Faculty of Earth Sciences University of Silesia
Zoological Institute University of Wrocław

Karst of the Częstochowa Upland and of the Eastern Sudetes

palaeoenvironments and protection

Edited by
Krzysztof Stefaniak, Andrzej Tyc, Paweł Socha

Sosnowiec – Wrocław 2009

Studies of the Faculty of Earth Sciences
University of Silesia
No. 56

Editors of this issue
Krzysztof Stefaniak, Andrzej Tyc, Paweł Socha
Linguistic Editor
Beata M. Pokryszko

Cover design
Mariusz Jeziorko
Cover photos
Krzysztof Blejczak, Tomasz Karpiński, Paweł Socha
Cover drawings
Jakub Zbyszyński, Magdalena Sudoł

Colour maps in the text
Bartłomiej Szypuła & Andrzej Tyc

Computer typesetting
Mariusz Jeziorko & Andrzej Tyc
Proofreading
Wioletta Tomala-Kania

Publication financed by the Faculty of Earth Sciences, University of Silesia, Faculty of Biological Sciences, Faculty of Earth Sciences and Environmental Management and the Zoological Institute, University of Wrocław (grant no. 2987/W/IZ/08, 1018/S/IZ/09)

with financial support

of the Centre of Nature Heritage of Upper Silesia (Katowice), the District Council of Ogrodzieniec and of the Lower Silesian Foundation of Sustainable Development "Eko-Raj" (Wrocław)

Published in the year of 35th anniversary of foundation
of the Faculty of Earth Sciences, University of Silesia

ISBN 978-83-61644-01-9
ISSN 1895-6777

Printed by
Przedsiębiorstwo Wydawniczo-Reklamowe Top-Art.
ul. Konstytucji 3 Maja 17a, 42-450 Łazy www.drukarnia-topart.pl

Contents

Karst and palaeoenvironments of the Eastern Sudetes

Contributors

Jerzy Bieroński
Institute of Geography and Regional Development, Faculty of Earth Science and Environmental Management, University of Wrocław, Pl. Uniwersytecki 1, 50-137 Wrocław, Poland,
bieronski@geogr.uni.wroc.pl

Sebastian Buczyński
Institute of Geological Sciences, Faculty of Earth Science and Environmental Management, University of Wrocław, Pl. Maksa Borna 9, 50-204 Wrocław, Poland, *sebastian.buczynski@ing.uni.wroc.pl*

Jan Michał Burdukiewicz
Institute of Archaeology, Faculty of Historical and Pedagogical Sciences, University of Wrocław, ul. Szewska 48, 50-139 Wrocław, Poland, *jan.burdukiewicz@archeo.uni.wroc.pl*

Wojciech Ciężkowski
Institute of Mining, Faculty of Geoengineering, Mining and Geology, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland, *wojciech.ciezkowski@pwr.wroc.pl*

Krzysztof Cyrek
Institute of Archaeology, University of Mikołaj Kopernik in Toruń, Szosa Bydgoska 44/48, 87-100 Toruń, Poland, *paleo@umk.pl*

Michał Gąsiorowski
Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, 00-818 Warszawa, Poland, *mgasior@twarda.pan.pl*

Helena Hercman
Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, 00-818 Warszawa, Poland, *hhercman@twarda.pan.pl*

Marcin Krajewski
Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, al. Mickiewicza 30, 30-059 Kraków, Poland, *kramar@geol.agh.edu.pl*

Józef Lewandowski
Department of Fundamental Geology, Faculty of Earth Sciences, University of Silesia, ul. Będzińska 60, 41-200 Sosnowiec, Poland, *jozef.lewandowski@us.edu.pl*

Teresa Madeyska
Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, 00-818 Warszawa, Poland, *tmadeysk@twarda.pan.pl*

Adrian Marciszak
Department of Palaeozoology, Zoological Institute, University of Wrocław, ul. Sienkiewicza 21, 50-335 Wrocław, Poland, *marcisz@biol.uni.wroc.pl*

Henryk Marszałek
Institute of Geological Sciences, Faculty of Earth Science and Environmental Management, University of Wrocław, Pl. Maksa Borna 9, 50-204 Wrocław, Poland, *henryk.marszalek@ing.uni.wroc.pl*

Jacek Matyszkiewicz
Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, al. Mickiewicza 30, 30-059 Kraków, Poland, *jamat@geol.agh.edu.pl*

Piotr Migoń
Institute of Geography and Regional Development, Faculty of Earth Science and Environmental Management, University of Wrocław, Pl. Uniwersytecki 1, 50-137 Wrocław, *migon@geogr.uni.wroc.pl*

Joanna Mirosław-Grabowska
Institute of Geological Sciences, Polish Academy of Sciences, ul. Twarda 51/55, 00-818 Warszawa, *jmirosla@twarda.pan.pl*

Błażej Muzolf
Archaeological and Ethnographic Museum in Łódź, Pl. Wolności 14, 91-415 Łódź, Poland,
blazejmuzolf@maie.art.pl

Adam Nadachowski
Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, ul. Sławkowska 17,
31-016 Kraków, Poland, *nadachowski@isez.pan.krakow.pl*
Department of Palaeozoology, Zoological Institute, University of Wrocław, ul. Sienkiewicza 21,
50-335 Wrocław, Poland, *nadachowski@biol.uni.wroc.pl*

Jacek Piasecki
Department of Climatology and Atmosphere Protection, Institute of Geography and Regional Development, Faculty of Earth Science and Environmental Management, University of Wrocław,
pl. Uniwersytecki 1, 50-137 Wrocław, Poland, *piasecki@meteo.uni.wroc.pl*

Jacek Różkowski
Department of Geomorphology, Faculty of Earth Sciences, University of Silesia, ul. Będzińska 60,
41-200 Sosnowiec, Poland, *jacek.rozkowski@us.edu.pl*

Bartłomiej Rzonca
Department of Hydrology, Institute of Geography and Spatial Management, Jagiellonian University,
30-387 Kraków, ul. Gronostajowa 7, Poland, *b.rzonca@geo.uj.edu.pl*

Tymoteusz Sawiński
Department of Climatology and Atmosphere Protection, Institute of Geography and Spatial Development, Faculty of Earth Science and Environmental Management, University of Wrocław, Pl. Uniwersytecki 1, 50-137 Wrocław, Poland, *t_sawinski@meteo.uni.wroc.pl*

Paweł Socha
Department of Palaeozoology, Zoological Institute, University of Wrocław, ul. Sienkiewicza 21,
50-335 Wrocław, Poland, *sochap@biol.uni.wroc.pl*

Stanisław Staśko
Institute of Geological Sciences, Faculty of Earth Science and Environmental Management, University of Wrocław, Pl. Maksa Borna 9, 50-204 Wrocław, Poland, *stanislaw.stasko@ing.uni.wroc.pl*

Krzysztof Stefaniak
Department of Palaeozoology, Zoological Institute, University of Wrocław, ul. Sienkiewicza 21,
50-335 Wrocław, Poland, *stefanik@biol.uni.wroc.pl*

Adam Szynkiewicz
Institute of Geological Sciences, Faculty of Earth Science and Environmental Management, University of Wrocław, ul. W. Cybulskiego 32, 50-205 Wrocław, Poland, *aszyn@ing.uni.wroc.pl*

Teresa Tomek
Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, ul. Sławkowska 17,
31-016 Kraków, Poland, *tomek@isez.pan.krakow.pl*

Andrzej Tyc
Department of Geomorphology, Faculty of Earth Sciences, University of Silesia, ul. Będzińska 60,
41-200 Sosnowiec, Poland, *andrzej.tyc@us.edu.pl*

Mirosław Wąsik
Institute of Geological Sciences, Faculty of Earth Science and Environmental Management, University of Wrocław, Pl. Maksa Borna 9, 50-204 Wrocław, Poland, *miroslaw.wasik@ing.uni.wroc.pl*

Krzysztof Wertz
Institute of Systematics and Evolution of Animals, Polish Academy of Sciences, ul. Sławkowska 17,
31-016 Kraków, Poland, *wertz@isez.pan.krakow.pl*

Stefaniak K., Tyc A., Socha P. (Eds) 2009. Karst of the Częstochowa Upland and of the Eastern Sudetes: palaeoenvironments and protection. Studies of the Faculty of Earth Sciences, University of Silesia, No. 56, Sosnowiec - Wrocław, 536 pp.

Upper Jurassic deposits in the Częstochowa Upland

Marcin Krajewski, Jacek Matyszkiewicz

Introduction

The Częstochowa Upland, a part of the Kraków-Częstochowa Upland, also called the Polish Jura, has a very varied landscape resulting from the presence of Jurassic rocks forming picturesque rocky hills. The present character of the Upland is a result of different geological factors including its Palaeozoic substratum, Jurassic basin development history, diagenetic, tectonics and erosion processes. Evidence of these processes, often superimposed on each other, can be observed today in various regions of the Kraków-Częstochowa Upland. The Upland's complex geological structure makes it necessary for studies conducted in the area to consider evidence gathered from very different geological disciplines. This article presents selected basic information on the origin and development of the Jurassic rocks, a characteristic feature of the Częstochowa Upland.

