Pan-European Correlation of the Epicontinental Triassic
4th Meeting

INTERNATIONAL WORKSHOP ON THE TRIASSIC OF SOUTHERN POLAND

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FIELDTRIP GUIDE

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Scientific Programme Schedule

First Day (4th September)

STOP I. 1. Gogolin – *Röt – Lowermost Muschelkalk (Lower Gogolin Beds)*
STOP I. 2. Tarnów Opolski – *Upper Terebratula Beds-Karchowice Beds*
STOP I. 3. Strzelce Opolskie – *Upper Gogolin Beds-Gorazdze Beds-Terebraula Beds-Karchowice Beds*
STOP I.4. Krasiejów – *Steinmergelkeuper*
STOP I. 5. Lipie Śląskie – *Steinmergelkeuper and Wozniki Limestone*
STOP I. 6. Napłatki – *Górażdze Beds*
STOP I. 7. Kamień Śląski – *Karchowice Beds-lower Diplopora Beds*

Second Day (5th September)

STOP II. 1. Libiąż – *Karchowice Beds – Diplopora Beds – Tarnowice Beds*
STOP II. 2. Podstoki gully near Płaza – *Middle Bunstandstein – Lower Röt*
STOP II. 3. Płaza – *Röt – Lower Muschelkalk*
STOP II.4. Stare Gliny – *Lower and Middle Muschelkalk, Upper Keuper, Lower Jurassic*

Third Day (6th September)

STOP. III. 1. **Laryszów –** *Upper Muschelkalk – Boruszowice Beds*
STOP III. 2. Żyglin – *Lower Gogolin Beds*
STOP III. 3. Cynków – *Wozniki Limestone (Norian)*

Fourth Day (7th September)

STOP. IV.1. **Zygmuntówka** - Permian conglomerates
STOPS. IV.2 and IV.3. Tumlin-Gród quarry and Sosnowica quarry – *Lower Buntsandstein aeolian sandstones*
STOP. IV.4. Zachełmie – Paleozoic/Triassic disconformity
STOPS. IV.5 and IV.6. Kopulak and Baranów – *Upper Buntsandstein fluvial depositional systems*

Fifth Day (8th September)

STOP. V.1. Czerwona Góra – *Lower Buntsandstein fluvial depositional system*
STOP. V.2. Witulin - *Röt –Muschelkalk transition*
STOP. V.3. Wióry – *Middle Buntsandstein fluvial deposits*
STOP. V.4. Museum of Nature and Technology at Starachowice - Ichnofauna and other fossils of Buntsandstein

Structural setting of the Germanic Triassic and problems with its stratigraphical setup
A preface

Joachim Szulc

During Triassic times the Germanic Basin was situated at the northern periphery of the Western Tethys Ocean hence this basin is called also Northern Peritethys Basin.

The Polish part of the Germanic Basin was strongly influenced by inherited Variscan structures which controlled the basin differentiation and subsidence pattern in Triassic times. The Mid Polish Trough, that played the role of the main depocentre, was controlled by the Teisseyre-Tornquist Line (TTL). The TTL gave also rise to the East Carpathian seaway communicated with the Tethys Ocean since Olenekian time. The other important faults were the Silesian-Moravian Fault forming another gateway and the Cracow – Odra- Hamburg Fault where another depocentre developed (Fig. 1). In the western part of the basin the main role played the Elbe Fault (EF) and the Saxothuringian Lineament (STL) while the NW part of the basin was influenced by the North Sea rifting belt.

Synsedimentary tectonics resulting in structural differentiation of the Germanic Basin was active practically throughout the entire Triassic. In Lower Triassic several phases of block tectonics resulted in basinwide unconformities for instance the Volpriehausen unconformity in the NW part of the basin. Basinwide tectonic activity during Middle Buntsandstein again dominated by block faulting resulted in two regional unconformities; the Detfurth and Hardegsen discordances. The latter can be correlated from the Netherlands and N Germany to central Poland. At the same time, the subsidence rate of the Mid Polish Trough (MPT), superimposed upon the Teisseyre – Tornquist Lineament, increased threefold, when compared to the rate for the Lower Buntsandstein (see Becker & Nawrocki, this volume).

Migration of the Muschelkalk depocentre in Mid Triassic times from Central Poland to Central Germany is another example illustrating well the crustal mobility (Szulc, 2000).

Differentiated crustal movements featured also the late Triassic when in Carnian times intensive rifting occurred in NW Germany (Frisch & Kockel, 1999) whereas the southern and eastern subbasins stayed intact. In contrast, during deposition of the Schilfsandstein did rifting occur across the whole basin, giving the concurrent up and down block movements. As a result the Schilfsandstein anastomosing fluvial channels were superimposed upon the graben network while the uplifted blocks were eroded, resulting in prominent local unconformities (Dittrich, 1989).

Vigourous translatory faulting in Norian times, produced an unconformity between the Middle and Upper Keuper successions. The strike-slip faulting is documented by the flower-like pattern of faults common in the Norian succession (Deczkowski & Gajewska, 1977; Frisch & Kockel, 1999). Finally, some additional, tectonically induced unconformities have been defined in the Rhaetian sequences in Germany (see also overview by Beutler, 2005).

Apart from the unconformities, there are numerous direct evidences of syndepositional crustal mobility such as small synsedimentary faults and dilation cracks that developed within the Triassic deposits and reached the basement rocks (Głazek & Roniewicz 1976) or seismically-induced liquefaction and fluidisation, are common features in Buntsandstein clastics sediments (Schüler *et al.,* 1989). Seismically-induced synsedimentary deformations are particularly common in the marine Muschelkalk carbonates (Szulc, 1993; Dualeh, 1995; Voigt & Linnemann, 1996; Rüffer, 1996) and in Upper Triassic deposits (Szulc, 2005; Szulc *et al.,* 2006) (see also Fig.38).

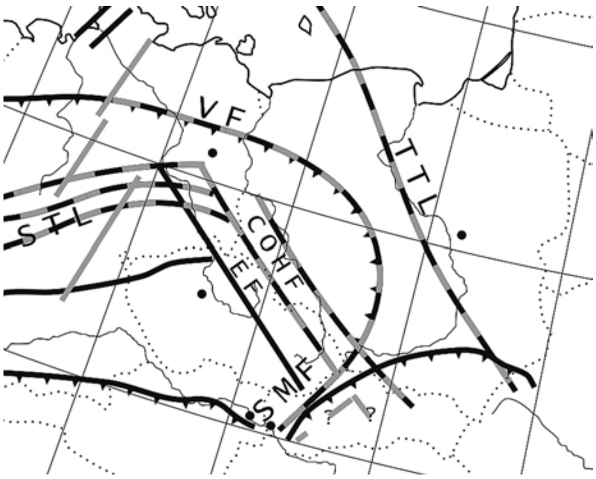


Fig. 1. Principal tectonic elements controlling the eastern part of the Germanic Basin in Triassic times. TTL – Teiseyere-Tornquist Line, VF – Variscan orogenic front, SMF – Silesian-Moravian Fault; COH – Cracow-Hamburg Fault line; EF – Elbe Fault; STL – Saxothuringian Lineament

In spite of the intense tectonic activity the main eustatic pulses in the Triassic are generally well seen in the Peri-Tethys basins, in particular for the late Olenekian – early Carnian interval. Significant progress of sequence stratigraphy and magnetostratigraphy has improved the potential and reliability of dating and correlation of the most pronounced transgressive-regressive pulses recognized in the area. The sequence stratigraphic frameworks from the Alpine and Germanic basins display good correlation at the level of 3rd order sedimentary sequences (see discussion in Szulc, 2000).

In addition to 3rd order depositional cycles, higher frequency cycles (4th and 5th order) have also been studied in the Triassic of Central Europe. Most of these high-frequency cycles are ascribed to Milankovitch orbital rhythms of different periodicity and they have been used for construction of chronostratigraphic scale of the Germanic Triassic and for further-going inferences including those about the stratigraphic boundaries (see discussion in Bachmann & Kozur, 2004).

However, the *a priori* assumed orbitally-driven cycles have not been verified by means of radiometric age dating. We should still bear in mind that Milankovitch cyclicity was similarly considered responsible for the high-frequency sedimentary cycles in the Middle Triassic carbonates of the Dolomites (Goldhammer *et al.*, 1987), but this has been totally disproved by detailed ammonoid examination and, first of all, by radiometric age data (Mundil *et al*., 2003). Therefore, the Triassic cycles in the Germanic domain, where no one radiometric age datum exists until now (**!**), should be treated cautiously, and for time being, the more far-reaching inferences seem to be purely speculative. Caution is especially needed because the Germanic Basin has been strongly influenced by non-cyclic phenomena such as storms and/or above discussed vigorous synsedimentary tectonism, which might have overprinted or even obliterated shorter-term climatic signals. In addition, the continental sedimentary successions, prevailing in the Lower and Upper Triassic, are poor in age-diagnostic fossils, what makes all the cyclostratigraphic speculations very doubtful.

Conclusion

It seems that considering the above outlined correlation hindrances, the Triassic of the Germanic Basin needs far-reaching, detailed sedimentological studies. I have an impression, that there is a major discrepancy between the basic understanding of the main controls of the "sedimentary factory" featuring the basin and the hypothetical cyclostratigraphical constructions. Certainly the better sedimentological recognition along with further progress in the bio-, magneto- and chemostratigraphy seem to be the most promising way for the reliable chronological, (i.e. stratigraphic) reconstruction of evolution of the entire Germanic Basin.

BUNTSANDSTEIN

Anna Becker, Jerzy Nawrocki

The results of Buntsandstein investigation in Poland were summarized by Szyperko-Teller et al. (1997) with references cited there. The following text is partly based on this work.

General setting

The Buntsandstein basin of Poland built the eastern part of the Central European Basin. The southeastern and eastern margin of the CEB was situated in Poland, whereas its north-eastern margin was located further to the north in Lithuania. The southeastern limit of the CEB stretches as far as the Holy Cross Mountains in Poland. The Buntsandstein sediments crop out only on small areas of basin margins including Holy Cross Mountain region, Upper Silesia and Sudetes. The main part of the basin was investigated in numerous boreholes.

The Buntsandstein of Poland in rank of a Group, was subdivided into three Subgroups of Lower, Middle and Upper Buntsandstein, called also „ret" from the German term „Röt". The sedimentary basin of the Lower Buntsandstein occupied an area situated beyond the reach of the relict basin of the uppermost Zechstein. In general the Lower Buntsandstein was formed of fine-grained clastic deposits of clayey and silty type, calcareous in places, sometimes with anhydrite nodules, with inserts of oolitic limestones or oolitic-sandy limestones and silty limestones. Sandy sediments prevailed in the southern part of the basin (Fig. 2). The thickness of the Lower Buntsandstein ranged from under 100 m on the basin margin up to 400 m in the main depocentres of the basin. The thickness pattern of the Lower Buntsandstein was relatively clear (Fig. 3). The main depocenter was built by the Mid-Polish Trough stretched from Szczecin in the north-west to Łódź in the south-east. The smaller depocenter was built by the Lower Silesian Trough stretched west-east between Zielona Góra, Zgorzelec and Wrocław. Between both trough structures a Szczecin-Wolsztyn Swell was situated. The north-eastern part of the basin, located on the East European Platform built

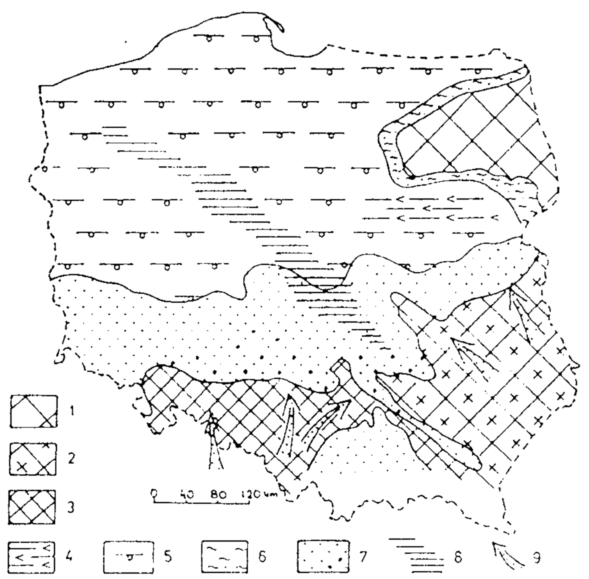


Fig. 2. Distribution of the Lower Buntsandstein lithofacies in the Polish basin, from Szyperko-Teller et al. (1997), modified

Fig. 3. Thickness pattern of the Lower Buntsandstein in Poland, from Szyperko-Teller *et al.* (1997), modified

also a swell structure named Pomerania-Masovia Swell. Southern of Lower Silesian Trough a Silesian-Częstochowa Monocline was subdivided. The southernmost part of the basin was built by the Kraków-Tarnów Low, situated under the alpine structures of Poland (Carpathian Foredeep, Outer Carpathians). The Buntsandstein sediments of this area were mostly eroded and were purely known. After Szyperko-Teller and Moryc (1988) the Lower Buntsandstein could have reached there up to 600 m in thickness.

The extent of the Middle Buntsandstein reached little further to the south and east than the Lower Buntsandstein, but not so far to the north. On the area of eastern part of the Polish sector of Baltic Sea only Lower Buntsandstein sediments were subdivided. A significant lithofacial differentiation was observed in the sediment succession of the Middle Buntsandstein (Fig. 4). The sediments of this succession were composed of few cyclothems mostly sandy or sandy-oolitic in the lower parts and fine-grained in the upper parts. Sandstone facies were the most common in the southern, north-western and north-eastern parts of the basin, especially in the upper part of the subgroup. Carbonates (oolitic and bioclastic limestones), which were present in the lower part of the subgroup, appeared in the western and north-eastern parts of the basin. At the end of the Middle Buntsandstein sedimentation the basin restricted itself to the axial part of the Mid-Polish Trough. Towards basin margins no sedimentation or even erosion proceeded. Significant thickness differences were characteristic for the Middle Buntsandstein of Poland as a result of a tectonic activity of the basement during the deposition of the Middle Buntsandstein and of the existence of a gap (Fig. 5). In the most part of the basin the thickness reached up to 200 – 300 m, but the maximal thickness reached the value of 1200 m in the south-eastern part of the Mid-Polish Trough. The thickness pattern was very similar to that one of the Lower Buntsandstein (Fig. 5). The main depocentre was the Mid-Polish Trough, which axe shifted slightly to north-east in comparison to its location in the Lower Buntsandstein

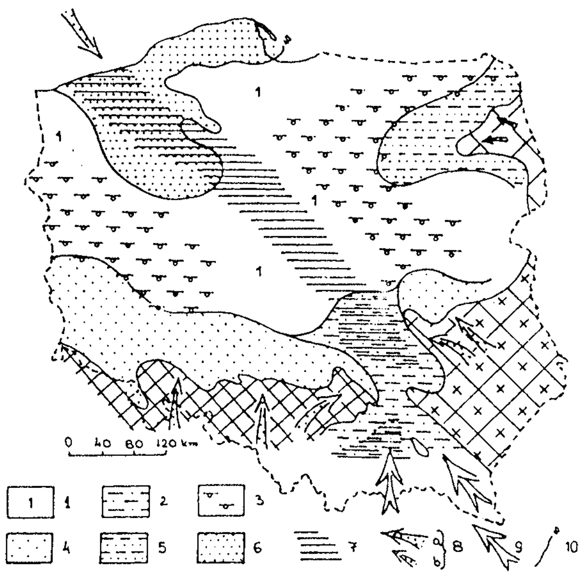


Fig. 4. Distribution of the Middle Buntsandstein lithofacies in the Polish basin in the earlier phase of sedimentation, from Szyperko-Teller *et al.* (1997), modified

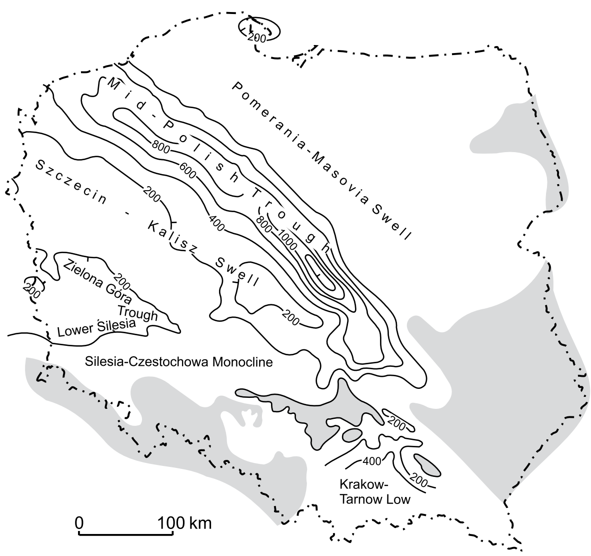


Fig. 5. Thickness pattern of the Middle Buntsandstein in Poland, from Szyperko-Teller *et al.* (1997), modified

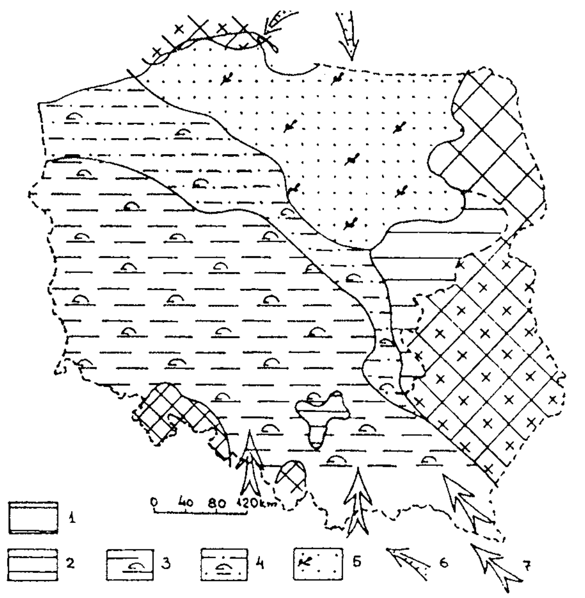


Fig. 6. Distribution of the Upper Buntsandstein lithofacies in the Polish basin, from Szyperko-Teller *et al.* (1997), modified

Fig. 7. Thickness pattern of the Upper Buntsandstein in Poland, from Szyperko-Teller *et al.* (1997), modified

basin. The Lower Silesian Trough extended further to the north. The axe of the swell between both troughs shifted to the north and the structure reached further to south-east and therefore it was named a Szczecin-Kalisz Swell. The north-eastern part of the basin located on the East European Platform was very stable and formed a Pomerania-Masovia Swell. In the southernmost part of the basin, formed by the Kraków-Tarnów Low, the thickness of the Middle Buntsandstein could have reached up to 400 m (Szyperko-Teller & Moryc, 1988).

The sedimentary basin of the Upper Buntsandstein developed as a result of ingression of the Alpine sea approaching from the south (Fig. 6). The thickness of the Upper Buntsandstein reached up to 200 m. The basin became dismembered in comparison to the thickness pattern of the Lower and Middle Buntsandstein (Fig. 7). The Mid-Polish Trough visibly lost its character. Instead of a distinct trough structure a few small depocentres were developed. The Lower Silesian Trough almost disappeared. The Szczecin-Kalisz and the Pomerania-Masovia Swells could be distinguished, but are indistinct because of the slightly thickness differentiation of the Upper Buntsandstein in the whole basin.

More detailed discussion is presented in the Röt – Muschelkalk chapter of this volume.

Stratigraphy and correlation with other Germanic subbasins

Lithostratigraphy

Because of the scarcity of fossils the lithostratigraphy was the main method used in Poland for the Bunsandstein sediments (Fig. 8). The lithostratigraphic subdivision based rather on facial development than on the cyclic development of sediments. Subdivision in formations and members was only partially formalized. The formalization especially succeeded in the north-western and north-eastern parts of the basin and in Mesozoic cover of the Holy Cross Mountains and adjacent regions.

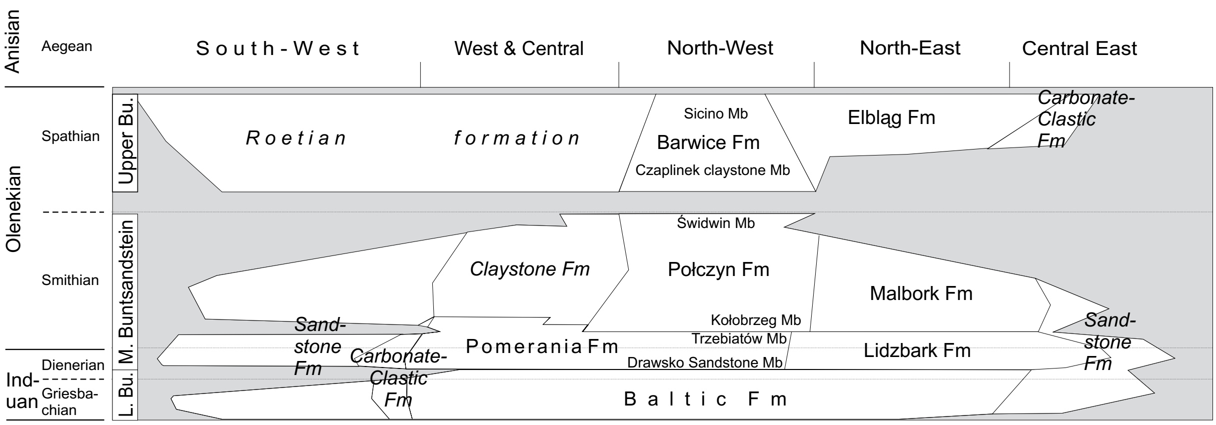


Fig. 8. Buntsandstein lithostratigraphy of the Polish Lowland, from Wagner (in press), modified

For the Lower Buntsandstein two formations were distinguished in the main part of the basin. The fine-grained sediments with oolitic intercalations were included in the Baltic Formation. Sandstone sediments with participation of siltstones and claystones which covered the southern part of the basin belonged to the informal Sandstone Formation.

In the Mesozoic cover of the Holy Cross Mountains, where the Lower Buntsandstein sediments cropped out, a detailed subdivision in formations and members were carried on (Kuleta, 2000; Kuleta & Zbroja, 2006; Fig. 9). In the far north-western margin of the Holy Cross Mountains the Opoczno Formation was distinguished in the lowermost part of the subgroup. It is built of clayey-silty heterolites with claystone, siltstone and sandstone intercalations as well as admixture of ooids. This formation is grading laterally towards the Paleozoic complex of the Holy Cross Mountains into Szczukowice, Siodła and Jaworzna formations. Siodła Fm is developed as reddish-brown siltstones with local sandstone and conglomeratic intercalations. Palaeosol horizons are very typical. Jaworzna Fm includes calcerous brownish-gray sandstones with heterolitic intercalations. Conglomeratic intercalations are also present, especially in the lowermost part of the unit, where Zachełmie Member was distinguished. Lithofacial development of the Szczukowice Fm is very variable. Intercalating sandstones, siltstones and claystones of brownish colors are typical for the lower part of the unit. Massive siltstones and claystones with bioturbation and pedogenic structures occur in the upper part of it. Zagnańsk Formation built the uppermost part of the Lower Buntsandstein in the region. It is formed of variable grained sandstones with conglomeratic intercalations included into the Czerwona Góra Member. Large-scale cross-bedded medium-grained sandstones were included into the Tumlin Member.

The lithostratigraphic subdivision of the Middle Buntsandstein (Fig. 8) was much more complicated than that of the Lower Buntsandstein. Two formations have been distinguished in the north-western part of the basin. A lower part of the Middle Buntsandstein contained deposits of the Pomerania Formation comprising two cyclothems with oolitic-sandstone lower member and the silty-clayey upper member. The basal coarser member of the Pomerania Formation was defined as Drawsko Sandstone Member. The whole upper cyclotheme was defined as Trzebiatów Member. The upper part of the Middle Buntsandstein was made up of the Połczyn Formation, composed of sandstones with siltstones and claystones. Within the Połczyn Formation two members were defined: Kołobrzeg Member in the lowermost part and Świdwin Member in the upper part of the formation. The extent of the Kołobrzeg Member was limited only to a small area in the north.

In the Middle Buntsandstein of the north-eastern part of the basin two formations have been distinguished as well. That included Lidzbark and Malbork formations, both comprising two consecutive megacyclothemes. The Malbork Formation constituted a typical sedimentary cyclotheme with a lower member represented by coarse-clastic sandy deposits and upper fine-clastic red member.

The remaining part of the Polish Lowlands was occupied by the formations of variable proportions of carbonate and clastic constituents, that were enclosed in informal lithostratigraphic units, such as the Sandstone Formation, Carbonatic-Clastic Formation, and Clayey Formation.

The subdivision developed in the north-western part of the basin became the most popular one in the lithostratigraphy of the Middle Buntsandstein of Poland.

For the Mesozoic cover of the Holy Cross Mountains a detailed subdivision into five formations was presented on the base of well and outcrop data (Kuleta, 2000; Kuleta & Zbroja, 2006; Fig. 9). The succession of the Middle Buntsandstein starts with the Goleniawy Formation. The unit is composed of fine-grained sandstones passing to the top into sandy oolitic-bioclastic limestones with heterolitic intercalations. Stachura Formation is composed almost entirely of clayey-silty-sandy-limy heterolites. The uppermost part of the succession is composed of Samsonów Formation, built of siltsones and claystones with clacerous and anhydritic nodules. In the lowermost part of the Samsonów Fm more sandy unit was distinguished as Cierchy Member. Described succession passes laterally into Piekoszów Formation (southwards) and Wióry Formation (towards south-east), built of sandstones with fine-grained intercalations.

The most part of the Upper Buntsandstein basin in Poland was covered by the informal Roetian Formation, composed of carbonates and evaporates, only in the lowermost part of clastic sediments (Fig. 8). The most popular informal subdivision of the formation included: sub-gypsum beds, lower gypsum beds, intra gypsum beds, upper gypsum beds and supra-gypsum beds. Clastic sediments of the Upper Buntsandstein of the north-western part of the basin were included in the Barwice Formation, whereas in the north-eastern part Elbląg Formation and informal Carbonate-Clastic Formation were distinguished. In the Barwice Formation two fine-grained members were subdivided: Czaplinek Claystone Member (correlated with the lower gypsum beds) in its lower part and Siecino Member in its uppermost part.

The Upper Buntsandstein of the Mesozoic cover of the Holy Cross Mountains was developed as Roetian Formation in the western and north-western part of the region. In the north-

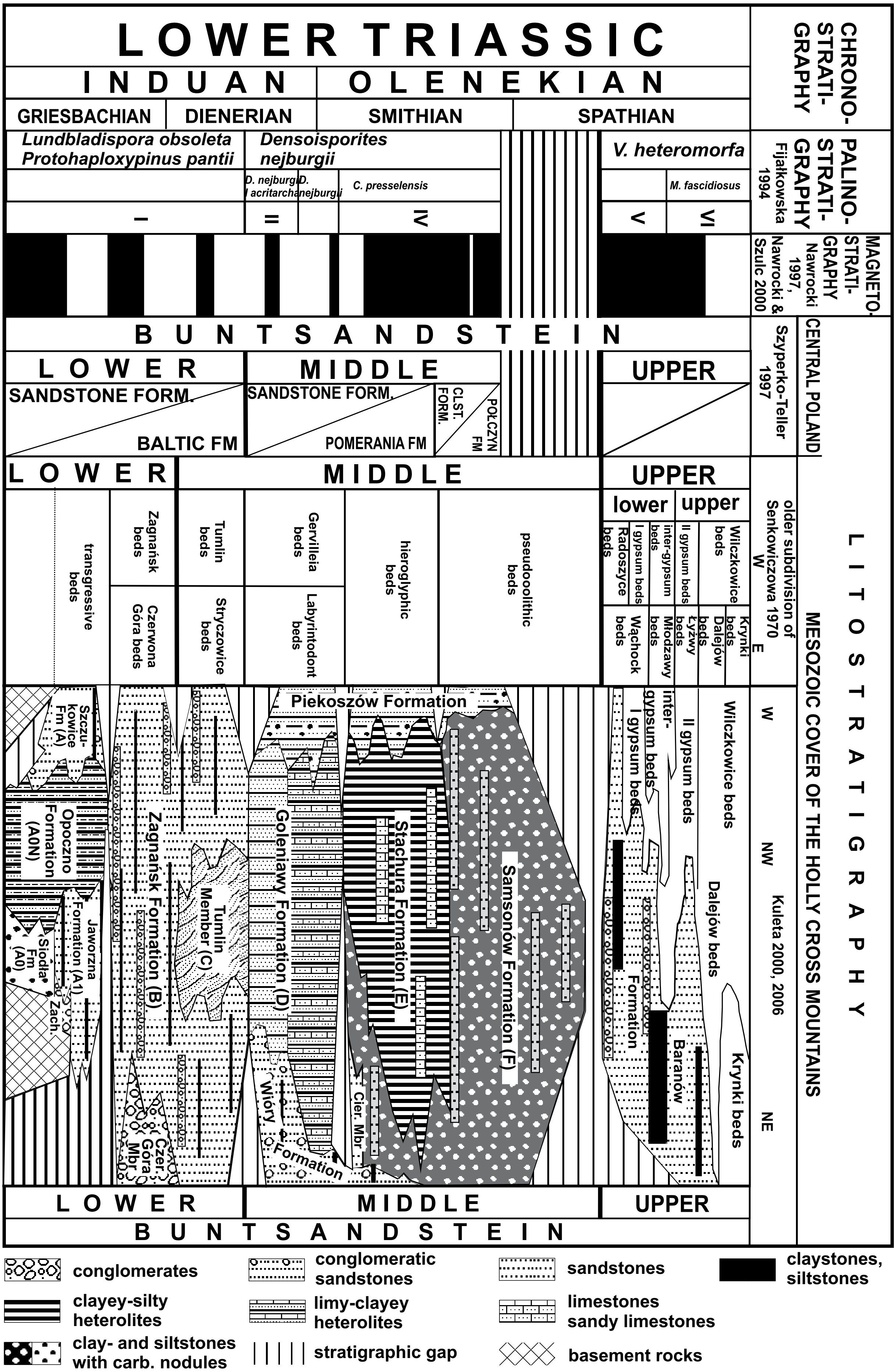


Fig. 9. Buntsandstein stratigraphy of the Holy Cross Mountains region, from Kuleta and Zbroja (2006), modified. A0, B – symbols of litostratigraphic complexes distinguished earlier by Kuleta

eastern part it was represented by clastic red deposits included in the Baranów Formation (Kuleta, 2000; Kuleta & Zbroja, 2006; Fig. 9).

The correlation of the lithostratigraphic subdivisions of Buntsandstein of different Poland regions was presented on Figs. 8 and 9.

Biostratigraphy

Scarcity of fossils and lack of index fossils were characteristic for the Buntsandstein of Poland and of the whole Central European Basin. Nevertheless biostratigrphic research was carried on very carefully in Poland especially in the term to correlate lithostratigraphic units within the basin. The best results were brought by palinostratigraphy based on miospores and megaspores. Other stratigraphically useful group of organisms were ostracodes. In the last years vertebrate tracks and conchostraca were used for preliminary stratigraphic interpretation.

Orłowska-Zwolińska (1977, 1984) established three miospore-zones within the Buntsandstein section on the base of the data from core sections of western, central and north-eastern Poland (Fig. 10). The assemblage zone *Lundbladispora obsoleta – Protohaploxypinus pantii* was distinguished in the lower part of the Lower Buntsandstein. The absence of the Upper Permian index species (*Lueckisporites virkkiae* Potonie *et* Klaus) and the presence of species of genera *Lundbladispora* (*L. obsoleta*, *L. willmotti*) and *Densoisporites* allowed to interpret Triassic age of the zone. The zone corresponds after Orłowska-Zwolińska (1984) to the association *Protohaploxypinus* (Balme, 1979) of Griesbachian age. The second assemblage zone, the zone *Densoisporites nejburgii*, was distinguished in the lower to middle part of the Middle Buntsandstein (Pomerania to lowermost Połczyn formations). This zone was subdivided into three subzones: PI *Densoisporites nejburgii* – Acritarcha with low frequency of miospores and abundant occurrence of acritarchs (*Micrhystridium* spp., *Verychahium* spp.), PII *Densoisporites nejburgii* dominated by *Densoisporites nejburgii* (Schulz) Balme and PIII *Densoisporites nejburgii – Cycloverrutriletes presselensis* characterized by regular occurrence of *C. presselensis* beside the species of genera *Densoisporites* and *Lundbladispora*. The age of the zone could not be precisely determined. It was interpreted as late Induan (Dienerian) to Olenekian. The third assemblage zone, the *Voltziaceaesporites heteromorpha* zone, was distinguished in the Upper Buntsandstein strata. Characteristic for the zone is domination of pollen grains over spores. The spores *Densoisporites nejburgii* are either absent or rare. Note worthy is the occurrence of pollen grains *Microcachryidites* in the upper part of the zone. The age of the zone was not definitively determined. The zone could be of Olenekian (Spathian) age or of Anisian age. It is also possible, that the lower part of the zone is of Olenekian age and the upper part with *Microcachryidites* pollen grains is of Anisian age.

Fijałkowska (1994) established a palynostratigraphic scheme for the Lower and Middle Buntsandstein of the Mesozoic cover of the Holy Cross Mountains (Fig. 9). She distinguished the *Lundbladispora obsoleta – Protohaploxypinus*

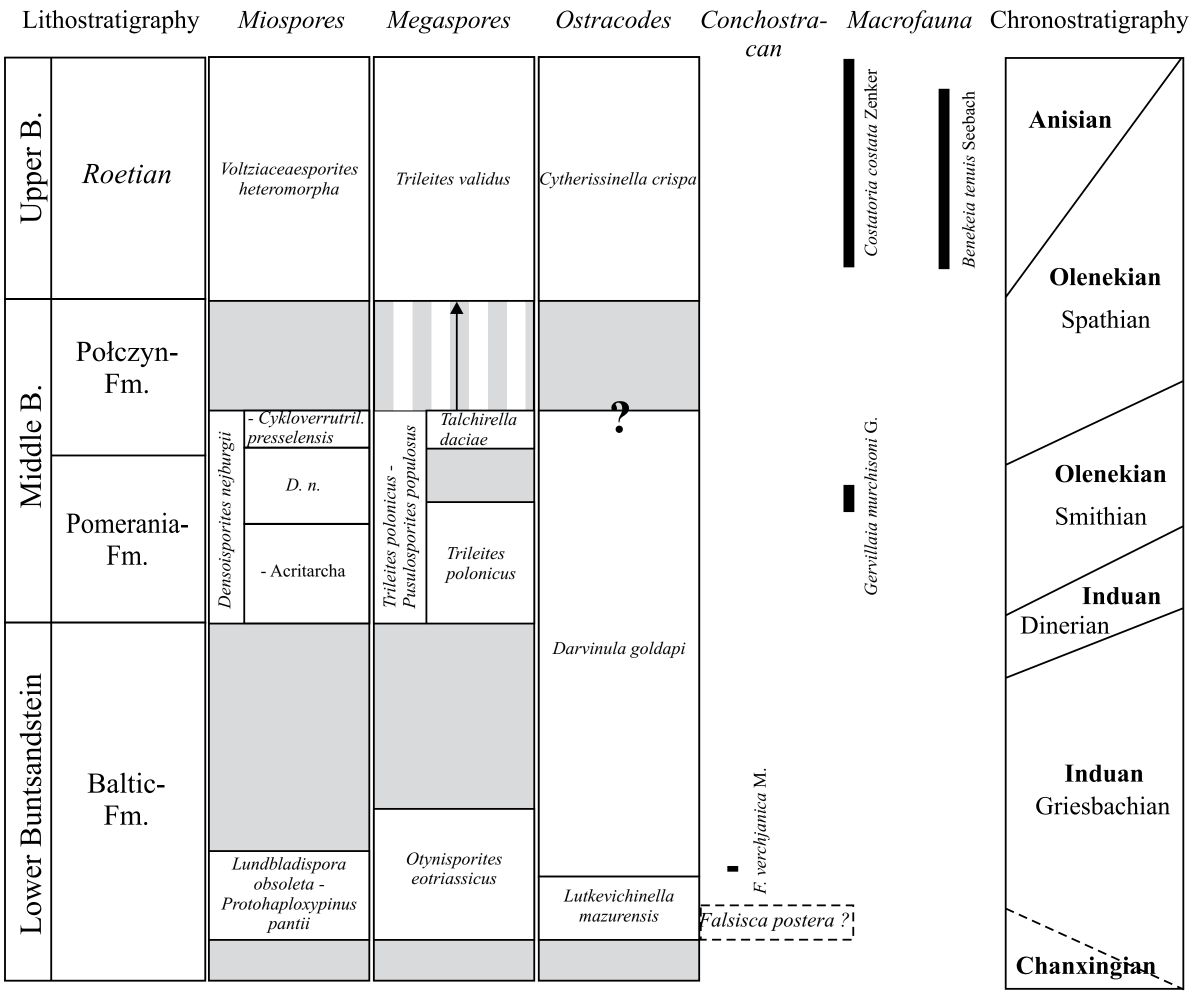


Fig. 10. Biostratigraphy of Polish Buntsandstein. For references see text

pantii zone in the deposits of the Opoczno Fm, Siodła Fm and Jaworzna Fm. The subzone *Densoisporites nejburgii* – Acritarcha was distinguished in the Goleniawy Fm, and the subzone *Densoisporites nejburgii – Cycloverrutriletes presselensis* in the deposits of the Stachura Fm and Samsonów Fm.

Fuglewicz (1980) and Marcinkiewicz (1992) established megaspore stratigraphy of the Buntsandstein on the base of core sections of Poland (Fig. 10). Four megaspore assablage zones were distinguished in the Buntsandstein section of Poland. The assemblage zone *Otynisporites eotriassicus* (Fuglewicz, 1980) characterized the Lower Buntsandstein sediments, especially its lower and middle part. The occurrence of species *Otynisporites eotriassicus* Fuglewicz, *O. tuberculatus* Fuglewicz, *Maexisporites ooliticus* Fuglewicz and *Echitriletes fragilispinus* Fuglewicz defined the zone. The age of the zone was interpreted by Fuglewicz (1980) as Late Permian. Marcinkiewicz (1992) revised the interpretation and dated the zone as Induan.

The assemblage zone *Trileites polonicus – Pusulosporites populosus* of Fuglewicz (1980) was divided by Marcinkiewicz (1992) into two assemblage zones: *Trileites polonicus* and *Talchirella daciae*. The *Trileites polonicus* zone is characterized by a massive occurrence of *Trileites polonicus* Fuglewicz and was dated as early Olenekian. The zone was distinguished in the lower part of the Middle Buntsandstein (Lidzbark Fm). In the upper part of the Middle Buntsandstein and partially also lowermost Upper Buntsandstein the zone *Talchirella daciae* was distinguished. Characteristic for the zone is massive occurrence of *Talchirella daciae* Ant. *et* Taug. Lantz. Its age was interpreted as late Olenekian by Marcinkiewicz (1992) in contradiction to Fuglewicz (1980) who dated the *Trileites polonicus – Pusulosporites populosus* zone as Induan. The uppermost megaspore assemblage zone, the *Trileites validus* zone (Fuglewicz, 1980), is connected with the Upper Buntsandstein. Abundant occurrence of *Trileites validus* Fuglewicz beside the reach assemblage of other megaspores is characteristic for the zone. Its age was interpreted on the base of correlation with the miospore zone *Voltziaceaesporites heteromorpha* as latest Olenekian to early Anisian.

Rdzanek (1982) distinguished the *Trileites validus* zone in the Röt of the Mesozoic cover of the Holy Cross Mountains.

Styk (1982) distinguished two ostracod zones in the Buntsandstein of Poland on the base of core sections (Fig. 10). The first zone *Lutkevichinella mazurensis* occur in the Lower and the lower part of the Middle Buntsandstein. The index species of the zone is *Lutkevichinella mazurensis* Styk, which occurs massive in the lower part of the zone distinguished as a subzone (Styk in Senkowiczowa, 1997). This subzone is limited to the lower part of the Lower Buntsandstein. In the upper part of the zone, distinguished as a subzone, *Darvinula goldapi* Styk and *D. adducta* Lubimova occur besides the *Lutkevichinella mazurensis* Styk. The second zone *Cytherissinella crispa* corresponds to the Upper Buntsandstein. It includes different species assemblage than the first zone with species: *Pulviella ovalis* Schneider, *P. aralsorica* Schleipher, *P. marinae* Starozhilova, *Cytherissinella crispa* (Schleipher), *Darwinula acmayica* Schleipher, *D. kiptschakensis* Schleipher, *Lutkievichinella minima* Starozhilova, *Paracypris pusilla* (Kozur) and others. The age of the ostracod zones was not determined. Their correlation to other biostratigraphic subdivisions was presented on the Fig. 10.

The vertebrate tracks investigated in the Buntsandstein sections of the Mesozoic cover of the Holy Cross Mountains (Fuglewicz *et al.*, 1990; Ptaszyński, 2000; Ptaszyński & Niedźwiecki, 2004; Kuleta *et al.*, 2005, 2006) were also used for stratigraphical interpretations. The vertebrate track assemblage found in the Tumlin Sandstone Mbr in the Tumlin quarry was determined as of latest Permian age (Ptaszyński & Niedźwiecki, 2004). Representatives of the typical Triassic ichnofamily Chirotheriidae are absent from this assemblage. The Tumlin Sandstone Mbr is correlated with the upper part of the Lower Buntsandstein of Poland (Kuleta in Fijałkowska, 1994; Nawrocki *et al.*, 2003; Kuleta & Zbroja, 2006). The vertebrate track assemblages found in the Wióry Fm, Samsonów Fm and in the Baranów Fm consider their Triassic age (Fuglewicz *et al.*, 1990; Ptaszyński, 2000; Kuleta *et al.*, 2005; 2006). These formations belong to the Middle and Upper Buntsandstein of Poland (Nawrocki *et al.*, 2003; Kuleta & Zbroja, 2006).

Preliminary conchostraca investigations were carried out in the Holy Cross Mountains region (Ptaszyński & Niedźwiecki, 2004; 2006). The most important founds of conchostraca assemblage with *Falsisca postera* Kozur & Seidel in the lower part of the Jaworzna Fm and of the species *Falsisca* cf. *verchojanica* (Molin) in the uppermost part of the formation were made in the Zachełmie quarry (Stop IV.4; Fig. 10). After Kozur (1999) the last appearence of the species *Falsisca postera* Kozur & Seidel indicate the Permian / Triassic boundary, whereas the species *Falsisca* cf. *verchojanica* (Molin) is an index species of the first Triassic conchostraca assemblage zone. Further conchostraca founds were mentioned by Ptaszyński and Niedźwiecki (2006). All conchostraca speciments found in the Bunsandstein sediments of the Mesozoic cover of the Holy Cross Mountains still need a real paleontological description and determination.

Few macrofaunal species were important for the Buntsandstein stratigraphy (Fig. 10). The bivalve Bakevellia (=Gervillia) murchisoni Geinitz occurred in the middle part of the Middle Buntsandstein in each part of the Polish Buntsandstein basin.

Magnetostratigraphy

The basic feature of the magnetostratigraphic correlation of the Buntsandstein strata from the Central European Basin (CEB) is connected with the assumption that the wide normal polarity zone of the lowermost Buntsandstein (Nawrocki, 1997; Szurlies *et al.*, 2003) should correspond to the thick basal Triassic normal polarity zone detected in the Borel and Tethyan sections (e.g. Ogg & Steiner, 1991; Scholger *et al.*, 2000). This assumption is supported by some biostratigraphical evidences (Nawrocki, 1997; Szurlies *et al.*, 2003). The next magnetozones recognized in the Buntsandstein fit well to the Lower Triassic polarity pattern as well (Fig. 11). The Griesbachian-Dienerian age of Lower Buntsandstein (Baltic Fm) and the lower part of Middle Buntsandstein (lower Pomerania Fm), as well as the Smithian age of the upper part of Middle Buntsandstein (uppermost Pomerania Fm and Połczyn Fm) seems to be supported and documented by the magnetostratigraphic correlation (Nawrocki, 1997; Szurlies *et al.*, 2003). This correlation shows also that the whole Röt succession in the southern Polish basin should be included to the Olenekian stage (Nawrocki & Szulc, 2000). Another solution i.e. the Anisian age of the Röt succession would imply a significant gap in the Buntsandstain section that would include the whole Spathian stage.

A precise location of the Permian-Triassic chronostratigraphic boundary in the CEB is not clear. In the stratotype section at Meishan it is located within bed 27, which revealed reversed polarity directions (Yin *et al.*, 2001). This reversed polarity record can be correlated with the magnetozone recognized in the Rewal Formation in Poland or in the lower part of the Bröckelschiefer (Fulda) Formation in Germany (see

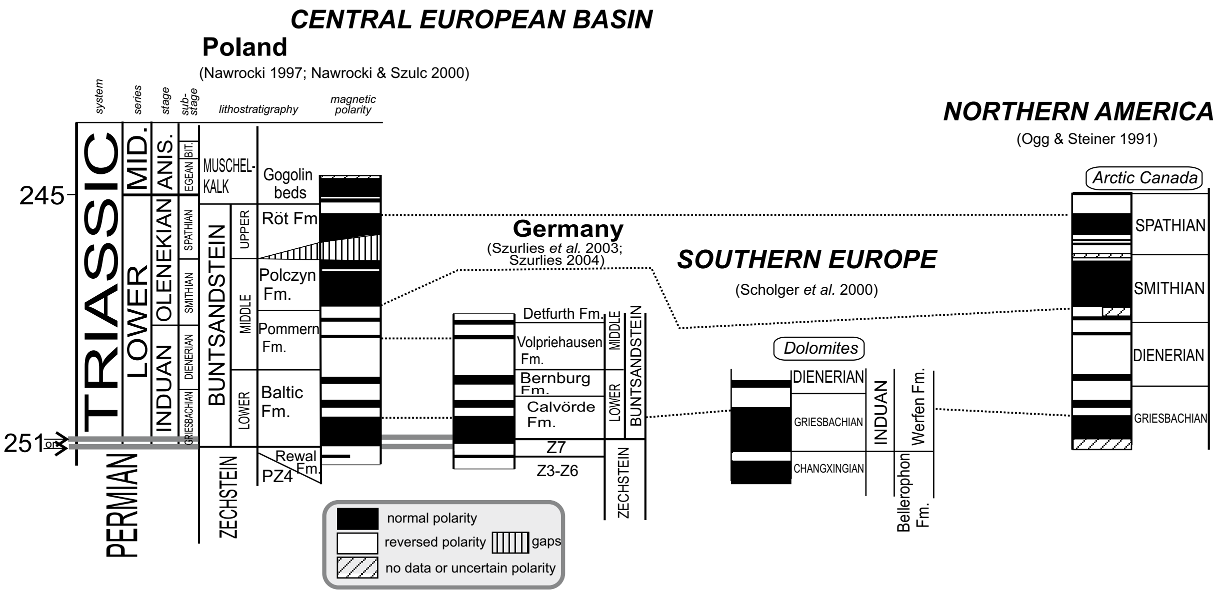


Fig. 11. The polarity stratigraphy and correlation of selected Lower Triassic sections from Europe and Northern America.

Nawrocki, 2004). A bit higher stratigraphic location of the Permian-Triassic boundary, i.e. inside the lowermost Buntsandstein, as is postulated by Szurlies *et al.* (2003), cannot be excluded but this requires a reversed polarity horizon to be found within the basal Triassic normal polarity zone. On the other hand, the correctness of the paleomagnetic studies at the Meishan section is not evident and they should be verified.

Sequence stratigraphy

Sequence stratigraphy of the Buntsandstein is very difficult as in all epicontinental basins. Only few preliminary sequence schemes were proposed for the Buntsandstein of Poland. Szulc (1995) and Beutler and Szulc (1999) distinguished six depositional sequences in the section (Fig. 12). The first sequence (1.1) enclosed deposits of the Baltic Fm. Pomerania Fm built the sequence 1.2. Połczyn Fm was enclosed into the sequence 2.1, whereas its uppermost part (Świdwin Mbr) built the next sequence 2.2. Investigations of H. Kiersnowski, G. Pieńkowski and A. Feldman-Olszewska (in Krzywiec, 2000, unpubl. data) showed, that the sequence boundaries are connected mostly with regionally correlable erosional surfaces, except of the basis of the sequence 1.1, which represents a transgressive surface (see also Pieńkowski, 1991). The Upper Buntsandstein contains two sequences, described in details by Szulc (2000). The lower sequence (2.3 or S1) enclosed the lower part of the Roetian, which was defined as Röt Dolomite in the Upper Silesia region. The base of the sequence is connected with a basinwide unconformity between the Middle and Upper Buntsandstein in Poland. The maximum flooding surface was defined at the horizon containing cephalopod *Beneckeia tenuis* (Seebach). Upper part of the Röt built the sequence S2 (2.4). Its lower boundary was defined on the subaerially weathered horizon upon the oolitic limestone in Upper Silesia. Its upper boundary was put on the meteorically altered halite bearing carbonates on the base of Myophoria Beds of the Lower Muschelkalk of Upper Silesia (Szulc, 2000).

