Field Trip A3: Triassic to Early Cretaceous shallow-water carbonates in the central Northern Calcareous Alps (Northwestern Tethyan realm)

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Abstract

The Triassic to Early Cretaceous sedimentary evolution in the northwestern Tethyan realm, very well preserved in the central Northern Calcareous Alps (Salzburg and Berchtesgaden Calcareous Alps, Salzkammergut region), is characterized by a complete Wilson cycle. After siliciclastic dominated Early Triassic sedimentation intense shallow-water carbonate production started around the Early/Middle Triassic boundary. Early/Middle Anisian shallow-water carbonates were deposited first under restricted (Gutenstein carbonate ramp) and later under more open marine conditions (Steinalm carbonate ramp). Late Anisian break-up of the Neotethys Ocean led to the drowning of this shallow-water ramp deposits. In the Ladinian again shallow-water carbonates start to form, and results in the complex Ladinian to early Carnian platform - basin pattern (Wetterstein Carbonate Platform). After the partial drowning of this platform by siliciclastic input in the Middle Carnian again shallow-water carbonate production starts and resulted in the huge Norian Hauptdolomit/Dachstein Limestone Carbonate Platform, with its classical lagoonal sediments - restricted lagoon (Hauptdolomit), open lagoon (Dachstein Limestone with Lofer cycles) - the reefs belt and its transition to the open shelf area (Hallstatt facies). In the Rhaetian the carbonate factories were again influenced by siliciclastic input, and resulted in the formation of a deepened lagoon (Kössen Basin).

In the Jurassic deep-water sediments are dominant: The Jurassic sedimentation in this realm is controlled by the palaeogeographic position of the depositional area between two oceans: the Neotethys Ocean to the east resp. southeast and the Alpine Atlantic to the west resp. northwest. The opening of the Central Atlantic Ocean with its continuation into the Alpine Atlantic (= Ligurian-Penninic Ocean) leads to a new Mediterranean plate configuration. The “Apulian” plate is formed. Successive spreading of the Alpine Atlantic is mirrored by the closure of parts of the Neotethys Ocean resulting in an early deformation of a former Triassic carbonate shelf since late Early Jurassic time. The former Triassic to Early Jurassic passive continental margin with its huge Triassic carbonate platforms came in a lower plate position and a thin-skinned orogen was formed. In the Late Jurassic to Earliest Cretaceous this mountain building process is sealed by the onset of shallow-water carbonate platforms (Plassen Carbonate Platform). Shallow-water platform carbonates were formed on top of the nappe stack.

1 Introduction

For an outline of the whole Permian/Triassic to Early Cretaceous sedimentary and geodynamic evolution of the northwestern Neotethys realm (e.g., Eastern and Southern Alps, Western Carpathians, Pannonian realm, Dinarides) see Gawlick et al. (2012).

During this field trip you will see (Fig. 1):

- Different Anisian shallow-water carbonates (restricted and open lagoon): Gutenstein and Steinalm carbonate ramps.
- Late Ladinian to Early Carnian Wetterstein Carbonate Platform sediments.
- The lagoonal facies belts of the Late Triassic carbonate platform: restricted Hauptdolomit facies belt with it's stromatolithes and the open lagoonal Dachstein Limestone facies belt with the classical Lofer cycles as well as the reefal framework.
- Formation of a palaeotopography in the latest Triassic due to siliciclastic influence and the response of the carbonate factories. Formation of a deep lagoon (Kössen Basin).
- Onset of shallow-water carbonate platforms on an uplifted nappe stack, progradation of shallow-water carbonates over older deep-water basins: different facies belts of the Plassen Carbonate Platform: lagoon, reef belts, reworked platform sediments in basinal *Calpionella* limestones.

To visit the classical Triassic and Jurassic shallow-water carbonate platforms of the tethys-side margin in their type region. This area is a geological highlight in one of the most classical geological areas of the world including classical, historical and more recent foraminifera and algae type-localities, e.g. the Anisian Clessinsperre section (Pia´s locality) and Mount Plassen (Kimmeridgian to Berriasian).

