Palynofacies patterns of Middle Triassic ramp deposits (Mecsek Mts., S Hungary): A powerful tool for high-resolution sequence stratigraphy

By

Annette E. Götz, Ákos Török, Susanne Feist-Burkhardt & Gyula Konrád

with 6 figures and 2 plates

Key words:
Palynofacies
Sequence Stratigraphy
Middle Triassic
Anisian
Southern Hungary

Addresses of the authors:
Annette E. Götz
Martin-Luther-University Halle-Wittenberg
Institute of Geosciences
D-06099 Halle (Saale)
Germany
Fax: +49-345-552 7178
e-mail: goetz@geologie.uni-halle.de

Ákos Török
Budapest University of Technology and Economics
Department of Construction Materials and Engineering Geology
Sztoczek u. 2.
H-1521 Budapest
Hungary
Fax: +36-1-463 2017,
e-mail: atorok@epito.bme.hu

Susanne Feist-Burkhardt
The Natural History Museum
Department of Palaeontology
Cromwell Road
London SW7 5BD, UK
Fax: +44-20-7942 5546
e-mail: s.feist-burkhardt@nhm.ac.uk

Gyula Konrád
University of Pécs
Department of Geology
Ifjúság útja 6
H-7624 Pécs
Hungary
Fax: +36-72-501 531
e-mail: konrad@ttk.pte.hu

Mitt. Ges. Geol. Bergbaustud. Österr.	46	S. 77-90	Wien 2003

Contents

Kurzfassung

Die vorliegende Arbeit beinhaltet die ersten Ergebnisse einer integrierten Analyse der sedimentären und organischen Fazies mitteltriassischer Karbonate Südungarns (Mecsek-Gebirge). Die untersuchte Ablagerungsserie des Anis, welche die Lapis- und Zuhánya-Limestone Formation sowie den basalen Teil der Kozár-Limestone Formation umfaßt, bildet einen Transgressions/Regressions-Zyklus dritter Ordnung. Die stratigraphischen Veränderungen in der Zusammensetzung der sedimentären organischen Substanz dokumentieren diese transgressiv-regressive Entwicklung des Ablagerungssystems. Charakteristische Palynofaziesmuster können daher für die sequenzstratigraphische Interpretation genutzt werden. Darüber hinaus ermöglichen palynostratigraphische Daten eine erste präzise Korrelation mit der Ablagerungssequenz des Unteren Muschelkalk im Germanischen Becken.
Das Beispiel aus der Mitteltrias Südungarns demonstriert das große Anwendungspotential der Palynofaziesanalyse in der hochauflösenden Stratigraphie mesozoischer Karbonatsysteme.

Abstract

Sedimentary facies and palynofacies of Muschelkalk ramp deposits were investigated in outcrop sections from the Mecsek Mountains in southern Hungary. The sedimentary series studied in detail comprises the Anisian Lapis Limestone Formation, Zuhánya Limestone Formation, and the lowermost part of the Kozár Limestone Formation, representing a 3rd order transgressive-regressive cycle. Stratigraphic variations of sedimentary organic matter reflect the long-term transgressive-regressive trend. The observed palynofacies patterns are interpreted in terms of sequence stratigraphy. Based on palynostratigraphic data a first precise correlation with the Lower Muschelkalk sequence of the Germanic Basin is discussed. This integrated approach highlights the potential of palynofacies analysis as a powerful tool for high-resolution sequence stratigraphy in Mesozoic carbonate systems.

1. Introduction

Sedimentary facies and palynofacies of Muschelkalk car-

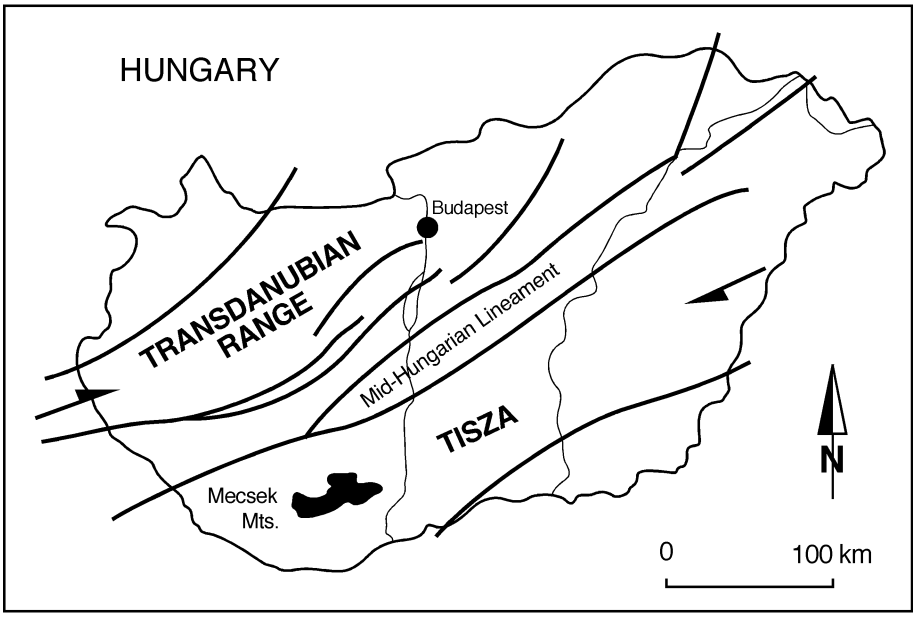


Fig. 1: Location of the study area in southern Hungary.

bonates were investigated in outcrop sections from the Mecsek Mountains in southern Hungary (Fig. 1). The succession studied in detail represents the second T/R-cycle recognized in the Middle Triassic of southern Hungary, comprising the Lapis Limestone Formation, Zuhánya Limestone Formation, and the lowermost part of the Kozár Limestone Formation (Török 2000).

In this study we present the first results of an integrated sedimentological and palynological analysis. Based on the well-established lithostratigraphic framework, the stratigraphic distribution of sedimentary organic matter has been analysed with respect to relative sea-level changes. Palynofacies patterns recognized in the investigated Muschelkalk ramp deposits are first applied to high-resolution stratigraphy and sequence stratigraphical interpretation. Palynostratigraphic data enable a first precise correlation with the Lower Muschelkalk sequence of the Germanic Basin.

2. Palaegeography

During Middle Triassic times several ramp systems developed at the northwestern margin of the Tethys Ocean (Dercourt et al. 1993). Recently, Anisian ramp deposits were described in detail from the western parts of the Northern Calcareous Alps (Rüffer 1995) and from the Dolomites (Zühlke 2000). A sequence stratigraphic interpretation was published by Rüffer & Zühlke (1995) and Rüffer & Bechstädt (1998). The 3rd order depositional sequences recognized in the Middle Triassic of the northwestern Tethys shelf were first correlated with those described from the southeastern gate areas of the Germanic Basin in Poland (Upper Silesia and Holy Cross Mountains) by Szulc (1999, 2000). The key sections (the "missing link") for correlating Middle Triassic sequences of the Alpine and Germanic realm are the Muschelkalk series of southern Hungary, which are interpreted as deposits of a homoclinal ramp (Török 1998) east of the Vindelician-Bohemian Massif (Fig. 2).

