1 Introduction

The end-Triassic mass extinction is the most poorly understood event among the five biggest mass extinction events in earth history (Hallam & Wignall 1997a) (Fig.1). The extinction event affected both environments, land and sea. At the end of the Triassic, 58 cephalopod families disappeared, including all 46 late Triassic ceratitid cephalopod families. In NW Europe, 92% of bivalves became extinct (Hallam 1981). All reef organisms were affected by the drastic reduction of diversity. Only 20% of the hexacorals survived the Triassic/Jurassic boundary, the sponges lost 8 families. 12 families of brachiopods and 13 families of gastropods disappeared. The extinction of the conodont animal is one of the most remarkable bioevents of this period. In the terrestrial realm insects lost 35 families. Even vertebrates have been affected by the Triassic/Jurassic boundary mass mortality, 6 tetrapod families died out. What could cause such an ecosystem collapse? Climatic changes, sea-level changes, oceanic anoxia (Hallam 1997, Hallam & Wignall 1997b), as well as flood basalt volcanism (Marzoli et al. 1999, Hesselbo et al. 2002, Pálfy 2003) and extraterrestrial impacts (Olsen et al. 2002) are frequently cited agents that could be responsible for this sudden decrease of diversity.

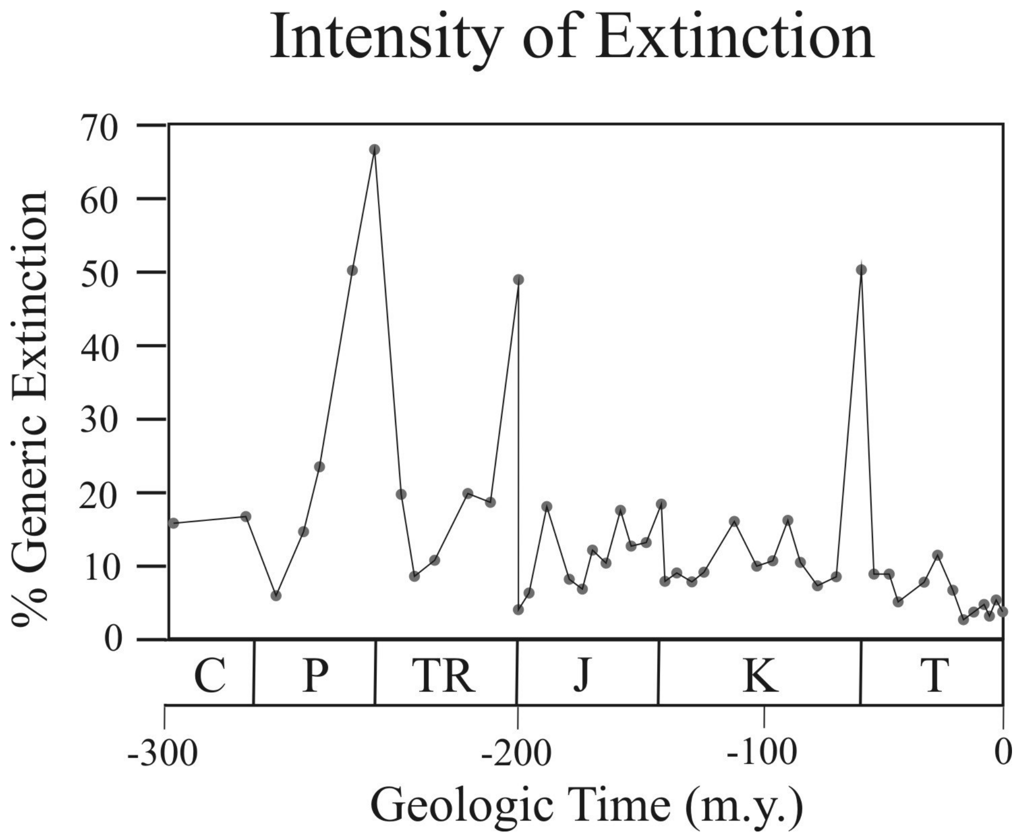

Fig. 1: Generic-level extinctions of marine organisms during the past 300 m.y., modified from Sepkoski (1996) and Olsen et al. (2002).

For a correlation of several remarkable events around the boundary interval in different palaeogeographic areas detailed biostratigraphic investigatons in terrestrial and marine settings are needed. Palynology provides to be an excellent tool for correlation of terrestrial and marine environments, because the sedimentary organic matter of marine sediments comprises two fractions, a terrestrial allochthonous fraction, build up by pollen grains and spores and a marine relatively autochthonous fraction composed of marine plankton. Palynological studies of the Triassic/Jurassic boundary with special focus on the extinction event are very rare. Fowell & Olsen (1993) describe a sudden floral turnover and a magnificent decrease in pollen and spore diversity coevally with an Iridium anomaly in terrestrial sediments of the Newark Supergroup (U.S.A.). In other palaeogeographical settings, indicators for a microfloral mass extinction are absent. In this study, key sections of the NW Tethyan realm, mainly defined as those due to their paleogeographic position and completeness of the deposits, have been investigated palynologically with respect to changes within the microfloral assemblage around the boundary interval. Three study areas representing different palaeoenvironments have been studied: Deep marine limestones of the Csővár section in N Hungary, shallow marine limestone-marl alternations of the Slovakian Tatra Mountains and terrestrial coal deposits of the S Hungarian Mecsek Mountains. The palynological analysis of these different environments and the comparison and interpretation of the palynological assemblages with respect to the Triassic/Jurassic boundary event were the main goals of this study. The idea of this investigation was initiated by geoscientists of the IGCP project 458 “Triassic/Jurassic boundary events: Mass extinction, global environmental change, and driving forces”; the study itself was funded by the German Science Foundation (DFG project, GO 761/2-1) and carried out in collaboration with Slovakian and Hungarian colleagues and the international research group of the IGCP project.

2. Materials and Methods

2.1 Study areas

2.1.1. Tatra MountainsOutcrop sections of the Slovakian Tatra Mountains (Western Carpathians) exposing the Triassic/Jurassic boundary interval were investigated in the Furkaska valley east of Oravice and the Kardolína section northeast of Stará Lesná. Additionally, an Upper Rhaetian series was sampled in the Hybe section south of Východná (Fig. 2). Recently, microfacies and geochemical signatures of the Furkaska and Kardolína sections were addressed within the scope of the IGCP 458 project (see Michalík 2003). Due to the lack of precise biostratigraphic data, the tremendous need of palynological studies was recognized by the scientific community (see Pálfy et al. 2000).

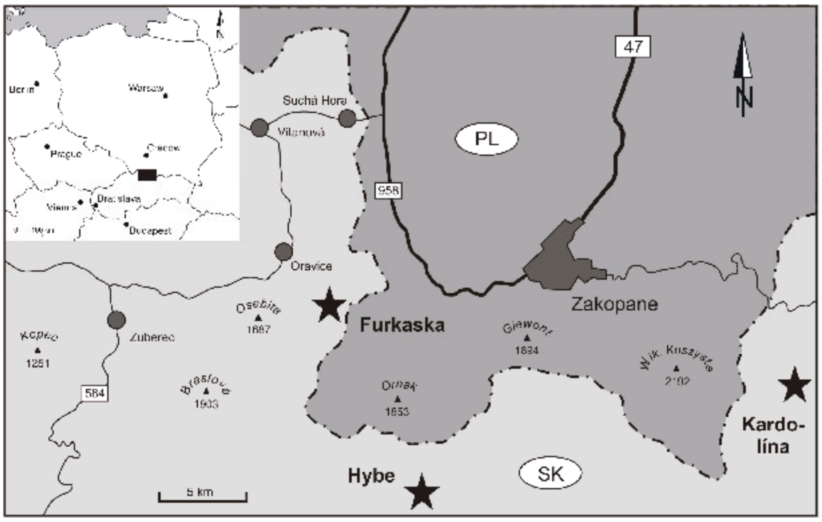

Fig. 2: Geographic map of the Tatra Mountains. Stars are indicating the studied sections.