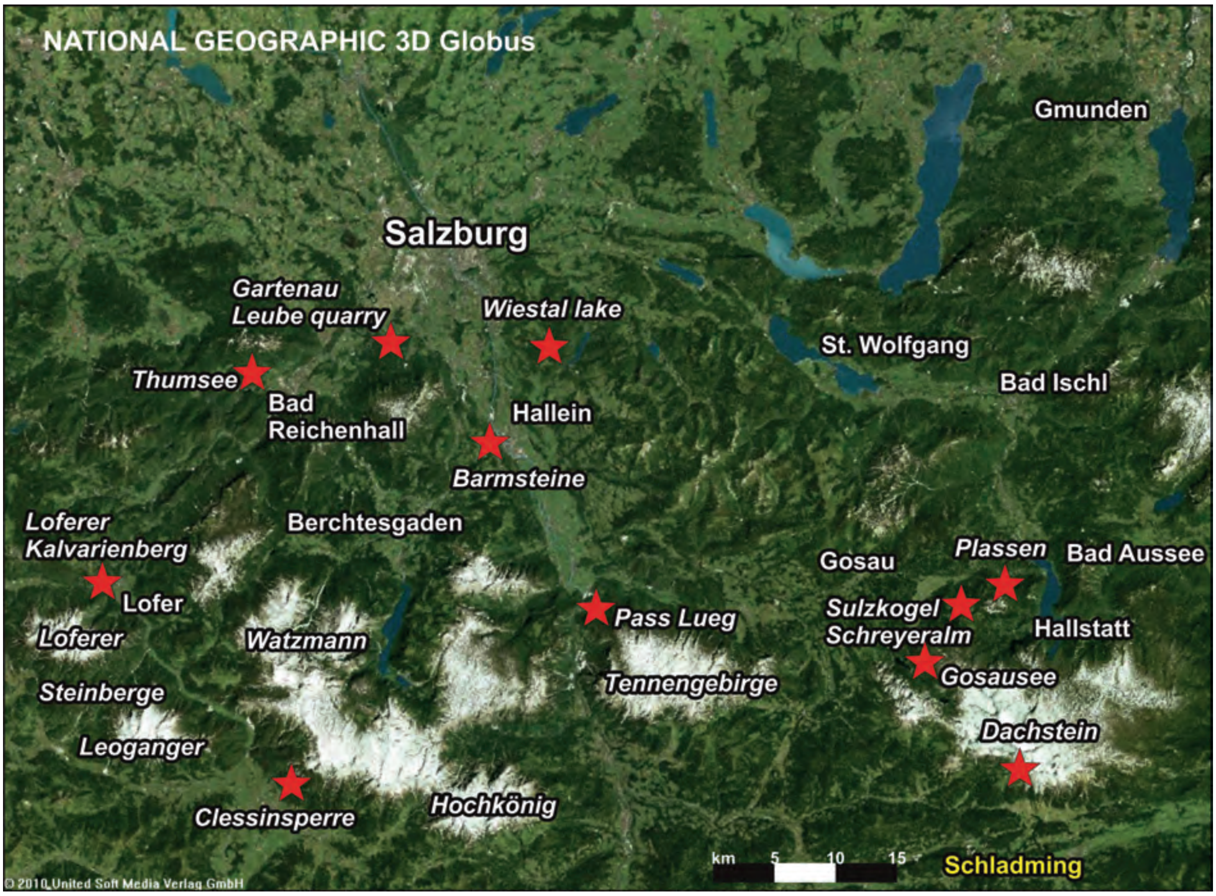

Figure 1: Satellite image of the central Northern Calcareous Alps, showing the localities which will be visited during this field trip (red stars). Sulzkogel/Schreyeralm and: Middle Anisian shallow-water carbonates, Late Anisian drowning. Clessinsperre: Early - Middle Anisian shallow-water carbonates, Late Anisian drowning, Late-Anisian to Late Ladinian deep-water sediments, Late Ladinian - Early Carnian Wetterstein Carbonate Platform. Thumsee and Wiestal lake: Norian Hauptdolomit. Dachstein and Pass Lueg: Norian Lofer cycles. Pass Lueg: Rhaetian Kössen Basin and Rhaetian lagoonal Dachstein Limestone. Gosausee: Late Norian/Rhaetian Dachstein reefal margin. Loferer Kalvarienberg: Lärchberg Carbonate Platform (Tithonian to ?Berriasian). Plassen: Plassen Carbonate Platform, reef and lagoon (Kimmeridgian - Tithonian). Mounts Barmsteine, Leube quarry: Late Tithonian - Berriasian resediments of the Plassen Carbonate Platform.

2 The Field Trip

To avoid confusion, the stop descriptions were sorted according to the different topics and not in strict chronological order according to the way of walking or driving.

2.1 Middle Triassic

Topics: Gutenstein and Steinalm carbonate ramp evolution (Early-Middle Anisian), Schreyeralm and Reifling Limestones (late Middle Anisian to Ladinian), Wetterstein Carbonate Platform (Late Ladinian to Early Carnian).

For a modern description of the Gutenstein and Steinalm Formations see LEIN et al. (2012). LEIN et al. (2012) discussed also the lithostratigraphic nomenclature of the Anisian, specially of the Gutenstein and Steinalm ramp evolution.

<u>Section Sulzkogel (Pelsonian)</u>

The section Sulzkogel is located southsoutheast of the township Gosau (central Salzkammergut area) west of Mount Plassen (Fig. 2).

On top the Early Anisian Gutenstein Formation a more open marine facies evolved linked to a continuing thinning of the continental crust (LEIN, 1987). The latter (Annaberg Formation) is characterized by bedded algal-rich limestones with shallow-water debris (Fig. 3) intercalated by hemipelagic influenced filament-bearing limestones with conodonts: e.g. *Nicoraella germanica, Nicoraella kockeli, Gondolella bulgarica*. Most probably the age of this level (Sulzkogel Member of the Annaberg Formation - LEIN et al., 2010) is early Pelsonian.

