Zitteliana

An International Journal of Palaeontology and Geobiology

Series B/Reihe B
Abhandlungen der Bayerischen Staatssammlung für Paläontologie und Geologie

26

4th International Symposium on Lithographic Limestone and Plattenkalk

Eichstätt/Solnhofen, Germany

September 12th-18th, 2005

- Abstracts and Field Trip Guides -

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– Abstracts and Field Trip Guides –

Zitteliana	B 26	96 Seiten	München, 05.09.2005	ISSN 1612-4138

Editors-in-Chief/Herausgeber: Reinhold R. Leinfelder, Michael Krings
Volume Editor: Winfried Werner
Production and Layout/Bildbearbeitung und Layout:
Stefanie Klug

Bayerische Staatssammlung für Paläontologie und Geologie
Richard-Wagner-Str. 10, D-80333 München, Deutschland
http://www.palaeo.de/zitteliana
email: zitteliana@lrz.uni-muenchen.de

ISSN 1612-4138
Druck: Gebr. Geiselberger GmbH, Altötting

Published with the support of the
Deutsche Forschungsgemeinschaft (DFG)

Cover illustration: *Mesolimulus walchi* Desmarest; horse-shoe crab with its trail; Lower Tithonian, Solnhofen (BSPG AS I 944).

Umschlagbild: *Mesolimulus walchi* Desmarest; Pfeilschwanzkrebs mit Fährte; Lower Tithonian, Solnhofen (BSPG AS I 944).

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Zitteliana **B26**	43-56	4th Int. Symp. Lithogr. Limestone	München, 05.09.2005	ISSN 1612-4138

Field Trip A

Basin-Platform Transitions in Upper Jurassic Limestones and Dolomites of the Northern Franconian Alb (Germany)

September 12th, 2005

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1. Introduction

Facies analysis within the last ten years in the Upper Jurassic of the Northern Franconian Alb (Hornung & Koch 2004, Koch et al. 2003, Pfeifenberger 2004, Tarasconi 1996, Wagner 2002, Weiss 2003) showed that the new depositional model of Upper Jurassic limestone in South-Germany (Koch et al. 1994) can also be applied for the dolomites of the Northern Franconian Alb. Regardless the intensive dolomitization of the "Frankendolomit", which generally results in a fine to coarse-crystalline fabric, some relic textures of former limestone, relics of microfossils, relative size of dolomite crystals as well as geochemical and mineralogical parameters can be used for facies analysis.

Moreover, even transitions from bedded limestones to dolomites with sponge buildups and also bedded dolomites can be found which allow the interpretations of a paleorelief. This sedimentary ramp situations within the transitional zones can be reconstructed revealing facies zonation from slightly deeper to more shallow water.

The topic of this excursion is to demonstrate most spectacular outcrops between the Trubachtal and the quarry of Bernhof of the Prüschenk Company in which these features can be recognized and a paleogeographic model within a small area of about 4 km^2 can be established.

2. The Upper Jurassic (Malm; White Jurassic): General Remarks

During the Lower and Middle Jurassic the Vindelician Land separated the shallow marine Jurassic sea in the North from the Tethys in the South. With the beginning of the Upper Jurassic the Vindelician Land was flooded and a shallow epicontinental sea established on the South German Plate, bordered to the North by the London Brabant Massif and the Rhenish Massif and to the East by the Bohemian Massif (Fig. 1).

Marked changes in lithofacies can be recognized above the biostratigraphic Callovian/Oxfordian boundary. Dark colored sediments of the Lower (black) and Middle Jurassic (brown) are overlain by light-colored, white and grey limestone and marls of the Upper Jurassic. They have a thickness of up to 500 m in the subsurface of the Molasse basin (Meyer & Schmidt-Kaler 1990).

The Molasse basin extends from the southern border of the Jurassic outcrops to the northern Alpine chains and is filled with Tertiary sediments underlain by Jurassic and Cretaceous sediments at various depths increasing from North to South (Fig. 2).

According to the former geologic/sedimentologic interpretation two characteristic lithofacies types are developed in the Upper Jurassic epicontinental sea of Central Europe. (1) The dominant, so-called "normal facies" composed of well-bedded limestones and marls with the representative ammonite succession, and (2) the so-called "reef facies" of buildups formed by sponges and microbial crusts (algal-sponge reefs) and in younger beds locally also by corals. The main development and largest extension of the "reef facies" occurred in the upper part of the Middle Kimmeridgian.

The most complete series of Upper Jurassic sediments are known only from Southern Franconia (Fig. 3). In the Northern and Central Franconian Alb sediments younger than the uppermost Kimmeridgian – lowermost Tithonian are unknown. They were probably eroded during the Early Cretaceous, if they were present at all.

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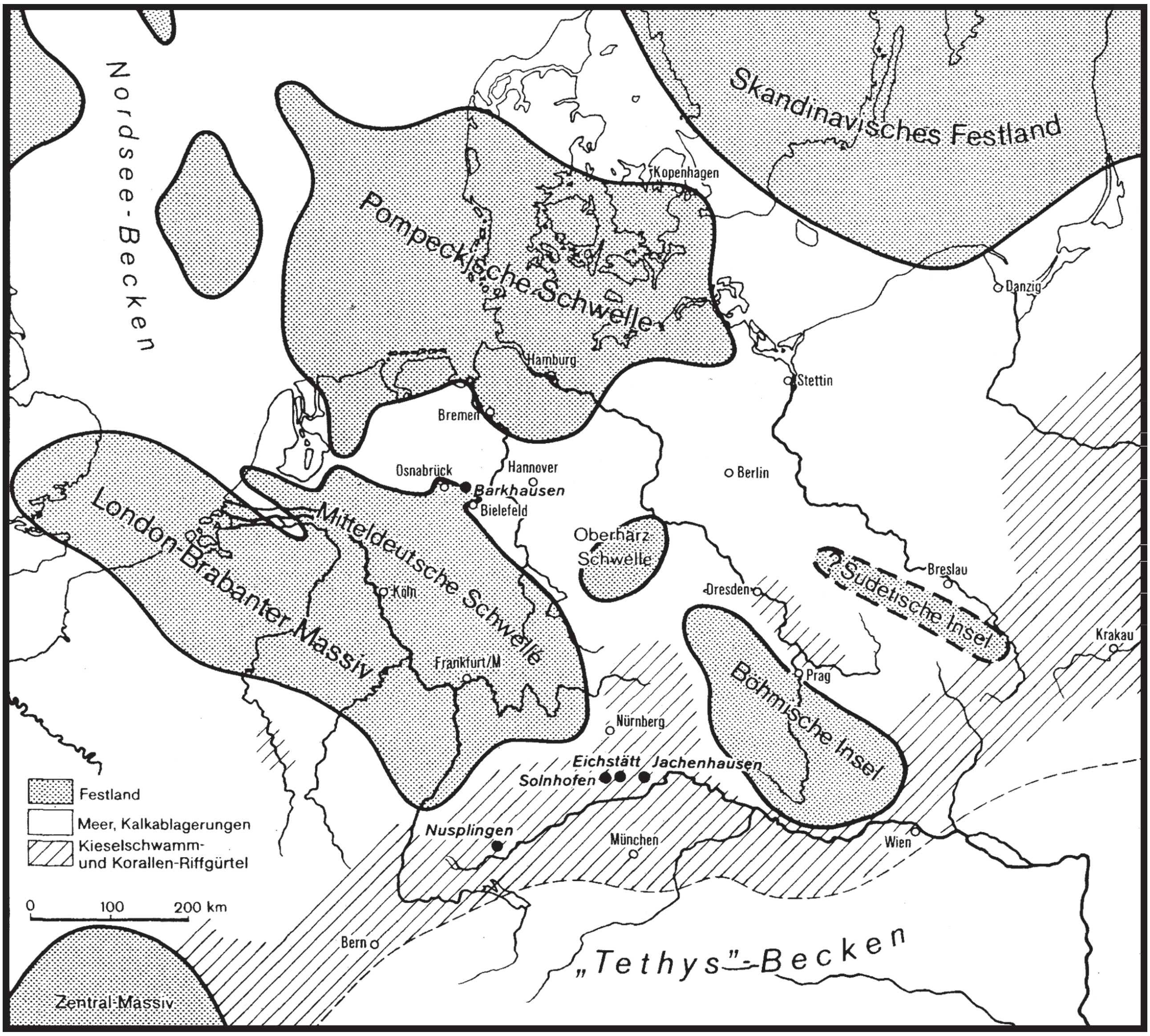

Figure 1: Distribution of land and sea in the Upper Jurassic and the position of the shallow epicontinental sea north of the Tethys (from MEYER & SCHMIDT-KALER 1992) indicating the distribution of siliceous sponges and corals.

3. Facies development from the Oxfordian to the Tithonian in the Franconian Alb

The Franconian Facies represents the northeastern part of the epicontinental sea. According to former models (MEYER & SCHMIDT-KALER 1983), "sponge-reef-barriers" (Figs. 3 and 4) separate it from the more marly Swabian facies in the West and allow also a subdivision in a Southern, Middle and Northern Franconian Alb.

The so-called Ries-Wiesent Barrier was thought to have a great influence on the sedimentation within the southeastern adjacent areas. According to MEYER & SCHMIDT-KALER (1992) this reef-barrier has hindered the clay suspension to be transported on the adjacent platform. Therefore limestones were deposited "behind" the reef whereas marls and limestones were deposited in front of the reef in the basin of Ebermannstadt. This basin is located west of the reef-swell and belongs to the marly Swabian facies development in general (Figs. 3 and 4).

