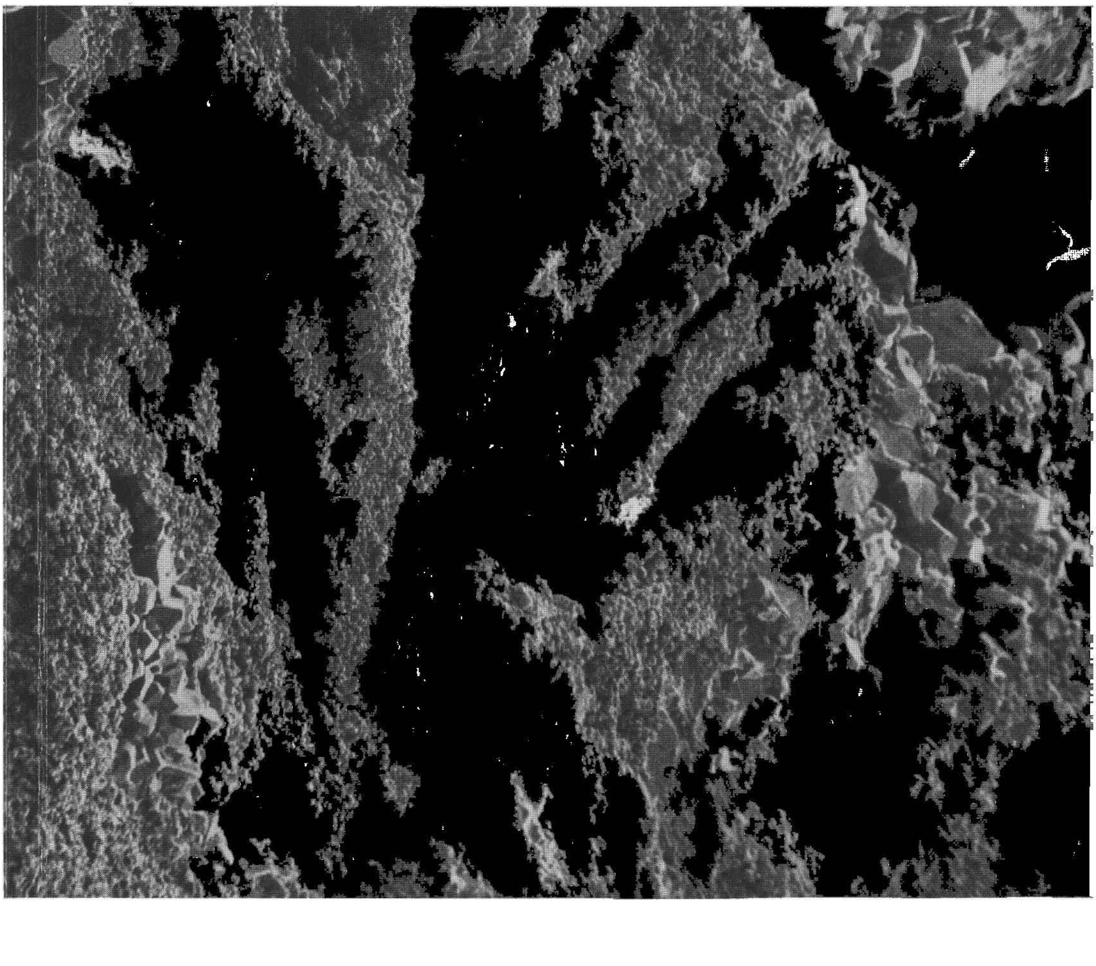
1975
ERLANGEN

GUIDE BOOK



INTERNATIONAL SYMPOSIUM ON FOSSIL ALGAE

INTERNATIONAL SYMPOSIUM ON FOSSIL ALGAE, ERLANGEN 1975

GUIDE BOOK

Devonian Reef and Shelf Environments of the
Eastern Rheinisches Schiefergebirge

Mesozoic shallow- and deeper-water facies
in the Northern Limestone Alps

Upper Jurassic of the Southern Frankenalb
(Algal-sponge - and coral-reefs, Solnhofen lithographic limestones)

with contributions by

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Edited by

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Erlangen 1975

Cover picture: Stereoscan Electron Microscope foto of Cayeuxia piae FROLLE from the Middle Tithonian of Kapfelberg, Southern Frankenalb. (250 x, 10 KV)

P r e f a c e

"Paleo-Algologists" are interested not only in taxonomy, biostratigraphy, and ecology of fossil algae, but also in environmental analysis and sedimentology. Therefore several excursions are offered to the members of the First International Symposium on Fossil Algae.

These field trips contact regions, whose facies and paleogeography are research projects of the Institut für Paläontologie of the University Erlangen-Nürnberg (Alps, Frankenalb). The excursion to the eastern Rheinisches Schiefergebirge considers new results of the Sonderforschungsbereich 48 of the Deutsche Forschungsgemeinschaft, earned by members of the Institut für Geologie und Paläontologie of the University Göttingen.

The investigations in the Northern Limestone Alps deal with synecology of Upper Triassic and Upper Jurassic reef communities with the genesis of shallow-water- and deeper-water limestones (project Fl 42/24, Fl 42/25, supported by the Deutsche Forschungsgemeinschaft).Quantitative and qualitative studies of paleontological and sedimentological characteristics have been started together with the systematic description of the flora and fauna of some Mesozoic reefs near Hallein (Salzburg) and Mitterndorf (Styria).

Facies, development of faunas, and paleogeography of the Upper Jurassic in Franconia is another research project of the Erlangen institute (Fl 42/20, 23). Together with members of the Institut für Mineralogie of the University of Erlangen, the genesis of algal-sponge-reefs, and of the famous Solnhofen lithographic limestones is studied. Paleontological investigations of ammonites, foraminifera and calcareous algae are carried out accompanied by Stereoscan Electron Microscope studies of ultraplanktonic constituents of micritic limestones.

I wish to thank all those who have contributed to the Guide Book and have assisted during the preparation of the Symposium.

Erik Flügel

Erlangen, 1.10.1975

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3. B i b l i o g r a p h y

1. Introduction: General paleogeography.

(W.EDER, W.ENGEL, W.FRANKE, F.LANGENSTRASSEN, H.UFFENORDE)

The Rheinisches Schiefergebirge represents a part of the Rhenohercynian in the Variscan fold belt, which extends in an E-W direction from western Poland through Central Europe towards the east coast of North America. During the Devonian and Carboniferous, the area belonged to the northern branch of the Variscan geosyncline (see MEISCHNER 1971). Its western continuation is seen in the Ardennes (northern France and Belgium), in southwestern England and southern Ireland.

The northern branch of the Variscan sea was subdivided by a metamorphic, synsedimentary cordillera ("Mitteldeutsche Schwelle" of BRINKMANN 1948), which formed the southern border of the later Schiefergebirge (remnants exposed in the Odenwald and Spessart Mountains, SE of Frankfurt). Thus, the Rheinisches Schiefergebirge represents the northernmost part of the geosyncline, immediately adjacent to the Old Red Continent in the NW. Though being only a part, the Rhenohercynian forms a palaeogeographic unit of its own. It is bordered by source areas on both sides, which include a great variety of geosynclinal sediments. The Palaeozoic outcrop of the Rheinisches Schiefergebirge covers a fairly complete cross-section through the Rhenohercynian area, and thus may be studied as a model of geosynclinal sedimentation (Geol.map. see fig.A1).

The depositional history of the Schiefergebirge is controlled by the source areas named above. As a generalization, two phases of sedimentation can be recognized. During the lower and middle Devonian, the bulk of clastic sedimentation is derived from the north (Old Red Continent). After an intermittent period (Upper Devonian), sediment-discharge from the north stops completely, and the southern source-area ("Mitteldeutsche Schwelle"), which has yielded only minor quantities of sediment during the first phase, takes over to dominate until the end of the geosynclinal sedimentation (Upper Carboniferous).

Fig. A 1 Geological map of the Rheinisches Schiefergebirge east of the river Rhine (from MEISCHNER 1971).

THE VARISCAN GEOSYNCLINE EAST OF THE RIVER RHINE

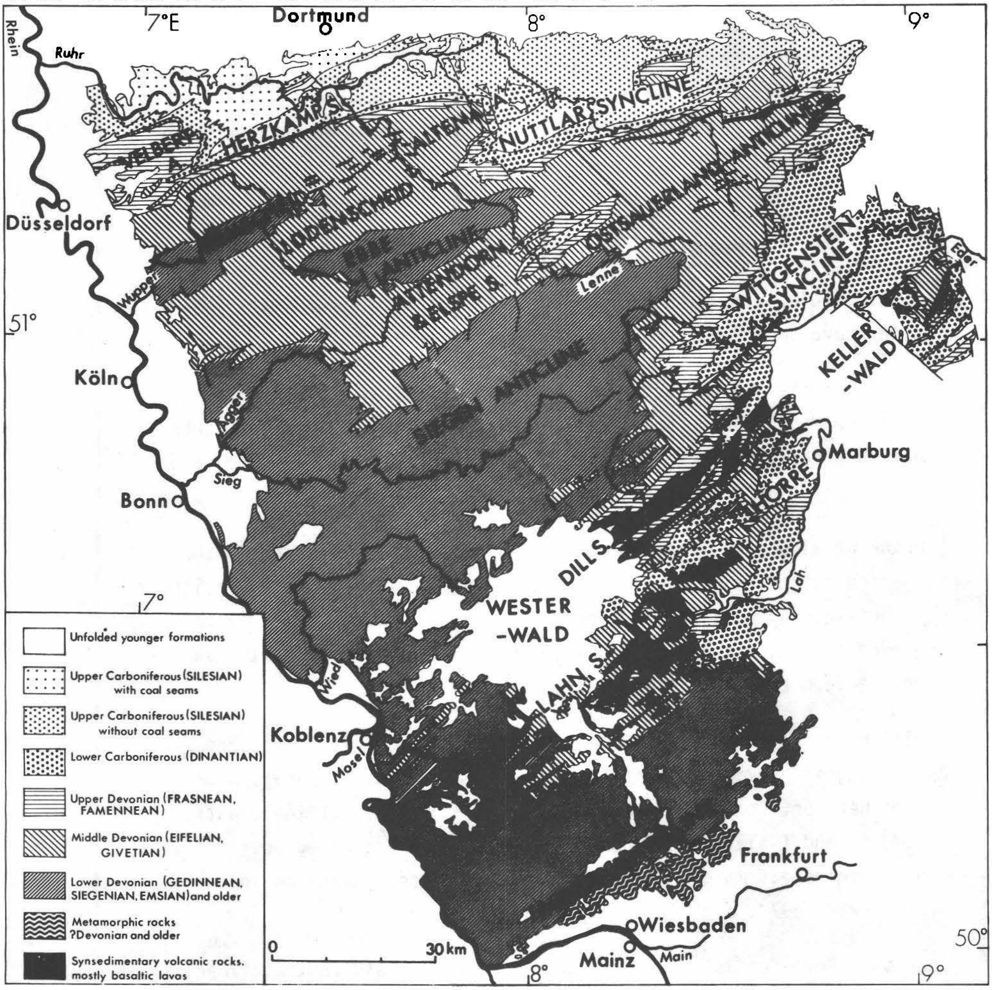

Fig. A 1

The first phase is initiated by the deposition of shallow-water clastics (Lower Devonian), which spread from the north throughout almost the entire Schiefergebirge. During the Lower and Middle Devonian, the depocenters retreat northwestwards. The terrigenous debris is amassed on an broad shelf. The inner, northwestern shelf is characterized by massive sandstones and redbeds with poor bottom faunas (partly delta-type sedimentation). The outer, southeastern shelf exhibits a variable lithology, partly with high carbonate-contents and a rich spectrum of benthonic organisms. The time-equivalent basinal sequences are monotonous alternations of clay-, silt- and sandstones. Most of the sandstone-intercalations have been deposited by turbidity currents.

The shelf facies is characterized by rapid accumulation (3000-5000 m during the Middle Devonian) and associated strong synsedimentary subsidence, whereas the basinal facies is relatively thin (500-1500 m) and tectonically stable (load-subsidence of the shelf-trough?).

Fracturing along the areas of contrasted subsidence give rise to the submarine extrusion of basaltic lavas and pyroclastics. The basin itself is subdivided by a major, midgeosynclinal rise-system, which may be regarded as an isostatic response to the sedimentary load of the surrounding depocenters (MEISCHNER 1968).

An interruption of the clastic discharge from the North (Givet and Adorf Stages) provides conditions favourable for the carbonate-producing benthos. Carbonate platforms cover large areas of the clastic basement, and isolated reef complexes grow up in preferred positions, e.g. on the shelf margin (Brilon and Attendorn reefs) and on volcanic rises (KREBS 1974; see fig. A 2).

The upper Devonian is a phase of sedimentological and tectonic inactivity. Most of the older palaeomorphological elements (shelves, reefs, rises) persist until the Lower Carboniferous. The margin of the northern shelf retreats into the northwesternmost corner of the Schiefergebirge

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Fig. A 2 Paleogeographical situation during the uppermost Middle Devonian in the Rheinisches Schiefergebirge; black areas: distribution of Massenkalk (modified after KREBS 1971).

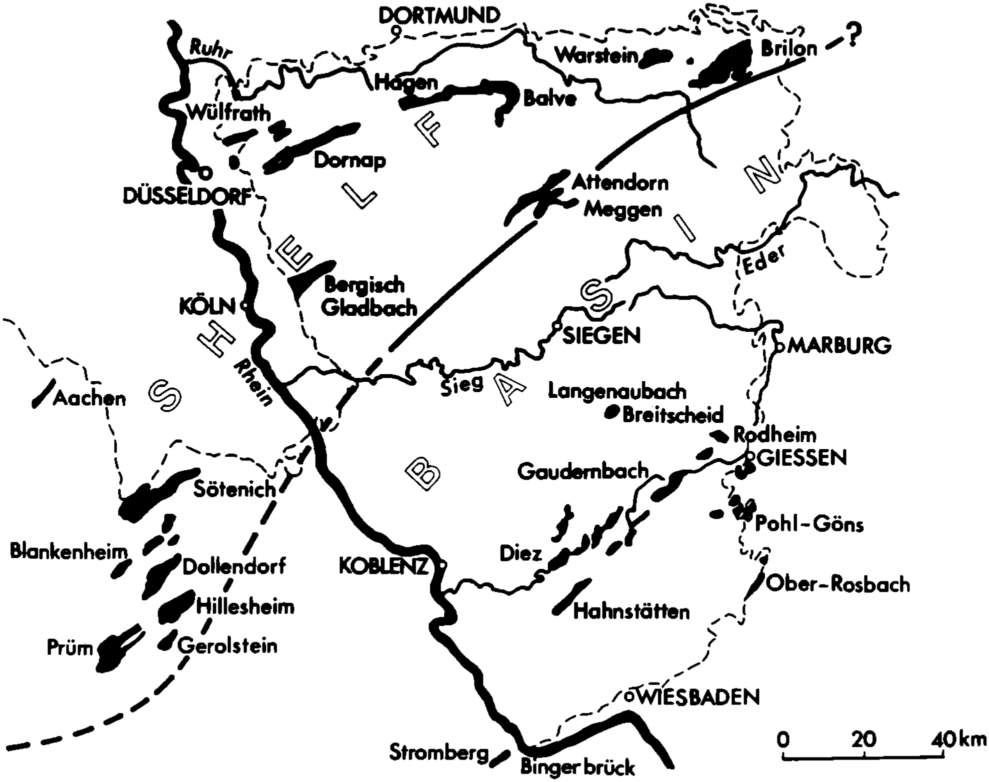

DORTMUND
Ruhr
Warstein
Brilon
?
Hagen
Balve
Wülfrath
Dornap
DÜSSELDORF
Attendorn
Meggen
Eder
Bergisch
Gladbach
KÖLN
SIEGEN
MARBURG
Rhein
Sieg
Aachen
Langenaubach
Breitscheid
Rodheim
GIESSEN
Gaudernbach
Sötenich
Pohl-Göns
Blankenheim
Dollendorf
Diez
KOBLENZ
Ober-Rosbach
Hillesheim
Hahnstätten
Prüm
Gerolstein
WIESBADEN
0
20
40km
Stromberg
Bingerbrück

Fig. A 2

and yields only a few hundred meters of shales and sandstone turbidites, which are deposited on the previous relief. Submarine rises (dead reefs, volcanic ridges) are characterized by reduced pelagic limestones.

There are only few and poor outcrops of Middle and Upper Devonian along the northern margin of the "Mitteldeutsche Schwelle". Presumably there was a narrow carbonate shelf with clastic fans, which may have formed a smaller counterpart to the northern, predominantly clastic shelf-trough (KREBS 1974).

From the Upper Devonian (into the Carboniferous), the clastic influx from the south is accelerating. Increasing volumes of unsorted terrigenous debris (greywacke-turbidites) are shed into the central, basinal area and fill up the previous relief with a northwestward foreset. This is the beginning of the flysch-type sedimentation, which accompanies the Variscan folding.

Reduced alum shales and cherts represents the background sedimentation of the remaining basin, beyond the reach of greywacke sedimentation (see fig. A 3).

The clastic influx from the north ends within the lowermost Carboniferous. Biogenic carbonate production takes over from terrigenous sedimentation. On the clastic basement of the northern shelf a large carbonate platform is built up, which extends over the British Isles, Belgium and Northern France into the northwestern corner of the Schiefergebirge (fig. A 3).

During the upper part of the Lower Carboniferous, the carbonate platform is integrated in the general subsidence, which is related to the approaching front of flysch greywackes. During the Lower part of the Upper Carboniferous, all the later Schiefergebirge is covered by greywacke turbidites, and the former basin is filled up. By that time, the zone of folding has advanced northwards into the Schiefergebirge.

Fig. A 3 Paleogeographical situation in the Lower Carboniferous (modified after MEISCHNER 1971).

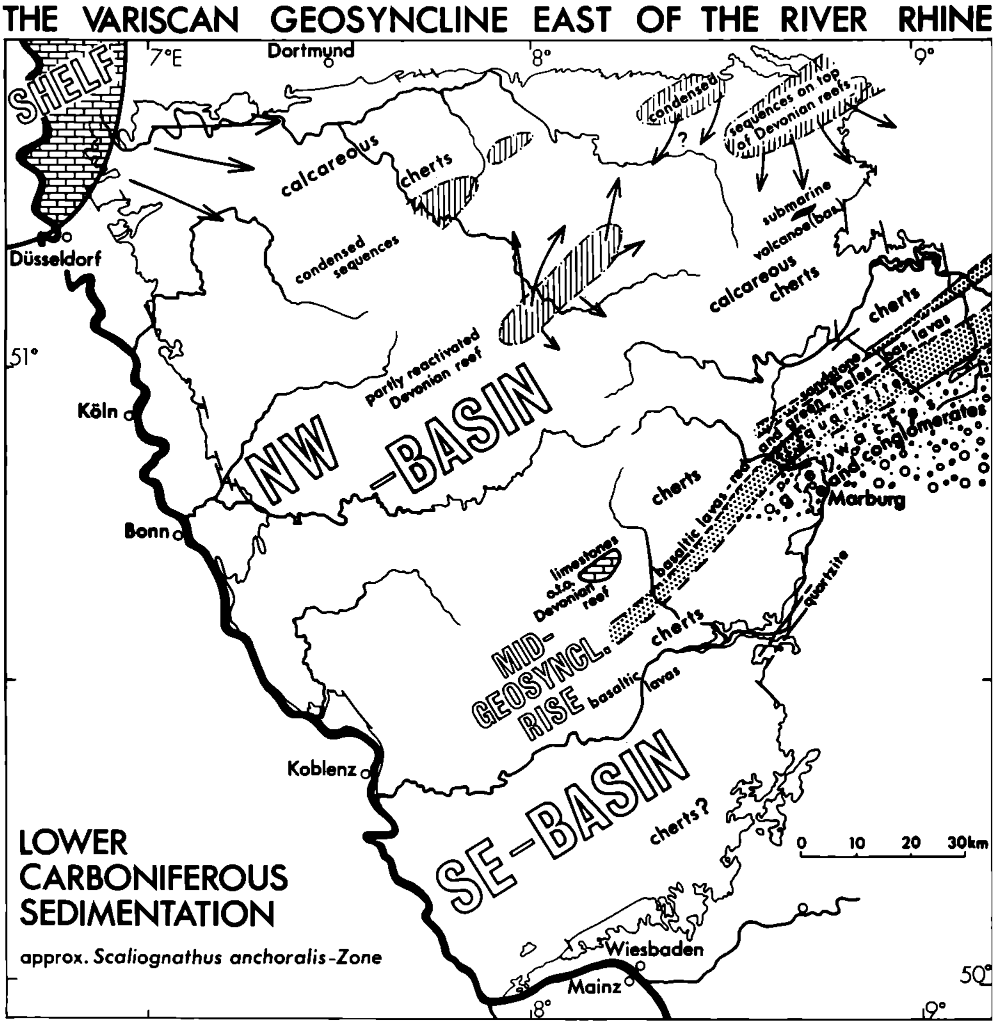

THE VARISCAN GEOSYNCLINE EAST OF THE RIVER RHINE
SHELF
7°E
Dortmund
8°
9°
calcareous
cherts
condensed sequences
condensed
?
sequences on top of Devonian reefs
submarine volcanoe (bas.)
calcareous cherts
cherts
Düsseldorf
51°
partly reactivated Devonian reef
NW-BASIN
Köln
Bonn
cherts
limestones o.t.o. Devonian reef
basaltic lavas
MID-GEOSYNCL. RISE
cherts
basaltic lavas
Marburg
quartzite
Koblenz
SE-BASIN
cherts?
0 10 20 30km
LOWER CARBONIFEROUS SEDIMENTATION
approx. *Scaliognathus anchoralis*-Zone
Wiesbaden
Mainz
50°

Fig A 3

The remaining depression north of the orogenic front still subsides corresponding to sedimentation and accomodates thick sequences of paralic sandstones, clays and coal-seams (molasse-phase).

The Carboniferous coal-district has only in part been incorporated into the Variscan folding. The area south of it has been transformed into an anticlinorium with fold-axes plunging gently towards the NE, so that the older beds crop out in the center of the Rheinisches Schiefergebirge. The strike of the tectonic elements (SW-NE) roughly reproduces the orientation of the former palaeogeographical units (shelf-margins, submarine rises, volcanic ridges ect.).

2. Excursion Route - Itinerary

October 1st

Subject: The early Upper Devonian Langenaubach-Breitscheid reef complex and its development until the Lower Carboniferous (Mississippian).

Guide: Werner BUGGISCH

General setting

The relief in the Dillmulde area is subdued from the late Lower Devonian to the Givet stage. Hence no great differences of thickness occur in the deposition of monotonous shales and sandstones. Then, late in the Givet stage, ground movements created a dense structure of rises and basins. These tectonic movements were accompanied by a strong submarine volcanism, which is explosive most of the time (diabase and Schalstein = palagonite tuff). The accumulation of volcanic material accentuates the relief even more. For these reasons we encounter within a couple of kilometers:

Hochschwellen (within the wave range) with reef building and emersion

Tiefschwellen (below the wave base) with slow sedimentation and cephalopod limestones

Becken (basins) with an increased deposition of clastic rocks.

A schematic classification is shown in a geologic column (see fig. A 4 after KREBS 1966, LIPPERT et al 1970).

In the Adorf stage the Langenaubach-Breitscheid reef complex builds on such a Hochschwelle. KREBS (1966) describes its paleogeographic development as follows:

1. The Middle Devonian Schalstein-volcanism produces a submarine rise.
2. On the rise an atoll reef is forming Massenkalk of the Adorf stage.
3. A complete sequence of sediments is settling on the slopes of this reef during the Upper Devonian and the Lower Carboniferous (continuous facies). On the decayed reef, sedimentation remains sporadic (discontinuous facies).

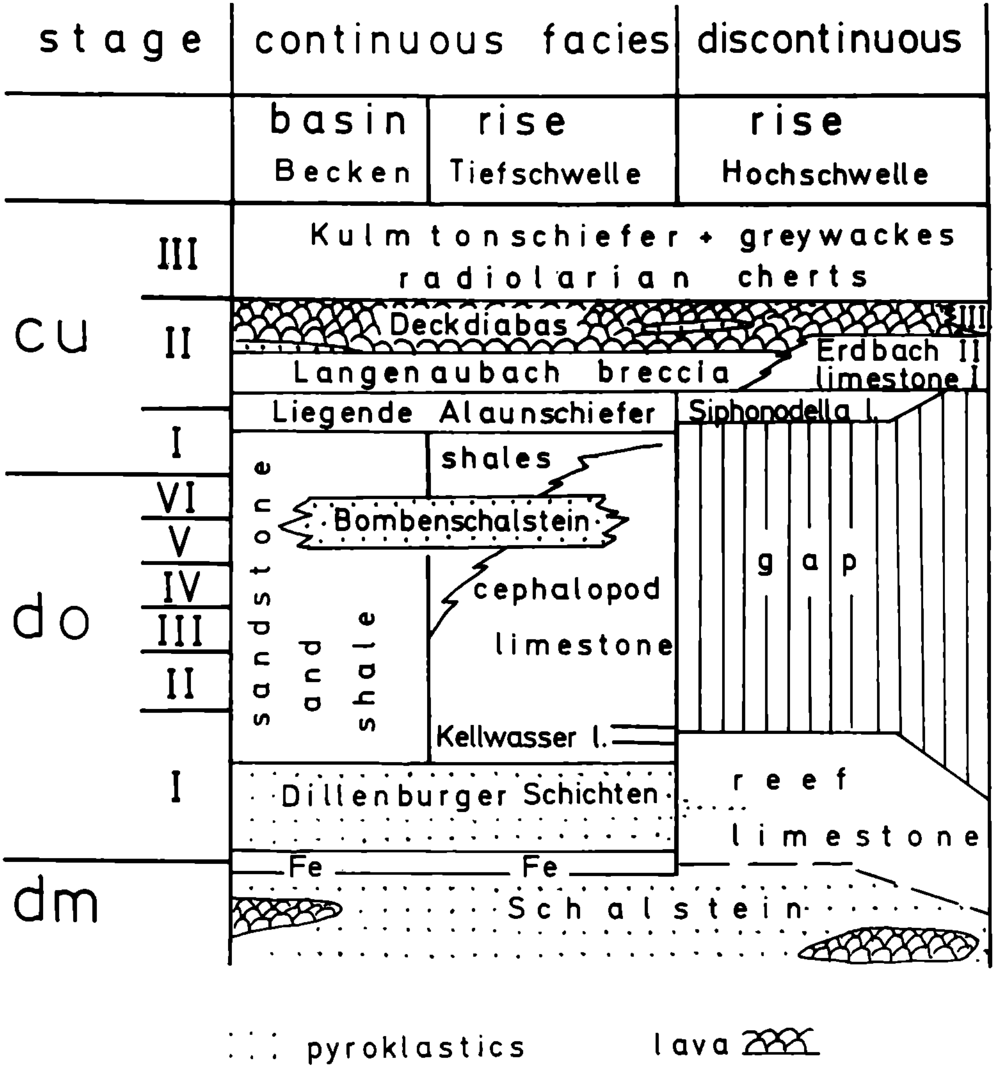


Fig. A 4 Schematic classification of Upper Devonian and Lower Carboniferous sediments in the Dillmulde/Rheinisches Schiefergebirge (according to KREBS 1966 and LIPPERT et al. 1970).

4. During the Lower Carboniferous the reef partly emerges and karstifies.
5. Soon after the emersion the northern part of the reef complex crumbles (linked to a volcanic earthquake). Blocks as high as houses are tumbling into the adjacent basin - less often into the lagoon. They form the Langenaubach breccia. The southern part remains stable.
6. The decayed reef is covered by sediments and the Deckdiabas.
7. During the Variscan tectogenesis intensive folding and slicing takes place. From the NW to the SE the following slices can be distinguished:

facies	Schuppe (slice)	sediment
continuous	I + IIa	sandstone and shale (basin)
	IIb + III	cephalopod limestone (Tiefenschwelle)
discontinuous	Ia, IV - VI	reef limestone
	VII	reef limestone and cephalopod limestone

Outcrops

1.1 Innersloch, disused quarry S of Langenaubach
(top.sheet 5215 Dillenburg, r 42580 / h 19480)

Age: Lowermost Upper Devonian (do I)
Tectonic position : Schuppe V
Sequence in Schuppe V:

Langenaubach breccia	(cu)
back-reef limestone	(do I)
Hunnacker tuffite	(10 - 20 m)
platform Massenkalk (= Hunnacker Limestone)	(do I)
Schalstein (=tuff)	(dm)

In this quarry the Hunnacker limestone at the base of the Massenkalk crops out (WIEGEL 1956). This dark, well stratified limestone is composed of fine pulp (bank-type or platform Massenkalk; compare classification of reef limestone facies on page25). It is overlain by the Hunnacker tuffite (WIEGEL 1956) which is made of yellowish brown, fine grained tuffs, and tuffites mainly of keratophyric composition. This athrogenic rock is supposed to be discharged by a tidal wave into the lagoon.

1.2 am "Kahn", disused quarry S of Langenaubach
(top. sheet 5215 Dillenburg, r 42720 / h 19550)

Age: Adorf stage
Tectonic position : Schuppe V
Reef-type Massenkalk, back-reef subfacies.

Well stratified limestones deposited in the lagoon of the Langenaubach-Breitscheid atoll reef with gastropods, amphiporids, rugose solitary corals, branchy tabulate corals, stromatoporids, ostracods, calcispheridae and pellets.

1.3 Quarry of Barbara Erzbergbau GmbH, NW of Erdbach
(top.sheet 5315 Herborn, r 44380 / h 17820)

Age: Givet stage (dm)
Tectonic position: Schuppe VII

Well stratified, gray Massenkalk (reef-type Massenkalk, back-reef subfacies) with intermittent tuff-layers. The tuffs which contain palagonitic material seem to be discharged by tidal waves into the lagoon.

1.4 Disused quarry, SW of Erdbach
(top. sheet 5315 Herborn, r 44450 / h 16950)

Age: Givet until Lower Carboniferous
Tectonic position: Schuppe VII

Sequence:	Kulm-greywackes
	Kulmtonschiefer
	Kulmkieselschiefer
	Deckdiabas III - IV
	Erdbacher limestone II
	Massenkalk

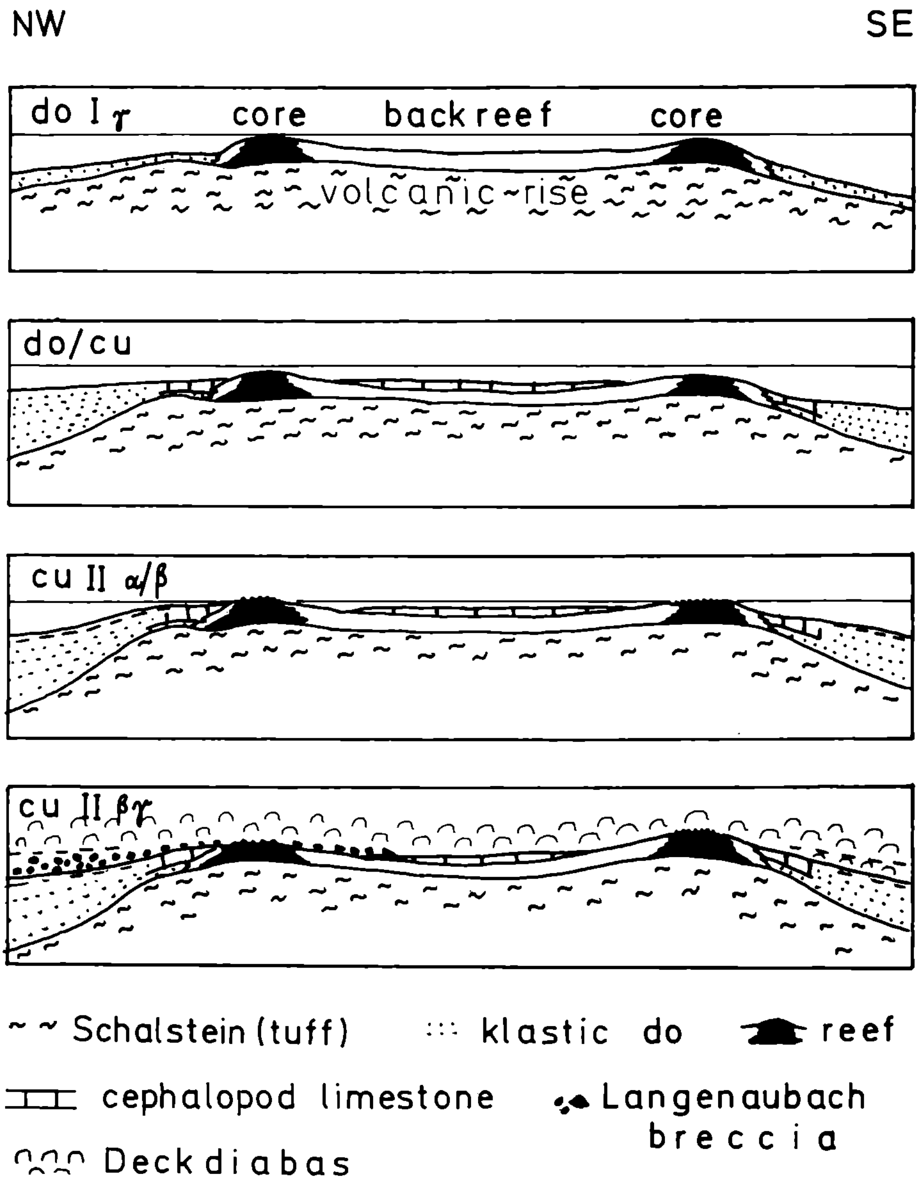


Fig. A 5 Paleogeographical development of the Langenaubach-Breitscheid reef complex (according to KREBS 1966).

a) Massenkalk (reef type, back-reef subfacies) close to the reef-core.

Assorted coarse debris-layers indicate the lee-side of the atoll, laminites and stromatolites the range close to emersion. Ooids are rock-forming sometimes.

b) Erdbach limestone II

Deep perpendicular fissures are filled with red crinoid limestone. These sedimentary dikes formed synsedimentary under the water. Ninety percent of the conodont fauna consists of reworked and rebedded older conodonts.

Fauna:	Scaliognathus anchoralis rebedded conodonts of the do	conodonts
	Liobole glabra glabra Archegonus sp.	trilobites

c) Deckdiabas III - IV

Thin Deckdiabas (cu) covers the uneven relief of the reef and fills the karst caves which formed after emersion.

1.5 Rombachtal E of Langenaubach
(top. sheet 5215 Dillenburg a: r /r
b: r 43260 /r 2o 3oo

a: "Marmorbruch"

Age: Upper Devonian

Tectonic position : Schuppe IIb

Sequence:	shales (Dasberg stage)	do VI
	"Bombenschalstein"	
	Cephalopod limestone	do I - V
	Kellwasser limestone	do I γ-δ
	Cephalopod limestone	do I γ
	Dillenburger Schichten(tuffit)	do I α-β

Typical pelagic limestones of the Tiefschwellen-facies.

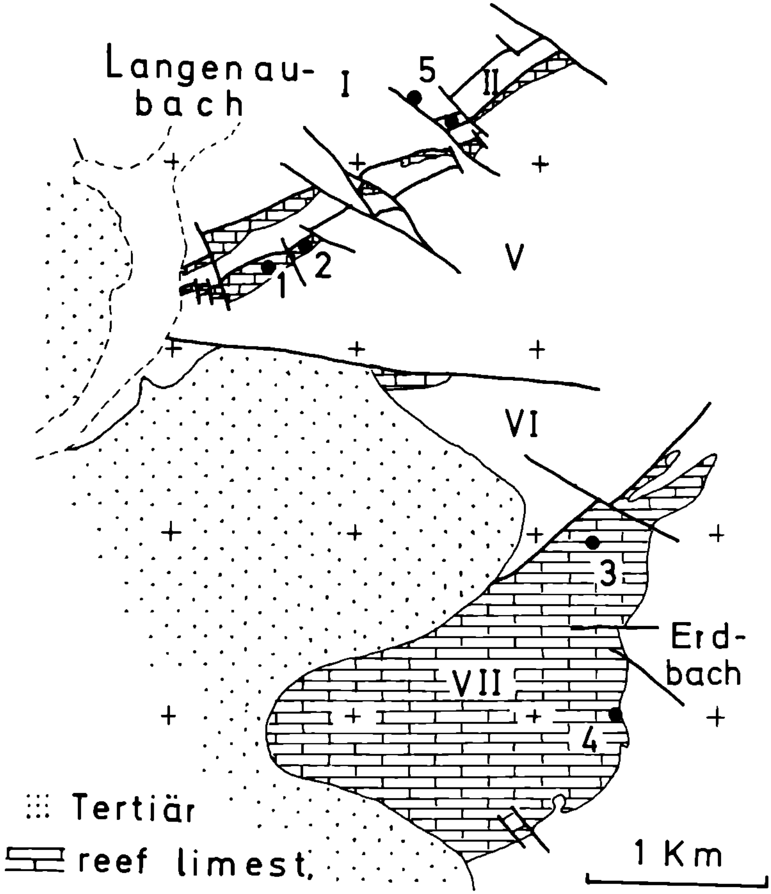


Fig. A 6 Simplified map of the Langenaubach-Breitscheid reef complex (according to WIEGEL 1956, and KREBS 1966).

B: Gorge and disused quarry "am Schleißberg"

Age: Upper Devonian until Lower Carboniferous

Tectonic position : Schuppe I (Beckenfazies)

Sequence: Deckdiabas
Langenaubach breccia II
Langenaubach breccia I
sandstone and shales (do VI - cu I)
Bombenschalstein
shales and sandstone (do I - V)
Dillenburger Schichten (do I)

Bombenschalstein: 25 m of diabasic bombs and limestone blocks with conodonts of the do V.

Shales and sandstones in typical "Beckenfazies" (basin).

The Liegende Alaunschiefer, supposed to follow here, is missing. However, black shale debris in the Langenaubach breccia shows that it was deposited, but eroded later by the down-sliding masses of the crumbling reef.

Langenaubach breccia: Blocks of reef limestone attaining the height of houses in a shaly ground mass. These blocks show a twofold filling of fissures: Settlement during the reef-building period opened fissures and cracks, which were charged with a red calcareous mud. Strain, probably caused by volcanic earthquakes, widened these fissures once again in the Lower Carboniferous. This time crinoid limestone poured in (with conodont Scaliognathus anchoralis). Continued earthquake activity led to the final partial destruction of the reef. The blocks slid down into the basin to form the Langenaubach breccia.

October 2nd

Subject: Carboniferous limestones of the Velbert Anticline (shelf to basin transition).

Guides: Wolfgang FRANKE, Wolfgang EDER, Wolfgang ENGEL

General setting

The Lower Carboniferous carbonate platform ("Carb.Limestone") of northwest Europe extends eastward as far as the Rheinisches Schiefergebirge. Immediately E of the Rhine, the platform sediments are replaced laterally by cherts, alum shales and nodular limestones of the Rhenohercynian basin ("Kulm"-facies).

The transitional area (Velbert Anticline) is occupied by limestone turbidites. Statistical investigation of bed thickness, internal organization, imbrication of the components and erosive channels indicate an unhindered discharge from the carbonate platform in an eastward direction (see fig. A 7).

Towards the SE, the total thickness of the limestone sequence and the number of individual beds decrease rapidly, while the proportion of graded breccia-beds increases. Breccia-beds prevail in the immediate vicinity of the Kulm-facies. This configuration - utterly abnormal for distal/lateral turbidites - is best explained by the influence of a NW-dipping palaeo-slope, which barred the turbidity currents from the SE. Hence, the turbidites must have been deposited in a moat-like depression extending along the shelf slope.

Evidently, the Kulm-facies is not only relatively thin, but also elevated above the level of turbidite sedimentation, and may thus be regarded as tectonically stable. This is in contrast to the rapid accumulation and synsedimentary subsidence of the shelf platform. The coupling of a subsiding shelf with a stable basin is typical for the Rhenohercynian area. The rapid subsidence of the shelves is attributed to sedimentary loads.

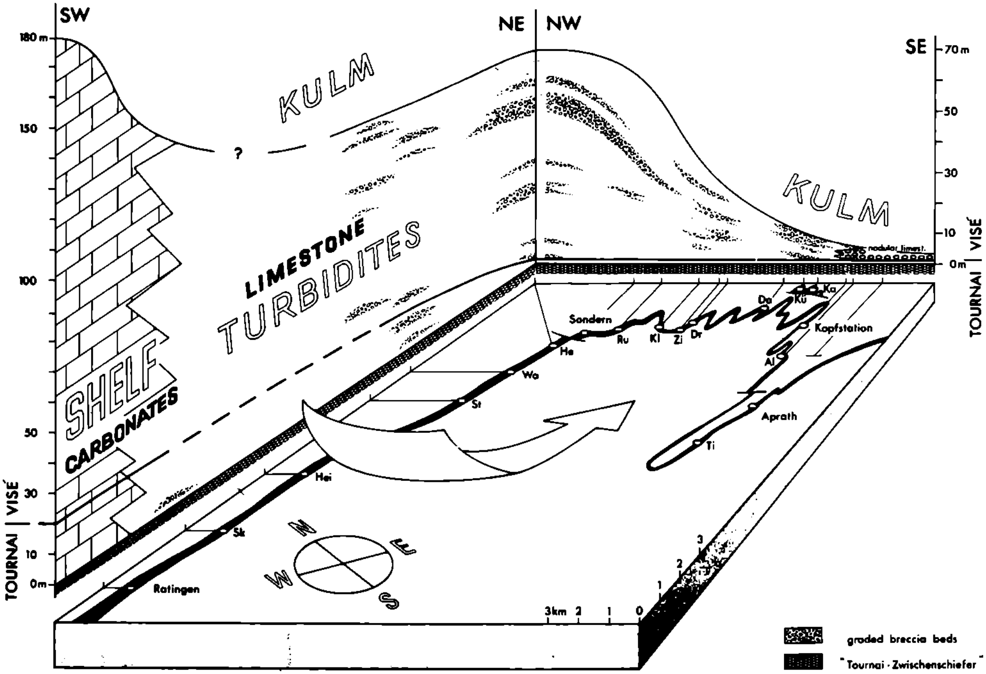


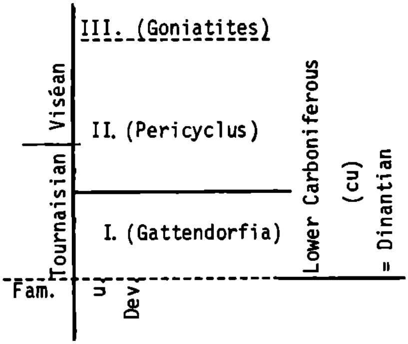
Fig. A 7 Diagrammatic summary of facies and thickness in the Lower Carboniferous sections of the Velbert Anticline. Individual sections have been projected onto two sides of a perspective block, constructed using metric projection (i.e. vertical scale and exaggeration remains constant). N.B. lower limit of Kulm is not isochronous.

