XXI International Congress of the Carpathian Balkan Geological Association (CBGA 2018)
Berichte der Geologischen Bundesanstalt, v. 126, p. 259 – 288

Field Trip Post-EX-5

Mass transport deposits, geometry, depositional regime and biostratigraphy in a Late Jurassic carbonate-clastic radiolaritic basin fill (Northern Calcareous Alps)

HANS-JÜRGEN GAWLICK[1], HISASHI SUZUKI[2] & SIGRID MISSONI[1]

[1] University of Leoben, Department of Applied Geosciences and Geophysics, Petroleum Geology, Peter-Tunner-Strasse 5, 8700 Leoben, Austria. hans-juergen.gawlick@unileoben.ac.at

[2] Otani University, Kyoto 603-8143, Japan

Abstract

This field trip will provide insights in the geometry of a Late Jurassic deep-water radiolaritic trench-like basin, which formation started in the Oxfordian. The Oxfordian phase (first cycle) of the marine basin evolution is characterized by a coarsening-upward trend in deposition, reflecting a compressional regime. In the mass transport deposits only redeposited Late Triassic to Middle Jurassic clasts occur. In the Kimmeridgian (second cycle) grey-greenish radiolarite deposition in a starved environment dominated. In the Tithonian (third cycle) restarted sediment recycling. The general sedimentation trend is a fining-upward cycle indicating an extensional regime. At the beginning of this third cycle, the mass-transport deposits contain (predominantly) Late Triassic to rare Jurassic clasts. Higher up in the succession, the deposits are firstly made of a mixture of older clasts and Tithonian reef debris. Upsection the clast spectra consist of shallow-water carbonates originated from a newly formed carbonate platform. In the Late Tithonian until the Jurassic/Cretaceous boundary occur mass transport deposits and turbidites made predominantly of shallow-water material from this carbonate platform, in parts also mixed with older components derived from the Late Permian - earliest Early Triassic Alpine Haselgebirge. In general, the sedimentation in the Tauglboden basin is characterized by fine-grained siliceous organic-rich sedimentary rocks with intercalation of various mass transport deposits (slumps, debris flows, olistostromes and slide blocks). In the proximal basin, the thickness of the Oxfordian part of the basin fill is nearly 700 m, whereas in the central basin the compacted thickness reaches nearly 150 m. In the most distal part of the basin deposited only few tens of meters of radiolarites. In the Tithonian to earliest Berriasian deposited in the more proximal parts roughly 300-400 m, and in the central to distal part of the basin an up to 800 m thick compacted sedimentary sequence. The triggering factors of the gravitational mass transport movements are earthquakes and volcanism, both can be studied in well preserved outcrops. In addition, the Jurassic geodynamic evolution of the Northern Calcareous Alps will be discussed.

1 Introduction

During this field trip in the central Northern Calcareous Alps (Fig. 1), as part of the Eastern Alps and one of the geologically most classical areas of the world, we will visit locations documenting the entire Late Jurassic (Oxfordian-Tithonian) to earliest Cretaceous (Early Berriasian) depositional history in basinal sequences.

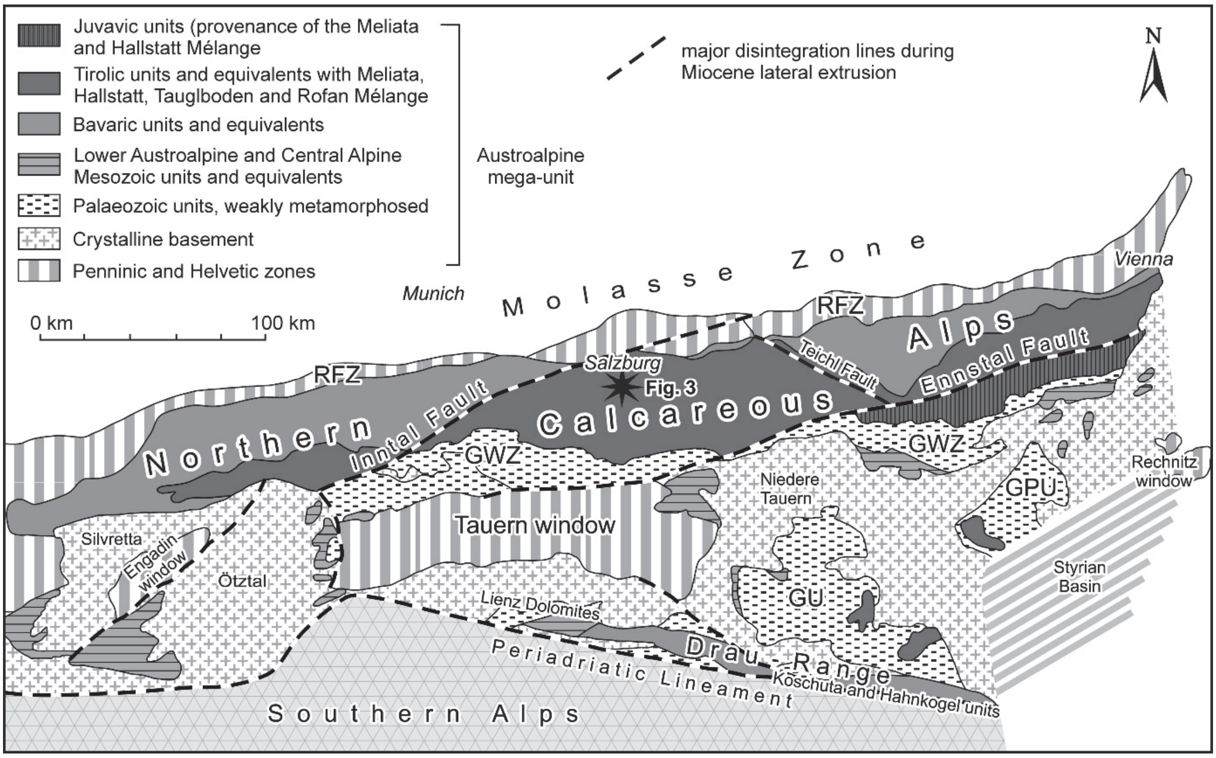

Fig. 1: Tectonic sketch map of the Eastern Alps. The field trip area is indicated by an asterisk (compare Fig. 2). After TOLLMANN (1977) and FRISCH & GAWLICK (2003). GPU Graz Palaeozoic Unit; GU Gurktal Unit; GWZ Greywacke Zone; RFZ Rhenodanubian Flysch Zone.

Until today a lively debate is ongoing on the Middle to Early Cretaceous geodynamic history and the Triassic-Jurassic arrangement of the different facies belts in the Northern Calcareous Alps. It is out of our scope to give a historical overview about the different views and interpretations during the history of investigations. Crucial for the understanding of the Mesozoic geodynamic history of the Northern Calcareous Alps is a restoration of the palaeogeography before the Neogene lateral tectonic extrusion of the Eastern Alps (RATSCHBACHER et al., 1991; LINZER et al., 1995; PUEYO et al., 2007).

Classical nappe concept and historical alternatives

The classic tectonic subdivision of the Northern Calcareous Alps (compare Fig. 1) (in its fundamentals established by HAUG, 1906; later modifications by, e.g., HAHN, 1913; KOBER, 1923; SPENGLER, 1951; PLÖCHINGER, 1980; TOLLMANN, 1976a, b, 1985; compare LINZER et al., 1995) was established in the Berchtesgaden Alps and in the Salzkammergut area and defined three nappe groups. These are, from bottom to top: Bavaric, Tirolic, and Juvavic nappe group. This concept is still widely accepted (see below). Later, a subdivision into three tectonic units ("Stockwerke" *sensu* LEBLING et al., 1935) was proposed: the Tirolic unit ("Tirolische Einheit" *sensu* HAHN, 1913) at the base, overlain by the Lower Juvavic unit ("Tiefjuvavische Einheit": Hallstatt nappes), and the Upper Juvavic unit ("Hochjuvavische Einheit": Berchtesgaden and Dachstein nappes). Subsequently, in the salt-mine of Hallein MEDWENITSCH

(1962) subdivided the Lower Juvavic nappe into a Lower ("Untere Hallstätter Decke": Zlambach nappe - grey Hallstatt facies rocks) and an Upper Hallstatt nappe ("Obere Hallstätter Decke": Sandling nappe - variously coloured Hallstatt Limestone nappe). In this concept fragmentary blocks of Lower Juvavic Hallstatt Limestones and/or the Alpine Haselgebirge Mélange (TOLLMANN, 1976b) framed the Upper Juvavic nappes (TOLLMANN, 1985 for details and figures).

In an alternative concept, the evaporitic (Alpine) Haselgebirge (Permian salt-mudstone succession; Haselgebirge Mélange according to SPÖTL et al., 1998) acted as ~~a~~ ductile deformation layer. The gravitational tectonic of the Juvavic units should have started in the Oxfordian (e.g., TOLLMANN, 1981, 1987; MANDL, 1982, LEIN, 1985, 1987a) or Late Tithonian (PLÖCHINGER, 1974, 1976, 1984), leading to Late Jurassic to Early Cretaceous sliding of the Alpine Haselgebirge and Hallstatt Limestone successions towards the north.

According to these models (TOLLMANN, 1987; LEIN, 1987b), sliding began in a phase of enhanced radiolarite sedimentation as troughs with deep-marine radiolaritic sedimentation arranged along the median longitudinal axis of the Northern Calcareous Alps (DIERSCHE, 1980). Slump folds are characteristic features in these sediments (e.g., GARRISON & FISCHER, 1969; SCHLAGER & SCHLAGER, 1973; DIERSCHE, 1980; TOLLMANN, 1987). An overall Oxfordian onset of radiolarite sedimentation was estimated, based on ammonite stratigraphy (DIERSCHE, 1980). Hence, the radiolarite basins were filled by deep-water cherty limestones to radiolarites with intercalated breccias and turbidites. The formation of the generally asymmetric radiolarite basins was attributed to extensional tectonics (e.g., SCHLAGER & SCHLAGER, 1973; DIERSCHE, 1980; VECSEI et al., 1989). Another group of authors attributed basin formation and breccia mobilization to strike-slip tectonics (e.g., FISCHER, 1965; WÄCHTER 1987; FRANK & SCHLAGER, 2006; ORTNER et al., 2008).

Current concept

In the current concept we follow:

1. The tectonic subdivision of the Eastern Alps of TOLLMANN (1977) with some modern modifications (FRISCH & GAWLICK, 2003, compare SCHMID et al., 2004) (Fig. 1). A new definition for the nappe groups in the Northern Calcareous Alps, based on new results for the traditional used nappe groups: Bavaric nappes, Tirolic nappes, and Juvavic nappes, is at moment in preparation and discussion (MANDL et al., 2017). In this new concept the Juvavic nappe system is seen as to be formed in Middle-Late Jurassic times with subsequent transport during the Early Cretaceous. The Tirolic nappe system should be formed in the frame of the still enigmatic Mid-Cretaceous ("eoalpine") tectonic revolution by thrust over the Bavaric unit, and the Bavaric nappe system should be formed post-gosauic by thrust over the Penninic and European units. In general, this proposal follows the concept of FRISCH & GAWLICK (2003): Formation of the Juvavic and Tirolic nappe system with tectonic shortening and nappe thrusting in Middle-Late Jurassic times. From the ancient Juvavic nappe stack mainly erosional products are preserved (Hallstatt Mélange), only in view cases exist remnants of the Juvavic nappes. During the Mid-Cretaceous tectonic period the Jurassic Tirolic nappe system carrying the Hallstatt Mélange and the (at that time still preserved) overlying Juvavic nappe stack with the ophiolite nappes and mélanges on top thrust over on the newly formed Bavaric nappe system. Post-gosauic the entire nappe system of the Calcareous Alps thrust over the Penninic and Europe derived units.
2. The palaeogeographic reconstruction for the Triassic (valid also for the Early/Middle Jurassic) of KRYSTYN & LEIN in HAAS et al. (1995) with some modifications.

3. The Jurassic geodynamic history of the Austroalpine domain mirrors its palaeogeographic position between two oceanic domains: A) To the west (northwest) the newly formed Penninic Ocean as part of the Alpine Atlantic, where continental extension started in the Hettangian and the first oceanic crust formed in the late Early Jurassic (Toarcian). B) To the east (southeast) the Neo-Tethys Ocean, in which closure started around the Early/Middle Jurassic boundary. Ophiolite obduction started in the Middle Jurassic (Bajocian).

The Juvavic nappe stack of the Northern Calcareous Alps represent the in Jurassic times accreted wedge of the former outer Triassic shelf area (FRISCH & GAWLICK, 2003), i.e. the Hallstatt zone (LEIN, 1987a) and the reef rim. In the central Northern Calcareous Alps remnants of the eroded nappe complex are preserved in the Middle to Late Jurassic radiolaritic trench-like basin fills. These basins were formed in sequence in front of the propagating thrust belt or on top of them and were later overthrust. In these radiolaritic basins occur redeposits of the Meliata facies zone, the Hallstatt facies zone (grey and various coloured Hallstatt zone), and from the reefal belt of the Triassic carbonate platforms. Some blocks or units show transported metamorphism (GAWLICK et al., 1994; GAWLICK & HÖPFER, 1999; MISSONI & GAWLICK, 2011a; compare FRANK & SCHLAGER, 2006).

In the Bajocian/Bathonian the sedimentary evolution in the southern (palaeogeographically southeastern) part of the Tirolic realm as well as in the Hallstatt realm differed from that in the northern (palaeogeographically northwestern) part. Deep-water trench-like basins formed in front of advancing nappes in the course of ophiolite obduction. The first basin group in the southern parts of the Northern Calcareous Alps received mass-flow deposits and large, up to nappe sized slides which derived from the Meliata and Hallstatt Zone (= Meliata and Hallstatt Mélange). The thickness of the Bathonian to Oxfordian basin fills may reach up to 2.000 metres. The nappe stack carrying the Hallstatt Mélange is defined as *Upper Tirolic nappe* (group) (Fig. 2).

The second basin group, the Tauglboden and the Rofan trench-like basins in the north were subjected to high subsidence and sedimentation rates in the Oxfordian to earliest Kimmeridgian. The Trattberg Rise eroded and supplied the Tauglboden Basin to its north with mass transport deposits and slides in Oxfordian times. The nappe carrying the Tauglboden Mélange is defined as *Lower Tirolic nappe* (Fig. 2).

2 Late Jurassic to earliest Cretaceous stratigraphy and formations

For definition and detailed description of the Jurassic formations (Fig. 2) see GAWLICK et al. (2009). The formations, which will be visited during this field trip, were deposited in the Tauglboden Basin (e.g. SCHLAGER & SCHLAGER, 1969, 1973).

The Tauglboden Basin formed in Early Oxfordian times as a trench-like basin in front of the Trattberg Rise representing the frontal part of the advancing upper Tirolic nappe (Fig. 2). In the Late Oxfordian ongoing compression moved to the north by forming the Brunnwinkl Rise. From this time onwards the Tauglboden Basin became an isolated basin between two topographic highs on which shallow-water carbonate platforms started to be established from the Early Kimmeridgian onwards (Plassen Carbonate Platform). During the Kimmeridgian, the sediment supply from the platforms into the Tauglboden Basin was rather low. The situation changed with the extensional collapse of the Trattberg Rise from the Early Tithonian onwards, which gave way for the Plassen Carbonate Platform in the south to shed resediments into the Tauglboden Basin to the north. Latest Jurassic (Late Tithonian) to earliest Cretaceous (Middle/Late Berriasian) deposition in the Tauglboden Basin was controlled by the carbonate platform evolution in a tectonically active regime. The tectonic is interpreted by MISSONI & GAWLICK (2011b) as expression of mountain uplift and unroofing (extensional collapse). In the field trip area this extension is expressed in the collapse of the Trattberg Rise, and the formation of steep escarpments and new relief which supplied the Tauglboden Basin again with resediments. Sediment supply from theses escarpments increased significantly and cut during the Tithonian more and more into the Kimmeridgian - Early Tithonian Plassen Carbonate Platform. Contemporaneously the evaporitic Haselgebirge Mélange became transported northward, and reached in the Late Tithonian the position of the collapsed Trattberg Rise. In this palaeogeographic position, the evaporitic mélange became reworked and occur as clasts in the coarse-grained breccias, whose components derive mainly from the Plassen Carbonate Platform. During the latest Tithonian to Middle Berriasian Plassen Carbonate Platform underwent backstepping as expressed in the fining-upward trend in the Tauglboden Basin. The final drowning of the Plassen Carbonate Platform in the Late Berriasian gave way for an increasing siliciclastic influx from the south. This siliciclastic influx was mainly controlled by sea-level changes and decreased tectonic activity during the Early Cretaceous. Successively the Tauglboden Basin (now the Tauglboden-Rossfeld Basin or Rossfeld Basin) became filled. Deposition ended in the Middle Aptian (for more details see this volume: KRISCHE et al., 2018).