Upsection first thin bedded dolomites and later thick bedded dolomites and massive limestones of the Steinalm Formation occur. In this unit the microfacies characteristics is hardly visible due to intense dolomitization.

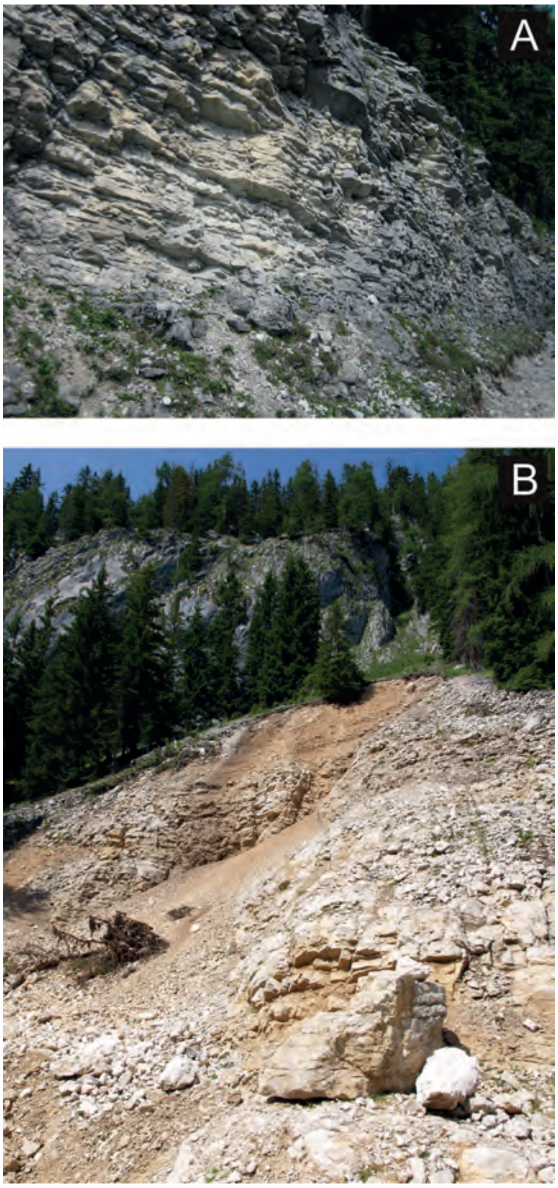

Figure 2: A) Bedded limestone succession of the Sulzkogel Member. B) The limestones of the Sulzkogel Member were first overlain by thin bedded dolomites and later by thick bedded dolomites of the Steinalm Formation.