Geological background

The Częstochowa Upland is a part of the Silesian-Kraków Monocline built mainly by Triassic, Jurassic and fragmentarily preserved Cretaceous sediments (Fig. 1) which cover the Palaeozoic European platform. The bedrock consists of locally preserved Permian formations which, with Mesosoic deposits, form part of the so-called Permian-Mesosoic structural complex (cf. Dżułyński 1953; Krokowski 1984; Żaba 1999). The Silesian-Kraków Monocline dips at a small angle to the NE, below the Cretaceous formations of the Nida Basin. Monocline formations discordantly overlay the varied Palaeozoic or Precambrian bedrock. This bedrock is dissected by an extensive Kraków-Lubliniec Fault Zone resulting in two tectonic blocks; Upper Silesian and Małopolska. Along the fault zone, an array of smaller or bigger intrusions, particularly granitoid plutons and volcanic deposits of Permian age, exists (Fig. 2; Żaba 1999; Buła *et al.* 2002; Jędrys *et al.* 2004).

Supported by UST-AGH statutory grant 11.11.140.560

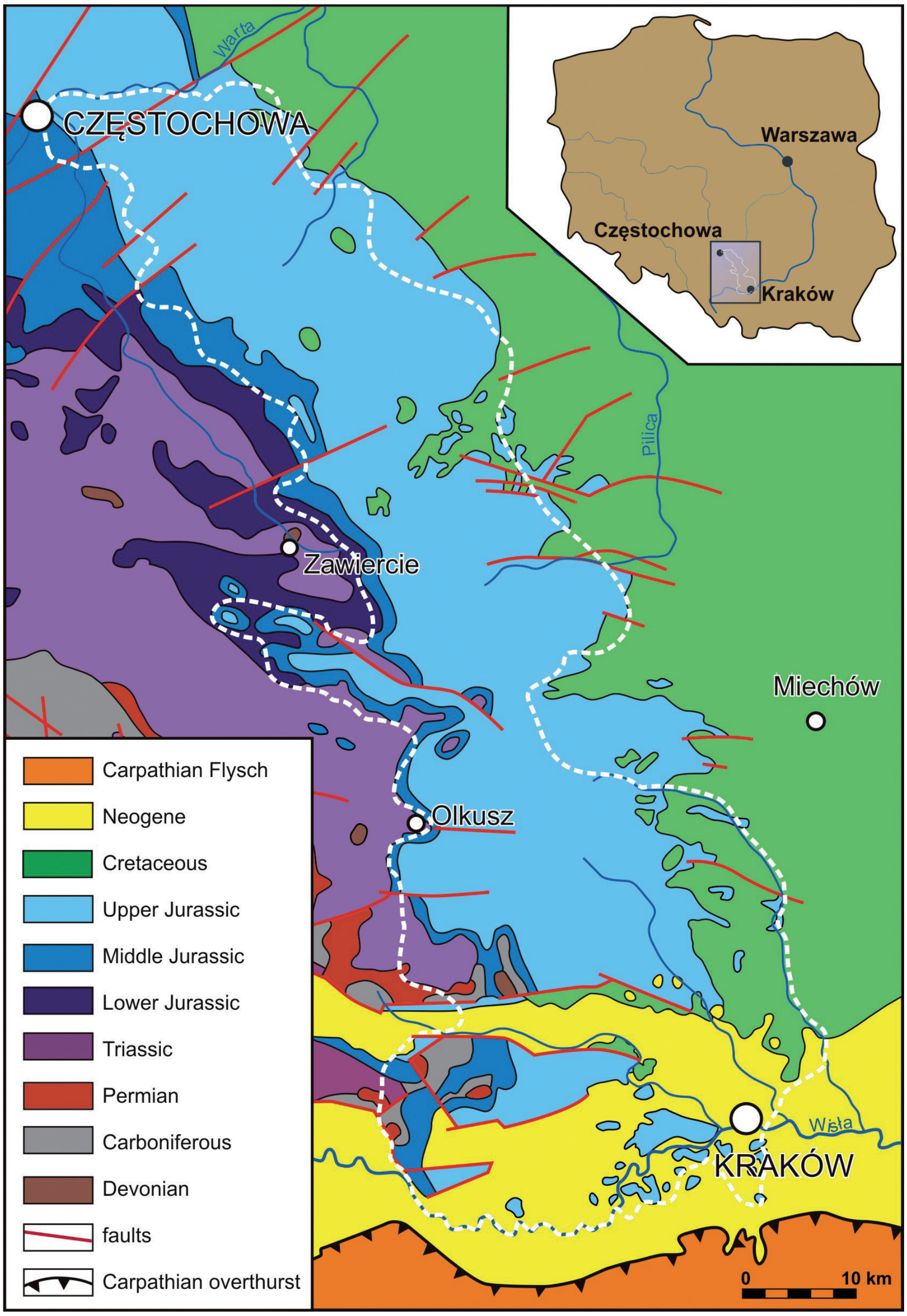

Fig. 1. Simplified geological map of the Kraków-Częstochowa Upland excluding Quaternary (after Rühle *et al.* 1977)

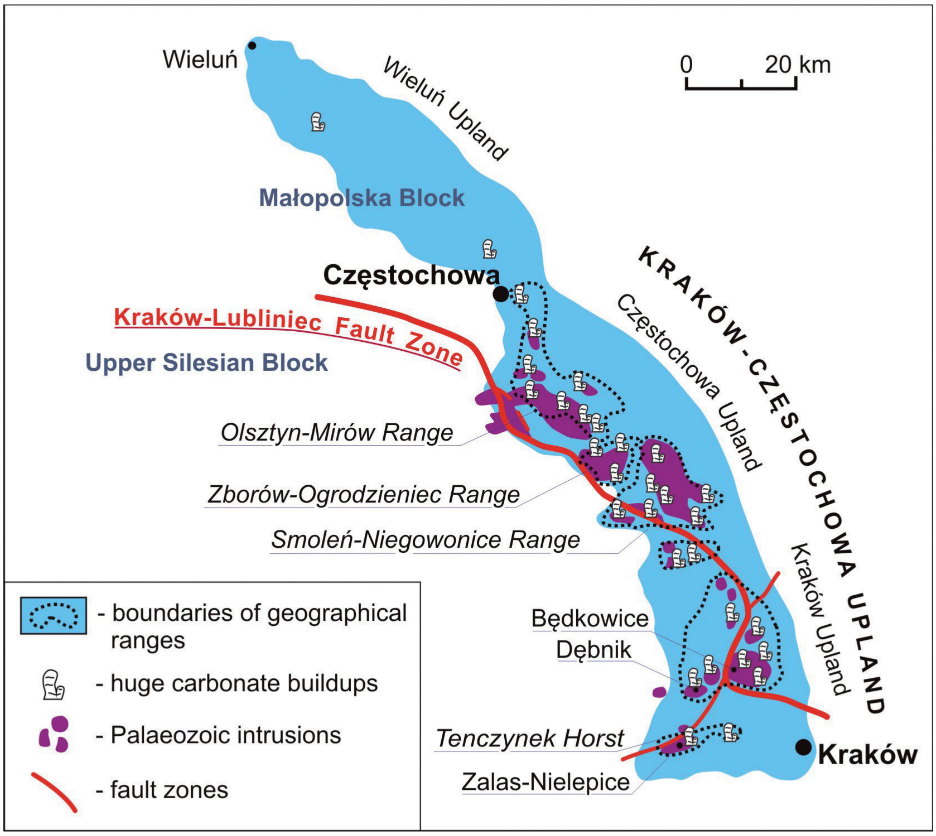

Fig. 2. Location of the main Upper Jurassic carbonate buildup complexes versus Palaeozoic intrusions in the Kraków-Częstochowa Upland (after Jędrys *et al.* 2004)

Lithology of Upper Jurassic deposits of the Częstochowa Upland

The geological structure of the Kraków–Częstochowa Upland is dominated by Upper Jurassic deposits of varied thickness reaching a few hundred metres, most often overlaying concordantly the Middle Jurassic deposits, rarely directly overlaying the Palaeozoic bedrock (Fig. 3). Upper Jurassic deposits of the Częstochowa Upland represent the Oxfordian and Kimmeridgian. This sequence of Upper Jurassic deposits starts with marls and marly limestones reaching approximately a thickness of dozen metres, in the referred to literature as the Jasna Góra Beds (Bednarek *et al.* 1978; Trammer 1985). They represent condensed strata of the Lower / lower part of the Middle Oxfordian, containing numerous calcified siliceous sponges and ammonites (Różycki 1953). Upwards these deposits pass into a thick complex of limestones formed as three main facial varieties: thin-bedded yellowish platy limestones, medium- and thick-bedded limestones with cherts and massive or nodular rocky limestones (*sensu* Dżułyński 1952; Figs 3, 4).

