ABHANDLUNGEN

2010

BAND 65

Harald Lobitzer, Christoph Janda (Eds.)

FIFTY YEARS OF GEOLOGICAL COOPERATION BETWEEN AUSTRIA, THE CZECH REPUBLIC AND THE SLOVAK REPUBLIC

Geologische Bundesanstalt

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Fossils from the Jurassic of Bad Mitterndorf.
MANDL et al. (2010), Verh. Geol. B.-A., 65, Wien.
Geological map of Austria 1 : 50.000, map sheet 8-Geras.
ROETZEL et al. (2001), Geol. B.-A., Wien.
Sedimentary structures in Cretaceous Ressen Formation.
LOBITZER et al. (2010), Verh. Geol. B.-A., 65, Wien.

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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

Foreword from the Director of the Czech Geological Survey

Joined for millions of years by the geological setting, hundreds of years together in one empire, then separated by state and political borders, and currently living all together in the European Union. Geologists of the neighbouring countries, Austria and originally Czechoslovakia, then Slovakia and the Czech Republic, have always been eager to collaborate closely and join efforts to solve common geological challenges. Geological units do not respect state borders, the Bohemian Massif stretches far into Austria, the Vienna Basin forms a part of Moravia, and the Carpathians straddle the boundaries. This year we commemorate 50 years of the official collaboration underpinned by agreements between the respective geological surveys. Let me remember those who organised the collaboration on the Czech side over the years: since the beginning it has been Dr. Dagmar Minaříková and for the last 18 years it has been Dr. Lenka Hradecká. This is the right opportunity to express my warm thanks for her work, that Lenka put into the international collaboration of the Czech Geological Survey.

Our intention was always for the collaboration to equally serve both parties. To tell the truth, however, it surely was of more benefit to us. Above all, before 1989 it helped open the doors of the European geology. We will also remember our Austrian colleagues who supported our admission in EuroGeoSurveys. Apart from the work on common geological problems like the correlation of stratigraphic and crystalline units, joint mapping and other topics, the research into the history of geology in both countries was fruitful. We should recall the role of Czech geologists in studies of Tyrol, Styria and Salzkammergut, as well as Austrian geologists mapping the Bohemian Massif. We are pleased that our colleagues appreciate the ongoing collaboration on the stratigraphy of the Eastern Alps, the Quaternary of the Pannonian Basin and other areas. As to future collaboration, I believe it lies in joint projects which deserve financing from the European research resources. Cross-border collaboration with Austria will always be a stable part of our future objectives.

Zdeněk Venera
Director of the Czech Geological Survey
Prague

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Foreword from the Director of the State Geological Institute of Dionyz Stur in the Slovak Republic

A few years after the creation of the two independent states of the Slovak and Czech Republics the directors of SGUDS and GBA signed the first cooperation agreement in Vienna on May, 26th 2005. The following topics were agreed upon:

Exchange of geological literature, documentation and geological materials.

Exchange of historical geological maps of both countries for digitalization purposes.

Cooperation in correlation studies:

- the Eastern Alps and Western Carpathians in general.
- the Small Carpathians versus Hundsheim Hills.
- Stratigraphy and facies in Mesozoic units.
- Neogene and Pleistocene volcanics.

Environmental geology, public awareness and raw materials.

Geological workshops and excursions.

Since then these topics of cooperation continued. The bilateral agreement was regularly updated annually and signed by the directors of both surveys in the framework of the Central European Initiative meetings.

Beside those recent projects, cooperation already existed before, as for example:

- the environmental project DANREG (1996–1998).
- the geological map of the Western Carpathians and adjacent areas 1 : 500.000 (1998–2000).
- the exchange of data from the Slovakian part of the Vienna basin and new geological data from the Hundsheim Hills (2009).
- intensive cooperation on the base of updating the libraries of both surveys (up to 2010) regarding books and journals.

Finally we need to mention a cooperation which was unofficial but very fruitful. The basic geological mapping in the Tauern region (1 : 50.000), when a group of geologists mainly from SGUDS remarkably contributed to the compilation of the geological map of this area in the course of four mapping seasons in the nineties of the last century.

An outline of possible future development of cooperation:

- cooperation in the CCS problematic within the Vienna Basin.
- cooperation by creation of a crossboundary geopark in the locality Hundsheim Hills – Devínska Kobyla area.
- cooperation in geological mapping at the scale 1 : 50.000 in Austria.

Branislav Žec
Director of the State Geological Institute of Dionyz Stur
Bratislava

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Foreword from the Director of the Geological Survey of Austria

Geology turned out to be a moderating factor in Central Europe during the time of cold war. This was proven during the second half of the 20th century by the excellent co-operation between our three surveys.

The gasfield Zwerndorf-Vysoka, straddling the boundary between Austria and the Slovak part of former ČSSR was the trigger for signing the cooperation agreement in 1960. Sharing data and building a combined geological model across borders has been a topic from the beginning and continued until today. Basic geological research, which included stratigraphy, sedimentology, tectonics as well as geological mapping, were the main tasks of our cooperation between 1960 and 1990. I myself was member of the Austrian delegation and attended several annual exchange meetings during the 1980s and remember them well. The sharp contrast between the spirit of understanding and cooperation between us, the geoscientists, and the official political climate of divergence and opposition between our countries, left a deep impression on me, which I will never forget. We believed that our work is important for society. We dealt with local subjects like facies developments, tectonics and on a bigger scale with the gravity field in Central Europe, the generation of hydrocarbons in the Vienna Basin and the Molasse, and age dating of granitic bodies in the Variscian realm and others. I want to express our deep gratitude to Dr. Harald Lobitzer, who managed the Austrian part of the scientific program in an excellent and efficient manner for decades.

The political changes in Europe in 1989 we regard today as positive developments. The impact on sciences and especially geosciences we did not foresee at all. The acceptance of governments in Europe, regarding Geological Institutes and their work as very important for society, was still there during the 1990s. In recent years this understanding diminished and nearly disappeared, mainly under the pressure of commercialisation of sciences in general and budget constraints. The reduced governmental share of our budgets forces us to search for so-called third party funds. This is reshaping our geological surveys just now.

The cooperation between our surveys turned from bilateral basic research issues into multiparty research subjects funded by EU money. Still, a few bilateral basic research projects are possible, persued by specialists, some of them already retired. We want to continue with this and support this as good as we can. In the future we will definitely participate in bigger European projects as partners together with others.

We believe, that in the framework of those big projects, there is still room for good understanding, scientific exchange and discussion of bilateral and trilateral questions of common interest. Together, as a group of friends and experts with excellent knowledge and skills, we will have a strong voice in Europe and the geoscientific community.

Peter Seifert
Director of the Geological Survey of Austria
Vienna

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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

50 Years of Geological Cooperation with the Czech Republic and the Slovak Republic – the Austrian Point of View

THOMAS HOFMANN*

5 Text-Figures, 1 Table

Cross-border cooperation
Geological correlation
Geological research
Geological maps
Iron Curtain
DANREG

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50 Jahre geologischer Kooperation mit der Tschechischen und Slowakischen Republik – Die österreichische Perspektive

Zusammenfassung

Im Zuge des 1960 begründeten bilateralen, später trilateralen Kooperationsvertrages zwischen Österreich und der damaligen Tschechoslowakei auf dem Gebiet der Geologie konnten in den letzten 20 Jahren aus österreichischer Sicht große Fortschritte für die österreichischen Geowissenschaften erzielt werden. Zu nennen sind hier insbesondere die geologische Kartierung und die Grundlagenforschung. Ohne Mithilfe tschechischer und slowakischer GeologInnen hätten in beiden Bereichen viele wichtige Ergebnisse nicht erzielt werden können.

Abstract

Due to the bilateral and later trilateral cooperation act between Austria and former Czechoslovakia in the fields of geology, which dates back to 1960, from the Austrian point of view great advances were achieved within the last two decades. This concerns especially geological mapping and basic research. Without the help of Czech and Slovak geologists many scientific results in both fields would never have been achieved.

Introduction

The geological cooperation between Austria, the Czech and the Slovak Republic (former Czechoslovakia) goes back to 1960. On January 23rd, 1960 an *"Agreement between the Federal Government of Austria and the Government of Czechoslovakia Republic in the principles of cooperation in the field of geology between the Republic Austria and the Czechoslovakia Republic"* was signed (MINAŘÍKOVÁ & LOBITZER, 1990a, p. 8) between Austria and Czechoslovakia to stimulate and to regulate the exchange of geological information between both countries. The agreement covered all fields in geosciences; an additional agreement – which was signed the same day – concerned the exploration and exploitation of hydrocarbons in the border area. Based on this agreement annual meetings alternating between both countries were arranged to discuss geological questions. Plans for the following year

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were worked out including a detailed program for the exchange of persons. Especially during the first three decades, when the Iron Curtain separated both countries, this exchange was the fundamental basis for geological cooperation and correlation. Based on this cooperation Austria supported Czechoslovakia in 1968, when the 23rd International Geological Congress (IGC) was held in Prague. Two excursions (32 C, 33 C) were organized by Austrian teams (Frasl et al., 1968; Grill et al., 1968), the excursion guides were published by the Geological Survey of Austria.

This contribution shows the Austrian point of view and focuses on the last 20 years of cooperation, the period from 1990 to 2010. Thus the results are outlined, especially in the fields of geological mapping and basic research (e.g. stratigraphy) which were achieved by the help of Czech and Slovak geoscientists.

Milestones in the Period 1990 to 2010

The first period (1960–1990) is documented in the festival volume "Thirty Years of Geological Cooperation between Austria and Czechoslovakia" edited by Dagmar Minaříková & Harald Lobitzer in 1990. This volume comprises 42 original papers and three informative reports in six thematic sections (Minaříková & Lobitzer, 1990b).

At the end of the 1980s and the beginning of the 1990s many states in Central and Eastern Europe (CEE) had a more or less turbulent change in the political regimes. The Iron Curtain separating Austria from Czechoslovakia since the end of World War II was cut through in December 1989 in an official act by the Austrian and the Czechoslovak Foreign Ministers in Laa an der Thaya, an old town in northern Lower Austria close to the border to Southern Moravia. Moreover, on January 1st, 1993, Czechoslovakia was divided into the Czech Republic and the Slovak Republic. The *"Agreement between the Federal Government of Austria and the Government of Czechoslovak Republic in the principles of cooperation in the field of geology between the Republic Austria and the Czechoslovak Republic"* was formally transformed into two identical agreements with the two countries with the same content as the previous one.

From Formal Bilateral Meetings to Multilateral Talks

The 34th meeting, which was held on July 30th, 1993, in Vienna was the first meeting of the new bilateral agreement with geoscientists of the Czech Republic, as well as the first meeting of the bilateral agreement with the Slovak Republic.

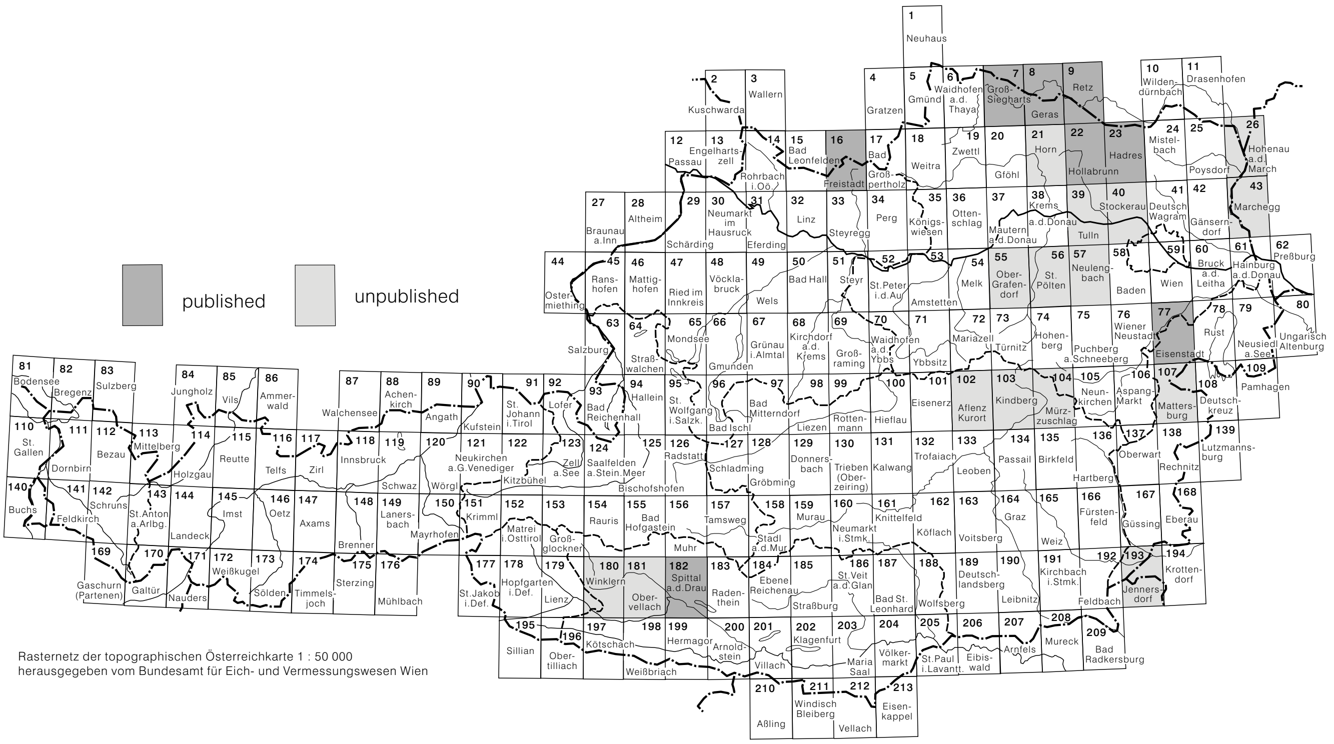
From then to the 45th meeting (2004) the directors met alternatively in one of the countries to discuss the working program, which has got two strong focuses: geological mapping and basic research on special topics. Meanwhile (1992) Czechoslovakia and Hungary became members in the Forum of WEGS (Western European Geological Surveys). This was initiated and strongly supported in 1990 by Traugott E. Gattinger (1930–2006), director (1983–1992) of the Geological Survey of Austria and member of WEGS. As a consequence of the entry of "eastern" countries into WEGS the Dutch and Austrian Directors suggested to rename WEGS into FOREGS (Forum of European Geological Surveys). This informal group ceased its activities in September 2005 and since then EuroGeoSurveys took over its tasks and responsibilities (EGS-Website, 2010).

In this period many more geoscientists from the Czech and Slovak Republic came to Austria to support Austrian geologists in their work with their know-how, than Austrians went abroad. The bilateral exchange became more and more a kind of a one way system. Harald Lobitzer was the central person in Austria managing all the exchange and cooperation between the Geological Survey of Austria and the Geological Surveys of the CEE-States like Czechia, Slovakia, Hungary and Slovenia.

It was the idea of Hans P. Schönlaub, director of the Survey from 1993 to 2007, to bring together the directors of the neighboring countries at one table for common discussions. On May 27th, 2005, one day after the official opening ceremony of the new building of the Geological Survey of Austria at Neulinggasse 38 the directors of the Geological Surveys of Czechia, Slovakia, Hungary and Slovenia met to share their experiences and to sign their bilateral agreements. In traditional counting it was the 46th meeting of the

Number of meeting / partners	Date	Location
47th / 14th Meeting A – CZ and A – SK	May 30th–31st, 2006	Prague (CZ)
Common meeting of the Geological Surveys of Austria, the Czech Republic, Slovakia, Slovenia, Hungary and Poland.		
48th / 15th meeting A – CZ and A – SK	June 5th– 6th, 2007	Krakow (PL)
Common meeting of the Geological Surveys of Austria, the Czech Republic, Slovakia, Slovenia, Hungary, Poland and Croatia.		
49th / 16th meeting A – CZ and A – SK	June 10th–11th, 2008	Banská Stiavnica (SK)
Common meeting of the Geological Surveys of Austria, the Czech Republic, Slovakia, Slovenia, Hungary, Poland and Croatia.		
50th / 17th meeting A – CZ and A – SK	May 21st–22nd, 2009	Krajnska Gora (SL)
Common meeting of the Geological Surveys of Austria, the Czech Republic, Slovakia, Slovenia, Hungary, Poland and Croatia.		
51st / 18th meeting A – CZ and A – SK	June 30th, 2010	Budapest (H)
Common meeting of the Geological Surveys of Austria, the Czech Republic, Slovakia, Slovenia, Hungary and Poland.		

Table 1:
Meetings of CEE Geological Surveys in the last five years.



Text-Fig. 1.
Scheme of maps 1:50.000 with contributions from Czech and Slovak geologists.

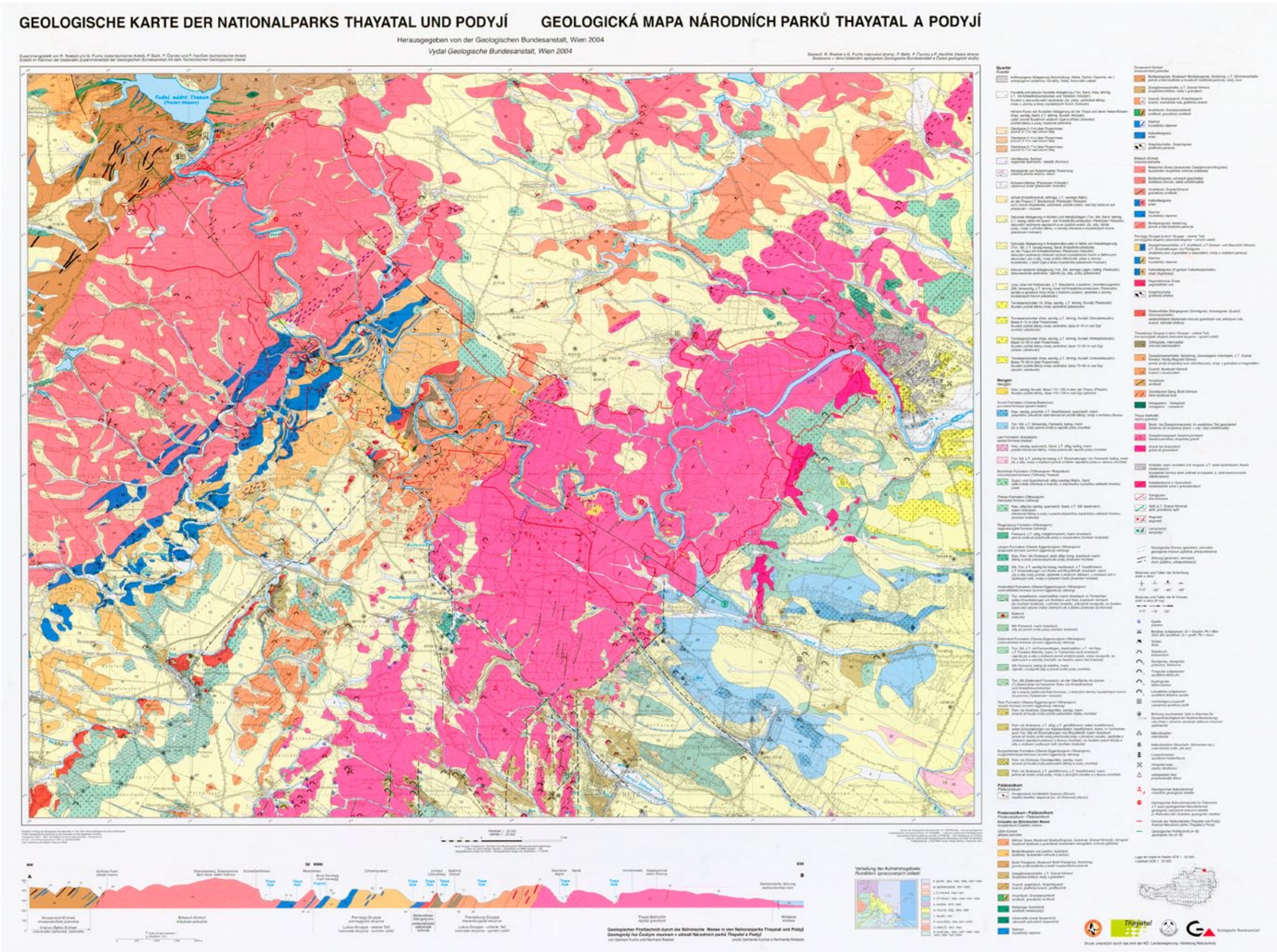
agreement with the former Czechoslovakia, i.e. the 14th meeting with the Czech Republic and the Slovak Republic.

Though the Directors of the Geological Surveys of Austria, the Czech Republic, Slovakia, Slovenia, Hungary, Poland and Croatia met in EuroGeoSurveys, they decided to keep the informal meetings once a year to share ideas and discuss common problems in "alpine" countries. This might also have been supported by the common history of the k.k. Geologische Reichsanstalt of the Austro-Hungarian Empire. In consideration of this rather regional point of view the Geological Survey of Austria (again) got a central position in CEE. EuroGeoSurveys turns out as a diverse group of 32 members ranging from Scandinavia to the Mediterranean covering the European point of view.

Geological Maps

Due to the fact, that geology ignores any political border, cross-border cooperation has always been one of the most important points especially in geological mapping. Matějovská (1990) resumes: *"There exists a good cooperation between the Geological Survey in Prague and the Geologische Bundesanstalt in Vienna focused on mapping of areas along the Czechoslovak-Austrian state border."* Map sheet Groß-Siegharts (Nr. 7) within the Series "Geological Map of the Republic of Austria 1:50.000" is an important example because it has been completed during the time of the "Iron Curtain". The map covers in its northern part Czech area, which was mapped by Vladimir Jenček and Olga Matějovská. The Austrian part was mapped to a great extent by Otto Thiele who compiled and edited the map in 1987 (Jenček et al., 1987). Further examples (Text-Fig. 1) of this very positive cross-border cooperation are the map sheets Geras (Nr. 8) by Roetzel & Fuchs (2001), Retz (Nr. 9) by Roetzel et al. (1999) and Hadres (Nr. 23) coordinated by Roetzel (2007). Other map sheets lying south of the above mentioned cross-border sheets, like Hollabrunn (Nr. 22) by Roetzel (1998) or Tulln (39) – the latter with ongoing mapping activities – could never have been realized without the massive help and support of mapping teams from the Czech Geological Survey. Examples like the above mentioned underline the importance of sharing knowledge in cross-border geological units like the Bohemian Massif, the Molassezone, the Vienna Basin or the Waschberg-Zdanice Unit. The experience was also shared to produce a series of four thematic geological maps of the Vienna Basin (1 : 200.000) including the Czech and Slovak regions of the basin. The corresponding explanatory notes (Kröll et al., 1993) are also a result of common research. The geological map of the Thayatal National Park (Text-Fig. 2) which also covers the area of the neighboring Podyji National Park is one more outstanding example of the bilateral cooperation. It is a bilingual product, titled as "Geologische Karte der Nationalparks Thayatal und Podyji 1 : 25.000 = Geologická mapa Národních parků Thayatal a Podyjí 1 : 25.000". Both languages are used equally even at the legend (for details see: Roetzel et al., 2004).

In addition to cross-border maps a number of other Austrian map sheets benefited from the support of Czech and Slovak geologists. In the early 1990s Slovak geologists (Kovac et al., 1992, 1993) contributed to map sheet Eisenstadt (77), published 1994 by Pascher & Brix. Some other Slovak geologists (Bezak et al., 1993, 1994, 1995) mapped at map sheet Spittal an der Drau (182) in Carinthia, which was published in 2006 (Pestal et al., 2006). On many other map sheets like Horn (21), Hohenau (26),



Text-Fig. 2.
The geological map of Thayatal National Park and Podyji National Park is an outstanding example of transboundary bilateral cooperation. Both languages are used equally for the title and the legend.

Mautern (37), Krems an der Donau (38), Stockerau (40), Marchegg (43), Obergrafendorf (55), St. Pölten (56), Neulengbach (57), Aflenz (102), Kindberg (103), Mürzzuschlag (104), Mattersburg (107), Winklern (180), Obervellach (181) and Jennersdorf (193) – most of them not yet published – some areas were worked out in detail (mostly mapping) by Czech and Slovak geoscientists. The reports of the mapping activities are regularly published in the "Jahrbuch der Geologischen Bundesanstalt" which can be found at the website (www.geologie.ac.at) as free download in PDF format. The manuscripts of all maps, published or not published yet, are stored in the archive of the Geological Survey of Austria.

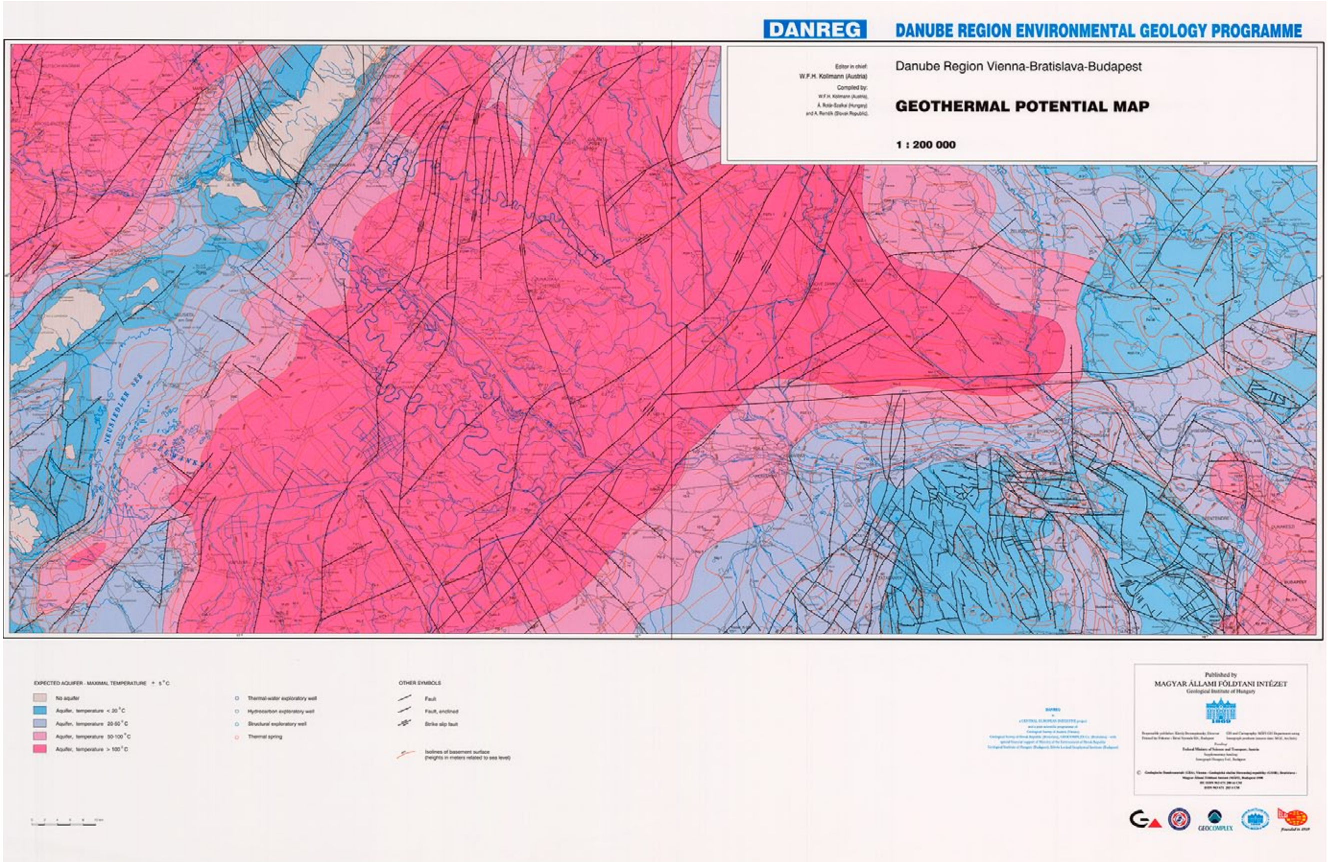
Basic Geological Research

In addition to mapping activities a lot of work has been made (and is still carried out) focusing on the fields of biostratigraphy, taxonomy, (micro)paleontology, micromorphology, microfacies, geophysics and petrology. Since the early 1980s Harald Lobitzer has been leading a working group of Czech, Slovak, Hungarian, and Austrian specialists in the Salzkammergut Region (Upper Austria, Styria) to work out details in the Mesozoic of the Northern Calcareous Alps, especially in the Gosau Group. The program is called "Studium mesozoischer Stratotypen/Studies of Mesozoic stratotypes".

Experts like Miloš Siblík (brachiopods), Lenka Hradecká (foraminifera), Jiří and Zlatko Kvaček (plant remains), Marcela Svobodová (pollen), Lilian Švábenická (nannofossils), Miloslav Rakús (cephalopoda), Jan Mello (cephalopoda), Slavomír Nehyba (sedimentology), Libuše Smolíková (micromorphology of loess), Miroslav Bubík (foraminifera), Karel Breiter (petrology), Ivan Gnojek (ground geophysics), Antonín Přichystal (ground geophysics), Zdeněk Vašíček (cephalopoda), Rostislav Brzobohatý (otoliths), Jiří Kovanda (molluscs), Anna Ondrejíčková (radiolarians), Bohumila Bezvodová (mineralogy, geochemistry), Żdeňka Řeháková (diatoms) and some others (only Czech and Slovak experts are listed here) largely contributed to solving a number of geoscientific questions. The results – so far a lot of published reports – are a fundamental basis for the explanatory notes of geological maps which are published after the issue of the maps, sometimes years later.

The DANREG Project

In 1989 Hungary and Slovakia started a bilateral project to prepare various geoscientific maps (with environmental focus) in the common Danube area, which was joined by Austria in 1990. Details are available at the Website of the Geological Institute of Hungary (MAFI Website, 2010):



Text-Fig. 3.
Geothermal potential map (1:200.000) published 1998 as part of the DANREG project.

“The main objective of the Danube Region Environmental Geological Program (DANREG) was to adjust the geological and geophysical data available in the cross-border region of the three partner countries (Slovakia, Austria and Hungary) in a harmonised framework with particular emphasis on the area along Danube river running across the three capitals. The project facilitated the harmonised interpretation of data providing thus considerable help to decision makers engaged in land management of the area. The Geological Institute of Hungary (MÁFI) and the Geological Survey of the Slovak Republic (Geologický ústav Dionýza Štúra [GÚDS]), later Geologická služba Slovenskej republiky (GSSR) and Státny geologický ústav Dionýza Štúra (SGÚDS) since 2000 signed a mutual agreement in 1989 aimed at compiling in co-operation the geological maps of the cross-border area along the Danube. In 1990 the Geological Survey of Austria (Geologische Bundesanstalt, GBA) also joined to the agreement. Geophysical surveying related to the program was executed by Geocomplex a.s (Bratislava), Eötvös Loránd Geophysical Institute of Hungary (Budapest), as well as the Vienna Meteorological and Geophysical Institute, the Vienna University and the OMV Aktiengesellschaft.”

The DANREG Project was also appreciated by the CEI (Central European Initiative). The official closing ceremony of the DANREG Project was in Budapest from 26th to 30th of May 1997, some maps and the explanatory book (CSÁSZÁR, 2000) were printed later.

Thematic Maps Compiled by the DANREG Project

1 : 100.000 maps

Surface geological map
Map of the environmental geohazards

1 : 200.000 maps

Bouguer anomaly map
Engineering geological map
Geothermal potential map (Text-Fig. 3)
Hydrogeological map
Neotectonic map
Lithofacies & thickness map of the Pannonian
Lithofacies & thickness map of Pontian and the Pliocene
Map of the Pre-Tertiary basement
Map of genetic types & thickness of Quaternary sediments
Tectonic map
Geological cross-sections

1 : 500.000 maps

Stripped gravity anomaly map
Magnetic ΔT anomaly map
Gravity lineament map
Results of the magneto-telluric measurements
Contour map of the Pre-Tertiary basement
Contour map of the Pannonian basement
Thickness of the Quaternary sediments
Apparent resistivity map AB = 200 m

Czech and Slovak Correspondents of the Geological Survey of Austria

One possibility to express recognition for geological merits is to nominate a person for being "Korrespondent der Geologischen Bundesanstalt" (Correspondent of the Geological Survey of Austria). This tradition dates back to the k.k. Geologische Reichsanstalt (founded in 1849). Persons making donations or having contact with the survey were called "Korrespondent der k.k. Geologischen Reichsanstalt". Their names were listed in the "Jahrbuch der k.k. Geologischen Reichsanstalt" (Yearbook). After the collapse of the Austrian-Hungarian Empire in 1918 this tradition was interrupted. When Heinrich Küpper (1904–2000) was director of the Survey (1950–1969), he re-established the tradition of "Correspondents" to express gratitude to people for contributing in some way to the survey. The Correspondents are listed in the respective annual reports. The list of Czech and Slovak Correspondents shows a rather high number of geoscientists in the years 1999 and 2009 underlining that the Austrian Geological Survey is grateful to many persons supporting the work of the survey in the recent past.

125 Years of the Geological Survey of Austria September 12th, 1975

Oto Fusan (Bratislava)
Josef Pravda (Prague)

Text-Fig. 4.
Zdeněk Stráník (Brno) left side, receives the title "Korrespondent der Geologischen Bundesanstalt" (Correspondent of the Geological Survey of Austria) from Director Peter Seifert (Photo: M. Brüggemann-Ledolter).

150 Years of the Mining Museum (Montanistisches Museum), the ancestor of the k.k. Geologische Reichsanstalt, November 15th, 1985

Jaroslav Vacek (Prague)
Jan Kuran (Bratislava)
Jan Gašparík (Bratislava)

150 Years of the Geological Survey of Austria November 15th, 1999

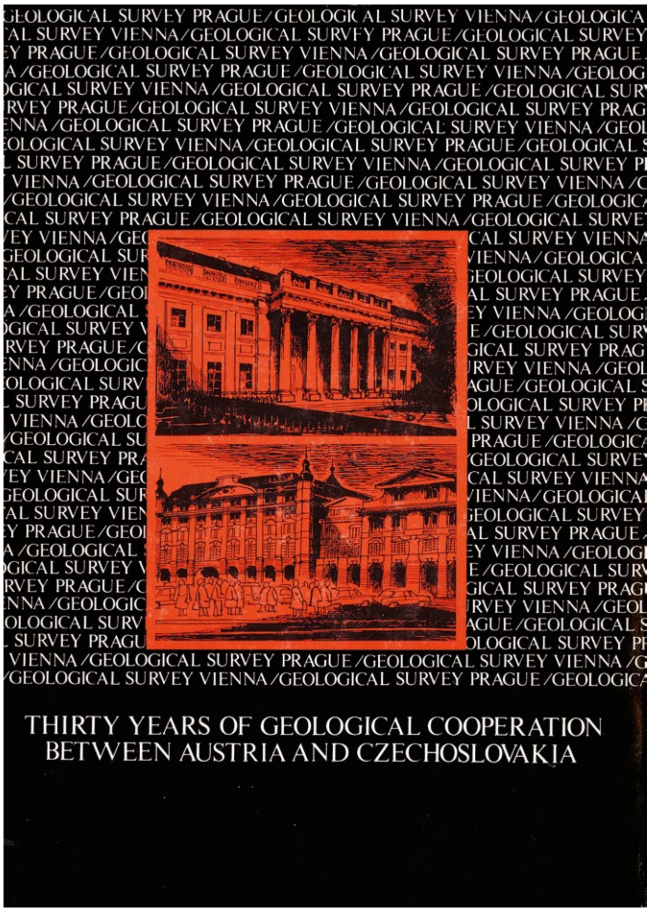
Lenka Hradecká (Prague)
Jan Mello (Bratislava)
Karel Pošmourný (Prague)
Miloš Siblík (Prague)
Lilian Švábenická (Prague)
Josef Vozár (Bratislava)
Eva Zacharova (Bratislava)

160 Years of the Geological Survey of Austria November 17th, 2009

Ivan Cicha (Prague)
Zdeněk Stráník (Brno)
Marcela Svobodová (Prague)

Festival Volumes

The festival volume of 30 years of geological cooperation (Minaříková & Lobitzer, 1990) was initiated at a meeting in Mikulov on November 30th, 1988 and completed in 1990 (Text-Fig. 5). It was produced and printed in Prague,



Text-Fig. 5.
"Thirty Years of Geological Cooperation between Austria and Czechoslovakia". The festival volume was published by D. Minaříková from the Czechoslovakian Geological Survey and H. Lobitzer from the Austrian Geological Survey in 1990.

and issued at the beginning of 1991. In the foreword the Directors of both surveys, J. Vacek and T.E. Gattinger, expressed the benefits of cooperation and pointed out some future aspects: *"As examples, the increase in understanding of the geological features of the Bohemian Massif or the Tertiary basins may be quoted. The publication in hand is a expression not only of the studious work of the geoscientists of both countries and of the multiplicity of the treated subjects, but it especially reflects the sense and spirit of cooperation in good neighbourly relationship. It can be called an 'European Challenge' to preserve and promote this sense and spirit for further decades of fruitful common geological research."* (Vacek & Gattinger, 1990).

On the occasion of the 150-years anniversary of the Geological Survey of Austria a festival volume was issued in the series of the Abhandlungen der Geologischen Bundesanstalt as volume **56**/1+2. The editors Harald Lobitzer (Wien) and Pavol Grecula (Bratislava) issued volume **56**/1 (28 papers, 460 pages) for the celebration act on November 15th, 1999. Volume **56**/2 was published one year later (30 papers / 738 pages). Both were printed in Slovakia (Kosice). This volume (Lobitzer & Janda, 2010) includes a total number of 14 papers dealing with various geological aspects from Austria, the Czech Republic and the Slovak Republic including also authors from Hungary.

Conclusion

Within the last 50 years the contributions of Czech and Slovak geoscientists for the geology of Austria became more and more important. Many examples from various disciplines in geosciences demonstrate that geology at large in Austria profited a lot from contributions of Czech and Slovak geoscientists. The Austrian-Czech-Slovak tradition of geological cooperation within the last fifty years (1960–2010) also has a greater dimension, showing that different political regimes cannot form a permanent obstacle for scientific work. Thus this example from CEE might encourage countries all over the world to work on common scientific themes, even if it seems impossible at first glance.

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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

Geochemical classification of Variscan Granitoids in the Moldanubicum (Czech Republic, Austria)

KAREL BREITER*

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Bohemian Massif
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Geochemistry
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Contents

Geochemische Klassifikation der variszischen Granitoide des Moldanubikums (Tschechische Republik, Österreich)

Zusammenfassung

Die variszischen Granitoide des Moldanubikums werden in Gruppen (Suiten) eingeteilt, die mit den aufeinanderfolgenden Stadien der variszischen Orogenese einhergehen. Es können folgende Gesteinssuiten unterschieden werden: 1. Durbachite und mit diesen assoziierte Gesteine (~340 Ma); 2. Weinsberger Granit (Biotitgranit vom I-Typ: ~328 Ma); 3. Lásenice Granit; 4. Čímĕř Granit („Zweiglimmergranit"); 5. Eisgarner Granit sowie begleitende Sn-, Nb-, Ta-, U-Muskowit-Granite (~324 Ma); 6. Mauthausener Suite (Granite vom Biotit-Typ I, späte Intrusionen mit Mo-Mineralisation: ~315 Ma); 7. Freistätter Suite (Biotitgranite und Granodiorite vom I-Typ: ~305 Ma).
Die relative Abfolge aller dieser Gesteinssuiten ist geologisch untermauert, dennoch können die Isotopenalter der verschiedenen Intrusions-Phasen innerhalb einer Gesteinssuite stark schwanken.

Abstract

Variscan granitoids in the Moldanubicum are classified in groups and suites, which represent successive evolutionary stages of the Variscan orogenic process. Proposed suites are: 1. durbachites with associated rocks (~340 Ma); 2. Weinsberg granite (I-type biotite granite, ~328 Ma); 3. Lásenice granite (granite minimum melt); 4. Čímĕř granite (peraluminous granite); 5. Eisgarn s.s. granite with associated Sn, Nb, Ta, U enriched muscovite granites (~324 Ma); 6. Mauthausen suite (I-type biotite granites, late fractionated intrusions with Mo-mineralization) (~315 Ma); 7. Freistadt suite (I-type biotite granites and granodiorites, ~305 Ma).
The relative succession of all rock suites is documented geologically; nevertheless, the isotopic ages of individual bodies (intrusions) within the suite may vary largely.

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Introduction

From the old classical geological maps of the Moldanubicum (HAUER, 1867–1871), granitoids are classified according to the petrographic rock name (granite, granodiorite, syenite etc.), their mineral composition (biotite, two-mica, amphibole etc.), and texture (fine- to coarse grained, porphyritic or equigranular). This "traditional" style of classification compatible with the international nomenclature (LE MAITRE, 2002) is accepted also in the most recent synthetic maps (CHÁB et al., 2007; SCHNABEL, 2002; KRENMAYER & SCHNABEL, 2006; TEIPEL et al., 2008) (Text-Figure 1).

Beside the general petrographic names, many granite bodies obtain specific local names during mapping and were classified as "type Xy". Especially among two-mica granites, tenths of local names ("types"), were defined, redefined, abandoned, and again used in a different sense. Geological names are mixed, and sometimes are in confusion, with traditional names of the quarrying districts. For example, KOUTEK (1925) and ZOUBEK (1949) introduced for granites in the "Central Moldanubian Pluton", according to their texture, the local names Mrákotín, Čímĕř, and Landštein. WALDMANN (1950) used the name Eisgarn originally for the coarse-grained porphyritic two-mica granite in the vicinity of the eponymous village N of Gmünd. This name was later incorrectly used as synonym for all varieties of medium- to coarse-grained two-mica-granites through the whole Moldanubicum. Similarly, the name "Mauthausen granite" (RICHTER, 1965) was used for all bodies of the fine-grained biotite or two-mica granites. Local rock names are also used in printed geological maps of larger scales (1:50.000, 1:25.000) in Austria and the Czech Republic. This style of classification complicated any discussion among geologists working in this area. And geologists not familiar with the history of the geological investigation of the Moldanubicum and the local literature, do not understand this terminology at all.

Massive entrance of chemical and later isotopic methods in the last forty years demonstrated a much more complicated structure of individual granite plutons and Moldanubian granitoids on the whole. The real geological units, defined geochemically and structurally, are not consistent with traditionally outlined "granite types". But the geological maps keep the old "classical" concepts.

Several attempts at a new genetic classification (FINGER et al., 1994, 1997; GERDES, 1997; GERDES et al., 1998) focused namely on the Weinsberg- and Freistadt-Mauthausen units and other granites typically developed in Austria. On the other side, the two-mica granites were preferentially studied in Bohemia (BREITER et al., 1998, 2007; BREITER & KOLLER, 1999; RENE, 2001).

Unfortunately, many isotopic ages are reported as "age of X-type granite" without accurate specification of the locality. This made usability of those data problematic, namely in case of the so-called Mauthausen and Eisgarn-type granites.

The purpose of this paper is, based on available geochemical data, to define major evolutionary units of Variscan granitoids in the Moldanubicum (South Bohemian Pluton, SBP), to outline these units in maps (Text-Figure 2), and provoke further discussion of this topic among Austrian and Czech geologists.

Data

The proposed classification is based on an extensive set of chemical, petrological and mineralogical data from all types of granitoids in the Czech part of the Moldanubicum, and from the peraluminous (two-mica) granites of the Austrian and German parts of the Moldanubicum collected by the author during the last twenty years of field investigation. Data from literature were used for classification of other types of granitoids from Austrian and German territories.

Proposed Geochemical Classification of Granitoids

All Variscan igneous rocks in the Moldanubicum should be, according to their geological relations (relative age), divided into three major rock groups:

1. granitoids older than major intrusions of peraluminous granites,
2. major intrusions of peraluminous two-mica granites (incorrectly called "Eisgarn-type granites"),
3. granitoids younger than major intrusions of peraluminous granites.

Each of the rock groups contains several intrusive suites of related granitoids. While the relative age of rock groups is well documented, the relative age of some suites, which are not in direct intrusive contact, remain in some cases unclear and may be interpreted in different ways (Weinsberg granites vs. glimmerites or Weinsberg granites vs. Lásenice granites).

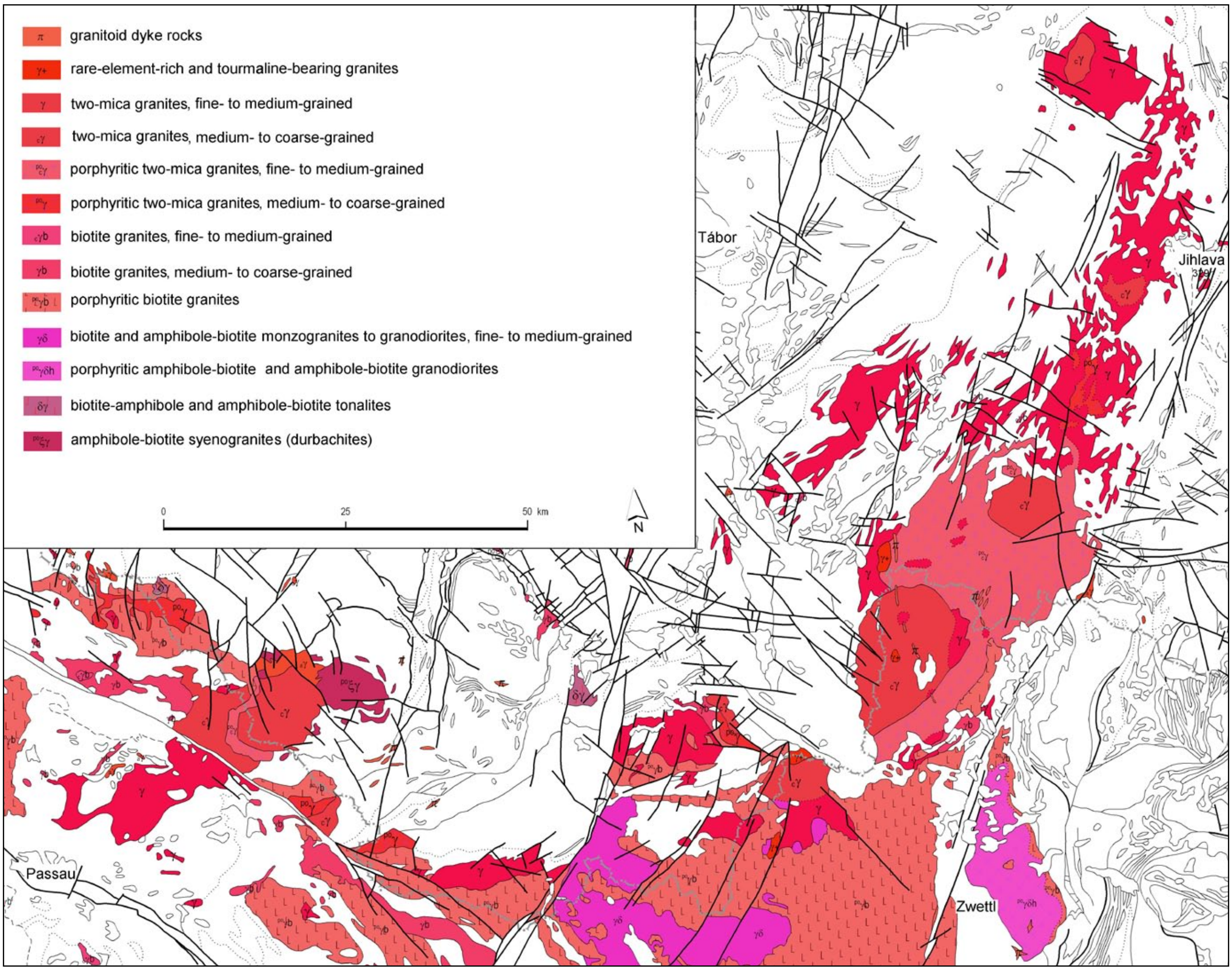
Older Group of Intrusions (pre-Eisgarn)

Suite of K- and Mg-rich Granitoids

Mafic K-Mg-rich biotite (± hornblende) melasyenite (with around 58–65 % SiO_2, 4–8 wt % MgO, 6.0–6.5 wt % K_2O, high in Ba, Sr, Th, U, Zr, xMg = 0.6–0.7), termed **durbachite,** is one of the most typical Variscan magmatic rocks of the Moldanubicum. Beside large well-known bodies through the southern Czech Republic (Třebíč, Knížecí stolec, Netolice), several small more basic (<50 wt % SiO_2) bodies were recently found in the Dreiländereck area (South Bohemia – Bavaria – Upper Austria) (BREITER & KOLLER, 2009). The very probable age of major durbachite intrusions is about 340 Ma.

The **Rastenberg granodiorite** in Austria is, in comparison with Bohemian durbachites, less potassic and less magnesian. Mingling of mafic and granodioritic melts occurs in some places within the Rastenberg pluton (FINGER et al., 1994); this phenomenon was not reported from Bohemian durbachites. The probable age of the Rastenberg granodiorite is 338±2 Ma (KLÖTZLI & PARRISH, 1996).

Several dykes of ultramafic rocks termed **glimmerites** appear in the endo- and exocontact of the Prachatice and Křišťanov granulite bodies. These rocks are mainly composed of phlogopite (xMg = 0.65–0.80) and actinolite (xMg = 0.75–0.85). Typical chemical composition (45–54 wt % SiO_2, 8–11 wt % Al_2O_3, 11–17 wt % MgO, 0.3–1.3 wt % Na_2O, 3.3–5.5 wt % K_2O, 1.2–2.4 wt % P_2O_5, 500–1000 ppm Cr, 200–600 ppm Ni) is rather unusual and differs from neighbouring durbachites (BREITER & KOLLER, 2009).



Text-Fig. 1.
Granitoid rocks in the Moldanubicum (according to Cháb et al., 2007).

Weinsberg Suite

Prevailingly coarse-grained conspicuously porphyritic biotite **Weinsberg granite** is the most widespread well-defined granite type within the whole Moldanubicum. Its equivalent in Bavaria is traditionally termed as "**Krystallgranit I**" (Propach, 1989; Teipel et al., 2008). Although distributed over the large area in the southern Moldanubicum, the Weinsberg granite is texturally as well as chemically notably homogeneous (61–65 wt % SiO_2). Nevertheless, Finger et al. (1994) mentioned some fractionation of this granite in Austria: Weinsberg I (SW part of the pluton) – Weinsberg II (NE part of the pluton) – Plochwald granite, unfortunately without any chemical data and mapping. The local fractionation centre of the Weinsberg melt was recently described also from the Bohemian Šumava Mts.: fine-grained biotite granodiorite – typical Weinsberg granite – medium-grained equigranular biotite granite (61.5–71.5 wt % SiO_2, 2.5–0.7 wt % MgO, 3.2–5.1 wt % K_2O) (Breiter, 2009). Probable age of the Weinsberg granite is about 331–327 Ma (Friedl et al., 1996; Gerdes et al., 2003).

The pyroxene-bearing domain within the Weinsberg granite near Sarleinsbach was interpreted in different ways (Klötzli et al., 2001 vs. Finger & Clemens, 2002). Poorly defined Engerwitzdorf granite is another, geologically slightly younger member of the Weinsberg suite (Finger et al., 1994).

Lásenice Suite

The **Lásenice granite** – fine- to medium-grained two-mica to biotite granite – forms the Klenov body NW of the town of Jindřichův Hradec and many small bodies near the NW margin of the SBP. Chemically, the Lásenice granite is characterised by very low contents of all compatible elements – Th, Zr, REE etc. and also U. The major element composition of this granite is near the "granite minimum melt" composition demonstrating an origin derived from crustal melting possibly during the thermal peak of the regional metamorphism in the sense of typical S-type granite (Breiter & Koller, 1999). The granite was affected by late-Variscan shearing (Klečka & Rajlich, 1984). The Lásenice granite is comparable to the **Altenberg granite** in Austria in chemical composition and shearing. According to field relations, the Altenberg granite is younger than Weinsberg granite, but older than the Mauthausen-Freistadt group of intrusions (Finger et al., 1994).

Group of Major Peraluminous Granites (Incorrectly Eisgarn s.l.)

The main intrusive event of peraluminous magmas is composed of two successive suites intruding probably in a short time interval.

Čímĕř Suite

The relatively slightly older fine- to medium-grained partly porphyritic peraluminous intrusions form an in detail variable, but generally chemically homogeneous suite of rocks with different textures and plenty of local names. These granites form the largest part of the "Central pluton" between the towns of Jihlava and Gmünd. Granites from the Novohradské hory Mts. and the Slepičí hory Mts. in southern Bohemia and some granites from the Šumava/Böhmerwald Mts. should be also related to this type. According to the gravity survey, granites of this group form plate-shaped bodies with a maximal thickness of about 3 km (ŠRÁMEK, pers. commun.). The medium- to coarse-grained porphyritic **Čímĕř granite** represents the most typical rock of this group. It forms the main part of the SBP in southern Bohemia around towns of Jindřichův Hradec, Nová Bystřice and Slavonice. Within the Austrian part of SBP, the eastern peri-contact stripe between the towns of Slavonice and Gmünd (quarries at Aalfang and Langegg) belongs also to this type. The quarrying district around the villages of Mrákotín is built up by fine- (to medium-) grained granite named by KOUTEK (1925) as Mrákotín granite, which is now interpreted as a local facies of the Čímĕř granite. Chemically, the Čímĕř granite represents a high-K peraluminous melt with higher contents of compatible elements, which implies melting conditions well above the "granite minimum melt" system within the deeper (lower?) parts of the continental crust. Inhomogeneities within the intrusion, well indicated by field gamma-ray measurements, imply insufficient homogenisation of the melt during intrusion.

Peraluminous mineralogy is expressed with abundant muscovite, microscopic sillimanite and occasionally also macroscopic pink crystals of andalusite (up to 1 mm).

Eisgarn Suite

The younger group of coarse-grained two-mica peraluminous granites (Eisgarn type in the original sense**)** forms ring-shaped bodies or stocks, often with zoned internal structure and highly fractionated late intrusions. From the NE to the SW there are bodies: Melechov, Čeřínek, Zvůle, Eisgarn s.s., and Plechý. These stocks, according to the concurrence with the gravity minima (MEURERS, 1992; BREITER et al., 1998), represent the deepest roots of the pluton (up to 10 km in the Melechov intrusion).

The most typical rock of this group is the coarse-grained porphyritic **Eisgarn granite s.s.** (WALDMANN, 1950), which forms the central part of the SBP between the towns of Nová Bystřice and Gmünd. The SW part of this body is buried below the Cretaceous and Tertiary sediments of the Třeboň basin.

The body of the Eisgarn granite s.s (N of Gmünd) shows distinct zonation: an increase of Rb, Na, P, and F and a decrease of K, Ca, Fe, Mg, Th, Zr, Sr etc. from the rim to the centre. This zonation can be explained as the product of an intensive inward oriented fractional crystallization after the intrusion. Internal zonality within the Čeřínek and Melechov bodies is less intensive. The Plechý intrusion is nearly homogeneous, only remnants of the slightly porphyritic roof-facies (Dreisessel granite) differ in the structure and the contents of Rb and Th. High peraluminity is expressed in a high content of muscovite which usually predominates biotite.

The Zvůle body represents the relatively scarce type of "reversal" zoned intrusion. The zonality is expressed here by increase of Rb and decrease of Sr from the centre towards the rims. The most fractionated part of this body is situated along its southern contact.

The Rb/Sr-age of the Eisgarn granite around 330 Ma (SCHARBERT, 1998) seams to be too high. The more probable age will be about 324 Ma (GERDES et al., 1998; BREITER & SULOVSKÝ, 2005; SIEBEL et al., 2008). The $^{87}Sr/^{86}Sr_i$ of Eisgarn and Čímĕř-type granites is similar ~0.712 (SCHARBERT, 1998).

Two types of younger more fractionated rocks intruded the Eisgarn granite:

A swarm of more than 30 dykes of **granite porphyries and dyke rhyolites** forms a 30 km long NNW–SSE trending zone between Lásenice in the north and Schrems in the south (KLEČKA, 1984; BREITER & SCHARBERT, 1998),

Muscovite granites (± topaz) form several stocks and irregular bodies in the axial part of the pluton (at Galthof), or on the pluton periphery (Homolka) (BREITER & SCHARBERT, 1995, 1998). These granites are the products of pronounced fractionation of the Eisgarn melt and are enriched in phosphorus, fluorine, uranium, and rare metals.

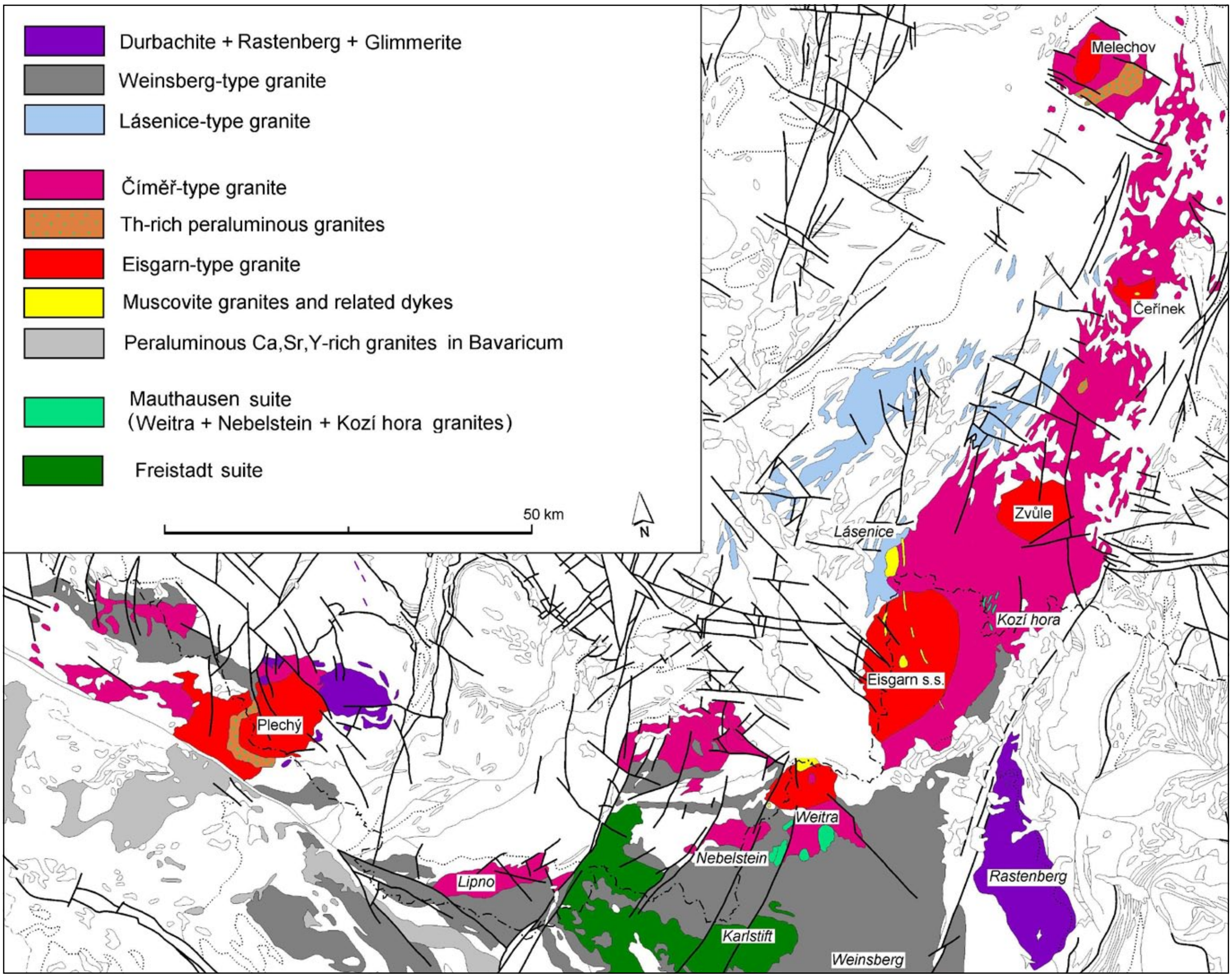
Other Peraluminous Granitoids

Between Gmünd and Weitra another body of coarse-grained porphyritic two-mica granite crops out, which chemically and mineralogically resembles the Eisgarn s.s. granite. But its substantially lower $^{87}Sr/^{86}Sr_i$ = 0.706 indicate melting of another source material. Also the following muscovite granite from Nakolice-Pyhrabruck differs from those from Homolka in much lower $^{87}Sr/^{86}Sr_i$ (0.705 vs. 0.716) (BREITER & SCHARBERT, 1995; 2006).

In the Bavaricum, SIEBEL et al. (2008) defined a group of peralumine granites (mainly fine- to medium grained, biotite to two-mica granites of the Fürstenstein and Hauzenberg plutons), in age similar to the main intrusive events of peraluminous granites in Austria and Bohemia (324–319 Ma), but differing chemically being enriched in Ca, Y and Sr. This was interpreted as result of the composition of the deeper crust in the Bavaricum being different in comparison to the Moldanubicum.

Granites highly enriched in Th represent a rather special type of peraluminous granites in the Moldanubicum being sporadically found as members of different intrusive suites.

The fine-grained biotite>muscovite Lipnice granite within the Melechov massif (Čímĕř suite) contain up to 60 ppm Th (MLČOCH et al., 1999) and the coarse grained biotite>muscovite Steinberg granite in the Plechý pluton (Eisgarn suite) contain up to 100 ppm Th (BREITER, 2005). Th-rich monazite is the only carrier of Th in these granites. Another Th-rich granite was found at Gutau, NE of Linz, as a small (2 km²) intrusion of fine-grained porphyritic biotite



Text-Fig. 2.
Proposed genetic classification of granitoids in Moldanubicum (contours of rock bodies according to CHÁB et al. 2007, slightly adapted).

granite (~67 wt % SiO_2) enriched in F (~0.4 wt %) and Th (up to 120 ppm) (GÖD et al., 1996). Genetic affiliation of this granite, in maps signed as Mauthausen type, is not clear.

Group of Late Intrusive Phases (post-Eisgarn)

Mauthausen Suite

High-K calc-alkaline metaaluminous to only slightly peraluminous granites and granodiorites (tonalites), rich in Ca and Sr, crop out in the southern part of the Moldanubicum, namely in Upper Austria and around Trhové Sviny in Bohemia. These rocks, traditionally termed as Mauthausen and Freistadt types bear typical features of I-type granitoids (FINGER et al., 1997) and represent the product of a new melting episode in the time interval of 315–300 Ma. Lower Rb/Sr-ratio and $^{87}Sr/^{86}Sr_i$ = 0.705–0.706 suggests melting of a tonalitic source in the deeper crust (GERDES, 1997).

The name **"Mauthausen granite"**, before synonym for all fine-grained granites in the SBP, should be used according to the original definition (RICHTER, 1965) only for relatively young granites in the southern part of the SBP around the town of Mauthausen (out of Text-Figs. 1, 2). Compared to rocks of the Freistadt suite, the more heterogeneous Mauthausen group of granites is richer in K and Rb and poorer in Ca and Sr. According to GERDES et al. (2003), the Mauthausen granite (or only some bodies among those designed as Mauthausen granite?) should be about 316 Ma old.

The biotite **Weitra granite** (name introduced by HUMER et al., 2003) comprises two macroscopically not distinguishable varieties differing only in the magnetic susceptibility. The magnetic variety crops out in the centre of the St. Martin magnetic anomaly (HEINZ & SEIBERL, 1990; GNOJEK & PŘICHYSTAL, 1997) and at "Steinerne Frau" SE of Harbach. The non-magnetic variety was found E of Nebelstein around the village of Althütten and in Weitra itself. Typical major element contents are: 71–72 wt % SiO_2, 0.7–0.8 wt % MgO, 2–3 wt % Fe_2O_{3tot}, 1.3–2.0 wt % CaO, 4.5–5.0 wt % K_2O and 2.8–3.1 wt % (in the non-magnetic variety up to 3.8 wt %) Na_2O. Characteristic features of the Weitra granite are high Sr (250–450 ppm) and low Rb (200–230 ppm). The $^{87}Sr/^{86}Sr_i$ of ~0.705 supports some relation of the Weitra granite to the Mauthausen suite.

The Weitra granite was followed by a group of dykes and stocks of muscovite granites with primitive chemical composition, which intruded the Weitra granite itself (St. Martin, Nebelstein), and also the foregoing two-mica granites

(Ober-Lembach). The evolution of the **Nebelstein magmatic centre** (two-mica to muscovite granite) finished in the formation of a small Mo-mineralization of greisen type (GÖD & KOLLER, 1989).

A small (5 x 2 km) body of fine-grained biotite granite near Schrems (Schremser granite) illustrates the problems with classification of granites according to their texture and mineral composition very well. The body was interpreted as homogeneous (WALDMANN, 1950; FUCHS & MATURA, 1976) and attributed to the Mauthausen type. Recently, KOLLER et al. (1993) discriminated here three domains with different chemical compositions and Rb-Sr characteristic. Only the central part of the body bears the composition of typical Mauthausen-type rocks. The SW part represents probably a fine-grained late portion of the Weinsberg magma and the NE part is isotopically similar to the peraluminous two-mica granites.

A ring-shaped system of small stock and dykes of biotite granite and zones of greisenization and complementary K-metasomatism at **Kozí Hora/Hirschenschlag** with occurrence of molybdenite-magnetite greisens (GÖD, 1989; BREITER et al., 1994) are only poorly known geochemically. The chemical composition of the rocks and the style of mineralization are similar to those of Nebelstein.

Freistadt Suite

The **Freistadt granodiorite** forms a composite pluton with a medium-grained rim and fine-grained core facies. Main chemical features are: 66–69 wt % SiO_2, only about 2.5 wt % K_2O, 70–80 ppm Rb and about 400 ppm Sr. The two-mica "Graben granite" is the youngest and slightly more evolved product of the fractionation of this pluton (FINGER et al., 1994).

The **Karlstift granite** (KLOB, 1970) is a fine- to medium grained biotite granite with high magnetic susceptibility cropping out between the villages of Karlstift, Sandl and Liebenau. The porphyritic variety crops out near the N and NE contact, the inner part of the body is mostly equigranular. Typical contents of SiO_2 are 67–69 wt %, K_2O 3.8–4.5 wt %, Na_2O 3.2–3.5 wt %, MgO 0.8–1.3 wt % and CaO 2.2–3.1 wt %. High concentrations of Sr (580–650 ppm) and Th (25–28 ppm) are characteristic of the porphyritic pericontact facies. The rock is markedly poor in Rb (150–170 ppm). The magnetic susceptibility and the contents of Ti, Ca, Fe, Sr and Th decrease towards the intrusion centre, while Si, K and Rb increase slightly. The $^{87}Sr/^{86}Sr_i$ = 0.706 is similar to the rocks of the Freistadt suite (BREITER & SCHARBERT, 2006).

Conclusions

Major types of granitoids in the Moldanubicum can be classified in several suites, which represent different evolutionary stages of the Variscan orogenic process. The relative succession of most rock suites is documented geologically; nevertheless, the isotopic ages of individual bodies (intrusions) within the suite may variegate in rather large intervals.

The proposed well defined suites are:

- K,Mg-rich granitoids (namely durbachites, ~340 Ma)
- Weinsberg granite (biotite I-type granite, ~328 Ma)
- Lásenice granite (granite minimum melt)
- Číměř granite (peraluminous granite)
- Eisgarn s.s. granite (peraluminous granites with very deep roots) with late fractionation to Sn, Nb, Ta, U-enriched muscovite granites (~324 Ma)
- Mauthausen suite (I-type biotite granites, late fractionated intrusions with Mo-mineralization) (~315 Ma)
- Freistadt suite (I-type biotite granites and granodiorites, ~305 Ma).

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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

A Short Note on the Occurrence of the Upper Triassic Oyster *Umbrostrea*? *montiscaprilis* (KLIPSTEIN, 1843) (Mollusca: Bivalvia) in the Northern Alpine Raibl Beds of the Schafberg, Salzburg, Austria

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3 Text-Figures, 1 Plate

Österreichische Karte 1:50.000
Blatt 65 Mondsee

Northern Calcareous Alps
Northalpine Raibl Beds
Salzkammergut
Schafberg
Bivalvia

Contents

Eine kurze Mitteilung über das Vorkommen der obertriassischen Auster *Umbrostrea*? *montiscaprilis* (KLIPSTEIN, 1843) (Mollusca: Bivalvia) in den Nordalpinen Raibler Schichten des Schafbergs, Salzburg, Österreich

Zusammenfassung

Aus den Nordalpinen Raibler Schichten des Schafberg-Nordfußes wird eine für das Karnium charakteristische Bivalven-Faunula, die drei Arten umfasst, beschrieben. Trotz Rekristallisation weisen die Schalenstrukturen einiger Exemplare von "Ostrea" *montiscaprilis* KLIPSTEIN, 1843 darauf hin, dass diese Art der Gattung *Umbrostrea* HAUTMANN, 2001 angehört.

Abstract

Northern Alpine Raibl Beds exposed at the northern foot of the Schafberg yielded a bivalve faunula consisting of three species characteristic of the Carnian stage. Although the shells are generally recrystallized, preserved structures of some valves of "Ostrea" *montiscaprilis* KLIPSTEIN, 1843 indicate that this species belongs to the genus *Umbrostrea* HAUTMANN, 2001.

Introduction

Oysters are a distinct and successful group of marine bivalves. Due to the predominantly calcitic composition of their shells, they have a good fossil record especially from the early Jurassic onwards. By contrast, key characters of classification such as inner features as well as mineralogy and structure of the valves are much less known in Triassic oysters, as a consequence of the frequent loss or recrystallization of their inner, presumably aragonitic shell layers (HAUTMANN, 2001a, 2006a, b). In fact, generic assignment of several Triassic species is still debated. The last decade saw the publication of a remarkable series of papers dealing with the origin and early evolution of oysters (CHECA & JIMÉNEZ-JIMÉNEZ, 2003; CHECA et al., 2006; HAUTMANN, 2001a, b, 2004, 2006a, b; MALCHUS, 2008; MÁRQUEZ-ALIAGA et al., 2005). In the light of this renewed interest, the occurrence of *"Ostrea" montiscaprilis* – originally described by KLIPSTEIN (1843) from the Carnian of the Monte Caprile (Goat Hill, if translated) of the Southern Alps – in the Northern Alpine Raibl Group of the Schafberg (Sheep Mountain, if translated) seems worth describing.

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Geological Setting and Localities

Since the paper by MOJSISOVICS (1866) fossiliferous exposures of the Northern Alpine Raibl Formation are known from the surroundings of the Eisenaueralm on the northern slope of Mt. Schafberg, south of the eastern end of the lake Mondsee. The outcrops form a largely WNW-ESE striking, approx. 2 km long, wedge-shaped patch on the northern slope of the hill Weinkogel. A good and easily accessible succession of Raibl Beds usually strikingly poor in fossils is exposed along a creek (Sch 1 in Text-Fig. 1, see also SIBLÍK, 2008). It comprises an alternation of limestones with grey marl and marly sandstones beds. At some places, however, bivalves occur in large quantities in limestone beds. Two localities were studied (Text-Fig. 1). Already MOJSISOVICS (1866) mentions fossil findings from there: in the grey sandstones of the Lunz Formation *"Equisetites"* fragments and from the overlying "Cardita Beds" *Avicula aspera* PICHLER, *"Cidaris"* spines, *Pecten*, *Plicatula* and a bed with *Ostrea Montis Caprilis*.

Locality Sch 1 was already reported by SIBLÍK (2008). At the point where the marked tourist path leading from Schafling to the Eisenaueralm crosses the creek, dark grey limestone slabs with abundant remains of *Umbrostrea*? *montiscaprilis* can be found in the drift of the creek. Although obviously transported, these slabs were found to provide the only opportunity to collect *U.*? *montiscaprilis* by hand tools.

Two types of fossiliferous Raibl limestones could be distinguished macroscopically, which differ from each other in microfacies as well. Microfacies of the greenish-gray limestone containing abundant shells of *U.*? *montiscaprilis* is characterized by shell fragments of the fore-mentioned species (Text-Fig. 2a). The bluish-grey limestone slabs contain abundant black onkoids of up to 15 mm. Identified fossils include solenoporacean(?) algae, small agglutinated foraminifers, gastropods and echinoderms (Text-Fig. 2b–d). A similar onkolithic bindstone microfacies was reported by BELOCKY et al. (1999) from the Raibl Beds of the Gaisberg/Kirchberg in Tirol.

Slightly upstream, above the small waterfall exposing unfossiliferous marl beds the bed of the creek is formed by limestone bedding planes displaying abundant bivalves among which *Schafhaeutlia*? sp. cf. *mellingi* (HAUER, 1857) and *U.*? *montiscaprilis* could be identified (Text-Fig. 3a, b).

Some tens of meters upstream, megalodontid? bivalves can be seen in large quantities in a limestone bank forming the right flank of the creek (Text-Fig. 3c, d). The specimens are preserved as internal moulds with conjoined, closed valves and can not be extracted from the compact rock with hand tools.

Raibl Beds are also exposed higher on the right flank of the creek valley, along the path leading from Kreuzstein to the Eisenaueralm (Locality Sch 2). Two bivalve specimens, representing *S. mellingi* and *Rossiodus* cf. *columbella* (HOERNES, 1855) were found there by Dr. Miloš Siblík, Prague.

Bivalves

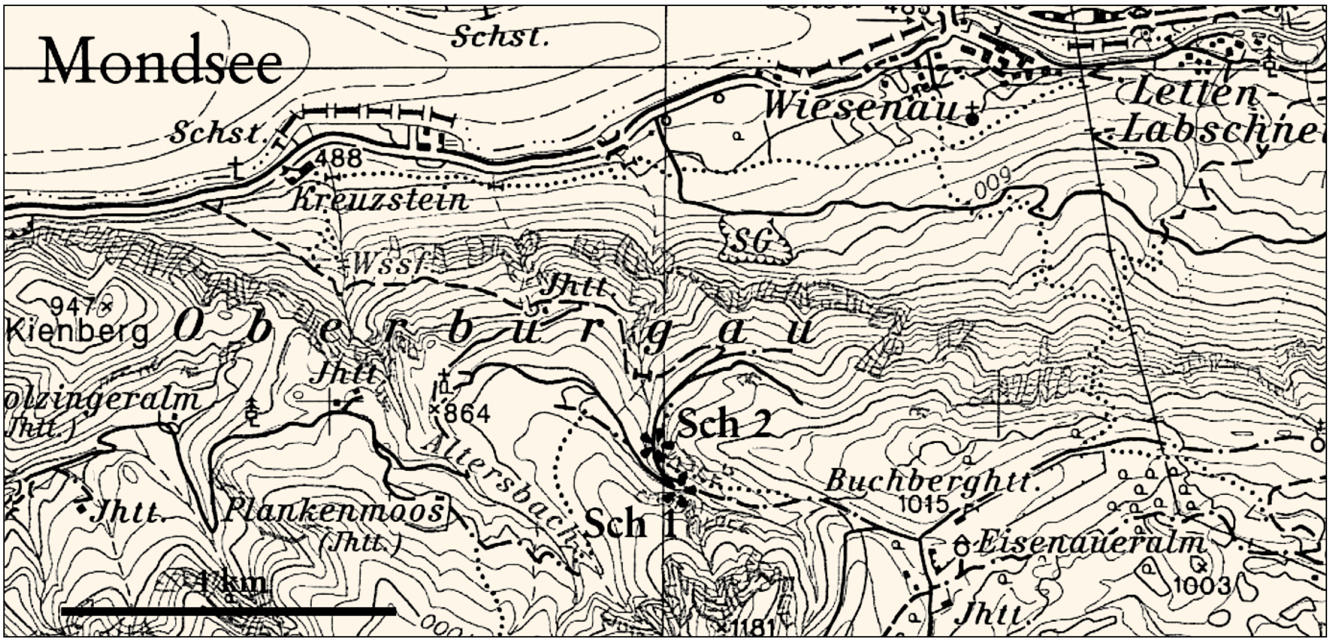
Umbrostrea? *montiscaprilis* (KLIPSTEIN, 1843)

(Pl. 1, Figs. 1–9, 11?)

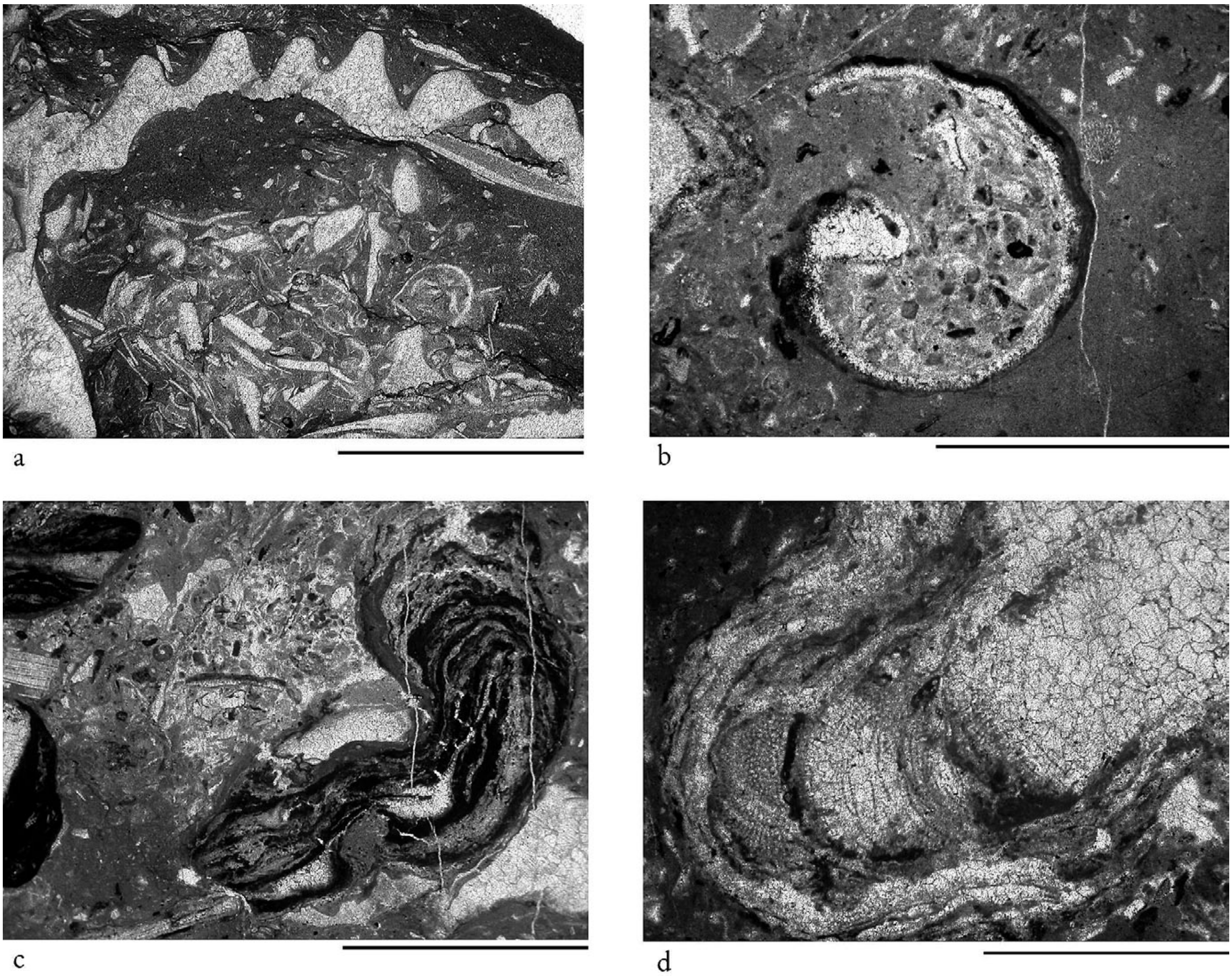
Material: about a dozen specimens, presumably all left valves, embedded in compact limestone.

Description: Inaequilateral, backward-curved, higher than long shells ornamented with up to 15 squamose, antimarginal ribs/plicae whose number increases with intercalation of new ones at the postero-ventral region. Attachment area is subordinate if compared with the height of the valve. Umbonal cavity is well defined. Internal features can not be studied in the available material.

The shell structure has been completely obscured by recrystallization in most cases (e.g. Pl. 1, Figs. 5, 6). Some sections, however, display two shell layers of different structure (Pl. 1, Figs. 7, 8). The outer one seems to be of prismatic nature while the inner one is formed by



Text-Fig. 1.
Map showing the bivalve localities studied.



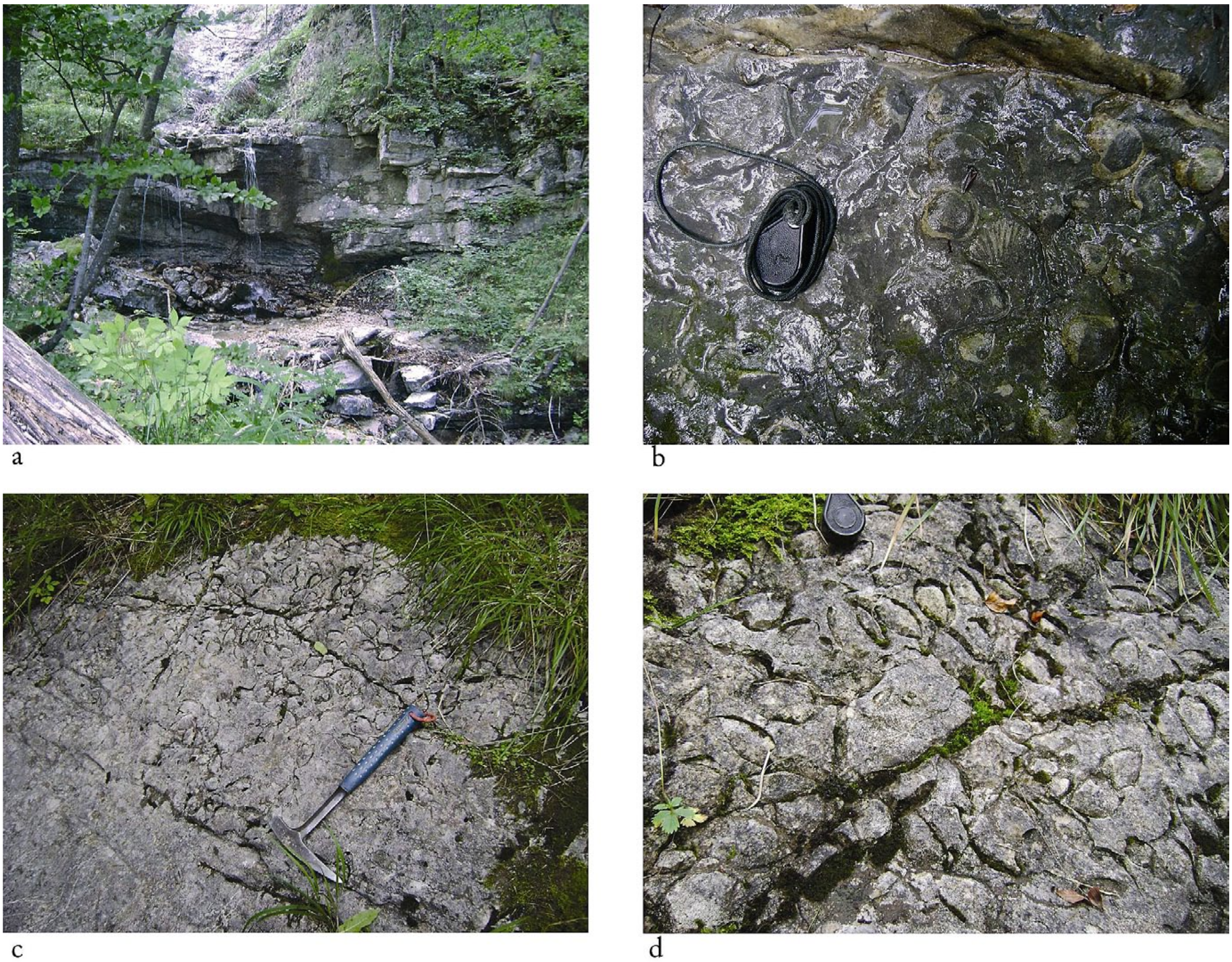
Text-Fig. 2.
Characteristic microfacies of Raibl limestones.
a: fragment of *U.*? *montiscaprilis*, ostracods and echinoderms; b: gastropod with coated and recrystallized shell; c: dark-coloured onkoids; d: partly recrystallized solenoporacean alga?
The bar represents 3 mm.

sparry calcite. In another section layering of the middle part of the shell was found to be still preserved (Pl. 1, Fig. 9). No structural chambers ("Hohlräume") were observed. Some sections show elongated bodies composed of sparry calcite, associated with finely foliated calcite structures (Pl. 1, Fig. 11). Their relationship to *U.*? *montiscaprilis* is, however, not justified.

Remarks: *"Ostrea" montiscaprilis*, usually assigned to the genera/subgenera *Lopha* or *Alectryonia* was frequently recorded from various Carnian formations of the Northern Calcareous Alps (see TOLLMANN, 1976) but it was only rarely described and figured (e.g. WÖHRMANN, 1889, p. 200, Pl. 6, Figs. 1–3). The Schafberg specimens agree well in shape with the type (KLIPSTEIN, 1843), as well as with those more recently described and figured in the literature, e.g. by JELEN (1989) and LIEBERMAN (1979) (see also DIENER, 1923 for older references). The species was also recorded from North America (e.g. STANLEY, 1979), however, the specimens referred to have never been described or figured thus it is doubtful whether they are conspecific (MCROBERTS, 1997).

U.? *montiscaprilis* differs from *Actinostreon haidingerianum* (EMMRICH, 1853), a common species in the Rhaetian of the Northern and Southern Alps as well as of the NW Carpathians, by having more ribs/plicae (see e.g. ZAPFE, 1967, p. 438, Pl. 3, Figs. 7a, b; GOETEL, 1917, p. 169, Pl. 9, Figs. 4a, b.) and – probably – by its aragonitic inner shell layers (see below).

Uncertainty concerning the generic assignment of *"O." montiscaprilis* roots in the lack of appropriate knowledge of its shell mineralogy and structure. Differences between Triassic lophate oysters and *Lopha* RÖDING, 1789 were already recognized by MALCHUS (1990) who erected the new genus *Palaeolopha* based on *Ostrea haidingeriana* as type species, and including – although doubtfully – *Palaeolopha montiscaprilis* as well. According to HAUTMANN (2001a), however, the shell of *"O." haidingeriana* is entirely calcitic and similar in microstructure to that of *Actinostreon* BAYLE, 1878 as documented by SIEWERT (1972). Thus, *Palaeolopha* should be considered as a junior synonym of *Actinostreon*. On the other hand, evidence presented by HAUTMANN (2001a, b) and MÁRQUEZ-ALIAGA et al. (2005) suggest that shells of



Text-Fig. 3.
Field occurrence of Northern Alpine Raibl Beds.
a: unfossiliferous marl and limestone beds; b: bedding plane with bivalves (*Schafhaeutlia*? sp. cf. *mellingi*, *U.*? *montiscaprilis*); c, d: megalodontid? bivalves.
The hammer is 33 cm long, the hand lens is 32 mm wide.

Middle and early Late Triassic oysters contained aragonite layers as well. On the basis of shell mineralogy, these forms should be assigned to *Umbrostrea* HAUTMANN, 2001, whose valves consist of an outer layer of calcitic prisms, a thin middle layer of foliated calcite and a thick, originally aragonitic inner layer. Although shell preservation of the Schafberg specimens is far from suitable, the data available make their assignment to *Umbrostrea* the most plausible. The almost exclusive appearance of recrystallized, presumably originally aragonitic shell parts may be due to the peeling off of the thin outer calcitic layers, in a way found by SANDERS et al. (2007) in diceratid rudists. Spalling of the outer, prismatic layer of *U. iranica* HAUTMANN, 2001 was also figured by HAUTMANN (2001a).

Schafhaeutlia mellingi (HAUER, 1857)

Pl. 1, Figs. 10, 12–14

An internal mould of a left valve and another one formed by conjoined, closed valves were found. The umbo placed near the mid-length of the valves as well as the strong conical cardinal tooth of the left valve preserved as external mould are characteristic features of *S. mellingi*, a species well represented in the Carnian of the Northern Calcareous Alps (see e.g. WÖHRMANN, 1889; TOULA, 1910). In the older literature it is referred to as *Gonodon, Gonodus* or *Corbis mellingi*.

Rossiodus cf. *columbella* (M. HOERNES, 1855)

Pl. 1, Fig. 15

A single internal mould of a left valve may represent *R. columbella*, a characteristic Upper Carnian – Norian megalodontid species as described and figured by VÉGH-NEUBRANDT (1982).

Acknowledgments

Dr. Miloš Siblík (Prague) provided us with bivalve specimens he collected. His help and kindness is gratefully acknowledged here. The field-work of I. Szente and H. Lobitzer was supported on the basis of the bilateral agreement between the Geologische Bundesanstalt (Vienna) and the Geological Institute of Hungary (Budapest). This is a contribution of the OTKA Project K 81298.

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Plate 1

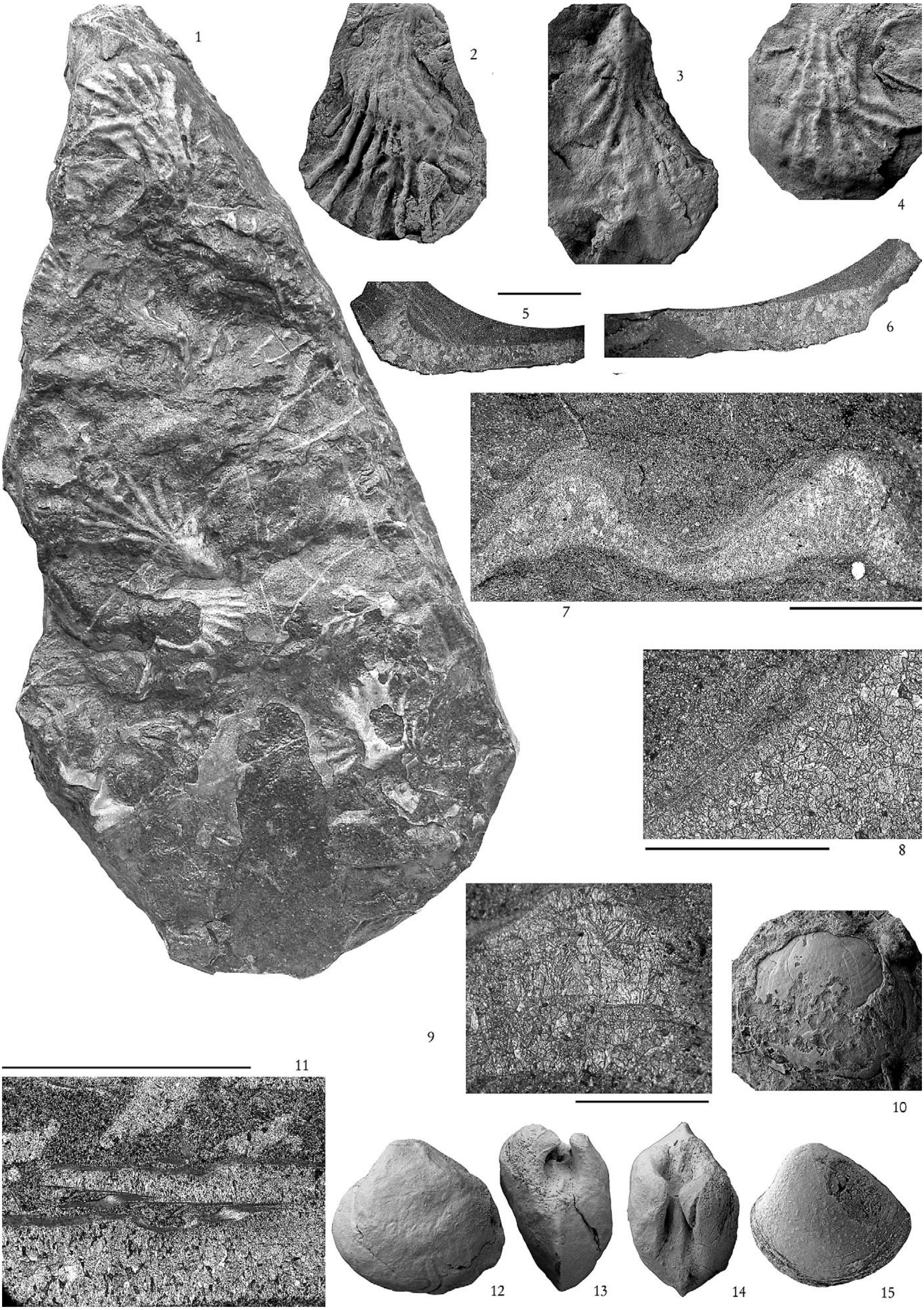
The specimens in Figs. 2–4, 10 and 12–15 are coated with ammonium-chloride.

The scale bar is 3 mm in Figs. 5–7 and 11, and 1 mm in Figs. 8, 9.

Figs. 1–9, 11?: *Umbrostrea*? *montiscaprilis* (KLIPSTEIN, 1843).
- Fig. 1: characteristic occurrence and preservation of valves, 0.6x.
- Figs. 2–4: left valves.
- Figs. 5, 6: longitudinal section of specimen in Fig. 2, umbo is to the left, acetate peels.
- Figs. 7, 8: cross section of ribs displaying traces of an outer calcitic prismatic? and an inner, originally aragonitic? shell layer, acetate peel.
- Fig. 9: preserved structure of the inner, recrystallized shell layer, acetate peel.
- Fig. 11: fine foliated calcite structures associated to recrystallized shell fragments, questionably interpreted as peeled off shell layers of *U.*? *montiscaprilis,* acetate peel.