3. Litho- and biostratigraphy

The Lapis Limestone Formation is a very characteristic Germano-type lithostratigraphic unit of the Hungarian Muschelkalk (Fig. 3). It consists of Anisian "Wellenkalk-type" ramp deposits, reaching a total thickness of more than 250 m. Five alternating lithological units are identified in this sedimentary series: Flaser-bedded mudstones with thin marlstone intercalations ("Wellenkalk") building the most prominent lithotype of the succession, as well as burrow-mottled to nodular limestones, coquinoid floatstones (Pl. 1a, b), crinoid-bioclast packstones and grainstones, thin partly dolomitized mudstones and marly mudstones (Török 1998). Dolomitization is very rare and restricted to the basal part and a narrow interval of the middle part of the Lapis Limestone (Pl. 1d). Burrow-mottled to nodular limestones (with small nodules) are also common lithotypes of this stratigraphic unit. They comprise slightly bioturbated limestones with recognizable trace fossils such as *Rhizocorallium* sp. or *Thalassinoides* sp., and intensively bioturbated limestones where trace fossils are broken into small nodules. Bioclastic beds are relatively rare and only found as intercalations in the muddy carbonate sequence. Two

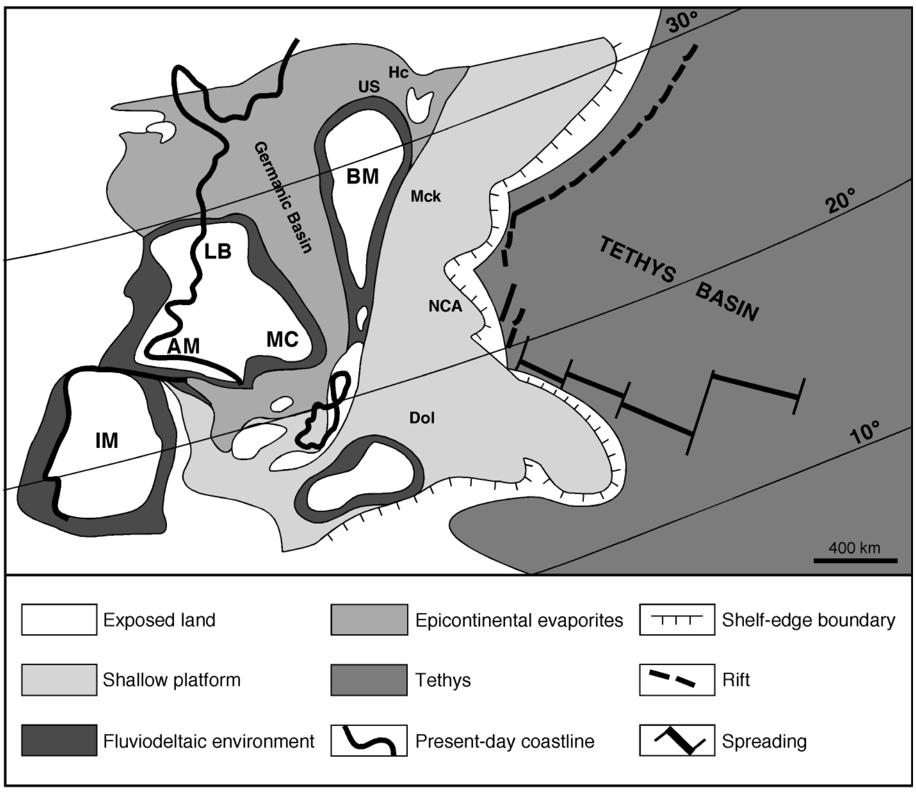


Fig. 2: Palaeogeography of the Late Anisian (after Dercourt et al. 1993). The study area (Mck) was located at the northwestern margin of the Tethys Ocean close to the latitude of 30° N. This area is considered to be the palaeogeographic key location for correlating Middle Triassic depositional sequences of the Alpine and Germanic realm. Abbreviations: AM - Armorican Massif, BM - Vindelician-Bohemian Massif, Dol - Dolomites, Hc - Holy Cross Mountains, IM - Iberian Massif, LB - London-Brabant Massif, MC - Massif Central, Mck - Mecsek Mountains, NCA - Northern Calcareous Alps, US - Upper Silesia (modified from Török 1998).

forms are distinguishable: Coquina layers reaching a thickness of only a few centimetres or building lenticular bodies and slightly thicker crinoidal-bioclastic beds. In mudstone beds sedimentary structures are very rarely recognizable, meanwhile in calcisiltite beds hummocky cross-stratification is observed. At the base of bioclastic beds or within mudstone sequences gutter casts are found. Slumps (Pl. 1c) and synsedimentary deformation structures such as sygmoidal beds or intraclastic layers (debris flows) are restricted to single horizons.

The bivalve fauna of the Lapis Limestone Formation shows a low diversity. It is characterized by scattered epibenthic and semi-inbenthic forms: *Entolium discites* (SCHLOTHEIM 1820) and *Modiola triquetra* (SEEBACH 1862). According to SZENTE (1997) the coquina beds contain specimens of *Pleuromya* cf. *elongata* (SCHLOTHEIM 1822) and *Pseudocorbula gregaria* (MÜNSTER in GOLDFUSS 1838), while the coarser bioclastic layers are characterized by *Lyriomyophoria elegans* (DUNKER 1848) besides *Entolium discites* (SCHLOTHEIM 1820). The Lapis Limestone Formation was divided into two crinoid zones by HAGDORN et al. (1997). The lower part belongs to the *Dadocrinus* zone, while the upper part is represented by specimens of the *acutangulus* zone, indicating a Lower Anisian/early Pelsonian age of the formation.

The nearly 100 m thick Zuhánya Limestone Formation represents the deepest and most open marine part of the entire Muschelkalk succession, which is documented by the appearance of ”Terebratula beds”. Nodular mud-/wackestones, brachiopod and bivalve shell beds and alternating lime-/marlstones are the prevailing lithotypes in the lower and middle part of the formation, whereas the upper part is characterized by mottled limestones. Nodular mud-/wackestones build the majority of rock types (Pl. 1e), while fossiliferous beds form pavements (Pl. 1f). Shell beds (5 to 20 cm thick) concentrate bivalves and brachiopods among which *Coenothyris vulgaris* (SCHLOTHEIM 1820) prevails. *Tetractinella trigonella* (SCHLOTHEIM 1820) and *Punctospirella fragilis* (SCHLOTHEIM 1820) are also common forms (TÖRÖK 1993), while bivalves are represented by *Plagiostoma lineata* (SCHLOTHEIM 1823), *P. striata* (SCHLOTHEIM 1823), *Hoernesia socialis* (SCHLOTHEIM 1823), *Bakevillia costata* (SCHLOTHEIM 1820), *Enantiostreon difforme* (SCHLOTHEIM 1823), *Entolium discites* (SCHLOTHEIM 1820), and *Pseudocorbula gregaria* (see TÖRÖK 1993 and SZENTE 1997 for details). Macrofossils occur in both allochthonous floatstones (disarticulated shells) and in parautochthonous shell beds (articulated brachiopods) (TÖRÖK 1998). Poorly preserved ceratites, single crinoid ossicles and pluricolumnars have also been collected from these beds.

The fauna becomes sparse in the upper part of the formation and yellowish, slightly dolomitic mottles appear. In these plastoclastic mud-/wackestones very few brachiopods, bivalves and crinoids occur. Rhombohedral-shaped pseudomorphs after gypsum are rarely recognized within the clasts. The fossil record, including conodonts (KOVÁCS & PAPSOVÁ 1986), ceratites, brachiopods (TÖRÖK 1993), and crinoids of the *dubius* and *silesiacus* zones (HAGDORN et al. 1997) suggests a late Pelsonian/early Illyrian age of the fossiliferous part of the Zuhánya Limestone Formation.