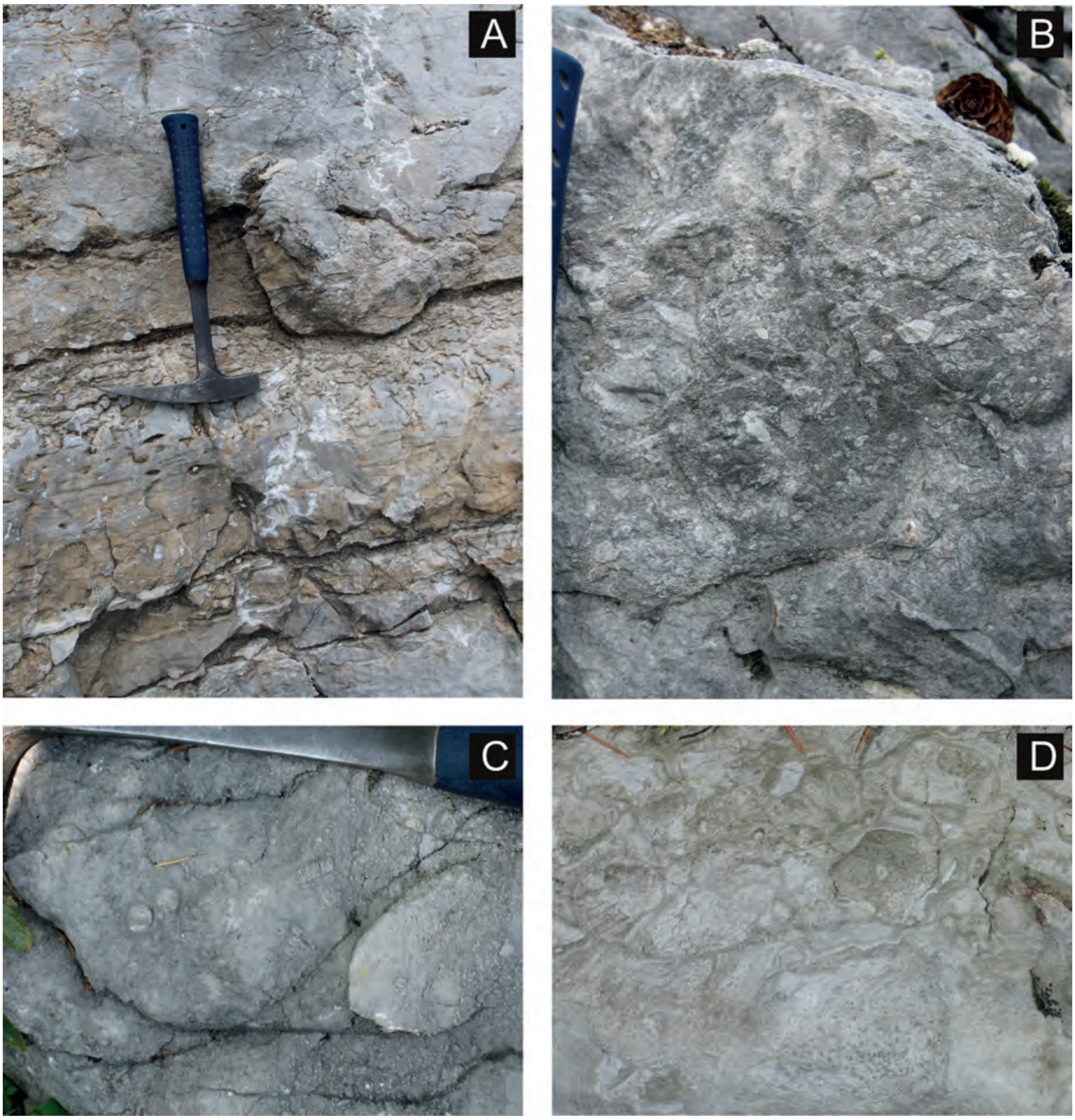

Figure 3: Lithological features of the coarse-grained bedded limestones with different shallow-water material (reworked microbial reefal framework) including calcareous algae.

Schreyeralm

Type-locality of the Schreyeralm Limestone.

The classical Schreyeralm section is located west of Mount Plassen north of the grassland area of the Schreyeralm. Red nodular limestones are exposed on the topmost part of the Steinalm Formation. The Schreyeralm Limestone represent the drowning sequence of the Steinalm carbonate ramp and is dated by ammonites and conodonts as Late Pelsonian (*binodosus*-Zone, e.g. ASSERETO, 1971; KRYSTYN & SCHÖLLNBERGER, 1972).
Both localities (Sulzkogel and Schreyeralm) combined show clearly, that the age of the Steinalm Formation (definition: PIA 1930; for algal-rich light coloured limestones) resp. the Steinalm carbonate ramp is restricted to the Pelsonian. These outcrops with the rich algal flora in the Steinalm Limestone in the area west of Mount Plassen provides for the first time the possibility to correlate the shallow-water fauna and flora with conodonts and cephalopods. The age of the Steinalm Formation can be restricted as Pelsonian.

Clessinsperre

Type-locality of the Steinalm Formation (PIA, 1930). Type-locality of several calcareous algae (OTT, 1972a, 1972b).

At the section Clessinsperre a continuous succession from the early Anisian Gutenstein Formation, deposited under restricted conditions, to the Ladinian - Early Carnian Wetterstein Carbonate Platform is exposed. The Steinalm Formation overlies the Gutenstein Formation directly. The Annaberg Formation is missing. The change from the restricted depositional environment of the Gutenstein Formation (dark grey micritic limestones with peloids and rare faunal elements, except few foraminifera) to the more open depositional environment of the lighter grey limestones of the Steinalm Formation is gradual. Also the floral and faunal content increases only slightly. The topmost part of the Steinalm Formation is characterized by in parts algal-rich beds with some filaments in the topmost part. These part of the succession (Fig. 4) is overlain by cherty limestones of the Reifling Formation (details in TOLLMANN 1976), dated by ammonites as *trinodosus*-Zone (early Illyrian). According to own investigations the uppermost part of the Steinalm Formation with the intercalations of the filament-bearing limestones contains Conodonts: e.g. *Gondolella bulgarica*, *Gondolella bifurcata*, and *Nicoraella.* sp. Therefore the drowning of the Steinalm ramp in the Clessinsperre section is contemporaneous with the drowning of the Schreyeralm section: Late Pelsonian.

Figure 4: Drowning unconformity: Late Anisian cherty limestones of the Reifling Formation on top of the Pelsonian Steinalm Formation. Section Clessinsperre.

The age of Reifling Formation is Late Anisian to Late Ladinian as dated by conodonts. In the Late Ladinian intercalations of volcanic ashes are characteristic. Upsection of these volcanic ash layers first shallow-water resediments of the prograding Wetterstein Carbonate Platform occur. Upsection we will see the here in this section dolomitized Wetterstein Carbonate Platform (Late Ladinian to Early Carnian). Due to intense dolomitization the microfacies characteristics of the Wetterstein Carbonate platform – typical are fore-reef carbonates, later reefal and back-reefal carbonates topped by lagoonal carbonates, are hardly visible. Dolomitization of the Wetterstein Carbonate Platform is a widespread phenomenon, especially in the Tirolic units of the Northern Calcareous Alps.