Figs. 10, 12–14: *Schafhaeutlia mellingi* (HAUER, 1857).
- Fig. 10: internal mould of a left valve bearing fine commarginal and radial ornamentation.
- Fig. 12: lateral view.
- Fig. 13: frontal view.
- Fig. 14: dorsal view.

Fig. 15: *Rossiodus* cf. *columbella* (M. HOERNES, 1855).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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

Transition Between the Massive Reef-Backreef and Cyclic Lagoon Facies of the Dachstein Limestone in the Southern Part of the Dachstein Plateau, Northern Calcareous Alps, Upper Austria and Styria

János Haas[1], Olga Piros[2], Tamás Budai[2], Ágnes Görög[3], Gerhard W. Mandl[4] & Harald Lobitzer[5]

4 Text-Figures, 6 Plates

Österreichische Karte 1 : 50.000
Blatt 127 Schladming

Northern Calcareous Alps
Dachstein Limestone
Microfacies
Paleokarst
Triassic
Norian

Contents

Der Dachsteinkalk im Übergangsbereich vom massigen Riff/Rückriff zur zyklisch gebankten „lagunären“ Entwicklung am südlichen Dachstein-Plateau, Nördliche Kalkalpen, Oberösterreich

Zusammenfassung

Im südlichen Dachstein-Plateau verzahnt massiger norischer Dachstein-Riffkalk gegen Norden zu mit zyklisch gebanktem „lagunärem“ Dachsteinkalk. Dieser Übergangsbereich wird beschrieben und interpretiert. Der zyklisch gebankte Dachsteinkalk wird aus Wechselfolgen von subtidalen mit peritidalen Ablagerungen aufgebaut. Die subtidalen Kalkbänke sind oftmals onkoidisch entwickelt und enthalten Megalodonten, Gastropoden und charakteristische Foraminiferen-Assoziationen. Einige der subtidalen Bänke zeigen pedogenetische und Paläokarst-Phänomene sowie Erscheinungen meteorischer Frühdiagenese. Die peritidalen Bänke sind durch umgelagertes Paläoböden-Material oftmals rot gefärbt und zeigen manchmal beginnende Pedogenese. Aufgrund der Foraminiferen-Assoziationen sowie der geologischen Situation kann der Dachsteinkalk in der Umgebung der Handgruben als obernorisch betrachtet werden. Schließlich werden unsere Profile mit gleichaltrigen zyklischen Ablagerungen der inneren Karbonatplattform des nördlichen Dachstein-Plateaus in der Umgebung des Krippensteins und mit den Dachsteinkalk-Abfolgen des nordöstlichen Transdanubischen Mittelgebirges in Ungarn verglichen, die ähnliche sedimentologische Phänomene sowie paläogeographische Muster aufweisen.

Abstract

Along the southern margin of the Dachstein Group Norian massive reef limestones are exposed that progress northward into well-bedded cyclic peritidal-lagoonal carbonates. Characteristic features of the transitional zone are described and interpreted. The cyclic succession is made up of an alternation of subtidal and peritidal beds. The subtidal beds are usually oncoidal and contain megalodonts, gastropods, and foraminifera. Some of the subtidal beds were affected by pedogenic alteration, karstification and meteoric early diagenesis. The peritidal beds are usually red; they contain reworked soil derived material and were also affected by incipient pedogenesis. Based on the foraminifera fauna and considering also the geological setting, the studied beds at Handgruben can be assigned to the Upper (?) Norian. The studied sections are compared with the coeval cyclic internal platform deposits, which occur in the northern part of the Dachstein Plateau (Krippenstein) and with the Dachstein Limestone successions of the NE part of the Transdanubian Range in Hungary showing similar sedimentological features and paleogeographic setting.

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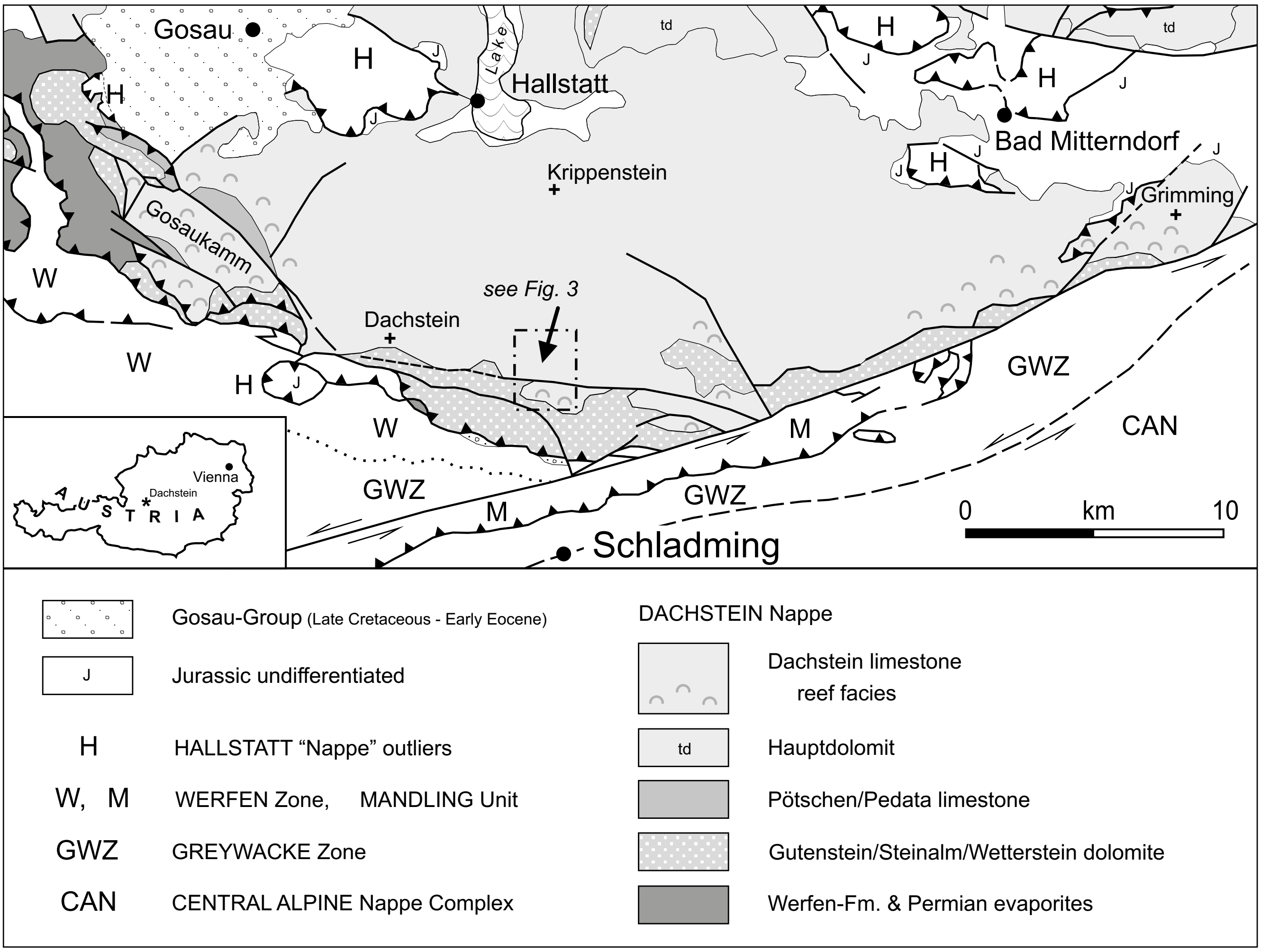
Introduction

The Dachstein Mountain range is the type locality of the Dachstein Limestone and the Dachstein-type carbonate platforms. This area is made up predominantly of the cyclic inner platform facies of the Dachstein Limestone. However, at the southern part of the Dachstein Group massive Norian reef limestones are exposed in a zone a few hundred meters wide (Roniewicz et al., 2007), while the transition to the slope, respectively, open-sea facies of the Hallstatt basin is mostly tectonically truncated. Only a few examples of this transition are preserved, e.g. at Gosaukamm (Wurm, 1982; Krystyn et al., 2009). The aim of the present paper is to display the transition between the two characteristic facies of the Dachstein platform. We tried to figure out how the massive reef facies progresses into the cyclic peritidal-lagoonal one. Determination and characterisation of the building elements of the near-reef but already cyclic successions are also the subject of the present work. A comparative analysis of the studied sections with those previously investigated in the Krippenstein area 5–6 km northward will also be performed. Facies conditions akin to that in the Dachstein Plateau are known in the NE part of the Transdanubian Range, Hungary. Therefore we extended the comparative facies analysis also to this area.

Geological Setting

The Dachstein Group represents a segment of the margin of the Tethys (Neotethys) Ocean and accordingly, stratigraphical and lithofacies characteristics of this area reflect the general evolutionary history of this realm. Permian evaporites are overlain by Lower Triassic shallow marine siliciclastics (Werfen Formation), that are followed by Lower to Middle Anisian shallow marine carbonates (Gutenstein and Steinalm Formations). These formations are exposed at the base of the Dachstein Nappe along the southern, southwestern margin of the Dachstein Plateau (Mandl, 2000) – see also Text-Fig. 1. In the Late Anisian, in connection with the Neotethys opening pelagic basins developed over large areas where grey cherty and variegated limestones were formed. However, in some places the shallow marine conditions prolonged giving rise to the development of Wetterstein-type carbonate platforms; then in the Ladinian to Early Carnian the platforms prograded onto the adjacent basins. The Wetterstein-type platform carbonates are also widely exposed along the southern slopes of the Dachstein Plateau. A sea-level drop in the Early Carnian led to subaerial exposure over a predominant part of the former Wetterstein platform and significant erosion (Text-Fig. 2). As a result of the Late Carnian transgression, the shallow marine-lagoonal conditions resumed in



Text-Fig. 1.
Geological sketch of the Dachstein area, displaying the area studied.

the depressions of the erosion affected previous platform (Waxeneck Limestone). The rising sea-level in the latest Tuvalian led to the extension of pelagic conditions, whereas on the local highs shallow marine conditions prevailed and reef-patches developed supplying the adjacent periplatform basins (Roniewicz et al., 2007). This episode was followed by rapid progradation of the Dachstein platform in the early Norian i.e. the onset of the Dachstein platform evolution (Text-Fig. 2). After an episodic transgression, aggradational evolution for the Middle Norian (Alaunian), slow progradation for the Late Norian (Sevatian) and accelerated progradation for the early Rhaetian was interpreted from the Gosaukamm and Gosausee marginal successions, and the Dachstein reef building came to an end by a drowning event in the middle Rhaetian (Krystyn et al., 2009).

The area of our study is located between the Guttenberg mountain lodge and locality "Bei der Hand", north to Feisterscharte, in the southern part of the Dachstein Plateau (Text-Figs. 1, 3). According to the geological maps (Mandl & Matura, 1995; Mandl, 2001), a northward regional dip characterises the southern part of the Dachstein Plateau, although there are several tilted blocks of various dip.

NE to the Guttenberg lodge at the base of the slope of Mt. Sinabell the erosion-formed uneven top of the Wetterstein Dolomite is well visible. Above it reddish dolomites occur from which Carnian conodonts *(Metapolygnatus polygnathiformis)* were encountered (Roniewicz et al., 2007). It is overlain by massive carbonates of very inhomogeneous facies composition (Text-Figs. 2, 3). According to facies investigations of Roniewicz et al. (2007) the reef-detritus facies are predominant; the proximal backreef facies are also common, whereas the biolithite facies are rare. Intercalations of pelagic facies containing reef-derived components were also encountered (Text-Figs. 2, 3). These beds yielded earliest Norian (Lacian 1) conodonts *Epigondolella primitia* (Lein, 1987), later on revised by Krystyn et al. (2009) as *Epigondolella quadrata*. In a sample taken on the path to Mt. Sinabel and on the NE side of Mt. Eselstein conodonts indicating Lacian 2 were found (Roniewicz et al., 2007).

According to Roniewicz et al. (2007) north to the inhomogeneous massive carbonates massive backreef facies occurs which extends over the Seetal Fault northward (Text-Figs. 2, 3). It is typified by a) biosparite (rudstone and grainstone) with poorly sorted bioclasts and grapestones and b) biopelmicrite with Rivulariaceans. At the base of this facies poorly preserved Middle Norian conodonts were reported.

Results

The Boundary Between the Massive and the Bedded Dachstein Limestone

From the massive limestones south to the Seetal Fault (Text-Fig. 3) we took only a few samples. Results of our microfacies studies met with observations of Roniewicz et al. (2007).

Reef-derived breccias with mm to cm-sized lithoclasts and bioclasts were usually found in the samples studied. Fragments of microbial crust (Plate 1, Fig. 2), micro-encruster microproblematicum *Radiomura cautica*, Rivulariaceans (Plate 1, Fig. 4), corals (Plate 1, Fig. 1), calcareous sponges (Plate 1, Fig. 3) (sphinctozoans and inozoans), crinoids, bivalves, gastropods, ammonites, ostracods were encountered in most of the samples. Encrusting foraminifera *(Tolypammina gregaria)* are common (Plate 1, Fig. 5). Miliolinids *(Agathammina austroalpina)*, Duostominidae, *Ophthalmidium triadicum*, *Ophthalmidium* sp., *Agathammina* sp., Textulariidae, *Austrocolomia* sp., *Turrispirillina* sp., *Kaevaria fluegeli*, *Miliolipora cuvillieri*, *Orthotrinacria expansa* were also found (Plate 2, Figs. 1–5). There are various lithoclasts (e.g. peloidal micrite, ostracodal micrite, ostracodal sparite, bioclastic micrite, oolitic grainstone).

The near reef or the protected platform was the habitat of the *Agathammina austroalpina* (e.g. Zaninetti, 1976; Bernecker, 1996). *Orthotrinacria expansa* is considered as a reefal porcelaneous foraminifer (Zaninetti & Martini, 1993). *Kaevaria fluegeli* was a reef-cavity dweller (e.g. Dullo, 1980; Senowbari-Daryan et al., 1982). Duostominids preferred the outer reef and the calcarenitic substrate; oncoid and grapestone facies (e.g. Hohenegger & Piller, 1975; Schäfer & Senowbari-Daryan, 1978; Dullo, 1980; Gaździcki, 1983; Bernecker, 1996).

According to our observation the boundary between the massive and the cyclic limestones can be recognised at a fault, 400 m north to the Seetal Fault (Text-Fig. 2). However, there is no abrupt change in the structural and textural features of the limestone at the fault. Accordingly the fault does not play a significant role in the determination of the present-day facies distribution.

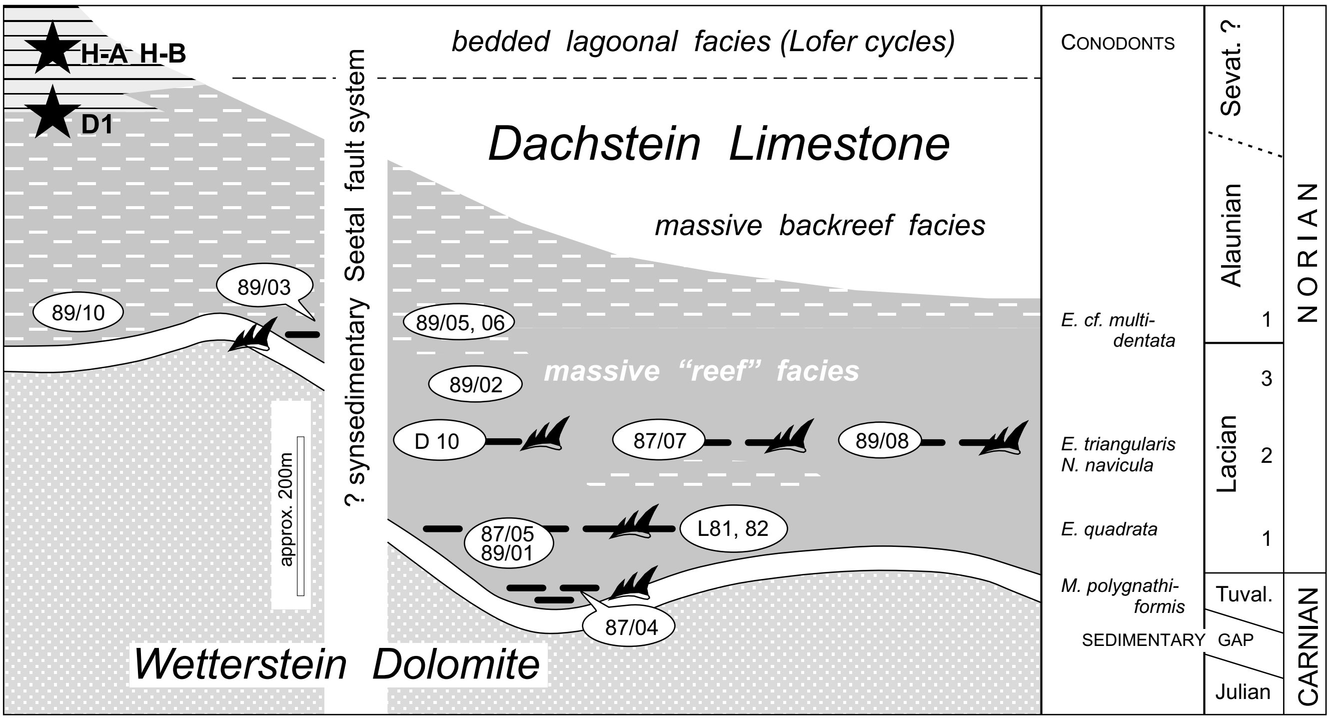
In a sample taken about 100 m south to the above-mentioned fault (that is 300 m north to the Seetal Fault) a boundstone type facies was recognised, that is characterised by abundance of microbial crusts (Plate 1, Fig. 7), and encrusting larger foraminifera, *Alpinophragmium perforatum* (Plate 1, Fig. 6). A few miliolinids, Textulariidae and microproblematicum *Baccanella floriformis* also occur (Plate 1, Fig. 8). There are a number of solution cavities, some of them after microbially encrusted bioclasts which are filled by sparry calcite. *Alpinophragmium perforatum* is a reefal larger foraminifera species, a typical encruster in the Norian–Rhaetian well-ventilated central reef or forereef environments (Flügel, 1967; Hohenegger & Lobitzer, 1971; Dullo, 1980; Bernecker, 1996; Wurm, 1982; Senowbari-Daryan et al., 1982; Gaździcki, 1983).

Another sample was taken just at the fault (marked by D1 on Text-Figs. 2, 3). It has a peloidal microsparite texture with a few bioclasts (fragments of molluscs, foraminifera, *Thaumatoporella)*. Duostominidae *(Variostoma* sp., *Diplotremina* sp.) are common; *Trochammina* spp. and microproblematicum *Messopotamella angulata* also occur (Plate 2, Figs. 6, 7). It is abundant in fenestral fabrics. This microfacies is similar to the biopelmicritic sub-facies of the massive backreef facies of Roniewicz et al. (2007).

Section Handgruben A

About 100 m north to the boundary between the massive and the bedded Dachstein Limestone, a more than 1 m thick brownish red limestone intercalation was found between grey limestone beds. In this outcrop (marked by H–A on Text-Figs. 2, 3) four beds could be distinguished (Plate 3, Fig. 1).

The lowermost exposed bed (Bed 1) is dasycladalean grainstone; fine to coarse-grained calcarenite (Plate 4, Figs. 1, 2, 3). The origin of the fine bioclast fraction cannot be recognised, probably detritus of calcareous algae



Text-Fig. 2.
Stratigraphic scheme of the Upper Triassic formations for the Feisterscharte area (after Roniewicz et al., 2007, modified). Not to scale!

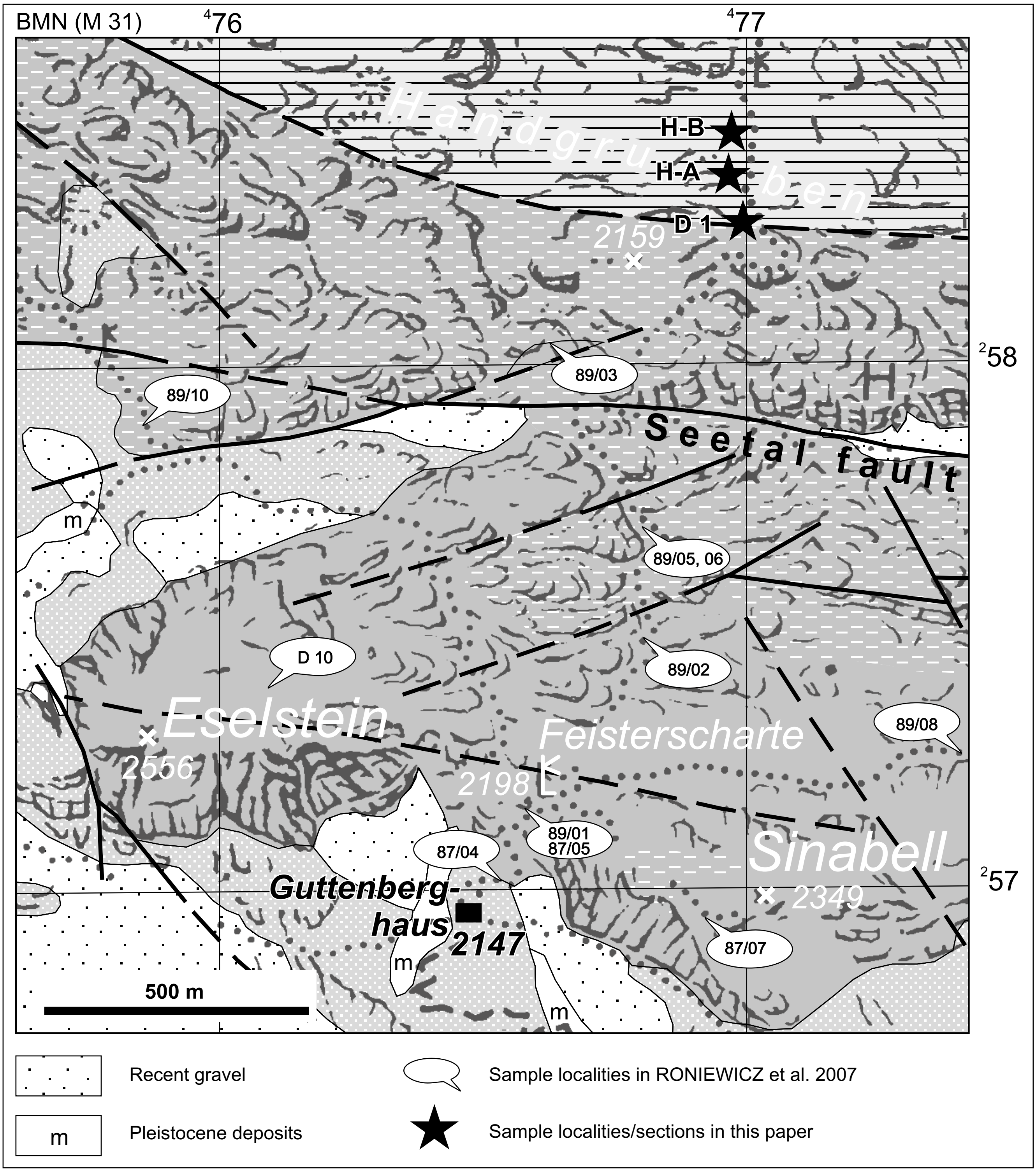
and molluscs. The coarse fraction is made up mostly of dasycladalean algae (1–8 mm in size), foraminifera, and gastropods. Foraminiferans are mostly recrystallised Aulotortidae *(Aulotortus sinuosus, A. impressus, A. friedli, A. communis)* beside them few specimens of *Ophthalmidium* could be recognised (Plate 2, Figs. 8–11). A few embryonic ammonites also occur. There are mm-sized solution vugs with sparitic fill similar to those in the moulds of dasycladaleans and gastropods.

The next bed is 25 cm thick (Bed 2) and dark grey limestone with black clasts. The texture is peloidal, bioclastic wackestone with a pedogenic overprint. There are fragments of molluscs, calcimicrobes, few gastropods and a relatively rich foraminifera fauna. *Turrispirillina minima* and Aulotortidae *(Aulotortus communis, A. impressus, A. tenuis, A. sinuosus, A. friedli)* are frequent (Plate 2, Fig. 12). Specimens of Duomostinidae, *Glomospirella* sp., *Gandinella falsofriedli* (Plate 2, Fig. 13), *Endoteba* sp., *Valvulina* sp., *Ophthalmidium* sp. and gymnocodiacean *Asterocalculus heraki* are also present. Some of the bioclasts were subject to blackening (Plate 4, Figs. 4, 5). Lumps and small blackened clasts are also visible. The matrix exhibits a patchy microsparitic alteration. Fenestral pores also occur.

The overlying 110 cm thick bed is dark red and abundant in black pebbles. In the lower part of the bed (Bed 3a) the black clasts are coarser (cm-sized). The typical texture is argillaceous micrite with great amount of unrounded and unsorted lithoclasts, intraclasts. In the studied sample a 10 mm-sized clast of peloidal bioclastic grainstone texture was encountered with gastropods and foraminifera and a number of fenestral pores. Micritization and traces of solution were observed on the margin of this clast (Plate 4, Fig. 7). Blackened *Rivularia*-like calcimicrobe, 1.5 mm in size was also encountered. The other clasts are of probably pedogenic origin; micritic or microsparitic with root casts, locally. In a 1 mm wide desiccation crack well-preserved thin-shelled ostracods were found in crystal-silt internal sediment (Plate 4, Fig. 6). In the upper part of this bed (Bed 3b) the micritic matrix is rich in 1–2 mm-sized mostly reef-derived bioclasts from Inozoan and Chaetetid sponges, calcimicrobes that are usually bioeroded, micritized and surrounded by a limonitic micrite envelope. Fragments of gastropods, bivalves, crinoids, and aulotortid foraminifera *(Aulotortus friedli, A.* cf. *communis)* also occur. Blackened calcimicrobes were also found. There are a few lithoclasts, abundant in fenestral pores and a number of intraclasts usually with limonitic staining.

The red limestone intercalation is overlain again by light grey limestone beds. The lowermost bed (Bed 4) is made up of peloidal bioclastic grainstone (Plate 4, Fig. 8). It is medium- to coarse-grained calcarenite with fragments of megalodontids and other bivalves, foraminifera (Duostominidae, *Trochammina* spp., *Endoteba* sp.), rivulariaceans and micritized microbial nodules. A few blackened calcimicrobes were also encountered. There are relatively large solution cavities after megalodont shells which are filled by coarse sparry calcite.

The beds of the studied outcrop were deposited in a backreef lagoon where along with the autochthonous carbonate grains, reef-derived, storm-transported bioclasts and lithoclasts were also deposited occasionally. In the foraminifera fauna the *Aulotortus* are predominant; some of them *(Aulotortus communis)* were dweller of the calcarenitic backreef environments whereas others *(A. tenuis, A. friedli)* preferred the protected muddy lagoon. The Duostominids commonly occur in the oncoidal facies (e.g. Dullo, 1980). The features of the red interbed indicate incipient pedogenesis during a subaerial exposure episode. Traces of meteoric diagenesis were encountered in the grey bed below the red one.

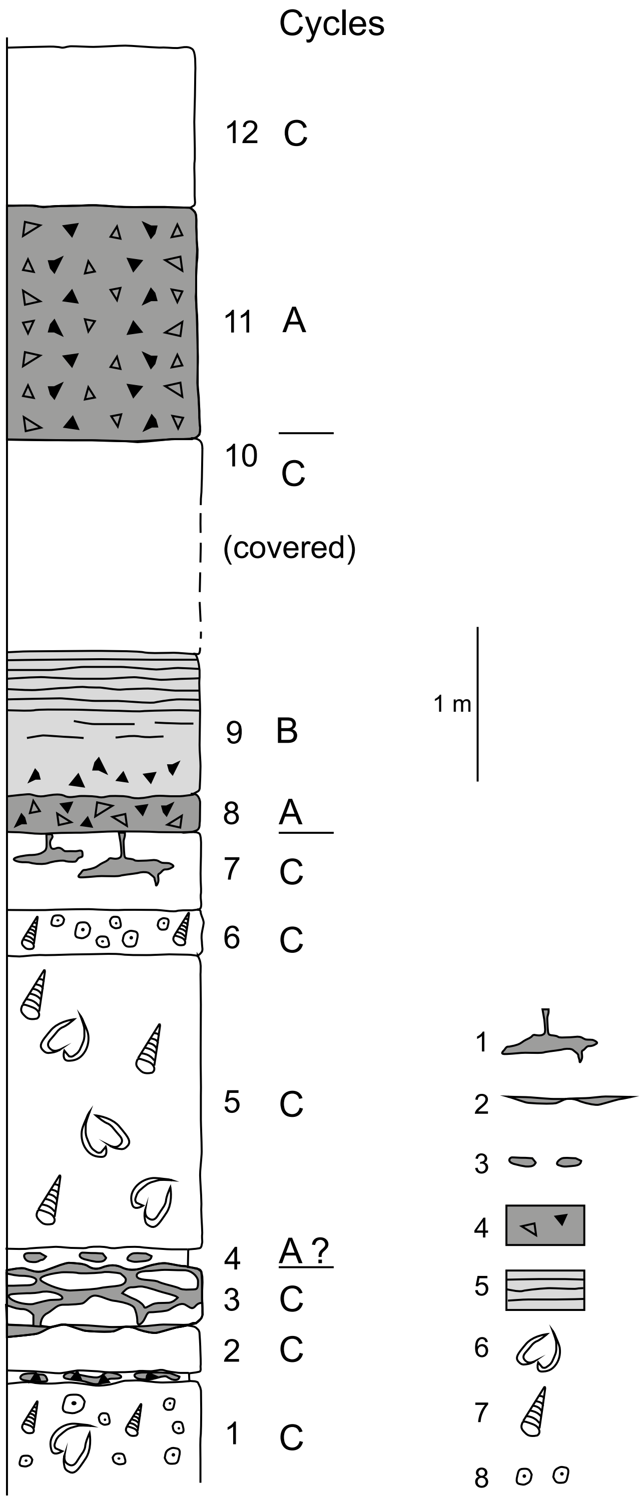


Text-Fig. 3.
Geological map of the Feisterscharte area, showing the studied sections and localities referred to in the text.

Section Handgruben B

Location of the sections studied is shown on Text-Fig. 3 (marked by H–B). On Plate 3, Fig. 2 gently dipping beds of the longer measured section are visible. Text-Fig. 4 displays the lithological column of the section with indication of the facies-types of the beds. The typical microfacies of the beds are presented on Plates 5 and 6.

The lowermost bed of the studied succession is light grey oncoidal limestone with megalodonts and gastropods (Bed 1). It has an oncoidal wackestone texture (Plate 5, Fig. 1). The matrix is peloidal microsparite, locally clotted. The size of oncoids is 1–4 mm. Generally, a lump of clotted microsparite serves as the nucleus of the oncoids (Plate 5, Fig. 2). There are intraclasts (plasticlasts) of peloidal grainstone texture. Centimeter-sized microbial clusters with only a thin microbial crust or without any crust also occur. From among the bioclasts a few, mostly agglutinated foraminifera (*Trochammina* sp., *Valvulina* sp., *Glomospira* sp., *Kaevaria fluegeli* and *Frondicularia wood-*



Text-Fig. 4.
Litho- and biofacies characteristics of section Handgruben B.
1 = cavities filled by red limestone;
2 = paleokarst pockets filled by red argillaceous limestone;
3 = reddish patches;
4 = limestone with lithoclasts and black pebbles;
5 = yellowish laminated limestone;
6 = megalodonts;
7 = gastropods;
8 = oncoids.

wardi), microbially encrusted mollusc shell fragments and a cm-sized embryonic ammonite test can be mentioned (Plate 5, Fig. 1). In small cavities formed by burrowing or desiccation micrite fill with thin-shelled ostracods were encountered. There are solution pores, 0.1–1 mm in size with sparitic lining and crystal silt fill. This bed is capped by a 5 cm thick horizon showing features of paleokarstification. Solution pockets and pipes filled by red argillaceous limestone are visible.

Bed 2 is light grey limestone displaying a vague lamination. The lower part of the studied sample is made up of peloidal micrite-microsparite containing peloidal grainstone plasticlasts. Moulds of thick-shelled bivalves and gastropods, and small sized agglutinated *(Trochammina* sp., Textularidae sp.) and miliolids *(Agathammina* sp., *Ophthalmidium* sp.) occur. This texture progresses upward into a laminitic one characterised by alternation of micrite and microsparite laminae (Plate 5, Fig. 3). The top of this bed is uneven due to karstic solution; there are pockets with red argillaceous carbonate fill.

Bed 3 consists of light grey limestone that is crosscut by a network of fractures and cavities filled by reddish fill. The texture is peloidal microsparite with small microbial nodules and mm-sized intraclasts. There are some mm-sized oncoids and a few well-preserved agglutinated foraminifera, mainly *Trochammina* spp. Bird's-eye pores are a typical feature of this bed and amalgamation of these pores to a network is also common. Mm- to cm-sized lenticular pores, sheet-cracks formed via desiccation and solution also occur. They often show geopetal fill with crystal silt at the base of the pores, in some cases with ostracods and coarse mosaic sparite above it (Plate 5, Figs. 4, 5).

Bed 4 is light brown limestone with red patches. The sedimentary texture is peloidal wackestone containing tiny peloids and a few foraminifera *(Trochammina* spp.) in a microsparitic matrix (Plate 5, Fig. 6). It is abundant in smaller or larger bird's-eye pores probably of desiccation origin. A 6 mm-sized red pedogenic clast was encountered. There are mm- to cm-sized cavities, usually of irregular rarely tubular shape. Geopetal fill is visible in some of the cavities with peloidal internal sediment (Plate 5, Fig. 7).

Beds 3 and 4 were formed in a shallow subtidal environment that was subsequently affected by desiccation, and karstic solution. Bed 3 was slightly subject to pedogenesis, the tubular cavities are probably root casts.

Bed 5 is of brownish grey colour with megalodonts and gastropods. Tiny black grains were observed in the lower part of the bed. The texture is bioclastic wackestone, abundant in globular biomolds. A few recrystallised involutinids *(Aulotortus tumidus, Aulotortus* sp.) and thin-shelled ostracods could be recognised. There are microbial nodules (Plate 5, Fig. 8) and some intraclasts.

Bed 6 consists of light grey oncoidal limestone with gastropods. Peloidal, bioclastic, oncoidal packstone–grainstone is the typical texture. The oncoids (2–7 mm in size) have no definite nucleus, cemented peloids and bioclasts occur in the inside of the coated grains. Lumps, composite grains are also common. Bioclasts are usually coated by a micrite envelope or microbial crust. Along with foraminifera (Duostominidae spp., *Trochammina* sp., *Valvulina* sp., *Glomospira* sp., *Alpinophragmium perforatum, Aulotortus friedli, Labalina* sp., *Frondicularia woodwardi, Reophax?* sp.) gastropods (Plate 6, Fig. 2), mollusc and echinodermata fragments and a well preserved dasycladalean alga *Poikiloporella duplicata* were found (Plate 6, Fig. 1). Irregular solution cavities with drusy sparry calcite fill are relatively common.

Bed 7 is of medium grey colour and rich in mm- to cm-sized oncoids (microbially coated microbial nodules) (Plate 6, Fig. 3). It is oncoidal, bioclastic grainstone. The bioclasts are abraded and coated by micrite. Along with calcimicrobes *(Rivularia, Girvanella)*, coral detritus, fragments of thick-shelled bivalves, gastropods, ostracodes a few well-preserved foraminifera *(Triasina hantkeni*, *Variostoma* sp., Duostominidae, *Valvulina* sp., *Sigmoilina schaeferae*, *Endoteba* sp.) were encountered (Plate 2, Figs. 15, 17). There are larger pores among the coarse grains, but in some cases the solution enlarged the pores. The pores and solution cavities commonly have geopetal fill. Centimeter-sized karst-related pockets with red carbonate fill also occur.

Bed 8 consists of red argillaceous limestone abundant in mm-sized black and white clasts. The texture displays a patchy pattern with intraclasts and lithoclasts (Plate 6, Fig. 4). In the micritic matrix there are fragments of molluscs, corals, thin-shelled ostracods and foraminifera *(Aulotortus impressus*, *Valvulina* sp., *Nodosaria* sp.). Mudstone lithoclasts and a larger wackestone clast with bird's-eye pores occur as well. There are a number of microsparitic clasts and globular grains with limonitic coating.

The lower part of Bed 9 is light grey limestone with scattered tiny black clast. The upper part of the bed is yellowish and laminated. The sample taken from the upper part clearly shows that the laminae are made up of fine calcarenite grainstone. Some of the laminae are graded suggesting storm-related tidal flat deposition. Peloids and biomolds are abundant; fragments of bivalves, foraminifera and *Rivularia*-type calcimicrobes are the recognisable bioclasts. Among the foraminifera specimens of *Aulotortus friedli* are relatively frequent, besides them other Aulotortidae *(A. impressus, A. tumidus, A. tenuis)* (Plate 2, Figs. 18, 19), *Sigmoilina schaeferae, Agathammina austroalpina* and *Trochammina* sp. also occur. There are tiny spar-filled pores of irregular shape (Plate 6, Fig. 5). Sheet cracks parallel to the lamination are common. They have usually an uneven roof and complex geopetal filling with micrite, microsparite in the basal part and isopach sparite cement above it (Plate 6, Fig. 6).

Bed 10 is light grey limestone with small bioclasts. It is characterised by peloidal microsparite texture with bioclasts usually in micrite envelope. Foraminifera are common; taxa in order of frequency are *Trochammina* sp., *Aulotortus friedli, Endoteba* spp., *Diplotremina* sp., *Tetrataxis inflata* (Plate 2, Fig. 14), *Frondicularia woodwardi* and *Galeanella panticae* (Plate 2, Fig. 16). Fragments of echinoderms, *Tubiphytes*, *Rivularia*-type calcimicrobes (Plate 6, Fig. 7), *Thaumatoporella* also occur sporadically. There are a number of tiny solution vugs with sparitic fill and larger bird's-eye pores. Circumgranular cement was observed around larger peloids.

Bed 11 is dark red aphaneritic limestone with a number of small blackened and non-blackened clasts. The original depositional texture of the rock cannot be recognised due to the pedogenic alteration. In the peloidal micritic matrix there are a few mollusc shell fragments and foraminifera *(Aulotortus friedli*, Aulotortidae indet., *Endoteba* sp., *Nodosaria* sp.). Several intraclasts were found which are made up of micrite containing thin-shelled ostracods and small pores with microsparitic fill. Fenestral pores of various sizes typify the entire sample (Plate 6, Fig. 8). The pores usually have geopetal fill with crystal silt internal sediment. Fractures with similar fill were also observed. There are alveolar structures and root cast shaped larger pores.

The topmost bed of the measured section (Bed 12) is light grey fine crystalline limestone.

Based on field observations and microfacies studies, it is plausible that the succession is cyclic. It shows the basic characteristics of the Lofer cycles since the succession is made up of alternation of subtidal and peritidal beds. The subtidal beds are usually oncoidal and contain megalodonts, gastropods and foraminifera. Among the foraminifera the *Aulotortus communis*, *Tetrataxis* and Duostominidae preferred the calcarenitic substrate whereas *Aulotortus tenuis, A. friedli, Trochammina, Agathammina* were inhabitants of the muddy lagoonal environments (e.g. Schäfer & Senowbari-Daryan, 1978; Dullo, 1980). Appearance of *Sigmolinia schaeferae* in Bed 9 suggests redeposition of some skeletal material from the reef zone (Bernecker, 1996).

Some of the subtidal beds were affected by pedogenic alteration, karstification and meteoric early diagenesis. There are beds, which probably deposited on the tidal flat. The shallow subtidal carbonate factory may have been the source of the carbonate mud also in these cases but these beds having usually reddish colour also contain reworked soil derived material and were also affected by incipient pedogenesis. Laminated structure of Bed 9 reflects storm deposition in the supratidal zone. Based on these features the beds of the studied succession correspond with Fischer's (1964) facies units (A, B and C facies) and the Lofer cycles are recognisable (Text-Fig. 4).

The foraminifera fauna may provide tools for the chronostratigraphic evaluation of the Handgruben sections. Some of the determined species have a long stratigraphic range (Upper Triassic or even Middle to Upper Triassic). There are some species probably of Norian to Rhaetian range, although their assignment is commonly debated. Examples are listed below. *Alpinophragmium perforatum*: Norian–Rhaetian (Flügel, 1967), Norian (Wurm, 1982); *Aulotortus communis*: Norian–Rhaetian (Koehn-Zaninetti, 1969); *Aulotortus impressus*: Rhaetian (Kristan-Tollmann, 1964), Lower Rhaetian (Salaj & Stranik, 1970), Rhaetian (Pantič-Prodanović & Radošević, 1981), Norian–Rhaetian (Koehn-Zaninetti, 1969), Carnian–Rhaetian (Salaj et al., 1983); *Aulotortus sinuosus*: Norian (Wurm, 1982), Rhaetian (Kristan-Tollmann, 1964), Norian–Rhaetian (Koehn-Zaninetti, 1969; Pantič-Prodanović & Radošević, 1981; De Castro, 1990); *Aulotortus tenuis*: Rhaetian (Kristan-Tollmann, 1964), Norian–Rhaetian (Koehn-Zaninetti, 1969; Pantič-Prodanović & Radošević, 1981), Ladinian? Norian–Rhaetian (Senowbari-Daryan et al., 2010); *Aulotortus tumidus* (Kristan-Tollmann, l964): Rhaetian (Kristan-Tollmann, 1964), Lower Rhaetian (Salaj & Stranik, 1970), Norian–Rhaetian (Koehn-Zaninetti, 1969; Pantič-Prodanović & Radošević, 1981), Norian (Wurm, 1982), Upper Triassic–Liassic? (Senowbari-Daryan et al., 2010); *Gandinella falsofriedli*: Upper Norian – Lower Rhaetian (Poisson et al., 1985), Upper Alaunian – Sevatian (Salaj et al., 1988), Upper Norian – Rhaetian (Zamparelli et al., 1995); *Sigmoilina schaeferae*: Norian–Rhaetian (Schäfer & Senowbari-Daryan, 1978); *Triasina hantkeni*: Norian–Rhaetian (Bernecker, 2005), Upper Norian – Lower Rhaetian *(Rhabdoceras suessi* zone – *Choristoceras marshi* zone – De Castro, 1990); *Turrispirillina minima*: Norian–Rhaetian (Salaj et al., 1983), Norian (Oravecz-Scheffer, 1987).

To summarize, on the basis of the foraminifera fauna the layers exposed in the Handgruben sections are probably of Late Norian to early Rhaetian age. Since there is no index foraminifera taxon for distinguishing the Upper Norian from Lower Rhaetian we cannot make more detailed biostratigraphically constrained assignment. On the basis of the geological setting of the section, and taking into account the general dip of the strata, the Upper Norian assignment seems to be more realistic (Text-Fig. 2).

Comparison with Sections Representing the Platform Interior

In the last years several Lofer cyclic Dachstein Limestone sections were studied on the northern part of the Dachstein plateau (Krippenstein-Schutzhaus and Gretl-Rast sections) 5–6 km northward to the presently studied outcrops (Haas et al., 2007, 2009). Based on the foraminifera fauna both sections are Norian, probably Upper Norian (Haas et al., 2009). Paleogeographically those sections represent the internal part of the Dachstein platform, far from the marginal reef tract (Mandl, 2000). So it is not amazing that there are significant differences in the basic characteristics of the cyclic successions near and far from the platform margin. In the section Handgruben B, the oncoidal facies is typical in the subtidal C facies. The A facies is relatively thick, and typified by the presence of reworked soil-derived clasts. The B facies is poorly developed, and no stromatolites were found.

In the sections studied near Mt. Krippenstein, in the northern part of the Dachstein plateau (Haas et al., 2007) the main characteristics of the Lofer cycles can be summarized as follows. The boundaries of the cycles are usually erosional disconformities showing features of karstification. Member A that is typically reddish or greenish argillaceous limestone is a few mm to 10 cm thick. It can be interpreted as tidal flat deposit consisting predominantly of subtidal carbonate mud redeposited by storms. It was mixed with reworked air borne fine carbonate particles and argillite that were accumulated and subjected to weathering on the subaerially exposed platform. Rip-ups from consolidated sediment, blackened intraclasts and skeletons of tidal flat biota may have also contributed to the material of facies A. The karstic solution pockets and cavities are commonly filled by the A facies. In micritic cavity-fills low-salinity to freshwater ostracods were encountered (Haas et al., 2007).

The basal disconformity or the A facies is usually followed by white to light yellow or darker grey stromatolites or mudstones with fenestral pores, sheet cracks and shrinkage cracks, showing features of member B. The thickness of member B is usually 10–50 cm but may exceed 1 m, rarely. The B facies can be interpreted as intertidal to lower supratidal tidal flat deposit. The B or rarely the A facies is overlain by light brown or greyish brown, light grey limestone commonly with megalodonts, i.e. member C. The typical microfacies is peloidal, bioclastic wackestone, packstone or grainstone with foraminifera (involutinids, nodosariids), fragments of dasycladalean algae, molluscs, echinoderms (Haas et al., 2007, 2009). The thickness of member C is 1–3 m.

In the studied sections the ABC facies succession was found at the base of many cycles suggesting a transgressive trend. In contrast, the regressive part of the cycles is frequently missing due to the post-depositional truncation. The facies differences between the marginal and the internal cyclic successions can be summarized as follows.

1. Above the erosional, karstic disconformity surface the A facies appear to be thicker in the marginal zone (Handgruben section) where traces of the in situ pedogenesis could also be observed.
2. The B facies (stromatolites, loferites) are usually present at the basal part of the cycles in the platform interior succession (Krippenstein), whereas similar facies (laminated mudstone but not stromatolite) was found only in a single cycle in the studied marginal succession.
3. The C facies is typically oncoidal packstone, grainstone in the marginal zone and peloidal bioclastic wackestone, packstone and grainstone in the platform interior area; megalodonts are common in both.

These differences probably reflect the differences in the paleogeographic setting. In the marginal zone, near the offshore edge of the platform oncoid shoals developed under relatively high-energy conditions above the fair-weather wave base. The marginal patch-reefs (knoll-reefs) may have been situated somewhat deeper. The wide platform interior area was located behind the marginal shoals and during the high sea level periods it was slightly deeper than the oncoid mounds. The sea-level drops led to subaerial exposure and related karstification both of the shoal belt and the interior lagoon. Rising sea level led to the establishment of tidal flat conditions on the platform interior whereas the subaerial conditions were prolonged on the slightly elevated previous shoals which resulted also in incipient pedogenesis.

Comparison with the Oncoidal Dachstein Limestone in the Transdanubian Range

In the Transdanubian Range (TR), Hungary, the Dachstein-type platform carbonates developed in a remarkable areal extension and great thickness. Paleogeographically this area was a segment of the Neotethys shelf which was located between the South Alpine and the Upper Austroalpine domain. Upfilling of the intraplatform basins by the latest Carnian made possible the establishment of the large platform. The facies polarity is straightforward; the NE part of the TR represents the offshore platform margin whereas its SW part was closer to the firm land (Haas & Budai, 1995). Over the predominant part of TR the platform carbonates are definitely cyclic showing characteristics of the Lofer cyclicity (Haas, 2004). The lower part (Upper Tuvalian to Middle Norian) of the cyclic succession is pervasively dolomitized, the upper part (Upper Norian to Rhaetian) is non-dolomitized, and there is a transitional interval between them. However, in the NE part of TR (Buda Hills, blocks in the eastern side of the Danube) the intraplatform basins developed in the Carnian preserved during the Late Triassic and on the smaller isolated platforms thick-bedded oncoidal limestones (the oncoidal facies of the Dachstein Limestone) and locally patch reefs were formed.

In the central part of the Buda Hills the Late Carnian to Early Norian cyclic dolomites (corresponding to the Dachstein Dolomite) is overlain by the oncoidal development of the Dachstein Limestone. It is typified by predominance of the oncoidal-oolitic grainstone subtidal facies (C facies) with megalodonts and gastropods. It is punctuated by disconformity surfaces, but the peritidal facies (member A and B) are scarce and thin. It means that the Lofer cyclicity is only rudimentary, amalgamation of the elementary cycles is common (HAAS, Ed., 2004).

In the blocks on the east side of the Danube (Nézsa–Csővár block), Late Carnian patch-reefs are known that are made up of calcareous sponges, various encrusting organisms, calcimicrobes and a few corals (KOVÁCS, 2004). In some places it is well visible that the reef patches are surrounded by oncoidal limestone. The higher, Norian part of the thick-bedded limestone is made up predominantly of oncoidal-oolitic grainstone akin to that in the Buda Hills. The lower part of the several hundred meters thick succession consists mostly of subtidal facies, the A facies is missing; the B facies is thin and typified either by fenestral laminated sheet-crack or stromatolite rip-up facies (BALOG & HAAS, 1990).

Comparing the oncoidal facies of the Dachstein Limestone in the southern part of the Dachstein plateau and the NE part of the TR it is plausible that both occur near the platform margin. In the case of the Dachstein plateau it is a relatively narrow belt, whereas in the TR it seems to be much wider. However, according to the relevant paleogeographic models (MANDL, 2000) the platform of the Dachstein plateau was in direct connection with the deep shelf basin of the Neotethys Ocean, whereas the platform margin was more articulated in the segment of the TR, where intraplatform basins existed among smaller platforms (HAAS, 2002). In the area of the Dachstein plateau the oncoidal zone may have been relatively elevated and that may be the cause of the striking paleokarst features and well-developed supratidal A facies which developed during the low sea-levels. In contrast, in the area of the NE part of the TR, the subaerial exposure surfaces and the peritidal facies are frequently missing, there are amalgamated cycles, that means that the area remained inundated even during the sea-level lowstands.

Acknowledgements

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Plate 1

Microfacies characteristics of massive limestones of reef and near-reef facies

Fig. 1: Reef derived breccias with sparitic cement. A coral fragment with microbial crust is visible in the left side.

Fig. 2: Fragments of microbial crusts and lithoclasts, surrounded by sparry calcite cement.

Fig. 3: Calcareous sponge fragment.

Fig. 4: Rivulariacean fragment.

Fig. 5: Encrusting foraminifera *Tolypammina gregaria.*

Fig. 6: Bioclasts and lithoclasts bounded by encrusting foraminifera *Alpinophragmium perforatum*.

Fig. 7: Domal microbial crust.

Fig. 8: Microproblematicum *Baccanella floriformis*.

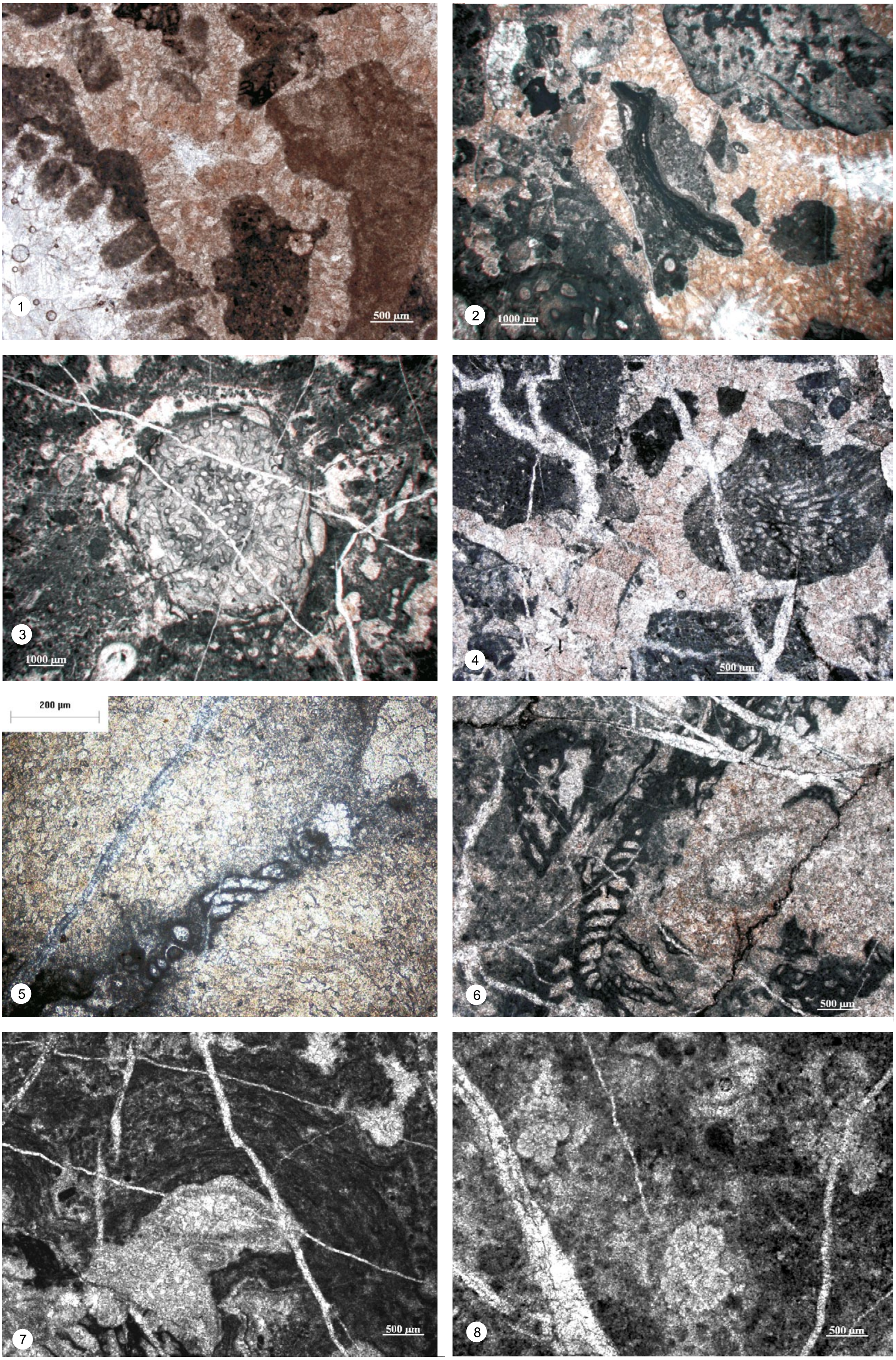
1
500 µm
2
1000 µm
3
1000 µm
4
500 µm
200 µm
5
6
500 µm
7
500 µm
8
500 µm

Plate 2

Foraminifera and microproblematica in the studied exposures

Figs. 1–5: Samples taken south to the Seetal Fault.
Fig. 1: *Miliolipora cuvillieri*.
Fig. 2: *Miliolipora cuvillieri*.
Fig. 3: *Ophthalmidium triadicum.*
Fig. 4: *Kaevaria fluegeli.*
Fig. 5: *Agathammina austroalpina.*
Figs. 6–7: Sample D1.
Fig. 6: Duostominidae.
Fig. 7: *Messopotamella angulata.*
Figs. 8–11: Section Handgruben A Bed 1.
Fig. 8: *Aulotortus sinuosus*.
Fig. 9: *Aulotortus impressus.*
Fig. 10: *Aulotortus communis.*
Fig. 11: *Aulotortus friedli.*
Figs. 12–13: Section Handgruben A, Bed 2.
Fig. 12: *Aulotortus friedli.*
Fig. 13: *Gandinella falsofriedli.*
Figs. 14–19: Section Handgruben B.
Fig. 14: *Tetrataxis inflata,* Bed 10.
Fig. 15: *Sigmoilina schaeferae,* Bed 7.
Fig. 16: *Galeanella panticae* and *Trochammina* sp., Bed 10.
Fig. 17: *Triasina hantkeni,* Bed 7.
Fig. 18: *Aulotortus tumidus* Bed 9.
Fig. 19: *Aulotortus tenuis* Bed 9.

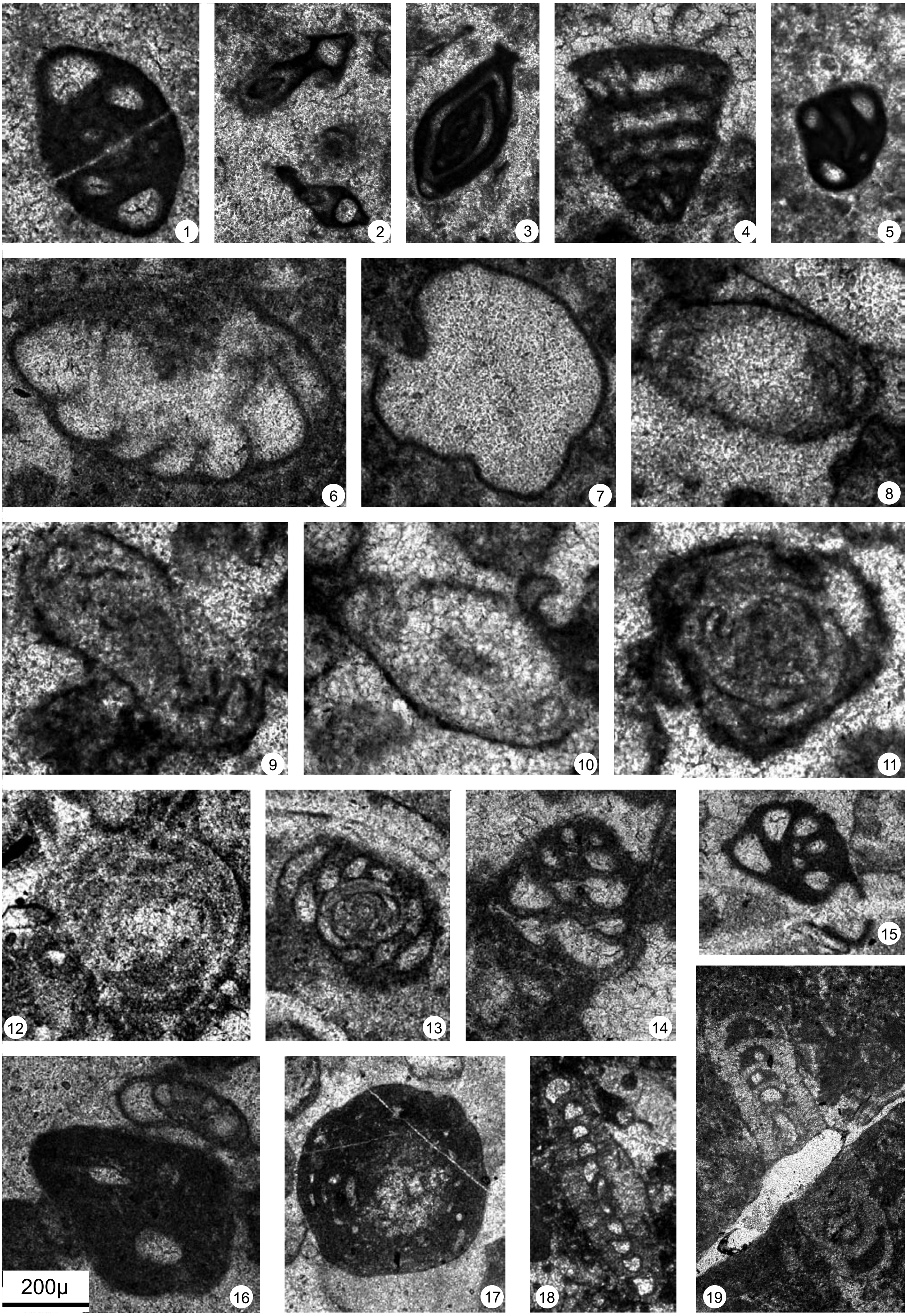
200μ

Plate 3

Measured and studied sections with numbers of the measured and sampled beds

Fig. 1: Section Handgruben A.

Fig. 2: Section Handgruben B.


4
3b
3a
2
1
1


9
10
11
12
1
3
4
2
5
6
7
8
2

Plate 4

Microfacies characteristics of section Handgruben A

Fig. 1: Peloidal, bioclastic (dasycladalean) grainstone; the intra- and intergranular pores and solution vugs are filled by bladed and drusy calcite cement (Bed 1).

Fig. 2: Peloidal, bioclastic grainstone with fragments of dasycladalean algae, bivalves and an embryonic ammonite (Bed 1).

Fig. 3: Fragments of bivalves, gastropods, and calcareous algae. The shelter pores are filled by isopach sparite cement (Bed 1).

Fig. 4: Peloidal microsparite with fragments of blackened (brown in thin section) Rivulariaceans. The small solution pores are filled by fine mosaic cement (Bed 2).

Fig. 5: Peloidal, bioclastic microsparite with blackened Foraminifera *(Aulotortus communis)* and other bioclasts (Bed 2).

Fig. 6: Pedogenic calcrete; red argillaceous micrite with lithoclasts. A shrinkage crack filled by ostracod-bearing microsparite is visible in the middle of the picture (Bed 3a).

Fig. 7: Peloidal bioclastic grainstone lithoclast in red argillaceous micrite matrix (Bed 3a).

Fig. 8: Peloidal bioclastic grainstone with fragments of Rivulariaceans and bivalves (Bed 4).

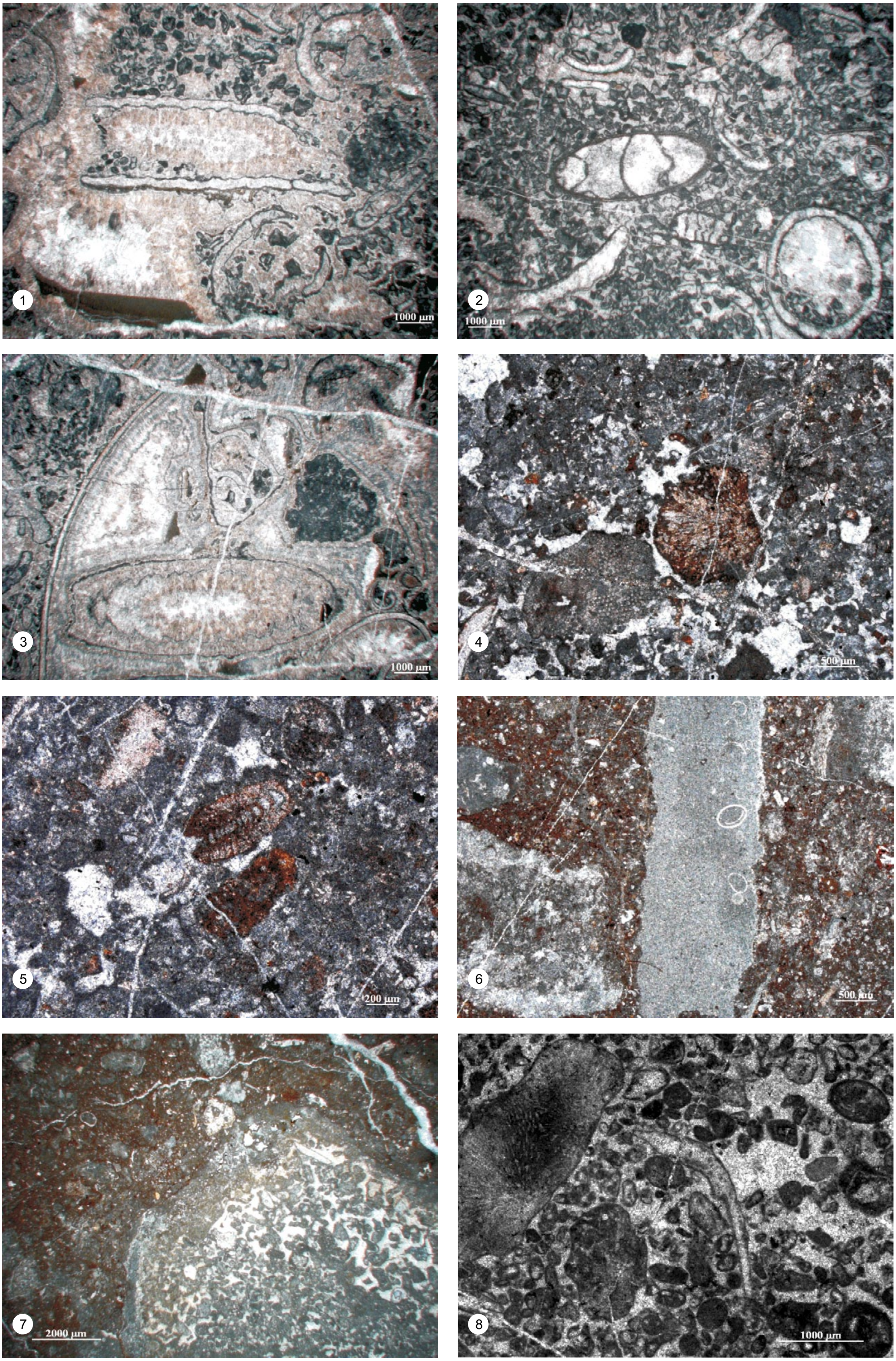
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Plate 5

Microfacies characteristics of section Handgruben B

Fig. 1: Oncoidal wackestone with an embryonic ammonite test (Bed 1).

Fig. 2: A lump of clotted peloidal microsparite serves as the nucleus of an oncoid (Bed 1).

Fig. 3: Peloidal micrite progresses upward to laminitic texture (Bed 2).

Fig. 4: Bird's-eye pore with geopetal fill; amalgamation of the pores is well visible (Bed 3).

Fig. 5: A network of the bird's-eye pores; some of them are partially filled by red crystal silt (Bed 3).

Fig. 6: Peloidal wackestone with bird's-eye pores (Bed 4).

Fig. 7: Solution cavity with geopetal fill; peloidal internal sediment occurs at the base of the cavity (Bed 4).

Fig. 8: Fragment of calcimicrobial remains in peloidal wackestone (Bed 5).

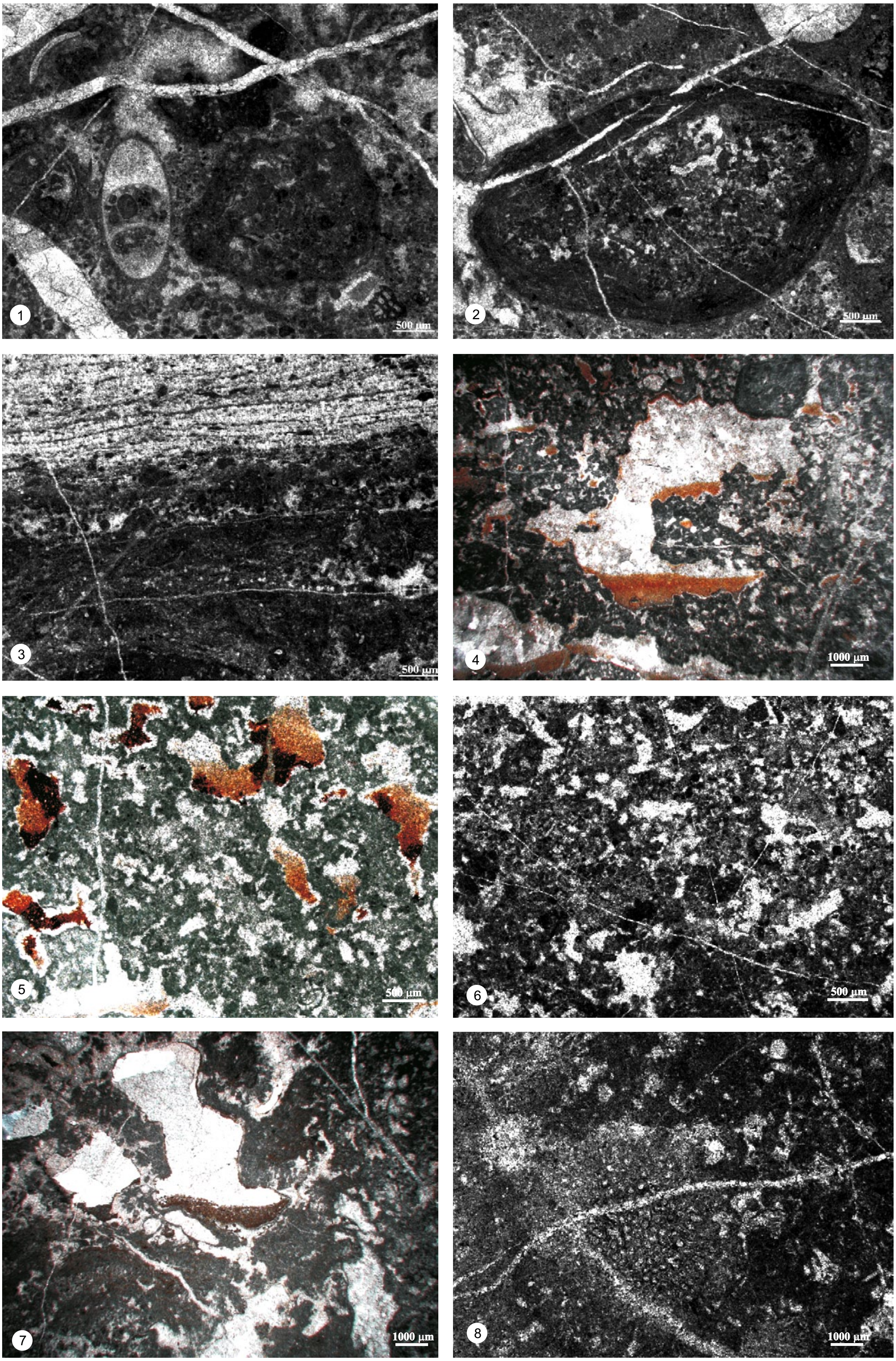
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Plate 6

Microfacies characteristics of section Handgruben B

Fig. 1: Fragment of dasycladalean algae *(Poikiloporella duplicata)* in peloidal, bioclastic, oncoidal packstone (Bed 6).

Fig. 2: Microbially encrusted gastropod (Bed 6).

Fig. 3: Microbially coated microbial nodule (Bed 7).

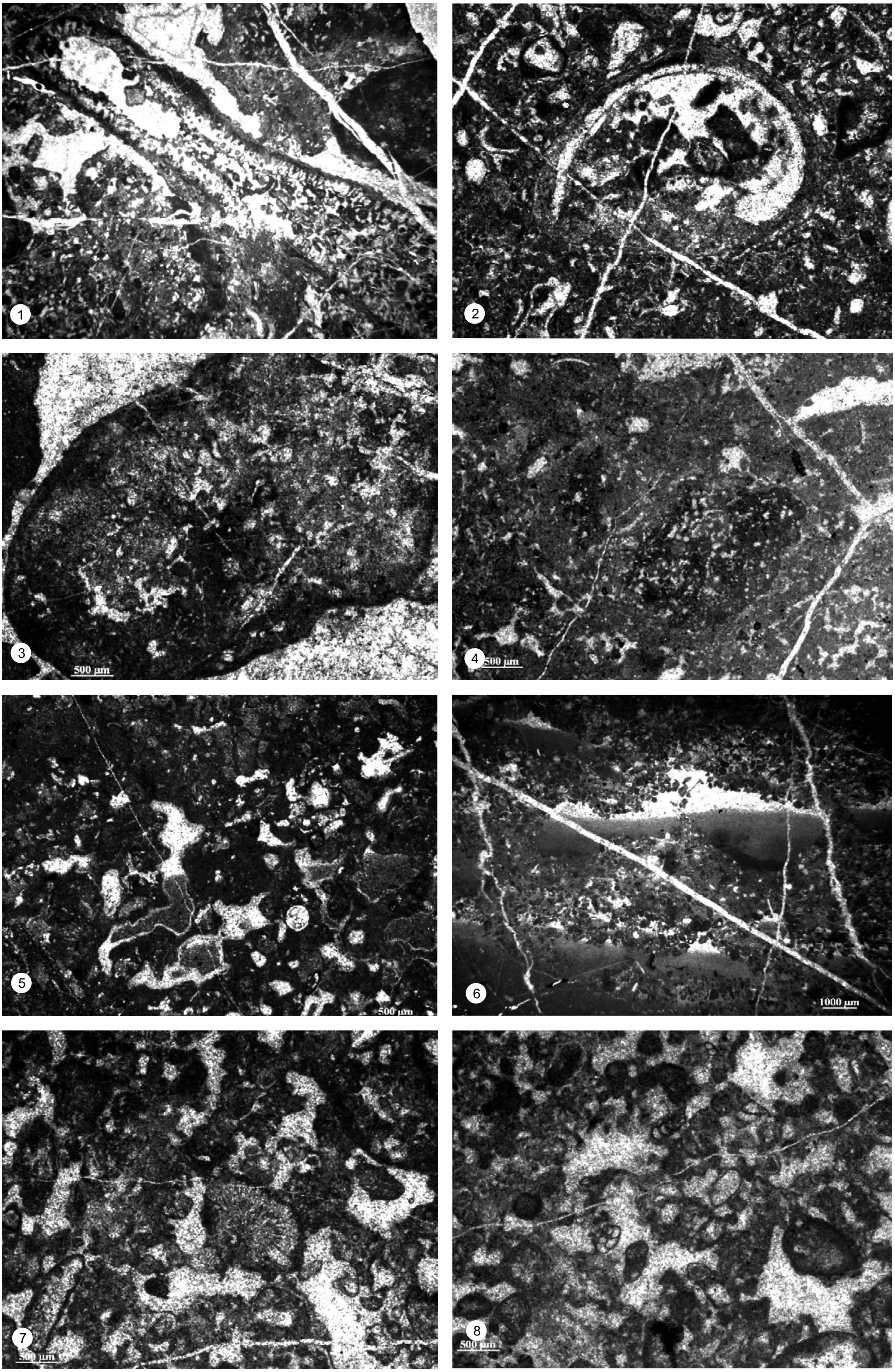
Fig. 4: Small intraclasts and lithoclasts in microsparitic matrix (Bed 8).

Fig. 5: Network of solution vugs with geopetal fill in some of the pores (Bed 9).

Fig. 6: Lenticular solution pore with geopetal fill (Bed 9).

Fig. 7: Peloidal microsparite with a *Rivularia*-type calcimicrobe fragment (Bed 10).

Fig. 8: Peloidal, bioclastic texture, rich in irregular fenestral pores (Bed 11).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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

An Invertebrate Faunula in the Kössen Beds of Starnkogel (Bad Ischl, Upper Austria)

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5 Text-Figures, 1 Plate

Österreichische Karte 1:50.000
Blatt 96 Bad Ischl

Dachstein Limestone
Kössen Formation
Totes Gebirge
Brachiopods
Ichnofossils
Bivalves

Contents

Eine Invertebraten-Faunula in den Kössener Schichten des Starnkogels (Bad Ischl, Oberösterreich)

Zusammenfassung

Aus mehreren Lagen von Kössener Schichten, die dem lagunären Dachsteinkalk des Steinbruchs am Starnkogel NNO von Bad Ischl bankparallel zwischengeschaltet sind, wird eine artenarme Bivalven- und Brachiopoden-Faunula beschrieben. Erstere setzt sich ausschließlich aus grabenden Formen zusammen, was für ein gut durchlüftetes Ablagerungsmilieu sowie ein kompaktes Substrat spricht. Die Brachiopoden-Faunula besteht lediglich aus 3 Taxa, wobei *Rhaetina pyriformis* (SUESS) bei weitem dominiert. Selten findet sich auf Schichtflächen von mergeligen Kössener Einschaltungen die Lebensspur *Thalassinoides*. Diese verzweigten Spuren sprechen für episodische Sedimentation und weisen wahrscheinlich auf Ablagerungs-Unterbrechungen hin.

Abstract

In the Starnkogel Quarry NNE of Bad Ischl the upper part of the cyclically bedded "lagoonal" Dachstein Limestone is coarsely bedded (0.5–3 m) and locally shows a peculiar development, namely intercalations of Kössen type limestones and marls. The exclusive presence of burrowing forms in the bivalve faunula of the Kössen intercalations indicates well oxygenated bottom waters and firm substrate during the deposition of the Kössen Beds. The brachiopod faunula consists of 3 taxa and is dominated by *Rhaetina pyriformis* (SUESS). Scarce findings of the ichnofossil *Thalassinoides* isp. are restricted to the marly intercalations of the Kössen Beds. *Thalassinoides* networks are characteristic for rather episodic sedimentation and probably indicate omission surfaces.

Introduction

On Starnkogel NNE of Bad Ischl Dachstein Limestone is mined in a large quarry by BauMit Co. Ltd. for the production of lime, mortars, etc. (Text-Figs. 1, 2). Tectonically this area belongs to the Tyrolic unit of the northwestern Totes Gebirge mountain range (SCHÄFFER et al., 1976, 1982); MANDL et al., in prep.). Here the higher parts of the cyclically bedded "lagoonal" Dachstein Limestone show a thickness of beds from 0.5–3 m. Locally a peculiar development, namely intercalations of Kössen type sediments, can be seen. These medium to dark grey or black, more or less marly limestones and clayey shales/marls are intercalated parallel to the bedding into the Dachstein Limestone

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Text-Fig. 1.
Topographic sketch of Starnkogel quarry.

sequence (Text-Fig. 3). Hit with the hammer, some of the Kössen layers show a bituminous smell and – in places – mineralization by disseminated pyrite is common (Text-Fig. 5). This fact probably points to an anaerobic depositional environment of part of the Kössen Beds in shallow subtidal pools within the Dachstein carbonate platform. Loferitic Dachstein limestone is missing.

For more details concerning palaeoenvironment see the discussions in the paragraphs below. Additional sedimentological data on the Starnkogel quarry were published by Moshammer (2004, 2008) and Leuprecht & Moshammer (2007).

In nearby Kössen type intercalations of the southwestern slope of Hohe Schrott bivalve coquinas and plant debris occur (Schöllnberger, 1967). A similar development is exposed in the lower course of Rettenbach stream just above Gasthaus Rettenbachmühle E of Bad Ischl. These outcrops were studied by Hohenegger & Piller (1975) in respect to foraminifera ecology. Also in the large quarry of Gmundner Zement Co. on Pfeiferkogel SE of Ebensee the coarse bedded Dachstein Limestone shows dark claystone intercalations of Kössen type.

The Faunula

Macrofossils are not very frequent in the quarry. Some Kössen layers are comparatively rich in fossils, in particular brachiopods and bivalves, scarcely also corals and gastropods can be found. Scarce findings of ichnofossils seem to be restricted to marly intercalations within the Kössen Beds. The faunula described below was collected in 2008 and 2009 by M. & J. Siblík, St. Druckenthaner (Bad Ischl) and H. Lobitzer and is kept in the collections of the Austrian Geological Survey in Vienna.

Bivalves

Three bivalve specimens were found. A somewhat incomplete, closed double-valved mould with preserved shell represents *Inoperna (Triasoperna) schafhaeutli* (Stur, 1851) (Pl. 1, Figs. 1, 2). This characteristic mytilid species was referred

Text-Fig. 2.
Areal photograph of Starnkogel quarry.

to as *"Modiolus"* or *"Mytilus"* for a long time (see HAUTMANN, 2001 for synonymy). REPIN (1996) when erecting the subgenus *Triasoperna* designated *Inoperna (Triasoperna) prima* REPIN, 1996 as type species. This latter taxon, according to HAUTMANN (2001), is a junior synonym of *"Modiola" schafhaeutli* STUR.

The most distinctive feature of *Inoperna (Triasoperna) schafhaeutli* is the divaricate plication of the thin shell. The plicae seem to be less developed near the ventral margin. This type of ornamentation indicates infaunal, burrowing mode of life (see e.g. SEILACHER, 1972), as it was also supposed for *Inoperna (Triasoperna) schafhaeutli* by HAUTMANN (2001) and for a species of *Inoperna* sensu stricto by HODGES (2000). Other authors (e.g. DELVENE, 2001), however, consider *Inoperna* s. s. as a semi-infaunal byssally attached form, by analogy of *Modiolus*.

Inoperna (Triasoperna) schafhaeutli is well known from the Rhaetian of both the Northern Calcareous Alps and the Southern Alps, as well as from the Carpathians and the Apennines (see DIENER, 1923; HAUTMANN, 2001). Outside Europe it was recorded from Iran by REPIN (1996) and by HAUTMANN (2001).

Two internal moulds of slightly open-valved specimens have been identified as *Homomya* sp. cf. *lariana* (STOPPANI, 1861) (Plate 1, Figs. 3, 4). Their umbonal and dorsal region cannot be extracted from the rock matrix. Their outline, however, recalls *H. lariana*, a Rhaetian species known from the Southern and Suisse Alps (see DIENER, 1923) and from Hungary (VÉGH, 1964). *Homomya lagenalis* (SCHAFHÄUTL, 1852), another species known from the Kössen Beds has a more elongated posterior region. The genus *Homomya* is not uncommon in the Kössen Beds. A fine specimen of *Homomya caffii* DESIO is figured even as a guide fossil of the Triassic in ROSENBERG & ZAPFE (1954).

The exclusive presence of burrowing forms in the bivalve faunula of the Starnkogel Quarry indicates well oxygenated bottom waters and firm substrate during deposition of the Kössen Beds exposed there.

Brachiopods

More or less fragmentary or damaged shells of *Rhaetina pyriformis* (SUESS, 1854) are the commonest findings there. This species was found also on other localities of the Totes Gebirge area, e.g. on Eibenberg ESE of Ebensee, from where rich assemblages of brachiopods and bivalves have been reported by ZAPFE (1949a, b). *Rhaetina pyriformis* (SUESS) has been described also from other regions in the Salzkam-

Text-Fig. 3.
Thin intercalation of Kössen-type marly limestone in bedded Dachstein Limestone.

mergut, as from the Kendlbach profile in the Osterhorn region south of lake Wolfgangsee.

Scarce and monospecific findings of the brachiopod *Rhaetina gregaria* (SUESS) have been published by ROSENBERG (1969) and SIBLÍK & LOBITZER (2003) from the surroundings of Knerzenalm near Altaussee. Occurrences of *Rhaetina pyriformis* (SUESS) are also known from other localities in these middle parts of the Northern Calcareous Alps, as e.g. from the "Oberrhät-Limestone" of the Rötelwand reef, from Steinplatte and from the Kössen Formation of Steinergraben in Wiestal, from Gaissau, in the eastern part of the Northern Calcareous Alps from the Tonion area and the Mariazeller Bürgeralm (see e.g. SIBLÍK, 1988).

Our brachiopod material includes 7 specimens of *Rhaetina pyriformis* (up to 54 mm of length, Pl. 1, Figs. 5–7), 2 specimens of *Zeilleria* cf. *austriaca* (ZUGMAYER, 1880) and 1 specimen of *Zeilleria norica* (SUESS, 1859). There was also material of 4 specimens of *Rhaetina pyriformis* and 1 damaged *Zeilleria* sp. at disposal for study, borrowed from the collection of the Austrian Geological Survey in Vienna (leg. B. Moshammer).

After GOLEBIOWSKI (1991) the Kössen type sediments of Totes Gebirge belong to his Hochalm Member, which is part of the Kössen Formation. The *Rhaetina*-Biofazies represents the shallowest depositional environment of all Kössen brachiopod biofacies with a water depth up to about 20 m.

Ichnofossils

Very scarce, imperfectly preserved findings of the ichnogenus *Thalassinoides* (mostly attributable to burrowing of the whole shrimp populations; cf. SEILACHER, 2007) seem to be restricted to the marly intercalations of Kössen type. Text-Fig. 4 shows at least one true "Y"-branching typical of *Thalassinoides*; also smooth surfaces, distances between the tunnels and their diameters correspond to the usual morphology of *Thalassinoides* (cf., e.g., UCHMAN, 1995). The *Thalassinoides* networks usually represent mid- to deep tier of burrowing structures (e.g., BROMLEY, 1996, p. 239). The ichnogenus is characteristic for rather episodic sedimentation which enables longer time intervals of development of colonization horizons. In some sequences, *Thalassinoides* networks marked gaps between turbidite or tempestite events and may indicate omission surfaces (e.g., MIKULÁŠ, 2006). However, if a firm ground (stiff mud bottom) develops, the tunnels bear scratch patterns and are classified as *Spongeliomorpha* (e.g., SEILACHER, 2007). *Thalassinoides* does not develop in day-by-day modelled shiftgrounds or in soupgrounds. If these substrates are affected by shrimp burrowing, the resulting form falls to the ichnogenus *Ophiomorpha*. Such burrows show a peculiar geometry of networks/boxworks and the tunnels have to be protected from a collapse by a wall lining (cf. SEILACHER, 2007).

Text-Fig. 4.
“Y”-branching *Thalassinoides* trace fossils in marly Kössen Beds.

Text-Fig. 5.
Mineralization by disseminated pyrite in Kössen Beds.

Plate 1

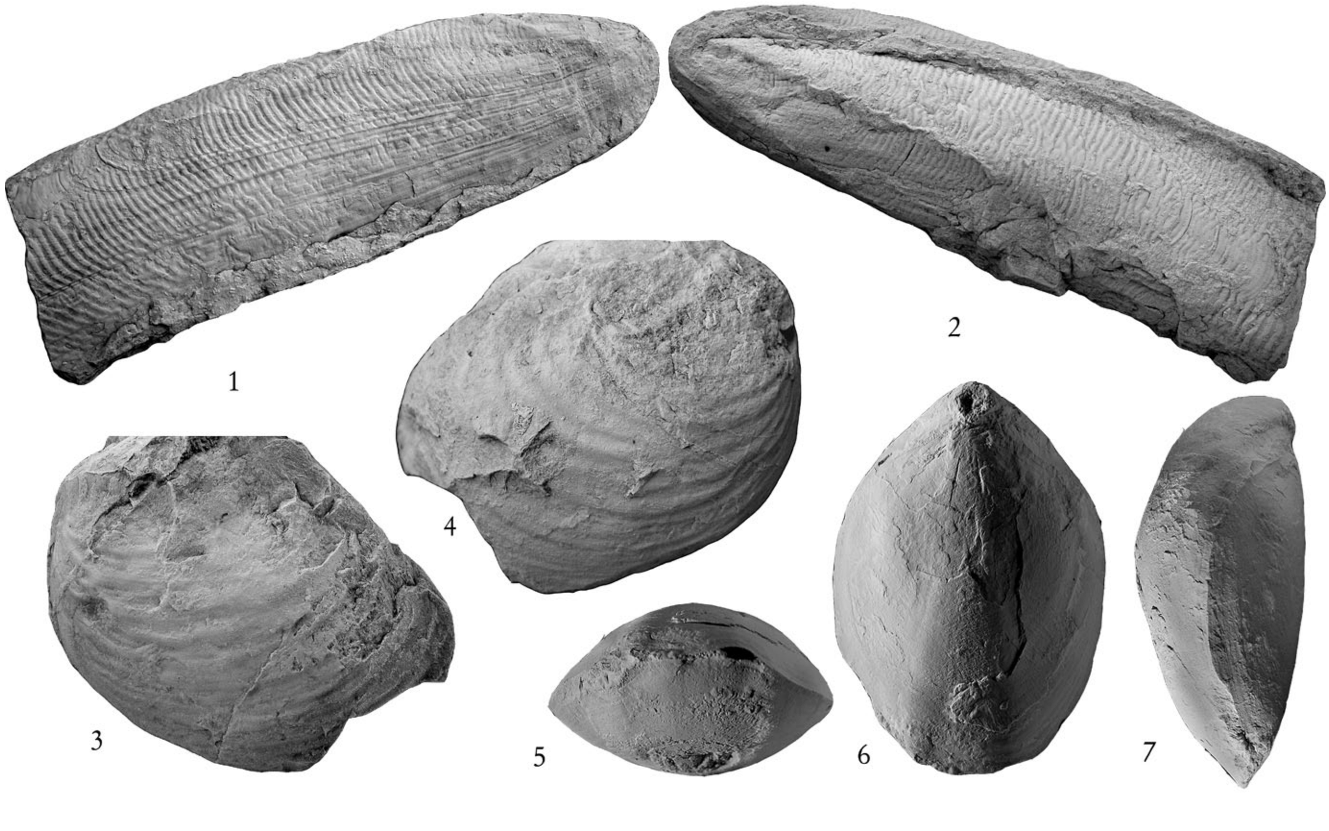
Bivalves and brachiopods from the Kössen Beds exposed in the Starnkogel Quarry.
The specimens are coated with ammonium-chloride.
All figures in natural size.

Figs. 1, 2: *Inoperna (Triasoperna) schafhaeutli* (Stur, 1851).
Fig. 1: right valve; coll. no.: GBA 2010/117/0001.
Fig. 2: left valve; same specimen

Figs. 3, 4: *Homomya* sp. cf. *lariana* (Stoppani, 1861).
Fig. 3: left valve; coll. no.: GBA 2010/117/0002.
Fig. 4: right valve, same specimen; coll. no.: GBA 2010/117/0002.

Figs. 5–7: *Rhaetina pyriformis* (Suess, 1854).
Coll. no.: GBA 2010/117/0004.
Fig. 5: anterior view.
Fig. 6: dorsal view.
Fig. 7: lateral view.

Photos of Figs. 5–7: J. Brožek (Prague).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Acknowledgements

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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

Catalogue of the Triassic and Lower Jurassic Brachiopod Holotypes (excl. Bittner) in the Collections of the Geological Survey of Austria

Miloš Siblík*

3 Plates

Geological Survey of Austria
Paleontological Collection
Type Specimens
Brachiopoda
Eastern Alps
Mesozoic

Contents

Katalog der triassischen und unterjurassischen Brachiopoden-Holotypen (exkl. Bittner) in den Sammlungen der Geologischen Bundesanstalt in Wien

Zusammenfassung

Diese Arbeit ergänzt den ersten Teil des Katalogs der triassischen und unterjurassischen Brachiopoden-Holotypen (Siblík, 2010) und umfasst die zusätzlich zu den von Bittner im ersten Katalogteil beschriebenen 19 weiteren Holotypen. Sie werden in den Sammlungen der Geologischen Bundesanstalt in Wien aufbewahrt.

Abstract

This paper follows the first part of the catalogue of the Triassic and Lower Jurassic brachiopod holotypes (Siblík, 2010) and offers the inventory of the 19 Triassic and Lower Jurassic brachiopod holotypes (excl. those of Bittner's authorship) currently deposited in the collections of the Geological Survey of Austria in Vienna.

Introduction

This paper is the second and final part of the catalogue of all Triassic and Lower Jurassic brachiopod holotypes deposited in the collections of the Geological Survey of Austria in Vienna. As in the first part where the holotypes of Bittner's authorship were dealt with (Siblík, 2010), the holotypes in the present contribution are divided into Triassic or Lower Jurassic ones and then sorted by the year of publication and by inventory numbers. At the end of each item, the valid name is introduced in bold according to present knowledge. Finally, the holotypes previously held or reported by their authors as deposited in the collections of the Geological Survey in Vienna but at present missing there, are mentioned.

In some newly described species the possibility exists that the species were established on the base of more than one specimen. According to the "Recommendation 73F" by Iczn (1999) it is recommended in such cases to proceed the way as in the case of the existence of syntypes, and to choose the lectotypes. It concerns the Lower Jurassic species *Terebratula Bersaskensis, T. Hinterhuberi, T. Dellegraziana, Rhynchonella Drenkovana* and *Rh. Sirinniae* (all by Tietze, 1872), and *Terebratula semiplana* and *Rhynchonella pilulaeformis* (both by Schmid, 1880).

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List of Type Specimens

Triassic

Discina Cellensis **SUESS, 1854**
(Pl. 1, Figs. 7, 7a)

Coll. no.: GBA 1854/006/0019.

Type level: Triassic, Rhaetian, Kössen Beds.

Type locality: Bürgeralpe near Mariazell, Styria, Austria.

Type figure: SUESS (1854): p. 63, Pl. 2, Fig. 18.

Remarks: Holotype by monotypy.

***Discinisca cellensis* (SUESS).**

Spirigera Deslongchampsi **SUESS, 1855**
(Pl. 1, Fig. 3)

Coll. no.: GBA 1855/005/0002.

Type level: Upper Triassic, Norian, Hallstatt Limestone.

Type locality: Steinbergkogel near Hallstatt, Upper Austria, Austria.

Type figure: SUESS (1855): p. 26, Pl. 1, Fig. 3.

Remarks: Holotype by monotypy. It was refigured by SÝKORA et al. (1998, Pl. 1, Fig. 2).

"Spirigera" deslongchampsi Suess.

Terebratula Schloenbachii **LAUBE, 1866**
(Pl. 1, Fig. 5)

Coll. no.: GBA 1866/005/0003/1.

Type level: Triassic, Cassian Beds.

Type locality: St. Cassian, Italy.

Type figure: LAUBE (1866): p. 5, Pl. 11, Fig. 3.

Remarks: Holotype by monotypy.

***"Spirigera" schloenbachi* (LAUBE).**

Retzia Arara **LAUBE, 1866**
(Pl. 1, Fig. 6)

Coll. no.: GBA 1866/005/0022.

Type level: Triassic, Cassian Beds.

Type locality: St. Cassian, Italy.

Type figure: LAUBE (1866): p. 21, Pl. 13, Fig. 2.

Remarks: Holotype by monotypy. In the box with the figured original specimen, another specimen most probably from Laube signed as *Retzia* aff. *arara* is deposited. Generic attribution by DAGYS (1974).

***Hungarispira arara* (LAUBE).**

Rhynchonella Edhemi **n. sp. var.** *plicata* **TOULA, 1896**
(Pl. 2, Fig. 2)

Coll. no.: GBA 1896/002/0003/1.

