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MIDDLE TRIASSIC EVOLUTION OF THE TATRICUM SEDIMENTARY BASIN: AN ATTEMPT OF SEQUENCE STRATIGRAPHY TO THE WIERCHOWA UNIT IN THE POLISH TATRA MOUNTAINS

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Abstract: The paper focuses on paleoenvironmental reconstruction and sequence stratigraphy of the Tatricum Basin for the late Scythian–Ladinian interval. The reconstruction is based on observations carried out in the Kominiarski Wierch section, situated in the Polish part of the Tatra Mts.

Sedimentological and geochemical studies indicate that during middle Triassic time the Tatricum Basin was situated upon an isolated and restricted carbonate platform dominated by shallow water carbonate and evaporitic sedimentation. The basin was a tectonically stable area controlled by eustatic fluctuations. Incipient tectonic movements first occurred in late Ladinian time only.

The studied sedimentary succession is composed of several stacked, shallowing-upward cycles that are interpreted as 3rd order depositional sequences. The constructed sedimentary sequence framework corresponds well with the sequence stratigraphic scheme of the Northern Alpine Triassic and enables a better chronostratigraphic resolution of the Triassic in the Tatra Mts.

Key words: basin analysis, paleoenvironments, sequence stratigraphy, late Scythian–Ladinian, Tatra Mountains.

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INTRODUCTION

The Triassic of the Tatra Mts. has been poorly recognised in terms of sedimentary basin evolution and its controlling factors. Moreover, owing to scarcity of index fossils, chronostratigraphy of the Triassic succession was very general and inaccurate.

The paper concerns evolution of the Tatricum Basin in middle Triassic times as exemplified by the late Scythian–Ladinian succession from the Kominiarski Wierch section in the Polish Tatra Mts. (Fig. 1). The discussed section represents the Wierchowa Unit also called the High-Tatric Unit (or nappe; Fig. 2). The Triassic succession begins with clastic, continental deposits (Roniewicz, 1959; Dżułyński & Gradziński, 1960) of early Triassic age (Werfen-type facies) succeeded by sabkha and shallow marine deposits (mainly carbonates) of the late Scythian and middle Triassic age.

The studied section displays a relatively thick succession of the middle Triassic reaching some 700 meters. The discordantly overlying Upper Triassic hardly attains 60 m in thickness, owing to numerous erosional and nondeposition hiatuses typical for the late Triassic history of the basin.

Basing on sedimentological study of the Kominiarski Wierch section, the authors have applied the procedure of sequence stratigraphy to determine the main stages of the basin evolution in middle Triassic times. Furthermore, the method has been employed to refine the stratigraphic framework of the Middle Triassic in the Wierchowa Unit.

GENERAL SETTING

The discussed section occurs within the Wierchowa Unit that is composed of sediments that directly overlie the Paleozoic igneous and metamorphic basement rocks (Fig. 2).

The Wierchowa Unit is covered by subsequent nappes called, respectively, Krížna nappe and the uppermost, Choč nappe. The nappes represent palinspastic units called the Tatricum, Fatricum and Hronicum Basins respectively (Rakús *et al.*, 1998). As postulated by Kotański (1979), remnants of another nappe, called the Stražov Unit, may be also present in the westernmost part of the Polish Tatra range.

Fig. 1. View on the Kominiarski Wierch massif from the Tomanowa Valley with outlined position of the stages boundaries. Photograph by A. Uchman

The Triassic deposits developed within the mentioned units display different facies. In particular, the Choč nappe is composed of deeper marine sediments (e.g., the Reifling and Partnach facies).

Stratigraphic resolution of the Triassic succession in the Wierchowa Unit is very general and vague since the index fossils are quite rare. The mentioned paucity of age-diagnostic fossils is related to generally unfavourable paleoenvironmental conditions dominating in the basin during Triassic times. Moreover, the lithofacies diversity hinders reasonable stratigraphic correlation between the Triassic of the Tatricum and the other basins, including the Northern Alpine Basin.

Using the occurrence of *Gervillea mytiloides*, *Modiola triquera* and *Pecten discites* Rabowski (1921, 1931) ascribed the discussed sequence to the Middle Triassic. The presence of *Naticella costata* and *Costatoria costata* within the lower part of the carbonate succession (in the so-called Myophoria beds) was used to distinguish the late Scythian sediments (lower and upper Campilian; Kotański, 1956, 1959b).

Rare occurrence of age-diagnostic fossils in the Middle Triassic hinders unequivocal defining of the Anisian and Ladinian stages in the section. The Anisian and Ladinian stages have been distinguished basing mostly on their lithological properties and scarce crinoidal and algal fossils (Kotański, 1959c; Piotrowski, 1965). Using the dasycladales remnants (*Physoporella pauciforata*, *Ph. prealpina*, *Diplopora annulatissima*, *Griphoporella* sp. *Macroporella* sp), Piotrowski (1965) outlined the probable range of the late Pelsonian–Illyrian interval. This statement has been partly supported by occurrence of foraminifers (among others *Glomospira densa*) found by Bełka and Gaździcki (1976).

OBJECTIVES AND METHODS

A composite measured section has been constructed for the area encompassing the Iwaniacki Stream Valley and Kominiarski Wierch Mount (Figs 2, 3). Detailed sedimentological field studies (Jaglarz & Piszczek, 2000) have been supplemented by microfacies observations and by stable isotopes (^{13}C, ^{18}O) examination of the carbonates. The respective values of $\delta^{13}C$ and $\delta^{18}O$ were determined using measurements made with mass spectrometer SUMY, at the Institute of Geological Sciences, Academy of Sciences of Belarus at Minsk. The samples were treated with 100% orthophosphoric acid. Carbon dioxide was then collected in a trap with liquid nitrogen and purified in vacuum. Measurement error was ±0.2‰. Stable isotope ratios in carbonate samples are presented in this paper in reference to the PDB standard.

It is worth noting that the discussed section has previously been studied by Piotrowski (1965) who described the basic lithological types and fossil composition of the middle Triassic rocks. However, this description is poor in information usable for sedimentological analysis, although the paleontological data are significant for stratigraphical procedure carried out in our study.

In order to recognise the main stages of the basin evolution, we have analysed the vertical changes of the main lithological and sedimentary characteristics in terms of their recurrence within the studied section. Applying the method of sequence stratigraphy (e.g., Sarg, 1988) enabled us to convert the distinguished genetic units (cycles) to sedimentary sequences.

RESULTS

The sedimentary succession studied shows apparent cyclic arrangement depending on repetitive occurrence of deeper and shallow water facies (Fig. 3). The most common cycle begins with fine-grained limestones (sometimes with benthic fauna) that grade upward either to coarser grained sediments (e.g., oolitic and bioclastic limestones) and/or to dolomitic deposits. Such a succession reflects increase in energy and shallowing of the sedimentary environment. This interpretation is supported by the occurrence of teepee fabrics and karstic surface at the tops of some of the shallowing upward successions.

The dolomitised upper member of the cycles usually displays sharp contact with the overlying limestones, commencing the subsequent cycle. This is interpreted as meteoric dolomitisation during the shallowing phases. Detailed stable isotopes study (P. Jaglarz, unpubl. data, 2000) confirms this conclusion.

As a result of the above outlined research and analytical strategy, several comprehensible genetic units have been distinguished. Generally, all the units represent shallowing upward cycles and they give rise to define the 3rd-order depositional sequences (Fig. 4).

Since the Tatricum platform was detached from any continental hinterland, the succession is lacking any siliciclastics usually underscoring the sequence boundaries. Sequence boundaries are typically characterised by pronounced emersion horizons (karst and paleosoils including teepee deformations, solution breccias) and dolomitic intervals that developed mostly during shallowing phases under the substantial influence of meteoric water.