In contrast, latest analysis in the Northern Franconian Alb indicates that these reef swells (barriers; Fig. 5) are not present and can be better interpreted as ramp situations (HORNUNG & KOCH 2004, KOCH 1997, KOCH et al. 1994, KOCH et al. 2003, TARSCONI 1996, WAGNER 2002, WEISS 2003).

The biostratigraphic subdivision of the Upper Jurassic beds in the Northern Franconian Alb is still today very problematic. Generally a combined biostratigraphy (with ammonites) and lithostratigraphy is used. Good results are obtained if ammonite-bearing, well-bedded limestones occur or if the stromatometric method can be applied, as in the beds of the Oxfordian and Lower Kimmeridgian. But if the carbonate rocks are completely dolomitized ("Frankendolomit") great problems arise because the formation of crystalline dolomite has destroyed the fossils necessary for biostratigraphy. This problem will also be a topic of our excursion and discussed in special outcrops.

Another problem arise from the different names used for the stratigraphic description of the Upper Jurassic beds in the

Swabian and in the Franconian Alb (White Jurassic, Malm) and their transformation into the international chronostratigraphy (Oxfordian, Kimmeridgian, Tithonian).

As a base for discussion in the recent paper the stratigraphic subdivision is used as presented by MEYER & SCHMIDT-KALER (1992). The most important ammonites for a biostratigraphic subdivision are documented in Fig. 6.

Furthermore, varying local names for the different lithological/stratigraphical units are used according to the geological maps constructed by DORN (1958; sheet 6333 Gräfenberg) and by GOETZE (1975, sheet 6334 Betzenstein) reflecting intensive lateral and vertical facies interfingering.

Generally the Upper Jurassic is subdivided in the Oxfordian (Malm Alpha and Beta), the Kimmeridgian (Lower Kimmeridgian; Malm Gamma, ki1; Middle Kimmeridgian, Malm Delta, ki2; and Upper Kimmeridgian, Malm Epsilon, ki3), and the Tithonian (Malm Zeta 1-6) as documented in Figs. 4 and 6. Biostratigraphic problems which arise due to intensive vertical and lateral facies changes will be discussed in outcrops exhibiting the important beds and features.

A lowermost Oxfordian age (Mariae and Cordatum Zones) has been established for the uppermost part of the dark, sandy marls overlying the Ornatenton (ZEISS 1962) of just 0.2-1.2 m thickness. These sediments have been preserved only in limited areas in the Northern and Central Franconian Alb, and only locally both biozones are present (Fig. 6).

The middle and upper Oxfordian sediments are composed of the "Weißjura (Malm) Alpha and Beta". The boundary between these two lithostratigraphic units is not equally descernible as in Swabia. To solve stratigraphic problems when correlating the three Franconian areas, the "stromatometric method" (FREYBERG 1966) was applied. With the supplementary control of bed-by-bed collection of ammonites and foraminifers good results were obtained.

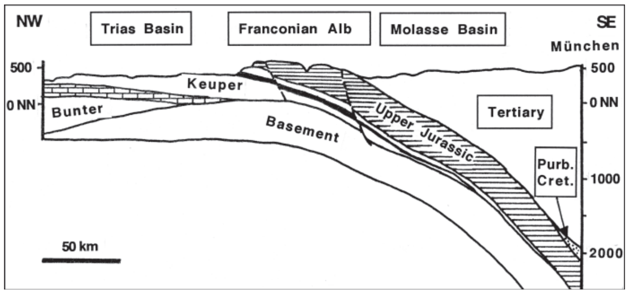

Figure 2: N-S section through the Swabian Alb with the "Albtrauf", the Molasse basin with Tertiary sediments to the Northern Alpine chains (after MEYER & SCHMIDT-KALER 1983). Upper Jurassic carbonate rocks occur in depth of more than 3000 m under the Alps.

The "stromatometry" was first used in the Southern Franconian Alb where the most complete sequence is developed (50-60 m). All beds were numbered bed-by-bed. By measuring their thickness in each quarry they can be correlated over a distance of more than 60 km (beginning with the bed no. S-79).

Moreover, a correlation of the upper part of the sequence ("*Planula* Beds") with profiles of the Malm Beta (= Wohlgeschichtete Kalke) in Swabia was provided by MEYER &

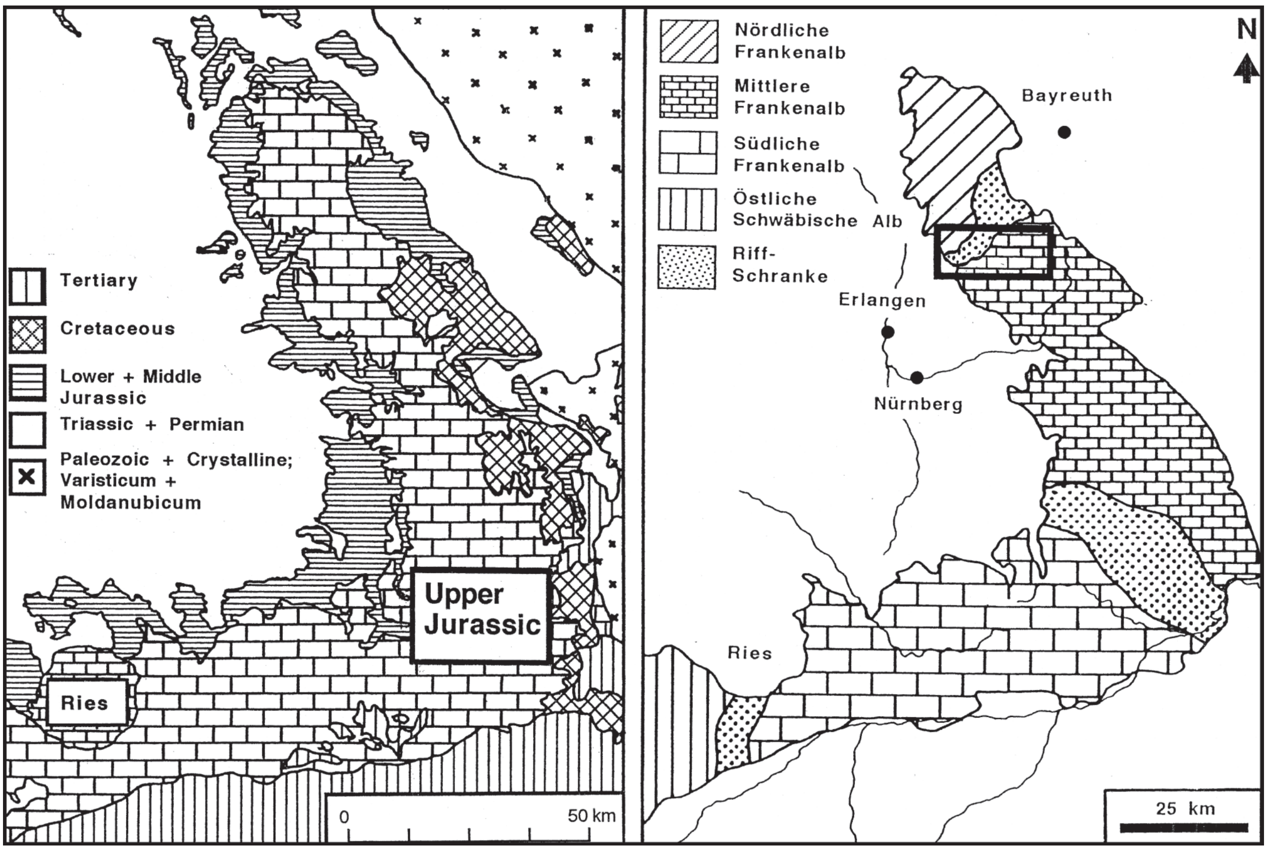

Figure 3a + b: (a) Simplified geological map of the pre-Quarternary sediments of the Franconian Alb and adjacent areas (after ZEISS 1977). (b) Main facies areas of the Upper Jurassic of the Franconian Alb. The area of the excursion is indicated in the rectangle.