2.1.2. Northern Hungary

The Csővár section (Fig. 3) northeast of Budapest (Transdanubian Range) exposes a continuous succession of late Triassic and early Jurassic age. The unique exposure of a complete slope-to-basin transition enabled detailed sedimentological and sequence stratigraphical analyses (Haas & Tardy-Filácz 2004). Up to now, hardly any palynological data of this section were available. Therefore, detailed investigations on terrestrial and marine palynomorphs are necessary to date the processes and additionally contribute to reconstruct the complex basin evolution.

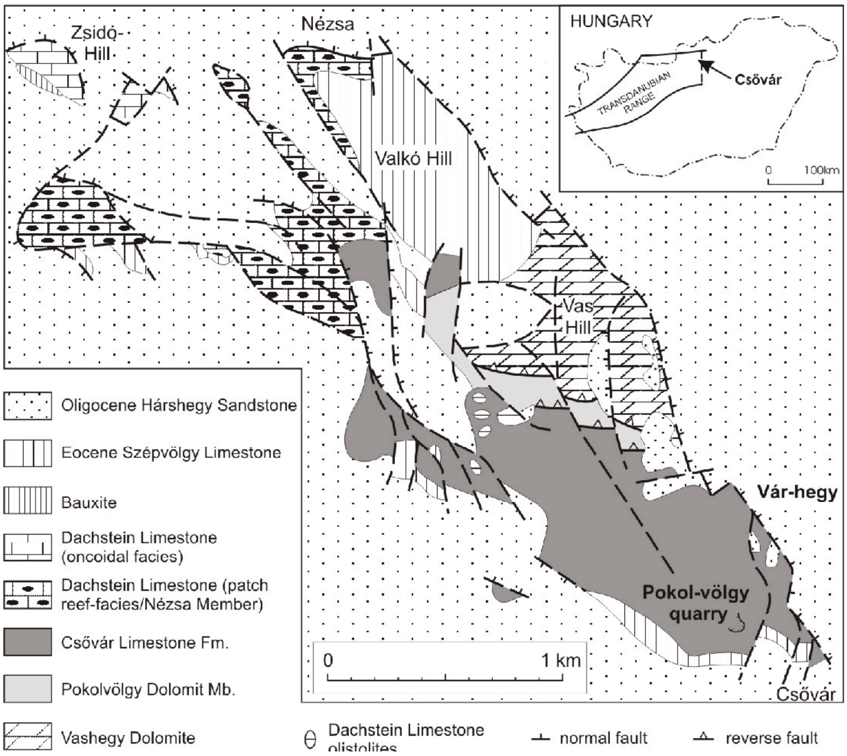

Fig. 3: Geological map of the N-Hungarian Csővár area.

2.1.3. Southern Hungary

The Mecsek Mountains north of Pécs (Tisza Unit) reveal complete sedimentary series of the Triassic and Jurassic (Haas 2001). The Triassic/Jurassic boundary interval was sampled in outcrops, coal pits, and wells (Fig. 4 and 5). Due to the intensive mining activities in this region during the Hungarian socialistic era, a significant number of wells is documented. Palynological investigations have been carried out during the 60ies and 70ies of the last century with special respect to economic mining and correlation of distinct coal seams (see compilation in Boná 1995). A detailed palynofacies analysis focussing palaeoenvironmental and climatic signatures was addressed for the first time in the present study.

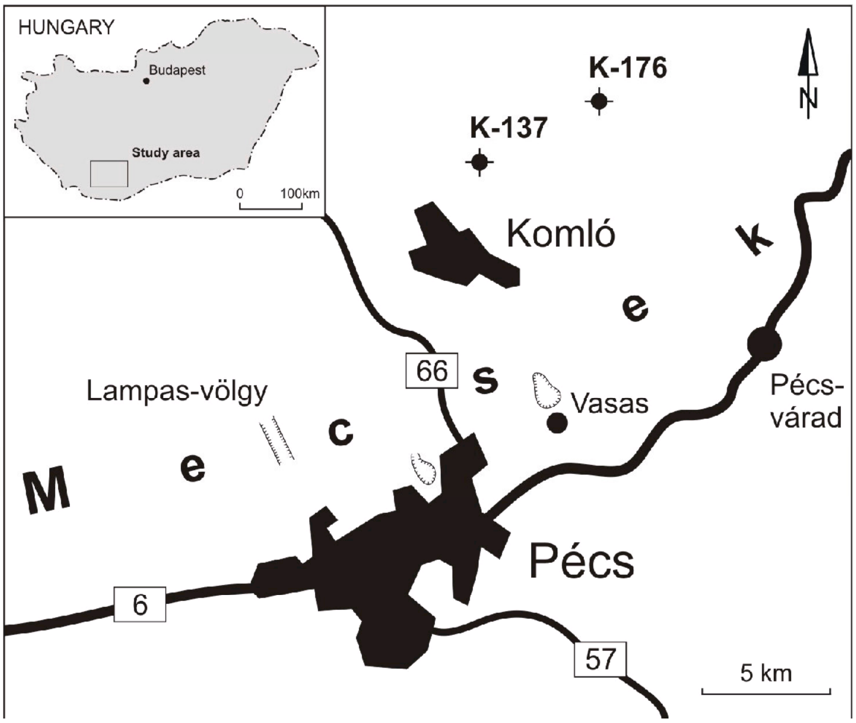

Fig. 4:Geographic map of the Mecsek area in South Hungary.

Number	**Region**	**Section**	**Depositional Environment**
1	Slovakia (Tatra)	Furkaska	marine
2	Slovakia (Tatra)	Kardolína	marine
3	Slovakia (Tatra)	Hybe	marine
4	N - Hungary (Csővár)	Vár-hegy	marine
5	N - Hungary (Csővár)	Pokol-völgy	marine
6	S - Hungary (Mecsek)	Pécs coal pit	terrestrial
7	S - Hungary (Mecsek)	Vasas coal pit	terrestrial
8	S - Hungary (Mecsek)	Lámpás-völgy	terrestrial
9	S - Hungary (Mecsek)	Komló core 176	terrestrial
10	S - Hungary (Mecsek)	Komló core 137	terrestrial

Fig. 5: Studied sections in Slovakia and Hungary.