Type level: Triassic, Anisian, Bithynian.

Type locality: Between Kazmali and Malumkiöi, east of Gebze near Izmîd, Turkey.

Type figure: TOULA (1896): p. 159, Pl. 18, Fig. 11.

Remarks: Holotype by monotypy. Most probably variant only of *Rhynchonella edhemi*, which was arranged within *Holcorhynchella* by DAGYS (1974) and SULSER (1993).

***Holcorhynchella edhemi plicata* (TOULA).**

Spiriferina (Mentzelia) Mentzelii **DUNKER var.** *propontica* **TOULA, 1896**
(Pl. 2, Fig. 1)

Coll. no.: GBA 1896/002/0004.

Type level: Triassic, Anisian, Bithynian.

Type locality: Between Kazmali and Malumkiöi, E of Gebze near Izmîd, Turkey.

Type figure: TOULA (1896): p. 159, Pl. 18, Fig. 7.

Remarks: Holotype by monotypy. In the box another smaller specimen is placed, both are indicated as syntypes. However, according to TOULA (1896) only one specimen was at disposal for description.

***Mentzelia propontica* TOULA.**

Retzia Bittneri **TOULA, 1913**
(Pl. 2, Fig. 3)

Coll. no.: GBA 1913/002/0025.

Type level: Triassic, Cordevolian (according to PLÖCHINGER & PREY, 1974).

Type locality: "Jägerhaus" (forester's house) in the valley called Rauchstall(brunn)graben near Baden, Lower Austria, Austria.

Type figure: TOULA (1913): p. 94, Pl. 5, Fig. 20.

Remarks: Holotype by monotypy. Most probably identical with *Hungarispira procerrima* (KLIPSTEIN, 1843). Generic attribution by DAGYS (1974).

***Hungarispira bittneri* (TOULA).**

Austriellula fuchsi **SIBLÍK, 1975**
(Pl. 3, Fig. 6)

Coll. no.: GBA 1975/003/0013.

Type level: Triassic, Anisian–Carnian (?).

Type locality: Ghyallong Rauna Lekh, Nepal.

Type figure: SIBLÍK (1975): p. 150, Pl. 19, Fig. 4.

Remarks: Holotype.

***Austriellula fuchsi* SIBLÍK.**

Costirhynchopsis ruttneri **SIBLÍK, 1991**
(Pl. 3, Fig. 1)

Coll. no.: GBA 1982/008/0003/1.

Type level: Triassic, Nazarkardeh Formation, Anisian, Bithynian.

Type locality: Aghdarband, Iran.

Type figure: SIBLÍK (1991): p. 166, Pl. 1, Fig. 5.

Remarks: Holotype.

***Costirhynchopsis ruttneri* SIBLÍK.**

Tethyspira persis **SIBLÍK, 1991**
(Pl. 3, Fig. 2)

Coll. no.: GBA 1982/008/0004.

Type level: Triassic, Sina Formation, Ladinian, Langobardian.

Type locality: Aghdarband, Iran.

Type figure: SIBLÍK (1991): p. 168, Pl. 1, Fig. 1.

Remarks: Genoholotype.

***Tethyspira persis* SIBLÍK.**

Dareithyris vulgaris SIBLÍK, 1991
(Pl. 3, Fig. 3)

Coll. no.: GBA 1982/008/0010/1.

Type level: Triassic, Nazarkardeh Formation, Anisian, Bithynian.

Type locality: Aghdarband, Iran.

Type figure: SIBLÍK (1991): p. 171, Pl. 1, Fig. 9.

Remarks: Genoholotype.

***Dareithyris vulgaris* SIBLÍK.**

Rhaetina tirolensis SIBLÍK, 1999
(Pl. 3, Fig. 5)

Coll. no.: GBA 1999/002/0005/1.

Type level: Upper Triassic, Carnian.

Type locality: Gaisberg near Kirchberg in Tirol, Austria.

Type figure: SIBLÍK (1999a): p. 118, Pl. 1, Fig. 6.

Remarks: Holotype.

***Rhaetina tirolensis* SIBLÍK.**

Lower Jurassic

Rhynchonella banatica TIETZE, 1872
(Pl. 1, Fig. 4)

Coll. no.: GBA 1872/002/0071.

Type level: Lower Jurassic, red brachiopod limestone.

Type locality: Muntjana near Bersaska, Banat, Romania.

Type figure: TIETZE (1872): p. 131, Pl. 7, Fig. 10.

Remarks: Holotype by monotypy.

***"Rhynchonella" banatica* TIETZE.**

Terebratula crassa NEUMAYR, 1879
(Pl. 2, Fig. 6)

Coll. no.: GBA 1879/003/0001.

Type level: Lower Jurassic, Hettangian, Kendlbach Formation.

Type locality: Breitenberg south of lake Wolfgangsee, Salzburg, Austria.

Type figure: NEUMAYR (1879): p. 12, Pl. 1, Fig. 10.

Remarks: Holotype by monotypy. NEUMAYR (1879) named his new terebratulid species *"crassa"* even though he knew that the Cenomanian *Terebratula crassa* D'ARCHIAC, 1847 already existed, arguing that the specific name had not been in use for a long time. Nevertheless, *Terebratula crassa* NEUMAYR is the junior homonym and should be thus substituted by *nomen novum*. Later on, Cenomanian *Terebratula crassa* D'ARCHIAC, 1847 became a type species of a new genus *Harmatosia* COOPER (1983, p. 196).

***"Terebratula" crassa* NEUMAYR.**

Waldheimia Hierlatzica OPP. var. *plicata* GEYER, 1889
(Pl. 1, Fig. 1)

Coll. no.: GBA 1889/001/0022.

Type level: Lower Jurassic, Sinemurian, Hierlatz Limestone.

Type locality: Hierlatz near Hallstatt, Upper Austria, Austria.

Type figure: GEYER (1889): p. 27, Pl. 3, Fig. 30.

Remarks: Holotype by monotypy. BAEZA-CARRATALÁ & TENT-MANCLÚS (2004) recorded this taxon as *Securina plicata* (GEYER).

***Securina hierlatzica plicata* (GEYER).**

Rhynchonella Cartieri OPP. var. *rimata* GEYER, 1889
(Pl. 1, Fig. 2)

Coll. no.: GBA 1889/001/0047.

Type level: Lower Jurassic, Sinemurian, Hierlatz Limestone.

Type locality: Hierlatz near Hallstatt, Upper Austria, Austria.

Type figure: GEYER (1889): p. 64, Pl. 7, Fig. 15.

Remarks: Holotype by monotypy.

***Cuneirhynchia cartieri rimata* (GEYER).**

Terebratula (?) Grossaviensis TRAUTH, 1909
(Pl. 2, Fig. 4)

Coll. no.: GBA 1909/001/0017.

Type level: Lower Jurassic, Gresten Beds.

Type locality: Grossau, Krenkogel, Lower Austria, Austria.

Type figure: TRAUTH (1909): p. 70, Pl. 2, Fig. 7.

Remarks: Holotype by monotypy.

***"Terebratula" grossaviensis* TRAUTH.**

Waldheimia (Zeilleria) opima TRAUTH, 1909
(Pl. 2, Fig. 5)

Coll. no.: GBA 1909/001/0021.

Type level: Lower Jurassic, Gresten Beds.

Type locality: Gresten, Lower Austria, Austria.

Type figure: TRAUTH (1909): p. 75, Pl. 2, Fig. 8.

Remarks: Holotype by monotypy.

***Zeilleria opima* TRAUTH.**

Tetrarhynchia inopinata SIBLÍK, 1999
(Pl. 3, Fig. 4)

Coll. no: GBA 1999/017/0003.

Type level: Lower Jurassic, Hettangian, Kendlbach Formation.

Type locality: Hochleitengraben near Gaissau, Salzburg, Austria.

Type figure: SIBLÍK (1999b): p. 425, Pl. 1, Fig. 3.

Remarks: Holotype.

***Tetrarhynchia inopinata* SIBLÍK.**

Holotypes Previously Held or Reported by the Authors as Deposited in the Collection of the Geological Survey, but now Missing:

Triassic

Discina Suessi GÜMBEL, 1861

Type level: Upper Triassic, Kössen Beds.

Type locality: Schobergraben near Adnet, Salzburg, Austria.

Type figure: *Discina* sp. in SUESS (1854): p. 63, Pl. 4, Fig. 24.

Remarks: Holotype by monotypy.

***Discinisca suessi* (GÜMBEL).**

Lower Jurassic

Terebratula brachyrhyncha SCHMID, 1880

Type level: Lower Jurassic.

Type locality: Vinica Mt. (Vinicaberg), SE of Karlovac (Karlstadt), Croatia.

Type figure: SCHMID (1880): p. 726, Pl. 11, Fig. 8.

Remarks: Holotype by monotypy.

***"Terebratula" brachyrhyncha* SCHMID.**

Rhynchonella Sapetzai SCHMID, 1880

Type level: Lower Jurassic.

Type locality: Vinica Mt. (Vinicaberg), SE of Karlovac (Karlstadt), Croatia.

Type figure: SCHMID (1880): p. 727, Pl. 11, Fig. 9.

Remarks: Holotype by monotypy.

***"Rhynchonella" sapetzai* SCHMID.**

Rhynchonella ungulaeformis SCHMID, 1880

Type level: Lower Jurassic.

Type locality: Vinica Mt. (Vinicaberg), SE of Karlovac (Karlstadt), Croatia.

Type figure: SCHMID (1880): p. 727, Pl. 11, Fig. 10.

Remarks: Holotype by monotypy.

***"Rhynchonella" ungulaeformis* SCHMID.**

Spiriferina aequiglobata UHLIG, 1900

Type level: Lower Jurassic, upper part of the Lower Liassic.

Type locality: Valesacca near Kimpolung, Bukowina, Romania.

Type figure: UHLIG (1900): p. 31, Pl. 1, Fig. 8.

Remarks: Holotype by monotypy. The specimen is missing, only the box with label exists.

***Liospiriferina aequiglobata* (UHLIG).**

Rhynchonella subcostellata GEMM. var. *alpina* HAAS, 1912

Type level: Lower Jurassic, Upper Pliensbachian (Domerian).

Type locality: Ballino, Trentino, Italy.

Type figure: HAAS (1912): p. 247, Pl. 19, Fig. 21.

Remarks: Holotype by monotypy.

***"Rhynchonella" subcostellata alpina* HAAS.**

Terebratula (Pygope)? rheumatica CAN. var. *decipiens* HAAS, 1912

Type level: Lower Jurassic, Upper Pliensbachian (Domerian).

Type locality: Ballino, Trentino, Italy.

Type figure: HAAS (1912): p. 262, Pl. 19, Fig. 28.

Remarks: Holotype by monotypy. *Terebratula rheumatica* CANAVARI was attributed to *Phymatothyris* by MANCEÑIDO (1993 etc.).

***Phymatothyris rheumatica decipiens* (HAAS).**

Index of Specific Names

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Plate 1

Fig. 1abc: *Securina hierlatzica plicata* (GEYER).
GBA 1889/001/0022.
2 x.

Fig. 2abc: *Cuneirhynchia cartieri rimata* (GEYER).
GBA 1889/001/0047.
3 x.

Fig. 3abc: *“Spirigera” deslongchampsi* SUESS.
GBA 1855/005/0002.
1.5 x.

Fig. 4abc: *“Rhynchonella” banatica* TIETZE.
GBA 1872/002/0071.
2 x.

Fig. 5abc: *“Spirigera” schloenbachi* (LAUBE).
GBA 1866/005/0003/1.
4 x.

Fig. 6abc: *Hungarispira arara* (LAUBE).
GBA 1866/005/0022.
4 x.

Fig. 7: Sample with *Discinisca cellensis* (SUESS).
GBA 1854/006/0019.
1 x.

Fig. 7a: *Discinisca cellensis* (SUESS).
GBA 1854/006/0019.
7 x.

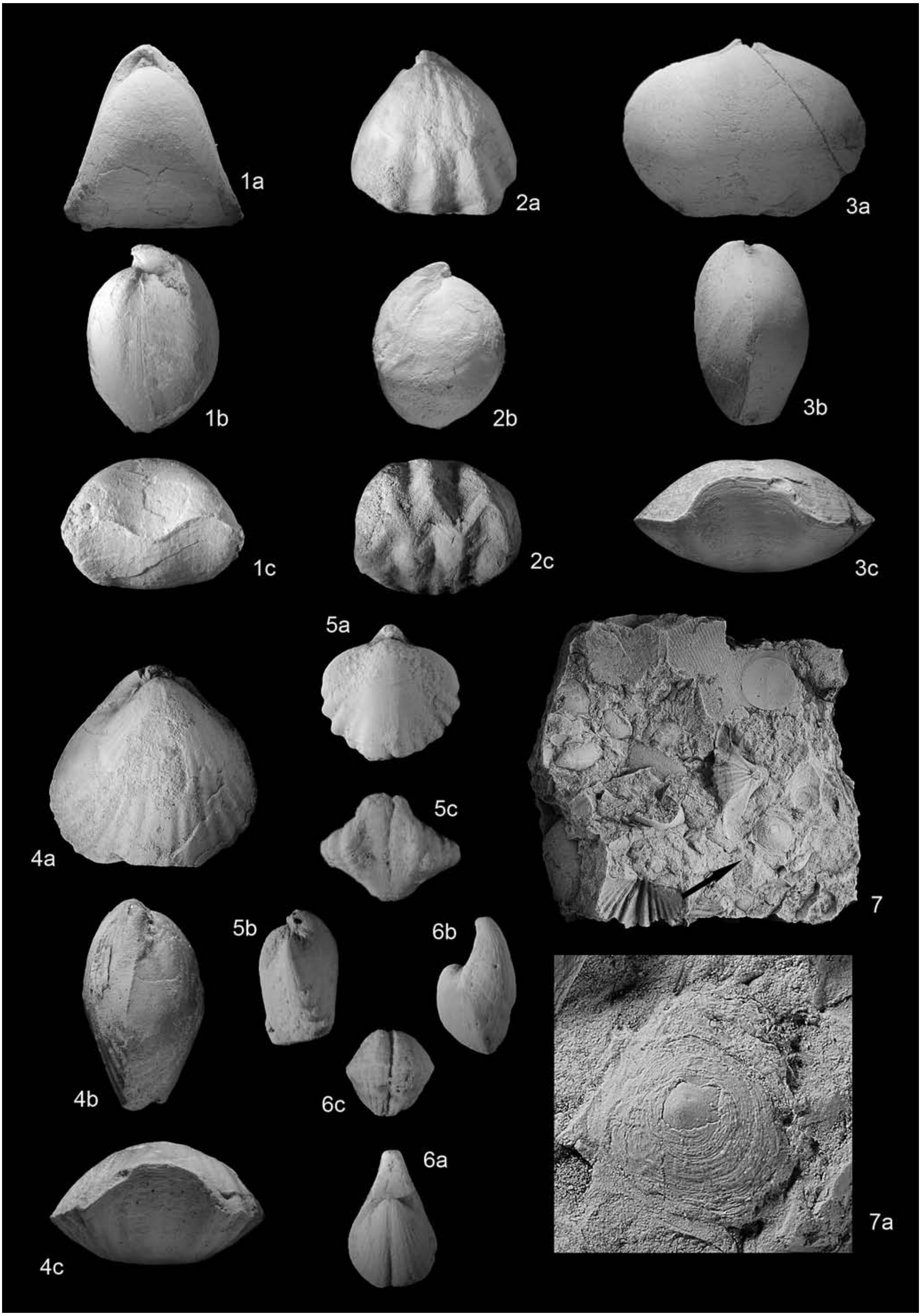
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Plate 2

Fig. 1abc: *Mentzelia propontica* TOULA.
GBA 1896/002/0004.
2 x.

Fig. 2abc: *Holcorhynchella edhemi plicata* (TOULA).
GBA 1896/002/0003/1.
2 x.

Fig. 3abc: *Hungarispira bittneri* (TOULA).
GBA 1913/002/0025.
3 x.

Fig. 4abc: *"Terebratula" grossaviensis* TRAUTH.
GBA 1909/001/0017.
1.5 x.

Fig. 5abc: *Zeilleria opima* TRAUTH.
GBA 1909/001/0021.
1.5 x.

Fig. 6abc: *"Terebratula" crassa* NEUMAYR.
GBA 1879/003/0001.
2 x.

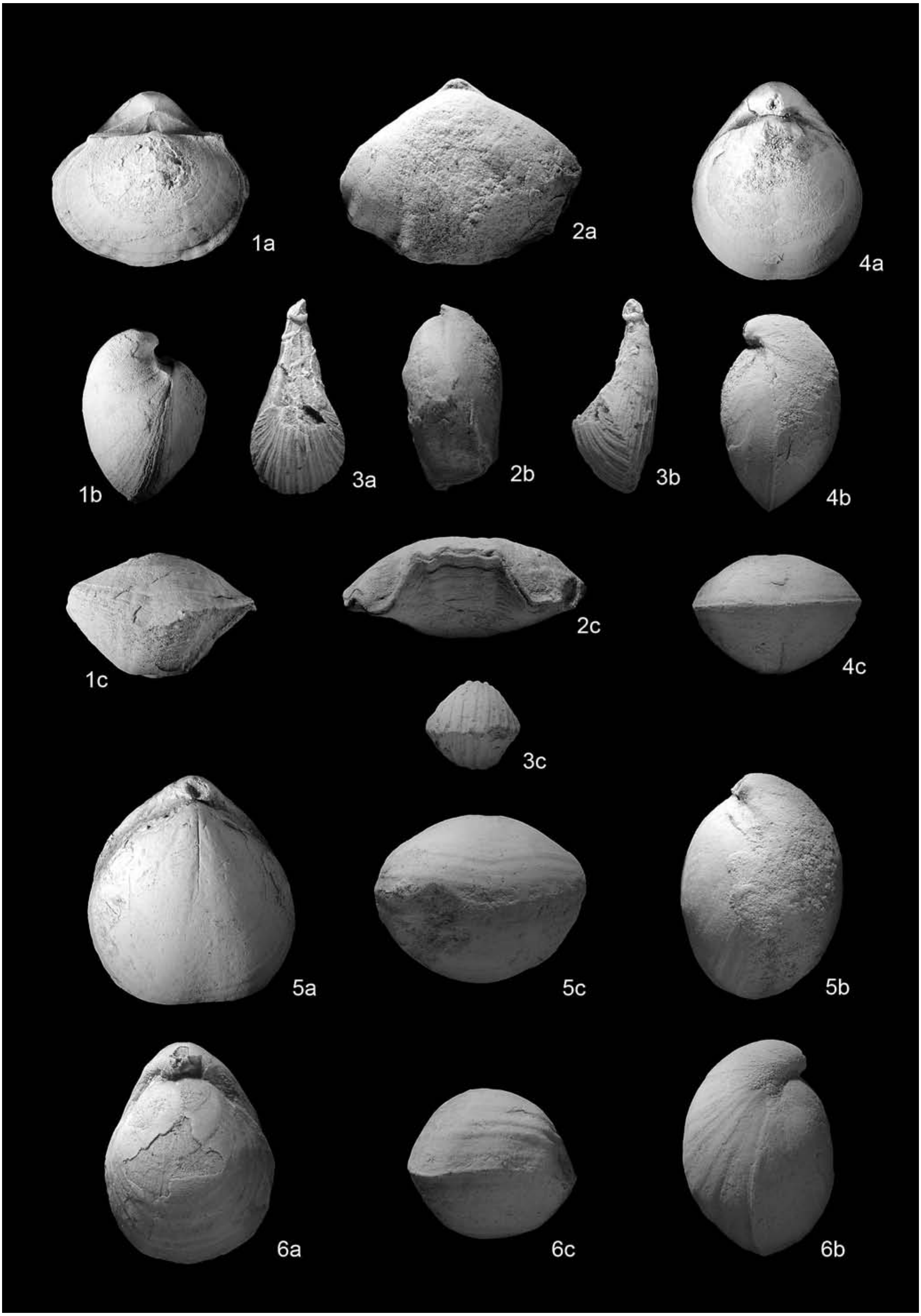
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Plate 3

Fig. 1abc: *Costirhynchopsis ruttneri* Siblík.
GBA 1982/008/0003/1.
2 x.

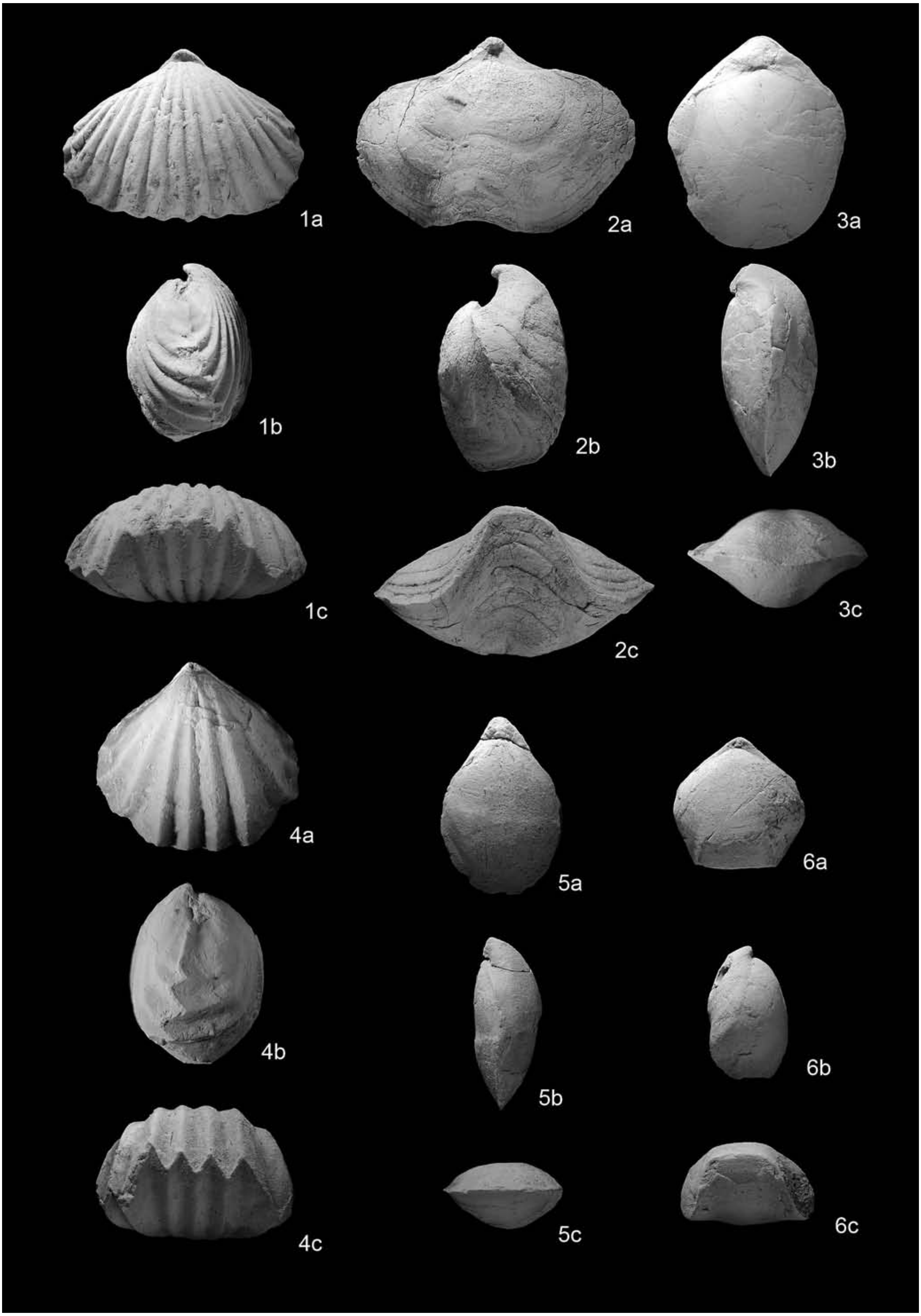
Fig. 2abc: *Tethyspira persis* Siblík.
GBA 1982/008/0004.
1 x.

Fig. 3abc: *Dareithyris vulgaris* Siblík.
GBA 1982/008/0010/1.
2 x.

Fig. 4abc: *Tetrarhynchia inopinata* Siblík.
GBA 1999/017/0003.
2 x.

Fig. 5abc: *Rhaetina tirolensis* Siblík.
GBA 1999/002/0005/1.
1.5 x.

Fig. 6abc: *Austriellula fuchsi* Siblík.
GBA 1975/003/0013.
2 x.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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

First Results on Stratigraphy and Faunal Content of the Jurassic between Bad Mitterndorf and Toplitzsee (Salzkammergut, Austria)

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4 Text-Figures, 17 Plates

Österreichische Karte 1:50.000
Blatt 97 Bad Mitterndorf

Northern Calcareous Alps
Jurassic
Olistolith
Ammonoidea
Brachiopoda
Gastropoda
Bivalvia

Contents

Erste Ergebnisse zu Stratigraphie und Faunen-Inhalt der Jura-Gesteine zwischen Bad Mitterndorf und Toplitzsee (Salzkammergut, Österreich)

Zusammenfassung

Die südwestlichen Ausläufer des Toten Gebirges zeigen eine Schichtfolge aus rhätischem Dachsteinkalk und jurassischen Beckensedimenten, die bis in das Kimmeridgium reichen. Wahrscheinlich existieren hier im Unter- bis (?)Mitteljura zwei unterschiedliche Schichtfolgen nebeneinander: Im Zwicker-Wolfskogel-Gebiet wird der Dachsteinkalk von Allgäu-Schichten überlagert, die Oberes Hettangium bis Unteres Pliensbachium umfassen dürften. Darüber folgt im Oberen Pliensbachium Hierlatzkalk. Rote Crinoidenkalke mit „Bositra"-Mikrolumachellen könnten den Mitteljura vertreten. Im Flodring-Klaushöfl-Gebiet fehlen hingegen die Allgäu-Schichten völlig, die Schichtlücke dürfte hier das gesamte Hettangium umfassen. Der Hierlatzkalk repräsentiert hier im Wesentlichen das Sinemurium. Einige wenige Ammonitenfaunen belegen Unteres Pliensbachium, von zwei Stellen stammen Faunen des Toarcium. Der Oberjura folgt diskordant über dem älteren Untergrund. Er wird hauptsächlich von detritischem Tressensteinkalk vertreten, der Bioklasten von der Plassenkalk-Plattform und deren Hang beinhaltet. Eng verknüpft damit sind Hornsteinkalke der Oberalmer Schichten. Der Tressensteinkalk beinhaltet auch große Olistholithe aus unterjurassischem Hierlatzkalk, sowie zentimetergroße Bruchstücke von untertriassischen Werfener Schichten. Das Gebiet dürfte von den Auswirkungen der jurassischen (Gleit-)Tektonik betroffen sein, die Zwicker-Wolfskogel-Schollen könnten Teile einer jurassischen Gleitmasse darstellen.

Eine bemerkenswert reiche und diverse Fauna von Ammoniten, Brachiopoden, Schnecken und Muscheln aus einem großen Olistholithen bestehend aus Hierlatzkalk des Sinemurium wird genauer beschrieben. Daneben wird der Fauneninhalt einer ganzen Reihe kurzlebiger Aufschlüsse dokumentiert, die unter zahllosen entwurzelten Bäumen während der starken Winterstürme von 2005 bis 2007 entstanden waren und durch die Wiederaufforstung in Kürze wieder unzugänglich werden.

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Abstract

The southwestern foothills of the Totes Gebirge expose a sedimentary succession from uppermost Triassic Dachstein Limestone to Jurassic basinal sediments, persisting until Kimmeridgian. There probably exist two different Lower to (?)Middle Jurassic successions: In the Zwicker-Wolfskogel area the Dachstein Limestone is covered by Upper Hettangian to Lower Pliensbachian Allgäu Beds, followed by Upper Pliensbachian Hierlatz Limestone and red crinoidal limestones with "Bositra" microlumachelles of (?) Middle Jurassic age. In the Flodring-Klaushöfl area the sedimentary gap between Dachstein Limestone and Hierlatz Limestone cover the entire Hettangian. No Allgäu Beds are present here. Hierlatz Limestone has yielded mainly Sinemurian, a few Lower Pliensbachian and two Toarcian ammonite associations. The Upper Jurassic rests discordantly on older rocks and is mainly represented by the detritic Tressenstein Limestone (bioclasts from coeval Plassen carbonate platform and slope) in close connection with basinal Oberalm Limestone. The former contains large olistoliths of Lower Jurassic Hierlatz Limestone as well as centimeter-sized clasts of Lower Triassic Werfen Beds. The area is probably affected by intra-Jurassic (gravitational) tectonic, the Zwicker-Wolfskogel succession might be part of a large gliding mass.

A remarkable rich and diverse fauna of ammonites, brachiopods, gastropods and bivalves is described in detail from a large olistolith of Sinemurian Hierlatz Limestone. Additionally the faunal content of a great number of short living outcrops is documented – outcrops beneath uprooted trees created during strong winter storms 2005–2007.

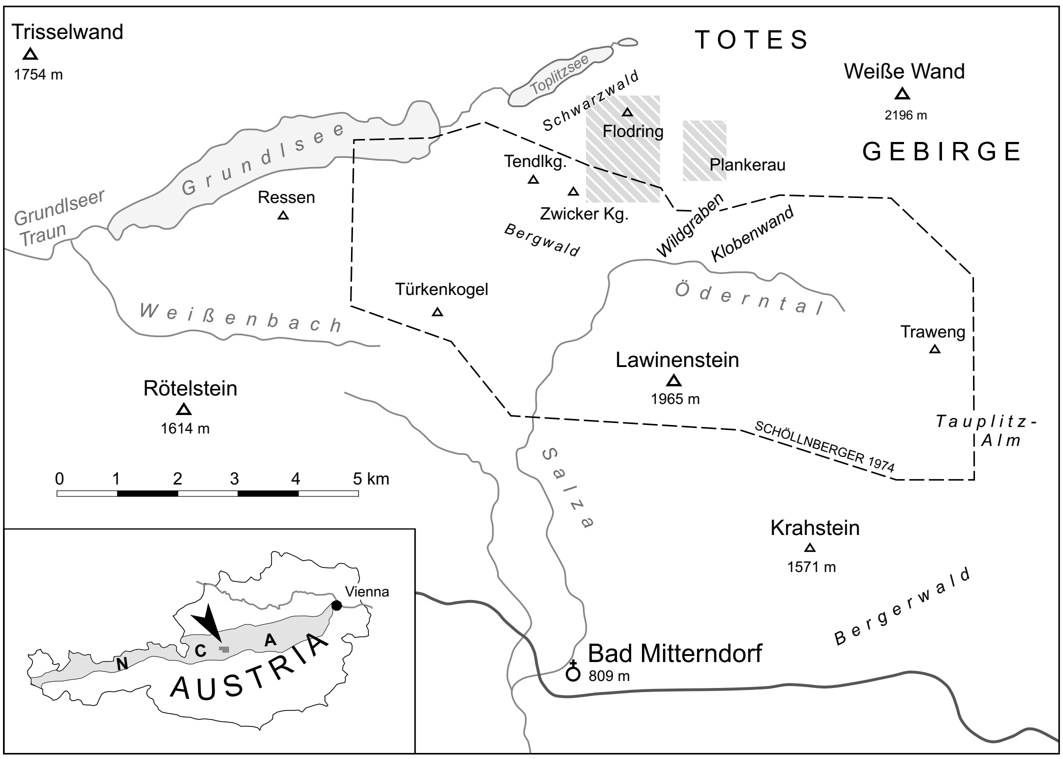
Introduction

Early investigations have reported on rich invertebrate faunas from several localities in the south-western Totes Gebirge, e.g. Geyer (1884, 1916). In recent times W. Kerndler, the custodian of the paleontological collections of the Kammerhof-Museum at Bad Aussee discovered a locality of Lower Jurassic fossiliferous limestones, which raised the hope to find a transition from Upper Triassic to Lower Jurassic. We started a first collecting campaign in 2005 in the framework of bilateral exchange between the Austrian Geological Survey and the Surveys of the neighbouring countries. During this fieldwork we became aware of the olistolithic nature of this Lower Jurassic limestone, resting within Upper Jurassic carbonate sediments. A rich fauna from the olistolith as well as diagnostic ammonites from the surrounding sediments have been obtained.

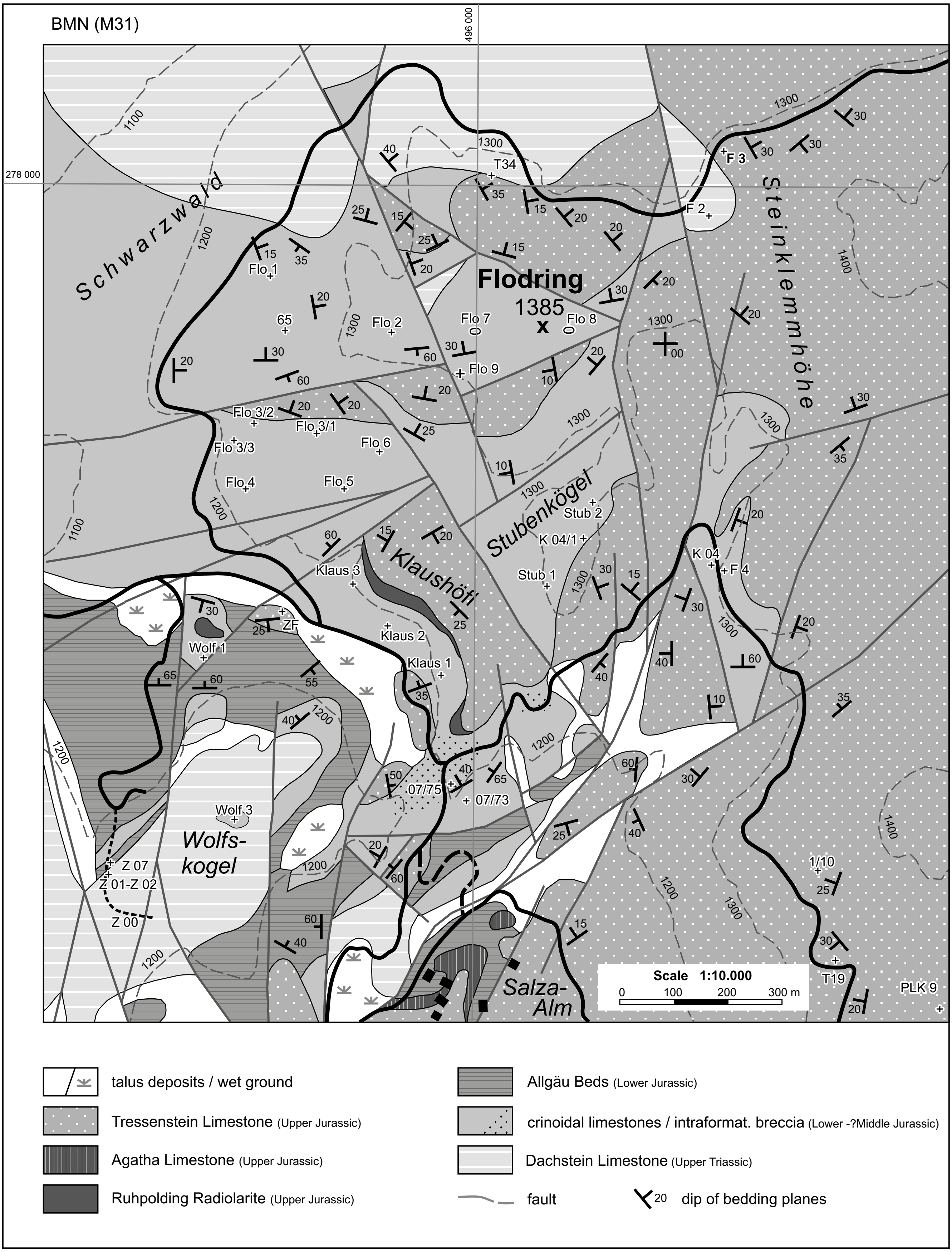
In the following winter 2005/2006 and 2006/2007 enormous winter storms destroyed large areas of forest and created countless small and discontinuous outcrops beneath uprooted trees. Due to this special situation the scope of our further fieldwork has changed into a documentation of the faunal content of these short living outcrops. Removing the wind-blown timber and reforestation will close these windows into the underground in the course of the next years.

Geological Setting

The area around Bad Mitterndorf belongs to those areas within the Northern Calcareous Alps (NCA), which are crucial points in revealing the complex geological history of the NCA. Still under discussion are the details of the palaeogeographic relationship between Triassic carbonate platforms and contemporary basinal sediments (Pötschen and Hallstatt facies), as well as Jurassic gravitational tectonics and sedimentation, Cretaceous to Palaeogene nappe tectonics and Miocene strike slip faults. For comparison of different viewpoints in this topic see e.g. Tollmann (1981), Mandl (2000), Frisch & Gawlick (2003) and Gawlick & Frisch (2003).



Text-Fig. 1.
Geographic sketch of the working areas and mentioned localities in the surroundings of Bad Mitterndorf.
Shaded areas (Flodring, Plankerau) indicate position of geological maps shown in Text-Figs. 2 and 3.



Text-Fig. 2.
Preliminary geological map of the southwestern foothills of Totes Gebirge between Salza-Alm and Flodring.

The most recent geological map by Schöllnberger (1974, scale 1:25.000) covers the southern part of the area discussed here – see Text-Fig. 1. For large areas only the geological map of Geyer (1918) at a scale 1:75.000 is available. During our field work just limited time could be used for mapping the surroundings of our fossil collecting sites. Text-Figs. 2 and 3 are showing two preliminary sketch maps, which try to give an impression of the complex small scale fault tectonics and the spatial relation between the Triassic to Jurassic rocks. Further detailed mapping would be necessary – especially the areas indicated as Tressenstein Limestone may contain additional large olistoliths as well as extended occurrences of lower parts of the Jurassic stratigraphic column.

In general the extended karstified mountain plateau of Totes Gebirge is built by Middle to Upper Triassic shallow water carbonates of Wetterstein Dolomite below, and Hauptdolomit and Dachstein Limestone above a thin and discontinuous layer of Lower Carnian "Cardita Beds" (Northern Alpine Raibl Group).

Dachstein Limestone originates mainly from a shallow water lagoonal environment and exhibits the typical cyclic bedding of Lofer cyclothems. Only in the surrounding of Lake Grundlsee and in the Tauplitz area reef limestones are known. It is still unproven biostratigraphically, if these reefs are remnants of a Norian to Rhaetian platform margin or patch reefs within the subsiding lagoon only during the Rhaetian. Schöllnberger (1974) has favoured the platform margin hypothesis, especially when he found a transition between the reef limestone and Zlambach Marls in the area southeast of Zwicker Kogel. Zlambach Marls are also the uppermost part of the stratigraphic column of the "Grey Hallstatt Facies" = Pötschen Facies. This transition became a connecting link between the Triassic carbonate platform of Totes Gebirge and contemporary basinal sediments south of Lake Grundlsee – the so called "Hallstätter Nordkanal" (= Northern Hallstatt channel) in terms of Tollmann (1981). As already shown in Tollmann (1981) extensive gravitational tectonics has changed the palaeogeographic situation during Jurassic times. If this fact is taken into consideration, it seems possible, that also the Dachstein reef limestone of Zwicker and the connected Zlambach Marls belong to the gravitationally transported masses of meter to kilometer-size. Our fieldwork has given no clear proof for this hypothesis so far, but some indications – see below.

The Dachstein Limestone is covered by Lower Jurassic crinoidal-brachiopodal facies of Hierlatz Limestone sensu lato, showing a wide range of lithologies. So far we did not see fissure fillings like at the Hierlatz type locality or as reported from the plateau mountains of Totes Gebirge. Due to our biostratigraphic data there exists a sedimentary gap between Dachstein Limestone and Hierlatz Limestone, embracing Upper Rhaetian and at least Lower Hettangian. The bulk of fossil samples indicate Sinemurian age, only very rare Pliensbachian and Toarcian have been proven. Beside the variegated limestones of Hierlatz facies grey marly limestones of Allgäu Beds have been found around Zwicker Kogel. Between Zwicker Kogel and Wolfskogel marly spiculitic limestones have yielded *Schlotheimia* sp. the only one of Late Hettangian age. In the Bad Mitterndorf area Allgäu Beds are more widespread; e.g. at Bergerwald ammonoids indicate an Early Pliensbachian age.

We have no proof of Middle Jurassic Klaus Limestone and also the earliest Upper Jurassic Ruhpolding Radiolarite was found only at a few places at Klaushöfl area. Toward south the "chert bearing Allgäu Beds" of Schöllnberger's map (1974) may also belong to the radiolarite (Schöllnberger, pers. comm. 2010).

Upper Jurassic (Kimmeridgian) sediments comprise Agatha Limestone (a few meters thick and discontinuous layer of nodular red limestone), Oberalm Limestone (micritic limestones with chert nodules) and Tressenstein Limestone (detritic limestones with detritus from the Upper Jurassic Plassen carbonate platform, as well as extraclasts and olistoliths). The Upper Jurassic rocks are following immediately above Upper Triassic and/or Lower Jurassic ones; a considerable part of the Jurassic succession is missing. This discordance is seen as an indication for intra-Jurassic tectonics, as well as the extraclasts of Lower Triassic siliciclastic Werfen Beds (from the Hallstatt realm) and the large olistoliths of Lower Jurassic limestone, probably coming from Jurassic scarp faults.

Stratigraphy

Upper Triassic

The oldest rocks of the succession of Totes Gebirge in the investigated area are represented by **Dachstein Limestone** in a near-reef facies. The most characteristic macroscopic feature of this light grey, massive limestone is the abundance of reef building organisms like colonies of branched corals as well as solitary corals and calcareous sponges. Fossils are often broken, covered by encrusting organisms and reworked again. The matrix is mostly fine grained reef debris, occasionally micritic limestone; remaining cavities are filled with sparry calcite.

Additional biotas are crinoids, gastropods, bivalves and brachiopods, for example forming a lumachelle east of Zwicker Kogel (brachiopod fauna see locality Z 00). The microfacies has not been studied.

Concerning the age we have conodont data only from the top of Dachstein Limestone (Zwicker locality Z 01 and Z 02). A greenish grey micritic limestone of about 20 cm thickness is directly covering the Dachstein Limestone. The conodont fauna – *Norigondolella steinbergensis* together with *Parvigondolella andrusovi* – indicates Rhaetian 1 *(Paracochloceras suessi* Zone) in the sense of the newly proposed Rhaetian Stage (Krystyn et al., 2007, 2009). According to the fauna we may compare this stratigraphic level to the pelagic interval PI 4 at the Gosaukamm-reef – see Krystyn et al. (2009, Fig. 3). That's an argument for a platform-margin origin of the Zwicker Dachstein Limestone, which fits very well the transition to basin sediments (Zlambach Beds) towards southeast, as supposed by Schöllnberger (1974).

The Upper Rhaetian (level of Zlambach beds) is missing here between Zwicker and Wolfskogel; the badly exposed succession of dark grey marls and crinoidal limestones following above is already of Late Hettangian age – see below.

Lower Jurassic

Zwicker-Wolfskogel Area

Along a tractor path between Zwicker and Wolfskogel the Dachstein Limestone is followed by grey micritic limestones, crinoidal limestones and shales. The first approx. 13 meters are not exposed, only debris of grey spotted limestones and dark, laminated, locally spotted or silicified shales are visible. In the following outcrop silicified crinoidal limestones, grey spotted limestones and chert layers are alternating. Several specimens of *Schlotheimia* sp. were found here in the debris and in situ as well, indicating Upper Hettangian *(S. angulata* Zone) – location Z 07. The microfacies is dominated by micrites with abundant sponge spicules (monaxon and triaxon forms) and crinoidal wacke- to packstones with echinoid spines, rare tiny gastropods, nodosariid foraminifers and fragments of thin (?)bivalve shells. The crinoidal layers contain intraclasts of spiculitic micrites. Spicules seem to be the source of partly strong silicification and of distinct chert layers.

The next approx. 3.5 meters show massive to bedded light grey crinoidal pack- to grainstone with a few intercalations of partly red or violet spiculitic micrites. Some dark shale layers and thin bedded crinoidal limestone lead over to dark shales with some chert layers at the northern end of the outcrop.

All dark grey marls and limestones of this section are attributed to **Allgäu Beds** in Text-Fig. 2. The area between this outcrop and the next outcrop toward the north at location Wolf 1 is covered with debris of this lithology. Thin-sections are showing mud- to wackestones with some sponge spicules, crinoids and rare radiolarians. Signs of bioturbation are common.

At locality Wolf 1 about 10 meters of **Hierlatz Limestone** follow above the Allgäu Beds; ammonites indicate a Late Pliensbachian age. It is a pinkish and red massive crinoidal wacke- to packstone, with ammonites, brachiopods, bivalves, and is showing "stromatactis" polarity structures. It is covered by a hardground with borings perpendicular to the surface, overlain by a red crinoidal packstone with clasts of the underlying Hierlatz Limestone. After 4–4.5 meters the lithology changes into a bedded, red, fine grained and well sorted crinoidal packstone, with some belemnites and occasionally centimetre thin layers or lenses of *"Bositra"* lumachelles. On top of this Jurassic succession probably **Ruhpolding Radiolarite** was following, here only represented by debris of bleached greenish to reddish chert.

This Jurassic succession, including Allgäu Beds of at least Late Hettangian to Early Pliensbachian age, seems to belong only to the Dachstein Limestone of Zwicker and Wolfskogel. It is quite different to the Flodring-Klaushöfl area.

Flodring-Klaushöfl Area

In contrast to the before described succession the time span from Sinemurian to Early Pliensbachian is represented in this area by **Hierlatz Limestone**. No fauna has been found close to the underlying reefoidal **Dachstein Limestone**, the Hettangian seems to be missing completely. The bulk of fossil associations indicates Early Sinemurian (e.g. locality Flo 1) to Early Pliensbachian age (locality Flo 3). Proof is scarce for Toarcian (localities Klaus 1, 2), probably reaching Aalenian.

The lithological variability is rather wide. The colour ranges from white to beige, pale pink and red. Greenish and violet shades are rare. Bedding planes are seldom visible, therefore the spatial orientation remains often unclear. Geopetal fillings in fossil shells must be proven carefully, because redeposition is common. Microfacies range from micritic limestones with scarce dispersed faunal elements to crinoidal pack- and grainstones and to float- and rudstones with large crinoid fragments, more or less frequent belemnites and ammonites. Brachiopods occasionally accumulate to dense packed lumachelles. Ferromanganese crusts on bedding planes, around fossils or around intraclasts are generally rare, more frequent in the Toarcian limestone. Within the microfauna *Involutina liassica* is a common foraminifer, frequent in the Hettangian and Sinemurian in the Alpine Jurassic. It is a useful tool to recognize small olistoliths without macrofauna (see Pl. 15, Fig. 6; Pl. 17, Fig. 4).

Redeposition affects not only fossils but also the sediment itself. Under good conditions as in location Flo 2 it was possible to get ammonite faunas of different age from different clasts. Breccia matrix is a micritic crinoidal limestone.

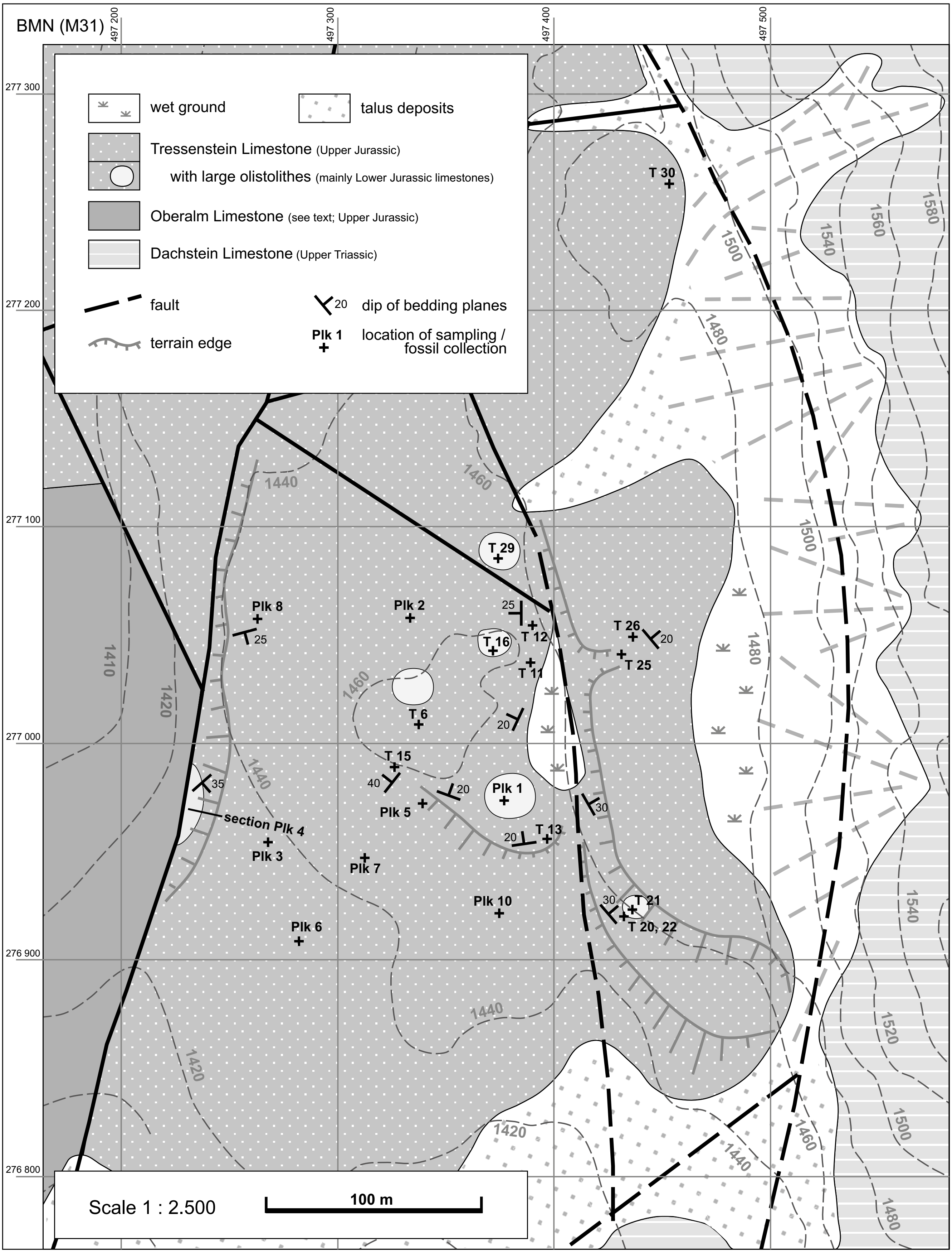
Another breccia is widespread enough, to indicate it on the map (Text-Fig. 2). The most interesting components consist of layers of dense packed, parallel or chaotic orientated thin shells of *"Bositra"*, alternating with crinoidal debris – see Pl. 15, Figs. 1–3. This biofacies has its first occurrence in the Alpine Jurassic in the Toarcian and becomes frequent in the Middle Jurassic. The other components can be assigned to several types of Hierlatz limestone. Unfortunately we have no fauna from the red limestone matrix. Probably this breccia is of Middle Jurassic age. Radiolarite or immediately Tressenstein Limestone follows above it.

Upper Jurassic

Around the beginning of Upper Jurassic, the greatest depth within the NCA depositional realm has been reached, characterized by wide spread sedimentation of radiolarites and by the onset of extensive gravitational processes, creating gliding nappes, olistoliths, breccias and turbidites – see Tollmann (1981), Mandl (2000), Frisch & Gawlick (2003) and Gawlick & Frisch (2003).

Within the area investigated we found only very locally (Klaushöfl area) a thin sequence of red **Ruhpolding Radiolarite**; biostratigraphic data have not been obtained. More widespread is the bedded to nodular red **Agatha Limestone**, e.g. south of Salza-Alm and Zwicker Kogel at the base of Tressenstein Limestone. A similar facies has been found at Plankerau area (e.g. locations Plk 4, Plk 6, T 6, T 25). At least parts of it seem to form local recurrences of this facies within the Tressenstein Limestone. Ammonites indicate Early as well as Late Kimmeridgian ages. Within the microfauna protoglobigerinids are very abundant, at Plk 4 also *Saccocoma* has been found – see Pl. 16, Fig. 9; Pl. 17, Figs. 9–10.

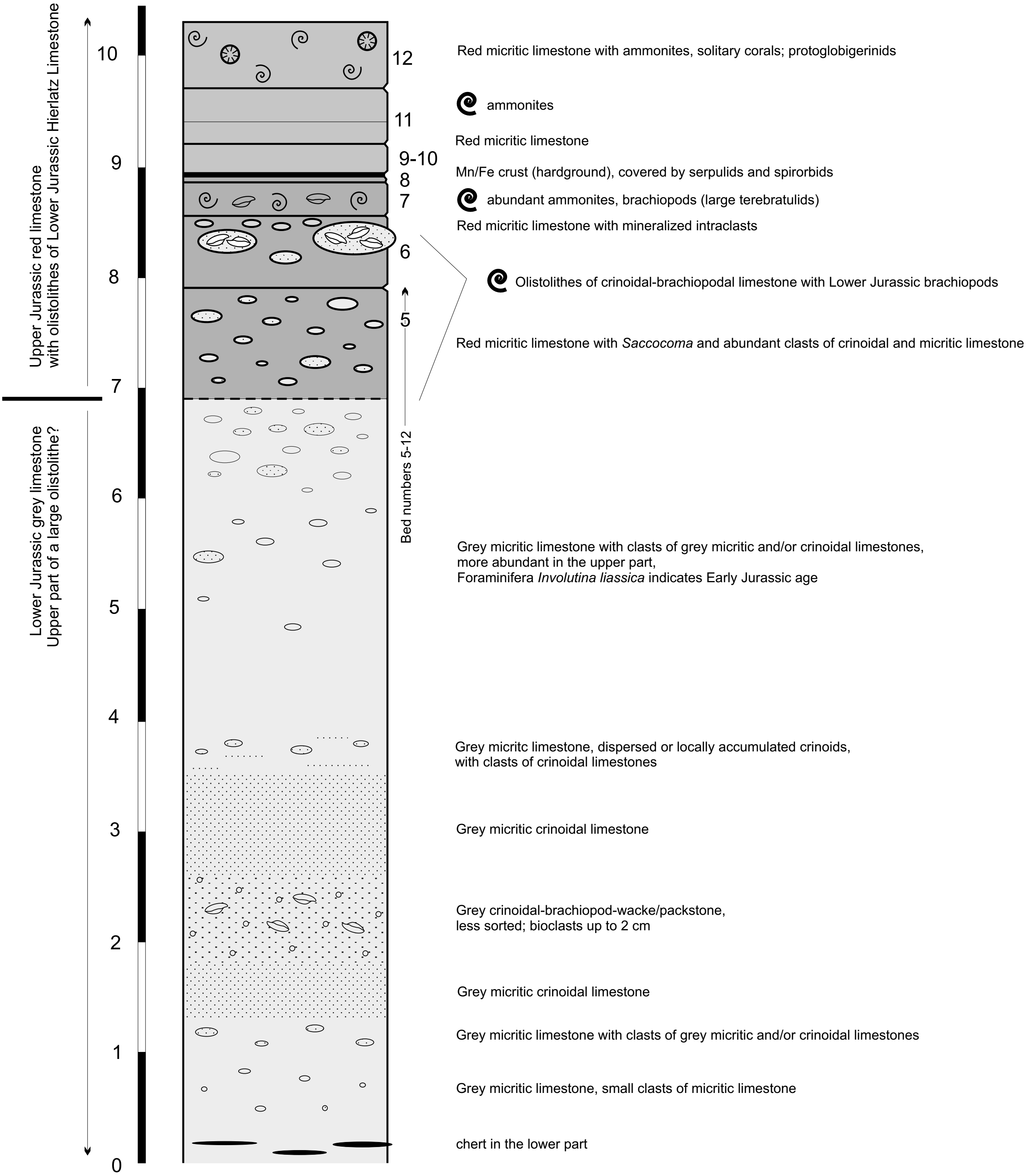
According to Schöllnberger (1974) **Oberalm Limestone** occurs between "cherty Allgäu Beds" (= Ruhpolding Radiolarite?) and Tressenstein Limestone in the Wildgraben area south of Plankerau. In contrast to the detritic Tressenstein Limestone it consists of well bedded, grey micritic limestones, with chert nodules or layers, locally bioturbated and with dispersed bioclasts of crinoids and ammonites. Blocks from the upper part of the slope yielded ammonites (Wild 1) indicating an age around the boundary between Early and Late Kimmeridgian. The wet meadows



Text-Fig. 3.
Geological map of the Plankerau area in the southwestern foothills of Totes Gebirge.

of Plankeraumoos and their continuation towards north (see Text-Fig. 3) probably also cover Oberalm Limestone, because chert fragments are very frequent there in the loamy soil.

Micritic limestones with and without chert also occur along the forest road northeast of Steinklemme (Pl. 16, Fig. 6), together with detritic **Tressenstein Limestone**. This leads to the problem of defining distinct formations. Recently Gawlick & Schlagintweit (2009) have discussed the term Tressenstein Limestone after a reinvestigation of sections at Mount Tressenstein. Due to the co-occurrence of calciturbidites (rich in echinoderms and bioclasts from the slope and fore-reef of the Plassen carbonate platform) with a biomicritic background sedimentation (= Oberalm Limestone with radiolarians, spicules and calpionellids) the detritic carbonates at Mount Tressenstein belong to



Text-Fig. 4.
Detailed stratigraphic section at the locality Plk 4 (scale in meters).

basinal deposits and cannot be interpreted as slope of the Plassen carbonate platform. The term Tressenstein Limestone shouldn't be used any longer to characterize the Upper Jurassic slope deposits. Despite this discussion we still have used this term as a preliminary one, to separate those areas in the map, where carbonate detritic limestones prevail against the micritic Oberalm Limestone. The lithology is similar as described for Mount Tressenstein: crinoidal calciturbidites are very common (see Pl. 17, Fig. 5), coarse grained detritus from the Plassen reef has occasionally been found (Pl. 17, Figs. 7–8). In contrast to Mt. Tressenstein and according to the Kimmeridgian age in our area we did not find calpionellids but abundant protoglobigerinids (Pl. 17, Fig. 6) in the intercalated biomicritic layers, similar to the Agatha Limestone.

In some cases the calciturbidites of Tressenstein Limestone change into micritic limestones with layers of crinoidal fragments and become macroscopically very similar to grey Hierlatz Limestone. Therefore the boundary between these two limestones in the map may not be accurate in some places (e.g. area around Stubenkögel). A useful distinctive mark is the occurrence of coral fragments, which are not rare in the Tressenstein Limestone as well as in the Agatha Limestone (!) but never have been found here in Hierlatz Limestone.

The (Early) Kimmeridgian age is proven by ammonites from several localities in the Plankerau area (Plk 6–7, T 12, T 26, T 30).

The Tressenstein Limestone rests in most cases discordantly on Upper Triassic and Lower Jurassic rocks. North and northeast of Flodring (localities F 2 and T 34) the basal Tressenstein Limestone contains clasts of Dachstein and Hierlatz Limestones – see Pl. 16, Figs. 1–2.

A remarkable feature of the Tressenstein Limestone in our area is the occurrence of extraclasts and large olistoliths from centimetre-size up to more than 10 meters – e.g. Pl. 17 and Text-Fig. 4. The fossil site at Plk 1, where we started our investigations in 2005, is one of these large bodies. Most of them consist of white to beige Hierlatz Limestone with abundant brachiopods. Also ammonites are not rare. The fauna of Plk 1 will be treated in detail below.

The embedding of a several meters large body of Lower Jurassic limestone within Upper Jurassic ones is very well visible at the Plankerau locality T 21 – see Pl. 17: Patches of micritic sediment between the sparitic lumachelles are rich in *Involutina liassica* (Fig. 2) indicating the Early Jurassic age of the olistolith. The surrounding Upper Jurassic sediment consists of carbonate detritic layers rich in echinoderms (Fig. 5), alternating with grey micritic beds with abundant protoglobigerinids (Fig. 6).

Also clasts of Lower Triassic Werfen Beds are remarkable – sandstones and red or greenish shales. Millimeter-sized fragments of this type can be found in the Tressenstein Limestone of Klaushöfl, larger ones up to a few centimetres at Pyrmoos-Brandalm, south of Salza-Alm (see Pl. 16, Figs. 3–4). The Late Jurassic age of the matrix is proven here by *Saccocoma* (Pl. 16, Fig. 5).

Clasts of greenish and red brown shale have also been observed in brecciated Agatha Limestone south of Zwicker Kogel.

Remarks on the Fauna of the Olistolith Plk 1

Ammonoidea

(Jan Schlögl)

On the type locality of Hierlatz limestone the fauna has been collected from dyke infillings. The observations made by Rakús (1999) in the type locality as well as his revision of the preserved part of original material of Geyer (1886) show a rather large stratigraphic range of the ammonite associations, thus a diachronic filling of the fissures. The earliest ammonite association indicates the *A. adnethicum* horizon of the *A. semicostatum* Zone, the latest is already of the Early Pliensbachian age, more precisely *P. taylori* / *Pl. brevispina* horizon of the *U. jamesoni* Zone.

The new locality Plk 1 has yielded a rich macro-invertebrate association. The majority of ammonite fauna seems to be represented by the taxa of Early Sinemurian age. But it is to note, that it contains several specimen not consistent with the age of the assemblage. Several specimens probably representing the inner whorls of the serpenticone, densely ribbed and keeled venter have also been collected. These are well comparable to *Plesechioceras*, but this taxon is already of Late Sinemurian age. Although there are no differences in the mode of preservation, body chamber infilling versus surrounding sediment etc., it can not be excluded that the fauna is more the effect of taphonomic condensation. Additional sampling is the only way to solve the problem.

Phylloceratids are dominated by constricted and moderately evolute *Togaticeras stella. Geyeroceras cylindricum* is also abundant but *Zetoceras* is rare.

The Lytoceratids are composed of rare *Lytoconites hierlatzicus* and several very small juveniles which remind of the internal whorls of *Bouhamidoceras* (Rakús, 1991). The genus *Bouhamidoceras* is a rather rare taxon in the Sinemurian of the NCA. His presence in the Sinemurian was supposed, but the majority of specimens come either from the condensed Adnet Formation or from old collections without a more precise stratigraphic position. It is completely absent in the type locality of Hierlatz.

The *Arnioceras* dominate the association (almost 60 %), unfortunately only juvenile specimens were found. This is related to an apparent sorting of bioclasts. The majority of specimens (or bioclasts) fall within an interval lying between 0.5 cm and 4 cm, exactly as in the locality Hierlatz (Rakús, 1999). If we take into account the division recently made by Corna et al. (1997) thus the majority of the studied *Arnioceras* fall within the morphological variability of the *Arnioceras* sp. gr. B (sensu Corna et al., 1997), indicative of the *A. semicostatum* Zone.

Relative abundance of the higher ammonite taxa:

Phylloceratina 46 sp. (24.35 %)
Lytoceratina 11 sp. (including ?*Bouhamidoceras*) (5.8 %)
Ammonitina 127 sp. (67.2 %)
  Schlotheimiidae 11 sp. (5.8 %)
  Arietitidae 112 sp. (59.3 %)
  Cymbitidae 4 sp. (2.1 %)
Indet. 5 sp. (2.65 %)

Brachiopoda

(Alfréd Dulai)

The Sinemurian Hierlatz Limestone is very common in the studied area and contains a very diverse brachiopod fauna. The preservation of brachiopods is good, and the outer morphological characters are well visible. However, their interior is recrystallized, cavernous or infilled with sparitic calcite. Therefore, the brachiopods from Totes Gebirge were identified at species level on the basis of external characters, but the internal character was not studied by serial sections. The generic attributions are based on recently published other faunas, containing more or less the same species (e.g. SIBLÍK, 2002; DULAI, 2003; VÖRÖS, 2009).

The main collecting point (Plk 1) has yielded 201 specimens, which represent 27 species of 14 genera. Concerning the taxonomic composition of the fauna, phosphatic-shelled Linguliformea and Craniiformea brachiopods are missing, and all studied specimens belong to the Rhynchonelliformea subphylum. Within the Rhynchonelliformea, the order Terebratulida is dominant with 51.7 % of the specimens (including unidentifiable fragments), however, they are represented by only three genera. *Lobothyris* (2 species) and *Linguithyris* (1 species) are relatively rare, but *Zeilleria* with 5 species is the most common genus (38.7 %) within the brachiopods. The order Spiriferinida (28.8 %) contains only 2 genera: *Cisnerospira* (2 species) is rare, however *Liospiriferina* is the second most common genus with 4 species (28.6 %). The order Rhynchonellida is less numerous than terebratulides and spiriferinides (19.5 %), however this is the most diverse brachiopod group with 13 species of 9 genera. None of them is really common, but *Pisirhynchia* and *Salgirella* is relatively more numerous (3.5 % and 2.5 %, respectively) than the other rhynchonellides (*Apringia*, *Jakubirhynchia*, *Prionorhynchia*, *Cirpa*, *Piarorhynchia*, *Cuneirhynchia*, *Gibbirhynchia*; all of them 0.5–1 %). At species level *Zeilleria alpina* (GEYER) (29.8 %) and *Liospiriferina alpina* (OPPEL) (17.9 %) are prominently exceeding all the other brachiopods.

Some other collecting points at Plankerau yielded even more diverse brachiopod faunas (e.g. Plk 3 and Plk 4) and their taxonomic composition was a little different (e.g. more diverse spiriferinides and terebratulides, or the presence of the order Athyridida by *Koninckodonta)*.

Gastropoda

(János Szabó)

In the studied area, the Hierlatz Limestone olistolith of the locality Plk 1 is the only collecting site, which has yielded a rather diverse and abundant but poorly preserved gastropod fauna. Because of the physical characters of this limestone, the specimens are fragile, thus their preparation is a long process. In the present stage of the studies, thirty-one gastropod species have been distinguished on about two hundred more or less isolated specimens (see faunal list location Plk 1 and examples on Pl. 13). Some further species are also indicated by poorly preserved fragments and inner moulds.

The preservation of the gastropod fauna is rather different here from that of the formerly studied Hierlatz Limestone associations. In the “usual cases”, the shells are present but their original structure was lost, recrystallized or substituted as a mosaic of calcite. Their interior is fully or partially filled by sediment and/or sparry calcite. In Plk 1, the originally nacreous shells are most frequently dissolved. These specimens are usually preserved as inner moulds that consist of a little sediment near the aperture, and calcite of geopetal structure with the central hole in the remaining inner space of the shells. The imprint of the outer shell surface (ornament) is mostly preserved around the steinkerns and the space of the former shell walls remained usually empty with few calcite crystals. The most common trochoidean species belong to this group and their outer morphology seems evident almost from their imprints only (Pl. 13: Fig. 1 C–E). Those nacreous shells in which a thin outer calcite layer may appear as a protective mantle, like in the pleurotomariids, are more frequently preserved (Pl. 13: Fig. 9). The gastropods of the originally crossed-lamellar aragonite main layer, the neritaemorphs (having also a calcite outer layer) and the caenogastropods, are usually preserved as shelly specimens (Pl. 13: Fig. 1 A, 6, 7). The frequent slitless limpets (Patellogastropoda) have never been found without shell in this locality (Pl. 13: Fig. 4–5). The shelly preservation is more frequent also in *Discohelix*, having unknown original shell-structure (Pl. 13: Fig. 8). Their preservation suggests a more resistant shell-structure than simply nacreous.

Taxonomic Notes

Patellogastropoda

Pseudorhytidopilus COX in KNIGHT et al., 1960 was established after HABER’s (1932) nomen nudum for simple, smooth shells of Mesozoic limpets; similar gastropods are usually named *“Scurria”* in the classical literature. COX regarded his new genus as a member of Patelloidea but doubtfully. Lack of knowledge about the shell structure and form of the muscle scar in the shell interior cause the uncertainty of the systematic position.

A similar shell form appears in several higher systematic groups but the preservation of *P. zitteli* suggests that this species has possessed calcitic shell structure; therefore it is most probably a patellogastropod. GATTO & MONARI (2010) revised a similar species from DE TONI’S (1912) collection in which the foliated calcitic shell structure was preserved. Within this group, some genera of the extant Lottiidae (Patelloidea) have comparable shell shape; in reality there are no significant conchological differences in their shells (*Acmaea*, *Scurria*, *Asteracmaea*, etc.), however the use of the name *Pseudorhytidopilus* seems better from the methodological point of view for the Jurassic forms.

Neritaemorphi

Neritopsis elegantissima HÖRNES, 1853 (Neritopsidae) is one of the most frequent species of the gastropod fauna in the type locality of the Hierlatz Limestone. It has two shell morphotypes, both appear also in the Plankeraumoos association; one has more prominent, sparser and sharper outer varices than the other that possesses moderately elevated, rounded varices / costae. These differences, though they are sometimes rather marked, seem to remain within the intraspecific variability.

There is a similar species in the Hochfelln Limestone fauna (*N. compressula* GÜMBEL, 1861) that differs in having a flattened ramp below the adapical suture with an angulation at its abaxial rim; this ramp is lacking *N. elegantissima*. However, phylogenetic relation between these species is probable.

Vetigastropoda

Pleurotomarioidea

Wortheniopsis sp. (Raphistomatidae), a single, poorly preserved specimen is found that has an obscure, weak ornament. Its shell shape is most similar to that of *Wortheniopsis* (*Wortheniopsis*) *urkutensis* SZABÓ, 2009 but this latter bears a rather marked ornament of collabral and spiral threads.

In the Plankeraumoos fauna three species of Pleurotomariidae occurred sparsely. *Pleurotomaria debuchi* DESLONGCHAMPS, 1849 is represented only by a flattened, almost discoidal morphotype. This is one of the rare species that occurs in common with the "stable" European Early Jurassic gastropod fauna. However, this species is so variable and so poorly known that further studies are necessary even to elucidate whether this name covers really a single species or more.

The name of *Pleurotomaria* aff. *anglica* (J. SOWERBY, 1818) refers to pleurotomariid specimens that have similar shape and ornament to those, which have been given the same name by SZABÓ (2009) in the Hierlatz Alpe fauna. Further material and studies are necessary to solve the identification problems.

Pleurotomaria aff. *emmrichi* GÜMBEL, 1861 belongs to a form group of conical or feebly gradate Early Jurassic *Pleurotomaria*, badly needing a revision in order to ascertain what the lots of applied names *(princeps*, *principalis*, *emmrichi*, *basilicata*, *precatoria*, etc.) really mean; in some cases they seem to be synonymous.

Fissurelloidea (slit and keyhole limpets)

This superfamily is represented by sporadic occurrence of two emarginulid species, *Emarginula nestii* G.G. GEMMELLARO, 1879 and *Emarginula (Tauschia)* cf. *busambrensis* G.G. GEMMELLARO, 1879 that have been never published from the gastropod fauna of the Hierlatz Limestone Formation before. The species are rather well identifiable with the original description and figuration from the Rocca Busambra (Sicily, Italy) Lower Jurassic limestone of shallow water plateau origin but the latter one is rather badly damaged.

Trochoidea

Four "epulotrochiform" species belong to this group, the inner moulds of which are the most frequent gastropod remains in the studied locality: *Muricotrochus*? sp. (low whorls with 3 granulose spiral threads), *"Epulotrochus"*? sp. 1 (smooth whorls, being higher than in "sp. 2"), *"Epulotrochus"*? sp. 2 (whorls smooth and lower than in "sp. 1"), *"Epulotrochus"*? sp. 3 (low whorls with 3 spiral threads without granules). These species are hardly distinguishable when they are preserved as inner mould without shell fragment or imprint of outer shell surface. The shell morphology of these species needs reconstruction.

Because of its frequency, this is one of the most important groups of gastropods for a palaeoecological analysis.

Eucycloidea

Two poorly preserved species, *Eucyclomphalus* aff. *hierlatzensis* AMMON, 1892 and *Riselloidea noszkyi* SZABÓ, 1995 were found from Eucyclidae. *E. hierlatzensis* is the most common gastropod in the type locality but the significantly different Plankeraumoos species is less frequent.

HICKMAN & MCLEAN (1990) placed these gastropods as "Eucyclini" into the Trochoidea mainly based on soft body characters; anyway, eucyclids seem to be good palaeoecological indices.

Turbinoidea

A rare species, *Ataphrus* (*Endianaulax*)? sp. represents Ataphridae, a mainly Mesozoic family that shows an Early Jurassic evolutionary explosion after an insignificant Triassic representation in the faunas. The Early Jurassic diversification, that is obvious from the Sinemurian, has not yet been recognized in the Plankeraumoos fauna.

New family (?Trochoidea)

A conical-trochiform species with never seen last whorl and aperture construction needs introduction. Its relations are still being investigated.

Cirroidea

Mainly poorly preserved inner moulds of *Discocirrus tricarinatus* (GÜMBEL, 1861) occurred, but imprints and shell fragments too support the identification. *Discocirrus* is a hyperstrophically (false) sinistral gastropod.

?Discohelicoidea (Vetigastropoda?)

Discohelicidae is an uncertain family, no species fits to the nacreous shell structure of the original diagnosis, therefore an emendation is wanted. *Discohelix hallstattensis* SZABÓ, 2009, *D. excavata* (REUSS, 1852), *D.* aff. *ornata* (HÖRNES, 1853) are identified in the Plankeraumoos fauna; all seem derived from a nodose ancestor, like *D. ferox* (GÜMBEL, 1861) of the Hochfelln Limestone or *D. lorioli* GEMMELLARO, 1879 from the Rocca Busambra (Sicily, Italy) limestone of shallow water plateau origin.

A probable predecessor of *Pentagonodiscus reussi* (HÖRNES, 1853), having already the peculiar pentagonal outline but in trochospiral shell, was also found in the Rocca Busambra limestone (*"Solarium" mellonii* GEMMELLARO, 1879).

Caenogastropoda

Zygopleuroidea

A well preserved shell helped to find the correct generic name for *"Chemnitzia" hierlatzensis* STOLICZKA, 1861 that had been known from its monotype, a fragmentary juvenile shell and a similar specimen from Rocche Rosse (Trapani, Sicily, Italy; GEMMELLARO, 1911). On the post-juvenile whorls of the new specimen, the costellae of the early shell parts, typical for *Anoptychia,* disappeared. However, *Anoptychia hierlatzensis* (STOLICZKA, 1861) remains a rare species with three well-known specimens.

The needle shaped, almost cylindrical *Anoptychia*? *acicula* (STOLICZKA, 1861) and a *Katosira*? species are also present as sporadic fragments.

?Pseudomelanoidea

Without the early whorls, the species identification of *Oonia*? cf. *pseudovesta* (GÜMBEL, 1861) remains dubious; the available shell may belong also to other smooth-shelled caenogastropod genera.

Cerithioidea

Cerithinella italica (GEMMELLARO, 1879) is a common component of the faunas of living plateau origin in Sicily and along the Apennines but has not yet been published from Hierlatz Limestone. The presence of the other two genera (*Procerithium* sp., *Cryptaulax*? sp.) mean also faunistical novelties in this lithological type.

Heterobranchia

The members of Heterobranchia belong also to the group of "exotic" gastropods in the Hierlatz Limestone. A single specimen of *Euconactaeon* aff. *concavus* (EUDES-DESLONGCHAMPS, 1842) is the first published representative of Actaeonoidea in this formation.

Clathrobaculus? cf. *alpicolus* (GÜMBEL, 1861) and *Promathildia*? sp. (?Mathildoidea) are present also with single specimens. *Clathrobaculus*? *fistulosus* (STOLICZKA, 1861), based on a monotype from the type locality of the Hierlatz Limestone, is the first species, which has been published from this group.

Depositional environment

On the highest systematic levels, the Plankeraumoos gastropod fauna shows a composition just slightly different from the typical Hierlatz Limestone assemblages. Vetigastropods predominate in the species list, and at the same time they are more abundant in the strata than the remaining groups, which represent the higher evolutionary levels. However, the fauna contains many "exotic" elements that hold important palaeoecological and faunal history information.

Most prominent species, unusual in the Hierlatz Limestone, is the patellogastropod *Pseudorhytidopilus zitteli* (GEMMELLARO, 1879). Its type stratum is of shallow water carbonate plateau origin (Lower Sinemurian, Rocca Busambra, Sicily, Italy). Patellogastropods are unknown in the previously studied Upper Sinemurian and Pliensbachian Hierlatz Limestones.

Recent patellogastropods are living typically on hard substrate in and above the tidal zone but also occur on the sea bottom of a constant shallow water cover; the Mesozoic occurrences suggest similar environmental preference. Their frequency in the studied fauna suggests rather shallow water origin of the Plankerau Hierlatz Limestone, at least partially.

Further species, in common with the Rocca Busambra fauna, also support this suggestion *(Emarginula nestii, Emarginula [Tauschia]* cf*. busambrensis* and *Cerithinella italica).*

Several species *(Pleurotomaria* aff. *emmrichi, Discocirrus tricarinatus*, *Oonia*? cf. *pseudovesta, Clathrobaculus*? cf. *alpicolus,* nodose species of *Discohelix* and "epulotrochiform" trochoideans) show strong relations to another fauna of not really deep water origin. This is known from the Hochfelln Limestone (AMMON, 1892); SEUSS et al. (2005) recognised the patch reef environment origin of this fauna.

The concomitant rarity of the eucyclids in the fauna supports the assumption of not very deep-water environment inhabited. HICKMAN & MCLEAN (1990) observed deep sublitoral to abyssal biotopes for the members of the family and the Jurassic species seemed to live on the sea bottom of similar depths (SZABÓ, 1995). Probably, the Plankerau Hierlatz Limestone preserved documents from an early phase of the subsidence of the former shallow water carbonate plateau. In contrast, *Eucyclomphalus hierlatzensis* is one of the two most common species of the type area of the Hierlatz Limestone (Hallstatt, Hierlatz Alpe, Upper Sinemurian).

Bivalvia

(István Szente)

The Hierlatz Limestone of this locality yielded the bulk of the bivalve material collected during this project. The moderately diverse fauna consists of about a dozen taxa. The lack of shallow-water forms indicates that the bivalves lived in a deeper-water marine environment. Only suspension feeders are present of which epifaunal forms are predominant, indicating that hard substrate necessary for attachment was well available. The assemblage slightly differs, both in taxonomic and ecological composition, from the fauna of the type locality of Hierlatz Limestone studied by STOLICZKA (1861) and SZENTE (1996). Infaunal, shallow burrowing forms are almost exclusively represented by *Praeconia tetragona* (TERQUEM, 1855) and are much less frequent (6 % of the specimens) than in the fauna of the type locality.

Parallelodon sp.

(Pl. 12, Fig. 8)

The material available consists only of about a dozen incomplete and relatively featureless specimens which cannot be assigned to any species described in the literature, including those recorded by STOLICZKA (1861) from the type Hierlatz Limestone.

Oxytoma (O.) inequivalvis (J. SOWERBY, 1819)

(Pl. 12, Figs. 11–13)

According to W.J. ARKELL (1904–1958, recognized British authority on Jurassic rocks and fossils) *O. (O.) inequivalvis* – due to its remarkable morphological variability – produced more differences of opinion than any other Jurassic bivalve species. It has an extremely long stratigraphic range from the Upper Triassic to the Lower Cretaceous and was widely distributed around the world. The valves are considerably unequal both in shape and ornamentation. The left ones are well inflated and bear radial ribs while the right ones are flat and smooth. Left valves can be found in the Hierlatz Limestone much more frequently than right ones. More than 20 specimens were found, most of them of remarkably small size.

Oxytoma sp.

(Pl. 12, Figs. 14)

A single, flat and incomplete valve bearing narrow ribs is assigned, with some uncertainty, to *Oxytoma*.

Praechlamys palosa (Stoliczka, 1861)
(Pl. 12, Figs. 16, 17)

Pectinids are common bivalves in the Hierlatz Limestone and the remarkable variability displayed by the specimens often makes their identification difficult. *P. palosa*, however, can be easily distinguished by the unequal nature of their valves of which the left one bear a few narrow riblets while the right one is smooth. Some ten specimens are available.

Praechlamys subreticulata (Stoliczka, 1861)
(Pl. 12, Figs. 19–24)

About a dozen scallop specimens of the Hierlatz Limestone exposed at Loc. Plk 1 bear fine radial as well as more or less developed commarginal ribs, forming a reticulate ornamentation. These features are also characteristic of *Agerchlamys*, a genus introduced by Damborenea (1993) for a suite of peculiar Early Jurassic pectinids widespread at high latitudes on both the Northern and Southern hemispheres. Fine antimarginal striae (i. e. perpendicular to the valve margin), a further distinctive feature of *Agerchlamys*, however, can not be observed on the Hierlatz Limestone specimens. Recently some low-latitude forms found in the uppermost Triassic and lowermost Jurassic of the Northern Calcareous Alps were also attributed – without any description – to *Agerchlamys*. Some of the figured specimens (Hillebrandt & Kment, 2009, Abb. 23) resemble to scallops known from the Hierlatz Limestone.

Until the presence of antimarginal ornamentation is proved, the abundant pectinids of the Hierlatz Limestone are most clearly attributed to *Praechlamys* Allasinaz, 1972 and are interpreted as representatives of the highly variable species *subreticulata*.

Terquemia pectiniformis (Eudes-Deslongchamps, 1860)
(Pl. 12, Figs. 25–28)

This irregular form is a characteristic element of the bivalve fauna of the Hierlatz Limestone. Some 20 specimens were found during this study.

Placunopsis? sp.
(Pl. 12, Figs. 33)

Variable and usually indistinct bivalves are assigned to the genus *Placunopsis* Morris & Lycett, 1853 whose taxonomy is thus far from clear. The specimen figured here is a small-sized left (free) valve bearing antimarginal ribs formed by imbricate lamellae, thus differing from *"Anomia" numismalis* Quenstedt, 1856 recorded from the Hierlatz Limestone by Stoliczka (1861).

Ctenostreon rugosum (Smith, 1817)
(Pl. 12, Figs. 29–31)

The Bad Mitterndorf specimens agree well with *C. rugosum* described in the literature. The genus *Ctenostreon* Eichwald, 1862 includes highly variable forms probably representing a single species for which several names are available. Among them, *"rugosum"* is the oldest one. It is now recorded for the first time in the Hierlatz Limestone.

Plagiostoma punctatum J. Sowerby, 1805
(Pl. 12, Figs. 34–36)

The specimens forming about 20 % of the material bear a high number of very low riblets separated by punctate grooves and thus can be assigned with certainty to the largely Early Jurassic species *P. punctatum*.

Myoconcha sp. B
(Pl. 12, Fig. 37)

A single internal mould of a right valve represents the first record of *Myoconcha* s.l. from the Hierlatz Limestone.

Praeconia tetragona (Terquem, 1855)
(Pl. 12, Figs. 38, 39)

This species is a characteristic element of the Sinemurian Hierlatz Limestone of the Northern Calcareous Alps. At the locality Plk 1 it can usually be found as internal moulds on which the muscle scars of the valve interior occur as protuberances.

Fossil Sites and Faunal Content

The specimens figured on Pls. 1 to 6 and on Fig. 8 of Pl. 11 are housed in the collection of the Hungarian Natural History Museum in Budapest (M 2010.xxx); the specimens on Pls. 7 to 11 are housed in the collection of the Geologische Bundesanstalt Vienna (GBA 2010/091/xxxx). All other figured specimens as well as rock-thin-sections of Pls. 15 to 17 are housed in the working collections of the respective authors.

Bergerwald east of Bad Mitterndorf [N 47° 33' 30,1" / E 14° 00' 02,8"]
Small outcrops in the creek.

Lithology: Allgäu Beds (spotted grey marly limestones and marlstones with ammonites, bivalves, rare belemnites).

Ammonite fauna (det. J. Schlögl):
Collection Schlögl from the studied outcrop.
Tropidoceras cf. *calliplocum* (Gemmellaro)
Coleoidea
Private collection (E. Pfusterer)
Partschiceras sp., *Metaderoceras* sp., *Uptonia jamesoni* (Sowerby), *Uptonia angusta* (Quenstedt), *Tropidoceras mediterraneum* (Gemmellaro), *Tropidoceras* cf. *zitteli* Fucini, *Atractites* sp.

Age: The studied outcrop is most probably of Early Pliensbachian age (probably Tragophylloceras ibex Zone), but the specimens from the private collection indicate a larger stratigraphic extent of the facies (starting in the early Early Pliensbachian Uptonia jamesoni Zone).

BWA 1 [N 47° 37' 12" / E 13° 55' 51"]
Bergwald south of Zwicker Kogel, outside of the area of Text-Fig. 2.
Lithology: Agatha Limestone (bedded to nodular red limestone).

Brachiopod fauna (coll. & det. M. Siblík):
Nucleata rupicola (Zitt.).

Age: Late Jurassic.

F 4 [locality see Text-Fig. 2]
Lithology: grey to pinkish micritic limestone.
Bivalve fauna (coll. & det. I. Szente):
Praechlamys valoniensis (Defrance, 1825) (Pl. 12, Fig. 1)
A single left valve bearing nearly 50 radial smooth plicae may represent this species whose remains are widespread in the Rhaetian as well as in the Lower Jurassic (Hettangian and Sinemurian stages) of Europe (Johnson, 1984).
Pectinid bivalvia, gen. et sp. indet. (Pl. 12, Fig. 2)

A single internal mould with traces of about 20 radial plicae seems to belong to the Pectinidae.

Liostrea? sp. (Pl. 12, Fig. 3)

Although broken surfaces of the rock samples yielded by the locality commonly display sections of dark-coloured oyster shells, only poorly preserved specimens are available for study. They are attributed, with doubt, to *Liostrea*, a long-ranging (Late Triassic – Late Cretaceous; MALCHUS, 1990) genus of Mesozoic oysters.

Promysidiella sp. (Pl. 12, Fig. 4)

A single mytiliform right valve most probably represents the Triassic genus *Promysidiella* WALLER, 2005.

Gruenewaldia? sp. (Pl. 12, Fig. 5)

A single right valve displaying strong commarginal ribs, well defined carina and an antecarinal depression as well as a commarginally ornamented area, is attributed to *Gruenewaldia* WÖHRMANN, 1889, a genus known from the Middle and Late Triassic. It may represent, however, the morphologically similar (see HAUTMANN, 2003) Permian–Triassic genus *Elegantinia* WAAGEN, 1906 (= *Lyriomyophoria* KOBAYASHI, 1954) as well.

Myoconcha sp. A (Pl. 12, Figs. 6, 7)

Three valves are attributed to the largely Mesozoic (Late Triassic – Late Cretaceous) genus *Myoconcha* J. DE C. SOWERBY, 1824 sensu lato.

Age: probably Late Triassic.

Flo 1 [N 47° 38' 15,5" / E 13° 56' 22,7"]

Many small outcrops and isolated blocks in a small valley.

Lithology: Hierlatz Formation. Mainly white and grey, micritic crinoidal limestones with many brachiopods, bivalves, gastropods and ammonites, rare belemnites. Some blocks contain numerous "stromatactis like" structures parallel with bedding.

Ammonite fauna (coll. & det. J. Schlögl):

Sample 1

Phylloceras sp., *Togaticeras stella* (SOWERBY, 1833), *Geyeroceras cylindricum* (SOWERBY, 1831), *Juraphyllites* sp., ?*Vermiceras* sp., *Arnioceras* sp., *Arnioceras* sp. 2, *Arnioceras* gr. *semilaeve* (HAUER, 1853), *Arnioceras ceratitoides* (QUENSTEDT, 1849).

Age: Early Sinemurian.

Sample 2

Zetoceras pseudozetes (FUCINI, 1908), *Togaticeras stella* (SOWERBY, 1833), *Geyeroceras cylindricum* (SOWERBY, 1831), *Lytoconites* cf. *pecchioli*, *Schreyenbachites* sp., *Vermiceras* sp., *Arnioceras* sp., *Arnioceras* sp. 2, *Arnioceras* gr. *semilaeve*, HAUER, 1853), *Promicroceras* sp.

Age: Early Sinemurian.

Sample 3

Arnioceras sp. 2

Age: Early Sinemurian.

Sample 4 (probably the same layer as Sample 1)

Phylloceras sp., *Arnioceras* sp. juv., *Paracymbites* aff. *dennyi* (SIMPSON).

Age: Early Sinemurian or early Late Sinemurian.

Sample 5

Zetoceras sp., *Arnioceras* sp., *Arnioceras* gr. *paucicostatum* FUCINI, 1902.

Age: Early Sinemurian.

Brachiopod fauna (coll. & det. M. Siblík):

Sample A

Red and white limestones in isolated blocks on the slope.

Apringia ex gr. *paolii* (CAN.), *Prionorhynchia guembeli* (OPP.), *P. polyptycha* (OPP.), *Salgirella albertii* (OPP.), *Jakubirhynchia latifrons* (STUR in GEYER), *Calcirhynchia* (?) *plicatissima* (QUENST.), *Cisnerospira angulata* (OPP.), *Liospiriferina* aff. *alpina* (OPP.), *L.* cf. *decipiens* (BÖSE-SCHL.), *Securina partschi* (OPP.), *Linguithyris aspasia* (ZITT.), *Zeilleria baldaccii* GEMM., *Z. mutabilis* (OPP.).

Age: Sinemurian.

Sample B

White Hierlatz Limestone in blocks along the old forest road and in the upper part of the slope.

Apringia ex gr. *paolii* (CAN.) (very variable specimens), *Cirpa subcostellata* (GEMM.), *Jakubirhynchia latifrons* (STUR in GEYER), *Calcirhynchia zugmayeri* (GEMM.), *Cuneirhynchia* cf. *cartieri* (OPP.), *Salgirella* cf. *magnicostata* (ORMÓS), *Prionorhynchia belemnitica* (QUENST.), *P. greppini rimata* (GEYER), *Liospiriferina acuta* (STUR in GEYER), *L.* aff. *alpina* (OPP.), *L.* cf. *decipiens* (BÖSE-SCHL.), *Securina partschi* (OPP.), *Bakonyithyris* aff. *meneghinii* (PAR.), *Zeilleria mutabilis* (OPP.), *Zeilleria* sp.

Age: Sinemurian.

Flo 2 [N 47° 38' 12,2" / E 13° 56' 33,3"]

Lithology: Hierlatz Formation. Probably synsedimentary breccias composed of clasts of red and white more or less crinoidal limestones, some clasts are rich in brachiopods and ammonites; bivalves and gastropods are locally also present. Breccia matrix is micritic, locally rich in crinoidal debris. Blocks (or clasts) were sampled separately under different numbers.

Ammonite fauna (coll. & det. J. Schlögl):

Remarks: Ammonite fauna come from different clasts of red micritic crinoidal limestones with radiaxial calcite, accumulated in a synsedimentary breccia, therefore the geological age of separate associations is not always the same. It ranges from Early Sinemurian to early Late Sinemurian, probably *A. obtusum* Zone.

Sample 1

?*Parasteroceras* sp.

Age: probably early Late Sinemurian.

Sample 7

Arnioceras sp., *Arnioceras* aff. *miserabile* FUCINI, 1902

Age: Early Sinemurian.

Sample 11

Juraphyllites sp., *Asteroceras* sp.

Age: early Late Sinemurian.

Sample 12

Arnioceras sp. juv.

Age: Early Sinemurian.

Sample 13–14

Arnioceras sp., *Arnioceras* gr. *ambiguum* (GEYER, 1886)

Age: Early Sinemurian.

Sample 15 (most numerous material)

Red micritic or sparitic limestone with ammonites, gastropods, bivalves and brachiopods. Abundant crinoidal debris. *Atractites* sp., *Phylloceras* cf. *costoradiatum* STUR m. s. in GEYER, 1886, *Partschiceras striatocostatum* (MENEGHINI, 1853), *Zetoceras pseudozetes* (FUCINI, 1908), *Juraphyllites planispira* (REYNÉS, 1868), *Lytoceras celticum* (GEYER, 1886), *Lytoceratina* indet., *?Euagassiceras* sp., *Angulaticeras* sp. juv., *?Arnioceras* sp. juv., *Asteroceras* cf. *brooki* (SOWERBY).

Age: probably late Early or early Late Sinemurian.

Sample 16

Phylloceras costoradiatum STUR m. s. in GEYER, 1886

Zetoceras sp., *Lytoceratina* indet., *Arnioceras* sp., *Arnioceras* sp. 2

Age: Early Sinemurian.

Sample 17
Arnioceras ceratitoides (QUENSTEDT, 1849)
Age: Early Sinemurian.

Brachiopod fauna (coll. & det. M. Siblík):
Sample A (white Hierlatz Limestone)
Prionorhynchia greppini (OPP.), *Liospiriferina brevirostris* (OPP.), *L. obtusa* (OPP.), *L. alpina* (OPP.), *Securina partschi* (OPP.), *?Antiptychina rothpletzi* (DI-STEF.), *Zeilleria batilla* (GEYER), *Z. mutabilis* (OPP.), *Z. alpina* (OPP.), *Z. venusta* (UHL.).
Sample B (red Hierlatz Limestone)
Prionorhynchia greppini (OPP.), *P. polyptycha* (OPP.), *P. fraasi* (OPP.), *Calcirhynchia zugmayeri* (GEMM.), *Cuneirhynchia retusifrons* (OPP.), *Homoeorhynchia* (?) *prona* (OPP.), *Cirpa planifrons* (ORMÓS), *Gibbirhynchia* (?) aff. *curviceps* (QUENST.), *Cisnerospira angulata* (OPP.), *Liospiriferina brevirostris* (OPP.), *L.* aff. *obtusa* (OPP.), *L.* cf. *decipiens* (BÖSE-SCHL.), *L.* cf. *alpina* (OPP.), *Lobothyris punctata* (SOW.), *L.* (?) aff. *sospirolensis* (UHL.), *Securina partschi* (OPP.), *Zeilleria mutabilis* (OPP.), *Z. venusta* (UHL.), *Z. choffati* (HAAS).
Age of both samples: Sinemurian.