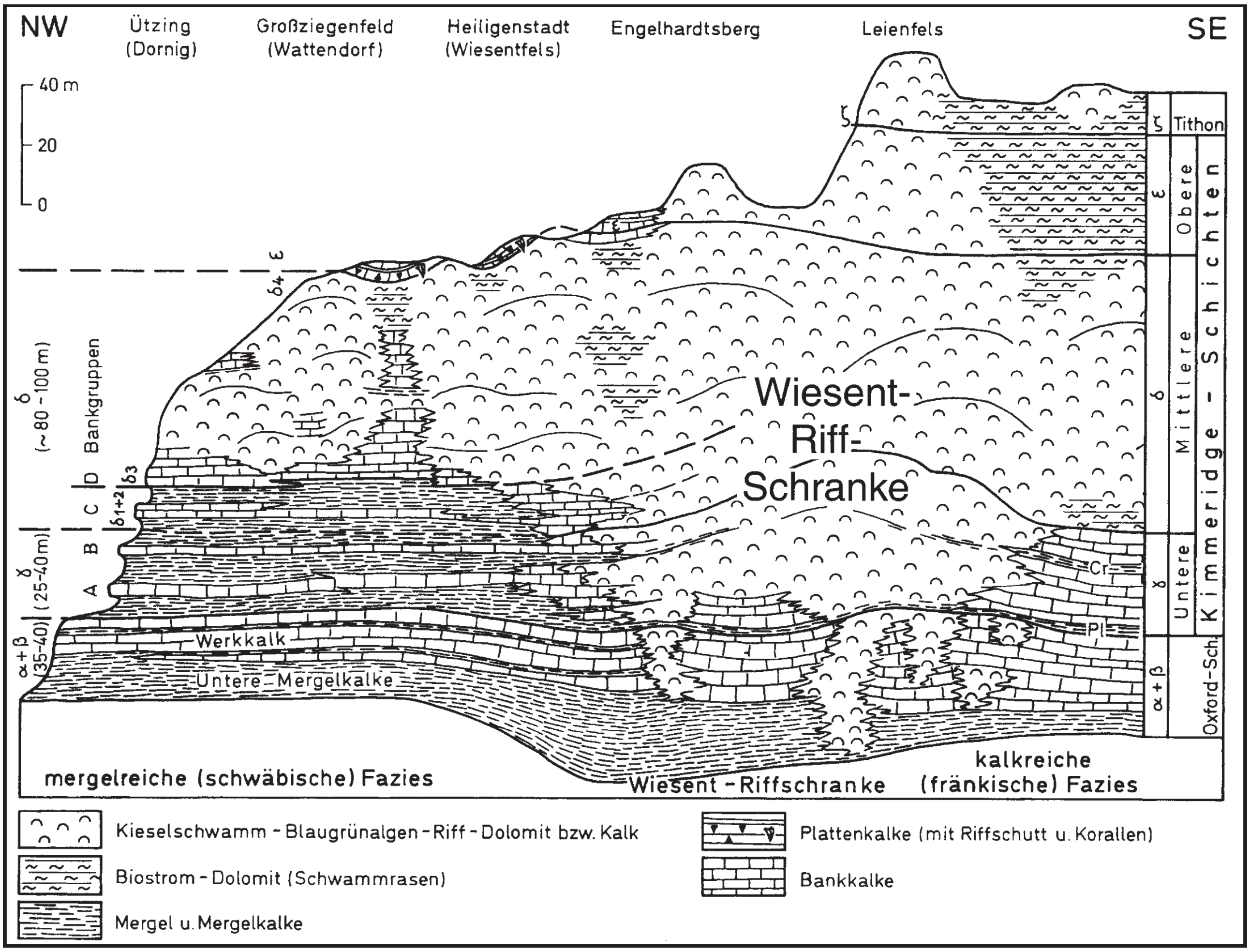

Figure 4: Facies scheme of the Northern Franconian Alb (after Meyer & Schmidt-Kaler 1992 and Mäuser et al. 2002) used in the last 40 years. The Wiesent-Reef barrier separates the sea floor in a more marly area (NW; Swabian Facies) and a carbonate platform in the SE (Franconian Facies). This reef barrier is especially effective in the Malm Alpha and Gamma/Lower Delta. Sponge reefs intensively develop during the Upper Malm Delta forming a reef platform expanded nearly over the complete area.

Schmidt-Kaler (1992). Nevertheless, great variations in thickness (25-40 m) hamper a correlation of the lower and middle part of the Oxfordian in the Southern, Middle, and Northern Franconian Alb. Only the upper part of the sequence (with *Idoceras planula*) can be well correlated. The most complete section is the type section of the "Feuerstein Bankfolge" (Freyberg 1966) near Ebermannstadt. This section corresponds to the Bimammatum-Galar subzones. The first occurrence of *Idoceras planula* in the bed F-88 marks the Malm Alpha/Beta boundary. A separate numerical system was established in the northern part of the basin due to reduced thickness (Hegenberger & Schirmer 1967).

The Lower Kimmeridgian (ki1) of the Northern Franconian Alb is composed of a marly facies which approximately corresponds to the Weißjura Gamma (= Lacunosamergel Formation) of the Swabian Alb. The biostratigraphy exhibits no great differences to the Middle and Southern Franconian Alb. Local biostratigraphic subdivisions were published by Hegenberger & Schirmer (1967), Meyer (1972, 1979), and Zeiss (1964). Schneid (1939, 1940, 1944) published descriptions of ammonites and Munk (1980) and Winter (1970) details of the microfauna.

The Middle Kimmeridgian (ki2) corresponds to the Weißjura Delta and the Treuchtlingen Formation in the Southern Franconian Alb which are according to Meyer (1975) characterized by thick and well-bedded sponge biostromes with abundant *Tubiphytes*. Moreover, the formation of reef-like structures is assumed to be due to an enhanced growth of sponges (Streim 1961, Schmidt-Kaler 1962, Zeiss 1964, Freyberg 1964, Meyer 1977). Furthermore, it is assumed that the biostrome limestones of the Treuchtlingen Formation are mainly influenced by surrounding reefs. In the Northern Franconian Alb only in the uppermost part of the Middle Kimmeridgian the whole area was covered by biostrome limestones and sponge bioherms which are often partly or even completely dolomitized (Meyer 1974).

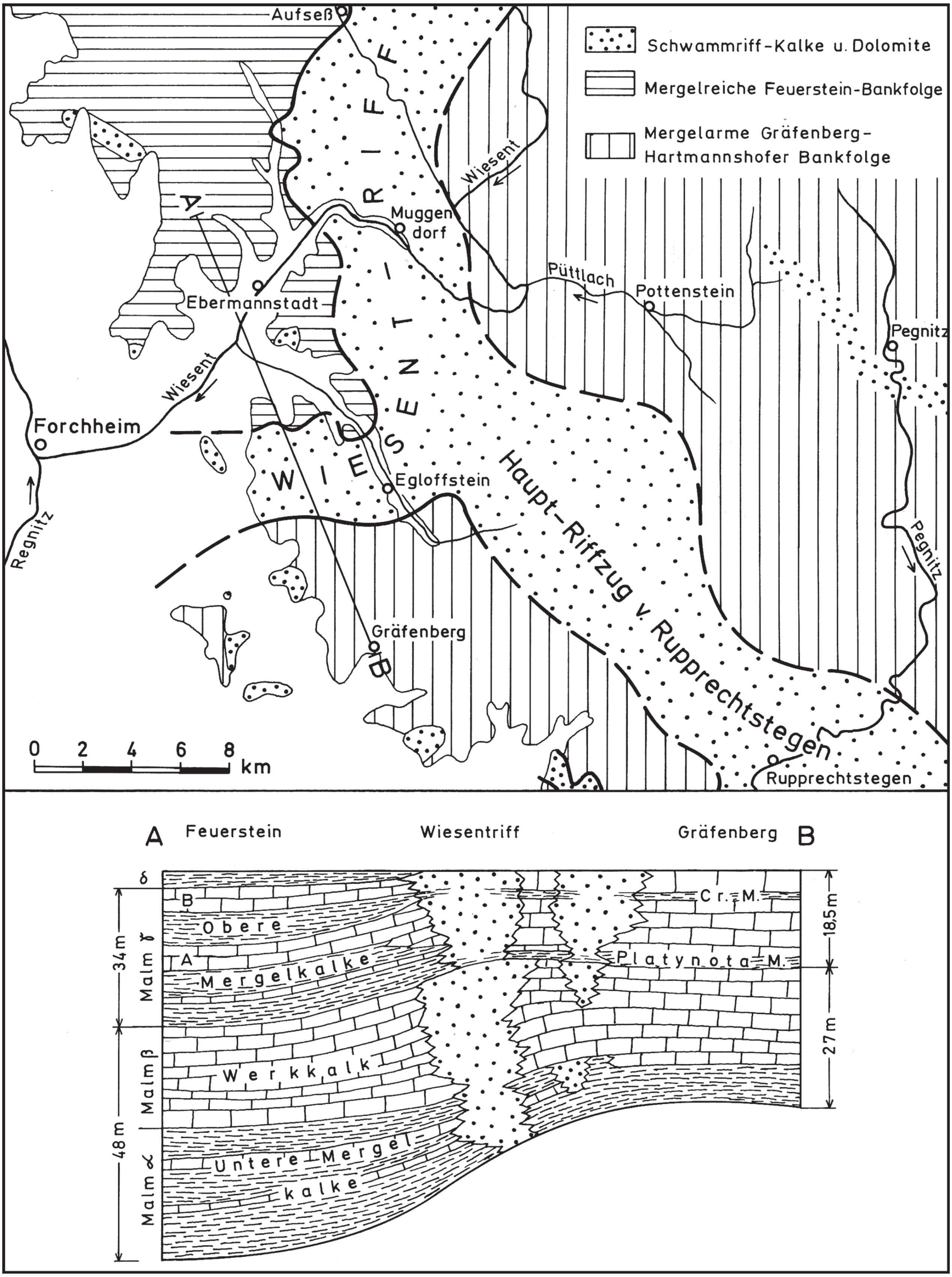

Figure 5: Cross section from west of the more marly Swabian Facies over the Wiesent-Reef Barrier into the more calcareous facies of the Northern Franconian Alb (after MEYER & SCHMIDT-KALER (1992).