Outcrops

1.1 Ratingen, flooded quarry "Blauer See"
(Top.sheet 4607 Kettwig, r 60 0000 / h 86 340

Upper Devonian and Lower Carboniferous shelf sediments. Sequence:

50 m Epigenetic dolomite
38 m Oolites and pellet limestones
73 m Limestone breccias and crinoidal limestones
1 m Phosphorite-bearing "Richrath Lst."
3 m Dark shales
15 m Limestone horizon ("Ostrakodenkalk") (poorly exposed)
Sandstones, shales, crinoidal lst. (Etroeungt facies)



Only outcrop of the Carboniferous shelf facies E of the Rhine. The dark shales are equivalent of the "Liegende Alaunschiefer" (cu II alpha alum shales), which form a marker horizon nearly throughout the Rheinisches Schiefergebirge. The Richrath Lst. represents a period of low rates of deposition (locally non-deposition) and marks the base of the Carb.Lst. in the Velbert area. The Visean breccias have been deposited on the shelf slope and are succeeded by shallow water limestones of the platform itself (southeastward enlargement of the platform).

1.2 Hefel, disused quarry N od federal road B 227, N of Velbert
(Top. sheet 4608 Velbert r 73 340 /h 91780)

Sequence:
58 m Limestone turbidites (uppermost Tournaisian and Visêan)
few cm Phosphorite-bearing Richrath Lst. (upper Tourn.)
0,7 m Dark shales & lst.
Limestones, oolites, shales (Tournaisian)

Typical exposure of the Carboniferous turbidite facies, situated near the main axis of transport, E of the zone of maximum bed thickness. Thick, graded breccia beds at the top of the section.

The basal limestones and oolites have been deposited immediately NW of the Tournaisian shelf margin, which was later integrated into the area of Visêan subsidence and subsequently covered by the turbidites.

1.3 Kleff, disused quarry at the Velbert-Langenberg road
(Top. sheet 4608 Velbert, r 75 620/h 89 960)

Limestone turbidites (Visêan). SE of Hefel (1.2), the sedimentation of turbidite facies is influenced by a NW-facing slope, which bars the turbidity currents from the SE. Only large high-energy turbidity currents are able to move up the slope. In consequence, the respective sections show a reduced total thickness (Kleff: 25 m) and a great portion of thick, graded limestone breccias. Erosive channels below breccia beds (see fig. A 8).

1.4 Zippenhaus, overgrown quarry SE of Kleff (1.3)
(Top sheet 4608 Velbert, r 76 060 /h 89 410)

Limestone turbidites (Visêan). Though there is only a distance of 500 m between 1.3 and 1.4, it is impossible to correlate individual beds. Due to the great loss of energy on the slope (see above), the turbidites may rapidly change their thickness and grain-size.

The upper part of the section exposes the transition into black lydites and shales of the Kulm facies (upper Visêan, L.Carboniferous III).

1.5 Kopfstation, small disused quarry E of Neviges (see fig. A 9)
(Top. sheet 4608 Velbert, r 78 210/h 86 130)

Nodular Limestones (uppermost Tournaisian and Visêan). The outcrop is situated on top of the rise, which blocked the flow of turbidity currents towards the SE. The fine-grained, nodular lst. represents the fine mud-clouds, carried along in the upper part of the suspension, and are able, therefore, to travel furthest onto the elevated area. Two coarse-grained, graded beds at the top of the section are the last traces of the normal turbidite facies in the NW. The limestones are overlain by black shales and lydites of the Kulm facies (L.Carbon. III).

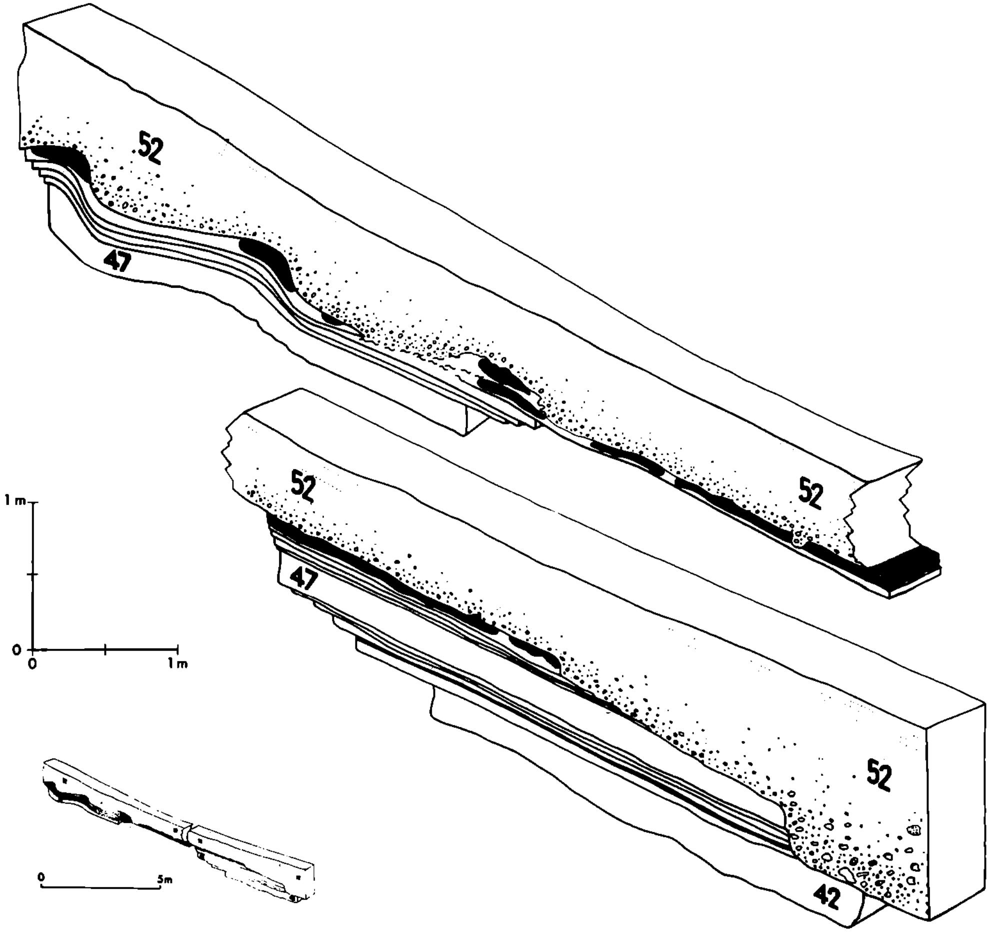


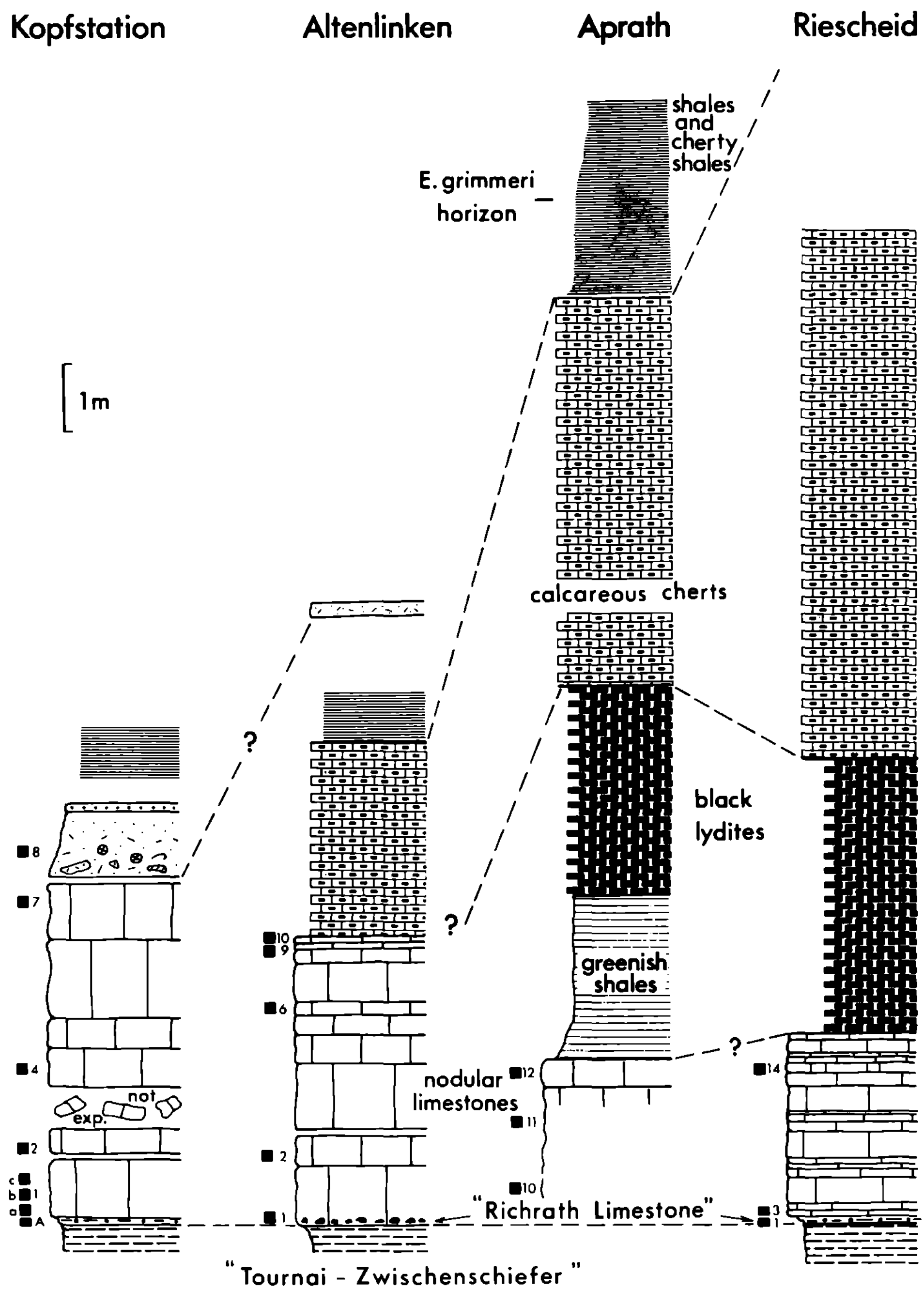
Fig. A 8 Erosional features below a graded breccia-bed (outcrop Kleff, bed no. 52). The erosive base tends to follow the bedding-planes and cuts down step by step. Pronounced channelling to the lower-right. Possible slumpfolding of beds no. 47 - 51 prior to erosion. Chert-lenses in black.

1.6 Aprath, (Gut Steinberg), small disused quarry NW of Elberfeld (Top sheet 4708 Wuppertal-Elberfeld, r 75 500/h 81 720)

Nodular limestones (Visêan), overlain by greenish shales, black lydites, calcareous cherts ("Kieselkalk") and black shales (normal Kulm sequence). Goniatites and trilobites frequent in the Kulm shales (BRAUCKMANN 1973).

In comparison with the Kopfstation section (1.5), the limestone facies is replaced earlier by the siliceous Kulm (see Fig. A 9). This is taken to indicate a gradual deepening of the water towards the SE, where the Carboniferous Lst. may be expected to wedge out completely (dissolution of carbonate in an euxinic environment).

Fig. A 9 Lithology and attempted correlation of the sections in the Herzkamp Syncline.



Kopfstation
Altenlinken
Aprath
Riescheid
shales
and
cherty
shales
E. grimmeri
horizon
1m
calcareous cherts
?
black
lydites
?
greenish
shales
?
nodular
limestones
not
exp.
8
7
4
2
c
b 1
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A
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9
6
2
1
12
11
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14
3
1
"Richrath Limestone"
"Tournai - Zwischenschiefer"

October 3rd

Subject: Clastic-shelf-sediments and carbonate-platform-sediments of the Middle Devonian in the region between Iserlohn-Balve and Meschede (Geol.map, see fig. 10).

Guides: Wolfgang EDER, Frank LANGENSTRASSEN

General setting

Thick sequences totalling up to 6000 m of predominantly clastic rocks of the Lower and Middle Devonian of the Sauerland are here considered to be shelf sediments which were deposited in a shallow neritic sea with adequately oxygenated and agitated water. The associated benthic fauna and trace fossils (especially in Middle Devonian formations) show a significant zonation depending on the distance from the shoreline and the kind and amount of sediment influx. In the inner region of the shelf there are intercalations of red beds, a larger amount of more or less fine-grained sandstones and a fauna which is fairly restricted in its diversity. The common sedimentological structures of the sandstones include large-scale cross-bedding (mega ripples), a certain type of ripple-drift cross-lamination, and often clay pebble layers.In the apparently more presorted sediments of the outer region of the shelf high diversity in the faunal spectrum and a larger content of carbonates among the sediments are characteristic. Small biostromes were built up by reef-builders which were able to overcome burial and suffocation by clayey and clastic sediments for only a relative short time. Conditions changed in the higher part of the Givetian (Massenkalk). Framebuilders like stromatoporoids, corals and bryozoans appeared in well-lit, high energy zones. There are other indicators for a very shallow neritic environment: e.g. relatively thin limesotne beds with ooliths and algal micrite or oncoliths within the normal sediments and a local dominance of characteristic vertical burrowers.

As the transition of normal shelf to the ore near-shore facies is a very gradational one, palaeogeographical zonation of the early Middle Devonian shelf(below the Massenkalk) is very difficult. There are tendencies to look for outer parts of huge deltaic regions in the NW of the Sauerland grading into a shallow sea without a strong relief to the SE.

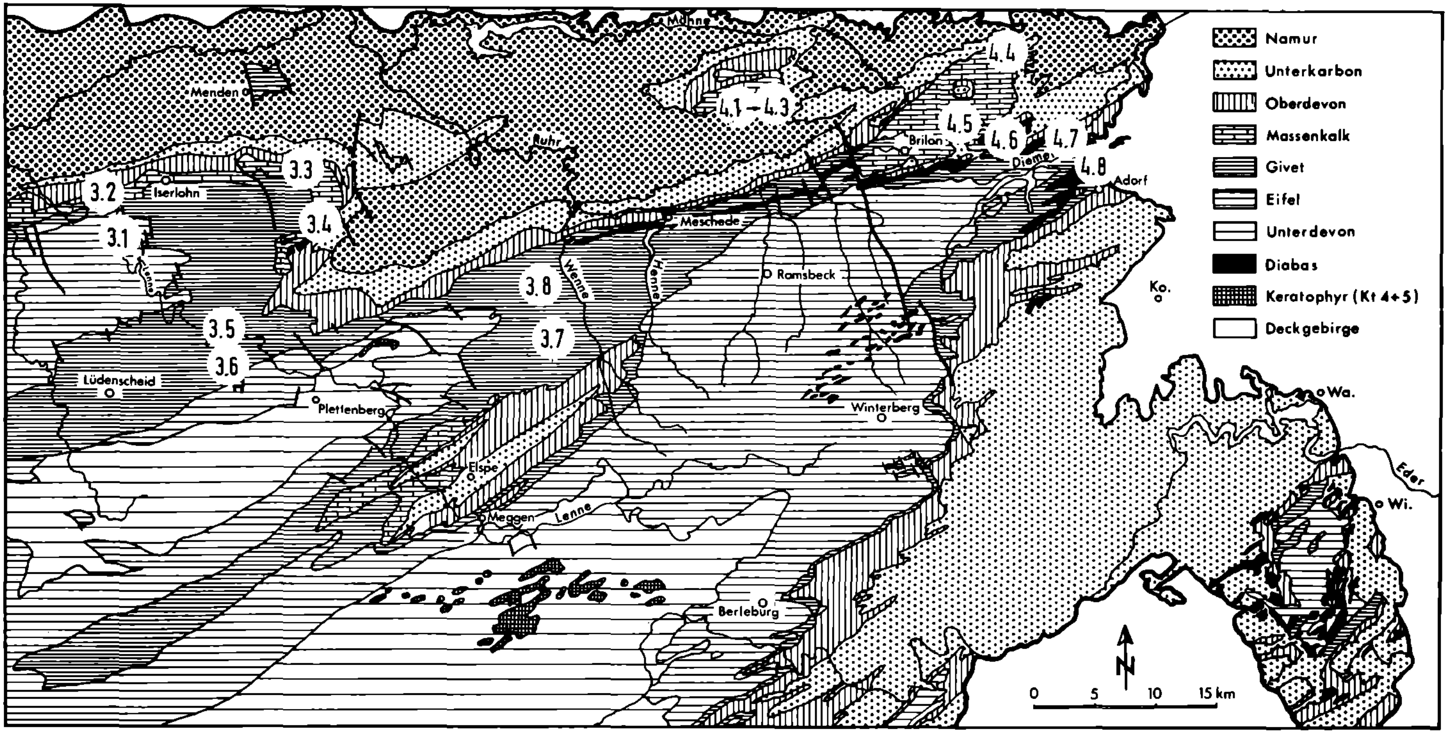


Fig. A 10 Geological map of the northeastern Rheinisches Schiefergebirge. Numbers indicate location of outcrops to be visited (Oct. 3rd and Oct. 4th).

The average rate of sedimentation or subsidence is about 0,5 mm/grassuming 6000 m maximum thickness of deposits during mid Devonian time.

At the end of the Middle Devonian a decrease of supply of sandy material (from the NW) (Old Red Continent) marks the beginning of a period more or less dominated by carbonates. Up to 1000 m thick, carbonate platform-sediments were established in different regions: One can find the Devonian reef limestones of the Rheinisches Schiefergebirge, which are generally termed "Massenkalk" (PAECKELMANN, 1913) on the shelf (Wülfrath, Dornap, Wuppertal, Hagen-Iserlohn-Balve, Warstein), near the shelf-margin (Bergisch-Gladbach, Attendorn, Brilon), and in the adjacent basinal area on the tops of volcanoes (Lahn-Dill)(see fig. A 2).

The form of the Massenkalk varies after KREBS (1968) from "bank-type-" and "reef-type-" to "cap-type-Massenkalk". The dominant facies is the bank-type, which can be found on the whole flat shelf area of the old Red Continent. The reef-and cap-type, however, represent more or less isolated structures on the margins of the shelf or bank-type-platforms and in the southeastwards adjacent open sea. There are no sharp boundaries between these three major facies-units; often one can recognize convergent or similar exposures in different regions. Nevertheless a short description according to KREBS, 1971, of the three major facies units is useful.

Bank-type- or platform-Massenkalk: This facies consists of a bedded or lens-like succession of homogeneous dark, bituminous, dense mikrosparites. The fossil content may vary from bed to bed: stromatoporoids, corals, brachiopods, echinoderms, gastropods, ostracods, calcispheres and algae. The organisms of this facies live in most cases below the level of strong wave action. A few marl- and shale beds alternate with the limestone banks.

Reef-type-Massenkalk: In general massive grey, debris-rich biosparites, which can be devided into fore-reef, reef-core and back-reef. Only a very low percentage of the reef-facies consists of the true reef-core ($<$ 5%). The main reef-building organisms in the Devonian reefs of the Rheinisches Schiefergebirge are the stromatoporoids, while tabulate and rugose corals as well as calcareous algae also play a minor but subordinate role in the formation of a wave-resistent organic framework.

Cap-type-Massenkalk: This facies consists of grey, sparry calcite-cemented brachiopod-crinoid-limestone, which is very similar to the fore-reef detritus. It represents the uppermost parts of the "Massenkalk" and is of early Upper Devonian age.

The reef-limestones of the Rheinisches Schiefergebirge are of great influence over a time-span of probalby 25 to 30 mio. y. Not only on the place, where they are growing but also in the surrounding areas they steered the conditions of sedimentation by their shear masses of biogenic debris.

2.1 Quarry on Lasbecker Tal W of Lasbeck/Lenne

(Top.sheet Hohenlimburg 4611, r 04 20/h 9090)

(Alternative: Quarry in Hamper Tal W of Ambrock/
(Top. sheet Hohenlimburg 4611, r 99 10/h 8845)

Fine-medium grained sandstone, siltstone, mudstones, red and green silty shales. Thick bedded sequence with characteristic pinching-out structures in the clastic beds, cross-bedding, a special type of ripple-drift cross-lamination, clay pebble-layers and well defined bioturbated horizons within the siltstones. Desiccation cracks can occur in the red siltstones. Impoverished fauna (ostracods, lamellibranchs) and large plant fragments.

Inner shelf region, brackish environment.
Upper Brandenburg beds, Upper Eifel-Stufe
NE-flank of Remscheid-Altena-Anticline.

2.2 Disused quarry E of Letmathe
(Top. sheet Hohenlimburg 4611, r 34 04 18/h 569315)

Lithology:

Topmost parts of the Massenkalk, Transition from unbedded reef-limestones to well-bedded, shallow water limestones. Intercalation of dm-thick, limestone-beds and marly shales. It is suggested that early diagenetic processes (solution and reprecipitation of carbonate) has formed this regularly bedded succession (EDER, 1975). Total thickness 30 m. In the uppermost parts of the section turbidite beds can be recognized.

Fossil content: Stromatoporoids (globular, lamellar) rugose and tabulate corals, brachiopods, echinoderms, gastropods, algae. The fauna is enriched in the shales.

Age: Uppermost Givetian

2.3 Upper floor of the disused quarry "Emil" (Rheinisch-Westfälische Kalkwerke) on the western side of the Hönne Valley, south of Oberrichinghausen.
(Top.sheet Balve 4613, r. 34 19 58/h 569336)

Southern wall

Transition from reef- to back-reef facies. Massive stromatoporoids of 50 cm and larger build up a reef-wall, in the interstices of the stromatoporoids colonies occur detrital limestones with crinoids, algal coated solitary rugose corals, and broken brachiopods. In the upper portion several types of back-reef limestones are existent.

Northern wall

Section of bank-type-facies; amphiporids and brachiopods are abundant.

2.4 Disused quarry at the railway station "Sanssouci", north of Balve
(Top.sheet Balve 4613, r 34 2208/h 56 9150)

Lithology:

Thickbedded, dark grey, micrite, very fossiliferous limestones of the bank-type facies are exposed.

Fauna: autochthonous, globular stromatoporids, amphiporids, tabular corals, gastropods, brachiopods. One tuffitic shale is probably time-equivalent to the submarine diabase volcanism in the Balve region.

2.5 Road cut 1,5 km SW of Werdohl opposite of the hotel "Forsthaus Beul"
(Top.sheet Altena 4512, r 12 52/h 8000)

Finegrained sandstone, bioturbated silt- and mudstones, calcareous shales. Gradual transition from sand- and siltstones with ripples and trace fossils (Chondrites f.ex) to silt- and mudstones with some typical species of brachiopods (Athyris amanshauseri) and to calcareous-argillaceous rocks rich in fenestellid bryozoans and ramose or incrusting tabulate corals finally ending in calcareous mudstone with branching and massive types of corals and stromatoporoids. The normal more clastic sediments should cover the whole sequence.

The gradual development of the coral beds from the normal sediments and the repetition of such sequences indicate more or less very similar bathymetric conditions of both the different lithologic types of rocks.

Relatively shallow shelf, lower Housel beds, early Givetian of the Lüdenscheid Syncline.

2.6 Road cut at the federal road B 229 N of Kleinhammer
(Top.sheet Altena 4512, r 1350,/ h 7910)

Finegrained sandstone, siltstones, mudstones, silty limestones in a well-bedded sequence. Sandstone with well-exposed bedding planes covered by large Chondrites and other trace fossiles. Silt- and mudstones highly bioturbated. Clay-pebble layers ripples, cross bedding and lamination are common sedimentary structures. The silty limestone beds show a very fine oolithic structure (grain diameter: 0,2 mm) and fragments of Dechenella burmeisteri. Some crinoid beds may occur in the lower part of the section shallow shelf with a poor benthonic fauna only.

Higher part of lower Housel beds,

Early Givetian of Lüdenscheid Syncline.

2.7 Disused quarry 0,7 km NW Niedersalwey
(Top.sheet Endary 4514 r 38 440/ h 80670)

Calcareous mudstone with small calcareous nodules, siltstones finegrained sandstones.

Rich benthonic fauna in calcareous mudstone within the more bioturbated lower part of the section: mainly brachiopods (Cystodentella beratophora, Chonetes "schlotheimi", Xystostrophia umbracula etc.), solitary rugosa and some tabulata, a few stromatoporoids.

Some beds show transportation of the fossils, other indicate more quiet conditions in preservation and arrangement of the fossils. In the more clastic sequence trace fossils such as small Chondrites, Zoophycos, Muensteria; plant fragments and crinoid debris are common. Outer shelf region.

Upper Finnentrop beds (Middle Gevetian)

SE-flank of Ebbe anticline.

2.8 Cutting behind VELTINS-brewery at Grevenstein
(Top.sheet Arnsberg-S 4614, r 3903/h 8596)

Steeply dipping silts- and sandstones. Fossiliferous mudstone in the upper part of the sequence.

Main part of the section with more or less bioturbated siltstones and laminated sandstone with ripple marks. Some shelly beds filled by Subrensselandia amygdala and Unispirifer gerölsteinensis. On the bedding surface trace fossils including small Chondrites and Zoophycos may occur. In the N. part of the section mudstone with broad faunal spectrum. Outer shelf region.

Lower Finnentrop beds and Blessenohl beds (Middle Givetian)

NE' Ebbe-Anticline

October 4th

Subject: Facies distribution of the Middle/Upper Devonian Brilon reef and contemporaneous limestone-turbidites (EDER, ENGEL, FRANKE). Lower carboniferous shallow water and down-slope sedimentation associated with the Devonian Warstein Carbonate complex (UFFENORDE).

Guides: Wolfgang EDER, Wolfgang ENGEL, Wolfgang FRANKE, Henning UFFENORDE

General setting

In the northeastern part of the Rheinisches Schiefergebirge the Brilon reef-complex marks the hinge line between the former late Middle Devonian shelf in the NW, and the pelagic area in the SE. The calcareous shales, underlying the reef-limestones, contain abundant benthonic faunas, whereas time-equivalent dark shales with planktonic and nektonic organisms settled in the adjacent basin.

The actual outcrop of the Brilon reef limestones shows a highly complex facies pattern in space and time. In general back-reef limestones and irregularly distributed patch-reefs are dominant in the NW, bordered by a rim of near-reef and fore-reef limestones in the SE (fig. A 11).

From the beginning of the reef growth onwards fore-reef material was shed into the southeastern pelagic area by the action of turbidity currents.

The transition from the reef limestones to the limestone turbidites is roughly marked by basaltic volcanics which extruded during the first stages of the reef growth, thus modifying the submarine topography of the reef-(shelf-) slope.

From the sedimentological analysis of the turbidite sequences (fig. A 12) follows, that the course of the turbidity currents is neither significantly influenced by the volcanic relief nor by a Schwellen-area as demonstrated for a similar paleotectonic position of the marginal lower carboniferous carbonate platform (compare 2nd day of this excursion).

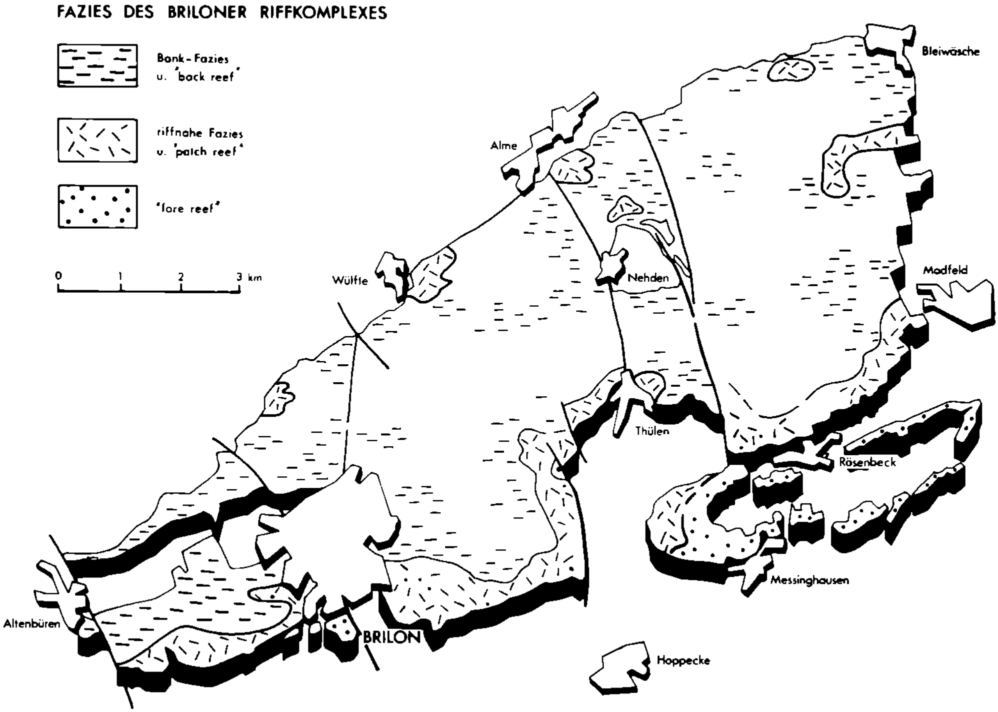


Fig. A 11 Idealized facies distribution in the Brilon reef complex.

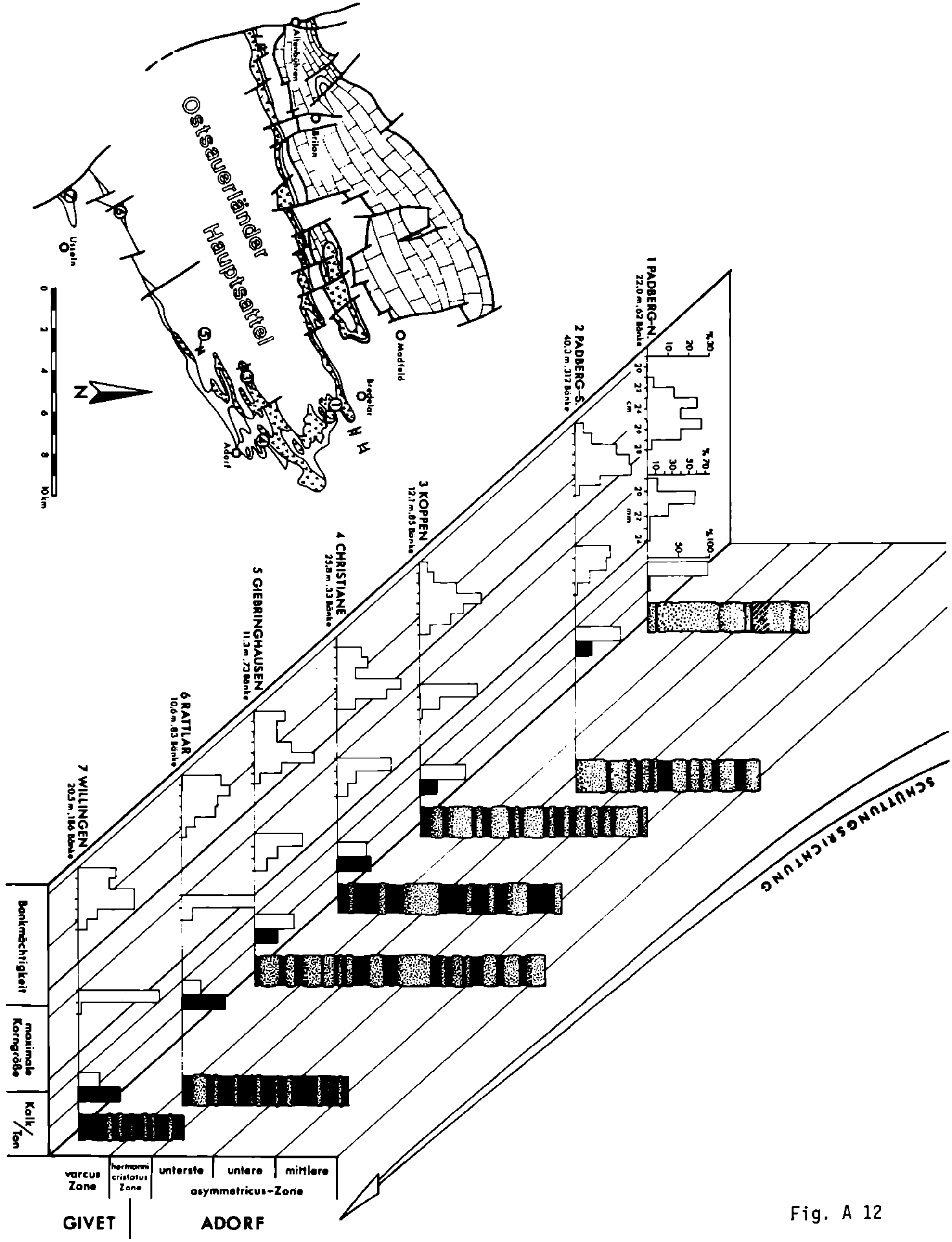
Obviously in the Brilon area the zone between the rapidly subsiding shelf (or reef complex) and the relative stable pelagic basin reacted by fracturing rather than by a flexure-like depression.

The accumulation of several hundred meter thick reef-limestones ends in the lowermost Upper Devonian. Nevertheless discontinuous condensed sequences of shallow water limestones are reported from the top of some inactive reef complexes (BÄR 1966, GWOSDZ 1972), showing that the former reefs still remain in a topographic high position during the Upper Devonian. Their influence on the adjacent deeper water sediments (micritic limestones, red and green shales) is documented by intercalations of arenitic limestones (FRANKE 1975, UFFENORED 1975).

During the Lower Carboniferous, shallow-water carbonate are not entirely restricted to the shelf areain the NW, but can also arise by recolonization of the former Devonian carbonate complexes, which still provide isolated shallow-water areas within the basinal environment (see fig. A 3).

While a reactivation of the Attendorn reef complex (at least in part) is obviously recorded by the large amount of detrital limestone to the north of this area(Hellefeld limestone R.GAUGLITZ 1967, Westenfeld limestone HELMKAMPF 1969; GWOSDZ 1972), little is known about eastern margin of the Rheinisches Schiefergebirge.

One of these carbonate sources in the "Kulm realm" has just been discovered in the Warstein carbonate complex near the NNE-margin of the Rheinisches Schiefergebirge (Kallenhardt limestone UFFENORDE, in prep.), where Upper Tournaisian limestones seem to overstep Upper Devonian micritic limestones (partly cephalopod limestones) and Middle Devonian bank-type limestones of the "dense limestone facies"(cf.KREBS 1974) and the stromatoporoid-coral facies. Both belong to the Schwelm facies. The paleogeographic position of the Middle Devonian Warstein carbonate complex seems to have been located more to the shelf interior than the Brilon reef (see fig. A 2).



Ostsauerländer Hauptsattel
Altenbüren
Brilon
Madfeld
Bredelar
Adorf
Usseln
N
0 2 4 6 8 10 km
1 PADBERG-N.
22,0 m, 62 Bänke
2 PADBERG-S.
40,3 m, 317 Bänke
3 KOPPEN
12,1 m, 85 Bänke
4 CHRISTIANE
25,8 m, 33 Bänke
5 GIEBRINGHAUSEN
11,3 m, 73 Bänke
6 RATTLAR
10,6 m, 83 Bänke
7 WILLINGEN
20,5 m, 186 Bänke
% 30
% 70
% 100
cm
mm
Bankmächtigkeit
maximale Korngröße
Kalk/Ton
varcus Zone
hermanni cristatus Zone
unterste
untere
mittlere
asymmetricus-Zone
GIVET
ADORF
SCHÜTTUNGSRICHTUNG

Fig. A 12

The southern margin of the Warstein inlier exhibits a succession of up to 40 m thick Carboniferous limestones with from W to E decreasing organic content and increasing redepositional intercalations. Submarine slumping marks the marginal parts of thick carbonate sedimentation as similarly observed in the Hellefeld limestone by HELMKAMPF(1966). North of the area of distribution of Upper Tournaisian limestones coeval and older redepositional breccias occur passing upward into graded units and laterally into pebbly mudstones suggesting a submarin channel deposition.

In terms of the German conodont zonation the limestones belong to the Upper Siphonodella crenulata-Zone and the lowermost part of the Scaliognathus anchoralis-Zone. The limestones are time-equivalents of the upper part of the widely distributed "Liegende Alaunschiefer" and the lower of the "Kulm-Kieselschiefer" in the basinal Kulm-facies.These limestones fill a paleogeographic and paleoecologic as a biostratigraphic gap in our knowledge of the Upper Tournaisian development of the Rhenohercynian Geosyncline.

O u t c r o p s:

The 3 localities to be visited show different parts of Lower Carboniferous carbonate complex and its margin, in a roughly SW to NE directed traverse from the carbonate platform to the base of slope.

3.1 Rock cave "Hohler Stein"
2.4. km SW of Kallenhardt (Top sheet 4516 Rüthen, r 58 560/h 00 400)

Wavy to thin-bedded biomicritic limestones, partly rich in intraclasts, with intercalations of stromatoporoids, corals, and crinoids stem fragments; poor in conodonts (mostly reworked).

The cave was formed by erosion of an intercalated crinoidal limestone bed (0,2 to 0,5 m thick, rich conodont ("ghost" fauna) by the Lörmecke Creek.

Important prehistoric locality: Middle Stone age (Kallenhardt stage), Iron age (Latène substage) cf. HENNEBÜLE 1963).

Fig. A 12 Proximal to distal development of the limestone turbidites south of the Brilon reef complex. Sedimentological profiles and parameters (bed thickness, maximum grain size, limestone/

3.2 Quarry 1.1 km SSW of Kallenhardt (Top.sheet 4516 Rüthen, r 59 820 / h 01 180)

Top 11.5 m mainly micritic limestones, as in the basal part of the section, with individual dolomite layers (mostly strongly boudinaged, partly dolomitic phacoids, intraclastic limestones, and rare stromatoporoid bioclasts.

8 m mainly slimps with phacoids of laminated lime-and dolostones (slump direction roughly S to N), intraclastic limestones with fibrous clacite veins in black shales.

11 m micrite limestones, banded, laminated, low angle cross-bedded, partly redepositional with slump-folds in cm to dm scale, intraclasts, locally with arenitic lenses; rather high tectonization (abundant calcite veins).
Base

3.3 Disused quarry on the old road from Kallenhardt-Heide to Rüthen, 750 m E of Kallenhardt (Top sheet 4516 Rüthen, r 6080/h 02 100)

Interstratification of marginal redepositional breccias ("Schlagwasser Breccie") into basinal shales.

Components mainly various micritic limestones (cephalopod limestones), seldom corals (e.g. Phillipsastraea) and stromatoporoids; age: mainly Frasnian to lower Famennian.

Final phacoidization and interstratification into shales in the Upper Tournaisian (by evidence in road cutting S of Kallenhardt).

3.4 Disused quarry S of Bleiwäsche "Onkel Franz" (Top sheet Madfeld 4518, r 347 972 / h 57 0360)

Thick bedded, dark grey limestones of the "Massenkalk-bank-facies" only partly rich in fauna. Transition to back-reef-facies.

3.5 Disused quarry E of Thülen, (Top.sheet Alme 4517, r. 347 540/h 56 9820)

Thick bedded dark grey, very fossiliferous limestones of a "near-reef= bank-type-facies are exposed. Specially some fissures are of interest filled with sediments of the Upper Devonian and Lower Carboniferous.

3.6 Active quarry at the eastern slope of Burg-Berg E' Rösenbeck (Top. sheet 4518, Madfeld, r. 79 750/h. 97 550)

Complete section from the Middle Devonian up to the Lower Carboniferous (Visêan, cu III alpha).

Above the volcanic rocks of the late Middle Devonian (Hauptgrünstein") follow fore reef limestones, which contain breccia beds in the lowermost part and fine grained detrital beds on top. These rocks were overlain by micritic cephalopod-bearing limestones with some intercalation of detrital layers especially in the lower part.

The Devonian/Carboniferous boundary is documented by the "Hangenberg" shales and limestones, a typical horizon, which is widely distributed over the whole Rheinisches Schiefergebirge.

Above follow dark shales and lydites which indicate the pelagic Kulm-facies of the Lower Carboniferous. The sequence is topped by the "crenistria beds", which normally consist of three micritic limestone beds containing abundant cephalopods (mainly Goniatites crenistria) and can be traced from the Harz mountains to south-western England.