Sequence scheme based on the base-level method was proposed by Becker (2005) for the Lower and Middle Buntsandstein of the eastern part of the Central European Basin (eastern Germany and western to central Poland; Fig. 12). Base-level cycles of large-scale and of medium-scale was distinguished on the basis of retrogradational and progradational facies patterns. The Baltic Fm built one large-scale cycle. Its uppermost boundary is connected with a weakly developed

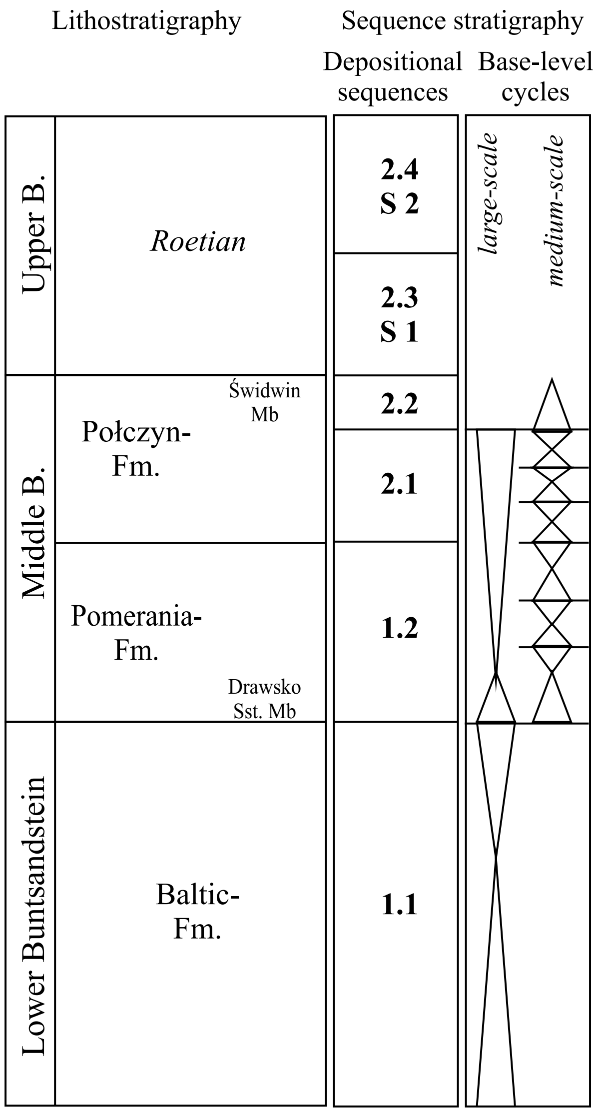


Fig. 12. Sequence stratigraphic schemata proposed for the Polish Buntsandstein by Szulc (1995), Beutler and Szulc (1999) and Becker (2005)

unconformity. In the Middle Buntsandstein six full medium-scale cycles and one incomplete cycle were distinguished. Three lower cycles built the Pomerania Fm of the Mid-Polish Trough. Four upper cycles built the Połczyn Fm, whereas the latter incomplete cycle is connected with the Świdwin Mbr. Boundaries between cycles 2 / 3 and 6 / 7 are connected with unconformities.

Kuleta and Zbroja (2006) distinguished transgressive-regressive sequences in the Lower and Middle Buntsandstein succession of the Holy Cross Mountain region. The first one (IIA) started with a marine transgression correlated with the global transgression of early Griesbachian (Pieńkowski, 1991). In the transgressive phase (IIAt) a shallow marine Opoczno Fm, fluvio-lacustrine Siodła and Piekoszów formations and fluvial Jaworzna Fm were deposited. Regressive phase of the cycle (IIAr) includes Zagnańsk Fm of fluvial and aeolian origin (Tumlin Mbr). Middle Buntsandstein sedimentation was enclosed into two further cycles: IIB and IIC. The cycle IIB started with a new transgressive pulse. Goleniawy Fm represents various marine sedimentary environments from offshore to lagune. Fluvial environments developed on the basin margins in form of lower Piekoszów and Wióry formations. The upper, regressive part of the cycle (IIBr) is represented by a stratigraphic gap. Only in the basin center deposition continued; offshore conditions passed into nearshore ones. The basin expanded southwards in the first phase of the cycle IIC. Stachura Fm represents a brackish lagoon, passing laterally into fluvial Piekoszów and lowermost Samsonów formations. Samsonów Fm built the regressive part of the cycle (IICr) representing fluvial environments of meandering river systems with broad floodplain passing into lakes.

Correlation with other Germanic subbasins

Buntsandstein sediments of the Polish subbasin were correlated with the German subbasin already by Puff (1976), Orłowska-Zwolińska (1977), Fuglewicz (1979), Szyperko-Śliwczyńska (1979) and Haubold (1983). Correlations based on the lithostraigraphic and biostratigraphic data. The newest correlations based especially on the magnetostratigraphy (Nawrocki, 1997; Szurlies *et al*., 2003). Correlation of the Zechstein / Buntsandstein boundary was proposed by Wagner (1991) and Nawrocki *et al*. (1993). Becker (2005) proposed a detailed correlation of the Lower and Middle Buntsandstein of eastern Germany and western to central Poland on the basis of cyclostratigraphic log-correlation and literature data. Ptaszyński and Niedźwiecki (2006) proposed a correlation of the Buntsandstein of the Holy Cross Mountains region with Turingian Basin on the basis of lithological development of sediments and of preliminary conchostraca investigation.

The Baltic Fm corresponds to the Upper Bröckelschiefer (upper Fulda Fm), Calvörde Fm and Bernburg Fm (Fig. 13). The basis of the Baltic Fm was put on deeper than the basis of the Calvörde Fm. In the Polish subbasin V-unconformity is very weakly developed on the top of the Lower Buntsandstein. It can be detected only on the basis of small-scale cycles correlation. In investigated Polish boreholes 20 to 21 small-scale cycles were distinguished in the equivalents of the Calvörde and Bernburg formations (Becker, 2005). On the basis of the Middle Buntsandstein very characteristic sandstone complex was developed (Drawsko Sandstone Mbr), which can be correlated very successfully with the Volpriehausen Sandstone. No equivalent of the Quickborn Fm had been detected in Poland up to now. The Pomerania Fm of the Mid-Polish Trough can be correlated with the Volpriehausen Fm, whereas the Pomerania Fm of the northwestern Szczecin-Kalisz Swell corresponds to the Volpriehausen Fm and the Detfurth Fm. The boundary between the Pomerania Fm and Polczyn Fm is diachroneous. The D-unconformity

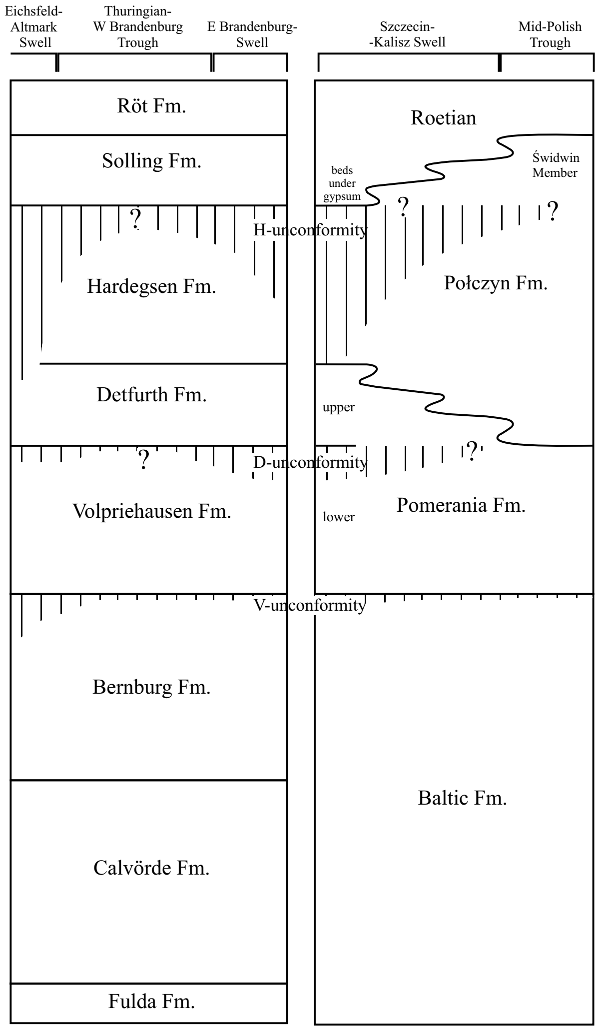


Fig. 13. Correlation of lithostratigraphic units within the eastern part of the Central European Basin.

was detected based on a log-correlation between the equivalents of the Volpriehausen Fm and Detfurth Fm on the Szczecin-Kalisz Swell (Fig. 13). Equivalent of the Hardegsen Fm built the most, middle part of the Polczyn Fm, or the whole formation. The uppermost part of the Polczyn Fm, the Świdwin Mbr was correlated with the Solling Fm. On the Szczecin-Kalisz Swell the Solling Fm corresponds to the lowermost Upper Buntsandstein ("sub-gypsum beds"). The H-unconformity was reported in Polish literature very often on the boundary between the Middle and Upper Buntsandstein (Fig. 13). A gap under the Świdwin Mbr was detected on the base of magnetostratigraphic studies by Nawrocki (1997).

Paleogeography and paleoenvironmental context

Sedimentation of the Lower Buntsandstein took part in a shallow, initially marine, then periodically drying inland basin or a system of smaller more or less connected subbasins of a slight salinity. Sandstones appearing in the southern part of the Polish Lower Buntsandstein are littoral and fluvial formations. Aeolian deposits were detected only in the north-eastern part of the Mesozoic cover of the Holy Cross Mountains (Tumlin Mbr). During the deposition of the Lower Buntsandstein a weak connection to the boreal ocean existed in the west. At the end of this sedimentary phase a change into arid climate happened and the basin was gradually approaching the stagnant phase. The most clastic input came from the

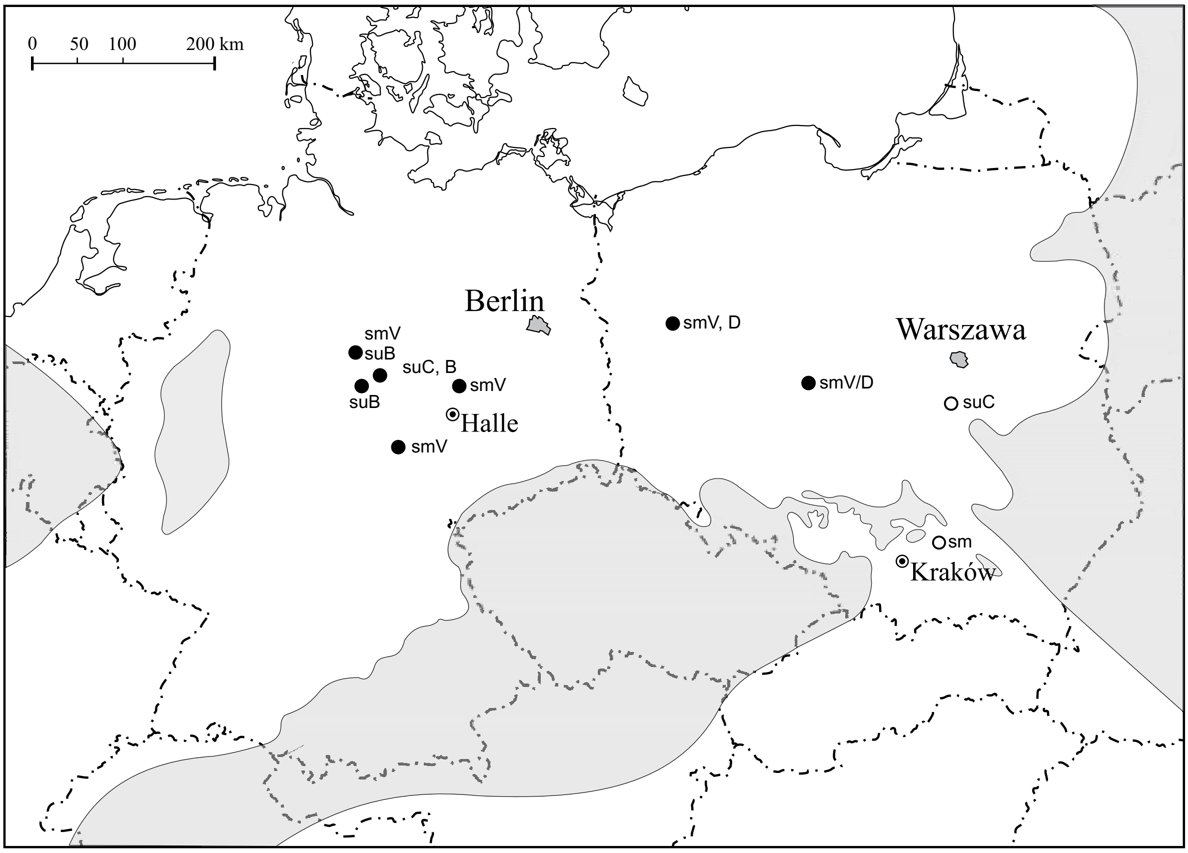


Fig. 14. Occurrence of acritarchs, prasinophytes and ostracodes in the eastern part of the Central European Basin, for references see Becker (2005).

southern lands built by variscan orogens. The land in the north-eastern part delivered only fine-clastic to sandy deposits. The land was already peneplenized.

At the beginning of the sedimentation of the Middle Buntsandstein the basin again reached expansive character. The Pomerania Fm started with the nearshore oolitic sandstones and then the most of the region built a brackish lagune with fine-clastic heterolites, oolitic carbonates and bioclastic carbonates. Very strong marine influence is characteristic for this phase. Mostly a connection to the Tethys is postulated, but a further connection to the boreal sea can not be excluded. In the second phase of the Middle Buntsandstein sedimentation the basin gradually became more shallow and restricted itself to the axial part of the Mid-Polish Trough. The Połczyn Fm represents mostly alluvial plain sediments. In the central part it was a more distal part of the system or even partly a playa lake, in the margins it represented more proximal alluvial plain with domination of channel sediments. Clastic input were very strong from the southern lands, but it was also significant from north-west. At the end of the Middle Buntsandstein deposition stopped possibly in the whole basin. It started again with an ingression of the Tethys sea from the south. The transgression developed gradually and reached its maximum at the final stage of sedimentation that was going on during the Upper Buntsandstein and Lower Muschelkalk as well. At the beginning of the Upper Buntsandstein phase clastic lagunal sediments developed with fluvial deposits at the basin margins. The basin developed gradually into a carbonate shelf with restricted conditions, which enabled precipitation of evaporates. At the basin margins a system of costal sabkhas and finally of costal sandflats developed. The transition to the Muschelkalk deposition was connected with the overall deepening of the sedimentary conditions. The clastic input was most significant from the north during the Upper Buntsandstein deposition.

Two specific problems of Buntsandstein stratigraphy and sedimentology will be discussed here. The first one is the position of the Permian/Triassic boundary in the light of palaeomagnetic data (Nawrocki, 2004; Bachmann & Kozur, 2004). The second one considers occurrence of marine environment in the Lower and Middle Buntsandstein.

Permian/Triassic boundary

In the stratotype profile for the Permian/Triassic boundary, the Meishan D, a short reversed polarity zone was detected exactly around the P/T boundary (Yin *et al.*, 2001). For this reason the P/T boundary in Poland was located in the uppermost part of the reversed magnetozone that precedes the basal Triassic normal polarity zone (Nawrocki, 1997; 2004; Nawrocki *et al.*, 2005) and correspond well to the Zechstein/Buntsandstein boundary. This correlation was also supported by results from the section Wulong in China where the P/T boundary is located in the topmost part of a longer reversed magnetozone (Chen *et al.*, 1992 in Nawrocki, 2004). In contradiction to the Polish interpretation is German magnetostratigraphic correlation (Szurlies *et al.*, 2003; Bachmann & Kozur, 2004). This correlation bases on the biostratigraphic correlation and locates the P/T boundary in the lowermost part of the first Triassic normal magnetozone, also in the lowermost part of the Lower Buntsandstein (Szurlies *et al*., 2003; Bachmann & Kozur, 2004). This interpretation is supported by results from the Alpine section where the P/T boundary occurs within a normal polarity zone (Scholger *et al*., 2000). Bachmann and Kozur (2004) published additionally a written communication of Prof. Yin Hongfu where he stated that the short reversed magnetozone around the P/T boundary in Meishan D was erroneously interpreted. Magnetostratigraphy is possibly the best method for stratigraphic correlation between marine and continental sections and could really help to determine the Permian/Triassic boundary in the Central European Basin. Therefore, as already stated in the subchapter considering magnetostratigraphy of Polish Buntsandstein, new investigation in the stratotype profile in Meishan should be carried out.

Marine environments in Buntsandstein

Marine depositional conditions in the Lower and Middle Buntsandstein of the Central European Basin (CEB) are a very interesting and controversial geological problem. On the one hand massive occurrence of fresh water fauna (conchostraca) and of emersion sedimentary structures (desiccation cracks) is observed. On the other hand glaucony in oolitic limestones and acritarchs in palynomorphes spectrum occur. The arguments for non marine sedimentary conditions are better known, therefore the arguments for the marine influences summarized on the basis of literature studies and preliminary investigations will be presented. The references are summarized in Becker (2005).

Most of the acritarch founds known from the literature are located in central Germany and western and central Poland (wells Remlingen 5, Hahausen 1, Straußfurt S4, Gorzów Wielkopolski IG-1, Florentyna 2; Fig. 14) The acritarchs are represented by the forms *Micrhystridium* spp. and *Veryhachium* spp. Like all acritarchs, both forms are known from open and rand marine environments. Few founds of acritarchs exist from terrestrial environments in Mesozoic, but the morphology of the microfossils is very different from those of the Buntsandstein. The marine microplanctone of the early Mesozoic is composed entirely of acritarchs and prasinophytes. The acritarch association of the marine Muschelkalk of the CEB is composed entirely of the two forms known from the Buntsandstein: *Micrhystridium* spp. and *Veryhachium* spp. Acritarchs and prasinophytes are especially abundant in the lower part of the Middle Buntsandstein (Volpriehausen Fm. in Germany, Pomerania Fm. in Poland). They can comprise almost 90% of palynomorphs spectrum.

Foraminifers of the subspecies *Textulariina* and *Fusulinina* were found in the Middle Buntsandstein sediments in southern Poland (Fig. 14). This area formed a subbasin in the Polish part of the CEB, which had better connection with the Tethys ocean, than the main part of the basin. A single found of the *Nodosariide* form was reported from the lowermost Buntsandstein of central Poland.

In oolitic limestones of the Pomerania Fm. of the western Poland a green mineral occurs. On the base of K_2O content (5 – 10% in preliminary investigations) it can be recognize as glaucony. This mineral originated during early diagenesis in a marine environment.

Most controverse is the origin of the oolithic facies and of stromatolites of the Buntsandstein. They were always interpreted as both: marine as well as non-marine facies. Preliminary results of stable isotopes measurements on oolites of the Lower and Middle Buntsandstein showed values of $\delta^{13}C$ between 0,1 and -2,7 (vs. PDB) typical for marine and non-marine carbonates.

The strongest marine influences or even open marine conditions are postulated for the lower part of the Middle Buntsandstein (Volpriehausen/Pomerania Fm.) and for its uppermost part. The location of the connection with the ocean is not clear. During the deposition of the Lower Buntsandstein the CEB could have been connected with the Boreal sea as in the Zechstein and during the deposition of the Middle Buntsandstein a connection to the Tethys ocean could have existed as in the Röt and Muschelkalk.

Röt and Muschelkalk

General setting

Joachim Szulc

In late Olenekian time, an unconstrained communication between the Tethys and Germanic basins established, and the southernmost part of the Polish basin became an integrate part of the Tethys Ocean. It concerns, first of all, the Upper Silesian area that formed tectonically mobile threshold block dividing the open ocean domain from a vast inner back-ramp ("lagoonal") basin (i.e. Germanic Basin *s.s.*) (Fig. 15). Such configuration resulted in paleocirculation pattern typical of semi-closed marine basin. Normal marine conditions dominated in the Upper Silesia and Holy Cross Mts area, whereas northward and westward from the Silesian and East Carpathians domains the environments became more and more restricted. On the other hand, the elevated Fennosarmatian Land bounding the basin from the north provided a significant clastic input and freshwater influx into the restricted-to-evaporitic basin.

Isopach and facies pattern of the Röt sediments show that the main depocentre was situated between western Poland and eastern England and that the main subsidence centre in the Polish basin was located along the Cracow–Odra–Hamburg Fault. Sedimentation in the depocentres was dominated by evaporites (halite and gypsum) whereas carbonates occur only as sporadic intercalations. The evaporitic facies grade into clastic mudflat and sandflat deposits at the western and northwestern basin margins.

Facies distribution of the Röt is typical of a semi-closed, evaporitic basin. Marine incursions were from the Tethys Ocean *via* the Silesian-Moravian Gate, while the other sides of the basin were closed. Normal marine water flowing from the SE accumulated in the depocentre and underwent evaporation, leading to halite/gypsum precipitation.

Paleooceanographic circulation pattern established in late Olenekian continued also in Anisian time. The main communication pathways between the Tethys and Germanic basins lead through the SMG and ECG. Since Pelsonian time also the Western Gate (former Burgundy Gate) became active.

The basin reorganisation commenced at the beginning of the Ladinian when intense crustal uplift in the eastern province resulted in an increase of clastic supply in uppermost Muschelkalk-Lower Keuper times and lead finally to emersion and a stratigraphic hiatus encompassing the late Ladinian (Fassanian) interval.

According to conodont and ammonoid data normal marine sedimentation in the Polish basin terminated three conodont zones and six ceratite zones earlier than in SW Germany.

Röt and Muschelkalk macrofaunas in Poland

Hans Hagdorn

In the earliest descriptions of Triassic fossils from Upper Silesia, Meyer (1847), Dunker (1851), Eck (1865) emphasized the close similarity of the Silesian Muschelkalk with the alpine Muschelkalk. In reviews of the Upper Silesian Muschelkalk faunas, Ahlburg (1906) and Assmann (1913–1944) demonstrated that the percentage of Tethyan macrofaunal elements reached its peak in the Anisian Karchowice Formation and in the Diplopora Dolomite. This data was specified by microfauna analyses during the 1970s (Kozur 1974 a, b, 1975, Zawidzka 1975). By this, research was done by Senkowiczowa (1956–1991) and Trammer (1972) on the Muschelkalk in the Holy Cross Mountains and its fauna in relation with the Tethyan realm (Trammer 1973). These authors established a zonal biostratigraphy that is based on conodonts, and to a less degree on ostracods and other microfossils. Crinoids and echinoids have been shown to be of biostratigraphic value during the Anisian and Ladinian by Hagdorn & Gluchowski (1993). However, the Lower Muschelkalk cephalopods are still the most important index fossils that allow correlation with the alpine Triassic (Brack *et* al. 1999). Until today, much detail has been added in many papers. Overviews of the Triassic faunas and floras in Poland, with a special focus on microfaunas and -floras, were compiled by Malinowska (1986) in Polish language, and by the same editor (1989) in English.

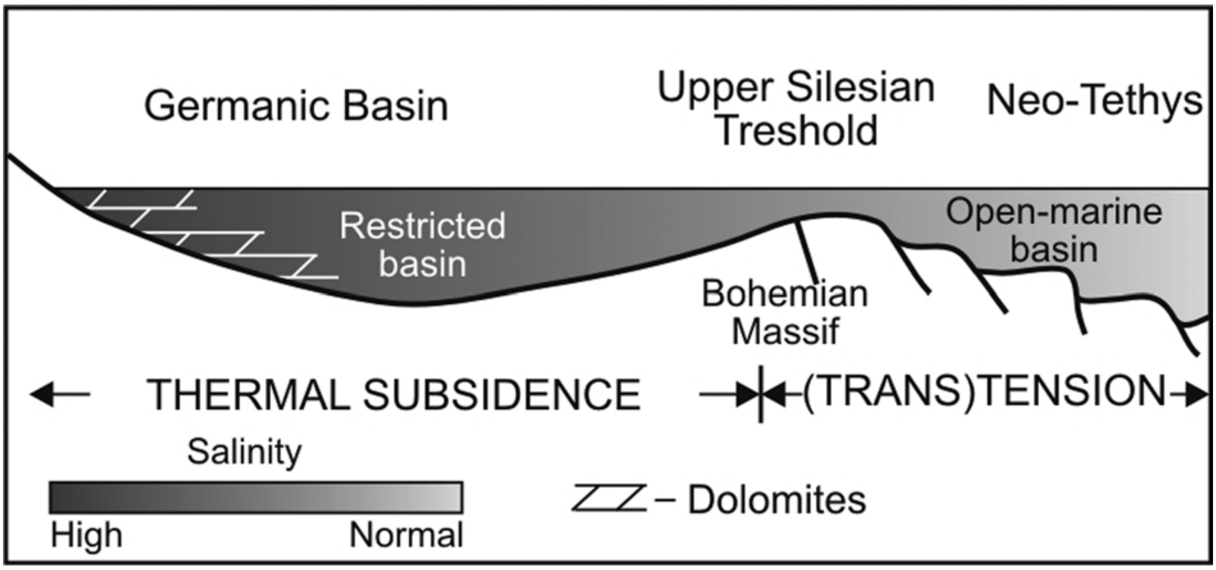


Fig. 15. Schematic model of basin dynamics and circulation regime in the Northern Peri-Tethys domain

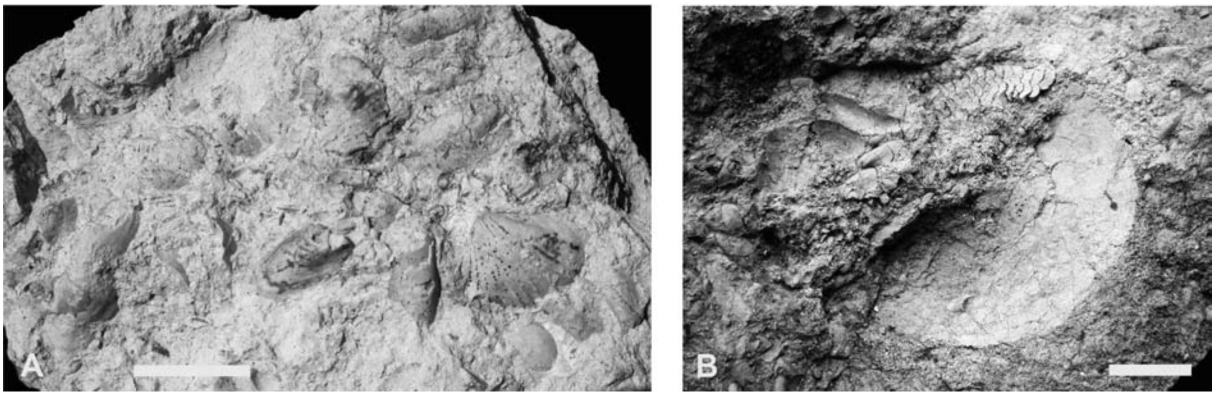


Fig. 16. Fauna of the Rötkalk: A – Soft bottom fauna with *Costatoria costata* and *Modiolus* sp. Podstoki near Plaza; B – *Beneckeia tenuis* and *Modiolus* sp. Podstoki near Plaza

Röt

The earliest marine ingression in Triassic times reached southeastern Poland during the late Olenekian when the Röt Dolomite was deposited. Its fauna, preserved as internal and external moulds, is dominated by the myophoriid bivalve *Costatoria costata* and by the modioliform *Modiolus* (?) *triquetrus* (Fig. 16a). Additional common fossils are the bakevelliids *Hoernesia socialis* and *Bakevellia costata*, the pectinoid *Leptochondria albertii*, *Pseudomyoconcha gastrochana*, and several undeterminable bivalves that were attributed to the collective genus *Myacites*; some of them may belong to *Pleuromya fassaensis*. The gastropods are represented by *Wortheniella* and small undeterminable genera, the cephalopods by the hedenstroemiid ammonoid *Beneckeia tenuis* (Fig. 16b). Locally, remains of actinopterygian fishes (*Saurichthys*) and small sauropterygian reptiles like *Dactylosaurus* and *Cymatosaurus* have been found. This fauna is indicative of a restricted marine environment with soft bottoms dominating. With the Tenuisbank of Thuringia that yielded abundant *Costatoria costata* and *Beneckeia tenuis*, this earliest marine ingression reached as far to the West as Central Germany. For more detailed data about the Röt fauna see Eck (1865), Roemer (1870), and Ahlburg (1906) who described a rich fauna from the Röt Dolomite of southern Upper Silesia. By means of *Costatoria costata*, the Röt Dolomite has already been correlated by Eck (1865) with the Olenekian Werfen Formation of the Tethyan Triassic, however, *Beneckeia* has not been found there. For this reason, Kozur, (1975) assumes faunal immigration via the East Carpathian Gate from the northern Palaeotethys branch.

Muschelkalk

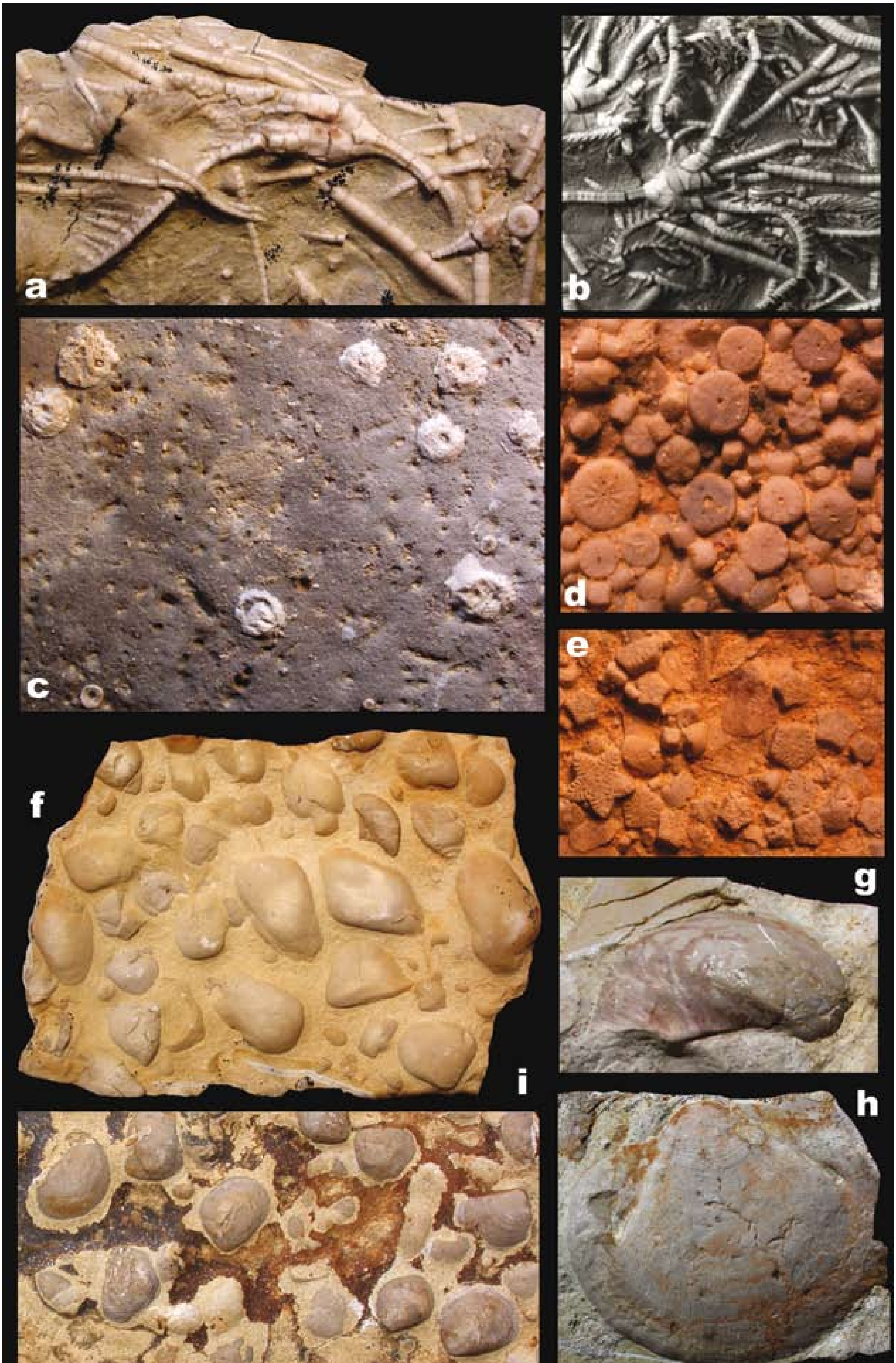
Due to normal salinity and a greater variety of substrates, the Muschelkalk faunas are much more diverse than the Röt faunas. The diversity depends on the changing palaeogeographic positions of the Polish Muschelkalk to the marine gates that connected the Central European Basin with the Tethys. Generally, in late Anisian (Pelsonian and lower Illyrian) times, Silesia rather belonged to the Tethyan faunal province than to the Germanic.

Gogolin Formation

In the **Lower Gogolin Beds**, as well as in the Röt Dolomite, fossil communities of different soft bottom environments are found. However, *Costatoria costata* has disappeared, and *Myophoria vulgaris* appeared for the first time and hence became a dominating faunal element in Muschelkalk and Lower Keuper soft bottom palaeocommunities, e.g. in the Muschelkalk basis bed of Plaza (Stop II.3). In the lower part of the Lower Gogolin Formation, *Dadocrinus* is the only crinoid, while *Holocrinus acutangulus* with pentagonal columnals (Fig. 17e) appears only in its upper part. With its discoid holdfasts, *Dadocrinus* encrusted hardgrounds (Fig. 17c) or shells of mudsticking bivalves, sometimes forming bunches of individuals. Several species of *Dadocrinus* (Fig. 17a, b, d) have been described, however, the species concept of this crinoid needs revision. *Dadocrinus* shared its habitat with ophiuroids (*Aspiduriella*, *Arenorbis*), and mudsticking bivalves like *Bakevellia mytiloides*, *Hoernesia socialis* (Fig. 17g; Hagdorn 1996), *Pseudomyoconcha*, the myophoriids *Myophoria vulgaris*, *Neoschizodus laevigatus*, *Elegantinia elegans*, *Pseudocorbula*, *Pleuromya cf. fassaensis* (Fig. 17f), the gastropods *Omphaloptycha gregaria* and other, undetermined gastropods. Epibenthic filter feeding bivalves are rare, as well as the cephalopod *Beneckeia buchi*. In the lower part of the formation, large *Filopecten* (?) cf. *discites* with radial color banding are found (Fig. 17h). The sediment was extensively bioturbated (*Rhizocorallium jenense* and other soft ground ichnofossils).

The Lower Gogolin Formation of Gogolin was famous for its rich vertebrate finds, among which are hybodont sharks (*Hybodus*, *Acrodus*, *Palaeobates* and actinopterygian fishes (*Saurichthys*, *Gyrolepis*, *Colobodus*, *Cenchrodus*. A few finds of ceratodont tooth plates from Gogolin indicate the nearby land, as well as temnospondyl labyrinthodonts and serrated teeth of the rauisuchian *"Zanclodon" silesiacus*. The marine reptiles are represented by the small pachypleurosaur *Dactylosaurus*, the early ancestral plesiosaur *Cymatosaurus*, the nothosaur *Eurysaurus*, the placodont *Cyamodus*, *Tanystropheus antiquus* and mixosaurs. Until today, isolated bones and scales are commonly found in shells beds with *Dadocrinus* columnals in the quarries of Zyglin (Stop III. 2). The Lower

Fig. 17. Fauna of the Gogolin Formation: a – *Dadocrinus* sp., crown and stem fragments of a small, still undescribed dadocrinid from the Lower Gogolin Fm. of Milowice (x 2,5); b – *Dadocrinus kunischi*, the largest dadocrinid. Lower Gogolin Fm., Gogolin (x 0,8); c – Holdfasts of dadocrinids on top of a large intraclast; note the openings of *Trypanites* borings. Lower Gogolin Fm., Zabkowice Bedzinskie (x 1); d – Dadocrinid columnals, Lower Gogolin Fm., Zyglin (x 2,5); e – *Holocrinus acutangulus*, columnals. Upper Gogolin Fm., Wojkowice Komorne (x 2,5); f – Soft bottom palaeocommunity of *Arcomya* cf. *fassaensis*, *Myophoria vulgaris*, *Bakevellia costata*, *Omphaloptycha gregaria*. Lower Gogolin Fm., Zyglin (x 0,8); g – *Hoernesia socialis*. Lower Gogolin Fm., Gogolin (x 1); h – *Entolium* cf. *E. discites*. Lower Gogolin Fm., Wojkowice Komorne (x 0,6); i – *Plagiostoma beyrichi*. Upper Gogolin Fm., Plaza (x 1). All specimens Muschelkalkmuseum Ingelfingen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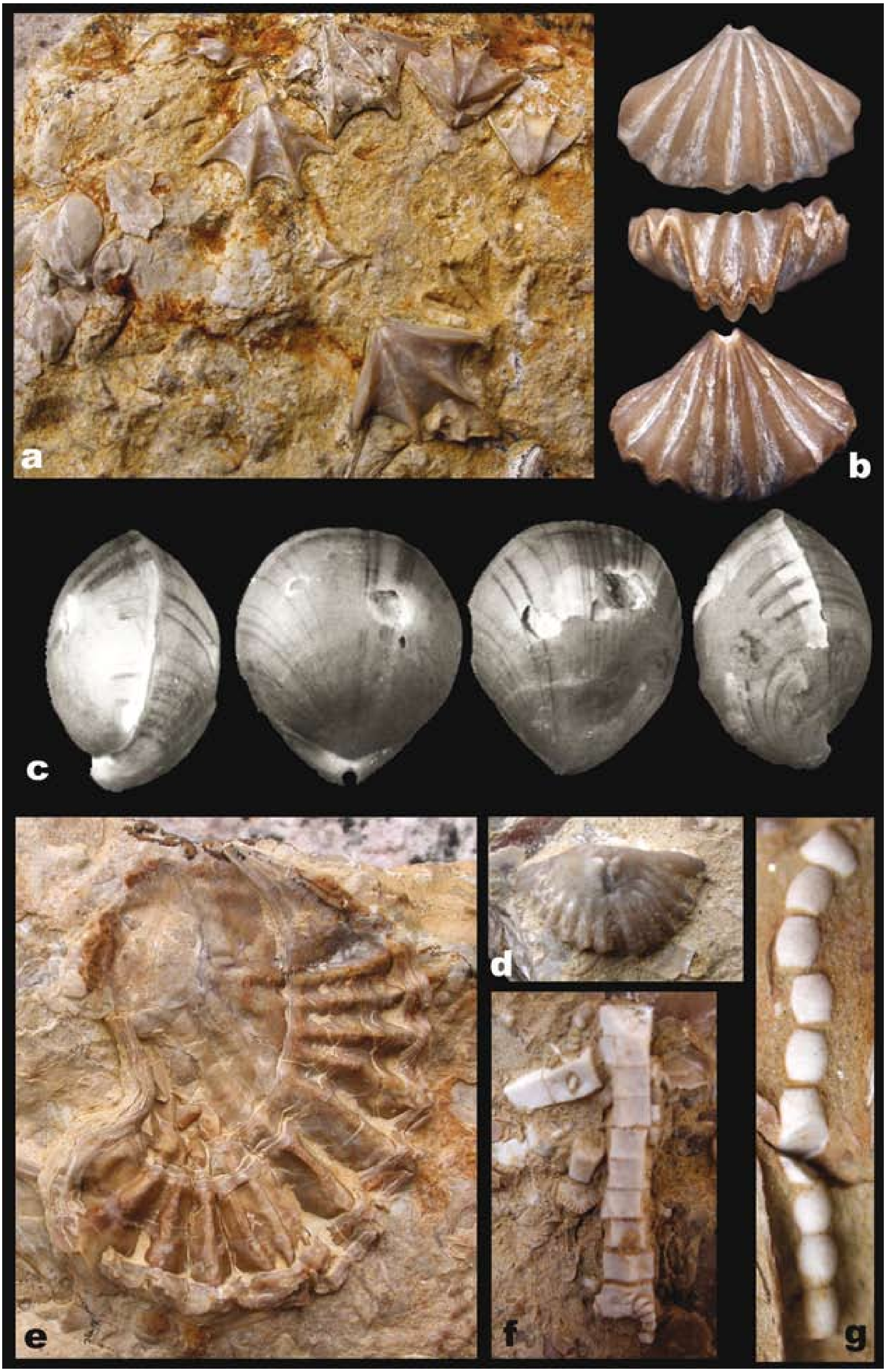
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Gogolin Formation is correlated with the *Myophoria* Beds of the Röt in East and Central Germany. However, with an increasing salinity gradient, the stenohaline crinoids disappear between Brandenburg (Rüdersdorf) and Thuringia, and *Beneckeia* disappears in South Thuringia together with the carbonatic facies of the Dornburg Subformation, while myophoriids reach farther to the west into the redbed facies of the Southwest-German Röttone (Fig. 25)

In the **Upper Gogolin Formation**, *Dadocrinus* is much rarer, and *Holocrinus acutangulus* is the most common crinoid. The earliest encrinids and echinoids, among them *Triadocidaris* with short, ornamented spines, are restricted to eastern Upper Silesia. Beautiful specimens of the long-armed ophiuroid *Arenorbis sqamosa* were found at Roitza at the beginning of the last century. Some shells beds are characterized by abundant small limid bivalves *Plagiostoma beyrichi* (Fig. 17i), others by *Pleuromya* cf. *fassaensis*. The larger intraclasts in the Conglomeratic Beds are extensively incrusted by the oyster-like bivalve *Placunopsis ostracina*. The Upper Gogolin Formation has yielded the nautiloids *Germanonautilus dolomiticus* and *G. salinarius* and, more rarely, the ammonoids, *Beneckeia buchi*, *Noetlingites strombecki*, *Balatonites ottonis*, *Acrochordiceras* that allow correlation with the Anisian Angolo Limestone of the Southern Alps. In the uppermost part of the Upper Gogolin Formation in eastern Upper Silesia, the articulate brachiopods *Tetractinella trigonella*, *Punctospirella*, *Mentzelia*, *Silesiathyris angusta*, and terebratulids appear. In the Upper Gogolin Formation, vertebrates are very rare. Generally, in eastern Upper Silesia and in the Cracow Upland, this formation yielded more diverse faunas.

The fauna of the Gogolin Formation was completely listed by Assmann (1944).

Gorazdze Formation

The fauna and the flora of the Gorazdze Formation can be easily separated from the Gogolin Formation. The thickly bedded limestones contain a macrofauna and -flora with elements that do not occur in the typical Germanic Muschelkalk. This is especially true for the dasycladacean green alga *Gyroporella minutula* that is very abundant in some beds of eastern Upper Silesia. For the first time, corals (*Pamiroseris, "Montlivaltia"*) and hexactinellid sponges occur, however, rarely. The crinoid fauna is dominated by encrinids (*Encrinus aculeatus*, *E. robustus*, *E. spinosus*, *Carnallicrinus carnalli*) that may be preserved with traces of violet colour pigmentation. The echinoid fauna contains rare elements with large spatula-shaped spines that seem to be restricted to this formation (*"Cidaris" ecki, "C." remifera*). Among the articulate brachiopods, *Silesiathyris* disappears, while *"Zeilleria" ladina* and *Decurtella decurtata* appear. Among the 25 taxa of the bivalve fauna, 8 have been reported exclusively from Upper Silesia, and among 21 gastropod taxa, this number is 13. Like the cephalopods *Pleuronautilus planki*, *Balatonites*, *Bulogites* and *Paraceratites*, these taxa give evidence for a strong influence of the alpine fauna that immigrated through the nearby Silesian-Moravian Gate from the Tethys.

The fauna of the Gorazdze Formation was completely listed by Assmann (1944) and described and figured by Assmann (1937).

Dziewkowice Formation (Terebratula Beds)

In the Terebratula Beds, the diversity strongly decreases, however, the shell beds are extremely fossiliferous (Kaim 1997, Niedzwiedzki 2000). The fossil palaeocommunities are dominated by epifaunal filter-feeding brachiopods and large bivalves that have well preserved calcitic shells. Encrinid crinoids are represented by *Carnallicrinus* and *Encrinus*, however, the most abundant crinoid is a small, still unidentified species with barrel shaped columnals (Fig. 18g). They form the up to 1.4 m thick Crinoidal Limestone that can be traced over the entire Muschelkalk outcrop of Upper Silesia. *Holocrinus dubius* with pentagonal columnals and cirri is much rarer (Fig. 18f). Among the echinoids, *Triadotiaris grandaeva* with unornamented, long and slender spines, and *Serpianotiaris* with shorter and thicker spines are the most common taxa. During deposition of the Upper and the Lower Terebratula Beds they were distributed over the entire Germanic Basin. This is also true for the brachiopods *Coenothyris vulgaris* (Fig. 18c), *Punctospirella fragilis*, and *Hirsutella hirsuta* (Fig. 18d), while *Tetractinella trigonella* (Fig. 18a), *Mentzelia mentzeli*, and *Decurtella decurtata* (Fig. 18b) are alpine elements that did not reach the central parts of the Muschelkalk Basin. The index fossil *Decurtella decurtata* allows correlation of the Terebratula Beds with the Pelsonian of the Tethyan Triassic. The bivalve fauna is dominated by the fixosessile oysters *Umbrostra difformis* (Fig. 18e), *Newaagia noetlingi*, and *Placunopsis ostracina*. The flexisessile epibenthos is dominated by *Plagiostoma lineatum* and *Entolium discites*, the enodobenthos by *Hoernesia socialis*. It can be assumed that the oysters formed biohermal buildups that were elevated a few decimetres above the seafloor and provided solid anchoring ground for crinoids and brachiopods. In the Terebratula Beds, a few specimens of the ammonoid *Discoptychites* have been found (Kaim & Niedzwiedzki 1999). A widely distributed system of thalassinoid burrows at the base of a shell bed gives evidence for decapod crustaceans. The producers of these burrows may have been *Lissocardia silesiaca, Litogaster,* or *Pemphix* that are reported from the Karchowice Formation. Among the rare vertebrates, the poorly known ichthyosaur *Tholodus schmidi* is the most spectacular element; jaw fragments and isolated crushing teeth have been found in the Strzelce Opolskie quarry.

The Dziewkowice Formation in Poland is regarded to correlate with the Terebratelbank Subformation in Germany. However, in their Central German oolitic shallow water facies, the Terebratelbänke may contain a more diverse fauna.

Karchowice Formation and Diplopora Dolomite

The fauna of the Karchowice Formation is basically different from that of the underlying Terebratula Beds. This may be due to the broader variety of palaeoenvironments that allowed different habitats, and to the open connection to the Tethys via the Silesian-Moravian Gate. The fauna is collected from weathered surfaces of big blocks that were etched by humic acids along joint faces. Aragonitic shells were recrystallized by blocky calcite cement, echinoderm remains may be silicified. A good deal of the mesofauna has been picked from karstic pouches after washing of the loose material.

Fig. 18. Fauna of the Terebratula Beds (Dziewkowice Formation): a – *Tetractinella trigonella, Silesiathyris angusta*. Strzelce Opolskie (x 2); b – *Decurtella decurtata*. Strzelce Opolskie (x 3,8); c – *Coenothyris vulgaris*, with color bands. Strzelce Opolskie (x 1,7); d – *Hirsutella hirsuta*. Gorazdze (x 3); e – *Umbrostrea difformis*. Strzelce Opolskie (x 2); f – *Holocrinus dubius*, noditaxis of 10 columnals, with a cirrinodal at its lower end indicating an intermediate stage of disarticulation. Strzelce Opolskie (x 3,4); g – Indeterminate encrinid or dadocrinid with barrel-shaped columnals. Strzelce Opolskie (x 5). All specimens Muschelkalkmuseum Ingelfingen

The fauna is characterized by stenohaline elements that did not reach the central parts of the Basin because of a salinity barrier. These faunal elements comprise hexactinellid sponges, namely the cup or vase shaped *Tremadictyon* and *Calycomorpha*, and *Silesiaspongia* and *Hexactinoderma*, that formed irregular sheets (Fig. 19a) and acted as frame binders in the sponge-coral bioherms (Bodzioch 1997). Many specimens have been collected with their silicious skeletons preserved that can be prepared by etching with acetic acid. Sponge sheets in the bioherms may have acted as anchoring ground for crinoids.

In the bioherms, the sponges are followed upsection by hermatypic corals. Bioherms of the tube shaped *Volzeia szulci* (Fig. 19c) have been found only in Tarnów Opolski, while thin sheets of *Pamiroseris silesiaca* (Fig. 19b) and *Eckastraea prisca* are known from many outcrops. "*Montlivaltia*" and *Pinacophyllum* are rare (Fig. 19e, f).

The wealth of echinoderms also clearly indicates the Tethyan realm. Additionally to the encrinids *Encrinus robustus*, *E.* cf. *aculeatus*, *Carnallicrinus carnalli*, *Chelocrinus* sp. indet., and *Holocrinus dubius* that were dispersed over the entire Muschelkalk Basin, typical *Encrinus aculeatus* (Fig. 20a-c), *E. spinosus*, *Holocrinus meyeri* (Fig. 20f), *Eckicrinus radiatus* (Fig. 20g, h), and the poorly known *Silesiacrinus silesiacus* (Fig. 20d, e) are Tethyan crinoids that are also found in the Alps and in Hungary (Hagdorn & Gluchowski 1993). The crinoids were attached to the framework of the bioherms by their holdfasts (encrinids), or by their cirry (holocrinids). Their disarticulated skeletons were accumulated between the bioherms and form inter-reef crinoidal limestones. Unfortunately, articulated individuals are rare. However, many isolated sclerites are diagnostic and can be used as index fossils. The same is true for the echinoids. *Serpianotiaris coaeva* (Fig. 20j, o) and *Triadotiaris grandaeva* are common Muschelkalk echinoids, while *Triadocidaris transversa* (Fig. 20i, l-n), "*Cidaris*" *ecki* and "*C.*" *remifera* (Fig. 20k) are Tethyan elements that have not been found in the centre of the basin or in the Holy Cross Mountains either. In some beds of the Karchowice Formation, the club shaped or spatula shaped, ornamented spines of *T. transversa* may occur abundantly, but due to the flexible test of the Middle Triassic echinoids, complete tests are extremely rare.

Compared to the Terebratula Beds, brachiopods are not any longer dominant in the Karchowice fossil assemblages, however, their diversity is still greater than in central parts of the basin. *Tetractinella trigonella* and *Punctospirella fragilis* (Fig. 21a) are most abundant, while the spiriferinid *Mentzelia mentzeli* (Fig. 21b), the rhynchonellids *Decurtella decurtata* and *Costirhynchopsis mentzeli*, and several terebratulids are less common. *Coenothyris* has become very rare and *Hirsutella* has disappeared.