2.2 Sampling procedure

Outcrop sections, quarries and drilling cores have been sampled for palynological investigations (Fig. 5). Depending on accessibility and lithology the sampling interval is varying. The marine sections have been sampled independently from lithology based on a constant sampling raster. Former investigations proved that this method works very well in marine limestone-marl alternations (Götz et al. 2008). The regular sampling interval in this sections amounts 0.4 m to 1 m. The terrestrial sections of the Hungarian Mecsek Mountains have been sampled with special respect to the cyclicity of the sediments. Due to the fact, that not all lithologies are suitable for palynological investigations, the sampling interval differs more than in the marine sections. Fault lines have been left out. In the wells of the Komló area, the loss of core material was an additional factor controlling the sampling raster. The unweathered condition of the material was a further criterion for the sampling. All samples have been washed, dried and scrashed to small pieces with a diameter between 0.6 mm and 2 mm. The carbonatic components have been solved in concentrated HCL (33 %). Siliciclastic particles have been removed by concentrated HF (73 %). A centrifugation in soluted $ZnCl_2$ with a density of 2.2 g/cm^3 devided the organic residue from heavy minerals. The residue has been washed with warm HCl and sieved with a gaze of 15 µm. Samples have been mounted in Eukitt. From each sample some material has been oxidized with HNO_3 to destroy the amorphous organic matter and to lighten up the palynomorphs. Slides with oxidized material have been mounted in Eukitt, too. In total, 358 palynological samples were analysed.

2.3 Palynofacies analysis

For palynofacies analysis, at least 500 organic particles have been counted per slide. The organic matter has been classified after Steffen & Gorin (1993) (Fig. 6) into a marine and a terrestrial fraction. Ratios between distinct palynomorph groups have been used for interpreting the depositional environment.

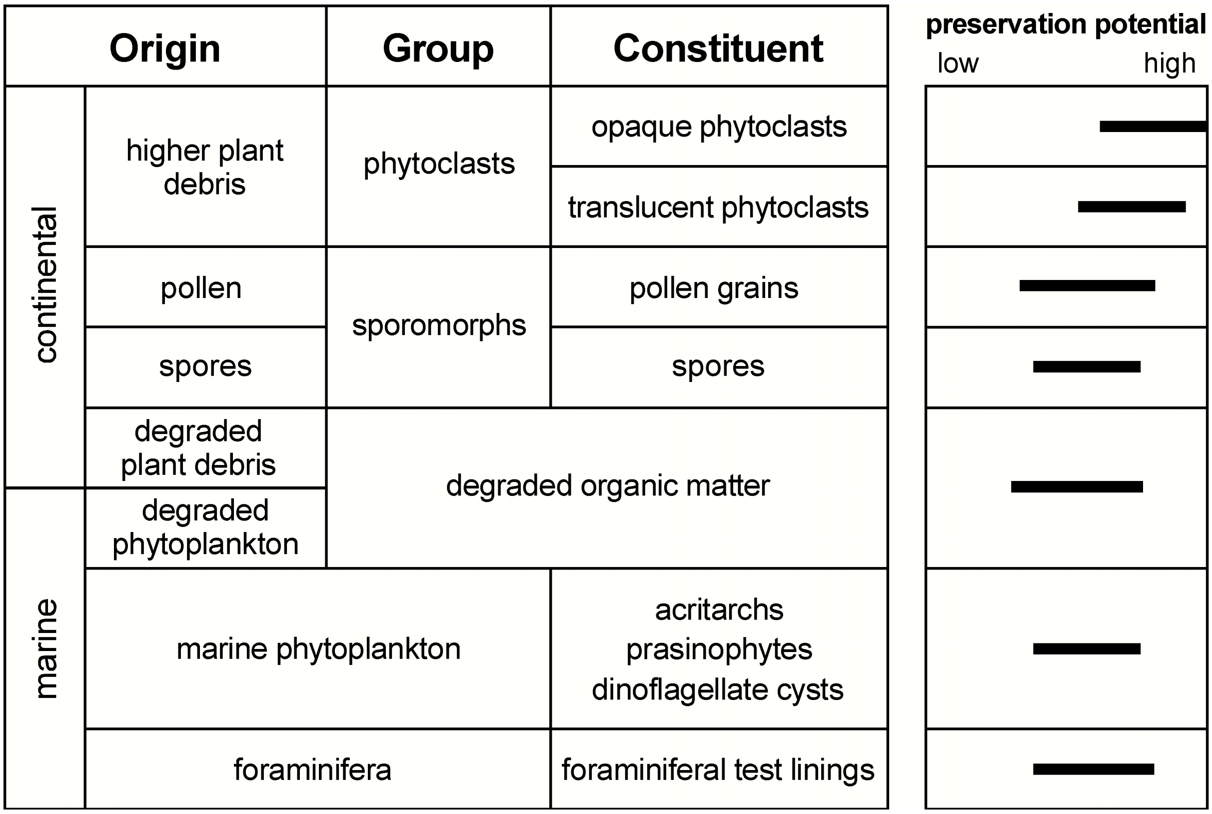

Fig. 6: Classification of sedimentary organic matter used in this study (modified after Steffen & Gorin 1993; in Götz et al. 2008).

2.4 Systematic palynology

At least 300 palynomorphs have been counted per sample. The terrestrial sporomorphs are grouped in several morphological groups. There are still difficulties with the terminology of terrestrial palynomorphs. The term "miospore" includes pollen and (iso)spores less then 200 µm. With special respect to different life cycles of the mother plants, the palynomorphs of this study are subdivided in "pollen" and "spores", excluding megaspores. Aquatic palynomorphs are subdivided into different marine plankton groups such as acritarchs, prasinophytes and dinoflagellate cysts, and multicellular freshwater algae.

2.5 Palaeo-ecogroups

The Sporomorph Ecogroup Model (SEG Model) of Abbink et al. (2001, 2004a) is applied to the Furkaska and Komló data set. Originally, this ecogroup model was defined for the Late Jurassic and Early Cretaceous of the North Sea. In this study, it is applied for the first time to Rhaetian and Hettangian assemblages. The SEG model is based on the fact that palynomorph assemblages reflect mother plant communities. In the Mesozoic, any application of palaeocommunity models is considerably hampered by uncertainties with respect to the botanical affinities of quantitatively important sporomorphs and the ecological preference of the extinct parent plants. However, based on actualistic principles, one may assume the presence of distinctive habitat-bounded palaeocommunity types, each of which is characterized by taxa with broadly similar ecological preferences. These palaeocommunity types serve as a palaeoecological framework for the conceptual Sporomorph Ecogroup Model of coexisting sources of dispersed spores and pollen grains. Abbink et al. (2001) defines six SEGs as follows:

SEG	Reflection	Description
Upland SEG	upland communities	vegetation on higher terrain well above groundwater level that is never submerged by water
Lowland SEG	lowland communities	vegetation on plains and/or in freshwater swamps; the plains may periodically be submerged by freshwater there is no influence of sea salt; except, perhaps, under extreme circumstance
River SEG	riverbank communities	vegetation on riverbanks which are periodically submerged and subject to erosion
Pioneer SEG	pioneer communities	vegetation at unstable and recently developed ecospace e.g., vegetation growing at places that had been submerged by the sea for a longer period
Coastal SEG	coastal communities	vegetation growing immediately along the coast, never submerged by the sea but under a constant influence of salt spray
Tidally influenced SEG	tidally influenced com.	vegetation influenced by daily tidal changes regularly submerged at high tide

2.6 Multivariate statistics

Multivariate statistics has been carried out using PAST (PAleontological STatistics), a free software by Hammer, Harper & Ryan. This program is designed as a follow-up to PALSTAT, an extensive package written by P.D. Ryan, D.A.T. Harper and J.S. Whalley. Two standard multivariate methods, Principal Component Analysis and Cluster Analysis, have been used in this study for simplifying the complex data sets and to detect different palynomorph assemblages.