3.7 Disused quarry S of Padberg-town (Top. sheet 4518 Madfeld, r 85 550 / h 96 300)

Limestone turbidites of the late Middle Devonian and early Upper Devonian. In the lowermost part of the section thick-bedded (up to 70 cm) partly indistinctly graded beds. Towards the top of the exposure thinner beds with distinct graded bedding and parallel lamination. Many of the beds exhibit erosive bases. Biogenic detritus mostly consists of crinoids, shell fragments and corals.

Rather proximal environment is indicated by the high grain-size/ bed-thickness ratio of individual beds as well as the high portion of turbidites compared with the shaly intercalations.

3.8 Road cutting at the former iron mine "Christiane", N.of Adorf (Top. sheet 4618 Adorf; r 86 150/ h 93 250)

Limestone turbidites of the uppermost Middle Devonian to lowermost Upper Devonian. Individual beds range in thickness up to 65 cm. They are considerably finer grained than beds of comparative thickness in the north. The low turbidite/shale-ratio and the structural organisation indicates deposition in a more distal environment.

October 5th

Subject: Attendorn Carbonate Complex (W. GWOSDZ)

Guide: W. GWOSDZ

General setting

The Attendorn carbonate complex is situated at the external shelf margin, which during the Middle Devonian marks the boundary between thick shallow water sediments in the northwest and thinner pelagic deposits in the southeast. The carbonate complex is built on thick clastic shelf sediments. The lower part of the carbonate complex is occupied by the Schwelm facies. According to GWOSDZ (1971), the Schwelm facies attains a thickness of 150 - 300 m at the northwestern flank of the Attendorn syncline, at the southern flank of the Dünschede anticline only 50 - 100 m. The higher part of the carbonate complex is occupied by the Dorp facies, which attains a maximum thickness of about 650 m in the Fretter Valley. The greater thickness of the Schwelm and Dorp facies in the northwestern part of the carbonate complex is certainly a consequence of strong subsidence in the Finnentrop-Eslohe Basin during the reef growth.

Although the carbonate complex is strongly folded and faulted, the spatial arrangement of subfacies types of the Dorp facies shows an original atoll-like formation. The back-reef subfacies covers the greatest portion of the area. The broad band of the fore-reef subfacies at the northwestern flank of the Attendorn syncline supports the assumption that an inter-reef basin must have been situated further to the northwest.

Southeast of the Attendorn carbonate complex, pelagic sediments of the trough border overlay the lagoonal facies at a great overthrust. Here the reef rim and the fore-reef area are tectonically reduced.

The pyrite-sphalerite-barite ore deposit of Meggen, situated about 4 km of the southeastern margin of the Attendorn reef is of great economic importance. The Meggen ore is bound to the pelagic shale facies of the trough and approximately belongs to the top of the Givetian.

The Meggen ore is timeequivalent to the upper part of the Dorp facies of the Attendorn reef. The amount of sulfide ore is about 60 millions tons on an average of 7% zinc.
Literature: W .KREBS 1971

Stop 1 : Quarry north of Weringhausen.
(Top.sheet Altenhundem, r. 3430 140, h. 5671 200)

On the east wall of the lower floor massive beds of reef-facies and bedded fore-reef-limestones are well exposed. In the reef autochthonous tabular stromatoporoids are dominating. The stromatoporoids grade in spherical and massive growth forms. Some colonies come to a size up to 50 cm. The more bedded fore-reef limestones belong to the detrital stromatoporoid-echinoderm facies. This type consists of calcirudites and calcarenites containing angular fragments of tabular to massive stromatoporoids. The stromatoporoid fragments - together with overturned Alveolites, dendroid Stromatoporoids, tabulate and rugose corals and brachiopods - are embedded in a sparite cement crinoid matrix. Some fore-reef beds show cross bedding. The alteration of in-situ stromatoporoids and detrital beds indicates that the detrital stromatoporoid-crinoid facies here was deposited in more turbulent water at the upper part of the fore-reef slope. Late diagenetic dolomitization occurs as euhedral rhombs along bedding planes, styliolites and margins of larger skeletal fragments.

Stop 2 : Wall at the road Weringhausen - Deutmecke.
(Top.sheet Altenhundem, r. 3430 900, h. 5671 850)

In the late Middle Devonian fore-reef limestones a local brachiopod-molluscan-coral accumulation occurs as nest or as cave-like depression. Well preserved goniatites, orthoceratids, brachiopods, lamellibranchiates, gastropods, trilobites, bryozoans and rugose corals, embedded in a sparite matrix, can be found. From this locality HOLZAPFEL (1895) discribed 35 brachiopod specimens. The goniatites belong to the genera Maenioceras and Tornoceras.

Stop 3 : Quarry in the Fretter Valley west of Deutmecke.
(Top.sheet Altenhundem, r. 3431 640, h. 5672 300).

The fore-reef limestones of this locality consist in the lower part of thicker bedded crinoid-brachiopod limestones. They are partly characterized by broken and overturned fragments of stromatoporoids, Alveolites, Heliolites and solitary rugose corals. One thick bed contains light gray carbonate fragments, together with several broken reef organisms which are embedded in a dark colored, fine grained echnoderm-rich matrix. This fragments include cavities which are filled with a fibrous calcite fabric. There is no doubt that these cavity fillings were formed before the seaward erosion took place. Consequently, the calcite filles, reworked cavities are an indication for an early void-filling cementation in the Devonian reef limestones (KREBS 1969).

In the upper part of the quarry, well bedded dark gray, fine-grained argillaceous limestones with crinoid ossicles occur. This fore-reef type forms the outer margin of the fore-reef slope and grades into the off-reef facies.

Stop 4 : Quarry north of the road Grevenbrück - Bamenohl.
(Top.sheet Altenhundem, r. 3430 620, h. 5668 400).

The well bedded, dolomitizised, dark gray limestones represent the dark Amphipora facies and dark fossil-poor micrite facies in the back-reef lagoon of the Attendorn reef complex. Individual beds contain branching tabulate corals and intraformational conglomerates. The cleavage planes dip steeper to the southeast than the bedding planes. Some organisms are slightly deformed by theschistosity. This section is interpreted as deposit in a quiet, semi-restricted environment in the central part of the Attendorn back-reef lagoon.

Stop 5 : Quarry southeast of Heggen.
(Top.sheet Attendorn, r. 3427 140, h. 5668 960).

In this quarry back-reef limestones, situated near the reef are well exposed. Within the back-reef limestones the detrital stromatoporoid-coral-algal facies predominates. This type is characterized by light gray, sparry skeletal rudite limestones. The reworked reef organisms consist of dendroid stromatoporoids of Stachyodes type and Amphipora type , fragmented or subordinately intact branching tabulate corals , solitary rugose corals, calcareous algae (Solenopora), brachiopods, echinoderms, ostracods and calcispheres. Micritic algal encrustions of the stromatoporoids and corals are very typical for this facies. In the highest part of the back-reef sequence some beds of Stachyodes facies and light Amphipora facies also occur. In several beds tabular stromatoporoids form inceptions of small, flat patch-reefs. Small sedimentary dikes, filled with red or gray clacilutites, are another characteristic feature of this locality. The stromatoporoid-coral-algal facies always occurs adjacent to the lee of the rim and represents a deposit of an agitated shallow water environment.

Stop 6 : Wall at the road Heggen- Ennest.
(Top.sheet Attendorn, r. 3426 160, h. 5669 230).

Schwelm facies: well bedded, fossiliferous, micritic limestones.

Stop 7 : Quarry at the Atta-cave, Attendorn
(Top. sheet Attendorn, r. 3424 150, h. 5666 400).

Reef facies with autochthonous tabular stromatoporoids; the stromatoporoids are well preserved and not recrystallized.

Fig. A 13 Thickness of Devonian bank and reef facies in the Attendorn carbonate complex (after GWOSDZ 1971).

Fig. A 14 Reconstruction of the original size of the Attendorn reef complex and palaeogeography during early Famennian. Distribution of black Nehden Shale in the former back-reef depression of the reef complex (after GWOSDZ 1971).

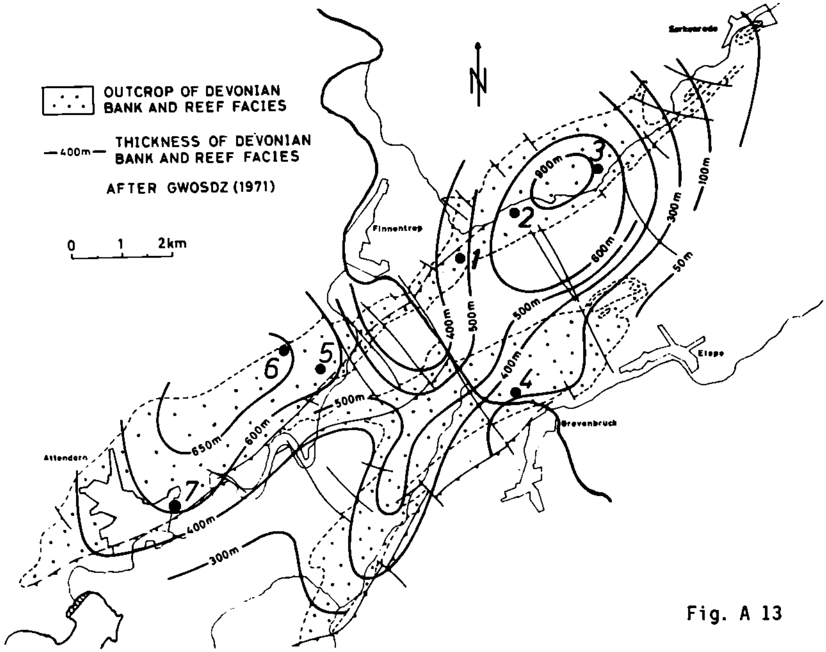


Fig. A 13

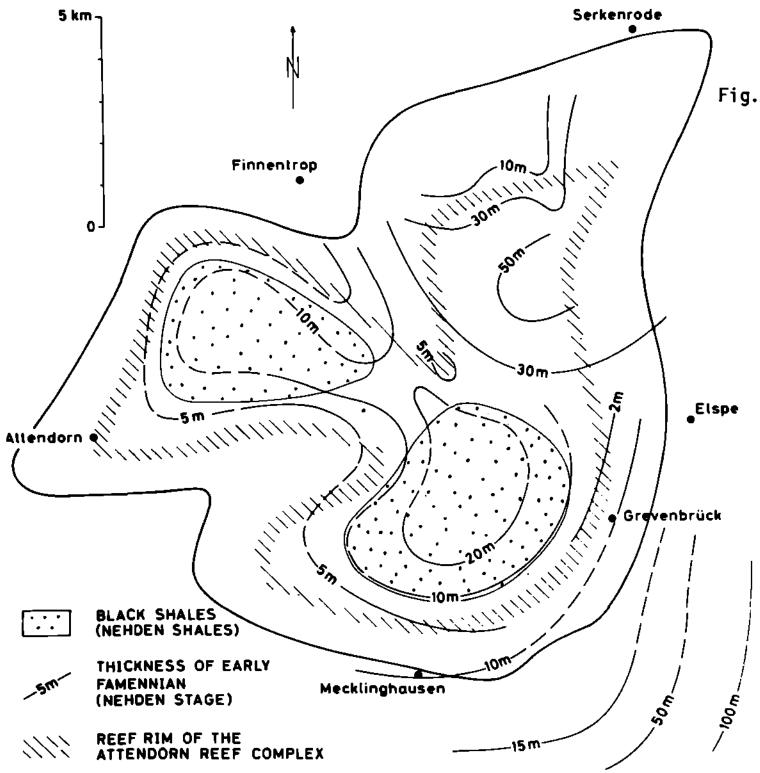


Fig. A 14

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E x c u r s i o n - B - Mesozoic shallow- and deeper-water facies in the Northern Limestone Alps

1. Introduction

During the last twenty years, facies of Triassic and Jurassic deposits of the Northern Limestone Alps has been thoroughly studied with regard to paleontological and sedimentological details. Sedimentation models have been developed for Upper Triassic Carbonate platforms, reef-complexes, and deep-water basins as well as for Liassic and Upper Jurassic deep-water environments, and Upper Jurassic carbonate platforms. Shallow-water environments and deep-water areas are often connected by facies sequences composed of submarine sliding deposits and limestone turbidites.

The goal of the excursion is to provide a general view of shallow-water and deep-water limestone types whose genesis is interrelated with the existence and activities of benthic and planktonic algae.

2. Stratigraphy and Sedimentation

(E. FLÜGEL, H. ZANKL)

The field trip area comprises the Salzburg Limestone Alps and the Salzkammergut in Upper Austria and Styria. These regions are located in the central part of the Northern Limestone Alps, and have been named after very thick sequences of Mesozoic limestones and dolomites. Three facies districts can be recognized for the Triassic and Jurassic: "Bavarian Facies" (="Tyrolian Facies"), "Berchtesgaden Facies" (or "Dachstein Facies", and "Hallstatt Facies".

Table 1 shows a generalized stratigraphic scheme for the Triassic, table 2 for the Jurassic. Investigations during the last few years have changed many biostratigraphical correlations especially for Middle and Upper Triassic formations (see H. ZAPFE 1973, 1974).

Sedimentation started in the Lower Triassic (Scythian) with the clastic Werfen beds (type locality: Werfen, south of Paß Lueg). These red and vari-coloured sand- and claystones are followed by carbonates during the Upper Scythian. Argillaceous evaporites ("Haselgebirge") seem to be Upper Permian and Scythian in age.

Triassic		Bavarian Facies	Berchtesgaden-Dachstein-Facies	Hallstatt Facies "Graufazies"	Hallstatt Facies "Buntfazies"
Upper	Raetian	Kössen beds; Raeto-Lias Reef Ls.	Dachstein Limestone; Dachstein Reef Limestone	Zlambach-beds	Zlambach-beds
Upper	Norian	Plattenkalk; Hauptdolomit	Dachstein Limestone	Pötschen-beds	Hallstatt limestones
Upper	Carnian	Raibl beds	Raibl beds	Reifling-beds	Hallstatt limestones
Middle	Ladinian	Partnach beds; Wetterstein limestone	Ramsau Dolo-mite	Reifling-beds	Hallstatt limestones; Reifling beds
Middle	Anisian	Alpine Muschelkalk	Alpine Muschelkalk; Ramsau Dolo-mite	Steinalm Ls.; Gutenstein ls.	Steinalm Ls.; Gutenstein ls.; Schreyer-Alm Ls.
Lower	Scythian	Buntsandstein	Werfen beds	Werfen beds	Werfen beds

Table 1 : Generalized stratigraphic table of the Alpine Triassic. See ZAPFE 1974 for correlations.

		Shallow-water facies	"Deeper-water" facies		
			grey	red	
			Siliceous facies	Cephalopod Ls. facies	Brachiopod-crinoid facies
Malm	Tithonian		Oberalm Limestone *	Aptychus Ls.	Mühlberg Ls.
	Kimmeridgian	* Plassen Ls. ; * Barmstein Ls. ; Tressenstein Ls. *	Taugl-boden-beds	Acanthicum beds	
	Oxfordian		Radiolarite		
Dogger	Callovian			Reitmauern Limestone	Vilser Ls.
	Bathonian		Hornstein-Kieselkalke	Klaus Ls.	
	Bajocian				
	Aalenian		Dogger Kieselschiefer		
Lias	Toarcien		Strubberg-beds		
	Pliensbachian		Liashorn-steinkalk *		*
	Sinemurian		Lias-Spongien-Kalk	Adnet Limestone *	Hierlatz Limestone
	Hettangian	Raetolias Reef Ls. *			

Table 2: Generalized stratigraphic correlation of some Jurassic units seen by the excursion. (*).

The onset of uniform carbonate deposition in the Late Scythian to Early Anisian marks a stratigraphical turning point (W.SCHLAGER & W.SCHÖLLNBERGER 1974)- the Reichenhall juncture. Siliceous clastics were replaced by areneaceous dolomites, shaly clays, rauwackes, and thin-layered mudstone carbonates with small-sized gastropods, crinoids, and lamellibranchs. In southern parts of the Northern Limestone Alps during the Upper Scythian, clayish limestones with pelagic fauna were deposited indicating an open-marine environment. These areas were later dominated by environments.

Following this sedimentation phase, shallow-water carbonates overlain by nodular limestones with cherts were deposited (Alpiner Muschelkalk). Another stratigraphic juncture (Reifling juncture) took place during Upper Anisian as indicated by the development of deeper-water marine cherty limestones, sometimes associated with volcanic tuffs. These deeper-water limestones are characterized by dark, bituminous, platy limestones, with abundant sponge spicules, nodular marly limestones with ammonites, and cherty limestones (Reifling limestones) with a pelagic fauna within the Hallstadt facies district, shallow-water algal limestones (Steinalm limestones) are overlain by red limestones with condensed ammonite faunas. According to W.SCHLAGER & W.SCHÖLLNBERGER (1974) the "deeper-marine" look of the bituminous limestones may be caused by hypersaline conditions.

During Ladinian time, large shallow-water carbonate platforms with eastern and northern marginal reefs were built. Main frame-builders are calcareous sponges and Tubiphytes MASLOV ; back-reef environments are characterized by typical associations of dasyclads (see E.OTT 1967). Within the uppermost Wetterstein limestones vadose pisolites may indicate subaerial exposure. These shallow-water platforms were separated by small basins filled by bituminous marls (Partnach beds) or by micritic limestones with deeper-water faunas (uppermost Reifling limestone).

Subaerial exposure of shallow-water carbonates and a large-scale spreading of deeper-marine marls (Raibl beds, Reingraben beds) characterize the "Reingraben juncture" during Lower Carnian, The Raibl beds show a rhythmic alteration of prabably deeper-water clastics (marls and sandstones) and shallow-water carbonates with algal oncoids (Sphaerocodium).

After this clastic intermezzo the Norian and Raetian Carbonate platform was formed. These widespread shallow-water regions are differentiated into marginal reef-zones (Dachstein reef limestone), and far-reef back-reef limestones with a cyclic sedimentation pattern (Loferites, A.G.FISCHER 1964) are developed. In restricted parts of the platform dolomites (Hauptdolomit) were formed (see fig. B 3).

The basin facies is developed as thin, frequently red limestones and marls with pelagic faunas (Hallstatt limestones). This facies is found in narrow channels and basins between platforms of various dimensions. Different sedimentation rates can be estimated for near-platform limestones of the basin facies (Pötschenbeds) and for far-platform limestones (Hallstatt limestones).

Toward the end of the Upper Triassic the Dachstein - Hauptdolomit platform was destroyed: During the uppermost Norian the Hauptdolomit areas were differentiated into basins with terrigenous influence (Kössen-beds) and with marginal reef complexes (Rätolias reef limestones resp. Upper Raetian Reef Limestones resp. "Steinplatte limestones (see fig. B 2). The partly deeper-marine Kössener beds and marly Zlambach beds of the Hallstatt basins indicate the beginning of the "Adnet juncture" which continued during Liassic times with deeper-marine sediments (Adnet limestone; Allgäu beds).

Submarine and subaerial erosion of Rätolias reef limestones is connected with the development of vertical and horizontal fissures which were filled with Jurassic sediment material. The subsidence of the Dachstein platform is often connected with deposition of crinoidal limestones (Hierlatz limestone . See JENKYNS 1971).

Starting with the Liassic deeper-water sedimentation becomes dominant. Grey marls and platy limestones as well as red cephalopod limestones are main rock types, indicating regions with incomplete oxidation and high sedimentation rates ("Graufazies"), and regions with complete oxidation and low sedimentation rates ("Rotfazies"). According to W. SCHLAGER & W. SCHÖLLNBERGER (1974) the red facies seems to have been deposited

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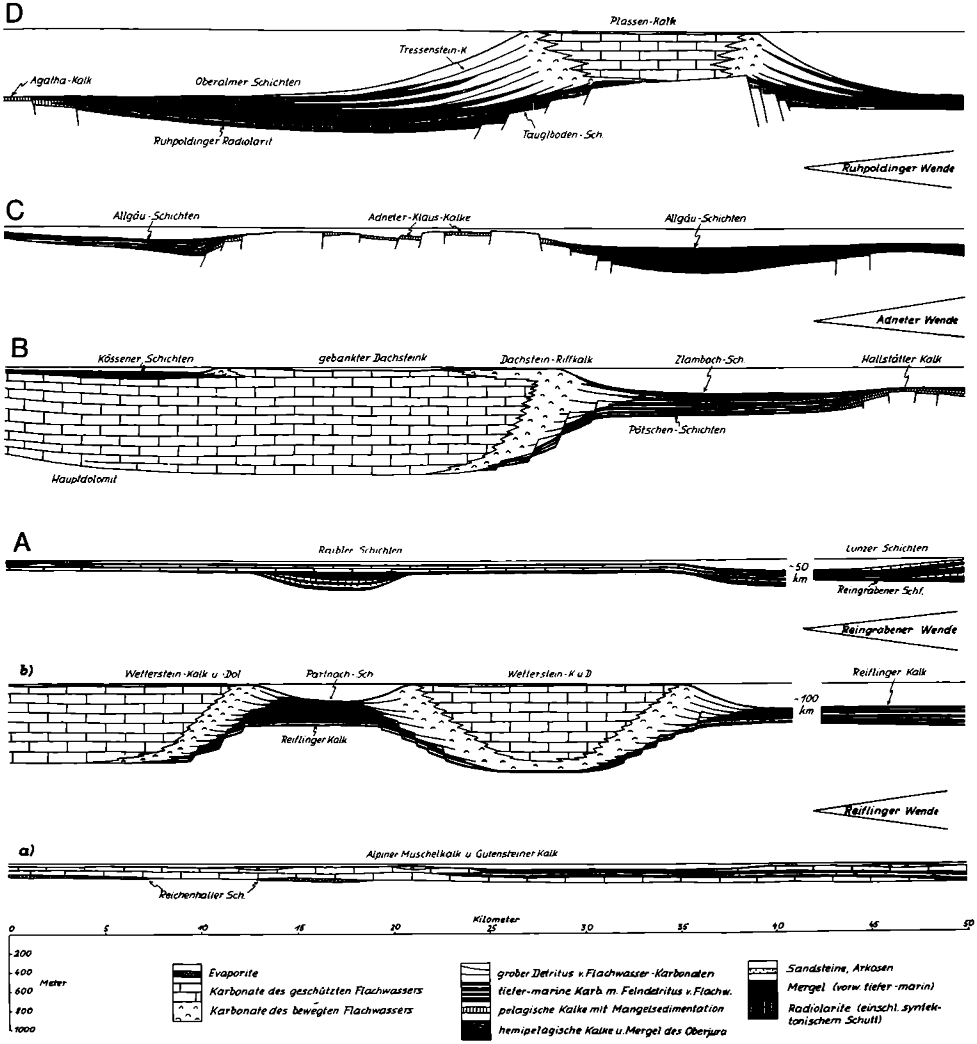
Fig. B 1 Facies development of the Northern Alpine Upper Triassic and


D
Plassen-Kalk
Tressenstein-K
Agatha-Kalk
Oberalmer Schichten
Ruhpoldinger Radiolarit
Tauglboden-Sch.
Ruhpoldinger Wende
C
Allgäu-Schichten
Adneter-Klaus-Kalke
Allgäu-Schichten
Adneter Wende
B
Kössener Schichten
gebankter Dachsteink
Dachstein-Riffkalk
Zlambach-Sch.
Hallstätter Kalk
Pötschen-Schichten
Hauptdolomit
A
Raibler Schichten
Lunzer Schichten
~50 km
Reingrabener Schf.
Reingrabener Wende
b)
Wetterstein-Kalk u. -Dol
Partnach-Sch
Wetterstein-K u D
Reiflinger Kalk
Reiflinger Kalk
~100 km
Reiflinger Wende
a)
Alpiner Muschelkalk u. Gutensteiner Kalk
Reichenhaller Sch.
Kilometer
0
5
10
15
20
25
30
35
40
45
50
200
400
600
800
1000
Meter
Evaporite
Karbonate des geschützten Flachwassers
Karbonate des bewegten Flachwassers
grober Detritus v. Flachwasser-Karbonaten
tiefer-marine Karb. m. Feindetritus v. Flachw.
pelagische Kalke mit Mangelsedimentation
hemipelagische Kalke u. Mergel des Oberjura
Sandsteine, Arkosen
Mergel (vorw. tiefer-marin)
Radiolarite (einschl. synsektonischem Schutt)

on ridges between regions with grey facies. Red limestones are represented by Liassic nodular limestones and by the Middle to Upper Jurassic Klaus limestone. The"Grey Facies" is characterized by marly, sometimes manganese shales ("Fleckenmergel", Allgäu beds).

During the "Ruhpolding juncture" after the Oxfordian different deeper-water sediments were overlain by siliceous rocks (radiolarites), followed by Upper Jurassic coccolith-micrites (Aptychus beds, Oberalm beds). Differences in water depth or a rapid evolution of nannoplankton may be the reason for the beginning of the pelagic carbonate sedimentation.

In addition to these open-marine environments, isolated shallow-water platforms (Plassen limestone, Tressenstein limestone) also existed (see FENNINGER & HOLZER 1972). These shallow-water deposits include algal,hydrozoan, and coral frame-builders, but true ecological reefs seem to be rare. The platforms were formed upon tectonically uplifted parts of the sedimentation area; during Lower Cretaceous most of this facies was again covered by deeper-water deposits.

Of special interest are frequent synsedimentary sliding masses (Tauglboden beds, see SCHLAGER & SCHLAGER 1973), and allodapic limestones resembling limestone turbidites (some of the so-called Barmstein limestones, see H.W.FLOGEL & PÖLSLER 1965).

During the "Rossheim-Tannheim juncture" pelagic to hemipelagic sedimentation of coccolith ooze (Aptychen beds) and red micritic limestones (Agatha limestone) were replaced by marls, clay mudstones and sandstones (Rossfeld beds; Tannheim beds). This facies change took place during Valanginian to Aptian.

According to W. SCHLAGER & W. SCHÖLLNBERGER(1974) these stratigraphical turning points are caused by irreversible changes of facies conditions: The Reichenhall juncture may be connected with regressions which favoured chemical (?) precipitation of carbonates. The Reiflinger juncture was caused by rapid subsidence and volcanic activity. Rapid subsidence of shallow-water platforms together with terrigenous influx initiated the Reingraben juncture. During the Adnet juncture subsidence of shallow-water platforms and reef areas below the euphotic zone,together with synsedimentary fracture tectonics,resulted in a general change of the sedimentation pattern (deeper-water sedimentation). The Ruhpolding juncture may have been connected with the rapid expansion of radiolaria caused by cold upwelling water. The Roßfeld and Tannheim juncture are characterized by tectonic movements which gave rise to terrigenous sedimentation.

Fig. B 1 shows the development of facies for the time between the Reingraben juncture (Lower Carnian, Cordevol) and the Rosenheim juncture (Lower Cretaceous) according to SCHLAGER & SCHÖLLNBERGER (1974, fig. 1). Width of the section is about 50 km.

At the transition from Early to Late Cretaceous intensive compressional forces resulted in faulting and thrusting. During this time the characteristic tectonic elements of the Northern Limestone Alps were formed. Later movements during Cretaceous and Tertiary only affected the shape of this initial layout through essentially vertical displacements. During Late Tertiary the Northern Limestone Alps as an entity were thrust northward onto the Flysch.

Upper Cretaceous sedimentation was restricted to some basins within the Alpine complex which were formed during the tectonic climax at the Early/ Late Cretaceous boundary. Coarse- and fine-grained clastics filled these basins while organic built-ups (with corals and rudists) existed at their margins (Gosau beds). This sedimentation pattern was continued during the Early Tertiary.

The latest history comprises the uplift of the entire Alpine complex in Late Tertiary and the development of the present topography which received its final relief during Pleistocene glaciation.

3. Facies of some Upper Triassic and Jurassic Environments (E.FLÜGEL & H.ZANKL).

In as much as the purpose of the excursion is to become aquainted with the shallow- and deeper-water facies types of the Alpine Mesozoic, this chapter deals with facies criteria, fossils, and interpretations of the localities we will visit.

3.1 Upper Triassic

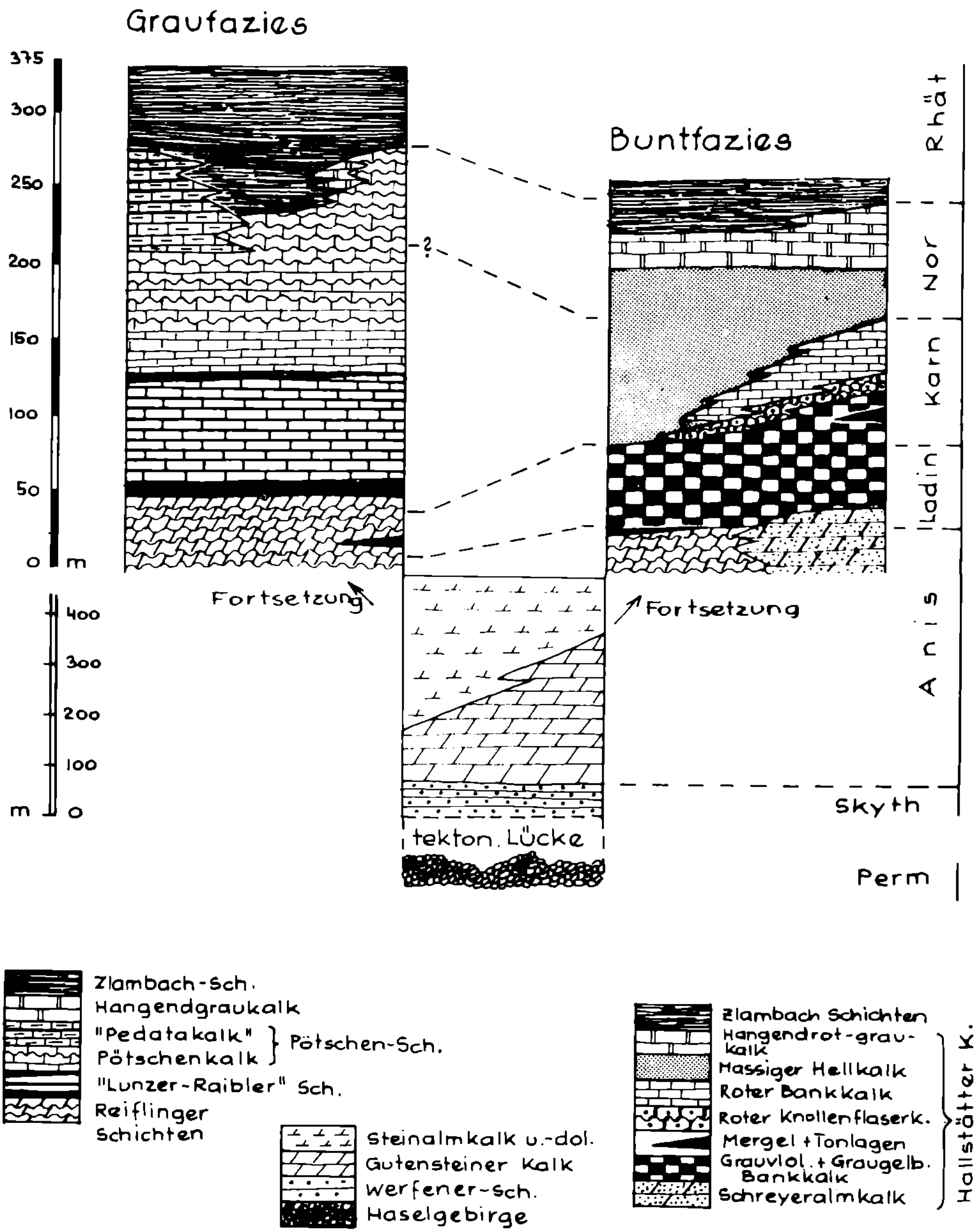
3.1.1 Hallstatt limestones (Anisian to Norian), Pötschen beds (Carnian to Norian), Zlambach beds (Norian to Raetian).

These typical Hallstatt sediments were deposited in open-marine environments as is indicated by a predominantly pelagic fauna. According to A.G. FISCHER (1964), W.SCHLAGER (1968), and H.ZANKL (1971 the sedimentation area was situated in relatively wide "channels" and basins between large carbonate platforms upon which reefs (Dachstein reef limestones) and shallow-water limestones (bedded Dachstein limestone; Hauptdolomit) were being deposited. (Fig.B 1). Investigations by SCHLAGER (1969) and KRYSTYN, SCHÄFER & SCHLAGER (1971) resulted in the recognition of two facies within the Upper Triassic Hallstatt basins. The "Buntfazies" (variegated facies, mainly red, typical Hallstatt limestone) is rich in limestones, and the "Grau-fazies" (grey facies; Pötschen beds and Zlambach beds) is rich in marls. No regular distributions of these facies types have been recognized. "Buntfazies" seem to have been deposited on well aerated submarine topographic highs, the clayish sediments of the "Graufazies" in topographic deeps.

Fig. B 2 shows the stratigraphic sequence of the Hallstatt facies types of the Salzkammergut area (after KRYSTYN & SCHÖLLNBERGER 1972). Biostratigraphic dating is based mainly on ammonites and conodonts. Overlying Anisian algal limestones (Steinalm limestone) is an approximately 250 m thick sequence developed within the "Hallstätter Buntfazies". It consists of the following members from bottom to top (description after SCHLAGER 1969 and KRYSTYN & SCHÖLLNBERGER 1972):

Fig. B 2 Stratigraphic sequence of the Hallstatt Triassic of the Salzkammergut. After L.KRYSTYN & W. SCHÖLLNBERGER 1972.

SCHICHTFOLGEN DER HALLSTÄTTER TRIAS DES SALZKAMMERGUTES (schematisch)



(1) Schreyeralm Limestone (Middle Anisian to Ladinian).
Thick-bedded red biomicrites, Fe-oxide and subsolution is common. Intensive stratigraphic condensation.

(2) "Grauvioletter Bankkalk" (grey-violet bedded limestone, Ladinian to Lower Carnian). Even to wavy-bedded, 10-20 cm thick beds; microsparites and pelsparites; sometimes siliceous cherts are abundant at the base.

(3) "Roter Knollenflaserkalk" (red nodular flaser limestone, Lower Carnian). Regularly bedded, (10-30 cm) flesh-red homogenous biomicrites, with nodular texture which was formed by pressure solution as a result of shearing subparallel to the bedding planes. In this way $CaCO_3$ was dissolved and insoluble residue (illite, chlorite, montmorillonite and kaolinite, RIECHE 1971) was enriched (from about <4% to about 30%). The Original microfacies is characterized by abundant filaments (? juvenile lamellibranchs), foraminifera, ostracods, radiolaria, and echinoderm fragments.

(4) "Roter Bankkalk" (red bedded limestone, Lower Carnian to Lowermost Norian). Flesh- to bright red biomicrites, very often with strong bioturbation. Evenly-bedded (20-50 cm) limestones, homogenous or with internal resedimentation. Subsolution planes with Fe-Mn-coating common. Typically developed in the stratotype area of the Tuval = Upper Carnian (Feuerkogel/Röthelstein near Aussee, Styria, see KRYSTYN & SCHLAGER 1971). Microfacies similar to type 3.

(5) "Massiger Hellkalk" (massive light limestone; ? Upper Ladinian, Carnian to Lower Norian). Micrite with some lamellibranch shells. Without bedding, or with meter-bedding.

(6) "Hangendrotkalk" (red limestone at the top of the sequence, Uppermost Lower Norian to Upper Norian). Platy to wavy-bedded biomicrites with mostly strong bioturbation. Subsolution is indicated in some places by erosion and Fe-Mn-crusts on hard-grounds.

Most of the classical ammonite localities and the stratotype of the Norian stage (see KRYSTYN, SCHÄFER & SCHLAGER 1971 b) are situated within this member. Typical for Upper Norian parts are beds with the globular hydrozoan Heterastridium REUSS (probably a milleporoid genus, see CUIF 1971) and with lumachelles of Monotis salinaria.

The Hallstatt limestones are well-characterized by macro-faunas, consisting mostly of cephalopods and some lamellibranchs, brachiopods, and crinoids found either in normal beds ("Schichtlager") or in synsedimentary fissures which were effective as traps ("Spaltenlager"). Fissure fillings and adjacent rocks are often of different age (see KRYSTYN, SCHÄFER & SCHLAGER 1970) a major pitfall for former stratigraphic schemes. Fissure genesis and brecciation is closely related to synsedimentary block-tectonics (SCHWARZACHER 1948, W.SCHLAGER 1969).

Many Hallstatt limestones and Liassic red limestones with stratigraphic condensations are characterized by Fe/Mn - concentration, which are distributed as impregnations and crusts on hard grounds or in reworked nodules. The autochthonous organism-association of these hard grounds consists of boring algae and sessil foraminifera (see WENDT 1969), as well as some serpulids, bryozoans and crinoids. According to these associations WENDT (1970) argues for the deeper littoral zone (50-100 m) as the bathymetrical region of these condensed deposits.

Water depth of the Hallstatt depositional environments is a matter of discussion: Most authors today agree that predominance of neritic faunal elements such as ammonites and conodonts, the relative insignificance of benthic organisms, and the interfingering of Dachstein reef limestones and Hallstatt sediments (see H.ZANKL 1967, U.PISTOTNIK 1974) suggest deposition on deeper shelf areas, probably 50-100-200 m. With respect to the rapidly subsiding Norian shallow-water platforms (Dachstein limestones, Hauptdolomit) with more than 1000 m thick accumulations of sediments, the less rapidly subsiding Hallstatt basins show correspondingly less sediment deposition (during the Norian only about 100 m). At the boundaries between areas of rapid and slow subsidence tension resulted in fissure formation.

The "Hallstätter Graufazies" (KRYSTYN & SCHÖLLNBERGER 1972) consists of the Pötschen beds (Carnian to Norian) and the Zlambach beds (Upper Norian to Raetian; Fig. B 2). These lithostratigraphic units can interfinger with Hallstatt limestones. Pötschen beds are mostly overlain by the Zlambach beds which perhaps may interfinger with the Dachstein reef limestone (see ZAPFE 1973 for a discussion of this problem).

(1) Pötschen beds

This unit, named after the Pötschen pass between St. Agatha and Bad Aussee (boundary between Upper Austria and Styria), according to SCHÖLLN-BERGER consists of the "Pötschen limestones", intercalated calcarenites, marly "Pedata limestones", and dolomites.

The Pötschen limestones are well-bedded (10-30cm), grey micrites and microsparites with abundant cherts. Bioturbat textures are common. Pressure solution is evident. Upon even or wavy bedding-planes marls with a poor foraminifera fauna (KRISTAN-TOLLMANN 1960), radiolaria, and sponge spicules are found.

Within the Pötschen limestones 10-50 cm thick brown, cherty calcarenites (intrabiosparites and micrites), sometimes with marls, are intercalated. These calcarenites sometimes yield redeposited calcareous algae and corals, together with echinoderms.

"Pedata limestones" (named after the brachiopod Halorella pedata) are characterized by interbedding of calcarenites and grey to black, thin-layered marly limestones. All limestones show lateral transitions in epidiagenetically formed dolomites.

(2) Zlambach beds

The Hallstatt limestones are overlain by, and locally interfinger with marly sediments of varying carbonate/clay ratio which grade up into the Lower Jurassic, The Upper Norian and Raetian portion is called the Zlambach beds (Zlambach near Hallstatt).

A lower part (cf. Upper Norian) and an Upper part (cf.Raetian, see ZAPFE 1973 and 1974 for discussion of this probelm!) can be differentiated on the basis of lithology: The lower part is characterized by interbedded pyritiferous, fine-grained mottled marly limestones, and mottled grey marls.

The upper part is composed of dark grey to black pyritiferous marls and argillaceous shale with quartz and micas. Calcarenites (10-100 cm thick beds) with many bioclasts (Algae - Dasycladaceae, Solenoporaceae; fragments of coral colonies, echinoderms, lamellibranchs, and brachiopods) are intercalated. This detritus, together with a rich coral fauna may indicate the existence of small patch reefs (fore-reef shoals), perhaps quiet water bioherms in shallow-neritic environment (see E.FLÜGEL 1962 b), ZAPFE 1967).