2.2 Late Triassic

Hauptdolomit (Norian), lagoonal Dachstein Limestone (Lofer cycles) (Norian-Rhaetian), reefal and fore-reefal Dachstein Limestone (Norian), Kössen Formation (Rhaetian): deep restricted lagoon.

The evolution of the Late Triassic (Norian-Rhaetian) Hauptdolomit-Dachstein Carbonate Platform is recently described in detail by RICHOZ et al. (2012) (compare ZANKL, 1971). For a detailed description of the different facies belts see also GAWLICK et al. (2012). The Hauptdolomit facies belt represents the restricted lagoonal environment of this platform, the lagoonal Dachstein Limestone represents the open lagoonal environment of the platform. The transition between these two facies belts is not preserved in the Northern Calcareous Alps.

Thumsee (Bad Reichenhall)

Hauptdolomit, rich in organic matter. Restricted lagoon. We will visit Hauptdolomit sections north of Bad Reichenhall (Thumsee). Here the Hauptdolomit is contemporaneous a source and a reservoir rock. Characteristic are beside the classical stromatolithes grainstone intercalations with foraminifera and algae (Fig. 5). The thickness of the Hauptdolomit in this area is around 1000 metres.

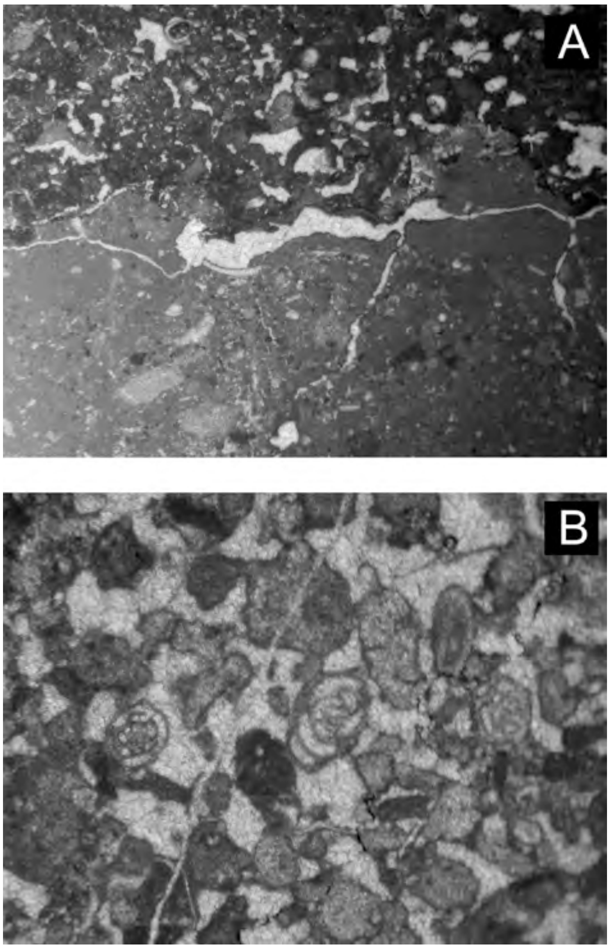

Figure 5: Microfacies characteristics of the Hauptdolomit around the Thumsee. A) Fenestral fabric made of microbial dolomite overlying a wackestone to packstone layer. B) Grainstone with e.g. foraminifera.

Wiestal lake (optional)

North of the Wiestal lake organic rich small scale basin intercalations in the Hauptdolomit are preserved (Fig. 6). The microfacies and the molecular indicators were recently investigated by BECHTEL et al. (2007).

Phytoplankton and photosynthetic bacteria are considered to be the major primary producers of the organic matter in these immature (~0.5% equivalent vitrinite reflectance), carbonate-rich rocks. Contributions from vascular plants are suggested from the n-alkane distribution pattern and high content of C_{29} steranes. Enhanced microbial activity in the depositional environment is proposed on the basis of the hopanoid content. The occurrence of aryl isoprenoids, probably derived from carotenoids of the photosynthetic green sulfur bacteria (Chlorobiaceae) indicates the presence of free H_2S in the bottom water. Mesohaline conditions in the upper part of the water column are deduced from the presence of dimethylated and trimethylated 2-methyl-2-(tridecylchromans) (MTTCs). Co-variation in the distribution of MTTCs and pristane/phytane ratio and the concentration of a C_{16} aryl isoprenoid argue for photic zone anoxia due to salinity stratification. The biomarker composition points to a high productivity marine environment with limited water exchange and a stratified water column confirmed by microfacies analysis.

Sedimentological and geochemical features provide evidence for the establishment of small-scale anoxic basins through erosion by currents or from the remnants of channels, which were possibly isolated periodically by small-scale sea level changes.

Figure 6: Wiestal lake section: the lower part of the section is characterized by dark-grey laminated and organic-rich dolomites. The upper part consists of “typical” light-grey Hauptdolomit.