Principal Components Analysis (PCA)

PCA is a multivariate analysis technique which enables a modeller to find patterns in data of high dimension. These patterns are investigated by examining the correlative relationships between the sampled variables. Once a correlation pattern is identified in the original data, this knowledge can be used to reduce the number of dimensions (variables) with only a reduced loss of information. The goal of PCA is to find a new set of uncorrelated variables which account for as much of the variance in the original variables as possible with the new variables being uncorrelated and mutually orthogonal. Principally, it is being looked for vectors which approximate best the point cloud in the multidimensional space of observations and variables. The first vector (component) will be chosen such that most of the data variance will be concentrated on it. Usually, the first component does not cover 100% of the variance which is why additional components covering the rest of the variance are needed.

Besides the use of PCA to reduce the dimensions of data sets, it can also be used as a means of classification to examine the relations between variables and observations (Bortz 1999, Davis 2002). For reasons of visual comprehension a 2-D principle plane which is used as a projection plane for the data points in the multi-dimensional space is formed by two principal components. Since the first two principal components cover most of the variance of the examined data set they are most frequently used to form this plane. Once points are projected on this plane, their Euclidean distance is a good measure of similarity: The smaller this distance, the higher the similarity of these points. Points that lie closely together on this plane can therefore be interpreted as belonging to the same data cluster. Other principal components can be used to form other projection planes as well which usually leads to different data clusters, thus implying different interpretations of the principal components.

Cluster Analysis

The term Cluster Analysis was first used by Tryon (1939). Cluster Analysis aims at classifying a set of objects into different groups, or more precisely, at partitioning a data set into subsets (clusters), so that the data within each group share one or more common traits – often proximity according to some defined distance measure, whereas the differences between groups is aimed to be as big as possible. The problem of structuring sampled data into more meaningful groups is common to many fields of science which has led to a widespread use of Cluster Analysis. Besides the term Cluster Analysis, there are a number of terms with similar meanings, including automatic classification, numerical taxonomy, and typological analysis (Bortz 1999).

Data clusters can be formed using the joining or tree clustering method that uses the dissimilarities (similarities) or distances between objects. Similarities are a set of rules that serve as criteria for grouping or separating items. These distances (similarities) can be based on a single dimension or multiple dimensions, with each dimension representing a rule or condition for grouping objects. Common means to visually show the results of a Cluster analysis are the icicle plot or the dendrogram (tree diagram).

In hierarchical tree plots as applied in this study, similarity can be read off on both axes of the diagram. The earlier a sample separates from the remaining sample population – whilst analysing the tree from bottom to top – the higher its dissimilarity. Whereas, if the tree is analysed from left to right, neighbouring samples have more in common than non-neighbouring samples. The most common way to compute distances between objects in a multi-dimensional space is the Euclidean distance method. In this study the distance is carried out using the Bray-Curtis method (Michie 1982) which is commonly used in botany, ecology and environmental sciences. The Bray-Curtis distance is a value between zero and one where a zero Bray-Curtis represents exact similarity. It is a special measure for non-abundance data, like the data set used in this study.

2.7 Geochemistry

Contents of total organic (TOC) and inorganic (TIC) carbon were measured with a C-MAT 550 mass spectrometer. TIC values were recalculated to $CaCO_3$ content to assess the carbonate content in the rocks and to select samples for the C isotope analyses of organic matter. Total organic carbon isotope analyses were measured after carbonate dissolution. Samples were boiled in diluted (10 %) hydrochloric acid and repeatedly rinsed with de-ionized water to remove chlorides and dried at 60 °C. The $\delta^{13}C$ measurements were performed by flash combustion in a Fisons 1108 elemental analyzer coupled with a Mat 251 isotope ratio mass spectrometer in a continuous flow regime. The sample size was adjusted to contain a sufficient amount of C to obtain external reproducibility of 0.15 ‰ for $\delta\ ^{13}C_{org}$ for all types of samples with NBS 22 as the reference material. Isotopic data are reported in the usual delta (δ) notation relative to the Vienna International Isotopic Standard (VPDB).

A set of 38 samples was selected from the Furkaska section for $\delta^{13}C_{org}$ analyses. Both types of isotope analyses were analyzed in the Czech Geological Survey Laboratory in Prague. The geochemistry investigations were carried out in collaboration with Otília Lintnerová (Comenius University, Bratislava).

2.8 Clay Mineralogy

Upper Triassic-Lower Jurassic sediment samples (claystones, mudstones, marls and marly limestones) of the Furkaska section were investigated by X-ray diffraction (XRD) in collaboration with Adrian Biroň (Slovak Academy of Science, Bratislava). The sampled interval covers the entire Fatra Formation and the lowermost part of the Kopienec Formation.

The samples used for clay mineralogy determination were washed, crushed and subsequently ground with pestle and mortar, sieved under 0.16 mm, soaked in distilled water, ultrasonically disaggregated, and then treated chemically following the standard procedure of Jackson (1975). The <2 and <0.2 µm fractions were obtained by gravity settling in Atterberg cylinders and centrifugation, respectively. The suspensions were then coagulated with saturated NaCl. The Ca^{2+} was introduced as the only exchange cation using $CaCl_2$ solution (three-times for 24 hours). Finally, suspension was cleaned of the excess electrolyte by repeated centrifugation followed by dialysis. The material was dried and oriented preparations were produced. The "infinite thickness" of preparations (10 mg/cm^2) required for semi-quantitative determination of clay minerals, was controlled by precise weighting (Moore & Reynolds 1997). XRD analyses were performed on a Philips PW1710 diffractometer using Cu*K*α radiation (40 kV, 20 mA) and a diffracted beam graphite monochromator.

3 Geology

3.1 Paleogeography

During late Triassic and early Jurassic times, the study areas were located at the NW Tethyan realm, bordering the Neotethys Ocean Branch (Fig. 7). The North Hungarian outcrops near Csővár were part of the Transdanubian Range located at the distal margin of the Dachstein Carbonate Platform in the western part of the Neotethys shelf region. This carbonate system was segmented by various intraplatform basins (Haas & Tardy-Filácz 2004).

The Tatra Mountains represent a part of the Tatro-Verporic Unit which was located close to the Upper Austroalpine Unit (Fig. 7). The sections studied belong to two different intraplatform basins. The Furkaska section and Kardolína section were part of the Zliechov basin (Plašienka 2001). The Hybe section belongs to the Hronic basin (Michalík 2003).