Flo 3/1 [N 47° 38,103' / E 13° 56,445']
Small valley with discontinuous outcrops of several types of Hierlatz Limestone.
Lithology: mostly white crinoidal wacke- to packstones, less sorted, rich in brachiopods; local red micritic limestones with dispersed crinoids and scarce fauna.

Ammonite fauna (coll. & det. J. Schlögl):
Sample 1
Greyish micritic limestone with dispersed scarce crinoids.
Asteroceras sp. juv. or *Caenisites* sp. juv.
Age: Late Sinemurian.

Sample 2
White crinoidal limestone.
Fauna: crinoids, brachiopods, gastropods, bivalves, ammonites.
Paltechioceras cf. *oosteri* (DUMORTIER, 1867), *Paltechioceras tardecrescens* (HAUER, 1856)
Age: late Late Sinemurian.

Sample 3
Red micritic limestones with dispersed crinoids, wackestones.
Juraphyllites sp., *Coeloceras* sp.
Age: early Early Pliensbachian.

Sample 4
Red and greenish micritic limestone with dispersed crinoids.
Lytoceras sp.
Paltechioceras sp. (aff. *romanicum* (UHLIG, 1900)), *Paltechioceras* cf. *tardecrescens* (HAUER, 1856)
Age: late Late Sinemurian.

Sample 5
Reddish to yellowish micritic limestone with dispersed crinoids.
Epideroceras cf. *lorioli* (HUG, 1899)
Age: late Late Sinemurian.

Sample 6
Red micritic limestone with dispersed large crinoids.
Gemmellaroceras sp., *Epideroceras* sp.
Age: late Late Sinemurian.

Sample 7
Red micritic crinoidal limestone.
Aegoceras (Aegoceras) cf. *maculatum* (YOUNG & BIRD, 1822)
Age: early Early Pliensbachian.

Brachiopod fauna (coll. & det. M. Siblík):
Sample A
White crinoidal limestones.
Prionorhynchia flabellum (GEMM.), *P. greppini* (OPP.), *P. belemnitica* (QUENST.), *Liospiriferina* cf. *obtusa* (OPP.), *Buckmanithyris nimbata* (OPP.), *Rhapidothyris beyrichi* (OPP.), *Securina* aff. *partschi* (OPP.), *Zeilleria alpina* (GEYER), *Zeilleria mutabilis* (OPP.)
Sample B
White micritic or poorly crinoidal limestones.
Prionorhynchia greppini (OPP.), *P. guembeli rimata* (OPP.), *Furcirhynchia* aff. *striata* (QUENST.), *"Rhynchonella"* aff. *belemnitica* (QUENST.), *Liospiriferina* sp., *Buckmanithyris nimbata* (OPP.), *Zeilleria mutabilis* (OPP.), *Zeilleria* aff. *perforata* (PIETTE).
Age of both samples: Sinemurian.

Flo 3/2 [BMN 495 577 / 277 555]
Lithology: Hierlatz Limestone (grey and red crinoidal limestones).
Brachiopod fauna:
Sample A (coll. & det. A. Vörös):
Apringia paolii (CANAVARI), *Jakubirhynchia* cf. *laevicosta* (GEYER), *Jakubirhynchia* cf. *latifrons* (GEYER), *Cirpa planifrons* (ORMÓS) ?, *Cirpa* ? sp., *Pisirhynchia* cf. *retroplicata* (ZITTEL), *Cuneirhynchia dalmasi* (DUMORTIER), *Cuneirhynchia* aff. *dalmasi* (DUMORTIER), *Saubachia* ? sp., *Liospiriferina* cf. *alpina* (OPPEL), *Rhapidothyris* cf. *beyrichi* (OPPEL), *Linguithyris* cf. *aspasia* (ZITTEL), *Bakonyithyris ewaldi* (OPPEL), Terebratulida indet.
Age: possibly Pliensbachian.

Sample B (coll. & det. M. Siblík):
Cirpa fronto (QUENST.), *Cuneirhynchia retusifrons* (OPP.), *Prionorhynchia greppini* (OPP.), *P. guembeli* (OPP.), *P.* cf. *greppini* (OPP.), *"Rhynchonella"* aff. *belemnitica* (QUENST.), *Liospiriferina* cf. *brevirostris* (OPP.), *L.* cf. *alpina* (OPP.), *Buckmanithyris nimbata* (OPP.), *Linguithyris aspasia* (ZITT.), *Bakonyithyris apenninica* (ZITT.), *Zeilleria* cf. *mutabilis* (OPP.).
Age: Late (?) Sinemurian.

Flo 3/3 (locality see Text-Fig. 2)
Lithology: grey and red micritic limestones.
Brachiopod fauna (coll. & det. M. Siblík):
Apringia aff. *paolii* (CAN.), *Prionorhynchia greppini* (OPP.), *P.* cf. *greppini* (OPP.), *P. fraasi* (OPP.), *P.* aff. *glycinna* (GEMM.), *Cisnerospira angulata* (OPP.), *Liospiriferina* cf. *alpina* (OPP.), *Antiptychina* (?) *rothpletzi* (BÖSE), *Linguithyris aspasia* (ZITT.), *Zeilleria mutabilis* (OPP.), *Z. catharinae* (GEMM.), *Zeilleria* sp.
Age: Late (?) Sinemurian.

Flo 4 [N 47° 38,047' / E 13° 56,341']
Lithology: Greenish, grey-greenish and red micrites with horizons of synsedimentary breccias and crinoidal packstones and brachiopod shell-beds (lenses).

Fauna: crinoids, brachiopods, scarce gastropods, bivalves, ammonites.
Ammonite fauna (coll. & det. J. Schlögl):
Samples 013/0
White to yellowish brachiopod and crinoidal-brachiopod shell-beds.
Juraphyllites sp., *Epophioceras* sp., *Arnioceras* sp., *Epideroceras* sp.
Sample 013/1 from debris
Geyeroceras cylindricum (SOWERBY), *Juraphyllites* sp., *Arnioceras* cf. *miserabile* (QUENSTEDT), *Arnioceras* cf. *semicostatum* (YOUNG & BIRD), *Arnioceras* cf. *ceratitoides* (QUENSTEDT).
Age: Late Sinemurian.

Brachiopod fauna (coll. & det. M. Siblík):

Samples 013/0

Apringia paolii (CAN.), *Zeilleria* ex gr. *mutabilis* (OPP.).

Sample 013/1

Jakubirhynchia latifrons (STUR in GEYER), *Prionorhynchia greppini rimata* (GEYER), *P. belemnitica* (QUENST.), *Cuneirhynchia* (?) *palmata* (OPP.), *"Rhynchonella"* aff. *latissima* FUC., *Cisnerospira angulata* (OPP.), *Liospiriferina acuta* (STUR in GEYER), *L. obtusa* (OPP.), *L.* cf. *obtusa* (OPP.), *L.* cf. *alpina* (OPP.), *L.* cf. *gryphoides* (UHL.), *Buckmanithyris nimbata* (OPP.), *Securina partschi* (OPP.), *S. hierlatzica* (OPP.), *Zeilleria mutabilis* (OPP.).

Age: Sinemurian.

Flo 5 [N 47° 38,045' / E 13° 56,486']

Lithology: Grey micritic limestones with dispersed crinoids and lenses of brachiopod accumulations (pack- to grainstones), scarce ammonites, geopetal structures.

Ammonite fauna (coll. & det. J. Schlögl):

Juraphyllites sp., *Lytoceras* sp., *Leptechioceras* sp., *Leptechioceras* cf. *meigeni* (HUG, 1899), *Leptechioceras macdonnelli* (PORTLOCK, 1843), *Paltechioceras* sp., *Gemmellaroceras* sp., Oxynoticeratidae indet.

Age: late Late Sinemurian.

Brachiopod fauna (coll. & det. M. Siblík):

Sample A (red micrite)

Apringia paolii (CAN.), *Prionorhynchia flabellum* (GEMM.), *P. polyptycha* (OPP.), *Pisirhynchia retroplicata* (ZITT.), ?*Piarorhynchia* sp., *Liospiriferina obtusa* (OPP.), *L. alpina* (OPP.), *L. cordiformis* (BÖSE), *L.* aff. *sicula* (GEMM.), *Koninckodonta* cf. *pichleri* (BITTN.), *Viallithyris gozzanensis* (PAR.), *Linguithyris aspasia* (ZITT.), *Securithyris adnethensis* (SUESS), *S.* aff. *paronai* (CAN.), *Bakonyithyris ewaldi* (OPP.), *B. ovimontana* (BÖSE), *B. apenninica* (ZITT.), *Zeilleria alpina* (GEYER), *Z. mutabilis* (OPP.), *Z. oenana* (BÖSE), Z. aff. *oenana* (BÖSE)? juv.

Age: Pliensbachian.

Sample B

Another block at the eastern part of the locality, light grey micritic and reddish crinoidal limestone.

Cirpa fronto (QUENST.), *Cirpa* ? *subfurcillata* (BÖSE), *Prionorhynchia greppini* (OPP.), *P. guembeli* (OPP.), *Cuneirhynchia* (?) *fraasi* (OPP.), *Liospiriferina alpina* (OPP.), *L.* ex gr. *alpina* (OPP.), *L. obtusa* (OPP.), *Securina partschi* (OPP.).

Age: Upper (?) Sinemurian.

Sample C (eastnortheast of Flo 5)

Pisirhynchia pisoides (ZITT.), *Apringia paolii* (CAN.), *Liospiriferina globosa* (BÖSE), *L.* cf. *alpina* (OPP.), *L.* aff. *cordiformis* (BÖSE), *L.* aff. *apenninica* (CAN.), *Viallithyris gozzanensis* (PAR.), *Linguithyris aspasia* (ZITT.), *Securithyris adnethensis* (SUESS), *Bakonyithyris ewaldi* (OPP.), *B.* aff. *pedemontana* (PAR.), *Zeilleria alpina* (OPP.), *Z. oenana* (BÖSE), *Z. mutabilis* (OPP.).

Age: Pliensbachian.

Flo 6 [N 47° 38,080' / E 13° 56,530']

Lithology: Red micritic crinoidal wacke- to packstones, lenses with coarse bioclasts of crinoids, brachiopods, ammonites.

Ammonite fauna (coll. & det. J. Schlögl):

Paltechioceras sp., *Epideroceras* sp.

Age: Probably late Late Sinemurian.

Flo 7 [locality see Text-Fig. 2]

Brachiopod fauna (coll. & det. A. Dulai):

Jakubirhynchia latifrons (STUR in GEYER), *Jakubirhynchia*? *fascicostata* (UHLIG), *Prionorhynchia* cf. *greppini* (OPPEL), *Prionorhynchia guembeli* (OPPEL), *Prionorhynchia polyptycha* (OPPEL), *Cirpa*? *subcostellata* (GEMMELLARO), *Calcirhynchia*? cf. *hungarica* (BÖCKH), *Cuneirhynchia cartieri* (OPPEL), Rhynchonellida indet., *Liospiriferina* cf. *acuta* (STUR in GEYER), *Liospiriferina alpina* (OPPEL), *Liospiriferina brevirostris* (OPPEL), *Liospiriferina* aff. *obtusa* (OPPEL), Spiriferinida indet., *Cisnerospira angulata* (OPPEL), *Cisnerospira darwini* (GEMMELLARO), *Cisnerospira sylvia* (GEMMELLARO), *Zeilleria alpina* (GEYER), *Zeilleria baldaccii* GEMMELLARO, *Zeilleria* cf. *mutabilis* (OPPEL), *Zeilleria venusta* (UHLIG), *Securina hierlatzica* (OPPEL), *Securina securiformis* (GEMMELLARO), Terebratulida indet.

Age: Sinemurian.

Flo 8 [locality see Text-Fig. 2]

Brachiopod fauna (coll. & det. A. Dulai):

Prionorhynchia polyptycha (OPPEL), *Salgirella* cf. *albertii* (OPPEL), *Gibbirhynchia* ? sp., Rhynchonellida indet., *Liospiriferina alpina* (OPPEL), Spiriferinida indet., *Zeilleria alpina* (GEYER), *Zeilleria engelhardti* (OPPEL), *Securina hierlatzica* (OPPEL).

Age: Sinemurian.

Flo 9 [locality see Text-Fig. 2]

Brachiopod fauna (coll. & det. M. Siblík):

Sample A

Fallen blocks of red Hierlatz Limestone.

Salgirella albertii (OPP.), *Liospiriferina* aff. *alpina* (OPP.), *Securina partschi* (OPP.), *Zeilleria alpina* (OPP.).

Age: Sinemurian.

Sample B

Reddish limestone along the steep forest road from Flo 9 to the Flodring summit.

Cirpa planifrons (ORMÓS), *Salgirella albertii* (OPP.), *Rimirhynchia* sp., *Prionorhynchia* cf. *polyptycha* (OPP.), *Liospiriferina obtusa* (OPP.), *L.* cf. *brevirostris* (OPP.), *Securina* cf. *partschi* (OPP.), *Zeilleria batilla* (GEYER), *Z. mutabilis* (OPP.), *Z. alpina* (OPP.), *Z. stapia* (OPP.).

Age: Sinemurian.

Klaus 1 [N 47° 37,860' / E 13° 56,626']

Lithology: pink to red micritic limestone with ammonites, bivalves, belemnites; signs of condensation, ammonites covered with ferruginous films, geopetal infillings of the chambers, fragmented, randomly oriented, Fe/Mn crusts.

Ammonite fauna (coll. & det. J. Schlögl):

Calliphylloceras nilsoni (HEBERT, 1866), *Ptychophylloceras (Tatrophylloceras) chronomphalum* (VACEK, 1886), *Lytoceras cornucopiae* (YOUNG & BIRD), *?Zugodactylites* sp., *Porpoceras vortex* (SIMPSON), *Catacoeloceras dumortieri* DE BRUN, *Catacoeloceras* cf. *crassum* (YOUNG & BIRD), *Hildoceras bifrons* (BRUG.), *Paroniceras* gr. *sternale* (D'ORBIGNY, 1844), *Phymatoceras robustum* HYATT, *Podagrosites* sp., *Podagrosites* cf. *aratum* (BUCKMAN), *Grammoceras* sp.

Age: Middle and early Late Toarcian. The listed taxa include only the ammonites collected during our fieldtrip in 2005. Revision of some private collections would be necessary. Stratigraphic extent of the red condensed limestone probably reaches at least Early Aalenian, because of e.g. Erycites fallifax Arkel, taxon of the L. opalinum Zone, found in the private collection of E. Pfusterer.

Bivalve fauna (coll. & det. I. Szente):

Parallelodon? *problematicus* (VACEK, 1886), (Pl. 12, Figs. 9, 10)

The poor fragments collected by the author and much more the fine specimens seen at the private collection of E. Pfusterer represent this characteristic species described from the Toarcian–Aalenian San Vigilio Oolite of the Southern Alps.

Praechlamys sp. (Pl. 12, Fig. 18)

Praechlamys subreticulata (STOLICZKA, 1861), (Pl. 12, Fig. 19)

A fragment found in pink crinoidal limestone represents *Praechlamys subreticulata* (STOLICZKA, 1861).

Klaus 2 [N 47° 37' 54,6" / E 13° 56' 32,9"]
Lithology: red micritic limestones, encrusted ammonites, scarce gastropods, bivalves. Small outcrop on the slope.
Ammonite fauna (coll. & det. J. Schlögl):
The fauna is not determined in detail, but contains some *Hildoceras* sp.
Age: Toarcian.

Klaus 3 [N 47° 37' 57,1" / E 13° 56' 29,9"]
Lithology: Hierlatz Limestone; red, mostly sparitic crinoidal limestones with mostly disarticulated big crinoidal particles, brachiopods and small ammonites. Crinoidal debris locally accumulated in laminae up to 3–4 cm thick with indications of sorting.

Ammonite fauna (coll. & det. J. Schlögl):
Sample 1
Phylloceras sp., *Juraphyllites* sp., *Polymorphites* sp. or microconchs of *Platypleuroceras* sp., *Platypleuroceras* cf. *brevispina* (SOWERBY), *Gemmellaroceras* sp.
Age: Fauna is indicative of Early Pliensbachian (Carixian).

Remarks: The geological age agrees well with the youngest ammonite association described by RAKUS (1999) from the Hierlatz type locality.

Sample 2
Red micritic limestones with dispersed or accumulated crinoids, ammonites and brachiopods.
Tropidoceras sp. *demonense* (GEMMELLARO, 1884) and 2 other different species of *Tropidoceras*, *Acanthopleuroceras* gr. *lepidum* (TUTCHER & TRUEMAN, 1925).
Age: Early Pliensbachian.

Sample 3
Yellowish to brownish micritic limestones with dispersed crinoids.
Juraphyllites sp., *Paltechioceras* sp.
Age: Late Sinemurian.

Sample 4
Reddish crinoidal packstones with rare ammonites.
?*Arnioceras* sp.
Age: Sinemurian.

Brachiopod fauna (coll. & det. M. Siblík):
Sample A
Red micritic limestones with rests of Fe/Mn crusts**.**
Prionorhynchia (?) *hagaviensis* (BÖSE), *P. flabellum* (GEMM.), *Apringia paolii* (CAN.), *A. atlaeformis* (BÖSE), *A. diptycha* (BÖSE), *Cuneirhynchia retusifrons* (OPP.), *Cirpa briseis* (GEMM.), *Cirpa* aff. *subcostellata* (GEMM.), *Pisirhynchia retroplicata* (ZITT.), *Liospiriferina alpina* (OPP.), *L.* aff. *alpina* (OPP.), *Viallithyris gozzanensis* (PAR.), *Antiptychina* cf. *rothpletzi* (DI-STEF.), *Bakonyithyris* aff. *ovimontana* (BÖSE), *B. apenninica* (ZITT.).
Age: Pliensbachian.

K 04 (locality see Text-Fig. 2)
Brachiopod fauna (coll. & det. M. Siblík):
Prionorhynchia greppini (OPP.), *P. greppini rimata* (GEYER), *Liospiriferina obtusa* (OPP.), *L. brevirostris* (OPP.), *L.* cf. *alpina* (OPP.).
Age: Sinemurian.

Bivalve fauna (coll. & det. I. Szente):
Pectinid bivalve, gen. et sp. indet. (Pl. 12, Fig. 15), *Praechlamys subreticulata* (STOLICZKA, 1861) (Pl. 12, Fig. 20).

K 04/1 (locality see Text-Fig. 2)
Lithology: pink and red Hierlatz Limestone.

Brachiopod fauna (coll. & det. M. Siblík):
Cirpa fronto (QUENST.), *Prionorhynchia polyptycha* (OPP.), *P. palmata* (OPP.), *Liospiriferina obtusa* (OPP.), *L.* cf. *alpina* (OPP.), *L.* cf. *brevirostris* (OPP.), *Lobothyris* ex gr. *punctata* (SOW.), *Securina partschi* (OPP.), *Securina hierlatzica* (OPP.), *Bakonyithyris ewaldi* (OPP.), *Zeilleria alpina* (GEYER), *Z. mutabilis* (OPP.).
Age: Sinemurian.

Samples dispersed between K 04/1 and Stub 1

Brachiopod fauna (coll. & det. M. Siblík):
Prionorhynchia greppini (OPP.), *P. albertii* (OPP.), *Liospiriferina alpina* (OPP.), *L.* cf. *sicula* (GEMM.), *Securina partschi* (OPP.), *Bakonyithyris ewaldi* (OPP.).
Age: Sinemurian.

Klb 1 [N 47° 37,056' / E 13° 57,884']
Deforested slope above the forest road, blocks and small outcrops.
Lithology: white, yellowish to red, more or less crinoidal limestones, breccias are less common.

Fauna: crinoids, brachiopods, ammonites, scarce gastropods. Fauna not yet determined.

Klb 2 [N 47° 37,068' / E 13° 57,992']
Lithology: white, grey and pink micritic crinoidal wackestone with ammonites, brachiopods, small bivalves and scarce gastropods.

Ammonite fauna (coll. & det. J. Schlögl):
Juraphyllites sp., *Geyeroceras cylindricum* (SOWERBY), *Arnioceras rejectum* FUCINI, 1902.
Age: Early Sinemurian.

Brachiopod fauna (coll. & det. M. Siblík):
Apringia aff. *paolii* (CAN.), *Cuneirhynchia retusifrons* (OPP.), *Calcirhynchia plicatissima* (QUENST.), *Prionorhynchia polyptycha* (OPP.), ?*Cirpa* sp., *Cisnerospira angulata* (OPP.), *Liospiriferina obtusa* (OPP.), *L.* cf. *obtusa* (OPP.), *L.* cf. *alpina* (OPP.), *Bakonyithyris ewaldi* (OPP.), *B.* (?) aff. *catharinae* GEMM., *Securina partschi* (OPP.), *Zeilleria mutabilis* (OPP.), *Z.* aff. *venusta* (UHL.).
Age: Sinemurian.

Klb 3 [N 47° 37,045' / E 13° 58,165']
Edge of a small plateau.
Lithology: red limestones with brachiopod accumulations (empty or with sparitic infill), crinoidal wacke- to pack-/grainstone. Levels with synsedimentary breccias, lithoclasts angular to rounded, mainly of micritic and coquina limestones in red micrite.

Fauna: crinoids, brachiopods, scarce ammonites, bivalves, gastropods.
Ammonite fauna (coll. & det. J. Schlögl):
Atractites sp., *Agassiceras* sp.
Age: Early Sinemurian.

Klb 4 [N 47° 37,054' / E 13° 58,178']

Lithology: Red stromatactis limestones with scarce ammonites, brachiopods.

Ammonite fauna (coll. & det. J. Schlögl):
Sample 1
Angulaticeras sp. (cf. *angustisulcatus* (GEYER, 1886)), *Arnioceras* sp. (2 species).
Age: Early Sinemurian.

Sample 2
Loose block some meters to the E from sample 1, large terebratulids and rhynchonellids.
Arnioceras sp.

Sample 3
Downslope, approx. 10 m to the S from sample 1, with ammonites, gastropods, brachiopods.
Cenoceras sp., *Angulaticeras* sp., *?Agassiceras* sp. juv., *Arnioceras* sp.
Age: Early Sinemurian.

Klb 5 [N 47° 37,052' / E 13° 58,127']
Lithology: Loose block sparitic grainstone with brachiopods, scarce ammonites.

Ammonite fauna (coll. & det. J. Schlögl):
Arnioceras sp.
Age: probably Early Sinemurian.

Klb 6 (locality see Text-Fig. 2)
Lithology: red micritic and crinoidal limestones, loose blocks on the slope.

Brachiopod fauna (coll. & det. M. Siblík):
Cirpa fronto (QUENST.), *Cuneirhynchia retusifrons* (OPP.), *C. cartieri* (OPP.), *Prionorhynchia polyptycha* (OPP.), *P. greppini rimata* (GEYER), *P.* aff. *calderinii* (PAR.), *Liospiriferina obtusa* (OPP.), *L.* cf. *darwini* (GEMM.), *Liospiriferina* sp., *Lobothyris* sp., *Bakonyithyris ewaldi* (OPP.), *B. pedemontana* (PAR.), *B.* aff. *meneghinii* (PAR.), *Zeilleria alpina* (GEYER), *Z. perforata* (PIETTE), *Z. venusta* (UHL.), *Z.* aff. *waehneri* GEMM., *Z.* aff. *choffati* (HAAS).
Age: Late (?) Sinemurian.

Nr. 1/10 (locality see Text-Fig. 2)
Brachiopod fauna (coll. & det. A. Dulai):
Jakubirhynchia? cf. *fascicostata* (UHLIG), *Prionorhynchia* cf. *pseudopolyptycha* (BÖCKH), *Cirpa*? *subcostellata* juv. (GEMMELLARO), *Homoeorhynchia prona* (OPPEL), *Cuneirhynchia* cf. *cartieri* (OPPEL), *Gibbirhynchia* sp., Rhynchonellida indet., *Liospiriferina* cf. *alpina* (OPPEL), *Liospiriferina* cf. *obtusa* (OPPEL), *Zeilleria* cf. *choffati* (HAAS), *Zeilleria mutabilis* (OPPEL), *Securina* cf. *hierlatzica* (OPPEL), Terebratulida indet.
Age: Sinemurian.

Nr. 08 Schwarzwald
Lithology: white Hierlatz Limestone.

Brachiopod fauna (coll. & det. M. Siblík):
Cirpa fronto (QUENST.), *Prionorhynchia greppini* (OPP.), *Liospiriferina obtusa* (OPP.), *L.* aff. *sicula* (GEMM.) *L.* cf. *alpina* (OPP.), *L.* cf. *obtusa* (OPP.), *Lobothyris* sp.
Age: Sinemurian.

Nr. 09 Schwarzwald [N 47° 38,345' / E 13° 55,871']
Lithology: light micritic limestone with lenses of crinoidal and lithoclastic packstones

Fauna: crinoids, brachiopods, bivalves, gastropods and ammonites.

Brachiopod fauna (coll. & det. M. Siblík):
Jakubirhynchia latifrons (STUR in GEYER*), Apringia paolii* (CAN.), *Tetrarhynchia zitteli* (GEMM.), *Prionorhynchia greppini rimata* (GEYER), *P. polyptycha* (OPP.), *Piarorhynchia* (?) *caroli* (GEMM.), *Homoeorhynchia* (?) aff. *ptinoides* (DI-STEF.), *Cirpa* aff. *subcostellata* (GEMM.), *"Rhynchonella" triquetra* GEMM., *"Rhynchonella"* aff. *latissima* FUC., *"Rhynchonella"* aff. *diptycha* (BÖSE), *Cisnerospira angulata* (OPP.), *Liospiriferina obtusa* (OPP.), *L. alpina* (OPP.), *L.* cf. *alpina* (OPP.), *L.* aff. *sicula* (GEMM.), *Lobothyris* cf. *andleri* (OPP.), *Securithyris* aff. *adnethensis* (SUESS), *Linguithyris aspasia* (ZITT.), *Securina partschi* (OPP.), *S. hierlatzica* (OPP.), *S. hierlatzica plicata* (GEYER), *Zeilleria batilla* (GEYER), *Z. alpina* (GEYER), *Z. mutabilis* (OPP.), *Z. livingstonei* (GEMM.), *Z.* aff. *fucinii* (Greco), *Z.* aff. *stapia* (OPP.).
Age: Late (?) Sinemurian.

Nr. 10 Schwarzwald [N 47° 38,289' / E 13° 55,800']
Lithology: Bedded limestones with brachiopod accumulations (shell beds), sparitic matrix, chaotical orientation, more or less parallel to bedding.

Brachiopod fauna (coll. & det. M. Siblík):
Nearly monospecific fauna of *"Terebratula"* aff. *ascia* GIRARD, rarely *Zeilleria mutabilis* (OPP.) and *Z. choffati* (HAAS).
Age: Sinemurian.

Plk 1 [N 47° 37,789' / E 13° 57,790] = [BMN 497 380 / 276 977]
Lithology: Hierlatz Limestone, pale-pink ammonite-brachiopod-echinoderm wackestone with abundant moulds of ammonites and white pack- to grainstone with gastropods, brachiopods and echinoderms (especially echinoid spines); very rich in fossils.

Ammonite fauna (coll. & det. J. Schlögl):
The ammonite fauna was collected separately from the uppermost 10 cm horizon and from the underlying horizon, 10–15 cm thick. Additional fauna that couldn't be related to a certain horizon will be dealt with separately below.
Sampling level 10–20 cm
Atractites sp., *Partschiceras striatocostatum* (MENEGHINI, 1853), *Togaticeras stella* (SOWERBY, 1833), *Geyeroceras cylindricum* (SOWERBY, 1931), *Juraphyllites* cf. *quadrii* (MENEGHINI), *Lytoceras* sp., ?*Bouhamidoceras* sp. juv., *Angulaticeras* sp., *Angulaticeras lacunatum* (GEYER, 1886), *Arnioceras miserabile* (QUENSTEDT, 1858), *Arnioceras* gr. *ambiguum* (GEYER, 1886), *Arnioceras* gr. *semilaeve* (HAUER, 1853), *Arnioceras insigne* FUCINI, 1902, ?*Cymbites* sp.
Not related collection
Zetoceras pseudozetes (FUCINI, 1908), *Juraphyllites dorsoplanatus* (FUCINI, 1908), *Juraphyllites* cf. *diopsis* (GEMMELLARO, 1884), *Angulaticeras angustisulcatus* (GEYER, 1886), ?*Plesechioceras* sp., *Microderoceras* cf. *olenoptychum* (FUCINI, 1903).
Age: probably Early Sinemurian, but see also the discussion in the Ammonoidea chapter

Brachiopod fauna (coll. & det. M. Siblík):
Cirpa fronto (QUENST.), *Prionorhynchia polyptycha* (OPP.), *P. greppini* (OPP.), *P. greppini rimata* (GEYER), *P. palmata* (OPP.), *Jakubirhynchia latifrons* (STUR in GEYER), *Cuneirhynchia retusifrons* (OPP.*), Salgirella* aff. *magnicostata* (ORMÓS), *Liospiriferina brevirostris* (OPPEL), *L. obtusa* (OPPEL), *L. darwini* (GEMM.), *L.* aff. *sicula* (GEMM.), *Liospiriferina* cf. *alpina* (OPP.), *Liospiriferina* sp., *Lobothyris* cf. *andleri* (OPP.), *Securina partschi* (OPP.), *Bakonyithyris* (?) aff. *engelhardti* (OPP.), *Zeilleria alpina* (GEYER), *Z. mutabilis* (OPP.), *Z. choffati* (HAAS), *Z.* aff. *venusta* (UHL.), *Z.* aff. *norica* (SUESS).
Age: Sinemurian.

Brachiopod fauna (coll. & det. A. Dulai):
Apringia paolii (CANAVARI), *Jakubirhynchia latifrons* (STUR in GEYER), *Jakubirhynchia*? *fascicostata* (UHLIG), *Prionorhynchia*? *flabellum* (MENEGHINI), *Prionorhynchia* cf. *greppini* (OPPEL), *Cirpa planifrons* (ORMÓS), *Salgirella* cf. *albertii* (OPPEL), *Salgirella* aff. *albertii* (OPPEL), *Piarorhynchia caroli* (GEMMELLARO), *Cuneirhynchia cartieri* (OPPEL), *Pisirhynchia inversa* (OPPEL), *Pisirhynchia retroplicata* (ZITTEL), *Gibbirhynchia* sp., Rhynchonellida indet., *Liospiriferina alpina* (OPPEL), *Liospiriferina salomoni* (BÖSE), *Liospiriferina* cf. *sicula* (GEMMELLARO), *Liospiriferina* sp., *Cisnerospira darwini* (GEMMELLARO), *Cisnerospira* aff. *darwini* (GEMMELLARO), Spiriferinida indet., *Lobothyris andleri* (OPPEL), *Lobothyris punctata* (SOWERBY), *Linguithyris aspasia* (ZITTEL), *Linguithyris aspasia* juv. (ZITTEL), *Zeilleria alpina* (GEYER), *Zeilleria choffati* (HAAS), *Zeilleria mutabilis* (OPPEL), *Zeilleria perforata* (PIETTE), *Zeilleria* cf. *subnumismalis* (DAVIDSON), Terebratulida indet.

Bivalve fauna (coll. & det. I. Szente):

Parallelodon sp., *Oxytoma (O.) inequivalvis* (J. SOWERBY, 1819), *Oxytoma* sp., *Praechlamys palosa* (STOLICZKA, 1861), *Praechlamys subreticulata* (STOLICZKA, 1861), *Terquemia pectiniformis* (EUDES-DESLONGCHAMPS, 1860), *Placunopsis*? sp., *Ctenostreon rugosum* (SMITH, 1817), *Plagiostoma punctatum* J. SOWERBY, 1805, *Myoconcha* sp. B, *Praeconia tetragona* (TERQUEM, 1855).

Gastropod fauna (coll. & det. J. Szabó):

Pseudorhytidopilus zitteli (G.G. GEMMELLARO, 1879), *Neritopsis elegantissima* HÖRNES, 1853, *Wortheniopsis* sp., *Pleurotomaria debuchi* J. A. DESLONGCHAMPS, 1849, *Pleurotomaria* aff. *anglica* (J. SOWERBY, 1818), *Pleurotomaria* aff. *emmrichi* GÜMBEL, 1861, *Emarginula nestii* G.G. GEMMELLARO, 1879, *Emarginula* (*Tauschia*) cf. *busambrensis* G.G. GEMMELLARO, 1879, *Eucyclomphalus* aff. *hierlatzensis* AMMON, 1892, *Riselloidea noszkyi* SZABÓ, 1995, *Muricotrochus*? sp., *"Epulotrochus"*? sp. 1, *"Epulotrochus"*? sp. 2, *"Epulotrochus"*? sp. 3, *Ataphrus* (*Endianaulax*)? sp., *Discocirrus* cf. *tricarinatus* GÜMBEL, 1861, *Discohelix hallstattensis* SZABÓ, 2009, *Discohelix excavata* (REUSS, 1852), *Discohelix* aff. *ornata* (HÖRNES, 1853), *Pentagonodiscus reussi* (HÖRNES, 1853), *Anoptychia hierlatzensis* (STOLICZKA, 1861), *Anoptychia*? *acicula* (STOLICZKA, 1861), *Katosira*? sp., *Oonia*? cf. *pseudovesta* (GÜMBEL, 1861), *Cerithinella italica* (G.G. GEMMELLARO, 1879), *Procerithium* sp., *Cryptaulax*? sp., *Euconactaeon* aff. *concavus* (E. EUDES-DESLONGCHAMPS, 1842), *Clathrobaculus*? cf. *alpicolus* (GÜMBEL, 1861), *Promathildia*? sp.

Plk 2 [N 47° 37' 50,2" / E 13° 57' 44,7"]

Very small outcrop.

Lithology: Hierlatz Formation; white micritic crinoidal limestones with brachiopods and rare ammonites. Probably a small olistolith within Upper Jurassic limestones.

Ammonite fauna (coll. A. Dulai, det. J. Schlögl):

Juraphyllites nardii MENEGHINI, 1853.

Age: Sinemurian.

Plk 3 [N 47° 37' 46,8" / E 13° 57' 41,9"]

Probably meter-sized olistoliths within the surrounding Upper Jurassic limestones**.**

Lithology: Hierlatz Limestone; white micritic brachiopod coquina with ammonites. Ammonites enveloped with radiaxial calcite.

Ammonite fauna (coll. & det. J. Schlögl):

Arnioceras gr. *mendax* FUCINI, 1902 or *A. dimorphus* PARONA, 1897, *Arnioceras insolitum* FUCINI, 1902.

Age: Early Sinemurian.

Brachiopod fauna (coll. & det. A. Dulai):

Sample Plk 3a

Jakubirhynchia? *fascicostata* (UHLIG), *Prionorhynchia forticostata* (BÖCKH), *Prionorhynchia greppini* (OPPEL), *Prionorhynchia* aff. *guembeli* (OPPEL), *Prionorhynchia*? *hagaviensis* (BÖSE), *Prionorhynchia polyptycha* (OPPEL), *Cirpa planifrons* (ORMÓS), *Cirpa briseis* (GEMMELLARO), *Cuneirhynchia retusifrons* (OPPEL), Rhynchonellida indet., *Liospiriferina brevirostris* (OPPEL), *Liospiriferina* cf. *obtusa* (OPPEL), *Liospiriferina* cf. *sicula* (GEMMELLARO), *Liospiriferina salomoni* (BÖSE), *Liospiriferina alpina* (OPPEL), *Cisnerospira darwini* (GEMMELLARO), Spiriferinida indet., *Lobothyris andleri* (OPPEL), *Lobothyris delta* (NEUMAYR), *Lobothyris punctata* (SOWERBY), *Zeilleria alpina* (GEYER), *Zeilleria baldaccii* GEMMELLARO, *Zeilleria choffati* (HAAS), *Zeilleria mutabilis* (OPPEL), *Zeilleria perforata* (PIETTE), *Zeilleria stapia* (OPPEL), *Zeilleria venusta* (UHLIG), *Zeilleria* sp., *Bakonyithyris ewaldi* (OPPEL), *Securina hierlatzica* (OPPEL), Terebratulida indet.

Sample Plk 3b

Jakubirhynchia? *fascicostata* (UHLIG), *Jakubirhynchia latifrons* (STUR in GEYER), *Prionorhynchia greppini* (OPPEL), *Prionorhynchia* aff. *guembeli* (OPPEL), *Prionorhynchia*? *hagaviensis* (BÖSE), *Prionorhynchia polyptycha* (OPPEL), *Calcirhynchia*? *hungarica* (BÖCKH), *Cirpa planifrons* (ORMÓS), *Cirpa*? *subcostellata* (GEMMELLARO), *Cuneirhynchia retusifrons* (OPPEL), *Gibbirhynchia sordellii* (PARONA), Rhynchonellida indet., *Liospiriferina alpina* (OPPEL), *Liospiriferina brevirostris* (OPPEL), *Liospiriferina* cf. *gryphoidea* (UHLIG), *Liospiriferina* cf. *obtusa* (OPPEL), *Cisnerospira angulata* (OPPEL), *Cisnerospira darwini* (GEMMELLARO), *Cisnerospira sylvia* (GEMMELLARO), Spiriferinida indet., *Koninckodonta waehneri* (BITTNER), *Lobothyris punctata* (SOWERBY), *Lobothyris andleri* (OPPEL), *Zeilleria alpina* (GEYER), *Zeilleria baldaccii* GEMMELLARO, *Zeilleria batilla* (GEYER), *Zeilleria* cf. *bicolor* (BÖSE), *Zeilleria choffati* (HAAS), *Zeilleria mutabilis* (OPPEL), *Zeilleria perforata* (PIETTE), *Zeilleria* cf. *venusta* (UHLIG), *Securina* cf. *hierlatzica* (OPPEL), Terebratulida indet.

Age: both samples Sinemurian.

Plk 4 [N 47° 37' 47,3" / E 13° 57' 40,4"]

Short stratigraphic section, showing Upper Jurassic red limestones with olistoliths of Lower Jurassic limestones, see Text-Fig. 4.

Ammonite fauna (coll. & det. J. Schlögl):

Sample 1 (from bed number 7 in the section)

Red micritic limestones with ammonites, brachiopods and bivalves.

Sowerbyceras loryi (MUNIER-CHALMAS, 1875), *"Haploceras" jungens* NEUMAYR, 1873), *Hemihaploceras (Hemihaploceras) nobile* (NEUMAYR, 1873), *Sutneria* cf. *eumela* (D'ORBIGNY, 1847).

Age: Late Kimmeridgian.

Sample 2 (from bed number 11 in the section)

Red and grey micritic limestone.

The fauna is still not prepared. But surprisingly it looks older than the above mentioned fauna of underlying bed number 7.

Trenerites sp. (aff. *evolutus* GEMMELLARO, 1876), *Trenerites* sp. (cf. *enayi* SARTI, 1993).

Age: Genus Trenerites is known mainly from the Early Kimmeridgian.

Brachiopod fauna (coll. & det. M. Siblík)

Sample A (from bed number 7 in the section)

"Terebratula" aff. *bilimeki* SUESS.

Age: Late Jurassic.

Sample B (olistolith [approx. 30×60 cm] in bed number 6 in the section).

Beige limestone with brachiopod lumachelle.

Prionorhynchia palmata (OPP.), *P. guembeli* (OPP.), *P.* aff. *belemnitica* (QUENST.), *Liospiriferina obtusa* (OPP.), *Liospiriferina* cf. *obtusa* (OPP.), *Liospiriferina* cf. *alpina* (OPP.), *Linguithyris aspasia* (ZITT.), *Bakonyithyris apenninica* (ZITT.), *Zeilleria alpina* (OPP.).

Age: Late (?) Sinemurian.

Sample C (small olistoliths in red limestones of bed number 6 and/or upper part of bed number 5).

Light red and spotted micrites with big crinoids.

Apringia paolii (CAN.), *Prionorhynchia flabellum* (GEMM.), *P.* cf. *polyptycha* (OPP.), *Linguithyris aspasia* (ZITT.), *Bakonyithyris ewaldi* (OPP.), *B.* aff. *pedemontana* (PAR.), *Zeilleria alpina* (OPP.).

Age: Late (?) Sinemurian.

Sample D (taken from the scree below the outcrop).

Grey micritic limestones.
Prionorhynchia fraasi (OPP.), *P. belemnitica* (QUENST.), *Apringia* ? *atlaeformis* (BÖSE), *Liospiriferina acuta* (STUR in GEYER), *L.* cf. *decipiens* (BÖSE-SCHL.), *Zeilleria* sp.
Age: Late (?) Sinemurian.

Brachiopod fauna (coll. & det. A. Dulai):
The fauna has been taken from the scree below the outcrop; probably it originates from the grey limestones in the lower part of the section.
Jakubirhynchia? *fascicostata* (UHLIG), *Jakubirhynchia*? cf. *laevicosta* (STUR in GEYER), *Prionorhynchia greppini* (OPPEL), *Prionorhynchia* cf. *guembeli* (OPPEL), *Prionorhynchia* aff. *guembeli* (OPPEL), *Prionorhynchia* cf. *polyptycha* (OPPEL), *Cirpa*? *subcostellata* (GEMMELLARO), *Cirpa* sp., *Calcirhynchia*? aff. *hungarica* (BÖCKH), *Calcirhynchia* aff. *zugmayeri* (GEMMELLARO), *Salgirella* cf. *albertii* (OPPEL), *Homoeorhynchia* ? cf. *prona* (OPPEL), *Cuneirhynchia cartieri* (OPPEL), *Cuneirhynchia* ? *fraasi* (OPPEL), *Cuneirhynchia retusifrons* (OPPEL), Rhynchonellida indet., *Liospiriferina alpina* (OPPEL), *Liospiriferina* cf. *obtusa* (OPPEL), *Liospiriferina* cf. *semicircularis* (BÖSE), *Liospiriferina* sp., *Cisnerospira angulata* (OPPEL), *Cisnerospira darwini* (GEMMELLARO), Spiriferinida indet., *Lobothyris delta* (NEUMAYR), *Lobothyris punctata* (SOWERBY), *Lobothyris* sp., *Papodina* cf. *bimammata* (ROTHPLETZ), *Zeilleria alpina* (GEYER), *Zeilleria baldaccii* GEMMELLARO, *Zeilleria engelhardti* (OPPEL), *Zeilleria mutabilis* (OPPEL), *Zeilleria perforata* (PIETTE), *Zeilleria subnumismalis* (DAVIDSON), *Zeilleria* cf. *venusta* (UHLIG), Terebratulida indet.
Age: Sinemurian.

Plk 5 [N 47° 37' 47,4" / E 13° 57' 45,3"]
Lithology: Hierlatz Limestone; white, poorly or moderately sorted crinoidal packstones with abundant brachiopods and rare ammonites.

Ammonite fauna (coll. & det. J. Schlögl):
Zetoceras sp., *Arnioceras* sp., Eoderoceratidae indet.
Age: probably Early Sinemurian.

Brachiopod fauna (coll. & det. M. Siblík):
Sample A (light grey Hierlatz Limestone)
Salgirella albertii (OPP.), *Prionorhynchia* aff. *flabellum* (GEMM.), *Cisnerospira angulata* (OPP.), *Liospiriferina* cf. *alpina* (OPP.), *Securina partschi* (OPP.), *Bakonyithyris ewaldi* (OPP.), *Zeilleria alpina* (OPP.), *Z.* cf. *alpina* (OPP.).
Sample B (red Hierlatz Limestone)
Salgirella albertii (OPP.), *Jakubirhynchia* aff. *latifrons* (STUR in GEYER), *Cirpa* sp., *Apringia* aff. *diptycha* (BÖSE), *Liospiriferina obtusa* (OPP.), *L.* cf. *alpina* (OPP.), *L.* cf. *brevirostris* (OPP.), *Securina partschi* (OPP.), *Zeilleria mutabilis* (OPP.), *Z. venusta* (UHL.), *Z. baldaccii* (GEMM.), *Z. alpina* (OPP.), *Z.* aff. *alpina* (OPP.).
Age of both samples: Sinemurian.

Plk 6 [N 47° 37,758' / E 13° 57,708']
Lithology: Reddish micritic limestones with dispersed to accumulated crinoids, ammonites, brachiopods, rare bivalves.

Ammonite fauna (coll. & det. J. Schlögl):
Nebrodites (Nebrodites) macerrimus (QUENSTEDT, 1888), *Taramelliceras (Taramelliceras) trachinotum* (OPPEL, 1863).
Age: Early Kimmeridgian.

Plk 7 [N 47° 37,777' / E 13° 57,729']
Lithology: Grey micritic limestones, locally dispersed crinoidal debris, ammonites.

Ammonite fauna (coll. & det. J. Schlögl):
Nebrodites (Mesosimoceras) herbichi (VON HAUER).
Age: Early Kimmeridgian.

Plk 8 [N 47° 37,834' / E 13° 57,687'] = [BMN 497 262 / 277 057]
Small outcrops on the slope.
Lithology: Grey and reddish micritic limestones with decimeter-sized olistoliths of white Hierlatz Limestone.

Sample from the matrix:
Ammonite fauna (coll. & det. J. Schlögl):
Nebrodites cf. *beogradensis* ANDELKOVIC, 1966; *Sutneria* cf. *cyclodorsata* (MOESCH, 1867).
Age: Kimmeridgian (late Early or early Late Kimmeridgian to Late Kimmeridgian).

Samples from olistoliths:
Ammonite fauna (coll. M. Siblík & det. J. Schlögl):
Geyeroceras cylindricum (SOWERBY, 1931).
Age: Sinemurian.

Brachiopod fauna (coll. & det. M. Siblík):
Cuneirhynchia retusifrons (OPP.), *Prionorhynchia polyptycha* (OPP.), *P. greppini* (OPP.), *Cisnerospira angulata* (OPP.), *Liospiriferina alpina* (OPP.), *L. obtusa* (OPP.), *Lobothyris punctata* (SOW.), *Securina partschi* (OPP.), *Zeilleria mutabilis* (OPP.), *Z. alpina* (GEYER), *Z. choffati* (HAAS), *Z. stapia* (OPP.), *Zeilleria* sp.
Age: Sinemurian.

Plk 9 (locality see Text-Fig. 2)
Lithology: Hierlatz Limestone; white and reddish micritic crinoidal limestones.

Brachiopod fauna (coll. & det. M. Siblík):
Prionorhynchia belemnitica (QUENST.), *P.* (?) aff. *belemnitica* (QUENST.), *Salgirella albertii* (OPP.), *Cirpa fronto* (QUENST.), *Liospiriferina alpina* (OPP.), *L. obtusa* (OPP.), *L. sicula* (GEMM.), *L.* cf. *brevirostris* (OPP.), *Rhapidothyris beyrichi* (OPP.), *Zeilleria mutabilis* (OPP.).
Age: Sinemurian.

Plk 10 (Upper Jurassic ammonite locality of private collectors, approx. position see Text-Fig. 3).
Lithology: Tressenstein Limestone.

Bivalve fauna (coll. & det. I. Szente):
Placunopsis cf. *radiata* (PHILLIPS, 1929) (Pl. 12, Fig. 32).
According to HÖLDER (1990), *Placunopsis* specimens referred to as *"P. tatrica* ZITTEL, 1870" in the literature of the peri-Mediterranean Upper Jurassic represent the long-ranging species *P. radiata.* The fine radial riblets characteristic of the species cannot be observed on the specimen. Their lack may be most probably due to the nature of preservation.
Brachiopod fauna (coll. & det. M. Siblík):
Sample from olistoliths (white and pink Hierlatz Limestone) in the surroundings of Plk 10
Cuneirhynchia retusifrons (OPP.), *Prionorhynchia greppini* (OPP.), *Liospiriferina brevirostris* (OPP.), *L.* cf. *semicircularis* (BÖSE), *Lobothyris punctata* (SOW.), *Bakonyithyris ewaldi* (OPP.), *B.* (?) *engelhardti* (OPP.), *Zeilleria alpina* (GEYER), *Z. mutabilis* (OPP.), *Z. thurwieseri* (BÖSE), *Z. venusta* (UHL.), *Z. catharinae* (GEMM.), *Z.* aff. *stapia* (OPP.).
Sample from olistoliths (beige micrites) in the surroundings of Plk 10:
Septocrurella uhligi (HAAS), *Liospiriferina* sp., *Zeilleria* sp.
Age of both samples: Sinemurian.

Stub 1 [N 47° 37' 56,9" / E 13° 56' 47,1"]
Lithology: Hierlatz Limestone; pink and red crinoidal wacke- to packstone.

Ammonite fauna (coll. & det. J. Schlögl):
Paltechioceras sp.
Age: Late Sinemurian.

Stub 2 (locality see Text-Fig. 2)
Lithology: Hierlatz Limestone; pink grainstone with ammonites.

Ammonite fauna (coll. & det. J. Schlögl):
Arnioceras sp.
Age: Probably Early Sinemurian.

T 6 (locality see Text-Fig. 3)
Lithology: red micritic limestone with crinoids, ammonites, gastropods, belemnites and coral fragments, matrix rich in protoglobigerinids. Components frequently coated with ferromanganese crusts, contacts affected by stylolitization. Intercalation within Tressenstein Limestone, the lithology resembles the Agatha Limestone.

Age: probably Late Jurassic.

T 12 (locality see Text-Fig. 3)
Lithology: Tressenstein Limestone

Ammonite fauna (det. J. Schlögl):
Aspidoceras sp.
Age: Late Jurassic.

T 13 (locality see Text-Fig. 3)
Lithology: grey micritic limestone of Late Jurassic age (Taramelliceras sp.) containing crinoids, coral fragments, protoglobigerinids and decimeter-sized olistoliths with Sinemurian brachiopods.

Brachiopod fauna (coll. & det. A. Dulai):
Jakubirhynchia? *fascicostata* (Uhlig), *Prionorhynchia greppini* (Oppel), *Prionorhynchia*? *hagaviensis* (Böse), *Prionorhynchia polyptycha* (Oppel), *Prionorhynchia* sp., *Cirpa planifrons* (Ormós), *Calcirhynchia*? cf. *hungarica* (Quenstedt), Rhynchonellida indet., *Liospiriferina alpina* (Oppel), *Liospiriferina obtusa* (Oppel), *Liospiriferina* cf. *sicula* (Gemmellaro), *Liospiriferina* sp. indet., *Cisnerospira* cf. *angulata* (Oppel), *Lobothyris andleri* (Oppel), *Zeilleria alpina* (Geyer), *Zeilleria choffati* (Haas), *Zeilleria mutabilis* (Oppel), *Zeilleria* sp., Terebratulida indet.
Age: Sinemurian.

T 14 (Pyrmoos-Brandwald south of Salza-Alm)
Lithology: grey and brownish detritic limestone (Tressenstein Limestone) with centimetre-sized clasts of Lower Triassic Werfen Beds (sandstone and shales). The fine grained matrix contains Saccocoma.

Age: Late Jurassic.

T 15 (locality see Text-Fig. 3)
Lithology: Tressenstein Limestone with a decimeter-sized olistolith of Hierlatz Limestone

Ammonite fauna (det. J. Schlögl):
Perisphinctidae gen. et sp. indet.
Age: Late Jurassic.

Brachiopod fauna from olistolith (coll. & det. M. Siblík):
Cirpa fronto (Quenst.), *Prionorhynchia polyptycha* (Oppel), *Prionorhynchia greppini* (Oppel), *Prionorhynchia greppini rimata* (Geyer), *Salgirella* aff. *magnicostata* (Ormós), *Liospiriferina* cf. *alpina* (Oppel), *Liospiriferina brevirostris* (Oppel) *Liospiriferina obtusa* (Oppel), *Liospiriferina* aff. *sicula* (Gemmellaro), *Liospiriferina darwini* (Gemm.), *Lobothyris* cf. *andleri* (Oppel), *Zeilleria alpina* (Geyer), *Zeilleria mutabilis* (Oppel), *Zeilleria choffati* Haas, *Zeilleria* aff. *venusta* (Uhlig).
Age: Sinemurian.

T 16 (locality see Text-Fig. 3)
Lithology: several meters-sized olistolith of Hierlatz Limestone

Brachiopod fauna (coll. & det. A. Dulai):
Jakubirhynchia latifrons (Stur in Geyer), *Jakubirhynchia*? cf. *fascicostata* (Uhlig), *Prionorhynchia greppini* (Oppel), *Prionorhynchia*? cf. *hagaviensis* (Böse), *Prionorhynchia* cf. *polyptycha* (Oppel), *Cirpa briseis* (Gemmellaro), *Cirpa planifrons* (Ormós), *Cirpa* sp., *Cuneirhynchia retusifrons* (Oppel), *Cuneirhynchia* sp., *Pisirhynchia inversa* (Oppel), Rhynchonellida indet., *Liospiriferina alpina* (Oppel), *Cisnerospira angulata* (Oppel), *Cisnerospira darwini* (Gemmellaro), Spiriferinida indet., *Lobothyris* cf. *delta* (Neumayr), *Zeilleria alpina* (Geyer), *Zeilleria baldaccii* Gemmellaro, *Zeilleria bicolor* (Böse), *Zeilleria choffati* (Haas), *Zeilleria mutabilis* (Oppel), *Zeilleria perforata* (Piette), *Zeilleria stapia* (Oppel), Terebratulida indet.
Age: Sinemurian.

T 19 (locality see Text-Fig. 2)
Lithology: several centimeters to decimeters-sized clasts of white to red crinoidal limestones (Hierlatz Limestone) within greenish-grey micritic matrix probably of Tressenstein Limestone.

Brachiopod fauna (coll. & det. A. Dulai):
Prionorhynchia cf. *guembeli* (Oppel), *Prionorhynchia*? *hagaviensis* (Böse), *Cirpa briseis* (Gemmellaro), *Calcirhynchia*? cf. *hungarica* (Böckh), *Pisirhynchia pisoides* (Zittel), Rhynchonellida indet., *Liospiriferina alpina* (Oppel), *Liospiriferina* sp., Spiriferinida indet., *Koninckodonta waehneri* (Bittner), *Linguithyris* cf. *aspasia* (Zittel), *Zeilleria alpina* (Geyer), Terebratulida indet.
Age: Sinemurian.

T 25 (locality see Text-Fig. 3)
Lithology: reddish and grey micritic limestone with ammonites, crinoids, gastropods and abundant protoglobigerinids, interbedded with detritic Tressenstein Limestone.
Age: Late Jurassic.

T 26 (locality see Text-Fig. 3)
Lithology: grey micritic beds of Tressenstein Limestone.

Ammonite fauna (coll. H. Meierl & det. J. Schlögl):
"Aspidoceras" sp.
Age: Late Jurassic.

T 29 (locality see Text-Fig. 3)
Lithology: Hierlatz Limestone, white to pale pink ammonite-brachiopod-echinoderm wackestone-floatstone.

Ammonite fauna (coll. G.W. Mandl & det. J. Schlögl):
Geyeroceras sp.
Age: Early Jurassic.

T 30 (locality see Text-Fig. 3)
Lithology: Tressenstein Limestone, grey-greenish to reddish micritic limestone with ammonites

Ammonite fauna (coll. G.W. Mandl & det. J. Schlögl):
Sowerbyceras loryi (MUNIER CHALMAS, 1875)
Laevaptychus sp.
Age: Late Jurassic, probably Kimmeridgian.

Wild 1 (approx. locality see Text-Fig. 1)
Eastern slope in the upper part of the Wildgraben valley.
Lithology: Oberalm beds; bedded grey micritic limestones with dispersed bioclasts (crinoids, ammonites), locally bioturbated or with cherts.

Ammonite fauna (coll. & det. J. Schlögl):
Lissoceratoides sp., *«Haploceras» balanense* NEUMAYR, *Taramelliceras (T.)* sp., *Pseudowaagenia micropla* (OPPEL, 1863), *Nebrodites (Nebrodites) macerrimus* (QUENSTEDT, 1888)
Age: late Early Kimmeridgian or early Late Kimmeridgian.

Wild 2 (approx. locality see Text-Fig. 1)
Wildgraben, middle part; talus blocks of red micrites.

Brachiopod fauna (coll. & det. M. Siblík):
Apringia paolii (CAN.), *Cirpa fronto* (QUENST.), *C.* aff. *briseis* (GEMM.), *Jakubirhynchia* aff. *latifrons* (STUR in GEYER), *Prionorhynchia* (?) *hagaviensis* (BÖSE), *Liospiriferina obtusa* (OPP.), *L.* cf. *brevirostris* (OPP.), *L.* cf. *alpina* (OPP.), *L.* aff. *sicula* (GEMM.), *L.* aff. *cordiformis* (BÖSE), *Bakonyithyris ewaldi* (OPP.), *B. ovimontana* (BÖSE), *B. apenninica* (ZITT.), *Linguithyris aspasia* (ZITT.), *Rhapidothyris* cf. *beyrichi* (OPP.), *Zeilleria alpina* (GEYER).
Age: Upper Sinemurian.

Wild 3 (approx. locality see Text-Fig. 1)
Crossing of the bottom of Wildgraben and Öderntal.

Brachiopod fauna (coll. & det. M. Siblík):
Talus blocks of white Hierlatz Limestone: *Prionorhynchia greppini* (OPP.), *Liospiriferina* cf. *obtusa* (OPP.), *L.* cf. *alpina* (OPP.), *Zeilleria alpina* (GEYER), *Z. thurwieseri* (BÖSE), *Z. baldaccii* (GEMM.).
Block of red micrites: *Piarorhynchia* aff. *pusilla* (GEMM.).
Age: Sinemurian.

Wolf 1 [N 47° 37,878' / E 13° 56,285']
Lithology: Contact of pinky crinoidal wacke- to packstone with violet bedded crinoidal packstone. On the southern side of the small hill is a hardground visible with borings.

Ammonite fauna (coll. & det. J. Schlögl):
Fuciniceras gr. *ambiguum* (FUCINI, 1904), *Fuciniceras* cf. *inclitum* (FUCINI, 1904), *Fuciniceras* cf. *cornacaldense* (TAUSCH, 1980), *Arieticeras* sp.
Age: Late Pliensbachian (Domerian).

Brachiopod fauna (coll. & det. M. Siblík):
Apringia paolii (CAN.), *A. diptycha* (BÖSE), *A. piccininii* (ZITT.), *Prionorhynchia* cf. *scherina* (GEMM.), *P.* cf. *flabellum* (GEMM.), *Liospiriferina* cf. *alpina* (OPP.), *L.* cf. *obtusa* (OPP.), *L.* aff. *sicula* (GEMM.), *Linguithyris aspasia* (ZITT.), *Securithyris* cf. *adnethensis* (SUESS), *Bakonyithyris apenninica* (ZITT.), *B.* aff. *ovimontana* (BÖSE), *Zeilleria mutabilis* (OPP.), *Z. alpina* (GEYER), *Z. bicolor* (BÖSE).
Age: Pliensbachian.

Wolf 3 [N 47° 37,720' / E 13° 56,327']
Lithology: sparitic monospecific brachiopod lumachelle.

Brachiopod fauna (coll. & det. M. Siblík):
Rhynchonellina suessi GEMM.
Age: Sinemurian.

ZF (locality see Text-Fig. 2)
Lithology: well bedded, greenish-grey siliceous(?) limestone with layers of crinoidal debris, on top of the hill also containing clasts of red Hierlatz Limestone and red "Bositra" limestone; in Text-Fig. 2 indicated as Tressenstein Limestone, but the Late Jurassic age of the matrix is not proved.

Brachiopod fauna (coll. & det. M. Siblík):
Cisnerospira cf. *sylvia* (GEMM.), *Liospiriferina* sp., *"Rhynchonella"* sp.
Age: Sinemurian.

ZS (outside the area of Text-Fig. 2, small outcrops on the SW slope of Kleiner Zwicker; for approx. position see Text-Fig. 1 and map of SCHÖLLNBERGER, 1974).
Lithology: Agatha Limestone, well bedded to nodular red limestone.

Brachiopod fauna (coll. & det. M. Siblík):
Nucleata rupicola (ZITTEL), *Fortunella* ? aff. *capillata* (ZITTEL).
Age: Late Jurassic.

Z 00 (locality see Text-Fig. 2)
Tractor road between Zwicker and Wolfskogel, curve in the uppermost part of the road.
Lithology: lumachelle with oysters and brachiopods within reefoidal Dachstein Limestone.

Brachiopod fauna (coll. & det. M. Siblík):
Fissirhynchia fissicostata (SUESS), *Oxycolpella eurycolpos* (BITTN.) juv.?, fragments of *Rhaetina gregaria* (SUESS) and *Laballa suessi* (ZUGM.).
Age: Norian–Rhaetian.

Z 01 (locality see Text-Fig. 2)
Tractor road between Zwicker and Wolfskogel, uppermost part of the road.
Lithology: 20 cm thick greenish-grey micritic limestone bed, directly resting on reefoidal Dachstein Limestone.

Conodont fauna (coll. G.W. Mandl, det. L. Krystyn):
Norigondolella steinbergensis (MOSHER); *Parvigondolella andrusovi* KOZUR & MOCK, *Zieglericonus rhaeticus* KOZUR & MOCK, *Chirodella* sp.
Age: Rhaetian 1 (Paracochloceras suessi Zone).

Z 02 (locality see Text-Fig. 2)
Tractor road between Zwicker and Wolfskogel, uppermost part.
Lithology: greenish-grey micritic limestone bed, directly resting on reefoidal Dachstein Limestone; same bed as Z 01.

Conodont fauna (coll. G.W. Mandl, det. L. Krystyn):
Norigondolella steinbergensis (MOSHER); *Zieglericonus rhaeticus* KOZUR & MOCK.
Age: Rhaetian 1 (Paracochloceras suessi Zone).

Z 07 [N 47° 37' 43,1" / E 13° 56' 06,1"]
Tractor road between Zwicker and Wolfskogel, uppermost part.
Lithology: grey spotted limestone with marly intercalations; crinoidal limestones, locally silicified (spiculite); with echinoid spines, rare brachiopods.

Ammonite fauna (coll. & det. J. Schlögl):
Schlotheimia sp.
Age: Late Hettangian (S. angulata Zone).

Plate 1

Sinemurian brachiopods from southwestern Totes Gebirge, coll. & det. A. Dulai.
The specimens are figured in dorsal (a), lateral (b) and anterior (c) views if not stated otherwise.

Fig. 1: *Appringia paolii* (Canavari, 1880).
Location Plk 1; L: 10.8 mm, W: 11.9 mm, Th: 5.6 mm.
M 2010.344.1, 2×.

Fig. 2: *Jakubirhynchia latifrons* (Stur in Geyer, 1889).
Location T 16; L: 13.8 mm, W: 16.3 mm, Th: 9.4 mm.
M 2010.345.1, 2×.

Fig. 3: *Jakubirhynchia latifrons* (Stur in Geyer, 1889).
Location T 16; L: 12.6 mm, W: 15.1 mm, Th: 8.0 mm.
M 2010.346.1, 2×.

Fig. 4: *Jakubirhynchia*? *fascicostata* (Uhlig, 1880).
Location T 16; L: 10.1 mm, W: 11.0 mm, Th: 4.8 mm.
M 2010.347.1, 2×.

Fig. 5: *Jakubirhynchia*? *laevicosta* (Geyer, 1889).
Location Plk 4; L: 10.7 mm, W: 12.4 mm, Th: 7.4 mm.
M 2010.348.1, 2×.
a – dorsal view, b – lateral view.

Fig. 6: *Prionorhynchia forticostata* (Böckh, 1874).
Location Plk 3a; L: 14.4 mm, W: 15.2 mm, Th: 10.8 mm.
M 2010.349.1, 2×.

Fig. 7: *Prionorhynchia*? *flabellum* (Meneghini in Gemmellaro, 1874).
Location Plk 1; L: 14.2 mm, W: 18.8 mm, Th: 8.6 mm.
M 2010.350.1, 2×.

Fig. 8: *Prionorhynchia greppini* (Oppel, 1861).
Location T 16; L: 17.4 mm, W: 20.0 mm; Th: 12.2 mm.
M 2010.351.1, 2×.

Fig. 9: *Prionorhynchia guembeli* (Oppel, 1861).
Location Plk 4; L: 16.8 mm, W: 17.0 mm, Th: 11.2 mm.
M 2010.352.1, 2×.

Fig. 10: *Prionorhynchia* aff. *guembeli* (Oppel, 1861).
Location Plk 3a; L: 14.6 mm, W: 15.7 mm, Th: 8.6 mm.
M 2010.353.1, 2×.

Fig. 11: *Prionorhynchia*? *hagaviensis* (Böse, 1898).
Location Plk 3b; L: 13.3 mm, W: 16.0 mm, Th: 7.3 mm.
M 2010.354.1, 2×.

Fig. 12: *Prionorhynchia polyptycha* (Oppel, 1861).
Location T 13; L: 19.2 mm, W: 24.0 mm, Th: 13.2 mm.
M 2010.355.1, 2×.

Fig. 13: *Prionorhynchia pseudopolyptycha* (Böckh, 1874).
Location Flo 7; L: 15.2 mm, W: 19.2 mm, Th: 10.7 mm.
M 2010.356.1, 2×.

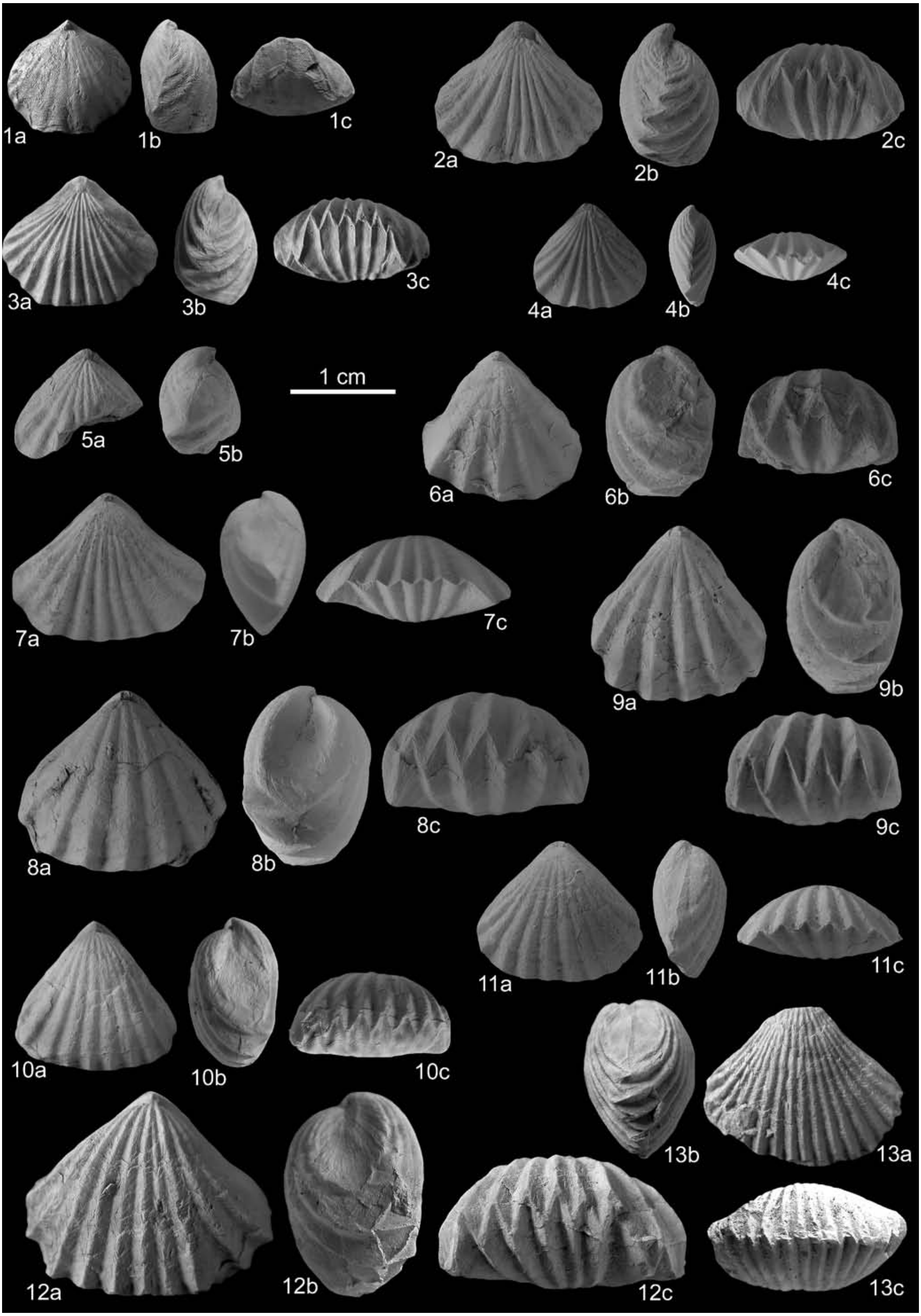

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Plate 2

Sinemurian brachiopods from southwestern Totes Gebirge, coll. & det. A. Dulai.
a – dorsal view, b – lateral view, c – anterior view.

Fig. 1: *Cirpa briseis* (GEMMELLARO, 1874).
Location Plk 3a; L: 17.1 mm, W: 17.4 mm, Th: 9.8 mm.
M 2010.357.1, 2×.

Fig. 2: *Cirpa planifrons* (ORMÓS, 1937).
Location T 16; L: 20.5 mm, W: 23.6 mm, Th: 15.1 mm.
M 2010.358.1, 2×.

Fig. 3: *Cirpa*? *subcostellata* (GEMMELLARO, 1878).
Location Flo 7; L: 10.5 mm, W: 11.9 mm, Th: 5.7 mm.
M 2010.359.1, 2×.

Fig. 4: *Calcirhynchia*? *hungarica* (BÖCKH, 1874).
Location Plk 4; L: 13.8 mm, W: 14.9 mm, Th: 7.5 mm.
M 2010.360.1, 2×.

Fig. 5: *Calcirhynchia*? *hungarica* (BÖCKH, 1874).
Location Plk 3b; L: 12.7 mm, W: 14.7 mm, Th: 6.7 mm.
M 2010.361.1, 2×.

Fig. 6: *Calcirhynchia*? aff. *hungarica* (BÖCKH, 1874).
Location Plk 4; L: 18.2 mm, W: 20.2 mm, Th: 12.0 mm.
M 2010.362.1, 2×.

Fig. 7: *Calcirhynchia* aff. *zugmayeri* (GEMMELLARO, 1878).
Location Plk 4; L: 13.6 mm, W: 12.9 mm, Th: 7.5 mm.
M 2010.363.1, 2×.

Fig. 8: *Salgirella* aff. *albertii* (OPPEL, 1861).
Location Plk 1; L: 16.2 mm, W: 18.3 mm, Th: 8.6 mm.
M 2010.364.1, 2×.

Fig. 9: *Homoeorhynchia*? *prona* (OPPEL, 1861).
Location T 1/10; L: 12.8 mm, W: 14.9 mm, Th: 6.4 mm.
M 2010.365.1, 2×.

Fig. 10: *Piarorhynchia*? *caroli* (GEMMELLARO, 1878).
Location Plk 1; L: 8.7 mm, W: 10.3 mm, Th: 6.3 mm.
M 2010.366.1, 2×.

Fig. 11: *Cuneirhynchia cartieri* (OPPEL, 1861).
Location Plk 4; L: 9.5 mm, W: 10.9 mm, Th: 6.2 mm.
M 2010.367.1, 2×.

Fig. 12: *Cuneirhynchia fraasi* (OPPEL, 1861).
Location Plk 4; L: 13.9 mm, W: 12.9 mm, Th: 10.5 mm.
M 2010.368.1, 2×.

Fig. 13: *Cuneirhynchia retusifrons* (OPPEL, 1861).
Location Plk 4; L: 8.3 mm, W: 10.0 mm, Th: 6.4 mm.
M 2010.369.1, 2×.

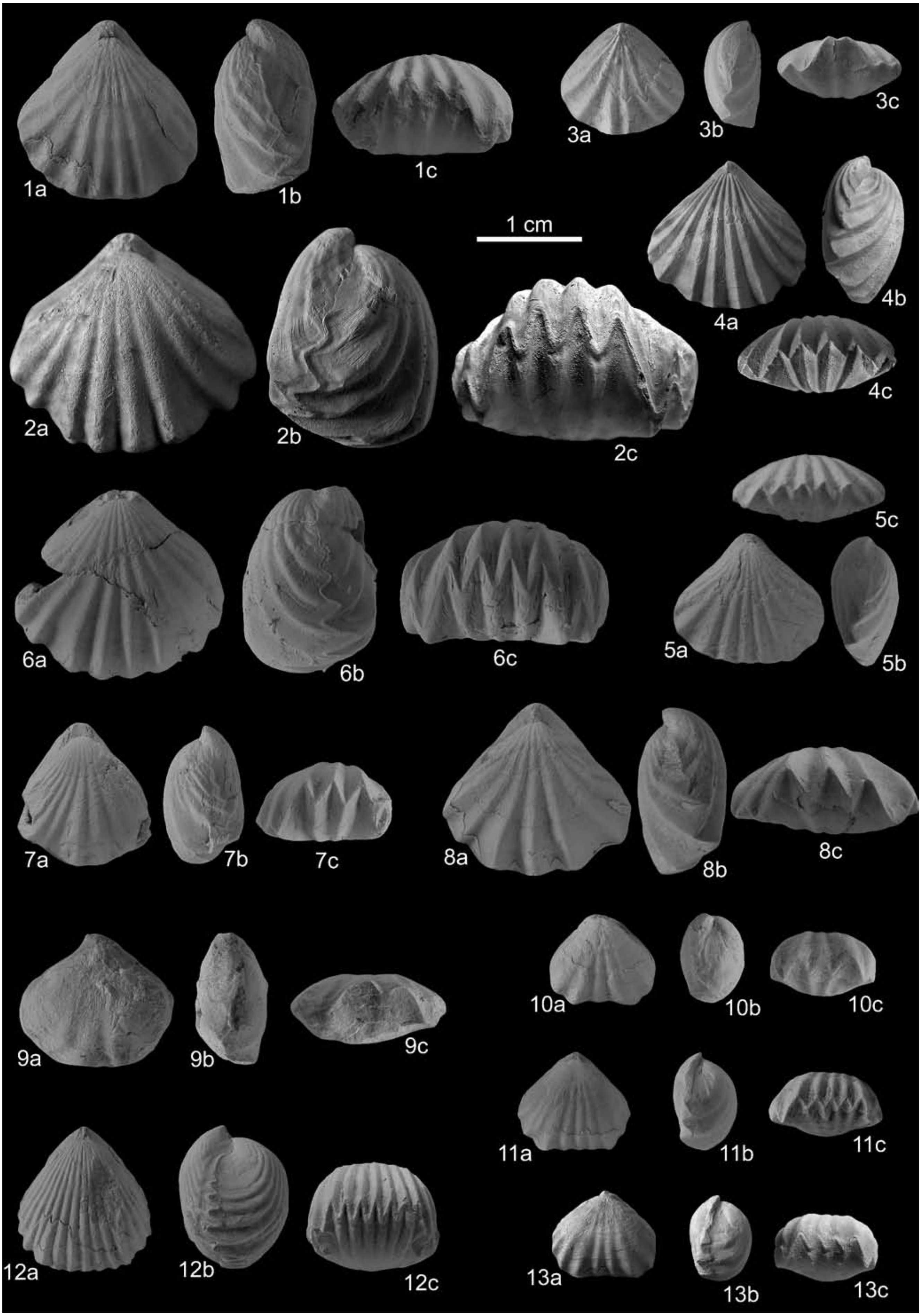
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Plate 3

Sinemurian brachiopods from southwestern Totes Gebirge, coll. & det. A. Dulai.

Fig. 1: *Gibbirhynchia*? *sordellii* (PARONA, 1880).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 3b; L: 13.3 mm, W: 13.1 mm, Th: 9.9 mm.
M 2010.370.1, 2×.

Fig. 2: *Gibbirhynchia*? *sordellii* (PARONA, 1880).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 3b; L: 13.4 mm, W: 12.9 mm, Th: 11.0 mm.
M 2010.371.1, 2×.

Fig. 3: *Liospiriferina acuta* (STUR in GEYER, 1889).
a – dorsal view, b – lateral view.
Location Flo 7; L: 13.3 mm, W: 14.5 mm, Th: 14.0 mm.
M 2010.372.1, 2×.

Fig. 4: *Liospiriferina alpina* (OPPEL, 1861).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 3a; L: 18.4 mm, W: 17.9 mm, Th: 10.7 mm.
M 2010.373.1, 2×.

Fig. 5: *Liospiriferina brevirostris* (OPPEL, 1861).
a – dorsal view, b – lateral view, c – anterior view.
Location Flo 7; L: 19.1 mm, W: 17.1 mm, Th: 11.1 mm.
M 2010.374.1, 2×.

Fig. 6: *Liospiriferina gryphoidea* (UHLIG, 1880).
a – ventral view, b – lateral view.
Location Plk 3b; L: 24.5 mm, W: 21.1 mm, Th: 14.1 mm.
M 2010.375.1, 2×.

Fig. 7: *Liospiriferina obtusa* (OPPEL, 1861).
a – dorsal view, b – lateral view, c – anterior view.
Location T 13; L: 15.6 mm, W: 18.6 mm, Th: 12.4 mm.
M 2010.376.1, 2×.

Fig. 8: *Liospiriferina* aff. *obtusa* (OPPEL, 1861).
a – dorsal view, b – lateral view, c – anterior view.
Location Flo 7; L: 12.7 mm, W: 15.4 mm, Th: 9.2 mm.
M 2010.377.1, 2×.

Fig. 9: *Liospiriferina salomoni* (BÖSE, 1898).
a – dorsal view, b – lateral view, c – ventral view.
Location Plk 1; L: 18.2 mm, W: 14.7 mm.
M 2010.378.1, 2×.

Fig. 10: *Liospiriferina sicula* (GEMMELLARO, 1874).
a – dorsal view.
Location T 13; L: 17.3 mm, W: 24.0 mm.
M 2010.379.1, 2×.

Fig. 11: *Liospiriferina semicircularis* (BÖSE, 1898).
a – dorsal view, b – lateral view.
Location Plk 4; L: 22.6 mm, W: 26.5 mm, Th: 13.2 mm.
M 2010.380.1, 2×.

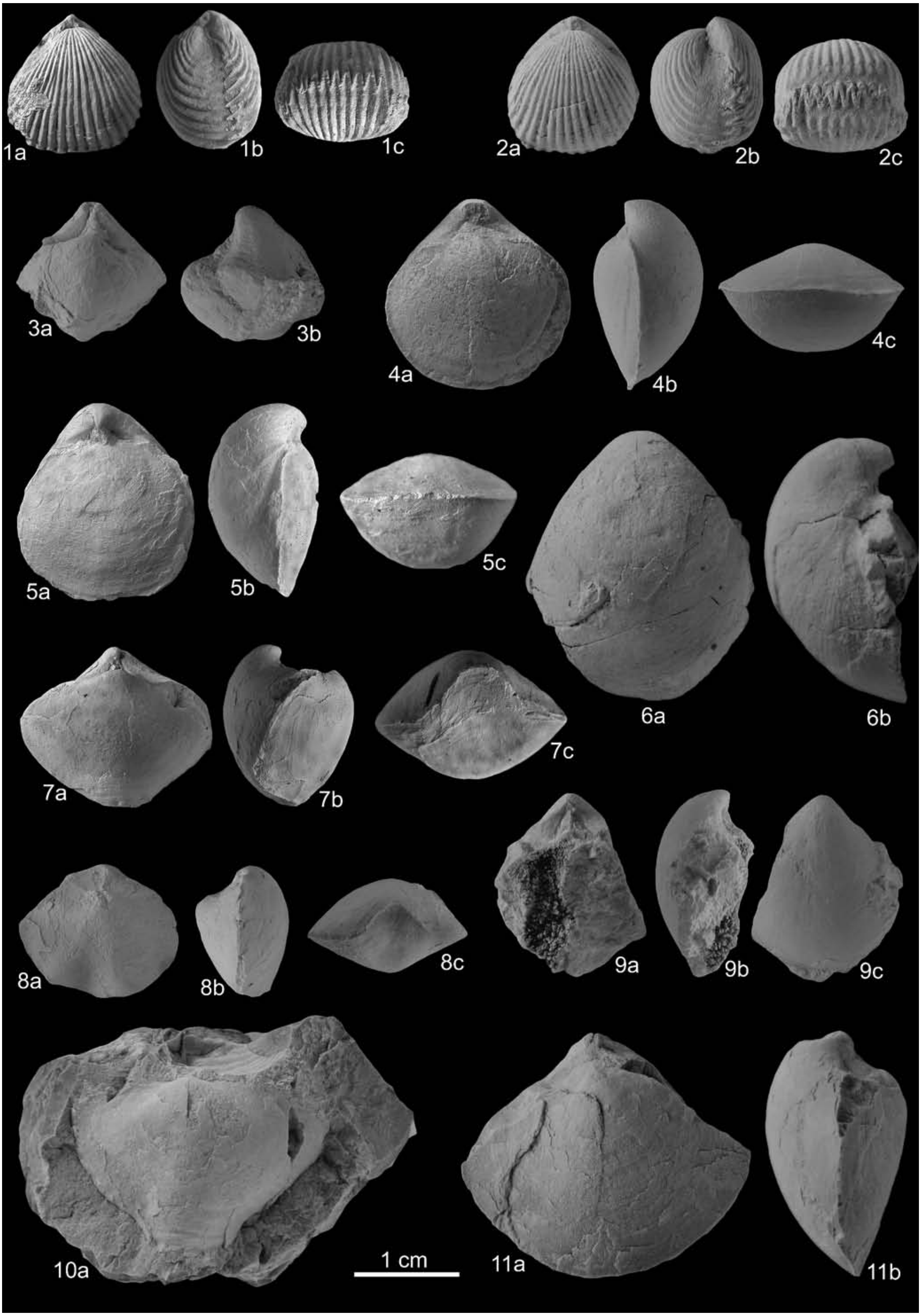
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Plate 4

Sinemurian brachiopods from southwestern Totes Gebirge, coll. & det. A. Dulai.

Fig. 1: *Liospiriferina* sp.
a – dorsal view, b – lateral view, c – ventral view.
Location Plk 1; L: 33.0 mm, W: 35.4 mm, Th: 23.2 mm.
M 2010.381.1, 2×.

Fig. 2: *Cisnerospira angulata* (Oppel, 1861).
a – dorsal view, b – lateral view, c – ventral view.
Location T 16; L: 21.3 mm, W: 24.2 mm, Th: 16.8 mm.
M 2010.382.1, 2×.

Fig. 3: *Cisnerospira darwini* (Gemmellaro, 1878).
a – dorsal view, b – lateral view.
Location Plk 3a; L: 16.3 mm, W: 13.6 mm, Th: 9.7 mm.
M 2010.383.1, 2×.

Fig. 4: *Cisnerospira darwini* (Gemmellaro, 1878).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 3a; L: 20.1 mm, W: 19.7 mm, Th: 14.0 mm.
M 2010.384.1, 2×.

Fig. 5: *Cisnerospira* aff. *darwini* (Gemmellaro, 1878).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 1; L: 11.7 mm, W: 14.4 mm, Th: 8.1 mm.
M 2010.385.1, 2×.

Fig. 6: *Cisnerospira sylvia* (Gemmellaro, 1878).
a – dorsal view, b – lateral view.
Location Flo 7; L: 16.4 mm, W: 14.9 mm, Th: 11.2 mm.
M 2010.386.1, 2×.

Fig. 7: *Lobothyris punctata* (Sowerby, 1812).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 3a; L: 17.6 mm, W: 15.8 mm, Th: 7.0 mm.
M 2010.387.1, 2×.

Fig. 8: *Lobothyris andleri* (Oppel, 1861).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 1; L: 26.2 mm, W: 23.2 mm, Th: 11.5 mm.
M 2010.388.1, 2×

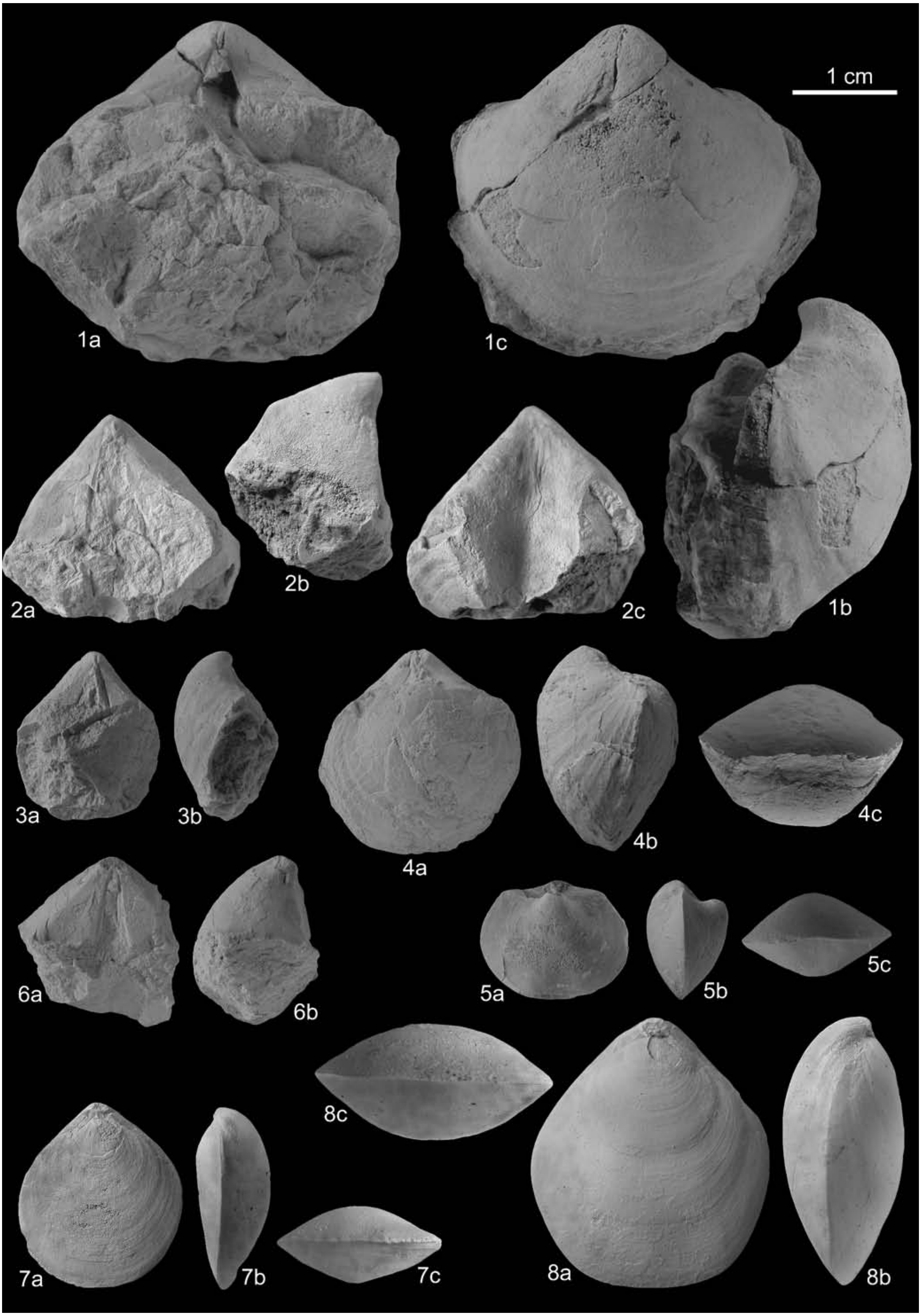
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Plate 5

Sinemurian brachiopods from southwestern Totes Gebirge, coll. & det. A. Dulai.
The specimens are figured in dorsal (a), lateral (b) and anterior (c) views if not stated otherwise.

Fig. 1: *Lobothyris delta* (Neumayr, 1879).
Location Plk 3a; L: 28.5 mm, W: 22.4 mm, Th: 15.2 mm.
M 2010.389.1, 2×.

Fig. 2: *Linguithyris aspasia* (Zittel, 1869).
Location Plk 1; L: 8.6 mm, W: 9.6 mm, Th: 5.0 mm.
M 2010.390.1, 2×.

Fig. 3: *Papodina bimammata* (Rothpletz, 1886).
Location Plk 4; L: 9.9 mm, W: 6.7 mm, Th: 5.6 mm.
M 2010.391.1, 2×.
a – dorsal view, b – lateral view.

Fig. 4: *Zeilleria alpina* (Geyer, 1889).
Location Plk 3a; L: 12.1 mm, W: 10.9 mm, Th: 4.8 mm.
M 2010.392.1, 2×.

Fig. 5: *Zeilleria baldaccii* Gemmellaro, 1874.
Location Flo 7; L: 14.6 mm, W: 12.3 mm, Th: 6.9 mm.
M 2010.393.1, 2×.

Fig. 6: *Zeilleria batilla* (Geyer, 1889).
Location Plk 3b; L: 11.9 mm, W: 10.4 mm, Th: 7.2 mm.
M 2010.394.1, 2×.

Fig. 7: *Zeilleria bicolor* (Böse, 1898).
Location Plk 3b; L: 12.3 mm, W: 10.6 mm, Th: 6.2 mm.
M 2010.395.1, 2×.

Fig. 8: *Zeilleria choffati* (Haas, 1885).
Location Plk 1; L: 17.6 mm, W: 15.7 mm, Th: 10.0 mm.
M 2010.396.1, 2×.

Fig. 9: *Zeilleria engelhardti* (Oppel, 1861).
Location Flo 8; L: 21.0 mm, W: 16.8 mm, Th: 11.7 mm.
M 2010.397.1, 2×.

Fig. 10: *Zeilleria mutabilis* (Oppel, 1861).
Location T 16; L: 16.5 mm, W: 16.0 mm, Th: 7.8 mm.
M 2010.398.1, 2×.

Fig. 11: *Zeilleria perforata* (Piette, 1856).
Location Plk 4; L: 11.8 mm, W: 10.9 mm, Th: 8.1 mm.
M 2010.399.1, 2×.

Fig. 12: *Zeilleria oenana* (Böse, 1898).
Location Plk 1; L: 13.2 mm, W: 13.7 mm, Th: 6.1 mm.
M 2010.400.1, 2×.

Fig. 13: *Zeilleria* aff. *oenana* (Böse, 1898).
Location Flo 7; L: 15.2 mm, W: 18.2 mm, Th: 6.9 mm.
M 2010.401.1, 2×.

Fig. 14: *Zeilleria subnumismalis* (Davidson, 1851).
Location Plk 4; L: 23.3 mm, W: 21.2 mm, Th: 12.0 mm.
M 2010.402.1, 2×.

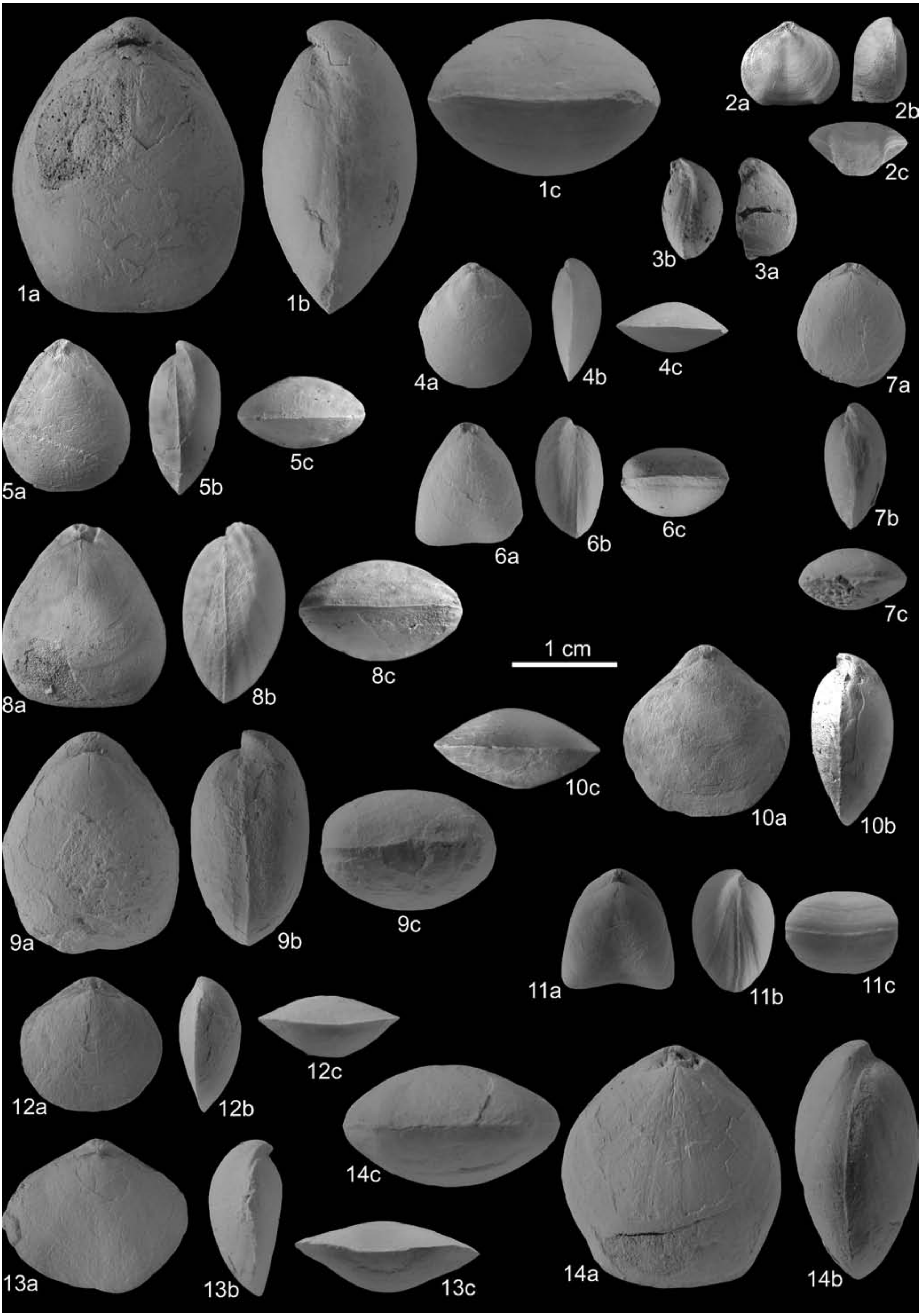
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Plate 6

Sinemurian brachiopods from southwestern Totes Gebirge, coll. & det. A. Dulai.

