Dr Renata Jach
Institute of Geological Sciences
Jagiellonian University

# Summary of professional accomplishments

1. Given name and surname: **Renata Jach**

2. Scientific degrees and diplomas held:

- 2003: Doctor of Philosophy in the field of the Earth Sciences at the Faculty of Biology and Earth Sciences of the Jagiellonian University, speciality: sedimentology; PhD thesis titled "Facies development of the Lower/Middle Jurassic deposits of the Krížna Unit, the Western Tatra Mountains", being supervised by Professor Alfred Uchman.
- 1998: Master of Science in geology, received at the Institute of Geological Sciences of the Jagiellonian University. MSc thesis titled „Geology of the Brodła region near Alwernia", being supervised by Professor Stanisław Dżułyński and Dr Joachim Szulc.

3. Information on previous employment in scientific institutions:

- 2005 – recent: assistant professor at the Institute of Geological Sciences of the Jagiellonian University, Department of Sedimentology and Palaeoenvironmental Analysis;
- 2003 – 2005: assistant at the Institute of Geological Sciences of the Jagiellonian University, Department of Sedimentology and Palaeoenvironmental Analysis.

4. Pursuant to art. 16. 2 of the Act of 14th March 2003 on the academic degrees and titles (Dz. U. No. 65, pos. 595, with later changes), as my scientific achievement, I present the set of two scientific articles under the united title:

"**Middle–Upper Jurassic carbonate-biosiliceous deposits of the Fatricum Domain in the Tatra Mts: integrated stratigraphy, facies and sedimentary environment**".

List of publications included in the main scientific achievement:

**Jach, R.**, Djerić, N., Goričan, Š. & Reháková, D., 2014. Integrated stratigraphy of the Middle Upper Jurassic of the Krížna Nappe, Tatra Mountains. *Annales Societatis Geologorum Poloniae*, 84: 1–33.

reviewed by: Daria Ivanova, José Sandoval, Hisashi Suzuki and Hubert Wierzbowski

**Jach, R.** & Reháková, D., 2019. Middle to Late Jurassic carbonate-biosiliceous sedimentation and palaeoenvironment in the Tethyan Fatricum Domain, Krížna Nappe, Tatra Mts, Western Carpathians. *Annales Societatis Geologorum Poloniae*, 89: 1–46.

reviewed by: Roman Aubrecht, Špela Goričan and an anonymous reviewer.

## Summary of main scientific achievement

### Introduction to the studied topics, previous knowledge and current research goals

The Jurassic period was the time of rapid changes in the pattern of land and sea distribution, reflecting progress in disintegration of the Pangea continent and the development of the extensive Tethys Ocean (Fig. 1). Rifting in the area of the so-called Alpine-Mediterranean Tethys resulted in formation of many partly isolated basins, at the beginning relatively narrow and elongated. They were founded on continental crust subject to stretching and thinning. In extreme cases, oceanic crust grew in some of them. The basins were bounded by normal or strike-slip faults and separated by elevations, usually of submarine high character.

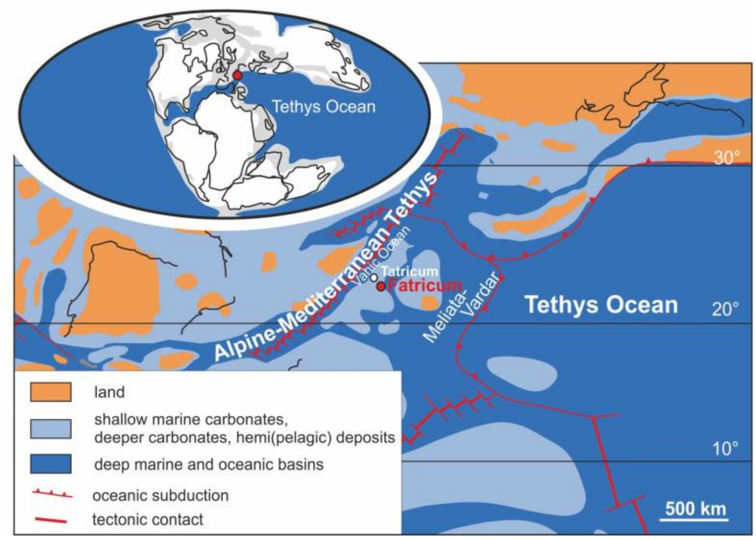


**Fig. 1.** General palaeogeographic position of the Fatricum Domain during the Callovian (after Thierry and Barrier, 2000, simplified; from Jach & Reháková, 2019).