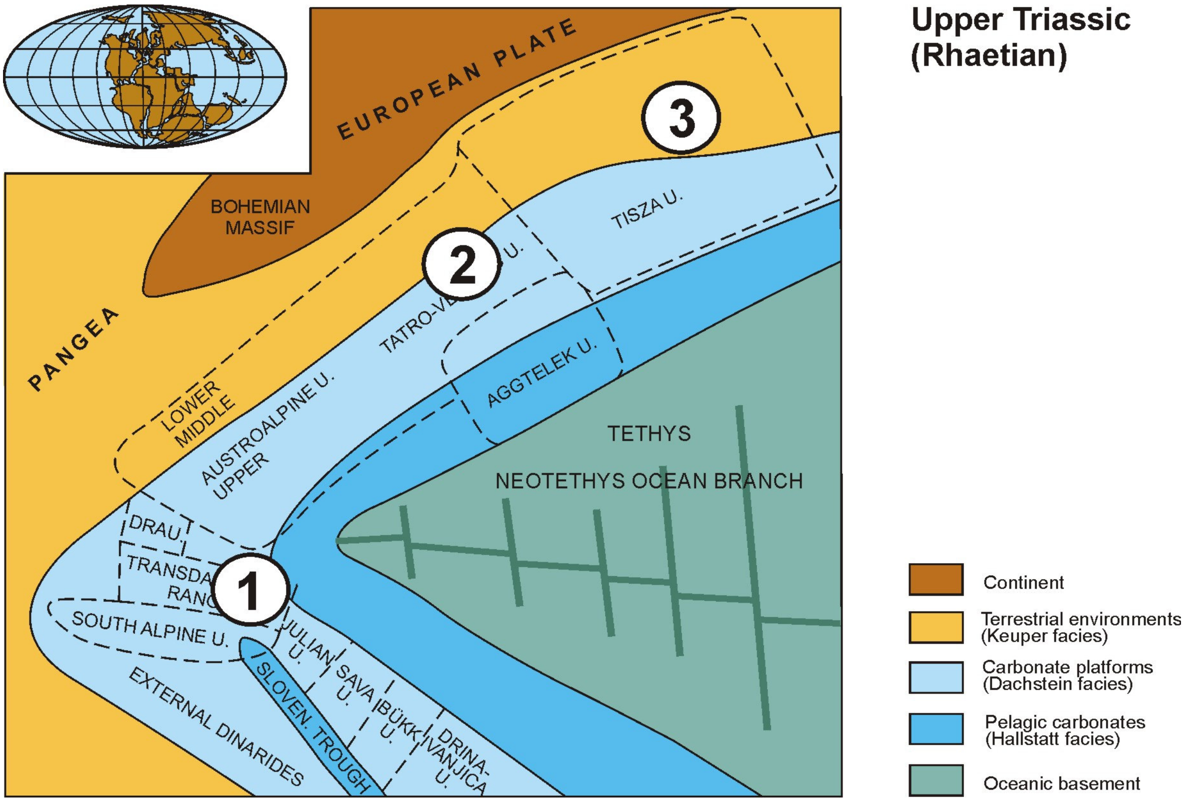

Fig. 7: The Shelf of the Neotethys ocean branch during Upper Rhaetian times (Haas 2001) and location of the study areas (1 – Tatra Mountains, Slovakia; 2 – Csővár, N Hungary; 3 – Mecsek Mountains; S Hungary).

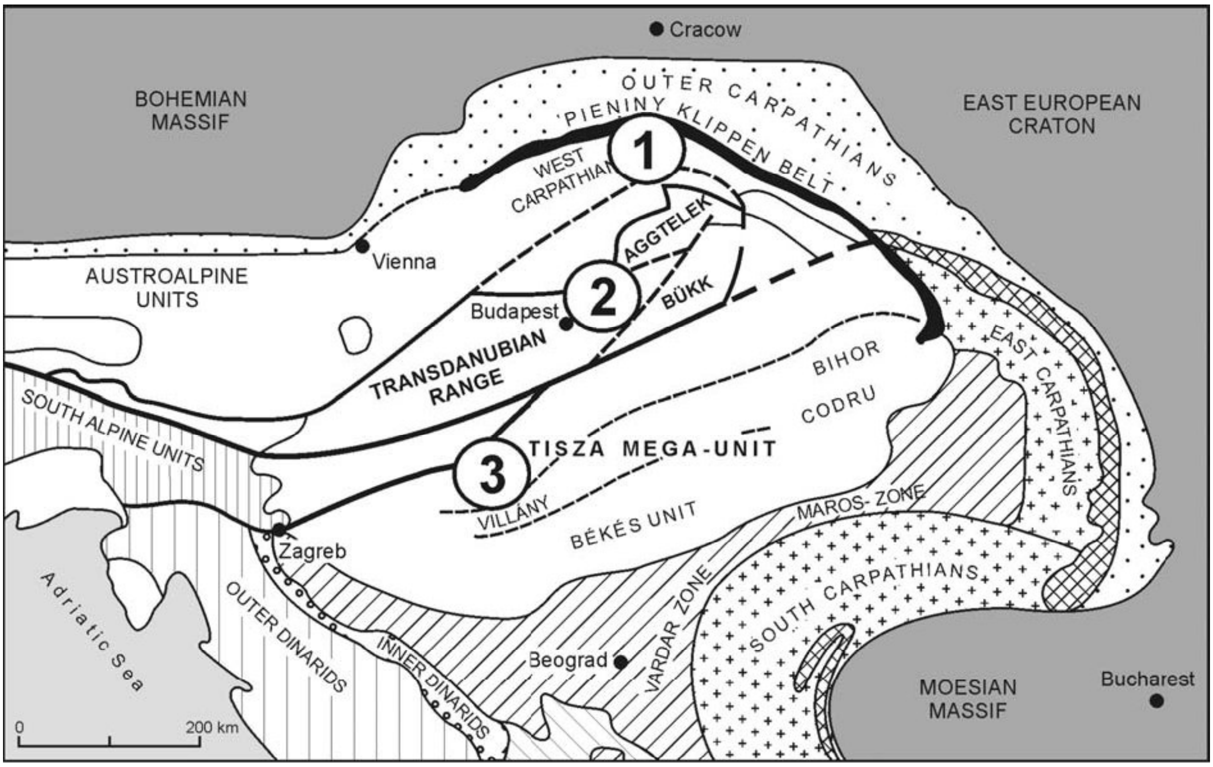

Fig. 8: Geological Units of Central Europe (Haas & Török 2008) and location of the study areas (1 – Tatra Mountains, Slovakia; 2 – Csővár, N Hungary; 3 – Mecsek Mountains; S Hungary)

The Mecsek Mountains of Southern Hungary are part of the Tisza Unit (Haas & Török 2008; Fig. 8), adjacent to the Tatro-Veporic Unit (Fig. 4). During late Rhaetian times, this area was characterized by a fluvial-lacustrine system. In the early Hettangian, this fluvial plane turned periodically to a swamp. Within the late Hettangian/Sinemurian the transgression of the Neotethys caused a significant environmental change from terrestrial to marine.

3.2 Stratigraphy

3.2.1 Definition of the Rhaetian

Gümbel (1861) defined the Rhaetian as equivalent to strata with the *Rhaetavicula contorta* ammonoid zone. The acceptance of the Norian Stage (1895) and biostratigraphic studies of the Kössen Beds of Austria suggested a significant overlap and thus the Rhaetian stage was eliminated in some time scales (e.g., Palmer 1983). Since 1991 the Rhaetian is an independent stage, but there is no acceptance about its extent (see Gradstein et al. 2004).