According to Assmann (1944), the bivalve fauna comprises 44 species, among which 15 are endemic in Upper Silesia, 12 are exclusively Germanic Muschelkalk, 4 are Alpine, and 13 occur both in the Alpine and the Germanic provinces. Many of the endemic Silesian and the Alpine bivalves are epibenthic, flexisessile filter feeders that were attached by byssus threads to the bioherm frames. Among these are *Mysidioptera* (Fig. 21m), *Pseudomonotis*, "*Pecten*" *crameri*, *Aviculomyalina*. *Cassianella* and *Macrodontella* belong to the endobyssate soft bottom fauna. Double valved specimens of the flexisessile *Promysidiella praecursor* (former *Mytilus eduliformis*) are commonly found in life position in the bioherms (Fig. 21 l). Endobenthic bivalves, like *Schaufhaeutlia* (Fig. 21p) or *Elegantinia* (Fig. 21o) play a rather subordinate role in the Karchowice reef habitats.

Among the 33 gastropod species, the Tethyan influence is even more evident. However, two thirds of the gastropod taxa, many of which have been found in a single specimen only, are endemic to Upper Silesia, 5 species are Alpine and 2 are Germanic. The most remarkable elements are large, ornamented archaeogastropods that inhabited the reefs. Among them are several species of *Wortheniella* (Fig. 21g) and *Coelocentrus* (Fig. 21h) The Heterostropha are represented by *Euomphalus* (Fig. 21e), the small *Amphitomaria* (Fig. 21d), and *Promathilda*, the Neritimorpha by *Neritaria* (Fig. 21f), the caenogastropod order Ptenoglossa is represented by *Zygopleura*. Several species of the following genera have been described from the Karchowice Formation: *Trypanostylus* (Fig. 21i), *Undularia*, *Pustularia*, *Loxonema*, *Omphaloptycha*. The Muschelkalk gastropod faunas urgently require revision. However, due to the recrystallization, the protoconchs of the fossils are too poorly preserved for their attribution to higher taxa.

Probably, the high percentage of endemic bivalves and gastropods is an artefact of the fossil record, because there are no other comparably well preserved late Anisian mollusc faunas.

Cephalopods (*Germanonautilus*, *Pleuronautilus*, *Bulogites*) are rare in the Karchowice Formation. Decapod crustaceans are represented by the glypheid *Litogaster*, the nephropid *Lissocardia*, and the small pemphicid *Pemphix silesiacus*. Fish and reptile remains are extremely rare.

For descriptions and a detailed list of the Karchowice Formation faunas see Assmann (1937, 1944).

Boruszowice Formation

Compared to the Upper Muschelkalk invertebrate faunas in Southwest Germany and in the Holy Cross Mountains, the faunas in Silesia are less diverse. The Trochitenkalk Formation is replaced by conglomeratic limestones devoid of crinoids. In the Holy Cross Mountains, *Encrinus liliiformis* is abundantly found, due to a re-opening to the Tethys via the east

Fig. 19: Sponges and corals of the Karchowice Formation: a – *Silesiaspongia rimosa*. Strzelce Opolskie (x 2,2); b – *Pamiroseris silesiaca*. Tarnów Opolski (x 2,5); c – *Volzeia szulci*. Tarnów Opolski (x 2,8); d – *Coelocoenia exporrecta*. Strzelce Opolskie. (x 2); e – *Pinacophyllum* (?). Tarnów Opolski (x 2); f – *Montlivaltia* (?). Tarnów Opolski (x 2,5). All specimens Muschelkalkmuseum Ingelfingen

Fig. 20. (see p. 24) Echinoderms of the Karchowice Formation and the Diplopora Dolomite: a, b – *Encrinus aculeatus*, columnals; a – proximal internodal; b – cirrinodal. Diplopora Dolomite, Piekary Slaskie (x 10); c – *Encrinus aculeatus*, crown. Karchowice Fm., Tarnów Opolski (x 1,4); d, e – *Silesiacrinus silesiacus;* d – pluricolumnal; holotype (x 4); e – internal mould of central canal after dissolution of the echinoderm calcite (x 10). Karchowice Fm., Kamin Slaski; f – *Holocrinus meyeri*, internodal. Diplopora Dolomite, Piekary Slaskie (x 10); g, h – *Eckicrinus radiatus*, columnals; g – distal internodal; h – proximal internodal. Diplopora Dolomite, Piekary Slaskie (x 10); i – *Triadocidaris transversa*, oral part of interambulacrum. Diplopora Dolomite, Piekary Slaskie (x 20); j – *Serpianotiaris* sp., oral part of interambulacrum. Diplopora Dolomite, Piekary Slaskie (x 25); k – *"Cidaris" remifera*, interambulacral. Diplopora Dolomite, Piekary Slaskie (x 20); l – n – *Triadocidaris transversa*, spines. Karchowice Fm., Tarnów Opolski (x 5); o – *Serpianotiaris* sp., spine. Karchowice Fm., Tarnów Opolski (x 2,7); a, b, f – h – Laboratory of Paleontology and Stratigraphy Silesian University Sosnowiec; d – Museum für Naturkunde Humboldt Universität Berlin; other specimens Muschelkalkmuseum Ingelfingen


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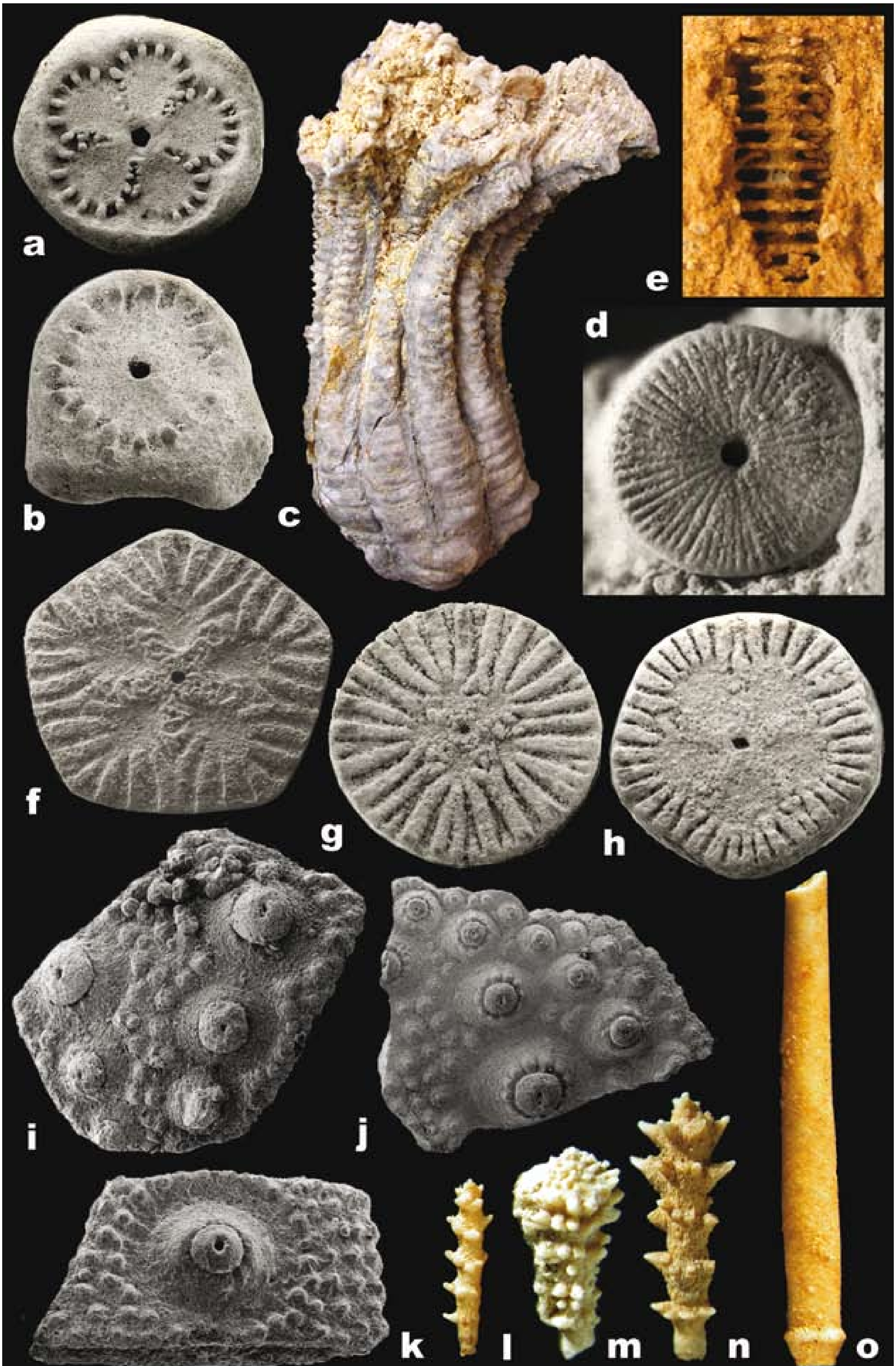
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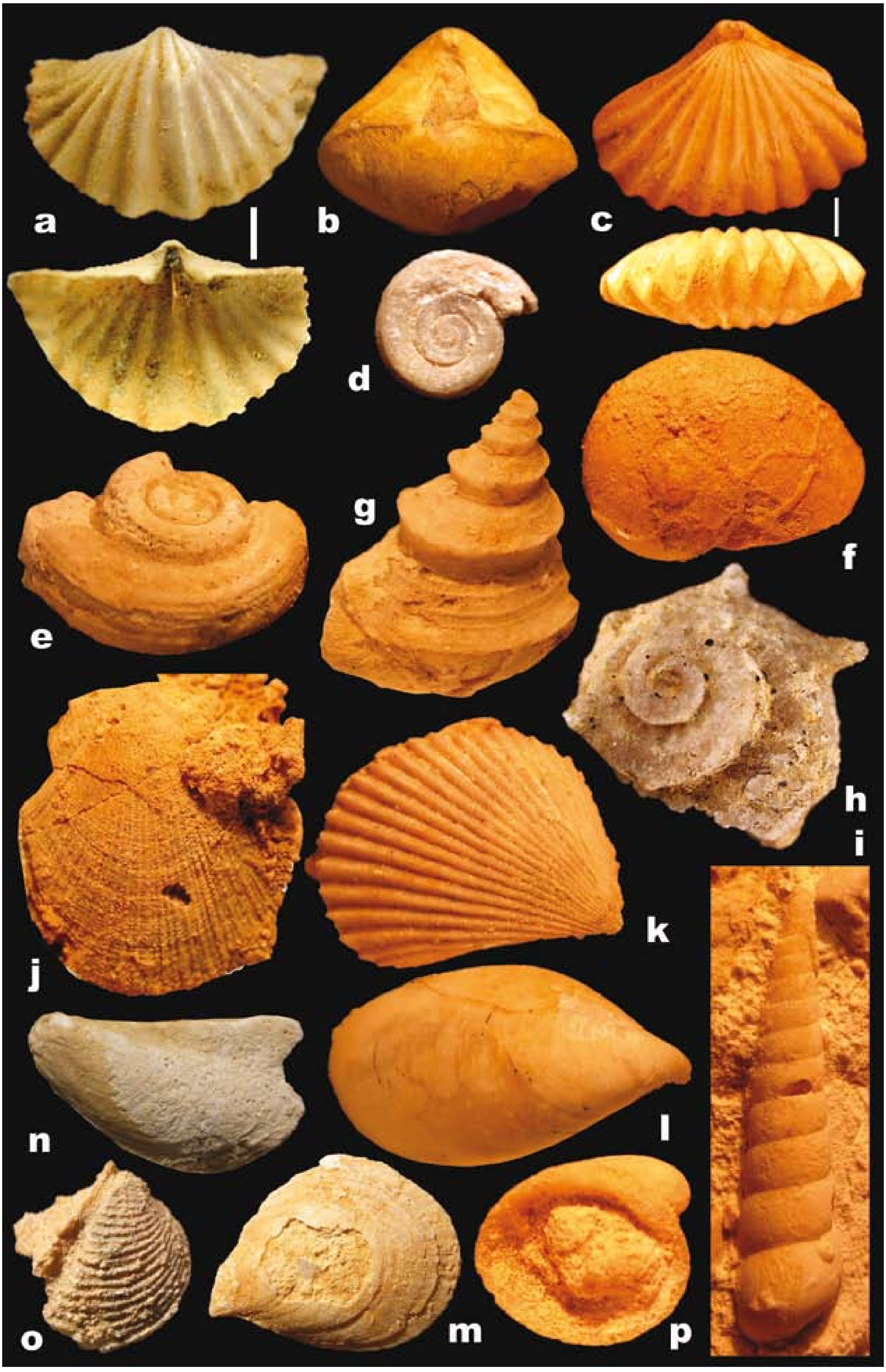
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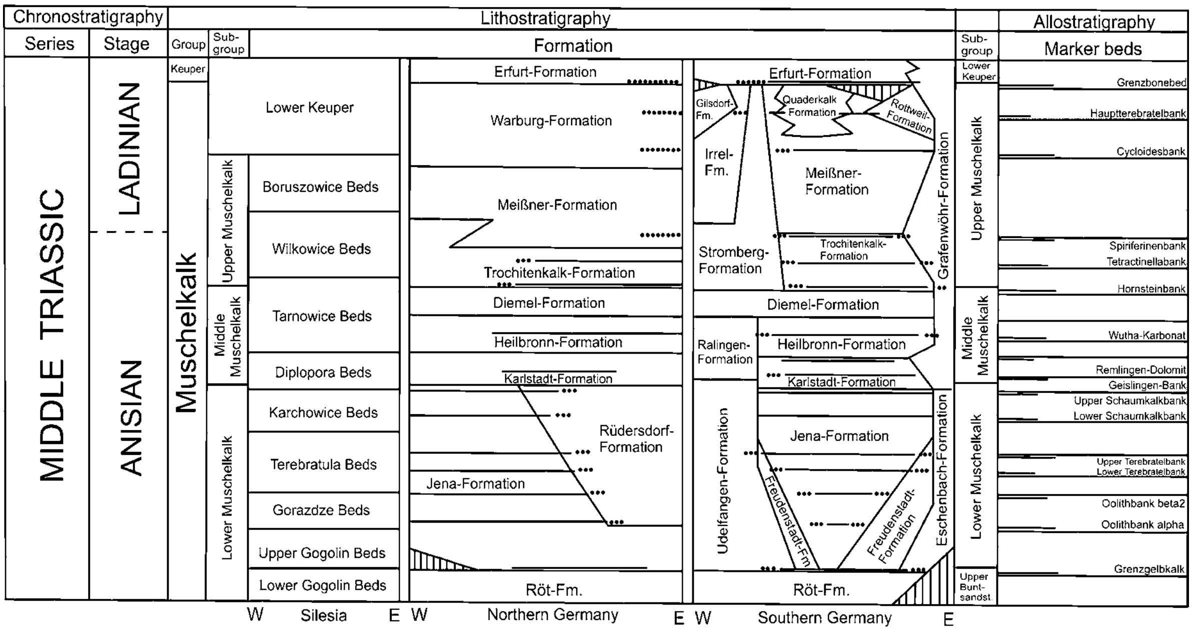


Fig. 22. Lithostratigraphy of the Middle Triassic of the Germanic Basin compiled by Goetz & Feist Burkhardt (in print, 2008), (mostly after Szulc (2000) and Hagdorn (2004))

Carpathian Gate. Other faunal elements are also exclusively germanotype. The ceratite chronokline is developed up to the Spinosus Biozone. Due to the marl dominated facies of the Boruszowice Formation, the subsequent ceratite lineage is not present (Niedzwiedzki *et* al. 2001). For this reason, in Poland the Muschelkalk/Keuper boundary is defined close to the base of the Upper Ceratite Beds (Enodis Biozone). Along the southern margin of the Holy Cross Mountains, the Cycloidesbank (Enodis Biozone) is well developed (Trammer, 1973). With its extension from the Black Forest to the Holy Cross Mountains, which is almost one thousand kilometres, the Cycloidesbank is the most widespread marker bed of the Germanic Muschelkalk.

In the 19th century, rich vertebrate faunas have been collected in eastern Upper Silesia from bonebed layers in the Boruszowice Formation of Laryszów (Larischhof; Meyer, 1847). They comprise teeth and fin spines of hybodont sharks, teeth and scales of actinoperygians, bones of the sauropterygian reptiles *Nothosaurus*, *Pistosaurus*, *Placodus*, the prolacertilian *Tanystropheus*, and large vertebrae of the ichthyosaur *Pachygonosaurus*.

Stratigraphy and correlation with Tethys and other Germanic subbasins

Joachim Szulc

The classical lithostratigraphical framework of the Triassic was established in Central Europe by Friedrich August von Alberti already in 1834. Since these times the basic lithostratigraphy has been improved and controlled by means of other stratigraphical coordinates, enabling fairly reasonable lithostratigraphic correlation throughout the entire Germanic basin (Fig. 22).

Biostratigraphy of the marine Röt - Muschelkalk succession bases mainly on condonts, ammonoids, and magnetostratigraphy, which provide quite detailed stratigraphic framework within Polish basin.

Conodonts are the most important marine microfossil group used for correlation of the Germanic and Tethyan realms. Kozur (1974*a*) proposed a first conodont zonation for the Germanic Basin. Conodont assemblages from the Polish part of the Germanic Basin were studied by Trammer (1975), Zawidzka (1975), Kędzierski & Szulc (1996) and Narkiewicz (1999). Recently, conodont appearance and distribution patterns (after systematic revision) within the Muschelkalk basin have been analysed with respect to relative sea-level changes (Narkiewicz & Szulc, 2004) (Fig. 23).

Since most of the Germanic ammonoids are endemic ceratites (Urlichs, 1999), their use for overregional correlation is limited. However, some index ammonoids (e.g., *Balatonites*, *Acrochordiceras*, *Discoptychites*, *Bulogites*) enable a correlation of Muschelkalk deposits with Tethyan successions (Brack *et al*., 1999).

Muschelkalk biostratigraphy has been improved by investigations on crinoids and echinoids, which appeared to be very useful tools for correlation with the Tethyan realm (Hagdorn & Gluchowski ,1993).

The Middle Muschelkak, devoid of cononodonts and other index-fossils, has been divided by Kotanski (1994) into 6 dasycladacean zones. According to Kotanski, the Pelsonian/Illyrian boundary lies in the lower part of the Diplopora Beds (Jemielnica Beds) and is defined by first occurrence of

Fig. 21 (see p. 25). Brachiopods, gastropods, and bivalves of the Karchowice Formation: a – *Punctospirella fragilis*, pedicle valve. Strzelce Opolskie (x 2,5); b – *Mentzelia mentzeli*. Tarnów Opolski (x 3,5); c – *Costirhynchopsis mentzeli*. Tarnów Opolski (x 3); d – *Discohelix (Amphitomaria) arietina*. Tarnów Opolski. (x 6); e – *Euomphalus semiplanus*. Tarnów Opolski (x 3,3); f – *Neritaria* cf. *N. comensis*, with encrusting serpulid (?). Tarnów Opolski (x 2,5); g – *Wortheniella* sp. Tarnów Opolski (x 2); h – *Coelocentrus silesiacus*. Tarnów Opolski (x 3,8). i – *Trypanostylus* sp. Tarnów Opolski (x 4); j – *Praechlamys schroeteri*. Strzelce Opolskie (x 2,5); k – *Lima acutecostata*. Strzelce Opolskie (x 2,5); l – *Promysidiella praecursor*. Tarnów Opolski (x 2); m – *Mysidioptera fassaensis*. Tarnów Opolski (x 2,5); n – *Bakevellia* cf. *B. costata*. Tarnów Opolski (x 2); o – *Elegantinia elegans*. Tarnów Opolski (x 2,5); p – *Schafhaeutlia* sp. Tarnów Opolski (x 5). All specimens Muschelkalkmuseum Ingelfingen

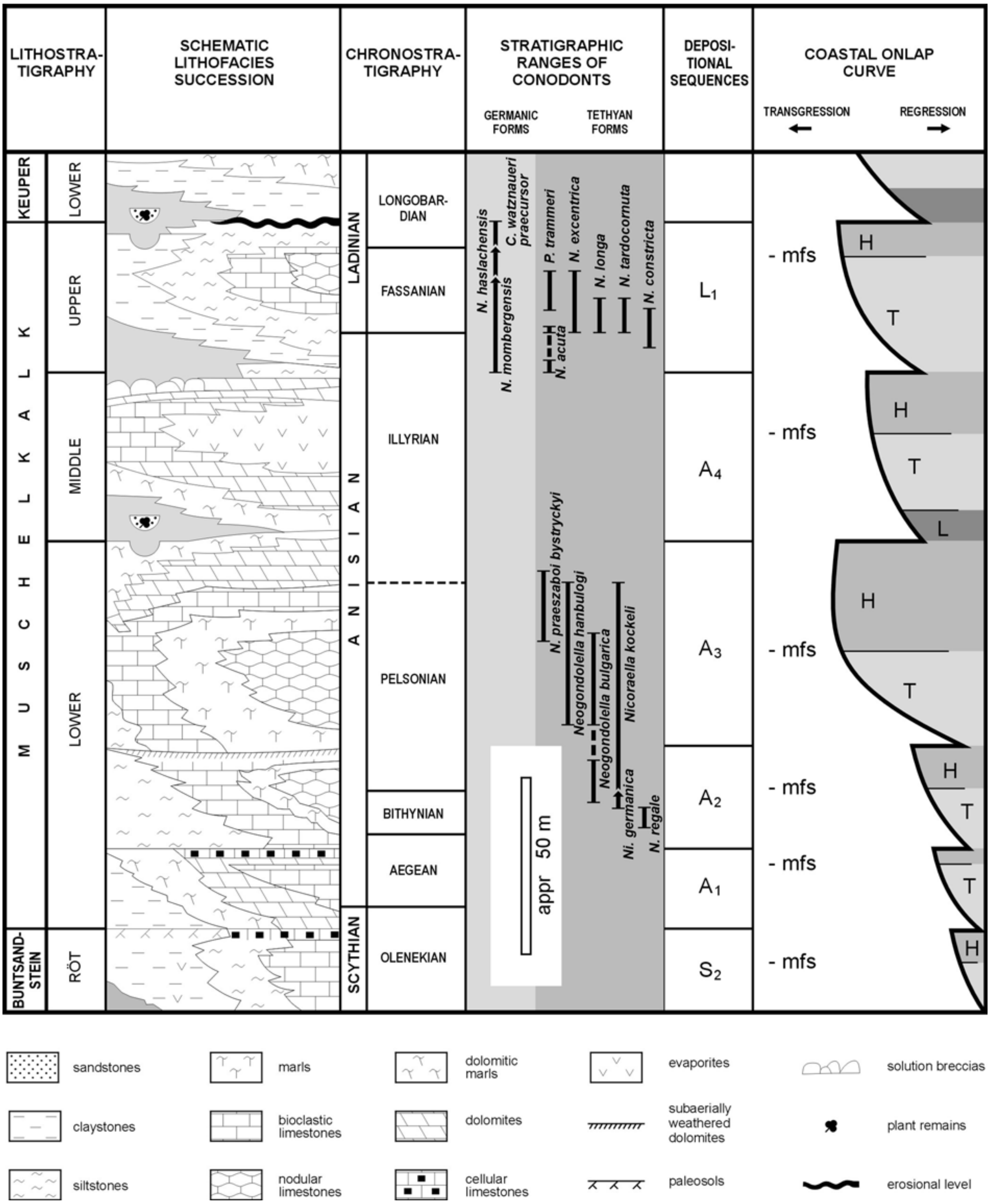


Fig. 23. Conodont ranges against the stratigraphy, facies succession and sea level changes in the Central European Muschelkalk (after Narkiewicz & Szulc, 2003)

several species of diplopores e.g., *D. annulatisima*, *D. silesiaca* and *D. multiserialis*.

Other non-index fossil groups (mostly facies-dependant organisms) including conchostracans (Kozur, 1999), ostracods (Kozur, 1974*a*; Beutler, 1988), foraminifers (Gazdzicki *et al.*, 1975) and megaspores (Fuglewicz, 1980; Wierer, 1997), are of limited biostratigraphical value and may be used for local correlation.

Recently, palynofacies analysis has been used as a tool for basin-wide correlation and high-resolution sequence stratigraphic interpretation in the Middle Triassic of the Germanic realm (Götz & Feist-Burkhardt , 2000; Rameil *et al.*, 2000; Götz *et al.*, 2005) as well as for correlation of depositional sequences of the northwestern Tethys shelf area with the northern Peri-Tethyan Basin (Götz *et al.,* 2003, 2005).

Up to now, magnetostratigraphy is seen as the most precise tool for correlation (Nawrocki & Szulc, 2000, Nawrocki, 2008 (in print). According to the magnetostratigraphical data the Röt/Muschelkalk boundary in Southern Poland is almost coincidental with the Olenekian/Anisian boundary. (Fig. 24) This statement has been accepted in *A Geological Time Scale* (Ogg, 2004) and strongly supported by recent, condont-calibrated, magnetostratigraphy from Southern

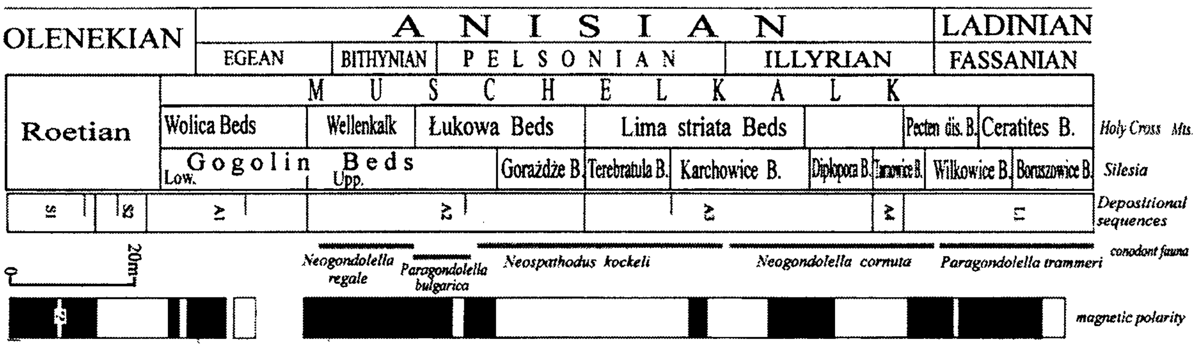


Fig. 24. The condont – calibrated polarity stratigraphy and correlation of Middle Triassic sections from Upper Silesia and Holy Cross Mts. (after Nawrocki & Szulc, 2000)

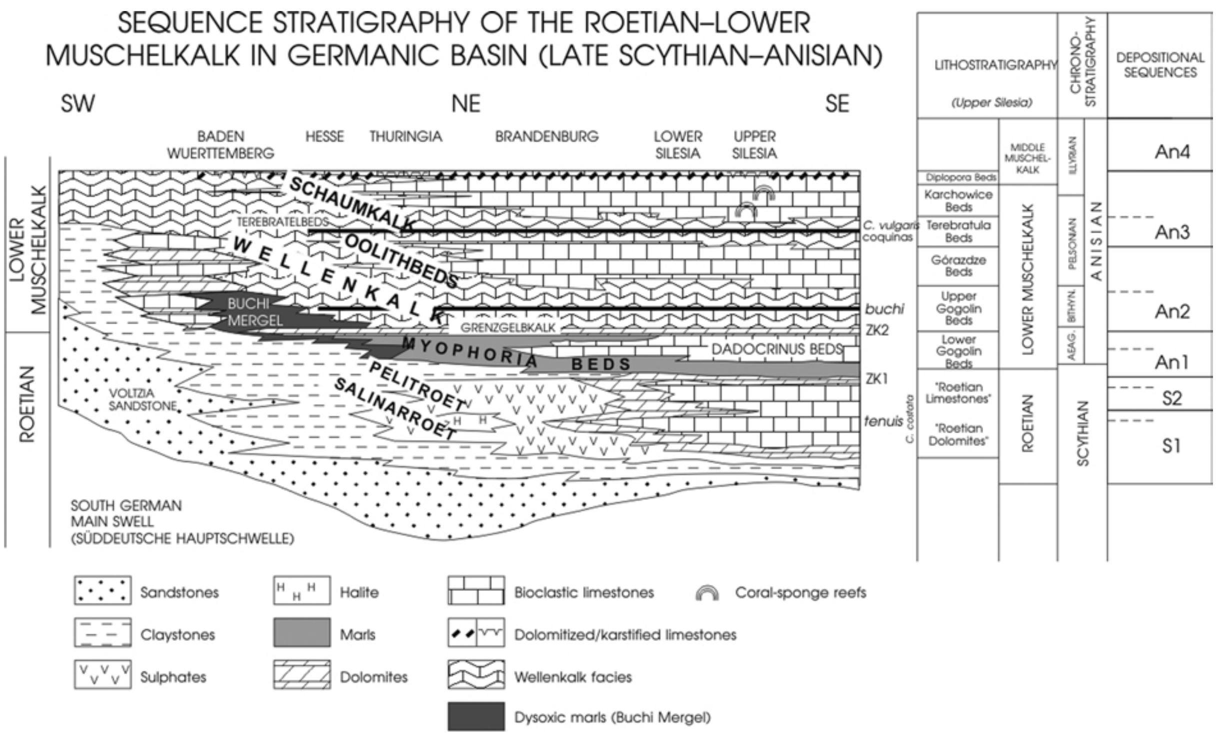


Fig. 25. Sequence-stratigraphic framework of the late Olenekian – early Carnian of the Germanic Basin (from Szulc 2000)

China (Lehrmann *et al*, 2006, Orchard et al., 2007) and finally, corroborated the recent achievements of chemostratigraphy. The Olenekian/Anisian boundary is well defined by a significant positive $\delta^{13}C$ shift, which appeared to be phenomenon in global scale (Szulc, 2000; Goetz *et al.*, 2005; Atudorei *et al.*, 2007).

Chronological outline of evolution of the eastern Germanic Basin in late Olenekian – early Ladinian times

Joachim Szulc

Röt (late Olenekian)

The Röt succession is bipartite. This is related to the two transgressions which came *via* the Silesian-Moravian Gate. Although the East Carpathian area was also controlled by open marine influences, but the marine influx did not extend beyond the western foreland of the Holy Cross Mountains.

The Röt deposits encompass two 3rd order depositional sequences (Szulc, 1999). The first one (S1) is very well developed in Upper Silesia where it commences with fine-grained clastics followed by dolomites, sulphates and bioclastic and oolitic limestones. The carbonates contain relatively rich assemblages of gastropods and bivalves; *Costatoria costata* coquinas are dominant. Limestone beds in the upper part of the succession contain numerous cephalopods (*Beneckeia tenuis*) and crinoids that record the first maximum flooding stage (Fig. 25). It is also worthy to note that the first crinoids appeared also in this time in southern Poland (Alexandrowicz & Siedlecki, 1960; Moryc, 1971).

After the first Röt transgression, sea level stabilized and the Germanic Basin began to fill progradationally during the following highstand phase. As a result, the basin shallowed and became emergent. Subsequent erosion led to the formation of the basin-wide intra-Röt unconformity (Geluk & Röhling, 1997). In the areas close to the Tethys Ocean, *i.e.* the East Carpathian and Silesian-Moravian gates, marine carbonate sedimentation persisted, but limestones were replaced by

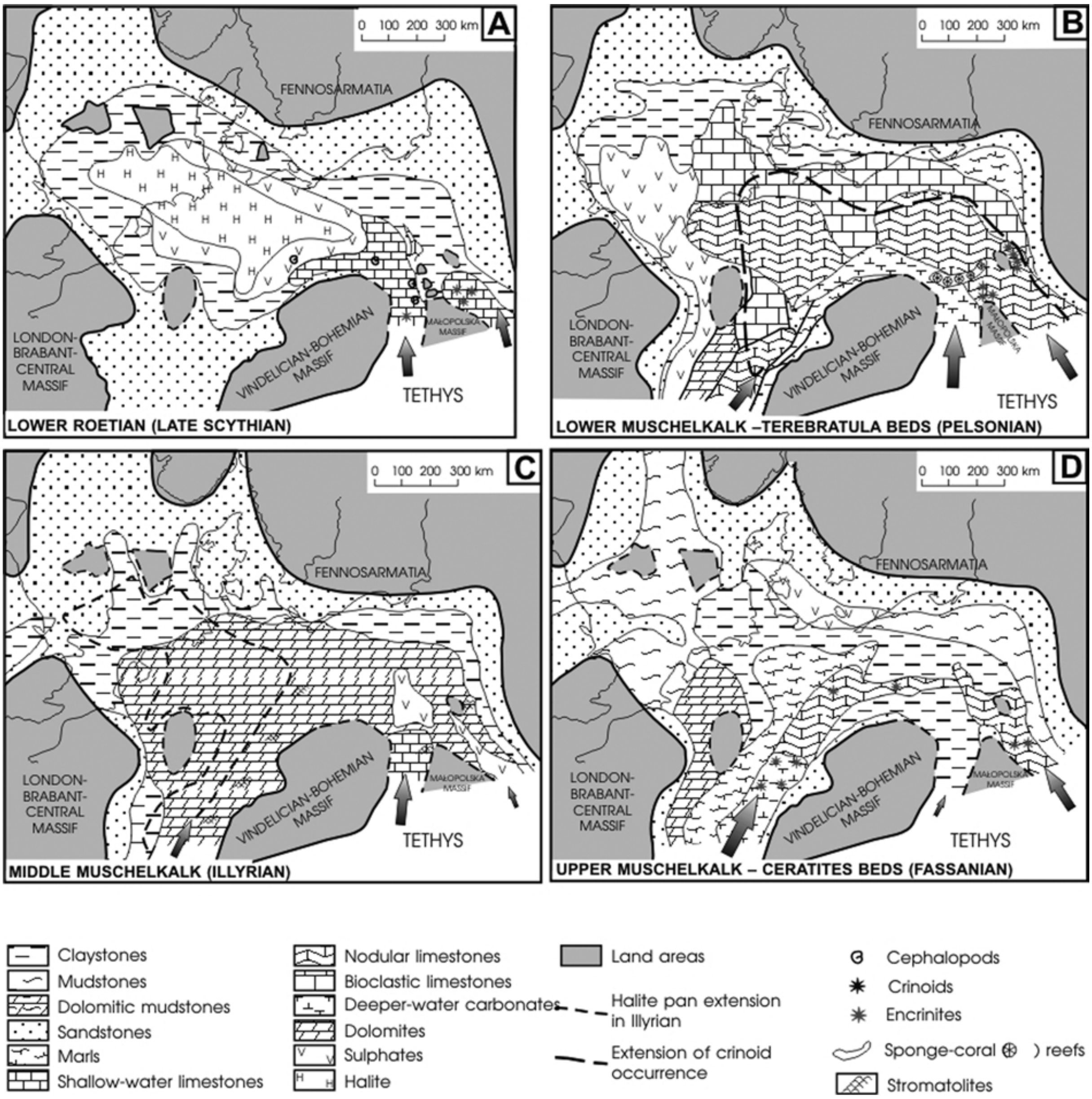


Fig. 26. Paleofacies maps of the Peri-Tethys domain in late Olenekian-Ladinian times (after Szulc, 2000)

sulfates-bearing dolomites (Fig. 26a, 27h). Due to elevated salinity, most of the normal marine organisms receded.

The second transgression in the Germanic Basin generally encompassed the same area as the first one. The lithofacies pattern shows a similar distribution; carbonate sedimentation was again dominant in the areas of the Silesian-Moravian and East Carpathian gates, while basinward both dolomites and sulphates were deposited.

Muschelkalk

Lower Muschelkalk – Middle Muschelkalk

Anisian to mid Illyrian

Myophoria Beds – Lower Gogolin Beds

1st Anisian Sequence (An 1)

Meteorically altered halite-bearing carbonates called "cavernous limestones" (*Zellenkalk* 1) form the sequence boundary in Upper Silesia (Fig. 25).

The TST is represented by bioclastic limestones occurring from Silesia to Thuringia and called informally "Myophoria Beds". (Fig. 27a) In Upper Silesia the TST is well expressed by tempestite set displaying fining and thinning upward trend, reflecting retrograding geometry (Fig. 27b). An interval with Dadocrinus crinoids (Hagdorn and Głuchowski, 1993) and hardground horizon encrusted by Plagiostoma oysters (Fig. 27c, d) can be pointed out as the maximum flooding zone. The above lying part of the set shows a reverse shallowing/thickening upward tendency typical of the HST. The subsequent marls, dolomites and cavernous, evaporites-bearing limestones (Fig. 25) build the uppermost part the HST.

The Silesian Lower Muschelkalk succession displays features of intense syndepositional tectonic activity (Fig. 27e, f).

Upper Gogolin – Górażdże Beds

2nd Anisian Sequence (An 2)

In Silesia the sequence boundary is defined by the second cavernous postevaporitic limestones (Zellenkalk 2) (Fig. 27h) dividing the Lower and Upper Gogolin Beds.

Gradual fining of grain size and faunal evolution suggest a relatively continuous course of the transgression (Szulc, 1999). The fining-upward trend in limestones (Upper Gogolin Beds) (Fig. 27f, g) shows a retrogradational stratal pattern indicative for the TST and correspond to the Wellenkalk facies in Germany.

First appearance of the index conodonts (e.g. *Neogondolella bulgarica, Neogondolella regale*, *Nicoraella kockeli*,) and tethyan ammonoids (*Balatonites ottonis*, *Acrochordiceras*) is the most important bioevent recorded during this stage. The conodonts have enabled a reliable correlation of the Muschelkalk deposits with the Tethyan successions (Kozur, 1974a, b; Zawidzka,1975; Trammer,1975; Götz; 1995; Kędzierski & Szulc, 1996). Also the crinoids have been successfully applied as precise tool of biogeographical reconstructions and chronostratigraphical zonation of the Lower Muschelkalk (Hagdorn and Głuchowski, 1993).

During the highstand phase the basin was progradationally filled with skeletal debris, oncoids and oolites building a thick calcarenitic bar of the Górazdże Beds, reaching up 15 m in thickness (Fig. 28a, b). In the Holy Cross Mts. the highstand deposits are represented by massive limestones of the Łukowa Beds, featured by *Balanoglossites* firmgrounds (Fig. 29, Fig. 39f). To the west and southwest the sandbody grades into 2-3 horizons of the so called Oolitic Beds (Oolithbänke) reaching 2-4m of total thickness in Hesse and Baden. The topmost part of the calcarenitic shoals of the Gorazdze Beds displays common features of subaerial exposure (ferricrete and meteoric dissolution) (Szulc, 1999) and defines the boundary of the next depositional sequence (Fig. 28d).

Terebratula Beds – Karchowice Beds – Diplopora Beds

3rd Anisian Sequence (An 3)

Emersion event(s) marked by meteoric diagenetic overprints affecting the shoal deposits (Szulc, 2000) or by direct paleontological evidences (Diedrich, 2000) determine the sequence boudary within the offshore part of the Germanic Basin (Silesia, Thuringia, Hesse). In the Holy Cross Mts. the sequence boundary is marked by quartzouse mudstones rich in gypsum nodules common in the upper Łukowa – lower Lima striata Beds (Fig. 29).

The next transgression was very rapid as suggests finely laminated, deep-water limestones (nodular dark limestones) overlying directly the sequence boundary (Fig. 28a, c, e). In Upper Silesia the deepening was tectonically forced (Fig. 28d) (Szulc, 1993). The fine-grained limestones of the TST are impoverished in body fossils and ichnofossils what indicates a poorly ventilated, starved basin and support the above inference about very fast progress of the transgression (Szulc, 1999). This interval is characterized by explosive appearance of *Coenothyris vulgaris* brachiopods building the so-called Terebratula Beds (Terebratelbänke) (Fig. 25). According to sedimentological citeria (Szulc, 1990; 1993) and palynofacies data (Götz *et al*., 2005) the transgressive Terebratula Beds represent the Anisian maximum flooding surface recognized over the whole basin (Aigner & Bachmann, 1992; Szulc, 1995).

After the drowning the basin was progradationally filled and the oxic condition improved gradually as indicate infauna activity expressed by *Thalassinoides*/*Balanoglossites* ichnofabrics (Fig. 28e, f) and by evolution of the benthic communities. During the advanced highstand phase, high energy deposits (calcarenitic subaqual dunes) developed (Karchowice Beds) (Figs.30a-c; Fig. 31a-f; In Upper Silesia the HST climaxed with sponge-coral-echinoderm buildups (Fig. 32a-f; Fig. 33a-h). Final stages of the HST in Silesia are represented by *Girvanella* oncoliths, dasycladacean debrites and finally by oolitic bars of the Diplopora Beds (Fig.30d, e; Fig. 34).

The sponge-bearing bioclastic limestones extended up to Holy Cross Mts., (Fig. 26b) but the topmost part of the HST deposits comprises sulphate intercalations indicating elevated salinity by the end of the highstand (Fig. 29).

In the central part of the basin (western Poland, Brandenburg) the reefal complex has been replaced by bioclastic and oolitic deposits of the sand shoal (Schaumkalk – *Warstwy piankowe*) (Fig. 25) reaching some 30-40 meters in total thickness. Like in the precedent sequence, the sandbody splits to SW and W, into 2-3 horizons of bioclastic and oolitic horizons sandwiched between the Wellenkalk facies. The HST terminates with dolomitic horizons enclosing sulphate pseudomorphoses and displaying a relatively uniform distribution over the whole basin (orbicularis Beds, Geislingen Bank, Sub-dolomitic Beds).

Exceptionally great number of Tethyan faunal elements: brachiopods, pelecypods, echinoderms, conodonts, corals and dasycladales occurring in Silesia (Assmann, 1944; Hagdorn, 1991 and in this volume) unequivocally indicates that during the time under discussion , the communication between the Germanic Sea and Tethys Ocean reached its optimum.

Tarnowice Beds

4 thAnisian Sequence (An 4)

The sequence boundary is clearly marked in the entire basin by subaerial exposure fabrics: paleosoils, karstic pavements as well as by playa clastics and evaporites of the Tarnowice Beds in Silesia (Fig. 30d) (Szulc, 1999).

Ubiquitous sponge-microbial stromatolites (Fig. 34a) (Szulc, 1997) along with the succeeding unfossiliferous dolomites represent the LST deposits. The TST is represented by dolomites and fossil-poor limestones in Silesia and by sulphates in the other parts of the Germanic Basin. Like in the first Röt sequence also during this transgression the maximum trangressive stage thick rock salt deposits formed in the depocenter situated in western part of the Germanic Basin (Fig. 26c).

The HST is represented by succession of sulphates, dolomites and limestones diplaying features of subaerial exposure.

Upper Muschelkalk

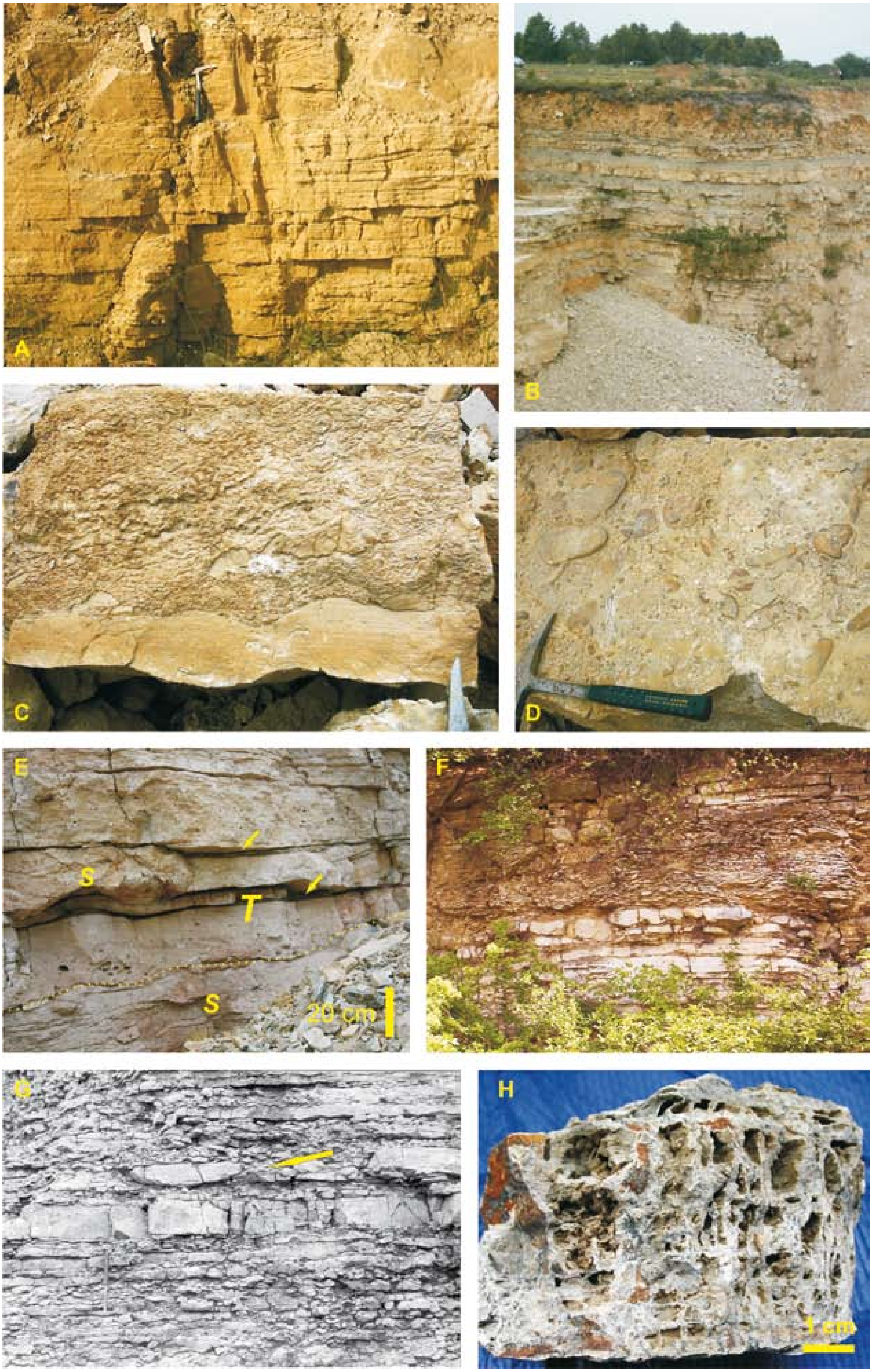
Late Illyrian to early Ladinian

Wilkowice Beds – Boruszowice Beds

1st Ladinian Sequence (La 1)

The sequence boundary in southern Poland is formed by paleosoil and karstic horizon (Szulc, 1999) and the following LST is represented by by dolomitic limestones.