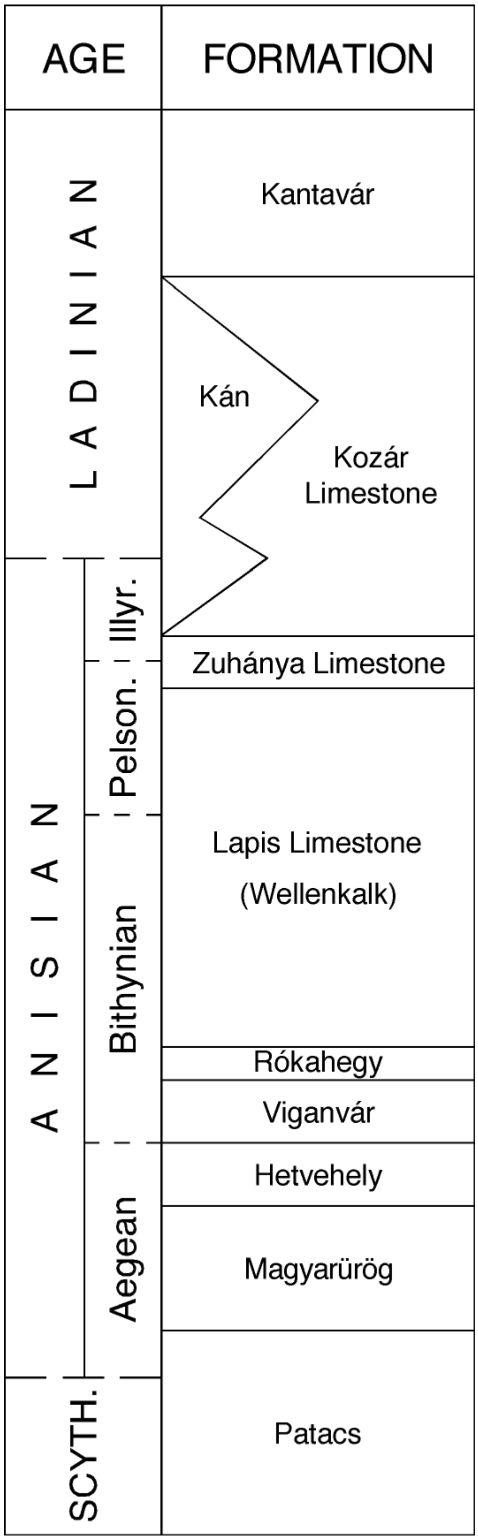


Fig. 3: Lithostratigraphic subdivision of the Middle Triassic in southern Hungary, Mecsek Mts. (after TÖRÖK 1998, 2000 and KONRÁD 1999).

In the central part of the Mecsek Mountains the Zuhánya Limestone Formation is overlain by a carbonate sequence building the Kozár Limestone Formation. In the western part occurs a dolomitized sequence called Kán Dolomite (Fig. 3). Primarily, the Kozár Limestone consists of platy mud-/

wackestones with very few bioturbated mudstones. The monotonous series is interrupted by rare intercalations of ooid-crinoid packstones and grainstones. These calcarenites form discrete beds of 0.5 m to 1 m thickness, or lenticular and fringing bodies. The small (0.2-0.5mm) rounded particles (ooids, micro-oncoids) and bioclasts show intense diagenesis and are often recrystallized. Despite these diagenetic alterations signs of cross-lamination and cross-bedding are still visible. Besides ooidal-bioclastic layers thin debris flow deposits (intraclastic layers and lenses), very small gutter casts and very thin (1 cm) coquinas are common sedimentological features of the mudstone sequence. The uppermost part of the formation becomes darker and locally passes to a thin oncoidal-bioclastic limestone (Plate 1g). These 1-2 metres thick black shell beds of *Trigonodus* sp. (SZENTE 1997), gastropods and plastically deformed large oncoids (7-8 cm in diameter) represent the lowermost part of the Kantavár Formation. Upsection black laminated calcareous marls and limestones form a thick monotonous succession (Pl. 1h). Besides gastropods also ostracods and charophytes were found in these sediments (MONOSTORI 1996). The pyritized and organic carbon-rich marls often show paper-lamination. Still the chronostratigraphic delineation of these formations remains unsatisfactory, although the bioclastic beds of the Kozár Limestone yielded a crinoid fauna, belonging to the *silesiacus* benthic crinoid biozone of Illyrian age. So far, there are no bio- or chronostratigraphic data available for the Kantavár Formation.

4. Sedimentary facies and depositional environment

The entire Hungarian Muschelkalk was deposited on a homoclinal ramp (TÖRÖK 1993) which was located at the northwestern margin of the Tethys Ocean. The carbonates of the Lapis Limestone Formation are interpreted as mid ramp deposits, representing the transgressive phase of the second 3rd order sedimentary cycle within the Middle Triassic (Fig. 4). Flaser-bedded mudstones with thin marlstone layers as well as burrow-mottled to nodular limestones document the mid ramp fair-weather facies. The lower grade of bioturbation in flaser-bedded mudstones indicates a higher sedimentation rate or moderately oxygenated bottom conditions. Hummocky cross-stratification and rare current ripples on bed tops refer to storms, whereas gutter casts are related to storm-induced bottom currents (TÖRÖK 1998). Coquinoid floatstones are interpreted as tempestites, displaying the mid ramp storm facies. The small thickness and the small size of transported bioclasts suggest a relatively distal mid ramp origin. Crinoid-bioclast packstones and grainstones are considered as redeposited shoals of a proximal mid ramp setting indicative of periods of severe storms. Thin, partly dolomitized mudstones and marly mudstones in the basal and middle part of the Lapis Limestone Formation are interpreted as inner ramp deposits, indicating short-term phases of shallowing.

The Zuhánya Limestone Formation includes the deepest and most marine facies of the southern Hungarian Triassic. Nodular mud-/wackestones and alternating lime-/marlstones are interpreted as outer ramp fair-weather deposits (Fig. 4). Most of the brachiopod and bivalve shell beds are records of storm activity. The high rate of disarticulated brachiopod shells and numerous amalgamated surfaces indicate multiple storm events. More distal and muddy tempestites are represented by parautochthonous shell beds. The regressive phase of the 3rd order sedimentary cycle is already documented in the uppermost part of the Zuhánya Limestone where mottled limestones occur. These carbonates are considered as redeposited sediments, which formed during downslope migration of semiconsolidated carbonate mud. They may mark synsedimentary tectonism (KONRÁD 1998), similar to the sediments described from the Polish Muschelkalk Basin (SZULC 2000) or the seismites of the western Germanic Basin (KNAUST 2002). They may also mark an initial steepening of the ramp.

The platy mud-/wackestones of the Kozár Limestone Formation are monotonous mid ramp deposits (Fig. 4). The lack of bioturbation may indicate dysaerobic bottom conditions similar to the Polish and German Muschelkalk (SZULC 1993). The ooid-crinoid packstones and grainstones are interpreted as inner ramp shoal deposits, a part of which were transported offshore by currents to mid ramp settings. The large oncoids with shell fragments were formed in a landward setting of the ooid shoals in a restricted backshoal environment. The high organic content and low faunal diversity suggests a stressed, slightly brackish environment.

The black paper-laminated marls and limestones of the Kantavár Formation were formed in a partly dysaerobic, brackish backshoal lagoon (Fig. 4). High amounts of land-derived plant fragments and charophytes as well as the presence of pyrite support this interpretation.

5. Palynofacies

The term palynofacies was first introduced by COMBAZ (1964) describing the total acid-resistant organic matter content of sedimentary rocks within a specific depositional environment (cf. TYSON 1995). The spatial and stratigraphic variations in the distribution of sedimentary organic matter reflect changes in the depositional system related to relative sea-level fluctuations. Detecting significant palynofacies patterns within sedimentary series enables the characterization of Transgressive deposits (TSd) and Highstand deposits (HSd) and the recognition of maximum flooding zones (mfz) and sequence boundaries (sb) in terms of sequence stratigraphy. Therefore, palynofacies analysis is a powerful tool for high-resolution stratigraphy.

