonian) – green claystone (sample 1), red claystone (sample 2 and 25), red silicic claystone (sample 4): In mineral composition these samples are similar to the Variegated Godula Member of the Silesian unit and to the variegated beds of the Fore-Klippen Zone. Alkali elements contents agree with the variegated Godula Member. Mineralogical and chemical maturities are very low. The

Tab. 2: Special geochemical characteristics (paleosalinity, chemical and mineralogical maturity and ratios of the selected major and trace elements) of pelites of the East Alpine Flysch and Klippen Zones (RF: Rheno-Danubic Flysch)

Tab.2: Special geochemical characteristics

Geological unit	Samp.nr	paleosalinity of sedimentary environment	relative maturity		equ.B	B/Ga	Al/Na	K/Na	Si/Al	K+Na /Al	Zr/Ni	Zr/Cr	Zr/Al	Zr/Rb	V/Zr	Cr/V	Ti/Cr	V/Ni	Nb/Y	Ti/Zr	Al/Si	Fe+Mg
			chemical	mineralogical																		
RF.: Main Nappe		marine env.																				
Altlengbach-Fm.																						
Eocene	18	-	low degree	low	-	-	15	3.1	3.3	0.27	1.2	0.7	5.8	0.5	1.5	1.02	21	1.8	0.44	31	0.30	2.95
-"-	20	normal salinity	middle-low d.	middle to low	345	5.6	27	4.4	3.7	0.20	2.0	1.9	7.8	1.0	1.1	0.72	38	2.2	0.56	32	0.27	6.13
Paleocene	15	normal salinity	low degree	low	400	8.5	17	3.7	4.1	0.27	3.3	1.0	11.2	1.0	0.8	1.18	21	2.7	0.71	21	0.24	5.10
-"-	16	normal salinity	middle-low d.	middle to low	451	6.5	26	5.1	2.7	0.24	2.2	1.2	6.7	0.6	1.2	0.65	49	2.8	0.89	40	0.38	8.63
Maastrichtian	21	normal salinity	middle degree	middle	401	11.2	30	8.6	3.1	0.33	2.8	1.3	7.2	0.5	1.2	0.66	44	3.3	1.18	35	0.33	8.10
Uppermost variegated beds	31	normal salinity	low degree	middle to low	357	7.8	20	4.2	3.6	0.26	1.9	1.3	7.3	0.9	1.1	0.70	46	2.1	0.58	36	0.28	10.80
Upper variegated beds	30	higher salinity	low degree	middle to low	597	16.0	19	4.1	3.6	0.26	1.7	1.2	8.7	1.0	1.0	0.84	32	1.7	0.41	27	0.28	8.10
RF.: Greifenstein Nappe		marine env.																				
Gablitz-Fm.	12	lower salinty	immature	very low	260	7.6	11	2.2	3.7	0.30	2.0	1.5	9.4	1.1	1.0	0.66	46	2.0	0.61	30	0.27	6.80
Irenental-Fm.	24	low salinity	high degree	middle to high	185	2.2	95	11.1	2.6	0.13	2.6	1.3	7.1	1.2	1.2	0.67	48	3.0	0.48	38	0.39	8.22
-"-	9	normal salinity	middle degree	middle	310	5.0	39	6.0	3.1	0.18	5.1	1.9	12.9	1.8	0.6	0.83	45	3.3	0.75	24	0.32	7.26
Greifenstein-Fm.: varieg. shales	10	low salinity	middle degree	middle	189	3.2	29	5.2	3.0	0.22	4.2	2.8	16.0	2.1	0.6	0.57	75	2.6	0.36	26	0.33	13.22
-"-	11	low salinity	middle degree	middle	160	2.3	33	5.7	2.6	0.20	3.6	2.3	11.8	1.8	0.9	0.50	82	3.2	0.67	34	0.38	15.10