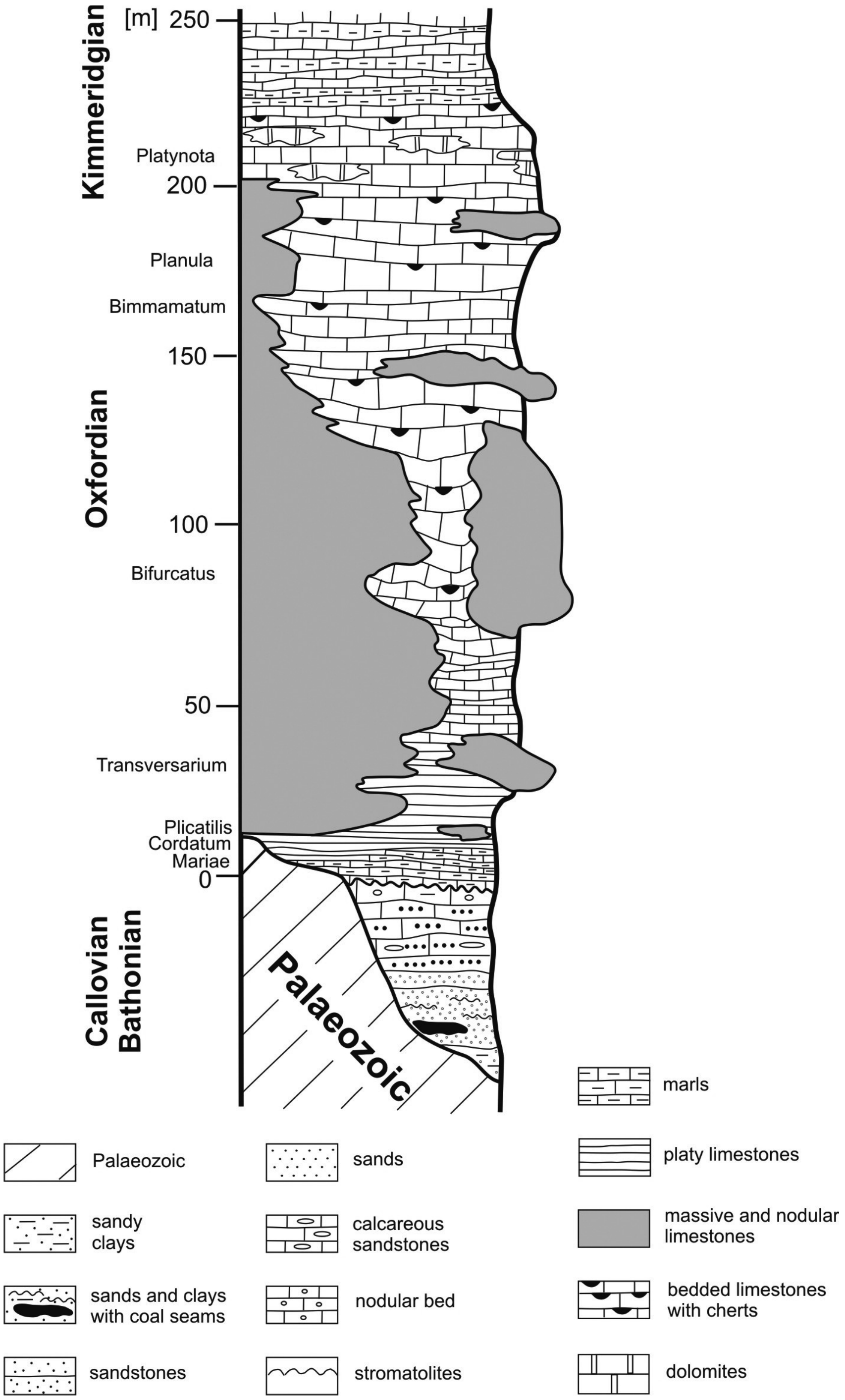

Fig. 3. Simplified lithological profile of Upper Jurassic deposits from the Kraków-Częstochowa Upland (after Krajewski, Matyszkiewicz 2004; modified)

Fig. 4. "Kaczor" rock cliff. Two lithological types are present in the rock; in the lower part thin-bedded limestones occur and in the upper part – massive ones. The transition between bedded and massive limestones is gradual and indistinct. Podzamcze. Photo by J. Matyszkiewicz

Initially platy limestones prevail; they represent the upper part of the Middle Oxfordian, and in the Częstochowa Upland have local names (cf. Kutek *et al.* 1977; Heliasz 1990). They are thin- and less often medium-bedded, porous, yellowish, with great numbers of ammonites. Upwards the platy limestones pass into rocky (massive or nodular) and bedded limestones with cherts that developed mainly in the late Oxfordian. At present, because of selective erosion of the Upper Jurassic rocks, the rocky limestones, being the most resistant, form the most characteristic monadnocks in the landscape of the Upland, whereas the bedded facies mostly form basins inbetween (Fig. 5).

Rock forms comprising compact, non-bedded rocky limestones are represented by fragments of complexes of carbonate buildups of various types. Laterally they pass into bedded slope and basin deposits, mainly in the form of bedded limestones with cherts (Fig. 5). Such limestones are usually formed by fine detrital deposits and benthic organisms. In the Kraków-Częstochowa Upland they are mainly represented by microbial forms, mostly thrombolites and siliceous

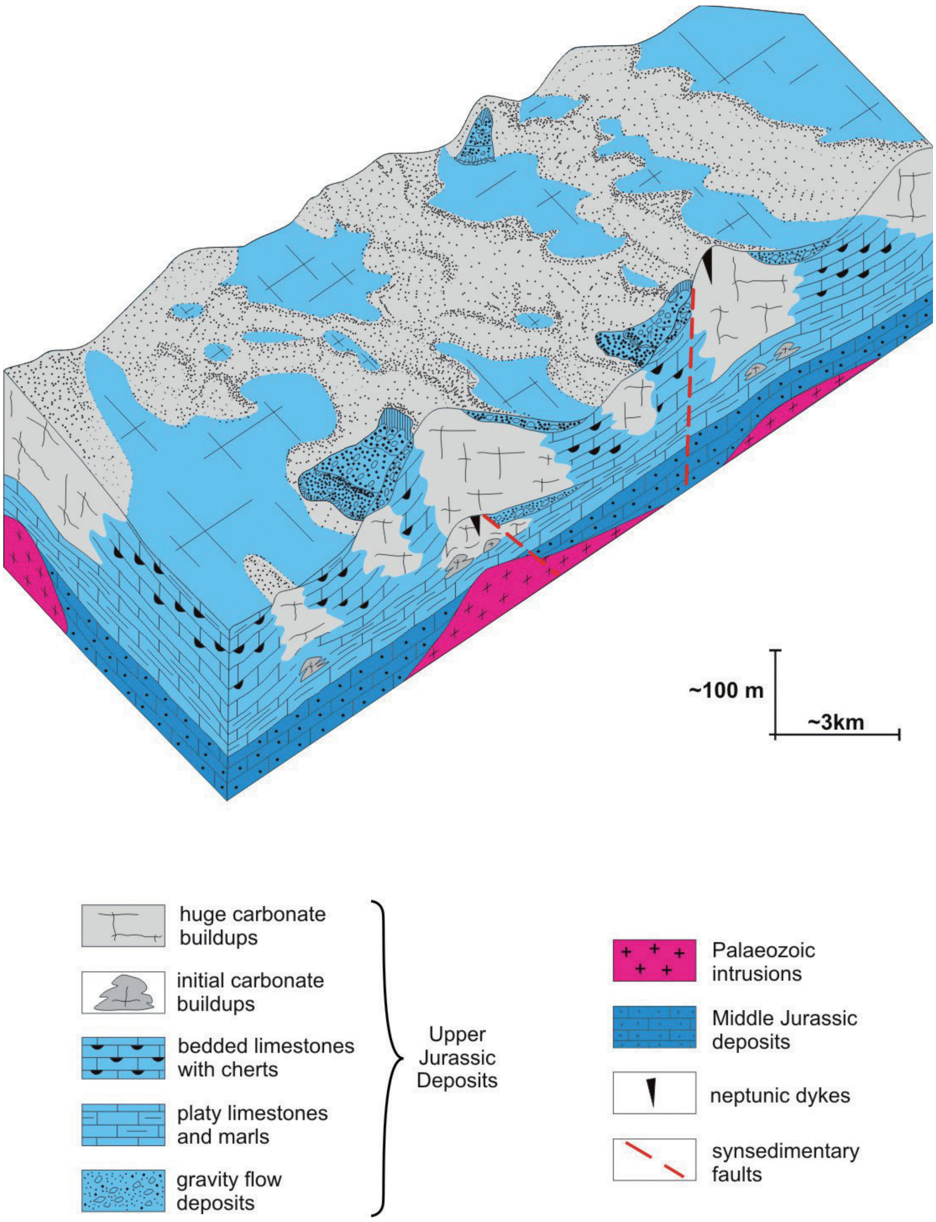

Fig. 5. Architecture of the Late Jurassic sedimentary basin in the Kraków-Częstochowa Upland (after Matyszkiewicz 1997; modified)

sponges. The bedded limestones with cherts represent mainly the so-called microbial-sponge biostromes which, contrary to buildups represented by rocky massive limestones, did not produce elevated forms on the sea bottom but developed in flat areas between such buildups (Heliasz 1990; Matyszkiewicz 1997, 1999, 2008; Krajewski 2001). In the highest situated parts of the Upper Jurassic deposit profile, marls and marly limestones become more abundant and the so-called chalky limestones appear, characterised by low density and high porosity (Kutek *et al.* 1977; Heliasz, Racki 1980; Matyszkiewicz 1999, 2008; Krajewski 2001). Within the upper parts of the sequence, small coral reefs can be observed, probably representing the uppermost Oxfordian and lower Kimmeridgian (Roniewicz, Roniewicz 1971; Heliasz, Racki 1980; Matyja, Wierzbowski 2004).