3.2.2 Definition of the Hettangian

The Hettangian stage is named after the village of Hettange-Grande in NE France, 22 km south of Luxembourg. Renevier (1864) proposed the Hettangian Stage to encompass the *Psiloceras planorbis* and *Schlotheimia angulatus* ammonite zones as interpreted by Oppel (1856-1858). The Hettangian spans the ammonite zones *Psiloceras planorbis, Alsatites liassicus* and *Schlotheimia angulata*. Due to the fact that the Triassic/Jurassic boundary is not defined yet, the base of the Hettangian is not assigned. The Hettangian is overlain by the Sinemurian. Its base is defined by the lowest occurrence of the arietid ammonite genera *Vermiceras* and *Metophioceras* (see Gradstein et al. 2004)

3.2.3 Definition of the Triassic/Jurassic boundary

The Triassic/Jurassic boundary Task Group of the International Stratigraphic Subcommission of the Jurassic System has to nominate a Global Boundary Stratotype Section and Point (GSSP) up to 2008. Therefore, a clear definition of the Rhaetian/Hettangian boundary is essential. A selection of different definitions is under discussion: The last occurrence of conodonts, the first appearance of the ammonite genus *Psiloceras* and the drastic turn over within the radiolarian assemblage are the possible biostratigraphic guide events within the boundary interval (see Gradstein et al. 2004). Another possible candidate is the sudden negative shift within the organic carbon stable isotope record, which has been detected from many boundary sections all over the world (Hesselbo et al. 2002, 2007).

The chronostratigraphic age of the Triassic/Jurassic boundary is based on a U-Pb zircon age from a tuff layer on Kunga Island in British Columbia, Canada, which is one of four possible candidates for the GSSP. The dated level is immediately below a prominent change within the radiolarian faunas and the last occurrence of conodonts (Pálfy et al. 2000). The estimated crystallization age of the tuff is 199.6 $\pm$ 0.3 Ma (Pálfy et al. 2000).

The other candidate sections for GSSP are St. Audrie's Bay (England), New York Canyon (Nevada, U.S.A.), and Karwendel Syncline (Austria). In these three sections, a profound change within the ammonoid faunas is the biostratigraphic criterion for defining the boundary (Pálfy 2008). This ammonite event has a very high global correlateability. Because of the long history of study of ammonite faunas, its details are extremely well documented. Currently, the first appearance of *Psiloceras tilmanni* seems to be the most promising definition for the Triassic/Jurassic boundary (Lucas et al. 2006). Its high distribution from Nevada to Chile is a big advantage and the close distance between its FAD and other marker events can be used to correlate Triassic/Jurassic boundary sections lacking ammonites (Fig. 9).

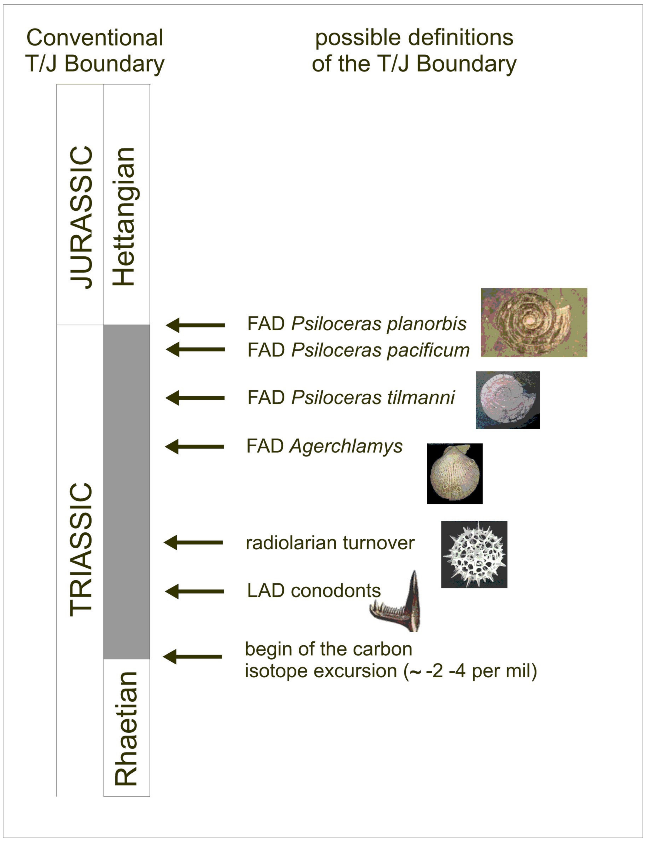

Fig. 9: Sucession of potentional marker events for definition of the Triassic/Jurassic (T/J) boundary, primarily based on the New York Canyon area, so exact position of radiolarian turnover is uncertain. The FADs of *P. pacificum* and *P. planorbis* may be equivalent, but this is uncertain (modified after Lukas et al. 2006).

3.3 Sediments and lithofacies

Tatra Mountains

Three sections have been investigated in the Slovakian Tatra Mountains: The Furkaska section near Oravice, the Kardolína section near Tatranská Kotlina, and the Hybe section south of Východná. Each section belongs to a different tectonic nappe. The sediments are representing deposits of different intraplatform basins of the Neotethyan ocean branch. The Kardolína section and the Furkaska section are build up by sediments of the Zliechov Basin, a small pull-apart basin which was formed by late Triassic extension and rifting of a former uniform Triassic shelf of the northern flanks of the Tethys ocean (Plašienka 2001). In the 300 km long and 100 km wide basin, ten facies areas were recognized by Michalík (1973, 1974, 1977). During Upper Rhaetian times, depositional environments varied from salt marshes through carbonate ramp to deeper neritic slope, and were populated by characteristic benthic associations (Michalík & Jendrejáková 1978, Michalík 1978a) dominated by brachiopods and bivalves (Michalík et al. 2007). The Upper Rhaetian shallow marine carbonate succession is covered by marine shales of Hettangian age.

Fig. 10: The Furkaska section, field work summer 2005.

The Furkaska section

The W slope of the Mt. Vel’ká Furkaska exposes a succession of Upper Triassic to Lower Cretaceous sediments of the Krížna Nappe. The investigated Triassic/Jurassic boundary interval is exposed in a small cascade section, only accessable during summer (Fig. 10). The basal part of the Rhaetian Fatra Formation is composed of dolomites and bioclastic limestones with marly intercalations. Two biostrome members are distinguished in the middle part of the formation, comprising a rich benthic fauna. The uppermost Rhaetian is build up by nodular limestones, marlstones and sandy limestones. The lower part of the Hettangian Kopieniec Formation comprises claystones (“Boundary Clay”) overlain by sandstones (“Cardinien Sandstein”, Goetel 1917).

The Kardolína section

The Kardolína section is part of the Bujači Nappe that is build up by a 880 m thick succession of mid-Triassic to mid-Cretaceous sediments. The section is exposed in the Mt. Pálenica slope, 975 m above sea level. The lower part of the outcrop is represented by dolomites of the “Upper Dolomite” of the Carpathian Keuper with intercalations of violet and grey claystones. The Carpathian Keuper is overlain by the Upper Rhaetian Fatra Formation. Bioclastic limestone beds at the base are covered by dolomites and dark brown marls with intercalated limestones (Michalík 2003).

The Hybe section

The Hybe section exposes Upper Rhaetian sediments of the Choč Nappe (Hronic Superunit, Hybe Formation). The Hybe Formation overlays the Dachstein Limestone Formation of Norian age (Michalík 2003). The base of the Hybe Formation is represented by dark grey crinoidal and coral limestones and continues upsection with dark grey to black marls with intercalated dark grey limestones.