Ruhpolding Formation: The Middle to Late Jurassic (Late) Bajocian to Early Tithonian Ruhpolding Formation (TRAUTH, 1950; for complete history and definition see GAWLICK et al., 2009), but with a diachronous onset and a diachronous end. This formation included black, green and red radiolarites to cherty limestones and silicified marls/shales in typical microfacies: radiolarian wacke- to packstones. Other organisms beside radiolarians are very rare, e.g. spicula, crinoids (*Saccocoma*), filaments, or in cases *Bositra* shells (DIERSCHE, 1980).

Tauglboden Formation: The Late Jurassic (Early Oxfordian to Early Tithonian) Tauglboden Formation (SCHLAGER, 1956; for complete history and definition see GAWLICK et al., 2009) is defined as radiolarite/cherty marl/cherty limestone succession with intercalated turbidites and mass transport deposits. The Tauglboden Formation can be subdivided into three parts of deposition: A) the lower (Early to ?early Late Oxfordian) part of the sequence is characterized by intense redeposition with a coarsening-upward trend. B) The Late Oxfordian to Kimmeridgian is characterized by a condensed radiolaritic-calcareous sequence. C) The Early Tithonian part of the succession is characterized again by intense redeposition of older material. This part changes gradually into the Oberalm Formation + Barmstein Limestone.

The components in the mass-flow deposits are: Hauptdolomit, lagoonal Dachstein Limestone, Kössen Formation, several limestones of the Adnet Group, Kendlbach and Scheibelberg Formations, Klaus Formation, radiolarites, distal Strubberg Formation and derive from the Trattberg Rise to the south (Fig. 2).

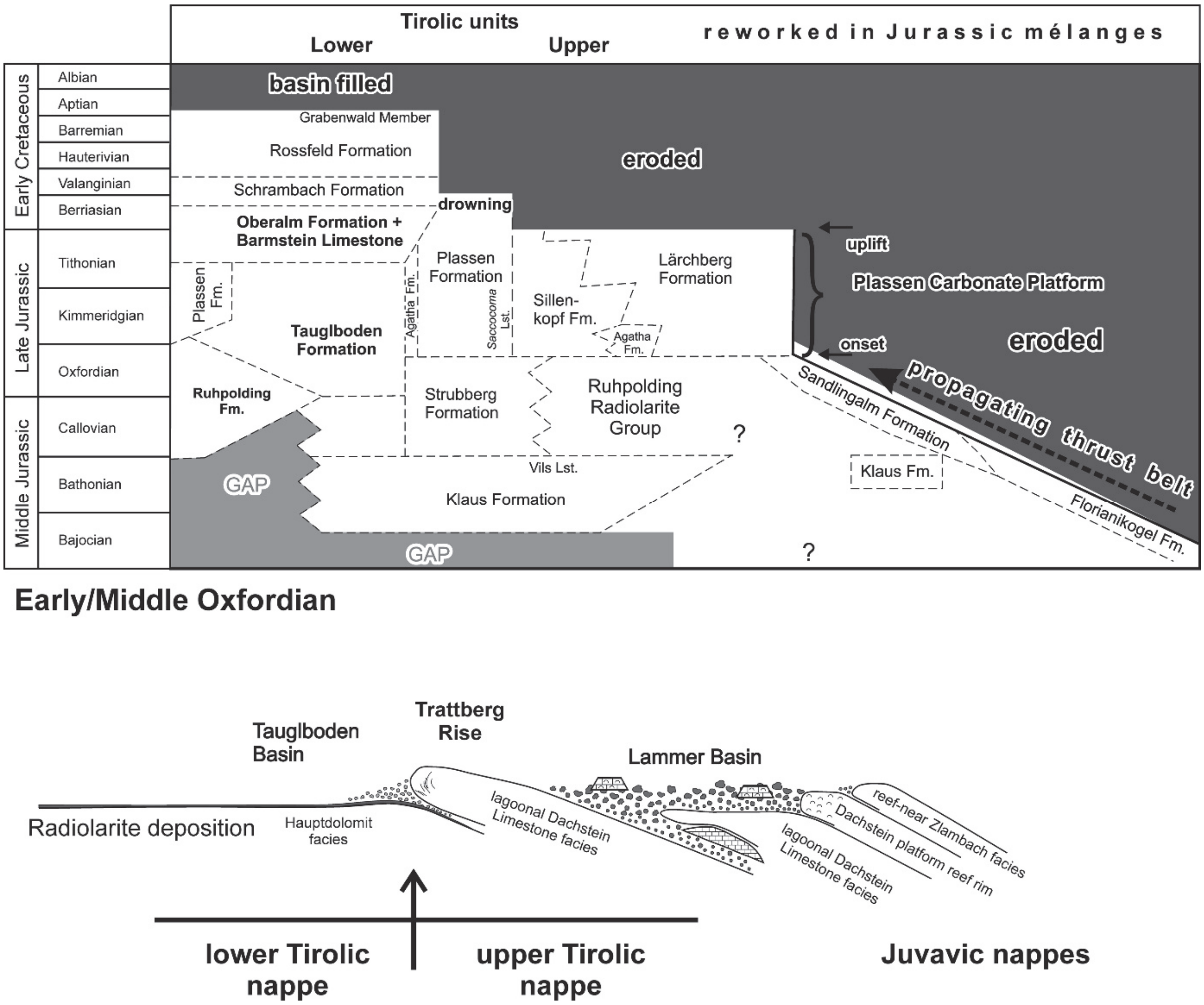

*Fig. 2: **A**) Middle Jurassic to Early Cretaceous stratigraphy of the central Northern Calcareous Alps with an overview of common formation names, simplified after MISSONI & GAWLICK (2011a). Middle Jurassic to earliest Cretaceous formation names, which will be visited during the field trip, are written in bold letters. **B**) After the Middle Jurassic imbrication of the Middle Triassic to Early Jurassic outer shelf region, a new nappe front was formed in the lagoonal Dachstein Limestone facies zone (= Trattberg Rise). North of this nappe front a new deep-water basin was formed (= Tauglboden Basin). In contrast to the more northern regions with thin sequences of radiolarites, the sedimentation in the proximal Tauglboden Basin was characterized by an up to 700 m thick Early-Middle Oxfordian succession, consisting of radiolarites, slump deposits and different types of mass transport deposits and slides. The Trattberg Rise separated the upper Tirolic nappe from the lower Tirolic nappe.*

Oberalm Formation + Barmstein Limestone: In the open-marine Middle/Late Tithonian to Middle Berriasian Oberalm Formation (LIPOLD, 1854; for complete history and definition see GAWLICK et al., 2009; redefined in its uppermost parts by KRISCHE et al., 2013) occur intercalated coarse-grained resediments (mass-transport deposits and turbidites) from the Plassen Carbonate Platform, named Barmstein Limestones (GÜMBEL, 1861). The overall depositional trend of the Oberalm Formation + Barmstein Limestone is fining upward (MISSONI & GAWLICK, 2011a, b). In the latest Tithonian a special type of Barmstein Limestones deposited. In the reworked material from the Plassen Carbonate Platform appear components of the evaporitic Haselgebirge Mélange. This type of mass transport deposit addressed PLÖCHINGER (1974) as "Tonflatschenbreccia" with its type area in the Leube quarry (for more details see this volume: KRISCHE et al., 2018).

In the upper Oberalm Formation a microfacies and lithological change can be observed between the late Early Berriasian and the Middle Berriasian. Deposition of the variegated, purple to reddish, siliceous to marly limestones with turbidites of roughly Middle Berriasian age (Gutratberg Member of the Oberalm Formation: KRISCHE et al., 2013) is the basinal expression of a stepwise demise of the Plassen Carbonate Platform due to the increasing siliciclastic and organic input. Carbonate production of the Plassen Carbonate Platform decreased significantly since the late Early Berriasian and resulted in its final drowning in the Late Berriasian (GAWLICK & SCHLAGINTWEIT, 2006).

3 The Field Trip

Figure 3 shows the localities that will be visited during this field trip. In the Taugl valley (Tauglboden) we will study the Oxfordian to Early Tithonian Tauglboden Formation (type-locality), which overlies the Early and Middle Jurassic condensed red nodular limestones of the Adnet and Klaus Formations. In the Mörtlbach valley, the Gaissau section offer the Callovian-Oxfordian Ruhpolding Formation (radiolarite) overlain by the Tauglboden Formation. Along the road from Gaissau to Krispl we will see the Late Tithonian part of the Oberalm Formation + Barmstein Limestone. Along the Barmsteine cliffs we will visit the type-locality of the Barmstein Limestone.

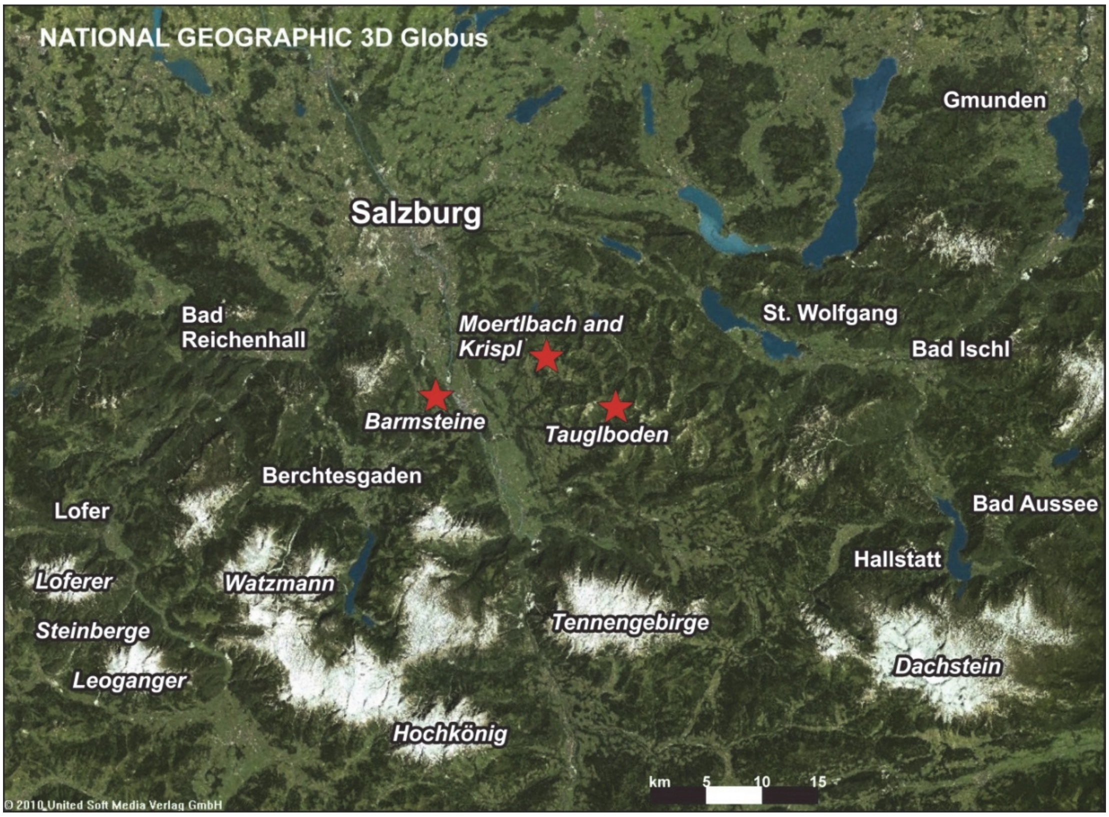

Fig. 3: Satellite image of the central Northern Calcareous Alps, showing the localities of which will be visited during this field trip (red stars).

3.1 Taugl valley (Tauglboden): Tauglboden Formation

In respect to facies, thickness and component content of the mass transport deposits the type area of the Tauglboden Formation in the inner parts of the Osterhorn Block (Fig. 3) represents a central position in the Tauglboden Basin. Proximal parts of the basin are not preserved in the type area, but can be seen in the Knerzenalm area (e.g., MANDL, 1982; WEGERER et al., 2001; GAWLICK et al., 2007) southeast of Bad Ischl, and in the Unken valley (GARRISON & FISCHER, 1969; VECSEI et al., 1989).

In the Taugl valley, geographically situated in the central to southern Osterhorn Mountains (Fig. 3), a complete late Early Jurassic to Late Jurassic sedimentary sequence is preserved. This area was investigated since the second half of the 19th century (SUESS & MOJSISCOVICS, 1868) (Fig. 4). As almost everywhere in the Northern Calcareous Alps, the carbonate successions, especially the Jurassic ones, were fairly well dated by means of ammonites (summarized in BÖHM, 1992). In contrast, the age of the radiolaritic sediments remained generally enigmatic until Recent. In the second half of the 20th century the radiolarites were attributed to the Oxfordian or reaching the Kimmeridgian (DIERSCHE, 1980; TOLLMANN, 1985). Recent radiolarian dating constrained the biostratigraphic ages of the radiolarite sequences in numerous areas within the Northern Calcareous Alps (for a review see GAWLICK et al., 2009).

The general sedimentological features and the thickness of the Tauglboden Formation in the type area investigated SCHLAGER & SCHLAGER (1969, 1973) in detail (Fig. 5), and later DIERSCHE (1980) in a more regional context. The age of the succession was attributed to the (Late) Oxfordian to Kimmeridgian on basis of the investigations of SCHLAGER & SCHLAGER (1969) and HUCKRIEDE (1971). HUCKRIEDE (1971) dated the silicified sedimentary rocks below the first red radiolarite bed by means of aptychi as early Oxfordian (Fig. 6). This aptychi-bearing layer yielded also a moderate preserved radiolarian fauna (see below). This radiolarian fauna cannot precise the age of this layer. SCHLAGER & SCHLAGER (1969) mentioned the occurrence of a Kimmeridgian ammonite in the Tauglboden Formation, which limited the age of radiolarite deposition in the Northern Calcareous Alps to the Oxfordian (-Kimmeridgian).

Detailed component analyses and direct biostratigraphic dating of the radiolaritic matrix sediments of various mass transport deposits were carried out since the end of the last century. Modern data resulted in a modified view of the situation of the Tauglboden Basin type-locality.

The radiolarian dating of this paper is based on BAUMGARTNER et al. (1995) and SUZUKI & GAWLICK (2003a), under implementation of the extended age ranges of some species (e.g., SUZUKI et al., 2001; O'DOGHERTY et al., 2006, 2009; SUZUKI & GAWLICK, 2009; AUER et al., 2009; GORIČAN et al., 2012). Nevertheless, we still use here for the presented radiolarian faunas the nomenclature of SUZUKI & GAWLICK (2003b, 2009) (compare O´DOGHERTY et al., 2017).