Fig. 27. Chosen sedimentary aspects of the Gogolin Beds: A – Cross-stratified bioclastic bar deposits of the Lower Gogolin Beds. Gogolin; B – Lower Gogolin Beds section of Zyglin; C – Intraclastic tempestites from Lower Gogolin Beds, Zyglin; D – Plane view of C; E – Seismite-tsunami dyads in Lower Gogolin Beds, from Zyglin, S – seismically disturbed sediments (seismite), T – tsunami backflow deposits (tsunamite) composed of offshore-derived intraclastic sediment and land-derived red clayey drape (arrows); F – Quake-triggered convolutions and slumped limestones ("Wellenkalk") of the lower Upper Gogolin Beds, Libiąż; G – Synsedimentary slide defermation within the Upper Gogolin Beds. Arrow indicates sense of sliding. Strzelce Opolskie quarry; H – Vuggy limestones from the "Zellenkalk 2", i.e. the boundary between the Lower and Upper Gogolin Beds (also boundary of the A2 deposition sequence). Gogolin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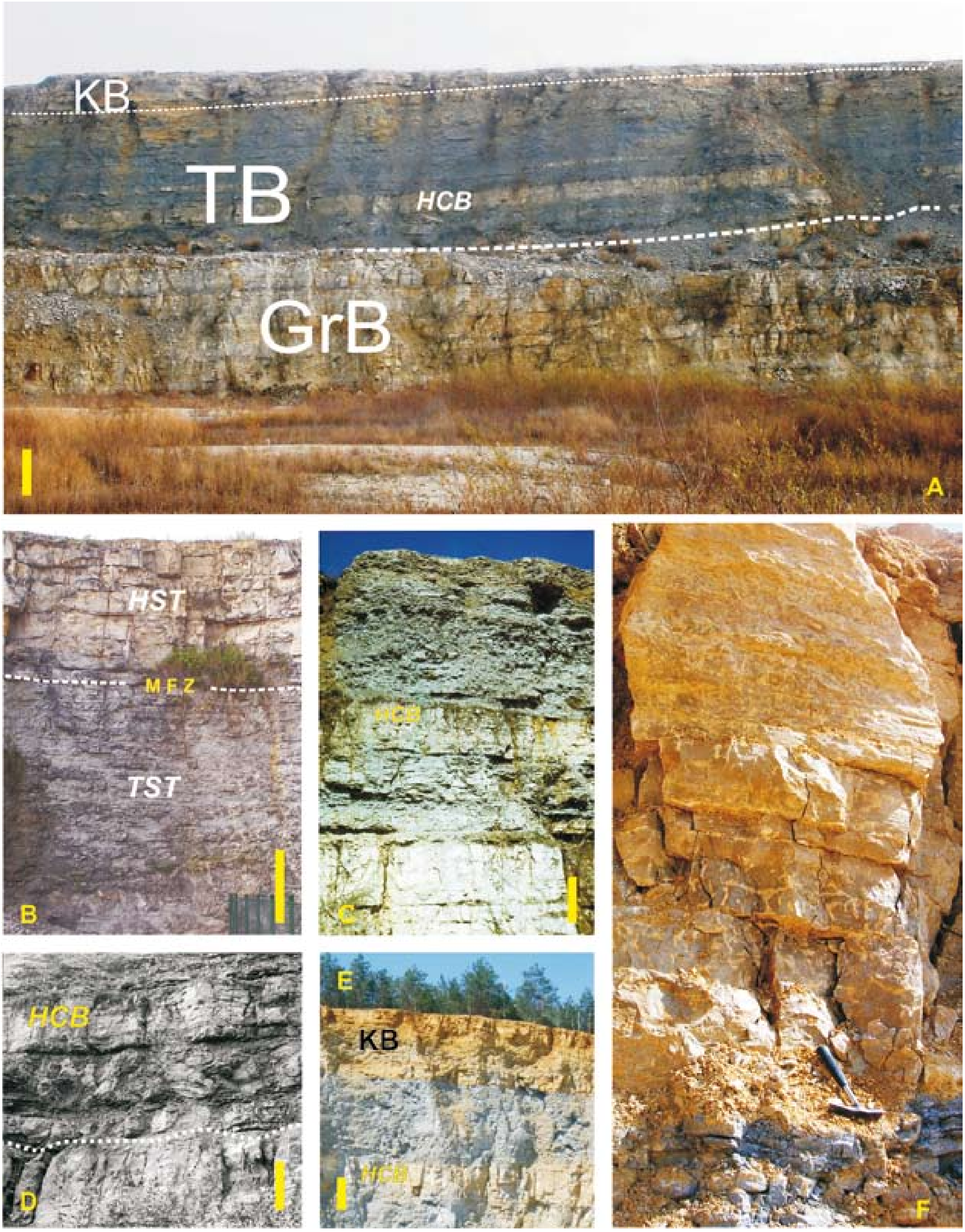


Fig. 28. Sedimentary aspects of the Terebratula Beds: A – General view of the Lower Muschelkalk section from Strzelce Opolskie quarry. GrB – Góraždže Beds, TB – Terebraula Beds, HCB – *Hauptcrinoidenbank*, KB – Karchowice Beds; B – Transition between TST (Upper Gogolin Beds) and HST (Gorazdze Beds) of the 2nd Anisian sequence (A2). Strzelce Opolskie quarry; C – Closer view of the topmost Goraždze Beds and the Terebratula Beds. Strzelce Opolskie quarry; D – Slumped lower part of the Terebratula Beds overlying undulated top of the Goraždze Beds (boundary of A3 sequence); E – Transition between deep water, fine grained Terebratula Beds and shallower water Karchowice Beds. Note the noticeable sediment colour change; F – Detail of E. The transition sueccession is composed of several firmground horizons. All scale bars – 2 meters

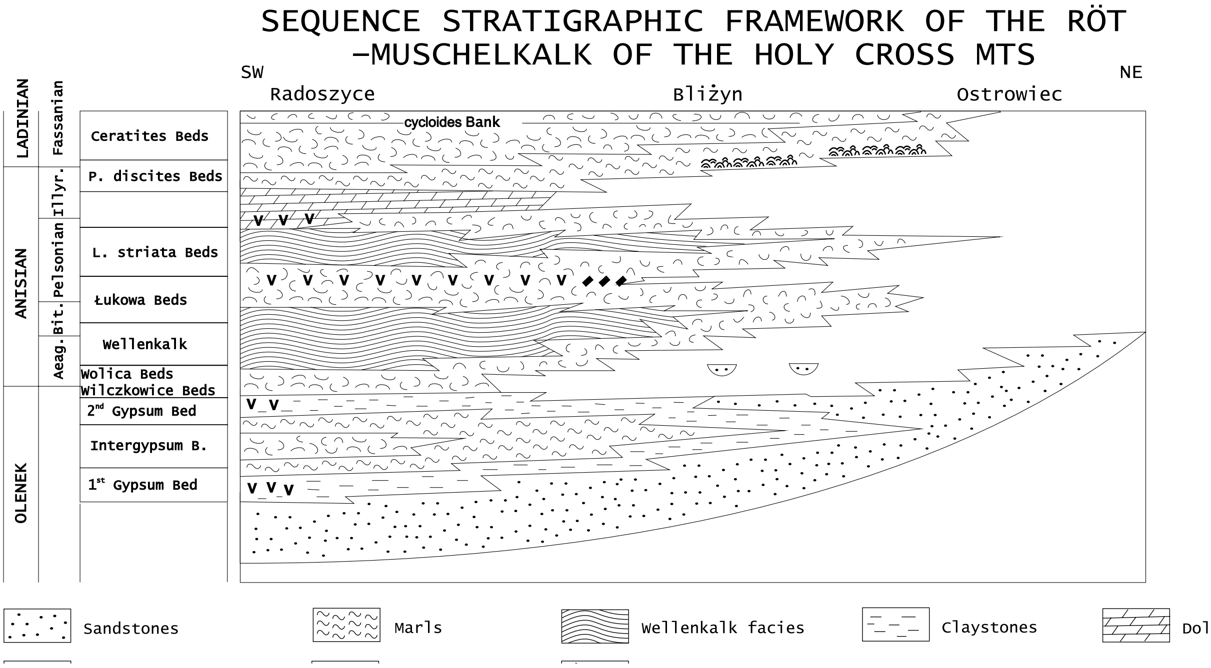


Fig. 29. Sequence-stratigraphic framework of the late Olenekian– early Carnian from the Holy Cross Mts. (from Szulc 2000)

The TST is built by coquina deposits (discites – Beds in Holy Cross Mts.) and condensed limestones (Wilkowice Beds in Silesia) which correspond with bioclastic or oolitic thick bedded limestones (Trochitenkalk, Glaukonitkalk) in Germany (Figs. 24, 29, 35).

Deep ramp marls and limestones of the Hauptmuschelkalk belong to the HST in the German basin. The maximum flooding surface of the Ladinian in the Germanic Basin is marked by horizon with *Coenothyris cycloides* (“*cycloides*” – Bank) (Aigner & Bachmann, 1992), occurring from the Holy Cross Mts. to SW Germany. The Hauptmuschelkalk deposits were succeeded by prograding shallow marine limestones and dolomites representing the late highstand stage (Aigner, 1985). To the east and north from Germany, the basin became more and more brackish and the limestones were replaced by marls and clastic marine deposits (Fig. 35). Carbonate sedimentation persisted in the Holy Cross Mts., where the Ceratites Beds evidence open communication with the Tethys *via* the East Carpathian Gate (Fig. 26).

The biostratigraphical data indicate that in the Polish basin the normal marine conditions have been replaced by brackish environments with the 4th conodont zone (*Neogondolella haslachensis*) (Fig. 23), *i.e*. 3 zones earlier than in the southwestern Germany (Kozur, 1974a; Trammer, 1975; Zawidzka, 1975). The end of the normal marine sedimentation in the Polish basin was coincidental with the *cycloides*-Bank i.e with the maximum flooding phase in the basin (Fig. 35). Nonetheless, despite of the environmental changes, the HST continued up to the Lower Keuper in terms of the sequence stratigraphy. An impoverished marine fauna, (including conodonts) which occurs in sediments ascribed to the Lower Keuper (Lettenkeuper) (Assmann, 1926; Gajewska, 1978; Narkiewicz, 1999) support the presumption.

The biostratigraphic data, including the palynostratigraphy (Orłowska-Zwolińska, 1983) suggest that the Lower-Middle Lettenkeuper (lower and middle Sulechów Beds) of the Polish basin is of Longobardian age i.e. they correspond to the Upper Hauptmuschelkalk in southwestern Germany.

Keuper

Joachim Szulc

General setting

Basin configuration in Upper Triassic did not differ significantly from that of the Muschelkalk. The Germanic Basin was bounded by the Variscan massifs, and the depocentre followed the Mid Polish Trough. Several smaller subsidence centres, were controlled by strike-slip faults and hence played the role of ephemeral depocentres.

The basin topography outlined above resulted in the following general facies pattern: fine-grained sediments, whether marine or terrestrial, accumulated in the depocentres, whereas coarser deposits, mostly sandstones, formed adjacent to the bounding massifs, in particular the Bohemian Massif. Therefore, the facies formed within the basin centres have their sandy proximal equivalents at the basin margins.

The most extensive Upper Triassic transgression of the Grenzdolomit, which took place in late Ladinian, came again through the Silesian gate, when marine sediments reached similar extent like those of the Muschelkalk; however, this marine basin was much shallower than its Muschelkalk predecessor (Fig. 36).

The subsequent stages of the Upper Triassic in Polish basin reflect essentially climatic fluctuations between arid and more humid conditions, what is illustrated well by “humid” Schilfsandstein fluvial clastics (mid Carnian) sandwiched between the arid Lower and Upper Gipskeuper intervals of respectively, early and late Carnian ages. Intensive fluviatile erosion along with tectonically controlled topographical rejuvenation, resulted in the Schilfsandstein resting discordantly on various older Triassic or even Palaeozoic formations. Only in the central part of the Mid Polish Trough erosion was less severe, and fine-grained lacustrine clastics deposited.

During Norian times, the climate underwent continual amelioration as indicated by the gradual declining of evaporites and their replacement by ephemeral and/or perennial fluvial sediments (Jarkowo and Zbaszynek Beds ≈ Steinmergelkeuper). This gradual climatic change probably reflects the drift of the stable European block into a higher palaeolatitude zone (40-45°) outside the subtropical dry belt (Kent & Tauxe, 2005).

Pluvialisation led to the gradual reestablishment of vascular plants which, in turn, favoured the development of tetrapods and the appearance of the first dinosaurs (*Plateosaurus*) in SW Germany and in Silesia (Schoch & Wild 1999, Dzik *et al.* 2000).

One of the most intriguing questions regarding the Norian succession is the problem of possible marine incursions suggested by Dadlez & Kopik (1963) on the basis of the isolated occurrences of foraminifers in Jarkowo and Zbaszynek Beds in central and NE Poland. The problem lies in the questionable communication links of this region with the marine basins. According to facies distribution patterns (Deczkowski, 1997), influx from neither the North Sea rifts nor from the S (i.e. from the Tethys) was possible at this time. On the other hand, the poor stratigraphic constraints on the Upper Keuper sediments in Poland make this a difficult problem to resolve.

Pluvialisation trend continued during the Rhaetian as indicated by well-sorted fluvial quartz sandstones, and siltstones with coal seams and much plant debris.

Stratigraphy and correlation with Tethys and other Germanic subbasins

The biostratigraphy of the Keuper deposits is founded mainly on the palynostratigraphical tools. Most recent palynostratigraphical subdivision of the Keuper deposits and correlation of Upper Triassic palynostratigraphic zones of the Germanic and Alpine realms are compiled and discussed in Schulz & Heunisch (2005). For the Polish Upper Triassic the palynostratigraphic scheme proposed by Orłowska-Zwolińska (1983, 1985) is still valid. Unfortunately, because of the dominating hostile subaerial conditions, the Keuper palynological material displays many gaps.

For the time being, the Upper Triassic stratigraphy of the Germanic domain is still basing on lithostratigraphy, which generally reflects alternating shallow marine and continental environments and/or fluctuations between arid and humid climatic conditions.

The general lithostratigraphical framework is broadly uniform throughout the basin (Fig. 37). However, the scarcity of age-diagnostic fossils impedes detailed bio- and chronostratigraphic work and magnetostratigraphic data are still very scarce. Therefore the higher levels of stratigraphical resolution and detailed basinwide correlations are difficult to achieve. It is particularly true for the upper part of the Keuper in the Polish basin where, owing to extreme facies variability, the lithostratigraphical framework is complex, with many local, uncorrelated units (see Polish Stratigraphical Table, 2007, in print). This facies variability resulted from complex tectonic mobility affecting the basin topography and involving multiple sedimentary and erosional gaps.

Summarizing, the main lithostratigraphical units of the lower intervals of the Keuper, *i.e.* the Lower Keuper, Lower and Upper Gipskeuper and Schilfsandstein, are relatively uniform and easy to correlate over the entire Germanic Basin (Fig. 37). In contrast, the lithostratigraphical units of upper division of the Keuper *i.e.* from the Upper Gipskeuper onward, reflecting changes in dominant climatic conditions but strongly modified by tectonic movements are difficult for unequivocal correlation, even in a distance of several kilometers.

Chronological outline of evolution of the eastern Germanic Basin in late Ladinian – Rhaetian times

Joachim Szulc

Lower Keuper and Middle Keuper

Lettenkeuper, (Sulechów Beds)
Late Ladinian
2nd Ladinian Sequence (La 2)

The biostratigraphic data, including the palynostratigraphy (Orłowska-Zwolińska, 1983) suggest that the Lower-Middle Lettenkeuper (lower and middle Sulechów Beds) of the Polish basin is of Longobardian age i.e. they correspond to the Upper Hauptmuschelkalk in southwestern Germany.

Tectonically-forced, regional angular unconformity marks the sequence boundary (Aigner & Bachmann, 1992). (Fig.35). Marine fine clastics and dolomites, affected by submarine condensation phenomenon represent the TST and HST in SW Germany (Aigner & Bachmann, 1992). The marine sediments pass into the brackish and deltaic clastic sediments of northeastern Germany and northern Poland. Farther to the north and east these onshore facies grade into continental mudflat sediments (Szulc, 1999) (Figs. 35 & 36).

Limited communication with the Tethys existed exclusively *via* the Western Gate. Because of the uplift of the Vindelico-Bohemian Massif, the eastern gates were closed. The southern Poland, including the fieldtrip area, was emerged and incised valleys system developed.

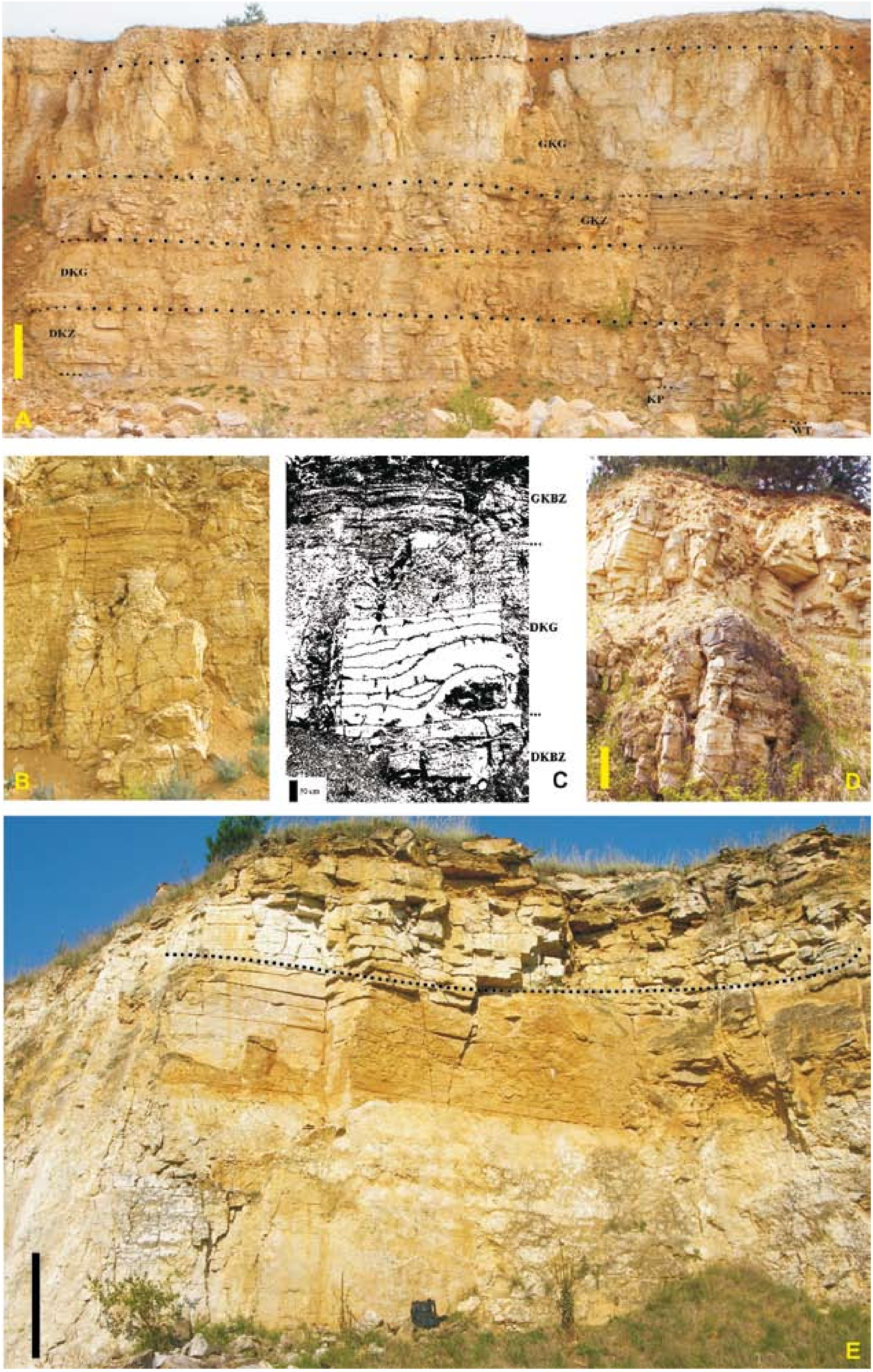
Grenzdolomit-Lower Gipskeuper
Late Ladinian early Carnian
3rd Ladinian Sequence

The emersion continued in Poland (beyond the Mid Polish Trough) during the next cycle hence it is not possible there to decipher the boundary between the La 2 and La 3 depositional sequences (Fig. 35).

In Germany the sequence boundary is outlined by incised valley system resulted from braided streams activity (Aigner & Bachmann 1992). The sequence boundary is emphasized by palynologically barren redbeds succession (Orłowska-Zwolińska, 1983) extremely impoverished in faunal fossils (Gajewska, 1978).

Fluvial deposits of the Hauptsandstein complex, filling the incised valley system, represent the LST deposits (Aigner & Bachmann, 1989). Lithological and geochemical properties of the fluvial clatics indicate the Scandinavian Land as a main source area (Paul & Ahrendt, 1998). The subsequent TST is represented by marine fine clastics in the central parts of the

Fig. 30. Sedimentary aspects of the Karchowice and Diplopora Beds. A – Complete succession of Karchowice Beds in Strzelce Opolskie quarry WT – Terebratula Beds, KP – Transitional Complex, DKZ – Lower Bioturbated Complex (LBK), DKG – Lower Spongean Complex (LSC), GKZ – Upper Bioturbated Complex (UBC), GKG – Upper Spongean Complex (USC); B – Details of A. Transition between LBC and LSC. Note a small sponge bioherm in the lower part of LBC; C – Digitised drawing from B; D – Diplopora Beds-Tarnówice Beds transition in Libiąż quarry. Note the discordant boundary between these units; E – Karchowice Beds-Diplopora Beds transition in Kamień Śląski quarry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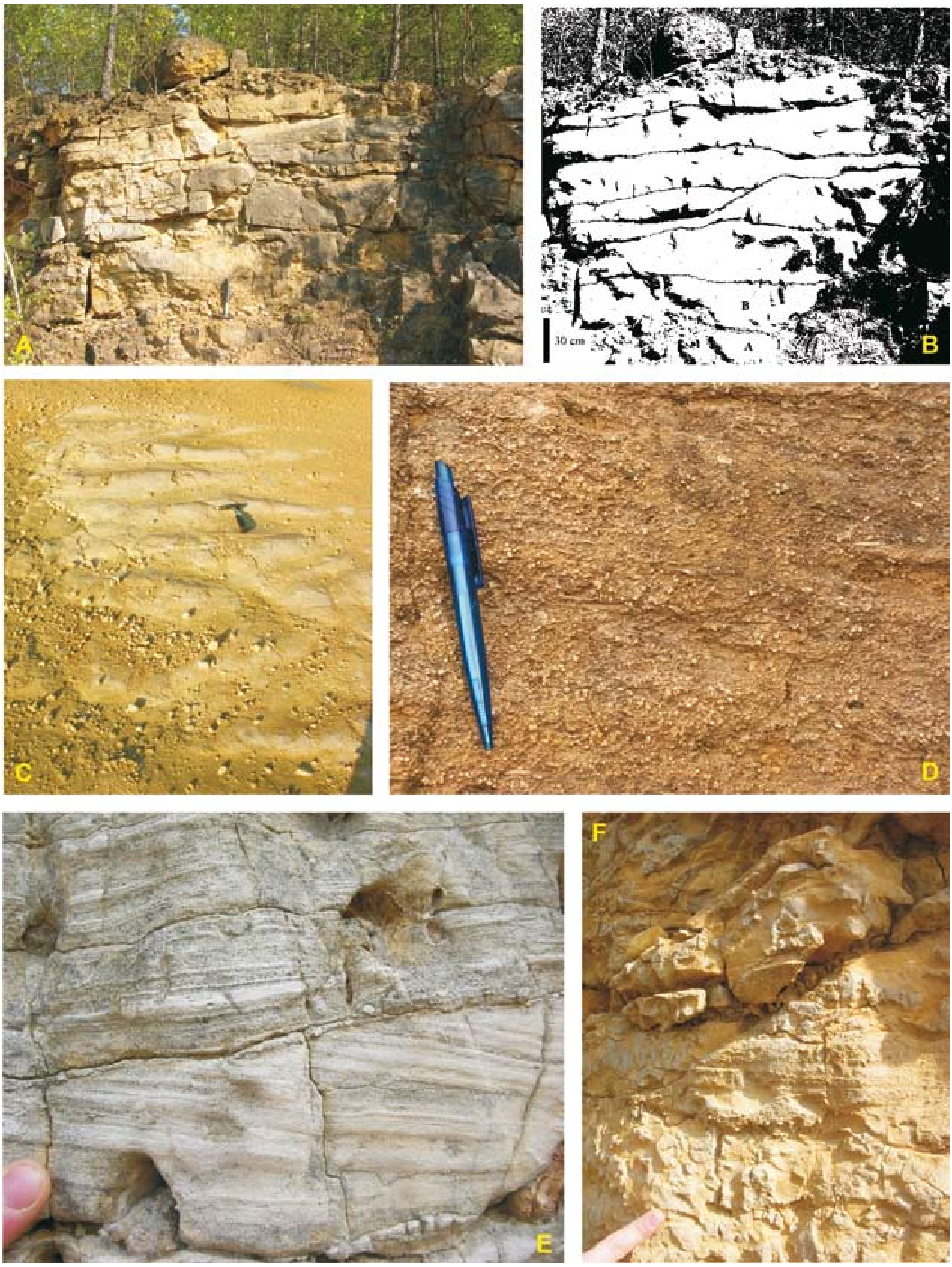


Fig. 31. Main sedimentary characteristics of the non-biohermal deposits of the Karchowice Beds: A – Internal composition of cross-stratified subaqual dune deposits; B – Digitised drawing of Fig. A; C – Oscillatory ripplemarks shaping the top of the dune surface; D – Ecnrinite calcareous sands; E – Erosional contact between two sets of calcarenites; F – Deeply eroded encrinite bed overlain by bioturbated calcisilites. Note the lateral amalgamation of the 2 bioturbated horizons (to the left)

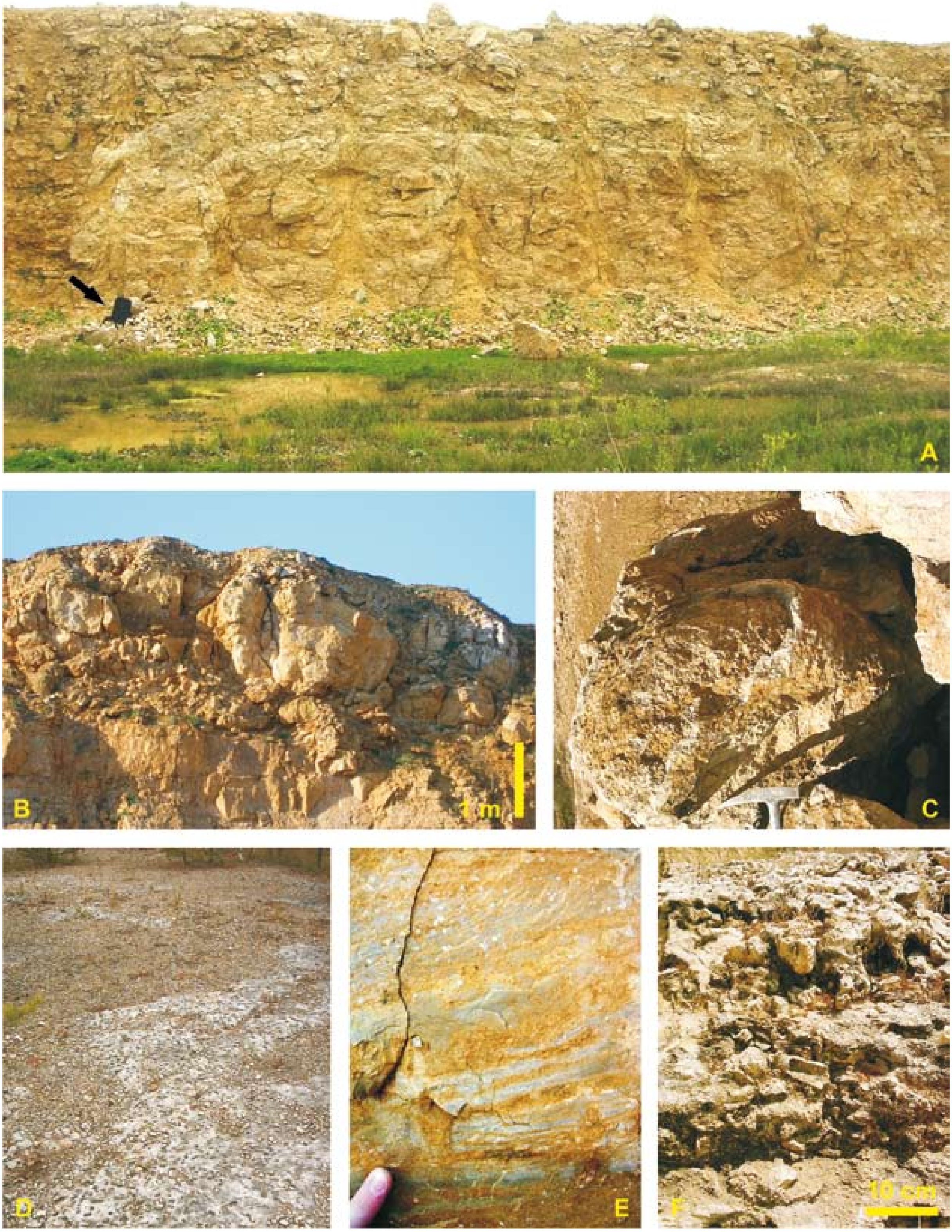


Fig. 32. Sponge buildups of the Karchowice Beds: A – Low-relief seponge bioherm. Kamień Śląski. Rucksack for scale (arrow); B – Knobby sponge reef. Strzelce Opolskie; C – Detail of B; D – Surface of biostrome built by prostrate sponges. Tarnów Opolski; E – Prostrate sponge colonies stabilising bioclastic sands. Tarnów Opolski; F – Thicker sponge biostromal construction

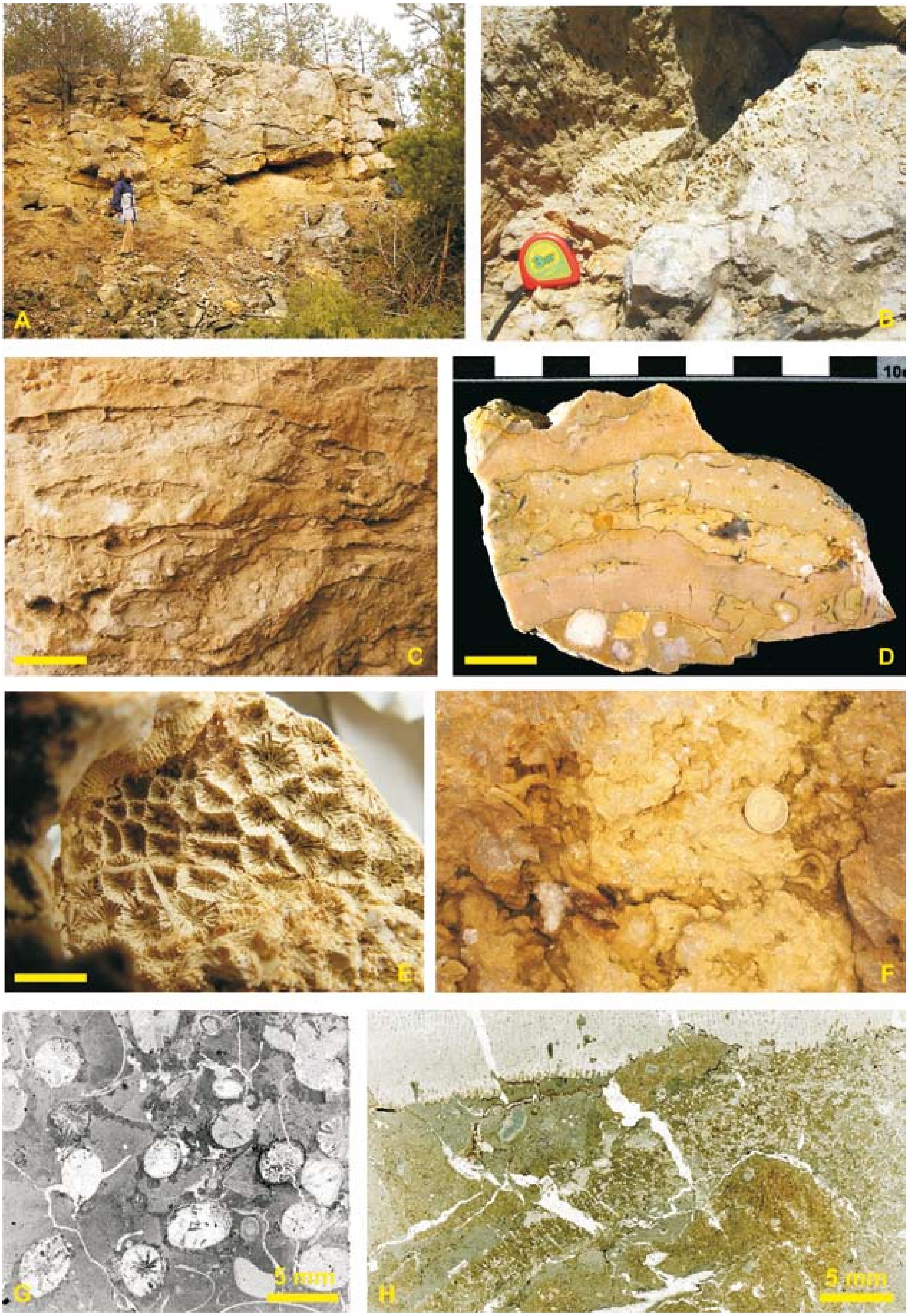


Fig. 33. Coral buildups of the Karchowice Beds: A – Sponge-coral reef from Tarnów Opolski quarry; B – Branching Volzeia szulci colony. Detail from A; C – Encrusting Pamiroseris silesiaca colony interlayered with bioclastic sediments. Detail from A; D – Polished slab of C; E – Eckastrea prisca colony from Tarnów Opolski quarry; F – Serpulid encrusters from the coral-sponge reef; G – Thin section of the Volzeia szulci colony; H – Thin section of the sponge-coral assemblage Scaler bars (if not defined) are 1 cm

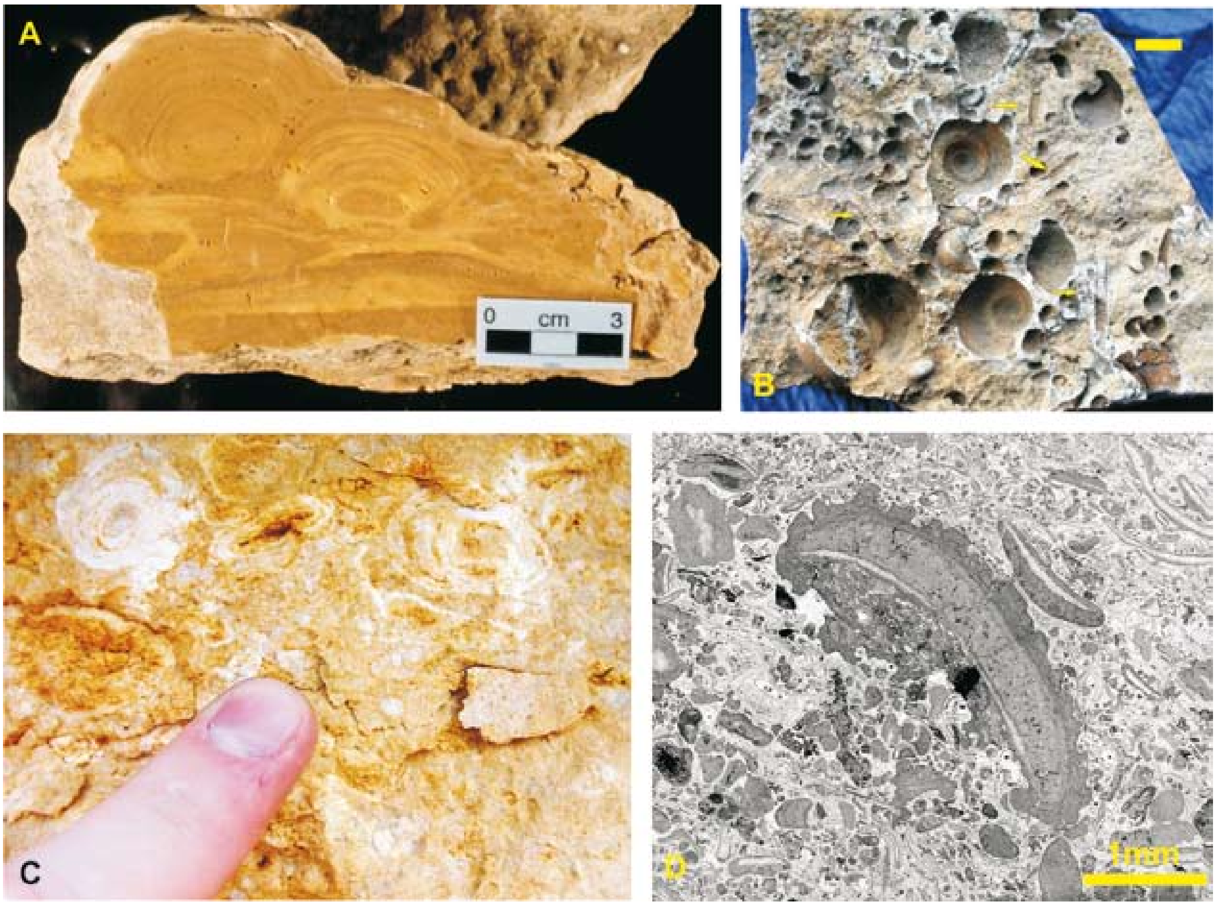


Fig. 34. Microbial and algal fabrics of the Middle Muschelkalk: A – Sponge-microbial stromatolites; B – Gastropods and *Physoporella* dasycladacean (arrows). Przełajka; C – *Girvanella* oncoids. Tarnów Opolski; D – Thin section of *Girvanella* oncoids

basin and by carbonates (mostly dolomites) in nearby areas of the Western and Silesian Gates. During the maximum flooding phase (*Grenzdolomit*), the transgression attained extent similar as in the Upper Muschelkalk (Fig. 36). During this time nectonic ammonoids migrated through the Western Gate reaching Thuringia (Müller, 1970) and rich assemblage of pelecypods and gastropods wandered *via* the Silesian Gate (Assmann, 1926).

The HST deposits are mostly playa evaporites and mudflat clastics of the Lower Gipskeuper which displays uniform thickness and facies distribution over the entire basin.

Schilfsandstein

Mid Carnian

Tectonically-controlled topographical rejuvenation and climate-related pluvialisation in Carnian times resulted in an increase in fluvial activity and clastic sedimentation across the entire Germanic Basin. The fluvial Schilfsandstein facies is interpreted as deposited in a complex and extensive braided river network that transported sandy material southwards from the area of the Fennoscandian Land (Köppen & Carter 2000). Intensive fluviatile erosion resulted in the Schilfsandstein resting discordantly on various older Triassic and even Palaeozoic formations (Schröder, 1977; Beutler & Häusser 1981). Only in the central part of the Mid Polish Trough was erosion less severe, and laminated, fine-grained lacustrine clastic sediments were deposited.

The Schilfsandstein unit can be subdivided into 3 parts. The lower and upper parts are dominated by sandstones while the middle part is mainly composed of siltstones. The topmost part of the Schilfsandstein unit consists of dolomitic mudstones and grey marls with intercalations of pink anhydrite suggesting a gradual increase in aridity.

Upper Gipskeuper

Late Carnian to early Norian

The fluvial sediments of the Schilfsandstein grade gradually into in evaporitic sediments of the overlying Upper Gipskeuper. The unit is dominated by sulphates and siltstones deposited in peneplained mudflat-playa environments. The scarcity of fossil remains (including plants) suggests harsh and stressful palaeoenvironmental conditions.

The facies pattern of this unit resembles that of the Lower Gipskeuper. In N Germany halite formed in inland playas controlled by local subsidence. The Upper Gipskeuper in N and central Germany and in W Poland terminates with several metres thick evaporitic complex (Heldburg Gips), which corresponds in Polish stratigraphy to *Anhydryt Stropowy* (Cover Anhydrite). This, up to 30 meters thick evaporitc complex, splits outside the depocenter (*i.e.* to E and S) into many thinner horizons that interfinger with thin-bedded claystones resulting in a cyclical succession. Similar high frequency sedimentary cycles are visible throughout the basin and probably reflect fluctuations between arid and semiarid climatic conditions.

According to palynological data (Orłowska-Zwolińska 1983) the upper part of the Upper Gipskeuper is of Norian age.

Steinmergelkeuper

Middle to late Norian

The Steinmergelkeuper overlies a prominent basinwide unconformity (Fig. 37) that resulted from intense tectonic

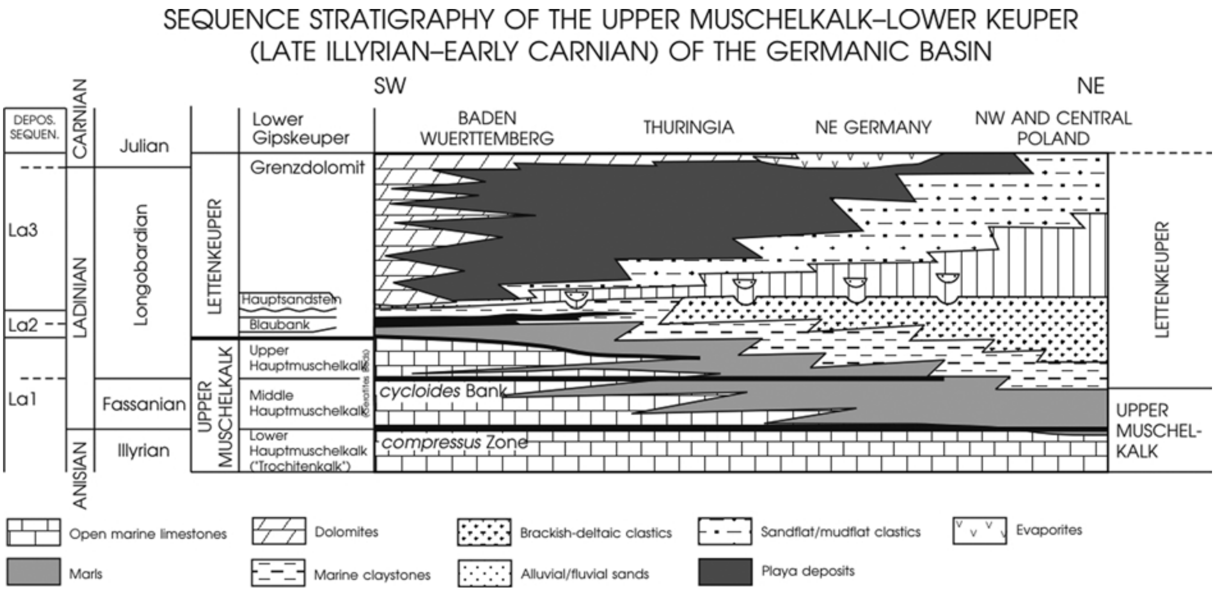


Fig. 35. Sequence-stratigraphic framework of the Upper Muschelkalk – Lower Keuper (late Illyrian – early Carnian) of the Germanic Basin (from Szulc 2000)

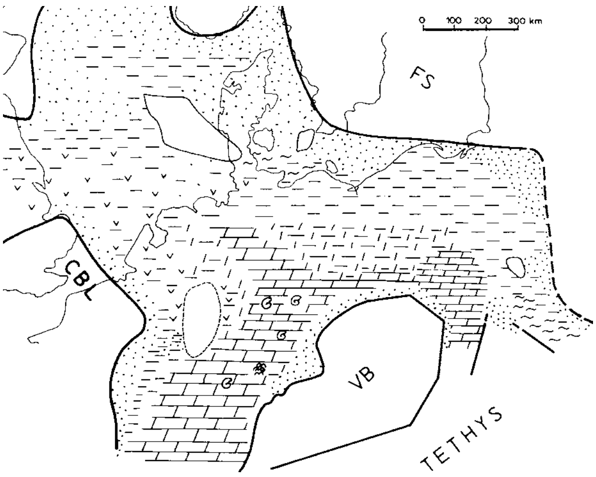


Fig. 36. Paleofacies map of the Peri-Tethys domain for the Grenzdolomit interval (after Szulc, 2000)

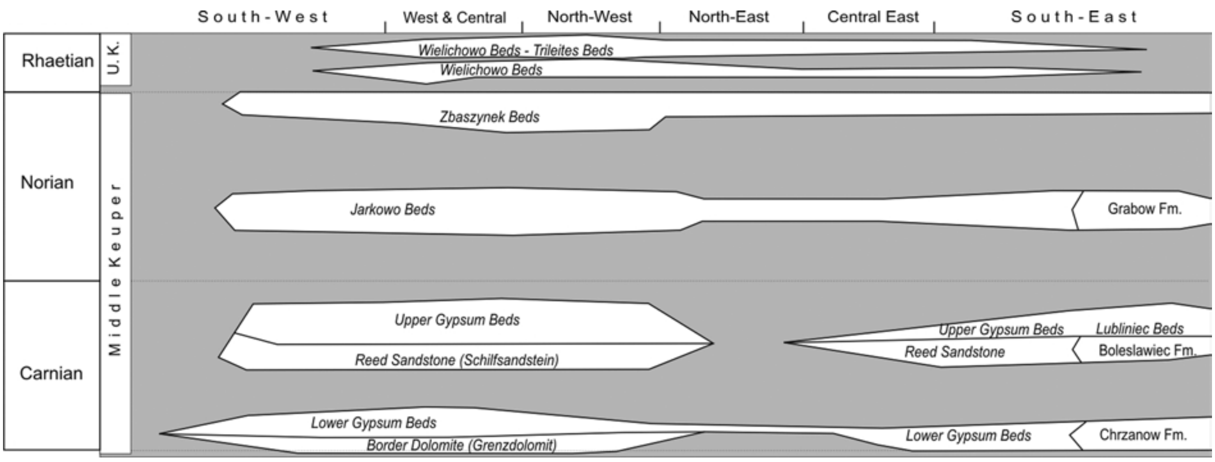


Fig. 37. Lithostratigraphical scheme of the Polish Upper Triassic (after Polish Stratigraphical Table, in print)

activity as well as increasing fluvial-related erosion driven by gradual pluvialisation. Amelioration of climatic conditions in mid to late Norian times caused a decrease in evaporite precipitation and their gradual replacement by mottled, marly mudstones frequently containing paleosoils and ephemeral stream deposits (Figs. 44, 45). Typical of the unit are alternating red and green and/or grey, fine-grained clastic sediments and dolomitic intercalations. The alternation is ascribed to orbitally-controlled climatic fluctuations which resulted in cyclic variation between lacustrine and mudflat environments (Reinhardt & Ricken, 2000).

In central and western Poland the Steinmergelkeuper equivalents encompass Jarkowo and Zbaszynek Beds, and in NE Silesia so called Grabowa Fm. (Fig. 37). In contrast however to the continental Steinmergelkeuper in Germany, its counterpart in central Poland shows some possible marine influences inferred from foraminifer occurrences (Dadlez & Kopik, 1963).

Within the basin fill there are many evidences of localised resedimentation. For example, in the eastern part of the Germanic Basin ephemeral streams reworked the previously-deposited muddy sediments and redeposited them in almost the same place. Such recycling is evidenced by pedogenic nodules that after reworking and sieve fractionation formed specific residual ”conglomeratic” deposits (Szulc 2005) (Fig. 44g), erroneously identified in the Polish lithostratigraphy as an individual correlation horizon termed the ”Lisow Breccia” (see also Stops. I.4 and I.5).

Upper Keuper

Rhaetian

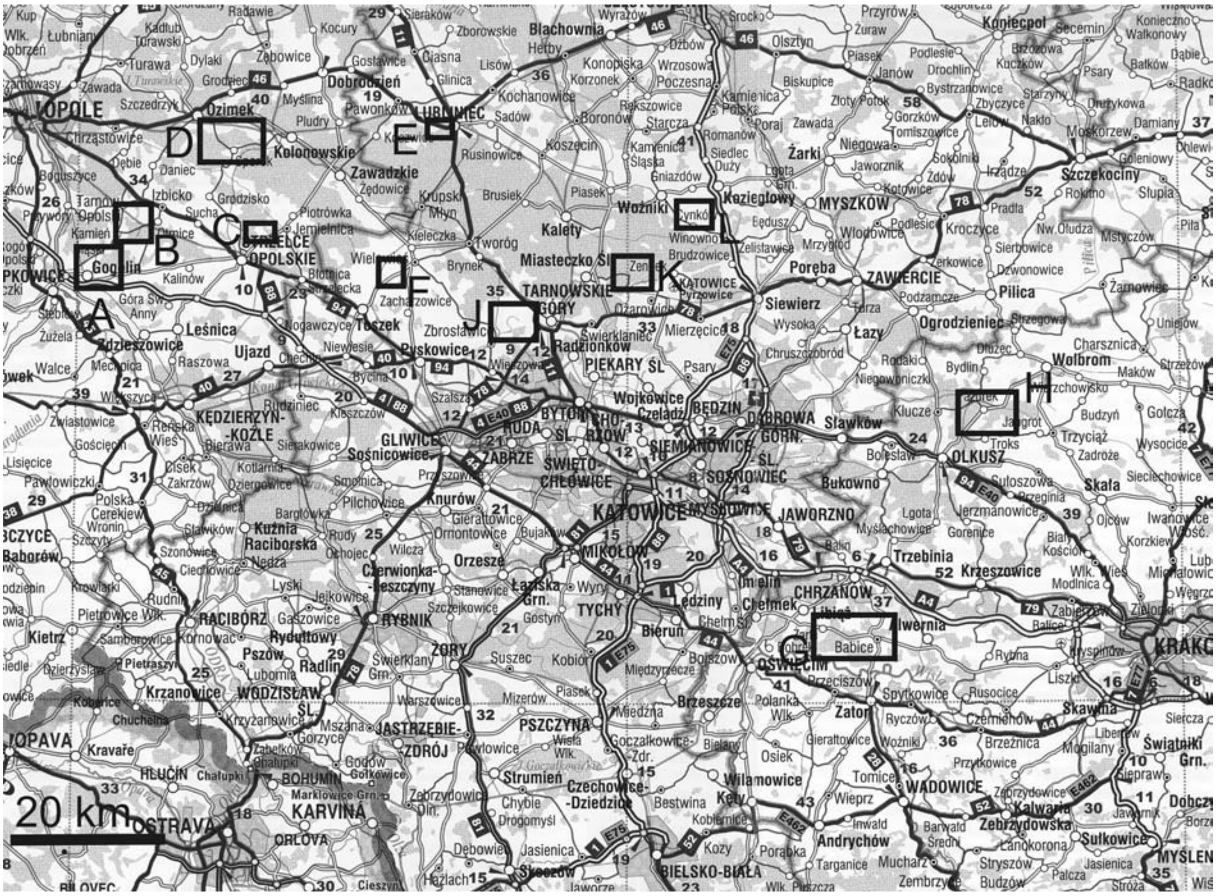
The climate-related pluvialisiation that began in the mid Norian intensified during the later Triassic. Sediments are dominantly fluvial and lacustrine, comprising organic-rich clastic deposits. Extensive vegetation led to the accumulation of plant debris and the development of coal seams or even coal layers accompanied by siderite and pyrite encrustations. Humid conditions also resulted in the weathering and decay of feldspar minerals, so that the Rhaetian quartz sandstones are readily distinguished from the feldspar-bearing clastic sediments of the Lower and Middle Keuper.

The Rhaetian is separated from the Steinmergelkeuper by a distinctive unconformity (Beutler, 1998). The unconformity was caused by fluviatile erosion. Additional gaps in sedimentation also resulted from weathering processes acting on the Steinmergelkeuper clayey sediments. For instance, in western Poland the humid climate caused intense kaolinisation of the exposed Norian claystones up to 20 metres below the palaeosurface.