Northern Hungary

The Csővár section is situated NE of Budapest, ca. 500 m W of the village of Csővár. A predominantly limestone succession is exposed in 2 outcrops: The Pokol-völgy (devil’s valley) quarry and the S slope of the Vár-hegy (castle hill). Facies analysis of the Rhaetian–Hettangian deposits reveals a long-term change in sea level, superimposed by short-term fluctuations. After a period of highstand platform progradation in the Late Norian, a significant sea-level fall occurred in the Early Rhaetian, exposing large parts of the platform.

A renewed transgression led to the formation of smaller build-ups fringing the higher parts of the previous foreslope that served as habitat of crinoids, representing the main source of carbonate turbidites. The higher part of the Rhaetian is characterised by proximal turbidites with intercalated lithoclastic debris flows. Distal turbidites and radiolarian basin facies become prevalent upsection, dominating in the earliest Hettangian. The next significant facies change in the Early Hettangian is marked by the appearance of redeposited oncoid-grapestone beds, indicating the end of the Rhaetian to earliest Hettangian sequence (Haas & Tardy-Filácz 2004).

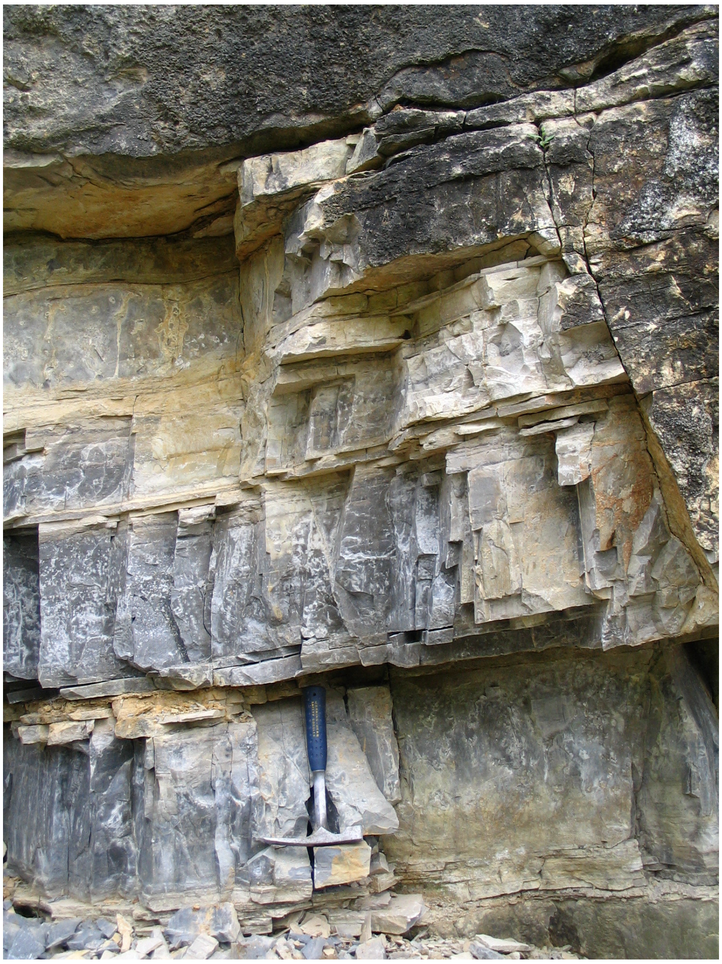

Fig. 11: Upper Rhaetian basinal deposits with turbidites, Csővár section (N Hungary).

Southern Hungary

Three outcrop sections and two well sections have been investigated in the Mecsek Mountains. In the area of Pécs and Komló Triassic/Jurassic boundary series reveal a fluvial-lacustrine succession continued by paralic coal deposits. The Upper Triassic Karolinavölgy Sandstone Formation is build up by arcosic sandstones and siltstones overlain by the coalbearing uppermost Triassic to Lower Liassic Mecsek Coal Formation (Haas & Török 2008). A rapidly subsiding half-graben structure developed in the eastern Mecsek Mountains (Fig. 12), resulting in the deposition of the up to 500 m thick Karolinavölgy Sandstone. Depositional environments include marginal marine, lagoonal, and deltaic to lacustrine settings (Nagy 1968). The upward transition of these beds into the Liassic Mecsek Coal Formation is continuous.

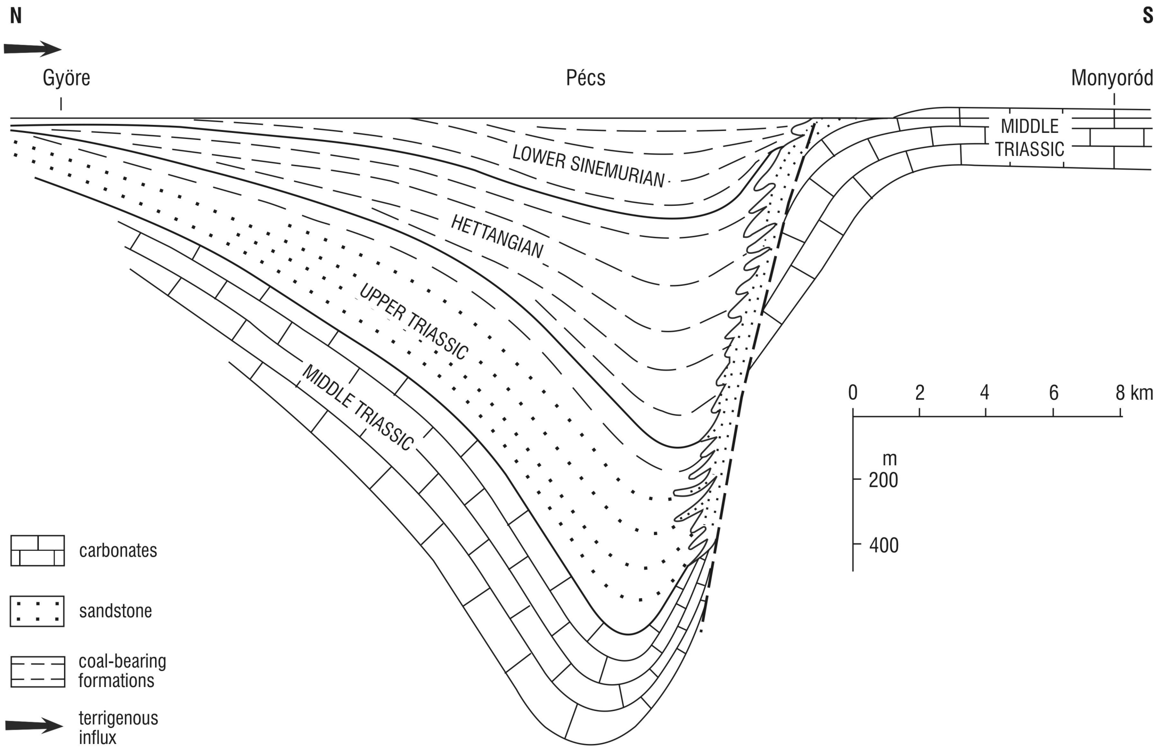

Fig. 12: Half-graben structure of the E Mecsek Mountains with sediments of Triassic and Jurassic age (from Haas 2001).

Pécs coal pit

The Pécs coal pit (Fig. 13) is situated NE of the city of Pécs. Active mining was terminated in 2003. The still exposed succession comprises sediments of the Rhaetoliassic “Lower Seam Group”, representing lacustrine and deltaic facies, fluvial to brackish deposits of the Liassic “Middle Seam Group” overlain by paralic coal seams of the Lower Sinemurian “Upper Seam Group”. The sediment series shows a characteristic cyclic pattern of metre-scale sedimentary cycles (Fig. 14). A basal sandstone bed is overlain by siltstones. The top of the cycle is build by a decimetre thick coal layer.