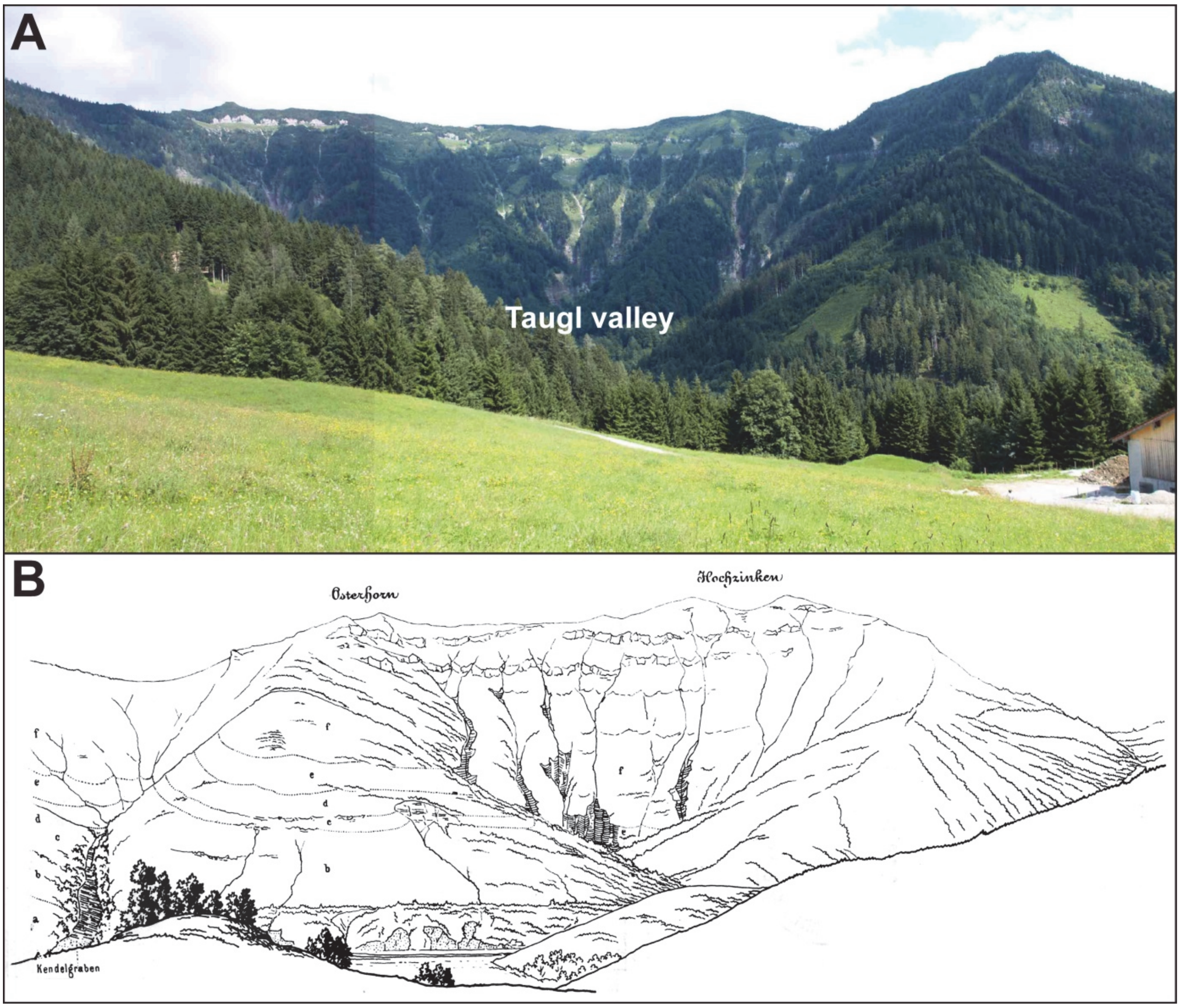

Fig. 4: ***A****) Photo of the central Osterhorn Unit with the Taugl valley. View from the west.* ***B****) Original drawing of the central Osterhorn Mountains from* SUESS *&* MOJSISCOVICS *(1868). The authors figured out the main characteristics and ages of the Late Triassic to Late Jurassic sedimentary succession. Legend according to* SUESS *&* MOJSISCOVICS *(1868) (translated): a - Norian limestones; b - Rhaetian sequence (Kössen Formation and Dachstein Limestone); c - Lower Jurassic and Adnet Limestone (= grey cherty limestones and red nodular limestones); d - bioturbated cherty limestones and marls ("Fleckenmergel"); e - Brown Jurassic (Middle Jurassic); f - White Jurassic (Upper Jurassic). In today´s terms, d and e correspond to the Oxfordian to Early Tithonian Tauglboden Formation, f to the late Early Tithonian to Berriasian Oberalm Formation + Barmstein Limestone.*

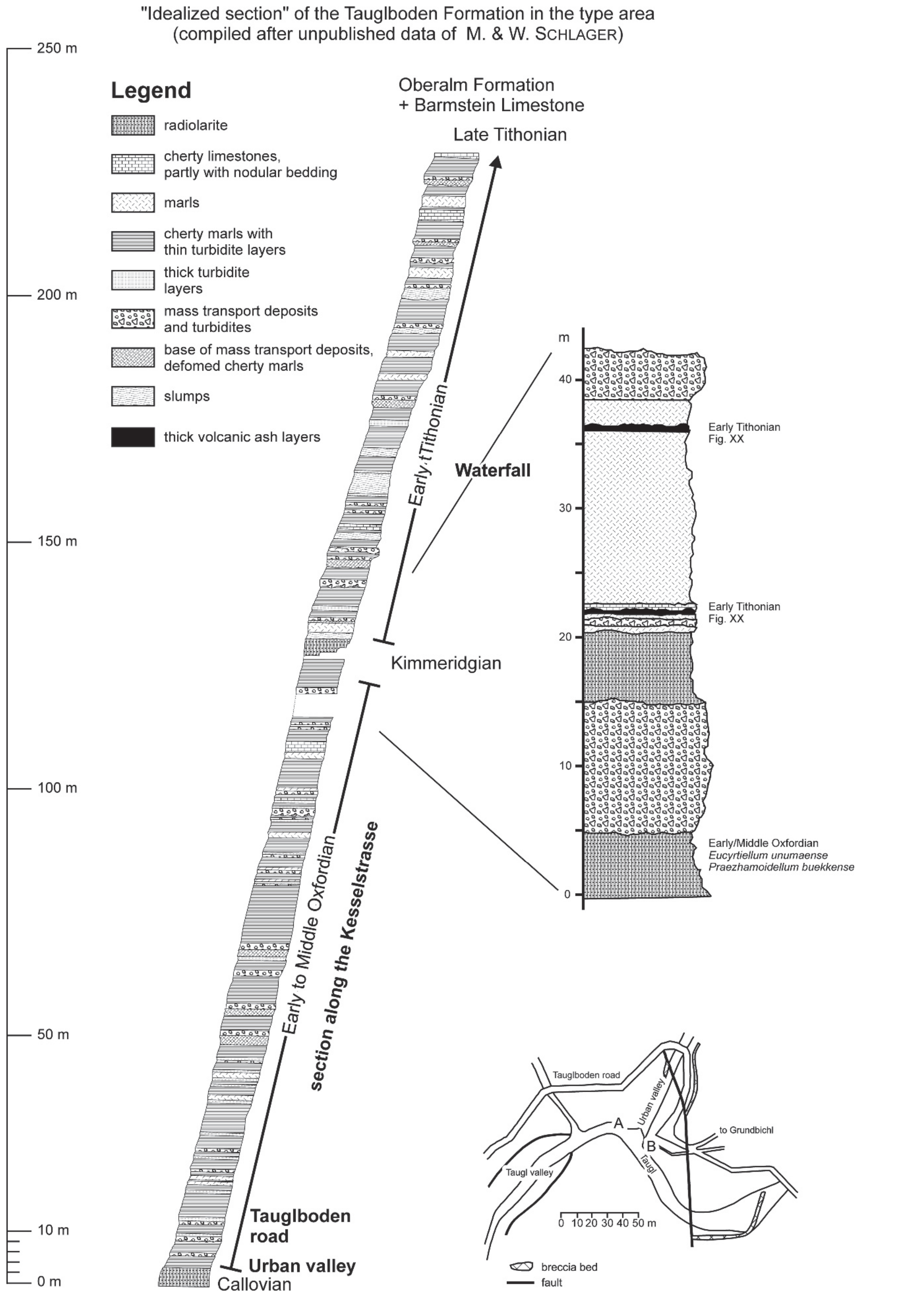

Fig. 5: "Standardized profile" of the Tauglboden Formation (left) in the type area (idealized type section - see SCHLAGER & SCHLAGER, 1973 for details), unpublished profile of M. SCHLAGER & W. SCHLAGER, the central Osterhorn Mountains in the Salzburg Calcareous Alps. Redrawn and printed with permission of

W. SCHLAGER (Amsterdam) in GAWLICK (2000), GAWLICK & FRISCH (2003) and GAWLICK et al. (2012). Ages of different parts of the section according to HUCKRIEDE (1971), GAWLICK et al. (1999), GAWLICK & FRISCH (2003), and new data. Detail section (right) modified from GAWLICK et al. (1999). Map inset: Area of the Urban/Taugl creek exposing excellent sections of the succession around the boundary Klaus Formation/radiolarite (Tauglboden Formation). The drawn detailed section in Figure 6 is from west of the Urban valley (A). An equivalent section is seen east of the Urban creek (B). Redrawn and added after HUCKRIEDE (1971).

Base of the Tauglboden Formation: Urban valley section

The contact between the Early to Middle Jurassic red nodular limestones and the overlying radiolarite sequence is exposed in the junction of the Urban valley with the Taugl valley. The section starts with red nodular limestones, whose age is Late Bathonian to Early Callovian according to HUCKRIEDE (1971) and BÖHM (1992). On top of these red limestones, a condensed layer with feldspar and other volcanic material contains rhyncholiths of (early) Oxfordian age (HUCKRIEDE, 1971). Moderate preserved radiolarians from this layer cannot precise the biostratigraphic age, because of the lack of an Oxfordian marker species. Following species could be determined: *Archaeodictymitra* sp., *Eucyrtidiellum* cf. *unumaense* (Yao), *Gongylothorax favosus* DUMITRICA, *Gongylothorax* aff. *favosus* DUMITRICA, *Lithocampium* sp. A, *Lithocampium* sp., *Loopus* sp., *Stichocapsa naradaniensis* MATSUOKA, *Tricolocapsa conexa* MATSUOKA, *Preazhamoidellum* cf. *parvipora* (TAN), *Tricolocapsa* aff. *fusiformis* Yao, *Tricolocapsa* sp. A sensu OZVOLDOVA, *Tricolocapsa* sp., *Unuma* sp., *Williriedellum crystallinum* DUMITRICA, *Williriedellum marcucciae* CORTESE, *Williriedellum* sp. B, *Zhamoidellum ovum* DUMITRICA, and *Zhamoidellum* sp. (sample TB-Grenzfuge).

The microfacies of the Oxfordian part (HUCKRIEDE, 1971) of the red nodular limestone correspond to that of the overlying red radiolarite: Radiolarian wacke- to packstones predominates. Therefore, this part of the section belongs already to the radiolarite succession.

From the red radiolarite, roughly 50 cm above the boundary layer, following species from a poor preserved radiolarian fauna could be determined: *Emiluvia* sp., *Archaeodictyomitra* sp., *Eucyrtidiellum* cf. *unumaense* (Yao), *Hsuum* cf. *maxwelli* PESSAGNO, *Protunuma* cf. *japonicus* MATSUOKA & Yao, *Triversus* sp., *Williriedellum* sp. B, *Zhamoidellum ovum* DUMITRICA, *Zhamoidellum* sp. (sample TB3).

The radiolarian fauna is similar to those from red radiolarite in the Fludergraben valley. In the Fludergraben valley a roughly two metres thick red radiolarite overlie red nodular limestones of the Klaus Formation (Callovian/Oxfordian boundary according to MANDL, 1982).

In the Tauglboden area the basal radiolarite is well-bedded, of red colour and has at maximum 2 metres thickness. Both, lithology and colour of the radiolarites change gradually upsection. Moreover, the colour of the radiolarites turns from red over grey to finally dark-grey. Only the grey radiolarites are fine laminated, others are massive. The intercalated clay layers between the radiolarite beds increase upsection (Fig. 7). The carbonate content rises as well, whereby the first turbiditic resediments occur after the red to grey colour shift, indicating a change in the basin geometry.

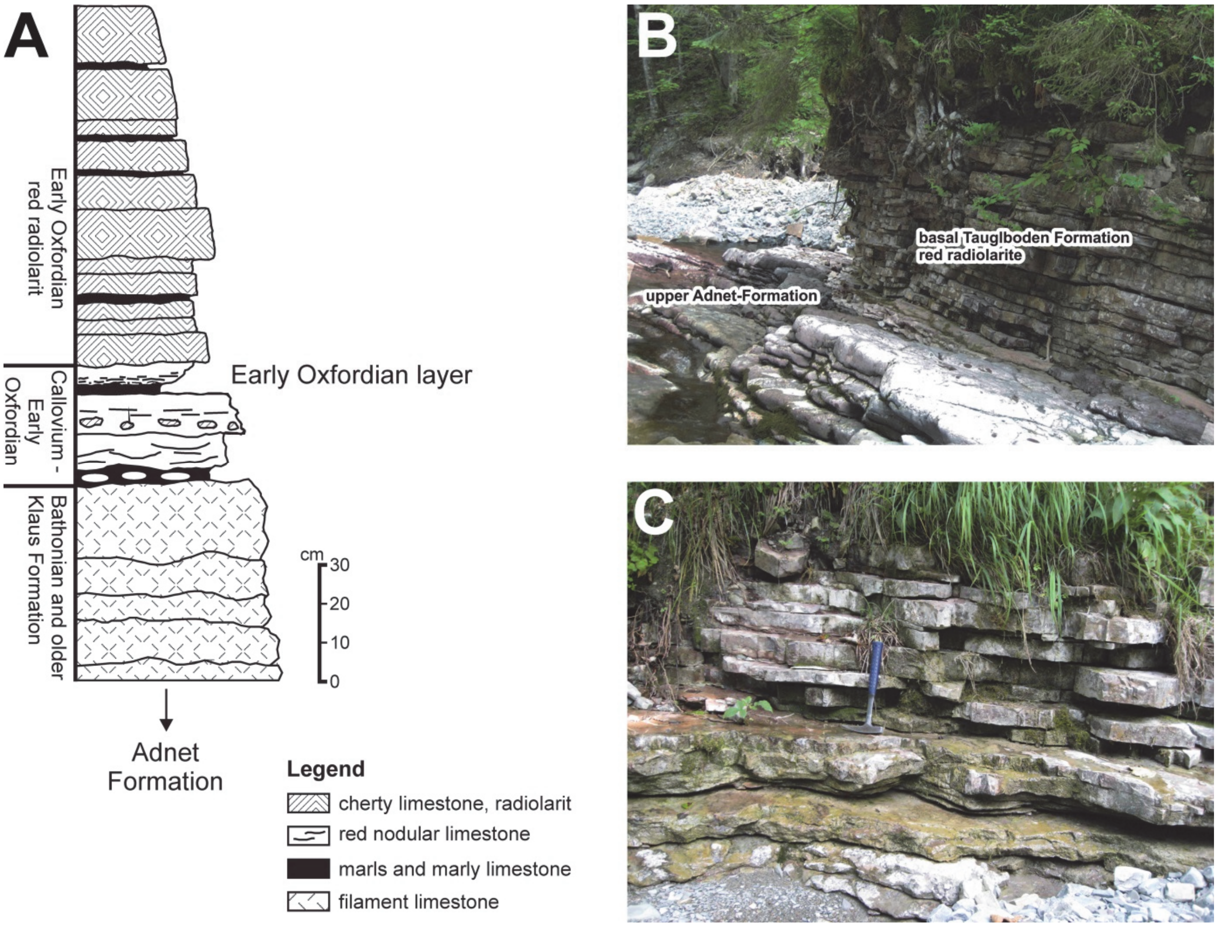

*Fig. 6: **A**) Boundary section Klaus Formation to basal Tauglboden Formation (red radiolarite) redrawn and added after* H*UCKRIEDE (1971).* ***B***) *Exposure east of the Urban creek.* ***C***) *Exposure west of the Urban creek.*

Fig. 7: Reddish-grey massive and laminated Early Oxfordian radiolarite layers with clay intercalations, located in the Taugl valley. Width of the photo: 80 cm.