Different sedimentary facies were being laid down in the basins and on the submarine elevations between them (Bernoulli & Jenkyns, 1974). Basins were mainly being filled with various hemipelagic sediments and products of mass redeposition – mainly of gravity flows (Eberli, 1987) – and radiolarites (Baumgartner, 2013; De Wever *et al*., 2014). Sedimentation on the submarine elevations resulted mainly in crinoidal limestones, *Bositra* limestones and red limestones, often nodular (Jenkyns, 1974; Santantonio, 1993; Martire, 1996). The sediments laid on the rises are usually condensed and are rich in various types of pelagic microbialites. At the Jurassic–Cretaceous transition widespread became micritic limestones, composed mainly of microplankton carbonate skeletons.

Though the rule outlined above is valid universally, Jurassic evolution of each basin in the Alpine-Mediterranean Tethys had its own peculiarities. This depended on various factors, local and regional in nature, such as: synsedimentary tectonic activity of a given area (Bertok & Martire, 2009; Picotti & Cobianchi, 2017), rearrangement of microcontinents (Lewandowski *et al*., 2005; Muttoni *et al*., 2005, 2013), changing patterns of oceanic circulation (Nieto *et al*., 2012; Vörös, 2012), changing trophic state of water column, in extreme cases leading to a crisis in carbonate production and deposition (Bartolini & Cecca, 1999; Morettini *et al*., 2002; Cecca *et al*., 2005; Baumgartner, 2013; De Wever *et al*., 2014), and evolution of calcium carbonate-precipitating organisms (Erba, 1989; Erba & Tremolada, 2004). These factors remained closely interdependent on one another.

Fatricum Domain was one of palaeogeographic domains in the Carpathian segment of the Alpine-Mediterranean Tethys. The rocks originated in this domain became incorporated into the Krížna Nappe in Cretaceous time. They are now present in various mountain ranges of the Central Carpathians, including the Tatra Mts. The Jurassic sediments record evolution of the Fatricum Domain from the initial stage, when continental and shallow marine conditions prevailed, to the Early Cretaceous extensive marine basin. In Jurassic time, the Fatricum Domain was bordered by a Tatricum Ridge on the north (according to the present-day orientation) and the so-called Cimmerian ridge on the south (Cimmerian wedge *sensu* Michalík, 2007).

Previous research has demonstrated that the Middle and Upper Jurassic sediments of the Fatricum domain in the Tatra Mountains are represented by a carbonate-biosiliceous series several tens of metres thick. The biosiliceous sediments have been hitherto interpreted as deep-water pelagic facies (Lefeld, 1974, 1981) and their age was determined on the grounds of aptychi and radiolarians as Bathonian–Kimmeridgian (Gąsiorowski, 1959, 1962; Polák *et al*., 1998; Bąk, 2001). The previous stratigraphic division of the carbonate-biosiliceous series was largely based on analogies with the sedimentary succession in the Pieniny Mountains (Lefeld, 1974; Lefeld *et al*., 1985), though some corrections (Pszczółkowski, 1996; Grabowski & Pszczółkowski, 2006) and extensive modifications of this division have been proposed (Polák *et al*., 1998).