Age position of the Anisian sequences has been established according to some indicative fossils discussed else-

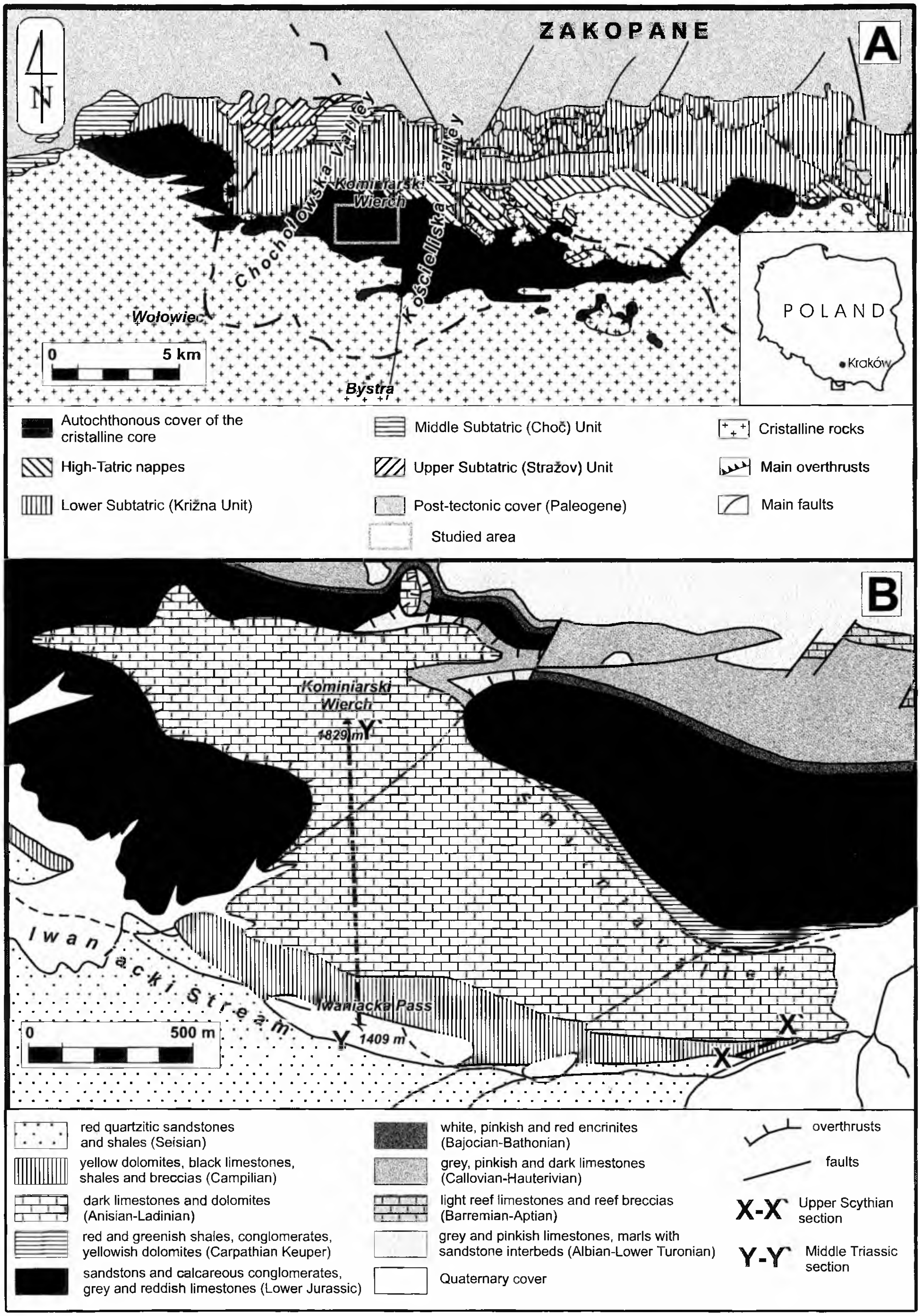

Fig. 2. **A.** Tectonic sketch map of the Tatra Mts. (after: Bac-Moszaszwili *et al.*, 1979). **B.** Close-up of the studied area (after: Bac-Moszaszwili *et al.*, 1979)

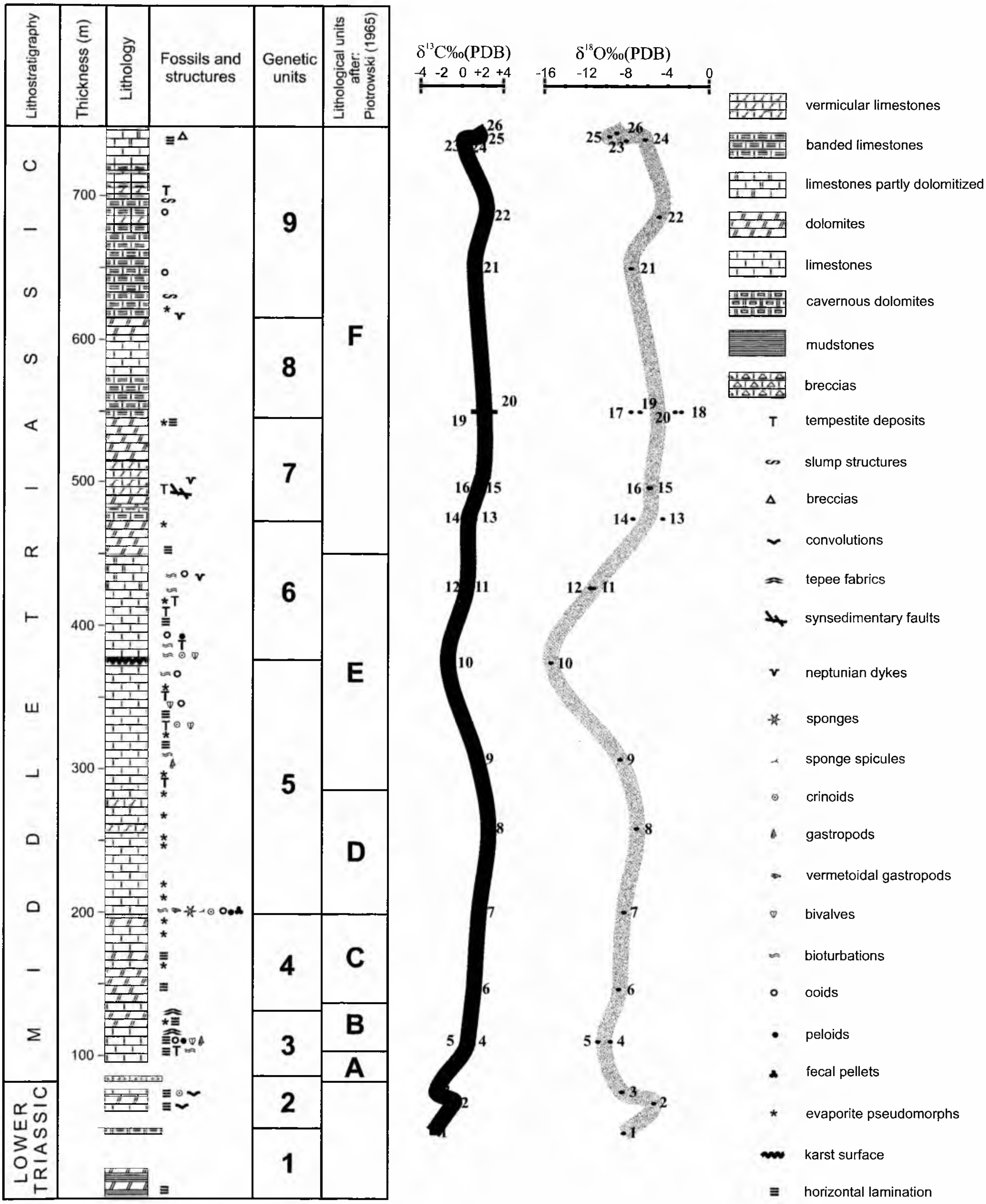

Fig. 3. Synthetic section and stable isotope curves of the lower-middle Triassic succession of the Kominiarski Wierch section. Numbers 1–9: genetic units distinguished in the present paper; A–F: lithological units distinguished by Piotrowski (1965)