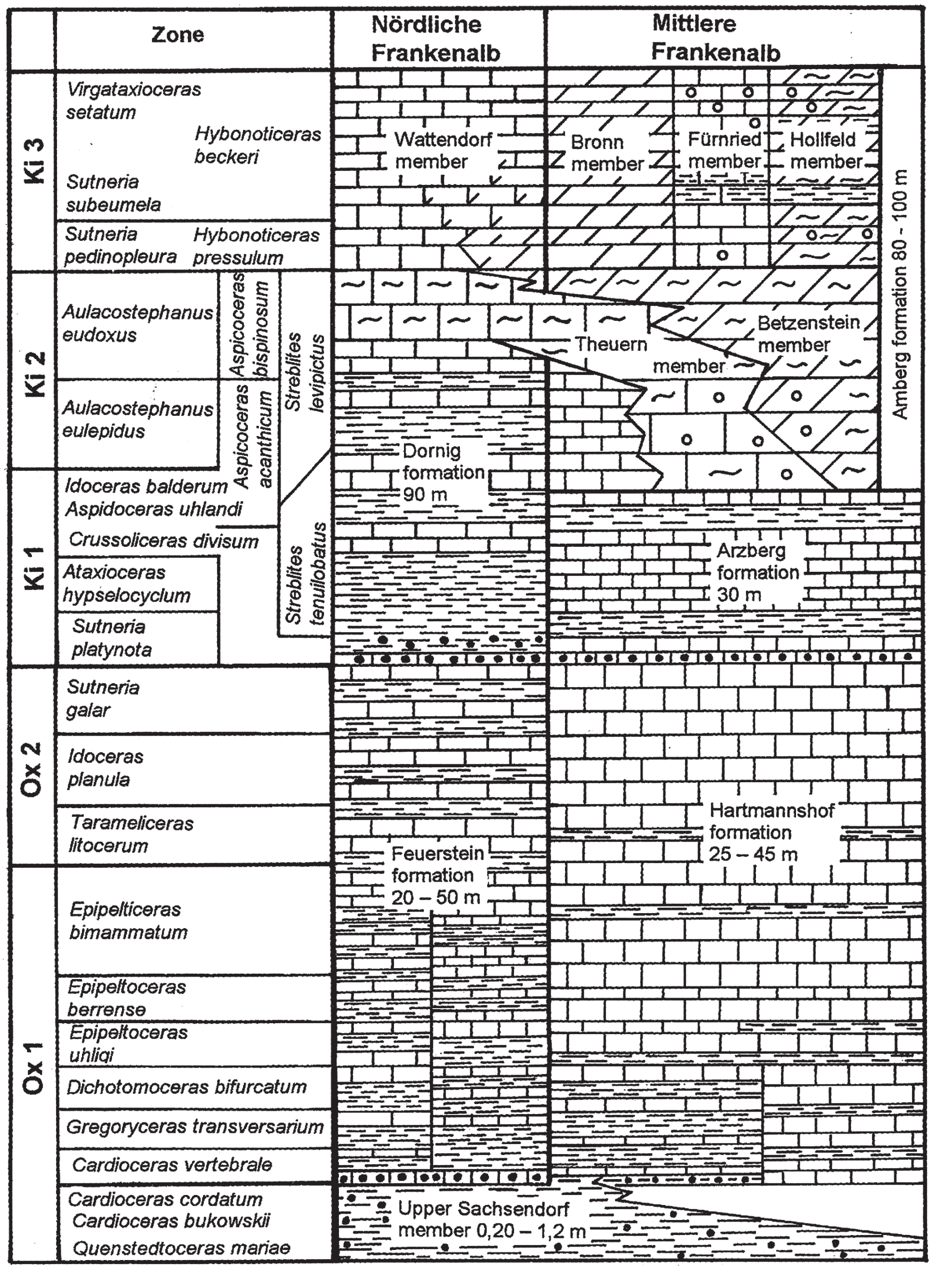

Figure 6: Biostratigraphic subdivision of the Oxfordian and Kimmeridgian, important ammonites, and facies differentiation in the Northern and Middle Franconian Alb (ZEISS 1966). The subdivisions of the lithologic columns in the Oxfordian indicate the different facies developments in the northern and southern part of the Northern Franconian Alb and of the western and eastern areas in the Middle Franconian Alb.

The Upper Kimmeridgian (ki 3) corresponds to the Weißjura Epsilon and occurs in varying amounts in the Northern and Southern Franconian Alb. Generally, a facies differentiation is absent above the Middle Kimmeridgian beds. Sediments of the Upper Kimmeridgian are interpreted to begin as basin fills ("Wannen Füllungen") between reef-complexes of different size. Thin-bedded limestones which develop to sublithographic limestones in the upper part of the sequence are deposited above reefs or recifal sediments and are interpreted to be surrounded by reefs (FESEFELD 1962, EDLINGER 1964).

The "Torleite Formation" is the type section in the Southern Franconian Alb. Within larger reef complexes of the Middle and Northern Franconian Alb only small basins of bedded, micritic limestones and dolomites exist. Fine-grained, thin-bedded dolomites occur in the NW between the villages of Betzenstein and Bronn (Figs. 4 and 5). In parts of the sequence which are not dolomitized microfossils indicate a probable Early Tithonian age. Generally only very small fossils occur in the lower part of the sequence probably indicating an Upper Kimmeridgian age. The Upper Kimmeridgian is characterized by the biozones of *Sutneria pedinopleura* or *Hybonoticeras pressulum*, *Sutneria subeumela*, and *Virgataxioceras setatum* which comprise the *Hybonoticeras beckeri* Zone (SCHNEID 1914, BERCKHEMER & HÖLDER 1959, FAY 1976, MEYER 1972, 1974).

These sediments are the main topic of debate. Marked outcrops will be visited during the excursion and facies interfingering, diagenesis and biostratigraphy discussed in detail. Opposite to large scale geological models it will be shown that small scale lateral and vertical facies development can be interpreted in different ways, taking into account that local outcrops just give a very punctual, local information on the sedimentologic development within a given time level. Furthermore, new data will be presented in chapters dealing with special outcrops in order to focus the discussion on the base of examples visited.

4. New data on the development of "sponge-reefs"

The massive limestones of the Malm Delta and Epsilon, formerly interpreted as sponge reefs, consist predominantly of thick-bedded pure limestones. They are rich in allochems (packstone and grainstones according to Dunham 1962) and generally characterized by the widespread development of peloid-lithoclast-ooid-sands. This was shown by detailed analysis of about 1500 hand specimens and 500 thin sections in the Swabian Alb (Koch et al. 1994).

Isopacheous cement seams reflect primary interparticle porosity (classification according to Choquette & Pray 1970) which was partly closed by marine phreatic cements and often completely closed by subsequent granular cements of different origin. The primary interparticle porosity and the presence of isopacheous cement seams suggests winnowing and therefore a moderate to elevated water energy level is assumed for the deposition of these carbonate sands. Sponge-rich areas occur at various locations in relation to the carbonate sand bodies.

In general, the following four main facies types can be recognized within and associated to the massive limestones according to Koch et al. (1994). They occur in varying amounts and spatial distribution (Fig. 7).

Peloid-lithoclast-ooid-sands are volumetrically the most important facies type of the massive facies. The layered sands are locally fixed by microbial crusts, which were probably formed in times of reduced or no sedimentation. The sand facies laterally changes into micritic and/or marly sediments of the bedded facies ("normal facies"), which was deposited in slightly deeper, lower energy environments (basins) between extensive sand areas.

Sponge-algal mud mounds of different sizes (meters to tens of meters) occur within the sand facies, commonly forming lenticular bodies. They are characterized by large saucer-shaped sponges (up to 1 m in diameter) floating in a white, dense micrite. Locally, the sediment is fixed by thin microbial crusts.