Radiolarites and mass transport deposits along the Tauglboden road

About five metres above the contact of the red nodular limestone with the radiolarite succession, coarse-grained mass transport deposits are intercalated in the radiolarite sequence. Up to 20 cm thick breccia layers overlie the radiolarite beds practically without basal erosion; obviously the breccia layers seem to be channels deposits (Fig. 8). The structure is fostered by early dewatering of the underlying radiolaritic sediments. Below the breccia layers exist ~~a~~ layers of green-grey volcanic ash, today altered to an illite-bentonite (REITER, 2009). These ashes are locally preserved and acted as slide-plane (Fig. 8).

The components in the slide-flow deposit derive exclusively from the lagoonal Dachstein facies zone. Components of the Early Rhaetian Kössen Formation are rare, whilst components of Rhaetian lagoonal Dachstein Limestone strongly predominate. Early to Middle Jurassic clasts occur in rock-forming quantities, too. Early Jurassic grey cherty limestones (Scheibelberg Formation), chert nodules and red nodular limestones (Adnet Formation) dominate. In contrast, Middle Jurassic *Bositra* Limestone components are rare (details in GAWLICK et al., 2012).

Forest road Kesselstrasse

A highly diverse outcrop situation will be visible on the walk along the forest road Kesselstrasse. In small valleys aside and along the forest road good outcrops with insights into the early evolution of the Tauglboden Basin exist. The age of the succession along the road is still Early to Middle Oxfordian as proven by radiolarians. Dark-grey to black laminated radiolarites with changing clay and carbonate content, slump deposits and mass flows are typical sedimentary features of the succession (Fig. 9). The slump deposits consist partly of cherty sediments without older components, large blocks of older components incorporated in the argillaceous matrix, and debris flows. Generally, the older clasts are the same as in the basal breccia layers (slide flows) along the Tauglboden road. Jurassic clasts are rarer and Triassic clasts older in age appear. The erosion cut deeper into the Norian lagoonal Dachstein Limestone as expressed in the component spectrum. Higher up in the succession the amount of mass transport deposits increased together with the component size. In the curve before the waterfall dark-grey laminated calcareous radiolarites underlie a thick mass transport deposit. According to the poorly preserved radiolarian fauna with *Eucyrtidiellum unumaense* (YAO) and *Praezhamoidellum buekkense* KOZUR (sample TB8) the age of this part of the succession is still Early-Middle Oxfordian. Thus, the entire ca. 150 m thick sequence below this mass flow (Fig. 5) is Early to Middle Oxfordian in age. Above this mass transport deposits follow a roughly 4 metre thick succession of well-bedded grey laminated calcareous radiolarites free of mass transport deposits or turbidites, which are again overlain by mass transport deposits (Fig. 9D). Above these mass transport deposits are up to 15 cm thick layers of volcanic ashes, intercalated between laminated calcareous radiolarites and slide flows (Figs. 9E and F).

Two volcanic ash layers (meta-bentonites) contain both a moderate preserved radiolarian fauna of Early Tithonian age (for details see GAWLICK et al., 1999). In the lower volcanic ash layer following radiolarians were determined: *Sphaerostylus lanceola* (PARONA), *Eucyrtidiellum pyramis* (AITA), *Archaeospongoprunum patricki* JUD, *Archaeodictyomitra apiarium* (RÜST), *Archaeodictyomitra minoensis* (MIZUTANI), *Tricolocapsa funatoensis* (AITA), *Zhamoidellum ovum* DUMITRICA, *Parvicingula boesii* (PARONA). In the upper volcanic ash layer following radiolarians were determined: *Archaeospongoprunum imlayi* PESSAGNO, *Eucyrtidiellum pyramis* (AITA), *Pseudoeucyrtis reticularis* MATSUOKA & YAO, *Cinguloturris cylindra* KEMKIN & RUDENKO, *Parvicingula mashitaensis* MIZUTANI, *Mirifusus mediodilatatus* (RÜST), *Ristola altissima* (RÜST), *Spongocapsula perampla* (RÜST), *Zhamoidellum ovum* DUMITRICA, *Parvicingula dhimenaensis* BAUMGARTNER, *Podobursa triancantha* (FISCHLI), *Podocapsa amphitreptera* FOREMAN, *Tricolocapsa funatoensis* (AITA).

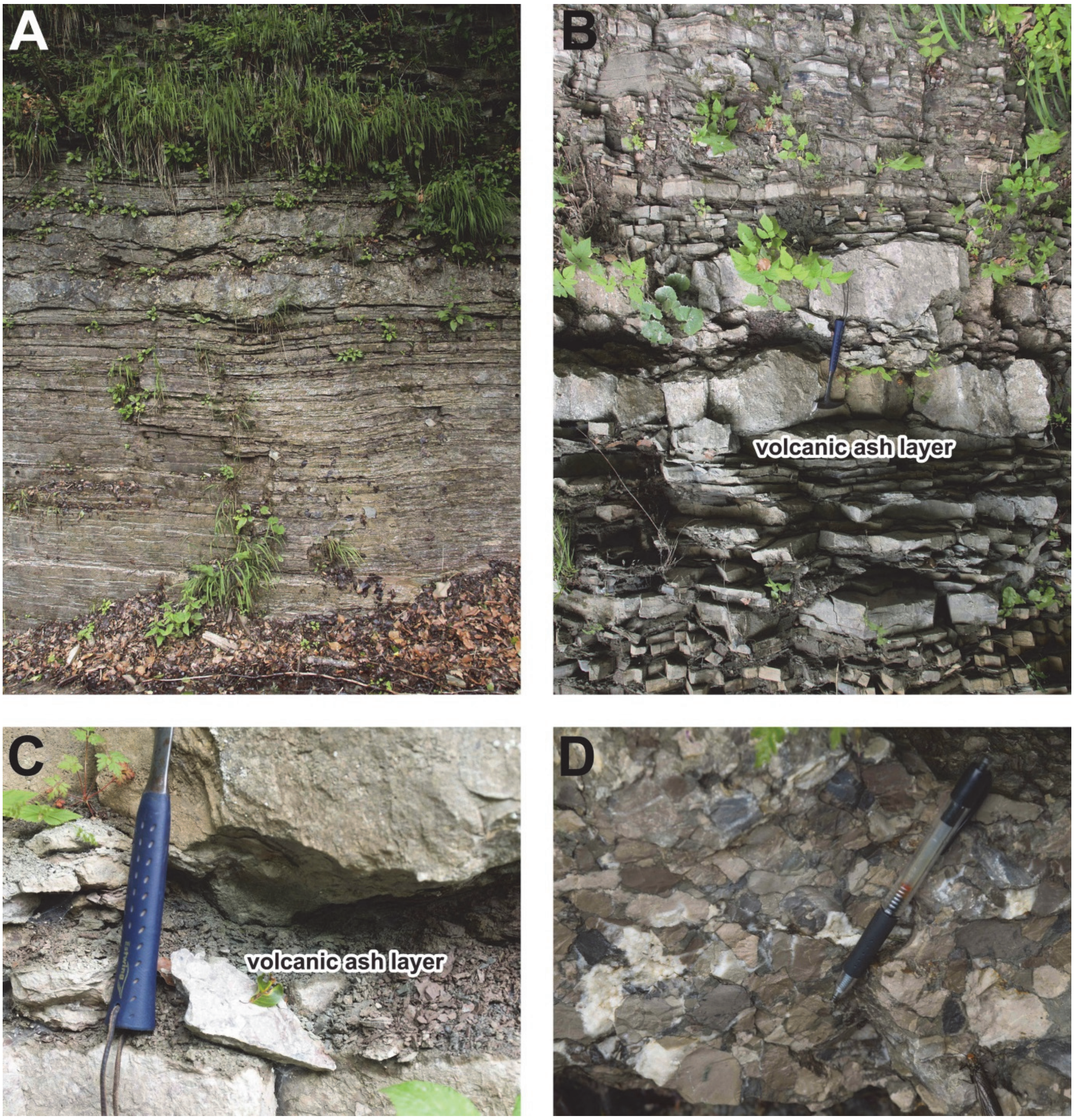

Fig. 8: Up to 20 cm thick breccia layers (slide flows) intercalated in the Early Oxfordian radiolarite sequence. Breccias cut slightly into the basal series (erosional contact), but more often they overlie the radiolarite sequence concordantly in a parallel manner. ***B*** *and* ***C****) Details from the succession in* ***A****). Below the breccia, a green layer of volcanic ashes is preserved. These fine-grained ashes acted as slide horizon for the slide flows.* ***D****) Angular to subrounded (rare) components of the Early Oxfordian breccias along the Tauglboden road.*

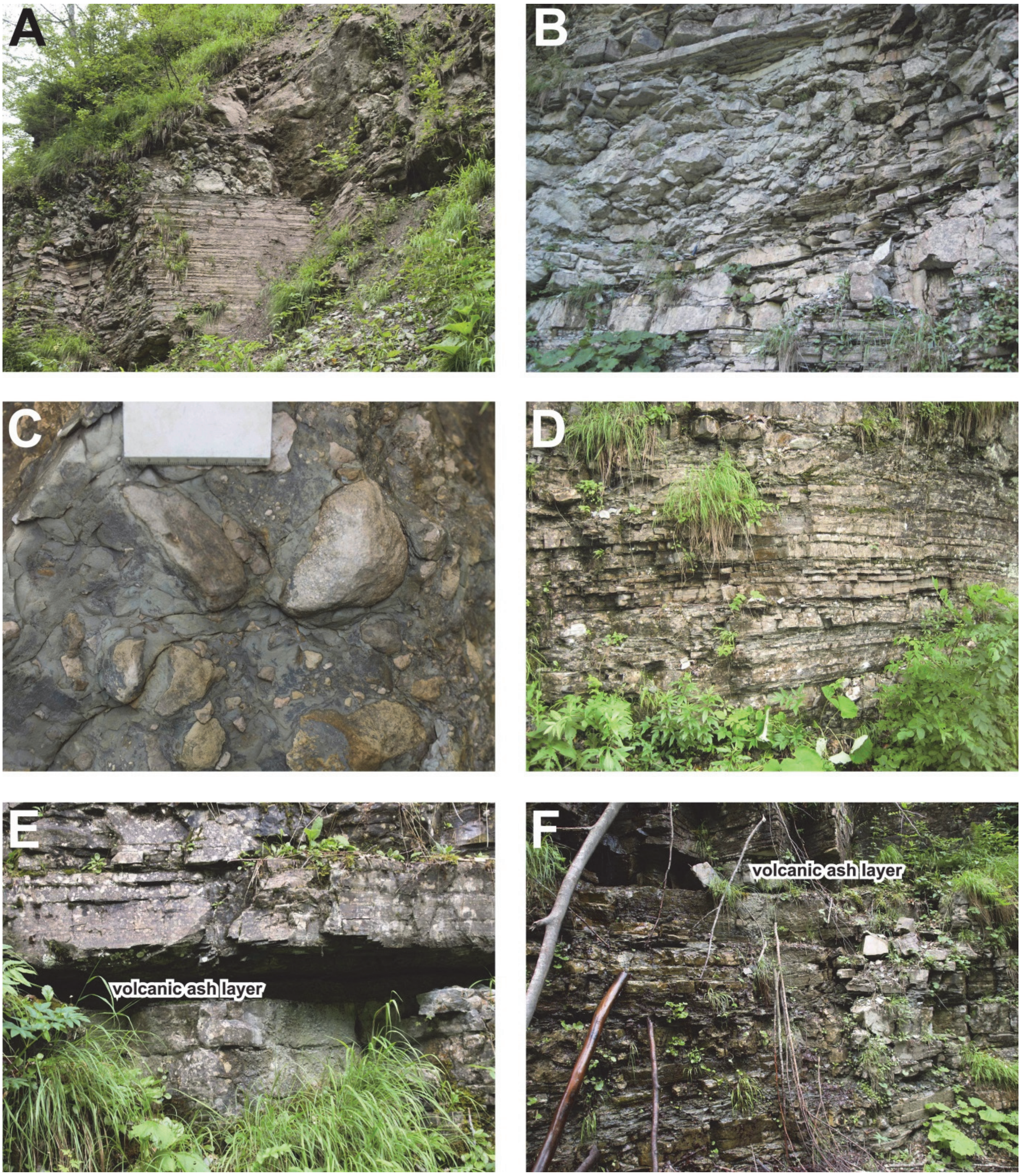

Fig. 9: Outcrops along the forest road Kesselstrasse. ***A, B, C****) Early-Middle Oxfordian Tauglboden Formation.* ***A****) Well bedded and laminated marly radiolarites overlain by a slide flow with large boulders of Late Triassic lagoonal Dachstein Limestone.* ***B****) Channelized debris-flow.* ***C****) Mud-flow deposit. Subrounded clasts of the Early Rhaetian Kössen Formation, and Norian to Rhaetian lagoonal Dachstein Limestone. The matrix consists of marly clays without radiolarians.* ***D****) Kimmeridgian condensed radiolarite succession overlain by Early Tithonian debris-flow deposits.* ***E****) Lower volcanic ash layer of Early Tithonian age overlain by a slide flow.* ***F****) Higher volcanic ash layer of Early Tithonian age overlain by a slide flow.*

This means, that the time span Latest Oxfordian to Kimmeridgian is characterized by a starved sequence. The volume of material shed into the basin decreased rapidly in the Late Oxfordian. The

Kimmeridgian is characterized by radiolarite sedimentation without deposition of resediments. In the Early Tithonian a new depositional cycle with mobilisation and redeposition of large volumes of rocks started, together with slump deposits mud and debris-flows. Whereas the older components in different chaotic deposits are similar to the Early to Middle Oxfordian sequence the content of Jurassic clasts is very low. Reworked Norian to Rhaetian clasts dominates the component spectrum. Radiolarites in this part of the succession are scarce, with silicified marls and silicified limestones being the matrix sediment. The preservation of the radiolarians in the matrix is generally very poor.

Waterfall

By reaching the waterfall we will see a several tens of metres thick sequence of dark-grey well bedded silicified marls and silicified limestones (Fig. 10). Slump deposits, mud flows, and debris flows are intercalated. The series is also characterized by intercalations of semi-consolidated volcanic ash layers.

Continuing the forest road along the waterfall Kesselstrasse, we reach the Late Tithonian sequence. The forest road provides several outcrops of different fine- und coarse-grained turbidites and mass transport deposits intercalated in grey silicified limestones. The components in these resediments consist of a mixture of older carbonate clasts (Norian to Rhaetian lagoonal and reefal Dachstein Limestone and Kössen Formation), as in the series below, and some shallow-water clasts from the Plassen Carbonate Platform to the south. The change from siliceous to calcareous sedimentation cannot be exactly dated, because of bad preservation stages of the organisms. The overlying silicified limestones with intercalated slope sediments (Barmstein Limestone) are of Late Tithonian to Early Berriasian age, palaeontological proven by radiolarians and calpionellids (e.g., STEIGER, 1981, 1992) as well as by shallow-water organisms (GAWLICK et al., 2005, 2009 for latest reviews).