Despite the studies summarized above, the Middle and Upper Jurassic succession of the Fatricum domain in the Tatra Mts remained incompletely studied. Details of many facies remained unknown (microfacies type, components, sedimentary structures etc.). There were even clear discrepancies in important details of vertical sequence of facies types. Enigmatic position of the nodular limestones (Niedzica Limestone Formation – Lefeld *et al*., 1985) within the carbonate-biosiliceous succession (Lefeld, 1974; Lefeld *et al*., 1985 *versus* Polák *et al*., 1998; see also Jach *et al*., 2019) is but one example. Lateral spatial relations of the distinguished sedimentary facies were also unknown. Stratigraphical data on radiolarites of the Krížna Unit, based on aptychi and radiolaria, required revision, mainly because these sediments have not been subject to detailed sampling combined with comprehensive microfaunal analysis. They also needed supplementing with independent data based on other biostratigraphic markers and chemostratigraphic data (isotope stratigraphy).

## The aim of research

The investigations conducted were aimed at establishing stratigraphy of the Middle and Upper Jurassic carbonate-biosiliceous series of the Fatricum Domain in the Tatra Mts, establishing the vertical sequence of facies and lateral facies variability, reconstruction of broadly understood palaeoenvironmental factors that controlled deposition of the studied sediments, such as sea-level changes, depth of sedimentary basin, role of the aragonite compensation depth (ACD) and the calcite compensation depth (CCD), trophic and climatic conditions.

## The accepted and realized research strategy

Taking into account the imperfect recognition of the vertical sequence of Middle and Upper Jurassic facies, key sections had been selected in the Western Tatra Mts and in the eastern part of the Tatra Mts (sub-Tatric zone of the High Tatra Mts and Belianske Tatra Mts in Slovakia), then logged in detail and sampled bed-by-bed. A total length of the logged sections amounted to 450 m. The next step was distinction and description of typical facies. Then, an integrated stratigraphy of the studied series has been built using the tools of isotope stratigraphy ($\delta^{13}C$ changes) and biostratigraphy (analysis of radiolarian assemblages, calcareous dinocysts and calpionellids) in cooperation with experts in biostratigraphy. The stratigraphic results have been presented in the first article that is a part of the main scientific accomplishment (Jach *et al*., 2014). I want to stress that the article was received positively in international literature as is shown by its 14 citations in 5 years. Resolving the stratigraphy of the studied rock succession made it possible to determine time relationships between the individual facies and to perform various farther analyses concerning the sedimentation rate, evolution of the studied part of the basin and the factors that governed it. These topics are included in the second article presented as a part of the main scientific accomplishment (Jach & Reháková, 2019).

## The results obtained – recognition of facies sequence and stratigraphy of the Middle and Upper Jurassic sediments in the Fatricum Domain (Krížna Unit) in the Tatra Mountains – presented in the article Jach *et al*. (2014)

Stratigraphy of the Middle and Upper Jurassic carbonate-siliceous sequence was established using standard biostratigraphic methods (radiolarians, calcareous dinocysts and calpionellids) integrated with analysis of isotope data ($\delta^{13}C$) in carbonates (Fig. 2).