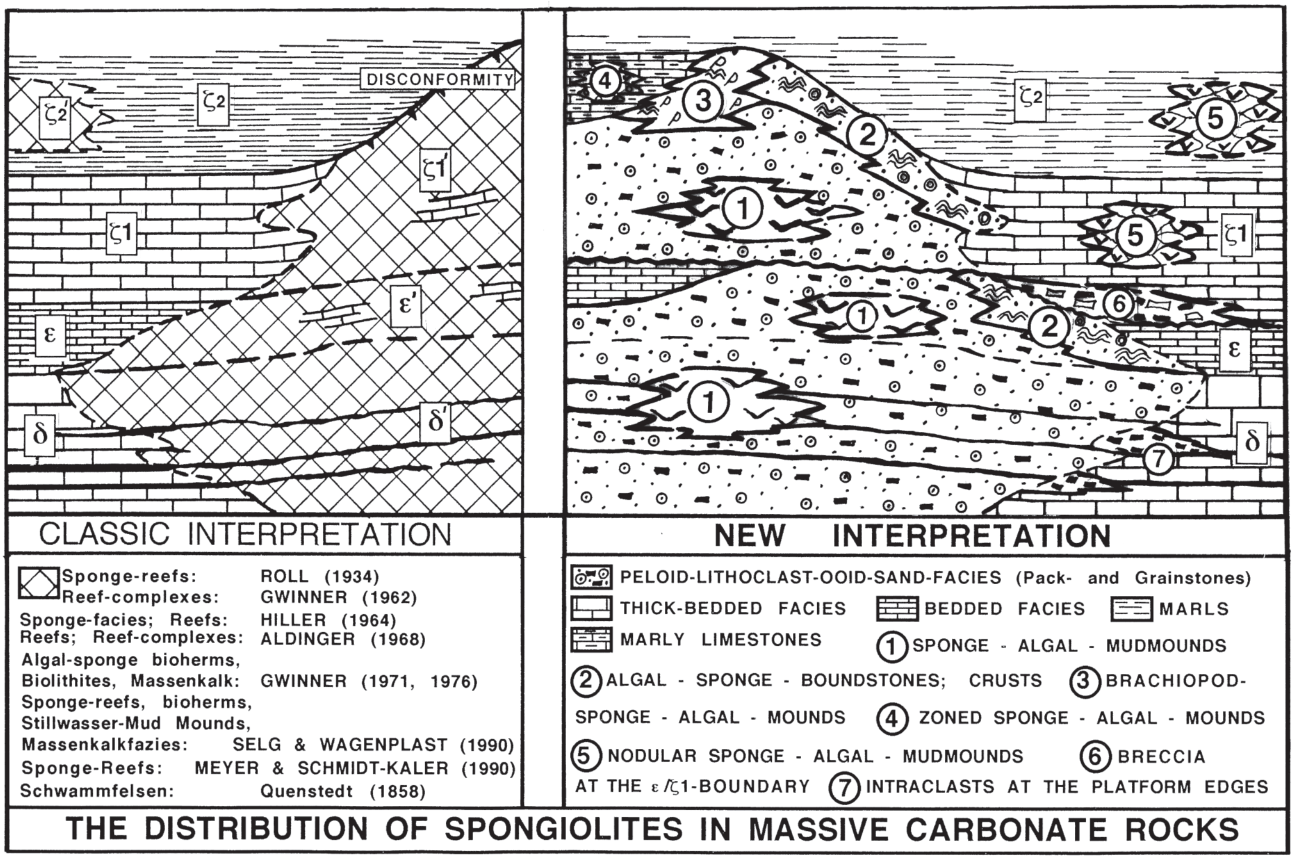

Figure 7: The distribution of spongiolites in massive carbonate rocks ("reef-complexes", Massenkalke etc.). Comparison of the classic interpretation and the new interpretation. Note that the peloid-lithoclast-ooid sand facies makes up the greatest amount of the "Massenkalke". The spatial distribution of real algal-sponge-buildups in and around the carbonate sand facies is interpreted to be caused by varying hydrodynamic conditions triggered by the paleogeographic distribution of the carbonate sand facies. The Malm Epsilon/Zeta 1 boundary-breccia marks a regressive maximum. The rapid growth of brachiopod-algal-sponge-mounds in the Malm Zeta is caused by a transgressive trend beginning at the Malm Epsilon/Zeta 1 boundary (from Koch et al. 1994).

Large fragments of echinoids occur abundantly.

The sand facies can form a relief of up to about 20 m interfingering with sediments in adjacent smaller or larger basins. The flanks are commonly stabilized by algal-sponge boundstones which are characterized by abundant microbial crusts and locally even by domal, stromatolitic structures which can have sizes of up to 1 m. Both protected the slopes against erosion and slumping. Additionally brachiopods, serpulids, and *Terebella lapilloides* are common in these boundstones, which interfinger with the well-bedded facies, rich in insoluble residue.

Brachiopod-algal-sponge mounds were formed at the slopes of intra-platform channels and at the top of the massive limestones in the Malm Zeta 1, extending above the carbonate sand facies by several meters. Brachiopods occur very abundantly in patches of several meters size. Furthermore microbial crusts, serpulids, and sponge spicules commonly occur.

These four main facies types can be subdivided into varying microfacies types. For instance, micritic layers can alternate with pure grainstone layers within the carbonate sand facies. Fine fossil debris can produce biogenic wackestones and packstones (microcoquina).

Furthermore, sponge-algal mounds with internal zonation occur in intraplatform channels (Malm Epsilon to Zeta 1) and nodular sponge-algal mounds occur in the marly basin sediments ("normal facies"). Moreover, another buildup type rich in brachiopods occurs in the basin facies.

5. Excursion route and stops

The excursion starts in the Ebermannstadt quarry (basin of Ebermannstadt) of the Northern Franconian Alb where beds of the Oxfordian and Kimmeridgian 1 crop out (Fig. 8; **Stop 1**). Subsequenly the route runs through the valley of the creek Trubach up to the village of Hardt where bedded limestones and marls as well as the sedimentation of sponge buildups in a slope situation are documented (Fig. 8, **Stop 2**). Near the village of Obertrubach one of the most spectacular outcrops is visited (Fig. 8; **Stop 3**) where a marked interfingering of different facies types can be studied. In Gräfenberg the quarry of the Endress company is visited revealing a complete profile from the Werkkalk (Oxfordian) to the Middle Kimmeridgian (Fig. 8; **Stop 4**).

The most prominent interfingering of facies and transition between basin and platform as well as transition from limestones to dolomites is visited between the villages of Ittling, Spieß, and Bernhof (Fig. 8; **Stops 5-8**). Near Großenohe a marked transition from bedded facies to dolomitic slope facies occurs.

Topics of the excursion will be the following questions:

- Is it possible to apply the model of carbonate sand deposition and of settling of sponges and microbial crusts on gentle dipping slopes also in the Northern Franconian Alb ?

- Is it possible to document facies transitions between carbonate sand facies and small basins of different size ?

- Can the model of reef-barriers be integrated in the recent model of carbonate sand deposition ?

- Are there new models for the dolomitization in the Northern Franconian Alb ?

- How is it possible to combine the existence of abundant sponges and sponge fragments with the environment of deposition that has to be more shallow due to the close position to the paleocoast at the Bohemian Massif ?

- Which parameters allow to translate the present dolomite types into the former limestone facies ?

Stop 1: Ebermannstadt Quarry "Feuerstein Section"

Well-bedded limestones of the Malm Beta and marls of the Malm Gamma are outcropping in the old quarry above Ebermannstadt (Meyer & Schmidt-Kaler 1992) which reaches up to the Bankgruppe A (compare Fig. 4) of the Lower Kimmeridgian (ki1). In the uppermost part, already disturbed beds occur indicating the beginning of the growth of local small sponge-algal buildups resulting in an early relief on the sea floor. Consequently the stromatometric bed-by-bed correlation can be well used in the horizontal beds of Malm Alpha, Beta, and Gamma whereas it will be difficult to correlate in the overlying beds of the Malm Delta, where sponge-rich limestones are indicated by Meyer & Schmidt-Kaler (1992: Fig. 57). This contact will be studied in greater detail at Stop 2 at Hardt in the Trubach valley.

Stop 2: Schießfels near Hardt

The „Schießfels" is located in the Trubach valley above the village of Unterzaunsbach close to Hardt (Fig. 8) and depicted in the geological map sheet 6233 Ebermannstadt. It represents the uppermost part of a complete profile of the Malm Alpha to the base of the Malm Delta studied by Tarasconi (1996). The goal of this stop is to present the beginning of the growth of sponge-algal buildups directly above a marked marl horizon which is interpreted to represent the *Crussoliensis* marls. The steep slope with vertical parts below the sponge buildups which are already visible from the valley consists of Malm Alpha and a marked vertical wall of Malm Beta ("Werkkalk"), overlain by Malm Gamma and by sponge facies of the Middle Malm (Malm Delta) which is the main goal of this stop.

First small sponge-algal buildups with a diameter of up to 1 m develop embedded in marly matrix. An increasing amount of buildups results in a fabric of closely-packed large nodules occurring in a wall of about 10 m high. Between these sponge buildups small local debris flows occur which are composed of angular components, graded beds of carbonate sands and fine-grained carbonate sediments in close alternation. This indicates episodic sediment input from higher energy areas into the low energy areas including reworking of already lithified sediments.

The general sedimentary transport occurred on a gentle dipping slope (ramp) with low morphology in the direction of the Ebermannstadt basin in the NW. Strings and lenses of fine- to medium-grained carbonate sands were transported basinwards between small sponge buildups.

In the upper part of the section autochthonous sponge-crust buildups occur with diameters of up to 2.50 m which were cut by a fault line running parallel to the recent slope of the valley. The structure of the complete sequence is deformed due to intensive compaction which is documented by vertical slickenside textures between sponge buildups.

Stop 3: Falkenhorst wall (Trubach valley; Schlöttermühle)

The area between Wolfsberg and Obertrubach in the Trubach valley is one of the most complicated areas regarding the biostratigraphic subdivision. This becomes obvious comparing the boundaries of the geological sheet 6333 Gräfenberg (DORN 1958) and 6334 Betzenstein (GOETZE et al. 1975) which is running close to the houses of Ziegelmühle. Whereas DORN (1958) just indicates dolomitic facies of the Lower, Middle and Upper Malm ("Frankendolomit"), a more detailed stratigraphy is indicated by GOETZE et al. (1975) directly on the neighbouring geological sheet including sponge limestone of the Lower Kimmeridgian (Malm Gamma, ki1) directly overlain by reef dolomite of the Middle Kimmeridgian which also can reach down to the Oxfordian without being subdivided. Generally it is very difficult to find a marker horizon to which the stratigraphic levels can be related regarding thickness and facies development because varying transitions occur. Furthermore the dolomitization of sponge-rich limestones can range down even into the Oxfordian. Thus, relating to the only possible marker horizon of the Dogger/Malm boundary which is marked by the Ornatenton (clay) at which commonly springs are found, a rough calculation of thickness might help to determine where in the stratigraphic record the different beds are positioned (Fig. 11).

Near Hammerbühl in the Trubach valley about 5 km in the West a complete section with a thickness of 60 m from the the Dogger/Malm boundary to the *Platynota* marls (base of Lower Kimmeridgian) which are directly overlain by undifferentiated Frankendolomit occurs. Due to this large thickness reef limestone and reef dolomites should be expected to occur below this marker horizon as documented in Fig. 11; but only bedded limestones occur. Opposite, for the development on bedded facies just a thickness of about 30 m is indicated in the lithologic legend of sheet 6334 Betzenstein (GOETZE et al. 1975).