The classification of sedimentary organic matter used in this study is modified from STEFFEN & GORIN (1993) and PITTET & GORIN (1997). Two groups of organic constituents are distinguished: A continental, allochthonous fraction including terrigenous phytoclasts, pollen grains, and spores and a marine, relatively autochthonous fraction composed of acritarchs, prasinophytes, and foraminiferal test linings (Fig. 5). The relative percentage of these organic constituents is based on counting at least 300 particles in each slide.

The relative abundance of marine plankton appears as most

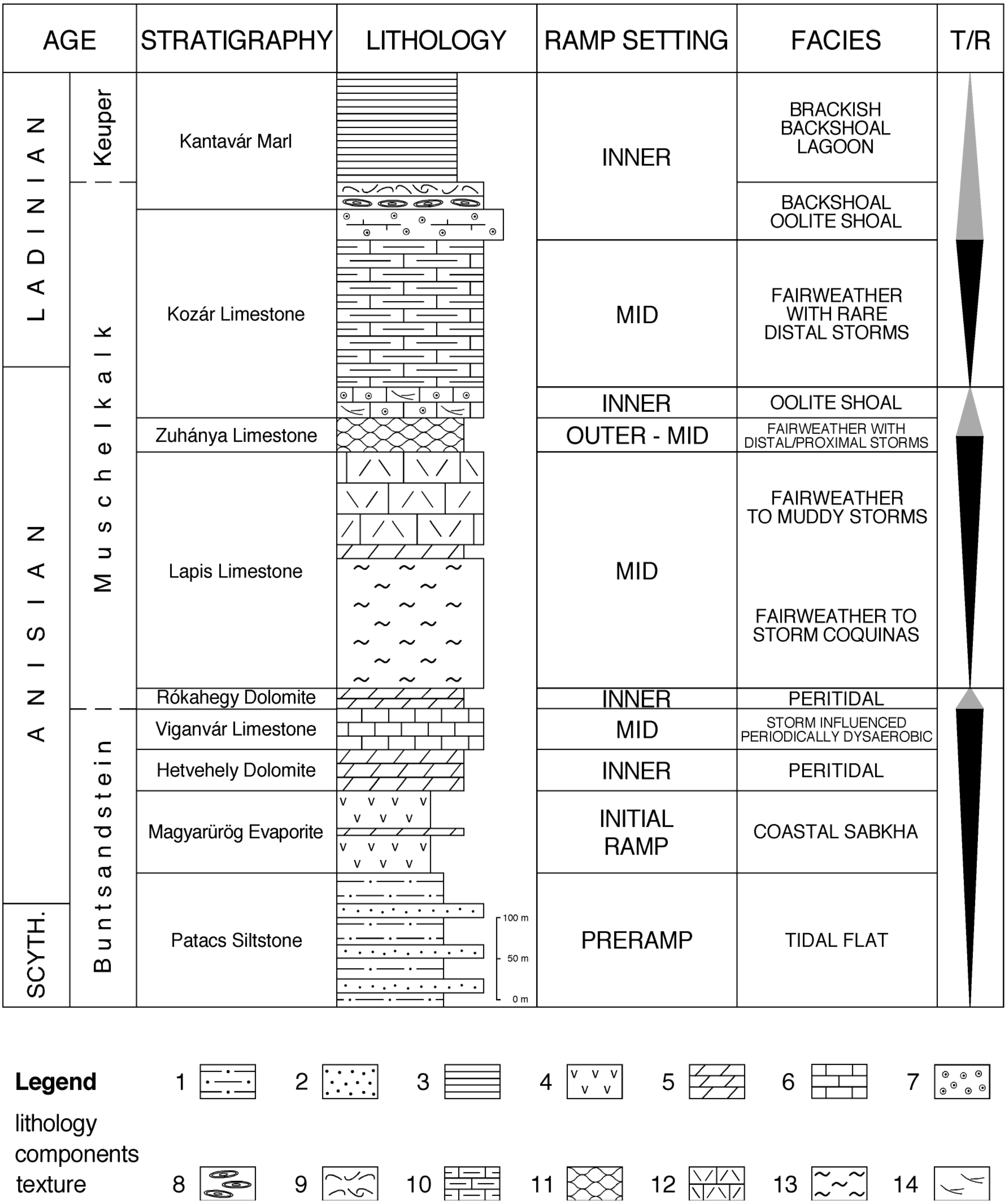


Fig. 4: Stratigraphy, sedimentary facies, depositional environment, and 3rd order transgressive-regressive cycles (T/R-cycles) of the Middle Triassic of southern Hungary (modified from TÖRÖK 1998, 2000). Legend: 1 siltstones, 2 sandstones, 3 marls, 4 evaporites, 5 dolomites, 6 limestones, 7 ooids, 8 oncoids, 9 bioclasts, 10 platy, 11 nodular, 12 thick-bedded, 13 flaser-bedded, 14 cross-bedded.

important palynofacies parameter displaying transgressive-regressive and proximal-distal trends respectively. Depending on proximity of land, water depth, temperature, salinity, and nutrient availability it is directly linked to the marine conditions of the water column. Another parameter reflecting proximality changes within the sedimentary series is the ratio of opaque to translucent phytoclasts (OP/TR ratio). Generally, marine sediments show an offshore increase in