Mount Dachstein (optional)

Type locality of the Norian lagoonal Dachstein limestone. The characteristic features of the lagoonal Dachstein Limestone were recently summarized by RICHOZ et al. (2012). This outcrop is optional and will be probably visited during the symposium Field trip.

The area around the Dachstein glacier provides excellent outcrops of the lagoonal Dachstein Limestone (Lofer cycles) (Fig. 7). Especially the Member C consists of different Pack- to Grainstone types with a rich fauna and flora, including microbial carbonates and calcareous algae.

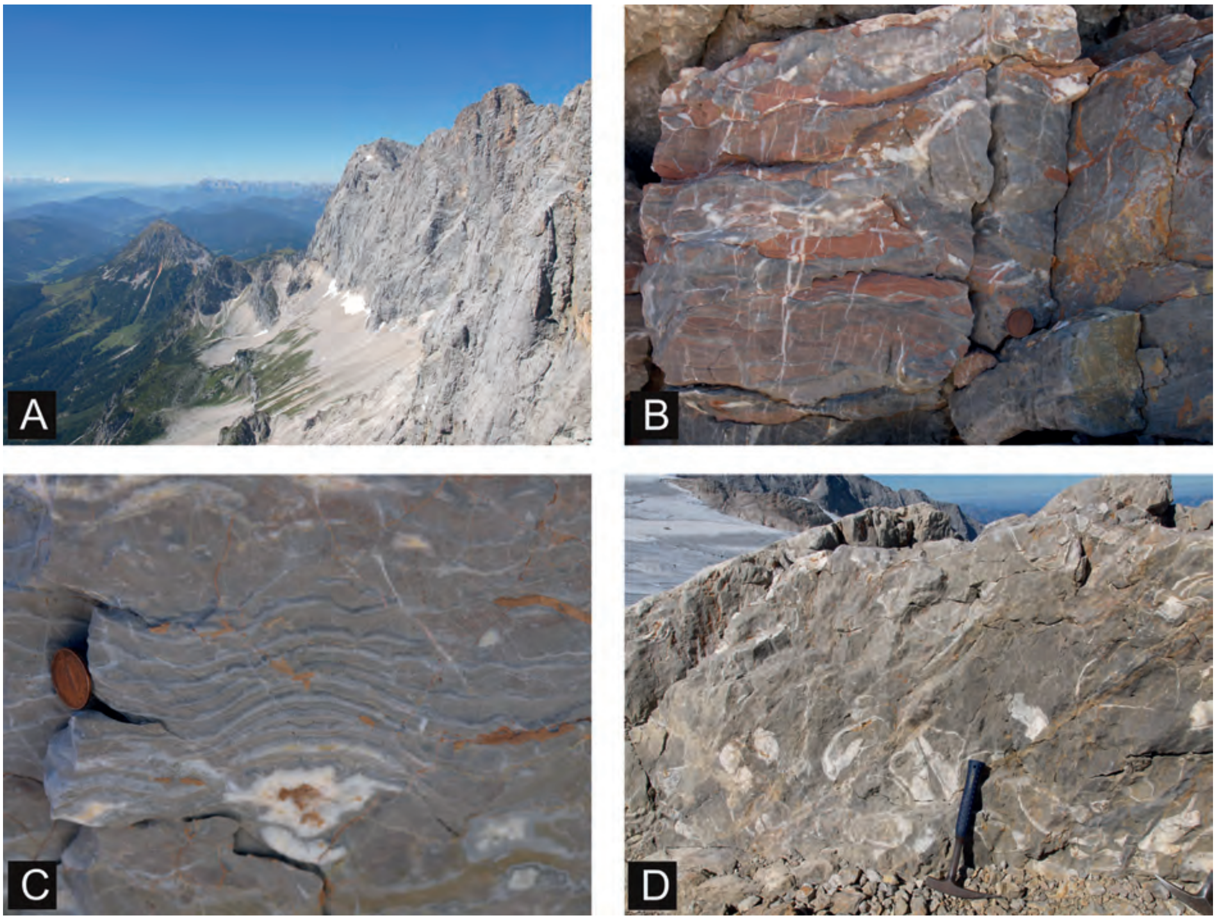

Figure 7: A) Southern Wall of the Dachstein massif with the bedded lagoonal Dachstein (Lofer cycles). Left: Mount Rettenstein (Kimmeridgian reef). B) Member A of the Lofer cycle sensu FISCHER (1964). C) Member B of the Lofer cycle sensu FISCHER (1964). C) Member C of the Lofer cycle sensu FISCHER (1964).

Pass Lueg (optional)

Norian lagoonal Dachstein Limestone, Rhaetian Kössen beds and Rhaetian lagoonal Dachstein Limestone.