Greifenstein-Fm.: sandst. facies	22	lower salinity	middle degree	middle	240	6.0	29	6.2	4.9	0.25	23.0	3.4	35.0	2.8	0.3	0.92	40	7.4	0.64	12	0.20	4.82
RF.:Laab Nappe		marine env.																				
Laab-Fm.: Agsbach-Sfm.	8	normal salinity	middle dgree	middle	310	5.5	32	6.7	6.7	0.24	2.2	1.2	9.5	0.9	1.0	0.89	34	2.1	0.61	30	0.15	5.82
-"-	7	normal salinity	low degree	low	407	6.3	14	2.5	3.4	0.25	2.0	2.0	7.5	0.9	1.3	0.81	32	2.5	0.72	33	0.30	8.62
-"-	26	lower salinty	middle-low d.	middle	250	4.0	27	5.0	3.0	0.22	1.7	1.7	7.8	0.9	1.4	0.80	30	2.4	0.58	34	0.34	8.34
Laab-Fm.: Hois-Sfm.	23	normal salinty	middle-high d.	high	340	10.8	74	22.9	2.7	0.33	5.2	5.2	10.1	0.8	1.0	0.63	41	5.4	0.45	26	0.37	7.42
-"-	3	normal salinity	middle degree	middle	363	10.0	31	9.0	2.9	0.33	3.2	3.2	7.8	0.5	1.2	0.61	37	3.9	0.64	27	0.33	6.02
transitional serie: calcareous	6	lower salinity	middle-low d.	middle	230	12.8	22	5.6	3.0	0.30	2.1	2.1	5.9	0.5	1.6	0.65	32	3.2	0.93	33	0.33	4.91
-"- :dark claystone	5	lower salinty	low degree	middle to low	262	5.2	19	4.0	4.9	0.26	1.5	1.5	10.0	1.1	0.8	0.73	48	1.2	0.50	28	0.20	6.08
Kaumberg-Fm.	4	higher salinty	low degree	middle to low	456	9.1	16	3.8	2.9	0.30	5.4	5.4	14.5	1.4	0.5	0.76	51	2.7	0.55	19	0.35	9.09
-"-	25	lower salinty	low degree	middle to low	202	5.8	20	4.5	2.9	0.27	3.5	3.5	8.5	0.9	1.0	0.66	45	3.6	0.46	30	0.34	9.76
-"-	1	normal salinty	low degree	middle to low	398	8.6	16	3.7	3.8	0.30	3.4	3.4	10.0	1.0	0.8	0.71	45	2.9	0.67	26	0.27	5.66
-"-	2	normal salinity	low degree	low	429	8.0	12	2.5	3.5	0.30	3.4	3.4	11.2	1.2	0.6	0.77	57	2.0	0.70	25	0.29	9.16
Ybbsitz Klippen Zone		marine env.																				
Ybbsitz-Fm.: santonian	19	higher salinty	low degree	low	403	10.0	13	3.2	3.8	0.31	2.5	2.5	12.2	1.3	0.7	0.83	38	1.8	0.52	22	0.26	9.44
-"-	28	higher salinity	immature	low	410	11.1	10	2.6	3.5	0.34	1.9	1.9	11.0	1.2	0.8	0.78	40	1.5	0.33	24	0.29	10.42
-"- :aptian-albian	17	normal salinity	immature	very low	349	8.0	9	2.1	3.4	0.35	2.6	2.6	11.6	1.2	0.8	0.87	34	2.0	0.52	22	0.29	9.62
Gresten Klippen Zone		marine env.																				
Buntmergelserie	13	normal salinity	low degree	low	408	9.9	16	2.2	2.8	0.20	2.8	2.8	7.9	1.0	0.9	0.74	40	2.5	0.71	27	0.36	5.69
-"-	14	weakly lower sal.	immature	very low	290	7.7	10	2.0	2.9	0.22	2.4	2.4	8.1	0.8	1.1	0.65	35	2.6	0.45	24	0.34	4.83
-"-	29	normal salinity	middle degree	middle	402	7.4	41	7.2	3.1	0.20	2.0	2.0	6.5	0.9	0.9	0.74	47	1.8	0.36	31	0.32	9.60
-"-	27	higher salinity	middle degree	middle	472	11.8	30	5.9	3.7	0.23	3.5	3.5	7.8	1.0	0.9	0.72	47	3.2	0.33	31	0.27	9.12