Development of the Upper Jurassic deposits in the Kraków-Częstochowa Upland

Late Jurassic deposition of carbonate formations in the Polish part of the epicontinental sea took place in the northern shelf of the Tethys Ocean. In extensive areas of Europe it took the form of a carbonate ramp, gently sloping to the south; numerous microbial-sponge buildups developed on it and are now observed as rocky limestones (Matyszkiewicz 1997, 2008; Krajewski 2000). The beginning of the sequence of Jurassic deposits in the Kraków-Częstochowa Upland is associated with sea transgression in the Middle Jurassic. Marl deposits of the Lower Oxfordian represent the maximum of transgression at a low rate of sedimentation, resulting in stratigraphic condensation of the deposits. Hence, the thickness of Lower and Middle Oxfordian deposits does not usually exceed about a dozen metres. The main deposition took place in the Late Oxfordian in conditions of gradual shallowing. In the Late Oxfordian, intensive aggradational growth led to the formation of large, microbial-sponge reef complexes sometimes producing small isolated carbonate platforms (Matyszkiewicz *et al.* 2006a, b). They acted as the alimentation areas of flow of submarine deposits (Fig. 5). At the end of Oxfordian the growth of the complexes stopped in favour of their secondary progradation and gradual replacement of the formations with biostromes, representing now some types of bedded limestones. The process, combined with erosion and submarine flows, led to a gradual levelling of the bottom relief and then to a gradual passage into marl sedimentation.

The widespread occurrence of rocky limestones is a characteristic feature of the Kraków-Częstochowa Upland. They form isolated rock complexes representing carbonate buildups (Fig. 2), now most often termed “microbial-sponge reef”, formed by sessile orgnisms and characterised by a distinct though generally rather small relief on the sea bottom (Dżułyński 1952; Matyszkiewicz 1997, 1999; Krajewski, Matyszkiewicz 2004; Matyszkiewicz *et al.* 2006a, b). Numerous varieties of carbonate buildups occur in the Kraków-Częstochowa Upland: from small initial sponge bioherms through extensive microbial-sponge and microbial-*Tubiphytes* reefs, where detrital sediments bound by microbial structures, most often of trombolite and stromatolite character, predominate. Classic coral reefs occur sporadically as small patch-reefs (Heliasz 1990). Depending on the degree of development of the rigid framework, the rocky limestones underwent diagenesis to various extent, hence they can be observed as massive or nodular varieties of rocky limestones (Fig. 4; Matyszkiewicz 1997). In the south-eastern part of the Częstochowa Upland, near Smoleń and Podzamcze, microbial-*Tubiphytes* and microbial sponge formations predominate; to the north-west they are gradually replaced by sponge-microbial formations observed in the region of Olsztyn near Częstochowa.

One of the key problems of contemporary studies is the origin of the facies diversity of the Upper Jurassic deposits, especially the intense reef development in some areas. In the Kraków-Częstochowa Upland, initiation of the intense development of these buildups was associated with the presence of elevations on the sea bottom (Fig. 5). On the elevations, due to the enhanced water circulation and associated nutrient supply, intensified carbonate production took place. Carbonate buildup was further enhanced by the development of benthic fauna on the elevations. Through progradation, the buildups fused into large complexes covering more extensive areas (Krajewski, Matyszkiewicz 2004; Matyszkiewicz *et al.* 2006a, b; Matyszkiewicz 2008). The origin of such elevations is associated with the structure of the varied Palaeozoic bedrock. Comparison of the structure of Palaeozoic bedrock with the local variation of facies development of the Upper Jurassic deposits reveals a distinct concordance in the occurrence of intrusion and volcanic phenomena along the Kraków-Lubliniec Fault Zone and the distribution of large complexes of carbonate buildups in the Polish Jura (Figs 2, 5, Jędrys *et al.* 2004). Some of the harder components of the bedrock, especially those built of magma rocks, had prior to the Jurassic become isolated through erosion and weathering, forming natural elevations on the sea bottom; carbonate formations developed most rapidly on such elevations. Most of the intrusions were not exhumed from the surrounding Palaeozoic rocks before the Jurassic, but they also indirectly contributed to the development of the carbonate buildups. In regions underlain by these intrusions, as a result of lower subsidence relative to the adjacent areas, they formed elevations on which intense growth of carbonate buildups took place (Fig. 5; Matyszkiewicz *et al.*, 2006a, b). Additionally, tectonic movements along the Kraków-Lubliniec Fault Zone took place in the Middle Jurassic (Kutek 1994), and they could favour formation of elevations as indicated by the considerable facial diversity of the Callovian deposits. Probably all larger complexes of carbonate buildups in the Kraków-Częstochowa Upland developed above the Palaeozoic elevations (cf. Kutek 1994; Matyszkiewicz 1997; Jędrys *et al.* 2004, Krajewski, Matyszkiewicz 2004; Matyszkiewicz *et al.* 2006a, b) dividing the carbonate ramp with longitudinal barriers into an array of smaller basins. Roughly the barrier fragments are represented by the present main ranges in the Częstochowa Upland: Smoleń-Niegowonice, Zborów-Ogrodzieniec and Olsztyn-Mirów (Fig. 2). At present an increasing amount of data idicates that, in conjunction with structural factors, the development of the Upper Jurassic reef complexes in the Kraków-Częstochowa Upland was affected by hydrothermal processes along the Kraków-Lubliniec Fault Zone, which could considerably modify the sedimentation environment (Matyszkiewicz *et al.* 2006a; Matyszkiewicz 2008).

Another important factor in the development of the facies diversification of the Upland was the extensive synsedimentary tectonics, associated with the Kraków-Lubliniec Fault Zone (Jędrys *et al.* 2004; Krajewski, Matyszkiewicz 2004; Matyszkiewicz *et al.* 2006a, b). Expressions of synsedimentary tectonics are commonly occurring deposits of submarine flows (Figs 5, 11) whose initiation could result from tectonic movements, and the so-called neptunian veins filled with detritus or brachiopods (Marcinowski 1972; Kutek *et al.* 1977; Kutek, Zapaśnik 1992; Vierek *et al.* 1994; Krajewski, Matyszkiewicz 2004; Jędrys, Krajewski 2007). The elevated morphological position of the Upper Jurassic complexes of carbonate buildups, combined with periodic tectonic activity of the nearby Kraków-Lubliniec Fault Zone (Żaba 1999), was the reason for displacement of large quantities of the deposit by gravitational flow into the lower situated parts of the basin, where platy and bedded limestones predominate (Fig. 5). Thick deposits of gravitational flows are known from the vicinity of Rodaki, Bydlin, Kromołowiec, Niegowonice, Siedlec, Złoty Potok or Wierbka (Matyszkiewicz *et al.* 2006a) which may support the conjecture that synsedimentary tectonics was one of the most important factors in the facial architecture of the Częstochowa Upland. Based on the geological processes mentioned above, it can be supposed that the most important factor that contributed to the intense development of the reef complexes in the Late Jurassic of the Kraków-Częstochowa Upland was the interaction between the structure of the Palaeozoic bedrock and the active Kraków-Lubliniec Fault Zone (morphological variation of the Palaeozoic basement, varied subsidence, synsedimentation tectonics and hydrothermal phenomena; Matyszkiewicz *et al.* 2006a).

Lithology and development of the Upper Jurassic carbonate buildups of the Częstochowa Upland as exemplified by the Zegarowe Rocks

The region of the Zegarowe Rocks near Smoleń (Fig. 6) is a classic example of the described geological phenomena in the Częstochowa Upland. Similar phenomena can be also observed in the Kraków Upland. The Zegarowe Rocks are located in the eastern part of the Smoleń-Niegowonice Range, on the eastern slope of the upper section of the Wodąca Valley. The region is located on the so-called Smoleń horst. The microfacies development of the Upper Jurassic limestones of the Zegarowe Rocks is much varied (Matyszkiewicz *et al.* 2006a, Fig. 7). Near the bottom of the profile wackestones and packstones with siliceous sponges and brachiopods, and with a faunal assemblage typical of the Upper Jurassic microbolithic megafacies are observed (Matyszkiewicz 1997, 1999). Micritized ooids are common in these formations. Locally the wackestones and packstones are stabilised by irregular thrombolites (Figs 8, 9).