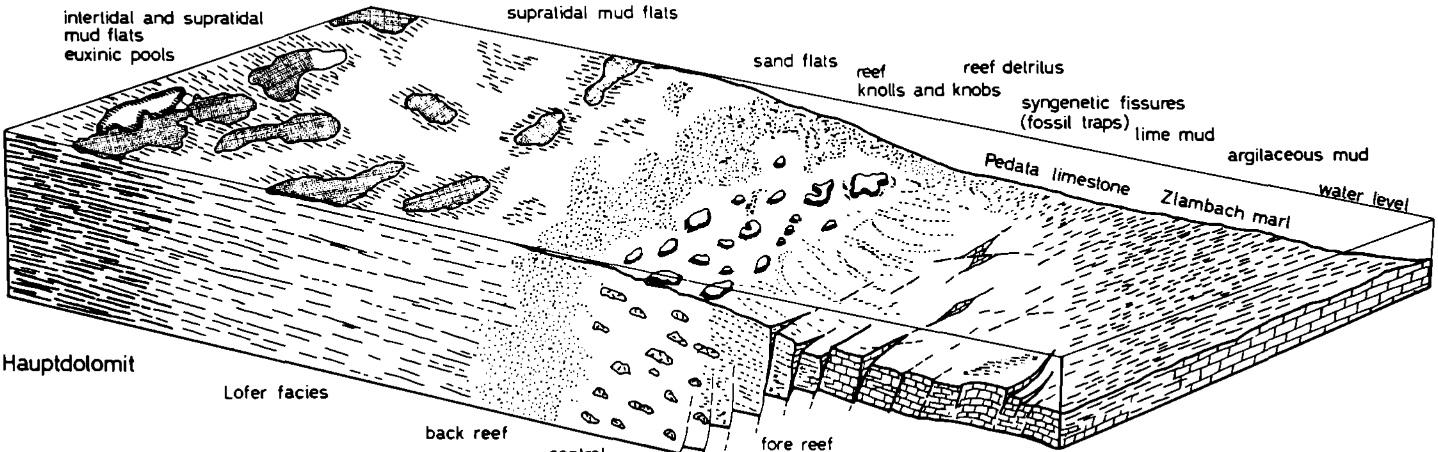
In contrast to the shallow environment supposed for the deposition of bioclastic limestones and marls with a highly diverse community, the shaly marls and micritic limestones of the lower Zlambach beds seem to have been deposited in a deeper-water environment (about 50 m). This is indicated by different fossil associations: Lower Zlambach beds - foraminifera and ostracods, rich lamellibranchs- and cephalopod faunas, conodonts. In contrast, the Upper Zlambach beds contain rich foraminifera and ostracod faunas, calcareous sponges, hydrozoans, corals, bryozoans, brachiopods, gastropods, lamellibranchs, some cephalopods, echinoderms, and calcareous algae.

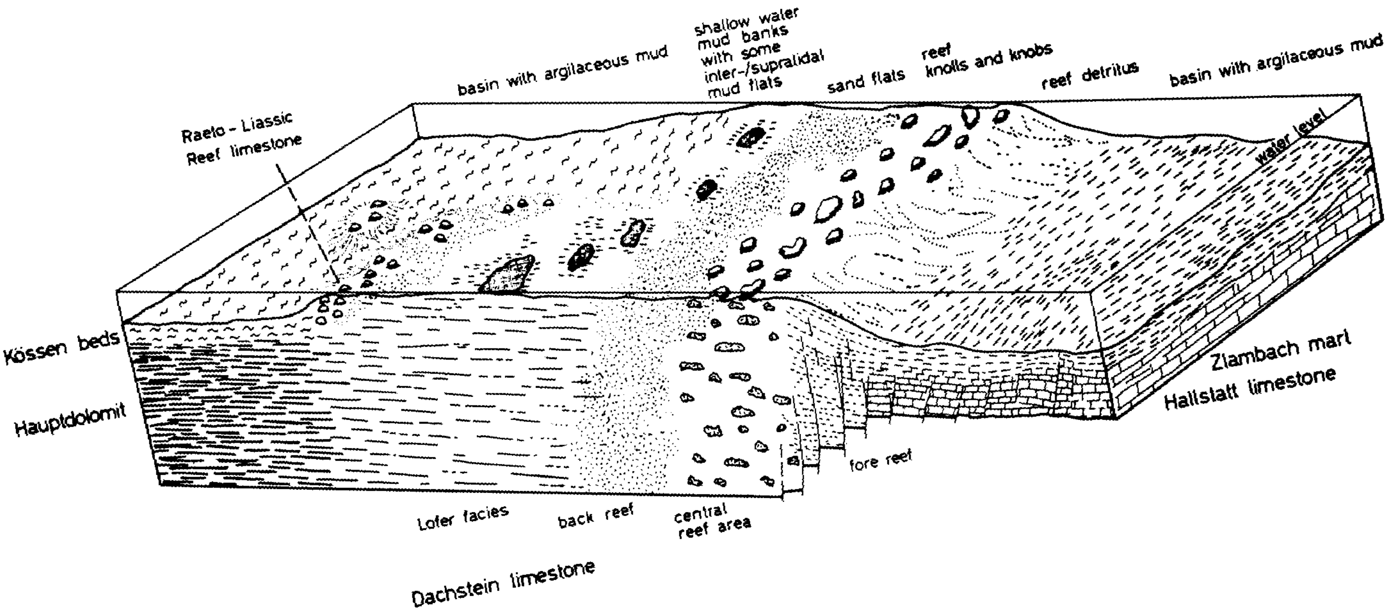
3.1.2 Dachstein formation

The Dachstein foramtion was deposited on large-dimensioned shallow-water platforms. The southern and western rims of these platform consist of massive Dachstein reef limestones of more than 1200 m thickness. According to detailed studies by E.FLÜGEL & E.FLÜGEL-KAHLER (1963, Sauwand reef near Gußwerk, Styria), H.ZANKL (1969, Hoher Göll, Berchtesgaden Alps), and H. LOBITZER (1974, Hochschwab area, Styria) reef zones developed parallel to the platform rim. Very low inclined fore-reef slopes generally show slump-transported coarse and very coarse material (reef boulders) intermixed with the fine material of the basin. Whereas sorting of fore-reef debris is very poor to poor towards the central reef area, the reef detritus gradually becomes bedded. Behind the narrow central reef area (composed of many small patch reefs and interstitial reef debris) a wide back-reef region is developed. Often within this region a near-reef zone with typical associations (Dasycladaceae, Codiaceae, Foraminifera et al.) and a far-reef zone with sediments of the Lofer facies can be recognized. To the north the Dachstein platform grades into the dominantly tidal area of the "Hauptdolomit" where various types of restricted environments prevailed (Fig. B 3).

Fig. B 3 Paleogeographical interpretation of the depositional environments during Late Norian (after H. ZANKL 1971). Not to scale.

Fig. B 4 Paleogeographical interpretation of the depositional environments during Late Rhaetian (after H. ZANKL 1971). Not to scale.


intertidal and supratidal
mud flats
euxinic pools
shallow water mud banks
with some inter - and
supratidal mud flats
sand flats
reef
knolls and knobs
reef detritus
syngenetic fissures
(fossil traps)
lime mud
argilaceous mud
Pedata limestone
Zlambach marl
water level
Hauptdolomit
Lofer facies
back reef
Dachstein limestone
central
reef area
fore reef
Hallstatt limestone


basin with argilaceous mud
shallow water
mud banks
with some
inter-/supratidal
mud flats
sand flats
reef
knolls and knobs
reef detritus
basin with argilaceous mud
water level
Raeto - Liassic
Reef limestone
Kössen beds
Hauptdolomit
Zlambach marl
Hallstatt limestone
fore reef
Lofer facies
back reef
central
reef area
Dachstein limestone

3.1.2.1 Reef facies

(a) fore-reef facies

Many fore-reef areas seem to be tectonically amputated due to zones of weakness between this part and the central reef area (see table 3). The fore-reef is characterized by the lack of in-situ reef building organisms, by poor sorted angular to subangular intraclasts and bioclasts of reef material, and by many fossils of the open-marine (Hallstatt) environment. Of special interest is the matrix (micrite and fine calcarenite) and the cement types which corresponds with typical early void fillings known from fore-reef rocks of different ages (see W. KREBS 1969). Fissures are filled with basin sediments of the Hallstatt facies.

Apart from allochthonous reef-builders most organisms seem to be inhabitants of the near-reef basin region.

(b) central reef facies

The central reef area (table 4) corresponds to a reef flat (width of several hundred meters to <1 km) covered by small irregularly distributed patch reefs and by a large area with interstitial reef detritus produced by biogenic and mechanical destruction. The proportion of the reef framework to interstitial reef detritus is about 1 : 9, probably even more in favour of the debris.

Each of the patch reefs ("Riffknospen") has a characteristic association of organisms which (for the Göll reef) often show a zonal arrangement according to their shape. In general reef builders occur in a well-defined sequence of several generations (ZANKL 1969) - a first generation composed by corals, calcisponges and calcareous algae (Solenoporaceae), a second generation of sessile foraminifera and algal crusts, a third generation with sessile and encrusting calcisponges, bryozoans, Cheilosporites and very rarely Solenoporaceae. The fourth generation has the same composition as the second one. The fifth and final generation consists of encrusting blue-green algae (Spongiostromata).

The main frame-builders of Dachstein reefs are unsegmented calcareous sponges and monomict coral associations (mostly "Thecosmilia" and Astraeomorpha). About 10 to 35 % of the reef-builders are calcareous algae (mostly red algae), spongiomorphid hydrozoans, bryozoans, encrusting foraminifera, and some problematica.

			Hoher Göll (ZANKL 1969)	Hochschwab (LOBITZER 1974)	Sauwand (E.FLÜGEL & E.FLÜGEL-KAHLER 1963)
dimension			tectonically amputated width of preserved zone = 500 m	tectonically amputated width of preserved zone = ca. 350 m	tectonically amputated width of preserved zone = ca. 10 m
carbonate textures	grains	types	mostly intraclasts; bioclasts of reef material	mostly intraclasts, partly micrite lithoclasts	intraclasts
		size	coarse arenite and rudite, max. 1 m	coarse arenite and rudite	rudite and arenite
		roundness	angular to subangular	angular	angular to subangular
		sorting	very poor to poor	poor	poor
		texture	poor bedding	no bedding	---
	Matrix		grey or red micrite or fine-calcarenite	micrite to fine-calcarenite	micrite and open-void filling sparite
biota	(mostly allochthonous; echinoderms and brachiopods parautochthonous)		cephalopods gastropods foraminifera, ostracods "filaments" no reef-builders in situ	echinoderm detritus brachiopods foraminifera (lagenids) "filaments" fish teeth no reef-builders in situ	echinoderm detritus brachiopods no reef-builders in situ

Table 3 : Facies characteristics of different fore-reef areas, Dachstein reef limestone.

	Hoher Göll (ZANKL 1969)	Hochschwab (LOBITZER 1974)	Sauwand (E.FLOGEL & E.FLÜGEL-KAHLER 1963)	Gesäuse (BÜCHNER 1970)
reef frame work	small (Ø <5 m) patch reefs without distributional pattern, distance about 50 m	small patch reefs, distance up to 100 m	small patch reefs distance 50 ± 100 m	small (some m^2) patch reefs, mostly isolated
reef-building communities	11 associations, dominating "Thecosmilia"-associations and calcisponge-associations	3 associations: Solenoporaceae-calcisponge - A., calcisponge - A., "Thecosmilia-A.	3 associations, dominating calcisponge-associations and "Thecosmilia-associations	4 associations, dominating calcisponge- and coral associations
vol. % of reef-building organisms	75% calcareous sponges + corals 25% algae, hydrozoans, bryozoa, foraminifera	calcareous sponges, corals, Solenoporaceae, bryozoan, hydrozoan,foraminifera	about 60% calcareous sponges + corals; Solenoporaceae, hydrozoans, bryozoan, foraminifera	>50% calcareous sponges, corals frequent; algal crusts, hydrozoans foraminifera
interstitial reef detritus	bio- and intraclasts; about 50% 2mm, 40% 2-20mm to 1 m	grain-size calcilutite to coarse calcirudite; matrix micrite or sparry cement	bio- and intraclasts, grain-size like calcarenite and calcirudite	bioclasts
ratio patch-reef-areas: reef detritus areas	1 : 9	0,5 : 9,5	1 : 9	1 : 9
reef-dwelling organisms	gastropods, brachiopods, holothuroids, crinoids, echinoids, ophiurids; rare lamellibranchs and ammonites: foramini-	---	rare gastropods, brachiopods and some lamellibranchs, echinoderms	vagile foraminifera, crinoids, brachiopods, gastropods

The central reef area is characterized by

a) relatively common frame-building organisms, in situ,
b) frequent biogene crusts (foraminifera: Alpinophragmium perforatum; Microtubus communis; Spongiostromata crusts et al.), and
c) very high amounts of commonly well-bedded skeletal debris supplied by erosion of the patch reefs.

(c) back-reef area

The portion of the back reef next to the central reef area is a near-reef zone characterized by well-rounded and organically coated calcarenites. Green and red algae (dasyclads, codiaceae, solenoporacea) and foraminifera are the dominant organisms of this zone, having contributed essential amounts of the sediment: Göll reef - calcareous algae about 50 vol.% foraminifera about 10%; Sauwand reef - calcareous algae about 15%, foraminifera about 25%). Megalodontid lamellibranchs may have invaded the near -reef sand flats from the far-reef platform.

Apparently, this zone did not always develop. LOBITZER (1974) describes a gradual transition between the central reef area and the Lofer facies, which according to A.G. FISCHER (1964) and H.ZANKL (1971) corresponds to a far-reef situation.

(d) Remarks on the Fauna and Flora of the Dachstein Reef Limestones

The first detailed investigation of reef-building organisms of the Dachstein reef limestones was made by E.FLOGEL (1962), and resulted in the recognition of new species and genera especially of calcareous sponges, hydrozoans, bryozoans, encrusting foraminifera, and calcareous algae. Only a few forms have been published up to the present (E.FLOGEL 1964, 1967, 1972). New studies have been during the past few years dealing with the foraminifera of the reef- and back-reef environments (HOHENEGGER & LOBITZER 1971) and with calcareous algae (E.FLOGEL 1975). Table 5 shows the distribution of calcareous algae.

	Central reef area		back-reef	far-reef, Loferfacies
	reef edge	reef flat	near-reef calcarenites	(Megalodontid ls.)
Red algae				
Solenoporaceae				
Solenopora cf.S.alcicornis OTT	 x			
Solenopora styriaca FLÖGEL	....	 x		
Solenopora endoi FLÖGEL	...... x ...	....	 x	
Solenopora sp.	....	....	.... x	 x
Parachaetetes maslovi FLÖGEL	....	 x		
Pycnoporidium ? eomesozoicum FLÖGEL	....	 x		
Thaumatoporella parvovesiculifera (RAINERI)	....	.... x	 x	
Green algae				
Codiaceae				
Boueina hochstetteri liasica LEMAITRE	....	 x		
Dasycladaceae	....	....	....	 x
Diplopora phanerospora PIA	....	....	 x	
Heteroporella crosi OTT	....	....	 x	
Heteroporella zankli OTT	....	....	 x	
Macroporella sp.	....	 x		
Griphoporella curvata (GÜMBEL)	....	....	.... x	 x
Blue-green algae				
Cayeuxia alpina FLÖGEL	....	..... x	.... x	 x

Table 5 : Distribution of calcareous algae in Dachstein reef complexes.

Similar distribution patterns within different reefs seem to exist for calcareous algae:
Within the central reef area blue-green algal crusts are widely distributed Two types can be recognized- one type of up to 20 mm thick micritic layers around corals, bryozoans, and calcisponges, and the other consisting of micritic structures without clear lamination. These crusts are often redeposited as angular fragments.Interstitial reef detritus and patch reefs yield about 12% calcareous algae, mainly solenoporids and Cayeuxia. The reef-edge area is characterized by solenoporid associations (Sauwand, Hoher Göll).

The near-far back-reef environment contains high portions of dasyclads, solenoporoids, and Cayeuxia (Hoher Göll up to 50% of skeletal grains, Sauwand up to 12%, Gosaukamm 50-80%).

Far-reef megalodontid limestones of the Lofer facies yield Griphoporella, Cayeuxia, and solenoporids.

1.2.2 Lofer facies

Beyond the reef zone on the Dachstein platform a shallow water facies developed in which 1000 - 1500 m of carbonates were deposited during the Norian and Raetian. The most striking characteristic of these limestones is a well-developed meter-rhythm of thick beds which are named Lofer facies after their type-locality in the Loferer Steinberge.

Schematically,these rhythmic beds are considered to be cyclothems composed of three members (see fig. B 13).

According to A.G.FISCHER (1964) a thin basal member A consists of breccias and conglomerates in a red or green clay-rich matrix; it overlies a disconformity.

Member B is up to 50 cm thick and consists of laminated dolomites ("Loferites") with mud cracks and shrinkage pores, and of dense micrites.

Finally,member C, which is several meters thick, is made up of calcarenites and calcilutites with large megalodontid lamellibranchs.

The upper boundary of a cyclothem is usally a disconformity. Red and green residual sediments of member A of the following cyclothem were trapped in solution cavernes which frequently penetrate the upper meters of the underlaying member C.

The cyclic sequence according to FISCHER can be interpreted as transitional from the supratidal environment (member A and member B partially), to intertidal environment (member B),and finally to subtidal environment (member C). The supratidal environment is characterized by erosional features. In the supratidal and intertidal environments conditions were favourable for growth of extensive algal mats which were subjected to syngenetic dolomitization. Reworked lithified dolomite crusts in the lowest part of member C indicates early cementation and dolomitization.

In the subtidal environment normal marine conditions prevailed. Megalodonts frequently are embedded in life position and exhibit a preferred orientation of their shells with the front in current direction. Close to the reefs and in the upper part of the Megalodon-beds (Member C) cross-bedded submarine dunes and large oncolites indicate deposition in turbulent water. In calmer areas bioturbation by the infauna (mollusks, echinoderms, ostracods, foraminifera) resulted in a complete obliteration of the bedding structures of these calcareous mud deposits.

A thorough study of the sedimentology and geochemistry of these sequences has been made by H. GÖKDAG (1974). According to this author, microfacies types of member C indicate conditions similar to the pellet-mud-, lime-mud, and grapestone-facies of the Bahama Bank.

According to FISCHER (1964) the formation of the cyclothems is caused by a periodic fluctuation of the sea-level which is superimposed on the general subsidence.

An alternative interpretation was given by ZANKL (1971): Current activity, together with sediment producing and sediment binding by algae, produced mud mounds and tidal mud flats. Over a period of several hundred years these were affected by erosion and were subjected to low amplitude (centimeter range) transgressions as a result of combined effects of subsidence and eustatic fluctuations.

Distribution of mud mounds and tidal flats on the platform, especially their increase in abundance towards the Hauptdolomit lagoon, was determined by current patterns.

1.3 Hauptdolomit

Northward the Dachstein platform grades into the dominantly tidal area of the Hauptdolomit (Norian), where, in contrast to the open marine conditions of the platform, various types of restricted environments prevailed (see fig. B 1). The maximum thickness of the sequence is found in the southern portion of this area and amounts to 2000 m. Towards the north the thickness decreases to a few hundred meters. The difference in thickness reflects a different rate of subsidence. All over the Hauptdolomit area the tidal environment predominated during Norian time.

Throughout large portions of the Hauptdolomit area secondary late diagenetic dolomitization replaced the original sedimentary structures with a coarse dolomite fabric. Where dolomites do not exceed a grain size of 5 microns (hence were formed during early diagenesis) sedimentary structures can be recognized.

The following lithofacies are distinguished:

1. greyish or brownish dolomite beds of 10 cm to 1 m thickness, which exhibit bioclasts, tiny shells, and pellet structures in thin section. Some beds are dismicrites exhibiting the characteristic spar-filled vugs which are caused by bioturbation. The tops of these beds frequently are reworked and the resulting intraclasts are found in the base of the overlying beds. External shape and crystal fabric of these clasts indicate that lithification and dolomitization terminated before reworking.

   In the upper part of the Hauptdolomit-facies these beds exhibit a more distinctive fauna of mollusks with megalodontids and gastropods.

2. Laminated dolomites make up a major portion of the Hauptdolomit profile and reach thicknesses of up to 1 m. There are two types of laminated dolomite. The first is composed of dense, very fine-grained millimeter rhythmites, the rhythms of which consist of alternating

dolomite and extremely thin black carbonaceous laminae. The dolomite laminae are irregularly undulose but are often lenticular or boundinage-like. Pores filled with sparite are missing. Thin coal seams may be interbedded with the dolomites.

The second type of laminated dolomite is characterized by an abundance of spar-filled pores and by the lack of carbonaceous laminae. The pores may have been formed by shrinkage of dolomite laminae. Hemispherical domes of up to 1 cm height are formed by arching laminae and these domes may be split by radial cracks. The filling of the resulting voids may consist of dolo- or calcisparite. Algal filaments in the microfabric of dolomite laminae indicate that algal mats were effective in the sedimentary processes. Shrinkage structures as well as mud cracks indicate temporary exposure of the sediment to the atmosphere, thus the environment of deposition must have been tidal. In contrast, the non-porous dolomite laminae of the first type were deposited in a subtidal environment as is evident from the incomplete decomposition of the organic matter of the black laminae; its preservation is due primarily to reducing conditions.

The laminated dolomites of the tidal environment are often associated with beds of a light, extremely fine-grained dolomite, which also lacks lamination and is speckled by numerous spar-filled pores; these beds are up to 20 cm thick.

3. Bituminous marly limstones: In the middle part of the Hauptdolomit series thin bedded marls or marly limestones, both bituminous, are frequently found. The "Ölschiefer" of Seefeld in Tyrol are well-known. Within the Salzburg Alps bituminous limestones of 10 m thickness occur in the Hauptdolomit of the Wiestal. Because of the abundance of fossil fish this was once a famous Fossillagerstätte.

   The decimeter to one meter thick beds are laminated due to changing proportions of bitumen. Slump structures and graded bedding indicate that these rocks represent the filling of small stagnant basins within the Hauptdolomit lagoon. Within and above the sediment reducing conditions with H_2S allowed for preservation of organic substance and fossils.

In summary, most of the Hauptdolomit lagoon was within the tidal environment. Where sediments were deposited in a subtidal environment, massive gray dolomites were formed. Stagnant conditions led to deposition of bituminous sediments. Algal mats were present in the subtidal, tidal and supratidal environments. On small supratidal flats plants grew which have been preserved as coalified remains, and root relicts within some beds indicate an autochthonous origin for the plants.

MÜLLER-JUNGBLUTH (1970) has made a detailed facies analysis of the Hauptdolomit of the Tyrolian Lechtaler Alpen. Figs. B 5 and B 6 show the facies criteria for subtidal, inter-, and supratidal environments based on sedimentological and microfacies investigation.

3.1.4 Kössen beds

In the northern part of the shelf platform a basin existed during Raetian time, the Kössen basin (fig. B 4; named after Kössen near the Tyrolian-Bavarian boundary). A detailed facies analysis of the sediment of this basin and of marginal patch reefs (Oberrätriffkalk or Rätolias reef limestones) was published by F.FABRICIUS (1966).

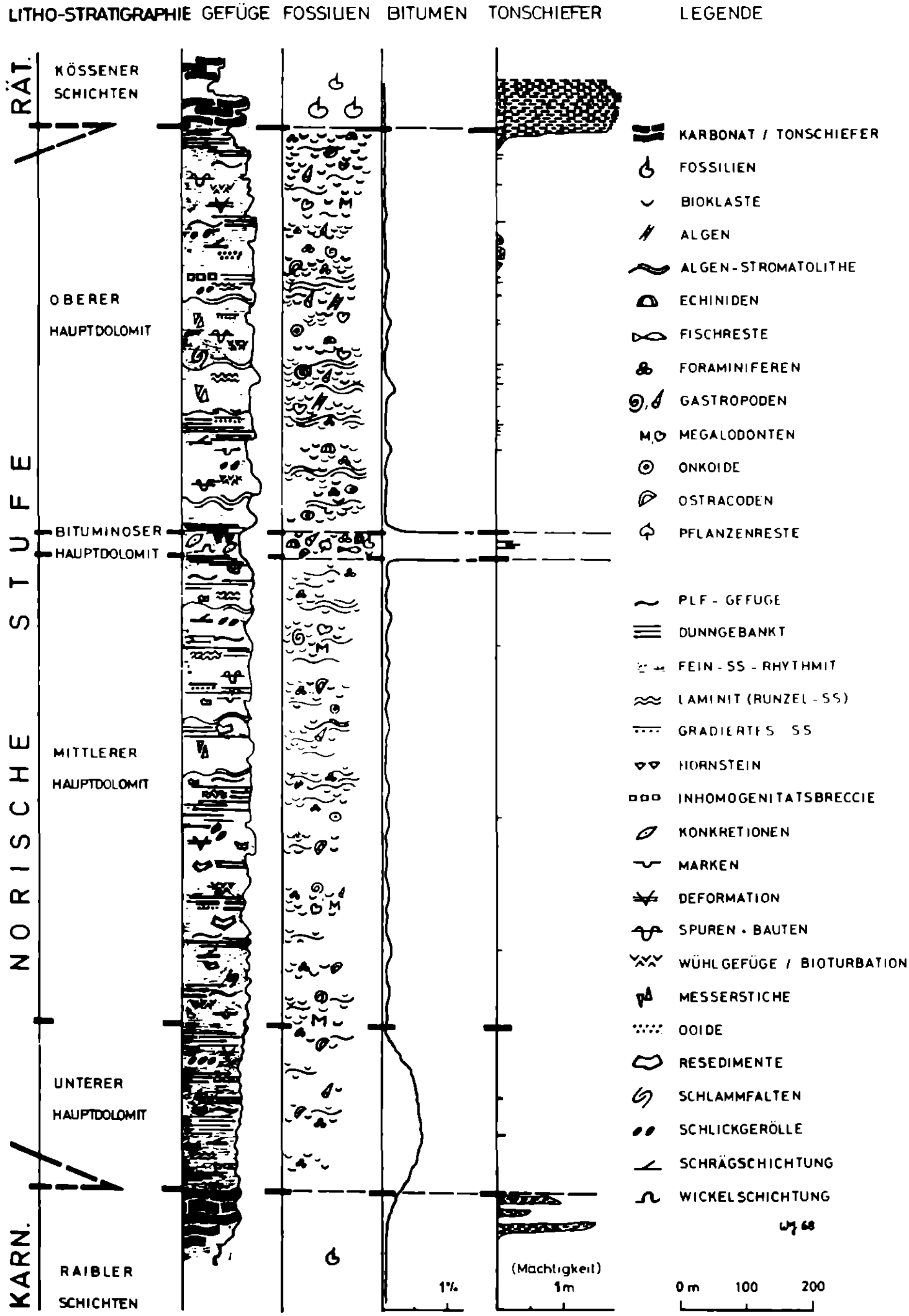
The sediments of this basin are predominantly fine-grained; they are characterized by the alternation of soft marls and hard limestones. At the edge of the basin the marls interfinger with the patch reefs of the Rhaetoliassic reef limestones and with the shallow water limestones of the Lofer facies, which here include oolites. The marly facies called Kössen marls, formed the soft bottom of the basin which was inhabited predominantly by a monotonous fauna of ostracods and foraminifera. Irregular composite aggregates of pyrite, abundant in insoluble residue, indicate reducing conditions during early diagenesis. The pyrite has been ascribed to bacterial activity by FABRICIUS (1961).

The limestone facies (Kössen limestone) is restricted to some strata interbedded with marls. Several limestone beds may combine to form a sequence in which the marls are reduced to thin beds. Two types of strata characterize this lithofacies:

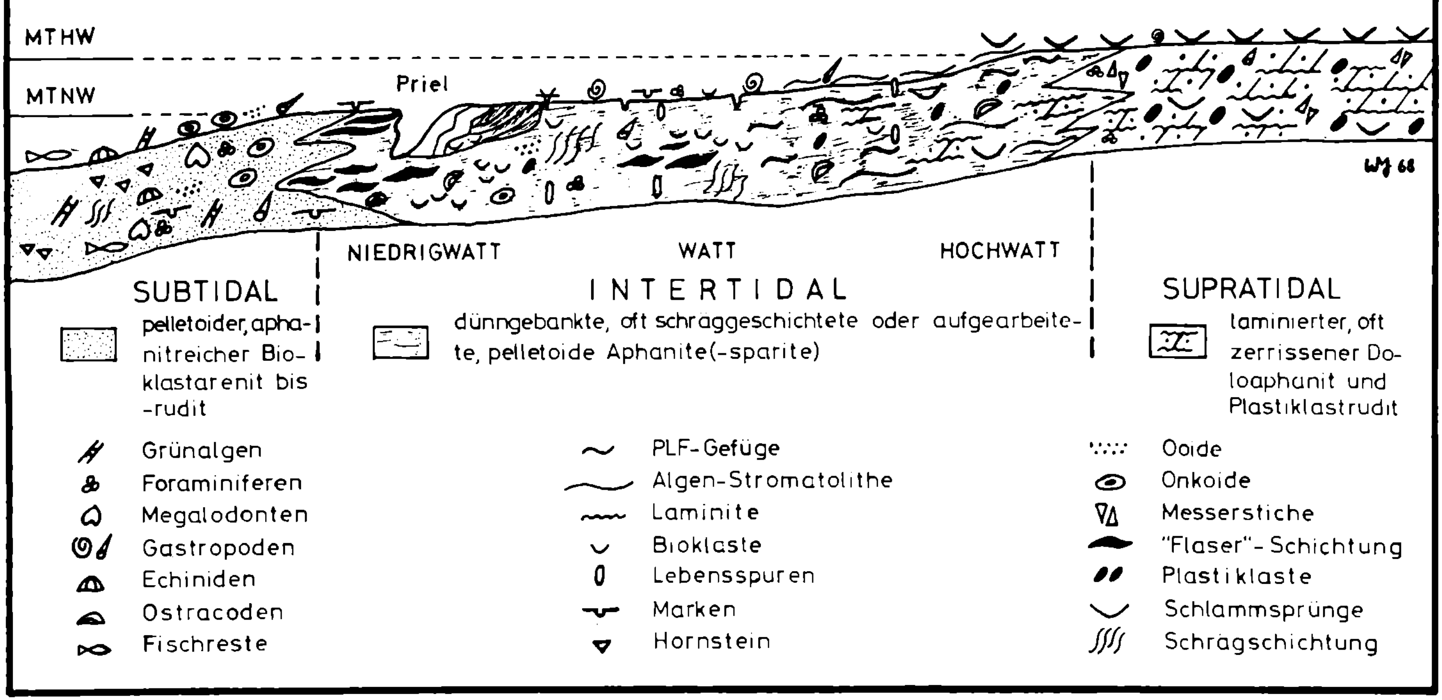
Fig. B 5 Generalized section of the Alpine Hauptdolomit, after MÜLLER-JUNGBLUTH 1970.

Fig. B 6 Environments of Hauptdolomit deposition areas, after MÜLLER-JUNGBLUTH 1970.

Schematisiertes Säulenprofil des Alpinen Hauptdolomits - (NOR)



IDEALISIERTES PROFIL EINES HAUPTDOLOMIT-ABSCHNITTES



1. Dense black marly limestones with smooth or undulose bedding planes. These beds may be reduced to nodules within the marls; the differential compaction evident in this way indicates early diagenetic concretionary lithification. The relative scarcity of megafossils, the small sizes of foraminifera and ostracods, and the abundance of trace fossils are characteristic of these beds. Simple boring holes which may be filled with coarse clastic material, zoophycus-like bioturbations and "Spreiten" structures have been observed. Sporadic coquina beds are found. In some beds, particularly in the central basins, Choristoceras occurs.

2.
The second type of limestone bed is characterized by low clay content, abundant biogenic debris, and irregular bedding planes. Some bedding surfaces have been burrowed and exhibit hardground features. The layers are rich in fossils; pelecypods and brachiopods are dominant, echinoderms, corals, calcisponges, and calcareous algae are subordinate, In some beds brachiopods markedly dominate all other faunal elements. These beds are known as Oxycolpos-limestones (Spirigera oxycolpos). The microfauna is made up largely of foraminifera.

Fossil orientation indicates a turbulent environment of deposition.

3.1.5 Raetolias Reef Facies

Within the Kössen facies two types of organic built-ups are developed:

1) Kössen coral limestones: Within the Kössen facies and parallel to the stratification there are coral beds up to 10m thick. The coral limestones are grey. Between the high branching corals of "Thecosmilia" the matrix is a very fine grained detrital limestone. At the upper boundary of these beds corals frequently are truncated; at the disconformity borings are found. These borings are filled with marls of the overlying Kössen facies.

2) Raetolias reef limestone: Laterally the thicker coral beds of the Kössen coral limestone may grade into reef limestones which resulted from the extensive build-up of an organic framework and the production of debris. In this way relief was developed, with forereef slopes, inclined toward basins containing marly Kössen facies (for example the Rötelwand reef in the Osterhorn group of the Salzburg Alps; SIEBER, 1937; M SCHLAGER 1965).

In the Steinplatte area near Waidring in Tyrol the transition from Kössen facies to Raetolias reef limestone is of a different nature The reef is underlain by Lower Kössen beds, in which isolated, lenticular reef structures are formed.These are up to several tens of meters high and of equal lateral extension (OHLEN'S A-reef, B-reef, C-reef of the Steinplatte, OHLEN, 1959). In the reef structures which are located toward the center of the basin, growth terminated within the Kössen facies, whereas several reefs located near the shallow water platform edge continued to grow and combined to form the large Steinplatte reef complex.

According to OHLEN (1959) the initial phase of reef growth resulted in shell (Oxytoma,"Avicula" Ostrea) and crinoid beds; during this phase especially, branching "Thecosmilia" and the hydrozoan colonies of Spongiomorpha contributed to the framework construction. These frameworks are limited in extent. They were overgrown by the platy hydrozoan Stromatomorpha rhaetica. In the reef complex of the Steinplatte the continous framework of the base breaks up into isolated patch reefs consisting of "Thecosmilia" colonies embedded in reef debris. During the middle phase of reef growth several organisms, some encrusting, constructed small reef structures which may have combined to form a ridge at the edge of the reef. In the Adnet reef, which is comparable to the Steinplatte reef, various hydrozoans, calcisponges, calcareous algae, and encrusting foraminifera played the dominant role in reef growth. The branching Thecosmilia colonies are characteristic of the calmer portion of the central reef area. During this phase the relative height of the reef with respect to the basin reached its maximum of one hundred meters. The fore reef slopes at an angle of about 28° toward the basin. On this slope coarse reef debris is found; toward the basin the grain size decreases rapidly.

During the final phase the reef was covered by calcarenites. In the near-reef zone of the Steinplatte reef complex,calcarenites of coated reef debris, of calcareous algae,and foraminfera were deposited during the entire period of reef growth. Megalodonts characteristic of the far-reef zone may occur in the near-reef zone ; a similar mode of occurence has been described above for the Dachstein facies.

Synecology and association patterns of small Raetolias reefs are currently under study (P.SCHÄFER - Adnet area and Rötelwand reef; B.SENOWBARI-DARYAN - Feichtenstein reef near Hintersee, Salzburg).

3.2 L i a s

Generally speaking three facies canbe recognized within the northern alpine Liassic: the sandy "Gresten" beds, marly to calcareous "Fleckenmergel" and a limestone facies. The last mentioned facies is of interest for the excursion: The well-bedded back-reef facies of the Dachsteinkalk is overlain with a hiatus by thin liassic red limestones. Within the Kössen basin small Raetolias reefs seem to have developed during the lowermost Lias as well.

According to FABRICIUS (1966) two facies-groups can be recognized within Lower Lias deposits laying on Kössen beds or Raetoliassic reef limestone:

(1) calcarenite bioclast-facies
  a) ± connected with Raetoliassic reef limestones
  sub-facies - crinoidal limestone (sometimes called "Hierlatzkalk")
  - glauconite limestone
  - sponge spiculite limestone
  (siliceous ls . with cherts)
  b) with continuous transition to the Kössen beds
  sub-facies - grey "Bankkalk"

(2) calcilutite microfossil facies
  a) red sediments
  sub-facies - red nodular limestones
  - red "Bankkalk"
  b) light transition facies (not mottled Lias limestone)
  C) grey sediments
  sub-facies - Lias -"Fleckenkalk und Mergel"

The excursion will study the changes which took place during the "Adnet-juncture" (see page60) at the Triassic/Liassic boundary. During this time, in some areas starting with the Norian (see SCHÖLL 1968), submarine fissure systems within the reef limestone were formed and filled with sediments of different age (e.g. Norian sediments in Carnian Hallstatt limestones of the Feuerkogel-Röthelstein area near Aussee; Lower Liassic fissures in Raetolias reef limestones of the Adnet region, see WENDT 1971)

Liassic "deeper-water" limestones

The excursion will see some of the most common Liassic facies types (see p. 97 - 107):

a) Adneter Knollenkalk (Adnet nodular limestone)- p. 104. This widely distributed type has been thoroughly studied by JURGAN (1967).

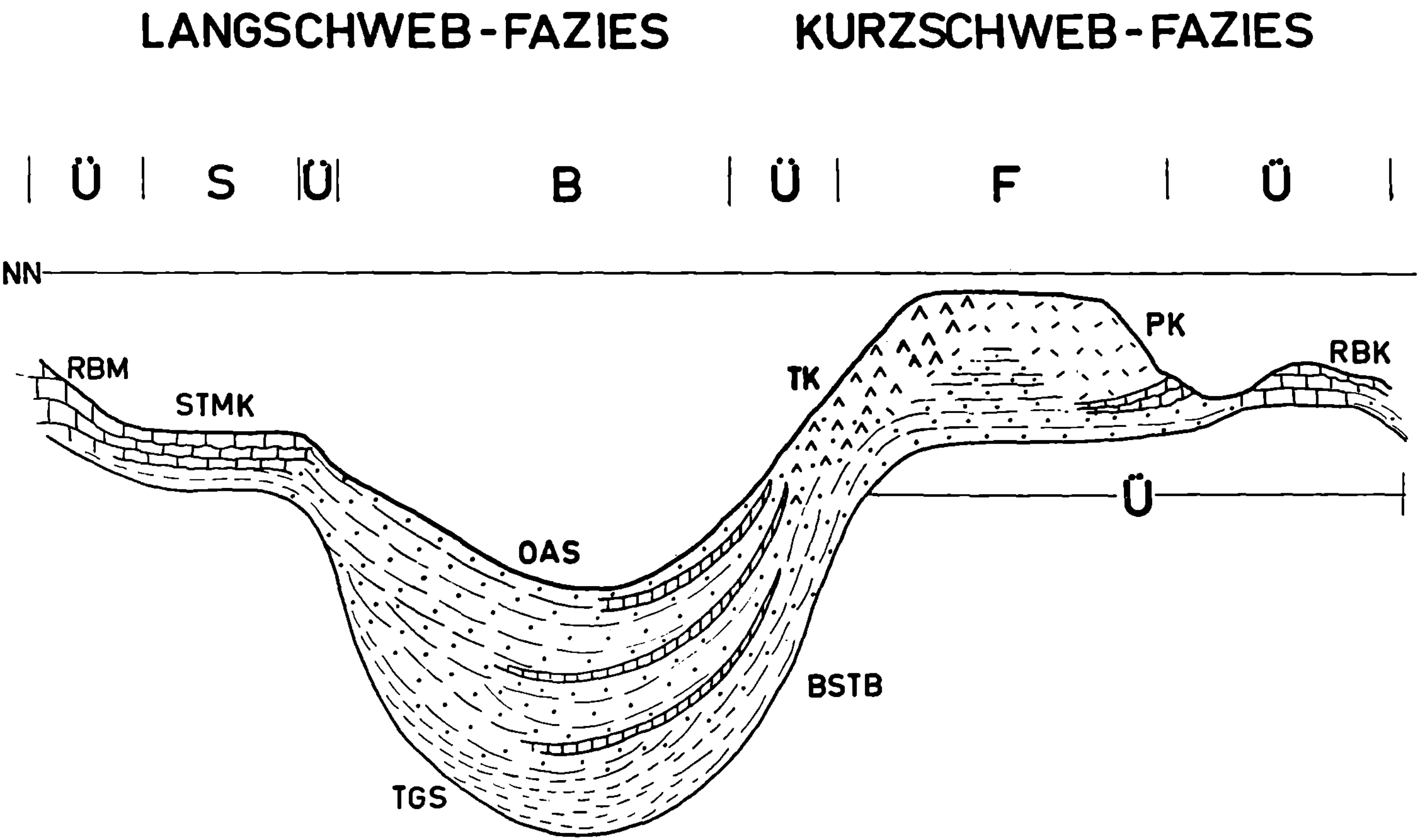
b) Limestone conglomerate - p. 105.

c) "Scheck" conglomerate - see p. 105 - 106.

d) Grey micritic limestones - we will see this type as internal sediment of fissures within the Upper Triassic reef- and back-reef limestones.

e) red and grey crinoidal limestones ("Hierlatz ls.") often in fissures.

All these types are generally interpreted as subtidal deposits, but there are certainly bathymetrical differences (some Hierlatz limestones may represent sea-mount deposits, some red limestones with boring algae may have been formed in Upper subtidal environments).



LANGSCHWEB-FAZIES
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3.3 Upper Jurassic

According to recent studies by A.FENNINGER, H.W.FLOGEL, R.E.GARRISON, H.HÖTZL, H.L.LOBITZER, B.PLÖCHINGER, M.SCHLAGER and W.SCHLAGER (summarized by FENNINGER & HOLZER 1972) the Malm deposits of the "Oberostalpin" tectonic unit of the Northern Limestone Alps may be attributed to three different environments (see fig. B 7).

(1) "Kurzschweb-Fazies" This was a zone of high turbulence, represented by up to 700m of shallow-water limestones (thin Oxfordian oolitic limestones, massive to thick-bedded micrite limestones of Upper Malm age (quiet water facies), and detrital fossiliferous limestones. Organic structures (built-ups, patch-reefs) are of subordinate importance. These shallow-water limestones (Plassen-and Tressenstein-limestones) are interpreted as deposits of a wide platform. Three main microfacies types have been recognized (A.FENNINGER 1967, H.W.FLOGEL & A.FENNINGER 1966, H.HÖTZL 1967):

Type I - Well bedded low-energy micrites and dismicrites with patchy distribution of hydrozoan faunas and algal associations.

Type II - Massive high-energy biomicrites, biointrasparites, oncosparites, and pelsparite-micrites, with up to about 30% biogenic components (foraminifera, hydrozoans, corals, red and green algae, oncoids).

Type III - Massive limestone breccias; high-energy environment with intramicsparite and breccias.