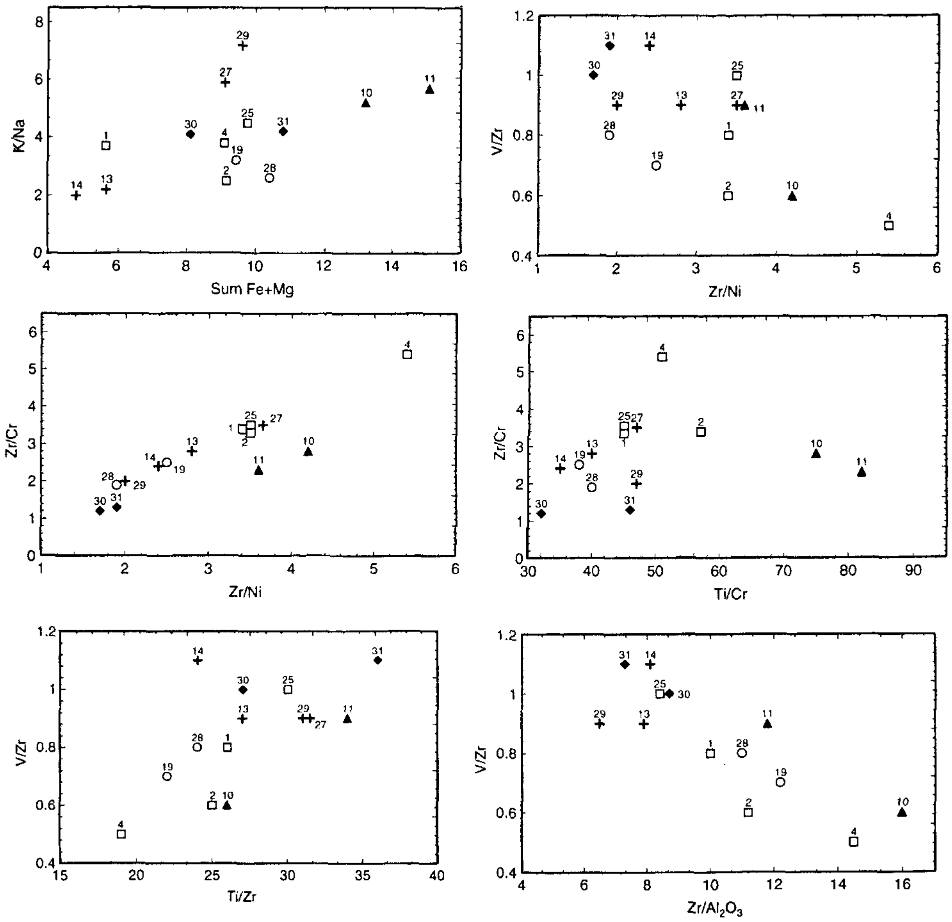


Fig. 2c: Diagrams of ratios of selected major and trace elements in the East Alpine Flysch: and Klippen Zones: Variegated shales.

paleosalinity of the sedimentary environment (except sample 25 with a lower content of B and value of equ.B) and the trace element concentration show close relationship to the variegated sediments of the Rača unit and Fore-Klippen Zone as well as to the Variegated Godula Member.

All these samples generally have more acidic material, particularly sample 4 (higher content of Zr and Ti; Zr/Ni, Zr/Al, V/Cr, Ti/Cr and Ti/Zr ratios Tab. 2; Fig. 2c).

It should be stressed that samples 25 and 4 are from the upper part of this formation, sample 4 from the uppermost part near the contact to the transitional serie (sample 5).

Transitional series. Dark claystone-series (age unclear) – black silicic claystone (sample 5): This black silicified claystone has lower mineralogical and chemical maturities, lower quantities of K_2O and higher contents of S and organic matter. The mineral composition has a marked similarity to the Veřovice Formation of the Silesian unit. The chemical composition also shows similarity to the Veřovice Formation, also to the Lhota Formation (Be, Co, Cr, Ga, Ni, Cu, Zn, V, Sn, Rb, Ti and Zr contents and Ni/Co, Ti/Zr, Cr/Ni, Ti/Zr ratios; Zr/Ni and Zr/Cr ratios are lower and closer to the Veřovice Formation, possibly Hradiště Member). Not comparable with these formations are the lower B and equ.B values and the B/Ga ratio.