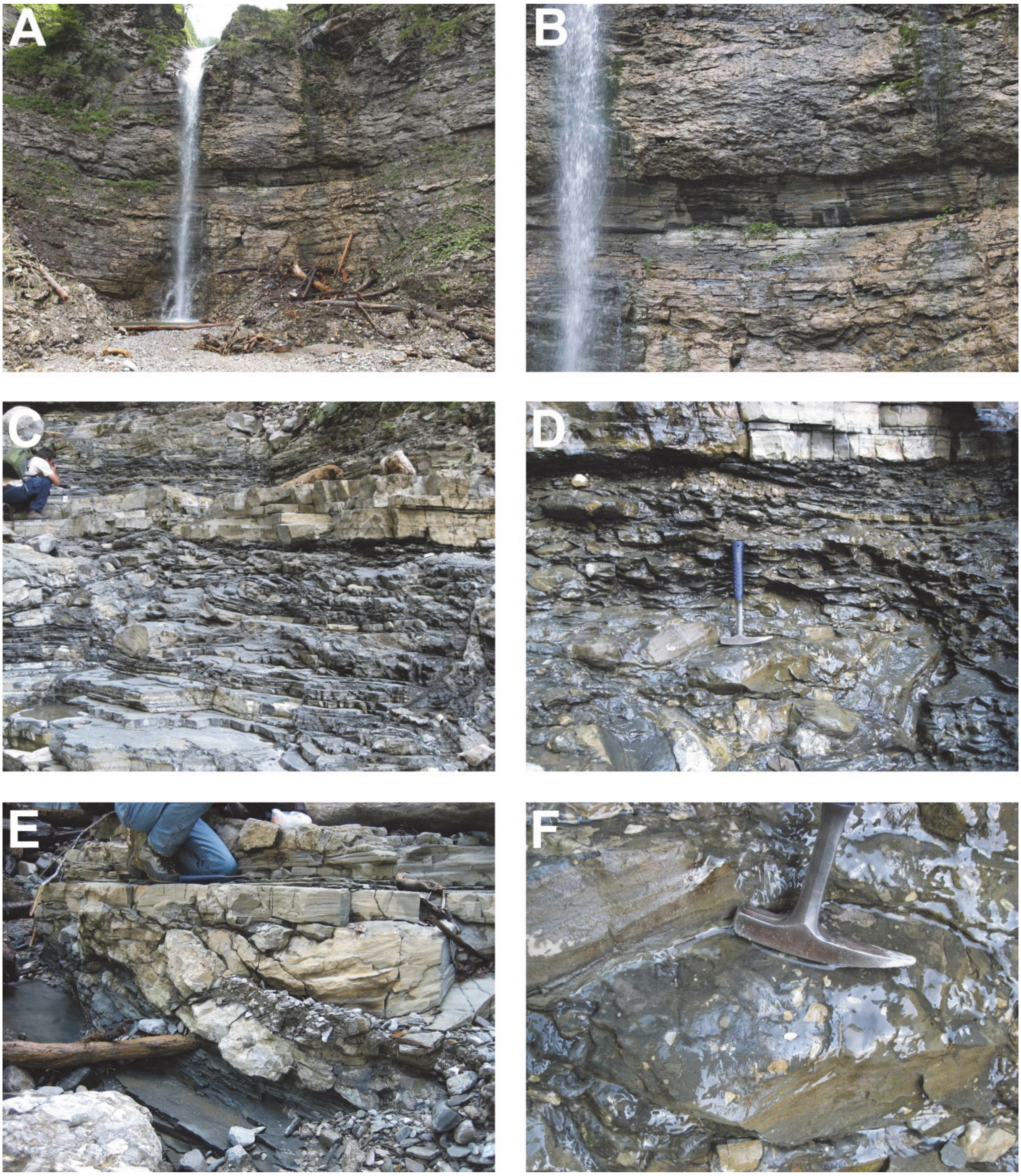

Fig. 10: Early Tithonian Tauglboden Formation of the waterfall Kesselstrasse section. ***A****) Early Tithonian sedimentary succession with slump deposits, mud flows, and debris flows in a matrix of laminated silicified marls to limestones.* ***B****) Enlargement of A). Above a series of amalgamated debris flows a series of thin bedded and laminated calcareous radiolarites were deposited topped by a volcanic ash layer, followed by a slide flow.* ***C****) Slump deposit overlain by fine grained silicified carbonate turbidites.* ***D****) Mud flow deposit reworked in a slump deposit.* ***E****) Amalgamated series of silicified marls with breccia layers, overlain by parallel bedded laminated silicified limestones with marl intercalations. Intercalated breccia layers with erosive base.* ***F****) Enlargement of D) Late Triassic pebbles dominate the component spectrum.*

3.2 Gaissau, Mörtlbach valley: Ruhpolding and Tauglboden Formations

Another Jurassic section, but in a more northernward position as the Taugl valley section, is the section Mörtlbach valley in the Osterhorn Block north of the village Gaissau, on the road to Gaissau/Krispl (parking place) (Figs. 3, 11). Following Jurassic strata developed above the Kössen Basin: the section starts with grey silicified limestones of Sinemurian to Early Pliensbachian age, whose sequence does not exceed a thickness of 5 metres. These grey limestones are overlain by reworked red nodular limestones forming a series of mass-flow deposits. This interval is rich in red marls making up the matrix of the different mass flows. The age of this interval is Late Pliensbachian to Toarcian. The lower Middle Jurassic (Aalenian) is preserved as very thin layer of *Bositra*-rich marly limestones (Böhm, 1992). On top of these Aalenian sedimentary rocks, a ferro-manganese horizon reflects a long lasting depositional gap (Bajocian to Bathonian). Directly above the ferro-manganese horizon deposited 2 cm thick red marls and a 3 cm thick layer of grey volcanic ash. According to X-ray diffraction this volcanic ash was transformed during shallow-burial diagenesis to ~~a~~ smectite-bentonite (following FISHER & SCHMINCKE, 1984). Above the bentonite deposited dm-bedded black radiolarites of ?Late Bathonian - Early Callovian age (Fig. 11), proven by following radiolarian faunas:

Sample GU 19/2001: *Archaeodictyomitra rigida* PESSAGNO, *Cinguloturris latiannulata* (GRILL & KOZUR), *Eucyrtidiellum semifactum* NAGAI & MIZUTANI, *Eucyrtidiellum unumaense* ssp. (YAO), *Eucyrtidiellum unumaense unumaense* (YAO), *Gongylothorax* aff. *favosus* DUMITRICA, *Hsuum* cf. *hisuikyoense* ISOZAKI & MATSUDA, *Parahsuum longiconicum* SASHIDA, *Parvicingula* cf. *dhimenaensis* BAUMGARTNER, *Praezhamoidellum yaoi* KOZUR, *Protunuma* cf. *quadriperforatus* O'DOGHERTY & GORICAn, *Protunuma* cf. *lanosus* OZVOLDOVA, *Theocapsomma medvednicensis* GORICAN, *Theocapsomma* sp. *Tricolocapsa* sp. A sensu OZVOLDOVA, *Tricolocapsa* sp., *Unuma* cf. *gorda* HULL, *Unuma* sp., *Williriedellum* sp. *Eucyrtidiellum semifactum*, *Hsuum* cf. *hisuikyoense* and *Gongylothorax* aff. *favosus* are typical forms of the UA zone 7 according to BAUMGARTNER et al. (1995). *Protunuma* cf. *quadriperforatus* occur according to BAUMGARTNER et al. (1995) in the UA 5-6, but appear in the radiolarite sections of Northern Calcareous Alps also in younger levels and may reach the UA 8. *Cinguloturris latiannulata* should be a precursor form of *Cinguloturris carpathica* with the first FAD in the UA 7. *Zhamoidellum ovum* could not be detected in this sample. The age for this sample is therefore ?Late Bathonian to earliest Callovian.

Sample GU 20/2001: *Archaeodictyomitra* sp., *Gongylothorax* aff. *favosus* DUMITRICA, *Parvicingula* sp. *Pseudodictyomitrella* sp. *Tricolocapsa conexa* MATSUOKA, *Tricolocapsa* aff. *fusiformis* YAO, *Tricolocapsa* cf. *parvipora* TAN, *Tricolocapsa* spp., *Williriedellum* cf. *dierschei* SUZUKI & GAWLICK, *Williriedellum* sp. This radiolarian association shows an age-range of Late Bathonian to Early Oxfordian. *Tricolocapsa* aff. *fusiformis* appear also in the section Fludergraben above the Callovian/Oxfordian boundary.

Sample Mörtl1//2001: *Archaeodictyomitra* cf. *amabilis* AITA, *Dictyomitrella* cf. *kamoensis* MIZUTANI & KIDO, *Eucyrtidiellum semifactum* NAGAI & MIZUTANI, *Eucyrtidiellum unumaense* ssp. (YAO), E*ucyrtidiellum unumaense unumaense* (YAO), *Gongylothorax* aff. *favosus* DUMITRICA, *Hsuum* cf. *brevicostatum* (OZVOLDOVA), *Hsuum* sp., *Parahsuum* sp., *Protunuma lanosus* OZVOLDOVA, *Protunuma* cf. *quadriperforatus* O'DOGHERTY & GORICAN, *Stichocapsa convexa* YAO, *Tricolocapsa* cf. *conexa* MATSUOKA, *Tricolocapsa tetragona* MATSUOKA, *Tricolocapsa* cf. *plicarum* YAO, *Tricolocapsa* sp., *Unuma* sp., *Williriedellum dierschei* SUZUKI & GAWLICK, *Williriedellum marcucciae* CORTESE, *Williriedellum* sp. *Gongylothorax* aff. *favosus*, *Archaeodictyomitra* cf. *amabilis*, *Dictyomitrella* cf. *kamoensis* and *Eucyrtidiellum semifactum* point to UA 7. In the Northern Calcareous Alps this radiolarian association is typical for the Early Callovian; but a Late Bathonian age cannot be excluded.

Sample GU14A/2001 from the transition black to red radiolarite: *Amphipyndax* sp., *Archaeodictyomitra mitra* DUMITRICA, *Archaeodictyomitra* sp., *Droltus galerus* SUZUKI, *Droltus* sp., *Eucyrtidiellum nodosum* WAKITA, *Eucyrtidiellum unumaense* ssp. (YAO), *Eucyrtidiellum unumaense unumaense* (YAO), *Eucyrtidiellum unumaense dentatum* BAUMGARTNER, *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, *Gongylothorax* aff. *favosus* DUMITRICA, *Hiscocapsa acuta* HULL, *Hsuum brevicostatum* (OZVOLDOVA), *Loopus* cf. *nudus* (SCHAAF), *Loopus* sp., *Praezhamoidellum buekkense* KOZUR, *Pseudodictyomitra* sp., *Stichomitra* sp. D sensu KIESSLING, *Tetracapsa* sp. A, *Tricolocapsa* undulata (HEITZER), *Tricolocapsa* sp. A sensu OZVOLDOVA, *Tricolocapsa* sp., *Triversus* spp., *Williriedellum carpathicum* DUMITRICA, *Williriedellum dierschei* SUZUKI & GAWLICK, *Williriedellum marcucciae* CORTESE, *Williriedellum* sp., *Zhamoidellum exquisita* HULL, *Zhamoidellum kozuri* (HULL), *Zhamoidellum* sp. The appearance of *Williriedellum carpathicum* indicates an age for the sample as Late Callovian to Early/Middle Oxfordian (*Williriedellum carpathicum* subzone of the *Zhamoidellum* zone; according to SUZUKI & GAWLICK, 2003a, updated in GAWLICK et al., 2009).

The thickness of the ?Late Bathonian to Middle Callovian black radiolarite is about 1 metre. Upsection graded the colour of the radiolarite to red. Between the black and the red radiolarite again a several cm-thick smectite-bentonite is proven (REITER, 2009).

The age of the less than 20 metres thick red radiolarite is Late Callovian to Oxfordian, most probably earliest Oxfordian according to in cases rich and well preserved radiolarian associations:

Sample GU1/2001: *Archaeodictyomitra patricki* KOCHER, *Archaeodictyomitra* sp., *Cinguloturris* cf. *carpatica* DUMITRICA, *Gongylothorax* sp., *Hiscocapsa* sp., *Parvicingula* sp., *Protunuma* cf. *multicostatus* (HEITZER), *Stichomitra annibill* KOCHER, *Stichomitra* sp. D sensu KIESSLING, *Williriedellum* cf. *crystallinum* DUMITRICA, *Williriedellum* sp., *Zhamoidellum ovum* DUMITRICA. The age range of this sample is according to the radiolarian association Callovian to Kimmeridgian. On base of the fact that the underlying sample gives a Late Callovian to younger age, the lower age limit of this sample is Late Callovian.

Sample GU 3/2001: *Acanthocircus* cf. *suboblongus* (YAO), *Actinomma* cf. *siciliensis* KITO & DE WEVER, *Archaeospongoprunum imlayi* PESSAGNO, *Archaeospongoprunum* cf. *tricostatum* STEIGER, *Archaeospongoprunum* spp., *Emiluvia chica* FOREMAN, *Emiluvia* sp., *Tritrabs* cf. *casmaliaensis* (PESSAGNO), *Archaeodictyomitra minoensis* (MIZUTANI), *Archaeodictyomitra* cf. *minoensis* (MIZUTANI), *Archaeodictyomitra rigida* PESSAGNO, *Archaeodictyomitra vulgaris* PESSAGNO, *Archaeodictyomitra* sp. B sensu WEGERER et al., *Archaeodictyomitra* spp., *Cinguloturris carpatica* DUMITRICA, *Cyrtocapsa* sp., *Droltus* sp., *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO), *Gongylothorax favosus* DUMITRICA, *Gongylothorax* aff. *favosus* DUMITRICA, *Hiscocapsa acuta* HULL, *Hiscocapsa* sp., *Hsuum brevicostatum* (OZVOLDOVA), *Lithocampium* sp., *Loopus doliolum* DUMITRICA, *Parahsuum carpathicum* WIDZ & DE WEVER, *Parahsuum longiconicum* SASHIDA, *Parvicingula dhimenaensis* BAUMGARTNER, *Parvicingula* spp., *Podobursa* sp., *Pseudodictyomitra* sp. D sensu MATSUOKA & YAO, *Stichomitra annibill* KOCHER, *Stichomitra* sp., *Syringocapsa* sp., *Tetracapsa* sp. A, *Tricolocampe* sp. B, *Tricolocapsa* cf. *leiostraca* (FOREMAN), *Tricolocapsa undulata* (HEITZER), *Tricolocapsium* sp. A, *Triversus hexagonatus* (HEITZER), *Triversus* spp., *Williriedellum carpathicum* DUMITRICA, *Wrangellium* aff. *hsui* (PESSAGNO), *Wrangellium* cf. *hsui* (Pessagno), *Wrangellium okamurai* (MIZUTANI), *Wrangellium* sp., *Zhamoidellum ovum* DUMITRICA. *Gongylothorax favosus* and *Gongylothorax* aff. *favosus* give UA 8 according to BAUMGARTNER et al. (1995). *Williriedellum carpathicum* has an FAD in the Late Callovian. Therefore the age of this sample is most probably Late Callovian to Early Oxfordian.

Sample GU 5/2001: *Tritrabs* sp., *Archaeodictyomitra minoensis* (MIZUTANI), *Archaeodictyomitra rigida* PESSAGNO, *Gongylothorax favosus* DUMITRICA, *Stichocapsa* sp., *Stichomitra tuscanica* (CHIARI, CORTESE & MARCUCCI), *Syringocapsa* sp., *Zhamoidellum* sp. The stratigraphic age is limited by the appearance of *Gongylothorax favosus*.