Fig. 1: *Zeilleria stapia* (Oppel, 1861).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 3a; L: 12.2 mm, W: 10.5 mm, Th: 7.4 mm.
M 2010.403.1, 2×.

Fig. 2: *Zeilleria venusta* (Uhlig, 1879).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 3a; L: 13.0 mm, W: 10.8 mm, Th: 10.0 mm.
M 2010.404.1, 2×.

Fig. 3: *Bakonyithyris ewaldi* (Oppel, 1861).
a – dorsal view, b – lateral view, c – anterior view.
Location Plk 3a; L: 15.6 mm, W: 16.9 mm, Th: 9.4 mm.
M 2010.405.1, 2×.

Fig. 4: *Securina hierlatzica* (Oppel, 1861).
a – dorsal view, b – lateral view, c – anterior view.
Location Flo 7; L: 15.7 mm, W: 13.6 mm, Th: 9.7 mm.
M 2010.406.1, 2×.

Fig. 5: *Securina securiformis* (Gemmellaro, 1874).
a – dorsal view, b – lateral view, c – anterior view.
Location Flo 7; L: 14.9 mm, W: 18.3 mm, Th: 10,9 mm.
M 2010.407.1, 2×.

Fig. 6: *Salgirella* cf. *albertii* (Oppel, 1861).
a – dorsal view, b – lateral view.
Location Flo 8; L: 23.9 mm, W: 27.2 mm, Th: 15.4 mm.
M 2010.408.1, 2×.

Fig. 7: *Jakubirhynchia*? *fascicostata* (Uhlig, 1880).
dorsal view.
Location Plk 3b; L: 5.5 mm, W: 6.1 mm, Th: 2.4 mm.
M 2010.414.1, 6×.

Fig. 8: *Prionorhynchia hagaviensis* (Böse, 1898).
dorsal view.
Location T 16; L: 7.7 mm, W: 6.9 mm, Th: 4.1 mm.
M 2010.409.1, 6×.

Fig. 9: *Pisirhynchia pisoides* (Zittel, 1869).
dorsal view.
Location T 19; L: 6.4 mm, W: 6.2 mm, Th: 5.0 mm.
M 2010.410.1, 6×.

Fig. 10: *Pisirhynchia inversa* (Oppel, 1861).
dorsal view.
Location T 16; L: 5.6 mm, W: 6.2 mm, Th: 3.7 mm.
M 2010.412.1, 6×.

Fig. 11: *Pisirhynchia inversa* (Oppel, 1861).
anterior view.
Location Plk 1; L: 6.3 mm, W: 7.0 mm, Th: 5.2 mm.
M 2010.413.1, 6×.

Fig. 12: *Pisirhynchia retroplicata* (Zittel, 1869).
dorsal view.
Location Plk 1; L: 7.0 mm, W: 7.8 mm, Th: 4.4 mm.
M 2010.411.1, 6×.

Fig. 13: *Koninckodonta waehneri* (Bittner, 1894).
dorsal view.
Location Plk 3b; L: 5.0 mm, W: 5.0 mm, Th: 1.6 mm.
M 2010.416.1, 6×.

Fig. 14: *Koninckodonta waehneri* (Bittner, 1894).
ventral view.
Location Plk 3b; L: 4.5 mm, W: 5.2 mm, Th: 1.8 mm.
M 2010.417.1, 6×.

Fig. 15: *Koninckodonta waehneri* (Bittner, 1894).
lateral view.
Location Plk 3b; L: 4.2 mm, W: 5.2 mm, Th: 1.5 mm.
M 2010.418.1, 6×.

Fig. 16: *Linguithyris aspasia* juv. (Zittel, 1869).
dorsal view.
Location Plk 1; L: 6.0 mm, W: 5.8 mm, Th: 2.4 mm.
M 2010.419.1, 6×.

Fig. 17: *Zeilleria alpina* juv. (Geyer, 1889).
dorsal view.
Location Plk 3a; L: 4.7 mm, W: 4.4 mm, Th: 1.8 mm.
M 2010.420.1, 6×.

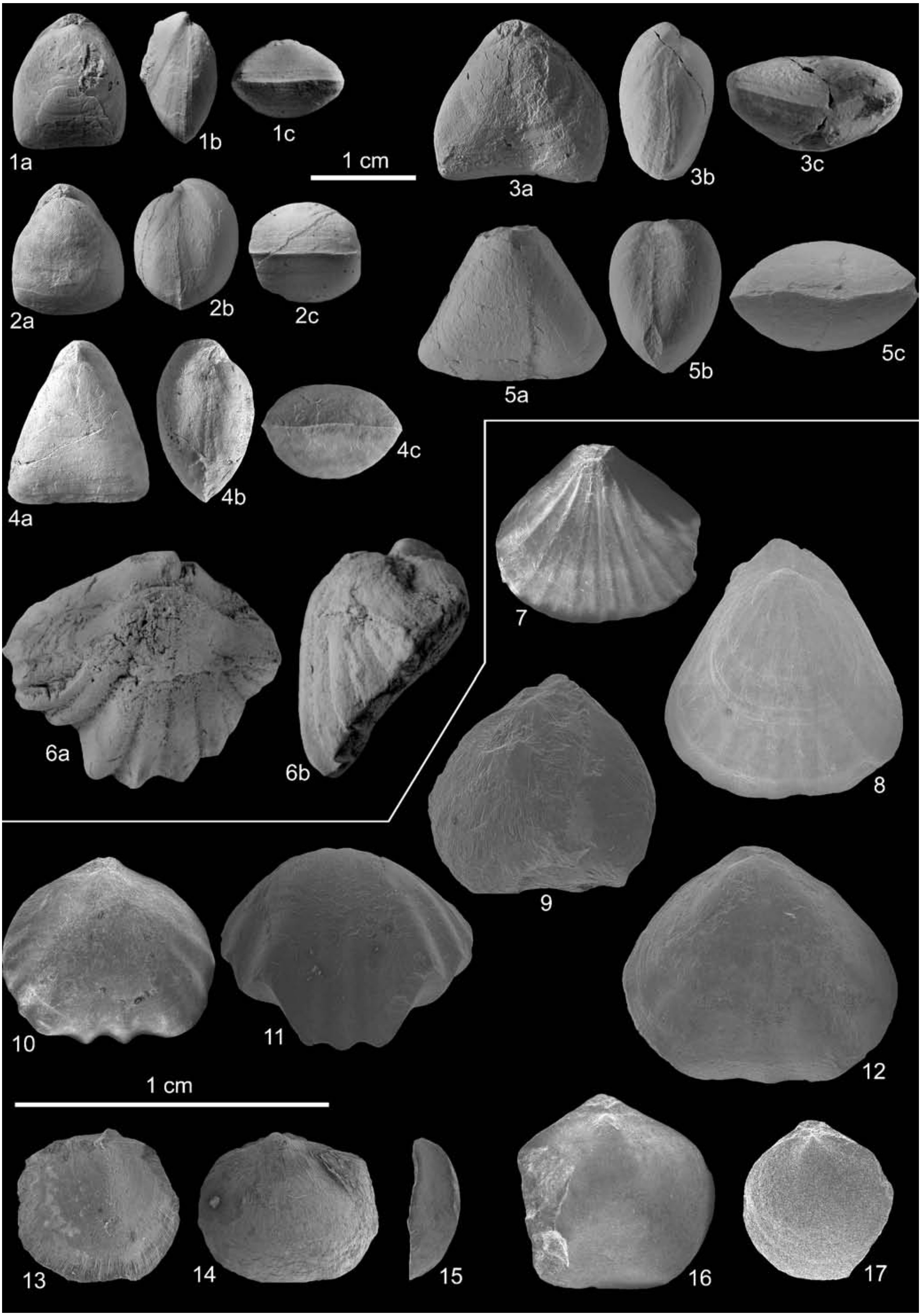
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Plate 7

Brachiopods from southwestern Totes Gebirge, coll. & det. M. Siblík.
The specimens are figured in dorsal (a), lateral (b) and anterior (c) views if not stated otherwise.

Fig. 1: *Cirpa briseis* (GEMMELLARO, 1874).
Location Klaus 3; L: 17.0 mm, W: 17.6 mm, Th: 12.4 mm.
Pliensbachian.
GBA 2010/091/0001, 2×.

Fig. 2: *Pisirhynchia retroplicata* (ZITTEL, 1869).
Location Flo 5; L: 6.5mm, W: 6.8mm, Th: 4.5 mm.
Pliensbachian.
GBA 2010/091/0002, 3×.

Fig. 3: *Cirpa fronto* (QUENSTEDT, 1871).
Location 8; L: 17.0 mm, W: 19.2 mm, Th: 13.5 mm.
Sinemurian.
GBA 2010/091/0003, 2×.

Fig. 4: *Prionorhynchia* (?) *hagaviensis* (BÖSE, 1898).
Location Klaus 3; L: 11.6 mm, W: 12.0 mm, Th: 7.0 mm.
Pliensbachian.
GBA 2010/091/0004, 2×.

Fig. 5: *Cirpa fronto* (QUENSTEDT, 1871).
Location Plk 9; L: 17.5 mm, W: 20.0 mm, Th: 13.0 mm.
Sinemurian.
GBA 2010/091/0005, 2×.

Fig. 6: *Salgirella albertii* (OPPEL, 1861).
Location Plk 5; L: 23.0 mm, W: 27.6 mm, Th: 17.7 mm.
red Hierlatz Lm., Sinemurian.
GBA 2010/091/0006, 1.5×.

Fig. 7: *Prionorhynchia belemnitica* (QUENSTEDT, 1858).
Location Flo 3/1; L: 15.0 mm, W: 17.8 mm, Th: 10.7 mm.
Sinemurian.
GBA 2010/091/0007, 2×.

Fig. 8: *Prionorhynchia greppini* (OPPEL, 1861).
Location 8; L: 17.5 mm, W: 18.5 mm, Th: 10.5 mm.
Sinemurian.
GBA 2010/091/0008, 2×.

Fig. 9: *Salgirella albertii* (OPPEL, 1861).
Between K 04/1 and Stub 1; L: 22.5 mm, W: 26.5 mm, Th: 14.5 mm.
red micrites, Sinemurian.
GBA 2010/091/0009, 1.5×.

Fig. 10: *Prionorhynchia* aff. *belemnitica* (QUENSTEDT, 1858).
Location Plk 4; L: 13.0 mm, W: 15.0 mm, Th: 10.4 mm.
Sinemurian.
GBA 2010/091/0010, 2×.

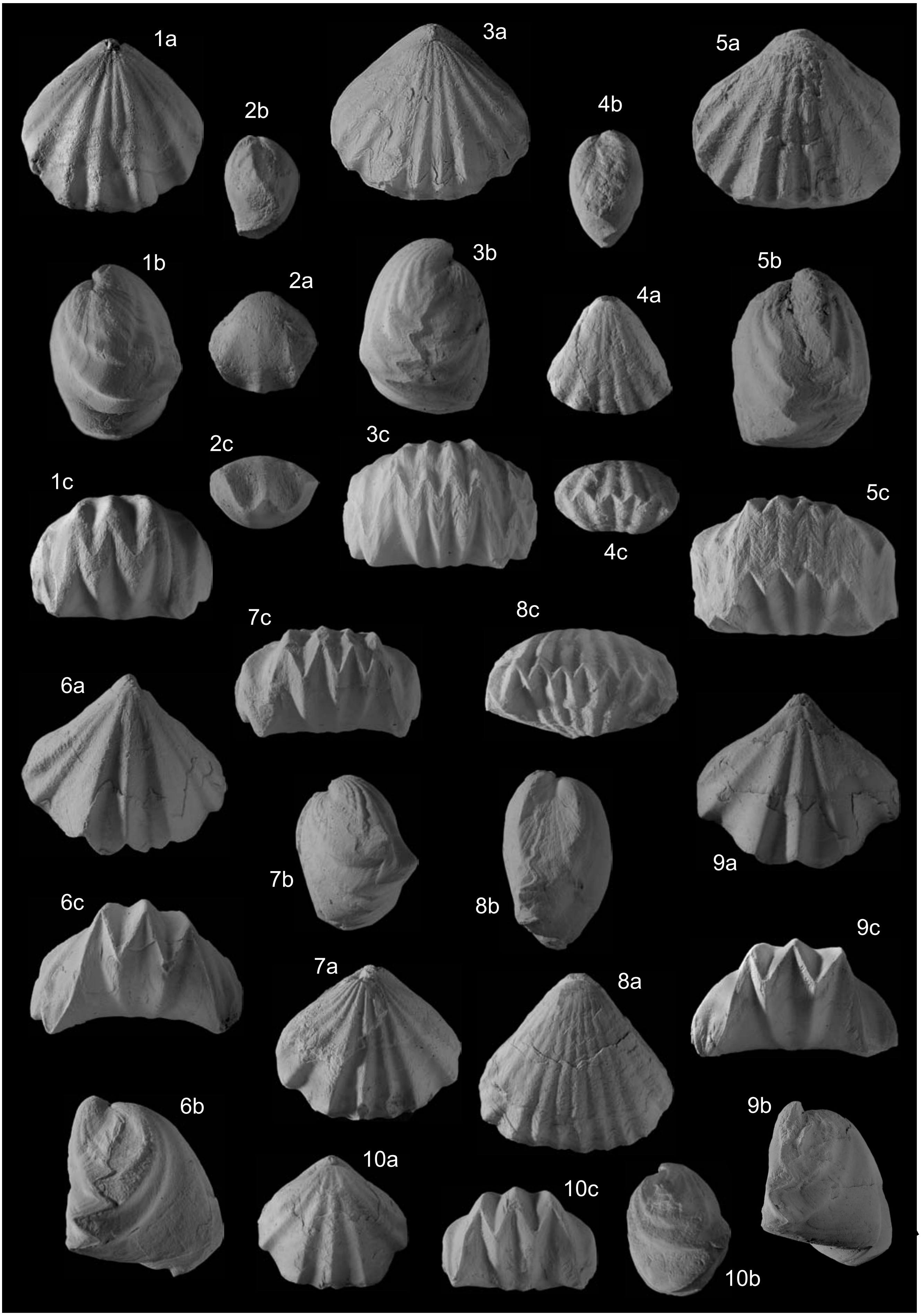
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Plate 8

Brachiopods from southwestern Totes Gebirge, coll. & det. M. Siblík.
The specimens are figured in dorsal (a), lateral (b) and anterior (c) views if not stated otherwise.

Fig. 1: *"Rhynchonella"* aff. *latissima* Fucini, 1894.
Location Flo 4; L: 15.5 mm, W: 20.2 mm, Th: 8.5 mm.
Sinemurian.
GBA 2010/091/0011, 2×.

Fig. 2: *"Rhynchonella"* aff. *latissima* Fucini, 1894.
Location 9; L: 18.0 mm, W: 22.8 mm, Th: 11.0 mm. Specimen with extreme plication.
Upper (?) Sinemurian.
GBA 2010/091/0012, 2×.

Fig. 3: *Cuneirhynchia* (?) *palmata* (Oppel, 1861).
Location Flo 4; L: 15.3 mm, W: 22.8 mm, Th: 11.5 mm.
Sinemurian.
GBA 2010/091/0013, 2×.

Fig. 4: *Prionorhynchia greppini rimata* (Geyer, 1889).
Location Klb 6; L: 20.2 mm, W: 22.4 mm, Th: 13.5 mm.
Sinemurian.
GBA 2010/091/0014, 2×.

Fig. 5: *Prionorhynchia* aff. *calderinii* (Parona, 1880).
Location Klb 6; ca. L: 19.0 mm, W: 26.0 mm, Th: 14.5 mm.
red Hierlatz Lm., Sinemurian.
GBA 2010/091/0015, 1.5×.

Fig. 6: *Apringia diptycha* (Böse, 1898).
Location Wolf 1; L: 14.2 mm, W: 14.5 mm, Th: 7.8 mm.
Pliensbachian.
GBA 2010/091/0016, 2×.

Fig. 7: *Septocrurella uhligi* (Haas, 1884).
Location Plankeraumoos, S of Location Plk 1; L: 11.2 mm, W: 13.0 mm, Th: 6.2 mm.
Sinemurian.
GBA 2010/091/0017, 2×.

Fig. 8: *Prionorhynchia flabellum* (Gemmellaro, 1874).
Location Flo 5; L: 14.8 mm, W: 17.0 mm, Th: 8.0 mm.
Pliensbachian.
GBA 2010/091/0018, 2×.

Fig. 9: *Cuneirhynchia retusifrons* (Oppel, 1861).
Location Klb 2; L: 10.0 mm, W: 12.8 mm, Th: 7.4 mm.
Sinemurian.
GBA 2010/091/0019, 2×.

Fig. 10: *Cuneirhynchia retusifrons* (Oppel, 1861).
Location Flo 3/2; L: 11.4 mm, W: 13.0 mm, Th: 8.5 mm.
Sinemurian.
GBA 2010/091/0020, 2×.

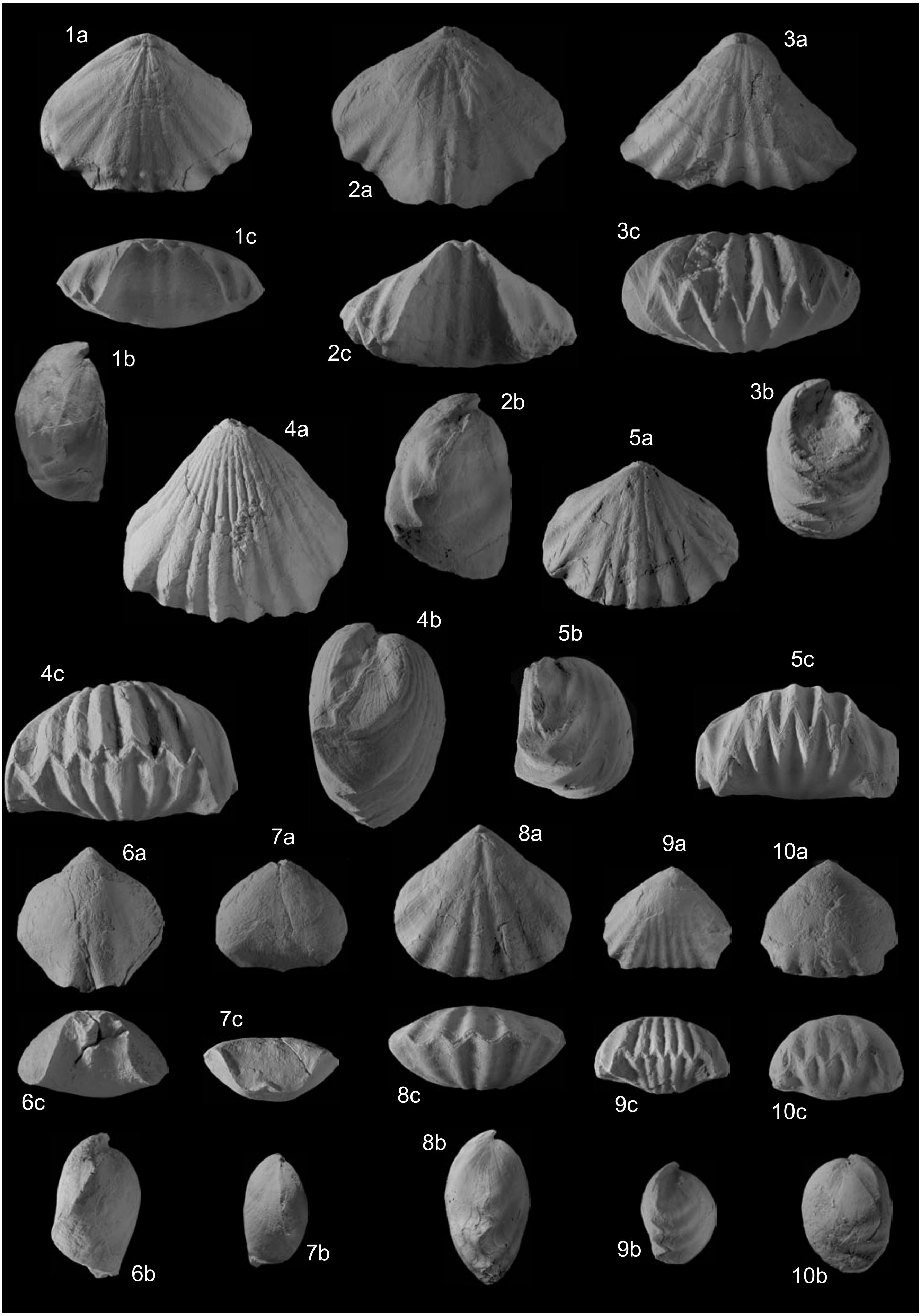
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Plate 9

Brachiopods from southwestern Totes Gebirge, coll. & det. M. Siblík.
The specimens are figured in dorsal (a), lateral (b) and anterior (c) views if not stated otherwise.

Fig. 1: *Securina hierlatzica* (OPPEL, 1861).
Location 9; L: 17.0 mm, W: 18.6 mm, Th: 11.5 mm.
Upper (?) Sinemurian.
GBA 2010/091/0021, 2×.

Fig. 2: *Koninckodonta* cf. *pichleri* (BITTNER, 1893).
a – ventral view, b – dorsal view.
Location Flo 5; L: 7.4 mm, W: 9.0 mm.
Pliensbachian.
GBA 2010/091/0022, 3×.

Fig. 3: *Liospiriferina* aff. *sicula* (GEMMELLARO, 1874).
Location 9; L: 14.8 mm, W: 18.2 mm, Th: 13.0 mm.
Upper (?) Sinemurian.
GBA 2010/091/0023, 2×.

Fig. 4: *Liospiriferina brevirostris* (OPPEL, 1861).
Location K 04; L: 20.7 mm, W: 18.4 mm, Th: 11.7 mm.
Sinemurian.
GBA 2010/091/0024, 2×.

Fig. 5: *Salgirella albertii* (OPPEL, 1861).
Location Plk 9; L: 14.2 mm, W: 16.0 mm, Th: 10.8 mm.
Sinemurian.
GBA 2010/091/0025, 2×.

Fig. 6: *Liospiriferina cordiformis* (BÖSE, 1898).
Location Flo 5; L: 13.0 mm, W: 13.0 mm, Th: 10.2 mm.
Pliensbachian.
GBA 2010/091/0026, 2×.

Fig. 7: *Oxycolpella eurycolpos* (BITTNER, 1890) juv.
Uppermost part of the section Z 1 – Z 15; L: 16.0 mm, W: 17.4 mm, Th: 10.0 mm.
Upper Triassic.
GBA 2010/091/0027, 2×.

Fig. 8: *Jakubirhynchia latifrons* (STUR in GEYER, 1889).
Location 9; L: 14.5 mm, W: 18.7 mm, Th: 9.0 mm.
Upper (?) Sinemurian.
GBA 2010/091/0028, 2×.

Fig. 9: *Liospiriferina obtusa* (OPPEL, 1861).
Location Klb 2; L: 15.3 mm, W: 17.5 mm, Th: 10.5 mm.
Sinemurian.
GBA 2010/091/0029, 2×.

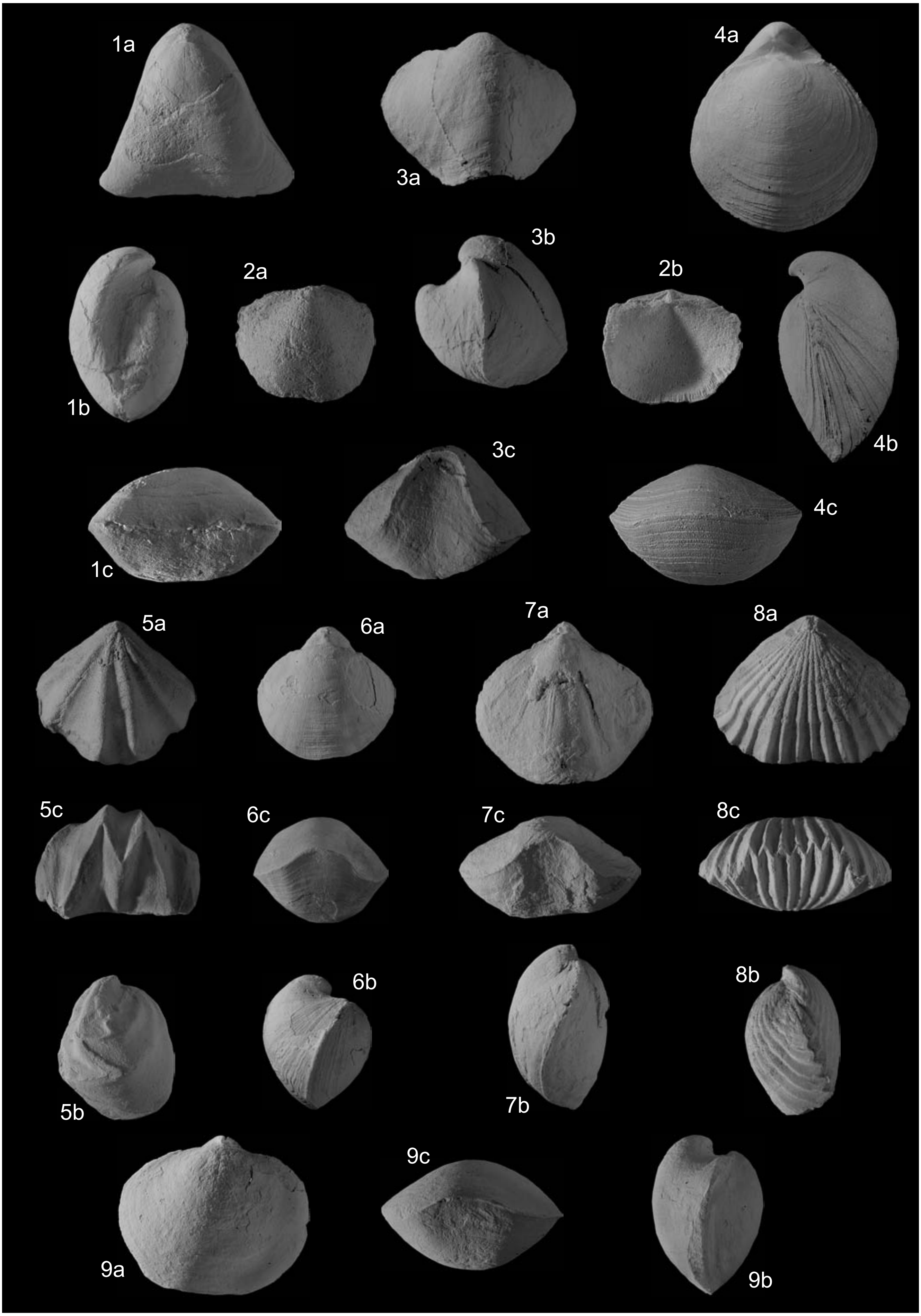
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Plate 10

Brachiopods from southwestern Totes Gebirge, coll. & det. M. Siblík.
The specimens are figured in dorsal (a), lateral (b) and anterior (c) views if not stated otherwise.

Fig. 1: *Securithyris adnethensis* (Suess, 1855).
ENE of Location Flo 5; L: 26.7 mm, W: 20.6 mm, Th: 16.4 mm.
Pliensbachian.
GBA 2010/091/0030, 2×.

Fig. 2: *Securithyris* aff. *paronai* (Canavari, 1880).
Location Flo 5; L: 17.3 mm, W: 20.8 mm, Th: 11.3 mm.
Pliensbachian.
GBA 2010/091/0031, 2×.

Fig. 3: *Viallithyris gozzanensis* (Parona, 1880).
Location Flo 5; L: 26.0 mm, W: 26.4 mm, Th: 16.0 mm.
Pliensbachian.
GBA 2010/091/0032, 2×.

Fig. 4: *Antiptychina* (?) *rothpletzi* (Di Stefano, 1891).
Location Flo 3/3; L: 16.5 mm, W: 15.0 mm, Th: 9.4 mm.
Sinemurian.
GBA 2010/091/0033, 2×.

Fig. 5: *Rhapidothyris beyrichi* (Oppel, 1861).
Location Flo 3/1; L: 17.5 mm, W: 16.3 mm, Th: 9.5 mm.
Sinemurian.
GBA 2010/091/0034, 2×.

Fig. 6: *Prionorhynchia* (?) aff. *belemnitica* (Quenstedt, 1858).
Location Plk 9; L: 13.6 mm, W: 16.8 mm, Th: 7.6 mm.
Sinemurian.
2010/091/0035, 2×.

Fig. 7: *"Terebratula"* aff. *ascia* Girard, 1843.
Location 10; L: 16.4 mm, W: 12.0 mm, Th: 8.6 mm.
Sinemurian.
GBA 2010/091/0036, 2×.

Fig. 8: *Linguithyris aspasia* (Zittel, 1869).
Wildgraben, middle part of slope; L: 10.8 mm, W: 17.2 mm, Th: 7.4 mm.
Upper Sinemurian.
GBA 2010/091/0037, 2×.

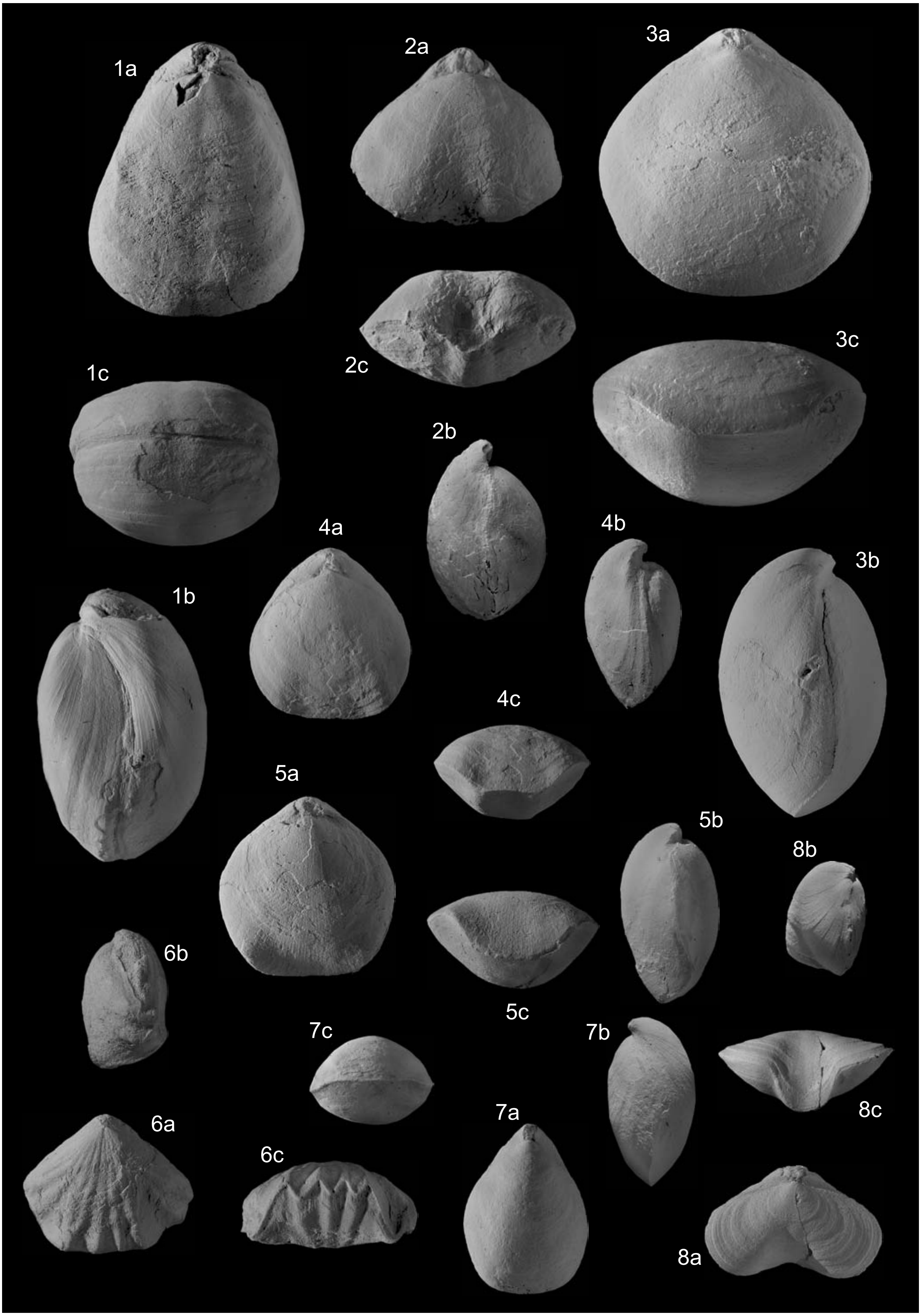
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Plate 11

Brachiopods from southwestern Totes Gebirge, coll. & det. M. Siblík.
The specimens are figured in dorsal (a), lateral (b) and anterior (c) views if not stated otherwise.

Fig. 1: *Bakonyithyris* (?) aff. *catharinae* (GEMMELLARO, 1874).
Location Klb 2; L: 13.8 mm, W: 14.5 mm, Th: 9.4 mm.
Sinemurian.
GBA 2010/091/0038, 2×.

Fig. 2: *Zeilleria mutabilis* (OPPEL, 1861).
Location Flo 4; L: 27.8 mm, W: 25.4 mm, Th: 14.8 mm.
Sinemurian.
GBA 2010/091/0039, 1.5x.

Fig. 3: *Buckmanithyris nimbata* (OPPEL, 1861).
Location Flo 3/1; L: 13.5 mm, W: 15.0 mm, Th: 9.0 mm.
Sinemurian.
GBA 2010/091/0040, 2×.

Fig. 4: *Bakonyithyris* (?) *engelhardti* (OPPEL, 1861).
Plankeraumoos, S of Location Plk 1; L: 15.9 mm, W: 15.0 mm, Th: 7.8 mm.
Sinemurian.
GBA 2010/091/0041, 2×.

Fig. 5: *Bakonyithyris* aff. *ovimontana* (BÖSE, 1898).
Location Klaus 3; L: 12.0 mm, W: 11.2 mm, Th: 7.8 mm.
Pliensbachian.
GBA 2010/091/0042, 2×.

Fig. 6: *Apringia paolii* (CANAVARI, 1880).
Wildgraben, middle part of slope; L: 16.5 mm, W: 17.9 mm, Th: 9.0 mm.
Upper Sinemurian.
GBA 2010/091/0043, 2×.

Fig. 7: *Rhynchonellina suessi* GEMMELLARO, 1871.
Location Wolf 3; L: 23.8 mm, W: 24.6 mm, Th: 11.8 mm.
Sinemurian.
GBA 2010/091/0044, 2×.

Fig. 8: *"Terebratula"* aff. *bilimeki* SUESS, 1858.
Location Plk 4 / bed 7; L: 38.1 mm, W: 34.9 mm, Th: 24.8 mm.
Upper Jurassic.
M 2010.510.1 (Coll. Hung. Nat.-Hist. Museum, Budapest), 2×.

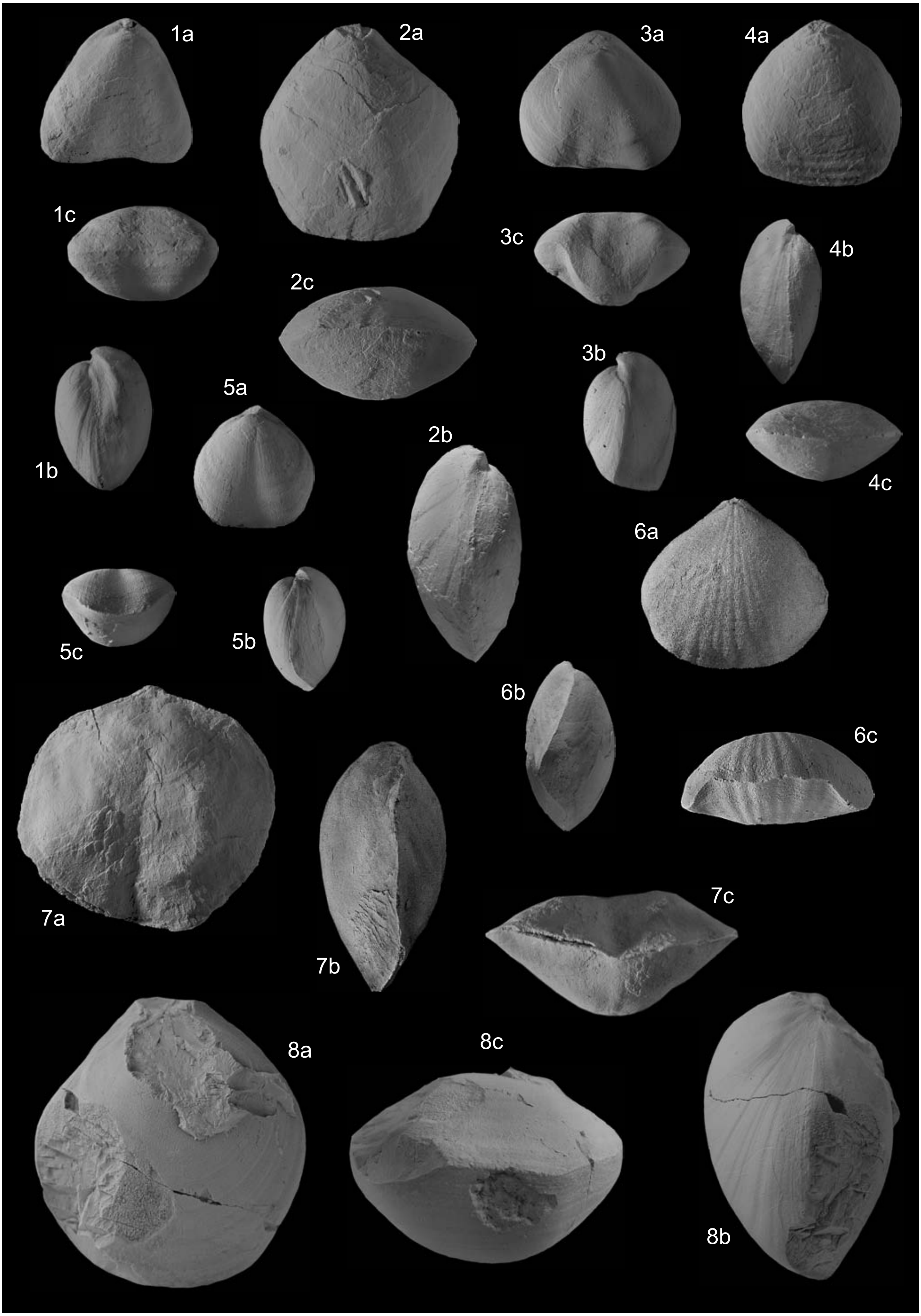
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Plate 12

Triassic (Figs. 1–7) and Jurassic (Figs. 8–39) bivalves from southwestern Totes Gebirge, coll. & det. I. Szente.
The specimens are figured in natural size unless indicated otherwise.

Fig. 1: *Praechlamys valonensis* (DEFRANCE, 1825).
Location F 4.

Fig. 2: pectinid, gen. et sp. indet.
Location F 4.

Fig. 3: *Liostrea*? sp.
Location F 4.

Fig. 4: *Promysidiella* sp.
Location F 4.

Fig. 5: *Gruenewaldia* ? sp.
Location F 4; 2×.

Figs. 6, 7: *Myoconcha* sp. A.
Location F 4.

Fig. 8: *Parallelodon* sp.
Location Plk 1.

Figs. 9, 10: *Parallelodon*? *problematicus* (VACEK, 1886).
Location Klaus 1; 2× (Fig. 9).

Figs. 11–13: *Oxytoma* (*O.*) *inequivalvis* (J. SOWERBY, 1819).
Location Plk 1; 2× (all).

Fig. 14: *Oxytoma* sp.
Location Plk 1; 4×.

Fig. 15: pectinid, gen. et sp. indet.
Location K 04

Figs. 16, 17: *Praechlamys palosa* (STOLICZKA, 1861).
Location Plk 1.

Fig. 18: *Praechlamys* sp.
Location Klaus 1.

Figs. 19–24: *Praechlamys subreticulata* (STOLICZKA, 1861).
Location Klaus 1; Fig. 19, 2×.
Location K 04; Fig. 20.
Location Plk 1; Figs. 21–24 (21, 24: 2×; 22: 4×).

Figs. 25–28: *Terquemia pectiniformis* (EUDES-DESLONGCHAMPS, 1860).
Location Plk 1.

Figs. 29–31: *Ctenostreon rugosum* (SMITH, 1817).
Location Plk 1.

Fig. 32: *Placunopsis* cf. *radiata* (PHILLIPS, 1829).
Location Plk 10.

Fig. 33: *Placunopsis* ? sp.
Location Plk 1; 1.5×.

Figs. 34–36: *Plagiostoma punctatum* J. SOWERBY, 1805.
Location Plk 1.

Fig. 37: *Myoconcha* sp. B.
Location Plk 1.

Figs. 38, 39: *Praeconia tetragona* (TERQUEM, 1855).
Location Plk 1.

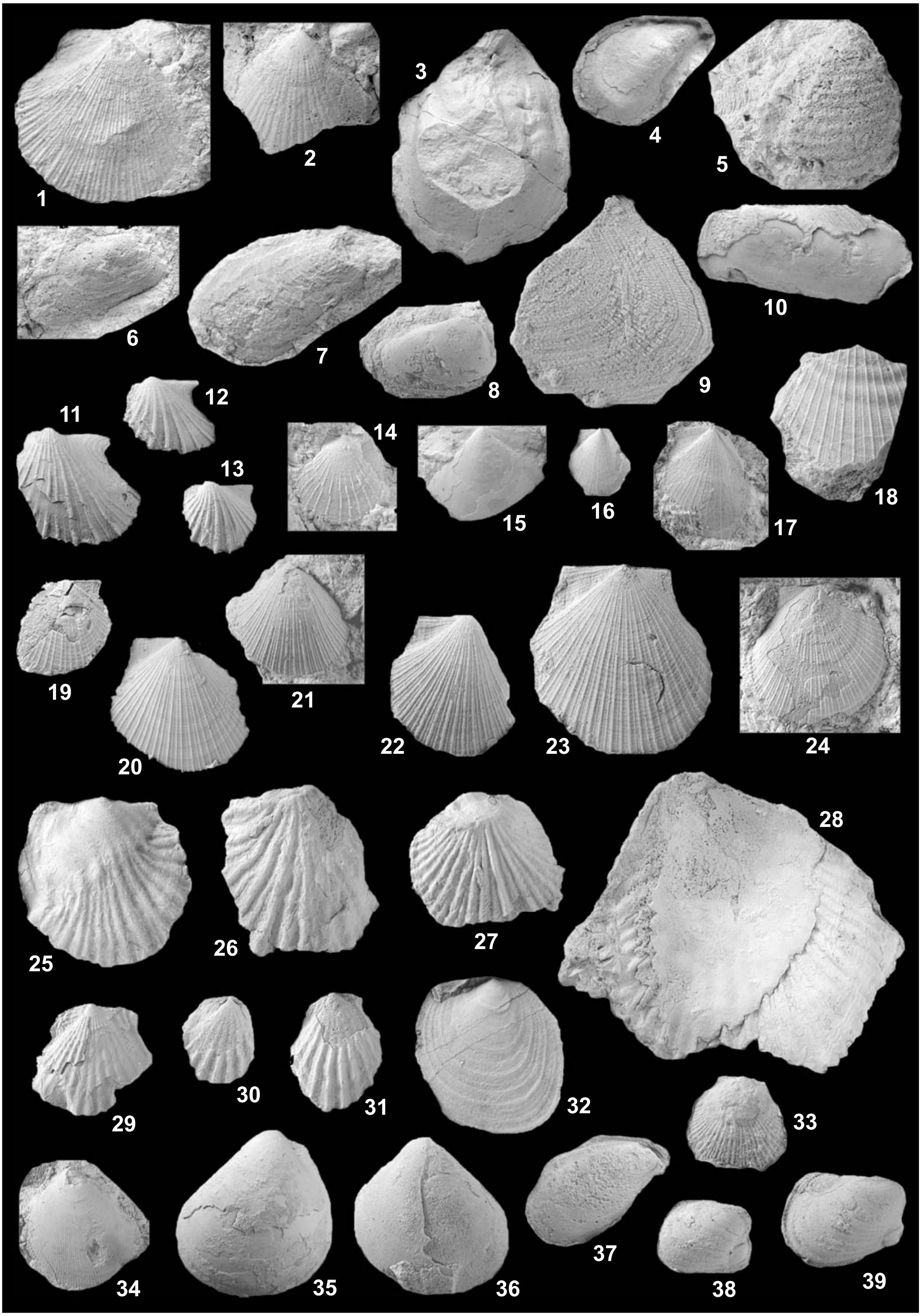
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Plate 13

Gastropods from southwestern Totes Gebirge, all from location Plk 1; coll. & det. J. Szabó.

Fig. 1: Surface of a sample from locality Plk 1 to demonstrate the preservation and some species from the faunal list; 2.5×.
A: *Katosira*? sp.
B: "*Epulotrochus*"? sp. 2 specimen (exceptionally with shell).
C: imprint of *Muricotrochus*? sp.
D–E: inner moulds of "*Epulotrochus*"? sp. 2.
F: the only specimen of *Clathrobaculus*? cf. *alpicolus* (VON GÜMBEL, 1861).

Fig. 2: *Discocirrus tricarinatus* (VON GÜMBEL, 1861); 2.5×.

Fig. 3: *Pentagonodiscus reussi* (HÖRNES, 1853); 2.5×.
The species is well identifiable even on the basis of the characteristic inner mould.

Figs. 4–5: *Pseudorhytidopilus zitteli* (G.G. GEMMELLARO, 1879); 2.5×.

Fig. 6: *Anoptychia hierlatzensis* (STOLICZKA, 1861); 2×.

Fig. 7: *Neritopsis elegantissima* HÖRNES, 1853; 2×.

Fig. 8: *Discohelix* aff. *ornata* (HÖRNES, 1853); 1×.

Fig. 9: *Pleurotomaria* aff. *emmrichi* VON GÜMBEL, 1861; 2×.

Figs. 10–12: *Euconactaeon* aff. *concavus* (J.A. EUDES-DESLONGCHAMPS, 1842); 2×.

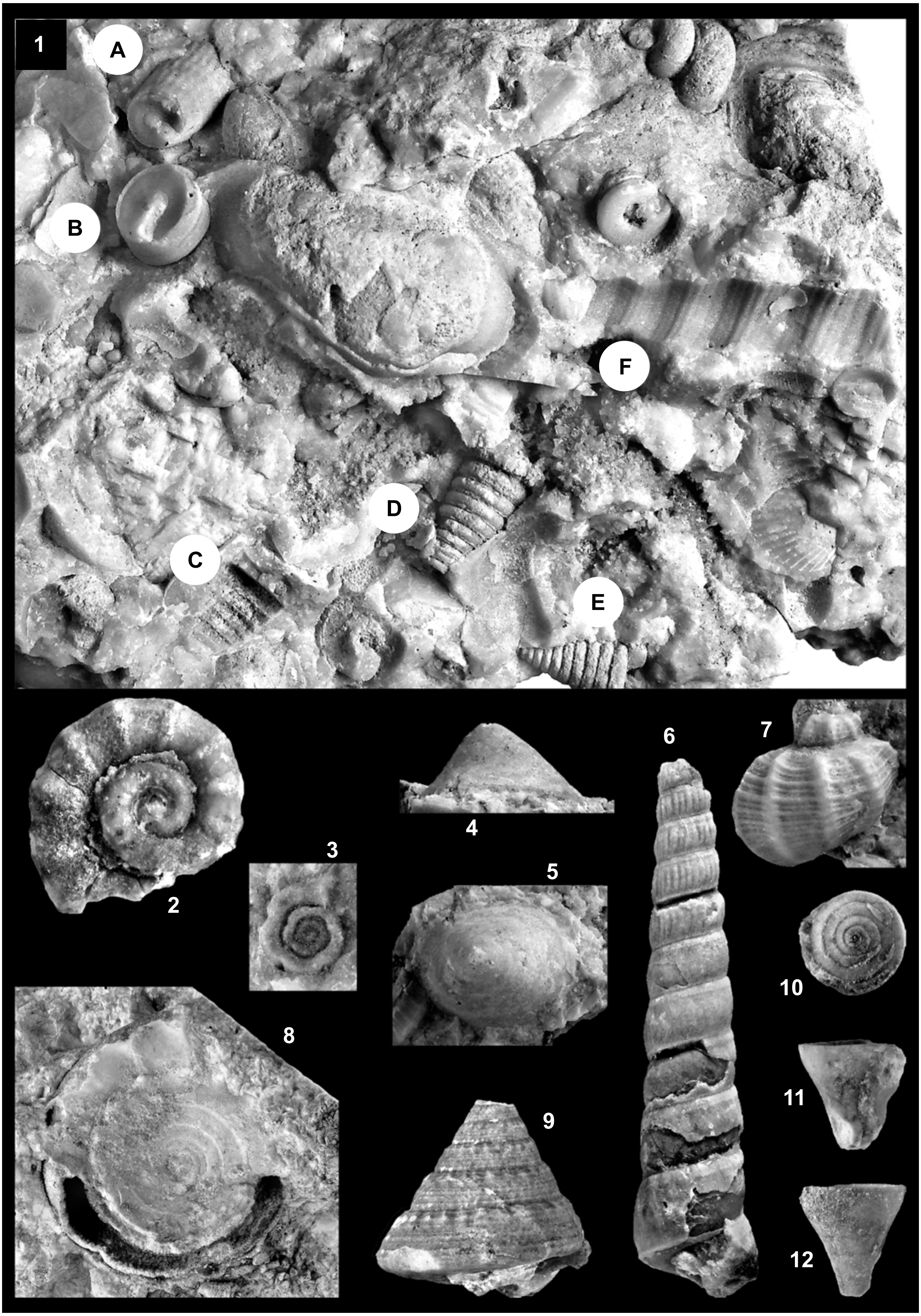
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Plate 14

Ammonites from southwestern Totes Gebirge, coll. & det. J. Schlögl.
Natural size, except Fig. 4 (1.5×).

Fig. 1: *Schlotheimia* sp.
Location Z 07, Upper Hettangian.

Fig. 2: *Arnioceras insigne* Fucini, 1902.
Location Plk 1, Lower Sinemurian.

Fig. 3: *Angulaticeras* sp.
Location Plk 1, Lower Sinemurian.

Fig. 4: *Arnioceras ambiguum* (Geyer, 1886).
Location Plk 1, Lower Sinemurian.

Fig. 5: *Arnioceras rejectum* Fucini, 1902.
Location Klb 2, Lower Sinemurian.

Fig. 6: *Asteroceras* cf. *brooki* (Sowerby, 1818).
Location Flo 2, probably late Lower or early Upper Sinemurian.

Fig. 7: *Paltechioceras* cf. *oosteri* (Dumortier, 1867).
Location Flo 3, late Upper Sinemurian.

Fig. 8: *Tropidoceras demonense* (Gemmellaro, 1884).
Location Klaus 3, Upper Pliensbachian.

Fig. 9: *Platypleuroceras* cf. *brevispina* (Sowerby).
Location Klaus 3, Upper Pliensbachian.

Fig. 10: *Fuciniceras* gr. *ambiguum* (Fucini, 1904).
Location Wolf 1, Upper Pliensbachian.

Fig. 11: *Paltechioceras* gr. *tardecrescens* (Hauer, 1856).
Location Flo 3, Upper Sinemurian.

Fig. 12: *Polymorphites* sp.
Location Klaus 3, Lower Pliensbachian.

Fig. 13: *Platypleuroceras* sp. 1.
Location Klaus 3, Lower Pliensbachian.

Fig. 14: *Platypleuroceras* sp. 2.
Location Klaus 3, Lower Pliensbachian.

Fig. 15: *Fuciniceras* cf. *inclitum* (Fucini, 1904).
Location Wolf 1, Upper Pliensbachian.

Fig. 16: *Hildoceras bifrons* (Bruguieres, 1792).
Location Klaus 1, Middle Toarcian.

Fig. 17: *Nebrodites (Nebrodites) macerrimus* (Quenstedt, 1888).
Location Wild 1, Kimmeridgian.

Fig. 18: *Nebrodites (Mesosimoceras) herbichi* (von Hauer, 1866).
Location Plk 7, Lower Kimmerdgian.

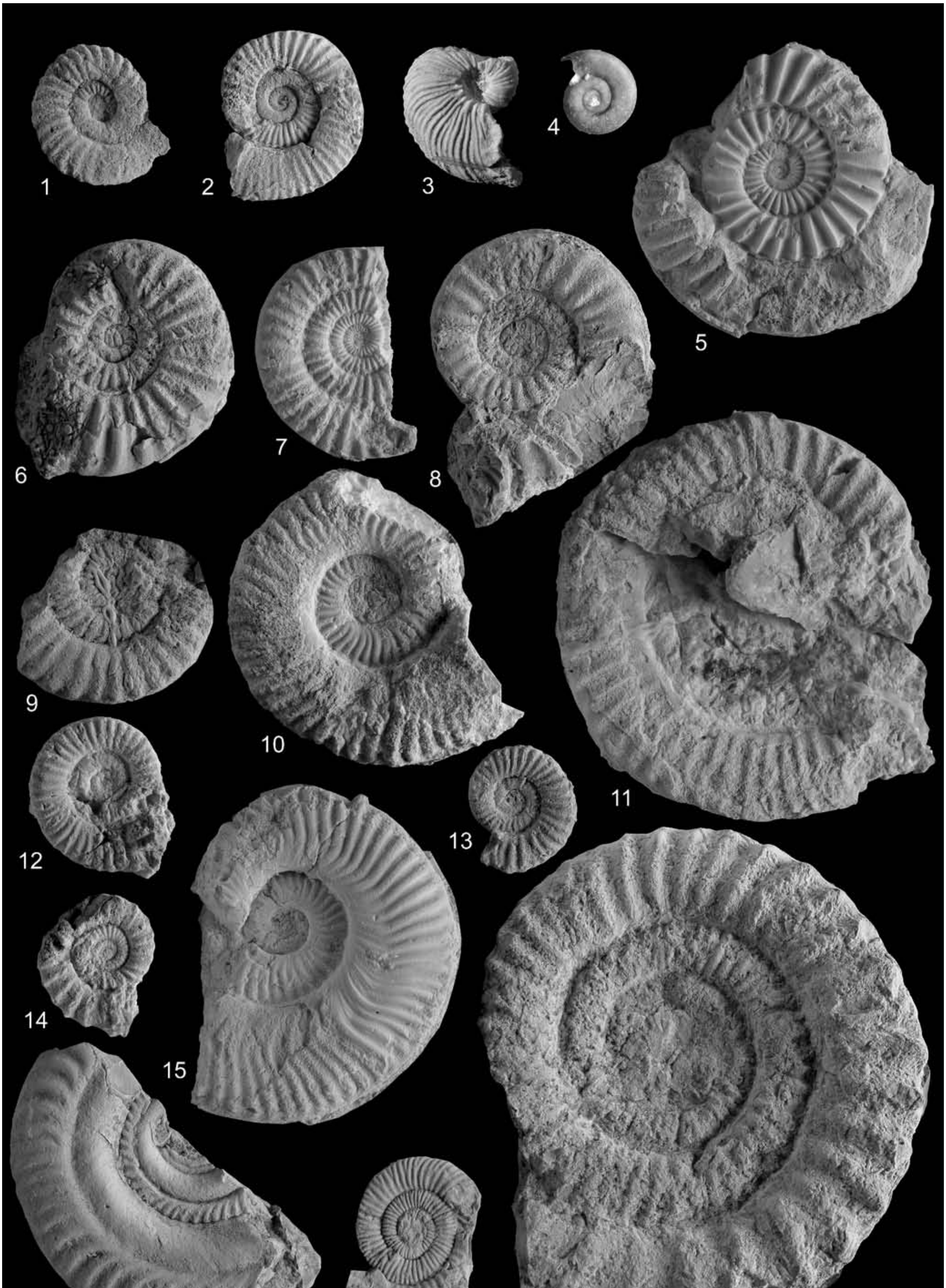
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Plate 15

Lower to (?)Middle Jurassic limestones in outcrops and rock thin-sections.

Fig. 1: (?) Middle Jurassic limestone breccia.
Outcrop at locality 07/73.

Fig. 2: (?) Middle Jurassic limestone breccia.
Clasts of various types of Hierlatz Limestone and red *"Bositra"* limestone (white arrows).
Polished slab, scale bar 1 cm. Locality 07/75.

Fig. 3: Detail of Fig. 1. Clast of red limestone with micro-lumachelle of mostly subparallel oriented *"Bositra"* shells and layers of crinoidal debris.
Acetat peel, scale bar 5 mm.

Fig. 4: Red micritic crinoidal limestone with intraclasts, angular fragments of ferromanganese crusts and abundant belemnites.
Scale bar 5 cm. Meter-sized block at Klaushöfl west.

Fig. 5: Hierlatz Limestone with abundant large crinoid fragments.
Scale bar 5 cm. Locality Klaus 3.

Fig. 6: Hierlatz Limestone; red micritic limestone with abundant mollusc shells and foraminifer *Involutina liassica* (enlarged insert picture) .
Thin-section, scale bar 5 mm.
Decimeter-sized olistolith at locality Plk 5.

Fig. 7: Allgäu Beds.
Grey micritic limestone with abundant sponge-spicules and a few mollusc shells with geopetal fillings.
Thin-section, scale bar 5 mm. Locality Z 07.

Fig. 8: Brachiopod lumachelle.
Nearly monospecific shell accumulation.
Scale bar 1 cm. Locality Nr. 10 Schwarzwald.

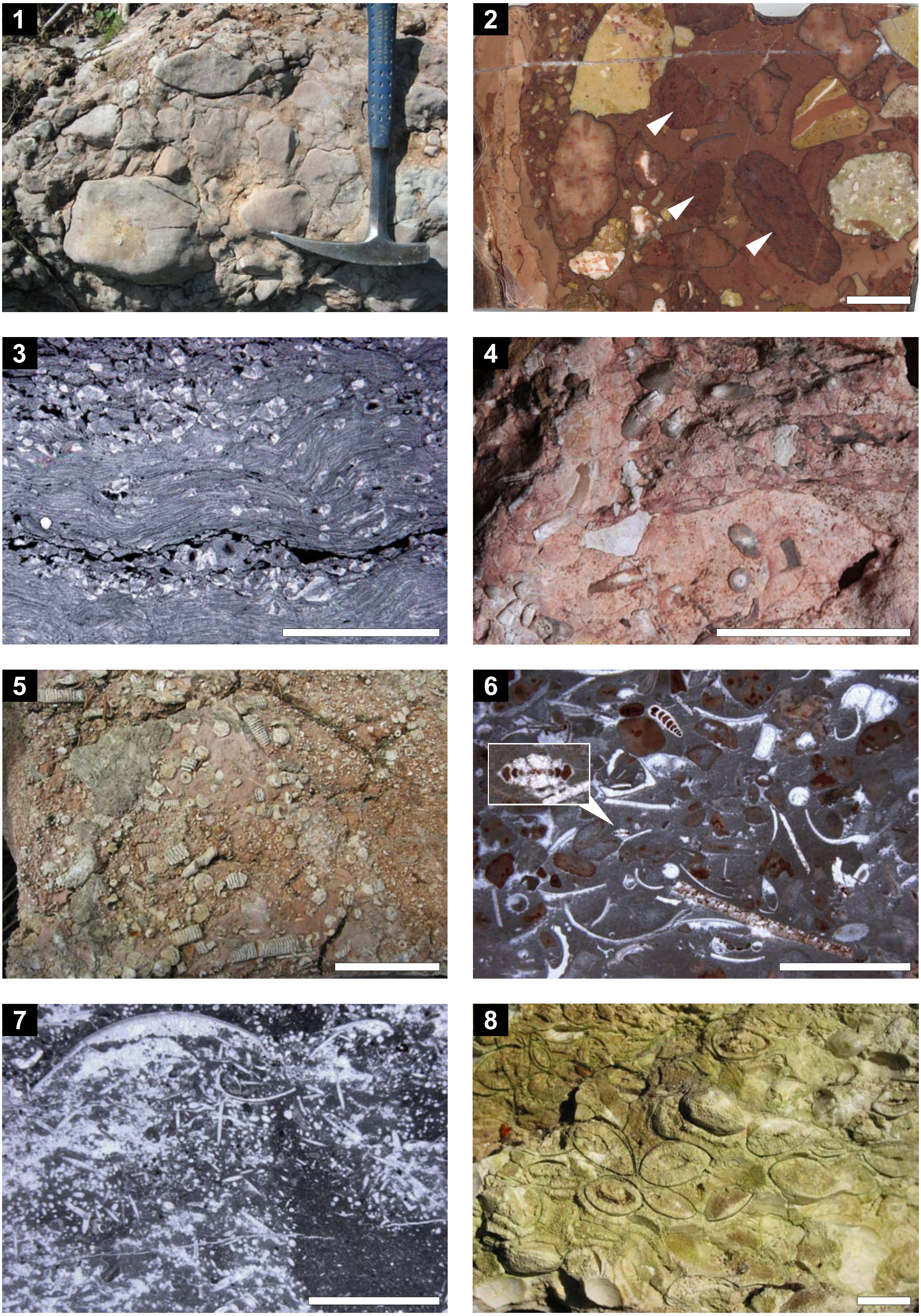
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Plate 16

Late Jurassic limestones in outcrops and rock thin-sections.

Fig. 1: Clasts in basal Tressenstein Limestone.
(A) Dachstein Limestone with corals; (B) yellowish-grey brachiopod lumachelle and (C) red crinoidal Hierlatz Limestone.
Scale bar 5 cm, outcrop at locality T 34.

Fig. 2: Basal breccia in Tressenstein Limestone: Dachstein Limestone with corals in contact to Upper Jurassic matrix of micritic/microsparitic laminated limestone.
Thin-section, scale bar 5 mm; locality F 2.

Fig. 3: Tressenstein Limestone with coarse grained detritus including angular clasts of redbrown to greenish Lower Triassic Werfen Beds.
Scale bar 5 cm. Outcrop at locality T 14 Pyrmoos-Brandwald south of Salza-Alm.

Fig. 4: Detail to Fig. 3. Angular clasts of Werfen sandstones and redbrown sandy shales in fine grained carbonate matrix.
Thin-section, scale bar 5 mm.

Fig. 5: Detail to Fig. 3. Fine grained carbonate matrix with several elements of *Saccocoma*.
Thin-section, scale bar 1 mm.

Fig. 6: Oberalm Limestone.
Decimeter-bedded micritic limestone with nodules and layers of chert.
Scale bar about 50 cm. Outcrops along the forest road northeast of Steinklemme.

Fig. 7: Micritic layers within Tressenstein Limestone, containing ammonites.
Thin-section, scale bar 5 mm. Locality T 15, Plankerau.

Fig. 8: Micritic layers alternating with fine grained bioclastic layers, containing sponge-spicules, radiolarians and ammonite fragments; intercalation in Tressenstein Limestone.
Thin-section, scale bar 5 mm. Locality F 3.

Fig. 9: Red to grey micritic limestone with abundant crinoids and ammonites and less frequent gastropods.
Not visible in this magnification frequent protoglobigerinids. Intercalation within Tressenstein Limestone at locality T 25, lithology resembles to Agatha Limestone.
Thin-section, scale bar 5 mm.

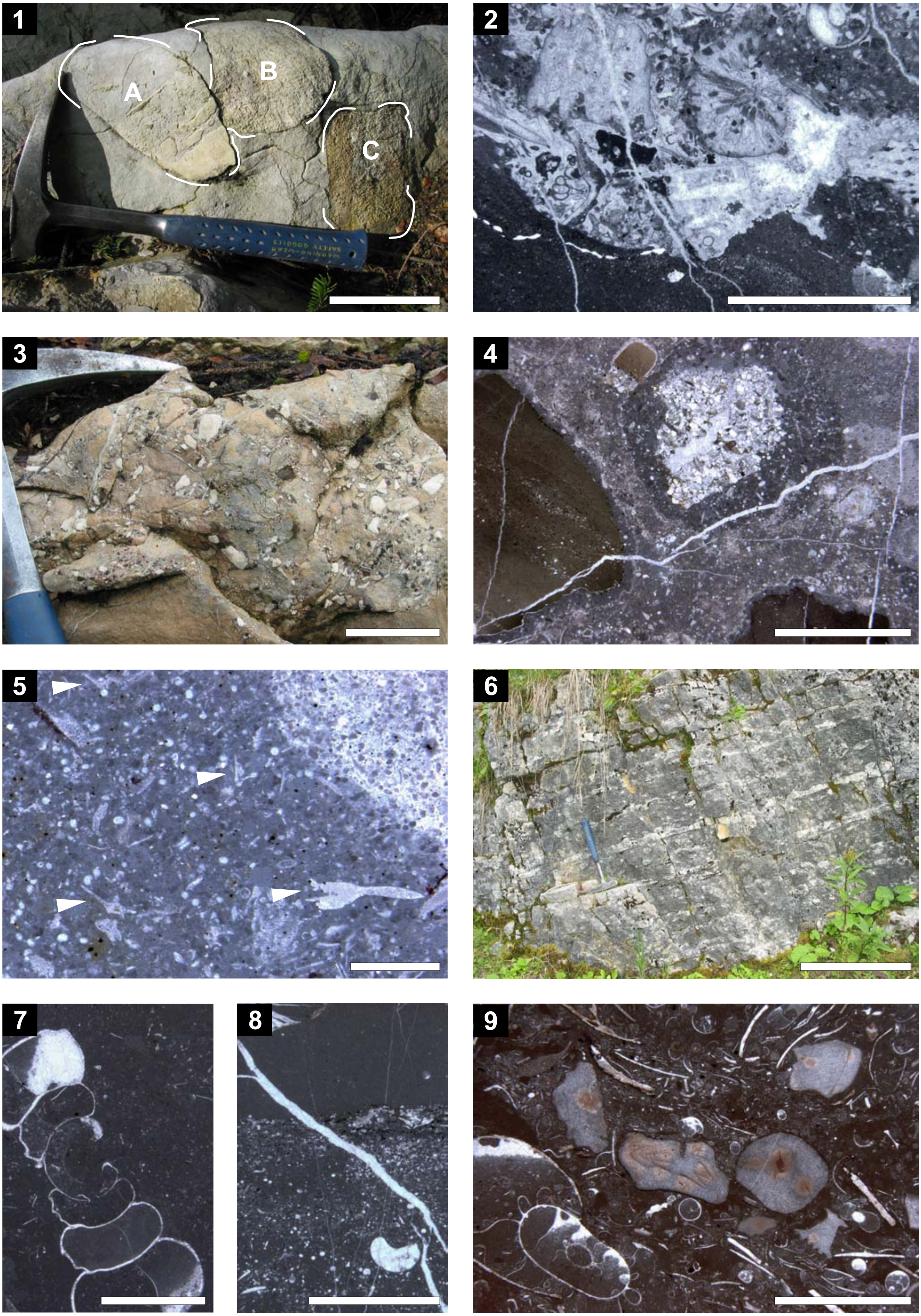
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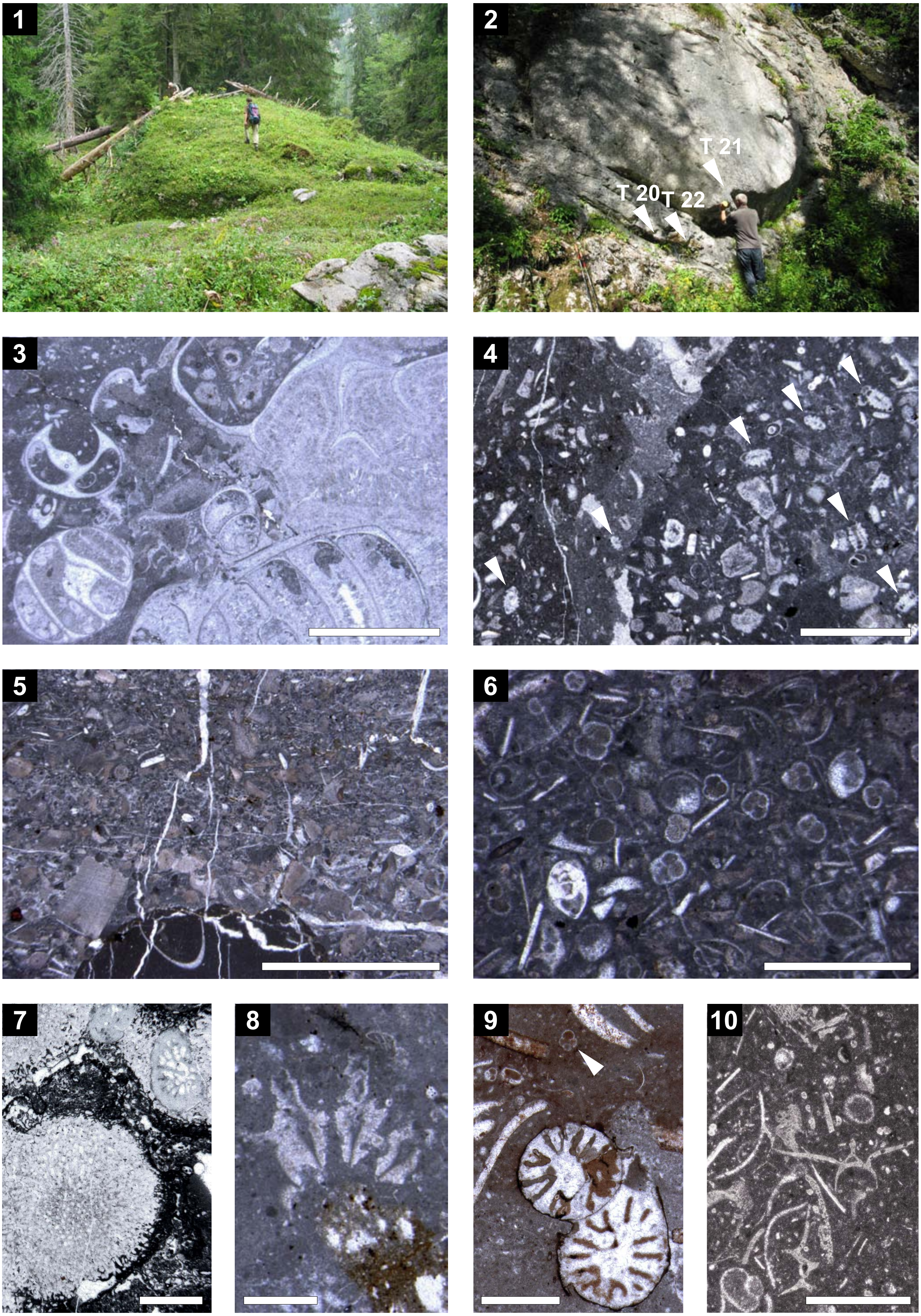
Plate 17

Olistoliths and surrounding Upper Jurassic limestones in the Plankerau area in outcrops and rock thin-sections.

Fig. 1: View of Plankerau locality Plk 1.
Large olistolith of Lower Jurassic Hierlatz Limestone.
Fig. 2: View of Plankerau locality Plk 21.
Meter-sized olistolith of Lower Jurassic Hierlatz Limestone embedded in Upper Jurassic Tressenstein Limestone.
Fig. 3: Sparitic cemented shell accumulations alternating with biomicritic limestone, containing crinoidal debris and also sponge spicules (upper left).
Hierlatz Limestone, olistolith at locality Plk 1.
Thin-section, scale bar 5 mm.
Fig. 4: Abundant foraminifer *Involutina liassica* (white arrows) in Hierlatz Limestone of olistolith T 21.
Thin-section, scale bar 2 mm.
Fig. 5: Example of carbonate-clastic facies of Tressenstein Limestone with dominant echinodermal fragments. Micritic filled ammonite shell in lower middle.
Thin-section, scale bar 5 mm; bed T 20 in Fig. 2.
Fig. 6: Example of micritic layer within Tressenstein Limestone with very abundant protoglobigerinids.
Thin-section, scale bar 5 mm; bed T 22 in Fig. 2.
Figs. 7–9: Examples (thin-sections) of platform derived bioclasts in Tressenstein Limestone:
Fig. 7: Spongiomorpha and corals (upper right), scale bar 2 mm, locality T 11.
Fig. 8: Fragment of dasycladacean *Clypeina*; scale bar 0.5 mm, locality T 11.
Fig. 9: Corals in a red micritic matrix with protoglobigerinids (white arrow).
Intercalation within Tressenstein Limestone, lithology resembles the Agatha Limestone.
Scale bar 1 mm, locality T 6.
Fig. 10: Red micritic limestone with abundant fragments of floating crinoid *Saccocoma*.
The lithology resembles the Agatha Limestone.
Section Plk 4, top of bed 5 (see also Text-Fig. 4).
Thin-section, scale bar 0.5 mm.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Conclusions

According to our biostratigraphic data the sequence of Jurassic rocks shows sedimentary gaps and seems to belong to two different successions.

In the Zwicker-Wolfskogel succession Upper Hettangian to Lower Pliensbachian Allgäu Beds are covering a Lower Rhaetian reefoidal Dachstein Limestone after a sedimentary gap (Upper Rhaetian – Lower Hettangian). Allgäu Beds are followed by Upper Pliensbachian Hierlatz Limestone and – after a hardground and a breccia horizon with Hierlatz components – by a fine grained red crinoidal limestone with *"Bositra"* microlumachelles of probably Middle Jurassic age. The succession is completed by a few indications of Ruhpolding Radiolarite.

The second succession represents the Jurassic of the southwestern Totes Gebirge in the Flodring-Klaushöfl area. Dachstein Limestone of a reefoidal facies is overlain by Hierlatz Limestone of mainly Sinemurian age. Hettangian is completely missing as yet, Pliensbachian and especially Toarcian have been found at a few localities. Middle Jurassic might be represented (at least partly) by a breccia, containing components of a red *„Bositra"* limestone. A few meters of red radiolarite of probably Oxfordian age appear only at the locality Klaushöfl.

Kimmeridgian basinal limestones are resting discordantly on both of the Lower to Middle Jurassic successions, thus indicating their neighbourhood at least since Late Jurassic times. Together with the phenomenon of extraclasts of Lower Triassic Werfen Beds and frequent olistoliths of Hierlatz Limestone within the Tressenstein Limestone all these observations support the hypothesis of intra-Jurassic (gravitational) tectonics, even if no strong proof for the allochthony of the Zwicker-Wolfskogel succession can be given at the moment.

The Hierlatz Limestone of the large olistolith at Plk 1 has yielded a remarkable rich invertebrate fauna:

The majority of ammonites point to an Early Sinemurian age (*A. semicostatum* Zone and/or *C. turneri* Zone) although some taphonomic condensation can not be excluded mainly due to the presence of scarce specimens reminding Upper Sinemurian echioceratids. The association is dominated by juvenile forms of various species of the genus *Arnioceras*.

The brachiopod fauna is diverse; twenty seven species of fourteen genera of Rhynchonelliformea subphylum have been determined within more than two hundred specimens prepared so far. *Zeilleria* and *Liospiriferina* are the most common genera.

Thirty one species of gastropods have been distinguished, vetigastropods predominate. Some "exotic" elements are of palaeoecological importance, pointing at a rather shallow origin contrary to the type locality of Hierlatz Limestone, where eucyclids are dominating.

Eleven taxa of bivalves have been found at Plk 1. Epifaunal forms of suspension feeders are predominating; infaunal burrowing forms are much rarer than at the Hierlatz type locality. In contrary to the gastropod data shallow water forms are missing amongst the bivalves.

Much more detailed mapping will be necessary, to find stronger field evidence, if the Dachstein reef limestone of Zwicker Kogel and the connected Zlambach Marls are part of the Totes Gebirge or a part of the Jurassic gliding masses. Maybe additional olistoliths of a lithology other than Hierlatz Limestone can be found. At two places (not indicated on the sketch maps) we have recognized small occurrences of Permian Haselgebirge (strongly weathered variegated shales and gypsum) with questionable contact to surrounding Jurassic rocks. Also the "cherty Allgäu Beds" should be revised for their age, for possibly enclosed olistoliths and for their contact to the Dachstein Limestone of Zwicker Kogel.

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We dedicate this paper to our colleague and friend Miloslav Rakús from Bratislava, who died in May 2005 after a short but malignant illness. We remember many years of cooperation and several excursions with him in the Triassic and Jurassic of the Northern Calcareous Alps, as well as in the Carpathian Mountains. In 2004 he just had visited in a joint excursion the newly discovered fossiliferous locality at Plankerau, but he wasn't granted anymore to participate in the following years of research. But his former research on the ammonite fauna of the Hierlatz Limestone type locality has contributed essentially to our stratigraphic knowledge and to all further investigations.

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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

The Lower Gosau Subgroup of the Kohlbachgraben and "Station Billroth" North of St. Gilgen (Turonian–?Coniacian, Salzburg, Austria)

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3 Text-Figures, 5 Plates

Österreichische Karte 1:50.000
Blatt 65 Mondsee

Northern Calcareous Alps
Calcareous nannofossils
Palaeoenvironment
Palynomorphs
Foraminifers
Fossil plants
Bivalves
Corals

Contents

Die Untere Gosau-Subgruppe der Lokalitäten Kohlbachgraben und „Station Billroth" nördlich von St. Gilgen (Turonium–?Coniacium, Salzburg, Österreich)

Zusammenfassung

Aus grauen Mergeln der Unteren Gosau-Subgruppe des linken Kohlbach-Seitengrabens N von St. Gilgen wird eine schlecht erhaltene fossile Flora beschrieben. Foraminiferen, Nannofossilien und Palynomorphen erlauben eine Einstufung in das Turonium bzw. die Turonium/Coniacium-Grenze. Die grauen Mergel werden von einem mehrere Meter mächtigen Rudisten-Korallen-Riff überlagert, woraus sowohl die Bivalven-, als auch die Korallen-Vergesellschaftung beschrieben werden. Weiters wurden im Umfeld der historischen Lokalität „Billroth" an zwei Lokalitäten Proben von grauen Mergel entnommen. Sie lieferten schlecht erhaltene Mikrofossilien sowie eine mäßig diverse Vergesellschaftung von Kolonie bildenden Korallen mit Rudisten, die auf ein Turonium-Alter hindeuten.

Abstract

Grey marls of the Lower Gosau-Subgroup exposed in a left tributary of the Kohlbachgraben north of St. Gilgen have yielded foraminifers, calcareous nannofossils and palynomorphs as well as poorly preserved plant remains. The microfossils indicate a Turonian or Turonian/Coniacian boundary age. On top of the grey marls a several meters thick succession of marly limestone and marl follows, whose fossil fauna is dominated by radiolitid rudists. Grey marls sampled in two exposures situated near the long-known fossil locality „Billroth" yielded poorly preserved microfossils as well as a moderately diverse colonial coral and rudist assemblage, indicating a Turonian age. The most important findings of palynomorphs and macrofossils are briefly described and figured.

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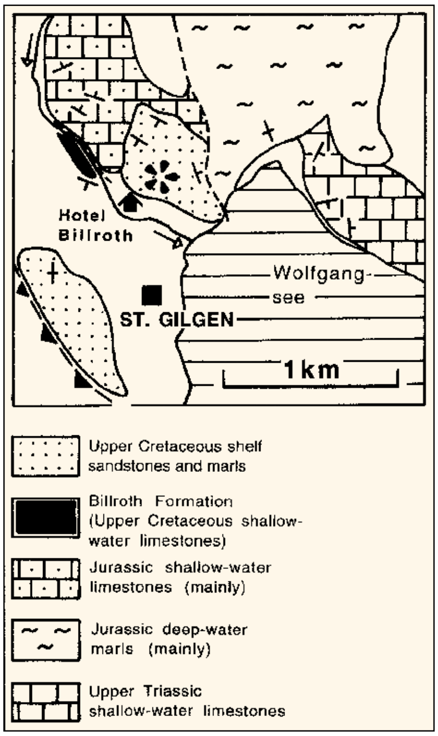
Introduction

Fossil-rich sediments of the Lower Gosau Subgroup cropping out in and around the village of Sankt Gilgen at the NW end of the Wolfgangsee have been known since the mid-19th century (see e.g. Reuss, 1854; Zittel, 1865–1866; Unger, 1867a, b; Douvillé, 1897; Kühn, 1967). Most of the fossils now housed in museums have been yielded by the former locality Billroth, named after the neighbouring post coach station "Station Billroth" (later Hotel Billroth), situated in the northern part of St. Gilgen, near the Bundesstraße "Mondseestraße". As it is usually the case of old collections, however, locality details are often lacking (e.g. Steuber, 2004). The aim of this paper is, based on studies of recently collected material as well as of specimens housed in the Heimatkundliches Museum of St. Gilgen, to contribute to the knowledge of Gosau-type sediments and fossil assemblages of this classical area.

Geological Setting

Two main types of Gosau deposits can be distinguished in the region (Plöchinger, 1964; Sanders et al., 1999). An at least 30 m thick coral-rudist buildup (= Billroth Formation, as recently defined by Sanders et al., 1999) is exposed along the right flank of the valley of Kohlbachgraben *sensu stricto*. To the east and to the south of the former a more than 100 m thick succession of shallow-water sediments, mainly sandstones and marls rich in corals, rudist bivalves and other molluscs, is known to crop out (Text-Fig. 1). The lowermost part of the sequence contains coal seams (Kohlbachgraben = Coal Creek, if translated) which were exploited in the past in small-scale mines (Woldřich, 1868; Günther & Tichy, 1979). The siliciclastic sequence overlies the Billroth Formation. The exact stratigraphic relationship of the two types of successions is, however, unknown, due to intensive Neogene strike-slip deformation (Sanders et al., 1999). According to the results of analyses of the strontium-isotope composition of rudist shells, rudist localities at St. Gilgen are Late Turonian in age (Steuber, 2001, 2004). The geological map sheet 65 Mondsee (van Husen, 1989) shows in the surroundings of "Station Billroth" a sequence of the Lower Gosau Subgroup with "Bitumenschichten" on the base (grey marls and sandstone, Coniacian), rudist limestones (Coniacian–Santonian) and sandstones and marls (Campanian–Maastrichtian). In the light of results of recent studies, however, these ages should be revised.



Text-Fig. 1.
Geological map of St. Gilgen and its surroundings (after Sanders et al., 1999).
The asterisk indicates the approximate position of studied localities.

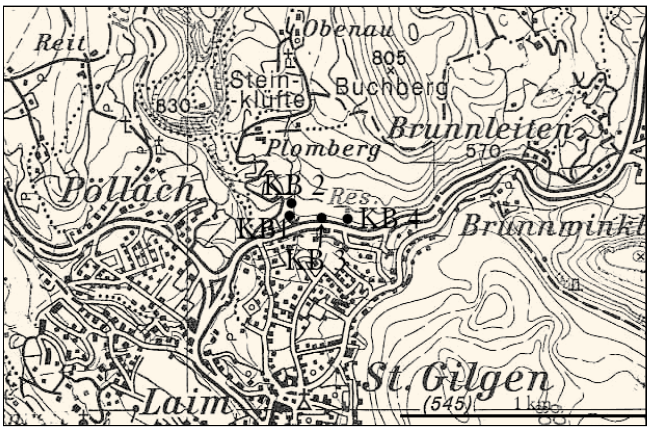
Localities

Four localities were sampled (Text-Fig. 2).

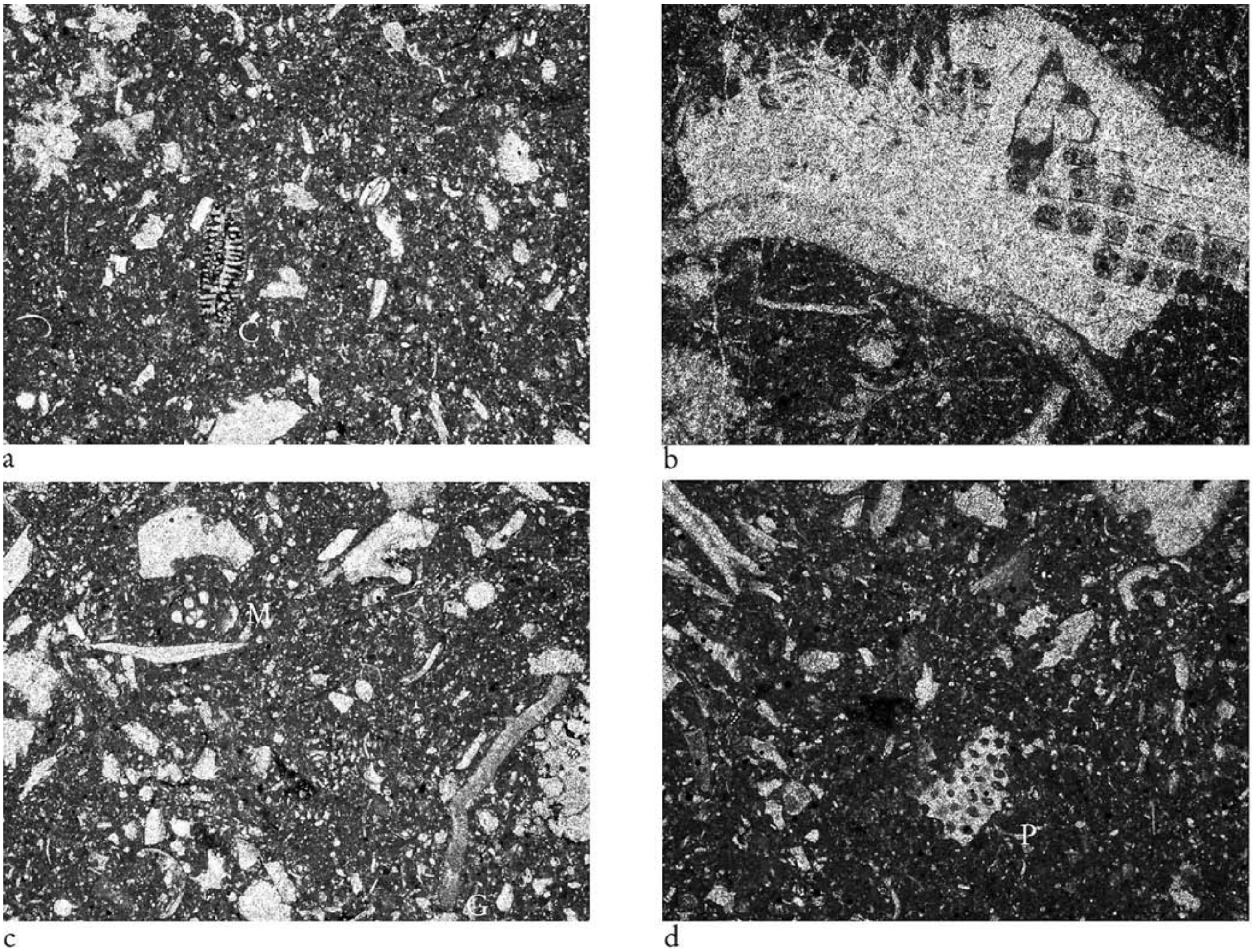
KB 1. A left tributary of the Kohlbachgraben *sensu stricto*, already reported by Hradecká et al. (2008). The exposures extend to the N of the Bundesstraße "Mondseestraße". Near the bridge on the right flank of the ravine a rock wall is formed by marly limestone. Its microfacies is characterised by *Milanovicella hammudai* (Radoičić), which is rather common in the Late Turonian – Early Coniacian interval of the Lower Gosau Subgroup. Other microfossils include *Permocalculus gosaviensis* Schlagintweit, *Neomeris mokragorensis* Radoičić & Schlagintweit, debris of *Gosavisiphon paucimedullaris* (Schlagintweit & Ebli), miliolid forams (e.g. *Vidalina hispanica* Schlumberger) and *Cuneolina*. Among other bioclasts, the coral *Pleurocora* sp. and debris of radiolitid rudists could be identified (Text-Fig. 3).

Immediately north of the rock wall a sequence of marls is exposed poorly on the right flank of the ravine, containing abundant although usually badly preserved radiolitid rudists, among which two types, *Radiolites* cf. *angeiodes* (Lapeirouse) and *Radiolites* sp. could be distinguished. Other rudists, such as *Vaccinites inaequicostatus* (Münster in Goldfuss) and *Plagioptychus uchauxensis* Mennessier occur only sporadically. A specimen of the colonial coral *Paraplacocoenia orbignyana* (Reuss) was also found there. The limestone-marl succession can not be identified with the Billroth Formation.

KB 2. Near the first waterfall of the creek light-coloured and partly dissolved bivalves were found in a seemingly displaced and disintegrated marl block. The taxa recorded are:



Text-Fig. 2.
Map showing the position of the studied localities.



Text-Fig. 3.
Characteristic microfacies and microfossils of marly limestone exposed at KB 1. a, *Cuneolina* sp. (C) ; b, shell fragment of radiolitid rudist bivalve; c, Miliolid foraminifera (M), *Gosavisiphon paucimedullaris* (G); d, *Permocalculus gosaviensis* (P). The width of pictures is 5 mm.

Crassatella macrodonta (J. SOWERBY), *Hippuritella resecta* (DEFRANCE). The plant fossils and microfossils (samples 2a and 2b) interpreted below were collected from the marl forming the bottom of the creek, below and near the waterfall.

KB 3. The road cutting of the Bundesstraße "Mondseestraße" exposes grey marls of the Lower Gosau Subgroup. Apart from some poorly preserved gastropods, bivalves and colonial corals these sediments yielded only microfossils. The foraminiferal assemblage, dominated by *Quinqueloculina angusta* (FRANKE) and *Spirillina cretacea* (REUSS) is clearly of shallow-water character. Ostracods, small gastropods, fragments of bivalves and rare Radiolaria were also found in the washed material. On the basis of comparison with foraminiferal assemblages of similar character (Weissenbachalm, Eisenbach [HRADECKÁ et al., 2006]) we can assume a Turonian age of the sample.

The poor and poorly preserved nannoflora with *Eiffellithus eximius* and *Lucianorhabdus maleformis* provides evidence of the Middle Turonian, zone UC8 (*sensu* BURNETT, 1998) and no evidence of a younger age. Rare occurrence of small specimens of *Braarudosphaera bigelowii* indicates shallow-water depositional environment.

The marl beds yielded corroded, pale yellow and very rare palynomorphs. Several triporate angiosperm pollen grains of the genera *Complexiopollis* sp. and *Trudopollis* sp., tricolporate pollen of *Retitricolporites* sp., spores of fungi (*Pluricellaesporites* sp.), broken dinocysts and foraminiferal linings were found. Despite of its low diversity, the assemblage was found to contain a form of some stratigraphical value: the angiosperm pollen *Trudopollis* appeared in the Middle Turonian. The presence of dinocysts and foraminifers gives evidence of marine environment.

KB 4. Some 200 m E of KB 1 blocks of fossil-rich marls can be found in the forest, below the water reservoir indicated as "Res." in the topographic map. The "archaeological finds" such as old-fashioned spades and beer bottles associated to the rocks and fossils suggest that the material came to the light when the reservoir was sunk.

The marl contains abundant colonial coral and rudist remains. Among corals, hemispherical ones of up to 20 cm diameter prevail, columnar and branching forms seem to be much less frequent. A preliminary survey has proved the presence of six taxa (see below).

The rudist assemblage is dominated by representatives of *Plagioptychus uchauxensis*. *Vaccinites* and other bivalves occur sporadically. No radiolitid rudists were found. Specimens of *Plagioptychus* are preserved almost exclusively with closed, conjoined and crushed right and left valves.

Short Description and Evaluation of Fossils Found at Localities KB 1, 2 and 4 During this Study

Nannofossils

Method

Nannofossils from KB 2 were investigated in the fraction of 2–30 µm, separated by decantation following the methodology described in SVOBODOVÁ et al. (2004). Simple smear-slides were mounted by Canada Balsam and inspected at 1000× magnification, using an oil-immersion objective on a Nikon Microphot-FXA transmitting light microscope. Biostratigraphic data and provincial preferences of nannofossil species were interpreted applying BOWN et al. (1998) and BURNETT (1998).

Results

Calcareous nannofossils were extremely poorly preserved (mostly fragmented, partly extensively overgrown with calcite, partly etched). Nannofossil abundance was very low (1–2 identifiable specimens per 1 field of view of the microscope), the majority of specimens cannot be identified at all. The assemblage is characterized by a relatively large number of *Watznaueria barnesae* and by the presence of specimens (both coccoliths and nannoconids) reworked from older deposits of the Uppermost Jurassic – basal Cretaceous interval and from the Lower Cretaceous. Recorded taxa are listed in Appendix 1.