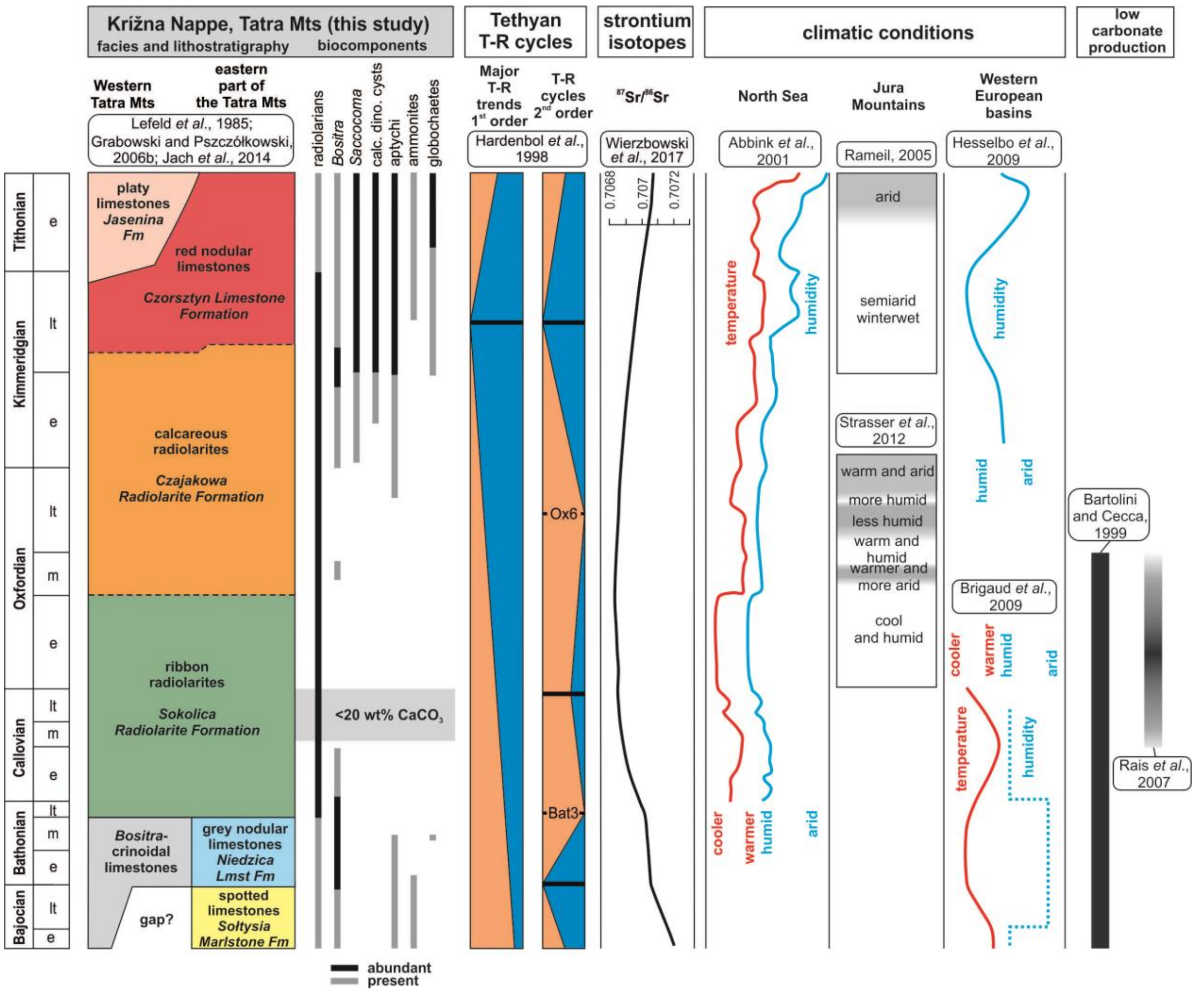


**Fig. 2.** Facies and range of selected biocomponents in the Tatra Mts sections studied, compared to general sea-level curve and $^{87}Sr/^{86}Sr$ curve, palaeoclimatic data and carbonate-platform productivity for the Bajocian – early Tithonian; from Jach & Reháková (2019).

Field investigations revealed significant facies diversity of the studied sediments, manifest in the vertical succession of facies and their lateral variability. The thick limestones and spotted marls in the eastern part of the Tatra Mts are overlain with grey nodular limestones. These limestones were apparently distinguished as the Niedzica Limestone Formation (Lefeld *et al*., 1985) and placed in the succession above within the carbonate-biosiliceous succession. Laterally equivalent, in the Western Tatra Mts, to the facies described above are partly condensed Bositra-crinoid limestones. An internally diversified radiolarite series, dominated by green radiolarites at base and red ones at top lies above them. The thickness of this series varies, but it is generally greater in the eastern part of the Tatra Mts. Radiolarites are in turn covered with red nodular limestones, thicker in the eastern part of the Tatra Mts and by grey platy limestones, thicker in the Western Tatra Mts and corresponding laterally in part to the red nodular limestones.