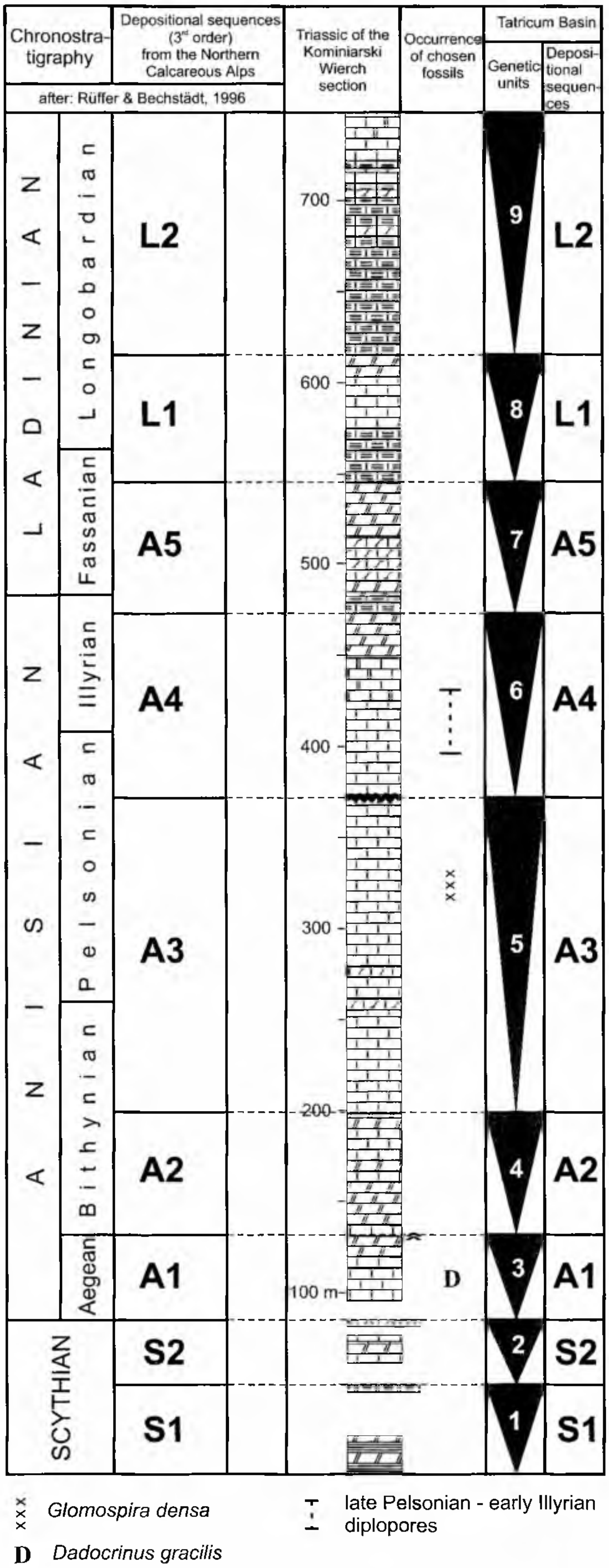

Fig. 4. Shallowing-upward cycles (units 1–9) and 3rd-order depositional sequences of the late Scythian–Ladinian succession from the Tatricum Basin (Kominiarski Wierch section), against the sequence stratigraphic framework and chronostratigraphy of the Northern Alpine Basin. Occurrence ranges; diplopores – after Piotrowski (1965), forams – after Bełka & Gaździcki (1976). Other explanations see Fig. 3

where. The Ladinian sequences have been supposedly proposed according to their superposition above the Upper Anisian. This age presumption has been confirmed by the comparing procedure with the Alpine sequences (see below).

DEFINING OF THE SEDIMENTARY UNITS AND DEPOSITIONAL SEQUENCES

Scythian

Unit 1 – Sequence S1

The lowermost, exposed part of the section is composed of alternated thin-bedded dololutites and grey mudstones. The mudstones become more and more reddish upsection. The middle to upper part of the unit is poorly exposed and comprises vuggy dolomites (rauhwackes; Fig. 5) and breccias composed of angular clasts of mudstones and dolomites, with dolomitic and calcite cement. Ubiquitous occurrence of pseudomorphs after sulphates enclosed in the dolomite clasts indicates that the vuggy and brecciated horizon developed by meteoric dissolution of the interbedded evaporites.

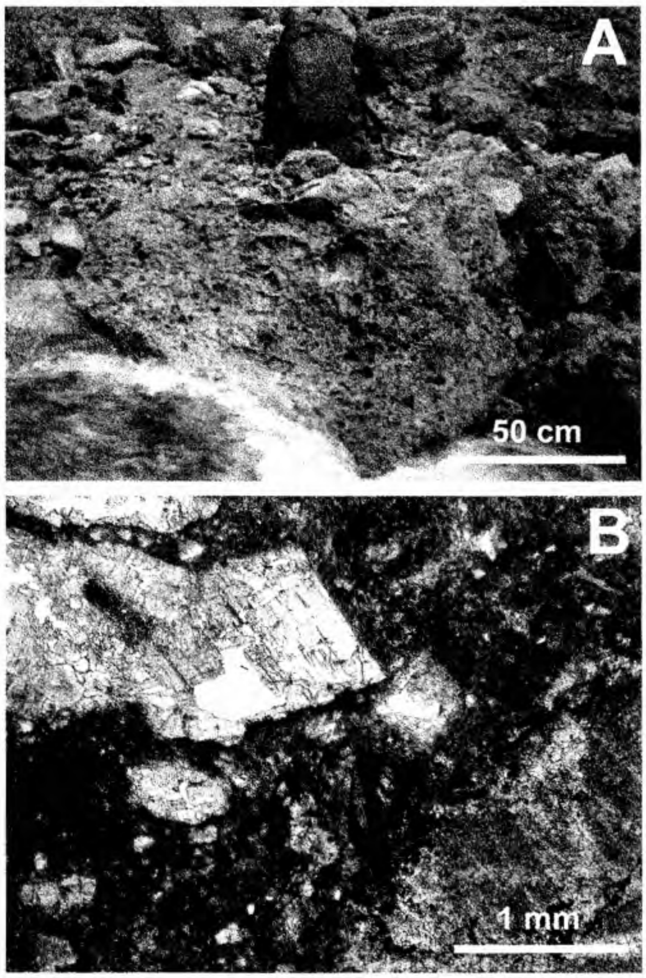

Fig. 5. Vuggy dolomites (rauhwackes) (**A**) with secondary pores filled with calcite cement (**B**). Unit 1

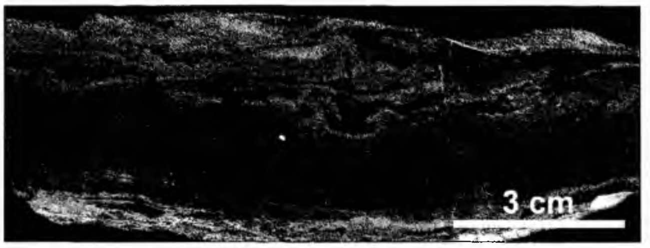

Fig. 6. Slump-deformed bituminous limestones, late Scythian (Campilian). Unit 2

Unit 2 – Sequence S2

The described above breccia is succeeded by bituminous- rich, microbially-laminated dolomites and limestones with thin mud intercalations. Scarce crinoidal debris has been found within the limestones. The sediments display common bioturbational and mechanical plastic deformations (Fig. 6).

Upper part of the unit contains polymictic breccia composed of angular carbonate clasts, reaching up to 2 cm in size (Fig. 7B). The intergranular voids are filled with muddy matrix and/or cemented by sparry calcite. The carbonate clasts contain numerous pseudomorphs after gypsum. This suggests that the breccia represents a collapse fabric formed after the solution of the evaporitic components. Angular shaped clasts and the lack of any lateral displacement confirm this interpretation. Our interpretation refutes the erosional origin of the breccias as basal sediment formed during transgression onset, as proposed by Kotański (1959a).

We define the solution breccia horizon from the top of the Unit 1 as sequence boundary (SB) of the sequence S2.

Total thickness of the Scythian reaches 85 m.