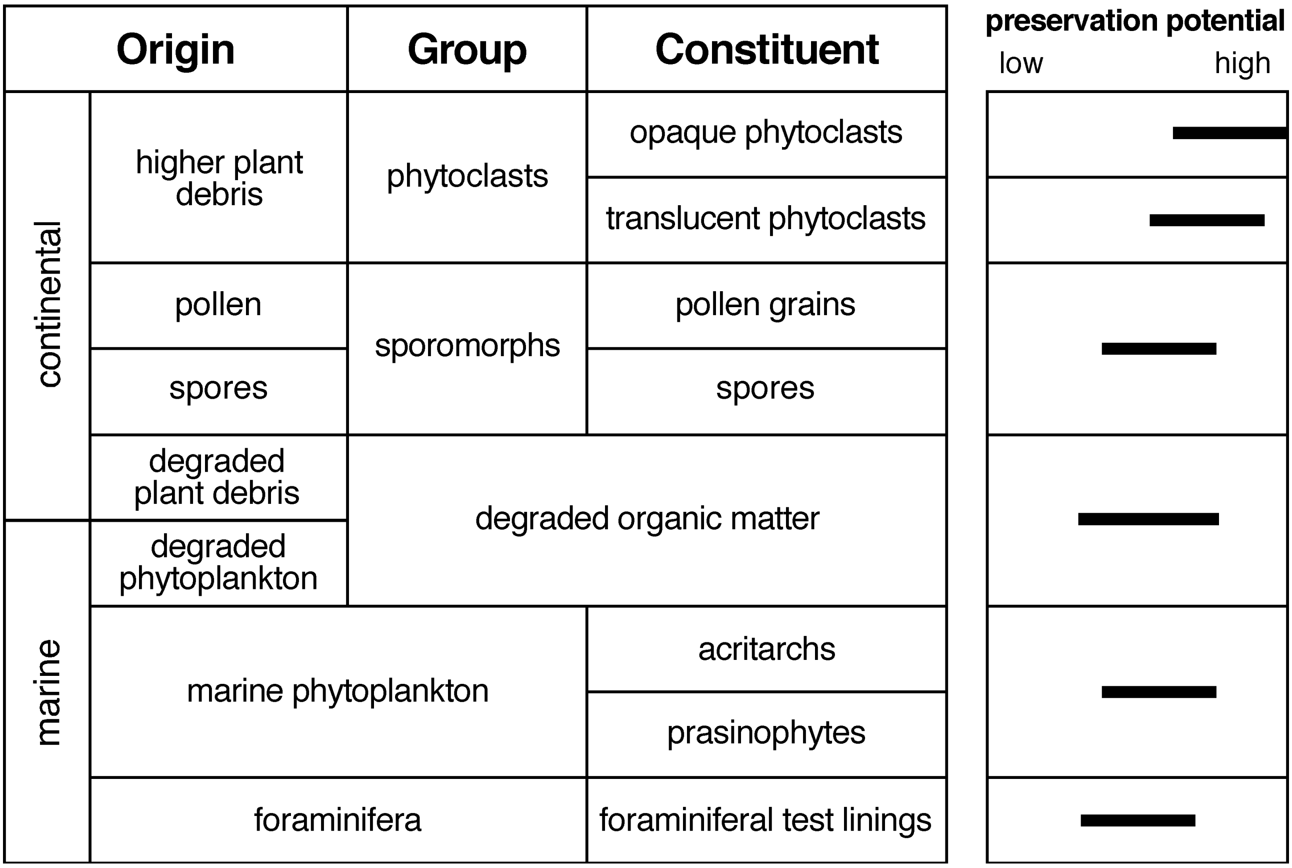


Fig. 5: Classification and preservation potential of sedimentary organic matter (modified from Steffen & Gorin 1993 and Pittet & Gorin 1997) applied to Muschelkalk carbonates of southern Hungary.

the ratio of opaque to translucent woody material due to fractionation during transport and the higher preservation potential of opaque phytoclasts. However, in proximal high-energy shelf areas this trend may be reversed by in-situ (bio)oxidation, enhanced by the high porosity and permeability of coarse-grained sediments (Tyson 1993). Therefore, the size and shape of refractory opaque particles are additionally used to decipher proximal-distal trends. Small, equidimensional woody fragments are characteristic of distal deposits, whereas in proximal settings large, blade-shaped particles are quite abundant (Steffen & Gorin 1993). In addition, proximal assemblages reveal a greater variety of particle sizes (Tyson 1993, Tyson & Follows 2000).

Palynofacies of the Lapis Limestone is characterized by a high amount of bisaccate pollen grains (up to 38 %), whereas spores remain rare (< 4 %) throughout the entire series (Pl. 2e). Most of the land-derived sporomorphs are highly degraded. Another striking feature is the high fragmentation of these organic particles. Within the phytoclast group a significant increase of opaque woody material is observed in this stratigraphic unit, whereas translucent ("fresh") particles follow the opposite trend: They are quite abundant in the lower part of the Lapis Limestone (Pl. 2f), decreasing towards the top. Marine components are dominated by acritarchs (*Micrhystridium* spp.). In the lower part of this unit the marine fraction reaches relative percentages up to 10 %. Within the upper part a significant increase is observed (Fig. 6). Maximum abundance of marine plankton (38 %) occurs in the lower part of the Zuhánya Limestone (Pl. 2c, d), representing the most prominent palynofacies signature. The highest amount of opaque, mostly equidimensional phytoclasts is recognized within the upper Zuhánya unit (Pl. 2a). Land-derived sporomorphs are almost completely absent.

The carbonates of the basal Kozár Limestone, which are building the uppermost part of the studied section, are very poor in sedimentary organic matter. Palynomorphs are poorly preserved and highly oxidized. The phytoclast group is dominated by opaque fragments with a significant proportion of blade-shaped particles (Pl. 2b).

Stellapollenites thiergartii (Mädler 1964) Clement-Westerhof et al. 1974, a marker species for the Anisian (Hochuli et al. 1989, Visscher et al. 1993), was identified in samples from all studied stratigraphic units.

6. Discussion

Sedimentary features and palynofacies patterns recognized in the investigated Muschelkalk ramp deposits of southern Hungary clearly reflect a long-term transgressive-regressive trend.

Stratigraphic variations of sedimentary organic matter may be interpreted in terms of sequence stratigraphy. Palynofacies parameters indicative of proximal conditions (high

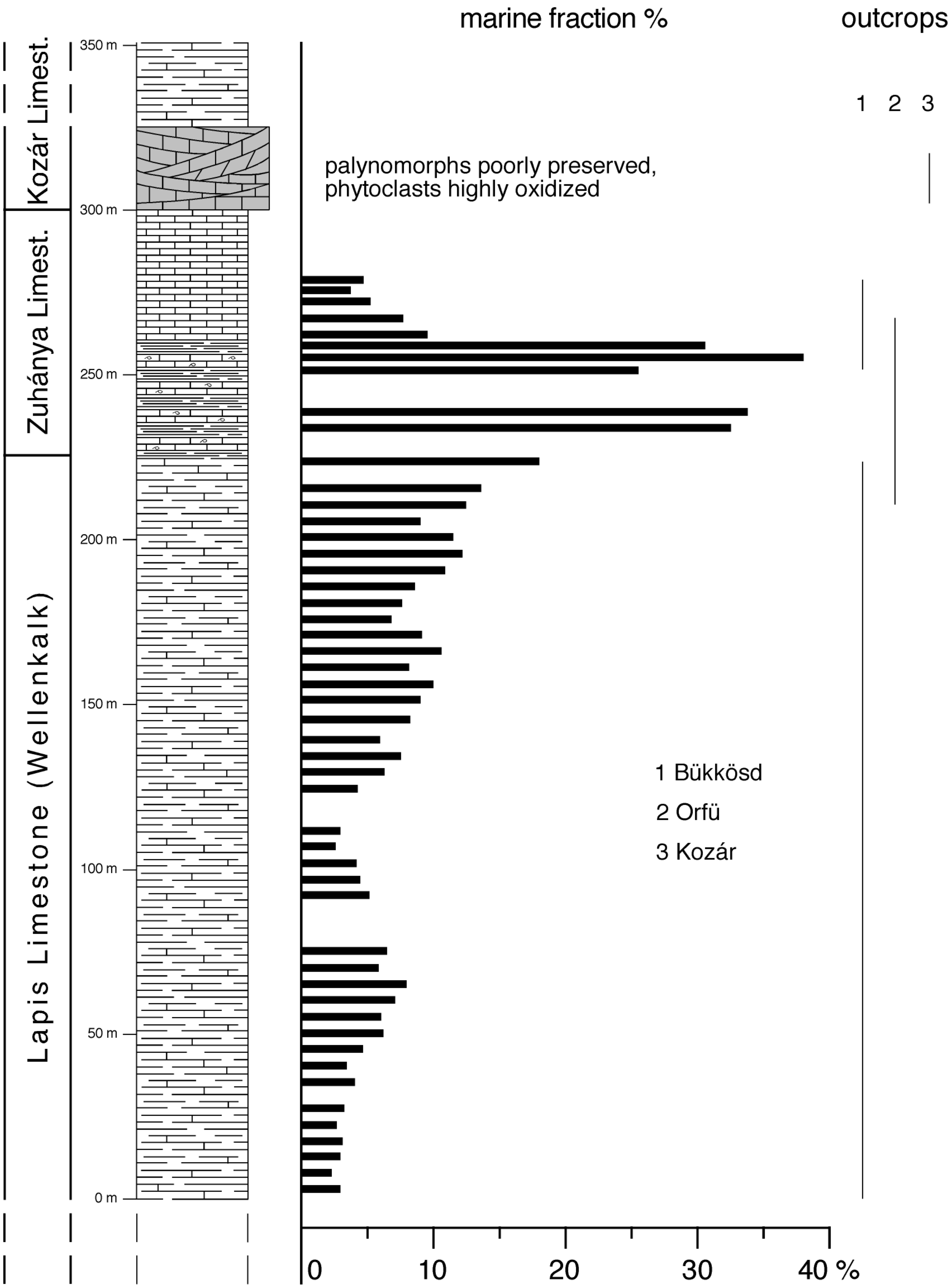


Fig. 6: Generalized section of the studied outcrops (Bükkösd, Orfü, Kozár) and relative abundance of marine plankton within the Anisian of southern Hungary (Mecsek Mts.).

amount of fresh, translucent phytoclasts and land-derived sporomorphs) decrease in the transgressive phase (Lapis Limestone), reaching a low within the interval of maximum flooding and early Highstand (Zuhánya Limestone). Their proportion increases again during the late Highstand (basal Kozár Limestone). Indicators of distal conditions (high percentage of opaque, equidimensional phytoclasts and marine plankton) follow the opposite trend. They are increasing in the transgressive interval, reaching a maximum during the phase of maximum flooding and in the early Highstand. A decrease is observed in the late Highstand.