– calcareous series (Campanian) – dark grey claystone (sample 6): This calcareous claystone up to marlstone does not resemble samples 23 and 3, it points to a more basic character of the source material. The mineral composition is more similar to the Lhota Formation, possibly the Lower Godula Member of the Silesian unit. The contents of Co, Cr, Y, Rb, Zn, V and in some respect Ti and Zr and Zr/Ni and Ni/Co ratios resemble the Lhota Formation (Zr and Ti are rather lower than in the Lhota Formation), the contents of B, Sn, Ni, Pb and the V/Ni, Zr/Ni, V/Cr ratios show greater similarity to the Lower Godula Member. The V/Zr, Ti/Zr and Zr/Cr ratios show a more basic nature of this sample (as in the Těšín-Hradiště Formation of the Silesian unit).

Laab Formation, Hois Subformation (? Maastrichtian – Paleocene) – grey claystone (sample 3): This strongly calcareous claystone is correlatable with the Svodnice Formation – White Carpathian unit (mineralogical and chemical maturities,

Tab. 3: Mineral composition (semiquantitative analyses) of pelites of the East Alpine Flysch and Klippen Zones (RF: Rheno-Danubic Flysch; ++++ high, +++ higher (= middle to high), ++ middle, + low content; tr: traces)

Tab.3: Mineral composition

\+ low content +++ higher (= middle to high) content
++ middle content ++++ high content tr traces

Geological unit	samp. nr.	quartz	plagiocl.	mica min. (illite)	kaolinite	chlorite	smectite	I/S	calcite	dolomite	pyrite	haemat.	anatase
RF.: Main Nappe													
Altlengbach-Fm.													
Eocene	18	(+)	+	+			+		++++				
-"-	20	++	+	+	++		(+)		++				
Paleocene	15	++(+)	+	++			+		+++				tr
-"-	16	+(+)	++	+++		+	+						+
Maastrichtian	21	++	+(+)	+++	+		+						tr
Uppermost variegated beds	31	+++	++	+++	++		(+)		tr			+	
Upper variegated beds	30	+++	++	++	+(+)		(+)		+(+)			+	
RF.: Greifenstein Nappe													
Gablitz-Fm.	12	++(+)	+++	+	++		+		++(+)				tr
Irenental-Fm.	24	+(+)	+	+	+++		++					tr	
-"-	9	++	+	++	+++								tr
Greifenstein-Fm.: varieg. shales	10	++	+(+)	+(+)	++(+)		++		tr			++	(+)
-"-	11	+(+)	+(+)	++	+++		+(+)					++	+
Greifenstein-Fm.: sandst. facies	22	++++	+	++	++								
RF.:Laab Nappe													
Laab-Fm.: Agsbach-Sfm.	8	++++	(+)	++		+	tr		tr				
-"-	7	++	++(+)	++		+			+(+)				
-"-	26	++	++	++(+)	tr	+			+				
Laab-Fm.: Hois-Sfm.	23	++	(+)	+++	+	+	+						
-"-	3	++	+	++(+)	tr	+	+		++				
transitional serie: calcareous	6	+(+)	+	++		+			+++				
-"- :dark claystone	5	++++	++	++		+		+	tr	tr	+		
Kaumberg-Fm.	4	++	++(+)	++(+)		+		+	tr			+	
-"-	25	++	++	+++	(+)	+						+	
-"-	1	++(+)	++	+++		+			+				
-"-	2	++(+)	+++	+++		+			+			+	
Ybbsitz Klippen Zone													
Ybbsitz-Fm.: santonian	19	++(+)	++(+)	++	++		tr			+(+)		(+)	tr
-"-	28	++(+)	+++	+++		+				+		+	
-"- :aptian-albian	17	++	+++	++		+			(+)	+(+)			
Gresten Klippen Zone													
Buntmergelserie	13	+(+)	++	+	++		+		+++				tr
-"-	14	+(+)	++(+)	+	++				+++(+)			(+)	
-"-	29	++	+	++	+							+	
-"-	27	+++	+(+)	+++		+	+(+)					+	

alkali elements contents, B, Ga, Rb, V, Cr, Ti, equ.B and Si/Al, V/Zr and Ti/Cr ratios etc. – Tab. 1, 2; Fig. 2b). In mineral composition it especially agrees with Suchov lithofacies of this formation. The contents of Zr, Ni, Co and the Zr/Ni, Cu/Ni and Ti/Zr ratios show a certain relationship to the Nivnice Formation.