Sample GU 6/2001: *Acanthocircus* cf. *suboblongus* (YAO), *Acanthocircus* cf. *trizonalis* (RÜST), *Acanthocircus* sp., *Angulobracchia* sp. A, *Archaeospongoprunum* cf. *imlayi* PESSAGNO, *Archaeospongoprunum* spp., *Paronaella broennimanni* PESSAGNO, *Paronaella* cf. *mulleri* PESSAGNO, *Emiluvia* cf. *chica* FOREMAN, *Emiluvia premyogii* BAUMGARTNER, *Emiluvia* sp., *Spongostaurus* sp., *Triactoma* sp., *Tritrabs* cf. *exotica* (PESSAGNO), *Tritrabs* sp., *Acotripus* sp., *Archaeodictyomitra minoensis* (MIZUTANI), *Archaeodictyomitra mitra* DUMITRICA, *Archaeodictyomitra rigida* PESSAGNO, *Archaeodictyomitra sixi* YANG, *Archaeodictyomitra* cf. *sixi* YANG, *Archaeodictyomitra* spp., *Cinguloturris carpatica* DUMITRICA, *Cinguloturris* sp., *Dictyomitrella* sp., *Droltus galerus* SUZUKI, *Droltus* sp., *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO), *Eucyrtidiellum unumaense* (YAO), *Eucyrtidiellum* sp., *Gongylothorax favosus* DUMITRICA, *Hiscocapsa acuta* HULL, *Hiscocapsa* spp., *Hsuum brevicostatum* (OZVOLDOVA), *Hsuum* cf. *cuestaense* PESSAGNO, *Lithocampium* sp. A, *Lithocampium* sp., *Loopus* cf. *nudus* (SCHAAF), *Parahsuum carpathicum* WIDZ & DE WEVER, *Parahsuum* sp. S sensu MATSUOKA, *Parahsuum* sp., *Parvicingula dhimenaensis* BAUMGARTNER, *Parvicingula spinata* (VINASSA), *Parvicingula* spp., *Parvifavus* sp. A, *Podobursa* sp., *Protunuma multicostatus* (HEITZER), *Pseudodictyomitra* cf. *primitiva* MATSUOKA & YAO, *Pseudodictyomitra* sp. D sensu MATSUOKA & YAO, *Pseudodictyomitra* sp. N sensu SUZUKI et al., *Solenotryma ichikawai* MATSUOKA & YAO, *Spongocapsula* sp., *Stichomitra annibill* KOCHER, *Stichomitra* sp., *Syringocapsa levis* (HORI), *Syringocapsa* sp. A sensu SUZUKI et al., *Syringocapsa* sp., *Tetracapsa* sp. A, *Tetracapsa* spp., *Thanarla* aff. *pulchra* (SQUINABOL), *Tricolocapsa* cf. *parvipora* Tan, *Tricolocapsa undulata* (HEITZER), *Tricolocapsium* sp. A, *Tricolocapsium* sp., *Triversus hexagonatus* (HEITZER), *Triversus* sp., *Williriedellum carpathicum* DUMITRICA, *Williriedellum crystallinum* DUMITRICA, *Wrangellium hsui* (PESSAGNO), *Wrangellium* aff. *hsui* (PESSAGNO), *Wrangellium* cf. *okamurai* (MIZUTANI), *Zhamoidellum ovum* DUMITRICA, *Zhamoidellum ventricosum* DUMITRICA, *Zhamoidellum* sp. From this rich and well preserved radiolarian association *Eucyrtidiellum unumaense*, *Gongylothorax favosus*, *Zhamoidellum ventricosum*, and *Williriedellum carpathicum* give an Late Callovian to Early Oxfordian age for this sample. *Loopus* cf. *nudus* and *Thanarla* aff. *pulchra* point to a younger age.

Sample GU 8/2001: *Archaeospongoprunum* sp. *Tritrabs* cf. *exotica* PESSAGNO, *Tritrabs* sp., *Archaeodictyomitra mitra* DUMITRICA, *Archaeodictyomitra* sp., *Gongylothorax favosus* DUMITRICA, *Gongylothorax* aff. *favosus* DUMITRICA, *Gongylothorax* sp., *Hiscocapsa* cf. *hexagona* (HORI), *Hiscocapsa* sp., *Loopus doliolum* DUMITRICA, *Protunuma japonicus* MATSUOKA & YAO, *Pseudodictyomitra primitiva* MATSUOKA & YAO, *Stichomitra tairai* AITA, *Stichomitra* sp., *Stylocapsa* cf. *oblongula* KOCHER, *Tricolocapsa* cf. *ruesti* TAN, *Tricolocapsa* sp., *Triversus* sp., *Williriedellum crystallinum* DUMITRICA, *Wrangellium rudabanyaense* (GRILL & KOZUR), *Zhamoidellum ovum* DUMITRICA, *Zhamoidellum* sp. *Gongylothorax favosus*, *Gongylothorax* aff. *favosus*, and *Stylocapsa oblongula* give UA 8 according to BAUMGARTNER et al. (1995).

Sample GU 1/2002: *Acanthocircus* cf. *suboblongus minor* BAUMGARTNER, *Archaeospongoprunum* cf. *elegans* WU, *Archaeospongoprunum* sp., *Plegmosphaera* ? sp., *Spongotripus* sp., *Tritrabs* cf. *ewingi* (PESSAGNO), *Tritrabs exotica* (PESSAGNO), *Tritrabs* sp., *Archaeodictyomitra rigida* PESSAGNO, *Archaeodictyomitra* sp. B sensu WEGERER et al., *Archaeodictyomitra* sp., *Cinguloturris carpatica* DUMITRICA, *Eucyrtidiellum unumaense* (YAO), *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, *Gongylothorax favosus* Dumitrica, *Gongylothorax* aff. *favosus* DUMITRICA, *Gongylothorax* sp., *Hsuum* *brevicostatum* (OZVOLDOVA), *Hsuum maxwelli* PESSAGNO, *Pseudodictyomitra primitiva* MATSUOKA & YAO, *Pseudodictyomitrella spinosa* GRILL & KOZUR, *Pseudodictyomitrella* sp., *Stichocapsa inflata* (BLOME), *Stichomitra annibill* KOCHER, *Tricolocampe* sp., *Triversus hexagonatus* (HEITZER), *Triversus* sp. The co-appearance of *Zhamoidellum ventricosum*, *Eucyrtidiellum unumaense*, *Gongylothorax favosus*, *Gongylothorax* aff. *favosus* and *Zhamoidellum ventricosum* point to UA 8.

In total, all radiolarian associations from the red radiolarite have an age range of Late Callovian to Early Oxfordian. A more exact biostratigraphic dating with radiolarian associations is yet not possible. Only the appearance of a few species give a hint for a slightly younger age, but age range and systematic order of these species is unproven at moment.

Rarely intercalated red clay layers, located in the middle part of the red radiolarite succession, consist also of smectite-bentonites (REITER, 2009). Still in the Early to Middle Oxfordian the red radiolarite passed into dark-grey radiolarites and cherty limestones. The radiolarite of this part in the section is laminated and contain the first fine-grained turbidites. The clasts are too small to be determined regarding their stratigraphic affiliation. Upsection the turbidites become coarse-grained with components consisting predominately of Late Triassic lagoonal Dachstein Limestone, whilst Early to Middle Jurassic clasts occur seldom. This component spectrum is identical to that of the Taugl valley resediments in the south.

To summarize, the age of the radiolarian-rich background sediment is Early to Middle Oxfordian according to the type-locality, even direct radiolarian biostratigraphic ages are not exact enough at moment (see above). In contrast to the thick succession in the Taugl valley, the thickness of the northern Tauglboden Basin succession does not exceed a few tens of metres (details in DIERSCHE 1980) with a maximal thickness of the intercalated mass flows of only 10-20 centimetres.

Radiolarian samples from the transitional part of the massive red radiolarite to laminated red-grey to grey calcareous radiolarites of the basal Tauglboden Formation yielded only moderate preserved radiolarian faunas. The radiolarian associations from this part of the succession gave a similar age as those from the red radiolarite below. A similar result was reached by the radiolarian associations from the Oxfordian boundary layer in the Urban valley (see above) and from the Fludergraben valley in the Salzkammergut region (SUZUKI et al., 2004), where first a red radiolarite and in turn the Tauglboden Formation overlie the Klaus Formation, dated in its upper parts by ammonites as deposited around the Callovian/Oxfordian boundary (MANDL, 1982).

Sample GU 9/2001: *Archaeodictyomitra sixi* YANG, *Eucyrtidiellum unumaense unumaense* (YAO), *Gongylothorax* sp., *Parvifavus* sp. A, *Stichocapsa* sp., *Zhamoidellum* cf. *ventricosum* DUMITRICA. This radiolarian association cannot be dated more precisely as UA 8 by the co-occurrence of *Eucyrtidiellum unumaense unumaense* and *Zhamoidellum* cf. *ventricosum.*

Sample GU 10/2001: *Eucyrtidiellum* cf. *unumaense* (YAO), *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, *Gongylothorax favosus* DUMITRICA, *Gongylothorax marmoris* KIESSLING, *Hiscocapsa acuta* HULL, *Tricolocapsa matsuokai* SASHIDA, *Williriedellum* sp., *Zhamoidellum ovum* DUMITRICA, This radiolarian association cannot be dated more precisely as UA 8 by the co-occurrence of *Eucyrtidiellum* cf. *unumaense*, *Eucyrtidiellum unumaense pustulatum* and *Gongylothorax favosus*.

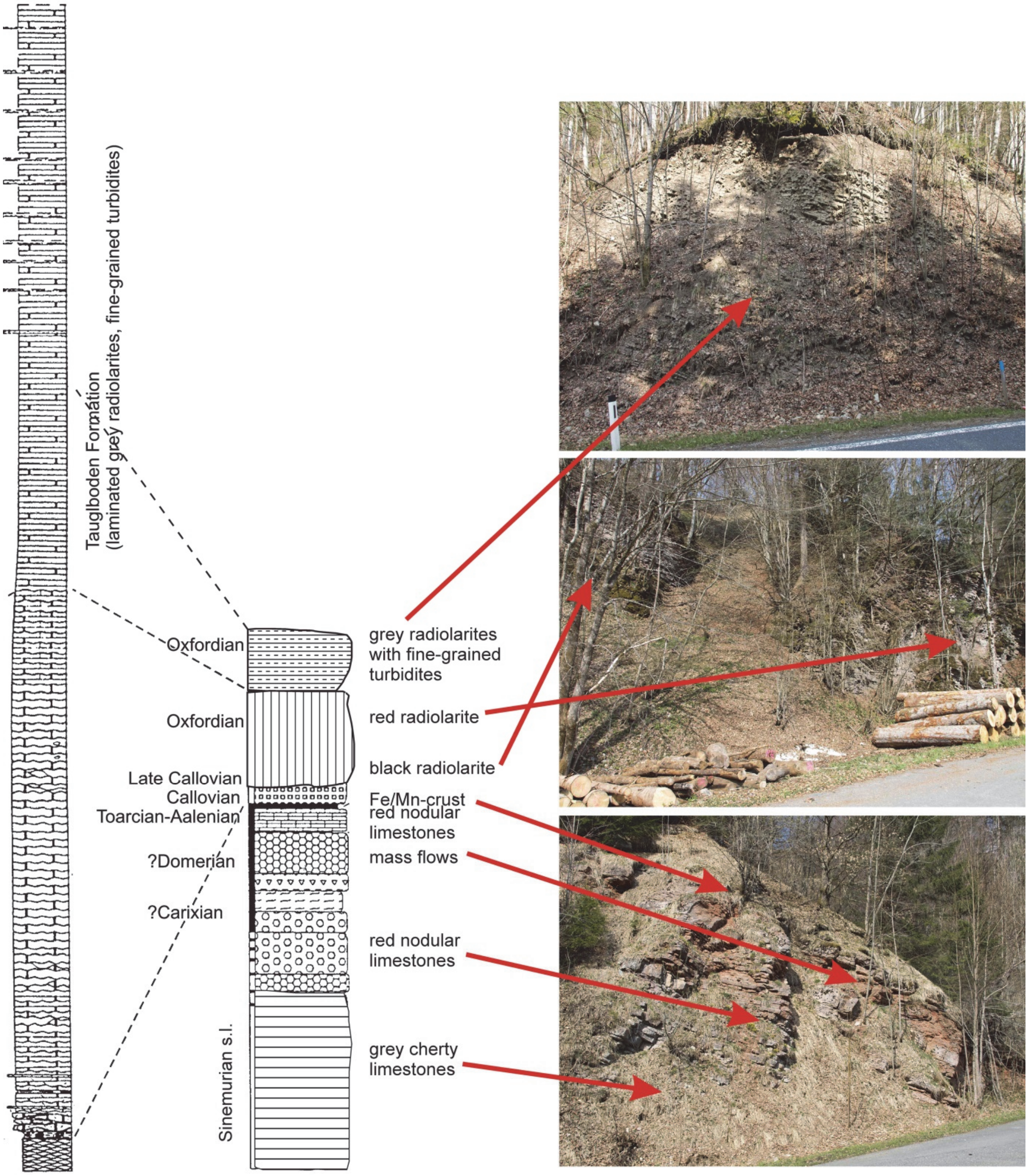

Fig. 11: Stratigraphy and facies of the Early to early Late Jurassic section along the road to the village Krispl in the Mörtlbach valley (compare G*AWLICK et al., 2012). Right section with photographs after* B*ÖHM (1992), modified and completed for the Callovian-Oxfordian part. Left section from* D*IERSCHE (1980).*

.

Sample GU 11/2001: *Archaeospongoprunum* sp., *Sphaerostylus lanceola* (PARONA), *Acotripus* cf. *sphaericus* OZVOLDOVA, *Archaeodictyomitra amabilis* AITA, *Archaeodictyomitra sixi* YANG, *Archaeodictyomitra* sp., *Droltus galerus* SUZUKI, *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO), *Gongylothorax favosus* DUMITRICA, *Hiscocapsa acuta* HULL, *Napora pyramidalis* BAUMGARTNER, *Parahsuum* sp., *Parvicingula dhimenaensis* BAUMGARTNER, *Tetracapsa* sp. A, *Tetracapsa* sp., *Tricolocapsa undulata* (HEITZER), *Tricolocapsa* sp. A sensu OZVOLDOVA, *Williriedellum dierschei* SUZUKI & GAWLICK, *Zhamoidellum ovum* DUMITRICA. The occurrence of *Archaeodictyomitra amabilis* together with *Zhamoidellum ovum* points normally to the Early Callovian. Therefore the age range of *Archaeodictyomitra amabilis* has to be shifted at least to the Late Callovian - Early Oxfordian.

Sample GU 12/2001: *Archaeodictyomitra* cf. *mitra* DUMITRICA, *Archaeodictyomitra* cf. *sixi* YANG, *Archaeodictyomitra* sp., *Eucyrtidiellum unumaense* ssp. (YAO), *Eucyrtidiellum unumaense unumaense* (YAO), *Gongylothorax* aff. *favosus* DUMITRICA, *Gongylothorax oblongus* YAO, *Hsuum* sp., *Quarticella* cf. *ovalis* TAKEMURA, *Stichocapsa convexa* YAO, *Stylocapsa oblongula* KOCHER, *Theocapsomma* sp., *Tricolocapsa* cf. *conexa* MATSUOKA, *Tricolocapsa* cf. *plicarum* YAO, *Tricolocapsa* sp., *Unuma* sp., *Williriedellum dierschei* SUZUKI & GAWLICK. The biostratigraphic age of this radiolarian association is not very precise: UA 7 to 8. Important is the occurrence of *Gongylothorax oblongus* assigned by BAUMGARTNER et al. for the UA 4. A similar form was described by HULL (1997) as *Gongylothorax* aff. *oblongus* from North America in the time interval Late Oxfordian to Kimmeridgian. The stratigraphic range of *Gongylothorax oblongus* has to be extended at least to the Late Callovian - Early Oxfordian.

Sample GU 13/2001: *Tritrabs* sp., *Eucyrtidiellum unumaense* (YAO), *Eucyrtidiellum* sp., *Stichocapsa* cf. *japonica* YAO, *Stichomitra takanoensis* AITA, *Syringocapsa* sp., *Tricolocapsa* cf. *plicarum* YAO, *Tricolocapsa* sp., *Triversus* sp., *Zhamoidellum ovum* DUMITRICA. According to the co-occurrence of *Stichomitra takanoensis* and *Zhamoidellum ovum* this sample would be normally assigned to the UA 7 (Late Bathonian to Early Callovian). The position of the sample is in the Tauglboden Formation and above a lot of younger samples than UA 7. The age range of *Stichomitra takanoensis* has at least to be prolonged to the Late Callovian - Early Oxfordian.