This outcrop is described in detail in GAWLICK (2000), GAWLICK & MISSONI (2013), and RICHOZ et al. (2012). Around Pass Lueg a complete Late Norian to Jurassic sedimentary succession is preserved. The Late Norian is characterized by a Lofer cycle succession similar to that of Mount Dachstein. On top of the Norian Dachstein Limestone a siliciclastic input led to the deposition of a marly sequence (Early Rhaetian). Upsection the carbonate increases rapidly and a 1-2 metre-thick succession of marly limestones with corals (“Lithodendron Limestone”) represents the most important lithofacies marker of the Kössen Basin. Whereas near the southern rim of this basin (this outcrop) this level is overlain by shallow-water lagoonal Dachstein Limestone this level marks in the central basin a deepening below the wave base (GOLEBIOWSKI, 1990, 1991; RICHOZ et al., 2012) and a transition phase between a deep, open marine lagoon and the intraplatform basin deposition milieu of the Eiberg Member.

The lagoonal Rhaetian Dachstein Limestone consists mainly of pack- to grainstones with rare megalodons and few corals, The Members A and B of the classical Lofer cycle are widespread missing.

Typical for this outcrop is *Coptocampylodon*? *rhaeticus* SCHLAGINTWEIT, MISSONI & GAWLICK. The type locality of *Coptocampylodon*? *rhaeticus* is located 3 kilometres west of Pass Lueg on Mount Kehlstein.

Gosau lake (optional)

Dachstein reef margin (Late Norian to Early Rhaetian).

This outcrop respectively the transect is described by RICHOZ et al. (2012). The succession around Gosausee (lake) provides insights in an intact microbial-sponge-coral barrier reef. We will visit the fore-slope facies as well as the reefal framework along and northeast of the Gosaussee, following the excursion route described by RICHOZ et al. (2012). This outcrop is optional and will be probably visited during the symposium Field trip.

2.3 Late Jurassic to Early Cretaceous

Plassen Carbonate Platform evolution (Late Oxfordian to Berriasian).

In the Early and Middle Jurassic no shallow-water carbonates were deposited in the northwestern Neotethyan realm. After the drowning of the Hauptdolomit/Dachstein Carbonate Platform red nodular or grey cherty limestones are the characteristic sediments in this realm.

After the Middle Jurassic to Oxfordian orogenesis a new shallow-water cycle starts in the latest Oxfordian (AUER et al., 2009). Since that time the Plassen Carbonate Platform, which consists of several - at least three- independent platforms evolved on the rising nappe fronts (for details see GAWLICK et al., 2009, 2012). These platforms differ in parts in their geometries, sedimentological evolution, subsidence history and faunal and floral content. As a consequence of this, the distribution of e.g. dasycladalean algae within the Plassen Carbonate Platform is not homogenous but shows several peculiarities (details in SCHLAGINTWEIT, 2011).

Mount Plassen

Plassen Carbonate Platform *s. str.* Slope and platform facies (Kimmeridgian), open and closed lagoon (Tithonian).

Mount Plassen is the type-locality of several species descriptions (“stromatoporids”, gastropods, foraminifera, coproliths, chaetitide) (details in SCHLAGINTWEIT et al., 2005). The different facies belts preserved on Mount Plassen provide an opportunity to visit the maximum a faunal and floral inventory of the whole Plassen Carbonate Platform evolution (GAWLICK & SCHLAGINTWEIT, 2006).

We will visit the southwestern respectively the southern wall of Mount Plassen where the complete Kimmeridgian to Tithonian sequence is preserved (Fig. 8). The stratigraphically oldest part of the sequence consists of Kimmeridgian slope to reefal sediments, followed by Tithonian open and closed lagoonal limestones.