– grey-brown claystone (sample 23): A noncalcareous claystone with a high K_2O-content, high mineralogical and chemical maturities, somewhat higher concentrations of Zr, Rb, B and of B/Ga ratio. The mineral composition corresponds to sediments of the Svodnice Formation, especially to the Suchov lithofacies. Also the chemical composition shows a close relationship to the Svodnice Formation, the contents of Pb, Ni, Co, and Ti and the higher V/Ni, Cr/Ni and Zr/Ni ratios are very close to the Suchov lithofacies. The higher concentration of Zr resembles some samples of the Nivnice Formation.

Laab Formation, Agsbach Subformation (Eocene) – green-grey claystone (sample 26): The mineral composition resembles claystones of the Kuželov Formation. The lower chemical and medium mineralogical maturity is similar to the Nivnice Formation. From the viewpoint of chemical composition, it has close relationship to sediments of the Kuželov Formation (contents of sumFe+Mg., P, F, S, H_2O+, H_2O^-, Be, Ni, Nb, Ga, Co, Li; V/Ni, Cr/Ni, Cu/Ni, Zr/Ni and K/Rb ratios) and to the Nivnice Formation (contents of alkali elements, Cr, Ti, B, Y, V; Ti/Al, Ti/Zr, V/Cu, Ti/Cr and B/Ga ratios).

– grey claystone (sample 7): This claystone has very low mineralogical and chemical maturities. The mineral composition, low maturity, the contents of sumFe+Mg, Na, Ba, B, Ga, Ni, Cr, Be and V/Ni, Cr/Ni, Zr/Ni, B/Ga, and K+Na/Al ratios are similar to the Kuželov Formation. The concentrations of Y, V, Zn, Pb, lower contents of Zr and Ti, Ti/Zr, V/Zr, Ti/Cr, Zr/Cr and K/Rb ratios show closest resemblance to sediments of the Nivnice Formation (White Carpathian unit).

– grey claystone (sample 8): This highly arenaceous claystone appears to have medium mineralogical and geochemical maturities (higher than the Kuželov and Nivnice Formations). In mineral composition it agrees with the Kuželov Formation (except for the very low content in plagioclase). The chemical composition is most similar to the Kuželov Formation; a certain relationship is evident to the Nivnice Formation (especially the ratios of Ti/Zr and Ti/Cr).

5.5. Ybbsitz Klippen Zone

Ybbsitz Formation (sample 17 – Aptian Albian), grey-green calcareous claystone: This claystone (ca. 13 % calcite and dolomite) is mineralogically and chemically entirely immature. The mineral composition is similar to the Godula Formation of the Silesian unit or to flysch claystones of the Fore-Klippen Zone (a higher content of MgO). The chemical composition shows a closer relationship to the claystones of the Godula Formation of the Silesian unit or Hostýn Member of the Rača unit (Cr, Ni, Nb, Y, Zn, As, Rb, B; Ti/Zr, Zr/Al, V/Zr, Nb/Y, Zr/Cr and B/Ga ratios Tab. 1, 2; Fig. 2b). The Zr and Ti contents are lower, which shows a certain similarity to the Lhota Formation of the Silesian unit.