Middle Triassic

Unit 3 – Sequence A1

The deposits overlying the above discussed polymictic breccia are dark grey calcilutites and sandy limestones (calcisiltites and calcarenites) displaying horizontal and low-angle cross stratification (Fig. 7A). Contribution of the coarse-grained limestones increases upsection where they are composed of oolites and skeletal debris (Figs 7C–F). The latter are dominated by crinoids, dwarf gastropods and bivalves. The occurrence of *Dadocrinus gracilis* dates the sediments to early Anisian. The topmost sediments of the unit are crinkled up and form teepee horizons. The unit is 65 m thick.

The polymictic breccia from the topmost part of the Unit 2 defines the sequence boundary of the first middle Triassic sequence (A1).

Unit 4 – Sequence A2

The teepee horizon is covered by dark, heavily bioturbated limestones (the so-called vermicular limestones; Fig. 8A) alternating with laminated calcilutites and dolomites. The dolomites are composed of medium-bedded dololutites that grade upsection into thick-bedded dolosiltites. The dolomites contain abundant pseudomorphs after sulphates, including also crystals and aggregates of celestite (Figs 8B–D). Some parts of the pseudomorph-rich dolomite are brecciated. Thickness of the unit is ca. 70 m.

The teepee horizon forms the boundary of the sequence A2.

Unit 5 – Sequence A3

The 170 m-thick unit starts with fine-grained limestones that become richer in skeletal debris upsection. Skeletal debris is composed of small gastropods (including vermetoidal forms; Fig. 9A), crinoids and sponge spicules (Fig. 9B). Mummified remnants of sponge colonies have also been recognised (Fig. 9D). Crinoid columnals underwent destruction owing to microboring activity (Fig. 9C). Beside bioclasts, the limestones comprise some cortoids, peloids and crab fecal pellets. Trace fossils *Planolites* isp. are quite common. A foraminifer assemblage has been described from the upper part of the unit (Bełka & Gaździcki, 1976).

Fossil-rich horizons are characteristic of the lower part of the unit whereas the middle part is poor or completely lacking in macrofaunal debris. The sediments are finely laminated, thin to medium bedded calcilutites, encompassing common pseudomorphs after celestite. Some intervals of the fine-grained limestones are intensively bioturbated giving vermicular beds (2 cm to 2 m thick). The uppermost 50 m-thick part of the unit displays increasing grain size and common tempestites (Fig. 10). Concomitantly, there is an increase in the proportion of oolites and bioclasts (gastropods, crinoids, bivalves). The fossils are particularly well visible upon a karstified surface separating the unit from the subsequent one. This karst horizon is the most remarkable example of emersion event found so far in the studied section (Jaglarz, 2002). The slightly uneven, karstic horizon displays reddish colour and beside remnants of the carbonate host substrate it also contains substantial amount of opaque ferruginous (hydro)oxides and residual clays.

The sequence boundary is placed at the top of the dolomitised package from the uppermost part of the Unit 4.

Unit 6 – Sequence A4

The karstified surface of the Unit 5 is directly overlain by vermicular calcilutites that grade into oolitic and calcisiltite beds which commonly exhibit low-angle hummocky cross-stratification. The uppermost 30 m-thick part of the unit is built up by dolomites. Some small neptunian dykes occur within this part of the section. The middle part of the unit contains diplopores dating it to the late Pelsonian–early Illyrian (Piotrowski, 1965). The unit is ca. 100 m thick.

The above discussed karst surface makes the boundary of the sequence A4.

Unit 7 – Sequence A5

The next distinguished unit begins with banded limestones. The banding depends on subtle, millimeter-scale alternation of grey calcisiltitic and dark brown calcilutitic layers, displaying subhorizontal stratification (Fig. 11A). The banded sediments are replaced upward by vermicular limestones (Fig. 11B) that, in turn, pass into dolomites with pseudomorphs after sulphates. Synsedimentary faults have also been found within this unit (Fig. 11D). Thickness of the unit reaches 75 meters.

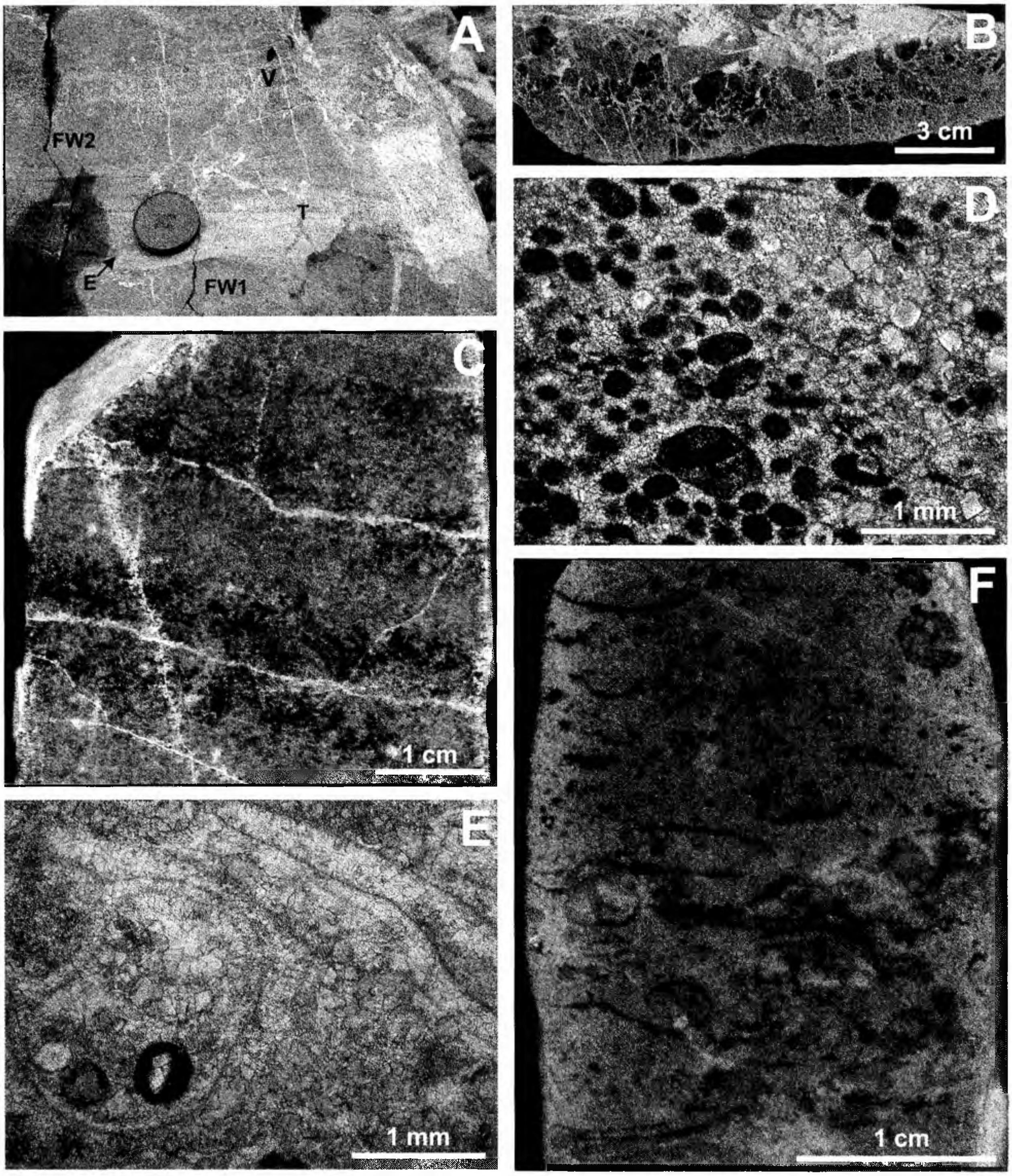

Fig. 7. Chosen aspects of the facies of the Units 2 and 3. **A.** Short-term cyclic succession of tempestite-fair weather couplet. FW1 – fair weather, fine-grained limestones, E – erosional base of tempestite (T), FW2– fair weather layer, bioturbated at the top part (V). Unit 3. **B.** Collapse breccia of the top part of the Unit 2. **C.** Oolitic limestones of the Unit 3. **D.** Thin section detail from C. **E.** Calcite-cemented gastropod packstone from the Unit 3. **F.** Graded bivalve wackestone from the Unit 3

The top of the sulphate-bearing dolomites from the upper part of the Unit 6 defines the boundary of the sequence A5.