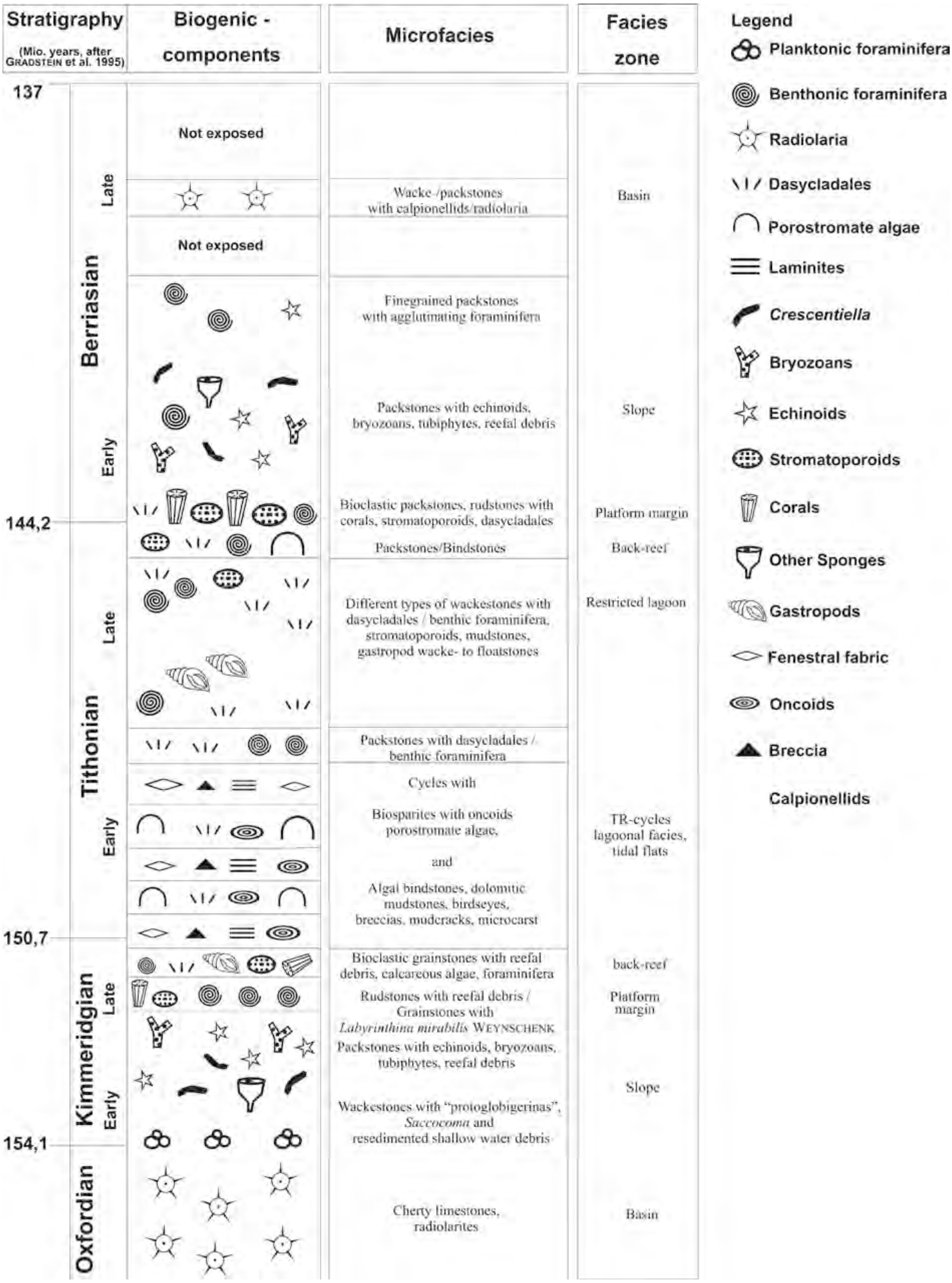

Figure 8: Sedimentary sequence of the Mount Plassen area (Oxfordian to Berriasian) after GAWLICK & SCHLAGINTWEIT (2006).

Loferer Kalvarienberg

Lärchberg Carbonate Platform. Tithonian to ?earliest Berriasian shallowing-upward cycle with final emersion.

As outstanding characteristic of the Lärchberg Carbonate Platform, in contrast to the Plassen Carbonate Platform *s. str.*, an overall terrigenous input can be stated. This and the occurrence of brackish-water influence in the latest platform stadium, pointing to a final emersion, are assumed as reasons for the discrete inventory of dasycladalean algae including 10 taxa not known from the Plassen Carbonate Platform *s. str.* (SCHLAGINTWEIT, 2011). A characteristic larger benthic foraminifer of the final series exhibiting increasing terrigeneous influx is represented by *Anchispirocyclina lusitanica* (EGGER). This foraminifer was already recognized by HAHN (1910) who described and illustrated the foraminifer as "Hydrocorallinen (?)stöckchen", meaning a stromatoporoid sponge. These strata are referred to as Lofer Beds, originally believed to represent basal, transgressive clastics sediments. In contrast, nowadays this succession is interpreted as deposit of a final coarsening- and shallowing-upward phase that finally led to platform emersion.

Mounts Barmsteine

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

Detailed description of the type locality in GAWLICK et al. (2005). The Barmstein Limestones (Fig. 9) represent various single mass-flow deposits, each with little varying component spectrum. These flows, partly containing clasts of radiolarites or *Saccocoma* Limestone probably deriving from the channel flanks, show minor variations only with respect to grain size and component spectrum. No other – older – clasts as Triassic Hallstatt Limestone clasts or clasts of the Permian Alpine Haselgebirge mélange were found at the type locality. 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 are discussed (GAWLICK et al., 2005, 2009).

Figure 9: The Barmstein Limestone type-locality west of the township Hallein.

Gartenau: old Leube quarry

Barmstein Limestone with exotic clasts of the Permian Alpine Haselgebirge mélange (Late Tithonian)

In the old Leube quarry a series of coarse-grained Barmstein Limestones with components from the Plassen Carbonate Platform *s. str.* and the Alpine Haselgebirge melange and intercalated wackestones with radiolarians and Calpionellids will be visited (details in GAWLICK et al., 2005; Fig. 10)). The age of the series is Late Tithonian. This type of Barmstein Limestone represents the second type of Barmstein Limestones indicating a tectonic event in the Late Tithonian.

Figure 10: Mass-flow deposit (Barmstein Limestone) with shallow-water clasts from the Plassen Carbonate Platform *s. str.* and the Permian Alpine Haselgebirge mélange.

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