Fig. 13: Overview of the Pécs coal pit, spring 2006 (Mecsek Mountains).

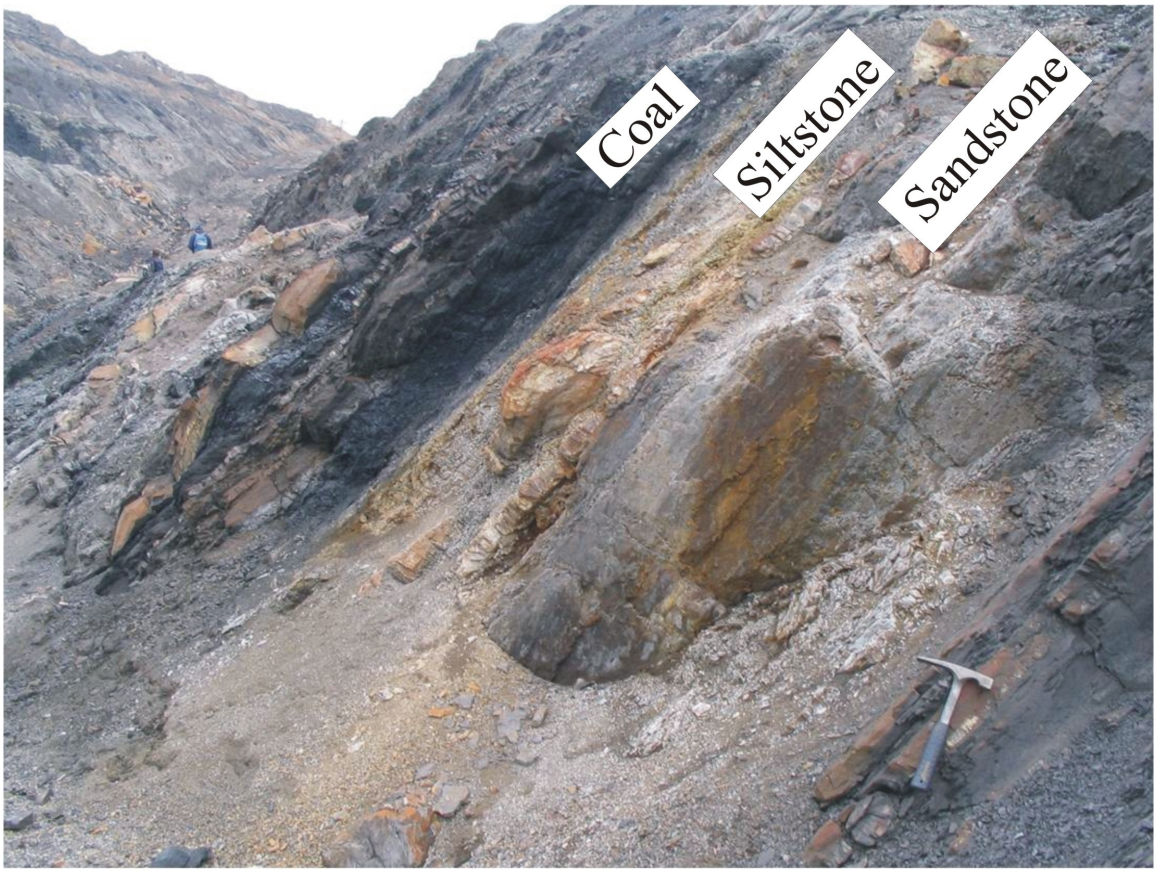

Fig. 14: Characteristic small-scale sedimentary cycle (Pécs coal pit, Mecsek Mountains).

Vasas coal pit

The Vasa coal pit is situated N of the city of Vasas. Active mining was terminated in 2003. The still exposed succession comprises the fluvial to brackish deposits of the Liassic “Middle Seam Group” overlain by paralic coal seams of the Lower Sinemurian “Upper Seam Group”. The 0.6 m thick tuff layer in the “Middle Seam Group” is a characteristic feature of the Vasas section (Fig. 15).

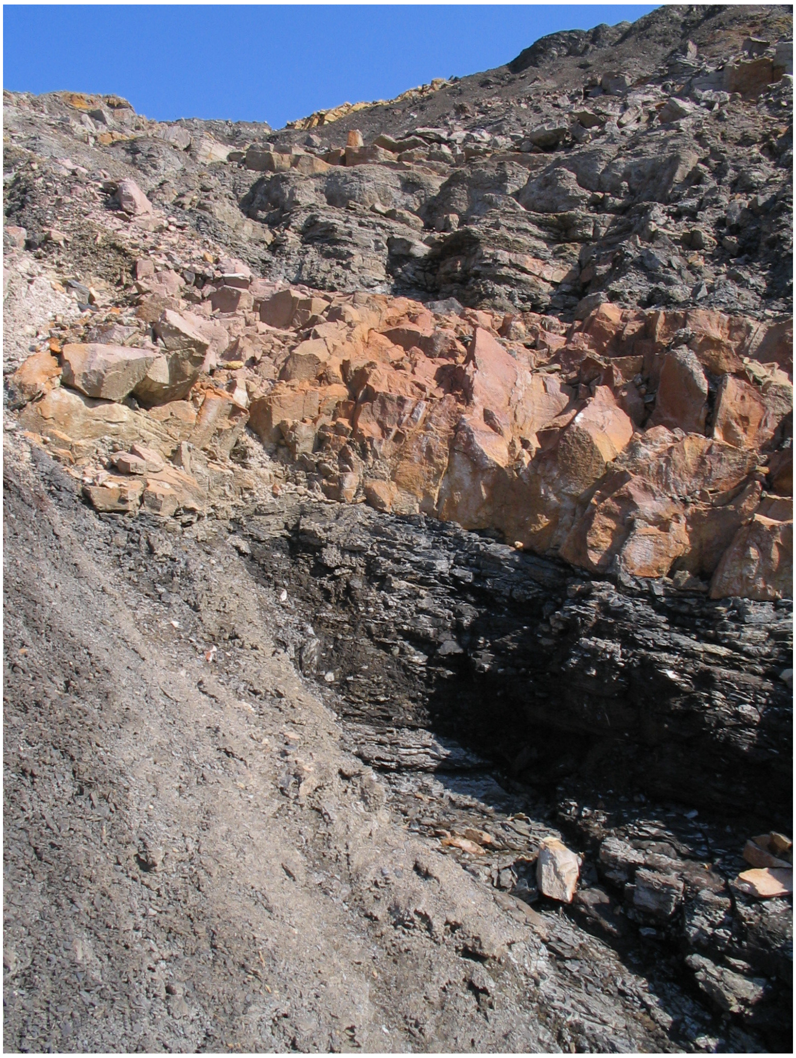

Fig. 15: Tuff layer within the lowermost Jurassic Middle Seam Group (Vasas coal pit, Mecsek Mountains).

Lampas-völgy

The Lampas Valley is situated N of Pécs and exposes sediments of the Upper Triassic Karolinavölgy Sandstone. Thin coal seams are a characteristic feature of the uppermost part of these clastic deposits (Fig. 16).