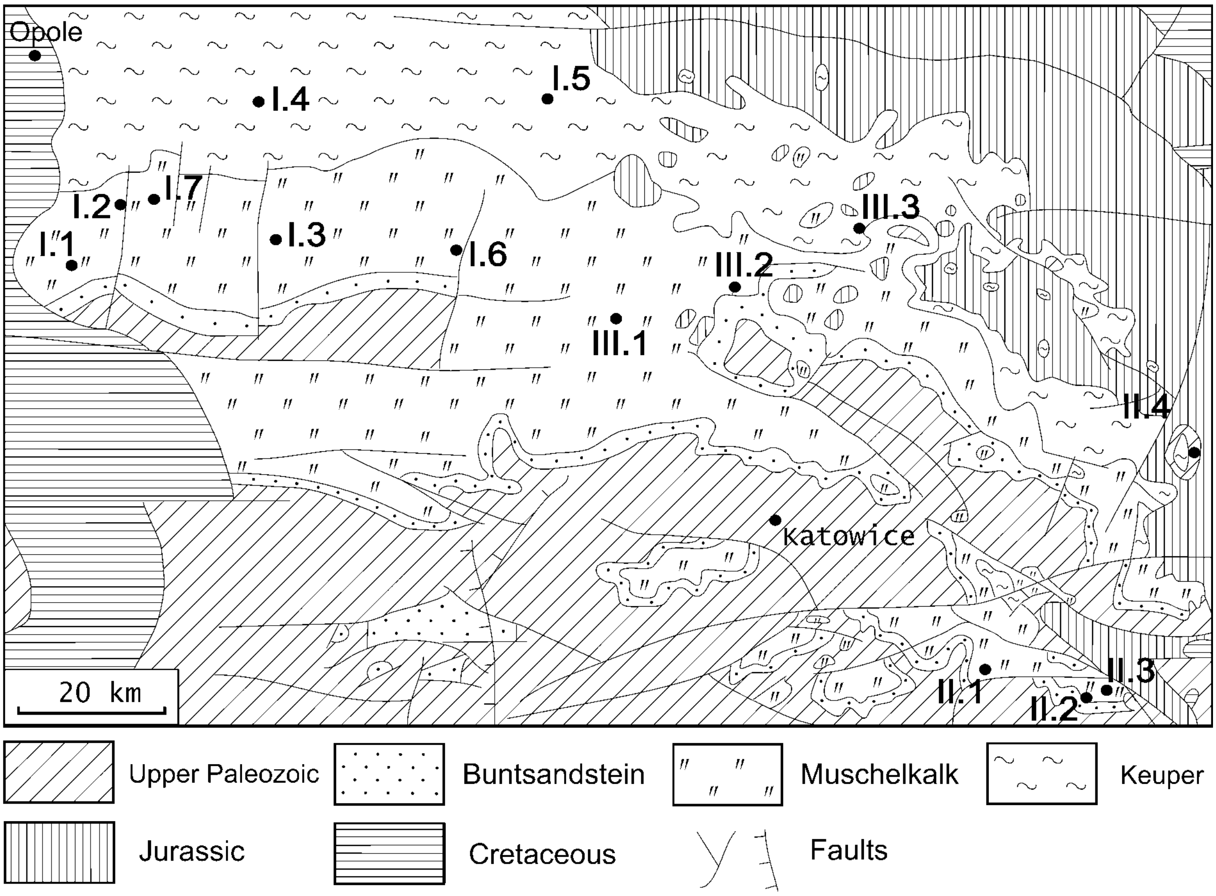
In addition to the change in climatic conditions and the ensuing sedimentary style, the Rhaetian also differs in containing sediments deposited during the first marine incursion that came from the W. These marine deposits were concentrated in the western part of the basin and passed eastwards through brackish to limnic and fluviatile facies.

The Rhaetian succession initiated the transgressive system, which is typical of the succeeding lower Jurassic stage.

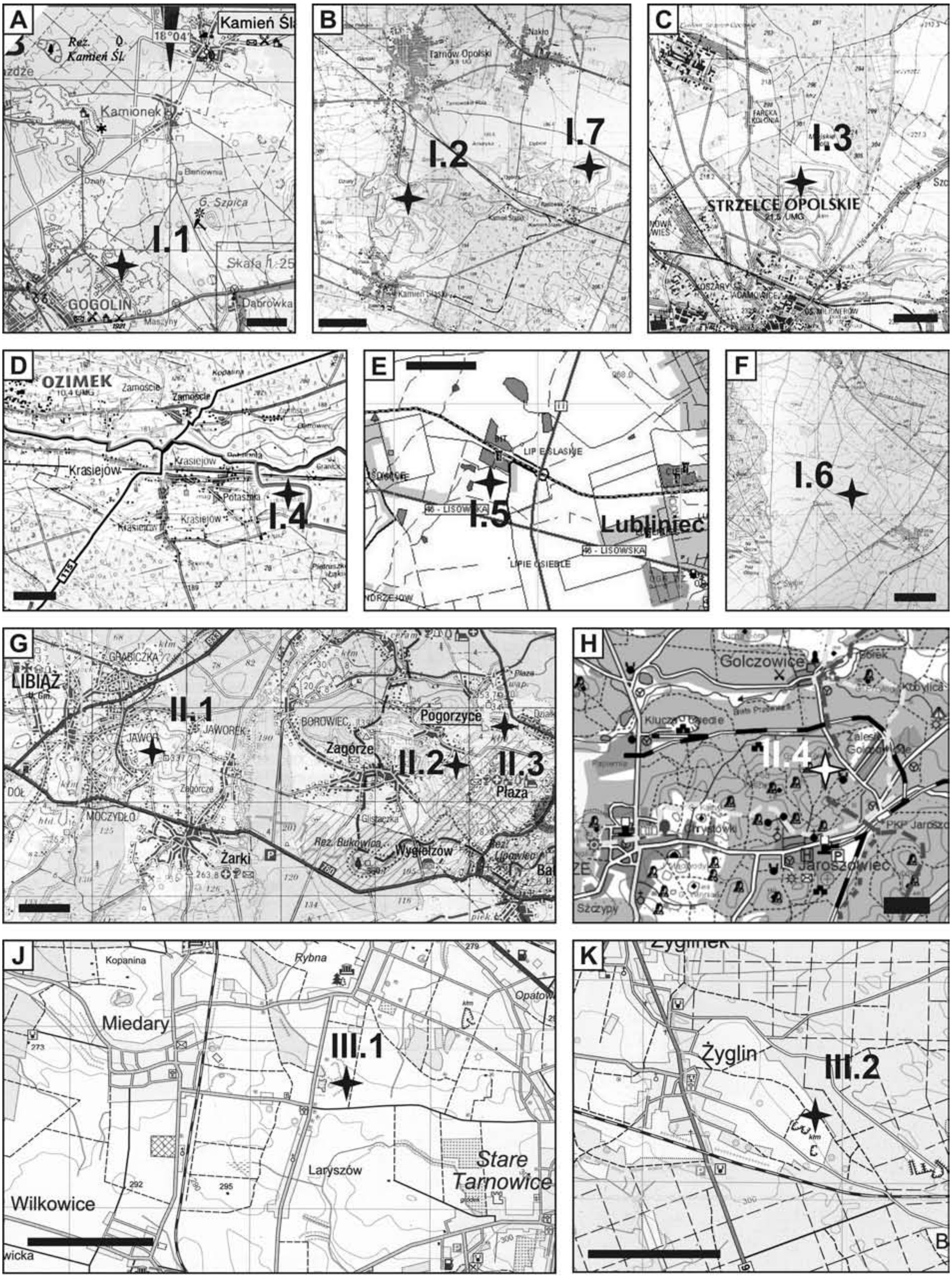
FIELDTRIP GUIDE

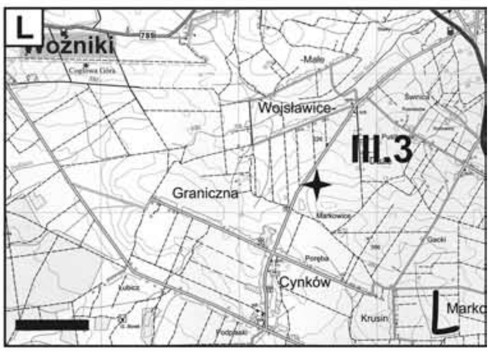


Road map of the fieldtrip area with marked inserts of the localisation maps



Simplified geological map of the fieldtrip area with marked position of the stops





Location maps of the presented stops (All scale bars – 1km): I.1. Gogolin; I.2. Tarnów Op.; I.3. Strzelce Op.; I.4. Krasiejów; I.5. Lipie Śl.; I.6. Naplatki; I.7. Kamień Śl.; II.1.Libiąż; II.2. Podstoki; II.3. Płaza; II.4. Stare Gliny; III.1. Laryszów; III.2. Żyglin; III.3. Cynków

Part .1.

Upper Silesian-Cracow Upland

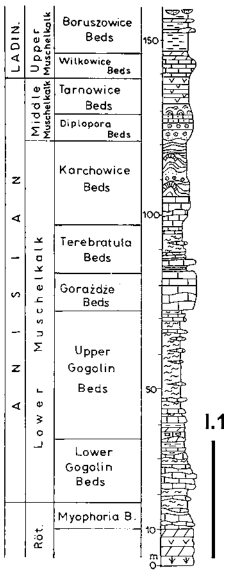
First Day

STOP I. 1. Gogolin – inactive quarry

Hans Hagdorn & Joachim Szulc

Röt – Lowermost Muschelkalk (Lower Gogolin Beds)

Topics:
1. Transition from coastal sabkha to open marine environments – sedimentary and paleoecological aspects
2. Synsedimentary seismic activity and its consequential phenomena



The section presents transgressive transition from evaporitic Röt sediments to normal marine limestones of the Lower Muchelkalk.

The Röt is represented by reddish and ochre coloured limestones and dolomites, comprising molds after gypsum and halite evaporites. Hopper halite crystals, displacive and reworked gypsum crystals and lack of fauna (but rare bones) as well as chertified stromatolites (Bodzioch & Kwiatkowski, 1993) indicate very shallow, coastal sabkha environments. Meteoric water influxes and emersion events are evidenced by quartzose conglomerate horizon and solution breccias (*Zellenkalk 1*) which mark the boundary of the 1st Anisian sequence.

The sabkha evaporites are succeeded by more and more open marine carbonates as evidenced by increasing faunal quantity and diversity. The transgression climaxed with bioclastic thick- bedded, cross-stratified limestones (Fig. 27) with stenohaline dadocrinids ("Beds with Pecten and Dadocrinus").

The following HST is formed by tempestitic shelly limestones and marls which grade uspection to evaporitic dolomites (*Zellenkalk 2*) (Fig. 25).

The section affords excellent structures related to synsedimentary seismic activity; faults, joints, liquefaction and debris flows with deplaced slabs reaching 4 meters in size (Fig 38).

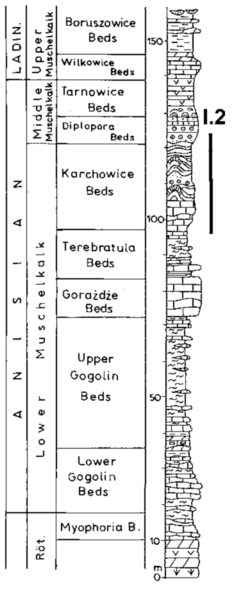
STOP I. 2. Tarnów Opolski
– active quarry of *Opolwap - Lhoist*

Hans Hagdorn, Marcelina Łabaj, Michał Matysik, Elżbieta Morycowa & Joachim Szulc

Upper Terebratula Beds-Karchowice Beds

Topics:
1. Transition from deep water to shallow water sedimentary environment
2. Composition and vertical succession of the sponge-coral buildups
3. Scleractinian coral colonies
4. Morphology of the basin floor and lateral facies transition
5. Presentation and discussion on early diagenetic processes within Karchowice Beds

The quarry exposes the uppermost part of the Terebratula Beds and the complete section of the Karchowice Beds.



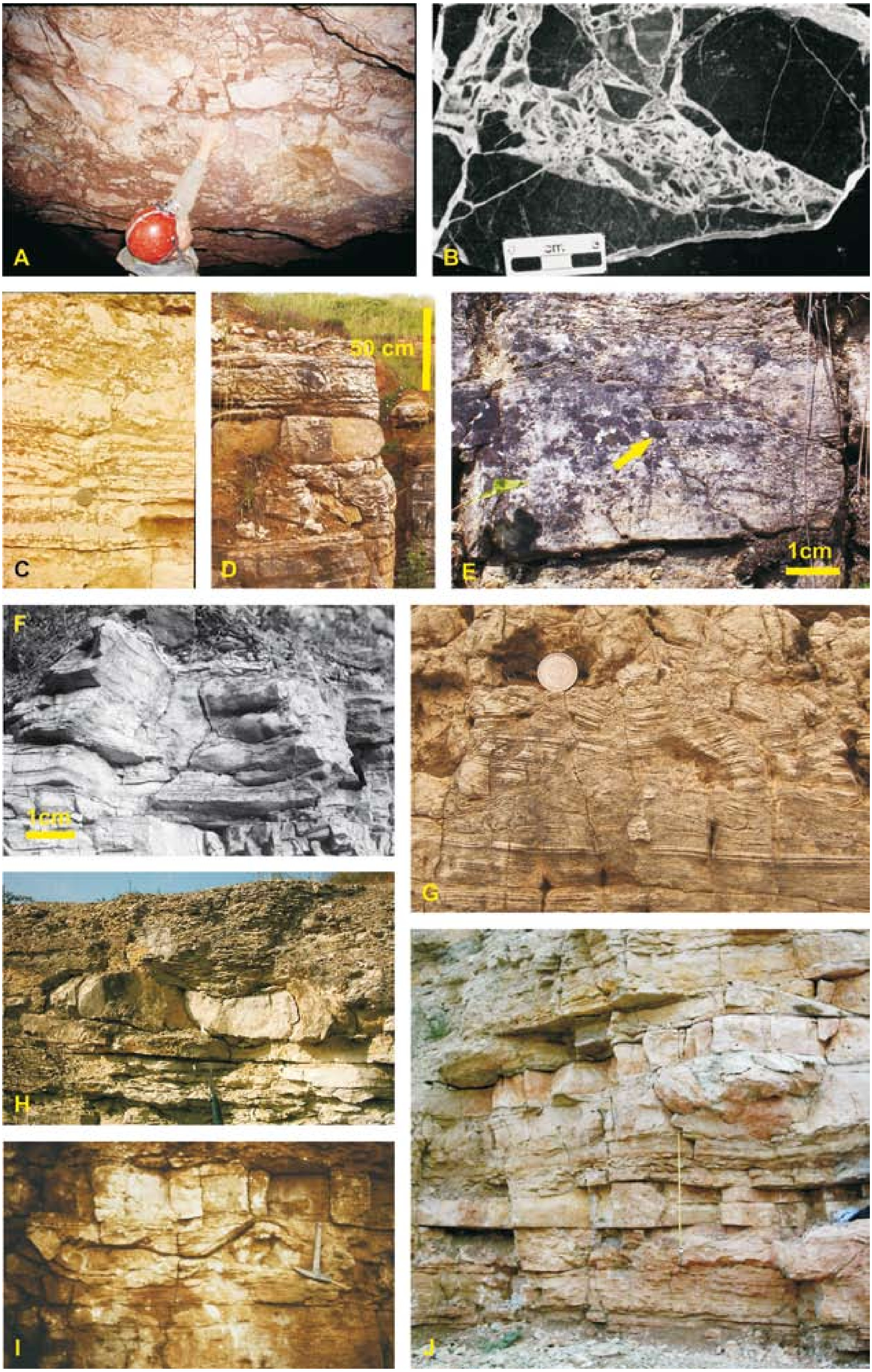
The deeper water, fine-grained limestones and marls of the Terebratula Beds evolve gradually into massive, bioclastic Karchowice Beds by 4 meters-thick set of firmgrounds alternated with tempestitic encrinites (Fig. 28f). The bioclastic sands form locally several meters high dunes, composed of amalgamated cross-stratified bodies.

Biolithic complex which developed upwards is dominated by sponge constructions; biostromes and, higher up by bioherms (Fig. 32d-f). The latter reach up to 7 m in height and several tens of meter in width. The other contributors of the bioherms are encrusting worms and forams, crinoids, brachiopods, gastropods and scleractinian corals (Fig. 33).

The corals are represented by some 20 species what makes this assemblage the oldest (and richest) known scleractinian coral colonies at all (Morycowa, 1988, Łabaj, 2007).

The biohermal complex of the Karchowice Beds is bipartite. In the lower part, between the hexactinelli d sponges, the colonies of denroid-phaceoloid *Volzeia szulci* occur (Fig.33b, g).

Fig. 38. Sedimentary and deformational fabrics related to Triassic synsedimentary tectonic activity in southern Poland
A – Synsedimentary hydraulic breccia of the Devonian limestones filled with Buntsandstein sandstone dykes. Chelosiowa Cave, Jaworznia quarry, Kielce Holy Cross Mts.; B – Agmatic breccia of Devonian dolomites from Stare Gliny, healed by fine-grained Muschelkalk dolomitic sediments; C – Synsedimentary fault in Lower Gogolin Beds. Gogolin; D – Synsedimentary fault in Górażdże Beds, Napłatki; E – Synsedimentary fault (arrow) in Lower Gogolin Beds, Libiąż; F – Seismically-triggered stationary crumpled deformations and joints, Lower Gogolin Beds. Gogolin; G – Small, quake-related synsedimentary faults, Górażdże Beds. Szymiszow; H – Quake-triggered debris flows in Lower Gogolin Beds. Gogolin; I – Three, quake-triggered, debris flows in Lower Gogolin Beds. Zyglin; J – Quake-triggered deformations in Lower Gogolin Beds. Plaza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B
cm
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50 cm
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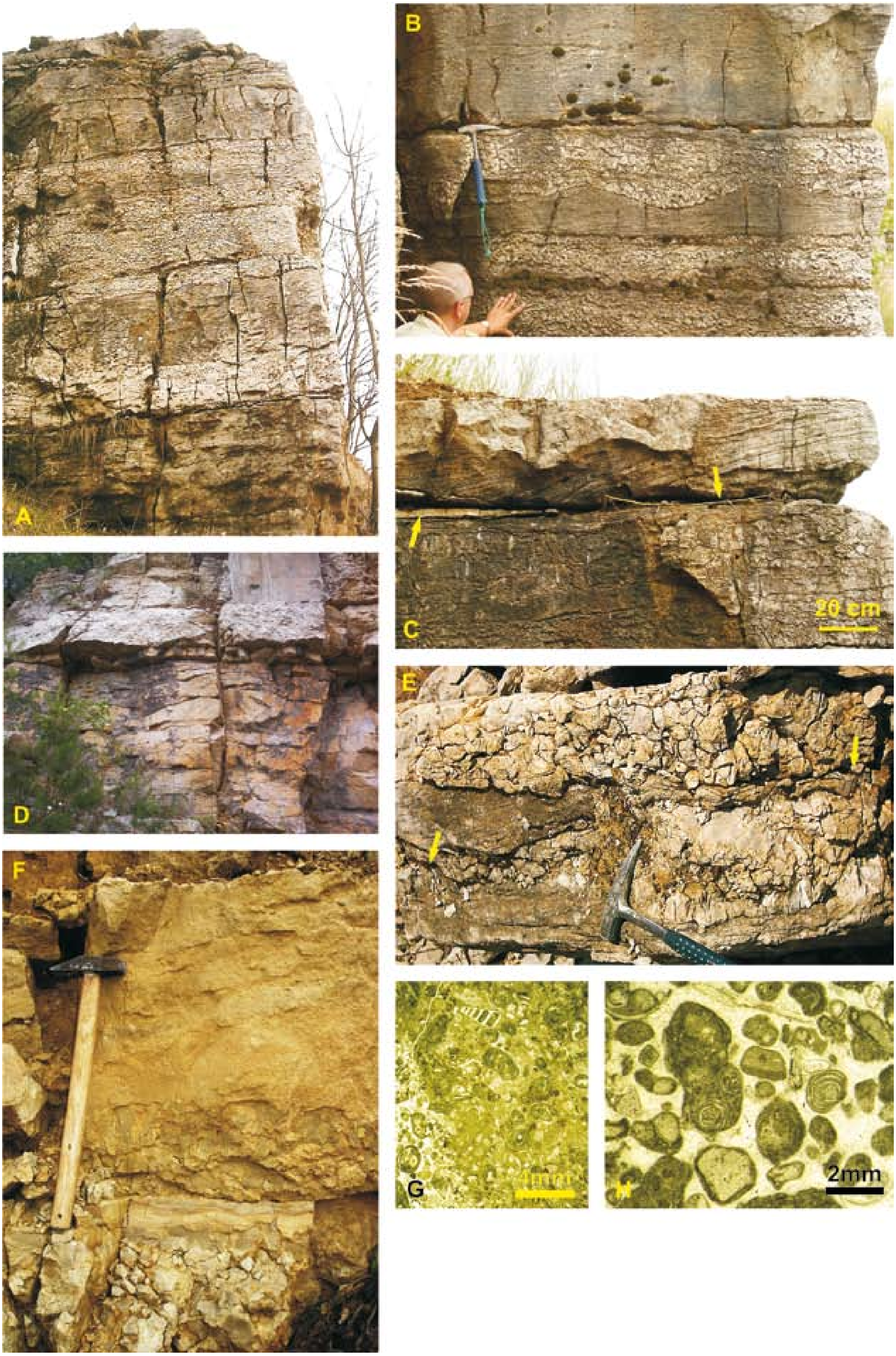
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20 cm
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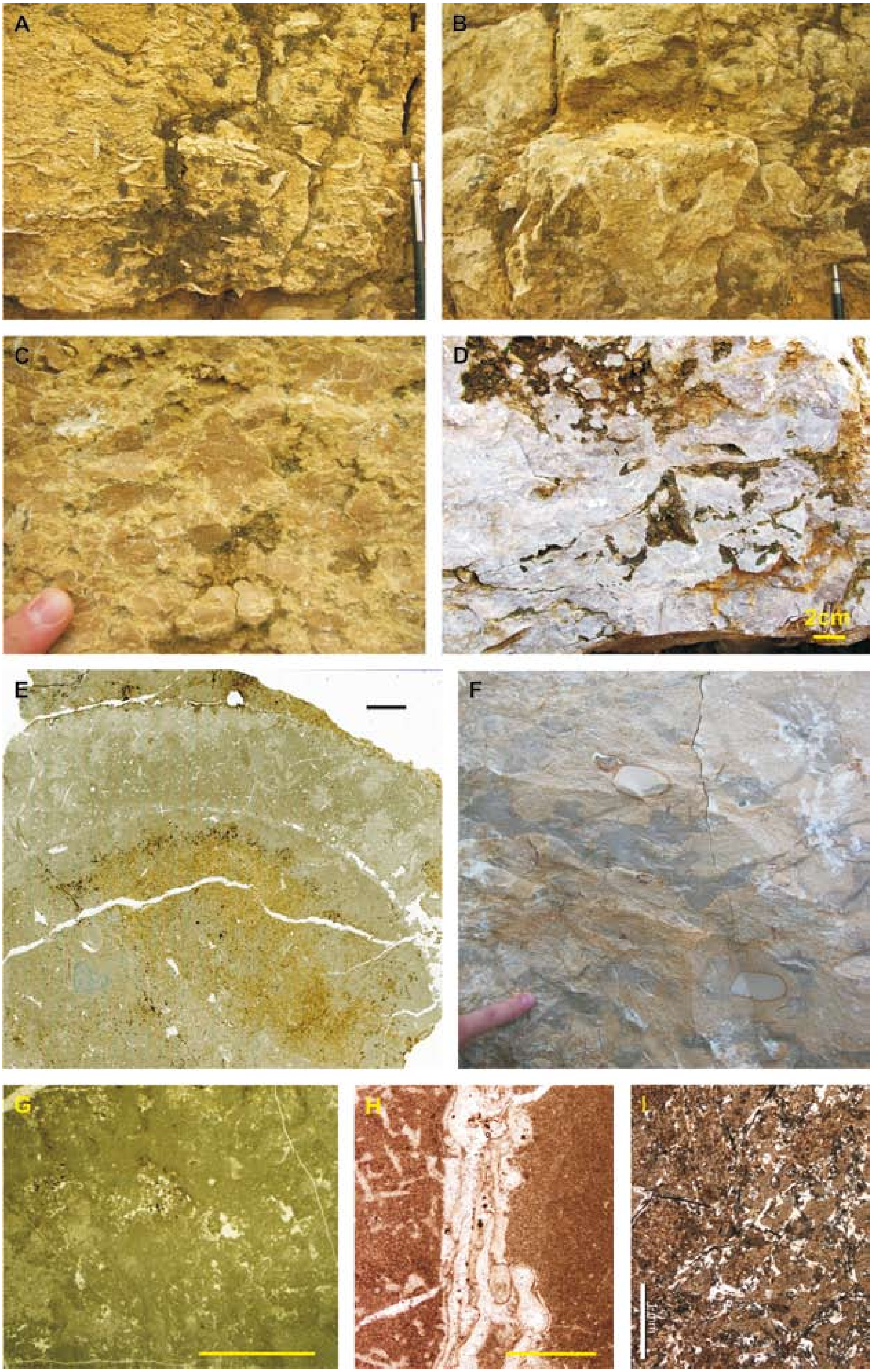
A
B
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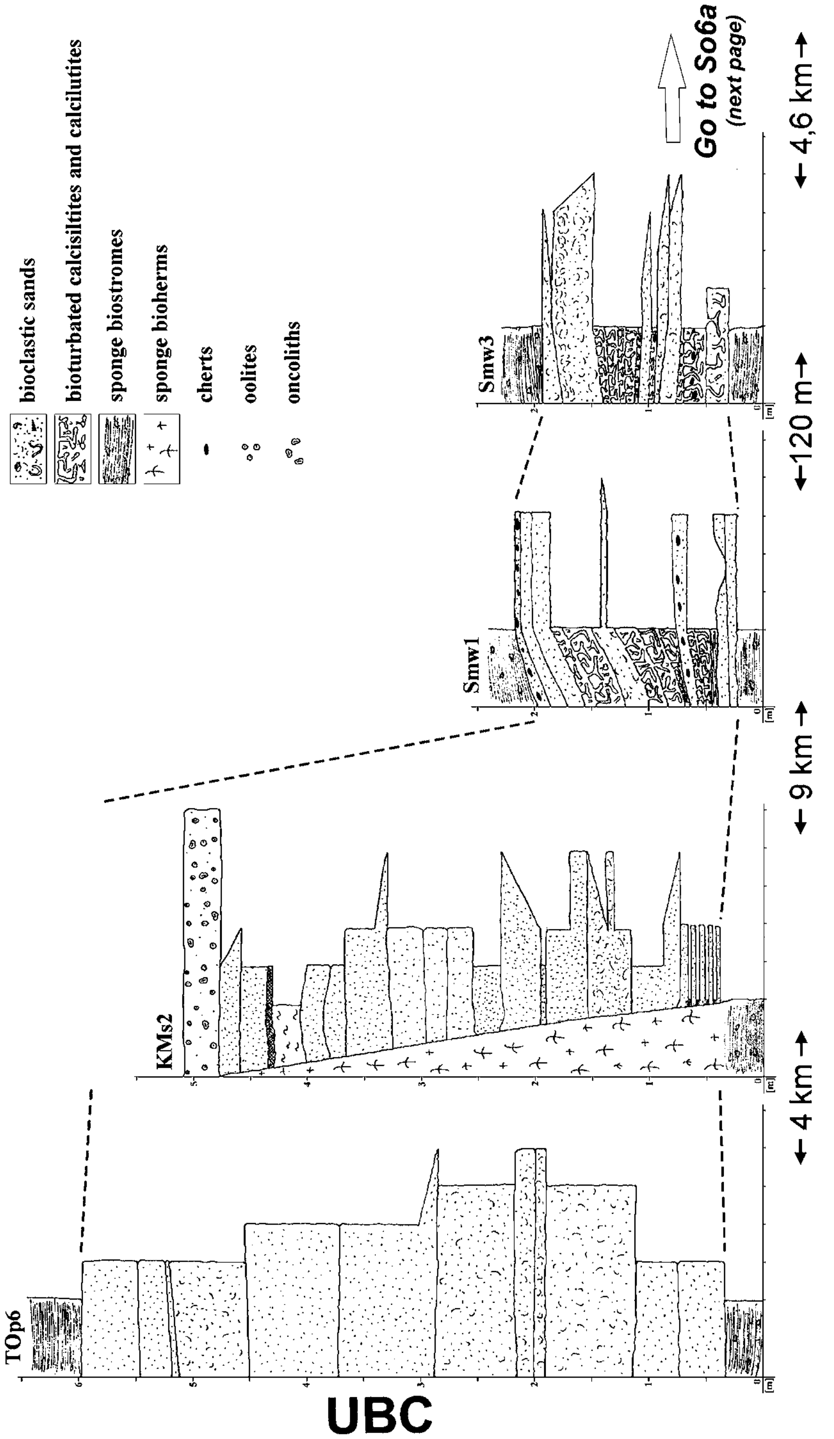
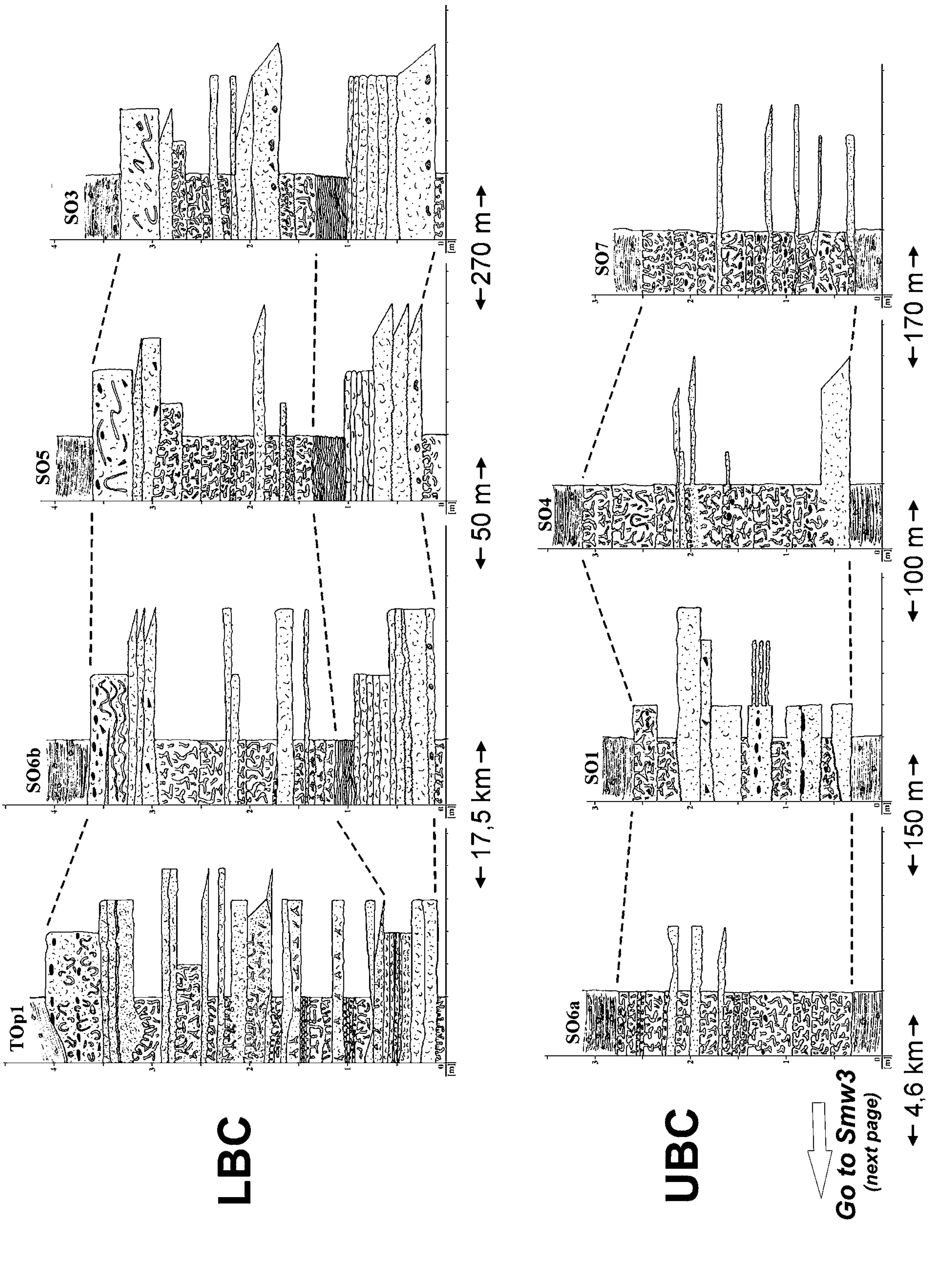


Fig. 41. Lateral variety of the lower (LBC) and upper (UBC) bioturbated facies complexes of the Karchowice Beds in western Upper Silesia. SO – Strzelce Opolskie quarry, TO – Tarnów Opolski quarry, KM – Kamień Śląski quarry; Smw – Szymiszów quarry.

Fig. 39 (see p. 48). Basic sedimentary characteristics of the Górażdże Beds: A – Typical succession of Górażdże Beds, composed of cross-stratified calcarenites (storm deposits) and bioturbated fine-grained limetsones (fair-weather deposits). Napłatki; B – Oscillatory ripplemarks in isolated storm layer. Usually these fabrics are not visible due to multiple amalgamation of the tempestitic sets. Napłatki; C – Nodular limestones eroded and covered by hummocky cross-stratified calcarenites. Note the multiple amalgamation phenomena (arrows); D – Shoalbar deposits composed of calcarenitic lenses. Dąbrówka; E – Lateral variety of bed-to-bed succession. Note the erosion and very complex multiple amalgamation (arrows). This sample illustrates well ambiguity of interpretation of the higher-frequency sedimentary cycles for high energy sedimentary environments; F – Firmground horizon, marking longer lag phase overlain by thick tempestitic sediments. Górażdże; G & H – Thin sections of the oncolithic limestones. Note the dominance of foraminiferal cortoids.

Fig. 40 (see p. 49). Macro- and microfabrics of the sponge-related carbonates of the Karchowice Beds: A – Bioclastic limestones with reworked sponge debris; B – Layer of prostrate sponge colony overlain by bioclastic limestones; C – Automicritic, spongean massive bioherm; D – Coral-sponge buildup; E – Thin section of mummified sponge body with spicules entombed in automicrite; F – Sponge automicritic buildup with cherts; G – Thin section of the clotted automicritic fabrics; H – Serpulid tubes encrusting sponge body. Thin section; I – Silicified sponge skeleton. Thin section. All scale bars in thin sections are 5 mm



LBC
TOp1
SO6b
SO5
SO3
←17,5 km→
←50 m→
←270 m→
UBC
SO6a
SO1
SO4
SO7
←4,6 km→
←150 m→
←100 m→
←170 m→
Go to Smw3
(next page)

Delicate branching coral habits, suggests relatively quiet environment. The corals and sponges form knobs clustered together. This complex is capped by crust of lamellar colonies of *Pamiroseris silesiaca* (Fig. 33c, d). Encrusting form of the coral colonies is typical for turbulent environment and indicates that the reefs reached their shallowest growth phase. The crests of the lower biohermal complex were partly emerged and underwent meteoric diagenesis (dolomitisation, karstfication), while the in local depressions the *Girvanella* oncoliths formed. The bioherms are composed mainly by relatively homogenous, massive or nodular micritic fabrics, which represent aggregates of the automicritic carbonate originated by microbially-mediated decay of the sponge bodies (Fig. 40c-i).

During the next transgressive pulse the second biohermal complex formed. Its structural framework is similar like in the lower one, but the absence of the branching corals.

Total thickness of the biohermal complexes in the reef-core area reaches up to 25 meters.

Vertical succession in the buildup composition reflects ecological evolution related to highstand shallowing trend, typical of the "catch-up reef" *sensu* James & Mcintyre (1985) (Szulc, 2000). As a rule, the succession begins with biostromes built by prostrate colonies of sponges (*stabilization-colonisation stages*) (Fig. 32d, e; Fig. 40a-b).

The biostromes are replaced, first by low-relief, and then by high-relief biohermal buildups, encompassing also branching corals and clusters of other organisms (*diversification stage*) (Fig. 40d). The reef cap formed by encrusting corals is typical for the final, *domination stage* of the reef evolution.

The final shallowing resulted in decline of the sponge-coral association which has been replaced by oncolithic and oolitic limestones of the Diplopora Beds.

It is worthy to note that the Karchowice Beds display intense lateral variation both on a bed level and within the entire unit (Fig. 41; Fig. 42.) as already noted by Bodzioch (1991). Very careful study done by Matysik (2007) made clear that the lateral facies variety reflects first of all differentiated subsidence rate within the Silesian basin. This phenomenon was, in turn, controlled by vigorous syndepositional tectonic activity, as evidenced by numerous quake-triggered fabrics presented during the fieldtrip.

Summing up, the evident, tectonically-controlled facies variation, challenges the merit of the cyclostratigraphical interpretations for the higher frequency (*i.e.* 4th and 5th orders) sedimentary cycles and makes them useless.

STOP I. 3. Strzelce Opolskie – active quarry of *Gorazdze-Heidelberger Zement*

Hans Hagdorn, Marcelina Łabaj,
Michał Matysik & Joachim Szulc

Upper Gogolin Beds-Gorazdze Beds-Terebraula Beds-Karchowice Beds

Topics:

1. Facies succession of two 3rd order sedimentary sequences (An2 and An3) and their attributes
2. Fauna composition – paleoecological and paleobiogeographical aspects
3. Synsedimentary seismic and tectonic activity and its consequences

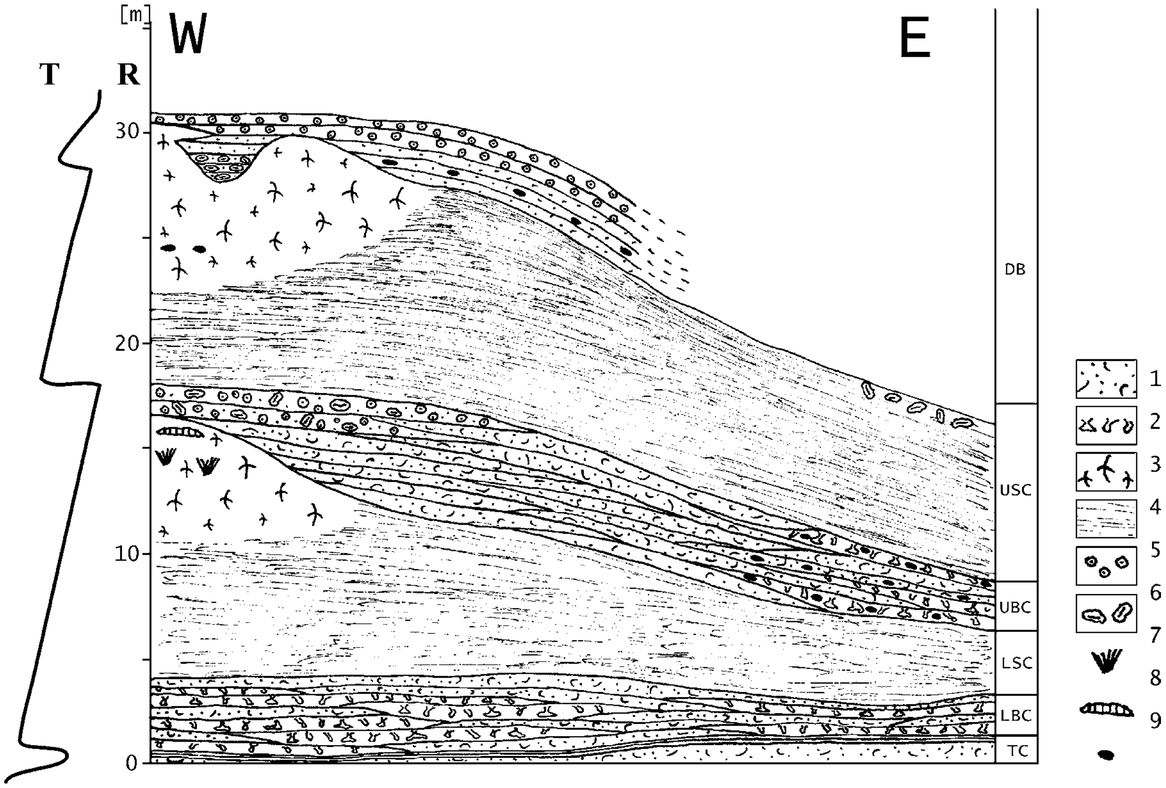
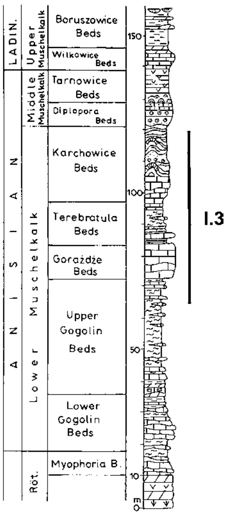


Fig. 42. Facies model of the Karchowice Beds.
TC – Transitional Complex; LBC – Lower Bioturbated Complex ; LSC – Lower Spongean Complex; UBC – Upper Bioturbated Complex; USC - Upper Spongean Complex , DB – Diplopora Beds
1. Bioclastic limestones; 2. *Balanoglossites/Thalassinoides* bioturbated limestones; 3. Sponge bioherms; 4. Sponge biostromes; 5. Oolites; 6. *Girvanella* oncolithes; 7. Branched corals; 8. Encrusting corals; 9. Cherts

4. Lateral transition within the high energy sedimentary facies and its consequences for high-frequency cycles interpretation



The section exposes most complete Lower Muschelkalk outcrop encompassing sediments of two Anisian depositional sequences; A2 and A3 (Fig. 28a).

The exposed section commences with marls and distal calcareous tempestites representing maximum flooding zone of the sequence A2, which is concurrent with beginning of the Pelsonian stage. First appearance of the index conodonts, ammonoids and crinoids is the most important bioevent recorded in this interval, indicating open communication with the Tethys.

The subsequent thick-bedded and coarse-grained bioclastic, oncoidal and oolitic limestones building a 15 m. thick shoalbar set of the Górazdże Beds

The Gorażdże Beds, which represent HST of the A2 sequence, are built by alternated calcarenites and finer-grained limestones (Fig. 39a). The calcarenites are cross-stratified, amalgamated oscillatory ripples, transported and deposited under storm wave and current action (Fig. 39b, c, d, e). The interbedded, fine-grained limestones are fair-weather sediments, intensively bioturbated what resulted in their nodular character (Fig. 39f). It is worthy to note, that the oncoids are built mostly by foraminiferal aggregates (Fig. 39h).The other bioclasts comprise debris of gastropods, pelecypods, crinoids, corals and sponge spicules (Fig. 39g).

Oomoldic porosity and ferricrete crust featuring the topmost part of the Goraždze Beds indicate meteoric influences as the shoalbar became emerged (Szulc, 1999). Therefore, one may assume the top of the Goraždze Beds as a boundary of the next depositional sequence.

This sequence boundary is covered sharply by dark, finely laminated limestones, typical for TST, beginning the Terebratula Beds. These calcilutites are impoverished in body- and ichnofossils, what indicates very fast advancement of the transgression and poorly ventilated, starving basin conditions. This horizon (ca 1.5-2 m thick) is slumped and totally contorted (Fig. 28d), what suggests a quake-triggered mechanism of the deplacement on one hand, and tectonically forced deepening on the other hand (Szulc, 1993).

The slumped set is replaced by 1.5 thick, amalgamated encrinitic bank (so called *Hauptcrinoidenbank* of Assmann, 1944) (Fig. 28c-e) indicating some shallowing trend. The *Hauptcrinoidenbank* is covered by 12 meters thick set of slightly dysoxic, grey marls intercalated with dm-thick coquinas, dominated by *Coenothyris vulgaris* shell debris. The Terebratula Beds represent the Anisian maximum flooding interval, recognized over the whole Germanic Basin (Szulc, 1990, Aigner & Bachmann, 1992). Total thickness of the Terebratula Beds reaches in the quarry ca. 20 meters.

The Terebratula Beds are followed by bioclastic (mostly crinoidal) calcarenites alternated with firmground horizons and then by spongean structures forming the Karchowice Beds. (Fig. 28f, Fig. 32b, c). The latter display virtual different succession as in Tarnow site (Fig. 41), what point to substantial lateral facies variability in the basin (Matysik, 2007).

STOP I.4. Krasiejów – inactive clay pit and tetrapod exposition

Joachim Szulc

Steinmergelkeuper

Topics:
1. Vertebrate taphocoenosis
2. Sedimentary environments and paleopedogenic processes. Problem of cannibalistic resedimentation and stratigraphic gaps
3. Synsedimentary tectonics

The section shows 18 metres of variegated mudstones and siltstones, with several coarser grained horizons (Fig. 43). The coarser-grained deposits are mostly composed of silty and

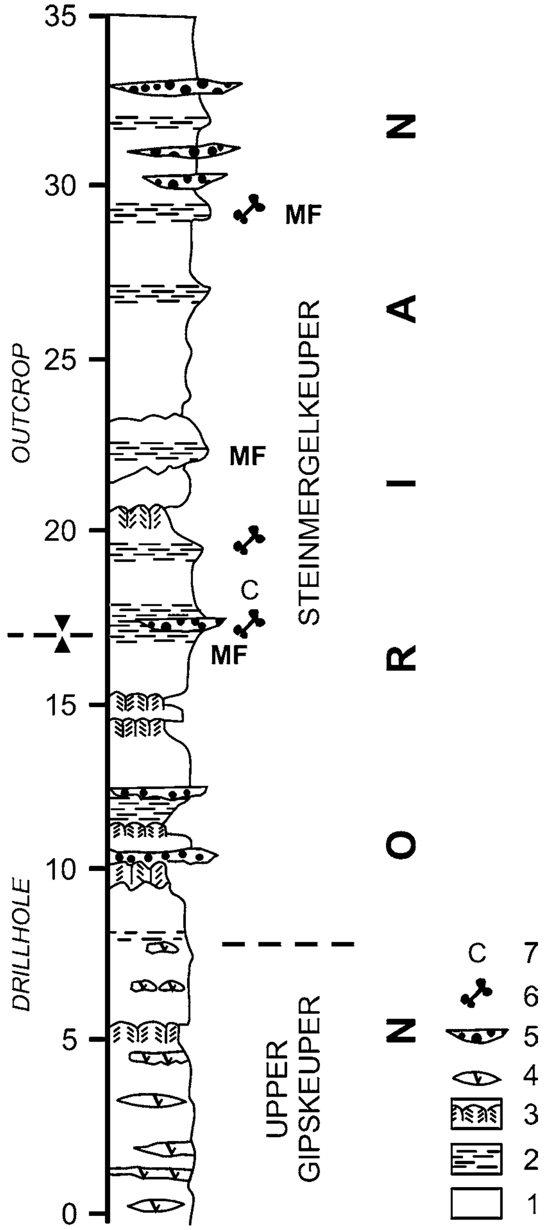
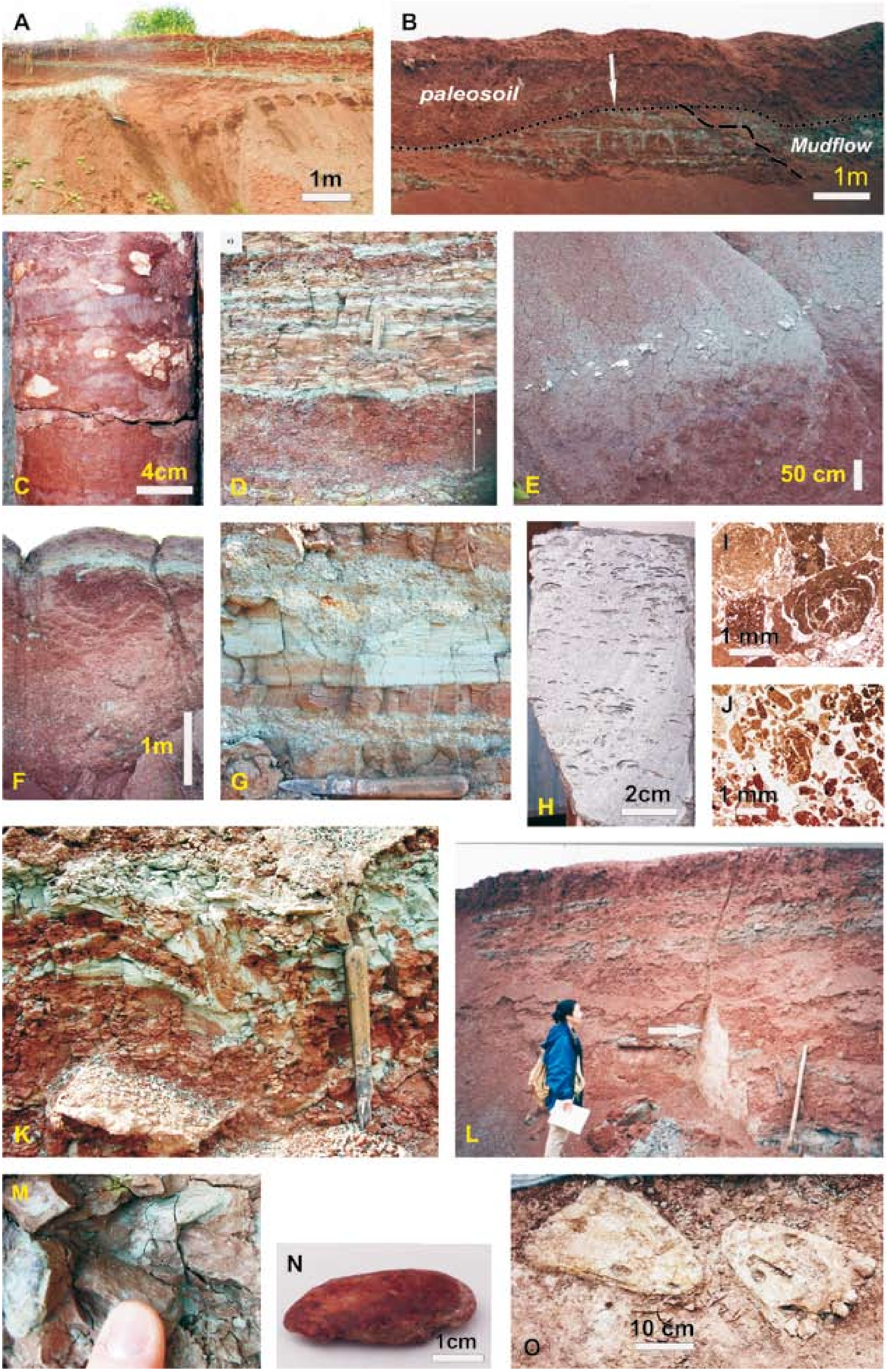


Fig. 43. Lithostratigraphic log of the Upper Triassic section in Krasiejów
1. reddish mudstones and siltstones; 2. grey-coloured horizons; 3. paleosoil horizons; 4. gypsum; 5. conglomerates (composed of redeposited vadoids); 6. bone-bearing horizons; 7. celestite aggregates; MF – mudflow deposits


A
1m
B
paleosoil
Mudflow
1m
C
4cm
D
E
50 cm
F
1m
G
H
2cm
I
1 mm
J
1 mm
K
L
M
N
1cm
O
10 cm

sandy material, that comprises the plane-bedded, cross-bedded and rippled alluvial sediments (Fig. 44a, d). One may recognize the parallel laminations and small scale ripple-drift cross-lamination.