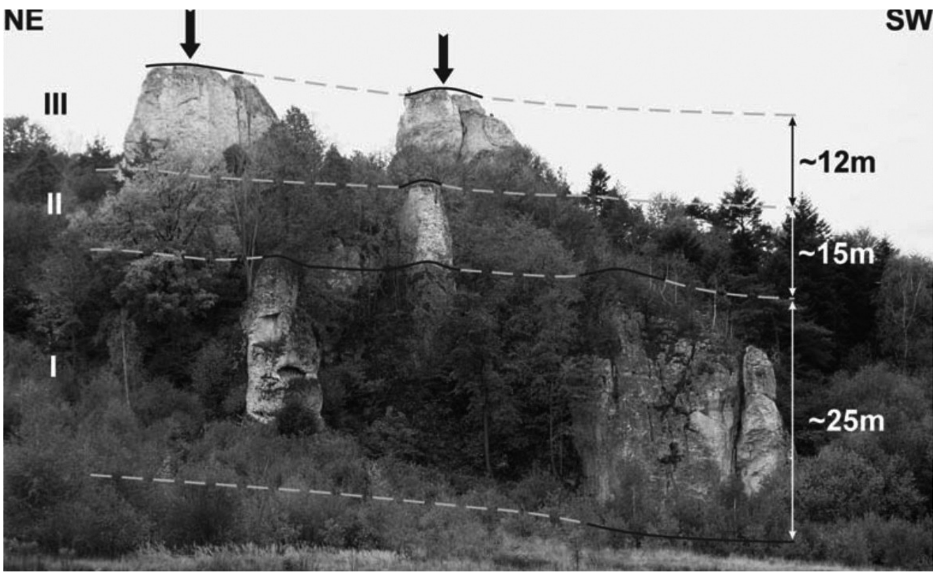

Fig. 6. Zegarowe Rocks complex bearing three morphological horizons marked with Roman numerals. Wodąca Valley, Smoleń.
Photo by J. Matyszkiewicz

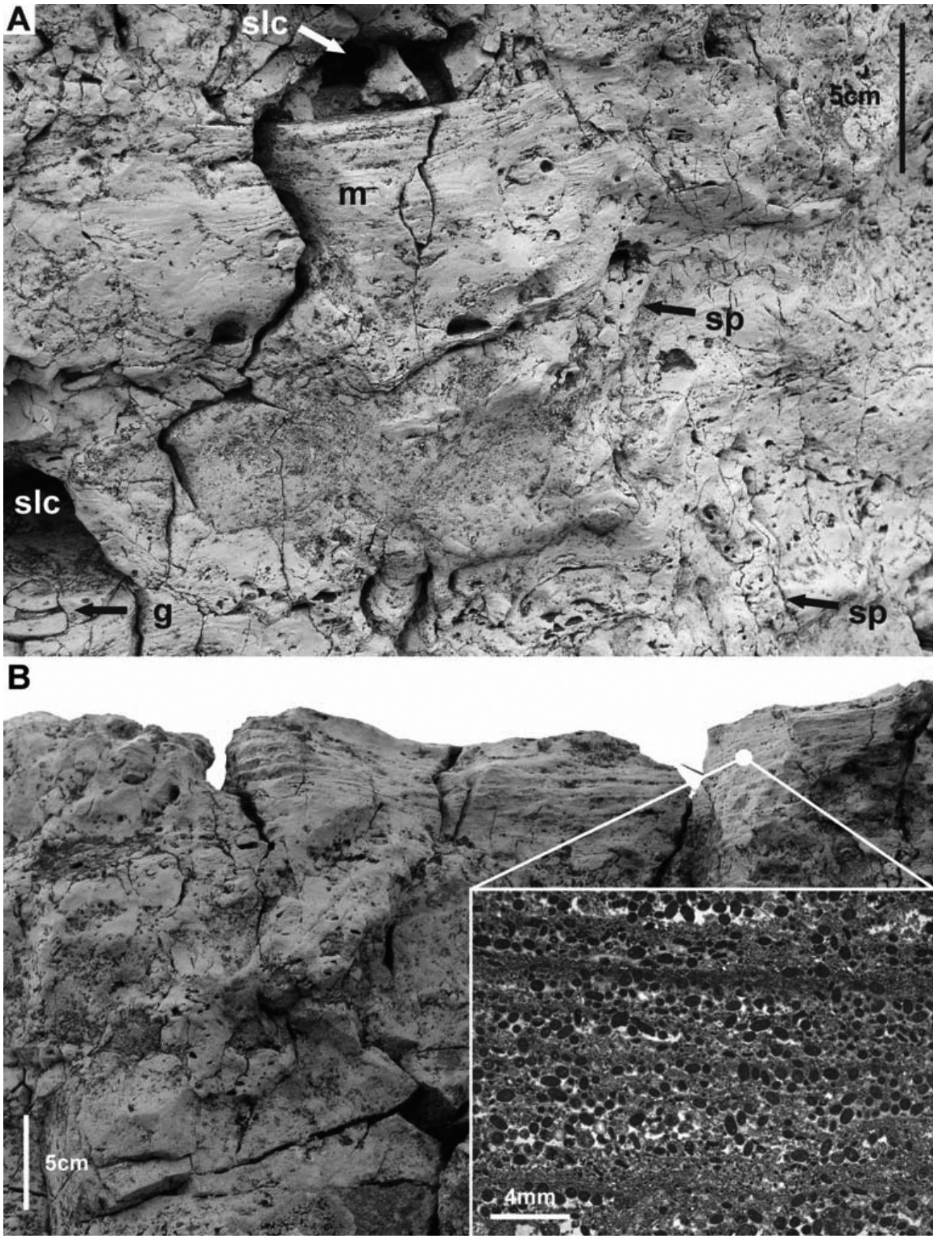

Fig. 7. Lithology of the Zegarowe Rocks
A – Peloidal and agglutinated stromatolites (m) in the uppermost part of the profile with concomitant gastropods (g) and siliceous sponges (sp). Above the gastropod and in the upper part of photo – stromatactis-like cavities (slc)
B – Laminite from the uppermost part of the Zegarowe Rocks complex developed as agglutinated stromatolite with plentiful coproliths. On the lower part of coproliths asymmetrical dissolution textures are observed. Thin section, parallel nicols. Scale bar 4 mm

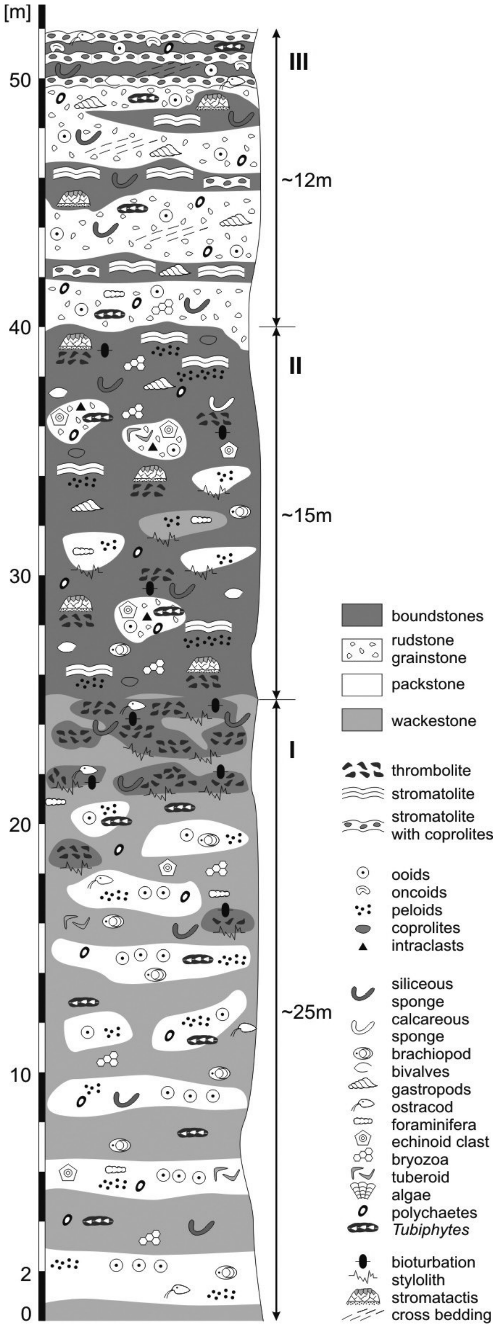

Fig. 8. Microfacies long throughout the section of the Zegarowe Rocks complex (after Matyszkiewicz *et al*. 2006a)

In the middle part of the profile mainly massive biolithites (bindstone-framestone) and detrital sediments (packstone-grainstone) are observed. The main components of biolithites are thrombolites which, with siliceous sponges, form a rigid frame with growth cavities. In places peloidal stromatolites and agglutinating stromatolites with coproliths and echinoderm plates are observed (Figs 8, 9).