The comprehensive approach to the stratigraphy of the studied sediments and application of the methods of integrated stratigraphy provided base for establishing a precise stratigraphic scheme of the studied sediments (Fig. 2). Generally uniform radiolarite deposition began in Late Bathonian and lasted till Late Kimmeridgian. Carbonate sedimentation returned in later Kimmeridgian (Moluccana Zone), when deposition of red nodular limestones began (see also Jach *et al*., 2012).

Another interesting result of the conducted studies was positive verification of the validity of stable carbon isotopes as a stratigraphic tool in biosiliceous facies very poor in calcium carbonate. The studies proved that analyses of $\delta^{13}C_{carb.}$ in samples of biosiliceous sediments, even those poor in $CaCO_3$ (ca. 12 wt%), provides credible data of chemostratigraphic value. The $\delta^{13}C$ curve obtained from samples of carbonate-biosiliceous rocks presents isotope events in Early Bajosian, Late Bajosian, Late Bathonian, Late Callovian, Middle Oxfordian and Late Kimmeridgian (Moluccana Zone). Moreover, this curve shows a trend toward higher values in Callovian; the high values persist in the Late Callovian – Middle Oxfordian interval. From Middle Oxfordian to early Tithonian there is a marked trend to diminishing values. The shape of the curve, established peaks and trends correlate well with $\delta^{13}C$ curves obtained in other areas of the Tethys (e.g., Bartolini *et al*., 1999; Jenkyns *et al*., 2002; O'Dogherty *et al*., 2006).

### The results obtained – carbonate-biosiliceous sedimentation and its controlling factors – presented in Jach & Reháková (2019)

Earlier palaeotopography of the basin bottom exerted marked influence on deposition of the Middle Jurassic sediments. Detailed analysis of facies, including determination of their sedimentation rates, has shown that spotted limestones with beds of resedimented crinoidal limestones and grey nodular limestones, known only in the eastern part of the Tatra Mts, were laid down in a local depression. However, the coeval *Bositra*-crinoidal limestones of the Western Tatra Mts represent a facies of a submarine rise. The grey nodular limestones were subject to downslope creep, which is recorded in their structural features.

The overlying radiolarites were laid down in response to a CCD rise. This was related to the Tethys-wide crisis in carbonate sedimentation at the Middle Callovian – Early Oxfordian time, in itself an effect of a combination of various processes, such as eutrophication and related acidification of the water column, increased humidity of climate, and possibly also increased supply of endogenic $CO_2$. Radiolarian sedimentation started quite rapidly, as is clearly recorded in the studied sections.

The upper part of the radiolarite series (Middle Oxfordian – Upper Kimmeridgian) features elevated contents of calcium carbonate. Its rate of deposition was also lower than in the underlying radiolarites. This is the result of gradual decay of biosiliceous sedimentation and very slow return of carbonate sedimentation. The process is synchronous with climatic drying and warming.

The analysis of facies has shown that earlier palaeotopography was levelled during the deposition of the lower part of the radiolarite series. The observed marked lateral diversity of limestone facies in the sections above the radiolarites, and of their sedimentation rates, point to the inversion of sea-bottom relief in late Jurassic time. Facies that were being laid down in the Western Tatra Mts (platy and nodular lithotypes of red nodular limestones, as well as grey platy limestones) were laid down in a local depression, while pseudonodular lithotype of the red nodular limestone facies, distinctive for the eastern part of the Tatra Mts, was laid down on a local submarine high.

The evolution of the studied fragment of the Fatricum Domain has been explained in reference to the pull-apart nature of this basin postulated by Michalík (2007), using the results of analog modeling of such basins conducted by Wu *et al*. (2009). This approach postulates that during the evolution of the Fatricum Domain it was tectonically modified and its depocentre shifted (Fig. 3). Conclusion from the studies performed demonstrate that the Fatricum Domain, similarly as many other basins of the Alpine-Mediterranean Tethys, was undergoing synsedimentary tectonics a long time after its rifting phase that took place at the Triassic-Jurassic break. These conclusions provide base for supposition that the tectonic evolution of the Fatricum Domain in Jurassic time could be controlled by subduction of the Meliata Ocean on the opposite side of the Cimmerian ridge that flanked this domain.