Some beds display erosional base, in particular the sheet-like grey, conglomeratic beds reaching up to 20 cm in thickness and composed of carbonate grains ranging between 1 – 5 mm in diameter (Fig. 44 g-j). The clasts are mostly reworked pedogenic carbonate nodules with random skeletal debris of bivalves (Fig. 44h). Beside it 3 massive mudflow horizons have been found in the section (Fig. 44m).

The transport direction frequently varied throughout the section but generally the N and NW–directed transport dominated.

The alluvia are divided by several paleosoil horizons. The pedogenic horizons form mostly brown and/or mottled, nodular and friable mudstones, interpreted as regolith (incipient paleoweathering horizons) (Fig. 44b, d-f). Beside the regolith a better developed paleosoils occur. All of them however represent the aridisols catena with vadoids and slickenside deformations, typical for for semi-arid climatic conditions, with dry and wet seasons.

The mentioned vadoid-bearing conglomerates are very useful tool for reconstruction of the cannibalistic re-sedimentation mechanism dominating the mudflat area. Since the clasts are derived from rewashing of paleosoil, we can estimate the rate of erosion and re-sedimentation scale (Szulc, 2005). This implies in turn the problem of cyclostratigraphic interpretations carried out for such environments. As a matter a fact , the multiple reworking and resedimentation of the sediments under discussion make all the cyclostratigraphic speculations futile.

The fauna assemblage comprises pelecypods (Fig. 44m, n) gastropods, conchostracans, ostracods and vertebrates. The plants are represented by poorly preserved debris of *Equisetum* and common *Characea* gyrogonites (Fig. 44j).

The most important for this section is the vertebrate *Fossillagerstätte* comrising mainly labyrinthodonts, aetosaurs and thecodonts and dinosauromorphs (Dzik et al., 2000). According to taphonomical analysis, the skeletal debris (found in ca. 1 m thick bed) comprise well preserved but mostly disarticulated skeletons of various vertebrates ((Fig. 44o),

The *Fossillagerstätte* is thought to be of secondary nature (Szulc, 2005) and represents redeposited taphocoenosis that formed originally by dying out in some shrinking shallow lacustrine or palustrine basin during drought periods. Subsequent catastrophic runoffs or synsedimentary faulting (Fig. 44l) triggered mass movement processes in the region, also involved the bone-bearing sediments.

Age of the fossils-bearing sediments is still a subject of debate. Dzik *et al.* (2000) and Lucas *et al.* (2007) correlate this interval with the Carnian, Lehrberg Schichten in Germany.

Regarding however the general lithofacies and climatostratigraphical context, the exposed section should be rather referred to the Steinmergelkeuper (Arnstadt Formation) which is most likely of Norian age (Szulc, 2005). The bone-bearing horizons lays ca 20 meters above the top of the Upper Gipskeuper succession (Fig. 44c).

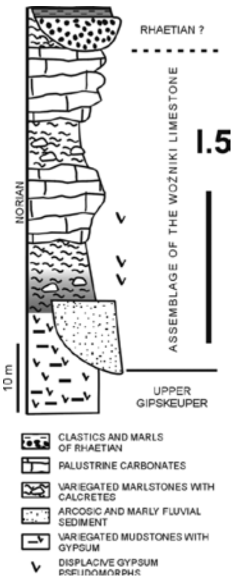
STOP I. 5. Lipie Śląskie – active clay pit of the brickyard "Lipie Śląskie"

Joachim Szulc

Steinmergelkeuper and Wozniki Limestone

Topics:

1. Sedimentary processes on the mudflat environments
2. Palustrine and pedogenic limestones.



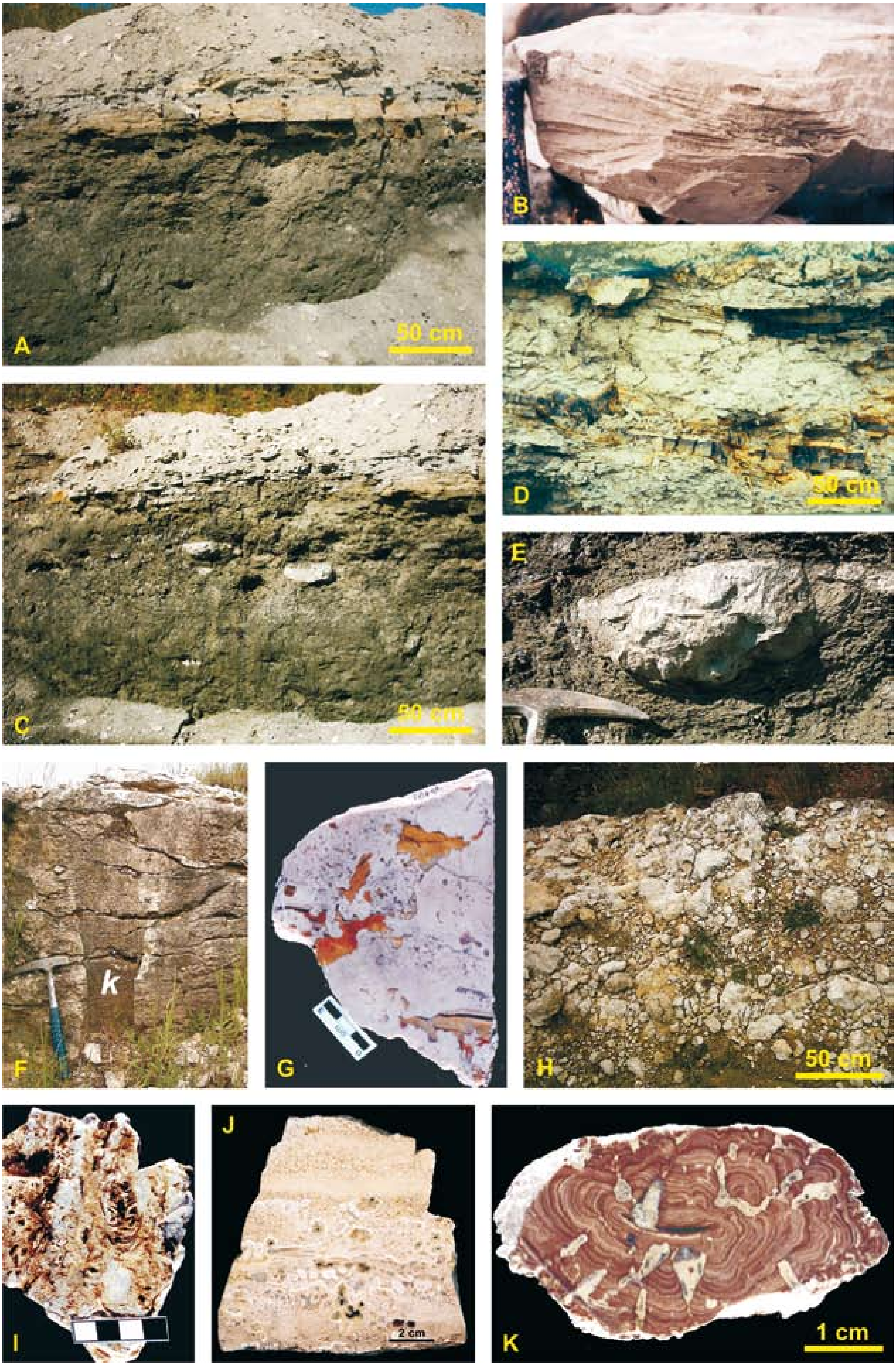
The section exposes 4 meters thick succession of grey mudstones and siltstones, interlayered with cross-stratified greywacke sandstones (Fig. 45). Several horizons with dispersed coalified plant stems up to 5 meters long and carbonate concretions developed around the plant debris occur within the muddy sediments (Fig. 45c-e). The mudstones display desiccation cracks and while the limestones comprise rare pelecypod coquinas.

These sediments of Norian age (Szulc *et al.* 2006) are interpreted as mudflat deposits with plane-bedded muddy and silty overbank deposits and dissected by braided-stream, fluvial sands (Fig. 45b).

In the other part of the section palustrine sediments of the Wozniki Limestone are cropping out (Fig. 50). These fossils-lacking carbonates are thick and medium-bedded, massive limestones comprising elongated cherts.

The presented section is the westernmost outcrop of the Wozniki Limestone, which is interpreted as carbonate formed in spring-fed palustrine basin, stretching at the distance of ca 100 km, along the SE segment of the Cracow-Hamburg Fault (here called also as Cracow-Lubliniec Fault) (Fig. 49)

Fig. 44. Main sedimentary characteristics of the Upper Triassic deposits in Krasiejów. A – Two discordant complexes of sheet-flow deposits; B – Section of paleosoil horizon (arrow) developed on the layered alluvial deposits and massive, mudflow complex. Note the grey dying of the small synsedimentary faults (middle of the section); C – Core fragment from the drilled gypsum-bearing variegated mudstones of the Upper Gipskeuper succession. Scale bar – 10 cm; D – Ripple-bedded silty and sandy alluvia sandwiched between 2 paleosoils horizons; E – Grey calcisol horizon with large, pedogenic calcareous nodules; F – Cambisol horizon featured with slicken-sided cracks and overain by fluvial conglomerates. Note the diffusively dyed contact between the soil and alluvium; G – Graded alluvial deposits composed of sieved pedogenic nodules and parallelly laminated reddish siltstones. Note the erosional base of the conglomerates; H – Current-transported conglomerate composed of convex-up disposed unionid shells and pedogenic nodules; I-J – Thin section views of the conglomerates composed of reworked pedogenic nodules featured with septarian cracks (I) and comprising charophyte gyrogonites (J); K – Close-up of chaotically arranged mudflow; L – Synsedimentary, transcurrent fault (arrow); M – Two, *in situ* preserved unionids in muddy sediment; N – Internal mold of unionid shell; O – Plane view of the main bone-bearing mudflow horizon with *Metaposaurus* skulls

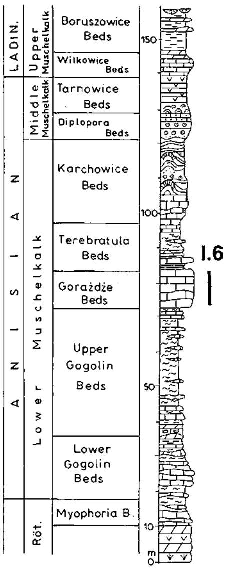

A
50 cm
B
D
50 cm
E
C
50 cm
k
F
G
H
50 cm
I
J
2 cm
K
1 cm

STOP I. 6. Napłatki
– small inactive quarry

Joachim Szulc

Góraždze Beds

Topics:
1. Lateral transition within the high energy sedimentary facies and its consequences for high-frequency cycles interpretation
2. Synsedimentary seismic activity and mass-movement processes



Weathered walls of the quarry afford excellent opportunity to study in details the sedimentary processes within the storm-controlled, migrating shoalbar. The perfectly preserved symmetrical ripples indicate the storm wave and current action as a main factor of shoal migration (Fig. 39b). The highly bioturbated calcisiltites and calcilutites represent fair-weather intervals.

Very fast lateral variation of the bed-to-bed transition is of particular interest. This section illustrates very well ambivalence of the high frequency cyclostratigraphical speculations and chronostratigraphic inferences (Fig. 39c, e).

STOP I. 7. Kamień Śląski - active quarry of *Opolwap – Lhoist*

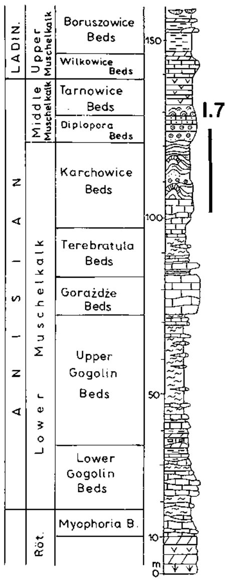
Hans Hagdorn, Marcelina Łabaj, Elzbieta Morycowa, Michał Matysik & Joachim Szulc

Karchowice Beds-lower Diplopora Beds

Topics:
1. Morphology of the basin floor and lateral facies transition
2. Presentation and discussion on early diagenetic processes within Karchowice Beds

The section shows 25 meters profile of the both biohermal complexes of the Karchowice Beds (Fig. 32a) and 2 metres of the oolitic Diplopora Beds (Fig. 30e).

The eventual shallowing after the maximum Anisian transgression resulted in decline of the sponge-coral association which has been replaced by oncolithic and oolitic limestones of the Diplopora Beds.



The outcrop provides an opportunity to observe spatial relationship between the sponge buildps and the interbiohermal sediments; bioclastic sands and *Girvanella* oncoliths.

The limestones underwent early dolomisation and karstification, featuring the late HST of the third Anisian depositional sequence.

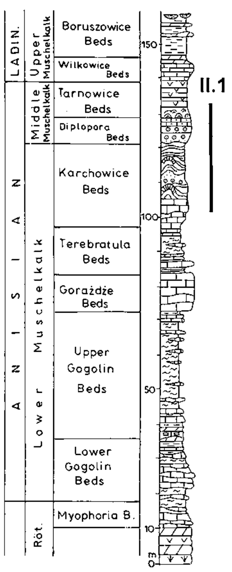
Second Day

STOP II. 1. Libiąż – active quarry

Joachim Szulc

Karchowice Beds- Diplopora Beds – Tarnowice Beds

Topics:
1. Lower/Middle Muschelkalk boundary
2. Regressive succession of the Illyrian and transition from open marine to sabkha environment
3. Extreme shallow water, intertidal sponge-microbial stromatolites and their evolutionary context.
4. Quake-generated deformations



About 35 meters of the upper Lower and Middle Muschelkak exposes in the quarry.

The lower part of the section encompasses bioclastic and sponge biostromal limestones (Karchowice Beds) which underwent stratabound, mixed-water dolomitisation (Szulc, 1997).

The overlying Diplopora Beds, represent the late HST. This 5 meters thick succession is composed by cyclically stacked oolitic and bioclastic limestones, interlayered with microbially-laminated dolomites (Fig. 30d). The sediments show common features of emersion (tepee) and storm reworking.

The Diplopora Beds terminate with unusual sponge-microbial

Fig. 45. Main sedimentary characteristics of the Upper Triassic deposits in Lipie Śląskie and of the Woźniki Limestone in Cynków vicinity. A – Sheet flood, alluvial deposits within mudflat overbank sediments. Lipie Śląskie; B – Cross bedded, micaceous channel sandstones. Lipie Śląskie; C – Overbank muddy alluvia with carbonate concretions. Lipie Śląskie; D – Coalified wood stems embedded in mudflat sediments. Lipie Śląskie; E – Detail from C; F – Typical, massive palustrine limestones of the Woźniki Limestone. k – paleokarstic sinkhole. Wozniki Limestone. Cynków; G – Microkarstic cavities from palustrine limestones, filled with internal silt and sparry calcite. Wozniki Limestone.Cynków; H – Paleoweathering surface developed upon exposed palustrine limestones. Plane view. Wozniki Limestone. Cynków site; J – Pisoidal travertine facies of Wozniki Limestone. Calcified debris of vascular plants. visible in the middle of the sample. Note the reversed grading of the pisolites. Scale bar is 3 cm long.. Wozniki Limestone. Poręba site, I – Calcified cone mould embedded in the travertines. Scale bar is 3 cm long. Poręba site; H – Oncoid enveloping a unionid shell. Polished slab.. Wozniki Limestone. Zawiercie site

stromatolites, recognized over the entire Germanic Basin (Szulc, 1997). The stromatolites, up to 50 cm thick, vary in morphology and composition from planar laminites to domal habit (Fig. 34a). The latter are richer in non-laminated, sponge fabrics. Extremely shallow occurrence of the sponges, evidenced for instance, by desiccation cracks, is untypical for this group and may be interpreted as their adaptation to abnormal life conditions after the P/T ecological crisis (Szulc, 2003).

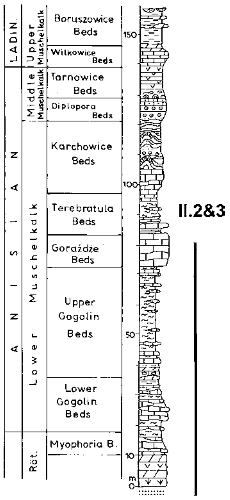
The presented rocks show many structures indicative for synsedimentary seismic shocks; from slicken-sided joints to slumps and debris flows (Fig. 38e).

The stromatolites are sharply covered by 4 meters thick complex of platy dolomites with rare ostracods and bones and mm-thin layers of micaceous sands. This complex, typical for coastal or lagoonal environments, represents the Tarnowice Beds.

STOP II. 2. Podstoki gully near Płaza

Joachim Szulc

Middle Bunstandstein –Lower Röt



Topic:

1. Open marine carbonates and fauna of the Lower Röt succession

The section commences with grey sandstones and siltstones underlying dolomitic marls. The dolomitic sediments grade into oolitic and bioclastic limestones encompassing rich pelecopod and gastropod fauna, including *Costatoria costata*, and common cephalopods *Beneckeia tenuis* (Fig. 16).

This ca 10 meters thick succession represents the 1st Röt depositional sequence (Fig.46). The sequence terminates with postevaporitic vuggy dolomites

STOP II. 3. Płaza – active quarry

Hans Hagdorn & Joachim Szulc

Röt – Lower Muschelkalk

Topics:

1. Transition from coastal sabkha to open marine environments – sedimentary and paleoecological aspects
2. Quake-generated deformations as stratigraphical tool
3. Facies succession of two 3rd order Anisian sedimentary sequences (An1 and An2)

In the quarry we can observe a continuation of the precedent Röt succession (Fig. 46). The ca 40 meters thick profile begins with the Upper Röt carbonates, which encompass dolomitic rocks displaying many indicators of extremely shallow environment (coastal sabkha) such as stromatolites, tepees, desiccation cracks and postevaporitic silicification. The fauna is limited to linguloids and vertebrate bones and scales

The sabkha sediments are passing upwards into hummocky cross-stratified limestones containing more open marine fauna *i.e. Myophoria vulgaris* and gastropods, designating this interval as Myophoria Beds. Higher up the first dadocrinids appear indicating open marine conditions. This part of the section comprises 3 slumped horizons (Fig. 38i).which could be used as excellent stratigraphic correlation tool with the equivalent sections of Gogolin (Stop I.1) and Żyglin (Stop III. 2). The *Placunopsis*-encrusted hardground occurring in this complex marks the MFS of the An1 depositional sequence. The sequence finishes with vuggy dolomites marking significant sea-level drop. The subsequent conglomeratic and wavy limestones alternated with tempestites (Upper Gogolin Beds) represent the TST deposits.

The relatively deep water facies grade into calcarenites and calcisiltites of the Górażdze Beds. These sediments representing the HST deposits terminate the presented profile.

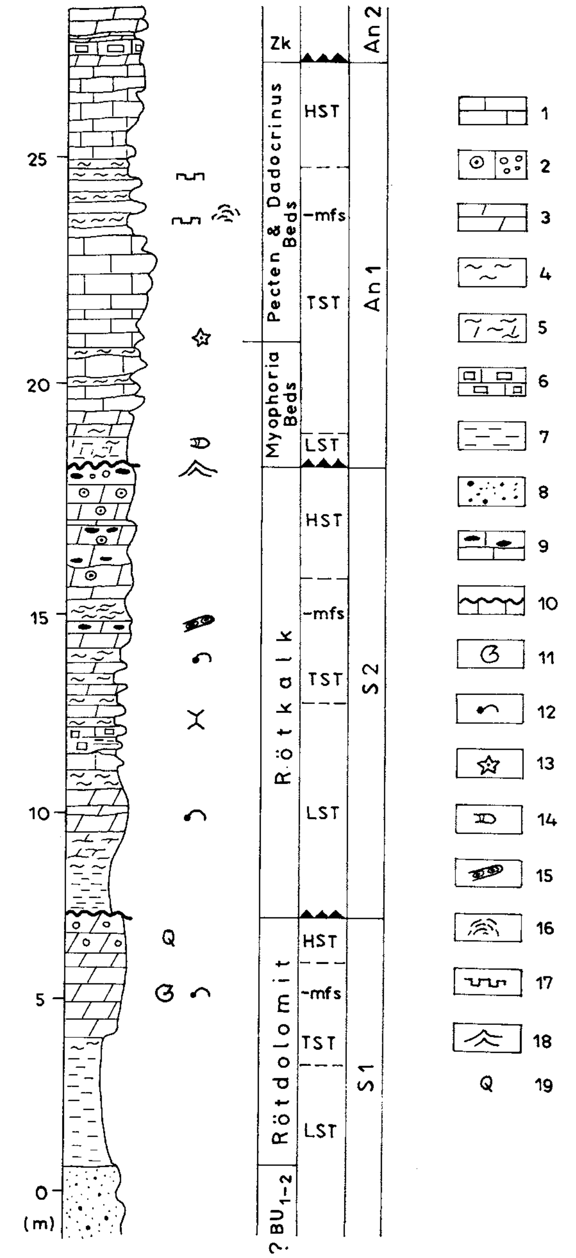


Fig. 46. Lithostratigraphic log of the Röt-Lower Muschelkalk succession from the Podstoki-Plaza region
1. bioclastic limestones; 2. oncoliths and oolites; 3. dolomites; 4. marls; 5. dolomitic marls; 6. vuggy limestones (Zellenkalk); 7. claystones; 8. sandstones; 9. cherts; 10. emersion surface; 11. *Beneckeia tenuis*; 12. *Costatoria costata*; 13. Crinoids, 14. *Glottidia tenuisima*; 15. dasycladacean debris; 16. *Placunopsis ostracina* bioherms; 17. hardground; 18. tepees; 19. sandy intercalations in limestones

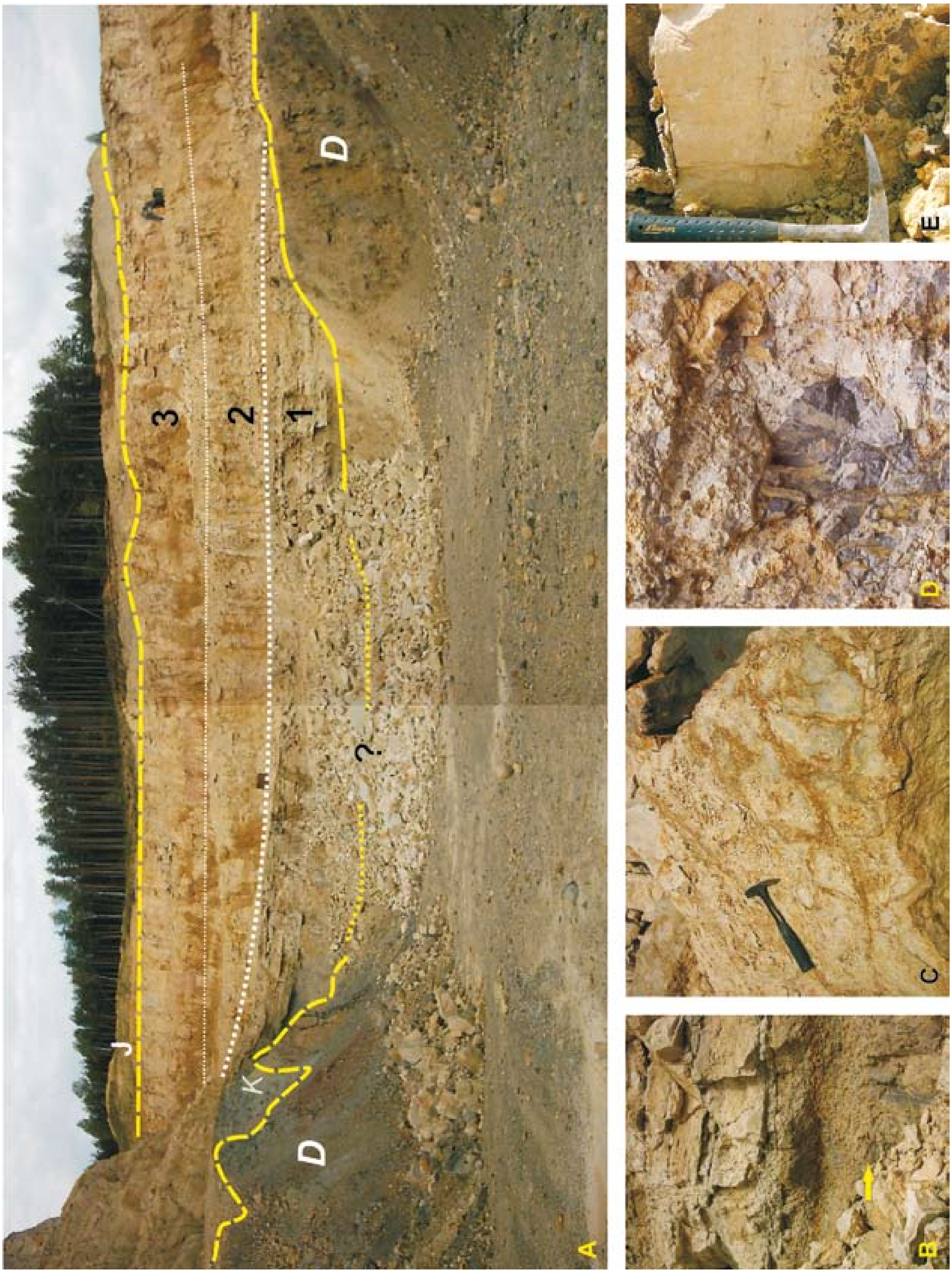


Fig. 47. Lower and Middle Muschelkalk of Stare Gliny quarry
A – General view of the Muschelkalk sediments overlapping the pre-transgression topography of the Stare Gliny paleoisland. *D* – karstified (*k*) Givetian dolomites. 1 – lagoonal, restricted dolomites; 2 – bioclastic limestones with Pelsonian fauna (corals, crinoids, brachiopods, sponges) equivalent of Terebratula-Karchowice Beds; 3 – bioclastic, ncolithic and oolitic dolomites of Diplopora Beds. The karstified Diplopora Beds are covered by red clays and remnants of the Upper Triassic Wozniki Limestone. J – Callovian transgressiove marls; B – Details of A. Contact between the Devonian basement rocks and the Muschelkalk sediments; C – Mudcracked dolomites of the complex 1 of the Muschelkalk deposits; D – 1 m-sized Devonian block entombed within the Muschelkalk deposits, E – Graded bed composed of Devonian clasts and Muschelkalk calcarenites

STOP II.4. Stare Gliny – active quarry

Joachim Szulc

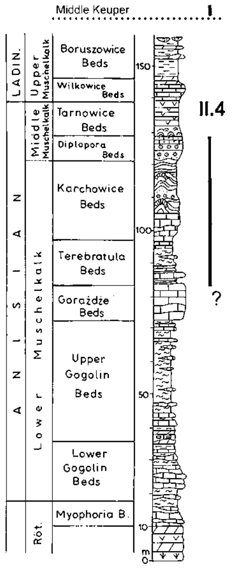
Lower and Middle Muschelkalk, Upper Keuper, Lower Jurassic

Topics:

1. Transgressive onlap of the Muschelkalk over Devonian paleo-island
2. Paleorelief of the Eastern Silesian Basin in middle and late Triassic
3. Syngenetic diagenesis of the Muschelkalk limestones

The section affords excellent example of the complex history of the Silesian basin from Triassic to early Jurassic times (Fig. 47a, Fig. 48).

The outcrop gives and opportunity to observe a transgressive onlap of the Lower and Middle Muschelkalk upon the pretransgressive topography. The Muschelkalk sea transgressed gradually over an archipelago of fault-bounded, high-topography islands built by Givetian dolomites. As indicates hydraulic breccias piercing the Devonian rocks and cemented by Triassic matrix, the island was a tectonic block shaken in Triassic times.



The Muschelkalk succession commences with conglomerates composed of Devonian angular clasts (Fig. 47d). Upward, dark-grey marls and laminated dolomites with desiccation cracks developed (Fig. 47b, c). This 5 meters thick sediment package fills small depression which formed an inlet between raising basement cliffs (Fig. 47a). This embayment was restricted as evidence dark color of the sedimentary fill and lack of fossils.

During the following transgression the environmental conditions ameliorated and rich faunal assemblage developed. The assemblage is typical for Karchowice Beds and includes corals, brachiopods, gastropods, bivalves and crinoids. The bioclastic carbonates pass gradually into more shallow water, oncolithic and oolitic Diplopora Beds.

The total thickness of the Karchowice-Diplopora Beds reaches ca 30 meters.

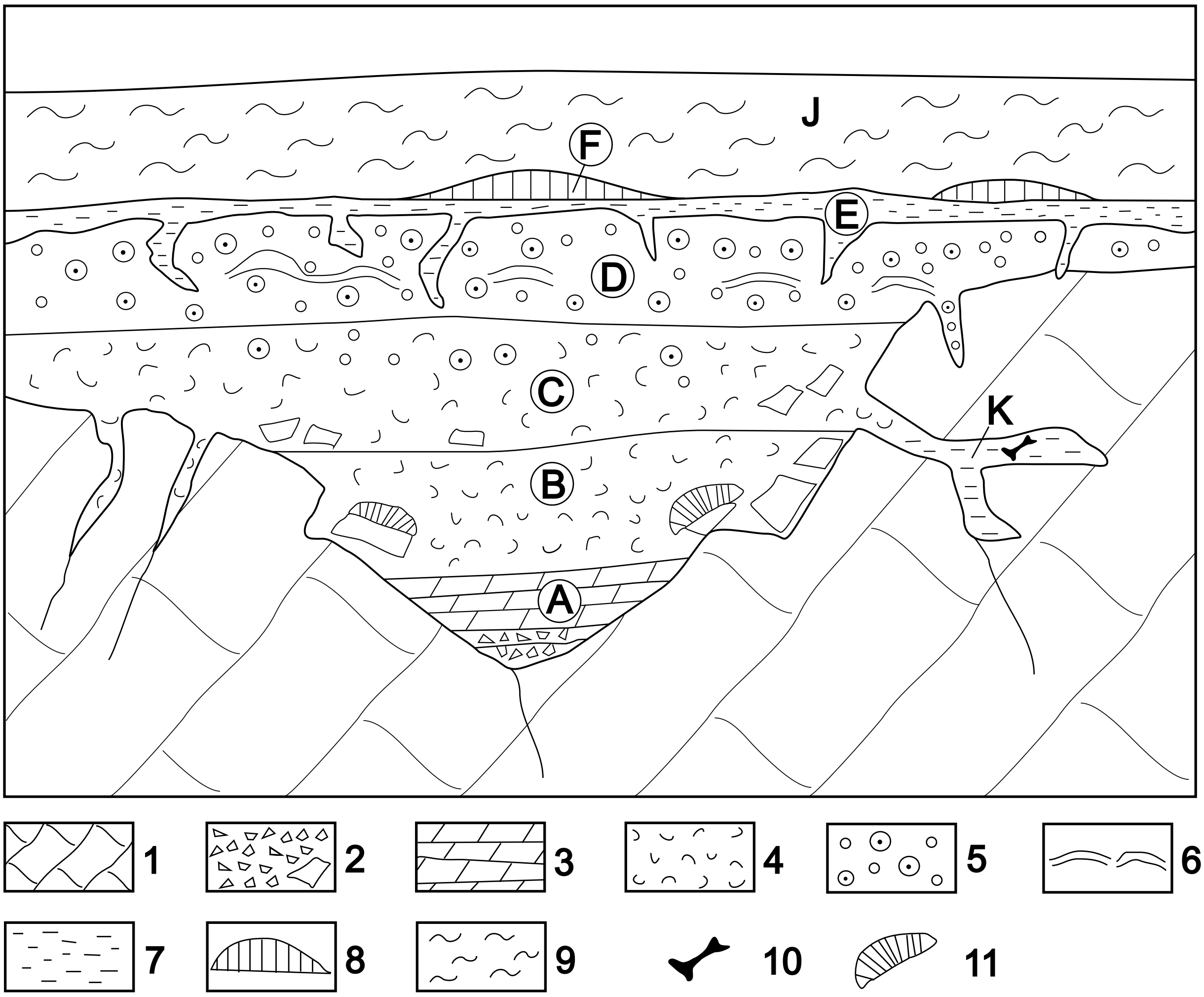


Fig. 48. Schematic setting of the Triassic succession in the Stare Gliny quarry.
A – sediments of the lagoonal embayment; B – Transgressive complex with coral and sponge reefs; C – Bioclastic sediments and oncoliths of the stabilized highstand phase; D – Late higshtand oncolithic and oolitic deposits; E – Emersion and karstification phase in Upper Triassic; F – Sedimentation of palustrine Wozniki Limestone (Norian); J – Middle Jurassic transgression; K – middle Triassic caves. 1. Givetian dolomites; 2. Devonian basement debris and rockfall deposits; 3. Evaporitic dolomites; 4. bioclastic carbonates; 5. *Girvanell*a oncoliths; 6. biolaminated carbonates; 7. continental clayey sediments; 8. remnants of Wozniki Limestone; 9. Callovian deepwater marls; 10. bone breccias; 11. coral and sponge buildups

The Muschelkalk carbonates are strongly altered due to complex diagenetic history. Most of them underwent dolomitisation and afterward a de-dolomitsiation. The both processes proceeded under strong influence of meteoric waters. As a most probable time of the meteoric diagenesis one may assume the late Triassic. The red Keuper clays and remnants of undolomitised Woźniki Limestone, which overly the karstified surface of the Muschelkalk, postdate fairly the dolomitisation phase.

It is also worthy to note, that before the Muschelkalk transgression, the Stare Gliny island underwent intense karstification as evidenced by caves developed within he Devonian basement. The cave was filled with voluminous breccia of fish and reptile (notosaurids mostly) bones (Lis & Wojcik, 1960, Tarlo, 1962).

The Triassic succession of Stare Gliny is discordantly covered by open marine sediment of the Callovian transgression.

Third Day

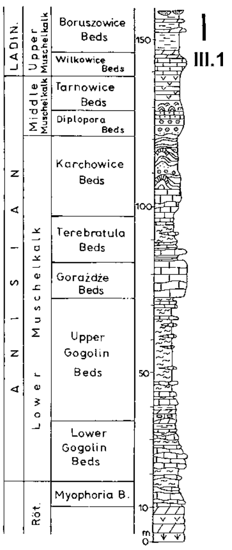
STOP. III. 1. Laryszów – communal waste depot

Joachim Szulc

Upper Muschelkalk – Boruszowice Beds

Topics:

1. Final stage of the Muschelkalk transgression in Silesia



The section displays monotonous series of dark-grey dolomitic mudstones with several coarser grained tempestites, comprising siliciclastic material.

Some of the tempestites contain also bones forming bone beds typical for the uppermost Muchelkalk over the entire Germanic Basin (Hagdorn & Reiff, 1988). Several vuggy dolomitic horizons indicate original presence of sulphate evaporites.

The fauna is represented by impoverished assemblage of bivalves (mostly myophorids), linguloids and rare cephalopods - *Ceratites spinosus.*

STOP III. 2. Żyglin – small active quarry

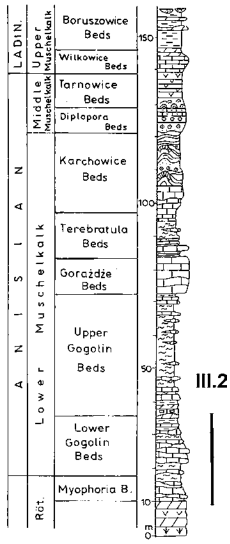
Hans Hagdorn & Joachim Szulc

Lower Gogolin Beds

Topics:

1. Quake-and tsunami generated structures and their employment for stratigraphical correlation

The outcrop exposes the Lower Gogolin Beds and enables a comparison with their counterparts in the other presented sections, *i.e.* in Gogolin (ca 50 km to W) and in Plaza (ca 40 km to SE). In spite of some subordinate differences all the sections display close similarity in general lithofacies and biota succession. Also the quake-triggered deformational horizons are recognizable in the mentioned section what enhances their reliable correlation (Fig. 27e, Fig. 38j).



The presented section comprises two lithofacies assemblages which reflect the progressing earliest Anisian transgression. The lower assemblage encompasses bioclastic, calcarenitic limestones (Myophoria- and Pecten and Dadorinus Beds) displaying features of proximal tempestites. Upsection, the bioclastic, calcareous sands are replaced by calcilutites with distal tempestitic layers, typical for advanced TST.

The limestones are, in turn, followed by dolomitic marls terminated by cellular limestones.

The cellular limestone itself, marks emersion event, identifiable over the entire Silesian subbasin (*Zellenkalk 2*).

However the most important correlation tool, are three contorted horizons which affect the lower part of the presented section. These, up to 1 m thick, deformed beds, may be easily correlated with their counterparts in Gogolin and Plaza sections. These horizons are of particular interest because their internal composition informs about the sequel phenomena of the seismic tremors. As a rule the deformed horizon commences with plastically deformed set which is eroded and overlying by gravity flow sediments. The last mentioned are mostly twofold: the lower part comprises skeletal debris of offshore fauna whereas the upper one is formed by reddish, kaolinitic clays. Such a sequence may be unequivocally related to seismic-tsunami succession, where the deformed lower part represents the seismite *s.s.* while the overlying offshore-derived sediments have been transported by surge, tsunami back flow (Fig. 38c).

STOP III. 3. Cynków – small abandoned quarry

Joachim Szulc

Wozniki Limestone (Norian)

Topic:

1. Spring-fed carbonate palustrine basin

The section shows massive and faintly stratified, white micrictic limestones formed in palustrine environment (Fig. 45f). The faint stratification is accentuated by intraformational breccias, sheet cracks, calcrete crusts or teepee structures.

The palustrine limestones are capped by massive calcrete horizon (up yo 0.5 m thick) and,or are intensively karstified. Surface of the karstified carbonates, as visible in the plane view, is jagged and featured by karstic fabrics such as sinkholes reaching 1 m in depth (Fig. 45h). The karstfied surface of the palustrine sediments is covered by variegated mudstones and claystones. They are filling also the karstic cavities. The smaller voids are filled wih internal silt and sparry cement (Fig. 45g). Some mineralisation by marcasite and pyrite have been also observed.

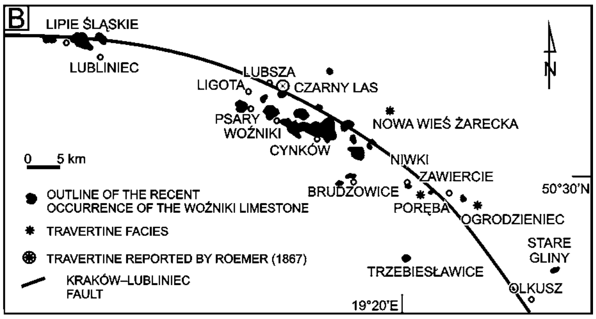


Fig. 49. Distribution of the Wozniki Limestone against the Cracow-Lubliniec master fault

The Norian Woźniki Limestone formed in swampy depressions, fed by huge, fault-bound, spring system (Fig. 49). The travertines formed directly nearby the spring orifices (Fig. 45i-k) while in the more distal area the palustrine carbonates deposited. The limestones formed mainly during dry intervals whereas the climate pluvialisation involved meteoric and clastic dilution and the final withdraw of calcareous deposition (Szulc et al., 2006). The visited section shows just such transition.

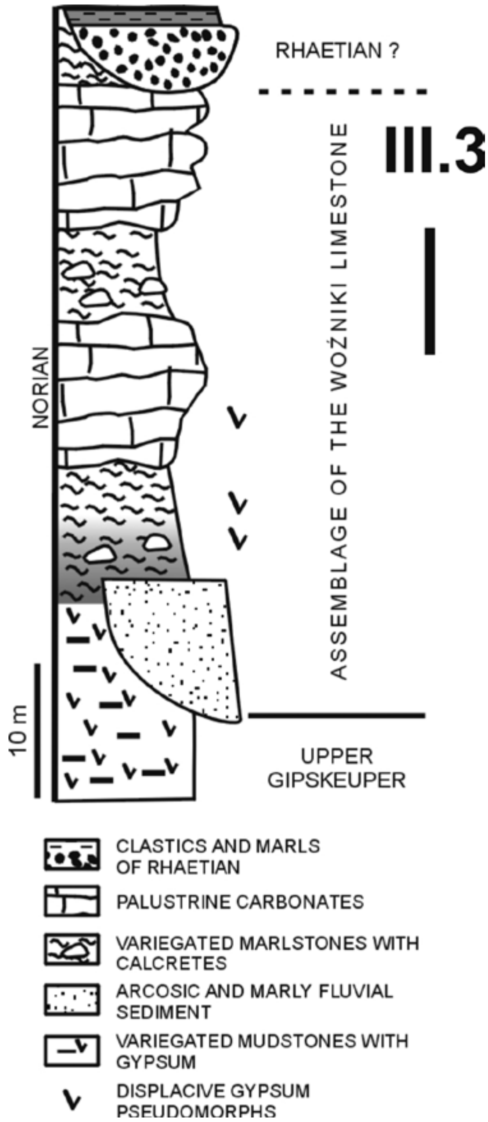
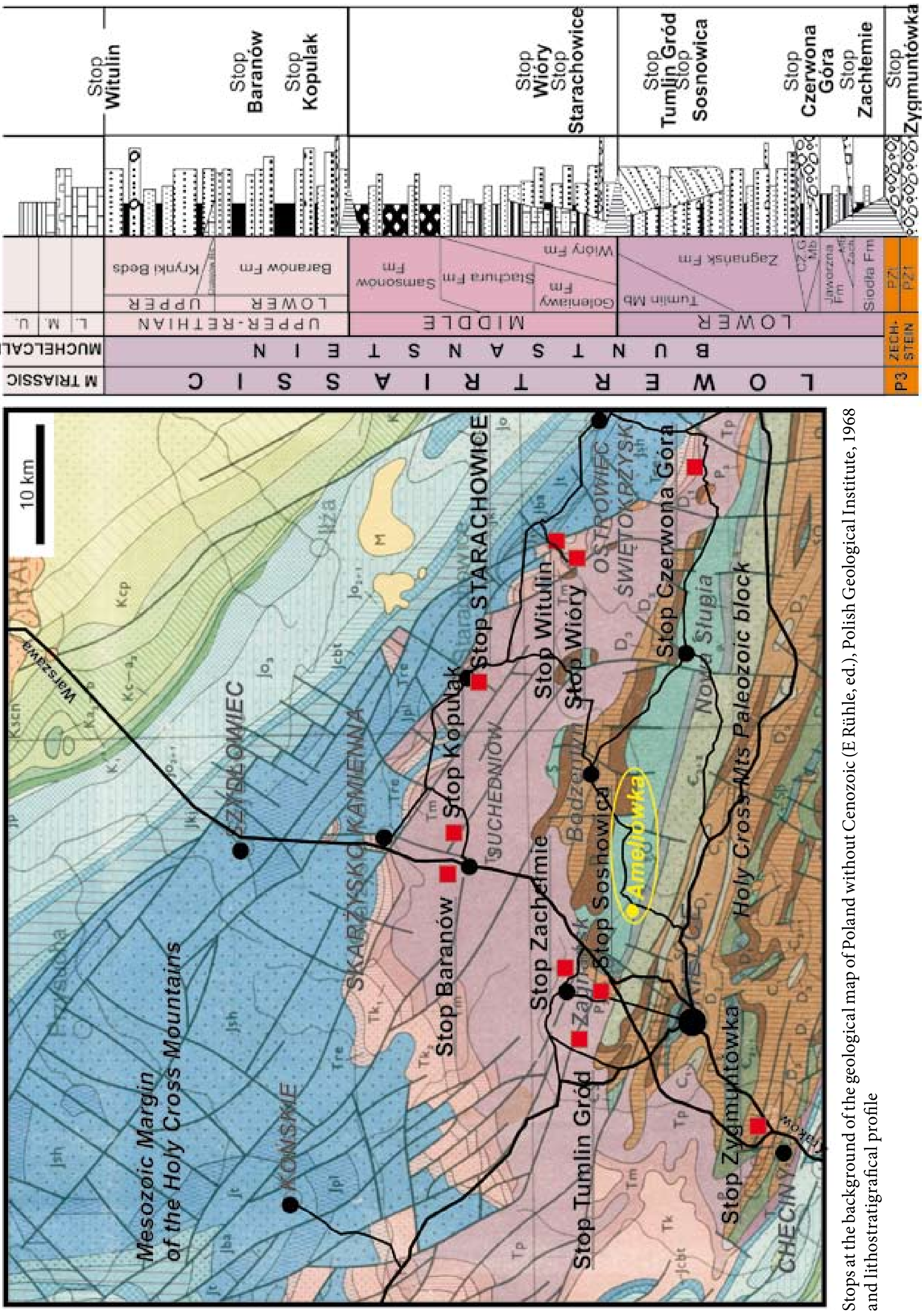


Fig. 50. Lithostratigraphy of the Wozniki Limestone with marked position of the outcrop in Cynków

Part. 2.
Holy Cross Mts.



Stops at the background of the geological map of Poland without Cenozoic (E Rühle, ed.), Polish Geological Institute, 1968 and lithostratigrafical profile

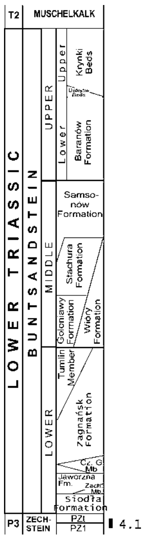
Fourth Day

STOP. IV.1. Zygmuntówka quarry

Maria Kuleta, Stanisława Zbroja & Jerzy Nawrocki

Topics:

1. Zechstein conglomerates
2. Stratigraphical context
3. Environmental context in the light of isotopic tests



Zygmuntówka quarry is an abandoned quarry of conglomerates located on a hill of Czerwona Góra, about 10 km south of Kielce (Fig. IV.1.2).

The Zygmuntówka quarry belongs to the oldest ones in the Holy Cross Mountains. Bbeginning of exploitation of the famous conglomerates and the acommpanied hydrothermal calcite, dates back to the 16th century at least. The stone block of which the column for the statue of King Sigismund (*Zygmunt*) III Vasa was erected in the 17th century in Warsaw was dug out in this quarry, hence the quarry obtained its name.

The quarry exposes in the quarry rca 30 meters of conglomerates (Fig. IV.1.1). They dip to the south at the angle of a few degrees and overlie discordantly the complex of the Givetian-Frasnian limestones which belong to the northern limb of the Gałęzice-Bolechowice-Borków Syncline. The conglomerates reach the maximum thickness – 100 m. in the axial zone of syncline. Presumable it is due to a transversal horst – the Chęciny Elevation – located in the vicinity (Czarnocki, 1923; Kowalczewski, 1963). Only the uppermost part of conglomerates (about 30 m) is exposed in the section of the northern wall of the quarry. Their complete profile was registered in the boreholes BZ1, located around 1,5 km to ESE of Czerwona Góra (Figs IV.1.2, IV.1.3).

The rocks mentioned above got cut with faults. The strike is N – S. The fault fissures got filled with hydrothermal crystalline veins of calcite spar – "różanka" (from "rose") that represents several generations (Migaszewski *et al.*, 1996). Some pebbles include vein calcite of the oldest phase and the veins of the younger phase cut the pebbles of conglomerate. The calcite of the youngest generation, includes insignificant additions of galena and sporadic cuprum sulphides. The calcite of the youngest generations forms also the intergranular cement of the conglomerates.

In the south-west wall of the quarry, intense karst phenomena can be observed.

The petrographic composition of the grain skeleton is uniform and composed mainly of grey, dark grey and pinkish grey Middle Devonian limestones. A little addition of clasts of beige and grey de-dolomitised limestones occurs. Less frequent are: neosparite dolomites and black micritic limestones (mudstones) probably of the Upper Devonian, various types of "różanka" and brown sinter deposits (Fig. IV.1.1c). Pebbles are usually poorly rounded and sorted. The average size is 3 - 6 cm, the largest ones achieve 35 - 80 cm.

The grain skeleton of the conglomerates is settled chiefly in detrital matrix. In some banks, it is composed of micrite, sporadically of recrystallised micrite (neosparite), clay minerals, limestone and calcite of psammitic and small-psephitic fractions, pelitic quartz grains as well as hydrated iron oxides and hydroxides. The binding material is also represented by calcite cement of hydrothermal origin that displaces the matrix along the linear zones. Calcite, mentioned above, forms irregular or pocket-type aggregations at some places. So far, no fauna has been found in the matrix, so the deifinite age of the conglomerates is not known.

According to the variety of features of the grain/matrix ratio and sedimentary structures five lithofacies types may be distinguished in the section (Zbroja *et al.*, 1998) modified according to Miall (1996) as follows (Fig. IV.1.1b):

Gcm – clast-supported massive conglomerates;
Gmm – matrix-supported massive conglomerates;
Gh – conglomerates with horizontal stratification;
Gp – conglomerates with cross-bedding;
Gt –conglomerates with trough-cross bedding.

The most frequent are lithofacies Gcm and Gmm, less Gh and Gt. The lithofacies Gp are scarce.

Two complexes of deposits - A and B - divided by a distinct erosional boundary have been distinguished in the section (Fig. IV.1.1a, IV.1.1d). The complex A lies in the bottom part of the quarry and includes the most of the profile (up to 25 m). It is formed of intercalating layers (or sets of layers) of Gcm, Gmm, Gh and Gp lithofacies. The overlying complex B is composed of deposits of lithofacies Gt up to 5,5 m thick. The grain size coarses upwards in both complexes. However the c normal gradation is not apparent.

The Zygmuntówka conglomerates have been compared to the fossil and recent equivalents and some conclusions about the conditions of deposition may be inferred. The conglomerates originated as the result of: 1. muddy-debris (cohesive) flows, with the domination of debris (Gcm) and mud (Gmm); 2. tractional transport by non-channelized planar flows (Gh) and by channelized flows (Gt), and small braided streams (Gp). The manner of transport and formation of the conglomerates are characteristic for the alluvial fans developing in dry and semi-dry climatic zones.