– (Turonian – Santonian), red and green claystones (sample 19) and red-brown claystone (sample 28): These weakly calcareous red claystones are highly immature (the lowest mineralogical and geochemical maturities in all the samples investigated here). The mineral composition and paleosalinity resemble the Kaumberg Formation of the Fore-Klippen Zone (especially sample 19; sample 28 rather more the Variegated Godula Member of the Silesian unit). Characteristics of these claystones are the higher contents of Zr and B and lower contents of Ti, Iron and Al contents are similar to the Variegated Godula Member, Mg and Ca contents show closer similarity to Fore-Klippen claystones. Generally these red claystones have the closest relationship to the Kaumberg Formation, especially to the Fore-Klippen Zone and the Variegated Godula Member (Ti, Rb, Ga, Ba, Co, Cr, Sn and Pb; higher alkali element contens, Zr/Al, Ti/Al, Si/Al, Ni/Co, V/Cr, V/Ni, Zr/Ni, Ti/Cr and B/Ga ratios etc. – Tab. 1, 2; Fig. 2c).

5.6. Gresten Klippen Zone

Buntmergelserie (Late Albian – Eocene). Samples from this formation were taken from the lower part, Turonian – Santonian (samples 27, 29) and the upper part, Campanian – Eocene (samples 13, 14), both groups show a certain variation in mineral composition and chemical and mineralogical maturity.

Noncalcareous claystones (samples 27 and 29): Mineral composition of sample 29 corresponds to the sediments of the Kaumberg Formation of the Fore-Klippen Zone and partially the Bílé Karpaty unit, of sample 27 to claystones of the Variegated Godula Member and possibly some samples of the Kaumberg Formation of the Fore-Klippen Zone. The concentrations of B and equ.B values and B/Ga ratio resemble a sedimentary environment like the Kaumberg Formation. The chemical composition of both samples 27 and 29 shows very narrow relationship to the claystones of the Variegated Godula Member and the Kaumberg Formation, especially of the Fore-Klippen Zone (Ti, Zr, Ba, Rb, Pb, Y, Nb, V; Ti/Al, Ti/Zr, V/Ni, Cu/Ni, Zr/Cr, Zr/Ni etc. – Tab. 1b, 2; Fig. 2c).

Strongly calcareous claystones (sample 13) up to marlstones (sample 14): The mineral composition is very similar to red sediments of the Submenilitic Formation of the Fore-Magura unit, possibly also to the Subsilesian unit. Both samples have very low mineralogical and chemical maturities, like the samples of the Ybbsitz Klippen Zone or some samples of the Kaumberg Formation of the Laab Nappe. The B and equ.B values and the B/Ga ratio show similarity to the variegated sediments of the Subsilesian unit (possibly also to the Fore-Magura unit). The chemical composition is most similar to the variegated sediments of the Fore-Magura and Subsilesian units and to the Variegated Godula Member of the Silesian unit.

On the whole, the material of the variegated sediments of the Gresten Klippen Zone (Buntmergelserie) is slightly more acidic than the material of the variegated beds of the Main Flysch nappe. It shows most similarity to the variegated sediments of the Godula Member (Silesian unit), the Subsilesian and the Fore-Magura units, with a certain trend to the Kaumberg Formation of the Bílé Karpaty unit and the Fore-Klippen Zone (Kaumberg Formation and Puchov marlstones have somewhat higher Mg and alkali elements, higher K and lower Na, higher maturities and lower Zr/Al and Ti/Al ratios).

6. Discussion and conclusion

Geochemical analyses, particularly the determination of trace elements, has so far been rarely carried out in flysch formations of the Alps. Whatever the reasons for this might be, it does provide a valuable, additional tool for the reconstruction of previous environmental conditions, basin analysis and paleogeographic implications. In our particular case, it should above all provide additional data for the correlation of formations and tectonic elements of the Alpine-Carpathian Flysch belt.

Despite our very unbiassed approach to these geochemical analyses, the data support surprisingly well the picture

Tab. 4: Localities of samples: P = mapping SCHNABEL; P&P = PLÔCHINGER & PREY 1993: Der Wienerwald (guide book, excursion points).