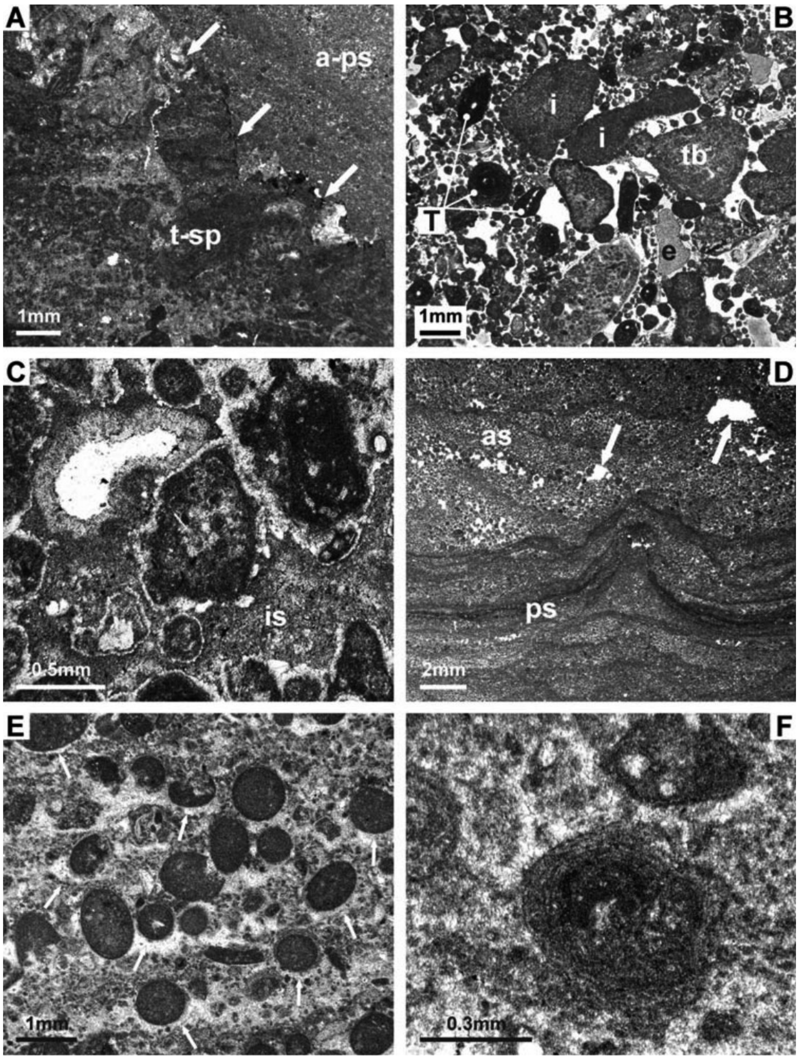

Fig. 9. Microfacies of the middle and upper parts of the section of Upper Jurassic carbonate buildups at the Zegarowe Rocks. A – Pseudonodular limestone. The thrombolite-sponge association (t-sp) forming rigid framework is separated from agglutinated and peloidal stromatolites (a-ps) by a stylolitic seam (arrowed). Traces of intense pressure-controlled dissolution visible along the stylolite. Middle part of the section. B – Talus of the carbonate buildup displays poor sorting and strong differentiation of the grain shape and size. The grains include: tuberoids (tb), *Tubiphytes* sp. (T), echinodermal plates with growing syntaxial cement (e), and intraclasts (i). Middle part of the section. C – Grainstone with traces of matrix dissolution. Inter-grain pores and small, few millimeter wide, cavities are filled with internal sediment (is), developed as Fe oxide-bearing carbonate silt. Cavity walls are mantled at places by a coating of isopachous granular cement. Upper part of the section. D – Peloidal stromatolite (ps) showing hemispherical and wavy lamination becomes replaced up the section by agglutinated stromatolite (as) with fenestral structures (arrow). Upper part of the section. E – Microbial mat developed as agglutinated stromatolite, bearing horizons of coproliths occurring in masses. Basal parts of coproliths show asymmetrical dissolution textures (arrowed). Top part of the section. F – *Girvanella* sp. builds cortex of infrequent oncoids which coexist with coprolithes within microbial mat. Top part of the section

Detrital limestones (grainstone) intercalated with laminites (bindstone) prevail in the top part of the profile. The limestone is very porous and contains siliceous sponges and gastropods. In the highest part of the Zegarowe Rocks a specific variety of agglutinating laminites occurs, as well as locally peloidal stromatolites with horizons of coproliths and algae, probably *Girvanella* sp. (Fig. 9).

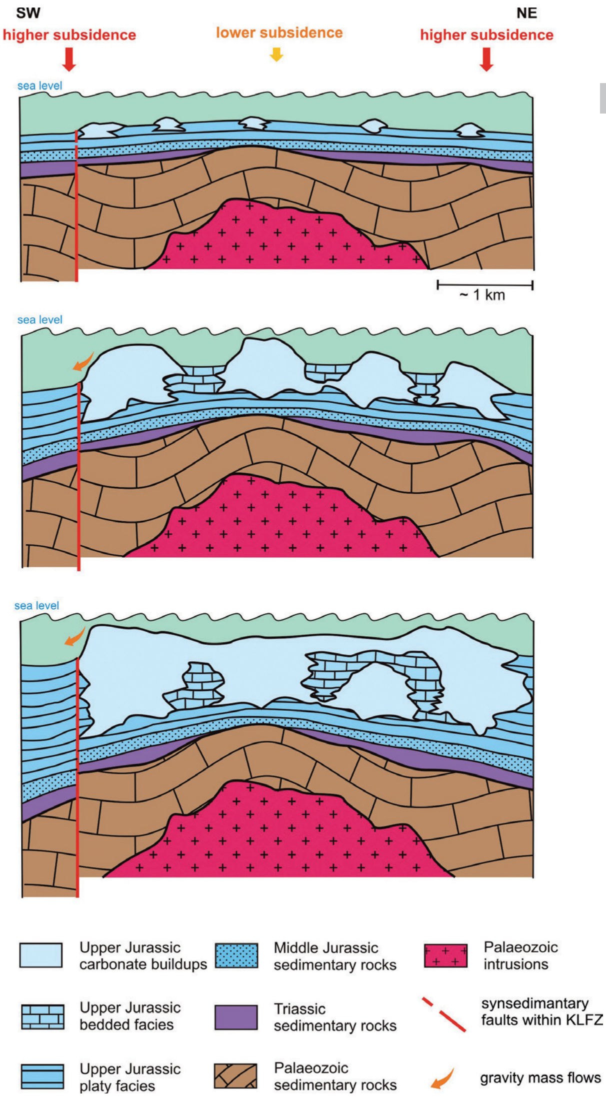

Fig. 10. Development of Smoleń carbonate platform in Late Jurassic (after Matyszkiewicz *et al.* 2006a)
A – differences in subsidence rate induced by presence of Paleozoic intrusion, associated with the Kraków-Lubliniec Fault Zone (KLFZ) caused the formation of the extensive sea bottom elevation, on which, at the beginning of the Late Jurassic, carbonate buildups had started to develop.
B – aggradational growth of initial carbonate buildups and increasing differences in subsidence rate contributed to the development of a large carbonate buildups complex, which took an elevated position on sea bottom. The talus sediments of these buildups were deposited in the interbiohermal depressions. Some of the sediments were periodically redeposited into adjacent, lower situated areas by submarine, gravitational mass flows. This was probably induced by periodic tectonic activity of the Kraków-Lubliniec Fault Zone.
C – Intensive progradation of carbonate buildups with simultaneous limitation of aggradational growth caused their coalescence, flattening of the bottom relief and consequently origin of wide, shallow-water Smoleń carbonate platform

Formation of the Zegarowe Rocks started on the bottom elevation whose origin was probably associated with an extensive granitoid intrusion in the Palaeozoic bedrock (Żaba 1999; Buła *et al.*, 2002; Jędrys *et al.* 2004). The presence of granitoids, underlined by a distinct magnetic anomaly, was the reason for the lower subsidence of the Smoleń region, compared to the adjacent areas (Fig. 10). Under the weight of accumulating deposits, the subsidence differences became gradually more pronounced resulting in the formation of an extensive bottom elevation on the late Jurassic shelf. Intense carbonate production started on the elevation, initially in the form of peloid-ooid sands. Then irregular thrombolites, stabilising the deposits, appeared locally on their surface which, in turn, enabled the development of microbial-sponge carbonate buildups.

As a result of the extensity of the Smoleń elevation, initially, single isolated carbonate buildups formed, eventually producing a distinct relief. In the sea with increased alkalinity most of the macrofauna was eliminated. Even the development of siliceous sponges, organisms providing the rigid framework of microbial-sponge buildups, ceased. This was the direct reason for the gradual levelling of the bottom denivelation and formation of an extensive complex of carbonate buildups with small internal relief. The total dominance of cynobacteria in the environment is manifested in the development of shallow-water stromatolithic laminites. Coproliths, occurring in the laminites, are probably effects of activity of crabs which fed on echinoids.

The intense carbonate production on the Smoleń platform affected sedimentation in the adjacent regions. The platform was probably the source of the gravitational flow deposits which are common in this part of the Częstochowa Upland.

Phenomena of Tertiary tectonics in the Częstochowa Upland

Tertiary tectonics had a great effect on the geological structure of Jurassic deposits of the Kraków-Częstochowa Upland (Dżułyński 1953; Żaba 1999). The area within the Silesian-Kraków Monocline tilted during the Laramian movements and was cut by an array of faults of various displacement values. The main phase of development of fault tectonics in the Upland is associated with Alpine movements of mainly NW-SE and W-E directions, which often reactivated older Variscinian structural directions (Krokowski 1984; Żaba 1999; Matyszkiewicz, Krajewski 1996; Matyszkiewicz 1999). They form numerous tectonic horsts and grabens (e.g. Smoleń Horst). The borders of hill ranges, like in the Kraków Upland, often have a tectonic erosion character of irregular course associated with the presence of numerous tectonic kinks (Dżułyński 1953). Besides, horizontal or slightly sloping, most often solutionally karst-enlarged fissures, are observed in most rocks (Fig. 11). Their origin is diverse and results from periodic breaks in sedimentation, from diagenesis, tectonics, karstification or even recent mass movements (Dżułyński 1952, 1953; Gradziński 1962; Matyszkiewicz, Krajewski 1996; Matyszkiewicz 1997; Pulina 1999; Krajewski 2000; Gradziński, Szelerewicz 2004). For the most part they represent vertical or steeply inclined, solutionally karst-enlarged joints (Dżułyński 1953; Krokowski 1984). A part of vertical fissures in the Jurassic limestones are fault surfaces near which paradislocation flexures can be observed (Krokowski 1984; Matyszkiewicz, Krajewski 1996; Fig. 14). The existence of various joints and fault systems in the rocky limestones is one of the most important factors shaping the present morphology of rock complexes of the Upland (cf. Dżułyński 1953; Matyszkiewicz, Krajewski 1996; Fig. 11).