The described palynofacies patterns are also known from Lower Muschelkalk carbonates of the intracratonic Germanic Basin (GÖTZ & FEIST-BURKHARDT 2000, RAMEIL et al. 2000). The phase of maximum flooding is recognized within the Terebratelbank Member, which is characterized by amalgamated bioclastic limestones with numerous hard- and firmgrounds and maximum abundance of marine plankton. This eustatic signal corresponds to a peak transgression in the Alpine realm during the Pelsonian (DE ZANCHE et al. 1993, RÜFFER & ZÜHLKE 1995, RÜFFER & BECHSTÄDT 1998, GIANOLLA et al. 1998). Transgressive deposits show a deepening-upward trend from the red shale facies of the Upper Buntsandstein to the shallow marine carbonates of the Lower Muschelkalk. Within this stratigraphic interval a significant increase of the marine fraction is observed. Highstand deposits document a shallowing-upward trend with prograding oolitic and peloidal limestones of the Schaumkalkbank Member followed by the basal dolomites of the Middle Muschelkalk. The relative abundance of marine plankton is decreasing again.
Furthermore, the appearance of *Stellapollenites thiergartii* (MÄDLER 1964) CLEMENT-WESTERHOF et al. 1974 enables a first precise biostratigraphic correlation of the Hungarian Lapis Limestone Formation, Zuhánya Limestone Formation, and the basal Kozár Limestone Formation with the Germanic Lower Muschelkalk (Jena Formation).

A major difference between Muschelkalk deposits of the landlocked intracratonic basin and the epicontinental shelf area is the influence of storms, which was much stronger on the Hungarian ramp system (TÖRÖK 1998). This is clearly documented by characteristic sedimentary features (e.g., coquinas, hummocky cross-stratification) and palynofacies signatures (e.g., intense fragmentation of palynomorphs, high percentage of refractory opaque phytoclasts).
In both depositional environments the high amount of bisaccate pollen grains within the continental sporomorph assemblage is associated with the proximity to land areas with coniferous vegetation (Vindelician-Bohemian Massif). The high degree of biodegradation is indicative of highly oxidizing, proximal settings.

7. Conclusions

Three transgressive-regressive cycles at a third order scale were distinguished within the Middle Triassic of southern Hungary (TÖRÖK 2000). Based on sedimentological signatures, palynofacies patterns, and palynostratigraphic data the second T/R-cycle is correlated with the Lower Muschelkalk (Jena Formation) of the Germanic Basin.
The Lapis Limestone represents the Transgressive deposits (TSd) of the lower part of the Lower Muschelkalk ("Wellenkalk"). Maximum flooding occurred within the basal unit of the Zuhánya Limestone, correlating with the Terebratelbank Member. The upper part of the Zuhánya Limestone represents the early Highstand deposits (eHSd), whereas the lowermost unit of the Kózar Limestone may be interpreted as late Highstand deposits (lHSd) which are the stratigraphic equivalent of the Schaumkalkbank Member.
Stratigraphic variations of sedimentary organic matter reflect the long-term transgressive-regressive trend. The major eustatic signal is documented by maximum abundance of marine plankton within the upper Anisian (Zuhánya Limestone). This interval represents a major transgression phase during Pelsonian times related to a global sea-level rise.

Acknowledgements

This study is part of a project on Lower Muschelkalk sequence stratigraphy supported by the Deutsche Forschungsgemeinschaft (project Fe 435/3-2). Financial support from the Hungarian National Science Fund (OTKA T 037652) to Á.T. and Gy. K. and the Széchenyi Fund to Á.T. is also acknowledged. We thank Prof. Dr. Richard Lein and Prof. Dr. Leopold Krystyn (Vienna) for carefully reviewing our paper. The palynological processing was carried out by Valbone Memeti and Joachim Krause at Darmstadt University of Technology. For technical assistance we want to thank Ulrike Simons (Darmstadt).

References

COMBAZ, A. (1964): Les palynofaciès. - Rev. Micropaléont., **7**: 205-218, Paris.

DERCOURT, J., RICOU, L.E. & VRIELYNCK, B. (1993): Atlas Tethys Palaeoenvironmental Maps: 1-307, 14 maps, 1 pl., (Gauthier-Villars) Paris.

DE ZANCHE, V., GIANOLLA, P., MIETTO, P., SIORPAES, C. & VAIL, P.R. (1993): Triassic sequence stratigraphy in the Dolomites (Italy). - Mem. Sci. geol., **45**: 1-27, Padova.

GIANOLLA, P., DE ZANCHE, V. & MIETTO, P. (1998): Triassic sequence stratigraphy in the Southern Alps (Northern Italy): definition of sequences and basin evolution. - (In: DE GRACIANSKY, P.-C., HARDENBOL, J., JACQUIN, T. & VAIL, P.R. (Eds.): Mesozoic and Cenozoic sequence stratigraphy of European basins), SEPM Spec. Publ., **60**: 719-747, Tulsa.

GÖTZ, A.E. & FEIST-BURKHARDT, S. (2000): Palynofacies and sequence analysis of the Lower Muschelkalk (Middle Triassic, German basin). - Zbl. Geol. Paläont. Teil I, **1998** (9/10): 877-891, Stuttgart.

HAGDORN, H., KONRÁD, Gy. & TÖRÖK, Á. (1997): Crinoids from the Muschelkalk of the Mecsek Mountains and their stratigraphical significance. - Acta Geol. Hung., **40**: 391-410, Budapest.

HOCHULI, P.A., COLIN, J.P. & VIGRAN, J.O. (1989): Triassic biostratigraphy of the Barents Sea area. - (In: COLLINSON, J.D. (Ed.): Correlation in Hydrocarbon Exploration), 131-153, (Graham & Trotman) London.

KNAUST, D. (2002): Pinch-and-swell structures at the Middle/Upper Muschelkalk boundary (Triassic): evidence of earthquake effects (seismites) in the Germanic Basin. - Geol. Rundsch., **91** (2): 291-303, Berlin.

KONRÁD, Gy. (1998): Synsedimentary tectonic events in the Middle Triassic evolution of the SE Transdanubian part of Tisza Unit. - Acta Geol. Hung., **41**: 327-341, Budapest.

KONRÁD, Gy. (1999): Sedimentary analysis of Lower and Middle Triassic sequences, Southeastern Hungary. - Unpublished PhD Thesis. Hungarian Academy of Sciences: 1-131, Budapest.

KOVÁCS, S. & PAPSOVÁ, J. (1986): Conodonts from the *Paraceratites binodosus* zone (Middle Triassic) from the Mecsek Mts., Southern Hungary and from the Choc Nappe of the Low Tatra Mts., Czechoslovakia. - Geol. Zbornik Geol. Carph., **37** (1): 59-74, Bratislava.

MONOSTORI, M. (1996): Ostracods and charophytes from the Triassic Kantavár Formation, Mecsek Mts., Hungary. - Acta Geol. Hung., **39**: 311-317, Budapest.