Unit 8 – Sequence L1

The unit is tripartite. The lower part is built up of banded limestones. The middle part is composed of coarse-grained and thicker bedded limestones. The upper part is dolomite with synsedimentary cracks at the top. Total thickness of the unit is ca. 75 m.

We place the sequence boundary of the first Ladinian sequence (L1) at the top of the dolomitic packages from the Unit 7.

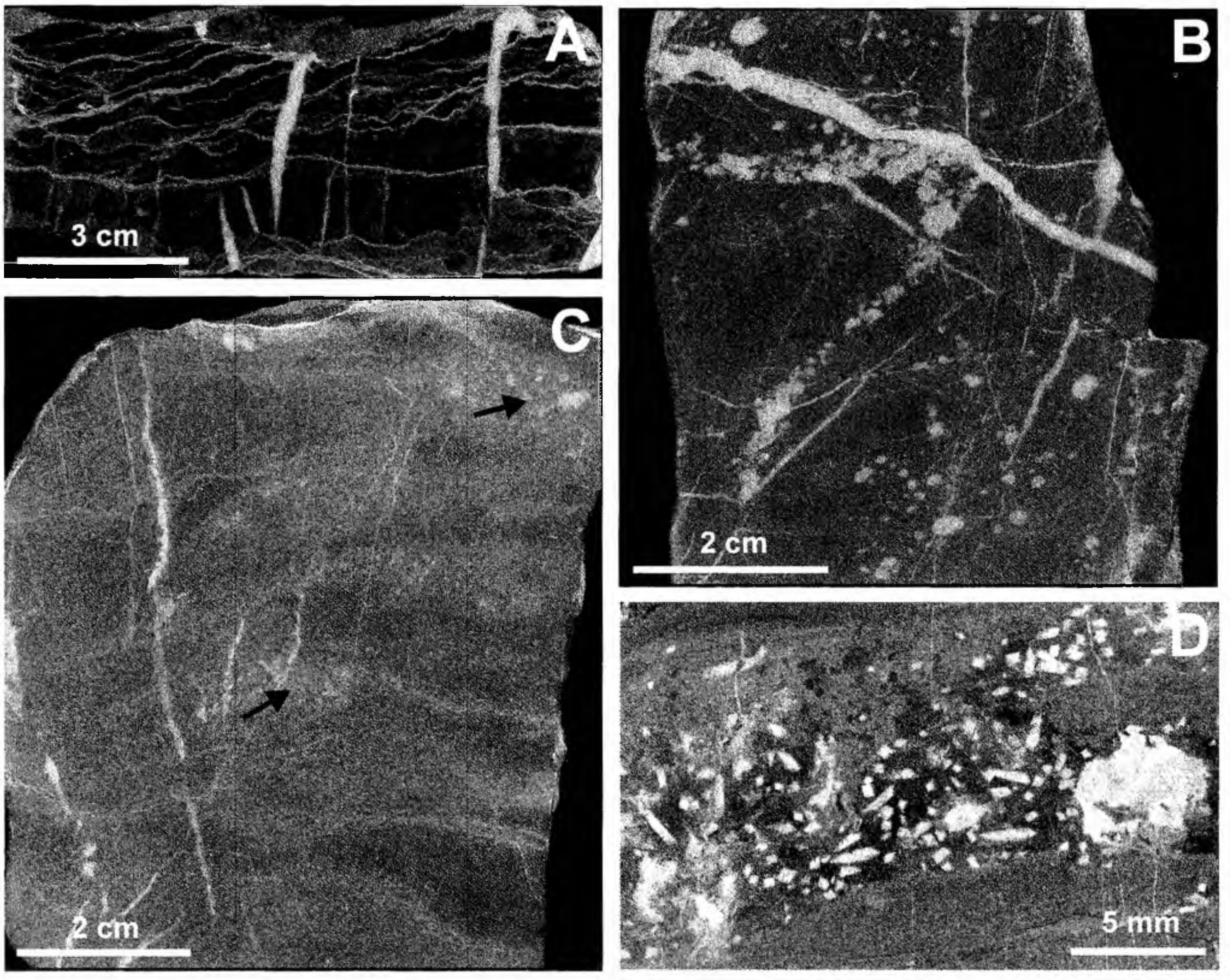

Fig. 8. Chosen facies and microfacies aspects of the Unit 4. **A.** Bioturbated, vermicular limestones. Note the partly slumped upper part of the layer. **B.** High concentration of celestite aggregates (pseudomorphs) within lime host sediments. Note the sulphate nodules lining sigmoidally bent structures (infaunal burrow?). **C.** Faintly laminated, partly disturbed dololutitic sediments. Note occurrence of sulphates (celestite) within deformed parts (arrows). **D.** Detail of C. Calcite pseudomorphs after displacive crystals and nodules of celestite

Unit 9 – Sequence L2

The last middle Triassic unit distinguished in the Kominiarski Wierch section shows a similar lithological succession as the preceding one, although it is much thicker and reaches 135 m. Like the underlying three previous units also the last one comprises common deformations indicating synsedimentary tectonic activity (Fig. 11C). Some firmground horizons developed within this unit mark nondeposition intervals (Fig. 11E).

The boundary of the L2 sequence is the topmost part of the cracked dolomites from the Unit 8.

DISCUSSION ON THE DEFINED DEPOSITIONAL SEQUENCES

The distinguished genetic units represent stacks of shallowing upward cycles and we interpret them as the 3rd order depositional sequences (see Fig. 4).

In order to check eustatic controls on the defined sequences we compare them with the sequences determined in other parts of the Western Tethys Ocean. As has already been mentioned, the chronostratigraphic subdivision of the Tatricum Triassic is very vague. Nonetheless, there are three intervals with better established stratigraphic position. The first one (sequence A1) is dated according to crinoids (*Dadocrinus gracilis*), and the other ones (sequences A3 and A4) are dated by means of foraminifers and diplopores, respectively. Using these three reference horizons we have found a reasonable conformity between the presented sequence stratigraphic pattern and its stratigraphically better positioned counterparts from the Northern Alpine Basin (Fig. 4). This, in turn, provides a unique opportunity to refine the chronostratigraphic framework for the Tatricum Triassic by way of comparing setting of the obtained sequence stratigraphic scheme with the synthetic sequence stratigraphic framework constructed for the Northern Alpine Basin (Rüffer & Bechstädt, 1996). As presented in Figure 4, the number and thickness of the sequences (used as very rough expression of time) in the Tatricum Basin are similar to the mentioned counterpart (cf. Rüffer, 1995), despite significant facies diversity.