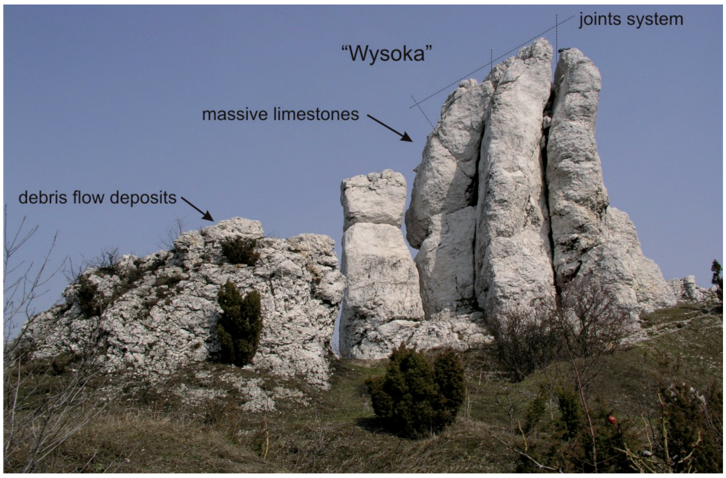

Fig. 11. In the "Wysoka" rock both the Upper Jurassic massive limestones and the debris flow deposits are observed; a joint system of numerous surface discontinuities; Rzędkowice Rocks. Photo by J. Matyszkiewicz.

Tectonics of Mt. Zborów in Podlesice

A classic example of the mentioned phenomena in the Częstochowa Upland is Mt. Zborów in Podlesice (Fig. 12), called also Mt. Berkowa. It forms a part of the Zborów-Ogrodzieniec Range and is located in the southern part of the Kroczyce Rocks. Its massif is composed of a few groups of Upper Jurassic limestone rock cliffs, classified as Oxfordian and representing an extensive complex of microbial-sponge carbonate buildups. Mt. Zborów is mostly built of massive and nodular rocky limestones and, to a lesser degree, of bedded limestones.

Fig. 12. Quarry in Zborów Hill with the Głęboka Cave entrances. Photo by J. Matyszkiewicz

Facies variation of the Upper Jurassic limestones can be observed in the region of Krucze Rocks, in an easily accessible quarry located in the western part of Mt. Zborów, near the entrance to Głęboka Cave (Fig. 12). The northern wall of the quarry is formed of massive rocky limestones, in a few places dissected by

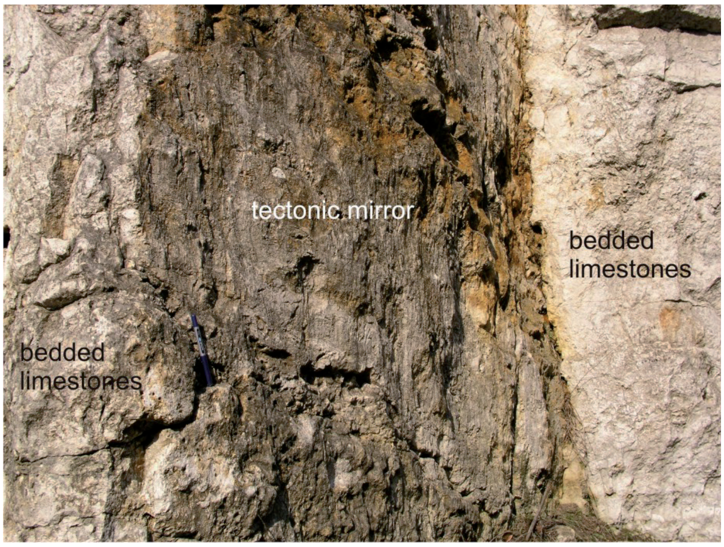

Fig. 13. A tectonic mirror from the quarry with Głęboka Cave. Photo by J. Matyszkiewicz

steep surfaces of tectonic discontinuities with locally developed karst pits filled with brown sands. On the eastern wall of the quarry, the massive limestones pass into bedded limestones. The entrance to Głęboka Cave is situated in the lower part of the wall, on the contact between the massive and the bedded limestones. Bedded limestones are inclined to NNW at a constant angle of about 25°. In the

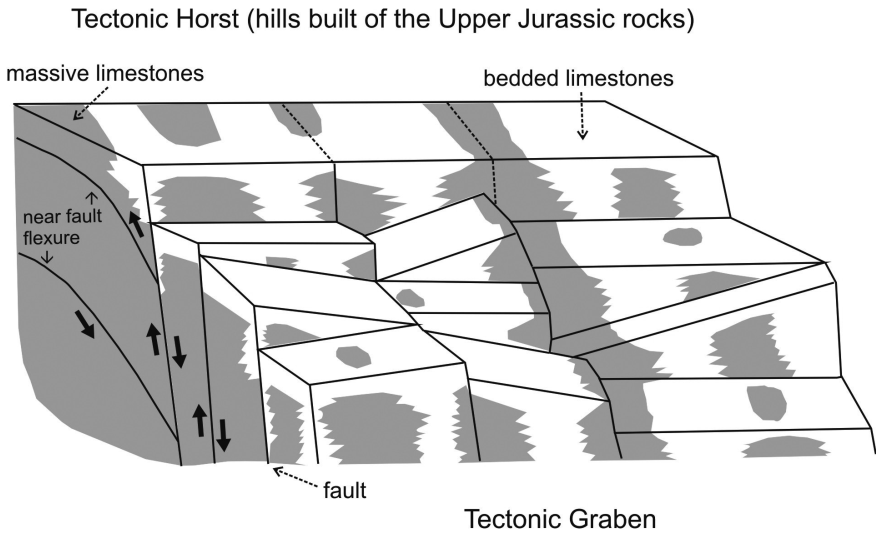

Fig. 14. Interpretation of the fault zone within the hills built of the Upper Jurassic limestones. Near-fault flexure passes southward into discontinuous deformations. Total fault vertical displacement consists of numerous secondary faults, some of which are hinge faults. This caused dipping of sediments in various directions, accompanied by a fault-related megabreccia (after Matyszkiewicz, Krajewski 1996)

northern wall the beds have varied thickness, and the angle of inclination is almost constant. In a few places, they are dissected by faults documented as the presence of tectonic mirrors (Fig. 13). Similar tectonic mirrors can be observed also in other parts of the rocks.

The present morphology of the rocks of Mt. Zborów is the effect of a combined influence of mainly Tertiary and probably older, Late Jurassic fault tectonics and intense karst processes on the facies-differentiated Upper Jurassic complex of carbonate buildups. Inclinations observed in the limestones, varying from steep near the microbial-sponge carbonate buildup to nearly horizontal in the bedded limestones in the northern part of the quarry, are only apparent. Actually, the angle of inclination of the bedded facies remains practically unchanged, and their apparent nearly horizontal arrangement in the northern wall results from intersection in the plane parallel to their course. The presence of tectonic mirrors indicates the presence of faults and suggests that the present position of the bedded limestones was to a large degree caused by fault tectonics (Figs 13, 14). Due to the varied morphology of the rock facies, the same crack surface can be observed in various planes in relation to the strike (Fig. 11). Consequently, the observed apparent angles, depending on the direction of observation, range from 0º to the greatest angle, perpendicular to the strike, creating an illusion of the inclination of the beds (Matyszkiewicz, Krajewski 1996). Exceptions are tectonic inclinations observed sometimes in the form of shear surfaces near paradislocation flexures (Krokowski 1984; Matyszkiewicz, Krajewski 1996; Fig. 14).

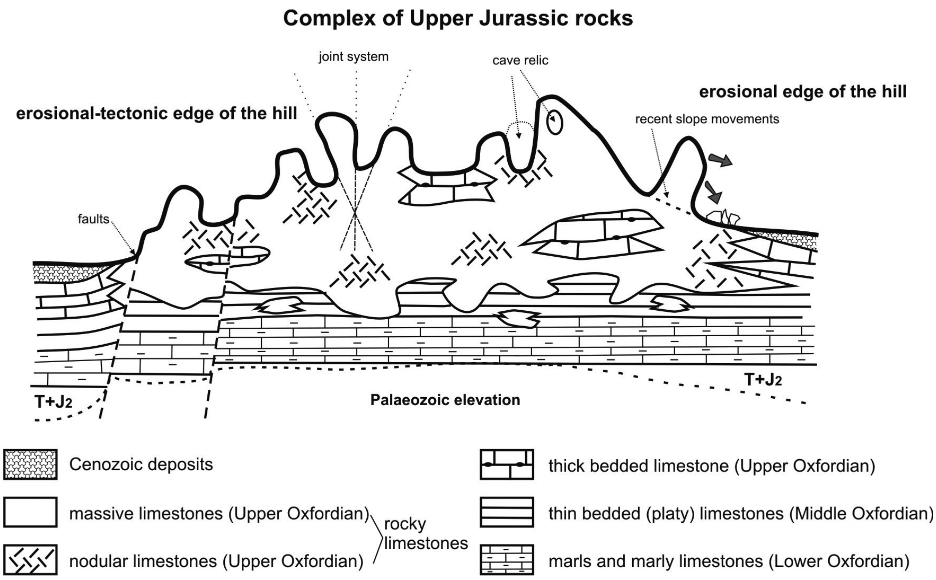

Fig. 15. A model presenting different geological factors forming the contemporary shape of the hills built of the Upper Jurassic limestones in the Kraków-Częstochowa Upland

The present shape of the edge of Mt. Zborów is a result of the considerable effect of tectonic and erosion processes and this renders spatial reconstruction difficult. The rock groups at various levels of the hill commonly represent deposits of different tectonic blocks which are often difficult to ascertain precisely. In extreme cases, limestones located in the highest situated parts of the hill may be lithologically and stratigraphically the same as those observed at its foot. Such phenomena also make it difficult to determine the thickness of the deposits. This may lead to overestimated deposit thicknesses, when deposit thicknesses in consecutive tectonic blocks are erroneously added as the total thickness (cf. Matyszkiewicz, Krajewski 1996; Matyszkiewicz 1999).