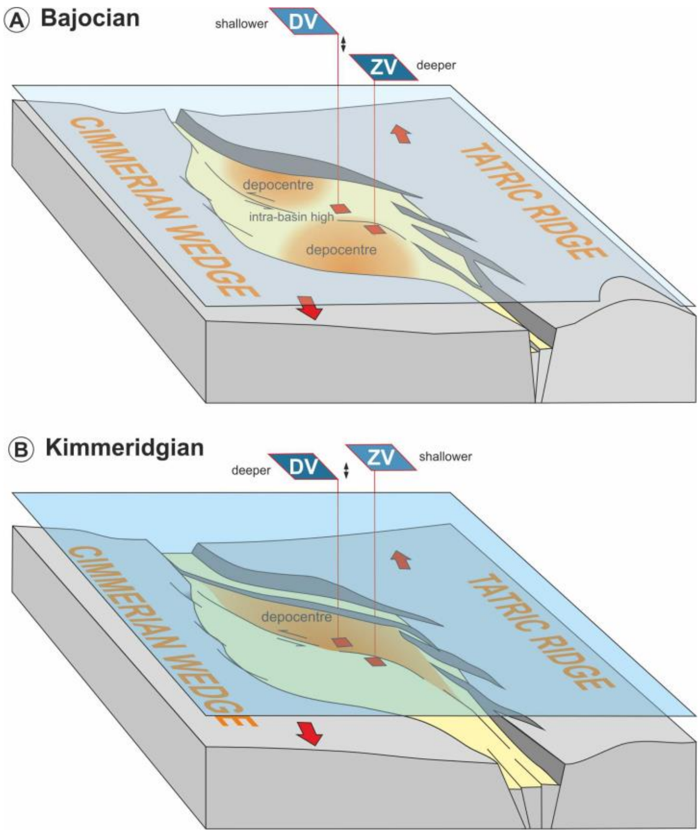


**Fig. 3.** Schematic tectonic model (not to scale, inspired by Michalík, 2007 and Wu *et al.*, 2009) for palaeobathymetric differences and changes in the study area between Długa Valley (DV) and Ždiarska vidla (ZV); from Jach & Reháková (2019).

## Other scientific achievements

Besides my investigations described above, which constitute my main scientific achievement, I am also studying sedimentation of other marine carbonates. I have also studied topics related to the origin of freshwater carbonates, palaeoenvironmental interpretation of subfossil borings produced by beetles, and geological structure of the Kraków region. My investigations are conducted mainly in the Tatra Mts, but also in the Kraków Upland. I have also conducted research in eastern Serbia and in Argentina as well.

## Sedimentation of Lower Jurassic deposits in the Krížna Unit of the Western Tatra Mts

This topic was the subject of my PhD thesis prepared under the guidance of Professor Alfred Uchman. The results of the studies conducted for the PhD thesis and funded by a tutor's grant from Committee on Scientific Research (KBN) were presented at international and domestic scientific conferences, and a part of them were published (Jach, 2002) before obtaining the PhD degree in September 2003. I have continued investigations on this topic after obtaining the PhD in cooperation with scientists from my parent institution and other scientific centres in Poland, also under the auspices of a next KBN research grant.

One of the major achievements was demonstrating a shallowing trend during the deposition of the Pliensbachian and early Toarcian sediments in the Krížna Unit in the Western Tatra Mts. This trend is manifest in changing composition of the biosiliceous sponge assemblage that colonized a submarine elevation (Jach, 2002) and the appearance of crinoidal tempestites, initially distal and then, upsection, proximal, distinguishable by amalgamation of beds, presence of symmetrical ripplemarks and hummocky cross-stratification (Jach, 2005). The crinoidal tempestites were deposited between the normal and storm wave bases, proximal tempestites probably near the normal wave base. Accumulation of thick tempestite series was favoured by location of the studied basin at the corner of the extensive and narrowing westward Tethys Ocean.