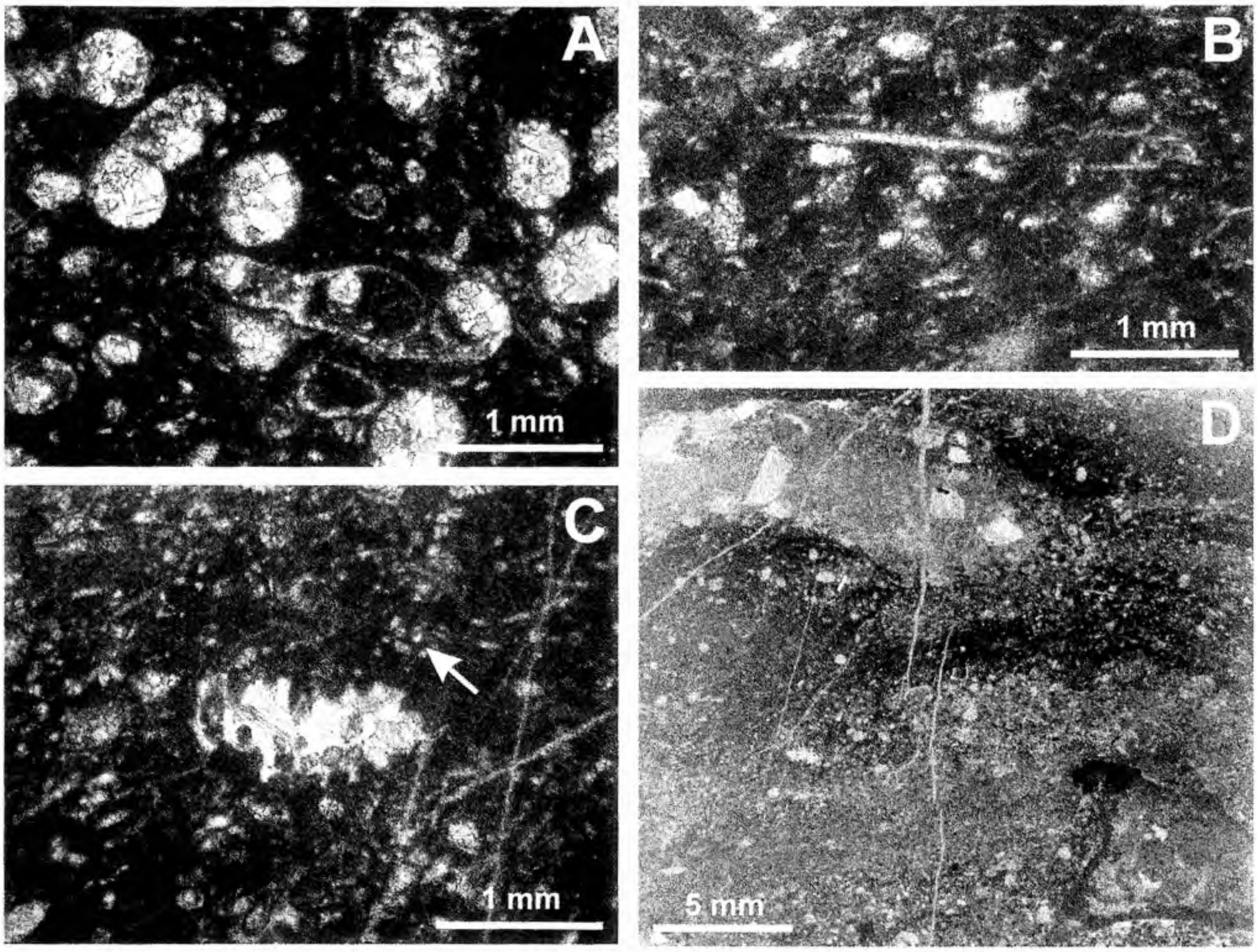

Fig. 9. Microfacies of the Unit 5, lower part. **A.** Bioclastic limestone composed of dwarf gastropods. **B.** Sponge spicules within micritic matrix. **C.** Micritic limestones with spicules and bored crinoid columnalium. Note calcite chips derived from bored trochite (arrow). **D.** Bioturbated micritic limestones with mummified remnant of sponge colony (lower right). Note also pseudomorphs after celestite within the burrow

We are not yet going to differentiate definitely other features of the depositional sequences, such as systems tracts or maximum flooding surfaces. More detailed resolution of the sequence stratigraphic framework needs further studies concerning the lower-order depositionary cycles, palynofacies analysis, and advanced geochemical examination.

SMALL-SCALE CYCLES

Within the distinguished main units one may also determine meter-scale cycles, reflecting short-time environmental changes. Some of the cycles reflect changes in oxygen availability. The best example of such fluctuation are the interbedded laminated and bioturbated (vermicular) limestones, already observed by Kasiński *et al.* (1978). The undisturbed parts represent periods of oxygen deficiency

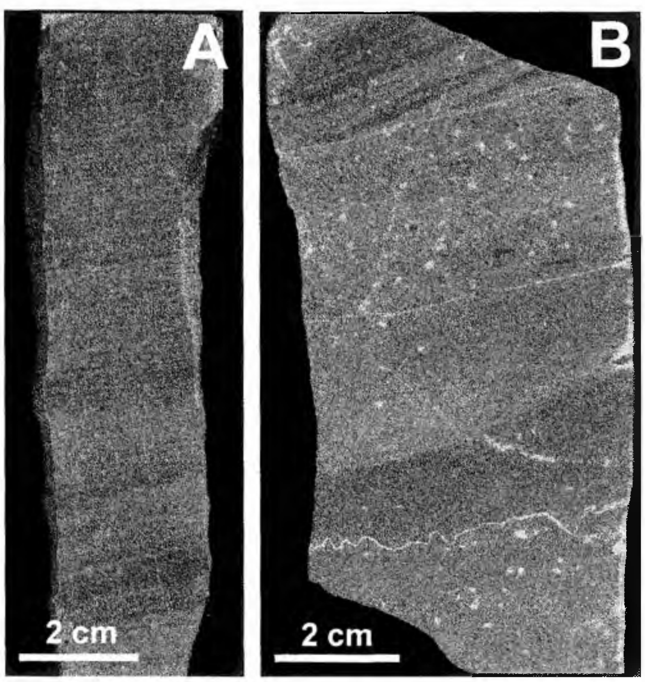

Fig. 10. Tempestites. Unit 5, upper part. **A.** Low-angle HCS within calcisiltitic limestones. **B.** Amalgamated tempestitic beds

whereas the vermicular fabrics originated during oxic amelioration in the bottom zone. Longer lasting oxic conditions resulted in the appearance of benthic organisms like crinoids and bivalves. These fluctuations reflect a changeable circulation regime between the open ocean and the Tatricum Basin. The circulation might have been controlled either by eustatic pulses or by local factors (e.g., tectonics). Hence, their direct interpretation as parasequences could be precarious.

Other short-time cycles, such as thickening-upward tempestite sets occurring within the Units 5 and 6, or limestone-dolomitic couplets from the Unit 4 are most probably parasequences.

It is worth to note that the frequent occurrence of storm deposits within the Units 5 and 6 (Pelsonian) suggests some overall climatic fluctuations, probably related to migration of the tropical storm pathway over the Western Tethys Ocean in Triassic times.