Thus, the massive sponge dolomites occurring above a marked marly horizon are interpreted to occur in different stratigraphic levels. The large reef-complex of about 120 m lateral extension and 40 m height is located within the so-called Wiesent reef (Fig. 5). Lateral interfingering of large sponge buildups (up to 10 m in size), bedded facies, and marly horizons can be studied. Laterally graded sediments indicate the formations of small, local basins between large sponge buildups within a distance of some tens of meters. These limestones contain fine debris of reworked micritic limestones, of sponges, microfau-

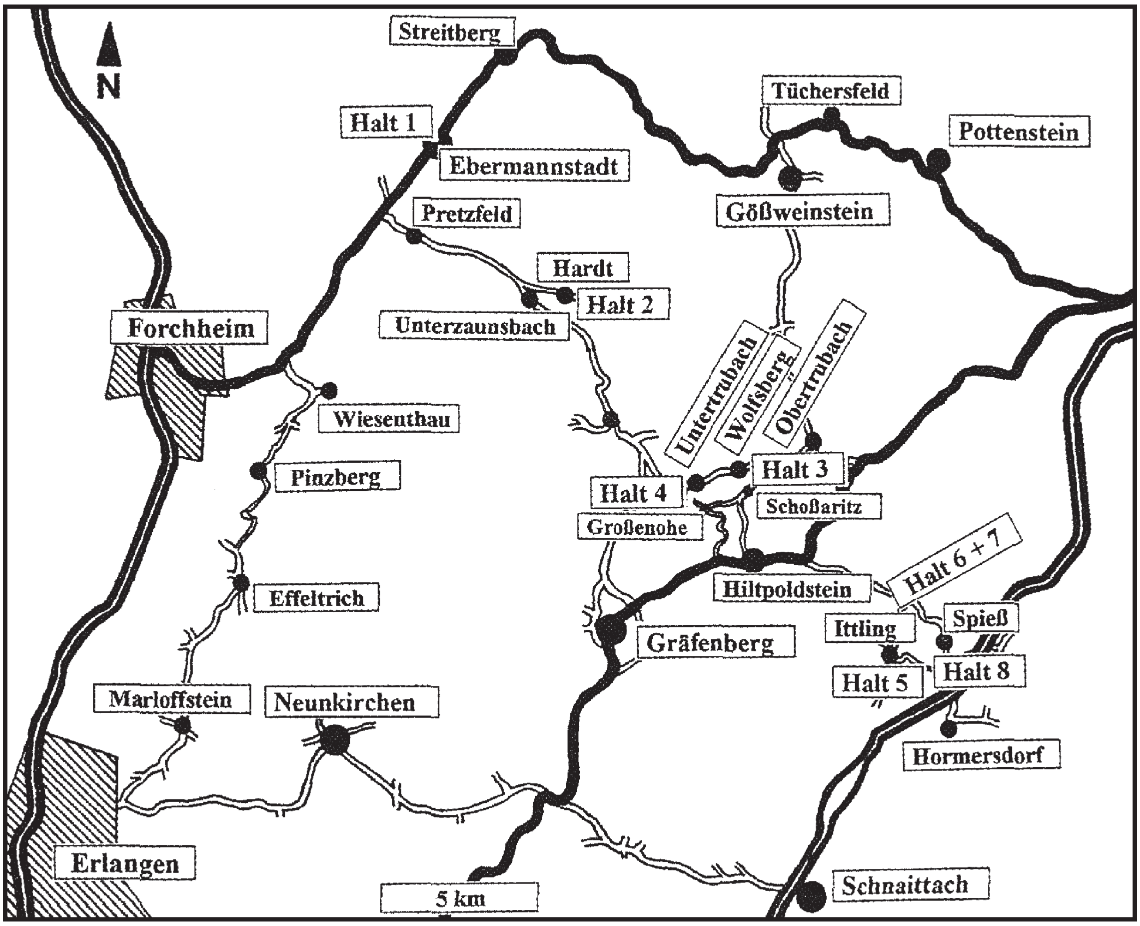

Figure 8: The excursion route including stops (Halt) 1-8 in the Northern Franconian Alb.

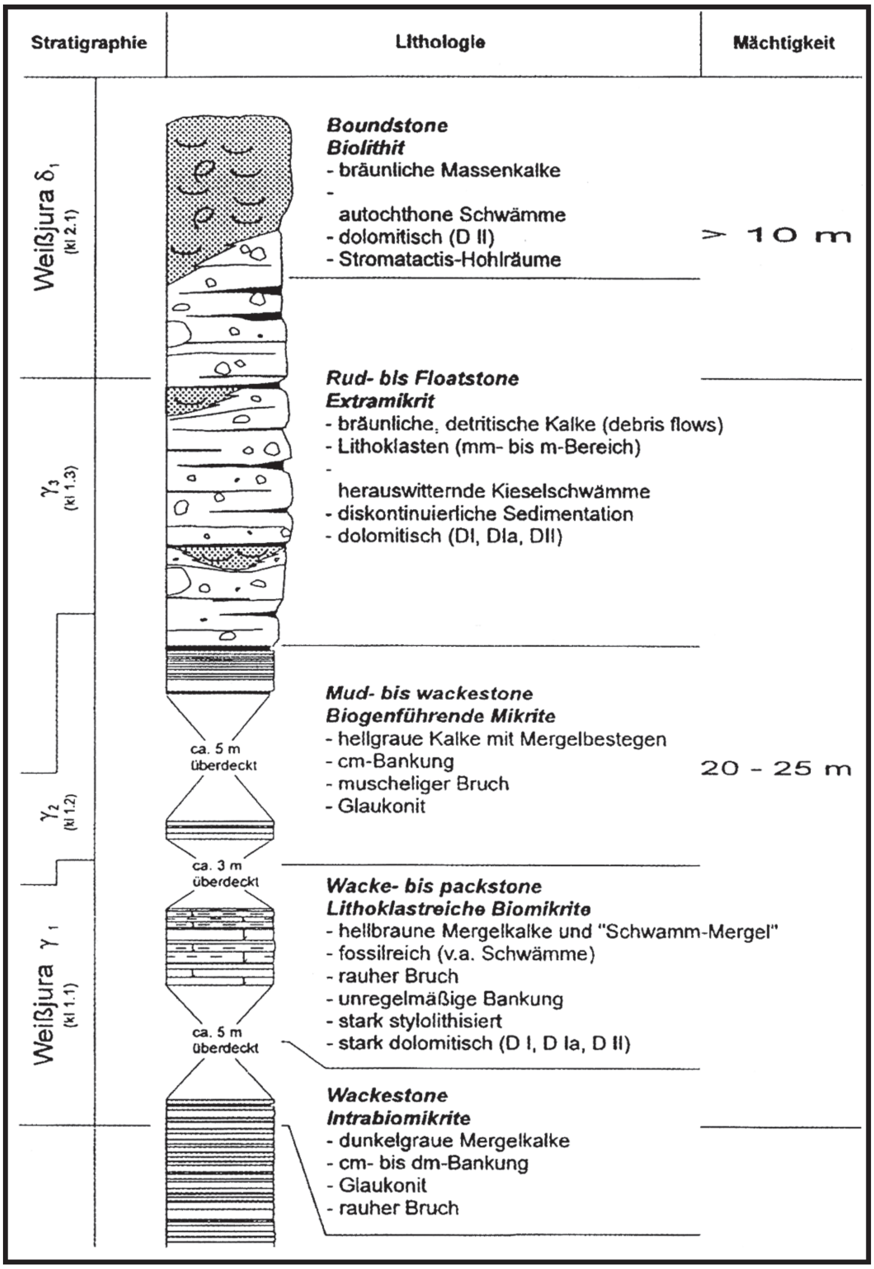

Figure 9: The profile up to the Schießfels near Hardt which marks the beginning of the growth of sponge-algal buildups in the uppermost Malm gamma (from Tarasconi 1996).

na, and compacted ammonites. Debris flows of some meters thickness pinch out within a distance of some tens of meters indicating a moderate relief on a gentle NW-dipping structure; i.e. in direction to the basin of Ebermannstadt.

This vertical and lateral facies development occurs directly above a marly horizon of 0.5-1 m thickness, rich in micro- and macrofauna (*Crussoliensis* marls) overlying limestone beds rich in flint nodules.

On the south side of the Trubach valley the basal beds indicating Lower Kimmeridgian are missing. There, only reef dolomites of the Middle Kimmeridgian are indicated in the geological map. Opposite to this Hornung & Koch (2004) describe sponge limestones of the Kimmeridgian 1 at the base of a sequence reaching up to a marked facies in the uppermost Middle Kimmeridgian which is characterized by abundant thick beds with marked inclination and selected weathering. In contrast to this observation, Meyer (2005, personal communication) determines a Lower Kimmeridgian age for the whole sequence of massive dolomites. Moreover, great doubts are mentioned on the general possibility of finding stratigraphic indications or relics of microfossils for facies analysis in dolomites.

A marked transition zone from dolomites to limestones (some decimetres) can be studied, although overprinted by a fault with vertical dislocation below the Falkenhorst Wand. Generally dolomitization first occurred in sediments rich in sponges and fragments of sponges. Subsequently it invaded some centimetres to decimetres into the neighbouring limestones which reveal only very minor amounts of sponge fragments. This field interrelationship supports the model of organic matter being responsible for the dolomitization of sediments rich in sponges.