PITTET, B. & GORIN, G.E. (1997): Distribution of sedimentary organic matter in a mixed carbonate-siliciclastic platform environment: Oxfordian of the Swiss Jura Mountains. - Sedimentology, **44**: 915-937, Oxford.

RAMEIL, N., GÖTZ, A.E. & FEIST-BURKHARDT, S. (2000): High-resolution sequence interpretation of epeiric shelf carbonates by means of palynofacies analysis: an example from the Germanic Triassic (Lower Muschelkalk, Anisian) of East Thuringia, Germany. - Facies, **43**: 123-144, Erlangen.

RÜFFER, T. (1995): Entwicklung einer Karbonat-Plattform: Fazies, Kontrollfaktoren und Sequenzstratigraphie in der Mitteltrias der westlichen Nördlichen Kalkalpen (Tirol, Bayern). - GAEA heidelbergensis, **1**: 1-288, Heidelberg.

RÜFFER, T. & BECHSTÄDT, T. (1998): Triassic sequence stratigraphy in the western parts of the Northern Calcareous Alps (Austria). - (In: DE GRACIANSKY, P.-C., HARDENBOL, J., JACQUIN, T. & VAIL, P.R. (Eds.): Mesozoic and Cenozoic sequence stratigraphy of European basins), SEPM Spec. Publ., **60**: 751-761, Tulsa.

RÜFFER, T. & ZÜHLKE, R. (1995): Sequence stratigraphy and sea level changes in the Early to Middle Triassic of the Alps: a global comparison. - (In: HAQ, B.U. (Ed.): Sequence stratigraphy and depositional response to eustatic, tectonic and climatic forcing), 161-207, (Kluwer) Amsterdam.

STEFFEN, D. & GORIN, G. (1993): Palynofacies of the Upper Tithonian - Berriasian deep-sea carbonates in the Vocontian Trough (SE France). - Bull. Centres Rech. Explor.-Prod. Elf-Aquitaine, **17**: 235-247, Boussens.

SZENTE, I. (1997): Bivalve assemblages from the Middle Triassic of the Mecsek Mts., Southern Hungary: systematics, palaeoecology and palaeogeographical significance. An overview. - Acta Geol. Hung., **40**: 411-424, Budapest.

SZULC, J. (1993): Early alpine tectonics and lithofacies succession in the Silesian part of the Muschelkalk Basin. A Synopsis. - (In: HAGDORN, H. & SEILACHER, A. (Eds.): Muschelkalk. Schöntaler Symposium 1991. - Sonderbände der Gesellschaft für Naturkunde in Württemberg, 2), 19-28, (Goldschneck) Korb.

SZULC, J. (1999): Anisian-Carnian evolution of the Germanic basin and its eustatic, tectonic and climatic controls. - Zbl. Geol. Paläont. Teil I, **1998** (7/8): 813-852, Stuttgart.

SZULC, J. (2000): Middle Triassic evolution of the northern Peri-Tethys area as influenced by early opening of the Tethys ocean. - Ann. Soc. Geol. Polon., **70**: 1-48, Krakau.

TÖRÖK, Á. (1993): Storm influenced sedimentation in the Hungarian Muschelkalk. - (In: HAGDORN, H. & SEILACHER, A. (Eds.): Muschelkalk. Schöntaler Symposium 1991. - Sonderbände der Gesellschaft für Naturkunde in Württemberg, 2), 133-142, (Goldschneck) Korb.

TÖRÖK, Á. (1997): Triassic ramp evolution in Southern Hungary and its similarities to the Germano-type Triassic. - Acta Geol. Hung., **40**: 367-390, Budapest.

TÖRÖK, Á. (1998): Controls on development of Mid-Triassic ramps: examples from southern Hungary. - (In: WRIGHT, V.P. & BURCHETTE, T.P. (Eds.): Carbonate Ramps), Geol. Soc. London, Spec. Publ., **149**: 339-367, London.

TÖRÖK, Á. (2000): Muschelkalk carbonates in southern Hungary: an overview and comparison to German Muschelkalk. - Zbl. Geol. Paläont. Teil I, **1998** (9/10): 1085-1103, Stuttgart.

TYSON, R.V. (1993): Palynofacies analysis. - (In: JENKINS, D.G. (Ed.): Applied Micropaleontology), 153-191, (Kluwer Academic Publishers) Dordrecht.

TYSON, R.V. (1995): Sedimentary Organic Matter: Organic Facies and Palynofacies. - 1-615, (Chapman & Hall) London.

TYSON, R.V. & FOLLOWS, B. (2000): Palynofacies prediction of distance from sediment source: A case study from the Upper Cretaceous of the Pyrenees. - Geology, **28** (6): 569-571, Boulder.

VISSCHER, H., BRUGMAN, W. A. & VAN HOUTE, M. (1993): Chronostratigraphical and sequence stratigraphical interpretation of the palynomorph record from the Muschelkalk of the Obernsees well, South Germany. - (In: HAGDORN, H. & SEILACHER, A. (Eds.): Muschelkalk. Schöntaler Symposium 1991. - Sonderbände der Gesellschaft für Naturkunde in Württemberg, 2), 145-152, (Goldschneck) Korb.

ZÜHLKE, R. (2000): Fazies, hochauflösende Sequenzstratigraphie und Beckenentwicklung im Anis (Mittlere Trias) der Dolomiten (Südalpin, Italien). - GAEA heidelbergensis, **6**: 1-368, Heidelberg.

Plate 1

Sedimentology of Middle Triassic ramp deposits of southern Hungary (Mecsek Mts.).

a) Synsedimentary deformation structure and thin storm coquina above (arrow), Lapis Limestone Formation (Gorica quarry).

b) Close view of thin storm generated bivalve coquina layer, Lapis Limestone Formation (Gorica quarry).

c) Slump in flaser-bedded mudstone (”Wellenkalk”), Lapis Limestone Formation (Gorica quarry).