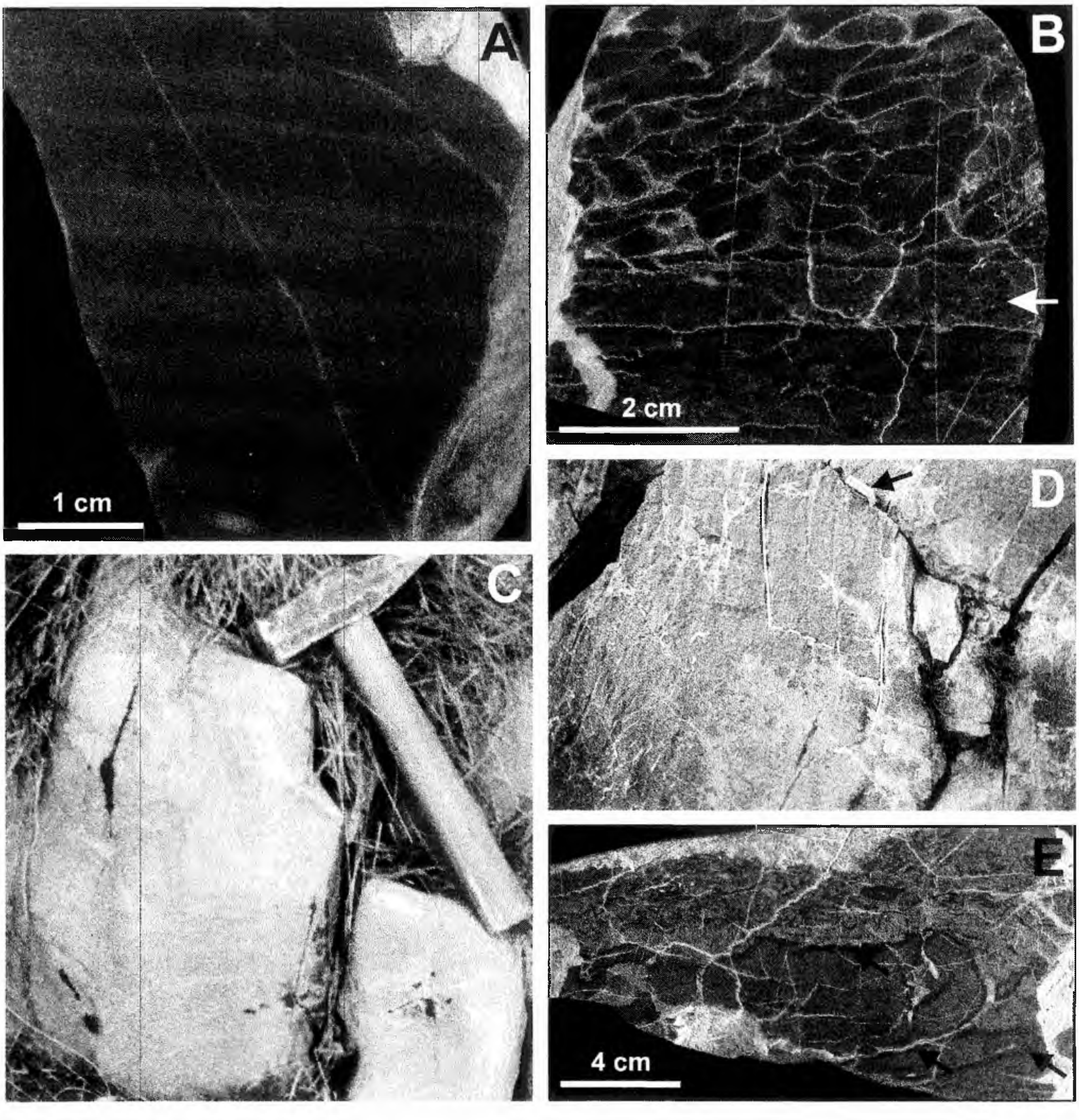

Fig. 11. Chosen sedimentary and deformational structures of the Units 7 and 9. **A.** Typical banded limestones formed most probably as tidal deposits. Unit 7. **B.** Two bioturbated vermicular horizons intermittent by storm layer (arrow). Unit. 7. **C.** Synsedimentary deformation. Grading of deformation style (brittle fractured bottom part and plastically failed upper part) evidences quake-related origin of the structure. Unit. 9. **D.** Synsedimentary, step-sided faulting in the Unit 7. Match box for scale (arrow). **E.** Firmground horizon, partly disintegrated (after seismic shock?) and covered by intraclasts (tsunamite ?). Note the dark, pyrite-rich lining of the burrows (arrows). Unit. 9

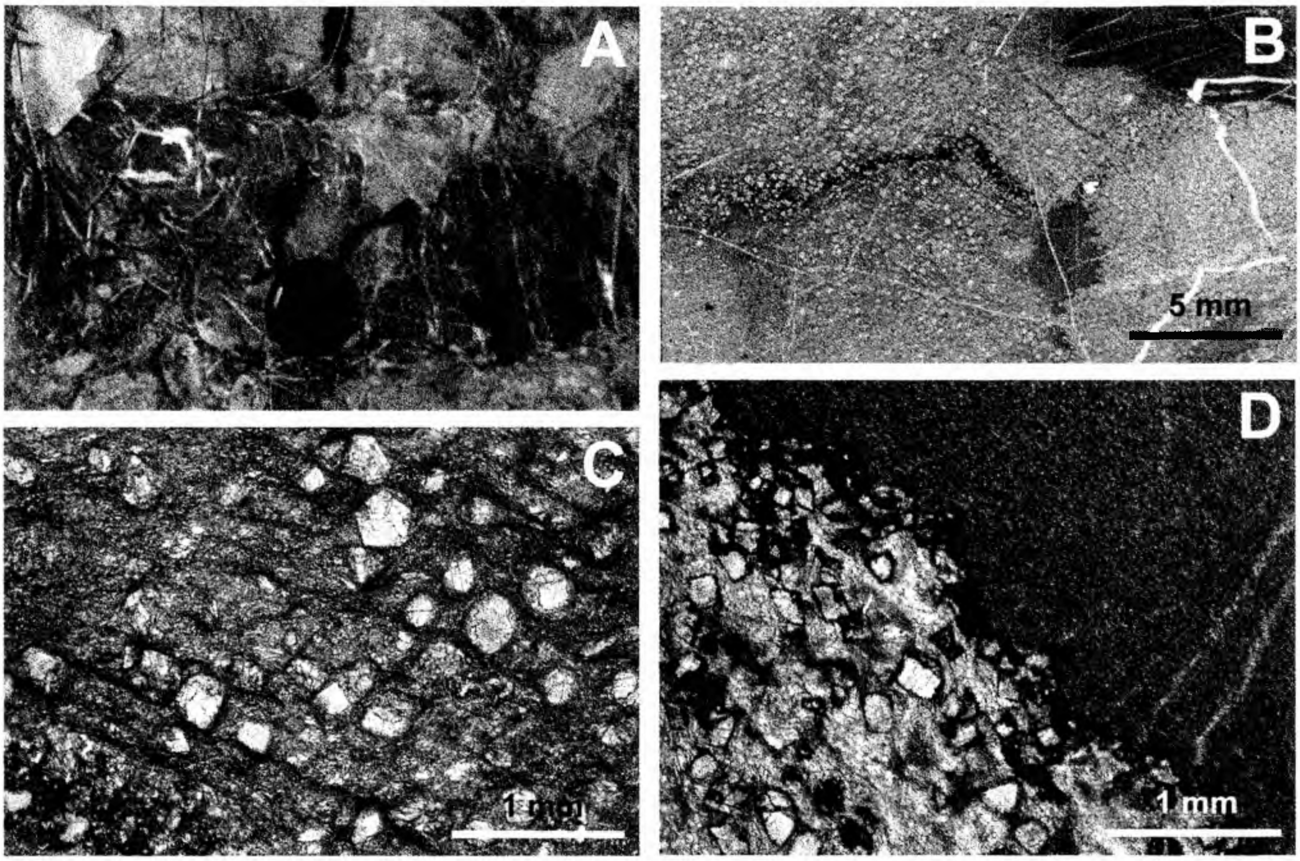

Fig. 12. Metasomatic dolomitisation in the Unit 9, top part. **A.** Jointed and dolomitised (light coloured fields) dark limestones. **B.** Slab of the dolomitised micritic limestones. Note pervasive style of dolomitisation and linear-oblique arrangement of neomorphosed dolomite crystals, indicating uniaxial shearing motion. **C.** Detail from B. Note the shear strain of the grains. **D.** Detail of the dolomitisation front along the limestone/dolomite boundary

GEOCHEMICAL PROXIES OF THE BASIN EVOLUTION

STABLE ISOTOPE SIGNALS

Preliminary results of the stable isotope examination from the section indicate rather stabilized geochemical conditions although one may distinguish some intervals displaying shifts related to paleoenvironmental changes (see Fig. 3).

The Unit 2 shows positive shift followed by rapid fall both in $\delta^{13}C$ and $\delta^{18}O$ signals. This reflects an evaporitic enrichment followed by water refreshing due to an input of meteoric waters. Since the decrease concerns dolomitic sediments, one may infer also a meteoric-driven dolomitisation of the Scythian limestones.

Distinctive positive shift of $\delta^{13}C$, accompanied by decrease in $\delta^{18}O$ visible in the Unit 3, may be plausibly interpreted as a consequence of rapid transgressive influx of normal, cooler marine waters. Appearance of benthic fauna (including crinoids) confirms such an inference.

The subsequent gradual enrichment in heavy isotopes seems to be related to evaporitic fractionation under stagnant conditions what is consistent with faunal recede and frequent pseudomorphs after evaporites.