3.3 Krispl: Oberalm Formation

Along the road to Krispl (Fig. 3) a Late Tithonian part of the Oberalm Formation can be studied (Fig. 12). Dm-bedded radiolarian wacke- to packstones intercalated by fine-grained resediments with shallow-water debris and greenish marl layers are the typical sedimentary rocks. Illite dominates the clay fraction from the greenish marls (VORTISCH, GAWLICK, unpublished data). In the calcareous turbidites two shedding directions are visible: some calcareous turbidites were shed from southern directions (Plassen Carbonate Platform s. str.), others came from the north (Wolfgangsee Carbonate Platform).

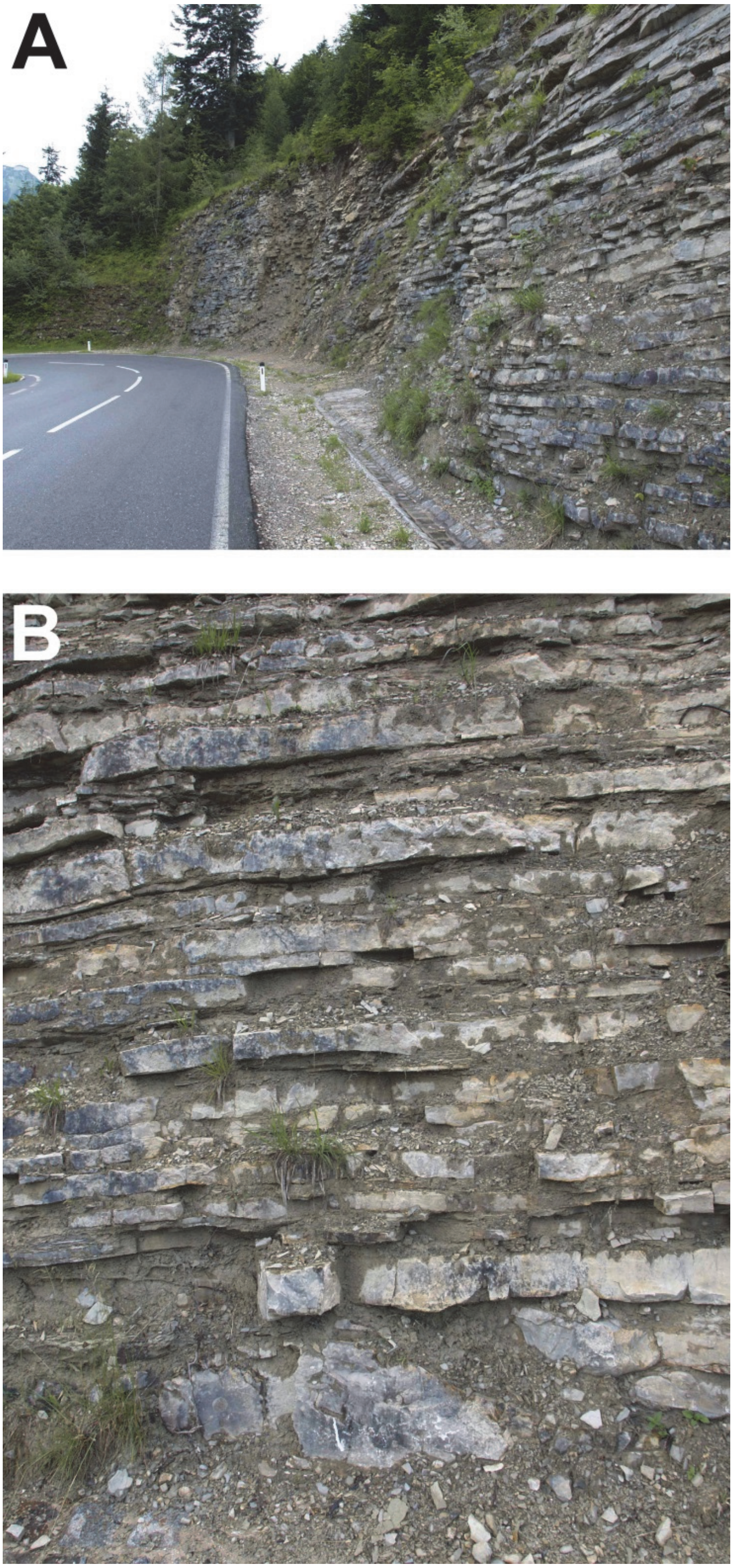

Fig. 12: Road cut with the Oberalm Formation along the road to Krispl. ***A****) Outcrop situation before the fixation of metal nets.* ***B****) Dm-bedded limestone beds with intercalated green marls.*

3.4 Mt. Barmsteine: Barmstein Limestone

Type-Locality: Resediments of the Plassen Carbonate Platform *s. str.* (Late Tithonian to Early Berriasian) intercalated in *Calpionella* Limestone.

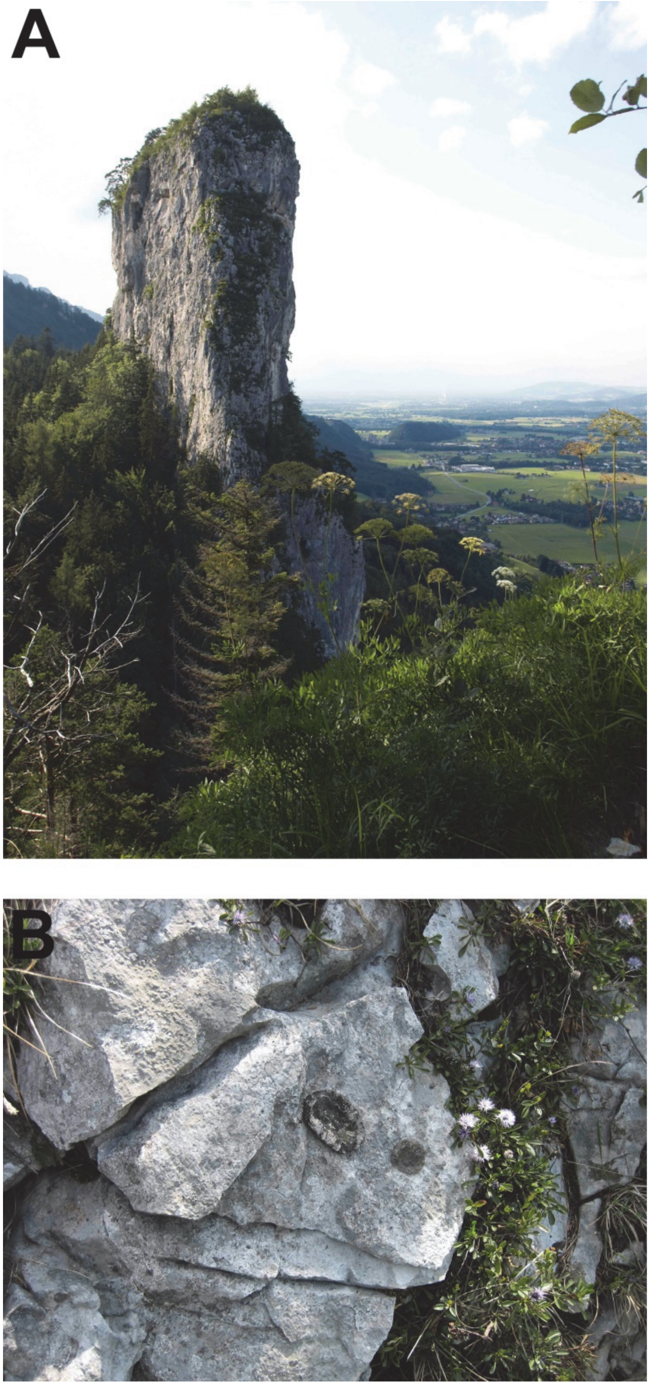

Fig. 13: The Barmstein Limestone type-locality west of the township Hallein. ***A****) Mt. Grosser Barmstein, view from the south.* ***B****) Coarse-grained Barmstein Limestone with chert nodules.*

Detailed description of the type locality in GAWLICK et al. (2005). The cliffs of the Barmstein Limestones on the type locality (Fig. 13) consist of a roughly 160 m thick latest Tithonian to earliest Cretaceous succession - according to the final definition of the Jurassic/Cretaceous boundary based on the FAD of the spherical variety of *Calpionella alpina* (Alpina subzone). In June 2016, the Berriasian Working Group voted by a large majority (76%) to adopt the *Crassicollaria/Calpionella* turnover as the primary marker for the base of the Berriasian (WIMBLEDON, 2017). But, the basal part of the succession has to be attributed to the highest part of the Tithonian (STEIGER, 1981, 1992; GAWLICK et al., 2005).

At the cliffs of the Barmstein Limestones, repeated shedding of mass transport deposits (olistostromes, debris and slide flows, and turbidites) resulted in a varying component spectrum, slightly varying dipping and variable grain size. In some Barmstein layers in the type area dominate (in cases slightly older) clasts of the inner lagoon of the Plassen Carbonate Platform, in other layers dominate reef-near clasts. In some channels older casts (e.g., dolomite, filament limestone, lagoonal limestones, *Saccocoma* limestone, radiolarite) can be found, which indicate deeper erosion in the provenance area. The component spectrum indicates an eroded sedimentary succession similar as found in the older Tauglboden Formation. Only the occurrence of Middle Triassic components in the Barmstein Limestones differs from the spectrum in the Tauglboden Formation. We suppose to see in these Triassic clasts erosion of deeper stratigraphic levels of the collapsed Trattberg Rise controlled by the formation of Late Tithonian escarpments.

In some flows appear clasts deriving from an evaporitic succession (STEIGER, 1981; PLÖCHINGER, 1974): pseudomorphs after gypsum, siltstones, and recrystallized dolomites with high porosity (most probably earliest Middle Triassic). A direct proof for the provenance from the Alpine Haselgebirge as in the “Tonflatschenbreccia” of the Leube quarry (PLÖCHINGER 1974, 1976) is not available for the Barmsteine type locality. A derivation from the Reichenhall Formation cannot be excluded. Together with the other Triassic-Jurassic components in the Barmstein layers, the Reichenhall Formation would complete the reworked Triassic succession from the Trattberg Rise (e.g., sedimentary sequence of the Berchtesgaden unit with Mt. Untersberg as frontal part). In addition, turbiditic grainstone layers occur intercalated in the *Calpionella* Limestone (Oberalm Formation). For the genesis of the Barmstein Limestones, tectonic control mechanisms as well as possible sequence stratigraphic cyclicity is discussed (GAWLICK et al., 2005, 2009). No Triassic Hallstatt Limestone clasts were found at the type locality.

References

AUER, M., GAWLICK, H.-J., SUZUKI, H. & SCHLAGINTWEIT, F. (2009): Spatial and temporal development of siliceous basin and shallow-water carbonate sedimentation in Oxfordian Northern Calcareous Alps. - Facies, 55: 63-87, Berlin Heidelberg.

BAUMGARTNER, P.O., BARTOLINI, A., CARTER, E.S., CONTI, M., CORTESE, G., DANELIAN, T., DE WEVER, P., DUMITRICA, P., DUMITRICA-JUD, R., GORICAN, S., GUEX, J., HULL, D.M., KITO, N., MARCUCCI, M., MATSUOKA, A., MURCHEY, B., O´DOGHERTY, L., SAVARY, J., VISHNEVSKAYA, V., WIDZ, D. & YAO, A. (1995): Middle Jurassic to Early Cretaceous Radiolaria Biochronology of Tethys based on Unitary Associations. - Memoires de Geologie, 23: 1013-1048, Lausanne.

BÖHM, F. (1992): Mikrofazies und Ablagerungsmilieu des Lias und Dogger der Nordöstlichen Kalkalpen. - Erlanger Geologische Abhandlungen, 121: 55-217, Erlangen.

DIERSCHE, V. (1980): Die Radiolarite des Oberjura im Mittelabschnitt der Nördlichen Kalkalpen. - Geotektonische Forschungen, 58: 1-217, Stuttgart.

FISCHER, A.G. (1965): Eine Lateralverschiebung in den Salzburger Kalkalpen. - Verhandlungen der Geologischen Bundesanstalt, 1965: 20-33, Wien.

FISHER, R.V. & SCHMINCKE, H.-U. (1984): Pyroclastic rocks. - 1-472, Springer.

FRANK, W. & SCHLAGER, W. (2006): Jurassic strike slip versus subduction in the Eastern Alps. - International Journal of Earth Sciences, 95: 431-450, Berlin Heidelberg.

FRISCH, W. & GAWLICK, H.-J. (2003): The nappe structure of the central Northern Calcareous Alps and its disintegration during Miocene tectonic extrusion - a contribution to understanding the orogenic evolution of the Eastern Alps. - International Journal of Earth Sciences, 92: 712-727, Berlin Heidelberg.

GARRISON, R.E. & FISCHER, A.G. (1969): Deep water Limestones and Radiolarites of the Alpine Jurassic. - SEPM Special Publication, 14: 20-56, Tulsa.

GAWLICK, H.-J. (2000): Paläogeographie der Ober-Trias Karbonatplattform in den Nördlichen Kalkalpen. - Mitteilungen Gesellschaft Geologie- Bergbaustudenten Österreich, 44: 45-95, Wien.

GAWLICK, H.-J. & FRISCH, W. (2003): The Middle to Late Jurassic carbonate clastic radiolaritic flysch sediments in the Northern Calcareous Alps: sedimentology, basin evolution and tectonics - an overview. - Neues Jahrbuch Geologie Paläontologie, Abhandlungen, 230: 163-213, Stuttgart.

GAWLICK, H.-J. & HÖPFER, N. (1999): Stratigraphie, Fazies und Hochdruck-Mitteltemperatur-Metamorphose der Hallstätter Kalke der Pailwand (Nördliche Kalkalpen, Österreich). - Zeitschrift der Deutschen Geologischen Gesellschaft, 150: 641-671, Hannover.

GAWLICK, H.-J. & SCHLAGINTWEIT, F. (2006): Berriasian drowning of the Plassen carbonate platform at the type-locality and its bearing on the early Eoalpine orogenic dynamics in the Northern Calcareous Alps (Austria). - International Journal of Earth Sciences, 95: 451-462, Berlin Heidelberg.

GAWLICK, H.-J., KRYSTYN, L. & LEIN, R. (1994): Conodont colour alteration indices: Paleotemperatures and metamorphism in the Northern Calcareous Alps - a general view. - Geologische Rundschau, 83: 660-664, Berlin Heidelberg.

GAWLICK, H.-J., MISSONI, S., SCHLAGINTWEIT, F., SUZUKI, H., FRISCH, W., KRYSTYN, L., BLAU, J. & LEIN, R. (2009): Jurassic Tectonostratigraphy of the Austroalpine domain. - Journal of Alpine Geology, 50: 1-152, Wien.

GAWLICK, H.-J., MISSONI, S., SCHLAGINTWEIT, F. & SUZUKI, H. (2012): Jurassic active continental margin deep-water basin and carbonate platform formation in the north-western Tethyan realm (Austria, Germany). - Journal of Alpine Geology, 54: 189-292, Wien.

GAWLICK, H.-J., SCHLAGINTWEIT, F. & MISSONI, S. (2005): Die Barmsteinkalke der Typlokalität nordwestlich Hallein (hohes Tithonium bis tieferes Berriasium; Salzburger Kalkalpen) - Sedimentologie, Mikrofazies, Stratigraphie und Mikropaläontologie: neue Aspekte zur Interpretation der Entwicklungsgeschichte der Ober-Jura-Karbonatplattform und der tektonischen Interpretation der Hallstätter Zone von Hallein - Bad Dürrnberg. - Neues Jahrbuch Geologie Paläontologie Abhandlungen, 236: 351-421, Stuttgart.