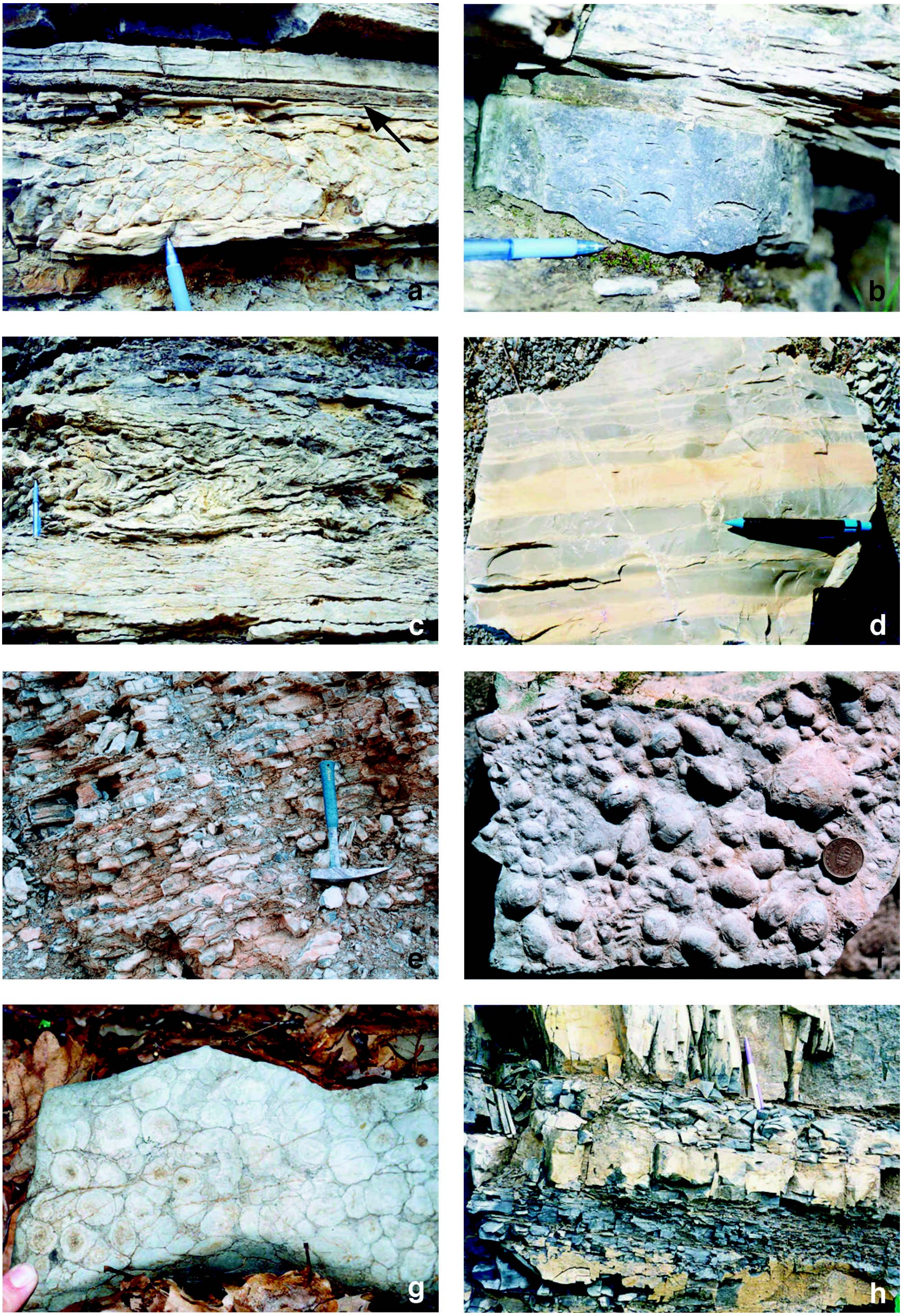
d) Alternating laminated dolomitic limestone (pale yellow) and limestone (grey), indicating short-term phases of shallowing within the Wellenkalk sequence, Lapis Limestone Formation (Bükkösd quarry).

e) Nodular mud-/wackestones, representing the deepest outer ramp facies of the entire Muschelkalk, Zuhánya Limestone Formation (Bükkösd quarry, upper level).

f) Bedding plane of brachiopod (*Coenothyris vulgaris*) and bivalve shell beds, indicating the maximum flooding interval within the Zuhánya Limestone Formation (Orfü, coin for scale is 1.5 cm).

g) Densely packed and plastically deformed large oncoids of the backshoal facies, basal part of the Kantavár Formation (small path to Kisrét).

h) Dark paper-laminated calcareous marls and intercalating limestones of restricted lagoonal origin, Kantavár Formation (Kantavár quarry).


a
b
c
d
e
f
g
h

Mitt. Ges. Geol. Bergbaustud. Österr., **46**: 77-90, Wien 2003

Plate 2

Palynofacies and sequence stratigraphical interpretation of the second 3rd order T/R-cycle within the Middle Triassic (Anisian) of southern Hungary (Mecsek Mts.).

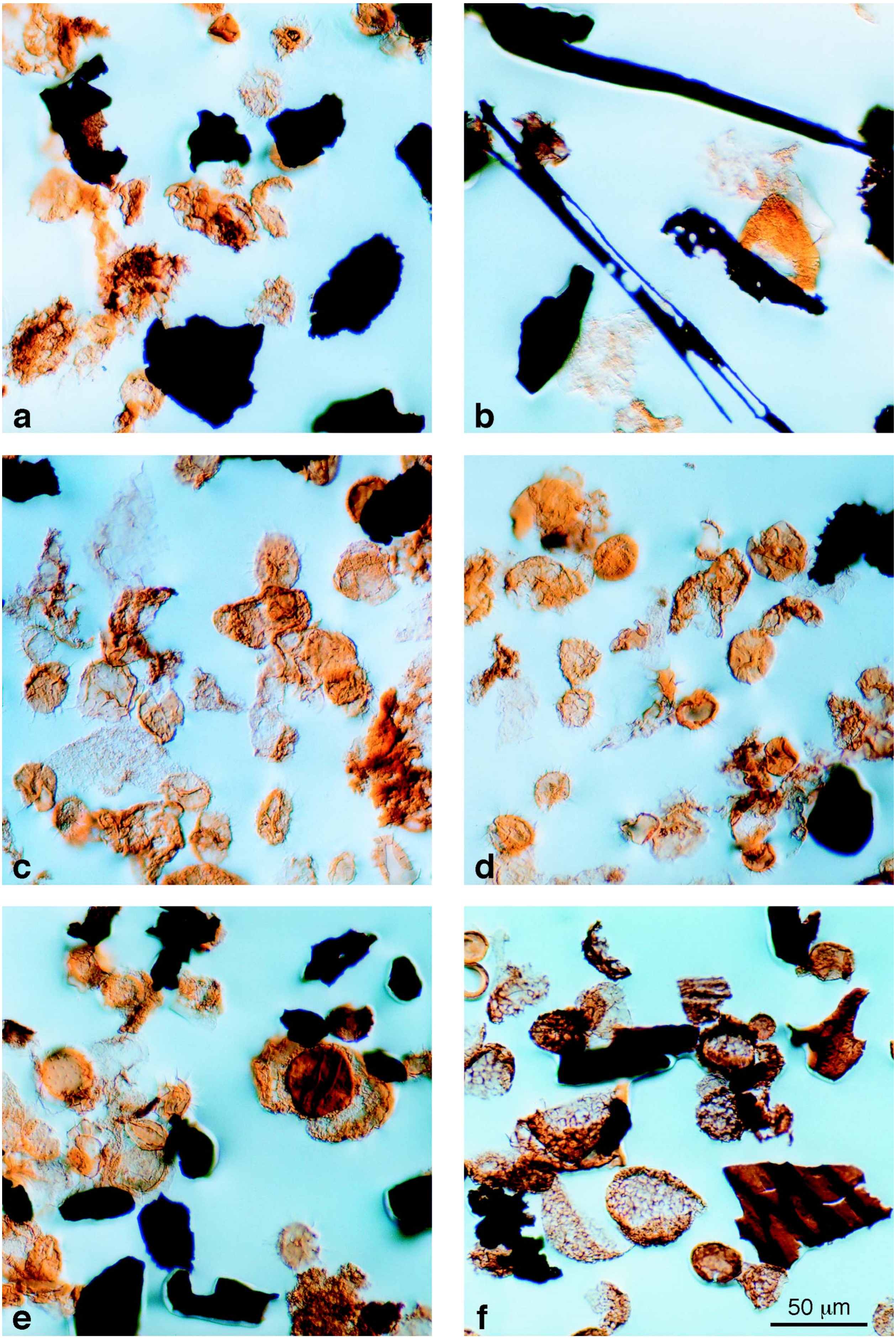
a) Upper part of the Zuhánya Limestone (early Highstand deposits, eHSd): Highest amount of opaque, mostly equidimensional phytoclasts.

b) Lowermost Kozár Limestone (late Highstand deposits, lHSd): Highest amount of blade-shaped particles within the phytoclast group.

c) and d) Lower part of the Zuhánya Limestone (maximum flooding zone, mfz): Maximum abundance of marine plankton.

e) Lapis Limestone (Transgressive deposits, TSd): High amount of bisaccate pollen grains.

f) Lower part of the Lapis Limestone (Transgressive deposits, TSd): High amount of translucent plant remains within the phytoclast group.


a
b
c
d
e
f
50 µm