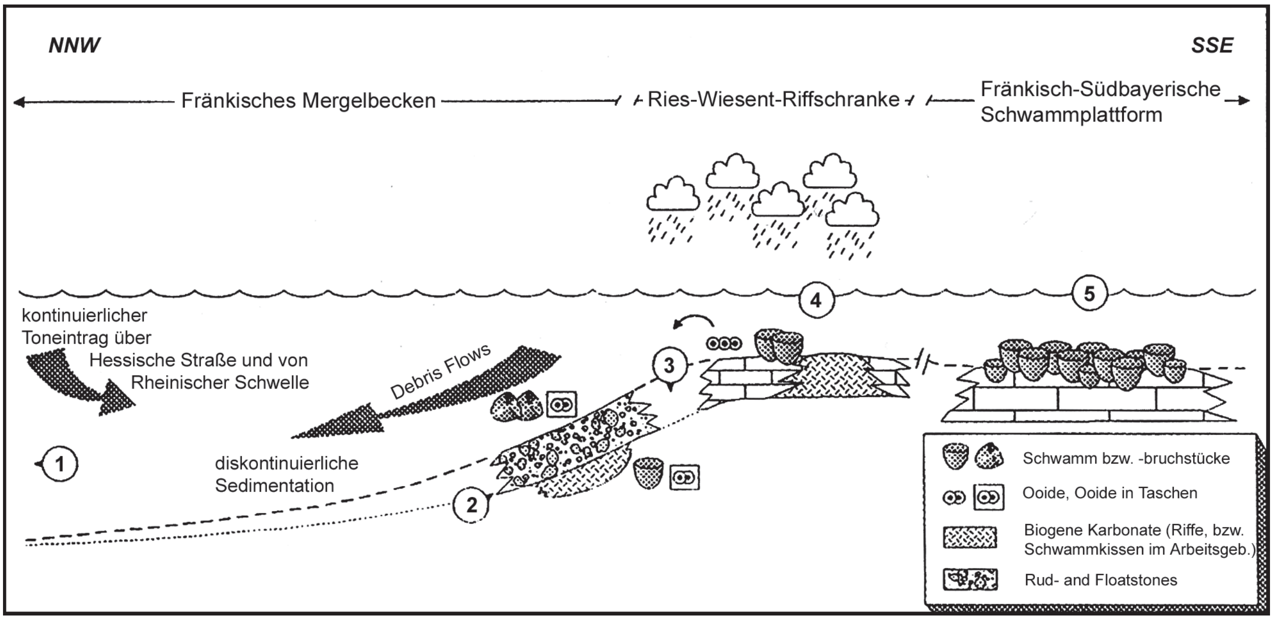

Figure 10: Sedimentation model for the Kimmeridgian 1 and 2 on the gentle dipping slope from the carbonate platform to the basin of Ebermannstadt at the outcrop of the Schießfels near Hardt. 1 = basin of Ebermannstadt, 2 = position of the Schießfels, 3 = thick-bedded platform limestones of Gräfenberg, 4 = ooid sands and sponge-algal crust facies on swells, 5 = facies of the Treuchtlingen Limestones in the Southern Alb (distance and relief not to scale; from TARASCONI 1996).

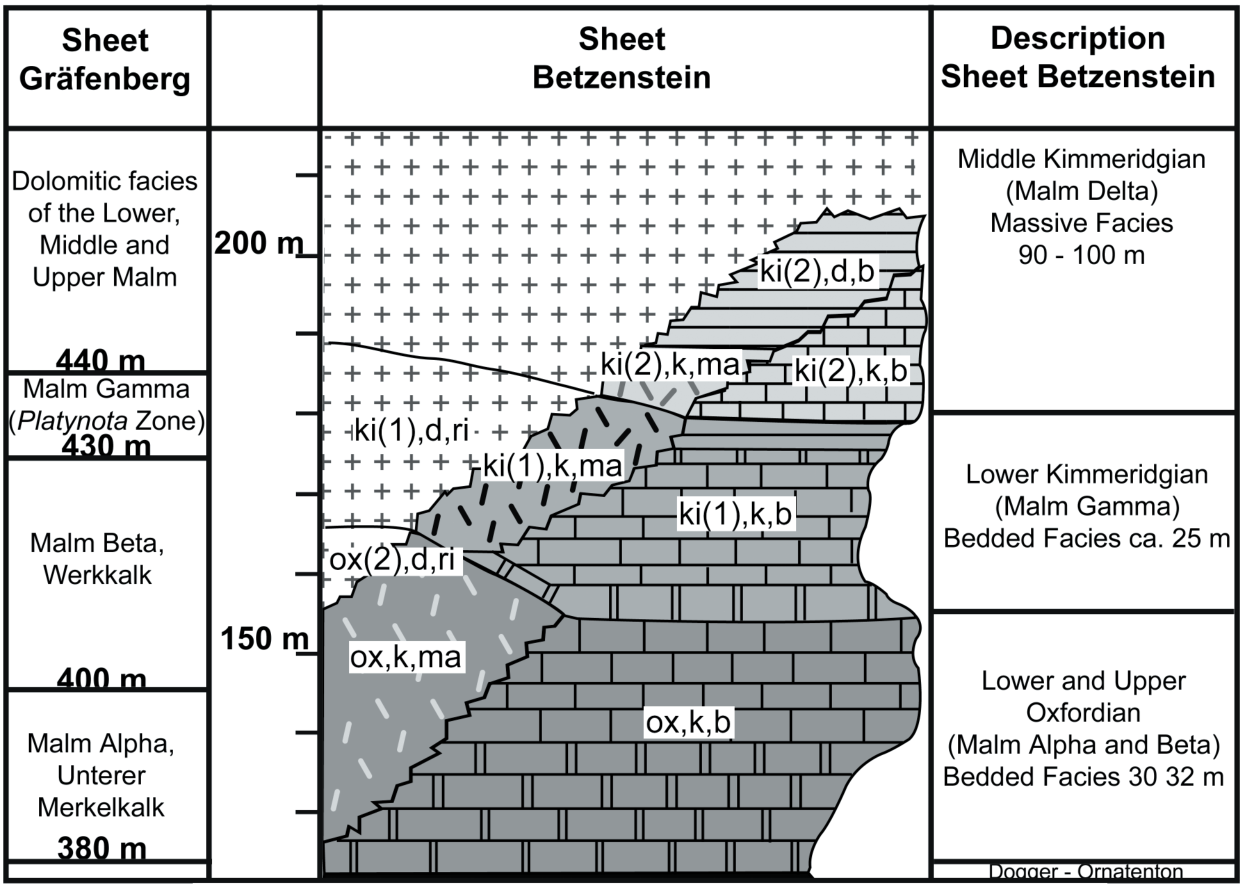

Figure 11: Comparison of the stratigraphic subdivisions and facies types documented in the geological sheet 6333 Gräfenberg (DORN 1958) and sheet 6334 Betzenstein (GOETZE et al. 1975). **ox,k,b** = bedded limestones and marls of the Oxfordian (Malm Alpha and Beta), **ox,k,ma** = sponge limestones of the Oxfordian, **ox(2)d,ri** = reef dolomite of the Oxfordian, **ki(1),k,b** = bedded limestones of the Lower Kimmeridgian (Malm Gamma), **ki(1),k,ma** = sponge limestones of the Lower Kimmeridgian, **ki(1),d,ri** = reef dolomite of the Lower Kimmeridgian, **ki(2),k,b** = bedded limestones of the Middle Kimmeridgian (Malm Delta), **ki(2),k,ma** = sponge limestones of the Middle Kimmeridgian, **ki(2),d,b** = thick-bedded dolomite (Tafelbankiger Dolomit) of the Middle Kimmeridgian, **ki(2),d,ri** = reef dolomite of the Middle Kimmeridgian.

Stop 4: Gräfenberg; Endress Quarry (Malm Beta - Malm Delta (3 ?)

In comparison to the bedded facies and dolomitic facies we have visited in the quarries before, we will visit a quarry revealing well-bedded and thick-bedded limestones throughout characterizing the platform facies (Figs. 6 and 10). Thick-bedded limestones of the Malm Delta predominante the Endress quarry. The complete section from Malm Alpha to Malm Delta (3 ?) has a thickness of about 40 m. In the lower part of the quarry, well-bedded limestones of the Malm Beta occur underlying the marked Platynota Zone where abundant ammonites can be found. The grey, dense, micritic limestones (bed thickness 5-40 cm) locally contain abundant dark green glauconite grains. The Platynota Zone consists of grey, fine-bedded marls of about 15 cm thickness. A close alternation of marls and limestone beds (1 – 40 cm thickness) is developed between the Platynota Zone and the *Crussoliensis* marls.

In general, a constant increase in the amount and size of particles of the limestones can be recognized from the Platynota Zone to the top of the quarry, where two marked layers (5 cm and 10 cm thickness) occur. Therefore the limestones of the Malm Delta must be classified as particle-rich limestones throughout, revealing a development from wackestones to packstones (according to the classification of DUNHAM 1962). In the uppermost part of the sequence some grainstone layers are intercalated. The matrix content is decreasing and the limestones show an increasing amount of primary interparticle porosity now filled by relics of isopacheous marine phreatic cements and by granular cement. This development indicates an increase in water energy probably due to a shallowing of the environment of deposition. Silica nodules and partly silicified fossil fragments occur revealing different stages of weathering.