GAWLICK, H.-J., SCHLAGINTWEIT, F. & SUZUKI, H. (2007): Die Ober-Jura bis Unter-Kreide Schichtfolge des Gebietes Sandling-Höherstein (Salzkammergut, Österreich) - Implikationen zur Rekonstruktion des Block-Puzzles der zentralen Nördlichen Kalkalpen, der Gliederung der karbonatklastischen Radiolaritflyschbecken und der Entwicklung der Plassen-Karbonatplattform. - Neues Jahrbuch Geologie Paläontologie, Abhandlungen, 243: 1-70, Stuttgart.

GAWLICK, H.-J., SUZUKI, H., VORTISCH, W. & WEGERER, E. (1999): Zur stratigraphischen Stellung der Tauglbodenschichten an der Typlokalität in der Osterhorngruppe (Nördliche Kalkalpen, Ober-Oxfordium - Unter-Tithonium). - Mitteilungen Gesellschaft Geologie- Bergbaustudenten Österreich, 42: 1-20, Wien.

GORIČAN, Š., PAVŠIĆ, J. & ROŽIĆ, B. (2012): Bajocian to Tithonian age of radiolarian cherts in the Tolmin basin (NW Slovenia). - In: DANELIAN, T. & GORIČAN, Š. (Eds.): Radiolarian biochronology as key to tectono-stratigraphic reconstructions. - Bulletin de la Société géologique de France, 183: 369-382, Paris.

GÜMBEL, C.W. von (1861): Geognostische Beschreibung des Bayrischen Alpengebirges und seines Vorlandes. I-XX. - 1-950, (Justus Perthes) Gotha.

HAAS, J., KOVÁCS, S., KRYSTYN, L. & LEIN, R. (1995): Significance of Late Permian - Triassic facies zones in terrane reconstructions in the Alpine - North Pannonian domain. - Tectonophysics, 242: 19-40, Amsterdam.

HAHN, F. (1913): Grundzüge des Baues der nördlichen Kalkalpen zwischen Inn und Enns. - Mitteilungen der Geologischen Gesellschaft in Wien, **6**: 238-357 and 374-501, Wien.

HAUG, E. (1906): Les nappes de charriage des Alpes calcaires septentrionales. - Bulletin de la Societé Géologique de la France, 6: 359-422, Paris.

HUCKRIEDE, R. (1971): Rhyncholithen-Anreicherung (Oxfordium) an der Basis des Älteren Radiolarits der Salzburger Kalkalpen. - Geologica et Palaeontologica, 5: 131-147, Marburg/Lahn.

HULL, D.M. (1997): Upper Jurassic Tethyan and southern Boreal radiolarians from western North America. - Micropaleontology, 43 (Supplement 2): 1-202.

KOBER, L. (1923): Bau und Entstehung der Alpen. - 1-289, (Bornträger) Berlin.

KRISCHE, O., BUJTOR, L. & GAWLICK, H.-J. (2013): Calpionellid and ammonite biostratigraphy of uppermost Jurassic to Lower Cretaceous sedimentary rocks from the Leube quarry (Northern Calcareous Alps, Salzburg, Austria). - Austrian Journal of Earth Sciences, 101: 26-45, Wien.

KRISCHE, O., GRABOWSKI, J., BUJTOR, L. & GAWLICK, H.-J. (2018, this volume): Early Cretaceous evolution of the central Northern Calcareous Alps. - Berichte der Geologischen Bundesanstalt

LEBLING, C., HABER, G., HOFFMANN, N., KÜHNEL, J., WIRTH, E. (1935): Geologische Verhältnisse des Gebirges um den Königs-See, 20. - Abhandlungen Geologische Landesuntersuchung Bayerisches Oberbergamt: 1-46, München.

LEIN, R. (1985): Das Mesozoikum der Nördlichen Kalkalpen als Beispiel eines gerichteten Sedimentationsverlaufes infolge fortschreitender Krustenausdünnung. - Archiv für Lagerstättenforschung, 6: 117-128, (Geologische Bundesanstalt) Wien.

LEIN, R. (1987a): Evolution of the Northern Calcareous Alps During Triassic Times. - In: FLÜGEL, H.W. & FAUPL, P. (Eds.): Geodynamics of the Eastern Alps), 85-102, (Deuticke) Wien.

LEIN, R. (1987b): Zur Verbreitung der Hallstätter Zone beiderseits des Pyhrn-Passes. - Oberösterreichische Geonachrichten, Folge 2: 21-37, Linz.

LINZER, H.-G., RATSCHBACHER, L. & FRISCH, W. (1995): Transpressional collision structures in the upper crust: the fold-thrust belt of the Northern Calcareous Alps - Tectonophysics, 242: 41-61, Amsterdam.

LIPOLD, M. v. (1854): Der Salzberg am Dürnberg nächst Hallein. - Jahrbuch der kaiserlich-königlichen Geologischen Reichsanstalt, 1854: 590-610, Wien.

MANDL, G.W. (1982): Jurassische Gleittektonik im Bereich der Hallstätter Zone zwischen Bad Ischl und Bad Aussee (Salzkammergut, Österreich). - Mitteilungen der Gesellschaft Geologie- Bergbaustudenten in Österreich, 28: 55-76, Wien.

MANDL, G.W., BRANDNER, R. & GRUBER, A. (2017): Zur Abgrenzung und Definition der Kalkalpinen Deckensysteme (Ostalpen, Österreich). - Tagungsband der Arbeitstagung der Geologischen Bundesanstalt, 2017: 254-255, Wien.

MEDWENITSCH, W. (1962): Die Bedeutung der Grubenaufschlüsse des Halleiner Salzberges für die Geologie des Ostrandes der Berchtesgadener Schubmasse. - Zeitschrift der Deutschen Geologischen Gesellschaft, 113: 463-494, Hannover.

MISSONI, S. & GAWLICK, H.-J. (2011a): Jurassic mountain building and Mesozoic-Cenozoic geodynamic evolution of the Northern Calcareous Alps as proven in the Berchtesgaden Alps (Germany). - Facies, 57: 137-186, (Springer).

MISSONI, S. & GAWLICK, H.-J. (2011b): Evidence for Jurassic subduction from the Northern Calcareous Alps (Berchtesgaden; Austroalpine, Germany). - International Journal of Earth Sciences **100**: 1605-1631, (Springer).

O'DOGHERTY, L., BILL, M., GORIČAN, Š., DUMITRICA, P. & MASSON, H. (2006): Bathonian radiolarians from an ophiolitic mélange of the Alpine Tethys (Gets Nappe, Swiss-French Alps). - Micropaleontology, 51: 425:485.

O'DOGHERTY, L., CARTER, E.S., DUMITRICA, P., GORIČAN, Š., DE WEVER, P., HUNGERBÜHLER, A., BANDINI, A.N. & TAKEMURA, A. (2009): Catalogue of Mesozoic radiolarian genera. Part 1: Triassic. - Geodiversitas, 31: 213-270.

O'Dogherty, L., Goričan, Š. & Gawlick, H.-J. (2017): Middle and Late Jurassic radiolarians from the Neotethys suture in the Eastern Alps. - Journal of Paleontology, 109: 142-159.

Ortner, H., Ustaszewski, M. & Rittner, M. (2008): Late Jurassic tectonics and sedimentation: breccias in the Unken syncline, central Northern Calcareous Alps. - Swiss Journal Geosciences, Supplement 1, 101: S55-S71, Basel.

Plöchinger, B. (1974): Gravitativ transportiertes permisches Haselgebirge in den Oberalmer Schichten (Tithonium, Salzburg). - Verhandlungen der Geologischen Bundesanstalt, 1974: 71-88, Wien.

Plöchinger, B. (1976): Die Oberalmer Schichten und die Platznahme der Hallstätter Masse in der Zone Hallein-Berchtesgaden. - Neues Jahrbuch Geologie und Paläontologie Abhandlungen, 151: 304-324, Stuttgart.

Plöchinger, B. (1980): Die Nördlichen Kalkalpen. - In: Oberhauser, R. (Ed.): Der geologische Aufbau Österreichs), 217-264, (Springer) Wien New York.

Plöchinger, B. (1984): Zum Nachweis jurassisch-kretazischer Eingleitungen von Hallstätter Gesteinsmassen beiderseits des Salzach-Quertales (Salzburg). - Geologische Rundschau, 73: 293-306, Stuttgart.

Pueyo, E. L., Mauritsch, H. J, Gawlick, H.-J, Scholger, R. & Frisch, W. (2007): New evidence for block and thrust sheet rotations in the central northern Calcareous Alps deduced from two pervasive remagnetization events. - Tectonics 26, TC5011.

Ratschbacher, L., Frisch, W., Linzer, H.G. & Merle, O. (1991): Lateral extrusion in the Eastern Alps, Part 2: structural analysis. - Tectonics, 10: 257-271.

Reiter, W. (2009): Climate changes in the Middle and Late Jurassic: Isotope analysis of radiolarites from the Northern Calcareous Alps. - Unpublished Dipl. thesis, 1-56, Tübingen.

Schlager, M. (1956): Geologische Studien im Tauglboden. - Mitteilungen der Naturwissenschaftlichen Arbeitsgemeinschaft am (vom) Haus der Natur in Salzburg, 5: 31-44, Salzburg.

Schlager, M. & Schlager, W. (1969): Über die Sedimentationsbedingungen der jurassischen Tauglbodenschichten (Osterhorngruppe, Salzburg). - Anzeiger der Österreichischen Akademie der Wissenschaften. Mathematisch-naturwissenschaftlichen Klasse, 106: 178-183, (Österreichische Akademie Wissenschaften) Wien.

Schlager, W. & Schlager, M. (1973): Clastic sediments associated with radiolarites (Tauglbodenschichten, Upper Jurassic, Eastern Alps). - Sedimentology, 20: 65-89, (Blackwell) Oxford.

Schmid, S.M., Fügenschuh, B., Kissling, E. & Schuster, R. (2004): Tectonic map and overall architecture of the Alpine orogen. - Eclogae geologicae Helvetiae, 97: 93-117, Basel.

Spengler, E. (1951): Die nördlichen Kalkalpen, die Flyschzone und die Helvetische Zone. - In: Schaffer, F.X. (Ed.): Geologie von Österreich), 302-413, (Deuticke) Wien.

Spötl, C., Longstaffe, F.J., Ramseyer, K., Kunks, M.J. & Wiesheu, R. (1998): Fluid-rock reactions in an evaporitic mélange, Permian Haselgebirge, Austrian Alps. - Sedimentology, 45: 1019-1044, (Blackwell) Oxford.

Steiger, T. (1981): Kalkturbidite im Oberjura der Nördlichen Kalkalpen (Barmsteinkalke, Salzburg, Österreich). - Facies, 4: 215-348, Erlangen.

Steiger, T. (1992): Systematik, Stratigraphie und Palökologie der Radiolarien des Oberjura-Unterkreide-Grenzbereiches im Osterhorn-Tirolikum (Nördliche Kalkalpen, Salzburg und Bayern). - Zitteliana (Abhandlungen Bayerischen Staatsammlung Paläontologie und historische Geologie), 19: 1-188, München.

Suess, E. & Mojsiscovics, E. v. (1868): Studien über die Gliederung der Trias- und Jurabildungen in den östlichen Alpen. Nr. II. Die Gebirgsgruppe des Osterhornes. - Jahrbuch der k.k. geologischen Reichsanstalt, 1868: 167-200, Wien.

Suzuki, H. & Gawlick, H.-J. (2003a): Die jurassischen Radiolarienzonen der Nördlichen Kalkalpen. - (In: Weidinger, J.T., Lobitzer, H. & Spitzbart, I. (Eds.): Beiträge zur Geologie des Salzkammerguts. Gmundner Geo-Studien), 2: 115-122, Gmunden.

SUZUKI, H. & GAWLICK, H.-J. (2003b): Biostratigraphie und Taxonomie der Radiolarien aus den Kieselsedimenten der Blaa Alm und nördlich des Loser (Nördliche Kalkalpen, Callovium-Oxfordium). - Mitteilungen Gesellschaft Geologie- Bergbaustudenten Österreich, 46: 137-228, Wien.

SUZUKI, H. & GAWLICK, H.-J. (2009): Jurassic radiolarians from the base of the Hallstatt salt-mine (Northern Calcareous Alps, Austria). - Neues Jahrbuch Geologie Paläontologie, Abhandlungen, 251: 155-197, Stuttgart.

SUZUKI, H., WEGERER, E. & GAWLICK, H.-J. (2001): Zur Radiolarienstratigraphie im unteren Callovium in den Nördlichen Kalkalpen - das Klauskogelbachprofil westlich von Hallstatt. - Zentralblatt Geologie Paläontologie, Teil 1, 2000: 167-184, Stuttgart.

SUZUKI, H., WEGERER, E. & GAWLICK, H.-J. (2004): Radiolarians from the lower Oxfordian of Fludergraben (Austria, Northern Calcareous Alps). - 2004 Annual Meeting, Palaeontological Society of Japan, 126, Kitakyushu.

TOLLMANN A. (1976a): Monographie der Nördlichen Kalkalpen. Teil II. Analyse des klassischen nordalpinen Mesozoikums. Stratigraphie, Fauna und Fazies der Nördlichen Kalkalpen. - 1-580, (Deuticke) Wien.

TOLLMANN, A. (1976b): Der Bau der Nördlichen Kalkalpen. Orogene Stellung und regionale Tektonik. - 1-449, (Deuticke) Wien.

TOLLMANN, A. (1977): Geologie von Österreich, Band **1**: Die Zentralalpen. - 1-766, (Deuticke) Wien.

TOLLMANN, A. (1981): Oberjurassische Gleittektonik als Hauptformungsprozeß der Hallstätter Region und neue Daten zur Gesamttektonik der Nördlichen Kalkalpen in den Ostalpen. - Mitteilungen der Österreichischen Geologischen Gesellschaft, 74/75: 167-195, Wien.

TOLLMANN, A. (1985): Geologie von Österreich, Band 2: Außerzentralalpiner Anteil. - 1-710, Wien (Deuticke).

TOLLMANN, A. (1987): Late Jurassic/Neocomian Gravitational Tectonics in the Northern Calcareous Alps in Austria. - In: FLÜGEL, H.W. & FAUPL, P. (Eds.): Geodynamics of the Eastern Alps), 112-125, Wien (Deuticke).

TRAUTH, F. (1950): Die fazielle Ausbildung und Gliederung des Oberjura in den nördlichen Ostalpen. - Verhandlungen der Geologischen Bundesanstalt, 1948: 145-218, Wien.

VECSEI, A., FRISCH, W., PIRZER, M. & WETZEL, A. (1989): Origin and tectonic Significance of Radiolarian Chert in the Austroalpine Rifted Continental Margin. - In: HEIN, J. & OBRADOVIĆ, J. (Eds.): Siliceous Deposits of the Tethys and Pacific Regions), 65-80, (Springer) Berlin Heidelberg New York.

WÄCHTER, J. (1987): Jurassische Massflow- und Internbreccien und ihr sedimentär-tektonisches Umfeld im mittleren Abschnitt der Nördlichen Kalkalpen. - Bochumer geologische geotechnische Arbeiten, **27**: 1-239, Bochum.

WEGERER, E., SUZUKI, H. & GAWLICK, H.-J. (2001): Zur stratigraphischen Einstufung von Kieselsedimenten im Bereich des Sandling (Nördliche Kalkalpen, Callovium-Oxfordium). - Mitteilungen Gesellschaft Geologie-Bergbaustudenten Österreich, **45**: 67-85, Wien.

WIMBLEDON, W.A.P. (2017): Developments with fixing a Tithonian/Berriasian (J/K) boundary. - Volumina Jurassica, XV: 181-186, Warszawa.