Together with M. Gradziński, J. Tyszka and A. Uchman I have studied origin, ecological and palaeoenvironmental conditions of the growth of microbial-foraminiferal ferruginous oncoids in the condensed Toarcian red limestones (Adnet-type limestones) of the Krížna Unit of the Tatra Mts (Gradziński *et al*., 2004). The oncoids grew on a submarine high in conditions of low sedimentation rate. A novel conclusion of our study was that the growth of the microbial assemblage and encrusting foraminifers that formed the oncoids was favoured by oligotrophy of seawater in the Krížna Basin (Fatricum Domain) near the end of Early Jurassic. This conclusion is valid universally, it concerns the general rules of the development of foraminiferal-microbial associations and it was received positively in literature, as is shown by numerous quotations of our article (38 citations).

A collection of ammonites and nautiloids gathered by me from the Toarcian red limestones was taxonomically studied by R. Myczyński and presented in our joint publication (Myczyński & Jach, 2009). The obtained data, thanks to the precise location of the studied specimens in a detailed section, allowed us to refine the age of the red Toarcian limestones in the western Tatra Mountains. The concentration of ammonites and nautiloids confirms the low sedimentation rate of the limestones, earlier demonstrated on the grounds of macrooncoids (Gradziński *et al*., 2004) and autochthonous glauconite grains (Jach & Starzec, 2003).

I have also recognized facies diversity of the *Bositra*-crinoidal limestones overlying the red Toarcian limestones and analysed the factors that controlled their origin (Jach, 2007). I have demonstrated that the sediments are highly diversified laterally, depending on palaeobathymetry of the substrate. Basing on their position in the section, I had postulated their Early Aalenian – Early Bathonian age, which I later revised to Bajosian – Middle Bathonian on the grounds of chemostratigraphic data (Jach *et al*., 2014).

The study within the scope of the Ministry of Science and Higher Education project executed in years 2004–2006 (PB 2P04D 03127), of which I was the initiator and leader, concerned enigmatic Toarcian sediments, present only locally between the Chochołowska and Lejowa valleys. The detailed and multifaceted investigation, encompassing the analysis of microfacies, mineral composition and geochemical characteristics (including rare earth elements) has demonstrated that these sediments are related to a submarine vent (Jach & Dudek, 2005). The vent was fed with geofluids ascending along active faults. Benthic microorganisms grew near the vent and stimulated precipitation of manganese oxides in the form of laminated crusts and oncoids. The area was settled also by a specific faunal assemblage dominated by sediment feeders (echinoids and holothurians). This interpretation replaced earlier views that the manganese concentration was related to the so-called Toarcian anoxic event (Krajewski *et al*., 2001). According to our interpretation the studied sediments are a rare example of the record of activity of a submarine vent active at neritic depths. Modern equivalents of this vent are known only in a few places on Earth, including Gulf of California (Prol-Ledesma *et al*., 2004). This interpretation was met with positive reaction in literature.

The studies of the vent sediments found their continuation by discovering in these sediments of a unique monospecific assemblage of agglutinated benthic foraminifers. I have studied this assemblage together with palaeontologists J. Tyszka and M. Bubík, which resulted in describing a new species *Recurvoides infernus* and determination of its specific environmental requirements (deficit of oxygen, low pH; Tyszka *et al*., 2010). This species in one of the oldest representatives of the Recurvoidacea superfamily.

### Sedimentation of the Tatra Eocene

I have also investigated deposition of the sediments known as the Tatra Eocene. Together with M. Gradziński and A. Uchman, we have found numerous stromatolites and cyanobacterial oncoids in the basal part of Eocene conglomerates in the Sucha Woda valley (Gradziński *et al*., 2006). We have presented evidence of freshwater origin of the studied sediments. In the light of the results obtained, the stromatolites and oncoids represent fossil calcareous tufas, and their presence indicates that the basal part of the Eocene conglomerates of the Tatra Mts was laid down in continental environment. Indirectly, they prove activity of karst phenomena in the Tatra Mts before the Eocene transgression. I have confirmed this conclusion by studying, together with M. Gradziński and H. Hercman relics of fossil karst deposits preserved locally in the Western Tatra Mts beneath the red Eocene conglomerates (Jach *et al*., 2016).