Limestone beds (up to 2 m thickness) in the upper part of the sequence consist of coarse-grained fossil debris, lithoclasts, coated grains, and minor superficial ooids representing a classical carbonate sand facies as similar deposited in modern areas of carbonate sediment production.

The double marl layers in the uppermost part of the outcrop are discussed to be correlated with the Lower and Upper Marl layer characteristic for the Treuchtlingen Limestone of the Southern Franconian Alb. Consequently, comparable sedimentary environments for the deposition of carbonate sands are assumed. This interpretation is underlined by the occurrence of *Tubiphytes morronensis* CRESCENTI and filaments which both can be used in a gross stratigraphic sense for correlation over large distances.

Stop 5: Ittling; quarry of the Geiger company

After a drive of about 20 km we reach the second centre of the excursion, the area between Ittling, Spieß, and Hormersdorf near the highway A9 to Berlin (Fig. 12). Here we will visit beds reaching from the Oxfordian to the Middle Kimmeridgian including marked lateral and vertical transitions between limestones and dolomites characterizing the platform-basin transition zone.

Lower Marls and well-bedded limestones of the Oxfordian (thickness 32 m) crop out on both sides of the valley of the Achtel near Ittling. They are predominantly composed of mudstones which contain only traces of fine fossil fragments. Mudstones and Wackestones of the Lower Kimmeridgian (ki1; Malm Gamma; thickness 28 m) are well exposed in the quarries of the Geiger and Bärnreuther companies which are neighboured directly. Therefore both quarries are summarized as "Ittling quarries" in the following text. The Lower Kimmeridgian can be well separated from the underlying Oxfordian beds (Malm Alpha and Beta) by the occurrence of marked thick marl beds. The Platynota zone is very rich in fossils. It is overlain by the *Ataxioceras* beds and by the double marl horizon of the *Crussoliensis* beds.

Thick-bedded limestones of the Middle Kimmeridgian (ki2; Malm Delta) have a thickness of 95 m (GOETZE et al. 1975) and are well exposed in the Ittling quarries. They consist of grey-brown wackestones and packstones. An increasing number of intercalations of peloid-*Tubiphytes*-packstones to grainstones occur towards the upper part of the section. This reflects a constant increase of water energy in the environment of deposition which is interpreted as increased shallowing of the Upper Jurassic sea. Parallel to this, an increase in thickness of the beds can be observed from the base to the top of the quarry. This corresponds to higher carbonate contents in the younger beds.

Abundant silica nodules (diameter up to 5 cm) and secondary silicification of sponges occur in the uppermost part of the Geiger quarry. Some meters higher in the profile the lateral transition to completely dolomitized sponge-rich beds occurs. Within a distance of about 20 cm, the dolomitization front can be found in sponge-rich beds. Similar observations are reported by FRITZ (1966) from limestone-dolomite transitions in the Middle Kimmeridgian of the Swabian Alb. In the zone of transition, single dolomite crystals occur first in the micritic matrix which become more and more abundant until matrix, cements and former pore spaces are completely replaced by dolomite. Only larger allochems as sponges, molluscs and fragments of echinoids are preserved as calcite. Commonly these allochems are partially or completely replaced by silica. Thus they are preserved and can be used for facies analysis even in medium- to coarse-crystalline dolomites.

The so-called dolomitic, porous rock ("Lochfels") has a thickness of about 10 m and invades vertically and laterally with different expansion into the underlying and neighboured bedded limestones. This indicates a primary interfingering of different facies types which locally can be recognized regardless the dolomitization. The dolomite beds with secondary silicified sponges change towards east in direction to the Prüschenk quarry into dolomites with large round molds, vugs, and caverns ("Lochfels"). These rocks represent interconnected small round sponge-algal buildups as shown by comparison with other areas.

Stop 6: Road crossing to Bernhof

On the road from Ittling to Schermshöhe we stop where a small road leads to Bernhof. Opposite, at the deepest part of the valley, we find a huge tower of limestone (about 25 m high) which consists of well-bedded limestones with thin marl intercalations. The composition of allochems within individual beds can change rapidly from bed to bed. One bed, e.g., rich in glauconite is overlain by a bed of pelletoidal wackestone and this is overlain by a packstone rich in *Tubiphytes*. Within a distance of some tens of meters from the tower (East direction) dolomite occurs. It is developing in western direction upwards the hill and finally overlays the large tower. This reflects the transition zone between limestone and dolomite indicating a slope gently dipping towards East. A comparable situation can be found on the opposite south side of the valley where the road leads up to the little village of Bernhof.

Stop 7: Road crossing to Bernhof

Following the road about 500 m in the direction to Schermshöhe the slope on the southern flank of the valley is composed of abundant sponge buildups of different size positioned within bedded facies. Thick-bedded dolomite containing abundant different-sized rounded molds, vugs and caverns alternate with massive sponge algal buildups. The slope of the valley up to the summit of the Schiepfen (569 m) documents an eastwards gentle dipping slope reaching from the top of the Ittling quarries down to the base of the Prüschenk quarry near Bernhof. This slope is covered by abundant sponge-algal buildups of varying size with interim facies of bedded limestone rich in sponges and biogenic fragments now presented as holes of varying size.

Stop 8: Prüschenk quarry near Bernhof

In the Prüschenk quarry, dolomite of different composition is exposed throughout in walls up 70 m high (500-570 m NN). Megascopic structures, bedding features and massive areas allow to reconstruct a general sedimentological model regardless the complete dolomitization which can be summarized as follows. Thick-bedded dolomite of 1-4 m bed-thickness in which areas of thin-bedded (dm-thickness) yellowish dolomite are intercalated occur at the base of the quarry. This facies can form lenses of some tens of meters in thickness and some 100 m in lateral expansion. Whereas the thick-bedded zones have carbonate contents of 94-98 % the thin-bedded zones just reveal carbonate contents of 86-90 %. This reflects a higher amount of insoluble residue (clay minerals). The crystal size of these “more dirty”, very hard dolomite is much smaller in comparison to the crystal size of the “purer dolomite”. These areas are interpreted as laterally limited layers in the form of pools in which clayey suspension load was settled between primary carbonate sands. This basal part has a thickness of about 20 m and develops upwards into more massive dolomite without traces of bedding. Locally, larger structures of sponge buildups are intercalated which are spongiolithes settling the gentle dipping slope.

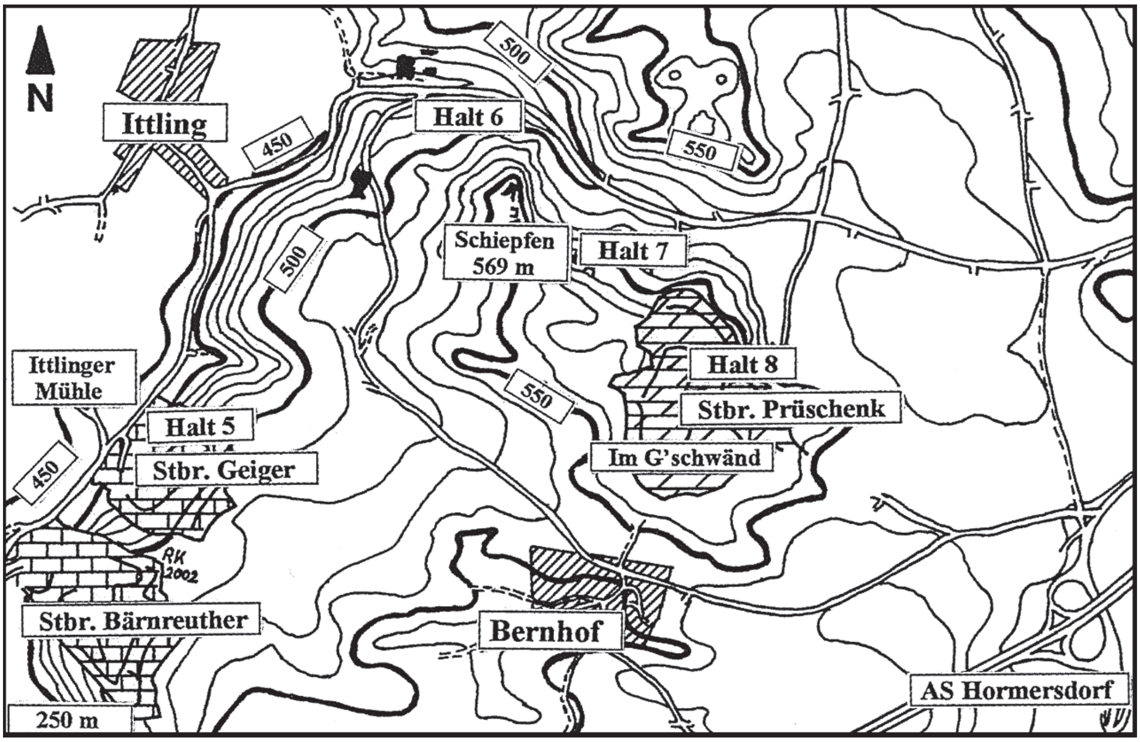

Figure 12: Detail map showing the eastern area of the excursion with the quarries of the Geiger and the Prüschenk companies as well the stops (Halt) 5, 6, 7, and 8 in stratigraphic order (from Koch et al. 2003).

Acknowledgements and remarks

We thank G. Schweigert (Stuttgart) for the review of the paper. Parts of the paper are translated from the excursion guides published by Zeiss (1975) and Koch et al. (2003).

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