Fig. B 7 Main environments of Upper Jurassic deposits in the Northern Limestone Alps after A. FENNINGER & H.-L. HOLZER 1972. Abbreviations: B = basin facies; F = shallow water facies; S = threshold facies; Ü = transition facies; Lithostratigraphic units: BSTB = Barmstein limestone beds; OAS = Oberalm beds; PK = Plassen limestone; RBK = Rettenbach limestone, RBM = Reitbauermauer limestone; STMK = Steinmühl limestone; TGS = Tauglboden beds; TK = Tressenstein limestone. Langschweb-Fazies = Zone of non-turbulence, Kurzschweb-Fazies = Zone of high turbulence.

Types I and II correspond to the Plassen limestone, type III to parts of the Tressenstein limestone.

Most of these limestones are found in the "Salzkammergut area" (Plassen mountain near Hallstatt, Tressenstein near Bad Aussee). Rich algal floras have been described from the Plassen- and Tressenstein limestone by A.FENNINGER & H.HÖTZL (1957), E.FLÜGEL (1964b) and FENNINGER & HOLZER (1972). Composition and stratigraphic sequences of the associations corresponds to Upper Jurassic floras from the Mediterranean region, (see table 6)

(2) "Langschweb-Fazies" (zone of non-turbulence): This region can be divided into a red threshold (Tiefschwellen) facies and a generally grey basin facies.

The threshold facies is represented by a thin sequence (Steinmühl limestone, Hasselberg limestone, Tithonflaserkalk, St. Agatha-Kalk, Acanthicus-Schichten) with very characteristic (widely distributed in the Tethys region) microfacies and microfaunal elements (globigerinoid-, filament limestones of the Dogger; radiolarites, siliceous limestones or globigerinoid limestones of the Oxfordian, Saccocoma- and Calpionella limestones of Kimmeridgian/Tithonian). Red nodular limestones are common.

The basin facies (Oberalm beds, Aptychen beds, Biancone) consists of lithologically uniform sequences of bedded micritic limestones and marls, sometimes with cherts. Maximum thickness is 900 - 1000m, but there are major differences in the thicknesses of these formations. Biostratigraphycally, Callovian to Berriasian have been proved by ammonites and calpionellids. The Oberalm limestones seem to be coccolith-ooze according to ultramicroscopic studies (H.W.FLÜGEL & A.FENNINGER 1966) and with regard to recent investigations by H.KEUPP (Erlangen). Frequent microfossils are radiolara and sponge spicules. Locally up to 5 layers of morphologically distinct thick limestone beds (Barmsteinkalk beds) are intercalated, often composed of calcarenites with shallow-water fossils. Some of these beds may represent limestone turbidites (allodapic limestones; H.W.FLÜGEL & P.PÖLSER 1965), see STOP 24 of the excursion.

	Plassen ls.	Tressen-stein ls.	Barmstein ls.	Sulzfluh ls.	Ernstbrunn ls.
	Salzkammergut			Rhätikon	Nieder-österreich
Dasycladaceae					
Actinoporella podolica (ALTH)	+	+	+		
Clypeina jurassica(FAVRE)	+	+	+	+	+
Clypeina parvula CAROZZI	+				
Griphoporella ehrenbergi BACHM.					+
Munieria baconica DEECKE	+		+		
Petrascula bursiformis (ETALLON)	+	+			+
Petrascula piai BACHMAYER					+
Pseudoepimastopora jurassica ENDO	+	+	+	+	
Salpingoporella annulata CAR.	+	+	+	+	
Salpingoporella gigantea (CAR.)	+				
Salpingoporella grudii (RADOICIC)			+		
Salpingoporella mühlbergii (LOR.)				+	
Salpingoporella pygmaea (GÜMBEL)	+		+		
Teutloporella obsoleta CAROZZI		+		+	
Teutloporella socialis PRATURLON		+		aff.	
Teutloporella ? striata (CAROZZI)	+			+	
Codiaceae					
Cayeuxia americana JOHNSON				+	
Cayeuxia austriaca FENN.&HÖTZL	+				
Cayeuxia doerflesiana KAMPTNER				+	+
Cayeuxia kurdistanensis ELLIOTT				+	
Cayeuxia mediterranea HERAK				+	+
Cayeuxia moldavica FROLLO		+		+	+
Cayeuxia piae FROLLO	+			+	+
Cayeuxia sp.			+		
Consinocodium japonicum ENDO	+				
Lithocodium morikawai ENDO	+				+
Lithocodium sp.		+	+		
Marinella lugeoni PFENDER				+	
Nipponophycus cf. ramosus YABE & TOYAMA	+			+	
Red algae					
Pycnoporidium lobatum ENDO	+				
Solenopora jurassica BROWN		+			
Solenopora sp.			+		+
Solenopora cf. sudakensis MASL.	+				
Stenoporidium chaetetiformis ENDO		+	+		
Thaumatoporella parvovesiculifera (RAINERI)	+	+	+	+	+

Table 6: Upper Jurassic calcareous algae from different shallow-water environments in the Northern Limestone Alps. Cayeuxia may belong to blue-green algae.

Lower Malm quiet-water deposits are developed as so-called Ta glboden beds and Ruhpolding beds - clastic and siliceous sequences with large-scaled slumping structures and olisthostroms (W. & M. SCHLAGER 1973).

(3) Transition facies between "Kurzschweb"- and "Langschweb" facies shows gradational transition of basin facies and threshold facies into shallow-water deposits ("wechselfarbige Oberalmer Schichten" PLÖCHINGER).

4. Excursion Route - Itinerary

(E.FLÜGEL, H.LOBITZER, P.SCHÄFER)

Although the excursion will show only a small part of the Northern Limestone Alps it may be appropriate to start with a short general view of the geology of the Eastern Alps (see EXNER 1966):

From the geomorphic point of view Northern Alps, Central Alps, and Southern Alps canbe distinguished.

The most important elements in the Northern Alps are the Northern Limestone Alps (Nördliche Kalkalpen). They consist of Mesozoic (mainly Triassic carbonates of the Upper Austro-Alpine Nappe (Oberostalpin). The limit between Northern and Central Alps follows the line (from West to East) Arlberg- Innsbruck - Leoben /Styria - Semmering.

The Central Alps consist mainly of metamorphic rocks of the Upper Austro-Alpine Nappe. Below this unit appear the Alpine metamorphic rocks of the Lower Austro-Alpine Nappe and of the Penninic Zone which outcrop in tectonic windows (Hohe Tauern).

The Southern Alps consist of Paleozoic (e.g. Karnische Alpen at the Austrian/Italian border) and Mesozoic (e.g. Dolomiten).

From N. to S one may distinguish the following tectonic zones in the Eastern Alps:

(1) Contrary to the Switzerland the Helvetic Zone of the Eastern Alps is only developed as a narrow thrust belt which has slipped off from its basement. It consists of Jurassic to Upper Eocene limestones, marls and rare sandstones of the miogeosyncline along the northern border of the Alps in western Austria and Bavaria. To the east the southern part of this zone passes into the "Gresten Klippen Zone" which shows some differences with respect to its facies. East of Salzburg as far as Vienna, the Helvetic Zone forms thrust slices and tectonic windows under the Flysch Zone. Together with the Flysch Zone, the Helvetic Zone underlies the Northern Limestone Alps in which they appear in tectonic windows.

(2) The Flysch Zone forms the continuation of the Ultrahelvetic Zone and of its border with the Penninic Zone of the Swiss Alps. It continues

north of Vienna in the very broad Flysch Zone of the Carpathians. In Bavaria and Austria the Flysch consists of Upper Cretaceous to Middle Eocene syn-orogenic sediments (marine sandstones, marls, breccias and conglomerates, some limestones, thickness up to more than 100 m). Several important tectonic slices can be recognized. The Northern Limestone Alps have overthrust the Flysch Zone during the Lower Oligocene orogenetic phase. The Flysch Zone appears in tectonic windows below the Northern Limestone Alps (e.g. in the Wolfgangsee region, Salzkammergut). These windows exist at distance up to 25 km south of the northern edge of the Northern Limestone Alps.

(3) The Penninic Zone outcrops in the Austrian Alps in tectonic windows (Unterengadin, Hohe Tauern, Wechsel). The Hercynian basement (?Precambrian and Older Paleozoic schists, Hercynian granites and migmatites) as well as the Permocarboniferous and Mesozoic strata have undergone an epi- to mesothermal Alpine metamorphism. The thin carbonate Triassic is developed partly in "Germanic" red bed facies, partly in miogeosynclinal facies. The Jurassic to Lower Cretaceous eugeosynclinal phyllites, calcischists and breccias have a thickness of over 1000 m. They are associated with thick bodies of greenschist, serpentines and remnants of Gabbro, pyroxenite and peridotite. All these rocks are deformed and show epi- to mesothermal recrystallization. Fossils are very scarce because of the Alpine metamorphism. The overthrust of the Lower Austro-Alpine and Upper Austro-Alpine nappes onto the Penninic Zone of the Tauern window may have become effective between the Lower and Upper Cretaceous time.

(4) An essential Carpathian tectonic element in the Alps appears in the (Pieninic) Klippen Zone near Vienna. It is formed of miogeosynclinal Mesozoic limestones (e.g. Tithonian Ernstbrunn ls. see table 6, p. 91), marls, sandstones and radiolarites.

(5) The Lower Austro-Alpine Zone is found along the boundary to Switzerland and the tectonic windows of the Unterengadin and of the Tauern and in the Semmering area. The Hercynian basement is covered by younger Paleozoic and Triassic to Lower Cretaceous sediments. Triassic and Liassic deposits yield well-preserved fossils. The carbonate Triassic shows a miogeosynclinal facies pattern similar to the Upper Austro-Alpine Zone. The rest of the Jurassic and the Lower Cretaceous is comparable to the Upper Austro-Alpine Zone,too. The overthrust of the Upper Austro-Alpine Nappe took place probably during the intra-Cretaceous orogeny. The emergence of the Lower Austro-Alpine Zone to the surface started before Upper Eocene.

Several nappes may be distinguished especially at the northeastern corner of the Tauern area and in the Semmering region.

(6) The crystalline basement of the Upper Austro-Alpine Zone (Oberostalpin) shows a weak or local, regressive Alpine metamorphism. The rocks are of ?Precambrian/Lower Paleozoic age. They consist of metamorphic schists, paragneisses, micaschists, marbles, migmatites, and orthogneisses.

Between the crystallin basement and fossiliferous Lower Paleozoic sediments a tectonic hiatus can be recognized. The Upper Paleozoic and Mesozoic strata are frequently stripped off. They form thrust slices and nappes.

The fossiliferous Lower Paleozoic consists of marine sediments (Ordovician to Lower Carboniferous). Lower Paleozoic strata are developed in the Graz region (Styria) and within the so-called "Grauwacken Zone" (Styria, Salzburg, Tirol) at the northern boundary of the Central Alps. Hercynian orogenesis took place at the end of the Lower Carboniferous. Upper Carboniferous and Permian sediments are characterized by mostly continental deposits. In the Northern Limestone Alps Permian to Lowermost Triassic evaporites can be found ("Haselgebirge",=the salt-bearing rock of the salt mines in the Salzkammergut area).

The Mesozoic of the Upper Austro-Alpine Zone consists of different miogeosynclinal marine sediments, deposited upon subsiding shelf. Triassic sediments show a maximum thickness of about 2000 m. The development of the facies pattern has been described above (see chapter 2 and 3). Lower Jurassic sedimentation often starts with a regresssion, followed by marine sedimentation throughout Jurassic and Lower Cretaceous times (limestones with brachiopods and cephalopods, marls with siliceous nodules, and radiolarites - Dogger and Malm ; shallow-water "reef"limestones (Malm), and deeper-water micritic limestones (Malm to Lower Cretaceous)). During the intra-Cretaceous orogeny the Northern Limestone Alps were overthrust upon the Lower Austro-Alpine and Penninic Zones. Marine Cenomanian clastics overlain transgressively folds and thrust slices of Upper Austro-Alpine units. During the Senon a mixed marine and paralic facies with conglomerates, breccias, limestones with pachydont mollusks, and marine marls with rich microfaunas, locally continental strata with coals, was deposited caused by the transgression of the "Gosau series". Locally Eocene limestones with nummulites can be found at the top of this facies pattern. During the second Alpine orogeny (Oligocene) the Northern Limestone Alps were overthrust onto the Flysch, the Klippen Zone, and onto the Helvetic Zone.

(7) The Southern Alps seem to have formed a more or less rigid block during the Alpine orogeny. The stratigrpahic sequence is characterized by a well-developed fossiliferous Lower Paleozoic, marine Upper Carboniferous and Permian, and about 300 m thick Triassic deposits. The Jurassic to Lowermost Tertiary series are similar to those of the Upper Austro-Alpine Zone.

NOTE: Since the Salzburg area and the Salzkammergut district are known for their rainy weather (the so-called "Salzburger Schnürlregen" may be a good "index-fossil" for that area!) it seems necessary to prepare some more STOPS than the excursion will see as secondary targets.

4.1 W e d n e s d a y, Oct. 1st 1975

Subject: Raetoliassic reef limestones (reef communities, role of the algae, destruction of the reefs, fissure fillings).Lower Liassic deeper-water limestone facies (limestone types, condensed sedimentation, submarine slumping, boring algae, fissure fillings).

Guides: E.FLÜGEL, P.SCHÄFER.

STOP 1 - Locality: "Tropfbruch", quarry east of the village Adnet, west-southwest of P.575, Top.sheet Hallein, Fig. B 8.

Stratigraphy: Upper Raetian. Fissure fillings with Lower Liassic sediments.

Facies: coral patch reefs within bioclastic calcarenites.

This quarry is famous for its varicoloured coral limestones which have been sectioned during former years for decoration stones. The name "Tropf-Bruch" (Tropf means drop) refers to the bead-like appearance of leached and recrystallized corals.

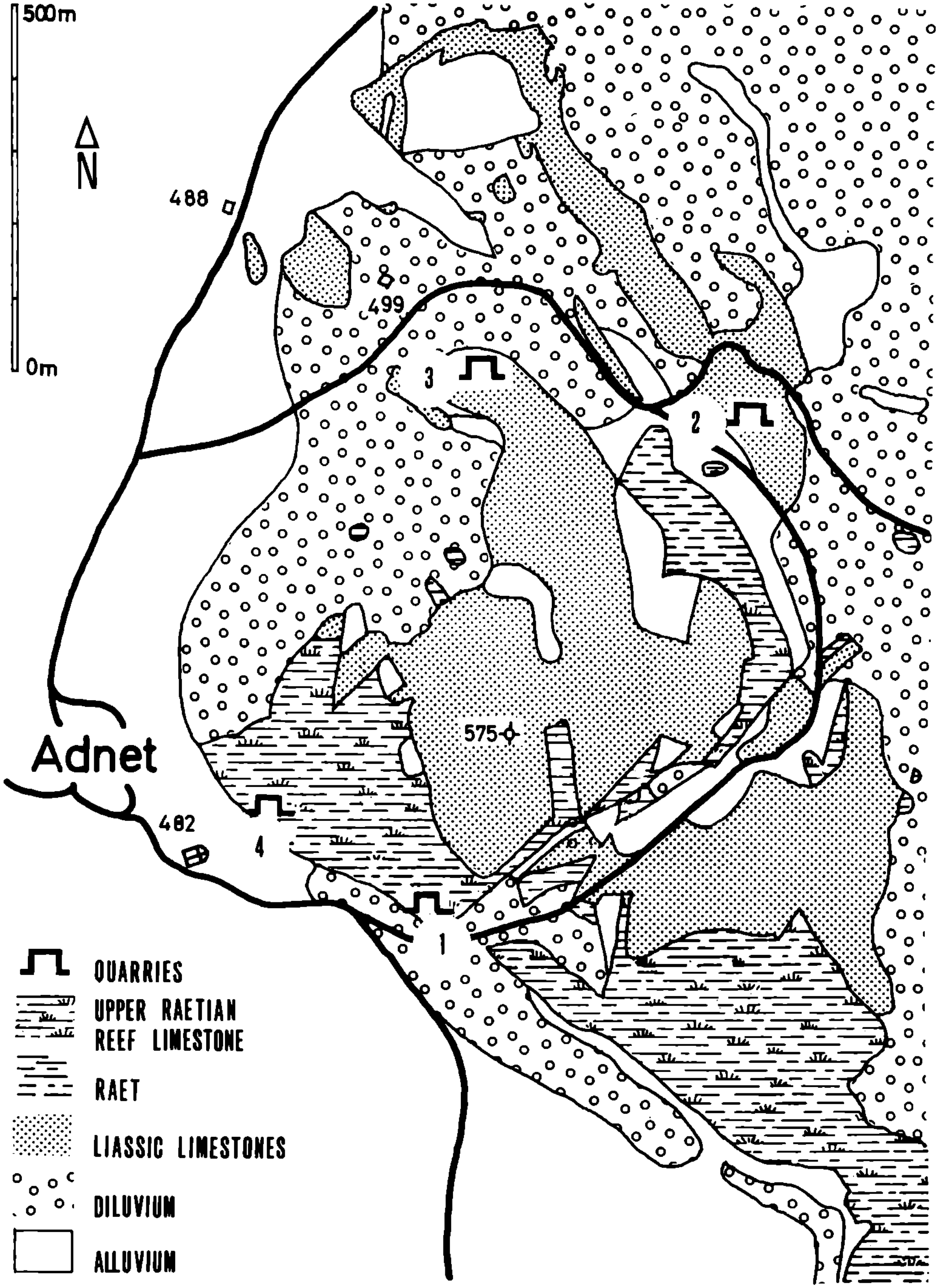
The well exposed walls of the quarry show the composition of the reef framework as well as many diagenetic solution phenomena:

(1) Reef communities: A quantitative survey of parts of the quarry wall (using line- and point-counting) resulted in the recognition of clearly differentiated facies types and communities difficult to typify (see figs. B 9 to B 11).

Three facies types can be recognized:

Type I - bioclastic calcarenites consisting of partly coated corals ("Thecosmilia", Thamnasteria), bryozoans, gastropods, and - clearly to be seen - areas with many dasyclads.

Fig. B 8 Excursion area near Adnet(Salzburg). Simplified, after M.SCHLAGER 1960, Geologische Karte von Adnet und Umgebung, 1 : 10 000.


500m
0m
N
488
499
3
2
575
Adnet
482
4
1
QUARRIES
UPPER RAETIAN
REEF LIMESTONE
RAET
LIASSIC LIMESTONES
DILUVIUM
ALLUVIUM

"*Thecosmilia*", type A (= *T. clathrata*) and type B (small branches)

Thecosmilia colonies

coated "*Thecosmilia*"

debris of "*Thecosmilia*"

Thamnasteria

Astraeomorpha

single corals (e.g. "*Montlivaultia*")

segmented calcareous sponges (Sphinctozoa)

non-segmented calcareous sponges (e.g. *Peronidella*)

"laminated" calcareous sponges

hydrozoans (mostly spongiomorphids)

bryozoans

dasyclads

solenoporids

reef-dwelling organisms

gastropods

brachiopods

echinoderms

megalodontid lamellibranchs

larger foraminifera (mostly *Alpinophragmium*)

leached areas

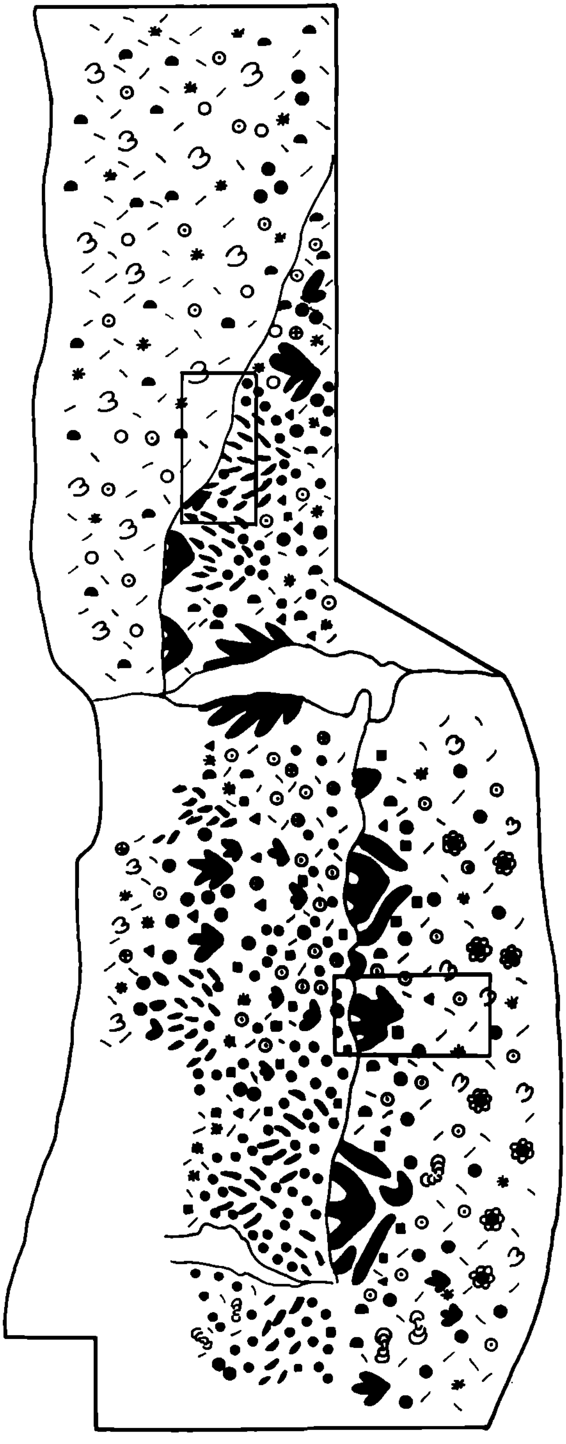
cavity, filled with micrite

cavity, filled with sparite

debris (mostly of broken shells)

Explanation of the Symbols for figs. B 9 to B 11.

Fig.B 9
Eastern wall of the "Tropfbruch" quarry with the distribution of organisms. 1 : 50.



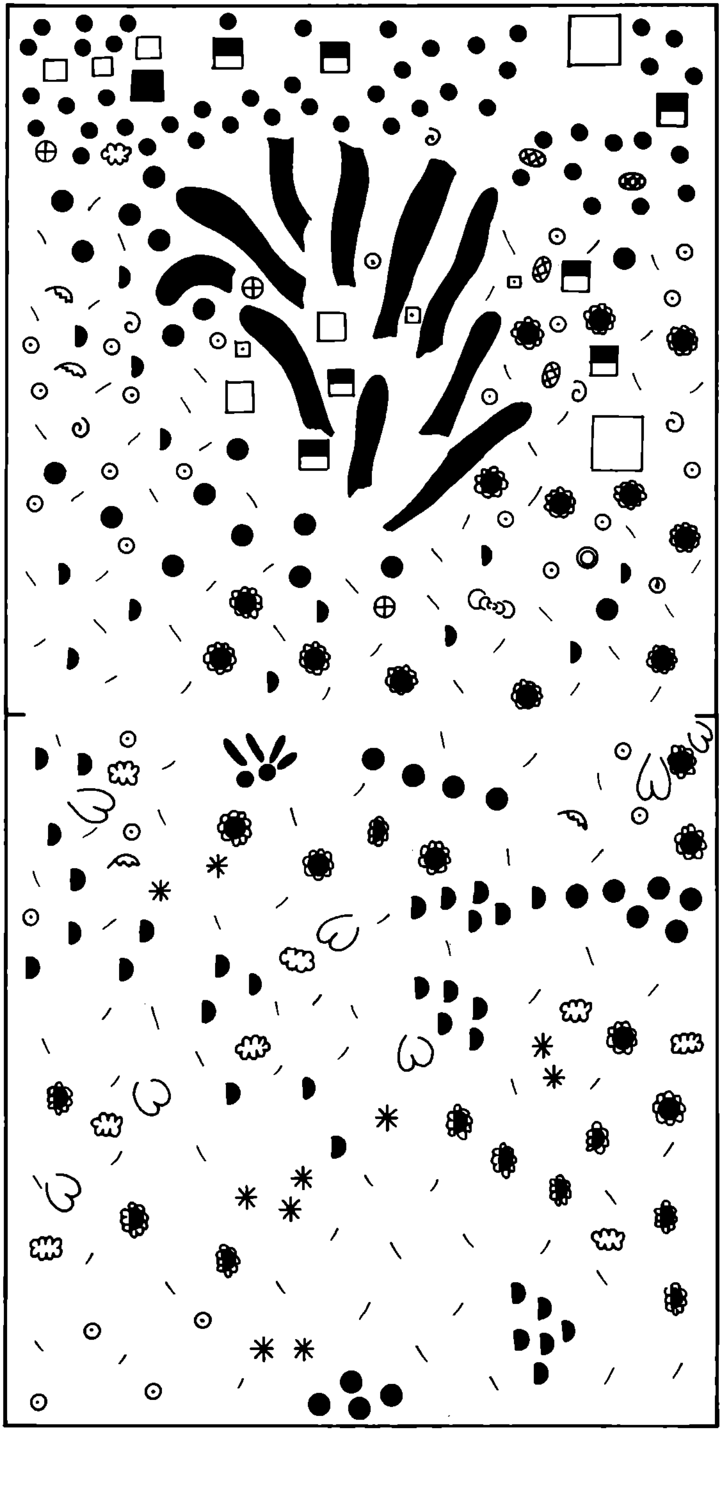
Megalodontids and encrusting large calcareous sponges are found in this facies type too. At the top of the branches of "Thecosmilia" colonies are cut off by a stylolitic solution zone. - Distribution: lower left part of the wall, see figs. B 9 and B 10.

Type II - micritic biolithite with high amounts of branchy "Thecosmilia" colonies, together with some colonies of Thamnasteria,hydrozoans, calcareous sponges, and single corals. This type is overlain and interfingers with type III. - Distribution: middle part of the wall, see figs. B 9 and B 11.

Type III - bioclastic calcarenite with megalodontid lamellibranchs. The dretitus consists of abraded thalli of red algae (Solenopora), small gastropods, echinoderms and some coral colonies (Astraeomorpha, Thamnasteria, "Thecosmilia". On the upper floor of the quarry very large colonies of "Thecosmilia" clathrata (EMMERICH) can be seen growing on the calcarenite.- Distribution: upper (right part of the wall, see figs.B 9 and B 11.

The matrix of all types is micrite indicating a low-energy environment.

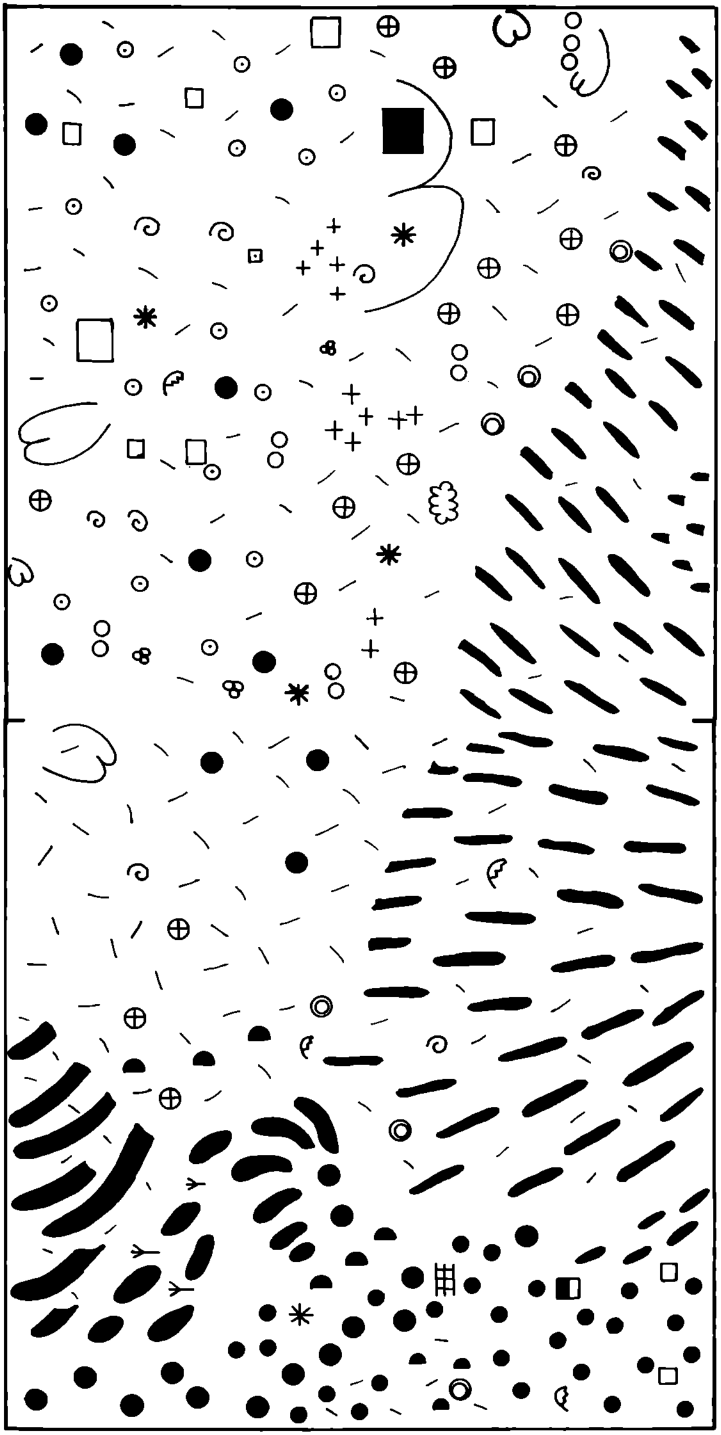
Fig. B 10 Generalized distribution of the organisms in a measuring area (counting fields 73 and 63 (80 x 160) within facies type I, see left part of fig. B 9. For symbols see p. 98. - Upper Raetian Reef Limestone, Tropfbruch Adnet.



	type I	type II	type III
modal composition:			
matrix and fine detritus	**45%**	35%	62%
leaches and sparry areas	**3,5%**	7%	0,5%
areas with fossils	**51,5%**	58%	37,5%
order of frequencies:	**1. Thecosmilia A**	1. Thecosmilia B	1. Thecosmilia A
	2. Dasycladaceae	2. Thecosmilia A	2. Thecosmilia B
	3. Thecosmilia B	3. Thamnasteria	3. Thamnasteria
	4. Thamnasteria	4. Dasycladaceae	4. Solenopora, Dasycl.
	5. Calc. sponges	5. calc. sponges	5. shell fragments
	6. various corals	6. hydrozoans	6. megalodontids
	7. single corals	7. shell fragments	7. calc. sponges
	8. megalodontids	8. single corals	8. brachiopods
	9. hydrozoans	9. megalodontids	9. hydrozoans
	10. bryozoans	10. echinoderms	10. single corals
	11. shell fragments	11. gastropods	11. various corals
	12. gastropods	12. brachiopods	12 gastropods
	13. brachiopods	13. bryozoans	13. bryozoans

(2) Calcareous Algae: This quarry is the type locality of Diplopora adnetensis E.FLOGEL, 1975. This algae can be found in the bright red green limestones of the facies types I and II. Samples will be provided for interested colleagues.

Fig. B 11 Generalized distribution of organisms in a measuring area (counting fields 25 and 26, 80 x 160 cm) at the boundary of the facies types II and III; see right part of fig. B 9. For symbols see p. 98. - Upper Reatian Reef limestone, Tropfburch Adnet.



Diplopora adnetensis is characterized by cylindircal, slightly bent thalli; cylindrical central stem without intusannulation; wall without segmentation. Metaspondyl arranged branches; two slender trichophorous branches are attached without a vestibulum directly to the central stem. Outer Ø between 900 and 2000 microns, inner Ø 200 to 450 microns, wide of the branches about 25 - 30 microns, length of the thalli up to 6 mm.

Red algae (Solenopora cf. S. endoi FLÜGEL are common in the calcarenites of facies type III.

(3) Destruction of the reef: At the western side of the quarry fissures filled with red Liassic sediments can be studied, These fissures show several generations of sediment fillings. The walls of the fissures show often tapestries of calcite indicating ommission periods. According to W.SCHLAGER and W.SCHÖLLNBERGER(1974) emersion and subaerial erosion of the top of the reef limestones may have been taken place:
The red colour of the upper parts of the reef limestones may be caused by the following events:
   (a) Emergence of the reef above sea-level
   (b) destruction of the reef by erosion
   (c) diagenesis in the vadose zone, connected with selective leaching of aragonite hard parts (e.g. corals) and with calcification of the micritic sediments.
   (d) subsidence of the reef to deeper-marine environments
   (e) sedimentation of the red Liassic calcareous muds

The fissures may have been formed during phase (b) and/or during phase (d).

Lit: KIESLINGER 1964, W.SCHLAGER & W.SCHÖLLNBERGER 1974, WÄHNER 1903.

STOP 2 - Locality: "Großer Kiefer-Plattenbruch " Wimberger Bruch, 1 km northeast of Adnet, Top. sheet Hallein. See fig. B 8.

Stratigraphy: Adnet formation (Sinemurian-Carixian, Lias alpha 3 to Lias gamma); "Scheck" limestone conglomerate (Domerian, upper Middle Liassic).

Facies: Deeper-water limestones with subsolution features and organic corrosion by thallophyte borings; submarine slumping sediments.

The working quarry shows the typical development of the "Adnet limestones" and of the "Scheck" conglomerate". Both of these rock types have been used for more than 800 years as decoration stones especially for gothic tombs (see the excelent description by A. KIESLINGER 1964).

Generalized section: top of the quarry

(3)	1,00 - 2,00 m	massive to thick-bedded Scheck conglomerate (red limestone clasts, up to about 10 cm, cemented by white calcite spar)
(2)	1,60 - 2,20 m	massive to thick-bedded limestone conglomerate (red limestone clasts, partly with ferro-manganese oxide crusts, ∅ up to about 40 cm, matrix bright red crinoidal calcilutite)
(3)	8,00 - 10,00m	thin- to middle-bedded red nodular limestones with marly partings (= typical "Adneter Kalk")

There will be the possibility to take characteristical samples for each of the facies types and to discuss some models proposed for the origin of these limestones (KIESLINGER 1964, HALLAM 1967, HUDSON & JENKYNS 1969, WENDT 1971):

(1) Adnet limestone: The typical Adnet limestone consists of pink nodules of fine-grained limestones in a matrix of slightly more marly and redder material. The nodules commonly range up to about 5 cm. Minor stylolitic partings and, sometimes , black manganese oxide staining along the margins of the nodules may be present. The microfacies of these highly oxidized, predominantly red skeletal wackestones is characterized by a micritic matrix with abundant foraminifera, crinoid ossicles and echinoid fragments, sponge spicules, planktonic algae (Globochaete), and (juvenile) mostly leached ammonites.

Sedimentation was slow, sometimes continuous, but more often interrupted by frequent periods of erosion and non deposition causing stratigraphic condensation, hardgrounds and submarine erosion surfaces. Depth of deposition is a matter of question (a few hundreds to several thousands of meters have been postulated for these and other red limestones of the Alpine Mesozoic); some hardgrounds with boring algae, algal-foraminifera associations, and sessile foraminifera may have been formed in depths between 50 to 100 m (WENDT 1970). Organic corrosion by boring algae (and fungi) is of great importance for the explanation of some features formerly interpretated as caused by "subsolution"(see W.SCHLAGER 1974).

Boring algae can be found in the uppermost part of the Upper Raetian Reef Limestone, in nodules of the Adnet limestones, in limonitic crusts on hard bottoms and in clasts within the limestone conglomerate below the "Scheck". According to the dimension two types of borings have been recognized (Ø 2 - 6 micron and 10 - 60 micron).

(2) Limestone Conglomerate and Scheck Conglomerate: Towards the top of the quarry, the nodular limestone is overlain by a thicker-bedded conglomeratic limestone, consisting of clasts from the Adnet Limestone. According to HUDSON & JENKYNS (1969) three types of clasts are present: Adnet limestone; small rounded micritic clasts, which are thinly coated with Fe/Mn-oxides; pink crinoidal limestone clasts bearing on their original top surfaces Fe/Mn-crusts. These clasts may be derived by submarine slinding from a nearby topographic high. The limestone conglomerate is overlain by the "Scheck", which consists almost entirely of red calcilutitic clasts cemented by white calcite spar. The clasts are much better than in the limestone-conglomerate; the spar shows a striking radiaxial fabric away from the clasts or from the patches of grey internal sediments.

HALLAM(1967) described the Scheck as a breccia, formed by in situ break-up of lime-mud as a result of emergence. JURGAN (1969) and HUDSON & JENKYNS (1969) have argued for the interpretation as resedimented conglomerate. Cementation was probably submarine.

Varicoloured nodular limestones are conspicuous: Very often in connection with fissures a secondary discolouring (red/green) can be seen probably caused by the reduction of Fe (see K SLINGER 1964). Other (generally circular) discoloured areas are due to vanadium minerals.

STOP 3 - Locality: "Leisbruch", 800 m northeast of Adnet, Top. sheet Hallein. See fig. B 8.
Stratigraphy: Adnet formation (Lower and Middle Liassic).
Facies: Deeper-water limestones; submarine sliding sediments.

This quarry exhibits a similar situation like STOP 2, but there are better possibilities to get good samples (Fe/Mn-crusts with boring algae; micro-fossiliferous red nodular limestones).

Generalized section: top of the quarry

(6)	3,50 - 5,00 m	massive to thick-bedded Scheck conglomerate (red limestone clasts, up to 3 cm, cemented by white calcite spar, grey and red internal sediment) , strongly disturbed
(5)	3,00 - 4,50 m	massive to thick-bedded, red micritic limestone conglomerate with Fe/Mn-crusts upon the bedding planes (clasts partly with Fe/Mn-crusts too, matrix with many echinoderms)
(4)	6,50 - 7,00 m	red-thin-bedded nodular limestones, about 140 beds, nodules parallel to bedding planes, ammonites (steinkern preservation) common, microfossils abundant
(3)	0,90 m	thick-bedded, yellowish and reddish limestones with nodular bedding planes, 4 beds
(2)	1,60 m	green to grey echinoderm-limestones, 6 beds wavy bedding planes. At the floor of the quarry ammonite casts
(1)	1,90 m	green to grey, calcilutitic limestone, wavy bedding planes, marly intercalations. 24 beds.

Remarks on the biostratigraphy of the Adnet formation (see WENDT 1971):

Corresponding to the facies differentiation of Raetian deposits two facies developments can be recognized for the Liassic of the excursion area: a) a continuous sedimentation above the marly and calcareous basin facies of the Kössen formation, and b) a discontinuous sedimentation on Upper Raetian reef limestones. Lowermost Lias has not quite exactly been proved paleontologically, but Lias alpha 2 with Schlotheimia donar (WÄHNER) was found at the top of a fissure filling. Hettangian is known with a relatively rich ammonite fauna out of a condensation zone (limonitic crusts). Of Sinemurain and Carixian age are the typical Adnet beds above the condensation zone; all ammonite zones between Lias alpha 3 and the top of Lias gamma have been recognized. Although the "Scheck" is poor in fossils a determination of Domerian was possible. Lower Toarcian has been proved in the Gaissau area by Hildoceras bifrons (BRUG.). In this area WENDT has been able to recognize Upper Toarcian to Aalenian. The boundary between the

the Middle Jurassic limestones and the probably Upper Jurassic siliceous platy limestones (Radiolarites") shows a sedimentary and stratigraphical gap. The most complete Jurassic section in the Adnet area is exposed near STOP 5 of the excursion (Mörtelbach valley, Gaissau). The section shows about 7 m siliceous limestones (about 1 m) and thin-bedded, nodular grey limestones with cherts (Hettangian), overlain by about 3 m red nodular, thin-bedded limestones (Sinemurian-Carixian), and by about 2 m nodular limestone (Domerian). 30 cm nodular crinoidal limestones characterize the Lower Toarcian, 70 cm red limestones with small Fe/Mn-nodules yield ammonites of Upper Toarcian to Aalenian age. At the top a 1 cm thick Fe/Mn-crust can be seen, overlain by red and grey thin-bedded, platy siliceous limestones with marly intercalations (probably lower Upper Jurassic).

STOP 4 Locality: "Kirchenbruch" quarry, northeast of the church of Adnet, Top.sheet Hallein. See fig. B 8.
Stratigraphy: Upper Raetian; fissures with Liassic fillings.
Facies: Upper Raetian Reef limestones, central reef area and fore reef slope.

This quarry has been famous for its well exposed Liassic fissure fillings within the fossiliferous Upper Raetian Reef limestones. Today the quarry is used as storage place for various limestones which are used for manufactoring "terrazzo".

Nevertheless there is the possibility to study the reef-building and reef-dwelling organisms which have been investigated by (E.FLÜGEL 1962 a, 1964; H.ZAPFE 1963):

Frame-builder: Corals - various species of "Thecosmilia"
Thamnasteria rectilamellosa WINKLER
Thamnasteria norica FRECH
Astraeomorpha confusa(WINKLER)
Procyclolithes triadicus FRECH
"Stylophyllum" polycanthum REUSS
"Montlivaultia reussi" MILNE-EDWARDS & HAIME
"Montlivaultia" marmorea FRECH

Hydrozoans - Lamellata wähneri FLÜGEL & SY
Stromatomorpha rhaetica KOHN

Calcareous sponges -	Peronidella sp.
	Polytholosia sp.
Bryozoans -	several undescribed species.
Sessile foraminifera-	Alpinophragmium perforatum FLOGEL
	Nubecularia sp.
	"Problematikum 3" E.FLOGEL 1964
	Microtubus communis E.FLOGEL
	Cheilosporites tirolensis WÄHNER
	(the systematic position of these two species is open!)
Algae -	Solenopora sp.
	Thaumatoporella parvovesiculifera (RAIN)
	"blue-green algal crusts"

The reef building fauna consists of lamellibranchs, gastropods, scaphopods, brachiopods and some ammonites. Mobile foraminifera are common. Of special interest for the discussion of the origin of the colours of limestones was a distinctly 170 m thick coloured zone within light grey reef limestones, which could have been seen formerly in the lower part of the quarry (see E.FLÜGEL & G.F.TIETZ 1971). The red colouration of this zone is caused by minerals of the insoluble residue (goethite, together with Fe-hydroxides). The intensities of the colouration depend on the amount of the residue (higher than 4%) and on the Fe-content (higher than 0,2%), The minerals of the residue were deposited in large cavities within the living reef, together with bioclasts of reef-frame building organisms (mainly corals) eroded from the reef flat. Molds of corals were filled with Liassic micrite, containing echinoderms and sponge spicules.