Conclusions

Summarising, the present morphology of the Częstochowa Upland is a result of combined actions by an array of geological factors such as limestone facial differentiation, the structural character of Palaeozoic bedrock, synsedimentary tectonics, karst processes and mass movements (Fig. 15). In the present landscape of the Upland, in addition to facies differentiation, the special role of disjunctive tectonic phenomena can be commonly observed in the Upper Jurassic limestones (Fig. 15). Such phenomena are among the main factors that shaped the present appearance of the Upland. Correct recognition of tectonic structures that are often poorly legible is crucial to correct geological interpretation, especially in sedimentation-facial studies of the area.

References

Bednarek J., Kaziuk H., Zapaśnik T. 1978. *Objaśnienia Szczegółowej Mapy Geologicznej Polski 1: 50 000 arkusz Ogrodzieniec*. Warszawa. Wydawnictwa Geologiczne.

Buła Z., Habryn R., Kurek S., Krieger W., Markowiak M., Woźniak P. 2002. *Atlas geologiczny paleozoiku bez permu w strefie kontaktu bloków górnośląskiego i małopolskiego 1: 200 000*. Państwowy Instytut Geologiczny.

Dżułyński S. 1952. Powstanie wapieni skalistych Jury Krakowskiej. *Rocznik Polskiego Towarzystwa Geologicznego*, 21: 125-180.

Dżułyński S. 1953. Tektonika południowej części Wyżyny Krakowskiej. *Acta Geologica Polonica*, 3: 325-440.

Gradziński R. 1962. Rozwój podziemnych form krasowych w południowej części Wyżyny Krakowskiej. *Rocznik Polskiego Towarzystwa Geologicznego*, 32: 429-492.

Gradziński M., Szelerewicz M. 2004. Jaskinie Wyżyny Krakowsko-Wieluńskiej – li-czba i rozmieszczenie, [In:] Partyka J. (Ed.), *Zróżnicowanie i przemiany środowiska przyrodniczo-kulturowego Wyżyny Krakowsko-Częstochowskiej*. Ojcowski Park Narodowy, 1: 69-82.

Heliasz Z. 1990. Sedymentacja wapieni górnej jury w regionie częstochowskim Jury Polskiej. *Prace Naukowe Uniwersytetu Śląskiego*, *Geologia*, 10-11: 9-49.

Heliasz Z., Racki Z. 1980. Ecology of the Upper Jurassic brachiopod bed from Julianka, Polish Jura Chain. *Acta Geologica Polonica*, 30: 175-197.

Jędrys J., Grabowska T., Krajewski M., Matyszkiewicz J., Żaba J. 2004. Założenia strukturalne górnojurajskich budowli węglanowych na Wyżynie Krakowsko-

Wieluńskiej w świetle danych magnetycznych, [In:] Partyka J. (Ed.), *Zróżnicowanie i przemiany środowiska przyrodniczo-kulturowego Wyżyny Krakowsko-Częstochowskiej*. Ojcowski Park Narodowy, 1: 19-26.
Jędrys J., Krajewski M. 2007. Wykształcenie i rozwój górnojurajskich osadów okolic Bębła na tle budowy podmezozoicznego podłoża, Wyżyna Krakowska. *Tomy Jurajskie,* 4: 95-101
Krajewski M. 2000. Lithology and morphology of Upper Jurassic carbonate buildups in the Będkowska Valley, Kraków region, Southern Poland. *Annales Societatis Geologorum Poloniae*, 70: 51-163.
Krajewski M. 2001. Upper Jurassic chalky limestones in the Zakrzówek Horst, Kraków, Kraków-Wieluń Upland (South Poland). *Annales Societatis Geologorum Poloniae*, 71: 43-51.
Krajewski M., Matyszkiewicz J. 2004. Rozwój i architektura facjalna górnojurajskich kompleksów budowli węglanowych w SW części Wyżyny Krakowskiej, [In:] Partyka J. (Ed.), *Zróżnicowanie i przemiany środowiska przyrodniczo-kulturowego Wyżyny Krakowsko-Częstochowskiej*. Ojcowski Park Narodowy, 1: 27-34.
Krokowski J. 1984. Mezoskopowe studia strukturalne w osadach permsko-mezozoicznych południowo-wschodniej części Wyżyny Śląsko-Krakowskiej. *Annales Societatis Geologorum Poloniae*, 54: 79-121.
Kutek J. 1994. Jurassic tectonic events in south-eastern cratonic Poland. *Acta Geologica Polonica*, 44: 167-221.
Kutek J., Wierzbowski A., Bednarek J., Matyja B. A., Zapaśnik A. 1977. Z problematyki stratygraficznej osadów górnojurajskich Jury Polskiej. *Przegląd Geologiczny*, 25: 438-445.
Kutek J., Zapaśnik T. 1992. Bydlin, large scale synsedimentary mass movements of Late Oxfordian, [In:] Matyja B. A., Wierzbowski A., Radwański A. (Eds), *Oxfordian & Kimmeridgian joint working groups meeting, Guidebook and Abstracts, International Subcommission on Jurassic Stratigraphy*, 22-26.
Marcinowski R. 1972. Turbidites in Upper Oxfordian limestones at Jaskrów in the Polish Jura Chain. *Bull. Pol. Acad. Sc. Ser. Geol.-Geogr.*, 18: 219-225.
Matyja B. A., Wierzbowski A. 2004. Stratygrafia i zróżnicowanie facjalne utworów górnej jury Wyżyny Krakowsko-Częstochowskiej i Wyżyny Wieluńskiej, [In:] Partyka J. (Ed.), *Zróżnicowanie i przemiany środowiska przyrodniczo-kulturowego Wyżyny Krakowsko-Częstochowskiej*. Ojcowski Park Narodowy, 1: 13-18.
Matyszkiewicz J. 1997. Microfacies, sedimentation and some aspects of diagenesis of Upper Jurassic sediments from the elevated part of the Northern peri-Tethyan Shelf: a comparative study on the Lochen area (Schwäbische Alb) and the Kraków area (Kraków-Wieluń Upland, Poland). *Berliner Geowissenschaftliche Abhandlungen*, E21, 111 pp.
Matyszkiewicz J. 1999. Sea bottom relief versus differential compaction in ancient platform carbonates: a critical reassessment of an example from Upper Jurassic of the Kraków-Wieluń Upland. *Annales Societatis Geologorum Poloniae*, 69: 63-79.
Matyszkiewicz J. 2008. The Kraków-Częstochowa Upland (Southern Poland) – The Land of White Cliffs and Caves. *Przegląd Geologiczny*, vol. 56 nr 8/1: 647-652.
Matyszkiewicz J., Krajewski M. 1996. Lithology and sedimentation of Upper Jurassic massive limestones near Bolechowice, Kraków-Wieluń Upland, South Poland. *Annales Societatis Geologorum Poloniae*, 66: 285-301.
Matyszkiewicz J., Krajewski M., Kędzierski J. 2006a. Origin and evolution of an

Upper Jurassic complex of carbonate buildups from Zegarowe Rocks (Kraków-Wieluń Upland, Poland). *Facies*, 52: 249-263.
Matyszkiewicz J., Krajewski M., Żaba J. 2006b. Structural control on the distribution of Upper Jurassic carbonate buildups in the Kraków-Wieluń Upland (south Poland). *Neues Jahrbuch für Geologie und Paläontologie Mh.*, 3: 182-192.
Pulina M. 1999. *Kras. Formy i procesy*. Wydawnictwo Uniwersytetu Śląskiego, 374 pp.
Roniewicz E., Roniewicz P. 1971. Upper Jurassic coral assemblages of the Central Polish Uplands. *Acta Geologica Polonica*, 21: 399-423.
Różycki S. Z. 1953. Górny dogger i dolny malm Jury Krakowsko-Częstochowskiej. *Prace Instytutu Geologicznego*, 17, 412 pp.
Rühle E., Ciuk E., Osika R., Znosko J. 1977. *Mapa geologiczna Polski bez osadów czwartorzędowych 1:500 000*. Inst. Geol.
Trammer J. 1985. Biohermy gąbkowe warstw jasnogórskich (oksford Jury Polskiej). *Przegląd Geologiczny*, 33: 78-81.
Vierek A., Heliasz Z., Zieliński T. 1994. Górnojurajskie osady podmorskich spływów; stanowisko 4 - Bydlin. [In:] Malik K., Bardziński W., Teper E., Waga J. M., Zieliński T. (Eds), *Sedymentacja normalna, katastroficzna i wyjątkowa; procesy i produkty. III Krajowe Spotkanie Sedymentologów*, Wydział Nauk o Ziemi, Uniwersytet Śląski, Sosnowiec, 26-30.
Żaba J. 1999. Ewolucja strukturalna utworów dolnopaleozoicznych w strefie granicznej bloków górnośląskiego i małopolskiego. *Prace Państwowego Instytutu Geologicznego*, 166, 162 pp.