The pronounced karstification at the top of the Unit 5 is recorded in striking negative excursion visible in both isotopes. Despite of it, the observed lighter (compared to the Unit 5) isotope values of the overlying Unit 6 mark, along with fauna reappearance, a next marine incursion. The part of the isotope curves encompassing the Unit 7 and 8 reflects again an evaporitic enrichment under stagnant conditions.

A conspicuous negative shift in $\delta^{18}O$, accompanied by opposite trend in $\delta^{13}C$ found in the topmost part of the section, is related to hydrothermal activity recorded also by pervasive metasomatic dolomitisation (Fig. 12; Jaglarz & Piszczek, 2000). It is not quite clear yet if the metasomatic fluids were expelled during the late Triassic rifting, or they accompanied the thrusting motion in Cretaceous time. The hydrothermal dolomitisation has been already reported by Kotański and Bełka (1979) in the studied area, however, they did not pinpoint any specific part of the section that underwent the process.

CELESTITE MINERALISATION

Owing to inclination of the Tatricum Basin toward stagnant conditions, the carbonate sedimentation was frequently accompanied by sulphate precipitation. No preserved sulphate minerals have been found so far. The dolomites and limestones comprise mostly calcite pseudomorphs after the displacive crystals and/or aggregates of sulphate minerals.

It is worth noting that between the pseudomorphs, those after celestite are particularly ubiquitous (Figs 8B–D). Celestite (or its pseudomorphs) is reported from the Triassic of the Tethys domain (Scherreiks, 1970; Kranz, 1973) and the Germanic Basin (Riech, 1978; Szulc, 2000). Since the precipitation of celestite from marine waters proceeds in early phase of brine evolution, that is, inbetween the carbonates and Ca-sulphates precipitation (Müller, 1962), its presence indicates that the brine was moderately saline. This also explains the common occurrence of celestite within the limestones including as well benthic fossils.

Potential sources of strontium to precipitate as celestite are manifold (see Warren, 1999). In the discussed case the origin of celestite as a by-product of the conversion of aragonite to calcite under restricted circulation seems to be very probable (cf. also Szulc, 2000). This process might have been particularly effective in the Triassic Aragonitic Ocean (Sandberg, 1983).

THE TRIASSIC FROM THE TATRICUM AND NORTHERN ALPINE BASINS – SIMILARITIES AND DIFFERENCES

There is a clear difference in evolution of the Tatricum and Northern Alpine Basins during their middle Triassic history. The difference depends essentially on more or less persistent platform geometry of the Tatricum Basin through the entire middle Triassic phase, whereas the Northern Alpine Basin underwent a more complex reconstruction leading to platform disintegration already by the end of the Anisian.

Generally, the initial phase of platform sedimentation was very uniform in both basins. During the late Scythian (Spathian) a mixed clastic, carbonate and evaporitic sedimentation predominated. Fossil-poor, bituminous limestones, alternated with clastics and postevaporitic vuggy dolomites (rauhwacken) typical of the upper Werfen and Reichenhall Formation (Campilian; see e.g., Tollmann, 1976), are common feature of all the compared basins. The facies uniformity continued also in early Anisian time when fine-grained, dark limestones and dolomites of the Gutenstein and Steinalm facies types prevailed.

In middle and late Anisian time, the Northern Alpine Basin underwent vigorous rifting (Schlager & Schöllnberger, 1974; Bechstädt *et al.*, 1978; Brandner, 1984) and transformation from platform to distally steepened ramp geometries (Rüffer, 1995). This resulted in contrasting facies pattern, including in the Northern Calcareous Alps both shallow-water carbonates (Wetterstein Formation) and basinal sediments (Reifling Formation and Partnach Formation). By contrast, the Tatricum Basin remained a flat platform area and, hence, the shallow water sedimentation and facies style continued up to the end of Ladinian. It is also noteworthy that both the Anisian and Ladinian deposits in the Tatricum platform are completely devoid of thicker clastic fraction. This indicates, in turn, that the platform was isolated from a possible direct terrigenous influx.

SYNSEDIMENTARY TECTONIC ACTIVITY

The examined succession contains some evidences for a synsedimentary tectonic mobility in the region, like small neptunian dykes and synsedimentary faults that occur from the 6th Unit onwards (Fig. 11D). In the uppermost part of the section, the brittle deformations were accompanied also by slump and sliding deformations (Fig. 11C). This suggests that the regional reconstruction of the Tatricum platform began as early as in Ladinian time. However, discussed the deformations are only a faint echo of the much more intense movements within the main rifting zone (see the above discussion). The platform destruction initiated in middle Triassic time progressed and intensified in the late Triassic and finally climaxed in early–middle Jurassic times (Radwański, 1959; Dumont *et al.*, 1996; Łuczyński, 2001).

CONCLUSIONS AND FINAL REMARKS

The Middle Triassic Tatricum Basin was situated upon an isolated and restricted carbonate platform dominated by shallow-water carbonate and evaporitic sedimentation.

The basin evolution was similar to that in the Northern Alpine Basin up to middle Anisian time. While the Alpine platform started to disintegrate from late Anisian onwards, the Tatricum Basin remained a shallow restricted platform. The platform was controlled by eustatic fluctuations. Weak tectonic movements first started in the late Ladinian.

Owing to negligible local tectonics we have assumed that the essential changes in sedimentary features were mainly controlled by eustatic fluctuations. The fluctuations are reflected in several shallowing-upward cycles. As a rule, the cycles begin with normal marine, fossiliferous limestones (transgressive deposits) that are gradually succeeded by sediments formed under more restricted conditions, that is dysoxic limestones and/or dolomites with sulphates.

These cycles as interpreted in terms of sequence stratigraphy as representing typical 3rd order depositional sequences. The defined sequence stratigraphy for the Tatricum Basin corresponds well with the Northern Alpine Triassic sequence stratigraphy. Therefore, sequence stratigraphy has been applied as a useful tool to chronostratigraphic refinement of the Triassic in the Tatra Mts.

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Streszczenie

EWOLUCJA I STRATYGRAFIA SEKWENCYJNA ŚRODKOWEGO TRIASU BASENU TATRICUM NA PODSTAWIE BADAŃ JEDNOSTKI WIERCHOWEJ TATR POLSKICH

Piotr Jaglarz & Joachim Szulc

Artykuł poświęcony jest rekonstrukcji paleośrodowiskowej oraz stratygrafii sekwencyjnej triasu środkowego jednostki wierchowej Tatr Polskich. Obiektem badań był profil osadów późnego scytyku i triasu środkowego odsłaniający się w rejonie masywu Kominiarskiego Wierchu (Fig. 1–3).

Jak wynika z przeprowadzonych badań sedymentologicznych i geochemicznych w środkowym triasie omawiany basen należał do izolowanej platformy węglanowej cechującej się okresami ograniczonej swobodnej cyrkulacji wód (Fig. 6, 11A). Sedymentacji węglanowej towarzyszyło wytrącanie ewaporatów występujących głównie w formie rozproszonej w obrębie wapieni i dolomitów (Fig. 5, 7B, 8). Z okresami polepszającej się cyrkulacji między otwartym oceanem, a omawianym basenem było związane pojawianie się organizmów bentonicznych (Fig. 9, 7E, F, 11B). Analizowany basen z facjami typowymi dla środowisk o niskiej energii, był poddawany jednak silnym wpływom sztormów subtropikalnych (Fig. 7A, 10).

Głównym czynnikiem kontrolującymi rozwój basenu były eustatyczne wahania poziomu morza. Początki ruchów tektonicznych miały miejsce dopiero w późnym ladynie (Fig. 11C–E, 12).

Omawiana sukcesja osadowa złożona jest z szeregu cykli płyciejących ku górze, które to cykle zostały zinterpretowane jako sekwencje depozycyjne trzeciego rzędu (Fig. 4). Skonstruowany schemat stratygrafii sekwencji koresponduje bardzo dobrze z odpowiednim schematem sekwencji z obszaru alpejskiego (Fig. 4) co z jednej strony potwierdza jego prawidłowość, a z drugiej strony umożliwia wykorzystanie tegoż schematu do ustalenia chronostratygrafii triasu w jednostce wierchowej.