Stratigraphic Interpretations

Nannofossil thaphocoenose consists of three different assemblages at least:

Upper Cretaceous (Upper Turonian to ?Coniacian) with scarce *Micula staurophora* (1 badly preserved and questionable specimen), *Marthasterites furcatus* (3 strongly owergrown specimens), and *Lucianorhabdus quadrifidus.* The Coniacian may be indicated by the presence of a questionable, unfortunately fragmentary specimen of a polycyclolith (6 rays) probably of the genus *Lithastrinus* (?*L. grillii*) or ?*Hexalithus/Rucinolithus,* as well as of fragments of ?*Lucianorhabdus* ex gr. *cayeuxii*.

Lower Cretaceous (?Hauterivian) with *Micrantholithus hoschulzii, M. obtusus, Cruciellipsis cuvillieri, Lithaphidites bollii*, and nannoconids.

Uppermost Jurassic – basal Cretaceous interval with *Conusphaera mexicana* and *Favioconus multicolumnatus.*

Palaeoenvironmental and palaeogeographic interpretations

The presence of calcareous nannofossils documents sea of normal salinity.

Upper Cretaceous (Upper Turonian to ?Coniacian, UC9–?UC10). Presence of *Braarudosphaera bigelowii* and *Lucianorhabdus* sp. reflects shallower marine conditions.

Lower Cretaceous. Presence of the predominantly Tethyan taxon *Cruciellipsis cuvillieri* (*sensu* BOWN et al., 1998) may document low latitudes. Nannoconids usually indicate shallow warmer waters and oligotrophic environment.

Discussion

The character of the nannofossil taphocoenoses, including the relatively large number of reworked specimens from older sediments of uppermost Jurassic and Lower Cretaceous age, is comparable to that of the sample collected at St. Gilgen Kühleitengraben.

The extremely poor preservation of specimens, especially carbonate dissolution and etching may be explained as a result of liberation of organic acids during decomposition of organic matter enclosed in the sediments (ŠVÁBENICKÁ et al., 2010). The large number of *W. barnesae* may be due to diagenetic processes.

Palynology

Preservation of the palynomorph assemblage is very poor. Almost all spores, pollen, organic-walled dinoflagellate cysts as well as foraminiferal linings are corroded by pyrite or pyrite crystals are found inside the grains (see e.g. Pl. 1, Fig. 2). Rare redeposited "early" angiosperm pollen, probably of Lower Cretaceous age, were also determined.

Chitinous microforaminiferal linings (Pl. 1, Figs. 8, 9) dominate the assemblage. Dinoflagellate cysts consist of *Kiokansium polypes, Pervosphaeridium pseudhystrichodinium, Oligosphaeridium complex, Circulodinium distinctum, Palaeohystrichophora infusorioides, Spiniferites ramosus, Dinogymnium* sp., aff. *Achomosphaera ramulifera* (Pl. 1, Fig. 7).

Spore-pollen taxa consist of triporate pollen of the *Normapolles* group – relatively most abundant are *Complexiopollis* sp., *Plicapollis* sp. and *Pseudovacuopollis* sp. (Pl. 1, Fig. 2). Rare reticulate tricolpate pollen *Retitricolpites* sp. (Pl. 1, Fig. 1), probably redeposited from the Lower Cretaceous, also appear.

Gymnosperm pollen consist of *Taxodiaceaepollenites hiatus, Corollina/Classopollis*, *Ephedripites* sp. associated with bisaccate *Pinuspollenites* sp. Pteridophyte spores are represented mainly by *Vadaszisporites urkuticus* (Pl. 1, Figs. 3, 4), *Stereisporites antiquasporites, Cyathidites minor.* Occasionally some fungal spores *Pluricellaesporites psilatus* occur. The palynofacies includes brown to black phytoclasts. Pyrite crystals are abundant.

The palaeoenvironment was warm and partly dry as evidenced by the presence of *Ephedripites* pollen and thick-walled pteridophyte spores. Sediments were probably deposited in shallow marine environment with lower oxygen content. It is documented also by common scolecodonts (jaw apparatus of Polychaeta worms) (Pl. 1, Figs. 5, 6). The composition of the triporate angiosperms as well as dinoflagellate cysts corresponds probably to the Turonian or Turonian/Coniacian age (GÓCZÁN et al., 1967; SIEGL-FARKAS, 1994; TSCHUDY, 1973). Redeposition of Lower Cretaceous miospores was also observed.

Recorded taxa are listed in Appendix 2.

Foraminifera

Two samples from layers 2a and 2b contain a relatively poor foraminiferal assemblage, which is composed only of about 10 benthonic species, plankton was not found. Specimen diversity of sample 2b is lower than that in 2a. Forms with agglutinated tests such as *Gaudryina trochus*

(D'ORBIGNY), *Gaudryina* sp., *Marssonella oxycona* (REUSS) and *Pseudotextulariella cretosa* (CUSHMAN) together with fine agglutinated sessile species of genera *Dictyopsella* and *Dictyopselloides* prevail. Among other agglutinated species, *Ammodiscus gaultinus* BERTHELIN and coarse agglutinated tests of *Ammobaculites* sp. and *Haplophragmoides* sp. are present.

Calcareous benthos is represented by frequent occurrence of *Quinqueloculina angusta* (FRANKE), *Quinqueloculina* sp., *Spirillina cretacea* (REUSS), *Trocholina* sp. and a few specimens of *Vaginulina robusta* (CHAPMAN).

Organic part of washed material of both samples is formed also by fragments of echinodermata (spines and small fragments), by green algae, fish teeth, fragments of bryozoa and corals, ostracoda and small pyritized gastropods. Pyrite is very frequent in sample 2a and less frequent in 2b.

Concerning the interpretation of palaeoenvironment we can suppose shallow-water conditions (*Vaginulina* and agglutinated species) with local fluctuation of salinity (occurrence of *Quinqueloculina*) and local dysoxic conditions. The benthos is represented by sessile or active epifaunal deposit feeders (*Trocholina* and *Spirillina*, etc.) with flat or conical tests, resting on and partially buried in the sediment-water interface.

On the basis of the character of foraminiferal assemblage the samples show a Turonian or Turonian/Coniacian boundary age.

Plant fossils

Already UNGER (1867a, b) reports about findings of fossil plant remains from the coal-bearing Bitumenschichten of the Kohlbachgraben. The flora has remained, however, largely undocumented until now.

Pinopsida

Brachyphyllum sp.

Pl. 2, Fig. 1

Material: K 962a.

Description: One coniferous twig No. K 962a was recorded. It shows a shoot with 3–4 branches arranged in one plane, bearing helically arranged poorly preserved leaves. They are intimately attached to branches including leaf apices. This can be caused also by poor preservation.

Discussion: In gross morphology *Brachyphyllum* sp. resembles *Brachyphyllum squamosum* from the Bohemian Cenomanian (VELENOVSKÝ, 1885a; KVAČEK, 2007). However its poor preservation does not allow closer comparison.

Gymnosperms *incertae sedis*

cf. *Dammarites albens* PRESL in STERNBERG

Pl. 2, Figs. 3, 4

Material: K 963, K 964, K 967, K 968, K 969.

Description: There are 5 specimens available in the collection of National Museum. They show fragments of entire margined leaves about 3 cm broad (Pl. 2, Fig. 3). The largest fragment showing basal part of leaf has 12 cm in length (Pl. 2, Fig. 4). The leaf fragments are coriaceous parallel-sided. Well pronounced parallel venation has density of 12 veins per 1 cm.

Discussion: The leaf type is known from the locality St. Wolfgang road tunnel excavations (KVAČEK & LOBITZER, 2010). After inspection of the material from St. Wolfgang, which shows completely the same venation type and density, it is clear that the specimens earlier assigned to the genus *Monocotylophyllum* (HRADECKÁ et al., 2008) must be transfered to the genus *Dammarites*. The only known species of *Dammarites* from central Europe is *D. albens* described from the Bohemian Cretaceous (PRESL in STERNBERG, 1838; VELENOVSKÝ, 1885a; HLUŠTÍK, 1976). It shows the same type of leaf base and venation density. Its leaves are also typically coriaceous.

Magnoliopsida

Dicotylophyllum sp. 1

Pl. 2, Figs. 5, 6

Material: K 962b, K 966

Description: There are numerous, poorly preserved leaf fragments of entire-margined narrow, linear to elliptical coriaceous leaves. The best preserved leaf figured on it is a leaf impression with clearly pronounced mid vein and poorly preserved secondary venation. Some of the leaves are preserved as leaf compressions (Pl. 2, Fig. 5), but preparation of cuticle failed.

Discussion: The leaves are poorly preserved, they can be compared with *Dicotylophyllum proteoides* (UNGER) HERMAN & KVAČEK known from the Cretaceous flora of Grünbach (HERMAN & J. KVAČEK, 2010). They also may be compared with *Myrtophyllum angustum* (HEER) KNOBLOCH from the Bohemian Cenomanian (VELENOVSKÝ, 1885b; KVAČEK, 1992).

Dicotylophyllum sp. 2

Pl. 2, Fig. 2

Material: K 965

Description: One leaf fragment in the collection is nearly entire-margined, however, it shows very fine needle-like teeth. Venation is very poorly preserved, only the midvein is visible. This is a leaf compression, however preparation of its cuticle failed.

Discussion: There is no similar leaf known within the Central European Cretaceous, more and better preserved material is necessary for its interpretation.

Remarks on the plant assemblage

Together with this foliage various axes and fragments of roots co-occur on the same bedding plane. The whole assemblage is clearly allochthonous. Only coriaceous leaves survived long transport. The conifer twig and small entire-margined leaves with spines argue for mesophytic/xerophytic flora. This situation is very similar to the Häuselkogel flora collected near Bad Ischl. As already published by HRADECKÁ et al. (2008) the palaeoenvironment of the flora was probably quite dry and warm. Salt-marsh flora is represented here as well as in the St. Wolfgang tunnel assemblage (KVAČEK & LOBITZER, 2010) by the genus *Dammarites.* In the Bohemian Cenomanian it co-occurs with the genus *Frenelopsis* (ULIČNÝ et al., 1997; KVAČEK, 2000).

Scleractinian corals

(Coral and bivalve remains collected during this study are housed in the collection of Geologische Bundesanstalt, Vienna)

Abbreviations:
d: corallite diameter.
c–c: distance of corallite centers.
s: number of septa in corallite.
s/mm: number of septa per mm.

Family Faviidae Gregory, 1900
Genus Cladocora Ehrenberg, 1834

***Cladocora gracilis* (d'Orbigny, 1850)**
Pl. 3, Figs. 1, 2

Material: KB 3-3.

Diagnosis: Phaceloid-dendroid colony; gemmation intracalicinal (polystomodaeal) and extracalicinal; costosepta compact, finely granulated laterally, dentate marginally; paliform swellings in front of S1 and S2 can be present. Pseudo-columella formed by trabecular extension of axial septal ends, irregularly parietal, spongy to papillose, sublamellar deeper in corallum; wall septothecal and septoparathecal; endothecal dissepiments and epithecal wall thin; d = 3–4 mm; s = 24–40.

Family Agatheliidae L. & M. Beauvais, 1975
Agathelia Reuss, 1854

***Agathelia asperella* Reuss, 1854**
Pl. 3, Figs. 3, 4

Material: KB 3-9; -10; -11; -12; -13; -22.

Description: Massive, plocoid colonies; extracalicinal budding; costosepta compact, radially or bilaterally arranged in 6 systems, with small denticles marginally and granules laterally; columella feebly developed, parietal-spongy to lamellar; endothecal dissepiments vesicular to subtabulate; exothecal dissepiments vesicular, abundant; septothecal wall covered by concentrical perithecal lamellae; d (adult) = 3.5–6 mm; s (adult) = 30–40.

Multicolumnastraea Vaughan, 1899

***Multicolumnastraea cyathiformis* (Duncan, 1865)**
Pl. 3, Fig. 5

Material: KB 3-2; -21.

Diagnosis: Colony massive, plocoid; gemmation extracalicinal; costosepta compact, dentate marginally; columella formed by a small number of trabecular pillars; pali in front of S1 and S2; wall septothecal; endothecal and perithecal dissepiments thin, vesicular; auriculae rare; d = 1.8–3.5 mm; s = 18–24.

Family Actinacididae Vaughan & Wells, 1943
Genus Actinacis d'Orbigny, 1849

***Actinacis remesi* Felix, 1903**
Pl. 3, Fig. 6

Material: KB 3-24; -26.

Diagnosis: Plocoid colony; extracalicinal budding; corallites embedded in vermiculate coenosteum; costosepta have few, but large perforations, granular laterally; anastomosis present, synapticulothecal wall incomplete; columella parietal, substyliform, or formed by elongated segments; synapticulae abundant; endothecal dissepiments sparse, thin; d = 1.8–2.5 mm; s = 18–24.

Genus Elephantaria Oppenheim, 1930

***Elephantaria lindstroemi* Oppenheim, 1930**
Pl. 3, Fig. 7

Material: KB 3-25.

Diagnosis: Subthamnasterioid-subplocoid-subceriod colony; gemmation extracalicinal; corallites embedded in a porous-reticulate coenosteum, connected by irregularly confluent septa; nonconfluent septa common; costosepta reduced, subcompact to porous, granulate laterally; synapticulae and trabecular columella present; endothecal dissepiments thin, vesicular; c–c = 3–6.5 mm; s/mm = 6–9/2.

Family Placocoeniidae Alloiteau, 1952
Genus Paraplacocoenia M. Beauvais, 1982

***Paraplacocoenia orbignyana* (Reuss, 1854)**
Pl. 3, Fig. 8

Material: KB 1-2.

Diagnosis: Plocoid colony; gemmation extracalicinal; costosepta compact, radial, granular laterally, beaded marginally, and dissociate into trabecular structures in distal areas; perithecal wall tabulo-columnar; columella small, trabecular-lamellar; endothecal dissepiments thin, subtabulate, abundant; wall septoparathecal; d = 4–5 mm; c–c = 4.8–6 mm; s = 24 + s4.

Family Haplaraeidae Vaughan & Wells, 1943
Genus Pleurocora Milne Edwards & Haime, 1848

***Pleurocora* sp.**
Pl. 3, Fig. 9

Material: KB 1-1.

Diagnosis: Fragment of a branching (?subdendroid) colony; corallite subcylindrical; costosepta compact or subcompact, finely granulated laterally; pali irregularly occur opposite all but last cycle; wall dense, synapticulothecal; columella trabecular; endothecal dissepiments thin, vesicular; d = 5.6 mm; s = 24.

Genus Brachymeandra Alloiteau, 1957

***Brachymeandra leptophylla* (Reuss, 1854)**
Pl. 3, Figs. 10, 11

Material: KB 3-1; -23.

Diagnosis: Thamnasterioid colony, which is plocoid to submeandroid superficially; gemmation intracalicinal; costosepta subcompact or porous, subconfluent or confluent, beaded marginally, finely granulated laterally; columella parietal-papillose; paliform structures present; synapticulae abundant; endothecal dissepiments thin, subtabulate; perithecal wall can be present; generally no wall between the calices; d = 3–10 mm; s/mm = 8–11/3.

Bivalves

Limaria? *sp.* cf. *marticensis* (MATHERON, 1843)

Pl. 4, Fig. 1

A single fragment of a left valve bearing well defined radial ribs resembles the specimens of *"Lima" marticensis* as figured by ZITTEL (1866, Pl. 16, Figs. 1, 1a) from the Hofergraben of Gosau.

Curvostrea madelungi (ZITTEL, 1866)

Pl. 4, Fig. 2

Remarks: the marl of KB 1 contains fragments of oyster shells similar to *"Ostrea" madelungi* ZITTEL (1866, p. 125, Pl. 19, Figs. 7a–c). Inner characters of the valves can not be studied. ZITTEL (l. c.) compared *O. madelungi* to *O. tetragona* BAYLE, 1849, a species described from the Upper Cretaceous of North Africa, from which the Gosau specimens were found to differ by their smaller size and by the lack of commarginal growth lamellae. *"O." tetragona* was designated as the type species of *Quadrostrea* VIALOV, 1936, which later was, however, considered as uncertain by STENZEL (1971) and was synonymised with *Curvostrea* VIALOV, 1936 by MALCHUS (1990). It is possible that *C. madelungi* represents an ecophenotypical variety of *C. tetragona*.

Crassatella macrodonta (J. SOWERBY, 1832)

Pl. 4, Fig. 3

The single specimen found clearly falls within the morphological range of *C. macrodonta* as illustrated by ZITTEL (1865, Pl. 8, Figs. 2, 3). According to DHONDT (1987), this variable species is an endemic element of the Gosau fauna. The specimen recorded here indicates, however, that its stratigraphic range is considerably longer than it was previously supposed (i. e. Santonian; DHONDT, 1987).

Plagioptychus uchauxensis MENNESSIER, 1957

Pl. 4, Figs. 4–8

Material: Two specimens from KB 1, 6 specimens from KB 3.

Description: inaequivalve forms of up to 70 mm commissural diameter. The right valve is relatively flat, gyropleuriform. About 11 primary pallial canals can be counted in the shell wall of the posterior part of the left valve. The walls of canals display three bifurcations. The tooth of the right valve is prominent, occupying the dorsal part of the posterior shell cavity.

Remarks: On the basis of the branching pattern of the wall of pallial canals and the dimensions of the shell the specimens are assigned to the Turonian species *P. uchauxensis*. The mode of preservation of the specimens found during this study is strikingly similar to those reported by STEUBER (2004) from an unknown locality of St. Wolfgang.

Hippuritella resecta (DEFRANCE, 1821)

Pl. 4, Figs. 9–13

Material: 8 right valves from KB 2.

Description: slender shells bearing fine ribs. The ligamental crest is triangular, wide and short. The pillar S is short and wide, the pillar E is longer than S.

Remarks: There is no general agreement in the literature on the generic assignment of *H. resecta*. Some authors (e.g. PLENIČAR & JURKOVŠEK, 2001; PLENIČAR, 2005) consider it as belonging to *Hippurites* LAMARCK, 1801. As it was pointed out by PLENIČAR (2005), the right valve of *H. resecta* is similar to that of *Vaccinites sulcatus* (DEFRANCE, 1821) (see e.g. SZENTE et al., 1999). The species is widely distributed in the Turonian of the peri-Mediterranean region (STEUBER, 1993).

Vaccinites inaequicostatus (MÜNSTER in GOLDFUSS, 1840)

Pl. 4, Figs. 14–16

Material: 3 specimens from KB 1.

Remarks: The dimensions of the shell as well as the shape and arrangement of pillars correspond well to *V. inaequicostatus* recently described in detail by STEUBER (1999). The species, which was already recorded from St. Gilgen – Billroth by DOUVILLÉ (1897), is a characteristic element of the Upper Turonian – Lower Coniacian rudist associations of the Gosau-type formations (STEUBER, 2001).

Vaccinites cf. *cornuvaccinum* (BRONN, 1831)

Pl. 5, Fig. 1

Remarks: A right valve belonging to the collection of H. Schiemer, displayed at the Heimatkundliches Museum of Sankt Gilgen differs considerably from *V. inaequicostatus* both in shape and arrangement of pillars and shows characteristic features of *V. cornuvaccinum*. On the label of the specimen St. Gilgen/Billroth is indicated as locality. According to STEUBER (2003), however, *V. cornuvaccinum* is restricted to the Coniacian, thus its occurrence at St. Gilgen somewhat contradicts the Turonian age of the Gosau successions of this area. Other *Vaccinites* species of similar shape and spacing of pillars, such as *V. chaperi* (DOUVILLÉ, 1897) and *V. ultimus* (MILOVANOVIĆ, 1935) are also younger than Turonian.

Radiolites cf. *angeiodes* (LAPEIROUSE, 1781)

Pl. 5, Figs. 2–5

Material: 11 more or less worn and crushed specimens from KB 1.

Description: Conical right valves ornamented with sharp and rarely interrupted longitudinal ribs. Details of the region of radial bands can not be studied on the specimens available. Shell lamellae are regularly plicated. Cells of the outer shell layer are usually hexagonal, rarely exceeding 0.5 mm in diameter. Possible structural modifications could be observed only in the ventral radial band.

Remarks: the specimens collected during this study as well as those collected previously at Billroth and now housed in the Heimatkundliches Museum of Sankt Gilgen, correspond well to *"Sphaerulites" angeiodes* as described and figured from various localities of the Northern Calcareous Alps by ZITTEL (1866, p. 150; Pl. 25, Figs. 4–12; Pl. 26, Figs. 1–4). The St. Gilgen specimens are, however, somewhat larger and less regularly conical than most of *R. angeiodes* described and figured in the literature (e.g. LUPU, 1976; CZABALAY, 1982; STEUBER, 1999; PLENIČAR, 2005). According to the valuable rudist database developed and maintained by Steuber (www.paleotax.de/rudists/s392.htm) the species has been hitherto recorded from the Coniacian to Campanian interval of the Gosau-type successions. Thus, if the St. Gilgen specimens are conspecific, they represent the stratigraphically oldest occurrence of *R. angeiodes* in the Gosau-type formations of the Northern Calcareous Alps.

***Radiolites* sp.**

Pl. 5, Figs. 6–8

A single, strongly worn specimen with closed valves from KB 1 appears to differ from *R.* cf. *angeiodes* by its larger size, more cylindrical shape and less continuous ribs.

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Plate 1

Organic-walled microfossils. Scale bar 10 µm.

Fig. 1: *Retitricolpites* sp. (redeposition from the Lower Cretaceous).
Fig. 2: *Pseudovacuopollis* sp. (small pyrite crystals inside miospore).
Figs. 3, 4: *Vadaszisporites urkuticus* (Deák) Deák & Combaz.
Figs. 5, 6: Scolecodonts.
Fig. 7: aff. *Achomosphaera ramulifera* (Deflandre) Evitt
Figs. 8, 9: Chitinous foraminiferal linings (Fig. 9: degradation by pyrite crystals).


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Plate 2

Plant remains

Fig. 1: *Brachyphyllum* sp.
Branched twig, 3×.

Fig. 2: *Dicotylophyllum* sp. 2.
Basal part of leaf, 3×.

Fig. 3: cf. *Dammarites albens*.
Leaf fragment with parallel venation , 1.5×.

Fig. 4: cf. *Dammarites albens*.
Basal part of leaf, 2×.

Fig. 5: *Dicotylophyllum* sp. 1.
Fragment of entire-margined leaf, 2×.

Fig. 6: *Dicotylophyllum* sp. 1.
Fragment of entire margined leaf, 2×.

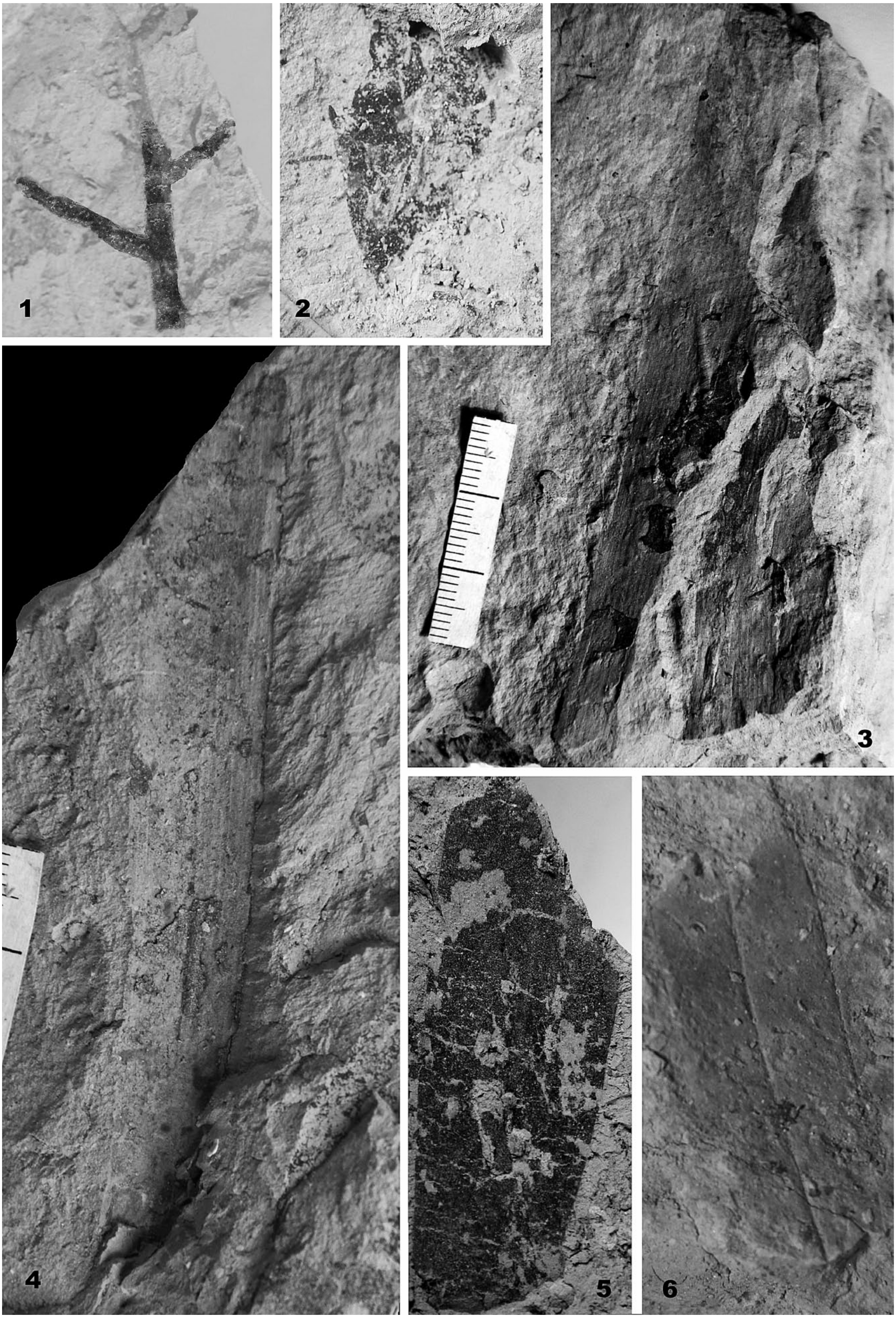
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Plate 3

Corals
The specimens in Figs. 1, 4 and 10 are coated with ammonium-chloride.
The scale-bar represents 3 mm in Figs. 2, 3, 5–9 and 11.

Figs. 1, 2: *Cladocora gracilis* (D'ORBIGNY, 1850).
Sample KB 3-3.
Fig.1: lateral view of colony.
Fig. 2: cross-section.

Figs. 3, 4: *Agathelia asperella* REUSS, 1854.
Fig. 3: Sample KB 3-22, cross-section.
Fig. 4: sample KB 3-13, upper surface of colony, 1,5×.

Fig. 5: *Multicolumnastraea cyathiformis* (DUNCAN, 1865).
Sample KB 3-2, cross-section.

Fig. 6: *Actinacis remesi* FELIX, 1903.
Sample KB 3-26, cross-section.

Fig. 7: *Elephantaria lindstroemi* OPPENHEIM, 1930.
Sample KB 3-25, cross-section.

Fig. 8: *Paraplacocoenia orbygniana* (REUSS, 1854) .
Sample KB 1-2, cross-section.

Fig. 9: *Pleurocora* sp.
Sample KB 1-1, cross-section.

Figs. 10, 11: *Brachymeandra leptophylla* (REUSS, 1854) .
Sample KB 3-1.
Fig. 10: upper surface of colony, 2×.
Fig. 11: cross-section.

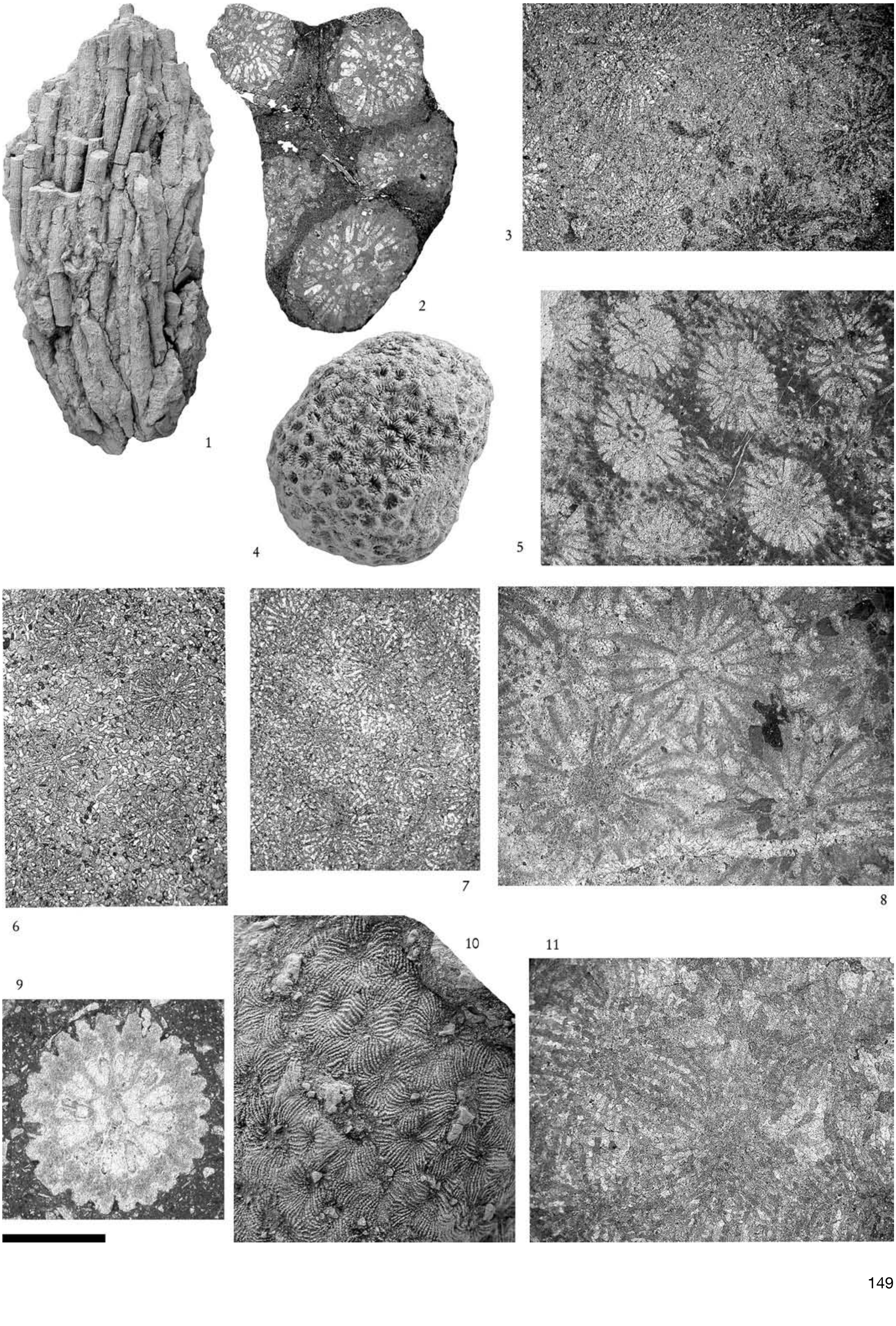
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Plate 4

Bivalves
(The specimens in Figs. 1–3, 11 and 15 are coated with ammonium-chloride).

Fig. 1: *Limaria*? sp. cf. *marticensis* (MATHERON, 1843), sample KB 3-5.

Fig. 2: *Curvostrea madelungi* (ZITTEL, 1866), sample KB 1-3.

Fig. 3: *Crassatella macrodonta* (J. SOWERBY, 1832), sample KB 2-1.

Figs. 4–8: *Plagioptychus uchauxensis* MENNESSIER, 1957.
Figs. 4, 5: sample KB 3-4.
Figs. 6, 7: sample KB 3-6.
Fig. 8 (mirror image): sample KB 1-4.
Figs. 5, 7: 2×.

Figs. 9–13: *Hippuritella resecta* (DEFRANCE, 1821).
Fig. 9: sample KB 2-2.
Figs. 10, 11: sample KB 2-3.
Figs. 12, 13: sample KB 2-4.
Figs. 9, 12: 2×, Fig. 13: 4×.

Figs. 14–16: *Vaccinites inaequicostatus* (MÜNSTER in GOLDFUSS, 1840).
Fig. 14: sample KB 1-5.
Figs. 15, 16: sample KB 1-6.

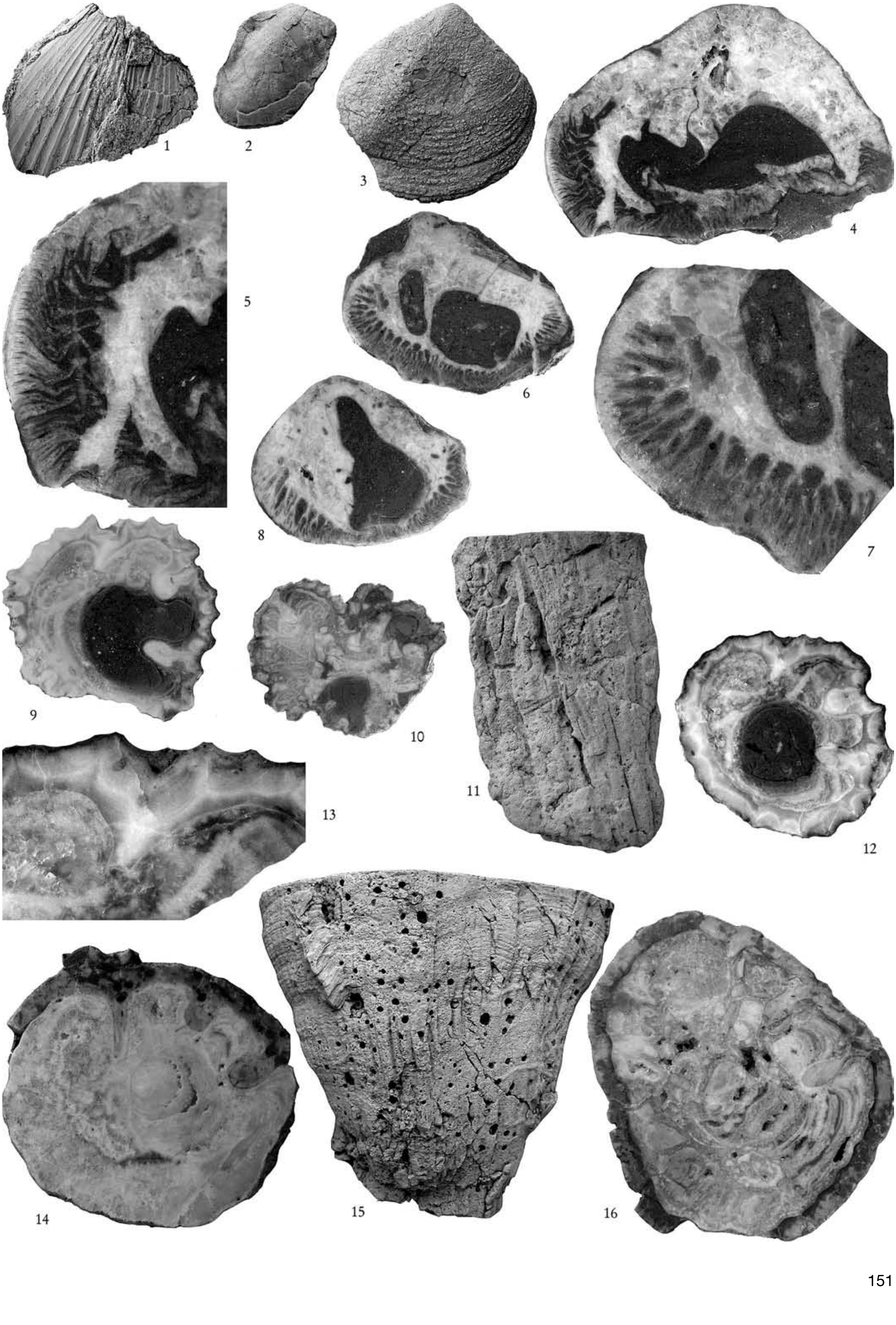
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Plate 5

Bivalves
(The specimens in Figs. 2 and 6 are coated with ammonium-chloride).

Fig. 1: *Vaccinites* cf. *cornuvaccinum* (BRONN, 1831).
Specimen at display at the Heimatkundliches Museum of St. Gilgen (mirror image).

Figs. 2–5: *Radiolites* cf. *angeiodes* (LAPEIROUSE, 1781).
Sample KB 1-7.

Fig. 2: ventral view.

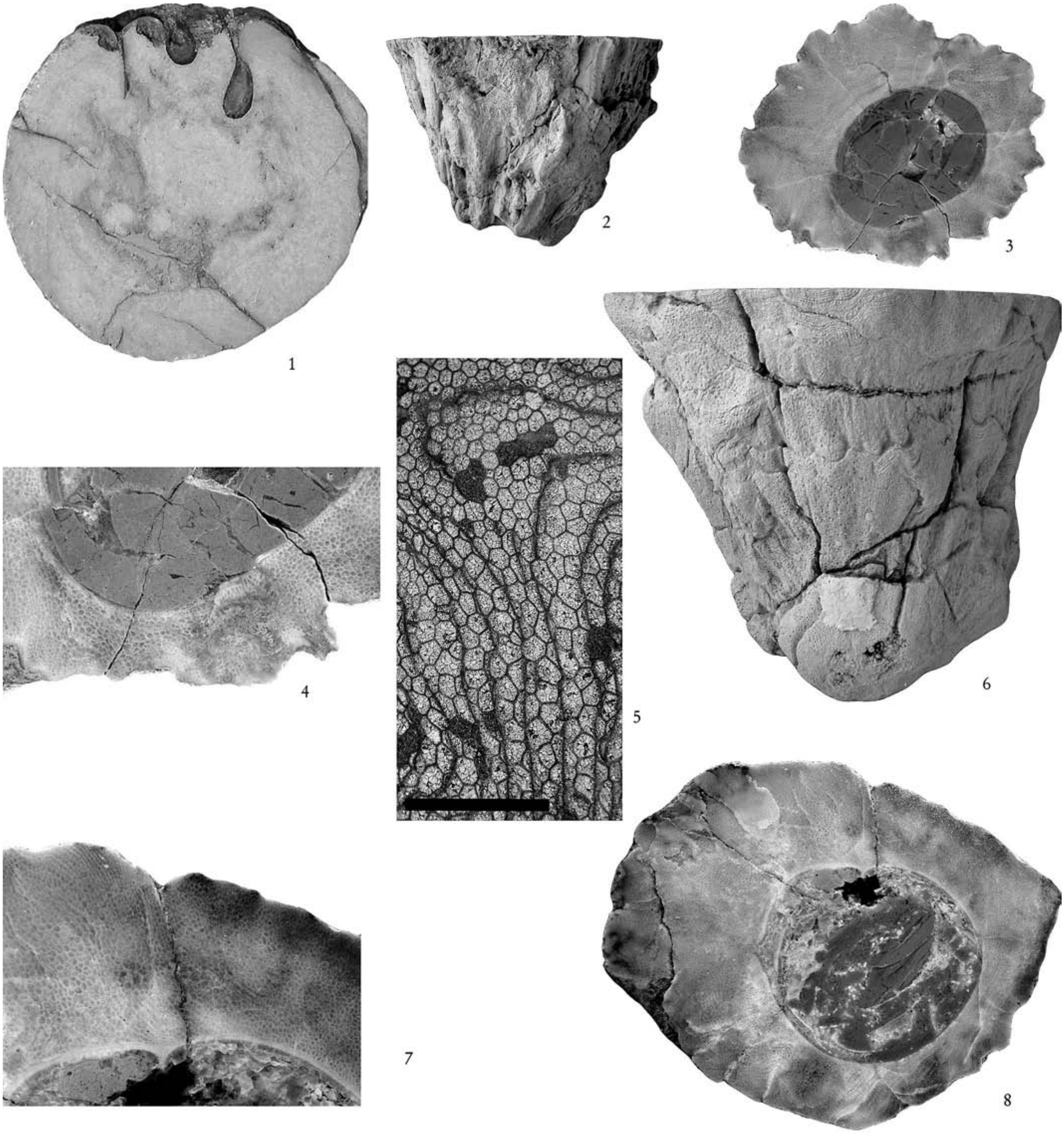
Fig. 4: region of posterior radial band.

Fig. 4: 2×.
The scale bar in Fig. 5 represents 3 mm.

Figs. 6–8: *Radiolites* sp.
Sample KB 1-8.

Fig. 6: ventral view.

Fig. 7: dorsal region with ligamental ridge, 2×.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Appendix 1

List of calcareous nannofossils found in sample St. Gilgen Kohlbachgraben, in alphabetical order of generic epithets:

Aptian-Albian and Upper Cretaceous:

Amphizygus brooksii BUKRY
Braarudosphaera bigelowii (GRAN & BRAARUD) DEFLANDRE
Calculites ovalis (STRADNER) PRINS & SISSINGH
Cribrosphaerella ehrenbergii (ARKHANGELSKY) DEFLANDRE
Eiffellithus eximius (STOVER) PERCH-NIELSEN
Eiffellithus gorkae REINHARDT
Eiffellithus turriseiffelii (DEFLANDRE) REINHARDT
Eiffellithus turriseiffelii-eximius
Lithastrinus grillii STRADNER
Lucianorhabdus cayeuxii DEFLANDRE
Lucianorhabdus maleformis REINHARDT
Lucianorhabdus quadrifidus FORCHHEIMER
Marthasterites furcatus (DEFLANDRE) DEFLANDRE
Micula staurophora (GARDET) STRADNER
Nannoconus ex gr. *truitti* BRÖNNIMANN
Prediscosphaera cretacea (ARKHANGELSKY) GARTNER
Prediscosphaera ponticula (BUKRY) PERCH-NIELSEN
Prediscosphaera spinosa (BRAMLETTE et MARTINI) GARTNER
Rhagodiscus angustus (STRADNER) REINHARDT
Russellia-Octolithus
Tranolithus orionatus (REINHARDT) REINHARDT

Lower-Upper Cretaceous (long-ranging species):

Helenea chiastia WORSLEY
Lithraphidites carniolensis DEFLANDRE
Manivitella pemmatoidea (DEFLANDRE) THIERSTEIN
Retacapsa angustiforata BLACK
Retacapsa crenulata (BRAMLETTE et MARTINI) GRÜN
Zeugrhabdotus diplogrammus (DEFLANDRE) BURNETT

Jurassic and Lower-Upper Cretaceous (long-ranging species):

Biscutum ellipticum (GÓRKA) GRÜN
Cyclagelosphaera margerelii NOËL
Watznaueria barnesae (BLACK) PERCH-NIELSEN
Watznaueria britannica (STRADNER) REINHARDT
Watznaueria manivitiae BUKRY

Lower Cretaceous:

Cruciellipsis cuvillieri (MANIVIT) THIERSTEIN
Lithraphidites bollii (THIERSTEIN) THIERSTEIN
Micrantholithus hoschulzii (REINHARDT) THIERSTEIN
Nannoconus kamptnerii BRÖNNIMANN
Nannoconus steinmannii KAMPTNER

Uppermost Jurassic-lowermost Cretaceous interval

Conusphaera mexicana TREJO
Favioconus multicolumnatus BRALOWER

Appendix 2

Palynoflora taxa mentioned in the text (in alphabetical order):

aff. *Achomosphaera ramulifera* (DEFLANDRE) EVITT
Circulodinium distinctum (DEFLANDRE & COOKSON)
Complexiopollis sp.
Corollina torosa (REISSINGER) KLAUS emend. CORNET & TRAVERSE
Cyathidites minor COOPER
Dinogymnium sp.
Ephedripites sp.
Kiokansium polypes (COOKSON & EISENACK) BELOW
Oligosphaeridium complex (WHITE) DAVEY & WILLIAMS
Palaeohystrichophora infusorioides DEFLANDRE
Pervosphaeridium pseudhystrichodinium (DEFLANDRE) YUN
Pinuspollenites sp.
Plicapollis sp.
Pluricellaesporites psilatus VAN DER HAMMEN
Pseudovacuopollis sp.
Spiniferites ramosus (EHRENBERG) LOEBLICH & LOEBLICH
Stereisporites antiquasporites (WILSON & WEBSTER) KREMP
Taxodiaceaepollenites hiatus (POTONIÉ) KREMP
Vadaszisporites urkuticus (DEÁK) DEÁK & COMBAZ

Redeposition from the Lower Cretaceous:

Retitricolpites sp.

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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

Ichnofossils of the Ressen Formation in Gosau (Campanian, Upper Gosau Subgroup, Upper Austria)

Radek Mikuláš[1], Marcela Svobodová[1], Lilian Švábenická[2] & Harald Lobitzer[3]

5 Text-Figures, 4 Plates

Österreichische Karte 1:50.000
Blatt 95 St. Wolfgang

Northern Calcareous Alps
Calcareous nannofossils
Upper Gosau Subgroup
Palaeoenvironment
Ressen Formation
Upper Cretaceous
Palynomorphs
Stratigraphy
Ichnofossils
Facies

Contents

Lebensspuren der Ressen-Formation in Gosau (Campanium, obere Gosau-Subgruppe, Oberösterreich)

Zusammenfassung

Aus feinkörnigen Sand- und Silt/Mergelsteinen der Ressen-Schichten des Vorderen Glaselbachgrabens auf der Gosauer Sonnseite wird erstmals eine gut erhaltene Lebensspuren-Vergesellschaftung beschrieben. Diese umfasst sowohl Bewegungsspuren von kleinen Bivalven *(Protovirgularia)* als auch Ruhespuren *(Lockeia)*. Auch die typischen Flysch-Ichnofossil-Taxa *Arthrophycus* und *Scolicia* sowie eine spezielle Erhaltungsform von *Scolicia* vom Typ *„Bolonia“* und auch der Fazies überschreitende *Planolites* isp. konnten beobachtet werden. Die Spurenfossilien-Vergesellschaftung ist charakteristisch für gut durchlüftete, mäßig dynamische Ablagerungsräume im Mittelabschnitt eines Turbiditfächers. Mit Hilfe von kalkigem Nannoplankton konnte die stratigraphische Reichweite der Ressen-Schichten dieses Vorkommens auf höheres Untercampanium bis Obercampanium (Zonen-Intervall UC14dTP–UC15) eingeengt werden. Dieses Alter wird durch den Nachweis von Hungaropollis-Pollen untermauert, die erstmals im frühen Campanium auftreten.

Abstract

A well preserved assemblage of ichnofossils is described for the first time from grey turbiditic fine-grained sand- and silt/marlstones of the Ressen Formation in Gosau, Upper Austria. The ichnofossil-assemblage comprises locomotion *(Protovirgularia)* and resting *(Lockeia)* traces of minute bivalves. Also the typical flysch ichnotaxa *Arthrophycus* and *Scolicia* occur as well as a specific preservation variety of *Scolicia* (type *“Bolonia”*) and the facies-crossing form *Planolites* isp. The ichnofossil-assemblage is characteristic for well-oxygenated, moderately dynamic settings in the middle part of a turbidite fan. Calcareous nannofossils confirm an age range of these “flyschoid” sediments from the upper part of the Lower Campanian up to Upper Campanian, zone interval UC14dTP–UC15. This age is also supported by Hungaropollis pollen, which show their FO in the Early Campanian.

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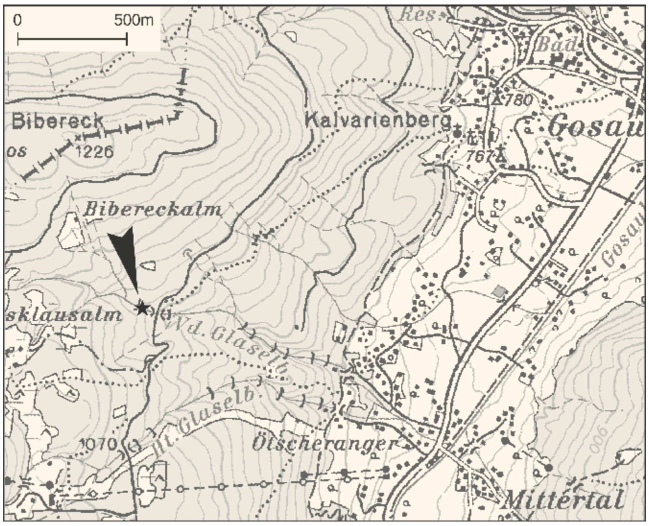
Lithology and Palaeoenvironment of the Ressen Formation

The classical region of the Gosau Group sediments is the surroundings of Gosau village. The Lower Gosau Subgroup is characterized by various continental and shallow marine sediments of Middle Turonian to Upper Santonian age. In the Lower Campanian, however, the sedimentary regime changed to deeper marine conditions with flyschoid sedimentation (e.g. FAUPL, 1978; FAUPL et al., 1987, FAUPL & WAGREICH, 1992a, b, 2000; WAGREICH, 1988, 2002; WAGREICH et al., 2000). This event marks the beginning of the Upper Gosau Subgroup. The "flyschoid" Ressen Formation is characterized by grey turbiditic sand- and siltstones with conglomeratic intercalations, which are bedded in a cm–dm scale. The classical locality of the Ressen Formation is situated on the upper part of Mt. Ressen (or Löckenmoosberg) in Gosau, Upper Austria. This formation is transgressively overlying a palaeokarst-relief of Upper Triassic lagoonal Dachstein Limestone.

In the early Campanian enormous quantities of clay and angular mineral grains and – somewhat less – crystalline rock fragments were transported by turbidity currents from the mainland into proximal pelagic environments and formed the coarse mass flow and turbiditic sand/silt/marlstone fan deposits of the Ressen Formation. The turbidites are thinning out in northwestern direction towards the Hornspitz-Bibereck region within a few kilometers (WAGREICH, 2002). Therefore the Ressen Formation of Vorderer Glaselbach creek on Mt. Bibereck, where our outcrops are situated, does not show more coarse grained sandstone-conglomerate sequences than on Mt. Ressen, but is generally much more finegrained (Pl. 1, Fig. 1; Text-Figs. 3–5).

The angular mineral grains (predominantly quartz) and rock fragments of the Ressen sandstones probably resulted from long-lasting, intensive rock weathering on the mainland. Due to a rising sea level repeated marine transgressions transported tremendous amounts of angular broken mineral- and rock-debris from the mainland via turbidity currents into deeper marine environments. Due to different specific weight and floating properties the material was separated into coarse, medium and fine grain sizes. Layers enriched in heavy minerals are characteristic for bottoms of the beds, while floating coaly plant debris often is spread on the bedding surfaces. Macrofossils occur only very scarcely.



Text-Fig. 1.
Topographic sketch of the surroundings of Gosau village.
Asterisk shows the Vorderer Glaselbach site.

Conspicuous sedimentary structures are rather scarce. Occasionally small-scale ripple marks can be observed on the silt/marlstone bedding surfaces (Text-Fig. 5).

The collection site of our samples is located in Vorderer Glaselbach creek in an altitude of about 1020 m, just below the waterfall (Text-Figs. 1–2; Pl. 1, Fig. 1).

Text-Fig. 2.
In the foreground settlements of Gosau Mittertal village.
The wooded ridge in the center of the photo with Mt. Bibereck (1226 m) consists in the higher part of deep(er) marine sediments of the Upper Gosau Subgroup (Ressen, Bibereck and Nierental Formations). Arrow points to location of the Vorderer Glaselbach site.
The high mountain in the background, Mt. Gamsfeld (2027 m), is built up by Upper Triassic Dachstein Limestone.

Text-Fig. 3.
Cm-bedded silt/marlstones alternate with dm-bedded sandstones, middle part of the turbidite fan of the Ressen Fm.

Early Exploration

The classical area of the Ressen Formation are the surroundings of the grindstone quarries ("Schleifsteinbrüche") on Mt. Ressen south of Gosau village. Already in the time of the Austro-Hungarian monarchy the grindstone was repeatedly the subject of scientific investigations. The famous German geologist Leopold von Buch visited the Salzkammergut along with Alexander von Humboldt in 1797. He defined the lithology of the Gosau grindstone as "red and white quartz pieces in a yellow-brown clayey matrix" (Buch, 1802). The Bohemian natural scientist August Emanuel Reuss described in 1854 the "grindstone layer" even more precisely as fine-grained sandstone, consisting of angular and sharp quartz grains, which are bound by clayey-calcareous cement. The paper by Švábenická et al. (2003) deals with the lithology and biostratigraphy of the Ressen Formation on the classical locality of the "Schleifsteinbruch" on Mt. Ressen and with the transition of the Ressen Formation into the variegated coloured Nierental Formation in the profile of Asterbach creek near our outcrops.

Weigel (1937) mentions already "Kriechspuren". Brinkmann (1934) postulates a second intergosavian tectonic phase between his middle and upper Gosau, which he called "Ressenphase". According to Weigel (1937) these movements took place after the late Early Campanian, but considerably earlier as the Maastrichtian, however, tectonics is not the topic of this paper.

Ichnology

Three rock samples were collected for the ichnologic study: 1, a fine-grained sandstone/siltstone slab around 30 mm thick; 2, a fine-grained sandstone/siltstone slab ca 26 mm thick; 3, a siltstone slab ca 25 mm in thickness. Sample 1 is covered on one side (= lower bedding plane according to the preservation of ichnofossils) with (mostly) well preserved, clearly defined specimens of trace fossils. Among them, *Planolites* cf. *P. beverleyensis* (Billings), *Protovirgularia* isp., *Lockeia* isp. and *Arthrophycus linearis* were determined. *Protovirgularia* and *Lockeia* represent locomotion (*P.*) and resting (*L.*) traces of minute bivalves. The sample shows a clear example of *Protovirgularia* connected with *Lockeia*; this situation upholds both the determination of the traces and the assumption of their common tracemaker. The fine-grained sandstone/siltstone slab (2) bears in its upper surface minute parallel ripples. The lower bedding plane preserved (in "sharp", minute hyporeliefs) the trace fossils of the ichnogenera *Protovirgularia* and *Arthrophycus* and large, poorly preserved (washed-out) ?*Scolicia* isp. and *Lockeia* isp. (Pl. 1, Figs. 2–4).

The second sample is a siltstone slab partly reworked by in-fauna (primary parallel lamination is preserved ca. from 50 %; thereby, the ichnofabric index = 3). Beside a "general reworking" (i.e., undeterminable spots), conspicuous traces with a prominent active backfill, 20 to 30 mm wide, are present. The backfill corresponds in minor parts of the traces to the "classical" meniscate backfill of the ichnogenus *Taenidium*; more often, the "menisci" reach only half of the trace width. In the trace axis, a zig-zag suture/pattern can be seen. Such a suture is typical, e.g., for the ichnogenus *Polykampton* which is a complex spreiten-structure with two size orders of laminae/lamellae; these, however, cannot be observed on the studied sample. Therefore, the only plausible determination of the traces is putting them to the ichnogenus *Scolicia* (relatively deeply subsurface burrows made by heart urchins and probably also some mollusk tracemakers) in a specific preservation variety (type *"Bolonia"*).

The above-mentioned features of ichnofabrics were proved by the study of thin sections of the siltstone slab (see Pl. 3 and its explanations).

All the above-mentioned ichnotaxa have already been found in the Cretaceous flysches (e.g., Uchman, 1999); the most common of them, i.e., *Planolites* isp., is a facies-crossing form. Also *Arthrophycus* and *Scolicia* have been reported manifold; they can be considered typical flysch ichnofossils of post-Jurassic strata. Bivalve traces (*Protovirgularia*, *Lockeia*) are not frequent in Cretaceous flysches; if present, they occur rather in middle parts of turbidite fans, in well-oxygenated, moderately dynamic settings. Ichnologically, it can be excluded that the samples come from distal turbidite sequences; these are, as a rule, characterized by the occurrence of graphoglyptids – the Nereites ichnofacies in a classical ichnofacies schedule (e.g. Seilacher, 1967).

Calcareous Nannofossils

Generally, sediments provided very poor and poorly preserved nannofossils. Placoliths are etched and mostly in fragments.

Text-Fig. 4.
Cm-bedded silt/marlstones from the middle part of the turbidite fan of the Ressen Fm.

The ***Gosau 1-I sample*** (fine-grained sandstone slab No 1, upper portion): smear slide contained rarely fragmented nannofossils specimens (±1/1 field of view of the microscope), some of them could not be identified. The assemblage is formed by *Reinhardtites levis, Broinsonia parca constricta, Hexalithus gardetae, Eiffellithus eximius, E. gorkae, Chiastozygus litterarius, Cyclagelosphaera margerelii, Prediscosphaera crenulata, P. grandis* (fragments of the broadly elliptical specimens), *Zeugrhabdothus bicrescenticus, Z. diplogrammus, Gartnerago obliquum, Watznaueria barnesae, Cribrosphaerella ehrenbergii, Calculites obscurus, Retacapsa crenulata, Broinsonia-Arkhangelskiella* (outer rims of large specimens), *Biscutum constans, B. coronum, Microrhabdulus attenuatus, Tranolithus orionatus*. The assemblage points to the upper part of the Lower Campanian up to Upper Campanian, zone interval UC14dTP–UC15 (Burnett, 1998) according to the common occurrence of *Reinhardtites levis, Broinsonia parca constricta* and *Eiffellithus eximius*.

The ***Gosau 2-I sample*** (upper portion of the mudstone slab) provided very rare and extremely badly preserved calcareous nannofossils (1–5 fragmented specimens / 10 fields of view of the microscope). Following species have been identified: *Broinsonia parca constricta, Arkhangelskiella cymbiformis, Watznaueria barnesiae, Zeugrhabdothus diplogrammus, Micula decussata, Retacapsa crenulata, Eiffellithus turriseiffelii, E. eximius, Cribrosphaerella ehrenbergii, Prediscosphaera cretacea, Gartnerago obliquum*. The assemblage confirms the Campanian age, zone interval UC14–UC15 (sensu Burnett, 1998) according to the common occurrence of *Broinsonia parca constricta* and *Eiffellithus eximius*.

The ***Gosau 3–I sample*** (lower portion of the mudstone slab) provided rare and badly preserved nannofossil assemblages with *Broinsonia parca parca-constricta* (fragments), *Arkhangelskiella* sp. (fragment), *Eiffellithus turriseiffelii, E. eximius, E. gorkae, Watznaueria barnesiae, Cribrosphaerella ehrenbergii, Zeugrhabdothus bicrescenticus, Z. diplogrammus, Retacapsa crenulata, Micula decussata, Hexalithus gardetae, Chiastozygus litterarius, Prediscosphaera* sp., *Cribrosphaerella-Psyktosphaera*? (one fragment of the large and broadly elliptical specimen), *Gartnerago obliquum, Calculites obscurus*. The assemblage points to the Campanian, zone interval UC14–UC15 (sensu Burnett, 1998) according to the common occurrence of *Broinsonia parca constricta* and *Eiffellithus eximius*.

Palynology

Gosau 1-I: The fine-grained sandstone sample provided a poor and mostly badly preserved palynomorph assemblage. The assemblage consists of pteridophyte spores – *Gleicheniidites senonicus* Ross, *Bikolisporites toratus* (Weyland & Greifeld) Srivastava, *Verrucosisporites* sp., triporate angiosperm pollen from the Normapolles group: *Trudopollis* sp.,

Text-Fig. 5.
Small-scale ripple marks on a siltstone bedding surface. The currents probably came from the left upper side.

Oculopollis sp., *Complexiopollis* sp. and dinoflagellate cysts *Odontochitina operculata* (O. WETZEL) DEFLANDRE & COOKSON, *Pervosphaeridium pseudhystrichodinium* (DEFLANDRE) YUN, *Dinogymnium* cf. *albertii* CLARKE & VERDIER and *Spinidinium* sp.

Gosau 2-I: The mudstone sample (upper part of the mudstone slab) provided rare palynomorphs, relatively better preserved than the previous one (see Pl. 4). The palynomorph assemblage yielded fern spores *Gleicheniidites senonicus* ROSS, *Plicifera delicata, Cyathidites minor* COUPER, *Echinatisporites varispinosus* (POCOCK) SRIVASTAVA, *Camarozonosporites ambigens* (FRADKINA) PLAYFORD, *Cicatricosisporites* sp., mostly triporate angiosperm pollen from the Normapolles group *Plicapollis* sp., *Hungaropollis* sp., *Suemegipollis triangularis* GÓCZÁN, *Interporopollenites* sp., *Krutzschipollis* sp. and dinoflagellate cysts *Pervosphaeridium truncatum* (DAVEY) BELOW, *Spiniferites multibrevis* (DAVEY & WILLIAMS) BELOW, *Surculosphaeridium? longifurcatum* (FIRTION) DAVEY et al., *Circulodinium distinctum* (DEFLANDRE & COOKSON), *Florentinia* sp., *Isabelidinium* sp., *Spiniferites ramosus* (DAVEY & WILLIAMS) LENTIN & WILLIAMS, *Achomosphaera ramulifera* (DEFLANDRE) EVITT, *Pterodinium cingulatum* (O. WETZEL) BELOW, *Spinidinium* sp. Chitinous foraminiferal linings appear as well. Fungal spores are relatively common.

The redeposited bisaccate pollen *Labiisporites granulatus* were originally described by LESCHIK (1956) from the Zechstein deposits in Neuhof near Fulda (Upper Permian) (determined by J. Drábková, Czech Geological Survey). KLAUS (1963) rarely recovered this species from black shales of the Upper Permian age from the Dolomites, Southern Alps (Grödener Sandstein and Bellerophonschichten). It is clear, that the Upper Permian pollen in our sample are redeposited from the nearby Haselgebirge deposits. Biostratigraphically important are *Hungaropollis* pollen with their first occurrence in Early Campanian (GÓCZÁN et al., 1967).

Gosau 3–I: The mudstone sample (lower part of the mudstone slab) provides very rare and badly preserved plant microfossils. Despite the fact that the assemblage comes from the same sample, bad preservation is probably caused by weathering. The palynomorph assemblage consists of the pteridophyte spores *Echinatisporites varispinosus* (POCOCK) SRIVASTAVA, *Plicatella* sp., *Zlivisporis* sp., *Gleicheniidites senonicus* ROSS, *the* rare fungal spores *Pluricellaesporites psilatus* CLARKE and dinocysts *Odontochitina* aff. *O. porifera* COOKSON, *Spiniferites crassipellis* (DEFLANDRE & COOKSON) SARJEANT, *Spinidinium* sp., *Pervosphaeridium pseudhystrichodinium* (DEFLANDRE) YUN. No angiosperm pollen occurred.

Discussion and Conclusions

A well preserved assemblage of ichnofossils is described for the first time from grey turbiditic fine-grained sand- and siltstones of the Ressen Formation in Gosau, Upper Austria. The ichnofossil-assemblage comprises locomotion (*Protovirgularia*) and resting (*Lockeia*) traces of minute bivalves. Also the typical flysch ichnofossil taxa *Arthrophycus* and *Scolicia* occur as well as a specific preservation variety of *Scolicia* (type *"Bolonia")* and the facies-crossing form *Planolites* isp. The ichnofossil assemblage is characteristic for well-oxygenated, moderately dynamic settings in the middle part of a turbidite fan. Ichnologically, it can be excluded that the samples come from distal turbidite sequences; these are, as a rule, characterized by the occurrence of graphoglyptids – the Nereites ichnofacies in a classical ichnofacies schedule (e.g., SEILACHER, 1967). Calcareous nannofossils confirm an age range of the upper part of the Ressen Formation ranging from the upper part of the Lower Campanian up to Upper Campanian, zone interval UC14dTP–UC15 (BURNETT, 1998). This age is also supported by *Hungaropollis* pollen, which show their FO in the Early Campanian.

Plate 1

Fig. 1: View of the collection site “Vorderer Glaselbach”.
Ressen Formation showing alternation of silt/marlstones with scarce sandstone layers of the middle part of a turbidite fan.
Dr. Gerhard W. Mandl for scale.

Fig. 2: Mudstone slab, *Scolicia* isp. in various taphonomic forms.

Fig. 3: Overall view of the fine-grained sandstone slab No. 1 (lower bedding plane) with trace fossils *Arthrophycus linearis*, *Protovirgularia* isp. and *Lockeia* isp.

Fig. 4: Detail of the previous image with *Arthrophycus linearis* (middle) and *Lockeia* isp. (randomly spread oval and almond-shaped knobs).

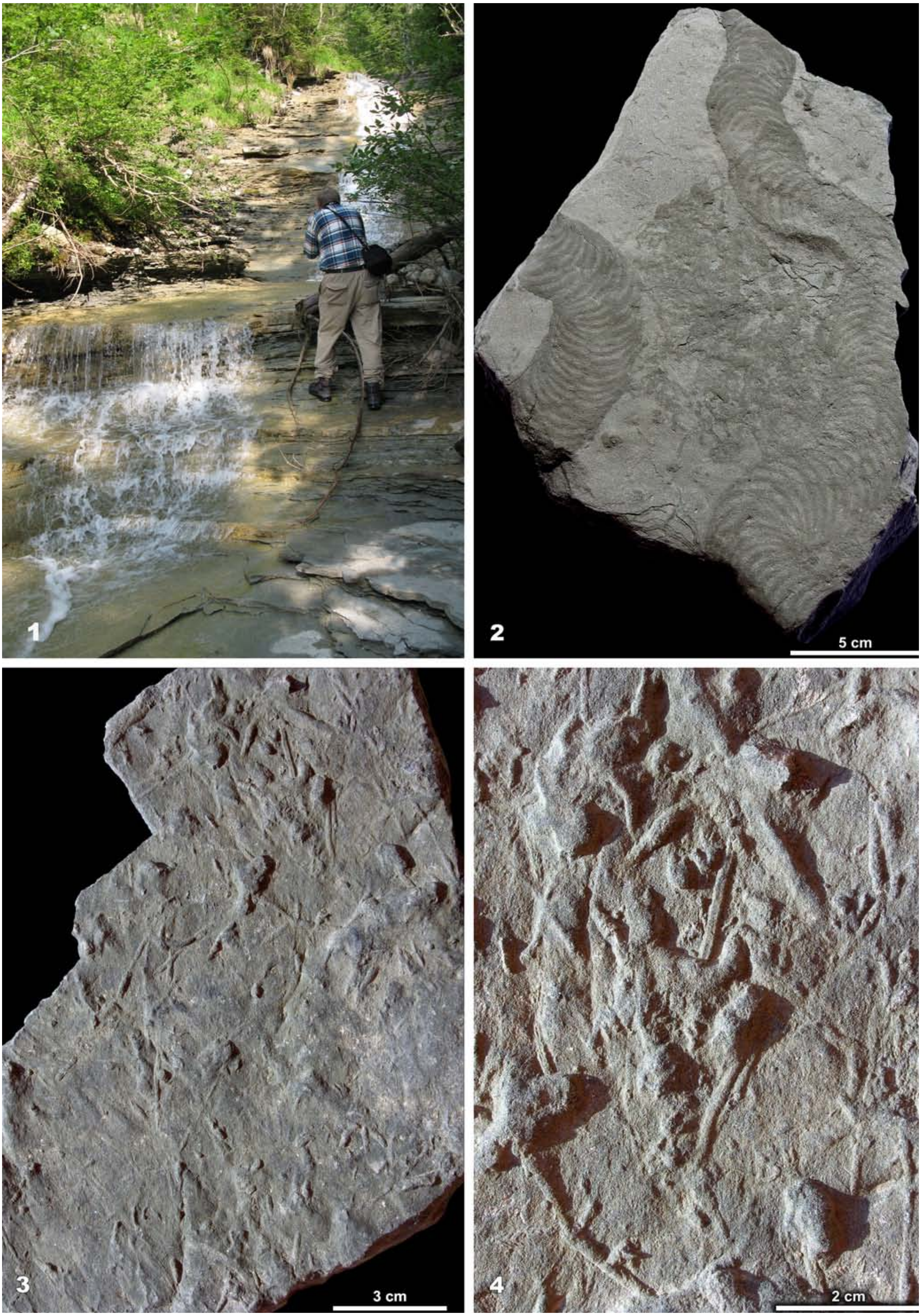

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Plate 2

Fig. 1: Mudstone slab, *"Bolonia"*, i.e. *Scolicia* isp. in a specific way of preservation.

Figs. 2, 3: Detailed views of the fine-grained sandstone slab No. 2 (lower bedding plane) with trace fossils *Lockeia* isp. and poorly preserved *Protovirgularia* isp.

Fig. 4: Detail of the fine-grained sandstone slab No. 1 (lower bedding plane) with well-preserved *Protovirgularia* isp.


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3 cm
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2 cm
4
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Plate 3

Fig. 1: Mudstone slab, vertically oriented thin section of its lower portion; well-visible ichnofabric (ca 12 % of the material removed; ichnofabric index = 2).

Figs. 2, 7: Mudstone slab, vertically oriented thin section, thin tunnels filled with material enriched in clay minerals.

Figs. 4, 6: Mudstone slab, vertically oriented thin section, clay minerals concentrated in the walls of tunnel-shaped trace fossils.

Fig. 3: Mudstone slab, horizontally oriented thin section, lamination resulted from active backfilling of the trace fossil *Scolicia* isp.

Fig. 5: Mudstone slab, vertically oriented thin section with undisturbed sedimentary laminae.

Fig. 8: Mudstone slab, vertically oriented thin section with foraminifer indet. (*Meandrospira*?).

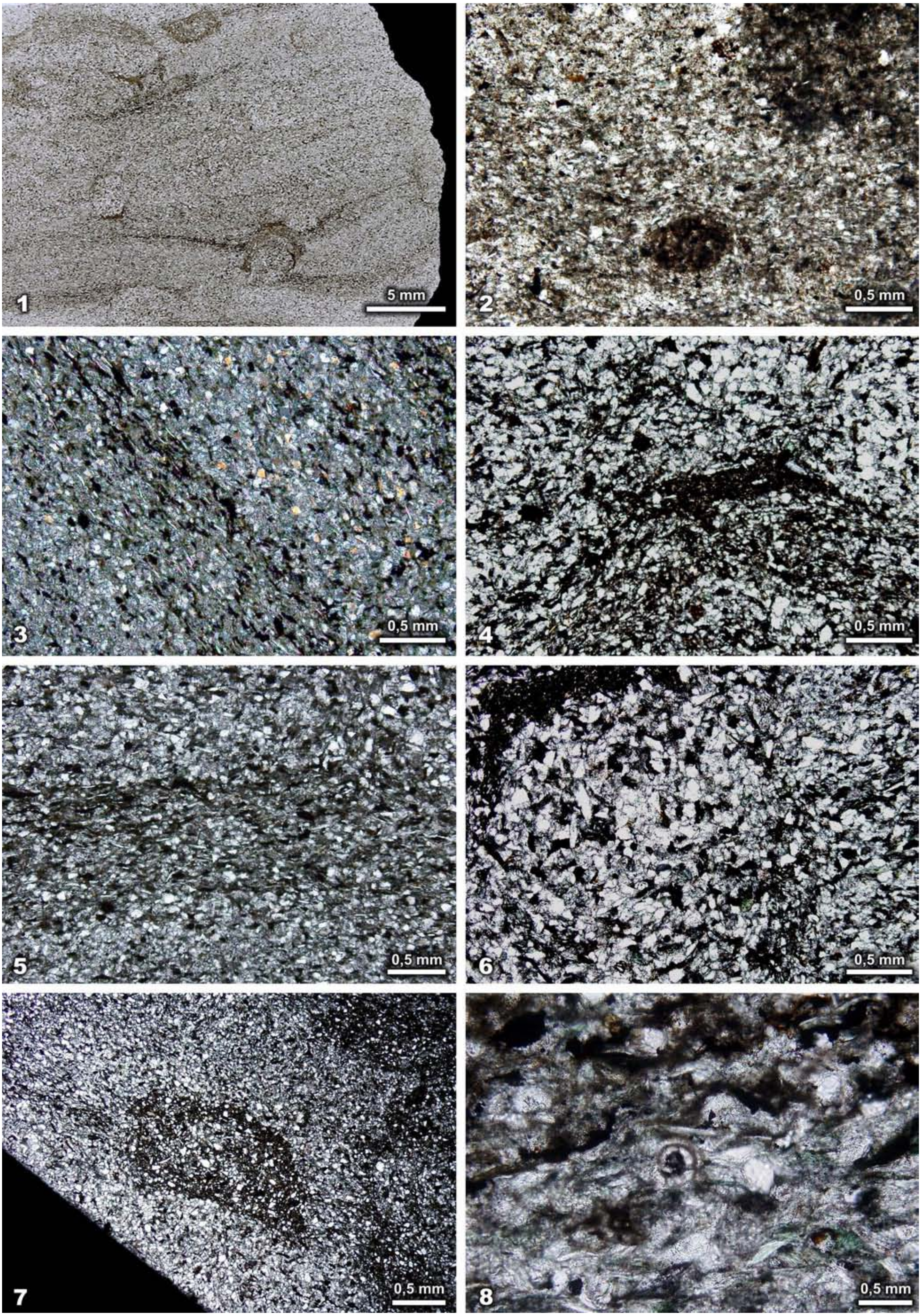
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Plate 4

Palynomorphs. Scale bar 10 µm.

Fig. 1: *Pervosphaeridium* cf. *truncatum* (DAVEY) BELOW 1982a.
Sample Gosau 2-I.

Fig. 2: *Achomosphaera ramulifera* (DEFLANDRE) EVITT 1963.
Gosau 2-I.

Fig. 3: *Odontochitina* aff. *O. porifera* COOKSON 1956.
Gosau 3-I.

Fig. 4: *Dinogymnium* cf. *albertii* CLARKE & VERDIER 1967.
Gosau 1-I.

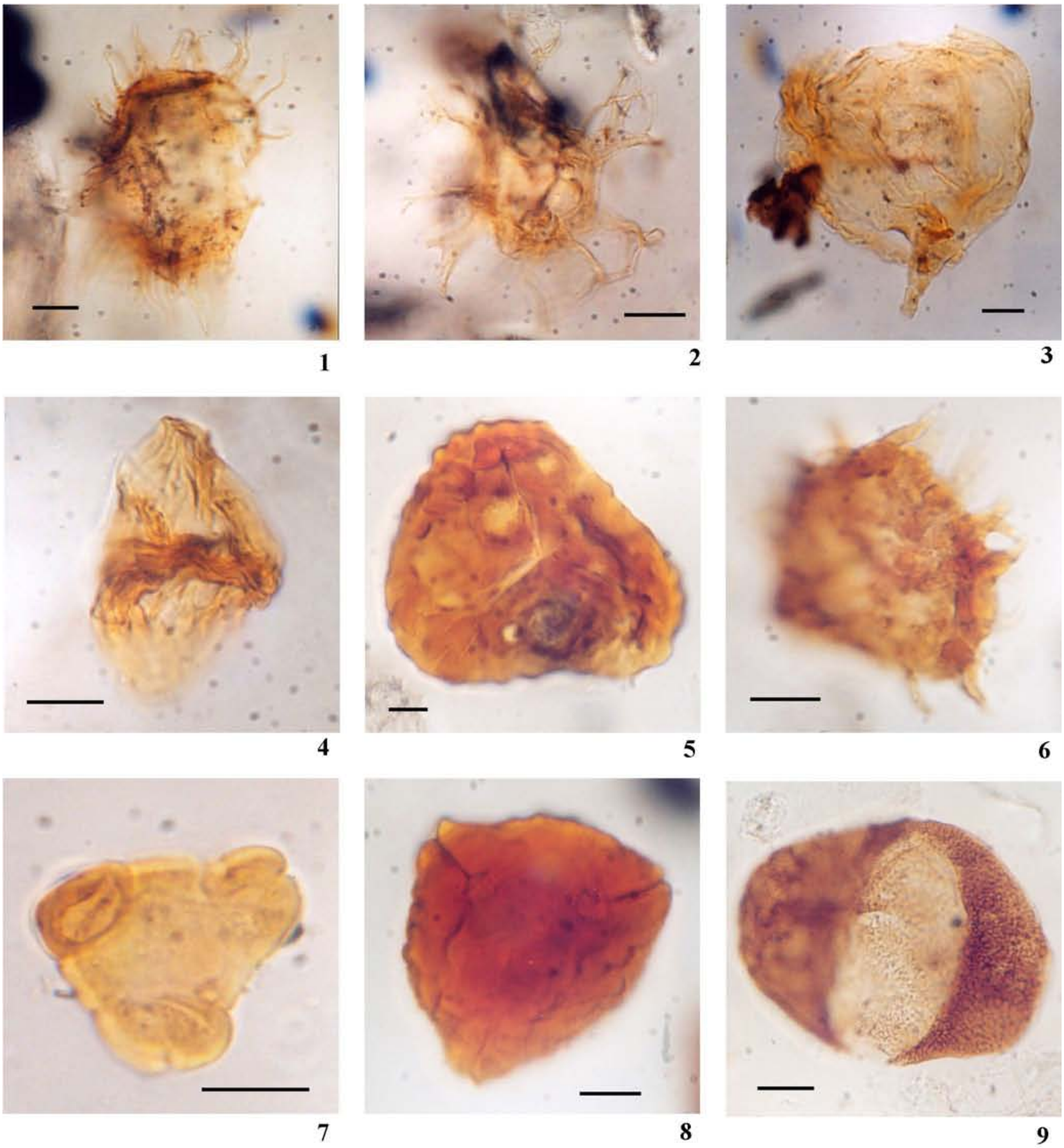
Fig. 5: *Bikolisporites toratus* (WEYLAND & GREIFELD) SRIVASTAVA 1975.
Gosau 1-I.

Fig. 6: *Echinatisporis varispinosus* (POCOCK) SRIVASTAVA 1975.
Gosau 3-I.

Fig. 7: *Suemegipollis triangularis* GÓCZÁN 1963.
Gosau 2-I.

Fig. 8: *Krutzschipollis* sp.
Gosau 2-I.

Fig. 9: *Labiisporites granulatus* LESCHIK.
Gosau 2-I, redeposition from the Upper Permian Haselgebirge.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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

Grindstone Mining in Gosau – the Classical Locality of the Ressen Formation (Lower Campanian, Gosau, Upper Austria)

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5 Text-Figures, 2 Plates

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Northern Calcareous Alps
Calcareous nannofossils
Upper Gosau Subgroup
Sandstone petrology
Ressen Formation
Palynomorps
Campanian
grindstone
Gosau

Contents

Der Gosauer Schleifsteinbruch – Locus Classicus der Ressen-Formation (Untercampan, Gosau, Oberösterreich

Zusammenfassung

Die Umgebung der Gosauer Schleifsteinbrüche ist die klassische Lokalität der Ressen-Formation. Kommerziell vertriebene Wetzstein-Produkte wurden petrologisch untersucht. Weiters wurden Proben der sandig-mergeligen Überlagerung des ökonomisch genutzten Sandsteins im Gosauer Schleifsteinbruch im Hinblick auf kalkiges Nannoplankton, Palynomorphen und Mineralogie studiert. Das Vorkommen des Nannoplankton-Taxons *Broinsonia parca parca* spricht für ein frühes Untercampan-Alter (Nanno-Zone UC14a sensu Burnett, 1998) am Beginn der mergeligen Überlagerung, die als Abraum verworfen wird.

Abstract

The grindstone quarries represent the classical region of the Ressen Formation (Upper Gosau Subgroup). Commercial grindstone products (whetstones) from Gosau were analyzed from a petrological point of view. In addition the marly caprock-layers on top of the economically exploited silt/sandstones were studied stratigraphically by means of calcareous nannoplankton and palynomorphs and also from a clay-mineralogical point of view. The presence of the nannofossil taxon *Broinsonia parca parca* evidences zone UC14a sensu Burnett (1998), which confirms an early Lower Campanian age for the beginning of the marly caprock sedimentation.

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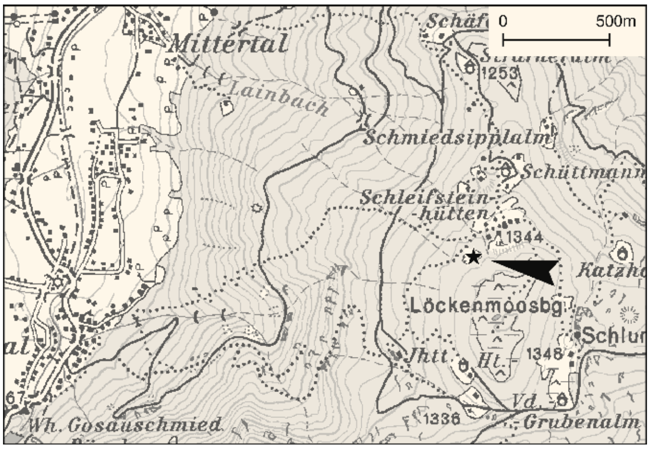
Early Exploration

The Gosau grindstone, which was mined on Mt. Ressen or “Löckermoosberg” (Text-Fig. 1), repeatedly was the subject of scientific investigations in the early time of geological research in the Austro-Hungarian monarchy. The famous German geologist Leopold von Buch visited the Salzkammergut along with Alexander von Humboldt in 1797. BUCH (1802) defined the lithology of the Gosau grindstone as “red and white quartz pieces in a yellow-brown clayey matrix”. Also LILL von LILIENBACH (1830) dealt with these commercially exploited sandstones. The Bohemian natural scientist August Emanuel REUSS (Text-Fig. 2) described in 1854 the “grindstone layer” even more precisely as fine-grained sandstone, consisting of angular and sharp quartz grains, which are bound by clayey-calcareous cement. Friedrich SIMONY (1889–1895) described in his unique monography of the Dachstein area also the grindstone mining in Gosau (Text-Fig. 3). Most of the later more comprehensive papers dealing with the geology of the Gosau region also refer to the peculiar grindstone mining on Mt. Ressen. For instance KITTL (1903) describes briefly the *“Schleifsteinbrüche am Löckermoos: On top of the fossil-rich marls of the Hofergraben follow marls poor in fossils ... and the slightly SSE dipping sandstones without fossils [of the Schleifsteinbrüche] represent the top of the sequence ...”.*

The transgressional clastic sediments on Mt. Ressen play also a role in Alpine tectonic literature. Brinkmann (1934) postulates a second intergosavian tectonic phase between his middle and upper Gosau, which he called “Ressenphase”. He also considers the sandstones of the Ressen Formation to represent in part a lateral equivalent of the Nierental Formation. According to Weigel (1937) the mentioned tectonic movements took place after the late Early Campanian, but considerably earlier as the Maastrichtian. Ganss (1954) deals with the peculiar petrological properties responsible for the excellent quality of the grinding stone: *“hard quartz grains embedded in a tough clayey-marly matrix”*. As Brinkmann before him (1934), he considered the Ressen Formation as being partly coeval with the lower part of the Nierental Formation. A series of more recent papers deals in particular with the depositional environment and the biostratigraphy of the Ressen Formation (e.g. Faupl, 1978; Faupl et al. 1987; Faupl & Wagreich, 1992a, b; Faupl & Wagreich, 2000; Kollmann & Summesberger, 1982; Wagreich, 1988; Švábenická et al., 2003).



Text-Fig. 1.
Topographic sketch of the area E of Gosau Mittertal village.
Arrow shows the grindstone quarry site.

Our paper is illustrated by a series of historic photos (Pl. 1, Fig. 1; Pl. 2; Anonymus, 1933).

Lithology and Palaeoenvironment of the Ressen Formation

Grey turbiditic (“flyschoid”) sand- and siltstones with conglomeratic intercalations of the Ressen Formation, which are bedded in a cm–dm scale, represent the base of the Upper Gosau Subgroup, which earlier was called “deeper water Gosau” or – in its lower part – “flyschoid Gosau”. The classical locality of the Ressen Formation is situated on the upper part of Mt. Ressen (also called Löckenmoosberg) in Gosau, Upper Austria. It is transgressively overlying a palaeokarst-relief of lagoonal Dachstein Limestone with an unconformity of 120 million years. Enormous quantities of clay and heavily weathered, angular broken mineral grains and – more scarcely – crystalline rock fragments were transported by turbidity currents from the mainland into proximal pelagic environments, where they formed the coarse mass flow and turbiditic sandstone/claystone submarine fan deposits of the Ressen Formation. According to WAGREICH (2002) the turbidites thin out within a few kilometers to the NW. Therefore the Ressen Formation in the Hornspitz-Bibereck area does not show thick sandstone sequences as on Mt. Ressen, but is generally more finegrained, consisting predominantly of (marly) sand/siltstones and marls.

Thin-Sections of Ressen Siltstone

Two thin-sections were made from a finer grained and a coarser grained commercial grinding stone product of the Ressen siltstone:

1. Finer grained equigranular siltstone, mean grain-size 30–50 µm, some grains up to 1 mm.

Mineralogy: quartz, plagioclase, potash feldspar, muscovite, biotite (partially replaced by chlorite), chlorite, sparry calcite grains (partially twinned). Accessory minerals include zircon, tourmaline, rutile, apatite, pyrite, limonite, leucoxene. Quartz is often splintery, with aspect ratios up to 1:4.

2. Coarser grained equigranular fine-grained sandstone/siltstone, mean grainsize 100–175 µm.

The mineralogy of the clastic grains is similar to the siltstone of finer grain-size described before. In this sample, however, rock fragments can also be recognized: they include microsparitic carbonate clasts with finely disseminated black organic content, showing clear syntaxial border. Accessory minerals are also similar to the finer variety. In this thin section a zoned tourmaline was also observed. Beside some granitoid clasts (quartz + feldspar), different metamorphic rock-fragments occur: very fine-grained graphite-sericite schists, a clast of serpentinite, and of chloritoid-bearing schist. The cement is composed of clay minerals, microcrystalline quartz and carbonate.

Therefore the Gosau grindstone is an equigranular quartz rich sand-/siltstone (showing different mean grain-sizes), in which predominantly angular mineral grains are embedded in a tough clayey matrix.

Text-Fig. 2.
The “geognostic” map of the Gosau valley by August Emanuel Reuss (1854) shows location of grindstone quarries (“Schleifstein-Brüche Auf der Ressen”). In the legend marl and sandstone without fossils are mentioned.

Text-Fig. 3.
The photo by Friedrich Simony from the year 1886 shows one of the grindstone quarries (?or the only one at that time) in about 1300 m altitude.
Grindstone products are prepared for the transport in the valley (Gosau, 736 m).

Provenance of Ressen Siltstones

On the basis of thin section mineralogy the provenance area of Ressen sandstones and siltstones was built up by metamorphic, magmatic and sedimentary rocks.

The greatest contribution was supplied by metamorphic rocks. They include very-low-grade slates, siltstones and quartzites with sericite ± chlorite and generally show a high, finely disseminated organic content. A rock-fragment with very-low-grade characteristics contained also a chloritoid crystal. Coarser-grained muscovite and biotite micaschist fragments witness a subordinate greenschist facies contribution. Only one serpentinite grain was observed in the siltstone.

Magmatic rocks are represented by different, basic to acidic aphanitic to spherulitic devitrified volcanic groundmass fragments. Coarser-grained polycrystalline quartz and feldspar fragments originated from a granitoid source; or else they came from higher-grade metamorphic rocks.

Cherts and microsparitic carbonates are the sedimentary rock contributions. Both in sandstones and siltstones glauconite grains are evenly distributed, moreover coalified particles are also present. Organic components include very scarce foraminifers and echinoid fragments. The accessory minerals (zircon, tourmaline, rutile, apatite, pyrite, limonite, leucoxene) support the conclusions described before.

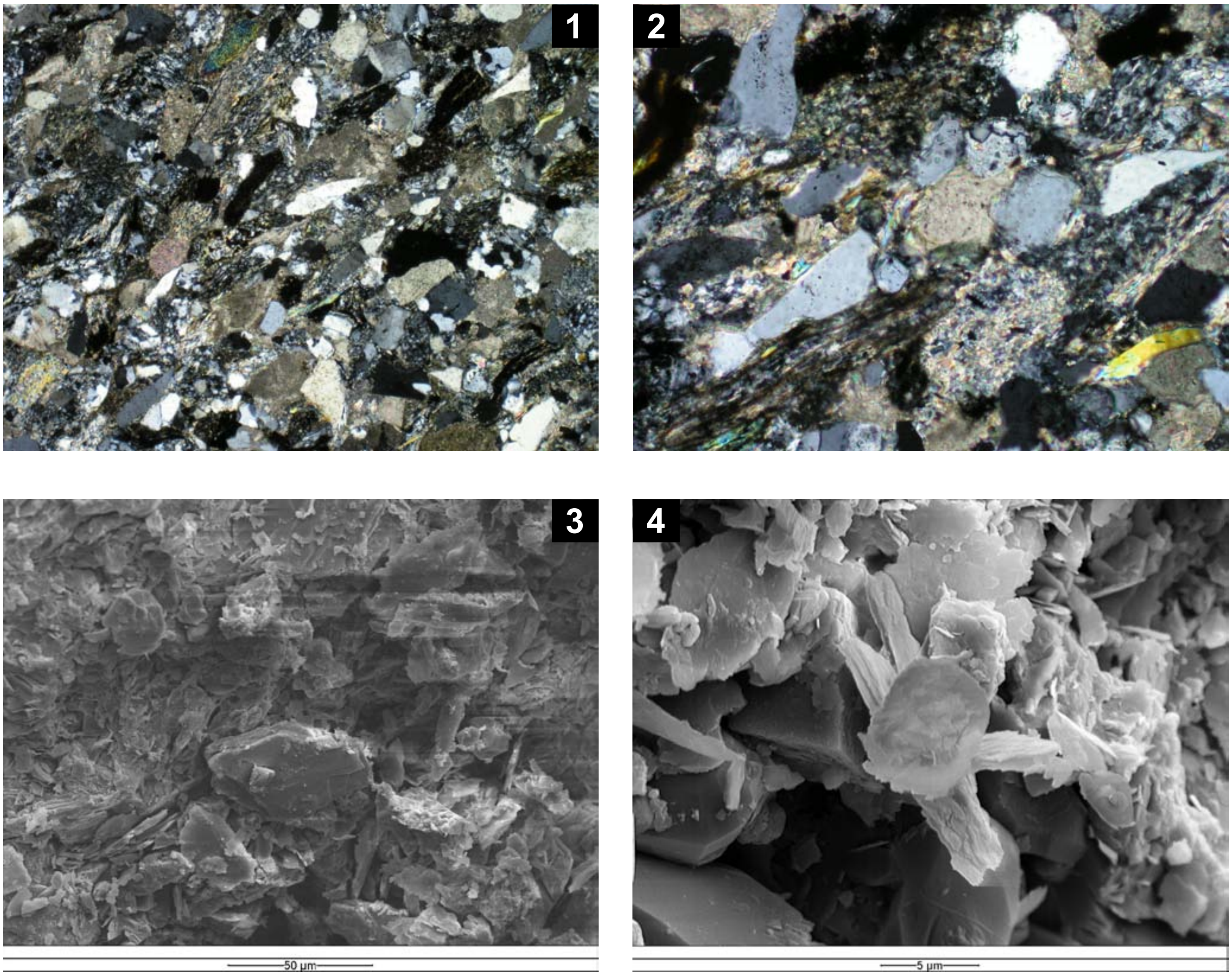
Why does the Gosau Grindstone grind so well?

So far we did not examine the grindstone by geotechnical methods. Therefore our interpretations are based only on petrological investigations in thin-sections and by SEM. The Gosau grindstone is a quartz rich sandstone known as Ressen Formation. The predominantly angular mineral grains are embedded in a tough matrix composed of clay minerals, microcrystalline quartz and carbonate (Text-Fig. 4). Rounded grains would scratch rather than grind, whereas the edges of angular grains regularly break away during grinding and polishing leaving the grinding function intact. Another important feature is a uniform grain size for each grindstone type. Angular mineral grains resulted from an especially long lasting weathering on the mainland. Caused by a rising sea level repeated marine transgressions transported tremendous amounts of intensively weathered sharp-edged mineral and rock debris via turbidity currents into deeper marine areas. Due to different specific weight and floating properties the material was separated into coarse, medium and fine grain sizes. Layers enriched in heavy minerals, sometimes breccias/conglomerates (Pl. 1, Fig. 3), are characteristic for the bottom of layers, while coaly plant debris often is spread on the bedding surfaces (Pl. 1, Fig. 2).

Ressen sandstone slabs of minor quality are used up to the present for the construction of local tourist trails (Text-Fig. 5).

The Schleifsteinbruch Caprocks (Upper Part of the Ressen Formation)

The Ressen Formation in the lower and middle part comprises a sequence of well bedded sandstones with soft and brittle fine-bedded (sandy) marl intercalations and conglomerates. On the bedding surfaces of the sandstones sometimes coalified plant debris (also small coal particles) can be observed. Except of scarce trace fos-



Text-Fig. 4: Petrology of Gosau-whetstones.
1: Thin-section of a commercial whetstone product (Ressen sandstone) showing angular mineral (mostly quartz) grains in a clayey matrix.
2: Thin-section of a commercial whetstone product (Ressen sandstone) showing angular mineral (mostly quartz) grains in a clayey matrix.
3: SEM micrograph of fine-grained Ressen sandstone (whetstone) showing angular mineral (mostly quartz) grains in a clayey matrix.
4: SEM micrograph of very fine-grained Ressen siltstone (whetstone) showing angular (mostly quartz) grains in a clayey matrix.

sils (*Planolites* s.l.) the sediments seem to be unfossiliferous. The sandstone of the grindstone quarry is overlain by well exposed caprocks of (sandy) marls. At present the basis of the grinding stone is not cropping out; however, Reuss (1854) mentions *"grey, thin-bedded sandy marls, which underlay the grinding stone"*.