The succession of sedimentary structures and the upwards coarsening of grains ,can be explained by a progradational character of the fan. Similar origin of the Zygmuntówka conglomerates was also assumed by Kostecka (1962, 1965, 1966), who classified them as the deposits of alluvial and colluvial fans. Czarnocki (1923) and Kowalczewski and Rup (1989) interpreted a significant part of the conglomerates of the Lower Zechstein as products of subaerial weathering processes.

The stratigraphic position of the conglomerates exposed in the Zygmuntówka quarry, was determined in the mentioned boreholes data: (Sitkówka 1 and Białe Zagłębie 1 - BZ1 see Figs IV.1.2a, IV.1.2b, IV.1.3) and by means of carbon and oxygen isotope analysis.

West of the boreholes, Zygmuntówka conglomerates, are overlain (with stratigraphic gap) by Lower Buntsandstein sandstones (Zagnańsk and Szczukowice Formations; Fig. 9),

Considering the general facies context known from the boreholes (e.g. limestone layers inbetween conglomerates) and the geochemical data, it can be assumed that most of conglomerate mass deposited in an extremely shalllow marine environment. This could be proved by isotope examination of the matrix cement (Migaszewski et al. 1996), indicating a direct environmental relations to the data from the borehole logs. The value of index Z, attaining more than 120, indicate marine sedimentary conditions. Values smaller than 120 indicate lacustrine (or vadose) environments. The values of index Z of investigated matrix ranges 118 to 123 suggesting a mixed, marine/fresh water cristallisation condition (Tab. 4.1.1). The value typical for marine Devonian limestones (Z=~126) was

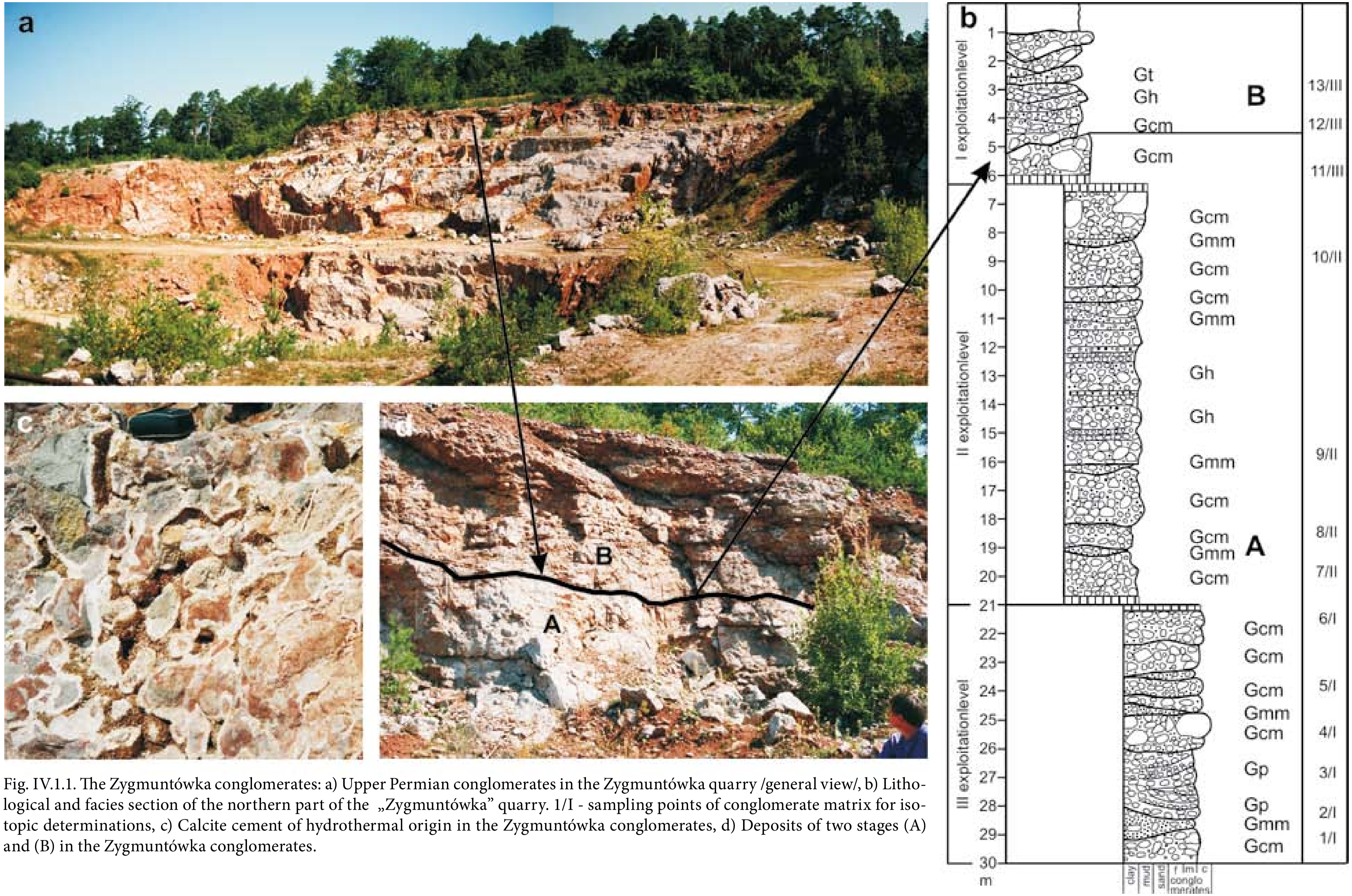


Fig. IV.1.1. The Zygmuntówka conglomerates: a) Upper Permian conglomerates in the Zygmuntówka quarry /general view/, b) Lithological and facies section of the northern part of the „Zygmuntówka" quarry. 1/I - sampling points of conglomerate matrix for isotopic determinations, c) Calcite cement of hydrothermal origin in the Zygmuntówka conglomerates, d) Deposits of two stages (A) and (B) in the Zygmuntówka conglomerates.

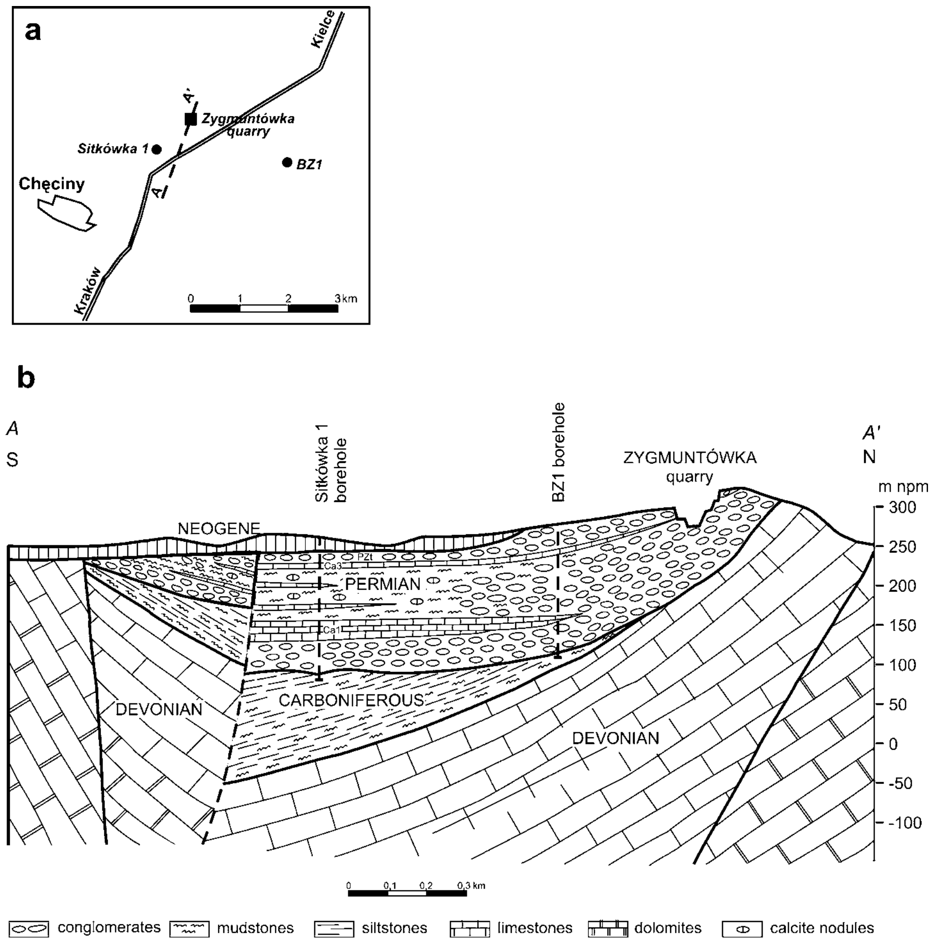


Fig. IV.1.2. Stratigraphic location of the Zygmuntówka quarry and adjacent boreholes: a) Geologic map of the central part of the Gałęzice-Bolechowice syncline (after J. Czarnocki, 1938), b) Cross section of the western part of the Gałęzice-Bolechowice syncline

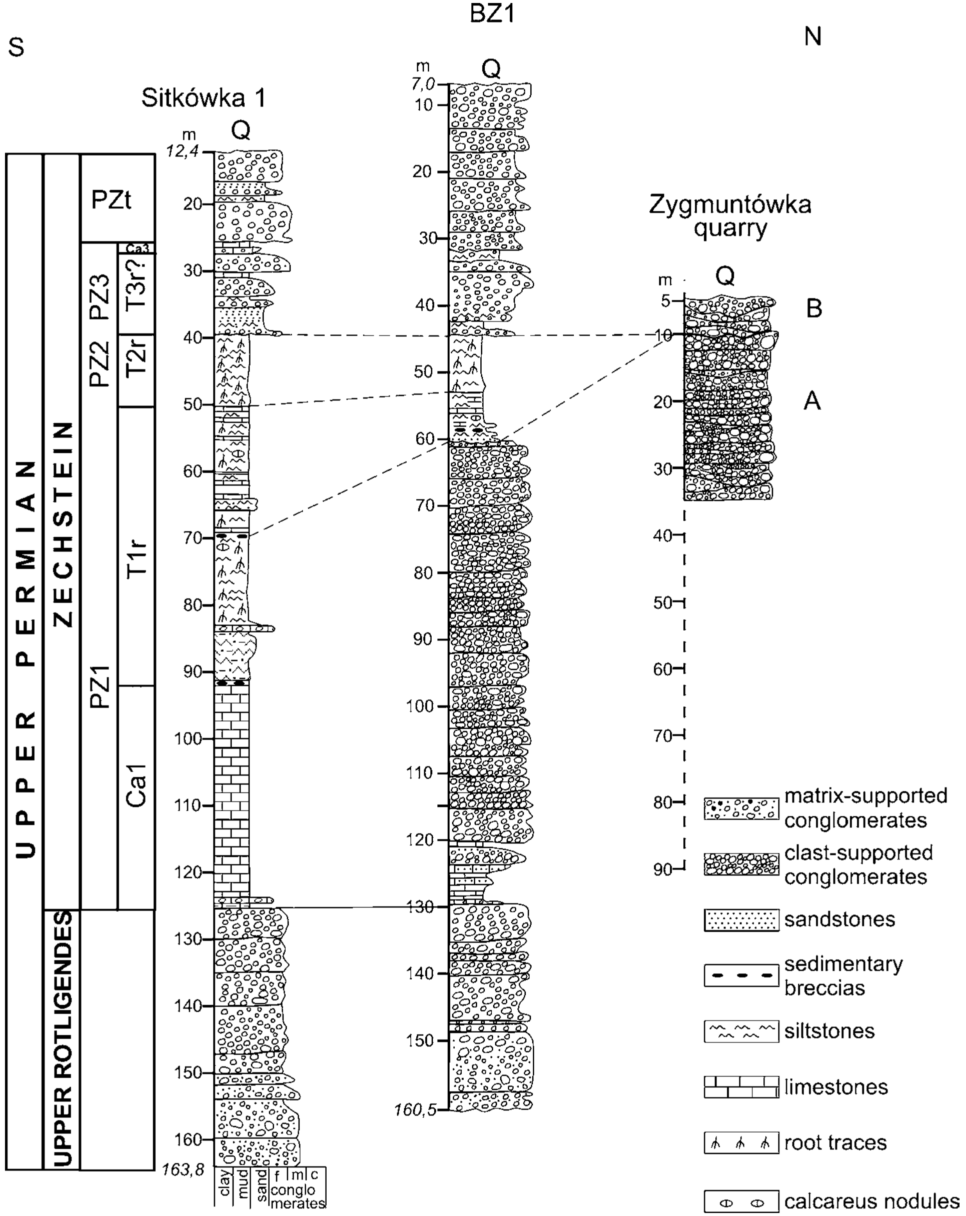


Fig. IV.1.3. Correlation of the upper Permian deposits in the middle part of the Gałęzice-Bolechowice-Borków syncline not attained. Based on these results it has been assumed that the conglomerates were formed mainly in delta fans system. The conglomerates from the Zygmuntówka quarry represent the uppermost, subaerially exposed part of the delta fan. The profile of the conglomerates represents here a transitional section of the conglomerates settled in the Zechstein marine (PZ1) cycle and top terrigenous series (PZt; Fig. IV.1.3).

Paleomagnetism and magnetostratigraphy

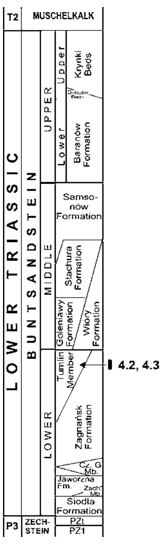
11 drill samples for paleomagnetic studies were taken from the reddish cement of conglomerates in the studied locality. Only four specimens displayed traces of Permian remanence, all with reversed polarity. Because of small number of specimens and a significant dispersion of obtained paleodirections they were not statistically evaluated.

Points of sampling (see Fig. 4.1.1b)	$\delta^{13}C$ (‰)	$\delta^{18}O$ (‰)	Index Z (Keith & Weber, 1964)
13/III top of profile	-0,67	-5,00	123
12/III	-1,61	-5,54	121
11/II	-1,56	-6,56	121
10/II	-1,37	-5,91	122
9/II	-2,45	-5,37	120
8/II	-2,99	-5,66	118
7/II	-268	-5,73	119
6/I	-1,44	-5,77	121
5/I	-0,67	-6,00	123
4/I	-0,48	-6,22	123
3/I	-2,57	-7,24	118
2/I	-1,31	-7,38	121
1/I bottom of profile	-0,65	-5,93	123

Table 4.1.1 Isotpic composition of micritic-ferric-clayey matrix of conglomerates in quarry "Zygmuntówka"

STOPS. IV.2 and IV.3. Tumlin-Gród quarry and Sosnowica quarry

Maria Kuleta, Tadeusz Ptaszyński, Grzegorz Niedźwiecki, Jerzy Nawrocki & Anna Becker



Topics:

1. Lower Buntsandstein aeolian sandstones
2. Ichnological context
3. Stratigraphic interpretation
4. γ-ray pattern

The Tumlin-Gród quarry is located on the slope of Grodowa Hill, about 10 km north of Kielce. The Sosnowica quarry is located on the slope of Sosnowica Hill, about 6 km north of Kielce. In both quarries the Lower Buntsandstein sandstones of Tumlin Member crop out.

The "Tumlin Sandstones" are almost exclusively fine- to medium-grained red sandstones, mostly laminated with subordinate structureless sandstones and mudstones. They are up to 100 m thick, however, only 20 meters are exposed in the quarry. The crucial feature of these sandstones is large-scale high-angle cross-bedding, formed on lee-slopes of eolian dunes due to a grain fall processes (Fig. IV.2.1a) (Gradziński *et al.*, 1979). Some of the bed surfaces are shaped by ripples that are an additional indicator of tractional processes. The massive sandstones and mudstone intercalations occur predominantly within inter-dune depressions or fill the erosional channels. They represent deposits of ephemeral steams or stagnant waters (ponds) that originated from periodic and short-lasting rainfalls. The shrinkage cracks and curled mud flakes, grooves, trace fossils, e.g. reptile footprints are reported from some bedding planes as well. The measured strikes and dips of the sedimentary lamina sets in these sandstones indicate northward migration of dunes due to prevailing unidirectional winds.

Petrographic composition corresponding to quartz and sublithic arenites was determined on the base of thin-sections investigation (after classification of Dott, modified by Pettijon *et al.*, 1973 and Jaworowski, 1987). Quartz (85-87%) with small addition of siliciclastic rocks (2-7%), feldspares (0,5-3%) and very rarely micas built the grain-framework of sandstones. Quartz cement and matrix composed of iron oxides and clay minerals are present. The sandstones are very compact (well cemented) and of low porosity. Within the lighter laminas pore space is almost completely filled with quartz cement, almost without ferric or clay minerals addition. The grain contacts are of tangential or rarely of long type. Amount of matrix is greater within the darker laminas. Long grain contacts and sutured grains are indicative of mechanical and chemical compaction.

Tumlin sandstones were distinguished by Senkowiczowa (1970) within the Middle Buntsandstein as Tumlin beds. Kuleta (Kuleta & Nawrocki, 2000; 2002) placed the deposits within the uppermost part of Zagnańsk Formation as Tumlin Member on the base of regional lithofacies analysis of Buntsandstein deposits in wells and outcrops. Zagnańsk Formation, earlier distinguished as Zagnańsk beds (Senkowiczowa, 1970), has been included into the Lower Buntsandstein.

After Ptaszyński (2000a) and Ptaszyński and Niedźwiedzki (2004b) the vertebrate tracks assemblage distinguished in the Tumlin-Gród quarry (see below) allows to interpret the age of the deposits as late Permian. This interpretation contradicts the lithostratigraphic and magnetostratigraphic results (Nawrocki *et al.*, 2003) and requires further investigation.

Palaeontology

In the Tumlin Sandstone Member cropping out at Tumlin Gród and Sosnowica, body fossils are extremely rare. To date, only few poorly preserved and fragmentary conchostracan carapaces were found at Tumlin Gród quarry. Their exact determination is still impossible and needs further collections. They do not represent any characteristic species known from the Lower or Middle Buntsandstein such as *Falsisca*, *Cornia*, *Euestheria, Estheriella* or *Magniestheria*.

Trace fossils of both vertebrate and invertebrate origin are very common there, occurring mostly in interdune deposits. Among invertebrate trace fossils, *Cruziana*, *Skolithos*, *Planolites*, *Palaeophycus*, *Gordia*, *Diplichnites*, *Octopodichnus* have been reported (Gradziński *et al.*, 1979, Gradziński & Uchman, 1994; Kuleta *et al.*, 2006). Vertebrate footprints, at first found in Tumlin Sandstone Member by Gradziński *et al.* (1979), were later subject to several papers (Gradziński & Uchman, 1994; Ptaszyński, 2000b; Ptaszyński & Niedźwiedzki, 2002; 2004a,b).

The most actual (Ptaszyński T. & Niedźwiedzki G., unpublished data, 2007), slightly modified to that in Ptaszyński and

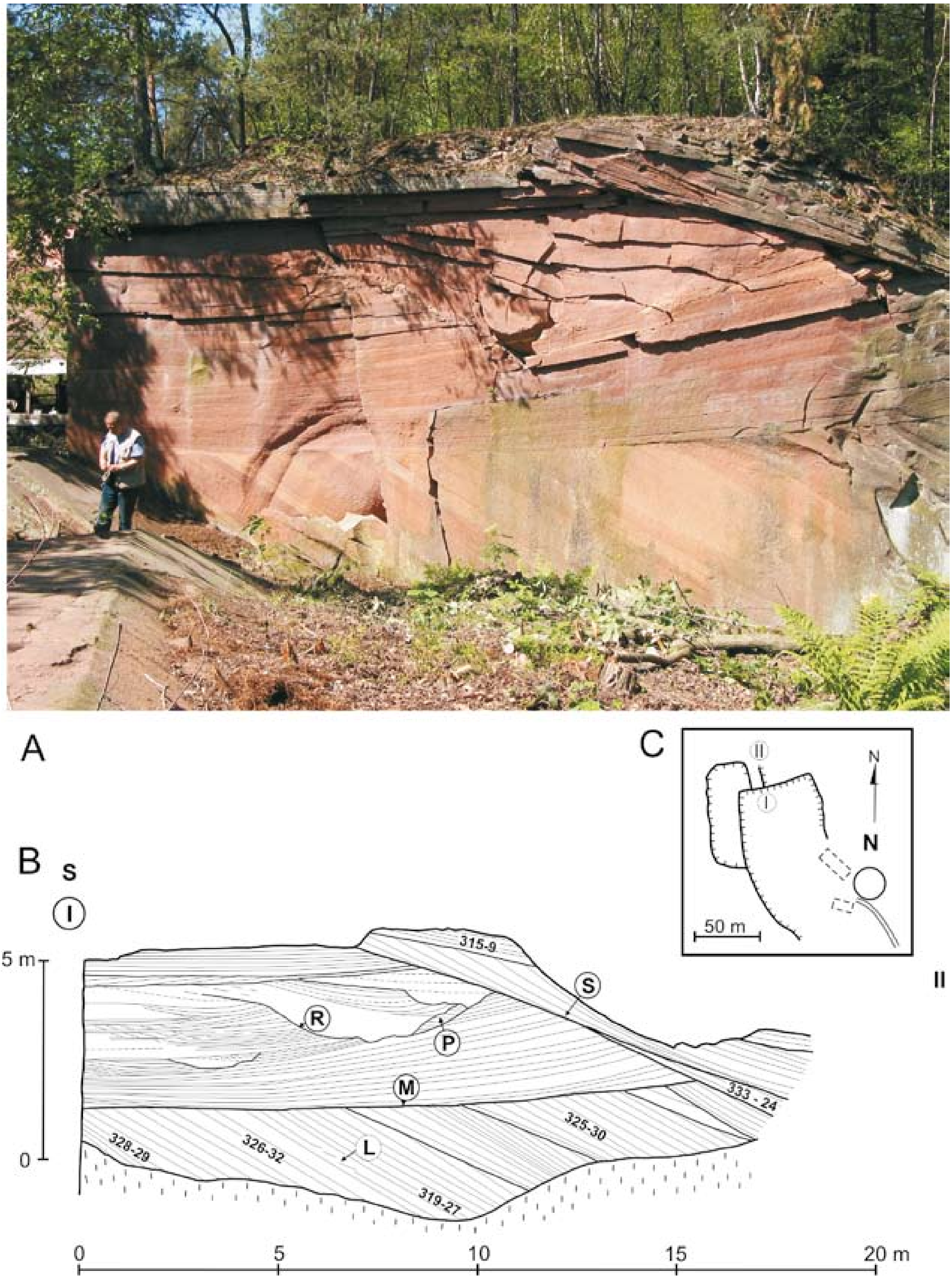


Fig. IV.2.1. Tumlin section: a), b) The upper wall of the quarry Tumlin-Gród (b - after Gradziński, Gągol & Ślączka, 1979): L – deformations of cross-laminae in form of overthrusts; M – subhorizontal main bounding surface; S – steeply inclined part of giant scoop-like surface; P – slided and rotated block at bank of erosional channel; R – deformations at bank of erosional channel; 326-32 – direction of true dip and angle of true dip (both values in degrees), c) Localization of the wall in the quarry Tumlin-Gród, after Gradziński, Gągol & Ślączka (1979)

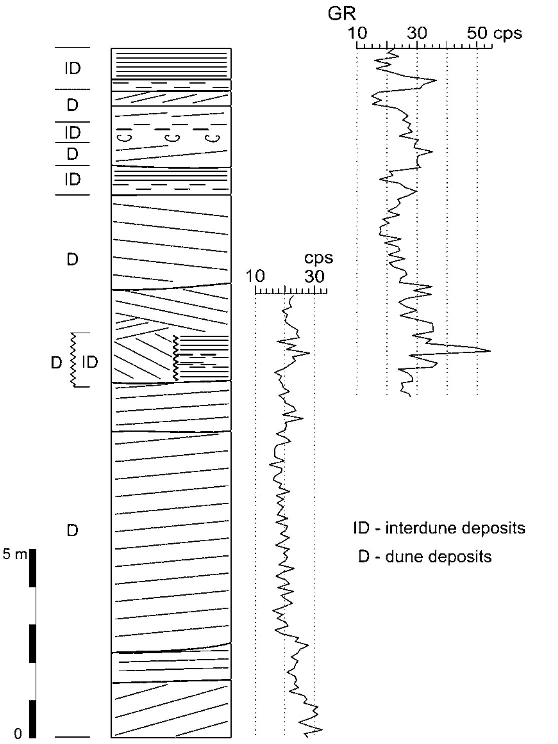


Fig. IV.2.2. Interbedding of dune and interdune deposits in the Tumlin-Gród quarry and its γ-ray pattern.

Niedźwiedzki (2004a) list of the vertebrate ichnofauna contains: *Amphisauropus* aff. *A. latus* Haubold 1970 (not identical with *A. latus* Haubold 1970); cf. *Batrachichnus salamandroides* (Geinitz 1861); not determined Chirotheriidae; *Ichniotherium* cf. *accordii* Ceoloni et al. 1988; *Limnopus* cf. *zeilleri* (Delage 1812); *Merifontichnus* isp. (Fig. VI A); ?*Pachypes* isp.; *Paradoxichnium tumlinense* Ptaszyński et Niedźwiedzki 2004; *Phalangichnus gradzinskii* Ptaszyński et Niedźwiedzki 2004; *Phalangichnus gagoli* Ptaszyński et Niedźwiedzki 2004; *Rhynchosauroiders kuletae* Ptaszyński et Niedźwiedzki 2004 and *Rhynchosauroides* isp. *sensu* Valentini et al., 2007. The previously reported presence of ?*Dimetropus* isp., *Dimetropus* isp., *Chelichnus* cf. *duncani* (Ptaszyński & Niedźwiedzki, 2004) can not be confirmed now; the presence of *Varanopus* cf. *microdactylus* is also very doubtful until confirmation by new specimens (Ptaszyński T. & Niedźwiedzki G., unpublished data, 2007).

Paleomagnetism and magnetostratigraphy

Four drill cores were taken from fine-grained sandstones and mudstones from Sosnowica locality. All samples were magnetized in reversed direction only. The mean direction ($D=211^{o}$, $I= -31^{o}$, $\alpha95 = 13.8^{o}$) is comparable with the expected early Triassic direction. Its reversed polarity is in agreement with the reverse polarity record characteristic for the uppermost part of the Lower Buntsandstein (Nawrocki, 1997) to with the dunes from the Sosnowica quarry are correlated (Nawrocki *et al.*, 2003).

Natural γ-ray measurements

Natural γ-ray measurements were carried out in the Tumlin-Gród locality. A very low γ-activity (15 – 28 counts per second in avarage, max. 32 cps) and a very low variability of radiation values (up to 10 cps) are the most characteristic features for the aeolian sandstones (Fig. IV.2.2). Highest radiation was detected in the inter-dune sediments with values of 28 – 37 cps in avarage, max. 53 cps. Variability of radiation values increases up to 22 cps in these parts of the section where dune sediments intercalate with the interdune ones.

STOP. IV.4. Zachełmie – dolomite quarry

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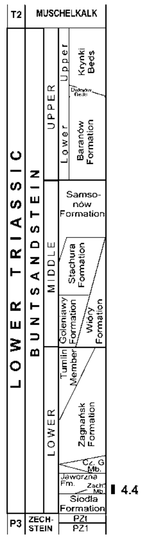
Topics:

1. Paleozoic/Mesozoic disconformity
2. Environmental context
3. Stratigraphical context



Zachełmie quarry is an abandoned quarry located on a slope of the Chełm Hill near Zagnańsk. The main part of the quarry built Devonian deposits of Wojciechowice Formation. In the uppermost part Jaworzna Formation and Zagnańsk Formation of Lower Buntsandstein crop out (Fig. IV.4.1a).

Basement Devonian rocks. Bulk of the rocks exposed in the quarry is represented by the Middle Devonian shallow water dolostones (Lower Eifelian) (Skompski & Szulczewski, 1994) that belong to the lower part of the Wojciechowice Formation (Czarnocki, 1957; Pajchlowa, 1957). The strike of these strata is about 280-290^{0}, dip 40-45^{0} towards NNE.

Lower Buntsandstein**.** The Buntsandstein deposits consist of red and brown conglomerates, sandstones and mudstones that overly, unconformity surface of the karstified Devonian carbonates. The total thickness of deposits exposed in the quarry is up to 11 m.

The stratigraphic position of the post-Devonian deposits has not been determined yet. They were included to the Lower Buntsandstein (Czarnocki 1939; Senkowiczowa 1970; Szulczewski 1995; Kuleta & Zbroja 1995, 2006; Kuleta 1996, 2000) or to Middle Buntsandstein (Mader 1985) and even to Zechstein (Filonowicz 1971, 1978). Kuleta (1996) as well as Kuleta and Nawrocki (2000, 2002) located discussed sediments in a similar stratigraphic position. They distinguished three lithostratigraphic units within the succession: Jaworzna Formation with Zachełmie Member and Zagnańsk Formation. The early Triassic age corresponds to magnetostratigraphic research carried out by Nawrocki *et al.* (2003) and the latest Permian may be supported by conchostraca found by Ptaszyński and Niedźwiecki (2004 a).

Nine lithofacies types have been distinguished in the Lower Buntsandstein section exposed here (Fig. IV.4.1c; Kuleta in Kuleta *et al.*, 2006):

1. B1 – Dolostone sedimentary breccias;
2. B2 – Mudstone sedimentary breccias;
3. Z1 – Clast-supported, massive dolostone conglomerates;
4. Z2 – Mud-supported, massive dolostone conglomerates;
5. P1 – Cross-bedded and horizontally laminated, various-grained sandstones and conglomerates;
6. P2 – The planar and trough cross-bedded, medium-grained quartz sandstones;
7. P3 – Quartz-calcareous, fine-grained sandstones of various sedimentary structures;
8. P4 – Cross-bedded and horizontally laminated, fine-grained, quartz-calcareous sandstones;
9. M – Laminated and massive quartz-micas mudstones.

The Buntsandstein section in the quarry consists of two parts distinguished by lithofacies associations and environmental criteria (Fig. IV.4.1d).

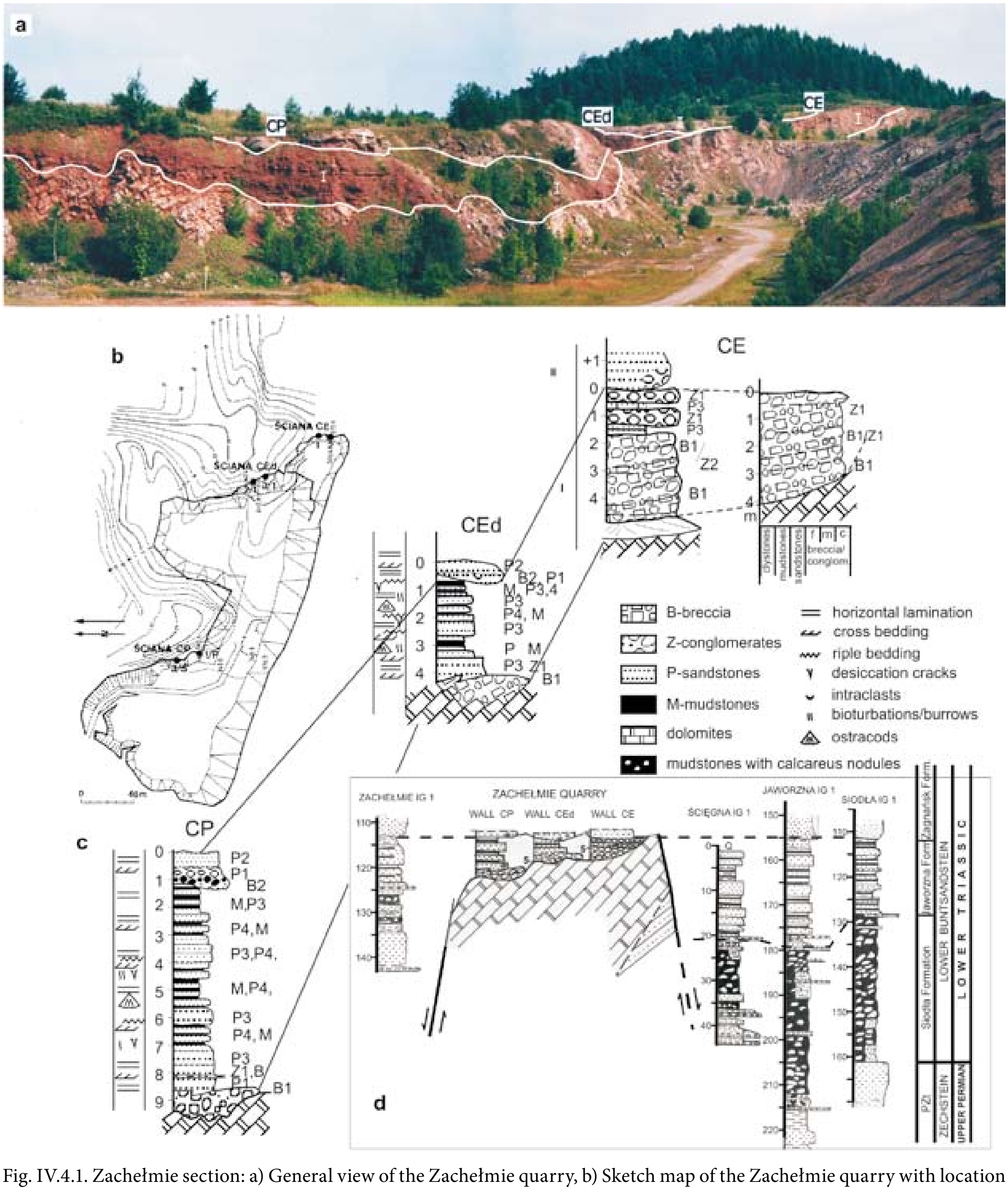


Fig. IV.4.1. Zachełmie section: a) General view of the Zachełmie quarry, b) Sketch map of the Zachełmie quarry with location of the Bundsandstein deposits and investigated sections, and isopachs of the overlying deposits; the bold arrow indicates direction of the paleoslope, c) Correlation of the lower Bundsanstein litofacies sections in the Zachełmie qarry, d) Schematic paleotectonic-litofacies sections of the lowermost Bundsanstein deposits nearby Zachełmie

The lower part I of the Buntsandstein succession (lithofacies: B1, Z1, P3, P4 and M) is related to marine deposition system that displays retrogradational facies pattern related to progressing transgression (with ooids and ostracods). It was a shallow-water environment (as indicate domichnia-type trace fossils and washouts) with intervals of subaerial exposure (evidenced by desiccation cracks). These deposits correspond to the Jaworzna Formation that was defined in the nearby Jaworzna IG-1 well, and was dated by spores and acritarchs of the *Lundbladispora obsoleta - Protohaploxypinus pantii* zone (Fijałkowska, 1994) indicative for the early Triassic age. The same age was determined by magnetostratigraphic research.

The breccias of lithofacies B1 are interpreted as transgressive lag deposits derived from eroded underlying Devonian basement. The breccias and conglomerates of lithofacies Z1 and Z2, included to Zachełmie Mbr., represent deposits of small fan-delta system, where sediment was partially accumulated due to debris flow slides. This resulted in interfingering of lithofacies Z1 and Z2 with litofacies P3 and P4 (outcropped in the CP wall; Fig. IV.4.1b, c).

The upper part II of the Buntsandstein deposits (lithofacies: P1, P2 and B2) represents environments of braided rivers. Their features are typical for the Zagnańsk Formation formed during regressive phase, that was detected in the upper part of the Lower Buntsandstein in the Holy Cross Mts. region.

The paleotectonics and lithofacies cross-section of the Lower Buntsandstein in Zachełmie vicinity clearly suggests that the Zachełmie Hill was located on an synsedimentary elevating block that formed an island during sedimentation of the Zechstein and Lower Buntsandstein (Siodła Formation – see Fig. IV.4.1). It was drown in a stage of maximum flooding of the Early Triassic transgression, progressing southwards, what corresponds to sedimentary record of the Jaworzna Formation. The uneven palaeorelief, with the Buntsandstein fillings in depressions, is clearly connected to the fluvial valley system that can be detected on the sketch map of the quarry with isopachs pattern (Fig. IV.4.1b).

Paleontology

In the 0 – 6 m thick Jaworzna Formation cropping out at Zachełmie quarry conchostracans are common (Ptaszyński & Niedźwiedzki, 2004b, 2005, 2006; Kuleta *et al.*, 2006). Among other body fossils, poor plant remains (Kuleta *et al.*, 2006) and rare fish scales are also present there. To date, *Euestheria gutta gutta* (Ljutkevič 1937)*, Euestheria gutta oertlii* Kozur 1980, *Palaeolimnadia* sp. aff. *cishycranica* (Novožilov 1970), *Falsisca postera* Kozur et Seidel 1983 (in the lower 3/4 part of the Jaworzna Fm section at Zachełmie site; Fig. VI B), *Falsisca verchojanica* (Molin 1965) (in the uppermost part of the Jaworzna Fm section at Zachełmie; Fig. VI C) are determined.

Invertebrate tracks are represented by *Skolithos*, *Scoyenia*, *Planolites*, *Palaeophycus*, *Diplichnites* and cf. *Gordia* (Kuleta *et al.*, 2001, 2006).

Results of about ten years vertebrate footprints collecting, have been a subject of a preliminary anouncement to date (Ptaszyński & Niedźwiedzki, 2002). The list of vertebrate ichnotaxa from the Jaworzna Fm, found at Zachełmie quarry, is still not completed. The following ichnotaxa were determined to date (Ptaszyński T. & Niedźwiedzki G., unpublished data, 2007): *Amphisauropus* aff. *A. latus* Haubold 1970 (not identical with *A. latus* Haubold 1970); *Batrachichnus salamandroides* (Geinitz 1861); *Hyloidichnus* cf. *tirolensis* Ceoloni et al., 1988; *Ichniotherium* cf. *accordii* Ceoloni et al. 1988; *Limnopus* sp. (Fig. VI D); ?*Paradoxichnium tumlinense* Ptaszyński et Niedźwiedzki 2004; *Phalangichnus gradzinskii* Ptaszyński *et* Niedźwiedzki 2004; *Phalangichnus gagoli* Ptaszyński et Niedźwiedzki 2004; *Rhynchosauroides kuletae* Ptaszyński et Niedźwiedzki 2004; *Rhynchosauroides* isp. *sensu* Valentini et al., 2007; not determined Chirotheriidae: *Synaptichnium*-like and *Brachychirotherium*-like; *Merifontichnus* isp.; and *Pachypes* isp. The latter represents largest footprints found at the site, reaching 30 cm of the pedal width.

Jaworzna Formation deposits known from adjacent boreholes contain microflora assemblage *Lundbladispora obsoleta – Protohaploxypinus pantii* (Fijałkowska, 1992, 1994; Fijałkowska-Mader, 1998; see also Ptaszyński & Niedźwiedzki, 2004b, 2005, 2006), described first by Orłowska-Zwolińska (1984, 1985) from the Lower Buntsandstein of the Polish Lowland.

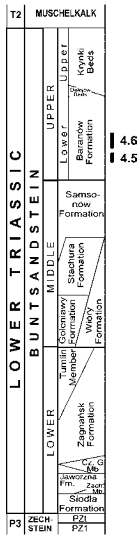
Thick sandstones above Jaworzna Fm belonging to Zagnańsk Formation (Kuleta, 2000) contain no body fossils. Some structures found there can be interpreted as poorly preserved, deformed by water current, large in size, not determinable vertebrate footprints (see Kuleta *et al.*, 2006).

Paleomagnetism and magnetostratigraphy

Eight hand samples for paleomagnetic studies were taken from the Buntsandstein rocks that cover the Devonian sequence in Zachełmie. Samples were collected in c.a. 1m of distance. The studied section contains normal polarity record only and the mean paleomagnetic direction (D=29°, I= 34°, α95 = 6.2°) corresponds well with the expected early Triassic direction. This normal polarity zone was correlated (Nawrocki *et al.*, 2003) with the normal polarity record noted in the base of Buntsandstein sediments from several places of the Central European Basin (Nawrocki, 1997; Katinas, 1997; Szurlies *et al.*, 2003). It is regarded to be the oldest Triassic normal polarity zone. However, it can not be excluded that its lower part is as old as the latest Permian.

STOPS. IV.5 and IV.6. Kopulak and Baranów – sandstone and claystone quarries

Introduction



The sediments exposed in the quarries of Kopulak and Baranów represent the lowermost and middle parts of the lower Röt, which is developed as braided and meandering river fluvial deposits. During last years these intervals subjected complex geological investigations: lithologic-sedimentological, petrological, geochemical, and paleonthological, the results of which are collected in an unpublished report (Kuleta *et al.*, 2004). Additionally, some preliminary lithologic and palaeontologic data were presented elsewhere (Kuleta *et al.*, 2001; 2005a). Moreover, an collection of vertebrate tracks, counting 102 specimens, has been worked out by Kuleta *et al.*, (2005).

The results of the studies prompted the authors to distinguish the Baranów Formation as new lithostatigraphic unit, comprising terrestrial sediments of the lower Roetian. This unit comprises three subdivisions, developed by Senkowiczowa (1970): the Wąchock beds, the Młodzawy beds and the Łyżwy beds. This corresponds to the classification of the Roetian of the Holy Cross Mts. proposed by Kleczkowski (1953) and Gągol (1974), where the discussed formation comprises is called "sub-ore complex".

On the basis of the studies in Baranów mine and Kopulak quarry, 8 lithofacies types have been distinguished: Gh – indistinctly horizontal laminated conglomerates; St – trough-cross bedded sandstones; Sp – planar-cross bedded sandstones; Sh – horizontal bedded sandstones; Sr – ripple cross-laminated sandstones; Fl – horizontal laminated siltstones and claystones; Fr – massive claystones and siltstones with roots; P(fm) – iron-manganese paleosoil horizons, cementing zones and nodules. Distinguished lithofacies form two natural associations within the profiles, that exhibit characteristic properties and facies succession for sandy-gravel braided rivers and sandy meandering rivers (Allan 1964, Cant 1982, Miall 1996). Sub-associations corresponding to channel deposits and over bank sediments were differentiated (Table 4.5.1).

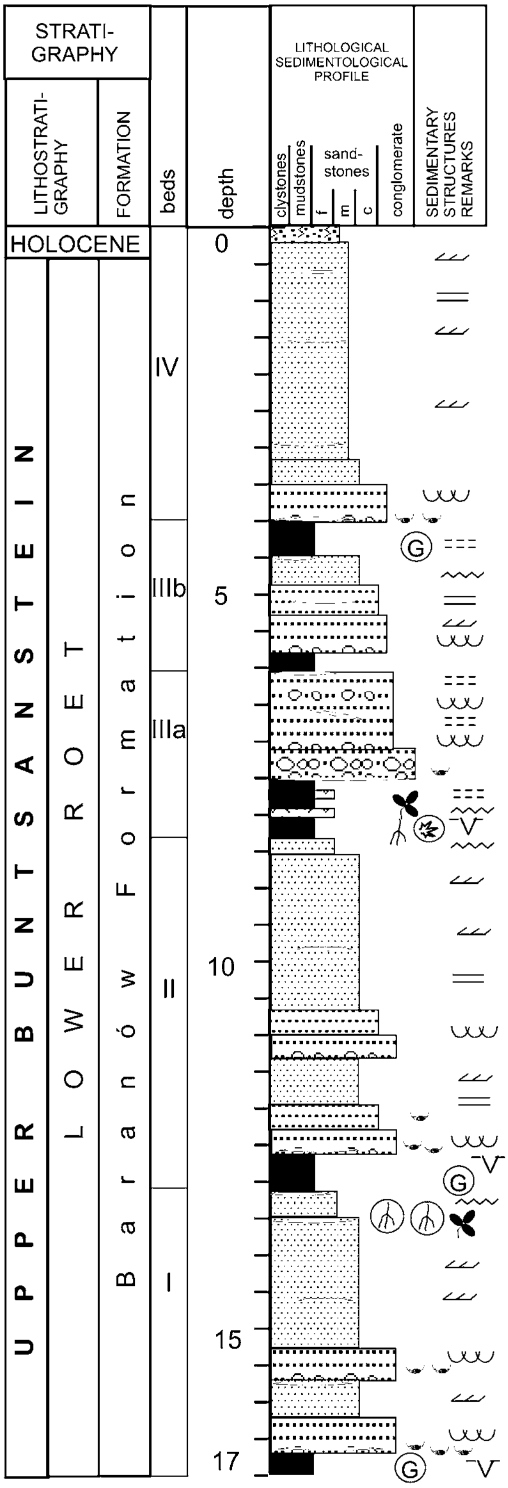
Facies succession typical of braided river is well exemplified in the profile of the Kopulak quarry (Stop. IV.5), whereas as the example of meandering river succession is shown in the Baranów mine (Stop IV.6).

STOP. IV.5. Kopulak – sandstones quarry

Maria Kuleta, Grzegorz Niedźwiedzki & Tadeusz Ptaszyński

Topics:

1. Braided river succession
2. Vertebrate and invertebrate ichnofauna
3. Traces of flora and plant roots



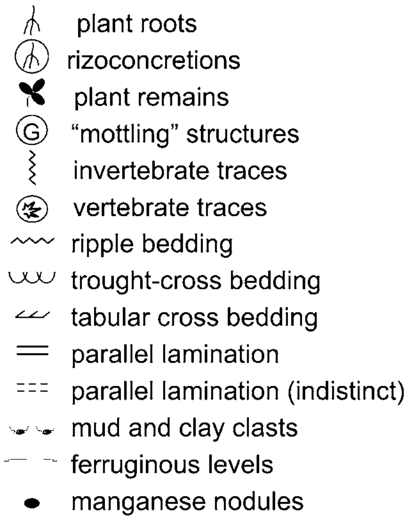


Fig. IV.5.1. Lithologic-sedimentological profile of the Röt-sediments in the Kopulak quarry

The inactive quarry is located on the Kopulak hill near Suchedniów.

The outcropping sediments in the quarry are included to the lowermost Röt and, according to Senkowiczowa (1970), they show properties of the Wąchock beds, distinguished by hematitic pebbles in the sandstones. Complex of 17 m thick sandstones is exposed in Kopulak quarry. It consists of 5 banks of red sandstones, that are separated by siltstone and claystone layers (Fig. IV.5.1).

The study conducted in the quarry allows to recognise the lithofacies succession as characteristic for fining-upward fluvial cycles, developed in sandy or sandy-gravel braided river sediments (Table 4.5.1).

Channel deposits

The lower, channel fill elements of the cycles are represented by sandstone banks up to 4,5 m thick (lithofacies sub-association 1a). Lithoclastic conglomerates (lithofacies Gh) and conglomeratic sandstones (lithofacies St), containing significant amounts of clayey intraclasts, that occur in the lowermost parts of the banks, represent channel lag sediments. Traces of desiccation have been be observed as well. The conglomerates (occurring in the base of the banks marked with symbols IIIA, IIIB, as well as IV; Fig. IV.5.1) are massive or show indistinct horizontal flaser and bedding. A characteristic property of the conglomerates is low grade of compaction of the sediments.

The lowermost parts of the I and II banks are composed of variably grained, large-scale trough-cross bedded sandstones with addition of psephitic fragments (lithofacies St). Conglomeratic sediments compose single trough-cross bedded sets that occur in upper parts of the banks or are concentrated in the lower parts of the cross bedded cosets.

The middle parts of the banks are composed of medium-grained sandstones with large-scale planar- and trough-cross bedding (lithofacies Sp and St), that can be interpreted as channel bars. Variation in structure types and succession can be observed along the banks.

The top part of the bank is normally composed of fine-grained, planar-cross bedded sandstones (lithofacies Sp and Sr). On the top plane of bank I, crests of mega-ripples and sandstone waves can be observed. On the top plane, additionally widespread traces of plant fragments and oval traces of roots appear too. Vertical traces of plant roots, empty or partly filled, can be observed in the cross-section of these banks. The measured strike of the small ripples and sandstone waves as well as dip directions of the cross-laminae amount to 170°-190°, whereas the plant debris are orientated in two directions: approx. 110° and approx. 20°.

Overbank deposits

The upper fine-grained flood plain sediments of the cyclothem (sub-association 1b – Table 4.5.1) are mainly represented by siltstones and claystones (lithofacies Fl and Fr), more rarely by fine-grained sandstones (lithofacies Sr) displaying ripple bedding. They reach up to few dm in thicknesses and are often erosively reduced by the superimposed cycle. These

Association	Sub-association	Dominating facies type	Other occurring facies types	Environmental interpretation
1				**Sandy-gravel braided river**
(from the quarry	1a	Sp, St	Gh, Sh, Sr	**Channel deposits**: channel lag, transversal and
Kopulak)				longitudinal channel bars
	1b	Fl, Fr	P(fm)	**Over bank deposits**: levees, floodplains
2				**Meandering rivers**
(from the quarry	2a	St, Sp	Sr, Gh	**Channel deposits**: channel lag, point bar
Baranów)				**Over bank deposits**:
	2b	Sp, Fl	Sr, Sh, Fr, P(fm)	crevasse-splays and levees
	2c	Fl, Fr		flood plain, lakes

Table 4.5.1 Lithofacies associations observed in Baranów and Kopulak sections.

sediments represent claystone formations of overbank and levees, formed intercalating thin beds of sandstones and silt-claystones. Within the discussed sediments, numerous small plant roots traces occur and destroy almost completely the primary bedding.. Moreover, on the bed surfaces, trace fossils of plants, vertebrates and invertebrates can be observed.

Special feature of these sediments are the color fading of the sandstones and the enrichment of iron and manganese oxides in cement zones (lithofacies P(fm)). They occur as patina of several cm in thickness and crusts on the bank top and base planes, underlining the original sedimentary structures: ripples or desiccation cracks.

The described iron enrichments are probably associated with changes of groundwater level, as well as paleo-pedogenic processes. A broader interpretation will be presented in the profile description from the quarry Baranów (Stop IV.6), where these phenomena occur on a larger scale.