Tab.4: Sample localities				
Geological unit	samp. nr.	ÖK50-map sheet	Field book nr.	Locality
RF.: Main Nappe				
Altlengbach-Fm.				
Eocene	18	71/Ybbsitz	P 71/1964	Small valley W Wiesberg
-"-	20	55/Obergrafendorf	P 55/600	Grünsbach, road junction
Paleocene	15	71/Ybbsitz	P 71/1918	Saurüsselgraben, road bend
-"-	16	71/Ybbsitz	P 71/1444	Urnbach Graben 16
Maastrichtian	21	55/Obergrafendorf	P 55/800	Rabenstein quarry
Uppermost variegated beds	31	71/Ybbsitz	P 71/1023	N Gresten, old quarry
Upper variegated beds	30	71/Ybbsitz	P 71/1196	NE St. Ägidi, Riegelgraben
RF.: Greifenstein Nappe				
Gablitz-Fm.	12	58/Baden	P 58/542	Hochram, small valley
Irenental-Fm.	24	58/Baden	P 58/65	Riedanleiten, valley
-"-	9	57/Neulengach	P 57/2082	Bärengraben
Greifenstein-Fm.: varieg. shales	10	57/Neulengach	P 57/330	Hinterleiten, river near highway junction
-"-	11	58/Baden	P 58/50	Irenental (upper part)
Greifenstein-Fm.: sandst. facies	22	58/Baden	P 58/252	Höbersbach quarry
RF.:Laab Nappe				
Laab-Fm.: Agsbach-Sfm.	8	57/Neulengach	P&P II/10	Agsbach, old quary
-"-	7	57/Neulengach	P&P II/9	Agsbach-river N Klausen-Leopoldsdorf
-"-	26	57/Neulengach	P&P II/4	Klammhöhe, road cut
Laab-Fm.: Hois-Sfm.	23	57/Neulengach	P&P II/3	S Klamm, road cut
-"-	3	57/Neulengach	P&P II/6	Hois, old quarry
transitional serie: calcareous	6	57/Neulengach	P 57/GA-9	Coronabach near Gadinger
-"- :dark claystone	5	57/Neulengach	P 57/GA-4	Coronabach near Gadinger
Kaumberg-Fm.	4	57/Neulengach	P 57/GA-3	Coronabach near Gadinger
-"-	25	57/Neulengach	P&P II/2	Glashütte near Klamm
-"-	1	57/Neulengach	P&P II/5	Triesting-river near Hofstätter
-"-	2	57/Neulengach	P&P II/5	Triesting-river near Hofstätter
Ybbsitz Klippen Zone				
Ybbsitz-Fm.: santonian	19	71/Ybbsitz	P 71/2715	Urnbach-river near Putzmühle
-"-	28	71/Ybbsitz	P 71/2715	Urnbach-river near Putzmühle
-"- :aptian-albian	17	71/Ybbsitz	P 71/1505	Fürnschliefgraben (lower part)
Gresten Klippen Zone				
Buntmergelserie	13	54/Melk	P 54/573	Zwickelsberg (E St.Georgen/Leys)
-"-	14	71/Ybbsitz	P 71/667	NE Gresten, Kriegerkapelle
-"-	29	71/Ybbsitz	P 71/2057	W Gresten, road to Ybbsitz
-"-	27	72/Mariazell	P 72/11	Klausgraben, N Hundsschlag

gained so far, of the transition of certain flysch units, between the Alps and the Carpathians. In addition, it provides further clues for the classification of relationships, which had been largely unclear to date.

This last paragraph refers to the non-variegated sequences. Geochemical data of the variegated sections do not give such a clear picture in most of the tectonic units. This is why they are treated separately.

Based on the geochemical and mineralogical data gained within this study, the following relationships concerning the correlation of tectonic units and formations can be confirmed. The paleogeographical and tectonical pattern of the Alpine and Carpathian Flysch belts is too complex to draw final conclusions from these very few samples. The data should therefore not be overinterpreted.

Flysch Main Nappe/Greifenstein Nappe – Rača unit: The close relationship between these units could once more be confirmed. The Maastrichtian of the Altlengbach Formation can best be compared with the Lower part of the Soláně Formation, the Paleocene shows some similarity to the Hostýn Member of this formation. The uppermost part of the Altlengbach Formation in the Flysch Main Nappe (Lower Eocene), together with the Irenental and the Gablitz Formations of the same age in the Greifenstein Nappe, match quite well with the Zlín Formation and its members.