4.2 Thursday, Oct. 2nd, 1975

Subject: Raetian basin facies - Kössen beds (coral biostroms): Norian basin facies - Hallstatt limestones; far-reef,back-reef facies of the Dachstein reef complexes (Lofer cyclothems); inter- and supratidal normal Hauptdolomit facies (algal mats) and subtidal special Hauptdolomit facies (bituminous marly limestones, so-called "Fischschiefer" or Ölschiefer").

Guides: E.FLÜGEL. P. SCHÄFER

STOP 5 - Locality: Mörtlbach valley, Gaißau. Top.sheet Hallein
See fig. B 12
Stratigraphy: Kössen beds, Raetian.
Facies: Thick coral biostroms intercalated with marly Kössen beds.

The excursion will study the section from north to south (from the older towards the younger beds), starting with unit 1. The profile ends at the bus terminal "Strub".

Section (H.ZANKL 1971)	(17)	14,00 m	bedded limestones alternating with thin marly beds, strong bioturbation
	(16)	3,30 m	marls with some limestone beds in the lower part
	(15)	2,10 m	3 limestone beds with strong bioturbation
	(14)	2,70 m	dark grey marls
	(13)	14,00 m	bedded limestone with strong bioturbation
	(12)	0,50 m	dark limestone with brachiopods
	(11)	13,00 m	massive coral limestone (Hauptlithodendron-Bank"): branching colonies of "Thecosmilia"in growth position, entirely recrystallized; massive head-like colonies of Stephanocoenia with boring pelecypods; plates of "Thamnasteria" norica. The corals are encrusted by biogene crusts.
	(10)	5,00 m	marls with some limestone nodules
	(9)	2,25 m	limestone beds, yellow waethering, rich in pyrite fauna: Pteria, Spiriferina, Choristoceras, corals
	(8)	8,30 m	marls with some limestone nodules
	(7)	5,00 m	nodular limestone beds with marls
Fault			
	(6)	0,50 m	limestone beds with corals ("Thecosmilia") in

growth position, coquina at the top; surface with pyrite concretions

(5) 1,50 m marls

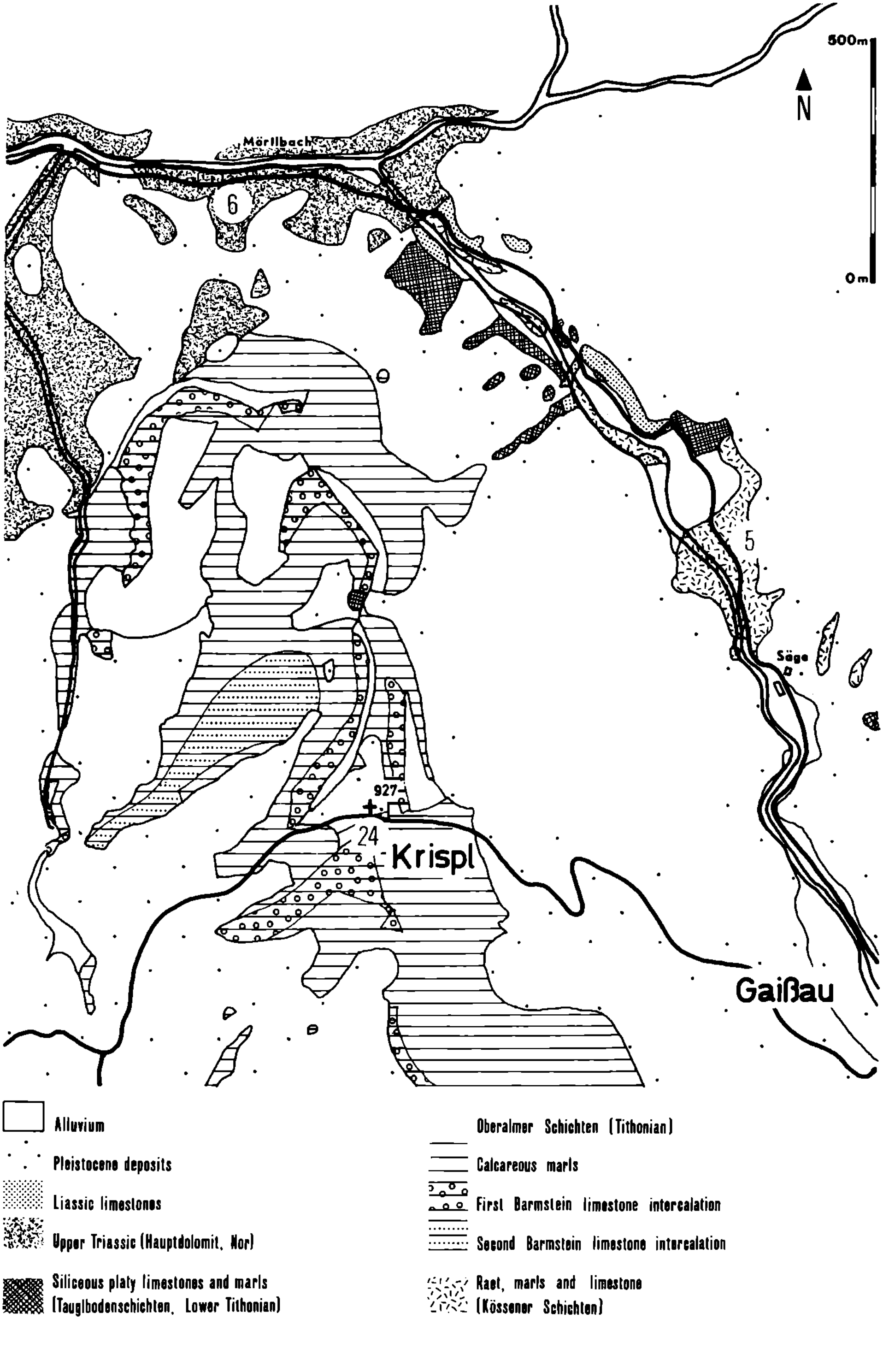
(4) 0,50 m limestone beds

(3) 1,05 m marls with concretionary limestone nodules, lined parallel to the bedding planes; pelecypod as below

(2) 1,50 m limestone beds (large scale bioturbation: pelecypods as below, with Myophoria lumachelles

(1) 7,10 m marls with some limestone beds (showing bioturbation and concretionary lithification); lamellibranchs: Hoernesia, Pteria, Pecten and fastened on hard substrate Placunopsis

Fig. B 12 Excursion area Mörtelbach valley - Gaissau (Salzburg). Simplified, after M.SCHLAGER 1960. - 1 : 10 000.


500m
N
0m
Mörllbach
6
5
Säge
927
24
Krispl
Gaißau
Alluvium
Pleistocene deposits
Liassic limestones
Upper Triassic (Hauptdolomit, Nor)
Siliceous platy limestones and marls (Tauglbodenschichten, Lower Tithonian)
Oberalmer Schichten (Tithonian)
Calcareous marls
First Barmstein limestone intercalation
Second Barmstein limestone intercalation
Raet, marls and limestone (Kössener Schichten)

STOP 7 - Locality: "Hirtensteiner Bruch", quarry, old Wiesthal road between Schöngut and point 640. Top.sheet Hallein. See fig. B 12.

Stratigraphy: middle part of the "Hauptdolomit", Upper Norian

Facies: bituminous sequences, pool-facies. Stagnation deposits with a famous fish fauna (see VOGELTANZ 1969, Aufschluß, vol. 20)

In the middle and upper part of the Norian "Hauptdolomit" of the Northern Limestone Alps bituminous sequences are known, some of which have been used for the extraction of low-temperature oil for medical purposes (Seefeld, Tyrol). Other localities like Wiesthal near Hallein have been studied as fossil traps. Geochemical and sedimentological investigations by K.CZURDA (1972, Mitt.Ges.Geol.Bergbaustud., vol. 21) resulted in the recognition of two facies types:

1) pool-facies (Kolk-Fazies): subtidal environment; micrites with interbedded micro-rhythmites and fluidal structures; clay mineral content 15 to 6% (mean 10%), only illite, dolomite content 30 to 95% (mean 64%); no algal structures. - Wiesthal; Seefeld.
2) tidal-flat facies (Flachwasser-Fazies):intra- to supratidal dolomicrites with interbedded stromatolitic dolomites and reworked dolomite layers; clay mineral content 35 to 3% (mean 13%), illite and kaolinite, dolomite content 40 to 95% (mean 92%); typical algal stromatolites.- Silbergraben, Allgäuer Alpen, and Drauzug, Carinthia.

The organic substances (lipides, polysaccarides, and amino acids) in both types are connected with the clay mineral contents; their large surface area makes these minerals most suitable as adsorbers. In the pool-facies the organic substance is predominantly finely distributed in the sediment; in the tidal-flat facies the organic substance is largely found collected in the intergranular space.

The analysis of the bitumen revealed a series of various amino acids and fatty acids, which must be caused by phyto-and zooplankton (pool-facies), and by benthic algal mats and micro-faunas (tidal-flat facies).

The Wiesthal quarry shows an exposed thickness of about 8 m bituminous limestones with intercalations of bituminous beds. The upper part of the section well-bedded dolomicrites can be seen.

Bus drive Wiesthal - Hallein - Kuchl - Golling - Pass Lueg:

Wiesthal - Hallein: at the north (right) the Oberalmberg (type locality of the Tithonian Oberalm formation, Upper Jurassic basin facies), at the south (left) the Adnet area with many quarries in Liassic and Upper Raetian limestones. West of Hallein two striking rock towers (Barmstein, type locality of the Barmstein limestones, Upper Jurassic shallow-water facies), southwest of Hallein the Dürrnberg (old salt mine).

Hallein - Pass Lueg: west (right) of Kuchl the Rossfeld and Schrambach (type localities of the Lower Cretaceous Rossfeld and Schrambach formations). To the southwest we see the Dachstein reef complex of the Hoher Göll (see H.ZANKL 1969 for a detailed facies analysis), to the south we enter the western area of the Tennengebirge. West of Golling widespread quarries within the back-reef facies of the Dachstein limestone can be seen. This facies we will study during the next stop.

STOP 8 - Locality: Pass Lueg, south of the street tunnel.

Stratigraphy: Dachstein limestone, Upper Raetian.

Facies: Lofer facies, back-reef, far-reef zone.

A "Lofer cyclothem"(A.G.FISCHER 1964) with partly reworked algal stromatolites (interpreted as intertidal deposits), brecciated layers (interpreted as supratidal deposits), and microfossiliferous limestones as well limestones with megalodontids and corals as well as with many echinoderms (see ZANKL 1965, Z.deutsch.geol.Ges. vol. 116) (subtidal) is exposed (see fig. B 13):

At the base micritic limestones with reworked chips of stromatolites and with reddish parts can be recognized. Above this unit about 2 m dark grey limestone without megalodontids are to be seen. This unit yields many microfossils (foraminifera, green-algae-Griphoporella sp); vertical fissures are filled with red sediment. Reworked algal mats characterize the next unit. Separated by a fault it follows a limestone bed with irregularly formed limestone clasts (size 3-20cm), overlain by a stromatolite zone (broken up at the top). The upper part of the section consists of thick-bedded limestones with many megalodontid lamellibranchs and with colonies of "Thecosmilia" (not in place).

Several species of Megalodus, Parmegalodus, and Conchodus have been described from this area (see H.ZAPFE 1964, Ann.Naturhist.Mus.Wien, vol. 67). Megalodontids are facies fossils, characterized for calcareous mud bottoms of shallow-water environments (mostly lagoons, sometimes near-reef areas). Most faunas are rich in individuals but poor in the number of species. This may be caused by perhaps hypersalinar conditions and/or by the consistence of the substrat(see TICHY 1974, Schriftenreihe Erdwiss.Komm.,Österr.Akad. Wiss., vol. 2)

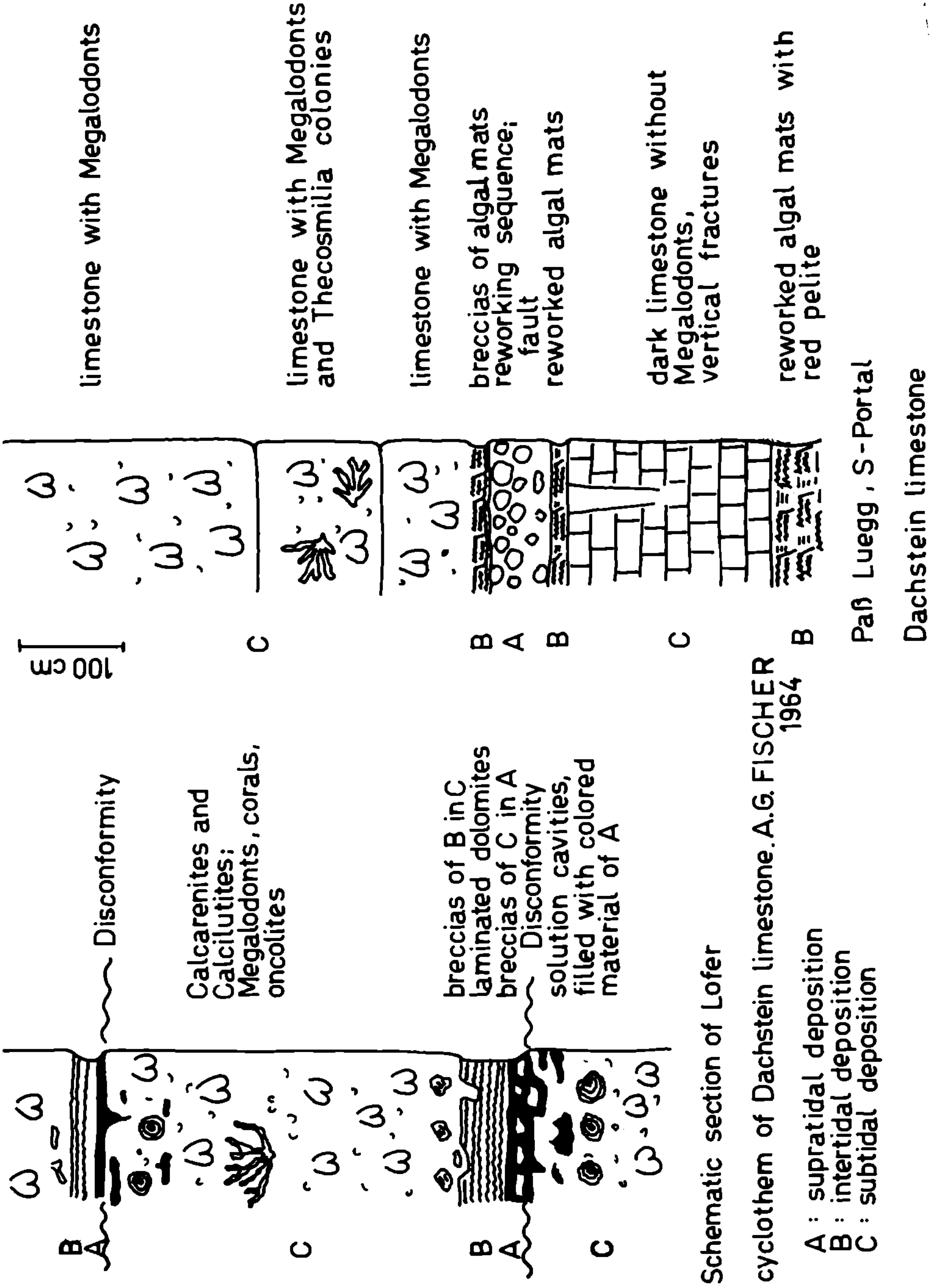


Fig. B 13 Lofer Cyclothem, Dachstein limestone. Generalized section according to A.G.FISCHER 1964, and Pass Lueg section.

If there is time, a short descent to the inner gorge of the River Salzach ("Salzachöfen") will show the intensive erosional activity of strong water movement.

Bus drive Pass Lueg - Scheffau - Abtenau - Rußbach - Paß Gschütt:

Between the high mountains of the Tennengebirge at the south (right) and the Osterhorn-Gruppe at the north the excursion passes a tectonically complicated zone (mainly Triassic and Liassic). West of Abtenau there is a possibility to see a Lower Triassic/Middle Triassic section with Werfen beds (quartzites, sandstones, marly shales) and Anisian bedded limestones red and green and dolomites (Gutenstein beds).

North and northeast of Abtenau large areas are covered by clastic sediments of the Upper Cretaceous Gosau formation (Rußbach - Pass Gschütt- Gosau).

Northeast of Russbach carbonate built-ups with pachydont lamellibranchs (Hippurites) of Santonian age can be seen.

STOP 9 - Locality: Pass Gschütt, between Abtenau and Gosau (boundary between Salzburg and Upper Austria).

Stratigraphy: Gosau formation, Upper Cretaceous.

There will be the possibility to have a short look on the rocks of the Gosau formation and on limestones with Hippurites. Micropaleontologically Coniac to Maastrichtian and Paleocene have been proved for the Gosau beds of the type locality in the Gosau area (OBERHAUSER 1963, Jb.geol.Bundesanst. Wien, vol. 1o6).

Bus drive Pass Gschütt - Gosau - Hallstatt:

We pass the Gosau -Becken (filled with Gosau formation and Pleistocene) and follow the road to Hallstatt. At the south and at southwest the Dachstein range with Gosaukamm range can be seen (stop 13).

STOP 10 - Locality:Hallstatt, Top.sheet Bad Ischl.

Stratigraphy: Hallstatt limestone, Norian.

Facies:basin facies, "Buntfazies".

Depending from weather conditions the excursion will visit one outcrop of Hallstatt limestones in order to study the lithology of these most interesting rocks. For a description of the stratigraphical sequences see p. 66.

West of Hallstatt the Steinbergkogel and the Sommeraukogel are situated; these localities include the stratotype of the Norian stage. Geology, ammonites, and conodonts of these sections have been studied thoroughly by KRYSTYN, SCHÄFER & SCHLAGER (1971).

A new biostratigraphical zonation has been established for the Alpine Upper Triassic (KRYSTYN 1973, Verh.geol.Bundesanstalt Wien) in connection with the re-investigations of all important fossiliferous localities of the Hallstatt limestones in the Salzkammergut area.

According to these studies the Alpine Upper Triassic has been newly subdivided in twelve ammonite zones based on world-wide correlatives. Some of the classical zones of MOJSISOVICS have been confirmed and are apparently equivalent to zones established by TOZER in North America. The new zonal sequence provides the basis for redefining the ranges of most of the ammonite genera and species found in the Hallstatt Limestones of the Northern Limestone Alps. A greater part of the zones is characterized by distinctive conodont faunas, which provide an additional tool for biostratigraphic correlations. The following ammonite zones have been recognized within the Hallstatt facies of the Salzkammergut:

stages	substages		ammonite zones
Rät			Choristoceras marshi HAUER
	SEVAT		Rhabdoceras suessi HAUER
	ALAUN	2	"horizon with Halorites"
		1	Cyrtopleurites bicrenatus (HAUER)
NOR		3	Juvavites magnus McLEARN
	LAC	2	Malayites paulckei (DINNER)
		1	Mojsisovicsites kerri (McLEARN)
		3	"Anatropites range"
	TUVAL	2	Tropites subbullatus (HAUER)
		1	not yet known in the Salzkammergut - in North America Tropites dilleri SMITH
KARN	JUL		Trachyceras aonoides MOJSISOVICS - in North America follows above this zone an unit with Sirenites nanseni, not known from the Salzkammergut
	CORDEVOL		Trachyceras aon (MUENSTER)

The name Hallstatt is connected not only with "Hallstatt limestone", Hallstatt facies", and Hallstatt zone, but also with the "Hallstatt time". (1000-400 B.C.) and with the remains of the La-Tene time (400 B.C. to year zero).

Bus drive Hallstatt - Gosaumühle - Gosau:

Near the locality Gosaumühle we pass below a pipe-line, which has been built 1757, named "Gosauzwang" for the transport of the salt brines from the Hallstatt Salzberg to Ebensee. The narrow valley is bordered by Dachstein limestones.

4.3 F r i d a y, Oct 3rd, 1975

Subject: Dachstein reef limestones (reef communities, role of algae, reef zones) and near-reef basin facies (Zlambach beds with patch reefs).

Guides: E.FLÜGEL, H. LOBITZER

The excursion will have the possibility to see parts of the most interesting Upper Triassic reef complexes in the Northern Limestone Alps. Fauna, flora, microfacies, and biostratigraphy of the Gosau range (Gosaukamm) have been studied during the last years by E.FLÜGEL, H.LOBITZER, L.KRYSTYN, W.SCHLAGER, A.TOLLMANN, and H.ZAPFE.

According to the paleogeographical model developed by H.ZANKL (1967, 1971), south of the "Hauptdolomit" sedimentation areas wide-spread carbonate platforms with marginal reef complexes (exposed to the south and to southwest) have been formed during Norian and Raetian times (recent investigations prove, that most of the reef limestones are Norian in age). These Dachstein limestone platforms are known with up to 1000 square kilometers in the Loferer and Leonganger Steinberge, Hochkalter and Watzmann, Hochkönig, Hagengebirge, and Tennengebirge. Besides this large platform, isolated platforms seem to be developed (Dachsteingebirge; Gesäuse and Hochschwab/Styria). Between these platforms several deeper-water basins with Hallstatt facies, connected by narrow "channels" can be recognized. The original transition between the Dachstein facies and the Hallstatt facies has mostly been disturbed tectonically, but some areas are known, which show the connection of Dachstein reef limestones and shallow-water Zlambach beds with coral patch reefs (Gosaukamm) or the connection between Dachstein reef facies and Hallstatt limestones (Hoher Göll, Berchtesgaden Alps) respectively Aflenz limestone (Hochschwab). Red biomicrites found as "chips" (Scherben) within Dachstein reef limestones ar other hints to the immediate neighbourhood of the two facies districts; these biomicrites yield typical Hallstatt facies fossils, e.g. ammonites, conodonts, and characteristic microfaunas.

Bus drive Gosau - Gosauschmied - Vorderer Gosausee:

The excursion follows the road to the south; the western and eastern slopes of the Gosaubach valley are formed by the Upper Cretaceous Gosau foramtion. After the locality Gosauschmied we see a high red rock wall at the right (Rote Wand; Nierental beds, Upper Campanian). Then Dachstein limestones are developed.

STOP 11 - Locality: Large talus slope, Vorderer Gosausee, southwest of Gosau. See fig. B 14.
Stratigraphy: Dachstein reef limestones, Norian.
Facies: Dachstein reef limestones, central reef area.

This locality provides a good possibility for sampling characteristic frame-building associations (calcareous sponges, corals; hydrozoans, bryozoans, algal crusts), and to study the composition of the interstitial reef detritus.

Current investigations of Dachstein reef limestones from the Gosaukamm show, that the associations of foraminifera and of calcareous algae are significant for distinctive environments within the reef zones. The study of more than 200 thin-sections of samples from the boulder talus near the Vorderer Gosausee (Steinriese) reveal the following associations:

(a) Foraminifera: Together with larger reef-building non-segmented calcareous sponges, corals, bryozoans and hydrozoans abundant mobile and sessile foraminifera can be found. The associations correspond strikingly with fossil assemblages described by HOHENEGGER & LOBITZER (1971) and HOHENEGGER (1974, N.Jb.Geol.Paläont.Abh., vol. 146).

(1) "sessile foraminifera" - associations: high percentage of *Alpinophragmium perforatum* E.FLÜGEL and *Nubecularia* sp.
(2) "*Galeanella* - sessile foraminifera" - association : about 10-20% *Galeanella panticae* BRÖNNIMANN & ZANINETTI, and other miliolids (*Ophthalmidium*, "*Sigmoilina*")
(3) "*Ophthalmidium* - sessile foraminifera" - association: many specimens of *Opthalmidium*, *Quinquelolulina*, and "*Sigmoilina*", together with *Nubecularia* sp.

The association 1 is connected with calcareous sponges (*Peronidella communis*), corals, and mollusk fragments; the limestones are biomicrosparites and biosparites. This type seems to be characteristic for patch reef areas only. Type 2 is found together with unsorted reef detritus (composed of fragmented frame-builders and pellets); the limestones are biomicrites and biopelsparites. This type has been recognized mostly in interstitial bioclastic reef detritus of the central reef flat. A similar distribution may be supposed for type 3 (biomicirtes; mudy environments of the central reef area).

Associations typical for back-reef environments (high percentage of Involutina et al.) are lacking at this locality.

(b) Calcareous algae: The algal flora consists of red algae (Solenopora endoi FLOGEL, Parachaetetes maslovi FLÜGEL, Pycnoporidium ? eomesozoicum FLOGEL , and Thaumatoporella parvovesiculifera (RAINERI), rare dasyclads (Griphoporella sp.), and common "algal crusts" (irregulary layered micrite crusts around or upon frame-building organisms, very often together with many tubes of Microtubus communis FLÜGEL).

The last mentioned crusts are found together with type 1 of the foraminfera association (small patch reefs on the reef flat); the red algae (especially branchy and small nodular solenoporids) seem to be relatively common (about 12% of the frame-building organisms) in the outer parts of the central reef flat, near the fore-reef area (see E.FLÜGEL 1975).

Cable - railway drive to the station Gablonzer Hütte, Zwieselberg Alm. The excursion will visit the fossiliferous Zlambach beds of the Rohrmoos - Hammertanger area southwest of the Zwieselalm- Thörleck, and then follow the "Austria" path, in order to study facies and fossils of the Dachstein reef complex. An one hour ascent on the path to the Großer Donnerkogel at the outer margin of the reef. If weather is bad we will walk along the "Austria" path and see patch reefs within interstitial reef detritus.
At the locality Schneckengraben there is the possibility to discuss the "transition" between the reef facies and the Zlambach facies.

STOP 12 - Locality : Hammertanger - Rohrmoos, west of the Gablonzer Hütte. See fig. B 14
Stratigraphy: Upper Norian Zlambach beds.
Facies: shallow-water coral built-ups, fore-reef or off-reef shoals.

The marly and calcareous Zlambach beds of this area are well known for a rich coral fauna (F.FRECH 1890), which can be found together with non-segmented calcareous sponges, spongiomorphid hydrozoans, bryozoans (Tubulitrypa maculata FLÜGEL), brachiopods, mollusks (e.g. Choristoceras haueri MOISISOVICS), echinoderms, and with serpulids. Arenaceous foraminifera have been found too as well as calcareous algae (solenoporids - NOTE: the cover picture of PROGRAMM AND ABSTRACT of the SYMPOSIUM shows some red algae from this locality!)

A microfacies study (E.FLÜGEL 1962b) resulted in the interpretation of the environment as off-reef shoals within a muddy somewhat deeper basin near to the fore-reef of the Gosaukamm reef. The facies transition between the Zlambach beds and the Dachstein reef limestones of the Donnerkogel and of the isolated "Kesselwand" southwest of the Thörleck is a question of discussion:

ZAPFE (1960) claims for an interpretation of the Zlambach beds as sedimentary intercalations in the slope area of the Gosaukamm reef. W.SCHLAGER (1967) recognized considerable tectonic complications in the Kesselwand area; only near the "Kanzel" (Austria path) and near the "Schneckengraben" (southwest of the Thörleck) a primary transition seems to be conservated. TOLLMANN & KRISTAN-TOLLMANN (1970) denied the primary transition for all localities studied; for the "Schneckengraben" only a primary connection between the Dachstein limestone and the Zlambach marls is recognized.

STOP 13 - Locality: western slope of the Donnerkogel group (northwestern part of the Gosaukamm range . See fig B 14.

The Dachstein reef limestone of the Donnerkogel group (Großer Donnerkogel 2055 m) dominately is composed of reef detritus with only small, widely distributed patch reefs (Riffknospen). A large-scaled bedding (some ten meters) can be seen. The original dip of the reef slope was not 30° as indicated today but about 10 - 15° (as shown by displaced geopetal fabrics, see KRYSTYN 1972, Öster.Akd.Wiss.Wien, math.-naturwiss.Kl., Anz.).

Composition of the patch reefs: Countings near the Donnerkogel path and at the "Austria" path show the dominating importance on the non-segmented calcareous sponges as main frame-builders:

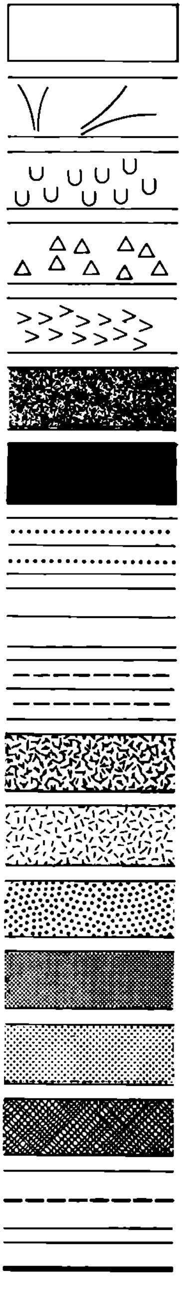
numbers of fossils	south of the Schneckengraben 750 qcm	north of the Sulzkar 1600	560	Sulzkar	Gr. Donnerkogel 1680 m 1000 qcm
sponges (Peronidella)	23	640	90	85	240
corals ("Thecosmilia") branches single corals	7	--	15	10	10
spongiomorphid hydrozoans	6	--	--	3	5
solenoporids (and "chaetetids")	4	--	15	15	8
gastropods	--	--	--	1	--

Fauna and flora of the patch reefs and of the detrital limestones:

More than 50 species contribute to the construction of the reef framework, more than 60 species must be regarded as benthonic reef-dwellers. Planktonic elements are known with Heterastridium, ammonites, and conodonts.

The fossil content consists of many species:

Foraminifera	22 species
Calcisponges	12
Hydrozoans	5
Corals	19
Bryozoans	8
Brachiopods	17
Gastropods	9
Lamellibranchs	15
Nautilids	2
Ammonoids	11
Ostracods	known
Crinoids	known
Echinoids	known
Conodonts	8
Calcareous algae	7



Quartenary, Pleistocene and Alluvial deposits

Talus slope

Slide masses

Boulder material

Talus breccia

Lower Tertiary to Upper Cretaceous, Gosau formation

Liassic

Raetian-Norian, Zlambach beds

Dachstein reef limestone

Dachstein dolomite

Norian-Carnian, Hallstatt limestone

Bedded ls. with cherts, Pötschen limestone

Carnian

Ladinian

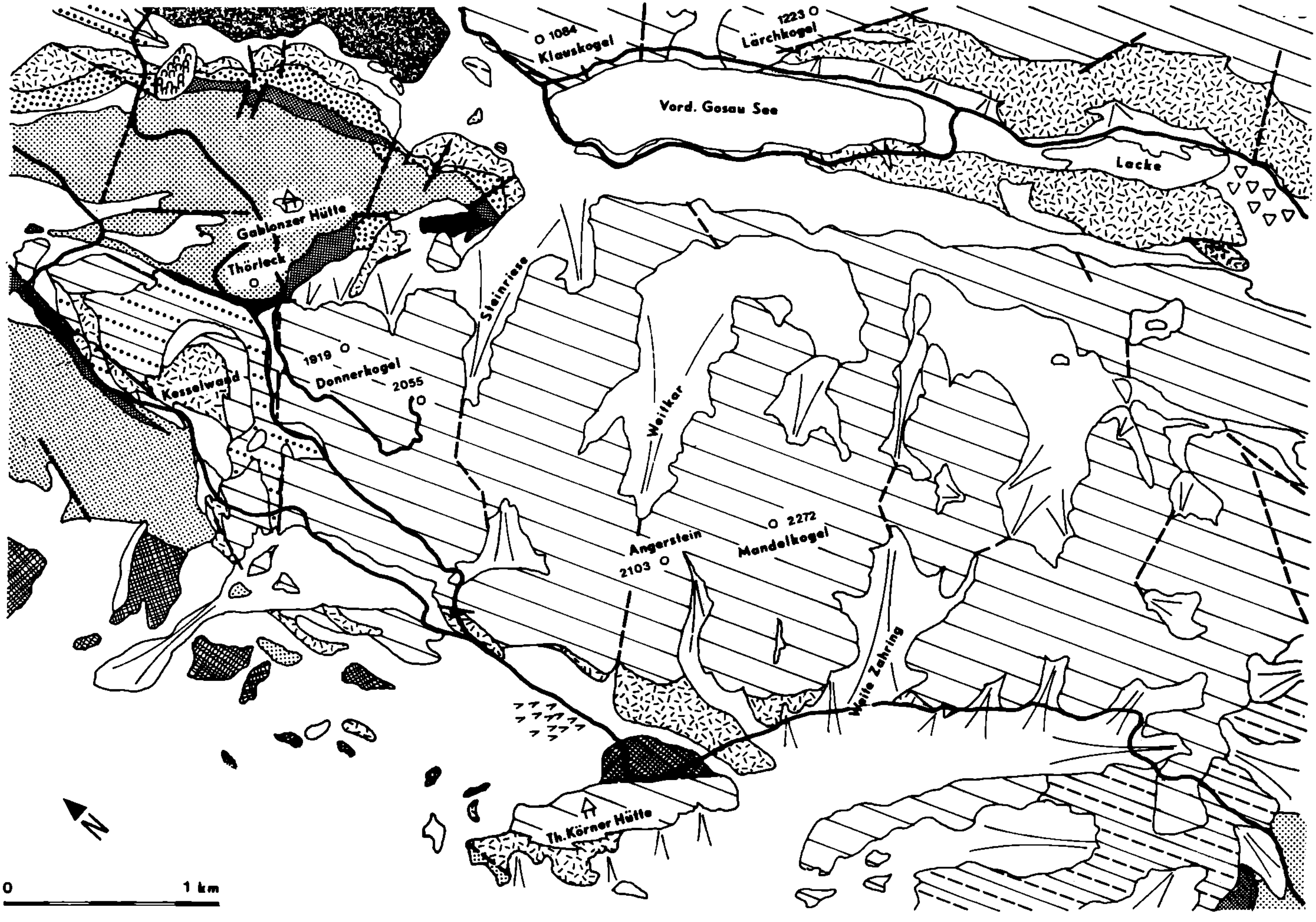
Anisian

Permoscythian

Faults

Excursion route

Fig. B 14 Simplified Geological Map of the excursion area, western Gosaukamm range, Upper Austria. After W.SCHLAGER 1967.



1084
Klauskogel
1223
Lärchkogel
Vord. Gosau See
Lacke
Gablonzer Hütte
Thörleck
Steinriese
1919
Donnerkogel
2055
Kesselwand
Weitkar
Angerstein
2103
2272
Mandelkogel
Weite Zahring
Th. Körner Hütte
N
0
1 km

STOP 14 - Locality: "Austriaweg", Schneckengraben 450 m WSW of the summit of Kl.Donnerkogel. See fig. B 14.
Stratigraphy: Norian Dachstein reef limestones, Norian Zlambach beds.
Facies: primary transition between Dachstein - and Zlambach facies.

At the western flank of the Schneckengraben the complicated connections between overturned Dachstein limestones and underlaying Zlambach marls can be seen. Thorough investigations by A.TOLLMANN et al. (1970) supports the interpretation as primary transitions. Dachstein limestones are intercalated with Zlambach marls.

Cable-railway drive to the Vorderer Gosausee, bus drive to Gosau.

4.4 Saturday, Oct. 4th, 1975

Subject: Hallstatt facies (Pötschen formation and coral-bearing Zlambach-beds, environment of the Zlambach beds); near-reef/back-reef environment of the Dachstein limestone (rich algal floras); shallow-water deposition of the Upper Jurassic Tressenstein limestone (transition facies between carbonate platforms and basin facies).

Guides: E.FLOGEL, H.LOBITZER.

Bus drive Gosau - Steg - St.Agatha - Pötschen Pass

The excursion leaves the Gosau basin and passes the Dachstein limestone. East of St.Agatha we will have a short stop:

STOP 15 - Locality: first bend of the Pötschen road, 680 m, southeast of St.Agatha.

From this point we can see the Dachstein limestone landscape south of the Lake Hallstatt. In the Background the summit area of the Hoher Dachstein. Looking southwest you see the type locality of the Upper Jurassic shallow-water Plassen limestone (pyramid of the Plassen, underlain by the most famous Hallstatt sequence, starting with the salt-bearing "Haselgebirge"). At the left of the Plassen the area with the type localities of the Norian stage.

Bus drive

STOP 16 - Locality: second bend of the Pötschen road, 940 m.

Looking north we see the classical localities of the Raschberg area (Carnian and Norian Hallstatt limestones with rich ammonite faunas), northwest we see the Zlambachgraben (type locality of the Zlambach beds), east of the Raschberg the Sandling with an Upper Jurassic section, showing transitions between the main facies (Oberalm basin facies, with a large landslide), overlain by Oberalm transition facies, overlain by shallow-water Tressenstein limestone and (summit) Plassen limestone .

The bus will wait for the excursion at the height of the Pötschen Pass. We will visit the type locality of the Pötschen limestones.

STOP 17 - Locality: Pötschen road between second road bend and Pötschen Pass. See. fig. B 15.
Stratigraphy: Pötschen limestones, Carnian to Norian.
Facies: "Graufazies" of the Hallstatt facies, see p. 62.

The type locality is an old unused quarry, better outcrops can be seen along the road. Lithology: thin-bedded, grey micrites and biomicrites, rich in cherts. Bedding planes with calcareous nodules. Microfacies: filaments, foraminifera, radiolaria, echinoderms. Thin greenish marls yield a poor microfauna (mostly arenaceous foraminifera), described by KRYSTYN-TOLLMANN 1960. Macrofauna: Heterastridium conglobatum REUSS, Monotis cf. salinaria (BRONN), Halorella pedata (BRONN), Halorella amphitoma (BRONN), Arcestes cf. intuslabiatus MOJSISOVICS, Rhacophyllites neojurensis (QUENSTEDT) et al. (see KRYSTYN & SCHÖLLNBERGER 1972).

Bus drive Pötschen Pass - Luppitsch
The excursion passes the Norian "Pedata" Limestones (see p.68).
In Luppitsch we leave the Bus for a short walk to

STOP 18 - Locality: Fischerwiese (= "Waldbach" or "Korallenbach") northwest of Luppitsch, west of Alt-Aussee. See fig. B 15.
Stratigraphy: Zlambach formation (type locality!), Raetian.
Facies: strongly differentiated subtidal and intertidal shallow-water environments.

The outcrop shows grey claystones and marls with some thin beds, consisting of fossil detritus. In the upper part of the trench thin calcarenite layers with abundant corals and mollusks can be seen. From these beds many macrofossils have been derived (described by FRECH 1890, O. HAAS 1909, and H.ZAPFE 1967). One of the most important Upper Triassic microfaunas has been found in this locality (foraminifera - KRISTAN-TOLLMANN 1964, ostracods - KOLMANN 1963, BOLZ 1971).

Fauna and Flora: foraminifera (about 250 species), a few radiolaria, calcisponges (4 species), spongiomorphid hydrozoans (3 species), corals (mostly solitary forms, 53 species), bryozoans (3 species), brachiopods (7 species), gastropods and scaphopods (15 species, often juvenile forms), lamellibranchs (26 species), cephalopods (12 species) with ammonoids, orthocerids and coleoids, ostracods (about 70 species), echinoderms (crinoids, echinids, holothurians, and ophiurids), a few fish teeth.

Calcareous algae are known with solenoporids and dasyclads (not yet described).

Microfacies: According to BOLZ (1974, Senck.leth.vol. 55) four microfacies types can be recognized in the limestone beds:

- MF 1 - Biomicrite with thin shells, ostracods, foraminifera, sponge spicules, and cephalopods; microcrystalline FeS_2. Strong bioturbation. - Interpretation: low-energy environment, somewhat deeper than other Zlambach depocenters.
- MF 2 - Biomicrosparite with angular to subangular fossil fragments, pellets, and intraclasts, Depending on different organisms several subtypes can be recognized (rich in corals, bryozoans, hydrozoans, mollusks, echinoderms, encrusted foraminifera, ostracods, and calcareous algae; another type rich in lamellibranchs, often circumcrusted).
- MF 3 - Biopelsparite with encrusted foraminifera, ostracods, echinoderms, gastropods, lamellibranchs and calcareous algae together with micritic pellets, intraclasts and some ooids.
- MF 4 - well-sorted and well-bedded biosparrudite with pellets, small foraminifera, echinoderms, and shells.