STOP. IV.6. Baranów – vitrified clay pit

Maria Kuleta, Stanisława Zbroja, Tadeusz Ptaszyński, Grzegorz Niedźwiedzki & Jerzy Nawrocki

Topics:
1. Meandring river succession
2. Paleosoil horizons
3. Fe-Mn cementing zones
4. Vertebrate tracks and invertebrate ichnofauna

Baranów locality is a vitrified clay pit situated on the Baranów hill near Suchedniów. Red vitrified clays have been mined for the production of structural ceramics. The mine openings emerged within the former quarry “Włochy”, where light, middle-grained sandstones, known for a long time, had been mined for construction purposes. These sandstone banks where removed as cap-rocks to access the vitrified clay beds. Currently, they are apparent only in the northern wall of the mine openings.

The currently exposed profile in Baranów is made up by middle part of the Baranów Formation. Senkowiczowa (1970) put the clays occurring here into the Młodzawy beds, which genesis was related to marine ingression. Mixed package of sand- and claystones occurring above the mined clays, she has included into the Łyżwy beds (upper Röt). According to later studies all the sediments can be included into one lithostratigraphic unit belonging to lower Röt.

The investigated profile of the Röt-sediment in the “Baranów” pit (50 m in thickness) shows the lithofacies succession and cyclicity characteristic for sandy meandering rivers. The compiled profile (Fig. IV.6.1) has been constructed on the base of investigations of the middle part of the northern quarry wall, as well as fragments of the southern wall. The dip angle of the individual layers is variable, amounts to 10° to 18° N and is to a great extend linked to the primary tilt of the sedimentary planes. Characteristic of the sediment architecture was based on the eight differentiated lithofacies, their associations and sub-associations (Table 4.5.1).

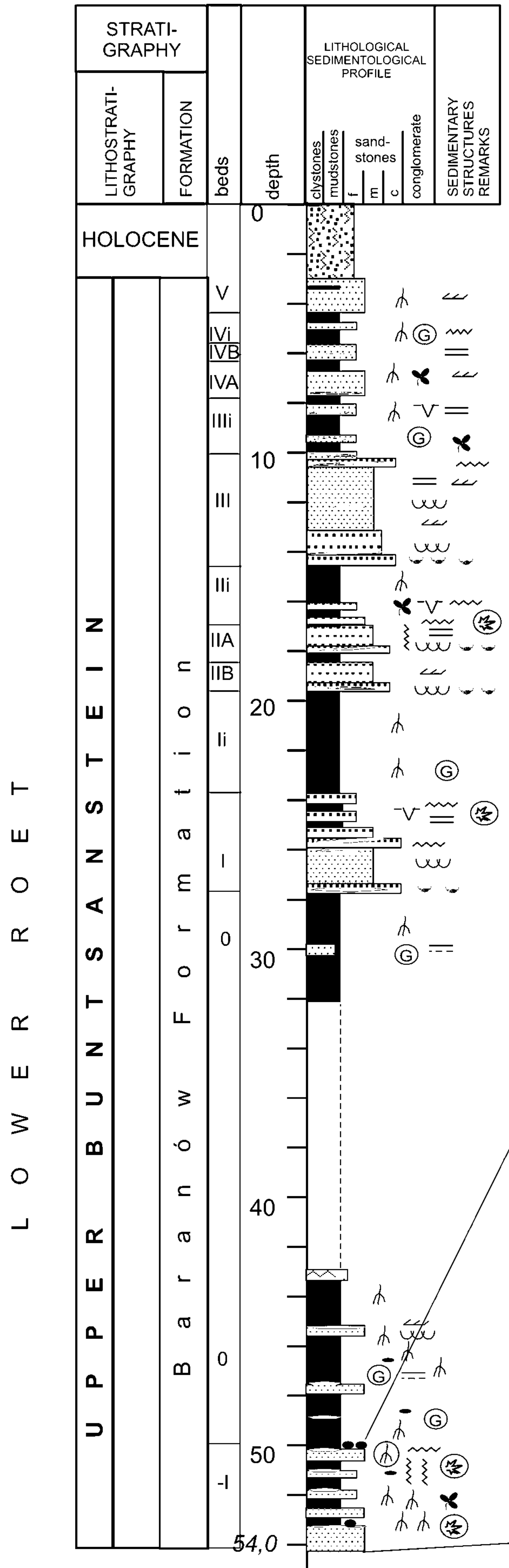
Channel deposits

The lower segments of the cycles are represented by channel deposits; point bar and channel lag successions occur in the Baranów profile (bank I, II A, B and III).

The bank marked with the symbol I is made up mostly by light, cream-colored/red, middle-grained sandstones with trough- and planar-cross bedding of large-scale (lithofacies St and Sp), building the core of point bars. The lowermost sections of the banks are coarse-grained and represent channel lag sediments. Besides fine-psephitic quartz and ferrous-clayey-siliceous rock fragments, silty-clayey intraclasts of various size occur. In the top of the banks fine-grained sandstones with ripple lamination occur (lithofacies Sr), preceded by sandstones with addition of gravel. They have trough-shaped outlines and may be related to the detachment of the topmost part of the sand bars during flooding periods.

The second of the investigated banks, 2,5 m in thickness, is partly bipartite (IIA and IIB) but the both parts amalgamate to one very soon. Main core of the bank II is built by middle-/fine-grained sandstones (lithofacies St, Sp and Sh), tightly, rather homogeneous and densely laminated, red-pink colored, with gray tinge. The lower part of the bed is made of middle- to coarse-grained sandstones with intraclasts (lithofacies St, Sp and Sh) and frequent iron-manganese-crusts (lithofacies P(fm)). In the upper part of the bed, occur fine-grained sandstones (lithofacies Sr) with well developed straight, tongue shaped and crescent ripples. This layer is almost completely removed, due to works to enlarge the scope of the pit.

The third bank (III), the thickest one, with up to 4,5 m in thickness, is present only over a short distance, but its surface is well preserved. The bank is developed as red-brown, partially pinkish, medium-grained sandstones with varying porosity (lithofacies St, Sp). Trough-cross bedding and planar-cross bedding occur. The lower part, similar to the other banks, is coarse-grained and conglomeratic, with iron-manganese-coatings.. The fine-grained top of the bank is developed similarly to bank I. Three horizons of iron-coatings can be



observed here, in which numerous invertebrate traces are preserved.

Overbank deposits

The floodplain deposits are developed as claystones and siltstones (lithofacies Fl and Fr), with intercalations of fine-, more seldom medium-grained sandstones (lithofacies Sh, Sr). They represent crevasse-splays, levees and lakes on the floodplain deposits. Accessible for direct observations are the crevasse-splays and floodplain lake deposits, that occur above the layer III of the channel deposits and in the lowermost part of the profile (layer symbols 0 and –I).

In the lowermost, 3 m -thick part of the profile (layer –I) occur sediments which are interpreted as distal crevasse-splays, passing laterally into floodplain fines. The superimposing clayey-silty sediments are interpreted as lake and floodplain sediments. They are mined in the quarry (layer 0).

Within the discussed sediment packet, occur paleosoil horizons (lithofacies Fr and P(fm)). Root traces and plant residues can be observed, on sedimentary surfaces of sandstones. According to Retallack (1984), the presence of root traces is one of the properties that point to pedogenic processes. Furthermore well visible are: horizontal dispersion of root traces, horizons of decolorization, blocky-flaky structures, characteristic for paleosoils, and occurrence of iron-manganese nodules, distributed horizontally.

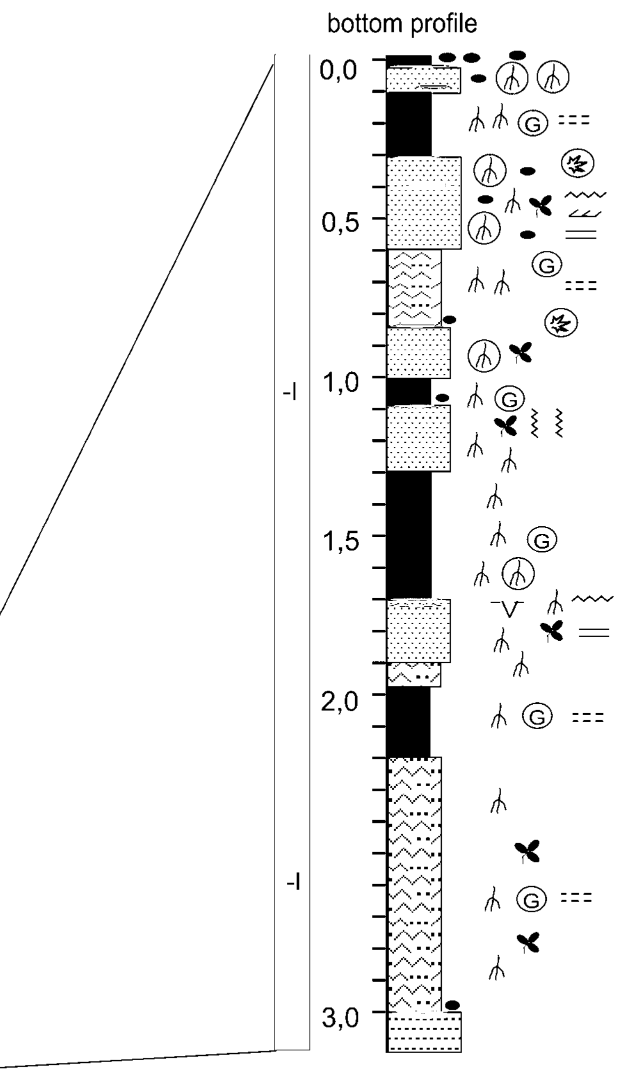


Fig. IV.6.1. Lithologic-sedimentological profile of the Röt-sediments in the Baranów pit. Legend like in Fig. IV.5.1.

Four types of rhizoliths and many transitional forms have been identified (Esteban & Klappa, 1983): channels with free or scarred opening and a zone of celadon decolorization, sediment-filled moulds with a zone of celadon decolorization, rhizocretions, roots encrusted with iron- and manganese-oxide.

On the bed surfaces of the sandstones beside the root traces occur aslo: traces of plant fragments, desiccation cracks, ripples, vertebrate and invertebrate tracks. No organic matter was found anywhere, neither in the outcrops, nor in the boreholes. It has been completely disintegrated (Gągol, 1974).

Within the profile part described here, is particularly rich in iron- and manganese-oxide concentrations (lithofacies P(fm)). The highest iron and manganese concentrations are present in the border zone between crevasse-splay and flood plain deposits. An iron-manganese bed of up to 30 cm in thickness occurs within the lower part of the layer 0. The iron- and manganese-oxide content reaches there 70 %. Crust-concretion type of structures, single concretions and concretion-clusters are visible on the top of the bed. Lamination, ribbon, fan and concentric structures resembling stromatolitic forms occur on the base of the bed and on the planes perpendicular to the bed extent (Starnawska, 2004). Separation of iron-oxides and manganese-oxides, which occur in different lamina, is visible already in macroscopic scale.

Concretions and their clusters from the uppermost part of the bed are almost exclusively composed of manganese-oxides with quartz grains scattered in the background. Laminations, fan and concentric structures are apparent within the concretions, emphasized by fracturing and porosity. Empty, central parts of concretions formed possibly by complete disintegration of plant fragments or roots, creating primarily their nucleus.

Roots occurring in the discussed zone are also encrusted by iron- and manganese-oxides. These minerals compose also cement enrichments on the top and base surfaces of crevasse-splay sandstone beds.

Iron-oxide enrichments in investigated sediments have been signalized already in older literature, whereas the manganese concretions have been detected here for the first time. Kozydra (1956) postulated late diagenetic, Tertiary origin of of decolorization and iron enrichment. Gągol and Kuleta (1973) suggested a synsedimentary, early diagenetic origin of iron and manganese enrichment. It could form in the same time as decolorization and development of light colored sandstones and white clays occurring in the pit.

Recent research confirmed early suggestions of connection between iron and manganese concentration and pedogenic processes (Kuleta & Nawrocki, 2000). The soils developed in a river valley, as a soil type of overbank deposits typical for different climatic zones. After Retallack (1990) it can be classified as oxisol.

Microbial structures, were detected on the base of structural and microchemical analysis of selected specimens taken from Fe-Mn covers and nodules (Starnawska, 2004). After Starnawska the paleosoil horizons from Baranów represent immature lateritic soils developed in tropical climate conditions.

Further investigation on the characteristic of paleosoils as well as on chemical, biochemical and climatic conditions of their development are necessary.

Paleontology

Baranów and Kopulak are closely situated outcrops containing identical fossils, including plant remains, vertebrate and invertebrate ichnofossils. Invertebrates are represented by *Cruziana*, *Skolithos*, *Scoyenia*, *Palaeophycus*, *Lockeia*, cf. *Gordia* (Kuleta *et al*., 2006).

The most characteristic of Baranów and Kopulak vertebrate ichnofauna, is the presence of the ichnofamily Chirotheriidae, including *Isochirotherium herculis* (Egerton 1839), *I. soergeli* (Haubold 1967), *Chirotherium barthii* Kaup 1835, *Brachychirotherium* isp. and *Synaptichnium* isp., with accompanying footprints of *Rhynchosauroides schochardti* (Rühle v. Lilienstern 1939, *R. bornemanni* Haubold 1966, ?*Rotodactylus* isp., and ?*Capitosauroides* isp. (Kuleta *et al*., 2005; Niedźwiedzki, G. and Ptaszyński, T., unpublished data, 2007). Very interesting are large footprints, bigger than any described to date from the Buntsandstein of the Central European Basin (Kuleta *et al*., 2006), reaching up to 50-55 cm of the pedal length (Fig. VI E). Footprints comparable in size are Southern American *Rigalites ischigualastianus* (Leonardi & Oliveira, 1990; Melchor & Valais, 2006), *Brachychirotherium kalkowensis* from Wióry, *Merifontichnus* isp. from Tumlin Sandstone Member and Jaworzna Fm, *Pachypes dolomiticus Leonardi* et al. 1975 from Val Gardena Sandstone Fm and *Brontopus giganteus* Heyler et Lessertisseur 1963 from La Lieude Fm, recently reported also from Vyatka Gorizon in Russia (Surkov *et al*., 2007). Most of vertebrate ichnotaxa from Baranów Formation is well known from the famous Thüringischer Chirotheriensandstein and Röt in Germany area.

Paleomagnetism and magnetostratigraphy

Three hand samples for paleomagnetic study were taken from hematite layers from the Baranów locality. Results of paleomagntic study indicate a secondary origin of magnetic remanence. The mean characteristic direction (D=356°, I= 56°, α95 = 2.1°) is concordant with the reference early Cretaceous paleomagnetic direction. It means that hematite is diagenetic in origin. It was formed about 150 Ma later than the host rock.

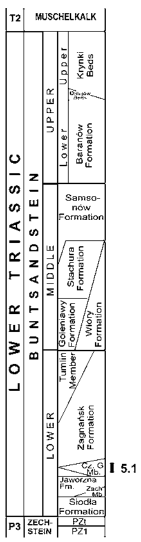
Fifth Day

STOP. V.1. Czerwona Góra near Ostrowiec Świętokrzyski

Maria Kuleta, Tadeusz Ptaszyński, Grzegorz Niedźwiecki & Jerzy Nawrocki

Topics:

1. Gravel-bed braided river succession
2. Lithostratigraphic position



Czerwona Góra locality is a slope quarry in the Kamionka river valley-side (a tributary of Kamienna river), about 300 m north of road through Czerwona Góra village, 15 km southwest of Ostrowiec Świętokrzyski.

A conglomerate succession cropping out in the quarry walls in Czerwona Góra (5 – 10 m in height, about 100 m in length) represents after Kuleta the Czerwona Góra Member (Kuleta & Nawrocki, 2002; Kuleta & Zbroja, 2006). It is an informal lithostratigraphic unit of the Lower Buntsandstein distinguished within the Zagnańsk Formation in the NE part of the Holy Cross Mountains (Fig. 9.). The succession was earlier described as Czerwona Góra beds and *transitional beds* (Senkowiczowa, 1970; Barczuk, 1979). The discussed conglomerates were located in the Middle Buntsandstein by Fuglewicz et al. (1981), Mader (1985) and recently by Ptaszyński and Niedźwiedzki (2006). This lithostratigraphic position can not be confirmed

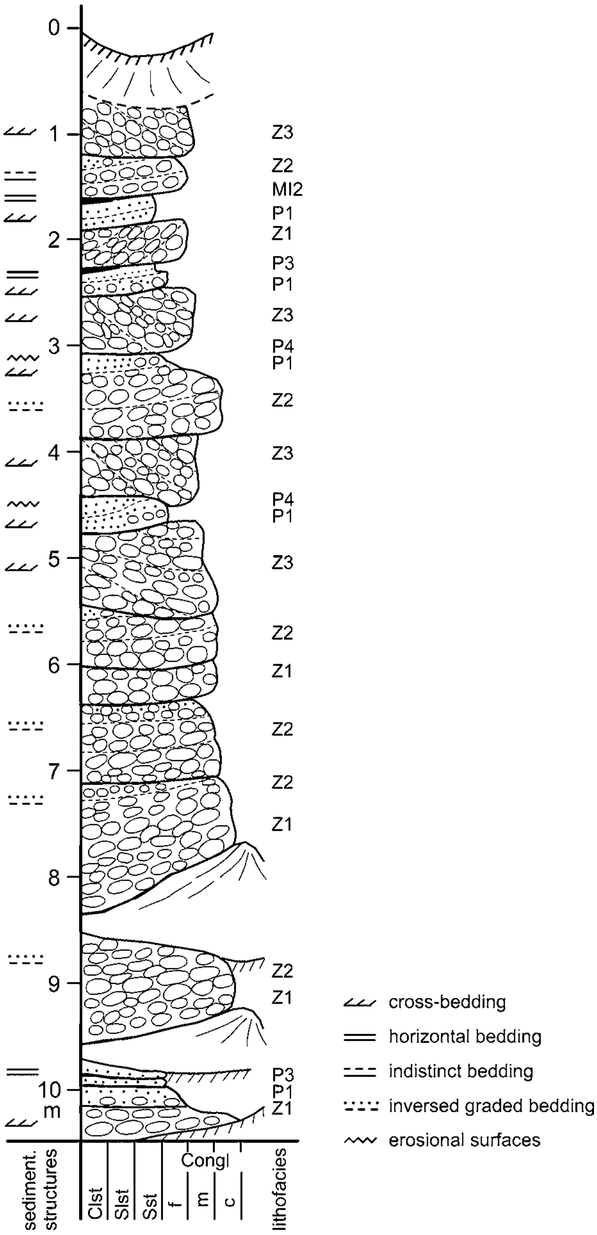


Fig. V.1.1. Lithofacies section of Czerwona Góra quarry

by a regional lithofacies analysis. Characteristic low consistency and bleaching (from reddish-brown to grayish-yellow) of the outcropping conglomerates (Fig. V.1.1) were caused by specific local weathering processes (the sediments in another part of the river-valley are well cemented). The rocks disintegrate very easily. They are exploited for road building from time to time.

The conglomerates form weakly distinguished banks 0,4 – 1,5 m in thickness, deepening 10 – 15o to north-east. Thin lenses (0,3 – 0,4 m in thickness) of fine-grained sandstones passing laterally in siltstones and claystones occur in the lowermost and upper parts of the quarry wall. The inner structures of the beds are weakly developed. Faint lamination is caused by grain size changes. Imbrications of pebbles and massive structures of beds are observed. Seven facies types according to Miall (1996) were distinguished within the outcropping rocks on the base of sedimentological investigation (Fig. V.1.1):

1. Gm – Clast-supported massive conglomerates
2. Gh – Horizontal bedded conglomerates
3. Gt – Trough cross-bedded conglomerates
4. Gp – Planar cross-bedded conglomerates
5. Sp – Planar cross-bedded sandstones
6. Sh – Horizontal laminated sandstones
7. Fl – Horizontal and ripple laminated siltstones and claystones

Conglomerate beds display mostly uniform sedimentary features. The section can be subdivided in two parts in terms of facies type composition and pebble size. Medium-grained, weakly sorted, massive conglomerates of facies type Gm occur in the lower part of the section. They form thick beds divided in the lowermost part by an intercalation of fine-grained sandstone of facies type Sh. Indistinct increase of pebble size can be observed toward the top of this part of the section (dmf from 6,5 cm up to 8,0 cm, dmax from 12,0 cm up to 20,0 cm). Medium-grained and fine-grained conglomerates divided by sandstone lenses occur in the upper, dominating part of the section. The conglomerate beds are partially horizontally laminated; pebble imbrication can occur. Flat planar cross-bedding can also occur (facies type Gp). Fine-grained conglomerates are partially trough cross-bedded. Decrease of pebble size and of pebble sorting can be observed toward the top of this part of the section (dmf from 3,3 – 4,0 cm to 1,2 cm, dmax from 8,0 – 11,0 cm to 4,5 cm).

Petrographic composition of the conglomerates is constant through the entire section. Pebbles are mostly composed of very fine- and fine-grained quartzitic sandstones (85 – 90%) and of vein quartz (10 – 15%, vein quartz participation increases within small-size pebbles). Additionally 1,2% of pebbles are composed of lidites, jaspers and non quartzitic sandstones. Pore cement and contact cement of matrix type are a mixture of clay minerals, iron oxides and very fine- to fine-psammitic quartz.

Lithofacies features and facies succession of the deposits cropping out in Czerwona Góra are typical for gravel-bed braided rivers of variable energy balance (Allen, 1964; Cant, 1982; Miall, 1996). Conglomerates represent channel deposits: channel lag and transversal and longitudinal bars. Sandstones, siltstones and claystones built abandoned channels fill. Transport direction towards north-west was determined on the base of dip direction of cross-bedding.

Conglomerates of Czerwona Góra Member, passing to the top and partially to the base in sandstones, lie on carbonate conglomerates of PZt (top terrigenous series) of Zechstein. A stratigraphic gap divides the both units. The gap encompasses erosionally various parts of the Zechstein succession. Therefore carbonate pebbles are present in so called *transitional beds* between Zechstein and Buntsandstein. The gap developed in the same time, as Opoczno, Siodła and Jaworzna formations were deposited in the north-western part of the Holy Cross Mountains (Fig. 9.; Kuleta & Zbroja, 2007, in prep.).

Paleontology

To date, no fossils have been found there, except of rare fragments of vertebrate bones present in other outcrops. In the adjacent area, within the conglomerate complex near Stryczowice, in thin layered sandstones with mudstone intercalations, few specimens of *Magniestheria rybinskensis* (Novozhilov) (Ptaszyński & Niedźwiedzki, 2006) and poorly preserved, not determined vertebrate footprints have been found.

Paleomagnetism and magnetostratigraphy

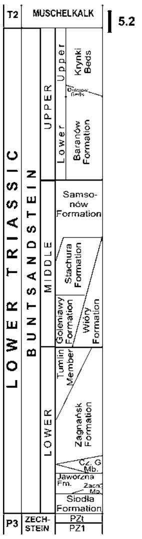
Five hand samples were taken from the section of about 5 m thick, compiled in the abundant quarry and the neighboring road cut. All samples studied were of reversed polarity only (Nawrocki *et al.*, 2003). The mean characteristic direction ($D=211^{\circ}$, $I= -31^{\circ}$, $\alpha 95 = 9.4^{\circ}$) matches well the expected Early

Triassic paleomagnetic direction. The reversed polarity of the Czerwona Góra section is in agreement with presumed age of these rocks. They are assigned to the lowermost part of the Middle Buntsandstein (Kuleta & Nawrocki, 2000) where reversed polarity predominate (Nawrocki, 1997).

STOP. V.2. Witulin – small abandoned quarry

Wiesław Trela, Jarosław Zacharski, Tadeusz Ptaszyński, Grzegorz Niedźwiecki & Joachim Szulc

Topics:
1. Röt sedimentary environments and fauna
2. Muschelkalk onlap and ingression-regression events in marginal zone of the basin.



Witulin quarry is located some 20 km SE from Starachowice.

The Triassic succession in the ouctrop is represented by sandstones of the uppermost Röt referring to as the Krynki Beds (Senkowiczowa, 1970), which pass upwards into limestones of the Lower to Upper Muschelkalk.

The Krynki Beds are composed of thick-bedded sandstones with subordinate contribution of sandy mudstones (Fig. V.2.1a). The sandstones are medium to coarse-grained, and reveal large scale planar cross-bedding and small-ripple bedding. They are overlain by the sandy mudstones alternating with thin to medium-bedded sandstones showing small-scale cross-bedding and current ripples on the top of beds (Fig. V.2.1). In places, the mudstones are truncated by channels (up to 2.2 m wide and 40 cm deep) filled by sandstones with coarse quartz pebbles and lithoclasts at the bed base.

The topmost, 1.4 m-thick sandstone layer of the Krynki Beds in Witulin rests on conspicuous erosional surface featuring the underlying mudstone/sandstone interval (Fig. V.2.1a).

The Krynki Beds are thought to represent regressive deposits, accumulated by river-dominated deltaic system entering the shore-zone where the siliciclastic material was delivered from the NE (Senkowiczowa & Ślączka, 1962; Senkowiczowa, 1970; Trela, 1998). The sandstones of the Krynki Beds at the northern and westernmost margins of the Holy Cross Mountains are intercalated by the marly sandstones and sandy dolostones with Costatoria costata (Zenker) (Senkowiczowa, 1970) indicating some marine incursions during deposition of these sediments.

The Lower Muschelkalk reaches ca. 8 meters in thickness and begins with ca. 50 cm-thick bed of sandstones cemented by dolomite and comprising rare trochites and echinoid spines (Zacharski, 1995) (Fig. V.2.1b). The overlying bioclastic sediments with brachiopods, pelecypods, crinoids and forams are also dolomitised and include some postevaporitic vugs (Zacharski, 1995; Bodzioch 2003). It is worthy to note that in these carbonates some condonts have been also found (Ptaszyński, 1981).

The dolomites grade first into limestones with similar fauna composition and then into nodular fine-grained limestones. The uppermost 2 meters of the Lower Muschelkalk are built by oolitic and oncolithic sediments, encompassing crinoid and brachiopod fauna.

The Lower Muschelkalk succession comprises several horizons of mudstones, which mark the shallowing and/or emersion events. During these events, the underlying primary bioclastic limestones underwent dolomitisiation and meteoric diagenesis.

The Middle Muschelkalk is ca. 4 m thick and commences with reworked stromatolites and paleosoil horizons. The overlying marly and thin-laminated dolomites (now de-dolomitised) are devoid of fauna and comprise sulphate pseudomorphs.

The Upper Muschelkalk in the section is represented by ca 1m-thick, dolomitised nodular limestones rich in pelecypods (*Leptochondria alberti*).

According to faunal composition and magnetostratigraphical study (Zacharski, 1995; Nawrocki & Szulc, 2000) the Muschelkalk transgression reached the NE margin of the Holy Cross Mts. as late as in late Bithynian -Pelsonian time i.e. during the 3rd Anisian transgression (Fig. 29)(Szulc, 2000). This illustrates well the facies diachroneity in the marginal zone of the Muschelkalk Basin and substantial stratigraphic gap encompassing almost the entire lowermost Anisian. The sea margin setting resulted in frequent shallowing (up to emersion) –deepening events recorded in the site. This explains well the apparent contradictions between the fauna composition and some lithofacies indicators (for instance occurrence of crinoids and conodonts within evaporitic rocks).

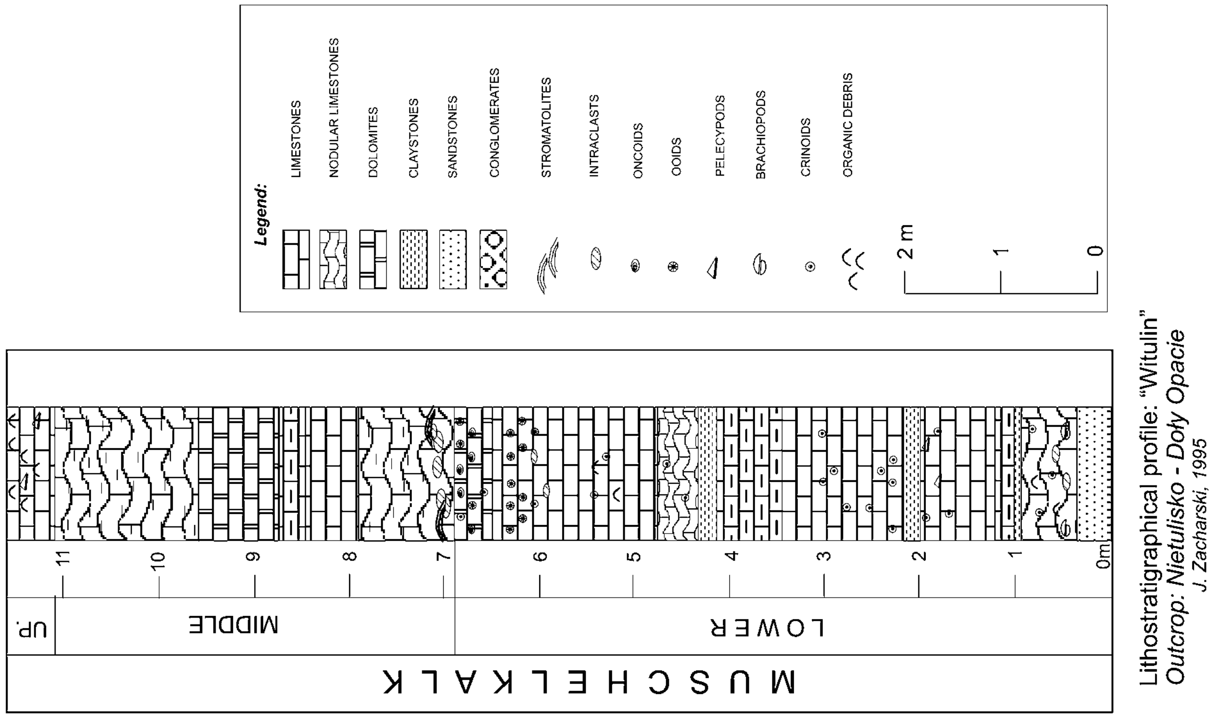
Fauna of the Krynki Beds

The "Krynki Beds" at Witulin site contain an interesting association of invertebrate ichnofossils and vertebrate footprints, found also in other outcrops in the north-eastern and central margin of the Holy Cross Mountains (Niedźwiedzki et al., 2007, in print). At Witulin, body fossils are represented by bivalves Costatoria costata (Zenker) occurring massively in some bedding planes (Fig. VI F), together with rare gastropods. Invertebrate trace fossils are represented by Planolites-like, Palaeophycus and cf. Gordia (Niedźwiedzki et al., 2007, in print). Numerous specimens of vertebrate tracks discovered there, representing the following ichnotaxa: Chirotherium barthii Kaup, 1835; Chirotherium cf. sickleri Kaup 1835; Synaptichnium cf. diabloense (Peabody 1948); Isochirotherium herculis (Egerton 1839); *Isochirotherium* cf. *herculis*; *Isochirotherium* isp.; *Rhynchosauroides* isp. and many other specimens often hard to determine precisely, belonging mostly to Rhynchosauroidae and Chirotheriidae ichnofamilies (Niedźwiedzki *et al.*, 2007, in print). No microflora was found there to date.

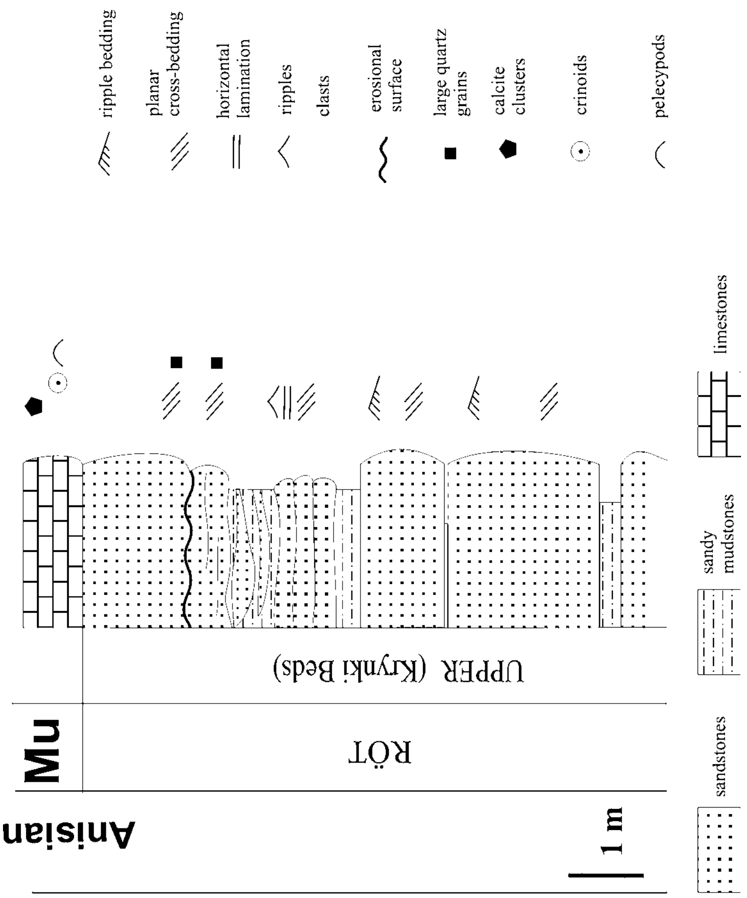
STOP. V.3. Wióry – road cut

Anna Becker, Tadeusz Ptaszyński, Grzegorz Niedźwiecki & Jerzy Nawrocki

Topics:
1. Middle Buntsandstein fluvial sandstones and claystones
2. Fluvial sedimentary cycles
3. Braided vs. meandering river style
4. γ-ray fluvial pattern
5. Ichnological context

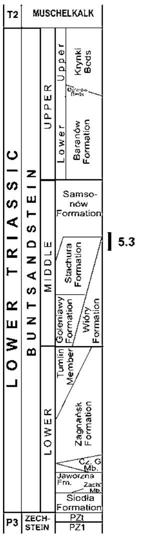


b



a

Fig. V.2.1a, b. Stratigraphy and lithology of the upper Röt (a) and Muschelkalk (b) in Witulin (NE margin of the Holy Cross Mts.).



The road cut "Wióry" is located on the left side of Świślina river, at the Świślina water dam, 15 km west of Ostrowiec Świętokrzyski.

In Wióry locality the lower 20 m of the outcropping section represent red sandstones and reddish-brown siltstones of the Wióry Formation (Middle Buntsandstein). The upper 10 m represent reddish-brown claystones of the Samsonów Formation (Middle Buntsandstein). The section is disrupted by a fault causing tectonic repetition of the lower part of the profile (Fig. V.3.1).

Sandstone facies dominates in the lower part of the section. It is built of fine to medium grained sandstones, partly coarse grained to conglomeratic. Facies types Sm, St and Sr (Miall, 1996) can be subdivided. In the lowermost part of the outcrop an intercalation of gravel facies type Gm can be observed. Fine clastic facies, built of claystones and siltstones is represented by facies types Fl, Fm and Fsm (Miall, 1996).

The sedimentary environment was interpreted as a moderately to weakly braided river system by Mader and Rdzanek (1985) but it will be discussed later.

Channel deposits (M) are represented by medium to coarse grained sandstones and fine grained sandstones mostly of the facies type St and by gravels of facies type Gm. Sandstones built multistory bodies of more than 1 m in thickness. Gravels form continuous sheets or limited lenses in the lowermost parts of the bodies where also clayey intraclasts are present. Lower boundaries of the bodies are erosive.

Sandstone facies built also the crevasse-splay deposits (P and D). Sandstones are fine to medium-grained and represent facies types St and Sr. Sandstones build continuous beds or isolated lenses seldom reaching 1 m in thickness. The bodies are mostly uniphase with even to gently erosional lower boundary. In terms of thickness and grain size two groups of crevasse-splay sandstones representing proximal (P) and distal (D) facies can be distinguished (Mader & Rdzanek, 1985).

Fine-grained sediments were deposited on a floodplain (F, L). Bioturbation occurs seldom in form of vertical burrows, whereas paleosoils are absent (Mader & Rdzanek, 1985).

Well developed fluvial sedimentary cycles are present in the section (Fig. V.3.1). They are fining upward successions of 1 to 5 m in thickness. Channel deposits are overlain by floodplain sediments with crevasse-splay intercalations.

The sediments cropping out in Wióry locality display features of braided river system and of meandering river system as well. Initially developed paleosoils, small thickness of fluvial sedimentary cycles in which channel deposits are dominating characteristic of braided systems (Miall, 1977; 1996). Relatively well developed floodplain, numerous crevasse-splays, absence of planar cross bedded sandstones are features of meandering system (Miall, 1977). The sedimentary environment was also transitional one between both classical river types.

<u>Paleontology</u>

The Wióry Formation contains vertebrate and invertebrate body fossils (vertebrate bones, fish scales, conchostracan carapaces), plant remains and especially interesting, vertebrate and invertebrate ichnofossils. To date, vertebrate bones (which mostly belong to Temnospondyli) and plant macrofossils were not subject to comprehensive palaeontological description. No plant microfossils have been found there. Among invertebrate body fossils, all represent Conchostracan carapaces:

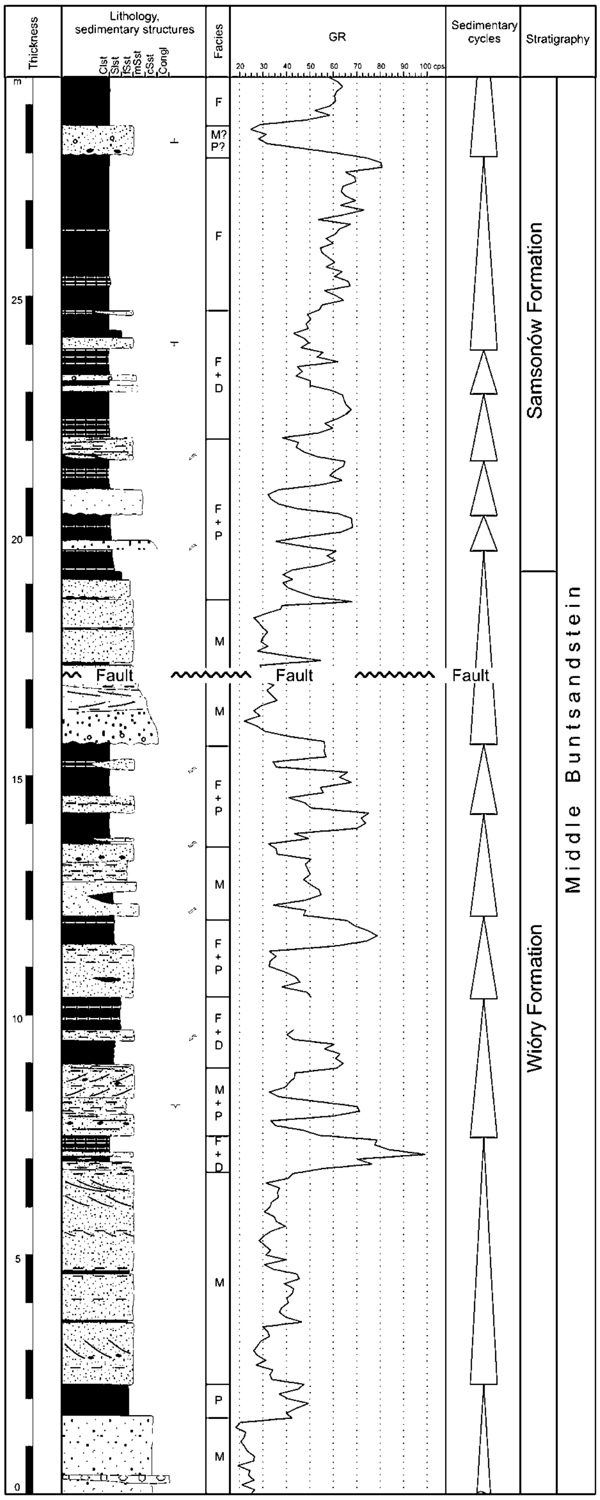
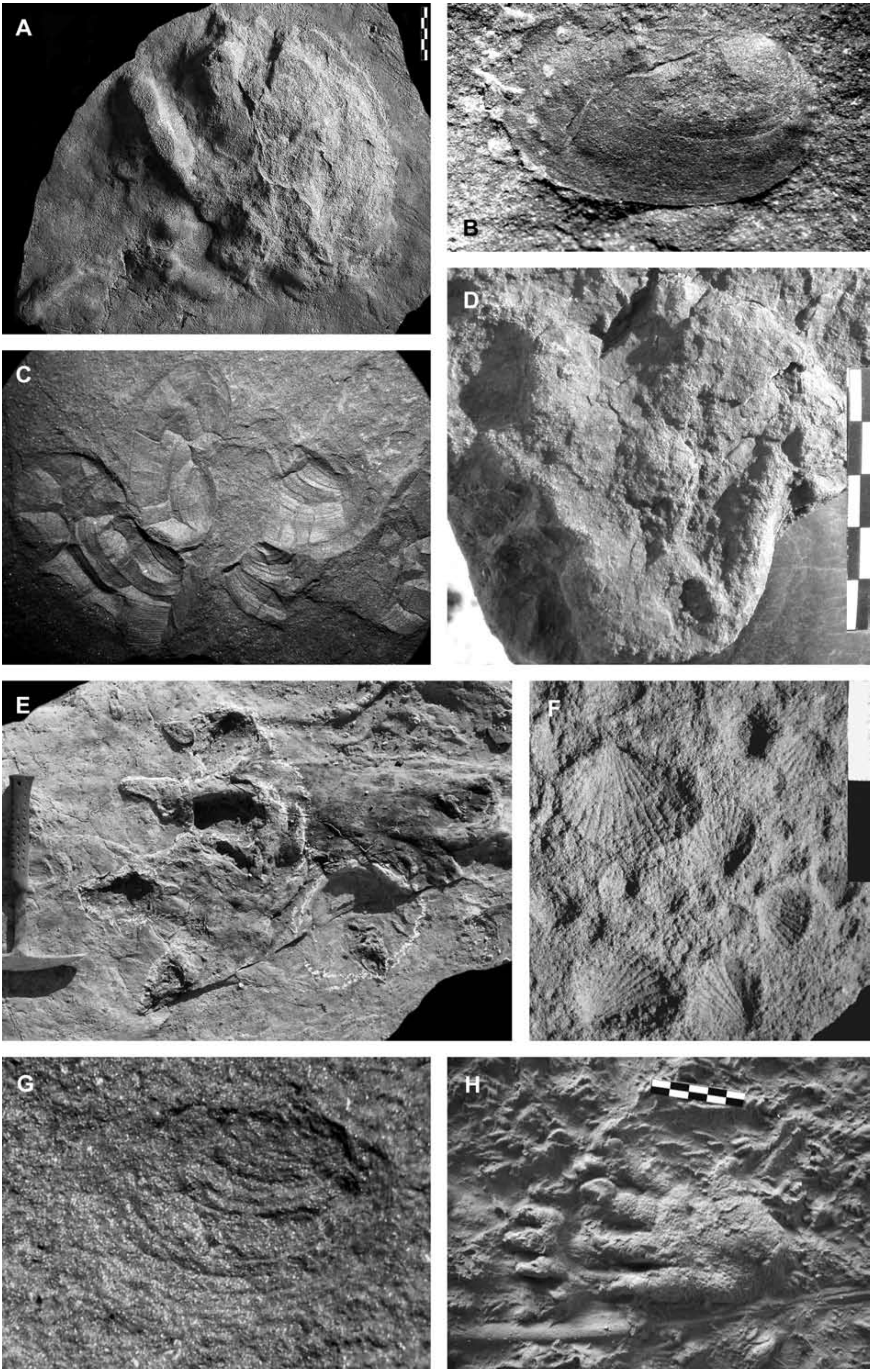


Fig. V.3.1. Lithofacies section of Wióry - road cut, with outcrop γ-ray log and cyclicity interpretation

Magniestheria deverta (Novozhilov 1946) (Fig. VI G), occurring numerously on some mudstone bedding surfaces, and occasionally *Palaeolimnadia alsatica detfurthensis* Kozur et Seidel 1983 and ?*Euestheria exsecta* (Novozhilov 1946) also found there (Ptaszyński & Niedźwiedzki, 2006).

Palaeontological findings, among others invertebrate ichnofossils, were subject to a doctorate theses by Kazimierz Rdzanek (1999), presented to the Jagiellonian University in Cracow. Unfortunately, those results were not published to date.

The number of vertebrate ichnotaxa described from the Wióry site (Fuglewicz *et al.*, 1990; Ptaszyński, 2000a;


A
B
C
D
E
F
G
H

Ptaszyński & Niedźwiedzki, 2004d) reached 13 and is still not complete. To date, the following ichnospecies have been distinguished: *Brachychirotherium hauboldi* (Ptaszyński 1990) (Fig. VI H); *Brachychirotherium wiorense* Ptaszyński 2000; *Capitosauroides fuglewiczi* Ptaszyński 2000 (not *Capitosauroides* sensu Haubold 1971, possibly new ichnogenus); *Isochirotherium gierlinskii* Ptaszyński 2000; *Isochirotherium sanctacrucense* Ptaszyński 1990; *Procolophonichnium polonicum* (Ptaszyński 1990); *Prorotodactylus mirus* Ptaszyński 2000; *Rhynchosauroides brevidigitatus* Ptaszyński 1990; *R. rdzaneki* Ptaszyński 2000; *Synaptichnium kotanskii* Ptaszyński 2000; *S. chirotherioides* Ptaszyński 1990. Trackmakers of *Prorotodactylus* were interpreted by Ptaszyński (2000a) as Archosaurs very close to dinosaur ancestors. The list of vertebrate ichnofauna known from Wióry is now supplemented by palaeoichnological description (Niedźwiedzki & Ptaszyński, 2007, in print) of two new, very large Chirotheriidae representatives: *Synaptichnium senkowiczowae* and *Brachychirotherium kalkowensis*. In opinion of T. Ptaszyński (unpublished, 2007) the trackmaker of the latter could represent a large Therapsid. The Wióry assemblage also contains rare, not described to date, other footprints related to Therapsida. Vertebrate footprint assemblages similar to that from Wióry are also known from Detfurth and Hardegsen Formations of Germany (Fichter & Lepper, 1997; Fichter *et al*., 1999; Fichter & Kunz, 2004).

<u>Paleomagnetism and magnetostratigraphy</u>

A total of 22 samples for paleomagnetic studies were collected from the Buntsandstein sediments c.a. 30 m thick. Almost all samples contained reverse polarity record. A thin normal polarity zone was detected in the bottom part (28 m of depth) of the section. It is correlated (Nawrocki et al., 2003) with the oldest normal polarity zone of the Middle Buntsandstein. This zone was defined in the middle part of the Pomorze Formation (Nawrocki, 1997). The mean paleomagnetic direction calculated for the Wióry section (D = 208°, I = -30°, α95 = 9.4°) is in agreement with the expected early Triassic direction.

<u>Natural γ-ray measurements</u>

Natural γ-ray measurements were carried out in the Wióry locality in order to compare that sequence with the classic German area and to recognize sediment cyclicity of different scales (Roman & Rdzanek, 2001; Becker, 2005). Abrupt transition from channel sandstones with low radiation (20-30 counts per second; cylinder-shape type of log) to floodplain fines with high radiation (70-100 cps) are characteristic for the Wióry Fm (Fig. V.3.1). A gradual transition from relatively low (30-40 cps) to higher values (60-80 cps) of γ-ray activity is typical of overlaying Samsonow Fm and reflects the transition from residual crevasse-splay to distal floodplain deposits (Fig. V.3.1). A clear subdivision in a lower part of low radiation and an upper part of higher radiation is typical for the recognised small-scale fluvial sedimentary cycles (Fig. V.3.1; see Galloway & Hobday, 1983).

STOP. V.4. Museum of Nature and Technology at Starachowice

Tadeusz Ptaszyński & Grzegorz Niedźwiecki

Topics:
1. Ichnofauna assemblage from Wióry Fm
2. Other Buntsandstein fossils

The large outcrop in Wióry had originated in 1980 when the construction of the river dam started (Fuglewicz *et al*., 1981, 1990; Ptaszyński, 2000). In the 80s and 90s the main wall of the quarry attained the length of about 250 m. Up to 50 m thick complex of fluvial sandstones, conglomerates, mudstones and siltstones (Fuglewicz *et al*., 1980, 1990; Ptaszyński, 2000) was easily accessible for a long time. First vertebrate footprints were found there in autumn of 1980 by Tadeusz Ptaszyński. During the next quarter of century, vertebrate footprints, and also other fossils were collected mainly by Kazimierz Rdzanek, but also by Ryszard Fuglewicz, Tadeusz Ptaszyński and later by Grzegorz Niedźwiedzki. Kazimierz Rdzanek collected about 300 tons of sandstone slabs containing vertebrate and invertebrate ichnofossils, plants and vertebrate bones. It is the largest collection of vertebrate tracks from a single outcrop gathered in one place in Europe, perhaps even in the world. In years 2000 – 2001, the collection housed previously on the river dam building area, finally found its place in the Museum of Nature and Technology in Starachowice. In the following years, the collection was mainly ordered by Grzegorz Niedźwiedzki and completed with other findings from the Holy Cross Mountains. Palaeoichnological material deposited there came also from Tumlin Gród, Sosnowica, Zachełmie, Baranów and Kopulak.

Fig. VI. Fossils of the Buntsandstein of the Holy Cross Mts. A – *Merifontichnus* isp. Pedal imprint; B – *Falsisca postera* Kozur et Seidel 1983, Zachełmie. Length of the carapace: 6 mm; C – *Falsisca verchojanica* (Molin 1965), Zachełmie. Length of the carapace of the largest specimen: 8 mm; D – *Limnopus* isp., manual imprint with four digits; E – One of largest, not determined footprints found at Baranów; F – *Costatoria costata* (Zenker), Witulin, “Krynki Beds”; G – *Magniestheria deverta* Novožilov 1946, Wióry. Length of the carapace 4 mm; H – *Brachychirotherium hauboldi* (Ptaszyński 1990), Wióry, set of left imprints with accompanying tail mark and Rhynchosauroidae footprints around (small)

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