Only one sample of a pelite from the Greifenstein Sandstone Formation (Upper Paleocene of the Lower Greifenstein Formation) has been taken, and this points to the Upper Soláně or Rusava Members rather than to the Luhačovice Formation. This is surprising, because of the distinct facial harmony of the Greifenstein and the Luhačovice Sandstone formations, regarded as a proximal (interchannel) facies of a deep sea fan, supplied mainly from a granitoidal source. In any case, the geochemical data yielded here reflect the most acidic source material of all the detected samples, which is in accordance with the other observations. Two explanations for the differences are possible: (a) the Lower Greifenstein Member extends to the East into the Upper Soláně Member, which is in accordance with the age and the mineral content of the prevailing sandstones, e. g. heavy minerals with zircon/tourmaline spectra (oral communication Zd. STRÁNÍK and unpublished data W. SCHNABEL); (b) the

Luhačovice fan is younger than the Greifenstein fan and the system becomes diachronously younger from W to E. This explanation is supported by stratigraphic data and also by slight geochemical indications from sample 9 in the Irenental Formation, overlying the Upper Greifenstein Sandstone Member.

A section of variegated flysch separates the Lower and the Upper Greifenstein Sandstone Member at the Paleocene-Eocene boundary (samples 10 and 11). Some data refer to the variegated beds of the Beloveža Formation (Rača unit), some to the Kaumberg Formation of the Bílé Karpaty unit. The distinctly high acidity fits well into the environment of the Rača sequence at that time, preference should therefore be given to a connection with the Beloveža Formation. In this respect the variegated beds within the Greifenstein Formation could be interpreted as the westernmost offset of the Beloveža Formation.

Laab Nappe – Bílé Karpaty unit. Data from the Laab Formation show a closer relationship to the Bílé Karpaty than to any other unit. The Hois Member shows similarity mainly to the Svodnice Formation and its subfacies, the Agsbach Member to the Kuželov more than the Nivnice Formations. This very clear result is surprising, as the field observations and sedimentological data do not show such a good agreement.

Data from the Kaumberg Formation of the Laab Nappe are identical with those of the Bílé Karpaty and Fore Klippen Zone, but also show features of the Variegated Godula member of the Silesian unit. The designation of the very internal Kaumberg Formation as an equivalent of the external Silesian unit would cause considerable tectonic difficulties, although this possibility is incorporated in the views of some alpine geologists (FUCHS, 1984; OBERHAUSER, 1991).

The relation between the Kaumberg Formation and the Laab Formation is not yet solved. Between these are two "transitional series", which may either represent a normal sedimentary transition, but may also imply a tectonical separation. These two series are (1) dark claystones and glauconitic sandstones, uncertain in age and (2) marly flysch of Campanian age. The geochemistry of (1) points to the Lower Cretaceous Veřovice or Lhota Formations of the Silesian unit, but this merely indicates that it was laid down under the same "anoxic" conditions. (2) is controversial. It shows similarity to the Lower and Mid-Cretaceous sediments of the Silesian unit, this is in contradiction with the Campanian age; the position of these "transitional series" therefore remains uncertain.

Summing up, it can be seen that the relations drawn from the older sequences of the Laab nappe (Kaumberg Formation and "transitional series") are much more uncertain than those of the younger sequences (Laab Formation).

As mentioned above, the ***Ybbsitz Klippen Zone*** has no equivalent in the Carpathians. Exceptional in the pelites is the dolomite content. The thin bedded flysch of Aptian/Albian age shows similarity with Lower and Mid-Cretaceous sequences of the Silesian unit, which merely points to a similar depositional environment, because such a paleogeographic relationship is unrealistic Also, the Upper Cretaceous variegated flysch, which shows similarity to the Silesian as well as to the Fore-Klippen variegated flysches gives no suitable indications.

The ***Buntmergelserie (Gresten Klippen Zone)*** with its variegated shales is the only non-turbiditic sequence treated here. As in most of the variegated sequences, comparison with the Carpathians is tenuous. The stratigraphically higher part shows some resemblance to the lithologically identical or similar Subsilesian nappe and the Fore-Magura unit. This is not surprising, as both were deposited on the continental slope or elevated zones having an analogous relation to the Southern European Continental Margin.

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