As a part of an MNiSW research project led by E. Machaniec, where I was a main investigator, I participated in sedimentological studies of marine sediments of the Tatra Eocene. We have demonstrated that the sediments exposed in the classic site at Pod Capkami quarry record reaction of benthic assemblages dominated by large foraminifers to dynamically changing conditions of sedimentation, rising of sea-level in particular (Machaniec *et al*., 2011).

These studies resulted also in distinguishing and describing, together with E. Machaniec and A. Uchman three morphotypes of trace fossil *Nummipera eocenica* (Jach *et al*., 2012). We have found that the walls of individual morphotypes are composed of large foraminiferal tests (*Discocyclina*, *Nummulites*) of various morphology, which we have attributed to changing energy state of environment during sedimentation. Concentration of the studied trace fossils was interpreted as the result of decreasing sedimentation rate during the progress of transgression.

As a continuation of the studies on the Tatra Eocene I have proposed revision of a museum collection of fossil flora from marine sediments of the Hruby Regiel area. The studied assemblage is dominated by well-preserved leaves of Fagaceae and Lauraceae; also found were fruits of a *Nypa* palm typical of mangrove forests (Worobiec *et al*., 2015). The features of the described flora indicate its relation to tropical or subtropical evergreen forest. The degree of preservation of the floral remains suggests its deposition near the shore.

### Other directions of research

During my field work in the Western Tatra Mts I have found an earlier unknown site of slope breccias. Together with M. Gradziński and E. Stworzewicz we have demonstrated that the breccia was cemented during the Atlantic phase of the Holocene and that cementation was mainly the result of physicochemical processes controlled by $CO_2$ escape from solution (Gradziński *et al*., 2001).

My tutoring of an MSc thesis by E. Górnikiewicz resulted in discovering not earlier described specific carbonate encrustations in fractures of the Kramnica crag (Pieniny Klippen Belt). Together with M. Gradziński we have recognized them as a kind of a "missing link" between pedogenic and cave carbonates. An original conclusion was also indication that amorphous calcium carbonates were precursors of the microcomponents making up the encrustations.

I have found, in Holocene alluvium of the Raba river, "black oak" trunks with well-preserved galleries of a great capricorn beetle (*Cerambyx cerdo*), complete with its subfossil larvae, pupae and adult individuals. This finding sparked interdisciplinary study conducted together with S. Knutelski, A. Uchman, H. Hercman and M. Dohnalik, which resulted in identification of various developmental stages of great capricorn beetle, description of its feeding ground with the aid of x-ray microtomography (micro-CT; Jach *et al*., 2018, Knutelski *et al*., 2018). An important part of the study was dendrochronologic and radiocarbon dating, which have shown that the subfossil "black oaks" and the subfossil great capricorn beetles within them correspond mainly to the Roman Warm Period (45 BCE to 558 AD). The mass accumulation of the oak trunks is related to the phase of climate humidification in the watershed of the Vistula River, after which the conditions for existence of great capricorn beetle deteriorated as a result of climate cooling in the Dark Ages Cold Period.

My scientific interests embrace also geological structure of the Kraków region, which is related to the topic of my MSc thesis on the geological structure of the vicinity of Brodła near Alwernia (Jach, 2000). This interest resulted in my co-authoring of a chapter on geological structure and karst phenomena of the Ojców National Park, published as a part of the OPN monograph (Gradziński *et al*., 2008).

A consequence of my scientific interset in geology of the Tatra Mts was co-editing, together with T. Rychliński and A. Uchman, a monograph which consists of detailed descriptions and illustrations of all the sedimentary rocks of the Tatra Mts (Jach *et al*., ed., 2014). The monograph including chapters written by 20 authors and contain 278 pages was published by the Tatra National Park.

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