List of Caprock Samples

Sample No. GO3: Marls overlying the sandstone in the grinding stone quarry (Schleifsteinbruch), which is quarried in small scale by Mr. Manfred Wallner.

Sample No. GO3A: brittle grey marls from the western part of the quarry;

Sample No. GO3B: soft, ochre weathered marls from the eastern part of the quarry.

Mineralogy

The bulk mineralogical composition of the two marl samples (Nos. GO3A/GO3B) from the top-set of the Schleifsteinbruch is rather homogenous. Calcite (12/24 mass-%) is present in moderate amounts, dolomite (7/4 mass-%) and feldspar (mostly plagioclase 5/8 mass-%) in rather low amounts. The predominant mineral group are the layer silicates (63/53 mass-%), which are represented mainly by muscovite and chlorite. Also traces of paragonite are present.

Also the clay mineralogical composition of samples Nos. GO3A/GO3B is quite homogenous. Illite (61/64 mass-%) predominates, chlorite (25/24 mass-%) can be found in moderate amounts, while smectite (11/10 mass-%) occurs in rather low quantities and kaolinite (3/2 mass-%) only in very low contents.

From the mineralogical composition it can be concluded, that the provenance region of the marls consisted of slightly metamorphic rocks rich in mica and chlorite.

Palaeontology and Biostratigraphy

Foraminifers

Above mentioned basal caprock sandy marls were washed for microfossils, however, despite of one poorly preserved specimen of the foraminifer *Ataxophragmium* in sample No. GO3A, no microfossils were found. This taxon is without any stratigraphic value (determination courtesy of Mrs. Lenka Hradecká, Czech Geological Survey, Prague).

Calcareous nannofossils

Sediments of samples Nos. GO3A, B provided very poor (1–3 specimens per 1 field of view of the microscope) and poorly preserved nannofossils. Placoliths are etched and mostly in fragments. Nannofossil assemblages contain rare specimens of *Lucianorhabdus cayeuxii* (both species A and B sensu WAGREICH, 1992) and rare specimens of *Broinsonia parca parca*. On rare occasions, *Rucinolithus hayi* and *Arkhangelskiella cymbiformis* are present. *Broinsonia parca parca* evidences zone UC14a (BURNETT, 1998), that is correlated with the lower part of Lower Campanian.

Concerning the Lower Campanian marker species *Broinsonia parca parca*, it is not easy to distinguish sometimes this subspecies from the other one of *Broinsonia parca expansa,* its first occurrence is mentioned from the uppermost Turonian (LEES, 2008). Probably transitional forms of *B. p. expansa-parca* were observed in sample No. GO3A. Unfortunately, their identification was problematical due to the poor preservation of specimens. Well identifiable specimens of *Broinsonia parca parca* were only found in sample GO3B. They show the following phenomena: 1. relatively large placolith, 2. broadly elliptical in outline, 3. broad outer rim, 4. approximately the same size of outer rim and central area in short axis of ellipsoid.

WAGREICH (1992) mentioned the first occurrence of *Lucianorhabdus cayeuxii* species B ("curved forms") within the upper part of the Santonian in the Lower Gosau Group of Austria.

Palynomorphs

Both marine microplankton and spore-pollen assemblages were studied. The preservation of most palynomorphs was rather poor and the quantity was low. Sample No. GO3B provided palynomorphs for biostratigraphical and palaeoecological evaluation.

The dinoflagellate cyst assemblage consists of *Spiniferites membranaceus* and of *Dinogymnium*, namely *Dinogymnium acuminatum* EVITT et al., *Dinogymnium denticulatum* (ALBERTI) EVITT et al., *Dinogymnium curvatum* (VOZZHENNIKOVA) LENTIN & WILLIAMS. *Dinogymnium denticulatum* was recorded so far from the Santonian and Campanian–Maastrichtian sections (EVITT et al., 1967).

Dinogymnium acuminatum was recorded from the Coniacian–Maastrichtian (WILLIAMS & BUJAK, 1985). *Odontochitina operculata* (O. WETZEL) DEFLANDRE & COOKSON also appears.

Pteridophyte spores consist of schizaeaceous forms – *Cicatricosisporites* sp. and *Plicatella* sp.

Triporate pollen from the Normapolles group are represented by *Minorpollis* sp., *Pseudoplicapollis* sp., *Oculopollis* cf. *principalis, Oculopollis* sp., *Interporopollenites* sp. and *Hungaropollis* sp. The dominance of *Oculopollis* pollen and the presence of *Hungaropollis* pollen correspond to the Late Santonian – Early Campanian age (GOCZÁN et al., 1967).

Text-Fig. 5.
Sandstone slabs are used up to the present for the construction of local tourist trails.

Rare redeposition of the Permian age (bisaccate pollen aff. *Lueckisporites* sp.) was observed (KLAUS, 1963; LESCHIK, 1956).

Palaeoecological Remarks

From the palaeoecological point of view, the presence of the dinoflagellate cyst of the genera *Odontochitina* and *Dinogymnium* reflects an environment with salinity fluctuations. The "flyschoid" sediments primarily were deposited in a shallow marine environment (MAY, 1977) and subsequently transported by turbidity currents into the open sea, where they form proximal fan deposits.

Acknowledgements

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Plate 1

Fig. 1: Contemporary grindstone quarry with 60 years old machines for grindstone cutting.

Fig. 2: Exposure of Ressen Formation along the forest road from Gosau Hintertal to the grindstone quarry. The sequence is dominated by sandstones and intercalated marls.

Fig. 3: Meter-thick conglomerate bed in proximal turbidites of the Ressen Formation along the forest road from Gosau Hintertal to the grindstone quarry.

Fig. 4: Bedding surface with spectacular loadcasted ripples in the Ressen Formation of the grindstone quarry (slab in property of Franz Fasl, Gosau).

Fig. 5: Drilling core of grindstone showing cross-bedded sandstone.

Fig. 6: Bedding plane of Ressen sandstone with coalified plant debris.

Fig. 7: Ressen sandstone with mineralized (?Fe/Mn) marl clasts.

Fig. 8: Ressen sandstone with mineralized (?Fe/Mn) marl clasts.

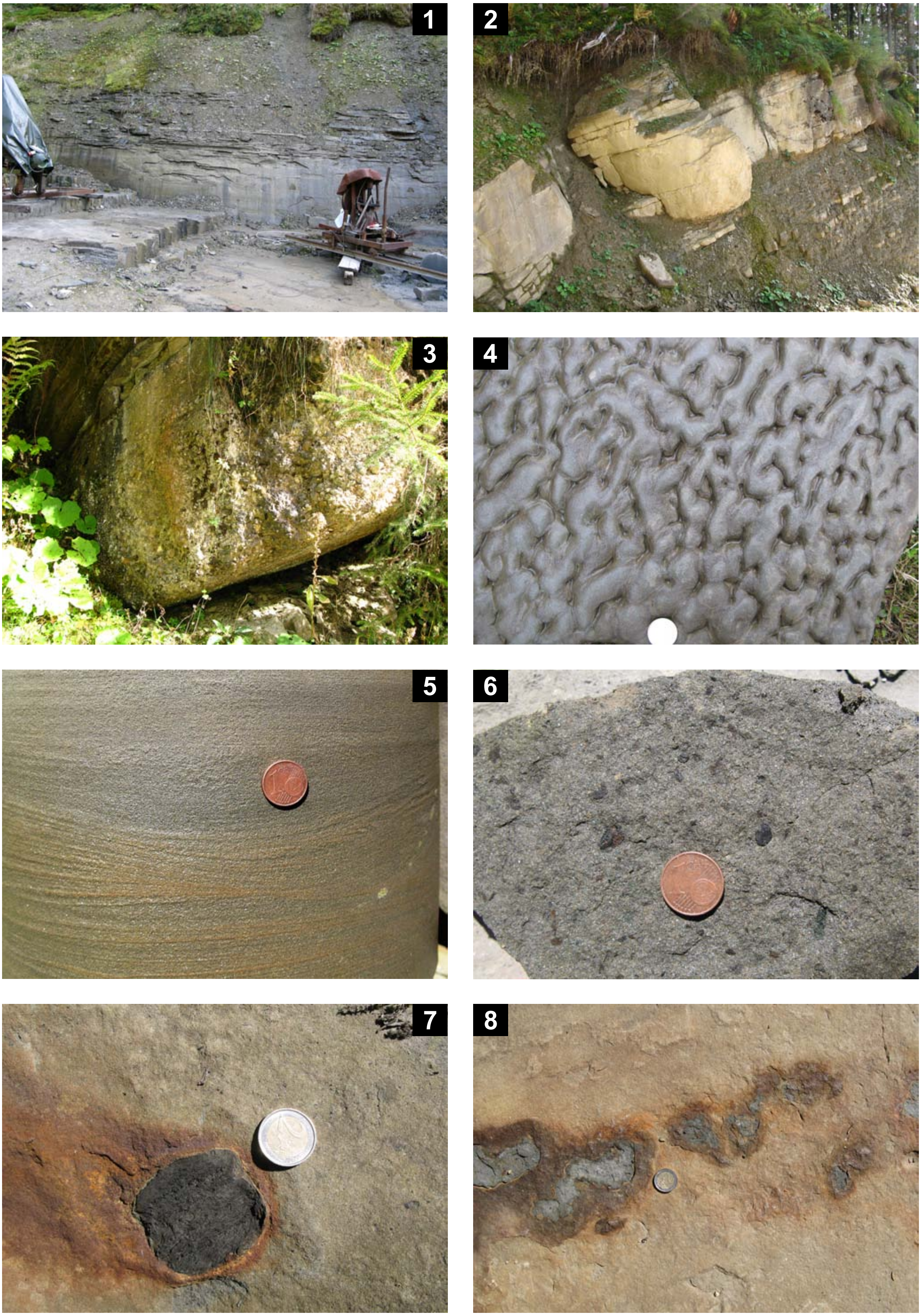
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Plate 2

Fig. 1: Traditional grindstone wheels for sharpening various tools.

Fig. 2: Group of workers proudly presenting a giant grindstone wheel in their quarry. Note typical shelter and tools.

Fig. 3: Ten years later (1933) proud workers present a giant grindstone wheel, diameter 1.80 m, weight 2000 kg.

Fig. 4: Careful transport of the giant grindstone wheel on a sledge downhill August 4th, 1933.

Fig. 5: Various tools and equipment for grindstone mining (1933).

Fig. 6: Various larger tools and equipment in connection with grindstone mining (1933).

Fig. 7: Punching the grindstone wheel with the “Zweispitz” (double pointed hammer) in 1933.

Fig. 8: Washing the grindstone products before selling – a job for women (1933).


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ABHANDLUNGEN DER GEOLOGISCHEN BUNDESANSTALT
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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

An Early Eocene Fauna and Flora from "Rote Kirche" in Gschliefgraben near Gmunden, Upper Austria

Alfréd Dulai[1], Lenka Hradecká[2], Magda Konzalová[3], György Less[4], Lilian Švábenická[2] & Harald Lobitzer[5]

4 Text-Figures, 7 Plates, 4 Tables

Österreichische Karte 1:50.000
Blatt 66 Gmunden

Ultrahelveticum
Salzkammergut
Gschliefgraben
Palynomorphs
Nannofossils
Foraminifera
Brachiopods
Rote Kirche
Ypresian

Contents

Beiträge zur frühеozänen Fauna und Flora der Lokalität Rote Kirche im Gschliefgraben bei Gmunden, Oberösterreich

Zusammenfassung

Erstmals wird eine Brachiopoden-Vergesellschaftung aus dem Eozän Österreichs beschrieben. Sie umfasst 6 Taxa (*Gryphus kickxii*, *Meznericsia hantkeni, Terebratulina tenuistriata*, *Orthothyris pectinoides*, *Megathiris detruncata*, *Argyrotheca sabandensis*?) und stammt aus mergeligen Kalken bzw. sandigen Mergeln des Ultrahelvetikums der Lokalität Rote Kirche im Gschliefgraben bei Gmunden. Die Dominanz der Genera *Gryphus* und *Terebratulina* spricht für einen relativ tieferen Ablagerungsraum, wahrscheinlich im äußeren Schelfbereich. Groß- und Kleinforaminiferen, kalkige Nannofossilien und Palynomorphen / Dinoflagellaten ermöglichen eine Einstufung der hangenden Ablagerungen des Aufschlusses Rote Kirche als frühes Eozän (spätes Ypresium). Eine neue Großforaminiferen-Chronosubpecies, *Orbitoclypeus multiplicatus gmundenensis*, die für die Zone SBZ 10 charakteristisch ist, wird beschrieben. Die Palynomorphen-Assoziation wird von marinen Dinoflagellaten dominiert. Es konnten aber auch Süß- bzw. Brackwasser-Algenzysten von Zygnemataceae (*Ovoidites elongatus*) nachgewiesen werden, die einen terrestrischen Einfluss bezeugen. Im Gegensatz zu den Pollen-Floren des Danium und des Thanetium Eurasiens stellen die ausgestorbenen Pollen-Leitformen der Normapolles im untersuchten (etwas jüngeren) Material lediglich einen geringen Anteil der Assoziation dar.

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Abstract

An integrated study of brachiopods, small and larger foraminifera (orthophragmines and nummulitids), calcareous nannofossils and palynomorphs / dinocysts was carried out from the marly limestones respectively sandy marls of the Ultrahelvetic zone at the locality Rote Kirche in the Gschliefgraben near to Gmunden in Upper Austria. Microfossils (including larger foraminifera) indicate the Early Eocene, more precisely the early-middle part of the late Ypresian (the NP 11 and NP 13 calcareous nannofossils, the P 7–8 planktonic foraminiferal and the SBZ 10 shallow benthic zones). Eocene brachiopods are described for the first time from Austria. Six species (*Gryphus kickxii*, *Meznericsia hantkeni, Terebratulina tenuistriata*, *Orthothyris pectinoides*, *Megathiris detruncata*, *Argyrotheca sabandensis*?) were identified, the taxonomic composition of which (based on the dominance of *Gryphus* and *Terebratulina*) refers to deeper water, probably outer shelf environment. These palaeoecological conditions are also confirmed by the composition of larger foraminifera. A new orthophragminid chronosubspecies, *Orbitoclypeus multiplicatus gmundenensis*, characteristic for the SBZ 10 Zone, is introduced. The palyno-association is dominated by marine dinoflagellates but freshwater-brackish algal cysts of Zygnemataceae (*Ovoidites elongatus*) are also present, testifying terrestrial input. In the Cretaceous and the Palaeocene (Danian and Thanetian) pollen floras of the Eurasian Normapolles Province Normapolles pollen are a characteristic element. In the investigated association, however, Normapolles are present only in low quantity.

Location and Geological Setting

The Gschliefgraben area comprises a large land slide (e.g. Koch, 1898; Baumgartner & Mostler,1978; Millahn et al., 2008; Weidinger, 2009; Weidinger & Niesner, 2009) SE of the town of Gmunden in Upper Austria, exposing rocks of Jurassic, Cretaceous and Palaeogene age, which are attributed to the Ultrahelvetic thrust unit. Due to the mass movement and an intense tectonic overprint by a major strike slip system (Egger et al., 2009), extended undisturbed sections do not exist. In the south, the Ultrahelvetic rocks are bordered by middle Triassic limestones of the northern rim of the Northern Calcareous Alps. In the north, Upper Cretaceous turbidites of the Rhenodanubian Flyschzone show a tectonic contact to the Ultrahelvetic unit (Text-Fig. 1).

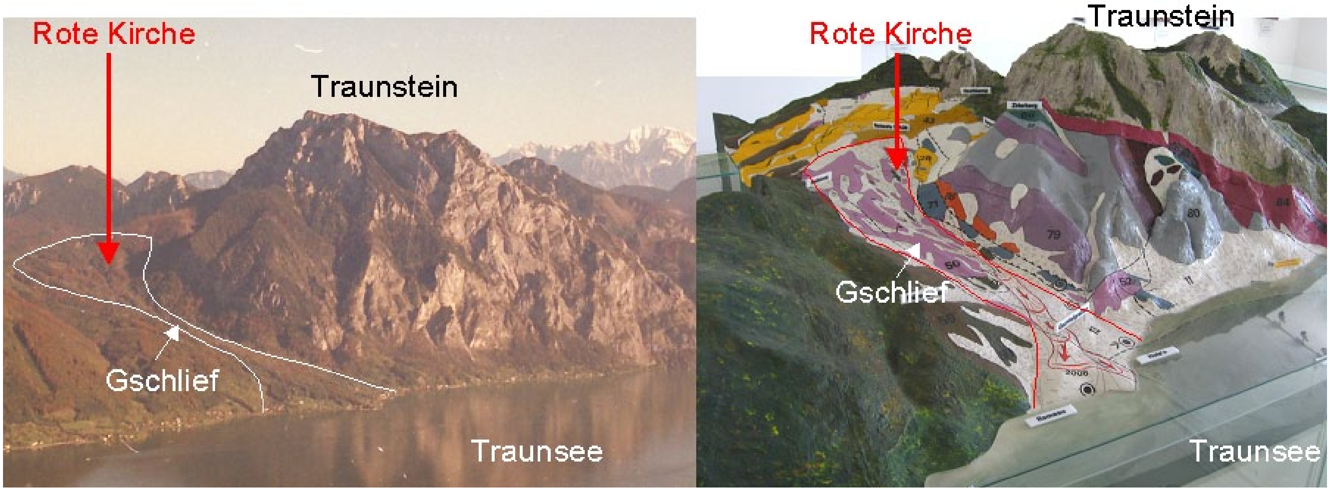
The slope, on which the Gschliefgraben is situated, extends from the eastern shore of Lake Traunsee (423 m) up to the small rock-cliff of the "Rote Kirche" (840 m), a famous site for the occurrence of Eocene fossils. The cliff consists mostly of yellow-orange coloured marly sandstones respectively sandy marls. On the top of the cliff limestones with nummulites, brachiopods, bivalves and echinoderms with intercalations of grey sandy marls, respectively brittle sandstones are cropping out (Text-Fig. 2). Glauconite is almost omnipresent, rarely also thin layers of "Bohnerz", i.e. finely distributed limonitic ooides.

Previous Work

In the early geological literature of the Salzkammergut region the Gschliefgraben is mentioned repeatedly. Among the earliest records are the papers by Joseph August Schultes (1809) and Paul von Partsch (1826). Carl Lill von Lilienbach (1830) was particularly surprised to find there nummulite-bearing sediments containing green mineral grains (glauconite). Ami Boué (1832) was the first who published a cross section through the Gschliefgraben. Finally Franz von Hauer (1858) described the complex lithologic sequence. He was also the first, who described in detail the Eocene sediments of the "Rote Kirche" location.

For a long period the sequence of the Gschliefgraben was considered being part of the Flysch zone or of the Upper Cretaceous / Palaeogene Gosau Group of the Northern Calcareous Alps (e.g. Fugger, 1903). However, Karl Götzinger in 1937 expressed the opinion, that from the palaeogeographic point of view this sequence is part of the Helvetic zone. From the tectonic point of view Ernst Kraus (1944) considered the Gschliefgraben as transgressively overlying the Flysch zone, while for Max Richter & Gotthold Müller-Deile (1940) it represents a tectonic window of the Helvetic zone underlying the Flysch unit.

Since 1951 the latter opinion was shared by Siegmund Prey. Prey's papers, published between 1949 and 1983, improved the biostratigraphic record of the lithologically



Text-Fig. 1.
Location, regional geology and tectonic position of "Rote Kirche" in Gschliefgraben.
Sketches courtesy Hans Weidinger, Kammerhofmuseum Gmunden.

Text-Fig. 2.
Uppermost stratigraphic sequence of the Rote Kirche section. Nummulite-limestone partly rich in "Bohnerz" (limonite ooides) alternating with grey, glauconitic sandy marls.

similar, but stratigraphically diverse rocks of the (Ultra)helvetic zone. In 1953 he argued that the Eocene sandy-marly-glauconitic sediments of "Rote Kirche" show Thanetian (Late Palaeocene) and probably also Ypresian (Early Eocene) age, while the top of this section is represented by a few meters of iron oolithic nummulitic limestones of Lutetian (Middle Eocene) age, which he considered as an equivalent of the "Roterz" beds in Bavaria (PREY, 1953). This opinion was supported later by an oral communication of Franz Traub (in PREY, 1975).

In his last paper PREY (1983) subdivided his Ultrahelveticum into two zones, namely the Northern Ultrahelvetic and the Southern Ultrahelvetic Klippen Zone. According to him "Rote Kirche" is part of his Northern Ultrahelvetic, which comprises a complex sequence of light to dark grey, partly variegated Albian to Maastrichtian marls, which are topped by Palaeocene to early Eocene glauconitic, more or less sandy marls and nummulitic limestones. Middle Eocene nummulitic limestones in Adelholzen facies and Clavulinoides szaboi Beds also occur regionally.

RASSER & PILLER (2001) deal in detail with facies patterns, subsidence and sea-level changes in ferruginous and glauconitic environments of the Palaeogene Helvetic shelf. According to these authors the Rote Kirche exposures belong to the Southern Helvetic facies of the Austro-Bavarian Helvetic Zone, which is part of the Helvetic Shelf and as such part of the Alpine Foreland. During the Palaeogene a peculiar shallow water carbonate sedimentation took place on a wide carbonate platform. The sediments are characterized by the most intensive ferruginisation and glauconitisation known from Cenozoic shallow water carbonates of the Eastern Alps (RASSER & PILLER, 2001).

According to EGGER (2007), the Rote Kirche outcrop is the easternmost exposure of the South Helvetic zone. There the nummulitic limestone of the Frauengrube Member and in particular the underlying marly sandstone (PREY, 1983) yielded calcareous nannoplankton of zone NP 12. This nannoflora is considered to indicate, that after a sea-level rise the nummulitic marlstones and limestones were deposited on the shelf of the European Platform during the Ypresian transgression within Zone NP 12.

Studied Material

Two of the authors (Harald Lobitzer and Alfréd Dulai) have visited the locality on 29.04.2010, with the guidance of two local private collectors, namely Ferdinand Estermann and Karl Bösendorfer from Pinsdorf. Several macromorphic brachiopod specimens were found in the field, and four samples were collected for washing and checking micromorphic brachiopods (sample 1: upper nummulitic limestone; samples 2–3: middle glauconitic sandstone; sample 4: lower *Assilina* sandstone). György Less (Miskolc) has also studied two of these washed residues for larger foraminifers (samples 1 and 4). During the field work two additional samples were collected from the upper part of the section (more or less identical with sample 1), for palynological (Magda Konzalová, Prague), nannofossils (Lilian Švábenická, Prague) and small foraminifera (Lenka Hradecká, Prague) studies. Karl Bösendorfer, one of the private collectors made it possible to use and study his brachiopod material from Rote Kirche locality. Collection of the Kammerhofmuseum in Gmunden also contains about a dozen brachiopod specimens from the same locality.

The newly collected brachiopods and the photographed specimens are deposited in the collection of the Hungarian Natural History Museum, Budapest (inventory numbers of illustrated specimens: M 2010.477.1. – M 2010.509.1). Figured larger foraminifera specimens marked by E. are deposited in the Eocene collection of the Geological Institute of Hungary, Budapest. Samples for study of small foraminifers and calcareous nannofossils were prepared in the Laboratory and deposited in the Collections and Material Documentation Department of the Czech Geological Survey, Prague. The palynological preparations were made in the Institute of Geology v.v.i., Academy of Sciences of the Czech Republic in Prague and are also deposited there. The samples for the palynological investigation were prepared in the Laboratory of the Czech Geological Survey, the preparations are deposited in the Institute of Geology v.v.i., Academy of Sciences, Prague.

Brachiopods

Brachiopods are generally rare in Eocene benthic assemblages, but they were published from several localities and numerous papers demonstrate their wide geographical distribution within the Western Tethys. Eocene brachiopods are known from England to Ukraine and from Belgium to Egypt (see details of their distribution in BITNER & BOUKHARY, 2009, BITNER et al., in press, DULAI, submitted). However, until now Eocene brachiopods were unknown from Austria. In some cases brachiopods were mentioned in faunal lists, but no description of Eocene brachiopods was published from Austrian localities.

Recently DULAI (submitted) studied the Late Eocene (Priabonian) micromorphic brachiopods of two boreholes of the Upper Austrian Molasse zone (Helmberg-1 and Perwang-1). These samples, due to the solving method in acetic acid by Kamil Zágoršek (Prague) (ZÁGORŠEK & VÁVRA, 2000), yielded about 2000 very small, micromorphic brachiopods, representing 10 species of 7 genera, including three new species. The paper describing this fauna is submitted, but the date of appearance of the proceedings volume is uncertain (6th International Brachiopod Congress, Melbourne, 1.–5. February, 2010).

Eocene deposits around Gmunden and their fossil contents are poorly known. PREY (1983) has listed fossils of different groups, including also two brachiopods from this area: *Terebratula aequivalvis* SCHAFHÄUTL and *T. hilarionis* MENEGHINI. Altogether 114 macromorphic brachiopods were collected during our fieldwork representing two species of large, smooth terebratulides: *Gryphus kickxii* (GALEOTTI, 1837) (108 specimen) and *Meznericsia hantkeni* (MEZNERICS, 1944) (6). Karl Bösendorfer's private collection also contains large-sized brachiopods of the same two species (70 *G. kickxii* and 5 *M. hantkeni*). The collection of the Kammerhofmuseum in Gmunden contains a dozen *Gryphus* specimens. All of the four washed samples yielded more or less small-sized, so-called micromorphic brachiopod specimens. The richest and most diverse fauna is from the uppermost sample, collected from the weathered part of nummulitic limestone (sample 1), where the macromorphic brachiopods were also collected: *Terebratulina tenuistriata* (LEYMERIE, 1846) (20), *Argyrotheca sabandensis*? (PAJAUD & PLAZIAT, 1972) (16), *Gryphus kickxii* juv. (3), *Orthothyris pectinoides* (KOENEN, 1894) (1) and *Megathiris detruncata* (GMELIN, 1791) (1). Two samples (sample 2 and 3) of the second outcrop (upper and lower part of a grey glauconitic sandstone) contain very fragmentary brachiopods. Sample 2 with *Terebratulina tenuistriata* (15) and *Gryphus kickxii* (5) and sample 3 with *Terebratulina tenuistriata* (28), *Gryphus kickxii* (15) and *Argyrotheca sabandensis*? (2). The lowest sample from yellow *Assilina* sandstone (sample 4) yielded only 2 fragments of *Terebratulina tenuistriata*.

All of the washed samples contain some other fauna elements, which are only partly studied in detail in this paper (larger foraminifers by Gy. Less).

Sample 1: small and larger foraminifers (several), worm tubes (several coiled and some straight), echinoderms (several echinoid needles and crinoid stalk fragments), bryozoans (several), decapods (some fragments).

Sample 2: small and larger foraminifers (several), echinoderms (several echinoid needles, some crinoid stalk fragments), fish teeth (few).

Sample 3: small and larger foraminifers (several), echinoderms (several echinoid needles, some crinoid stalk fragments), molluscs (few ostreid fragments), worm tubes (few), bryozoans (few), fish and shark teeth (few).

Sample 4: small and larger foraminifers (several), echinoderms (some echinoid needles and crinoid stalk fragments), molluscs (few ostreid and pectinid fragments), corals (few fragments), bryozoans (few), and decapods (few).

Systematic Notes on Brachiopods

Phylum Brachiopoda DUMÉRIL, 1806

Subphylum Rhynchonelliformea WILLIAMS, CARLSON, BRUNTON, HOLMER & POPOV, 1996

Class Rhynchonellata WILLIAMS, CARLSON, BRUNTON, HOLMER & POPOV, 1996

Order Terebratulida WAAGEN, 1883

Superfamily Terebratuloidea GRAY, 1840

Family Terebratulidae GRAY, 1840

Subfamily Gryphinae SAHNI, 1929

Genus *Gryphus* MEGERLE VON MÜHLFELD, 1811

Gryphus kickxii (GALEOTTI, 1837)

(Pl. 1, Figs. 1–11)

1843 *Terebratula Kickxii* GALEOTTI – NYST, p. 335, Pl. 19, Fig. 4.

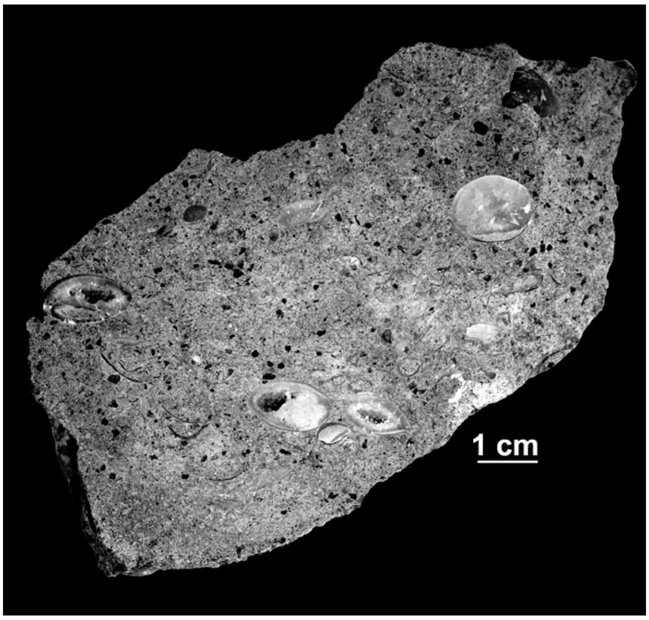
in press *Gryphus kickxii* (GALEOTTI) – BITNER et al. (p. X), Figs. 3D–I, 4, 5A, B (cum syn.).

? 2010 *Carneithyris subregularis* (QUENSTEDT) – SULSER et al. p. 261–264, Text-Figs. 3, 4, 5.

Material: 213 specimens.

Notes: *G. kickxii* is a medium-sized, smooth brachiopod with rectimarginate anterior commissure and short incurved beak. The outline is very variable: elongate oval to subpentagonal or subcircular, as demonstrated on the figures of Pl. 1. This is the most common brachiopod of the Rote Kirche locality and it was very widespread in the whole of Europe during the Eocene (BITNER et al., in press). About 70 percent of the studied Austrian specimens belong to this species, which has a very complex taxonomic history and was described under different names. The two species names mentioned by PREY (1983) from Rote Kirche (*T. aequivalvis*, *T. hilarionis*) are probably also synonyms of *G. kickxii*. Critical revision of this species was given just recently by BITNER et al. (in press) on the basis of an extensive Middle Eocene material from the Szőc Limestone of the Bakony Mts., Hungary. Very similar forms were mentioned from the Swiss and Austrian Alpine area in different names: *T. kickxii* by OOSTER (1863) and MOESCH (1878), *T. aequivalvis* and *T. picta* by SCHAFHÄUTL (1863) and *T. subregularis* by QUENSTEDT (1868–1871). All of these records may also refer to *G. kickxii*, but until now detailed study or revision of these faunas / localities is missing.

The online version of the SULSER et al. (2010) paper appeared just during the preparation of this manuscript. They have studied Lutetian (Middle Eocene) brachiopods from NE Switzerland. Beside some undetermined *Terebratulina* specimens, they have identified their common smooth terebratulides as *Carneithyris subregularis* (QUENSTEDT). They regarded *T. aequivalvis* SCHAFHÄUTL and *T. hilarionis* DAVIDSON as separate species, and also assigned them to the genus *Carneithyris*. However, the outer morphology of the Swiss specimens is similarly variable, than in case of Lutetian fauna of the Bakony Mts. (BITNER et al., in press) as in the case of the studied Rote Kirche fauna. The three assemblages seem to be overlapping in outer morphological characters and in variability. The same is true for *subregularis* / *aequivalvis* length / width comparisons (see Fig. 8 in SULSER et al., 2010). SULSER et al. (2010) attribute their material to the species *subregularis*, because *Gryphus kickxii* is “ill-defined” and its thorough revision is missing (although they also recognized the close relationship between *kickxii* and *subregularis*). However, a paper parallel to SULSER et al. (2010), a recent critical revision on *G. kickxii* is just prepared on a rich material from the Hungarian Middle Eocene by BITNER et al. (in press). As this latter paper justifies the



Text-Fig. 3.
Polished surface of nummulitic limestone from Rote Kirche upper locality. The small sample contains several macromorphic brachiopods (both double valves and separated valves; probably *Gryphus kickxii*). The thin sediment infillings in some specimens indicate the original position of the rock sample. The mostly sparitic infilling refer to relatively quick sedimentation. Scale bar: 1 cm.

validity of the *G. kickxii* species, and it has priority over *subregularis* as well as over *aequivalvis* and *hilarionis*, in my opinion the Swiss Lutetian material probably also represents a new record of *G. kickxii*. Concerning the generic assignment, on the basis of the internal morphological characters and the shell ultrastructure, the Hungarian specimens clearly belong to the short-looped *Gryphus* (BITNER et al., in press). The internal characters of the Swiss specimens seem to be poorly preserved (at least on the basis of Fig. 5a–b in SULSER et al., 2010). Therefore their generic assignment to the fundamentally Cretaceous *Carneithyris* on the basis of some selected sections seems to be uncertain. Supposedly, the internal morphological characters of these terebratulides are variable similar to the external ones. For a more certain species and generic assignment of Alpian Eocene short-looped terebratulides, we need more studies in the future, including statistical comparisons of outer morphological characters, and serial sections of well-preserved specimens.

The very limited time to prepare this paper inhibits the investigation of the internal morphology of the brachiopods by serial sections of the specimens at Rote Kirche. Later on it would be useful to check the intraspecific internal variability of specimens with different outer morphology. However, on the basis of the polished surface of the nummulitic limestone (Text-Fig. 3), most of the brachiopod specimens are infilled with sparitic calcite, therefore unfortunately the serial sectioning seems to be a little hopeless.

Distribution: Europe: Belgium, Italy, Switzerland, Austria, Hungary, Poland, Romania, Bulgaria, Ukraine and Turkey; Asia: Caucasus and Kazakhstan (see details in BITNER et al., in press).

Family Gibbithyrididae MUIR-WOOD, 1965

Subfamily Gibbithyridinae MUIR-WOOD, 1965

Genus *Meznericsia* BITNER, DULAI & GALÁCZ, 2010

Meznericsia hantkeni (MEZNERICS, 1944)

(Pl. 2, Figs. 1–2)

1944 *Magellania* (s.l.) *Hantkeni* n. sp. – MEZNERICS, p. 46, Pl. 3, Figs. 13–16; Pl. 5, Figs. 21–23.

1975 *Gryphus inkermanicus* ZELINSKAJA sp. nov. – ZELINSKAYA, p. 94, Pl. 8, Fig. 1.

in press *Meznericsia hantkeni* (MEZNERICS, 1944) – BITNER et al., p. X, Figs. 5C, D, 6–8.

Material: 11 specimens.

Notes: *M. hantkeni* is a large-sized, strongly biconvex, smooth terebratulide with a massive, strongly incurved beak and paraplicate anterior commissure. The species was described by MEZNERICS (1944) as *Magellania* (s.l.) *Hantkeni*. However, on the basis of the distinctive external and internal morphological characters, BITNER et al. (in press) recently erected a new genus, *Meznericsia* for this species. ZELINSKAYA (1975) described the same morphology as *Gryphus inkermanicus* from the Ukraine and its smaller size probably refers to a juvenile specimen. The specimens from the Rote Kirche locality have widened the known palaeogeographical distribution of this rare species.

Distribution: Eocene of Hungary, Ukraine and Austria (see BITNER et al., in press).

Superfamily Cancellothyridoidea THOMSON, 1926

Family Cancellothyrididae THOMSON, 1926

Subfamily Cancellothyridinae THOMSON, 1926

Genus *Terebratulina* D'ORBIGNY, 1847

Terebratulina tenuistriata (LEYMERIE, 1846)

(Pl. 3, Figs. 1–11)

2000 *Terebratulina tenuistriata* (LEYMERIE) – BITNER, p. 118–120, Figs. 2, 3, 4A–F, 5B–G (cum syn.).

in press *Terebratulina tenuistriata* (LEYMERIE, 1846) – BITNER et al., p. X, Fig. 3A–C (cum syn.).

Material: 65 specimens.

Notes: *T. tenuistriata* is relatively frequent at the Rote Kirche locality, mainly in the washed residues. This is the commonest species in the Eocene brachiopod assemblages of the Western Tethys. BITNER (2000) gave detailed analysis of this species and its great variability during the ontogeny. Different sized Rote Kirche specimens confirm this variability (see Pl. 3, Figs. 1–11). Adults of this species are characterized by numerous fine ribs and an elongated oval outline, while juveniles have only 10–12 granular ribs which increase rapidly in number with the age of brachiopods.

Distribution: Europe: Great Britain, Belgium, France, Spain, Italy, Poland, Hungary, Romania, Bulgaria, and Ukraine (see BITNER et al., in press; DULAI, submitted); Africa: Egypt (see BITNER & BOUKHARY, 2009).

Family Chlidonophoridae MUIR-WOOD, 1959

Subfamily Orthothyridinae MUIR-WOOD, 1965

Genus *Orthothyris* COOPER, 1955

Orthothyris pectinoides (KOENEN, 1894)
(Pl. 2, Fig. 3)

1894 *Terebratulina pectinoides* KOENEN – KOENEN, p. 1354–1355, Pl. 99, Figs. 8–9.

2008 *Orthothyris pectinoides* (KOENEN) – BITNER & DULAI, p. 35, Fig. 4.9–16 (cum syn.).

Material: 1 specimen.

Notes: This species seems to be very rare at the Rote Kirche locality, but it is a dominant faunal element in the recently studied nearby Helmberg and Perwang samples (Upper Austrian Molasse Zone, Late Eocene) (DULAI, submitted). The small, subcircular specimen agrees well with those hitherto described, however it is more similar to the Hungarian specimens (BITNER & DULAI, 2008, Figs. 4.10, 4.14) than to the more juvenile Austrian ones. Until recently, this species was attributed to the genus *Terebratulina*, but BITNER & DIENI (2005) and later BITNER & DULAI (2008) and DULAI (submitted) attributed it to the genus *Orthothyris* created by COOPER (1955) for Late Cretaceous brachiopods. On the basis of the Helmberg and Perwang materials, DULAI (submitted) recognized that *Orthothyris* and the very similar *Terebratulina* alternate with each other along the Upper Eocene layers and probably were competitors of the same ecological niches.

Distribution: Eocene of Germany (KOENEN, 1894), Ukraine (ZELINSKAYA, 1975), Italy (BITNER & DIENI, 2005), Hungary (BITNER & DULAI, 2008) and Austria (DULAI, submitted; and this paper).

Superfamily Megathyridoidea DALL, 1870

Family Megathyrididae DALL, 1870

Genus *Megathiris* D'ORBIGNY, 1847

Megathiris detruncata (GMELIN, 1791)
(Pl. 2, Fig. 4)

2007 *Megathiris detruncata* (GMELIN) – DULAI, p. 2–3, Figs. 2, 1–2 (cum syn.).

2008 *Megathiris detruncata* (GMELIN) – BITNER & DULAI, p. 35–36, Figs. 5.1–4 (cum syn.).

Material: 1 specimen.

Notes: *M. detruncata* has very wide distribution both stratigraphically and geographically. It is one of the most common species in Palaeogene, Neogene and Recent shallow water assemblages. However, it is rare in deeper water environments, as it is also confirmed by the Helmberg and Perwang samples (DULAI, submitted), as well as the Rote Kirche locality (1 known juvenile specimen only).

Distribution: Eocene: Italy, Hungary, Austria (see details in BITNER & DULAI, 2008; DULAI, submitted); Oligocene: Hungary (DULAI, 2010); Miocene: Central Paratethys (see details in BITNER & DULAI, 2004 and DULAI, 2007); Recent: Mediterranean, Eastern Atlantic and Caribbean Sea (LOGAN, 1979; BRUNTON & CURRY, 1979; COOPER, 1977).

Genus *Argyrotheca* DALL, 1900

Argyrotheca sabandensis? (PAJAUD & PLAZIAT, 1972)
(Pl. 2, Figs. 5–11)

1972 *Cistellarcula sabandensis* nov. sp. – PAJAUD & PLAZIAT, p. 450–451, Text-Figs. 2–3, Pl. 1, Fig. 2.

Material: 18 specimens.

Notes: This small sized micromorphic species is relatively frequent in the washed residues of the Rote Kirche locality. Although all of the studied specimens are small and not very well preserved, they show remarkable similarity with *A. sabandensis* described by PAJAUD & PLAZIAT (1972) from the Late Palaeocene of Spain. The outline of the specimens, the shape of the beak area, the length of the hinge, the number and character of the ribs seem to be consistent with *A. sabandensis*. However, some uncertainties are caused by the very poor illustration of this species in the original description. Based on external and internal morphological characters, genus *Cistellarcula* was synonymised with *Argyrotheca* by CALZADA & URQUIOLA (1994). If the identification of these specimens is correct, the known stratigraphical distribution of this species is widened by this record from Late Palaeocene to Early Eocene.

Distribution: Late Palaeocene (Thanetian) of Spain, and Early Eocene (Ypresian) of Austria (Gmunden).

Taxonomic Composition of the Brachiopod Fauna

Linguliformea and Craniiformea brachiopods are missing; all studied specimens belong to the Rhynchonelliformea subphylum. Within Rhynchonelliformea, all specimens belong to the order Terebratulida (rhynchonellides and thecideides are missing). Within terebratulides the short-looped superfamily Terebratuloidea is dominant (*Gryphus* 69 %, *Meznericsia* 3.6 %) but Cancellothyridoidea is also significant (*Terebratulina* 21 %, *Orthothyris* 0.3 %). Two genera belonging to the superfamily Megathyridoidea are much less numerous (*Argyrotheca* 5.8 %, *Megathiris* 0.3 %).

The above mentioned taxonomic composition is based on all studied specimens and therefore supposedly little biased against the micromorphic species: both the private collection and the material from the Kammerhofmuseum contain only macromorphic brachiopods (they did not examine washed materials). However, if we check only the new material of the upper nummulitic limestone (from where both macromorphic and micromorphic brachiopod specimens were intensively collected), the taxonomic composition does not change significantly: *Gryphus* 71 %, *Meznericsia* 3.9 %, *Terebratulina* 13.2 %, *Orthothyris* 0.7 %, *Argyrotheca* 10.5 % and *Megathiris* 0.7 %). The only significant difference is that *Argyrotheca* is more frequent, while *Terebratulina* is less common.

Palaeoecology, Palaeoenvironment

According to LOGAN (1979) and LOGAN et al. (2004) *Argyrotheca*, *Megathiris* and *Lacazella* dominate in shallow water environments (ranging down to about 200 m) of the Recent Mediterranean, while *Gryphus*, *Terebratulina*, *Platidia* and *Megerlia* characterize the eurybathic species, which are more typical of the bathyal zone. The absence of thecideids, the limited rate of Megathyridoidea (*Argyrotheca*, *Megathiris*) and the dominance of *Gryphus* and *Terebratulina* clearly refer to deeper water environment at the Rote Kirche locality, maybe in outer shelf environments, as suggested also by larger foraminifera (see later). The distributional pattern of Recent *Gryphus vitreus* along the Mediterranean upper bathyal continental slope was intensively studied by EMIG & ARNAUD (1988) and EMIG (1989a, b).

Ecologically, the described brachiopods belong to three categories. Most of the species are attached by a strong and short pedicle to hard substrates: *Gryphus*, *Argyrotheca*, *Megathiris*, *Orthothyris*. However, *Terebratulina* is attached directly to the loose sediment by a root-like, divided pedicle. *Meznericsia* is an extinct genus without recent representatives, but the very convex valves, and extremely incurved small beak may refer to non functional pedicle, at least in the adult phase. It should mean that after the "normal", attached juvenile stage, the large-sized, nearly globular adult specimens secondarily became free-living, probably on soft substrate.

Larger brachiopods can offer hard substrate for epifaunal encrusters, but the amount of epibionts is very variable both on fossil and Recent forms. Only two out of 213 studied specimens (0.9 %) of *Gryphus kickxii* show remains of worm tubes (some similar worms were also seen on large nummulitids). Both coiled worm tubes are situated on the ventral valve, very near to the terminal part of the anterior margin (Pl. 1, Figs. 10–11). Taking into consideration the life position of *Gryphus*, the ventral valve and mainly the terminal part of the ventral valve is situated at the highest point. These brachiopods are sometimes densely packed, and only these parts of the shells are available as solid substrate for the settlement of larvae. It suggests that they encrusted the ventral valves of *Gryphus* during the life of the brachiopods. As they attached very near to the anterior margin, the worms probably benefited from the feeding currents of the brachiopod. Similar situations were reported e.g. on the Palaeozoic *Mucrospirifer* (SCHUMANN, 1967), on the Devonian *Anathyris* (ALVAREZ & TAYLOR, 1987), on the Eocene *Paraplicirhynchia* (BITNER, 1996), on the Miocene *Argyrotheca* (DULAI, 2007) and on the Cenozoic and Recent *Tegulorhynchia* (LEE, 1980).

Small Foraminifera

Material and method

One sample from the locality Rote Kirche was collected for foraminiferal analysis. The sample was washed in the Laboratory of the Czech Geological Survey in Prague using the standard washing method. The size of the sieve of 0.063 mm and coarse fraction was kept. The foraminiferal assemblage was studied by a Nikon binocular microscope.

Results

The studied sample contains a relatively rich foraminiferal assemblage but the preservation of foraminiferal tests is mostly bad. Bryozoa and Echinodermata remains were also found, as well as some ostracods and fish teeth. In the anorganic part of the material grains of glauconite appear.

In the foraminiferal assemblage benthic species prevail, especially *Heterolepa eocaena* (GUEMBEL). Among other benthonic foraminifers *Spiroplectammina pectinata* (REUSS), *Globorotalites* sp., *Planulina costata* (HANTKEN), *Pararotalia lithothamnica* (UHLIG) and *Textularia* sp. are present.

Planktonic species are less abundant. Specimens of *Truncorotalia aequa* (CUSHMAN & RENZ), *Subbotina triloculinoides* (PLUMMER), *Turborotalia primitiva* (FINLAY) and *Globorotalia aragonensis* NUTTALL were found. Some of the recognized species were mentioned in previous papers from the Palaeogene of the Austrian Helvetic Zone (GOHRBANDT, 1963, 1967; WILLE-JANOSCHEK, 1966).

Stratigraphic interpretation

The presence of *G. aragonensis* in the studied sample allows to attribute this assemblage to the planktonic Zone P7 *(Globorotalia formosa)* to P8 *(Globorotalia aragonensis)* of the Early Eocene according to BLOW (1969) and BERGGREN (1971).

Palaeoecological interpretation

Abundance of benthic foraminifers and a smaller amount of planktonic ones characterize shallow-water conditions at certain times.

Larger Foraminifera

Introduction

Larger foraminifera occur in great quantity in two samples. These are the uppermost nummulitic limestone (sample 1) and the lower outcrop with *Assilina* (sample 4). They are represented by nummulitids (genus *Nummulites* and *Assilina*) and orthophragmines, which is an informal collective term for Eocene orbitoidal forms uniting two systematically independent families, such as Discocyclinidae (consisting of genus *Discocyclina* and *Nemkovella*) and Orbitoclypeidae (with genus *Orbitoclypeus* and *Asterocyclina*). The preservation of fossils is average in both samples, megalospheric (A) forms are in great majority.

Methods

The inner morphology of larger foraminifera could be studied by opening them by the splitting method with pliers and painting with violet ink (described in detail in LESS, 1981). In the determination of larger foraminifera the morphometric method (described in detail by DROOGER, 1993) was followed, i.e. in each sample specimens were grouped into populations, the members of which are clearly distinguishable from the specimens of the other populations of the same sample. Taxonomic determinations are based on these populations (as a whole) and not on their separate individuals. These taxa are in most cases the members of a long-lasting and continuous evolutionary chain called lineage or phylum. In the case of orthophragmines lineages correspond to species while for the genus *Nummulites* and *Assilina* they form a series of chronospecies.

In the determination of orthophragmines we focused on the internal features found in the equatorial section, thus we adopted principles and nomenclature used by LESS (1987) as illustrated in Text-Fig. 4 and explained in the header of Table 1. Numerous orthophragminid lineages (their validity is proven biometrically by LESS & Ó. KOVÁCS, 2009) are used for biostratigraphic purposes after being artificially segmented into chronosubspecies separated from each other by arbitrary biometric limits of the mean deuteroconchal size, the most rapidly evolving parameter. A synopsis of subspecies identification based on the outer cross-diameter of the deuteroconch (parameter d) is given in ÖZCAN et al. (2010). A revised stratigraphy of late Ypresian to middle Lutetian orthophragmines is presented in ÖZCAN et al. (2007b).

Representatives of nine orthophragminid lineages could be found in the Gmunden samples. They are figured in Pl. 4, biometric data are summarized in Table 1. Because of the limited space, a complete statistical evaluation with the number of specimens (№), arithmetical mean and standard error (s.e.) is given only for parameter d, the crucial parameter in subspecific determination. If the population consists of only a single specimen, no subspecies is determined, in the case of only two or three specimens, the subspecies is determined as "cf.". Since most orthophragmines found in the Gmunden samples are recently discussed in Özcan et al. (2007a, 2007b, 2010) and Less et al. (2007), we do not repeat here their description with the exception of *Orbitoclypeus multiplicatus gmundenensis* n. ssp. (see in the systematical part), which represents the most advanced developmental stage of the lineage known so far.

Nummulitids appeared to be less diverse in the Gmunden samples. Four lineages could be identified, some small *Nummulites* have not been determined on the specific level. The segmentation of lineages into chronospecies by Schaub (1981) is typological and based mainly on microspheric (B) forms, however we also could use the mean proloculus (the first chamber) diameter of the megalospheric (A) forms in the Schaub collection measured by Less (1998b). Nummulitids are figured in Pl. 5, biometric data of the inner cross-diameter of the proloculus (parameter P) are summarized in Table 2. The specific determination within lineages is briefly discussed at particular samples.

Results

Sample 1 consists of a relatively rich assemblage of larger foraminifera dominated by both orthophragmines and nummulitids. The specific composition is as follows:

Orthophragmines:

Discocyclinidae

Discocyclina archiaci cf. *archiaci* (Schlumberger) – Pl. 4, Fig. 6.
D. fortisi fortisi (d'Archiac) – Pl. 4, Figs. 1–3.
D. pulcra cf. *landesica* Less – Pl. 4, Fig. 5.
D. dispansa taurica Less – Pl. 4, Figs. 4, 7.
Nemkovella evae evae Less – Pl. 4, Figs. 8, 9.
N. strophiolata cf. *fermonti* Less – Pl. 4, Fig. 10.

Orbitoclypeidae

Orbitoclypeus schopeni crimensis Less – Pl. 4, Figs. 12–14.
O. multiplicatus gmundenensis n. ssp. Less – Pl. 4, Figs. 15–19.
Asterocyclina alticostata (Nuttall) indet. ssp. – Pl. 4, Fig. 11.

Nummulitidae

Nummulites nemkovi Schaub – Pl. 5, Figs. 1–4.
N. irregularis Deshayes – Pl. 5, Figs. 6–8.
N. indet. sp. (radiate forms)
Assilina plana Schaub – Pl. 5, Figs. 9, 10.

Comments on nummulitids: According to Schaub (1981) *Nummulites nemkovi*, *N. irregularis* and *Assilina plana* are members of the *N. distans*, *N. irregularis* and *A. spira* lineage, respectively. Specific identification within lineages is based on the measurements by Less (1998b). Concerning the *N. distans* lineage, the mean proloculus diameter (P_{mean}) given in Table 2 best fits to *N. nemkovi*. It is considerably larger than the characteristic values of *N. haymanensis*, the ancestor of *N. nemkovi*, and significantly smaller than those of *N. distans*, the offspring. In the case of the *N. irregularis* lineage, the dimension of the proloculus fits well *N. irregularis* and is considerably smaller than that of *N. maior*, the successor. Finally, the proloculus diameter of *Assilina* with an open spi-

Parameters		Outer cross-diameter of the embryon					Adauxiliary chamberlets			Equatorial chamberlets			Subspecific determination
		deuteroconch			protoconch		number	width	height	annuli/ 0.5 mm	width	height	
		d (µm)			p (µm)		N	W (µm)	H (µm)	n	w (µm)	h (µm)	
Species	Sample	N°.	range	mean±s.e.	range	mean	range	range	range	range	range	range	
Discocyclina archiaci	Gmunden 1	3	415–510	462	260–295	278	25–30	40–45	65–75	8–9	35–40	70–90	cf. *archiaci*
D. fortisi	Gmunden 1	18	550–910	719±26	260–440	352	38–52	40–55	50–70	8–10	35–40	65–80	*fortisi*
	Gmunden 4	1		800		–	–	45	60	9–14	40	70	indet. ssp.
D. dispansa	Gmunden 1	11	165–260	214±9	110–160	129	13–21	30–35	45–60	11–15	25–30	50–70	*taurica*
	Gmunden 4	4	160–260	205±18	90–150	122	13–20	30–35	45–55	12–15	25	45–60	*taurica*
D. pulcra	Gmunden 1	2	570–665	618		260	48	40–50	80–110	6–7	25	100–120	cf. *landesica*
Nemkovella evae	Gmunden 1	10	205–290	246±9	105–180	153	11–15	50–60	45–60	11–13	30–40	40–60	*evae*
N. strophiolata	Gmunden 1	2	115–145	130	60–90	75	6–7	40	25–30	18	25–30	30–35	cf. *fermonti*
Orbitoclypeus schopeni	Gmunden 1	17	295–550	418±13	150–335	235	28–40	40–50	50–60	8–10	30–40	60–100	*crimensis*
O. multiplicatus	Gmunden 1	11	455–790	613±32	250–430	318	32–48	45–80	50–70	6.5–8	40–45	75–100	*gmundenensis* n. ssp.
Asterocyclina alticostata	Gmunden 1	1		255		185	8	60–120	60	13	30–35	35–45	indet. ssp.

Table 1.
Statistical data of orthophragminid populations. No: number of specimens, s.e.: standard error.

ral (the basic feature of their arrangement into the *A. spira* lineage) in sample Rote Kirche 1 falls between *A. adrianensis* (the ancestor) and *A. laxispira* (the offspring) and corresponds well to *A. plana*.

Age: This assemblage clearly determines the SBZ 10 Zone by SERRA-KIEL et al. (1998) and the OZ 6 Zone by LESS (1998a), indicating the early part of the late Ypresian (= Cuisian). Moreover, the OZ 6 Zone suggests the higher part of the SBZ 10 Zone. The correlation of orthophragminid (OZ) zones with shallow benthic (SBZ) and planktic zonations is given in ÖZCAN et al. (2010). *Discocyclina fortisi fortisi*, *Nummulites nemkovi* and *Assilina plana* are zonal markers, whereas the range of all the other taxa includes this zone. *Discocyclina archiaci archiaci* and *Orbitoclypeus multiplicatus* are not known from younger strata, moreover this latter species in older layers is represented by *O. m. kastamouensis*, a more primitive developmental stage than the newly described *O. m. gmundenensis*. In the meantime *Orbitoclypeus schopeni crimensis*, *Discocyclina dispansa taurica*, *D. pulcra*, *Nemkovella strophiolata*, *Asterocyclina alticostata* and *Nummulites irregularis* are unknown from older horizons.

Facies: The richness of orthophragmines and the presence of nummulitids with an open spiral in combination with the lack of *Nummulites* with granules and porcellaneous forms (alveolinids and genus *Orbitolites*) indicate the deeper part of the photic shelf, very probably the outer ramp.

Sample 4 contains a considerably less diverse assemblage, in which the genus *Assilina* dominates. Orthophragmines and the representatives of the genus *Nummulites* are subordinate. The specific composition is as follows:

Orthophragmines:

Discocyclinidae

Discocyclina dispansa taurica LESS
D. fortisi indet. ssp.
Nemkovella indet. sp. (only a B-form was found)

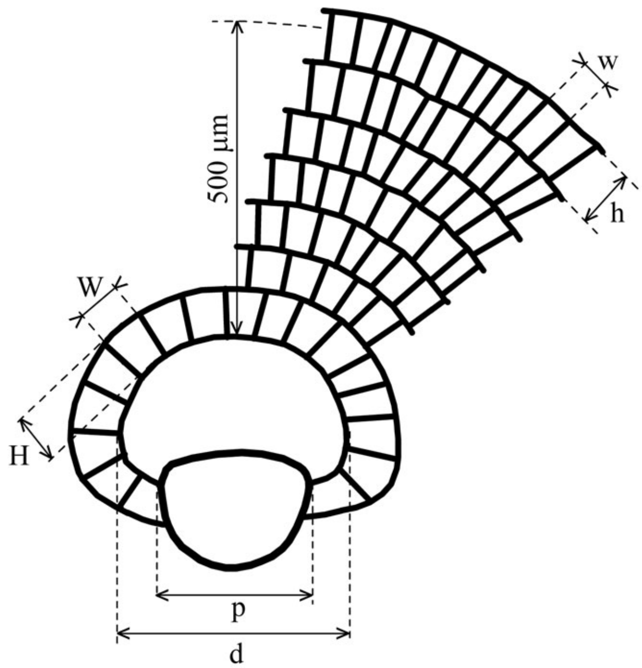
Nummulitidae:

Assilina aff. *placentula* (DESHAYES) – Pl. 5, Figs. 5, 11, 12.
Nummulites indet. sp. (small radiate forms).

Comments on *Assilina*: The representatives of this genus in sample 4 have a considerably tighter spiral than that in sample 1. Therefore, they are ranged into the *A. exponens* lineage. Based on the measurements by LESS (1998b), the proloculus diameter in the given sample (see Table 2) is intermediate between *A. placentula* (characteristic for the Lower Cuisian, see SERRA-KIEL et al., 1998) and *A. cuvillieri* (occurring in the Upper Cuisian). Such forms are determined by SCHAUB (1981) as *A.* aff. *placentula*, mainly from the Middle Cuisian.

Taxon	Sample	N°	Proloculus diameter (P) in mm	
			Range	Mean ± s.e.
Nummulites nemkovi	Gmunden 1	15	260 – 620	482,3 ± 17,6
N. irregularis	Gmunden 1	8	150 – 350	241,9 ± 22,6
Assilina plana	Gmunden 1	17	185 – 390	321,5 ± 18,8
A. aff. *placentula*	Gmunden 4	15	270 – 560	350,3 ± 21,5

Table 2.
Statistical data of the inner cross-diameter of the proloculus of nummulitid populations (in µm).
No: number of specimens, s.e.: standard error.



Text-Fig. 4.
The measurement system of megalospheric orthophragmines in equatorial section. See the header of Table 1 for explanation.

Age: Although the presence of *Assilina* aff. *placentula* suggests Middle Cuisian (SBZ 11) as discussed above, this rather narrow time-span cannot be confirmed by other larger foraminifera. The range of *Discocyclina dispansa taurica* is SBZ 10–12 (ÖZCAN et al., 2007b, updated by ZAKREVSKAYA et al., in review), i.e. the whole late Ypresian (SBZ 10–12), which is a more cautious age-estimate for sample 4.

Facies: This sample indicates a slightly less deep environment than that of sample 1, since orthophragmines are subordinate and *Assilina* aff. *placentula* with a tighter spiral replaces the representatives of the *A. spira* lineage with a more open spiral. Meanwhile forms, characteristic for the middle ramp (*Nummulites* with granules) or for the inner ramp (porcellaneous forms like alveolinids and the genus *Orbitolites*) are still missing. To sum up: the shallower part of the outer ramp seems to be the most realistic assumption.

Systematic Part

Order Foraminiferida EICHWALD, 1830

Family Orbitoclypeidae BRÖNNIMANN, 1946

Genus *Orbitoclypeus* Silvestri, 1907

Orbitoclypeus multiplicatus (GÜMBEL, 1870)

Emended diagnosis: Average-sized, inflated, unribbed forms with "marthae" type rosette. The medium-sized to moderately large embryon is excentrilepidine, rarely eulepidine. The numerous, "varians" type adauxiliary chamberlets are rather wide and medium high as well as the equatorial chamberlets. The annuli are usually moderately undulated; the growth pattern is of the "varians" type. *O. multiplicatus* is subdivided into four successive subspecies as defined below:

O. m. haymanaensis d_{mean} < 310 µm
O. m. multiplicatus d_{mean} = 310–420 µm
O. m. kastamonuensis d_{mean} = 420–550 µm
O. m. gmundenensis d_{mean} > 550 µm.

Orbitoclypeus multiplicatus gmundenensis n. ssp. LESS
Pl. 4, Figs. 15–19.

Etymology: Named after the city of Gmunden.

Holotype: Specimen E.10.31 (Pl. 4, Figs. 18, 19.).

Depository: Geological Institute of Hungary, Budapest.

Paratypes: All the other specimens from Gmunden, sample 1, illustrated in Pl. 4, Figs. 15–17.

Type locality: Gmunden (Austria), sample Rote Kirche 1.

Type level: Lower Upper Ypresian, the OZ 6 orthophragminid and the SBZ 10 shallow benthic zone.

Diagnosis: *Orbitoclypeus multiplicatus* populations with d_{mean} exceeding 550 µm.

Description (see also Table 1): Moderately large (3–5 mm), inflated, unribbed forms with "marthae" type rosette. The embryon is rather large, mostly excentrilepidine, sometimes eulepidine. The numerous "varians" type adauxiliary chamberlets are rather wide and relatively high. The equatorial chamberlets are also fairly wide and moderately high. The annuli can be slightly undulated; their growth pattern is of the "varians" type.

Remarks: Representatives of the *Orbitoclypeus multiplicatus* lineage are mostly known from the Thanetian and early Ypresian (Ilerdian), in the SBZ 3 to 8 and OZ 1b to 4 Zones. ÖZCAN et al. (2007b) reported one single specimen with similar characteristics as in Gmunden from the SBZ 10/11 or OZ 6/7 Zones corresponding to the lower part of the Upper Ypresian (Cuisian) of Kiriklar (N Turkey). Our material from Gmunden consisting of eleven specimens allows us to introduce the most advanced developmental stage of the lineage as a new chronosubspecies.

Orbitoclypeus multiplicatus gmundenensis is hardly distinguishable from *O. schopeni schopeni* and *O. zitteli* with similar embryonic size and type. Its equatorial chamberlets, however, is slightly wider than those of the other two taxa, which have a different stratigraphical position.

Range: Early part of the late Ypresian (Cuisian), the SBZ 10 and OZ 6 Zones. It may include the SBZ 9 and 11 as well as the OZ 5 and 7 Zones.

Gmunden (Austria) and very probably Kiriklar (Turkey).

Calcareous Nannofossils

Method

Nannofossils were investigated in the fraction of 2–30 µm, separated by decantation following the methodology described in SVOBODOVÁ et al. (2004). Simple smear-slide was mounted by Canada Balsam and inspected at a 1000× magnification, using an oil-immersion objective on a Nikon Microphot-FXA transmitting light microscope. Biostratigraphic data were interpreted applying the zonations of MARTINI (1971) and VAROL (1998).

Results

The studied fraction 2–30 µm (samples A and B) contained predominantly anorganic material. The nannofossil abundance in sample A was generally 10–20 specimens per 1 field of view of the microscope, whereas sample B was extremely poor, only 1–3 specimens per 1 field of view of the microscope. Calcareous nannofossils were poorly preserved in both samples. Discoasterids and large placoliths were mostly fragmented and discoasterids and the central fields of placoliths partly etched, partly overgrown with calcite. Some specimens cannot be identified due to the poor preservation especially in sample Rote Kirche B.

Sample A

The nannofossil assemblage is characterized by a higher number of discoasterids exclusively of rosette shape, and by the rare presence of specimens of the genera *Reticulofenestra, Helicosphaera* and *Lophodolithus* (Pl. 6).

The following species have been found*: Coccolithus pelagicus, C. eopelagicus, Sphenolithus radians, S. moriformis, S. editus, Campylosphaera dela, C. eodela, Helicosphaera seminulum, H. lophota, Neococcolithes protenus, N. protenus-dubius, Cyclococcolithus (Ericsonia) formosus, Zygrhablithus bijugatus, Calcidiscus protoannulus, Micrantholithus flos, Pontosphaera pulcheroides, P. pulchra, Thoracosphaera* sp.*, Discoaster barbadiensis, D. lodoensis* (7 rays, mostly in fragments)*, D. kuepperi, D.* sp.*, Toweius rotundus, T. crassus, Girgisia gammation, Clausicoccus fenestratus, Chiasmolitus solitus, C. eograndis* (fragments)*, C. consuetus, C*. sp.*, Lophodolithus mochloporus, L. nascens, Braarudosphaera turbinea* (probably reworked from the older sediments of the lowermost Palaeocene, Danian age).

Sample B

Poor nannofossils are characterized by a higher number of specimens of the genus *Toweius*. The assemblage consists of species *Coccolithus pelagicus, C. eopelagicus,* rare *Ellipsolithus macellus, Chiasmolithus solitus, C. bidens, C. eograndis, Discoaster binodosus, D. barbadiensis, D. kuepperi, D. multiradiatus, Zygrhablithus bijugatus, Neochiastozygus junctus, Lophodolithus nascens, Sphenolithus moriformis, Campylosphaera eodela, Pontosphaera pulchra, Coronocyclus* sp., rare pentaliths of *Braarudosphaera bigelowii bigelowii*, *B. bigelowii parvula* and *Micrantholithus* sp., *Clausicoccus fenestratus, Toweius crassus, T. rotundus, T. pertusus.*

The assemblage also contained reworked species from older sediments of the lower and middle Palaeocene age, such as *Fasciculithus* cf. *ulii, Cruciplacolithus tenuis, Sullivania danica* and *Markalius astroporus* (Danian).

Stratigraphic interpretation

Sample A: Upper part of Lower Eocene (Ypresian), zone NP 13 sensu MARTINI (1971) according to the presence of *Discoaster lodoensis* (7 rays), rare *Lophodolithus mochloporus* and *Reticulofenestra dictyoda*.

Sample B: Lower Eocene (Ypresian), the uppermost part of zone NP 11 (MARTINI, 1971), i.e. NNTe1D (sensu VAROL, 1998) according to the joint presence of *Discoaster kuepperi* and *Ellipsolithus macellus,* and the relative abundance of *Toweius* spp.

Palaeoecologic interpretation

The presence of calcareous nannofossils indicates a sea of average salinity, with an abundance of discoasterids, relatively warm waters, the presence of the genera *Pontosphaera, Helicosphaera* and penthaliths shallow-water conditions; the etching of placoliths and discoasterids may be the result of carbonate dissolution caused by the release of carbon dioxide during the oxidation of organic matter (ŠVÁBENICKÁ et al., 2010).

Discussion

Calcareous nannofossils of the Rote Kirche outcrop have already been studied by EGGER et al. (2009). They mentioned an assemblage of zone NP 12 with *Discoaster lodoensis* and *Tribrachiatus orthostylus* (Type B). Sample Rote Kirche A of the present study provided nannofossils of zone NP 13 with the genus *Reticulofenestra.* This small difference in results might be caused by taking samples from dissimilar places of outcrop.

VAROL (1998) mentioned the first occurrence of the genus *Reticulofenestra* within zone NNTe5 and correlated it with the uppermost part of the standard nannoplankton zone NP 12, i.e. with the upper part of the Lower Eocene. The first occurrence of *Lophodolithus mochloporus* is stated by PERCH-NIELSEN (1985) within NP 13.

Joint occurrence of *Discoaster kuepperi* and *Ellipsolithus macellus* in sample B delimits the short stratigraphic range within zone NNTe1D (VAROL, 1998). This is supported also by the occurrence of *Discoaster multiradiatus,* its last occurrence known from NP 11 (PERCH-NIELSEN, 1985).

The nannofossil content and stratigraphic interpretation of samples published by EGGER et al. (2009) different from this study (samples A and B) may indicate a deposition in a longer period of time, spanning an interval from NP 11 (upper part) up to NP 13.

Microflora – Preliminary Results

Taxonomically varied microfossils of dinocysts, spores, pollen, remains of foram linings, tiny cuticles and xylitic splinters were obtained from the aleuritic sample derived from the section at Rote Kirche. Marine dinocysts, lack of typical Mesozoic cheirolepidaceous conifers and rare Normapolles characterize the assemblage. Reworked specimens from the Upper Cretaceous, composition of pollen taxa (Icacinaceae, cf. Sapotaceae) and comparable Dino-Zones point to the early Palaeogene. Observable organic matter originated rather in a near-shore than a far offshore environment.

Characteristic of the assemblage

Residues obtained by solution and maceration of the sample (Laboratory of the Geological Survey, Prague; geology and location of the sample site, EGGER, 1996, 2007) contained no rich assemblage of palynomorphs. They are mainly composed of dinocyst microplankton (Table 3), with co-occurrence of foraminiferal linings and accessories of terrestrial plants, spores, pollen and other organic debris (Table 4).

F e r n spores belong to the Osmundaceae, Schizaeaceae, Lygodiaceae, Gleicheniaceae and document presence of the terrestrial flora of the nearby coastland area.

C o n i f e r s are represented by at least two groups. The first is documented by inaperturate pollen, resembling taxodiaceous pollen, the second comprises pollen provided with a bisaccate apparatus (bladders), grouped within Pinaceae. Both are commonly known from the Cretaceous and Tertiary pollen assemblages.

Characteristic feature of the present microflora is a small number of coniferous pollen. Cheirolepidaceae pollen grains, common in the Cretaceous deposits, were not recorded. This could be in good accordance with their disappearing in the Palaeogene.

F l o w e r i n g - p l a n t pollen genera (Normapolles and other angiospermous pollen) were represented by solitary species and single records (Table 4), in contrast to the non marine environments (e.g. Menat, Borna, Geiseltal a.o.).

D i n o c y s t s dominated in the assemblage, pointing together with other organic remains to the ample nutrient supply. Some of dinocysts show poor preservation (broken cysts or only partly preserved specimens). These features may be interpreted as the result of reworking and/or transport on the shelf.

Striking is relatively abundant dark organic matter, amorphous or with preserved structure.

According to the residual phyto- and microzoo-remains, the flourishing associations can be considered in the time of silty clay deposition.

Conclusions

The pollen and several dinocyst records provided data for the preliminary evaluation of the relative age of the investigated assemblage (CHATEAUNEUF, 1980; KEDVES, 1969, 1970; KEDVES & RUSSEL, 1982; KRUTZSCH, 2004; KRUTZSCH & VANHOORNE, 1977; DAVEY et al., 1966; KÖTHE, 1990; LENTIN & WILLIAMS, 1993; STANLEY, 1965 ex WILLIAMS et al., 1998); based on the dinocysts and several flowering plant taxa, it is obviously the Palaeogene age, mostly the Palaeocene (Zone D 3) and Early Eocene (Zone D 4, D 5, D 6). The Early Eocene (Ypresian) age has also been supported by nannofossil zones NP 11 with *Discoaster kuepperi* and *Ellipsolithus macellus* and NP 13 with *Discoaster lodoensis* and *Reticulofenestra dictyoda,* as well as larger benthic foraminifera indicating the SBZ 10 Zone. Dinocysts, preliminarily recorded, show their range often within the Zone D 4, D 5, in comparison with the palynological investigation of the borehole sections in NW Germany, Lower Saxony area (KÖTHE, 1990). The fragmentary remains of some plankton specimens and taxa predominantly known from Cretaceous deposits (ILYINA et al., 1994; MARHEINECKE, 1986) are considered as results of reworking and bioturbation processes, possible also at a very short time scale and within thin layers.

The observation of amorphous organic matter and evidently organic remains allows to consider rather bay or near shore sedimentation, not a far offshore environment. Calcareous nannofossils indicate a warmer sea of normal salinity. The presence of organic remains in the depositional area is supported also by the mode of nannofossil preservation: carbonate dissolution of coccoliths is usually caused by the release of carbon dioxide during oxidation of organic matter.

Dinoflagellates	**Remarks**	**Age**	**D Zones and Subzones**	**References**
cf. *Adnatosphaeridium vittatum* WILLIAMS & DOWNIE 1966	partly preserved	Early Eocene	D 6b	KÖTHE (KÖ), 1990, NW Germany, Gartow, Early Eocene (E Eo)
cf. *Achomosphaera* aff. *triangulata* (GERLACH 1961) DAVEY & WILLIAMS 1969		Early Eocene		KÖ, 1990, Gartow, E Eo
cf. *Apteodinium* sp.	partly preserved	Early Eocene		KÖ, 1990, Gartow, E Eo
Cordosphaeridium sp. – compared with *C. fibrospinosum* DAVEY & WILLIAMS 1966 and *C. trompetum* (COOKSON & EISENACK 1982) LENTIN & WILLIAMS 1985 Pl. 7, Figs. 1, 2 in present paper		Late Palaeocene, Early Eocene, Late Eocene (LO?) Palaeocene	D 4, D 5b D 3	KÖ, 1990, D 4 Late Palaeocene, Gartow, D 5b E Eo; (D 7 a. D 8 Late Eo, more in KÖ, 1990) Palaeocene, bore Söhlingen, ibid.
Areoligera senonensis LEJEUNE-CARPENTIER 1938 sensu KÖTHE 1990 [now *Areoligera (Achomosphaera) danica*] Pl. 7, Fig. 6 in present paper	probably reworked	Early Eocene, whole Palaeocene D 4 Upper Cretaceous, particularly in L./U. Maastrichtian	D 5b D 4, 4na, nb	KÖ, 1990; D 5b E Eo, Gartow D 4 Palaeocene, bore Penningsehl, KÖ, 1990 Cretaceous, MARHEINECKE, 1986
Dipsilidinium pastielsii (DAVEY & WILLIAMS 1966) BUJAK, DOWNIE, EATON, WILLIAMS 1980		Early Eocene	D 5b	KÖ, 1990, Gartow
cf. *Odontochitina* sp.	partly preserved	Palaeocene	D 4a (rare)	KÖ, 1990
? *Ceratiopsis* sp.	partly preserved	Palaeocene (e.g.)	D 4	KÖ, 1990
Isabelidinium sp. (former *Chatangiella* VOZZHENIKOVA 1967)	probably reworked	Upper Cretaceous (Campanian, Maastrichtian); Palaeocene, Early Eocene (another type, with broad cingulum)		e.g. Canada, Siberia, ILYINA et al., 1994; *Chatangiella* ?, Palaeocene, South Dakota, STANLEY, 1965 (ex WILLIAMS et al., 1998); Isabelidinium sp., Early Eocene, NW Germany, KÖ, 1990
Isabelidinium cf. *cooksoniae* (ALBERTI 1959) LENTIN & WILLIAMS 1977	reworked	Cretaceous	Coniacian, Campanian	Late Cretaceous, Coniacian, Campanian, e.g. Siberia, ILYINA et al., 1994
cf. *Homotryblium* aff. *tenuispinosum* DAVEY et al. 1966		Eocene	London Clay	DAVEY et al., 1966
Thalassiphora cf. *pelagica* (EISENACK 1954) EISENACK & GOCHT 1960, *T. delicata* DAVEY et al. 1966		Cretaceous, Palaeogene, Neogene	London Clay	KÖ, 1990, e.g. Early Eocene, NW Germany, Gartow, DAVEY et al., 1966, Eocene
? *Fromea* sp.	vermiculate surface			
Chlorophyta – Zygnemataceae, freshwater green algae				
Ovoidites elongatus (HUNGER 1952) KRUTZSCH 1959		Cretaceous, Tertiary, Pleistocene	freshwater and brackish water	genus commonly known from the basinal deposits

Table 3.
Plankton (selected taxa).

Filicinae – ferns		
Leiotriletes adriennis (Potonié & Gelletich 1933) Krutzsch 1959	Mesozoic, Tertiary	Schizaeaceae, *Lygodium* type
Leiotriletes microadriennis Krutzsch 1959	Palaeocene (e.g. Menat), Eocene (Geiseltal, Messel) and other sites of Tertiary deposits	Schizaeaceae, *Lygodium* type
Gleicheniidites sp.	Mesozoic, Palaeogene (predominantly)	Gleicheniaceae
Appendicisporites cf. *auritus* Aggassie in Singh 1983	Mesozoic, reworked	Schizaeaceae
Cicatricosisporites sp.	Mesozoic, Palaeogene	Schizaeaceae
Trilites menatensis Kedves 1982	Palaeocene, Eocene	Lygodiaceae (after Kedves in Kedves & Russel, 1982)
Rugulatisporites quintus Pflug 1953	Mesozoic, Tertiary	Osmundaceae
Conifers		
Pityosporites sp. – *Pityosporites minutus* (Zaklinskaja 1957) Nagy 1985, ?*Pityosporites strobipites* (Woodehouse 1933) Krutzsch 1971	?Palaeocene, Eocene, Neogene	Pinaceous conifers
Pityosporites sp. Pl. 7, Fig. 3 in present paper	Cretaceous, Tertiary	Pinaceae
Inaperturopollenites Thomson & Pflug 1953 *Inaperturopollenites hiatus* (Potonié 1931) Thomson & Pflug 1953 (as *Taxodiaceaepollenites* sp.) in Mesozoic	Cretaceous, Tertiary	Taxodiaceous pollen – commonly known from Cretaceous and Tertiary
Angiospermae - Flowering plants Normapolles	Cretaceous, Palaeogene	extinct Upper Cretaceous, Palaeocene, Early Eocene common
Minorpollis sp.	Cretaceous, Palaeogene	extinct
cf. *Complexiopollis vancampoe* Diniz et al. 1974, smaller-sized form	Cretaceous reworked	Portugal, Upper Cretaceous, L. to M. Turonian is considered
Angiospermae - Flowering plants		
cf. *Triporopollenites robustus* Pflug 1953 subfsp. *minor* Kedves 1970		cf. Betulaceae (after Kedves, 1970)
cf. *Compositoipollenites* sp.	Palaeogene	cf. Icacinaceae
aff. *Intratriporopollenites* sp.	Palaeogene, Neogene	cf. Malvaceae, Tilioideae
Tricolpites, Tricolpopollenites – Tricolpo(roi)pollenites group – reticulate morphotypes s.l.	Early Cretaceous, Tertiary	Hamamelidaceae, Platanaceae, partly extinct
Tricolporopollenites exactus (Potonié 1931) Thomson & Pflug 1953	Palaeogene, Neogene	Fagaceae, Castaneoideae
Tricolporopollenites cf. *gracillimus* Krutzsch & Vanhoorne 1977	Palaeogene, Epinois „Bild“ sensu Krutzsch	Late Landenian, palynozone 11 after Krutzsch (in Krutzsch & Vanhoorne, 1977), Early Eocene
aff. *Tricolporopollenites globus* Deák 1960 Pl. 7, Fig. 4 in present paper	Eocene (Hungary)	Incertae sedis; Sapotaceae (after Kedves, 1969)
Tetracolporopollenites sp. Pl. 7, Fig. 5 in present paper		Incertae sedis, ?Sapotaceae
Other plant remains		
filamentous Algae or Cyanobacteria	Precambrian – Recent, environmentally controlled	
charcoal splinters (rare)		
tiny cuticle fragments		
Remains of zoo-plankton		
different linings of microforaminifera		
Animal cuticle / epidermis remains		

Table 4.
Vascular plants

Plate 1

Fig. 1: *Gryphus kickxii* (GALEOTTI, 1837).
a – dorsal view, b – lateral view, c – anterior view.
Rote Kirche 1; L: 11.4 mm, W: 10.8 mm, Th: 5.5 mm.
M 2010.477.1., 2×.

Fig. 2: *Gryphus kickxii* (GALEOTTI, 1837).
Dorsal view.
Rote Kirche 1; L: 12.4 mm, W: 9.7 mm, Th: 6.3 mm.
M 2010.478.1., 2×.

Fig. 3: *Gryphus kickxii* (GALEOTTI, 1837).
a – dorsal view, b – anterior view.
Rote Kirche 1; L: 18.8 mm, W: 17.3 mm, Th: 10.0 mm.
M 2010.479.1., 2×.

Fig. 4: *Gryphus kickxii* (GALEOTTI, 1837).
a – dorsal view, b – lateral view, c – anterior view.
Rote Kirche 1; L: 19.5 mm, W: 20.5 mm, Th: 12.1 mm.
M 2010.480.1., 2×.

Fig. 5: *Gryphus kickxii* (GALEOTTI, 1837).
Dorsal view.
Rote Kirche 1; L: 19.2 mm, W: 16.1 mm, Th: 10.1 mm.
M 2010.481.1., 2×.

Fig. 6: *Gryphus kickxii* (GALEOTTI, 1837).
a – dorsal view, b – lateral view, c – anterior view.
Rote Kirche 1; L: 24.4 mm, W: 24.5 mm, Th: 12.9 mm.
M 2010.482.1., 2×.

Fig. 7: *Gryphus kickxii* (GALEOTTI, 1837).
Dorsal view.
Rote Kirche 1; L: 25.8 mm, W: 20.9 mm, Th: 11.8 mm.
M 2010.483.1., 2×.

Fig. 8: *Gryphus kickxii* (GALEOTTI, 1837).
a – dorsal view, b – lateral view.
Rote Kirche 1; L: 28.5, W: 24.0 mm, Th: 14.6 mm.
M 2010.484.1., 2×.

Fig. 9: *Gryphus kickxii* (GALEOTTI, 1837).
Dorsal view.
Rote Kirche 1; L: 27.7 mm, W: 31.2 mm, Th: 14.0 mm.
M 2010.485.1., 2×.

Fig. 10: Tube worm on *Gryphus kickxii* (GALEOTTI, 1837).
Ventral view.
Rote Kirche 1; L: 21.8 mm, W: 23.6 mm, Th: 12.0 mm.
M 2010.486.1., 2×.

Fig. 11: Tube worm on *Gryphus kickxii* (GALEOTTI, 1837).
Ventral view.
Rote Kirche 1; L: 21.2 mm, W: 19.3 mm, Th: 10.6 mm.
M 2010.487.1., 2×.

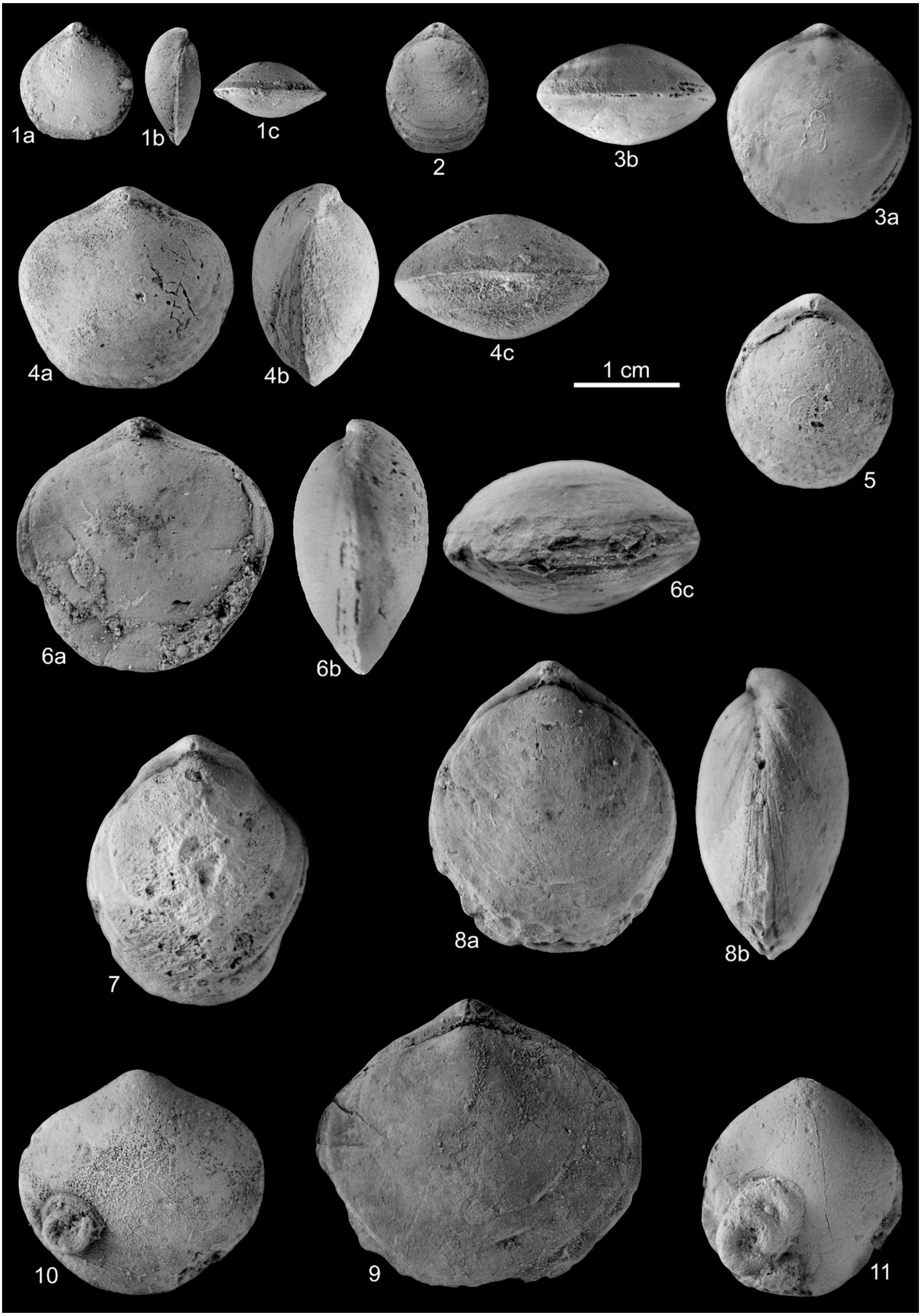

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Plate 2

Fig. 1: *Meznericsia hantkeni* (Meznerics, 1944).
a – dorsal view, b – lateral view, c – anterior view.
Rote Kirche 1; L: 30.8 mm, W: 27.8 mm, Th: 18.2 mm.
M 2010.488.1., 2×.

Fig. 2: *Meznericsia hantkeni* (Meznerics, 1944).
a – dorsal view, b – lateral view, c – posterior view.
Rote Kirche 1; L: 29.1 mm, W: 25.6 mm, Th: 19.0 mm.
M 2010.489.1., 2×.

Fig. 3: *Orthothyris pectinoides* (Koenen, 1894).
Dorsal view.
Rote Kirche 1; L: 2.7 mm, W: 2.6 mm.
M 2010.490.1., 20×.

Fig. 4: *Megathiris detruncata* (Gmelin, 1791).
Dorsal view.
Rote Kirche 1; L: 1.8 mm, W: 2.1 mm.
M 2010.491.1., 20×.

Fig. 5: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Dorsal view.
Rote Kirche 1; L: 2.4 mm, W: 2.0 mm.
M 2010.492.1., 20×.

Fig. 6: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Dorsal view.
Rote Kirche 1; L: 2.3 mm, W: 2.0 mm.
M 2010.493.1., 20×.

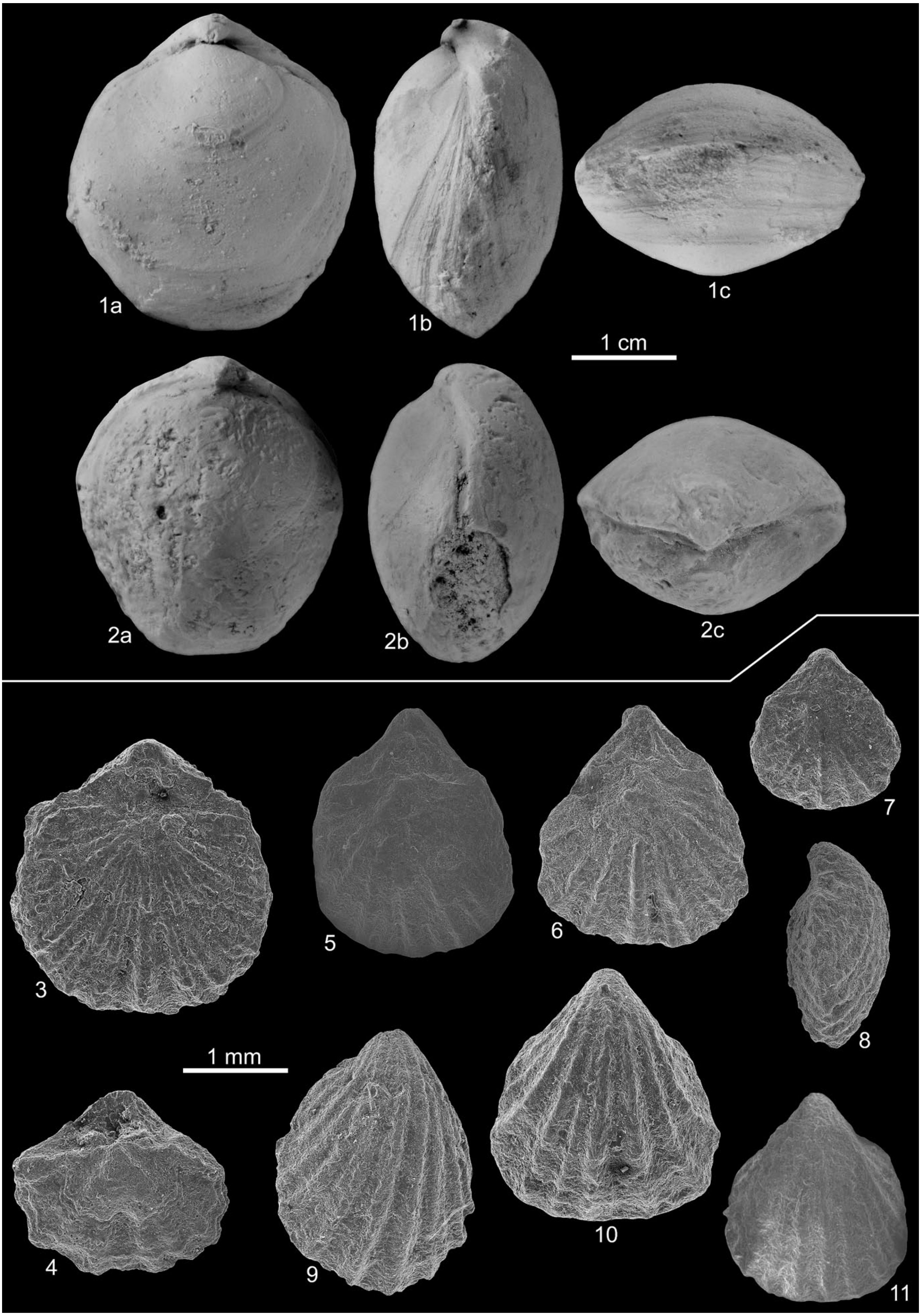
Fig. 7: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Dorsal view.
Rote Kirche 1; L: 1.6 mm, W: 1.5 mm.
M 2010.494.1., 20×.

Fig. 8: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Lateral view.
Rote Kirche 1; L: 2.0 mm, Th: 1.0 mm.
M 2010.495.1., 20×.

Fig. 9: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Oblique lateral view.
Rote Kirche 1; L: 2.6 mm, Th: 1.4 mm.
M 2010.496.1., 20×.

Fig. 10: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Ventral view.
Rote Kirche 1; L: 2.4 mm, W: 2.2 mm.
M 2010.497.1., 20×.

Fig. 11: *Argyrotheca sabandensis*? (Pajaud & Plaziat, 1972).
Ventral view.
Rote Kirche 1; L: 2.0 mm, W: 1.8 mm.
M 2010.498.1., 20×.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1 mm
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Plate 3

Fig. 1: *Terebratulina tenuistriata* (Leymerie, 1846).
Dorsal view.
Rote Kirche 1; L: 2.1 mm, W: 1.5 mm.
M 2010.499.1., 20×.

Fig. 2: *Terebratulina tenuistriata* (Leymerie, 1846).
Dorsal view.
Rote Kirche 1; L: 3.1 mm, W: 2.6 mm.
M 2010.500.1., 20×.

Fig. 3: *Terebratulina tenuistriata* (Leymerie, 1846).
Dorsal view.
Rote Kirche 1; L: 2.5 mm, W: 1.8 mm.
M 2010.501.1., 20×.

Fig. 4: *Terebratulina tenuistriata* (Leymerie, 1846).
Ventral view.
Rote Kirche 1; L: 2.6 mm, W: 1.9 mm.
M 2010.502.1., 20×.

Fig. 5: *Terebratulina tenuistriata* (Leymerie, 1846).
Ventral view.
Rote Kirche 1; L: 2.5 mm, W: 2.2 mm.
M 2010.503.1., 20×.

Fig. 6: *Terebratulina tenuistriata* (Leymerie, 1846).
Lateral view.
Rote Kirche 1; L: 2.6 mm, Th: 1.1 mm.
M 2010.504.1., 20×.