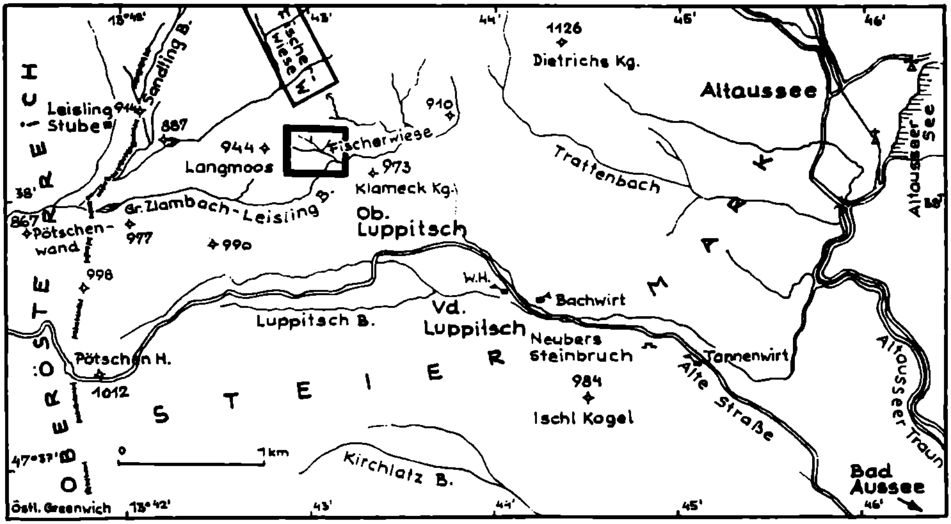


Fig. B 15 Location of the type locality of the Zlambach beds (Fischerwiese, Zlambach-Graben) and of the Pötschen limestones (Pötschen Pass). After H. ZAPFE 1967.

Facies interpretation: The relatively broad grain-size distribution together with the existence of clearly different microfacies types indicate a redeposition of allochthonous material in the "normal" marly Zlambach environment. The Zlambach beds of the Fischerwiese can be used as general model for the sedimentation pattern of these sediments (BOLZ 1974):

The ostracods studies by BOLZ, provide together with other fossil groups, and with sedimentological studies reliable data for the following interpretation:

The Zlambach beds were deposited in shallow-marine, tropical water (about 23^{0} - 26^{0}, salinity some 35^{0}/oo, depth some 10-30 m, occasionally more). Generally good light conditions and good oxygenation of the water ensured supply of nutrients.

Within this "mega-environment" variations in sedimentological factors (in particular $CaCO_3$ content of the water, water turbulence, clastic influx and water depth) are clearly reflected by changes in the faunal assemblages. Shallow mounds composed of coarse deposits of a high-energy environment with intensive skeletal carbonate production (especially by corals and algae) were separated by shallow depressions. In these depressions predominately low energy sediments(suspension fractions and clay muds) were deposited. Slopes around the mounds were generally less than 3^{0} - 4^{0}. Coarse biodetritus and intraclasts were periodically transported from the mounds into the depressions; sliding of semilithified sediment package took place locally. Thus, the sediments in these depressions represent originally different ecologic environments. In particular topographic positions true reefs were formed. The Zlambach beds form the direct basinward continuation of the fore-reef detritus beds which were deposited close to the Dachstein reefs and in somewhat shallower depths. The Zlambach beds also include inter-reef deposits within tongue-line zones extending into the Kössen bed facies.Layers of coarse biodetritus within the Zlambach beds are distinctly different in faunal and floral aspect from the detritus layers in the Dachstein limestone close to the reef complexes. Thus, the coarse material of the Zlambach beds must have been derived from mounds within the Zlambach sedimentation areas itself.

STOP 18 - Locality: Loser

Bus drive: Luppitsch - Bad Aussee - Altaussee - Loser road - Loser Hütte-
walk to the Loser Hütte

STOP 19 - Locality:Loser, Top.sheet Altaussee (96/2).
Stratigraphy: Upper Jurassic.
Facies: deeper-water and shallow-water sediments.

East of the Loser Hütte outcrops of red radiolarites and thin-bedded micritic limestones with radiolaria and sponge spicules (sometimes with intercalations of beds rich in echinoderms)can be seen above the Liassic and Upper Triassic section we will study in STOP 20. These siliceous sediments are overlain by a sequence consisting of bedded limestones with cherts (Oberalm formation, transition facies). The lower part is characterized by sediment structures indicating synsedimentary slidings. Intercalations of pelsparites show the transition between this deeper-water facies and the overlaying shallow-water facies of the Tressenstein (or Plassen?) limestones, which forms the summit of the Loser. These limestones are Lower Tithonian in age, according to the occurence of the algae Clypeina jurassica (FAVRE) Munieria baconica DEECKE,and Salpingoporella annulata CAROZZI. The thickness of the whole section is about 450 m.
Lit.: FENNINGER & HOLZER 1972, H.LOBITZER 1972.

Walk to the parking place Augstalm, 1400 m.

STOP 20 - Locality: upper part of the Loser road, walk down the road, starting at the parking place Augstalm. Top.sheet Altaussee (96/2).
Stratigraphy: Dachstein limestones, Upper Norian (?); fissure fillings of Liassic age.
Facies: bedded back-reef limestones with ommission planes. Supra-,inter-,and subtidal environments.

General remarks (H.LOBITZER)

More than six km long are the exposures of Dachstein limestone (Norian; Raetian) along the Loser Road. The D.L. is considered to be deposited in a back-reef lagoon with normal salinity. Lithofacies and Biota generally point to shallow marine environments, but there it is also evidence of supratidal exposition of the uppermost parts of Dachstein Limestone (D.L.)

The "Megalodontid Limestone" is the main sediment type containing a variety of biota, like the pelecypod Dicerocardium, mollusks, echinoderms, calcareous algae, corals, hydrozoans, bryozoans, foraminifera and some problematica. Generally it is a white, micritic or sparitic limestone, rich in pelletoids and aggregates. Small patch reefs, e.g. biostroms of calcispongea combined with the problematicum Cheilosporites tirolensis or small bioherms of corals occure on some places.

Algae (mainly red algae) are relatively common in an intraclast-rich grey marly limestone which sometimes represents the uppermost parts of D.L. In this mottled limestone also massive corals, hydrozoans, bryozoans and some problematica are abundant. The biota is quite similar to the Zlambach Beds of locality "Fischerwiese".

A very interesting phenomenon are fissures of liassic limestone and coquina of brachiopods in D.L. The fissures occure both diagonal and parallel to the bedding. Diagonal fissures sometimes display an interaction of submarine sedimentation and of vadose origin (calcareous sinter).

The excursion will study subtidal shallow-water communities, cyclothems, and fissure fillings. An investigation of the Loser area is currently made by H.LOBITZER.

(1) Subtidal facies: a near reef position of these Dachstein limestones is indicated by distinctive associations of calcareous algae, gastropods colonies of "Thecosmilia", echinoderms, ostracods, megalodontids, some ammonites, and a very characteristic foraminifera fauna (Involutina - associations). The sediment types are characterized dominantly by grainstones (biointrasparites, oosparites, grapestone-sparites) and biomicrites. Intercalations of mm-laminated limestone rhythmites (stromatolites?) are relatively common.

The algal flora consists of

Heteroporella crosi (OTT)	-	common
Heteroporella zankli (OTT)	-	common
Macroporella sp.		
Palaeodasycladus sp.		
Cayeuxia alpina FLOGEL	-	common
Garwoodia sp.	-	common
Solenopora endoi FLOGEL		

(2) Cyclothem : several sequences have been observed. Incomplete cyclothems are common (C - A - C). Red limestone chips within the member C may have been reworked material of member A (indicating sporadic dessication). Thus, the red chips ("rote Scherben") within the Dachstein limestones are of different origin (see p. 120).

(3) Fissure fillings: Several types of fissures fillings can be seen (red micrites - Adnet facies; crinoidal limestones - Hierlatz facies; grey brachiopod limestones, grey micrites et al.), up to 13 sediment generations have been recognized within the fissures.

STOP 19 - Tressenstein

Bus drive Loser road - Altaussee - Bad Aussee:

Looking southeast (left) we see the type locality of the Upper Jurassic Tressenstein limestone, described by H.HÖTZL (1966). Oberalm transition facies (with intercalations of Barmstein facies) interfinger with, and are overlain by the shallow-water Tressenstein limestone (consisting of intraclasts derived from high-energy environments with hydrozoans, corals, calcareous algae; partly near-coast lithoclasts). The summit of the Tressenstein (and the Trisselwand, Totes Gebirge) consists of micritic and sparry Plassen limestones.

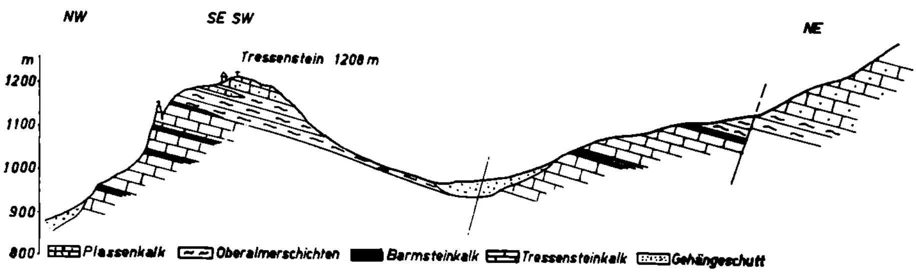


Fig. B 16 Profile Tressenstein - Trisselwand, showing the transition between the Upper Jurassic facies types (compare with fig. B !) After HÖTZL 1966.

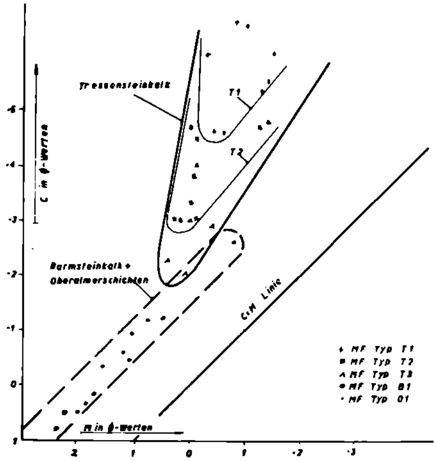


Fig. B 17 CM-diagram (PASSEGA) of Tressenstein- and Barmstein limestones, indicating near-coast conditions for the Tressenstein environment, and turbidity deposits for the "Barmstein" beds intercalated in the Oberalm beds. After HÖTZL 1966.

4.5 <u>S u n d a y, Oct. 5th, 1975</u>

<u>Subject:</u> Upper Jurassic shallow-water and deeper-water facies (Plassen limestones, Oberalm beds with Barmstein limestones).

<u>Guide</u>: E.FLÜGEL

<u>Bus drive</u> Aussee - Pötschen Pass - Bad Ischl - Strobl :

STOP 21 - <u>Locality</u>: northeastern edge of the Brustwand, Point 560, south of Strobl. Top.sheet Strobl (95/2).
<u>Stratigraphy</u>: Plassen limestone, Kimmeridgian - Tithonian,
<u>Facies</u>: micrite and sparite shallow-water limestones,

This locality will be visited in order to get samples of the algal-bearing Plassen limestone.

Bus drive Strobl - Zinkenbach
We leave the bus in Zinkenbach and visit the Zinkenbach valley.

STOP 22 - Locality: Zinkenbach-Graben valley, the section starts at the second bridge. Top.sheet St.Wolfgang (95/1).
Stratigraphy: "wechselfarbige Oberalmer Schichten", Tithonian.
Facies: Oberalm transition facies. Micritic limestones with calpionellids.

This section has been studied by FENNINGER & HOLZER (1972):

biomicrites with radiolaria, Globochaete alpina, Crassicollaria brevis, Cr. massutiniana, Cr. parvula, Calpionella alpina, C. elliptica, Tintinnopsella carpathica

pel- and biopelsparite with Globochaete alpina, Crassicollaria brevis, Cr. massutiniana, Cr. parvula, Calpionella alpina, C. elliptica, Tintinnopsella carpathica

biomicrites with Globochaete alpina, radiolaria, sponge spicules, Crassicollaria parvula, Calpionella alpina and Cadosina sp.

biomicrite with Globochaete alpina, Crassicollaria brevis, Calpionella alpina, Tintinnopsella carpathica, Cadosina lapidosa; aptychus

silicified biomicrites with radiolaria, spicules, tintinnids, and foraminifera

oopelsparites with Protopeneroplis striata,Thaumatoporella parvovesiculifera

homogenous micrites with pyrite

biopelmicrites with radiolaria, spicules, cadosinas and tintinnids

sequence of marls and limestones with wavy bedding planes and slumping structures, mostly biomicrites with many tintinnids and cadosinids, spicules, Globochaete alpina. Intercalations with foraminifera and Thaumatoporella.

bedded biomicrites with tintinnids, radiolaria, some dolomite, rogen-pyrite

biomicrite with radiolaria

biomicrite with Globochaete alpina, Crassicollaria parvula, Calpionella alpina, Tintinnopsella carpathica, Cadosina fusca

f a u l t

massive to thick-bedded oo-and oopelsparites with Trocholina elongata, Thaumatoporella parvovesiculifera

biomicrites with pelsparitic areals, radiolaria and sponge spicules

biomicrites with radiolaria and spicules (70 cm thick)

f a u l t

biomicrites with radiolaria and spicules (80 cm thick)
thin bedded oo- and pelsparites with radiolaria and spicules (thickness 190 cm)

bedded micrites with radiolaria (near the bridge)

b a s e

Bus drive Zinkenbach - St. Gilgen - Fuschl

STOP 23 - Locality: Ellmauerstein / Eibenseekopf area, Top.sheet Mondsee (65/3).
Stratigraphy: Middle Triassic Wetterstein dolomite.
Facies: lagoonal deposits with dasyclads; reef facies

If there is time the excursion will stop in order to get samples with Middle Triassic green algae; Diplopora annulatissima PIA (Upper Anisian to Lower Ladinian) has been found in these limestones.

Bus drive Fuschl - (Hintersee) - Gaißau - Krispl

STOP 24 - Locality: Krispl, Top.sheet Hallein
Stratigraphy: Upper Tithonian Oberalm beds (transition facies) with Barmstein beds 1 and 2.
Facies: transition facies; micrites with radiolaria, tintinnids, and coccolithophorids; allodapic limestones with shallow-water detritus (Barmstein beds).

Fig. B 18 shows the section. Three facies types are clearly distincted:

a) mud- and wackestones, with wavy bedding planes and thin marls between the beds

b) fine grained detrital packstones

c) coarse-grained detrital pack- and grainstones

The microfacies of these types indicates different environments:

a) The mud- and wackestones are characterized by biomicrites with tintinnids, cadosinids, radiolaria, sponge spicules, and some echinoderms.Bioturbation can be seen. Crassicollaria brevis, Crassicollaria massutiana, and Calpionella alpina have been determined.

b) Packstones consist of pelsparites and pelbiosparites with very small micritic pellets (see fig. B 19 for the grain-size distribution), ooids, many foraminifera (textularids, miliolids et al.), many small echinoderm fragments (generally of the same size as the micritic pellets), and some algae (Thaumatoporella sp., fragments of dasyclads).

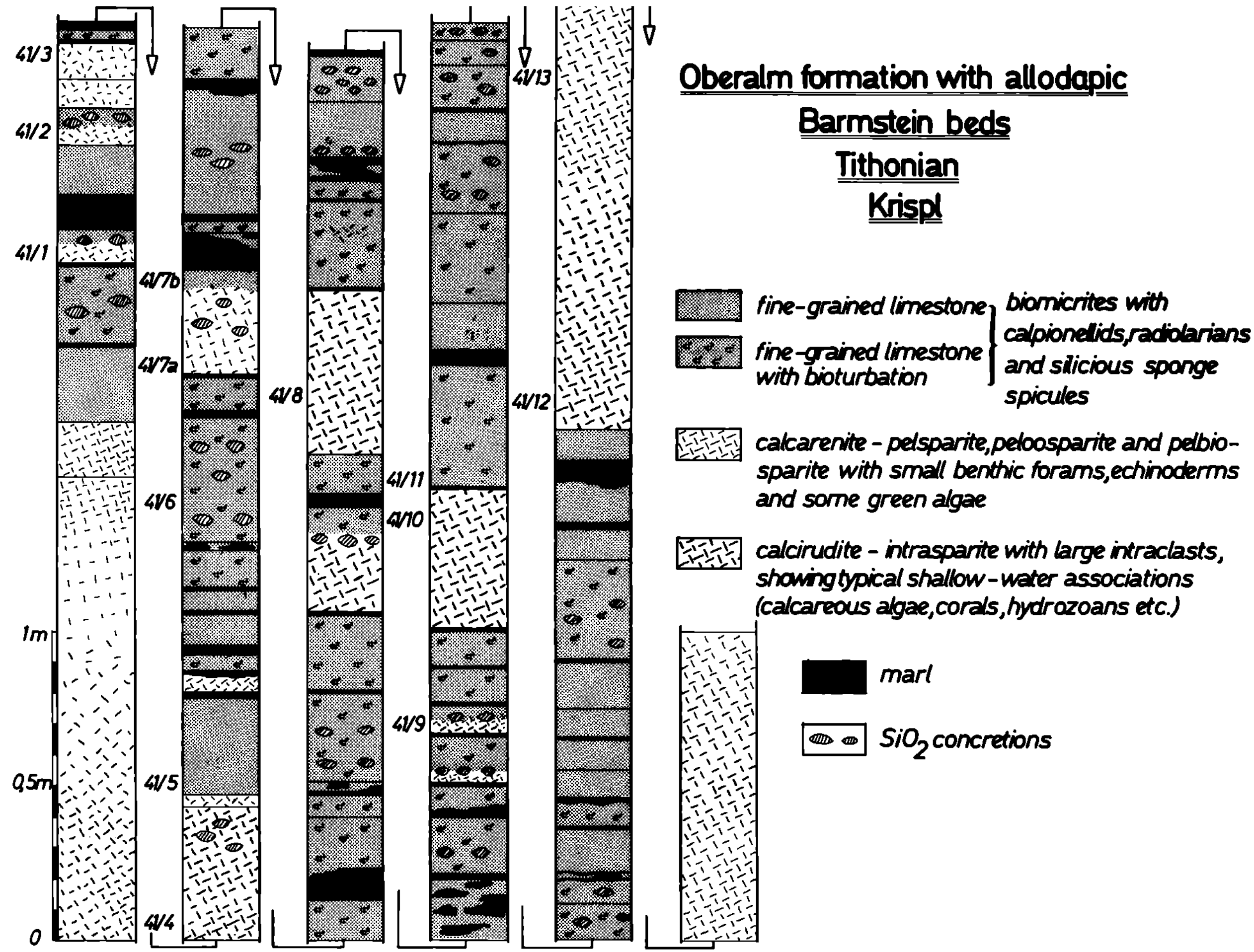
c) The thick-bedded to massive coarse-grained grain- and floatstones consist of very irregularly sized, subangular to angular bioclasts, intraclasts, and perhaps some lithoclasts.
The bioclasts are formed by fragments of shallow-water organisms e.g. bryozoans, hydrozoans, calcareous sponges, and calcareous algae. (Thaumatoporella parvovesiculifera, Salpingoporella pygmaea, Salpingoporella annulata, Petrascula sp., and Cayeuxia sp.) together with fragments of lamellibranchs and echinoderms. Generally the components show a dense packing but no preferred orientation of the particles. Nevertheless graded bedding seems to be common. Together with these bioclasts, ooids, oncoids, and micritic intraclasts as well as grapestones have been found in thin-sections. Regarding these intraclasts, different source areas must be supported for the material of the coarse-grained limestones.

Samples: microfacies (a) 41/2, 41/3, 41/5, 41/6, 41/7b, 41/11
microfacies (b) - 41/1, 41/4, 41/7a, 41/8, 41/10 41/13
microfacies (c) - 41/12

The thick bed 41/12 at the top of the section corresponds with the "Barmstein-Bank B2" used as stratigraphic marker bed within the Oberalm formation.

This bed can be interpreted as allodapic limestone (calcareous turbidite). A similar interpretation for microfacies (b) is difficult because of the homogenous grain-size distribution of all components. An intensitive sorting must have taken place before or during the transport of this shallow-water material to the deeper-water environment which is indicated by tintinnids, many radiolaria, sponge spicules, and by abundant coccolithophorids, seen in REM studies.

Fig. B. 18 Section of the Tithonian Oberalm formation with allodapic limestones (Barmstein ls./Krispl, near Hallein (Salzburg).


Oberalm formation with allodapic
Barmstein beds
Tithonian
Krispl
fine-grained limestone
fine-grained limestone with bioturbation
biomicrites with calpionellids, radiolarians and silicious sponge spicules
calcarenite - pelsparite, peloosparite and pelbiosparite with small benthic forams, echinoderms and some green algae
calcirudite - intrasparite with large intraclasts, showing typical shallow-water associations (calcareous algae, corals, hydrozoans etc.)
marl
SiO2 concretions
41/3
41/2
41/1
41/7b
41/7a
41/6
41/5
41/4
41/8
41/11
41/10
41/9
41/13
41/12
1m
0,5m
0

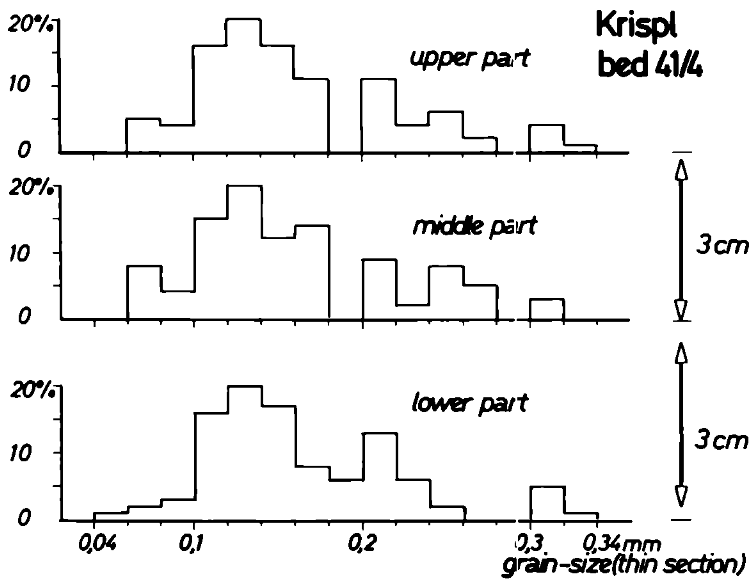


Fig. B' 19 Grain-size distribution of micritic pellets in detrital layers of the Oberalm formation, Krispl.

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E x c u r s i o n - C - Upper Jurassic of the Southern Frankenalb.

Algal-sponge reefs, coral reefs, Solnhofen lithographic limestones.

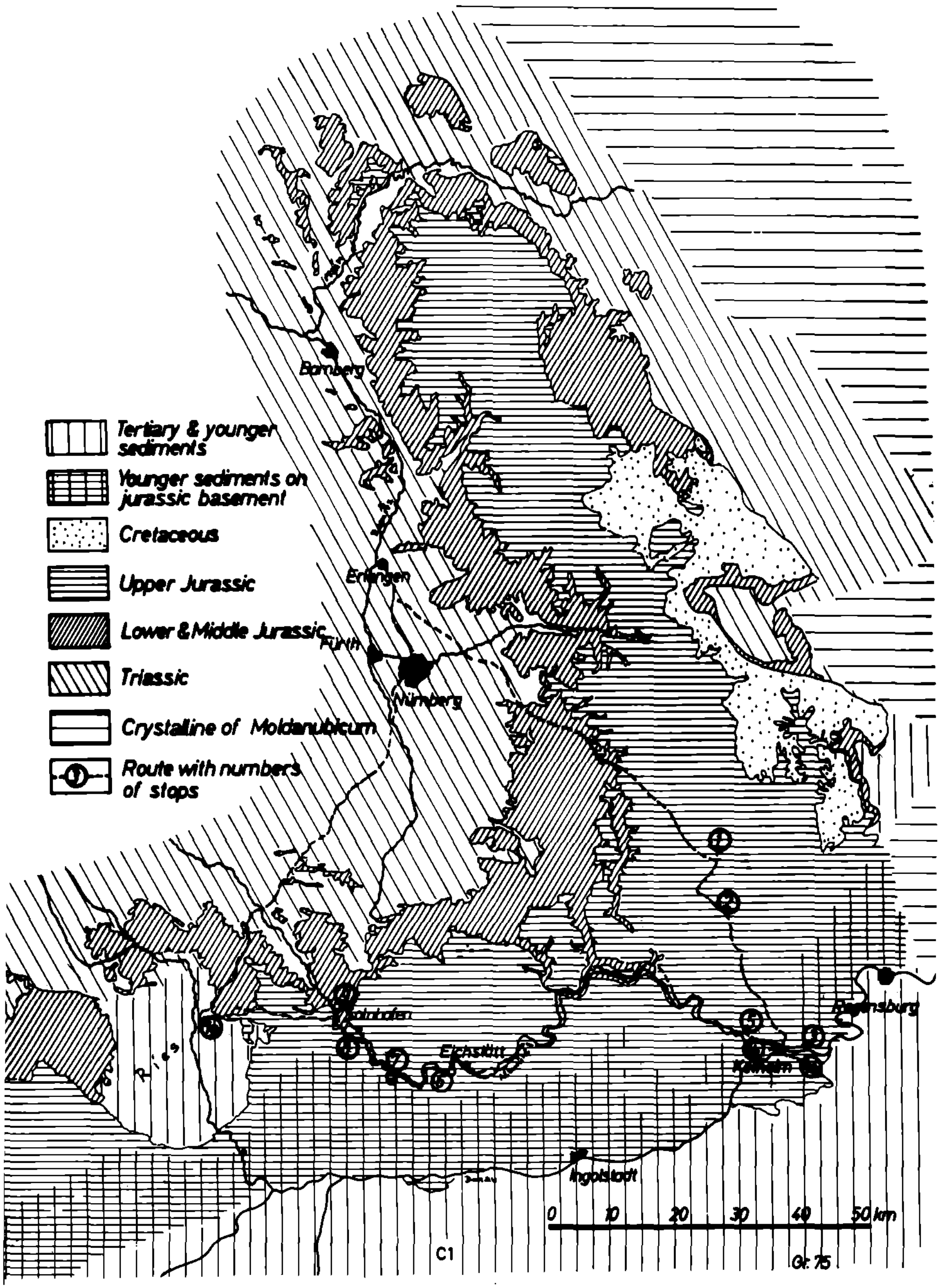
1. Stratigraphy (A.ZEISS)
2. Facies
2.1 General Review of Carbonate Rocks (R.MEYER)
2.2 Solnhofen Lithographic Limestones (H.KEUPP)
3. Algae and Algal Products (E.FLÜGEL)
4. Appendix - The Ries Story (J.Th.-GROISS)
5. Excursion Route (E.FLÜGEL, H.KEUPP, R.MEYER, A.ZEISS)
6. Bibliography (Chr. MUNK)

I N T R O D U C T I O N

Main research objects of the Institute of Paleontology in Erlangen deal with biostratigraphy, facies, and paleogeography of the Franconian Upper Jurassic. These studies, supported by the Deutsche Forschungsgemeinschaft (project Fl 42/23, 42/24) concern ammonites and foraminifera, microfacies and genesis of algal-sponge organic built-ups, and ultrafacies of the Solnhofen environment.

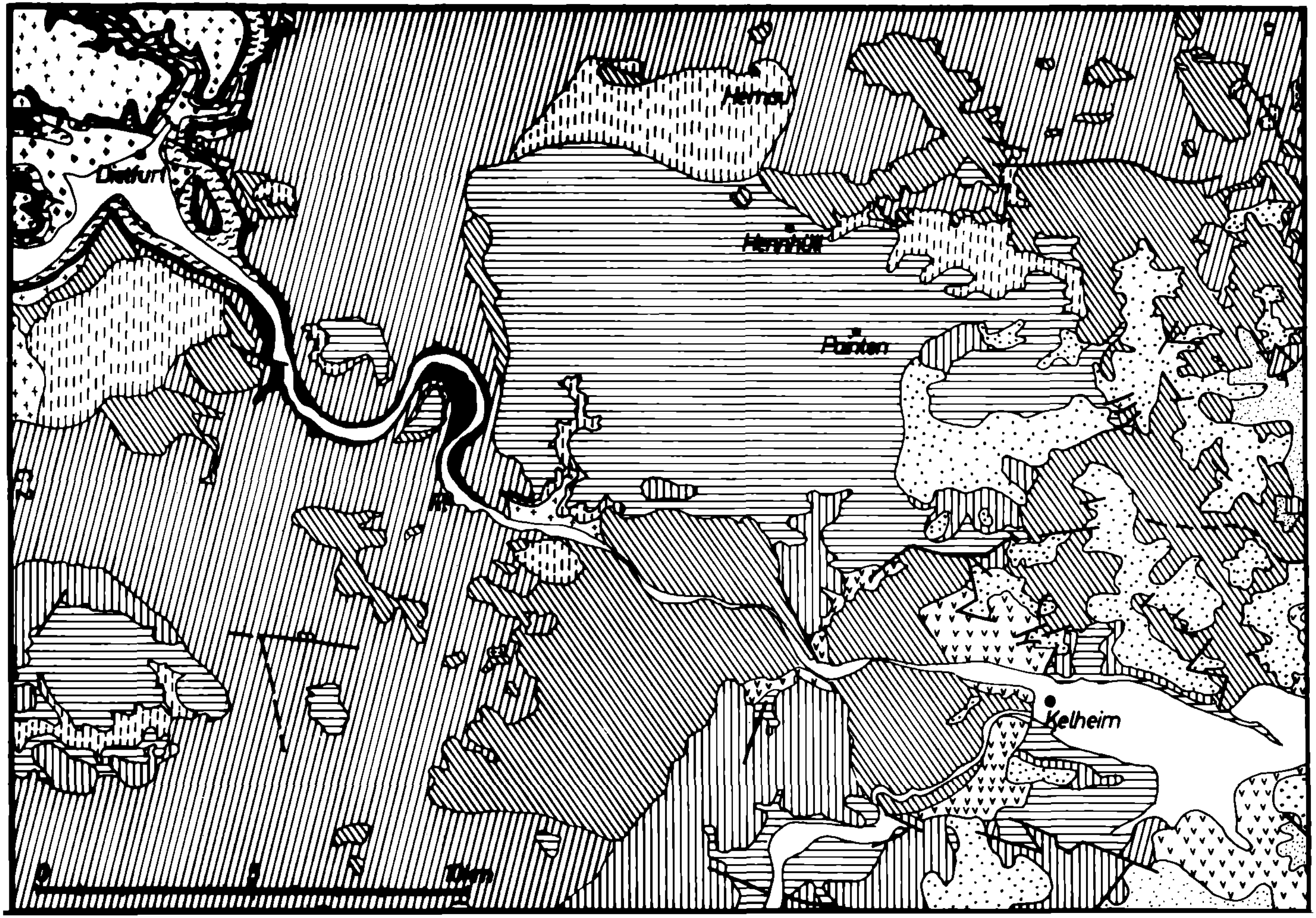
The excursion offers the possibility to present some results together with many questions. Any suggestion is welcomed!

E. F.



Tertiary & younger sediments
Younger sediments on jurassic basement
Cretaceous
Upper Jurassic
Lower & Middle Jurassic
Triassic
Crystalline of Moldanubicum
Route with numbers of stops
Bamberg
Erlangen
Fürth
Nürnberg
Eichstätt
Kelheim
Ingolstadt
0 10 20 30 40 50 km
Gr. 75

C1


Dietfurt
Hemau
Painten
Kelheim
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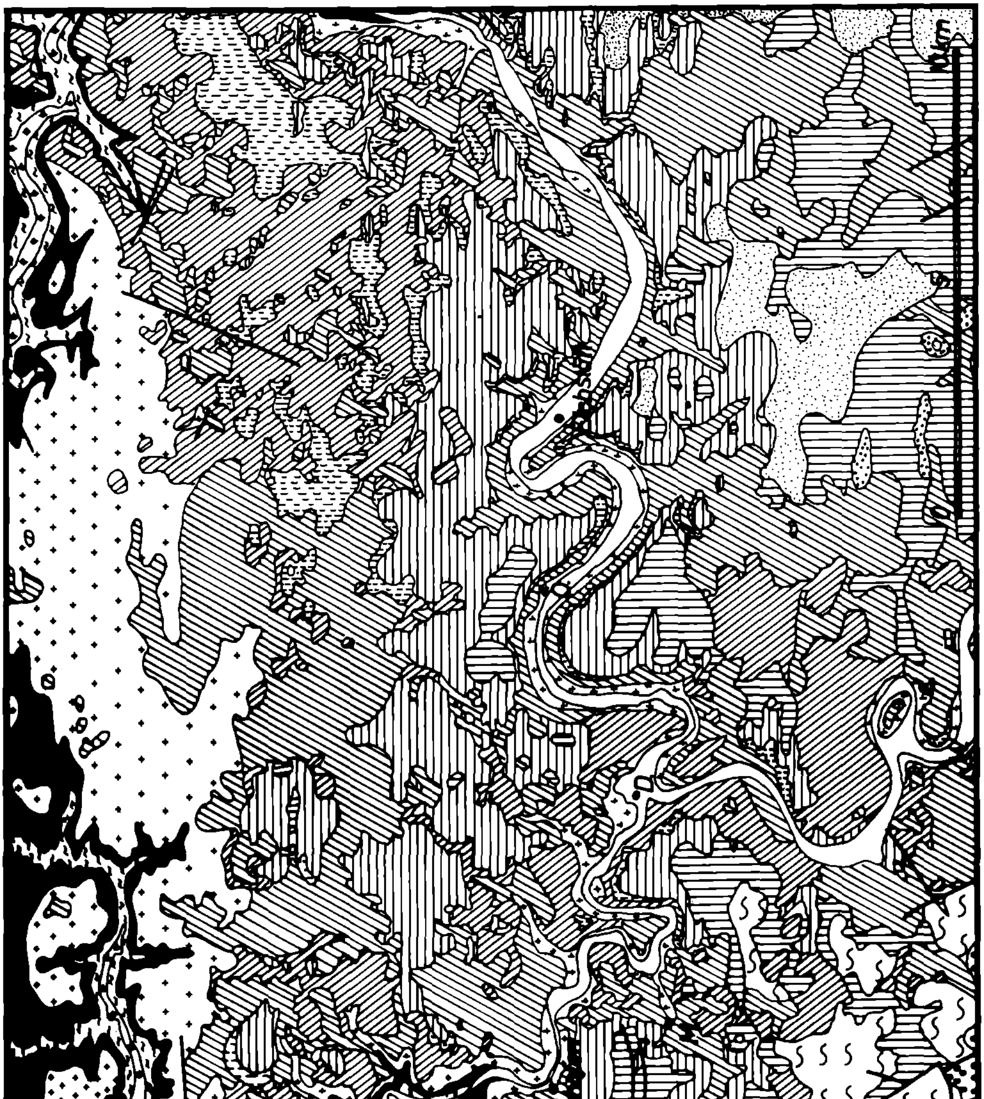
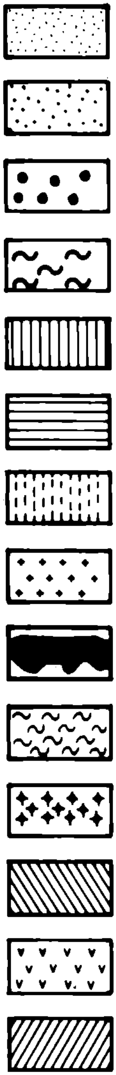




Tertiary and younger

Cretaceous

Lower Tithonian (Rennertshofen beds, ζ_6)

(Usseltal beds, ζ_4)

(Mörnsheim beds, ζ_3)

(Rögling & Solnhofen beds, ζ_{1+2})

Upper Kim̄eridgian (ε)

Middle Kim̄eridgian (Treuchtlingen beds, δ)

Lower Kim̄eridgian (γ)

Oxfordian ($\alpha + \beta$)

Middle Jurassic (Dogger)

Reef complexes of the Upper Jurassic

Detrital reef limestone

Dolom. reef complexes

Both geol. maps after B. von Freyberg 1968

STRATIGRAPHY (A. ZEISS)

1. Introduction

In Bavaria north of the river Danube exists a two-arched mountain range of intermediate character surrounding the southern and eastern limits of the central basin. This mountain range, the "Fankenalb" is built up by layers, which belong into the time span Upper Triassic - Upper Jurassic (fig. C 5).

Quite often these layers are covered by younger,cretaceous, tertiary or quaternary deposits. Partly this younger deposits may also be found in cavity-forms of the "Alb"-body caused by the "Karst".

The Frankenalb has been divided into three large areas (Northern, Middle and Southern Frankenalb) which, as far as the development of rocks and the thickness of the layers is concerned, are more or less differentiated (see A.ZEISS 1968 b) Figure C 6 shows these facies areas and the reef-belts/ or swells separating them during Upper Jurassic time.

The exact geological investigation of the Frankenalb started in the last century. For the first time the stratigraphical column has been treated in an useful form by L.v. BUCH (1839) in his contribution: "Ober den Jura in Deutschland".

The further exact biostratigraphic investigation we owe to authors like A. OPPEL (1856-1865), L. WAAGEN (1866) and C.W.v. GOMBEL (and L.V.AMMON) 1891. At the beginning of this century authors like L.REUTER (1908), Th. SCHNEID (1915 and 1916), L. WEGELE (1929), P. DORN (1930/31, 1935), and L. KRUMBECK (1932-1944) have to be mentioned. These authors have established the base for the biostratigraphical subdivision, however many problems remained still open.

After 1945 the investigation of the Frankenalb got many new impulses; particularly careful attention was paid on an exact litho- and bio-stratigraphical survey in the Upper Jurassic. To control the parallelisations gained by the application of lithostratigraphical and stromatometric methods layer of layer was inspected for ammonites.

By this a lot of surprises were the result, for example the "Arietensandstein" of the Sinemurian or the "Untere graue Mergelkalke" and "Werkkalke" of the Oxfordian proved to be heterochronic sediments instead of isochronic as until that time believed. Also some biozones could be recognized for the first time in the Frankenalb. This investigations were mainly carried out by the members of the Institutes of Geology and Paleontology of the University of Erlangen-Nürnberg. However colleagues from München have contributed to the researches, too (Institut für Paläontologie und historische Geologie, Universität and Bayer.Geologisches Landesamt).

In order to give a brief information of the investigations, the most important papers are summarized in the following survey:

1.Rhetian, Hettangian and Sinemurian

EMMERT,U.(1964); FREYBERG,B.v.(1974); HOFFMANN,D.(1967); JUNG,W.(1960); KESSLER,G.(1973); URLICHS,M.(1966); VIOHL,G.(1969); WEBER,R.(1968); ZEISS,A.(1965).

2. Pliensbachian and Toarcian

JAHNEL CH. et al (1969); KOLB,H.(1964); SCHIRMER,W.(1965); URLICHS,M. (1971 & 1975); WELZEL, E.(1968); ZEISS,A.& SCHIRMER,W.(1965).

3. Aalenian

FREYBERG,B.v.(1951, 1960, 1961); HÜRAUF, M.(1959); ZEISS,A.(1960).

4. Bajocian, Bathonian and Callovian

KOLB,H.(1965); SCHMIDTILL,E.(1953); ZEISS,A.(1957, 1961); ZIEGLER,J. (1959).

5. Oxfordian

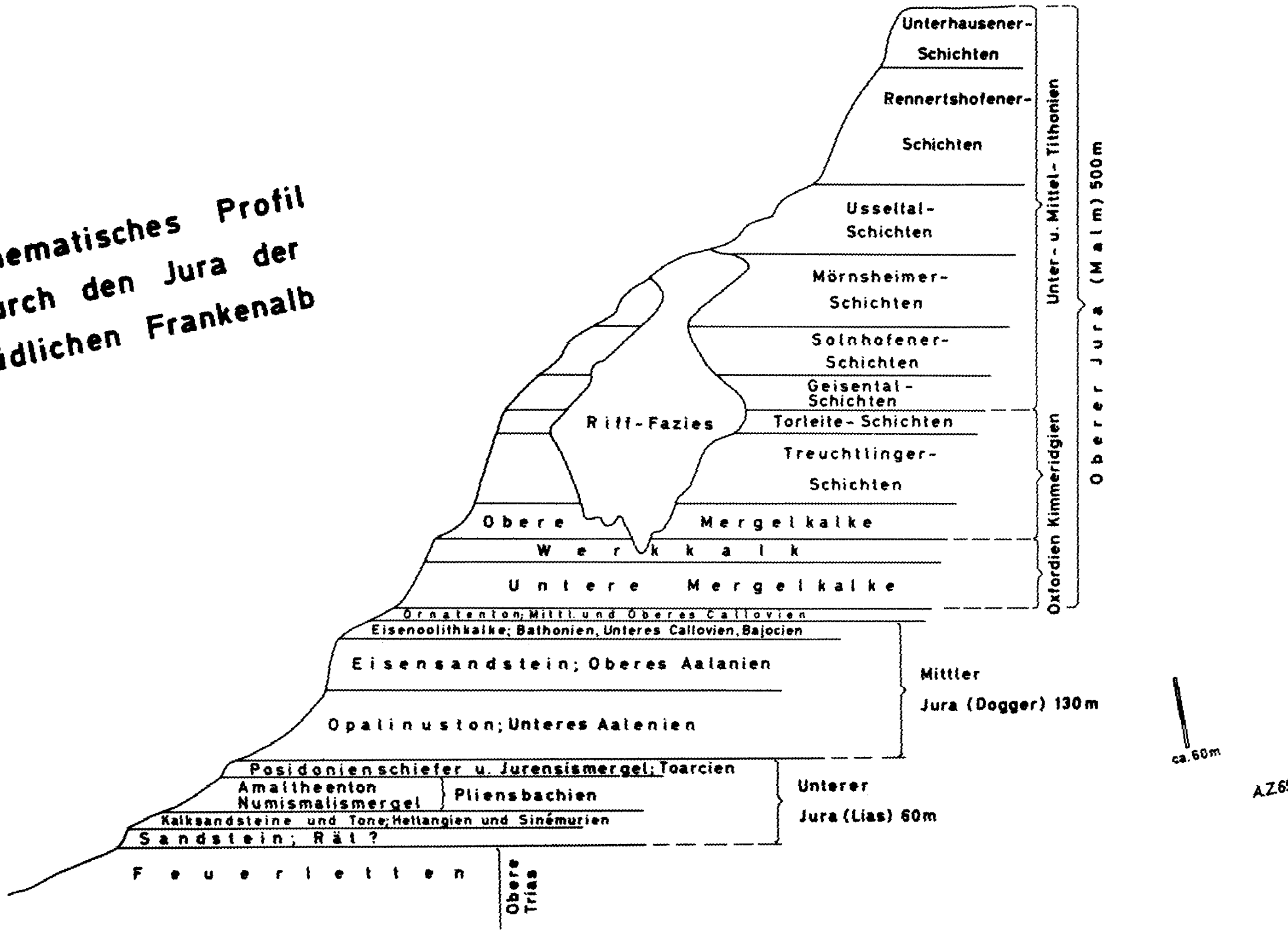
BECHER,A. (1960); FREYBERG,B.v.(1966);GROISS,J.Th. (1966, 1970); HERTLE,A.(1962); NITZOPOULOS,G.(1973); SCHMIDT-KALER,H. (1962 a); SCHULER,G. (1965); STREIM,W. (1960); ZEISS,A. (1962,1966).