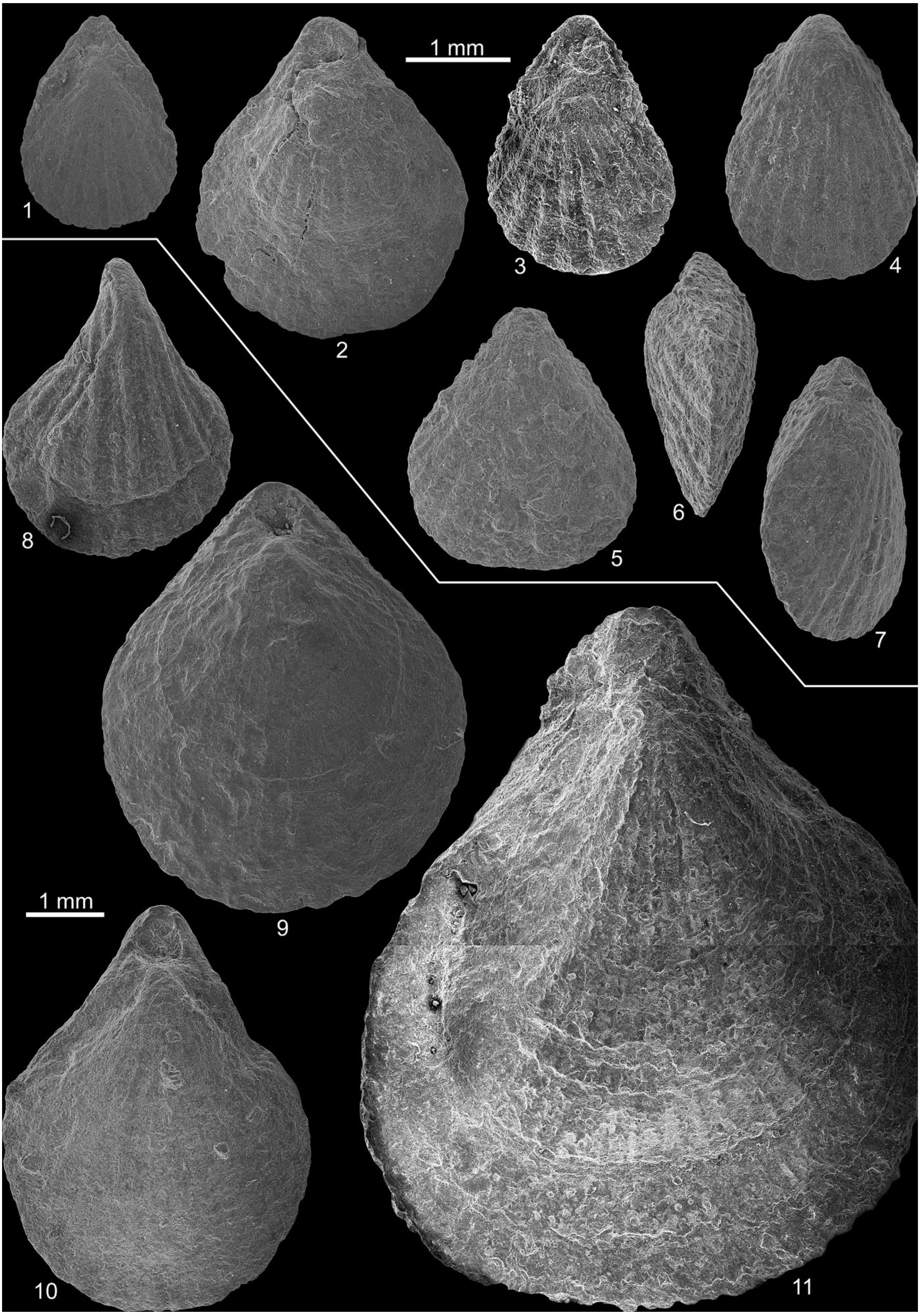
Fig. 7: *Terebratulina tenuistriata* (Leymerie, 1846).
Oblique lateral view.
Rote Kirche 1; L: 2.7 mm, W: 1.3 mm.
M 2010.505.1., 20×.

Fig. 8: *Terebratulina tenuistriata* (Leymerie, 1846).
Ventral view.
Rote Kirche 1; L: 3.9 mm, W: 2.9 mm.
M 2010.506.1., 15×.

Fig. 9: *Terebratulina tenuistriata* (Leymerie, 1846).
Dorsal view.
Rote Kirche 1; L: 5.5 mm, W: 4.6 mm.
M 2010.507.1., 15×.

Fig. 10: *Terebratulina tenuistriata* (Leymerie, 1846).
Dorsal view.
Rote Kirche 1; L: 5.2 mm, W: 3.9 mm.
M 2010.508.1., 15×.

Fig. 11: *Terebratulina tenuistriata* (Leymerie, 1846).
Dorsal view.
Rote Kirche 3; L: 9.1 mm, W: 7.5 mm.
M 2010.509.1., 15×.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1 mm
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11

Plate 4

Megalospheric orthopragmines (A-forms) from Gmunden, Gschliefgraben, sample Rote Kirche 1.

Figs. 1–3: *Discocyclina fortisi fortisi* (D'ARCHIAC)
Fig. 1: E.10.16.
Fig. 2: E.10.17.
Fig. 3: E.10.18.

Figs. 4, 7: *Discocyclina dispansa taurica* LESS.
Fig. 4: E.10.20.
Fig. 7: E.10.21.

Fig. 5: *Discocyclina pulcra* cf. *landesica* LESS.
E.10.05.

Fig. 6: *Discocyclina archiaci* cf. *archiaci* (SCHLUMBERGER).
E.10.19.

Figs. 8, 9: *Nemkovella evae evae* LESS.
Fig. 8: E.10.22.
Fig. 9: E.10.23.

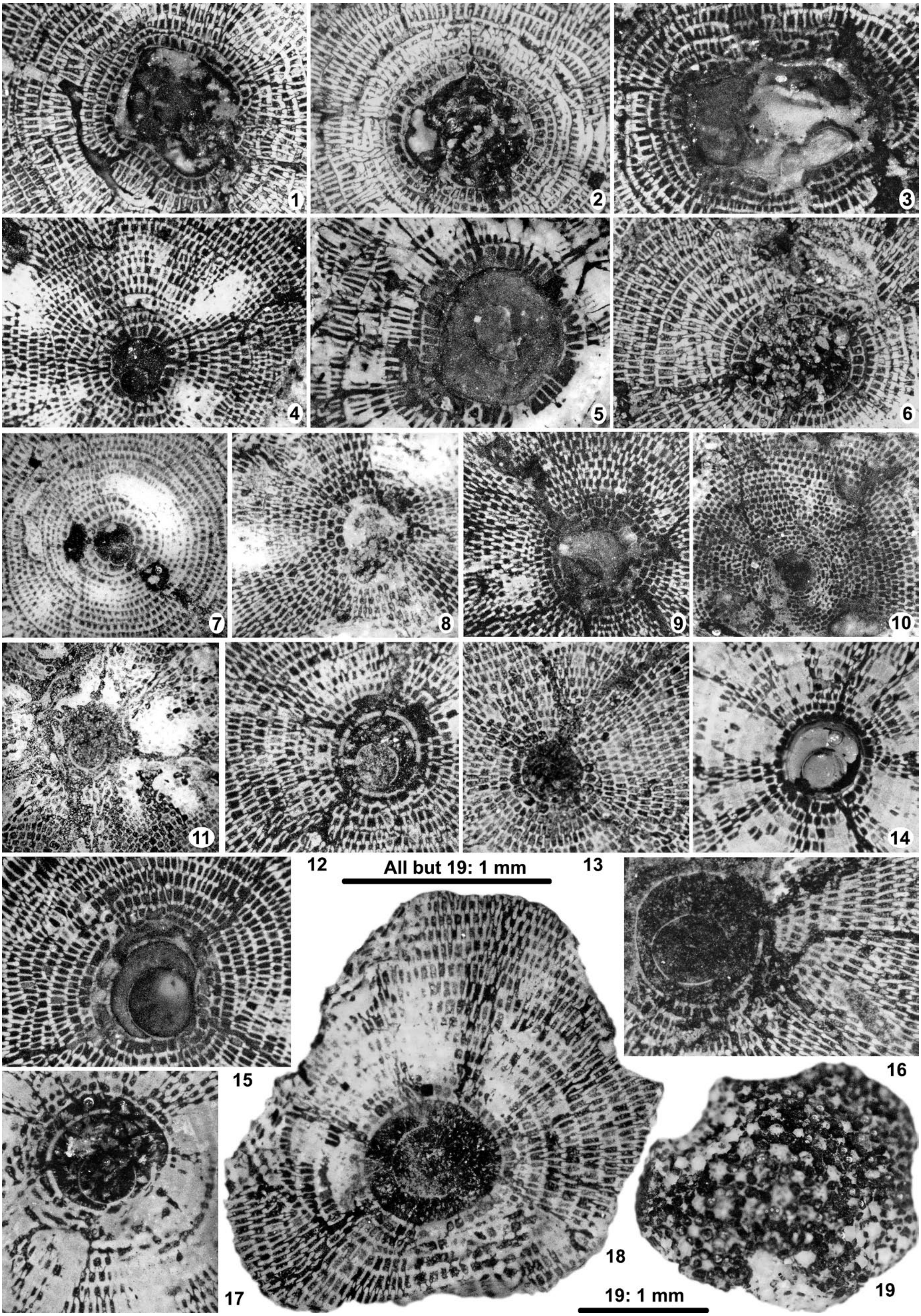
Fig. 10: *Nemkovella strophiolata* cf. *fermonti* LESS.
E.10.32.

Fig. 11: *Asterocyclina alticostata* (NUTTALL) indet. ssp.
E.10.24.

Figs. 12–14: *Orbitoclypeus schopeni crimensis* LESS.
Fig. 12: E.10.26.
Fig. 13: E.10.27.
Fig. 14: E.10.25.

Figs. 15–19: *Orbitoclypeus multiplicatus gmundenensis* n. ssp. LESS.
Fig. 15: E.10.28.
Fig. 16: E.10.29.
Fig. 17: E.10.30.
Figs. 18, 19: holotype, E.10.31.

Figs. 1–18: Equatorial sections, 40×.
Fig. 19: External view, 25×.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All but 19: 1 mm
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19: 1 mm
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Plate 5

Nummulitids from Gmunden, Gschliefgraben.

Figs. 1–4: *Nummulites nemkovi* SCHAUB.
sample Rote Kirche 1.
Figs. 1, 2: E.10.06.
Fig. 3: E.10.07.
Fig. 4: E.10.08.

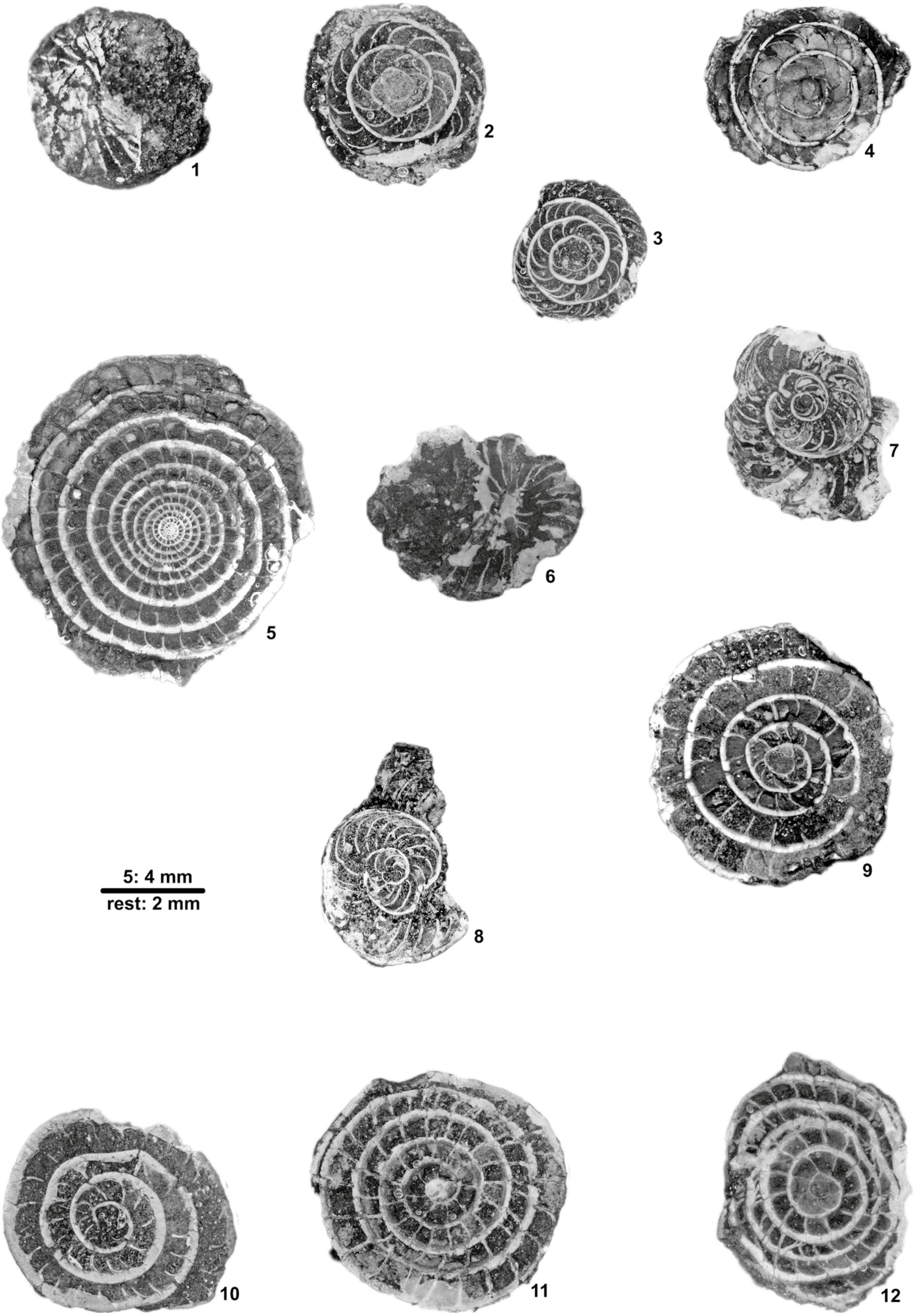
Figs. 5, 11, 12: *Assilina* aff. *placentula* (DESHAYES).
sample Rote Kirche 4.
Fig. 5: E.10.11.
Fig. 11: E.10.12.
Fig. 12: E.10.13.

Figs. 6–8: *Nummulites irregularis* DESHAYES.
sample Rote Kirche 1.
Figs. 6, 7: E.10.09.
Fig. 8: E.10.10.

Figs. 9, 10: *Assilina plana* SCHAUB.
sample Rote Kirche 1.
Fig. 9: E.10.14.
Fig. 10: E.10.15.

Fig. 5: B-form, 5×, all the others are A-forms, 10×.

Figs. 1, 5, 6: External views, all the others are equatorial sections.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5: 4 mm
rest: 2 mm
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Plate 6

Calcareous nannofossils, samples Rote Kirche A, B.
PPL – plane-polarized light, XPL – cross-polarized light. For magnification see Fig. 1.

Fig. 1: *Braarudosphaera turbinea* STRADNER.
Sample A, XPL.

Fig. 2: *Markalius astroporus* (STRADNER) HAY & MOHLER.
Sample B, XPL.

Fig. 3: *Girgisia gammation* BRAMLETTE & SULLIVAN.
Sample A, XPL.

Fig. 4: *Toweius crassus* (BRAMLETTE & SULLIVAN) PERCH-NIELSEN.
Sample B, XPL.

Fig. 5: *Toweius rotundus* PERCH-NIELSEN.
Sample A, XPL.

Fig. 6: *Clausicoccus fenestratus* (DEFLANDRE & FERT) PRINS.
Sample A, XPL.

Fig. 7: *Ellipsolithus macellus* (BRAMLETTE & SULLIVAN) SULLIVAN.
Sample B, XPL.

Fig. 8: *Lophodolithus nascens* BRAMLETTE & SULLIVAN.
Sample A, XPL.

Fig. 9: *Lophodolithus mochloporus* DEFLANDRE.
Sample A, XPL.

Fig. 10: *Helicosphaera seminulum* BRAMLETTE & SULLIVAN.
Sample A, XPL.

Fig. 11: *Helicosphaera lophota* BRAMLETTE & SULLIVAN.
Sample A, XPL.

Fig. 12: *Calcidiscus protoannulus* (GARTNER) LOEBLICH & TAPPAN.
Sample A, XPL.

Fig. 13: *Discoaster multiradiatus* BRAMLETTE & RIEDEL.
Sample B, PPL.

Fig. 14: *Discoaster binodosus* MARTINI.
Sample B, PPL.

Fig. 15: *Discoaster barbadiensis* TAN.
Sample A, PPL.

Fig. 16: *Discoaster* sp.
Sample A, PPL.

Figs. 17, 18: *Discoaster kuepperi* STRADNER.
Sample B, PPL.
Fig. 17: high focus.
Fig. 18: low focus.

Fig. 19: *Discoaster lodoensis* BRAMLETTE & RIEDEL.
Sample A, PPL.

Fig. 20: *Chiasmolithus bidens* (BRAMLETTE & SULLIVAN) HAY & MOHLER.
Sample B, XPL.

Fig. 21: *Chiasmolithus solitus* (BRAMLETTE & SULLIVAN) LOCKER.
Sample A, XPL.

Fig. 22: *Chiasmolithus* sp.
Sample A, XPL.

Fig. 23: *Reticulofenestra dictyoda* (DEFLANDRE) STRADNER.
Sample A, XPL.

Fig. 24: *Reticulofenestra* sp. cf. *R. dictyoda* (DEFLANDRE) STRADNER.
Sample A, XPL.

Figs. 25, 26: *Sphenolithus moriformis* (BRÖNNIMANN & STRADNER), BRAMLETTE & WILCOXON.
Sample A, XPL, 25–0°, 26–45°.

Figs. 27, 28: *Sphenolithus radians* DEFLANDRE.
Sample A, XPL, 27–0°, 28–45°.

Fig. 29: *Rhabdosphaera* sp.
Sample A, XPL.

Fig. 30: *Zygrhablithus bijugatus* (DEFLANDRE) DEFLANDRE.
Sample A, XPL.

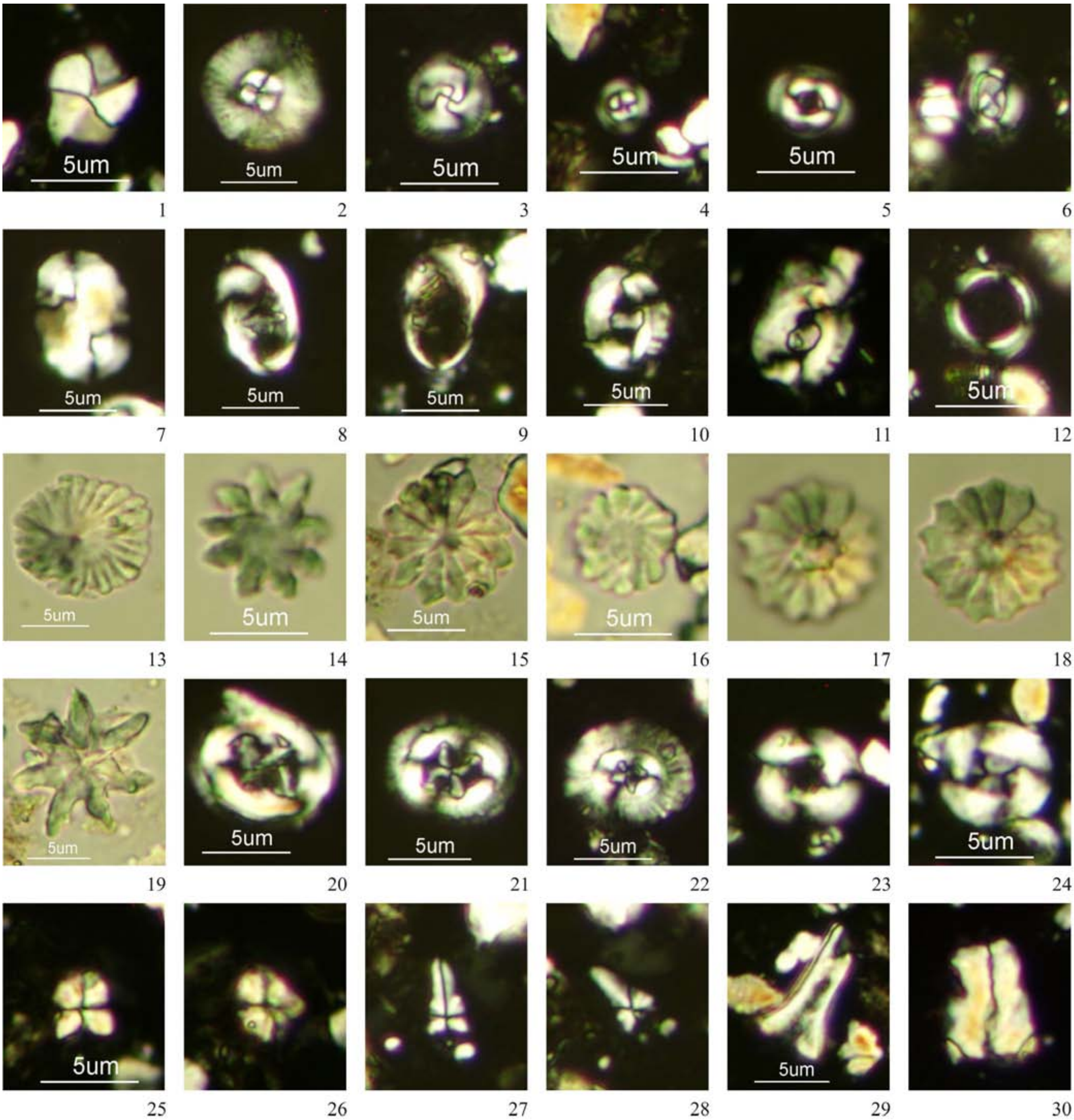
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Plate 7

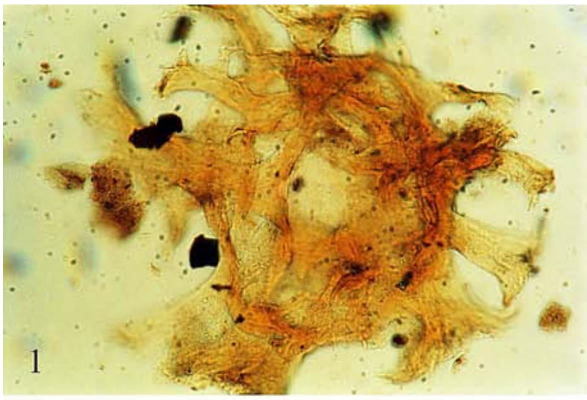
Figs. 1, 2: *Cordosphaeridium* sp.
Dinocyst, one specimen at two optical levels.
Size 110 µm. Light microscope photo.

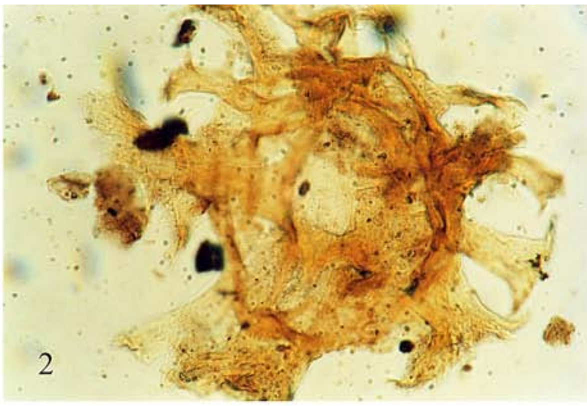
Fig. 3: *Pityosporites* sp.
Pollen of Pinaceae.
Size 90 µm. Light microscope photo.

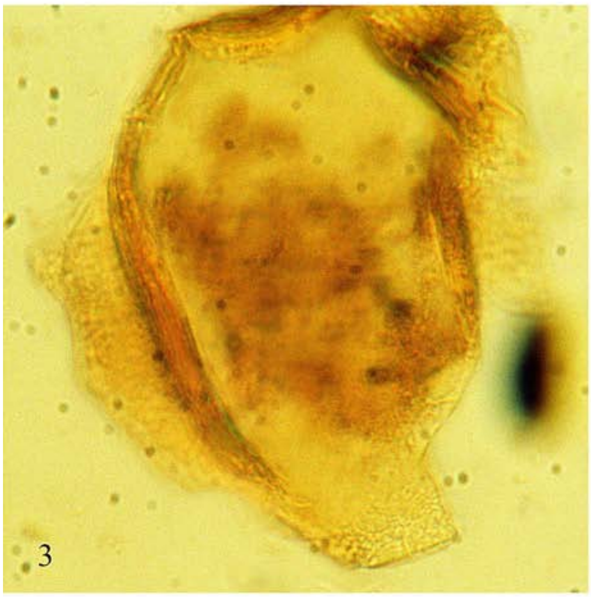
Fig. 4: aff. *Tricolporopollenites globus* DEÁK 1960.
Angiospermous pollen, incertae sedis vel Sapotaceae.
Size 30 µm. Light microscope photo.

Fig. 5: *Tetracolporopollenites* sp.
Angiospermous pollen, incertae sedis vel ?Sapotaceae.
Size 44 µm. Light microscope photo.

Fig. 6: Remains of dinocyst.
?*Areoligera (Achomosphaera) danica* type. Probably reworked.
Size of the remains 75 µm. SEM micrograph.

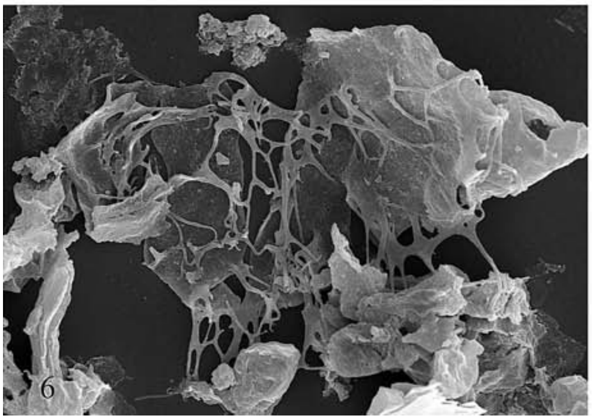

1


2


3


4


5


6

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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

Quaternary Sediments at the Southeastern Margin of the Bohemian Massif in the Borderland of Austria and the Czech Republic (Lower Austria – South Moravia)

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7 Text-Figures, 1 Table

Österreichische Karte 1:50.000
Blatt 8 Geras
Blatt 9 Retz
Blatt 22 Hollabrunn
Blatt 23 Hadres

Quaternary sediments
Micromorphology
Paleogeography
South Moravia
Lower Austria
Stratigraphy
Weinviertel
Fossil soils

Contents

Quartäre Sedimente am Südostrand der Böhmischen Masse im Grenzgebiet von Österreich und der Tschechischen Republik (Niederösterreich – Südmähren)

Zusammenfassung

Am Südostrand der Böhmischen Masse wurden im Grenzgebiet von Österreich und der Tschechischen Republik in Niederösterreich und Südmähren quartäre Sedimente untersucht. Neben der geologischen Detailkartierung der quartären Schichtfolgen erfolgte die mikromorphologische Untersuchung der in den Löss-Komplexen eingeschalteten fossilen Böden. Damit konnten die Paläoböden in diesem Raum typologisch bewertet und stratigraphisch eingestuft werden.

Die meisten Löss-Komplexe mit ihren fossilen Böden blieben im Bereich des Kartenblattes Hadres im Pulkautal und südlich von Hollabrunn und auf tschechischem Gebiet auf dem Kartenblatt Retz vor allem im Nationalpark Podyjí entlang des Thayatales erhalten.

Die untersuchten Aufschlüsse beinhalten Paläoböden der Bodenkomplexe PK II bis PK X aus dem gesamten Pleistozän. Neben unterpleistozänen Böden des Ferreto-Typs, die sich auf sandigen Kiesen der Hollabrunn-Mistelbach-Formation bildeten, kommen hier vor allem Böden des Ober- und Mittelpleistozäns im Löss vor. Letztere können den Bodenkomplexen PK II und PK III bzw. PK IV bis VI zugeordnet werden. Die ältesten Böden der Bodenkomplexe PK VII und PK X, die sich zuletzt im Cromer-Interglazial (Mittel/Unterpleistozän) bildeten, wurden in Österreich nördlich des Pulkautales und bei Lukov in Tschechien gefunden. Die meisten Böden befinden sich in autochthoner Position, ein geringerer Teil auch in parautochthoner Lage. In manchen Bereichen wurden jedoch nur Bodensedimente gefunden.

Abstract

Quaternary sediments were studied in the Austrian-Czech borderland at the southeastern margin of the Bohemian Massif in Lower Austria and South Moravia. Besides detailed geological mapping of the Quaternary strata intercalated fossil soils in loess complexes were studied by means of soil micromorphology, leading to a typological evaluation and stratigraphical integration of the paleosoils in this area.

Most of the loess complexes with fossil soils were preserved on sheet Hadres in the valley of the river Pulkau and south of Hollabrunn and in the Czech territory of sheet Retz along the Dyje valley, mainly in the National Park Podyjí.

The investigated outcrops show paleosoils from the whole Pleistocene from soil-complexes PK II to PK X. Beside Lower Pleistocene soils of ferreto type on sandy gravel of the Hollabrunn-Mistelbach Formation, especially Upper and Middle Pleistocene soils occur here, mainly on loess. The latter soils are determined to the soil-complexes PK II and PK III, resp. PK IV to VI. North of the river Pulkau and in the Czech Republic near Lukov the oldest soils of PK VII and PK X could be verified, which were formed for the last time in the Cromer Interglacial (Middle/Lower Pleistocene).

Most soils were preserved in autochthonous position, a smaller part also in para-autochthonous position. In some places only soil sediments were found.

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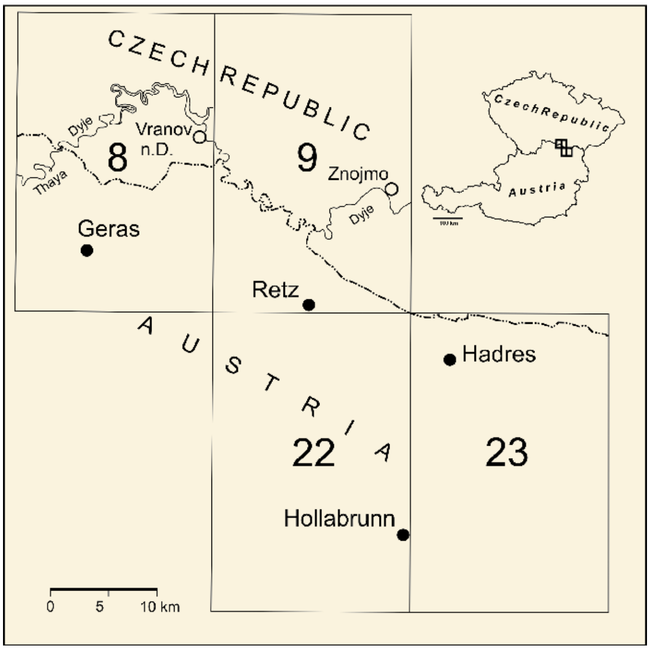
Introduction

In the past in Austria only little attention was paid to Quaternary sediments at the southeastern margin of the Bohemian Massif in the vicinity to the Czech Republic because in this area the occurrence of fossil soils is not as rich as in other regions, like Krems, Horn, and Hollabrunn. This lack in Quaternary research changed radically since 1982, when the Geological Survey of Austria started mapping and geological investigations in this area with significant cooperation of geologists from the Czech Geological Survey (Text-Fig. 1) (P. Batík †, I. Cicha, P. Čtyroký †, J. Čtyroká, T. Hájek, P. Havlíček, O. Holásek, O. Krejčí, Z. Novák, P. Pálenský, J. Rudolský †, M. Růžička, Z. Stráník, L. Švábenická, M. Vůjta). The results were published in numerous mapping reports and other publications (Batík et al., 1993, 1994; Cicha & Rudolský, 1996, 1997, 1998, 2000a, b; Čtyroká & Čtyroký, 1991; Čtyroká et al., 2002; Čtyroký, 1995, 1996, 1997, 1998; Havlíček, 1995, 1996, 1997, 1998, 2000a, b, 2002, 2003; Holásek, 1996, 1997, 1998, 2000a, b; Novák, 1997, 2000a, b; Novák & Stráník, 1998; Pálenský, 1996, 1997, 1998; Roetzel, 1983, 1988, 1989, 1990, 1991, 1992, 1993, 2003a, 2007; Stráník, 1996, 1997, 2000), as well as in the geological map sheets 8 Geras, 9 Retz, 22 Hollabrunn, 23 Hadres, and in the map of the National Park Thayatal-Podyjí (Roetzel et al., 1998, 1999, 2001, 2004, 2007; cf. Batík, 1992; Čtyroký, 1983, 1987) and their explanatory notes (Roetzel et al., 2005, 2008, 2009).

Additionally to the mapping on the scale of 1:10.000 P. Havlíček and O. Holásek carried out detailed documentation and sampling of exceptional Quaternary geological profiles. L. Smolíková dealt with micromorphological research of fossil soils and J. Kovanda did malacofauna analysis (cf. Havlíček et al., 1998a, b, 2003, 2006; Smolíková, 1994, 1998a, b).

During the Pleistocene the formation of sediments on the southeastern margin of the Bohemian Massif was very complex. In the region of Geras – Vranov nad Dyjí – Retz – Znojmo – Hadres and southwest to southeast of Hollabrunn partly thick loess complexes with fossil soils and their derivates correspond to repeatedly recurring erosion and accumulation phases with alternating periods of sedimentation and stagnancy of erosion. At the end of the Pliocene and at the beginning of the Pleistocene the Bohemian Massif was uplifted and the foreland of the Alps declined. River courses at the border of the Bohemian Massif were cutting deeply into the Miocene sediments and crystalline rocks. In the foredeep along the Dyje (Thaya) and Pulkau rivers fluvial terraces support a slower deepening originating in different accumulation levels (Roetzel et al., 2005, 2009). In the Quaternary rocks weathering, denudation and redeposition was strong, which particularly was the determining factor in the creation of deluvial, deluvial-aeolian and deluvial-fluvial sediments.

The aim of the presented work is predominantly the typological evaluation and stratigraphical integration of fossil soils found during the geological mapping on sheets 8 Geras, 9 Retz and 23 Hadres by means of soil micromorphology. The paleopedological research was primarily aimed at the Pleistocene soils developed in loess complexes, to a lesser degree also at the terrace gravel.



Text-Fig. 1.
General map of the investigated area.

Geological Setting

On the southeastern margin of the Bohemian Massif Quaternary sediments with loess and partly intercalated paleosoils are widespread. They can be found in the vicinity of Lančov, Vratěnín, Mašovice, Weitersfeld, east of Retz, north and south of Hadres, south and east of Hollabrunn, and in the vicinity of Herzogbirbaum. Numerous fossil soils of different age within loess accumulations are of great stratigraphical and palaeogeographical importance.

Erosion relicts of fluvial Pleistocene sediments are not so common but still of considerable importance. These relicts of terraces can be mainly found in valleys of bigger watercourses, e.g. the rivers Pulkau, Dyje (Thaya), and Göllersbach. On sheet Hadres the fluvial gravel predominantly occurs on the gentle northern and northwestern slopes below an elongated range of hills formed by sands and gravel of the Upper Miocene Hollabrunn-Mistelbach Formation. The Pleistocene gravel mainly was reworked from these older Neogene sediments. Their relicts are lying in different levels most frequently extended in the flow directions of the rivers Pulkau and Göllersbach. They were formed during the deepening of the drainage area in the Pleistocene. In the investigated area the occurrences of Pleistocene fluvial sediments are divided into four stratigraphic levels from the Lower to Upper Pleistocene according to different altitudes (Roetzel et al., 2009).

Other Quaternary sediments like deluvial, deluvial-aeolian and deluvial-fluvial sediments are of lesser extent and of lesser importance.

In most parts of the Alpine-Carpathian Foredeep in the investigated area the Quaternary sediments cover Neogene (Miocene) deposits whereas in the Bohemian Massif mainly crystalline rocks form the pre-Quaternary basement. However, in the northwestern crystalline region in shallow basins also marine to brackish sediments are the bases for Quaternary deposits (cf. Roetzel et al., 2005, 2008, 2009).

In the Lower Miocene (Upper Eggenburgian – Ottnangian) mainly nearshore sediments of the Retz Formation occur. These fine to coarse sands with intercalations of fossil-rich calcareous sandstones are overlain by fine-grained, clayey basin sediments of the Zellerndorf Formation. Towards the south and southwest in the Pulkau area the Retz Formation passes into calcareous sandstones of the Zogelsdorf Formation.

In the West, in isolated basins on the elevated plain of the Bohemian Massif, brackish-marine, very fine grained, carbonate-free and smectitic clays of the Weitersfeld Formation represent the equivalent to the marine sediments of the Ottnangian Zellerndorf Formation (ROETZEL et al., 2005, 2008).

Still further to the West, in the area of Langau, but also northward around Niederfladnitz and Znojmo, shallow marine to brackish sandy to gravely, kaolin-rich silts and clays of the Langau Formation were deposited in shallow, isolated depressions and flooded valleys. North of Langau and around Šafov and Nový Petřín the sediments show the influence of fresh water, where in the Ottnangian brown coal was formed in an estuary with half-bogs and swamps. These coal bearing sediments are overlain by shallow marine, micaceous fine sands and silts of the Riegersburg Formation, which mark the highstand of the sealevel in the Ottnangian (ROETZEL et al., 2005, 2008).

In the area of Niederfladnitz, Weitersfeld and Theras poorly sorted, reddish brown to yellowish brown, silty-sandy quartz-gravel of the Theras Formation overlie the older, marine sediments above an erosional contact plane. These sediments may indicate the retreat of the sea in the Upper Ottnangian but since no fossils have been found in these coarse sediments so far, their age cannot be determined for certain (ROETZEL et al., 2005, 2008).

During the Karpatian and Early Badenian shallow seas covered the edge of the Bohemian Massif and even temporarily intruded far inland towards the west.

Deposits of the Laa Formation (Karpatian) constitute mostly carbonaceous clays, silts and micaceous fine sands, often alternating with quartz-rich sandy gravel. In the foredeep they are widespread north and south of the Pulkau valley between Watzelsdorf and Laa an der Thaya and continue towards the north far into the Czech Republic (ROETZEL, 2003b; ROETZEL et al., 2009).

Overlying the Laa Formation, sediments of the Grund Formation (Lower Badenian) similarly consist of carbonaceous silts and clays with mica-rich intercalations of fossil-bearing fine- and medium-grained sands (ĆORIĆ et al., 2004). The sediments mainly can be found northwest to northeast of Hollabrunn but they also crop out northeast of Retz between Unterretzbach and Chvalovice. West of Mailberg in the Grund Formation intercalations of biogenic red algae limestones of the Mailberg Formation occur (cf. MANDIC, 2004; ROETZEL et al., 2009).

Early Sarmatian sediments from a short-lived transgression of the sea into an incised valley can be found in the surroundings of Hollabrunn along the Göllersbach valley. These deposits of the Ziersdorf Formation are mainly fine sands, silts and clays with coarse grained intercalations of sands and gravel (MANDIC et al., 2008; ROETZEL et al., 2009).

After the final retreat of the sea from the foredeep a river system was established in the Upper Miocene, draining the foredeep towards the east (NEHYBA & ROETZEL, 2004). This Paleo-Danube accumulated in the Pannonian gravel and sands of the Hollabrunn-Mistelbach Formation, which today can be found in an elongated range of hills between Krems, Hohenwarth, Ziersdorf, Hollabrunn, and Mistelbach.

The crystalline basement on the sheets Geras and Retz is formed by numerous metamorphic and plutonic rocks which belong to the Moravian tectonic unit and the westerly Moldanubian unit. These rocks are opened in a unique cross section in the deeply incised valley of the river Dyje (Thaya) in the National Park Thayatal-Podyjí (ROETZEL et al., 2005).

The lowest structural unit within the Moravian unit west of the Waitzendorf fault is the plutonic complex of the Thaya Batholith. Above these cadomic granitoids metamorphic sediments of the Therasburg Group and the overlying Pernegg Group are following. In the Czech Republic these two units are described as the lower and upper parts of the Lukov Group. In the central part of the Moravian unit, the “Weitersfelder Stängelgneis”, which is granitic gneiss associated with metamorphosed sediments, lies between the Therasburg and the Pernegg Groups, resp. within the Lukov Group. Both groups mainly contain micaschists and paragneisses, but the Pernegg Group differs from the lower Therasburg Group by a general lack of quartzite and the abundant occurrence of marble and calc-silicate-gneiss. The structurally highest unit above the Pernegg Group is the Bittesch unit with the Bittesch gneiss as the most typical rock type. The lower part of the Bittesch unit contains layers of calc-silicate-gneiss, marble, but also micaschists, aplites and pegmatites.

Further to the west the Moldanubian Drosendorf unit (equivalent to the Vranov Group of the Moravian unit in the Czech Republic) mainly comprises biotite-paragneiss closely associated with biotite-muscovite-schist. Quartzite, graphitic quartzite, amphibolite, marble, calc-silicate-gneiss as well as graphitic schist and graphitic gneiss exist as intercalations. The Moldanubian Gföhl unit (equivalent to the Šafov Group of the Moravian unit in the Czech Republic) overlies the Drosendorf unit and consists mostly of rather uniform biotite-muscovite-schist and fine-grained biotite- or biotite-muscovite paragneiss. These include thin intercalations of graphitic quartzite, ultramafic rocks and marble.

Development of Quaternary Sediments

During the Pliocene, about 5–2.5 million years ago, the course of the river Danube changed southwards to the area of the current stream, probably triggered by tectonically induced river capturing. Due to the associated large-scale erosion at that time, only a small amount of sediments was preserved from this period.

The main development of today’s morphology of the territory took place in the Pliocene, however, considerable changes occurred in the Pleistocene (roughly 2.5 million to 11.700 years ago), when colder and warmer climatic periods oscillated inducing periods of sedimentation and erosion. Gradual incision of water courses into Neogene sediments and crystalline basement rocks resulted in a deepening of the river Dyje (Thaya) in the National Park Thayatal-Podyjí by more than 120–135 m. Along the river Dyje gravelly relicts were preserved in different levels illustrating the gradual deepening of the water course. Today the oldest sandy gravel can be found approximately 110–135 m above the present fluvial plane of the Dyje-river. They probably are remains of a Pliocene river course, which passed through at this level in the initial phase of the river incision. As a consequence of alternating erosion and accumulation phases during the Pleistocene in the Dyje valley levels with fluvial gravel were formed, now preserved in 75–90 m (Lower Pleistocene), 12–50 m (Middle Pleistocene), and 1–5 m (Upper Pleistocene) above today's river. In tributaries like in the Fugnitz valley similar accumulations originated, which probably are also of Upper Pleistocene age, showing a base level of 8–10 m. In the east during the Pleistocene a gradual redeposition of sandy gravel of the Hollabrunn-Mistelbach Formation took place. Their relicts occur today in different levels at the northwestern rim of this formation, north- and westward towards the valleys of the Pulkau and Göllersbach. They irregularly cover gentle slopes, mostly following directions of local brooks and to a limited extent forming local terraces. They were preserved in 25–50 m (Lower Pleistocene), 5–25 m (Middle Pleistocene) and 1–5 m (Upper Pleistocene) above today's watercourses.

Loess originated both on the plateau in the vicinity of the river Dyje and in valleys of watercourses (Dyje, Pulkau, etc.). Predominantly on eastern and southeastern gentle slopes drifts created and loess was preserved to a lesser extent as banks or flat covers. The sources of material for loess development were Neogene sediments and deposits transported by meltwaters on flat territories. As a consequence of increased precipitation mainly in higher positions a secondary decalcification took place and thus loess-loam originated. In the warmer and more humid interglacial and interstadial periods of the Pleistocene, soils were formed in periods of stagnancy of sedimentation, again interrupted by a new deposition of younger loess. The micromorphological investigation of fossil soils proved the development of soils in the studied area during the whole Pleistocene (soil complexes PK II – PK X).

On the foot of slopes and in shallow depressions and hollows deluvial-aeolian deposits locally originated as a consequence of loess repeatedly being blown onto slopes, where deluvial sediments were formed. Silts and clays which are shifted by solifluction and gravitational movement irregularly interchange with aeolian silt to silty-sandy intercalations.

In the Pleistocene at the beginning of warmer periods the creation of deluvial sediments started as well. Most frequently their development carried on after melting of the surface of permafrost beds, when sediments and weathering products were oversaturated by water and flowed down the slopes. The lithological composition depends on the character of weathering, residues of sediments and crystalline rocks in the nearby vicinity and basement.

At the beginning of the Holocene (about 11.700 years ago) considerable climate warming and humidification took place. In that time nearly in all valleys, erosion furrows and hollows enormous quantities of fluvial and deluvial-fluvial deposits developed. The lithology of fluvial sediments depends on the geological composition and the character of weathering of rocks in the whole catchment area. Therefore accumulations in floodplains are relatively variable in lithology. Deluvial-fluvial sediments fill up bottoms of occasionally flown-through shallow depressions, broader gorges and hollows. Water courses of tributaries either are continuously connected or form visible outwash cones. Their lithological composition too is closely linked to the character of weathered rocks and sediments in the nearby vicinity.

Distribution of Aeolian Sediments and Fossil Soils

Just as in South Moravia loess also was deposited in vast and very massive blankets along the southeastern margin of the Bohemian Massif in Lower Austria. Their sedimentation, interrupted by periodic hiatuses, took place on leeward sides of slopes during the whole Pleistocene. Thus massive loess series with complicated structure and polygenetic, mostly interglacial soils arose.

On the geological maps on scale 1 : 50.000 (Roetzel et al., 1998, 1999, 2001, 2004, 2007) it clearly can be seen how their extent and thickness is changing in dependence of altitude, basement geology and morphology. The morphology of the southeastern margin of the Bohemian Massif in the surroundings between Geras and Retz is very rugged. In this territory between the villages Dallein, Fronsburg, Merkersdorf and Niederfladnitz the distribution of loess and loess-loam is limited to the lower lying areas between 520–400 m above sea level, mostly at the southeast to eastward slopes. Due to this very pronounced morphology occurrences of aeolian sediments are very frequent but discontinued here. Their thickness mostly ranges up to 4 m, around Zissersdorf maximally up to 7 m. Loess covers not only gentle eastern to southeastern slopes, but in some places also flat areas. They frequently are connected to deluvial sediments, additionally containing weathered rock debris. In the vicinity of outcrops of weathered crystalline rocks it is difficult to distinguish weathered residua from deluvial-aeolian or deluvial sediments (cf. Roetzel et al., 2008).

On sheet Retz the Quaternary sediments continue on the Czech side, forming extensive loess covers with fossil soils northwest of Znojmo and also around this town (Znojmo-Dřevařské závody, Sedlešovice, etc.). Southeast of the crystalline escarpments of the Waitzendorf fault and the Diendorf fault on the sheets Retz and Hollabrunn distribution and thickness of Quaternary sediments is increasing strongly. On mildly sloping or flat territories in substantially lower altitude, loess forms extensive complexes of strata above the Neogene sediments up to 10–17 m thick (cf. Roetzel et al., 1998; Havlíček et al., 1998b).

In the western part of sheet Hadres extensive loess blankets rapidly fade away towards the east and occur less in disjointed areas. In the northeastern part of this territory loess is even missing. The biggest loess blankets in the area of sheet Hadres form drifts and banks south of the Hollabrunn-Mistelbach Formation, mostly in the territory between Großstelzendorf – Bergau – Porrau and Großmugl – Herzogbirbaum – Nursch. In smaller areas loess is situated in the vicinity of Weyerburg and Enzersdorf im Thale. In the northwestern part of this territory aeolian sediments are preserved, for example, in the vicinity of Wullersdorf and Immendorf. North of Großkadolz they merge into relatively massive drifts of deluvial-aeolian sediments. The thickness of loess ranges mostly up to 4 m; in some places between Großstelzendorf and Obergrub up to 8 m. In Göllersdorf (brickyard Wienerberger) loess and deluvial-aeolian sediments, 6 to 8 m thick, are exposed (cf. ROETZEL et al., 2007, 2009). Loess, about 20 m thick, was quite sporadically found south of the hunting lodge Gflez northwest of Bergau (cf. ROETZEL et al., 2007, 2009).

The stratigraphically most important loess series from the Lower to Middle Pleistocene with the best developed interglacial fossil soils were predominantly preserved along the Pulkau valley, as proved in the vicinity of Alberndorf, Untermarkersdorf, Hadres, Großkadolz, and Mailberg. South of the rim of the Hollabrunn-Mistelbach Formation fossil soils mainly were discovered in the vicinity of Großstelzendorf, to a lesser extent also around Bergau and Porrau (cf. ROETZEL et al., 2007, 2009).

Text-Fig. 2.
Track-cut in the NP Podyjí between Podmolí and Lukov. Rotlehm (soil-complex PK X; Middle / Lower Pleistocene) developed on weathered mica schist.
Photo: O. Holásek & P. Havlíček.

Description of Fossil Soils

In the Austrian part of sheet Hadres fossil soils mostly can be found northwest and northeast of Hadres, around Alberndorf and Seefeld, northwest of Mailberg, and in the southwestern part of the territory near Großstelzendorf, Obergrub and Porrau. In the Czech Republic important outcrops with fossil soils are concentrated in the area of the National Park Podyjí.

In a track-cut between Podmolí and Lukov a typical reddish rotlehm is developed on weathered Proterozoic mica schist of the Lukov Group. This is one of the oldest paleosoils in this area, which might have formed at the latest in the Cromer Interglacial (Middle/Lower Pleistocene) (HAVLÍČEK & SMOLÍKOVÁ, 2003a) (Text-Fig. 2).

In the Austrian part the oldest fossil soils are brown earthificated braunlehms and braunlehm-like pseudogley, rotlehm and rubefied braunlehms of the soil-complex PK VII and PK X, which occur northwest of Großkadolz and north-northwest of Hadres (Text-Fig. 3) (HAVLÍČEK et al., 1998a; SMOLÍKOVÁ, 1998a). Fossil soils of soil-complex PK VII or maybe an older one also occur close to the chapel in Porrau and near the Hubertuskapelle north of Obergrub.

Text-Fig. 3.
Outcrop in a vineyard NNW of Hadres with soil-complex PK X; Middle/Lower Pleistocene. Spade for scale.
Photo: O. Holásek & P. Havlíček.

On the northern edge of the National Park Podyjí east of Mašovice loess with five fossil soils concentrated into three soil-complexes from the Middle Pleistocene were exposed in excavations of Neolithic trenches. The basal soil corresponds to a braunlehm (minimum soil-complex PK VII). A spotted fossil soil in its overburden belongs to soil-complex PK VII or PK VI–V (?) and an overlying chernozem resembles some of the Holstein Interglacial soils (PK VI-V). At last a pair of youngest luvizems belongs to soil-complex PK IV (HAVLÍČEK & SMOLÍKOVÁ, 2003b) (Text-Fig. 4).

In the Trausnitz valley between Konice and Popice (HAVLÍČEK & SMOLÍKOVÁ, 2002), close to the confluence to the river Dyje, a loess drift with two fossil soils of braunlehm-type (minimum soil-complex PK VII) is exposed on the eastern slope (Text-Fig. 5).

In the brickyard Wienerberger in Göllersdorf at the bottom a brown earthificated luvizem (soil-complex PK VI) is preserved in the profile. After a long hiatus it is overburden by a PK II chernozem.

Text-Fig. 4.
Outcrop in the NP Podyjí east of Mašovice. Three soil-complexes with five fossil soils (PK IV–VII) in loess, exposed in an excavated Neolithic trench. Hammer in centre of photo for scale.
Photo: O. Holásek & P. Havlíček.

Text-Fig. 5.
Outcrop in the Trausnitz valley in the NP Podyjí. Two fossil soils of braunlehm-type (minimum soil-complex PK VII) in loess.
Photo: Th. Hofmann.

Further, two fossil soils of PK V and one of soil-complex PK VI (Holstein) – a braunlehm-like parabraunerde – are preserved south and north of Alberndorf (Text-Fig. 6) (Havlíček et al., 1998a).

In the National Park Podyjí Cílek et al. (1996) described a group of strata of deluvial sediments and loess with two fossil soils (soil-complex PK II or PK IV) 10 m above the alluvial plain of the river Dyje. In Vranov nad Dyjí near the pseudocarst cave "Ledové sluje", the same authors recorded 2.2 m thick loess and loam with a soil horizon of Bt1 parabraunerde. Finally on the southeastern slope of Gališ in the cut of a path a B horizon with a substantial carbonate horizon transmitted by solifluction can be seen which, most probably, is an interglacial soil.

In Vranov nad Dyjí close to a petrol station a series of deluvial and aeolian sediments with a fossil soil was exposed in the overburden of a fluvial terrace 15–20 m above the river. It is the Bt horizon of a luvizem (probably soil-complex PK III, the last interglacial). A similar interglacial fossil soil of soil-complex PK III, including two interstadial chernozems of Upper Pleistocene age is developed in the loess profile below the dam in Vranov nad Dyjí (Havlíček & Smolíková, 2003a; Roetzel et al., 2005, 2008).

Text-Fig. 6.
Outcrop in the vineyards SSW of Alberndorf in the Pulkau valley. A soil of soil-complex PK VI above Miocene sediments. Spade for scale.
Photo: O. Holásek & P. Havlíček.

Text-Fig. 7.
Outcrop in the western cellar lane in Mailberg with two fossil soils (PK II and III) in loess.
Photo: O. Holásek & P. Havlíček.

Brown basal soils (parabraunerde) of soil-complex PK III – Stillfried A were found west and northwest of Mailberg, near Porrau and Großstelzendorf. Chernozems were preserved in places in their overburden in parautochthonous position (Text-Fig. 7) (Havlíček et al., 1998a).

Northwest of Alberndorf two chernozems (PK II – Stillfried A) rest in superposition above PK III.

Conclusions

In the studied territory the occurrence of fossil soils is not as rich as in the Danube region. However, systematic geological mapping led to the discovery of numerous localities with paleosoils from the whole Pleistocene (soil-complexes PK II – PK X).

Besides Lower Pleistocene soils of the ferreto type on sandy gravel of the Hollabrunn-Mistelbach Formation, especially Middle and Upper Pleistocene soils occur here (cf. Tab. 1). A lower rate of polygenesis in the soils in most cases signifies younger age. Intensity and a number of individual polygenetic processes quite depend on the course of Pleistocene climatic, sedimentary and pedogenetic cycles.

Most of the Middle to Upper Pleistocene loess complexes with fossil soils were preserved on sheet Hadres in the valley of the river Pulkau and south of Hollabrunn and in the Czech territory of sheet Retz along the Dyje valley, mainly in the National Park Podyjí. In these regions not only fossil soils from soil-complexes PK II and PK III, but also PK IV–VI occur. North of the river Pulkau and in the Czech Republic near Lukov the oldest soils of PK VII and PK X could be verified, which were formed for the last time in the Cromer Interglacial.

Most soils were preserved in autochthonous position, some also in parautochthonous position. In some places only soil sediments were found.

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Stratigraphy	PK	Fossil soils	Localities
Upper Pleistocene	II II/III	chernozem (perhaps degradated) illimerized soil (parabraunerde - Stillfried A)	Vranov n. D., Alberndorf, Großstelzendorf, Porrau, Vranov n.D., Mailberg
Middle Pleistocene	IV V VI VII	luvizem chernozem, braunlehm-like parabraunerde braunlehm-like parabraunerde, spotted fossil soil, brown earthificated luvizem braunlehm	Mašovice, NP Podyjí Mašovice, Alberndorf Alberndorf, Göllersdorf, Mašovice Großkadolz, Hadres, Mašovice,Trausnitz valley, Porrau,Obergrub
Lower Pleistocene	X	rubefied braunlehm, brown earthificated braunlehm, braunlehm-like pseudogley (ev.also PK VII?), rotlehm rubefied ferreto	Großkadolz, Hadres Podmolí-Lukov Znojmo, Sedlešovice

Table 1:
Scheme of development and classification in soil complexes (PK) of the studied fossil soils.

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Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

Stratigraphy of Quaternary Fossil Soils along Highway A5 between Wolkersdorf and Schrick (Vienna Basin, Lower Austria)

Libuše Smolíková[1], Pavel Havlíček[2] & Reinhard Roetzel[3]

8 Text-Figures, 2 Tables

Österreichische Karte 1: 50.000
Blatt 25 Poysdorf
Blatt 41 Deutsch Wagram
Blatt 42 Gänserndorf

Micromorphology
Palaeopedology
Pleistocene
Quaternary
Fossil soil
Loess

Contents

Stratigraphie quartärer Böden an der A5 Nordautobahn zwischen Wolkersdorf und Schrick (Wiener Becken, Niederösterreich)

Zusammenfassung

Beim Bau der A5 Nordautobahn im nordöstlichen Niederösterreich zwischen Wolkersdorf und Schrick konnten komplex aufgebaute pleistozäne Schichtfolgen dokumentiert werden. Die dort häufig in den Lössen eingeschalteten fossilen Böden wurden durch mikromorphologische Untersuchungen den Bodenkomplexen PK II bis VI aus dem Ober- bis Mittelpleistozän zugeordnet.

Die vollständigste Löss-Abfolge war über miozänen Silten und Tonen (Sarmatium–Pannonium) nordwestlich von Gaweinstal entwickelt. Dort konnten in einer Senke mit bis zu 7 m quartärem Löss sechs mittel- und oberpleistozäne Bodenhorizonte bzw. Bodensedimente der Bodenkomplexe PK V–VI, PK III, PK II–III und PK II nachgewiesen werden.

Abstract

Short time exposures during the construction of highway A5 in northeastern Lower Austria between Wolkersdorf and Schrick were used for documentation of complex Pleistocene loess sections. Abundant intercalated fossil soils were assigned by micromorphological investigations to the soil complexes PK II to VI (Upper to Middle Pleistocene).

The most complete loess section was developed northwest of Gaweinstal above Miocene silts and clays (Sarmatian and Pannonian), where a depression was filled with at least 7 m Quaternary loess interrupted by six Middle and Upper Pleistocene soil horizons and soil sediments of soil complexes PK V–VI, PK III, PK II–III, and PK II.

Introduction

In cooperation with the Geological Survey of Austria, the University of Vienna and the Czech Geological Survey Prague important loess profiles, exposed during the construction of highway A5 north of Vienna, were studied. In 2007 and 2008 Pavel Havlíček investigated nine sections in the surroundings of Schrick, Gaweinstal and Wolkersdorf (Text-Fig. 1, Tab. 1). In these outcrops the exposed loess profiles with many soil complexes were documented in detail and sampled for 22 micromorphological analyses (Tab. 2). Afterwards a detailed palaeopedological elaboration of all sections and micromorphological investigation was done by Libuše Smolíková (cf. Smolíková, 2009).

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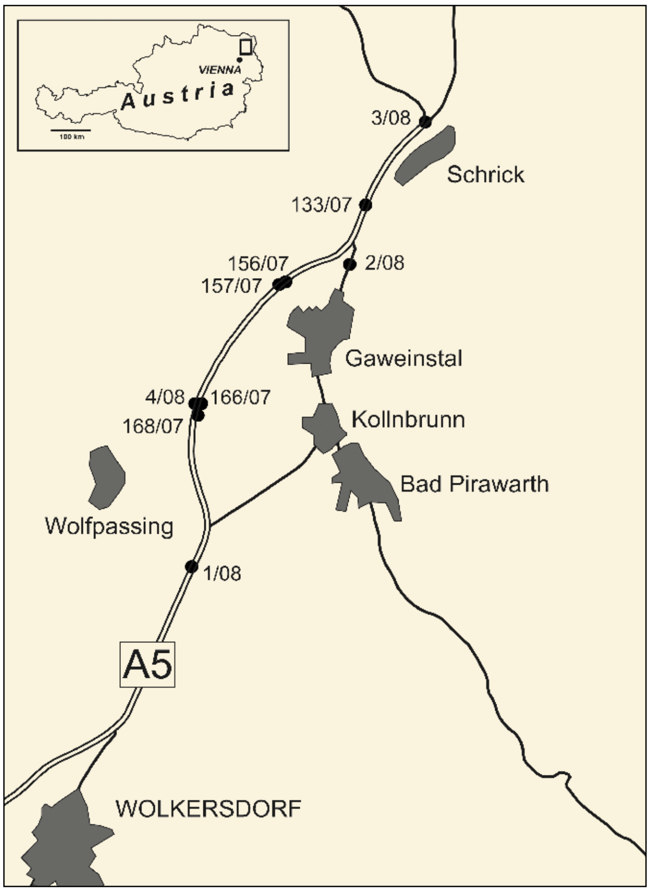
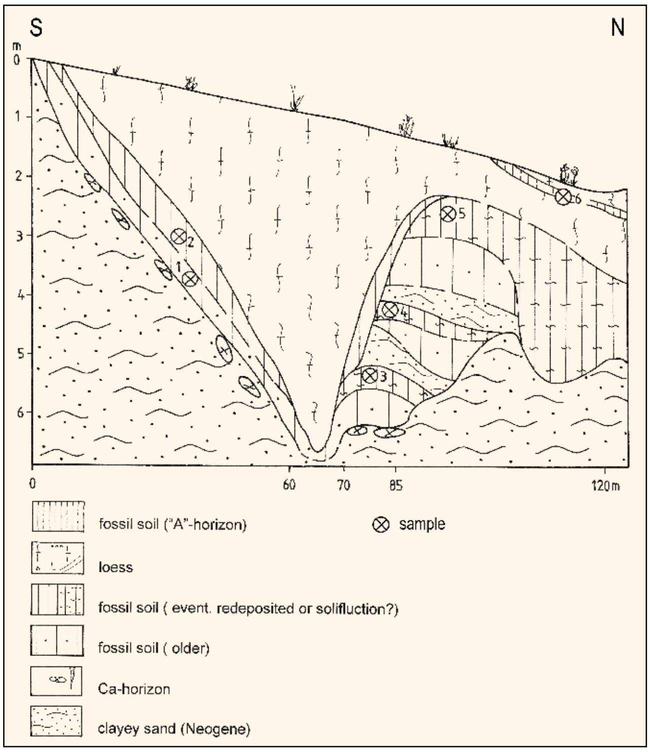


Text-Fig. 1.
General map with the studied sections on highway A5 between Wolkersdorf and Schrick (cf. Tab. 1).



Text-Fig. 2.
Sketch of section 157/07 northwest of Gaweinstal.
157/6/07: youngest Pleistocene chernozem, PK II; 157/2/07: chernozem of Stillfried A, PK II–III; 157/5/07: original basal soil of Stillfried A, PK III; 157/4/07: soil sediments; 157/3/07: mixed soil sediments; 157/1/07: braunlehm-luvizem, corresponding to one of the interglacial intervals of Holstein, PK V–VI.

Geological Setting

The investigated section of highway A5 between Schrick and Wolkersdorf is located in the Vienna Basin. In some parts sediments of the Miocene basement are exposed below the Quaternary cover. Between Wolkersdorf and Gaweinstal mainly sediments of the Sarmatian are cropping out, whereas in the north, southwest of Schrick, the Pannonian deposits prevail (Grill et al., 1954, 1961; Schnabel et al., 2002). The marine Sarmatian sediments mainly consist of sands, sandstones and silty clays, which are in some areas very fossiliferous. In the fluvial to lacustrine Pannonian deposits silts and clays with intercalations of sands and gravel dominate (Grill, 1968; Harzhauser et al., 2004). However, most of the investigated area is covered by loess, where in many locations fossil soils are intercalated (cf. Grill, 1968).

Lithology of Quaternary Sediments

The loess series exposed by the huge excavations during the construction of highway A5 cover a pre-Quaternary morphology with an erosion surface on the Neogene sediments. They show, in some areas, a thickness up to more

Sample	Locality	Latidude	Longitude
133/07	N Gaweinstal	N 48° 30´ 06.1´´	E 016° 36´ 05.3´´
156/07	NW Gaweinstal	N 48° 29´ 14.3´´	E 016° 34´ 44.5´´
157/07	NW Gaweinstal	N 48° 29´ 12.8´´	E 016° 34´ 38.1´´
166/07	W Kollnbrunn	N 48° 27´ 51.4´´	E 016° 33´ 18.1´´
168/07	W Kollnbrunn	N 48° 27´ 44.6´´	E 016° 33´ 14.3´´
1/08	NE Wolkersdorf	N 48° 26´ 02.03´´	E 016° 33´ 09.1´´
2/08	N Gaweinstal	N 48° 29´ 26.2´´	E 016° 35´ 48.9´´
3/08	N Schrick	N 48° 31´ 05.5´´	E 016° 37´ 05.8´´
4/08	W Kollnbrunn	N 48° 27´ 51.4´´	E 016° 33´ 15.1´´

Table 1.
List of investigated outcrops with WGS84 coordinates.

than 10 m. Beside the typical loess also sandy intercalations occur, showing the character of wind-blown sands in the aeolian series. However, soliflucted sediments occur here as well. The numerous fossil soils frequently grouped into soil-complexes (PK) illustrate hiatuses of varying duration in the loess deposition during the periods of sedimentation stagnancy.

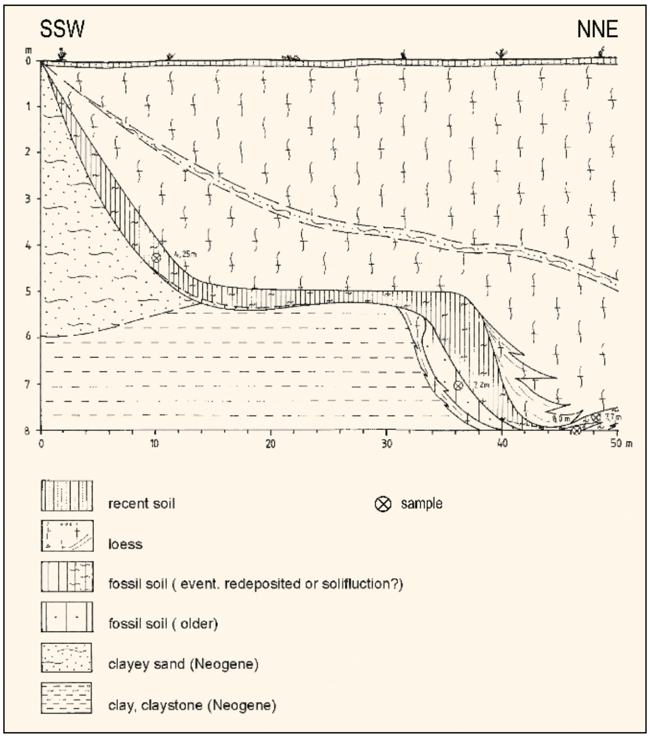
In the sections 4/08 west of Kollnbrunn and 2/08 north of Gaweinstal (cf. Text-Figs. 1, 7) the fossil soils are penetrated by desiccation cracks, filled by younger loess; the surface of the soils is affected by Upper Pleistocene solifluction (palsen, frost turbulences). Within the loess formation up to three soil horizons are intercalated, corresponding to PK II–III. Also krotovinas in the upper chernozem in section 166/07 (cf. Text-Fig. 6), filled by loess are remarkable, exemplifying the soil-life of this soil. In this loess exposure, more than 13 metres thick, three soil horizons are developed, of which the lower two are affected by solifluction.

Section 157/07 northwest of Gaweinstal (Text-Figs. 2, 3) opened a complex loess profile filling up a valley in east-west direction with at least 7 m of Quaternary sediments. Here above Miocene silts and clays three Middle Pleistocene soil horizons could be found. The youngest Upper Pleistocene chernozem horizon of soil complex PK II and PK II–III (Stillfried A, sample 157/2/07 and 157/6/07) is developed within the loess, and above an older fossil soil (157/1/07).

Text-Fig. 3.
Section 157/07 northwest of Gaweinstal.
Northern part of the section with mixed soil sediments (157/3/07) at the base followed by soil sediment (157/4/07) and basal soil of Stillfried A (PK III, 157/5/07) above. The depression on the left is partly filled with young loess.
Photo P. Havlíček.

Stratigraphy	PK	Fossil soils	Localities
Upper Pleistocene	II	carbonate chernozem - the youngest humus soil of Stillfried A	133/3/07 (N Gaweinstal)
		chernozem	157/6/07 (NW Gaweinstal)
		carbonate chernozem; upper soil PK II	166/3/07 (W Kollnbrunn)
		chernozem - lower soil PK II	166/2/07 (W Kollnbrunn)
	II-III	chernozem Stillfried A	2/08 (5.6 m; N Gaweinstal) 157/2/07 (NW Gaweinstal)
		chernozems	4/08 (3.1 m, 4.0 m, 4.7 m, W Kollnbrunn)
	III	A - chernozem horizon - the oldest humus soil of Stillfried A	133/2/07 (N Gaweinstal)
	III	B-horizon of weakly earthificated luvizems; the oldest soil of Stillfried A	133/1/07 (N Gaweinstal)
		luvizem (parabraunerde - illimerized soil); basal interglacial soil (R/W)	166/1/07 (W Kollnbrunn)
		B-horizon of luvizem; basal soil of Stillfried A	168/07 (W Kollnbrunn)
		B-horizon of luvizem; soil is typical for the last Interglacial	1/08 (4.25 m; NE Wolkersdorf)
	III	XXX	
		fossil soil sediment after redeposition of humus horizon; this position probably corresponds to the original basal soil of Stillfried A	157/5/07 (NW Gaweinstal)
Middle Pleistocene	IV	B-horizon of luvizem, upper soil PK IV	1/08 (7.2 m; NE Wolkersdorf)
		A-horizon of luvizem, lower soil PK IV	1/08 (7.7 m; NE Wolkersdorf)
	V-VI	braunlehm-luvizem; this soil corresponds to one of the interglacial intervals (M/R, Holstein)	157/1/07 (NW Gaweinstal) 1/08 (8.0 m; NE Wolkersdorf)
	V-VI	XXX	
		soil sediment from chernozem	156/07 (NW Gaweinstal)
		mixed soil sediment	157/3/07 (NW Gaweinstal)
		soil sediment	157/4/07 (NW Gaweinstal)

Table 2.
Scheme of development and classification in soil complexes (PK) of the studied fossil soils along highway A5 between Wolkersdorf and Schrick.



Text-Fig. 4.
Sketch of section 1/08 northeast of Wolkersdorf.
At the base of the depression a relic of a braunlehm-luvizem PK V or PK VI (8.0 m). Above (7.7 m) a fragment of an A-horizon of a weakly developed luvizem (lower soil of PK IV). At 7.2 m a B-horizon of a weakly developed luvizem (upper soil of PK IV) affected by solifluction. On Neogene sediments at 4.25 m a B-horizon of a finely brown earthificated luvizem (PK III, interglacial climate optimum).

Similarly section 1/08 northeast of Wolkersdorf has a complex structure (Text-Fig. 4, 5). In a huge depression on greenish-grey Miocene clays with abundant calcareous concretions and sands Middle Pleistocene fossil soils of soil complex PK IV–VI (samples 7.2 m, 7.7 m, and 8.0 m) are developed. In the SSW part of the profile relicts of soil complex PK III (sample 4.25 m) were determined in their overburden, which originated after a longer hiatus. After another hiatus of sedimentation and soil creation this depression was filled up with Upper Pleistocene loess with distinguishable deposition of deluvial sands and silts in the centre and wind-borne deposits removed by solifluction, showing the complex development with a number of interruptions in sedimentation even in this youngest loess.

Text-Fig. 5.
Detail of section 1/08 northeast of Wolkersdorf.
At 7.7 m of the section an A-horizon of a weakly developed luvizem affected by solifluction, corresponding to the lower soil of PK IV.
Photo P. Havlíček

In section 133/07 north of Gaweinstal three soil horizons of soil-complex PK II–III were developed in Upper Pleistocene loess, more than 10 m thick. Between the middle and upper soil, loess is removed by solifluction, probably proving a hiatus in sedimentation.

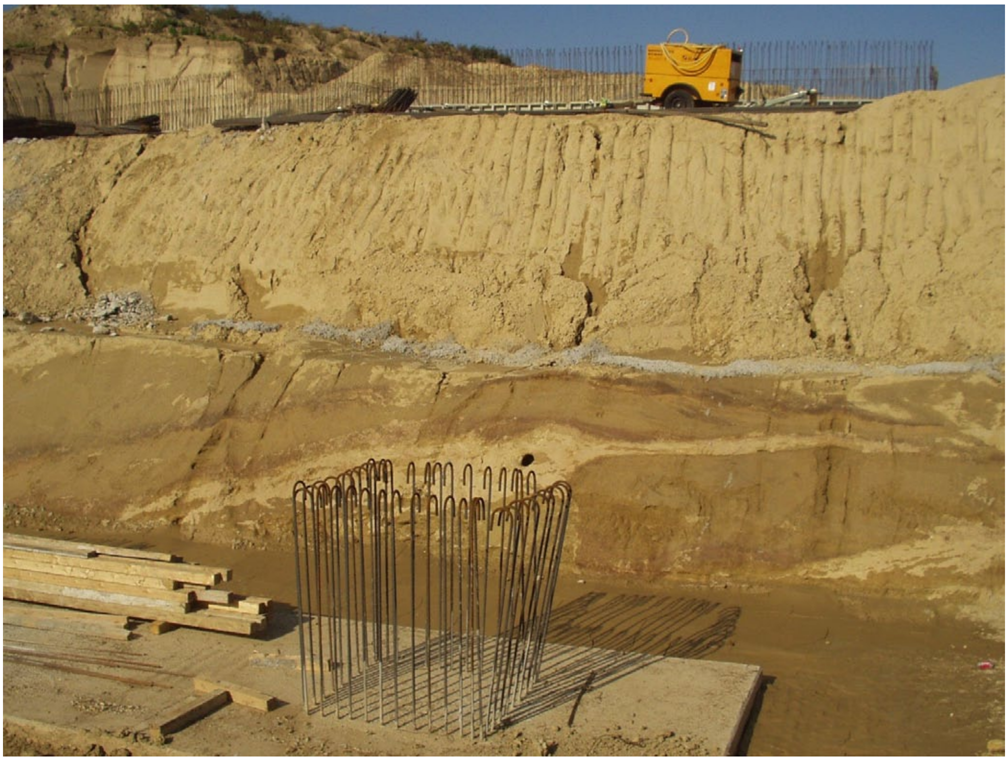
Erosive surfaces of fossil soils in places or possibly lacking soil complexes in superposition as well as occurrence of solifluction and interchanging of loess with mixed deluvial-aeolian and soil sediments from chernozem demonstrate the complex palaeogeographical development of Pleistocene sediments in this part of the Vienna Basin (cf. sections 156/07, 157/07 northwest of Gaweinstal).

No fossil soil was observed in section 3/08 north of Schrick near the crossing of highway A5 with the Schrick – Mistelbach road. There, an erosional depression in Miocene claystones and silts is filled with loess and sands, 7 m thick.

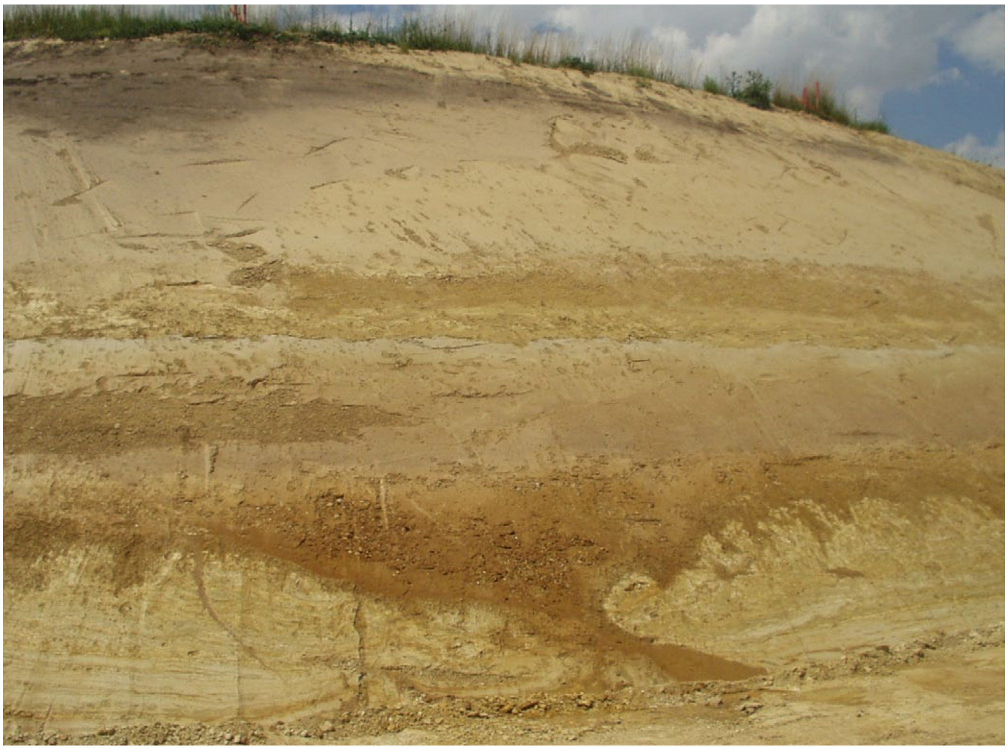
Micromorphology of Fossil Soils

All principal data on Quaternary geology and soil micromorphology of the investigated sections including the stratigraphical classification are summed up in Table 2. The micromorphological determination of fossil soils is one of the most important methods of research of loess formations. It considerably helps solving stratigraphical and palaeogeographical problems. The studied sections of highway A5 between Wolkersdorf and Schrick provided significant contributions to the explanation of the landscape evolution during the Pleistocene in this part of the Vienna Basin. The sections opened fossil soils and soil sediments of the Upper and Middle Pleistocene, assigned to the soil complexes PK II to VI.

The highway cuttings west of Kollnbrunn (Text-Fig. 6) altogether showed three fossil soils, where the youngest is a typical carbonate chernozem (166/3/07 – upper soil of PK II), whereas the middle soil (166/2/07) corresponds to a mildly para-autochthonous chernozem (lower soil of PK II). The lower soil (166/1/07), partly displaced by solifluction, is an intensively brown earthificated luvizem (para-



Text-Fig. 6.
Section 166/07 west of Kollnbrunn.
Loess formation with three fossil soils. The youngest soil (166/3/07; below the compressor) is a typical carbonate chernozem (upper soil of PK II). In the lower part of the section a mildly para-autochthonous chernozem (166/2/07; lower soil of PK II). At the base an intensive brown earthificated luvizem (parabraunerde – illimerized soil; 166/1/07), displaced by solifluction, which is a basal interglacial soil of R/W (Eem; PK III).
Photo P. Havlíček.



Text-Fig. 7.
Detail of section 2/08 north of Gaweinstal.
Typical chernozem penetrated by frost wedges (depth 5.6 m). This chernozem belongs to one of three humus horizons of Stillfried A (PK II–III).
Photo P. Havlíček.

braunerde – illimerized soil). It is a basal interglacial soil of R/W – Eem (PK III).

In another outcrop west of Kollnbrunn (168/07) a brown soil horizon is developed. It is a B-horizon of granulated to weakly earthificated luvizem (basal soil of Stillfried A).

The micromorphological research at section 4/08 west of Kollnbrunn close to a highway bridge proved that even all three soils at depths of 3.1 m, 4.0 m, and 4.7 m correspond to chernozems of PK II–III, where the best developed soil was the middle one at a depth of 4.0 m. A similar chernozem was developed in an outcrop at an underpass approx. 480 m south of section 4/08 (Peticzka et al., 2009, p. 53ff., cf. Text-Fig. 8).

In section 2/08 north of Gaweinstal (Text-Fig. 7) a typical chernozem was developed originating from a thin loess cover, which means, that gravels at its basement do not correspond to its C-horizon, but to the D-horizon. This chernozem belongs to one of three humus horizons of Stillfried A (PK II–III; sample 5.6 m).

Text-Fig. 8.
Outcrop west of Kollnbrunn at an underpass, approx. 480 m south of section 4/08. Strongly developed chernozem of PK II–III above Neogene sands and silts. Photo R. Roetzel.

In the same period the loess strata north of Gaweinstal (133/07) with three fossil soils originated. The youngest soil is a deep black humus A-horizon of typical carbonate chernozem; probably it is the youngest humus soil of Stillfried A (PK II, 133/3/07). The middle fossil soil is an A-chernozem horizon with a relatively higher portion of humus soils with braunlehm concretions. Bioturbation came from the genetically underlying but separated B-horizon. It is likely that this partially polygenetic soil corresponds to the oldest humus soil of Stillfried A. The A-horizon of a fossil chernozem is the oldest humus soil of Stillfried A (PK III, 133/2/07). The oldest soil horizon is polygenetic and formed when the relief of partial braunlehm-like plasma (luvizem under forest) arose. In the warm and humid climate the granulation to brown earthification of partial braunlehm-like plasma (drying and partial temperature lowering) occurred. It was followed by a mild pseudogleying (declining interglacial period) and enrichment with carbonates as a consequence of new loess creation (very cold climate). The oldest soil of Stillfried A is a B-horizon with granulated to weakly earthificated luvizems (PK III, 133/1/07).

One of the most important sections is the highway cutting northwest of Gaweinstal (157/07) (Text-Fig. 2, 3). In the upper part probably the youngest Pleistocene chernozem PK II (157/6/07) is preserved within the loess, which eventually is younger than a soil in the southern part of the section (157/2/07) pointing to PK II–III (Stillfried A). Below, on the base of the loess filling in a noticeable depression a complex formation of fossil soils and soil sediments is developed. On the top fossil soil sediments are developed on relocated silts after redeposition of the humus horizon; strong, intensive illimerization and earthification took place and pseudogleying and re-calcification followed. The last Pleistocene illimerization took place in the last interglacial R/W, so that this position probably corresponds to the original basal soil of Stillfried A (PK III, 157/5/07). In the soil horizon below (157/4/07) the soil sediments or sands, in which removed and weakly humus remains of soil prevail, are exemplified. In the horizon 157/3/07 mixed soil sediments, which consist of redeposited soils with a small portion of peptisated plasma and flocculated and weakly humus soil, are preserved. Both described soils are developed on overblown silts. The oldest fossil soil in this profile (157/1/07) is a brown soil horizon. This para-autochthonous soil corresponds to a brown soil (braunlehm-luvizem). The development of this soil was affected by extensive disquiet braunlehm-like, slightly brown earthificated parabraunerde? (granulated luvizem), which are typically developed in PK V–VI, where it recurs four times. This soil corresponds to one of the interglacial intervals (Holstein; PK V–VI).

In the section 156/07 northwest of Gaweinstal a soil horizon affected by solifluction is developed on Neogene sands. It is the soil sediment from a chernozem, which consequently underwent pseudogleying and was slightly recalcificated.

The last important section northeast of Wolkersdorf (1/08) is a loess formation with fossil soils filling a depression (Text-Fig. 4, 5). In a depth of 4.25 m a B-horizon of a finely brown earthificated luvizem is developed on Neogene sands and calcareous clays. This soil is typical for the last Interglacial (PK III), where it represents the (interglacial) climate optimum. In the NNE part of the section in a depth of 7.2 m a B-horizon of a weakly developed luvizem affected by solifluction is developed (upper soil of PK IV). In a depth of 7.7 m a fragment of an A-horizon of a weakly developed luvizem corresponding to the lower soil of PK IV was discovered. It is rather more intensively developed than the upper soil, which for that matter is valid for all soil complexes. The oldest remain of a fossil soil is a small relict in 8.0 m, which is a B-horizon of a braunlehm-luvizem (= braunlehm-like parabraunerde) of soil complex PK V or PK VI.

Conclusions

By the investigation of the Pleistocene sections new insights into the formation of loess with fossil soils and soil sediments could be gained in this part of the Vienna Basin. Sections from the Upper and Middle Pleistocene with fossil soils classified into the soil complexes PK II to PK VI were found. They demonstrate the complex development of sediments and fossil soils in the Pleistocene, when periods of sedimentation, erosion and solifluction periodically alternated with calm development of fossil soils (hiatuses).

In the most important section 157/07 northwest of Gaweinstal (Text-Fig. 2, 3) during the development extraordinary intensive dynamics appeared. This outcrop demonstrates how in the course of one certain interval of a Pleistocene climatic cycle on the habitat not only various soil types, but also their occurrence (modes) alternate in the sense of KUBIĔNA (1956). It involves a diverse variability of both (soil types and modes – i.e. a form of occurrence; cf. KUBIĔNA, 1956). In that section three different soil types occur: braunlehm-like luvizem, typical to weakly developed luvizem and various humus soils, including the chernozems overlying the primary loess. Here a series of various soils and their transition forms occur from the oldest autochthonous fossil soils up to fossil soil sediments, corresponding to modes 6, 9, 12 (e.g. fossil luvizem of mixed soil sediments; sample 157/5/07, modus 9).

By micromorphological analyses of soil sediments it may be possible to determine original autochthonous soil types and to use them for palaeoclimatic and palaeogeographic reconstruction, not only for this habitat but also for the surrounding territory.

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Book Reviews

ABHANDLUNGEN DER GEOLOGISCHEN BUNDESANSTALT
Abh. Geol. B.-A. | ISSN 0378-0864 | ISBN 978-3-85316-058-9 | Band 65 | S. 231–232 | Wien, 10. 11. 2010
Fifty Years of Geological Cooperation between Austria, the Czech Republic and the Slovak Republic

Book Reviews

PŘIKYL, R. & TÖRÖK, À. [Eds.] (2010): Natural Stone Resources for Historical Monuments. – Geological Society, Spec. Publ. **333**, 237 pgs., ill., London. ISBN: 978-1-86239-291-5; £ 80.00.

Following the introduction of the Editors, Richard Přikyl from the Charles University in Prague (CZ) and Àkos Török from the Budapest University of technology and Economics (HU), the reader learns more about the structure of the book, as well as about its origin: *"This volume brings together one general introductory and twenty original research papers grouped in four sections mirroring the major aims of the volume and dominant trends in the current research field. These are: (1) decay processes, (2) performances and compatibility of natural stone, (3) properties of natural stone and (4) provenance studies and stone databases. Most of the papers were presented during the 'Natural stone resources for historical monuments' special session held under the framework of the 'Energy, Resources, Environment' program sessions on the General Assemblies of the European Geosciences Union held in Vienna (Austria) annually during 2006–2008"* (p. vii). From this point of view the book focuses on Europe: The articles cover aspects from Austria, Germany, The Czech Republic, Slovakia, Italy, England, Ireland, France, the Netherlands, Portugal and even Japan. The geographical aspect is very important for building stones, as different climatic conditions (atlantic influence in Ireland versus continental or mediterranean climate in southern Europe) cause various damages to stones.

In the introduction the editors underline the importance of the availability of traditionally used stone for architects and restorers. This received a new dimension in the late 20th and early 21st century, due to the fact, that great masses of cheap stone were and still are imported (e.g. from China, India …). As a result many local quarries of smaller dimension had to be closed; as a consequence many local stones are not available any longer. *"This lack of locally available stones is a significant drawback in monument restoration practice, since replacement stones are no longer available."* (p. 7).

Some articles deal with special forms of weathering (processes), like: *"Alveolar weathering of Cretaceous building sandstones on monuments in Saxony, Germany"* (by Heiner Siedel from Dresden [D]) or *"Black-crust growth and interaction with underlying limestone microfacies"* by Gilles Fronteau and coworkers (all from France). Four papers discuss problems with various aspects of sodium and salt crystallization, two deal with recent examples from Japan. In addition to these problems a German team from Munich examined the Teplá monastery (CZ) focussing on the effects of a fire damage in the 17th century to the trachytic building stone. Beside color changes from yellow-beige to red, minerals like goethite and limonite turned into hematite. In this context the Austrian geologist Alois Kieslinger (1900–1975) proves to be a pioneer writing two fundamental papers on fire damage (1932 and 1949).

A Spanish group of authors concentrates on weathering problems of some the widely used varieties of serpentinites from Cabo Ortegal region (Galicia, Spain) which do not meet the requirements for an ornamental stone.

Stephen Mccabe and coworkers *("A legacy of mistreatment: conceptualizing the decay of medieval sandstones in NE Ireland")* analyze the complex history of a sandstone and point out what might happen in future with this building stone considering climatic changes.

Among the wide range of building stones, a paper about tuff *("Evaluation of three Italian tuffs (Neapolitan Yellow Tuff, Tufo Romano and Tufo Etrusco) as compatible replacement stone for Römer tuff in Dutch built cultural heritage")* shows the problems of using another stone, when the original stone is no longer available.

Lisa Cooke from the UK entitles her work as: *"The 19th century Corsi collection of decorative stones: a resource for the 21st century?"* The collection consists of 1,000 polished samples (15 x 7,5 x 4 cm) of natural stone collected by Faustino Corsi (1771–1845) from 1800 to 1827. These stones might even now serve as a resource for the identification of ornamental stone used in historical buildings.

Finally two papers deal with electronic databases which offer experts from various fields information on different aspects of building and ornamental stone.

To conclude: This book illustrates a broad spectrum of aspects which should be kept in mind, when working with historical building stones. Thus geology turns out as a discipline connecting architecture, history, meteorology and many other aspects of science.

Thomas Hofmann

PEDLEY, H.M. & ROGERSON, M. [Eds.] (2010): Tufas and Speleothems: Unravelling the Microbial and Physical Controls. – Geological Society, Spec. Publ. **336**, 362 pgs., ill., London. ISBN: 978-1-86239-301-1; £ 72.00.

"This volume was conceived at a 'Tufas and Speleothems' workshop organized around 'research in progress' which was held in the Geography Department, University of Hull, UK in May 2008. … The articles herein reflect the work of 63 specialists (principally bacteriologists, microbiologist, hydro- and geochemists and sedimentologists) based mainly in academic institutions. The remit of this volume is to develop a better understanding of the biological and chemical influences on carbonate precipitation associated principally with ambient temperature freshwater carbonates", thus the editors, H.M. Pedley and M. Rogerson explain in the introduction the origin, as well as the aim of this book.

Seventeen contributions deal with various aspects from different countries like Germany, Spain, Indonesia, Turkey, Italy, Austria, Slovakia, Poland and the UK. The first 13 papers focus on carbonate precipitation associated with microbial processes. The following four point out the necessity to consider also the hydrochemistry (of cavewaters), the geochemistry of speleothems and the physical control on depositional morphology.

To give some examples: M. Gradzinski (Poland) made a field experiment on the growth of tufa. He found out, that tufa is growing faster on a carbonate substratum, than on a copper substratum. He observed, that tufa is growing more efficient in a fast flowing regime, than in a sluggish environment and that the chemistry of the water is the most important factor for tufa growth. In addition to this outdoor experiment M. Rogerson et al. checked the *"Microbial influence on macroenvironment chemical conditions in alkaline (tufa) streams: perspectives from in vitro experiments"*.

The major part of articles deals with aspects at a rather small scale, like the contributions from Bindschedler et al. *("Calcitic nanofibres in soils and caves: a putative fungal contribution to carbonatogenesis")* or A. Pentecost *("The fractionation of phosphorus in some modern and late-Holocene calcareous tufas in North Yorkshire, UK")*. In the last contribution of this book by Ø. Hammer et al. (all from Norway) *"Travertin terracing: Patterns and mechanism"* investigations at a larger scale were made. The authors try to solve the question about the origin of large terraces, like those, well known, from Yellowstone National Park (USA) or from Pamukkale in Turkey. They conclude: *"There is probably not a single mechanism responsible for localization of precipitation at the rim in all circumstances … In spite of recent results, travertine terracing remains an intriguing problem. … In addition the accessibility of this earth-surface system, the availability of analytical and computational techniques, the cross disciplinary nature of the problem and the sheer beauty and mystique of travertine terraces all make travertine terracing an attractive area of research"*.

The mixture of high quality articles dealing with all aspects of tufas and speleothems including various disciplines, like sedimentology, geochemistry, biology and some others, makes this book with its valuable index an indispensible reference for all researchers.

Thomas Hofmann

SMITH, B.J., GOMEZ-HERAS, M., VILES, H.A. & CASSAR, J. [Eds.] (2010): Limestone in the Built Environment: Present-Day Challenges for the Preservation of the Past. – Geological Society, Spec. Publ. **331**, 257 pgs., ill., London. ISBN: 978-1-86239-294-6; £ 68.00.

Limestone has been used since ancient times as building material. Many of the important historic buildings, which are built of limestones – some of them being even part of the UNESCO World heritage list – show significant signs of decay. This fact raises not only questions of restoration and preservation, but shows also the need to make the best use of new limestones in today's buildings. To characterize limestones in all details is a fundamental requirement. Furthermore the effect of the polluted atmosphere on the surface of stones turned out to be a key question, like the question what mortars to use.

This book is a compilation of 22 papers with a strong focus on mediterranean case studies; thus, the cover shows an impressive picture of severe honeycomb weathering of Globigerina Limestone in the Cittadella walls in Rabat at Gozo, an island of Malta. J.P. Calvo and M. Regueiro give a comprehensive overview of important building stones of the region *("Carbonate rocks in the Mediterranean region – from classical to innovative uses of building stone")*. First they characterize the most important rocks, in addition they sum up the recent situation of carbonate building stones by countries starting with Italy, Spain, Greece, France concluding with Israel and the African countries (Egypt, Algeria, Tunesia and Morocco).

Additionally there are also contributions from Germany by Siegesmund et al. *("Limestones in Germany used as building stones: an overview")* and from the UK. The first one by M.J. Thornbush is entitled as *"Measurements of soiling and colour change using outdoor rephotography and image processing in Adobe Photoshop along the southern facade of the Ashmolean Museum, Oxford"*. The contribution by O. Sass and H.H. Viles *("Two-dimensional resistivity surveys of the moisture contents of historic limestone walls in Oxford, UK: implications for understanding catastrophic stone deterioration")* shows the problems with a Jurassic oolithic limestone, which was used to build Oxford. The geophysical monitoring of some selected wall sites showed complex patterns of moisture distribution.

The book summarizes many aspects of today's situation in working with (ancient) building stones. Contributions dealing with different kinds of weathering as well as restoration make this compendium important for geoscientists in their daily work in seeking answers for the preservation of our cultural heritage; which, in many cases, is built of limestones.

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