6. Kimmeridgian

BANTZ,U. (1970); MEYER,R.(1972, 1974 a); SCHAIRER,G.(1970, 1974); SCHMIDT-KALER,H. (1962 b); SCHÜTZ,D. (1962); WINTER,B.(1964, 1970); ZEISS,A. (1964, 1964 b).

Fig. C 5 Generalized section of the Jurassic system of the "Südliche Frankenalb".

Schematisches Profil durch den Jura der Südlichen Frankenalb



C5

7. Lower Tithonian

BANTZ,U.(1969); BARTHEL,K.(1959); BAUSCH,W.(1963); COPE,J. & ZEISS,A. (1964); EDLINGER,G.V.(1964, 1966); FESEFELDT,K.(1962, 1963); FREYBERG,B.v. (1964); GROISS,J.(1963, 1967 a); MAYR,F. (1967); MEYER,R.(1974 b,c,); MÜLLER,M. (1961); PATZELT,W. (1963); RUTTE,E.(1962); SCHAIRER,G. & YAMANI, S.A. (1973); SCHNITZER,W. (1965); STREIM,W. (1961 a, b); ZEISS,A. (1964 a,c,d; 1968 b, 1975).

8. Middle and Upper Tithonian

BARTHEL,K. (1962, 1965, 1969, 1975); GROISS,J.-Th. (1967 b); KUTEK,J. & ZEISS,A. (1974).

9. Jura alltogether / or larger divisions

FREYBERG,B.V. (1968); MEYER,R.(1972, 1974 a); SCHMIDT-KALER,H. (1969); SCHMIDT-KALER,H. & ZEISS,A. (1973); SCHIRMER,W. (1974); TREIBS,W. (1964); ZEISS, A. (1968 b).

10. Postjurassic sediments

ANDRES,G.(1951); BAUBERGER,W., CRAMER,P. & TILLMANN,H. (1969);BIRZER,F,(1969); BOLTEN,R. & MÜLLER (1969); GROISS,J.-Th.(1964); HOLLAUS,E.(1969); OSCHMANN,F.(1958); SCHNITZER,W. (1956); TILLMANN,H. & TREIBS,W. (1967).

11. Tectonics

FREYBERG,B.v.(1969); POLL,K. & ZEISS,A.(1970); REUL,R. (1953).

12. Reeditions of classic works

BAIER,J.J.; Oryctographica Norica: HORNUNG,H.,HELLER,F.& FREYBERG,B.v.(1958); REINECKE,J.M.C.; Nautilos et Argonautas ...: HEUBECK,A.,HELLER,F.,ZEISS,A.(1972);

13. Official geological maps (only along the excursion route)

Geologische Karte von Bayern 1: 500.000 (1964)

Geologische Karte von Bayern 1: 25.000 Blatt Abenberg (1965)
Blatt Altdorf (1974)
Blatt Deinig (1973)
Blatt Erlangen S (1966)
Blatt Erlangen N (1968)
Blatt Gunzenhausen (1970)
Blatt Heidenheim (1970)
Blatt Kelheim (1962)

Geologische Karte von Bayern 1 : 25.000 Blatt Neumarkt/Opf. (1969)
Blatt Nürnberg (1956)
Blatt Röthenbach/Pegnitz (1968)
Blatt Schwabach (1957)

Geological maps from:

Erlanger geologische Abhandlungen
Gesamtübersicht: Heft 70
Jura-Karten 1 : 25.000: Heft 36,38,40,44,46,49,54,55,56,57.

1.2 Stratigraphy of the excursion area (see fig. C 5)

As on our journey we are only crossing the sediments of the Upper Triassic, Lower and Middle Jurassic (see fig. C 1), the stratigraphy of these will be discused briefly. The main purpose of the excursion id to show some interesting points of the Upper Jurassic. Therefore, for the post-jurassic deposits also, only a brief survey is provided.

1.2.1 Triassic

The excursion passes a part of the Upper Triassic (Keuper) beds, that means firstly the 70-75 m thick "Burgsandstein", a terrestrial-fluviatil formed sediment (sandstones with some layers and lenses of dark red marls, sometimes radioactive, and secondly the overlying "Feuerletten", 45 m thick (reddish hard marls, occasionally with intercalations of sandstones).

Owing to the faune the deposition of the Feuerletten may partly be traced back to a brackish milieu.

1.2.2 Rhetian - Liassic Transition beds

Rhetian and Hettangian, if there, are developed as limnish-fluviatil bedded layers (sandstones, clays with plants) with a considerably fluctuating thickness.

1.2.3 Liassic (Lower Jurassic)

The marine transgression commences earliest in the Lower Sinemurian, sometimes also in the Middle and Upper Sinemurian (2-3 m Sinemurian sandstone, sporadically intercalated by marls).The Lower Pliensbachian (3-5 m thick) is developed as blue-grey limestone- and marl-series, whereas the Upper Pliensbachian (30-35 m thick) is represented by a grey marlstone series (Amaltheen-Ton). This series is followed by thin-laminated paper shales, reaching about 2-3 m thickness, the Lower Toarcian; some calcareous layers are intercalated. The Upper Toarcian, approx. 2 m thick, consist of marls, rich in fossils which, in the lower part have a laminated splitting.

1.2.4. Dogger (Middle Jurassic)

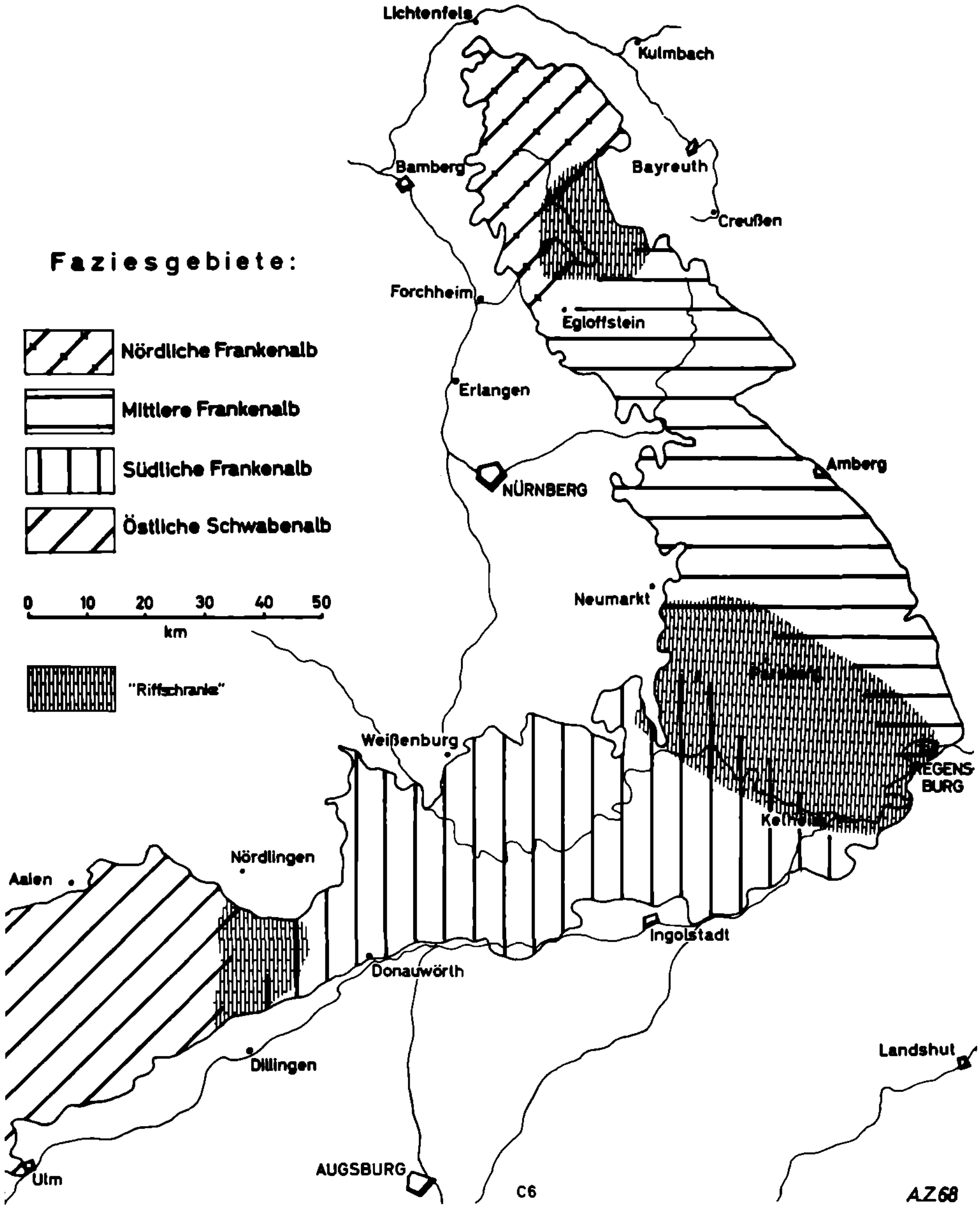
The Middle Jurassic starts beginning with a marl stone series of 60 m thickness (Opalinuston, Lower Aalenian),followed by the 60-70 m thick layers of the Eisen- or Dogger-Sandstein (Upper Aalenian) which possesses a few iron ore beds in former times worth to exploit. The sediments of the Bajocian, Bathonian and Callovian together mount up from 2 to 11 m thickness and, beginning at the bottom, consist of calcareous sandstones, brown iron oolitic limestones and marls and dark marls with phosphorits; in the uppermost Callovian the latter marls have a fine sandy component, additionally.

1.2.5. Malm (Upper Jurassic) (see figs. C 6 and C 7)

1.2.5.1. Oxfordian

The Lower Oxfordian, thin, dark, fine-sandy marls is missing within the Southern Frankenalb while in the Middle and Northern Alb the Lower Oxfordian can be traced here and there by the evidence of ammonites. The Middle and Upper Oxfordian is everywhere present. These beds reach approximately 50-55m thickness; they begin with a glauconitic limestone bed at the base, which contains a high number of ammonites and which has to be placed in the Plicatilis (Transversarius zone).

Fig. C 6 Facies distribution within the Frankenalb; Facies region and reef ridges (Riffschranken);(after ZEISS 1968 b).



Lichtenfels
Kulmbach
Bamberg
Bayreuth
Creußen
Faziesgebiete:
Forchheim
Egloffstein
Nördliche Frankenalb
Mittlere Frankenalb
Südliche Frankenalb
Östliche Schwabenalb
0 10 20 30 40 50
km
"Riffschranke"
Erlangen
Amberg
NÜRNBERG
Neumarkt
Weißenburg
Nördlingen
Aalen
Ingolstadt
Donauwörth
Dillingen
Landshut
Ulm
AUGSBURG
C6
AZ68

The section which follows it is characterized by grey marls. Limestone beds are retreating (20-25 m, Heidenheim member). A precise faunistic investigation of this part is still missing due to the devoid of outcrops. On the other hand the sequence which follows above the Heidenheim member could be faunistically investigated more carefully and has been divided into biozones.

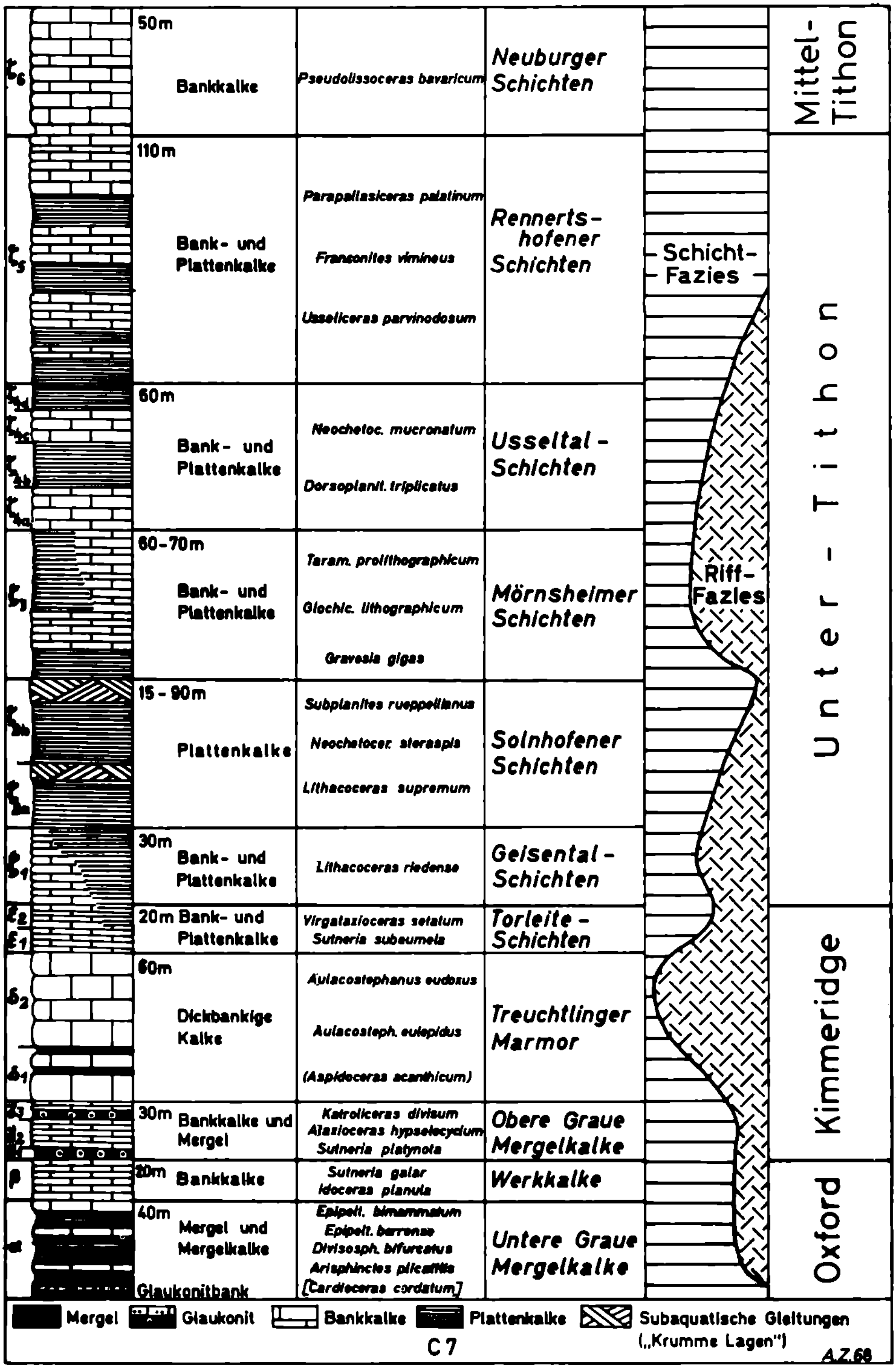
At the base of the 20 m thick calcareous marl and limestone series (Gelbebürg members) there is an approximately 2-3 m thick key horizon (zone of the Epipeltoceras berrense), which is nearly found in all profiles. The higher beds of the series contain E. bimammtum, an only rarely occuring ammonite(zone of E. bimammatum).

Following towards the top, the marl components decrease. In places where they are almost missing the walls of clearly stratified limestones appear (Oberweiler member). These 10-15 m thick series of calcareous limestones are characterized by the occurence of Taramelliceras litocerum, Idoceras planula, Sutneria galar. This sequence of layers (zone of I. planula) almost corresponds to the zone of Ringsteadia pseudocordata in England.

1.2.5.2 Kimmeridgian

The Kimmeridgian begins with 7 m of characteristic glauconitic calcareous marls and limestones. Ammonites are quite common within this lowermost member. Good guide fossils are Sutneria platynota and Ataxioceratids (Schlittenhart member). The 20 m thick limestones which follow are predominated by Ataxioceratids (zone of A. hypselocyclum), named therefore "Ataxioceraten-Schichten"(Degersheim member). After a short intercalation of marls (Crussoliensis Mergel) follow again limestones (Uhlandi-Kalke), both together are also named after I. balderum, the Balderum beds. Whereas the lower part of the limestone (4,50 m) is developed in the normal limestone facies (Rohrach member) the upper part (6,50 m) is characterized by algal sponge limestones and belong to the lower part of the Treuchtlingen formation. This change of facies has been used to unite all Upper Jurassic beds below that as Hahnenkamm formation (NITZOPOULOS 1974) those above as Treuchtlingen formation. Partly the normal limestone facies of these two formations may be replaced by reef facies (see R.MEYER, this guide).

Fig. C 7 Stratigraphy of the Upper Jurassic of the Southern Frankenalb; (from ZEISS 1968b).



50m
Bankkalke
Pseudolissoceras bavaricum
Neuburger Schichten
Mittel-Tithon
110m
Bank- und Plattenkalke
Parapallasiceras palatinum
Franconites vimineus
Usseliceras parvinodosum
Rennertshofener Schichten
Schicht-Fazies
60m
Bank- und Plattenkalke
Neochetoc. mucronatum
Dorsoplanit. triplicatus
Usseltal-Schichten
60-70m
Bank- und Plattenkalke
Taram. prolithographicum
Glochic. lithographicum
Gravesia gigas
Mörnsheimer Schichten
Riff-Fazies
15-90m
Plattenkalke
Subplanites rueppellianus
Neochetocer. steraspis
Lithacoceras supremum
Solnhofener Schichten
Unter-Tithon
30m
Bank- und Plattenkalke
Lithacoceras riedense
Geisental-Schichten
20m Bank- und Plattenkalke
Virgataxioceras setatum
Sutneria subeumela
Torleite-Schichten
60m
Dickbankige Kalke
Aulacostephanus eudoxus
Aulacosteph. eulepidus
(Aspidoceras acanthicum)
Treuchtlinger Marmor
Kimmeridge
30m Bankkalke und Mergel
Katroliceras divisum
Ataxioceras hypselocyclum
Sutneria platynota
Obere Graue Mergelkalke
20m Bankkalke
Sutneria galar
Idoceras planula
Werkkalke
40m
Mergel und Mergelkalke
Epipelt. bimammatum
Epipelt. berrense
Divisosph. bifurcatus
Arisphinctes plicatilis
[Cardioceras cordatum]
Glaukonitbank
Untere Graue Mergelkalke
Oxford
Mergel
Glaukonit
Bankkalke
Plattenkalke
Subaquatische Gleitungen („Krumme Lagen")
C 7
A.Z.68

The algal-sponge facies of the Treuchtlingen beds ("Treuchtlinger Marmor") is very characteristic for the stratified limestones of Middle Kimmeridgian age (see R.MEYER, this guide). This facies type is limited to the Southern Franconian area. The thickness reaches 50-60 m, the upper part may be replaced by true algal-sponge reef facies, that exceed the banked facies by about 20 m.

Biostratigraphically the Treuchtlingen formation represents the zones of Aulacostephanus eulepidus and Au. eudoxus. Other characteristic ammonites are Streblites levipictus, Taramelliceras compsum, T. pseudoflexuosum, T. klettgovianum, Sutneria eumela, Creniceras dentatum, Aspidoceras liparum., A. bispinosum, A. acanthicum.

The following more thinly bedded, sharply splitting limestones of the Upper Kimmeridgian(20-30m) are not /or scarcely influenced by the sponges. The Torleite formation lays above the Treuchtlingen formation in the centre of the "Wannen" and above the sponge reef-complexes, more on the margins of the Wannen. The Torleite formation (20-30m) is built up by limestones in the western parts of the southern Frankenalb. They are replaced to some extent by sublithographic limestones when going to the east (see fig. C 8). Thus, east of Eichstätt, e.g. in the region of Painten, the upper part is represented by thin, partly silicified sublithographic limestones, while the lower part consists of white marly limestones.

Biostratigraphically the Torleite beds include two zones:

1. zone of Sutneria subeumela below
2. zone of Virgataxioceras setatum above.

Both together are sometimes also considered as only one zone, that of Hybonoticeras beckeri. These beds contain, besides the three indexes, a lot of other ammonites especially those of the genera Virgataxioceras, Taramelliceras, Och-etoceras, Aspidoceras, Oxyoppelia.

In the farther surrounding of Eichstätt there are characteristic red marls above the top of the limestones of the Torleite beds, with which the beginning of the Lower Tithonian is indicated as they delivered characteristic faunal elements of that substage.

1.2.5.3. Tithonian

The lower part of the Lower Tithonian substage, the Altmühltal foramtion, is characterized by a predominance of lithographic and sublithographic limestones with intercalating submarine slumps. They have been subdivided into three members, Geisental, Solnhofen and Mörnsheim member (see ZEISS 1975), which are better considered as subformation; reef sediments occur,too (see R.MEYER this guide).

1.2.5.3.1. Geisental subformation

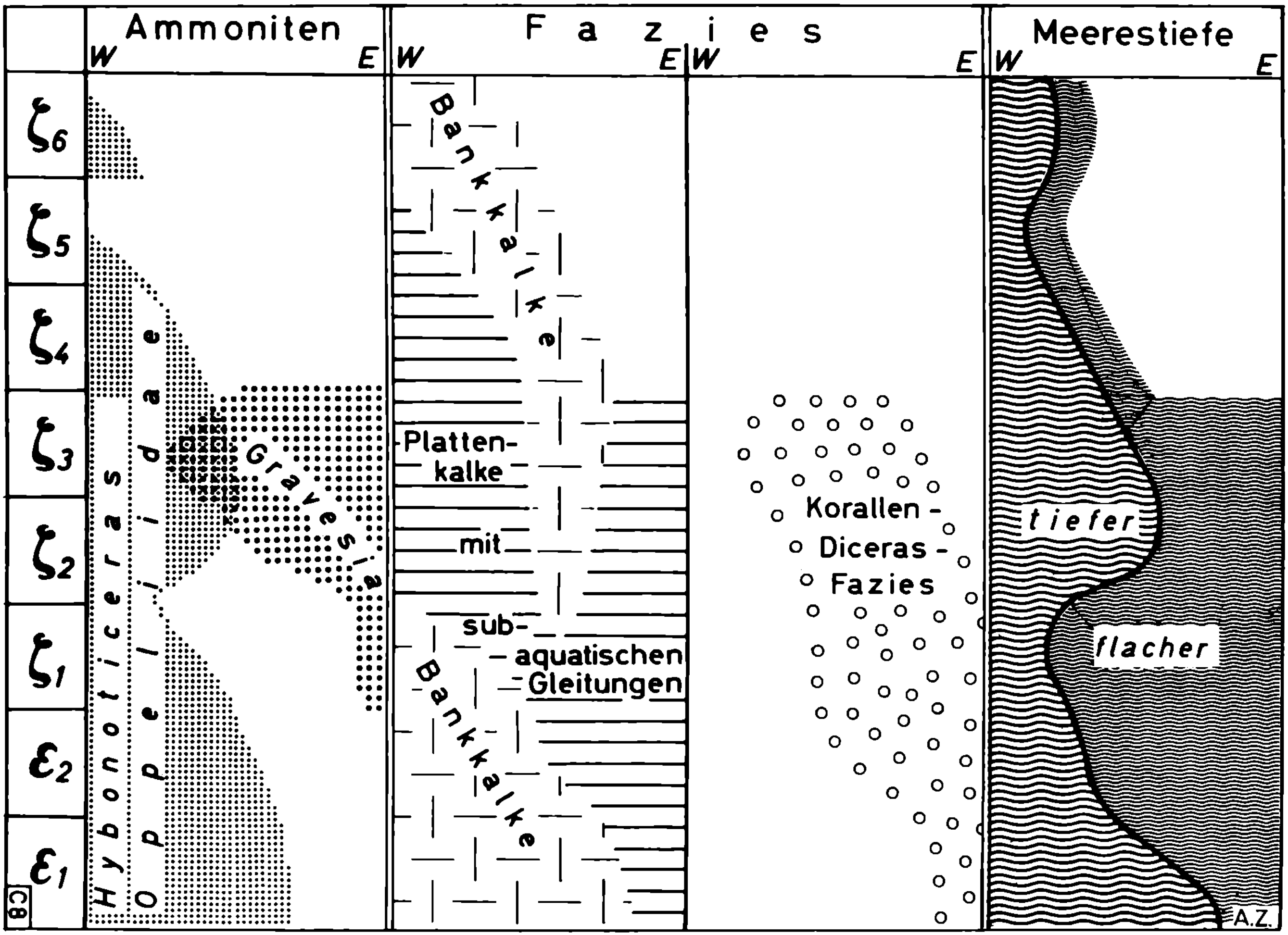
The Geisental subformation (approximately 30 m) is composed of limestones in the western,Solnhofen region (Rögling member) which are partly replaced by sublithographic limestones in the Eichstätt area (Geisental member s.str.). Further east a series is developed which may consist of sublithographic limestones and/or limestones with many submarine slumps. These beds gradually pass into the lithographic limestone facies of the Solnhofen subformation (Öchselberg, Zandt members and other equivalents). As in these eastern parts the equivalents of the Geisental and Sonhofen subformation are not clear separable, they are united as the Painten subformation, consisting of the Hennhüll sublithographic limestones below and the Zandt, Öchselberg, Jachenhausen lithographic limestones above. All these members have intercalated submarine slumps.

The ammonites of the Geisental subformation are e.g.: Hybonoticeras hybonotum, Gravesia gigas (rare), Neochetoceras praecursor, Lithoceceras riedense, L. subulmemse.

1.2.5.3.2. Solnhofen subformation

The Solnhofen subformation(up to 90 m)is built up by a lot of varying facies types; most of them have not be named in strong lithographical terms, but only in a provisional manner.

Fig. C 8 Bathymetrical diagram, based on ammonite distribution and facies development. Upper Kimmeridgian (epsilon 1-2) and Lower Tithonian (zeta 1-6); (from ZEISS 1968 a).



Ammoniten
Fazies
Meerestiefe
W
E
W
E
W
E
W
E
ζ6
ζ5
ζ4
ζ3
ζ2
ζ1
ε2
ε1
Hybonoticeras
Oppeliidae
Gravesia
Bankkalke
Plattenkalke mit subaquatischen Gleitungen
Bankkalke
Korallen - Diceras - Fazies
tiefer
flacher
A.Z.
C8

In the region of Solnhofen and Eichstätt there can be distinguished two cycles of lithographic limestones below and submarine slumps above("Untere Schiefer mit Trennender Krummer Lage und Obere Schiefer mit Hangender Krummer Lage", corresponding to Lower and Upper Solnhofen subformation).

The Eichstätt lithographic limestones differ from those of Solnhofen by minor thickness, as well of the whole series as of the single layers. Further to the east the two cycles are not so clear separable e.g. in the Pfalzpaint, Zandt, Painten, Hienheim district, where tney are also sometimes replaced by normal limestones, e.g. the Dencken-dorf-Hepberg limestone. Chacacteristic ammonites are: H.mundulum, Gravesia gigas (rare), Neochetoceras steraspis, N. bous, Lithacoceras supremum, L. ulmense, Taramelliceras prolithographicum, Glochiceras lithographicum, Subplanites rueppellianus.

1.2.5.3.3. Moernheim subformation

The thickness of the bedsbelonging to this subformation reaches about 60-70 m. There is a big lot of varieties in facies. In the Solnhofen area there can be observed especially sublithographic limestones which are partly silicified and rather rich in fossils.There are limestones rich in reef detritus and other which are marly. This marly facies is widespread in the east; in the lower parts of the subformation there occur also limestonesor sublithographic limestones, whereas in the higher parts limestones predominate.

The fauna is rather similar to that of the Solnhofen beds, new elements are Subplanites moernsheimensis, S. reisi, Gravesia gigas (numerous) . Oppeliids(Taramelliceras, Glochiceras)are rather abundant, especially in the lower parts.

1.2.5.3.4. Usseltal, Rennertshofen and Neuburg formations.

As the beds of this units will not be visited during the excursion only a short review will be given. For faunistic details see ZEISS (1968).Beds of this age are limited to the Solnhofen-Neuburg area (Middle Lower Tithonian- Lowermost Upper Tithonian).

Usseltal formation

The middle part of the Lower Tithonian Substage is 65 m thick and is built up by two cycles of limestones and lithographic limestones.

1) Tagmersheim limestones and Spindeltal lithographic limestones below, and
2) Gansheim limestones and Störzelmühle sublithographic limestones above.

There are characteristic ammonites of the genera Usseliceras, Subplanitoides, Dorsoplanitoides and Neochetoceras (mucronatum group) see ZEISS 1975 (Tab. 1). Reef limestones and detrital reef limestones occur rarely.

Rennertshofen formation

The upper part of the Lower Tithonian Substage, the Rennertshofen formation, begins with marly limestones of the Bertholdsheim member, followed by normal limstones of the Ammerfeld member and the upper part with limestones and intercalation of sublithographic limestones of the Finkenstein member. The thickness of the whole formation is 110 m.

The fauna of the Bertholdsheim member is rather similar to that of the Usseltal formation. Ammerfeld and Finkenstein member yield besides others the following characteristic species: Franconites vimineus, Danubisphinctes palatinus, Dorsoplanitoides bavaricus, Tithonosphinctes stephanovi, Parakeratinites communis, etc. For further details see ZEISS 1975 (Tab. 1).

Neuburg formation

This formation has two members: Unterhausen member (below) and Oberhausen member (above) consisting of 45 m white limestones. For further information see BARTHEL (1962, 1969). The age is Middle Tithonian except the uppermost part of the Oberhausen beds which is of Upper Tithonian age.

1.2.6 Cretaceous System

The cretaceous system has to some extent been found in cavity-forms of the karst, to some extent it is overlaying (superposing) the Jurassic beds of different age. There are two main areas of distribution within the Southern Frankenalb: a western part in the area Solnhofen-Neuburg/ Donau and an eastern part between Kelheim/Laber and Regenburg.

The most ancient layers are the so called "Schutzfels-Schichten". They consist of sands, sandy rocks and clays of different colours. According to TILLMANN (1969, S.108) they are not older than Middle Cenomanian.

The true transgression of the sea occured in the upper Cenomanian with the "Grünsandstein", which is widely distributed in the region around Regensburg. However, in the western part it is only known from some places (ZEISS 1964 a, S. 36). While in the west the cretaceous deposits end with the Lower Turonian, in the east the Middle and Upper Turonian, too, can be observed in outcrops. Younger cretaceous deposits are only known from drillings (see OSCHMANN 1958, BEUBERGER, et al 1969). More about the cretaceous sequence in known in the northern Oberpfalz (see TILLMANN et al. 1967 fig. 4). Here in the region Amberg/Erbendorf the upper cretaceous layers represent the time period Lower Cenoman-Campan, partly in marine, partly in terrestrial (limnic-fluviatil) developments.

.2.7 Tertiary System

The tertiary sediments consist of limnic/fluviatil, clayish, finesandy sediments, soft coal, calcareous fresh-water limestones of different facies types. They belong to the Miocene and Pliocene and may be found in karst fillings or overlain, especially in the south and east, parts of the Alb plateau. There are relatively few outcrops within these sediments. Only where more coarse sediment types or coals can be found larger outcrops are to be expected. A quarry in the western part of the Alb (Ries region) (Heinsfarth) will be visited at the end of this excursion. It is situated in the reefs of the fresh-water facies.

1.2.8 Quaternary System

Within the quaternary system we are mainly concerned with gravels, detritus caused by frost, aeolic sands, calcareous tuffs, loess and cave sediments. They can be found at the slopes of the valleys and on the plateau.

A summary is found in BAUBERGER et al. (1969 Tab. 1); in this paper has been tried to correlate the altitude of pleistocean gravel terraces with the level of the caves.

2. F a c i e s (H. KEUPP, R.MEYER)

2.1 General Review of Carbonate Rocks (R.MEYER)

2.1.1 Introduction

The Franconian Alb (Frankenalb) is the eastern end of the great Jurassic chain which starts with the French Jura Mountains. The paleogeographic situation of the Franconian-Swabian shelf area during Upper Jurassic times is characterized by the Central-German-Ridge (Mitteldeutsche Schwelle) acting as north-western margin, a wide connection with the Helvetic Basin of the Tethys in the south and an eastern margin somewhere in the region of Bohemia, and by connections to North Germany and Poland.

The Frankenalb consists of two parts: the north-south directed North- and Middle Alb between Kulmbach and Regenburg and the eastwest-directed South Alb adjacent to Swabia (see fig. C 6). Both parts are differentiated as far as morphology and geology is concerned:

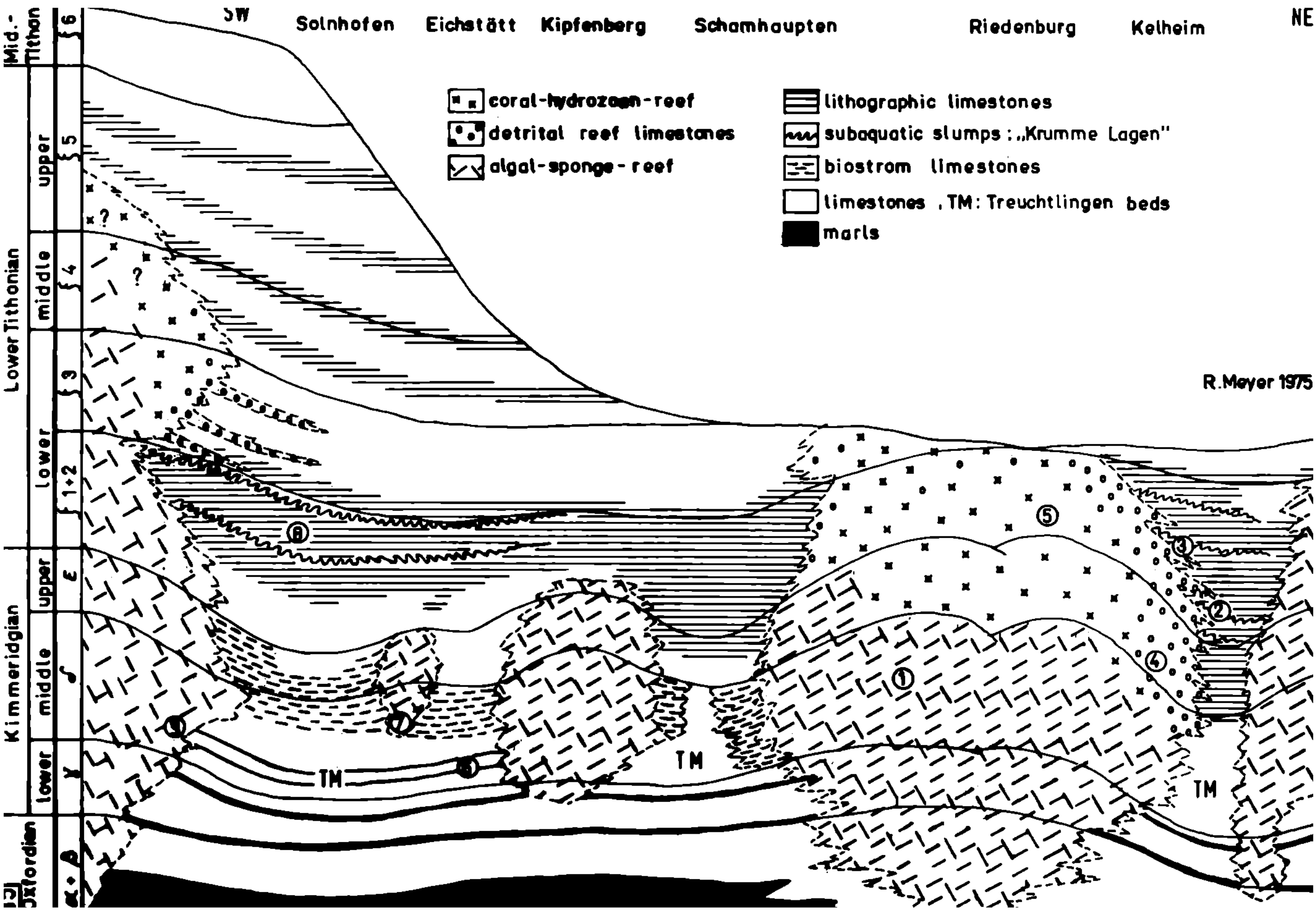
While the Middle and North Alb is dominated by dolomite hills (formed by lower Cretaceous and Tertiary subtropic kegelkarst?), the Southern Alb is characterized by an Eocene peneplain. The narrow dolomite valleys of the North Alb have been formed after the Pliocene, the wide drainage system seen in the South Alb before Upper Miocene (BIRZER 1969).

The "WhiteJurassic"(Weißer Jura) of the Southern Frankenalb shows a sequence of limestones, epi- and syngenetic dolomites, and calcareous marls. The total thickness of this Upper Jurassic section reaches to about **600 m** (Oxfordian 60 m, Kimmeridgian 120 m, Lower Tithonian 350 m, parts of the Middle Tithonian 50 m). Fig. C 2-4 shows the facies distribution according to v.FREYBERG (1968).

Two ecologically different environments can be recognized within the Malm of the Southern Alb: a) "Schichtfazies" (see 2.1.3.1) with alternating sequence of generally well-bedded limestones and calcareous marls. b) "Reef-facies" with algal-sponge-reefs (lower Oxfordian to Lower Tithonian) and spongiomorphid-coral-reefs (Lower Tithonian).

According to distribution and geometrical forms of the reef structures algal-sponge-bioherms- and -biostroms can be differentiated. Often reefs incompletely overgrow areas with well-bedded limestones leaving so-called "Restlücken" (ROLL 1934) - gaps between reefs. Beginning with Malm epsilon the algal-sponge reef development becomes regressive, at the top of the biostrom facies depressions were formed (so-called "Wannen") which were filled successively with well-bedded carbonate sediments of the Schichtfazies. A new reef period with coral- and spongiomorphid reefs started during Malm zeta 3. During this time the "Wannen" areals show very typical sedimentation patterns, characterized by extremely fine-grained carbonates (Solnhofen platy limestones (=Lithographic Limestones). The fossils of these beds are known all over the world, the genesis of the sediments is a question of discussion just until today.

Fig. C 9 Generalized facies scheme of the Upper Jurassic of the Southern Frankenalb, with STOPS of the excursion.



SW
Solnhofen
Eichstätt
Kipfenberg
Schamhaupten
Riedenburg
Kelheim
NE
coral-hydrozoan-reef
detrital reef limestones
algal-sponge-reef
lithographic limestones
subaquatic slumps: „Krumme Lagen"
biostrom limestones
limestones, TM: Treuchtlingen beds
marls
R. Meyer 1975
Mid.-Tithon
Lower Tithonian
Kimmeridgian
Oxfordian
upper
middle
lower
6
5
4
3
1+2
TM

2.1.2 Facies types

2.1.2.1 Schichtfazies

This facies consists of well-bedded limestones and calcareous marls. The stratigraphy is based on lithology and on ammonite zones (see fig. C 7). Besides relatively common ammonites foraminifera are abundant, rarely thin-walled lamellibranchs. Rock-forming microorganisms like Globochaete alpina LOMBARD and coccolithophorids have been recognized locally (DOBEN 1970; GUMBEL 1889, E.FLÜGEL 1967). The microfacies is characterized by micrites, biomicrites and - in the neighbourhood of sponge-reefs-biointramicrites with non sorted algal products (oncoids, fragmented algal crusts) and with tiny remains of calcified siliceous sponges.

Clay minerals and strontium contents have been investigated by W. BAUSCH (1965, 1971) who found a kaolinite - illite distribution on the French and Southern German epicontinental shelf. Opposed to this in the Tethys kaolinite is missing.

The source area for the clay minerals is unknown.

A continuous clay sedimentation together with a cyclic carbonate sedimentation has been proved for the Swabian Upper Oxfordian (E. SEIBOLD 1952). This sedimentation pattern, however, can not be adopted to all periods (increasing clay content in Lower Kimmeridgian).

The stratified sections of the Upper Oxfordian and Middle Kimmeridgain are to be correlated bed by bed more than 100 km. This indicates a calm, low-energy environment. Other conditions seem to be responsible for the origin of the Tithonian platy limestones. Here the water was shallow and the reefs grew around isolated depressions ("Wannen") with a special sedimentation pattern. In these regions normal deposition can be interrupted by submarine slumps "Krumme Lage" with reef-material (see STOP 2 , Hennhüll).

2.1.2.2 Sponge-Algal-Bioherms

Synchronous with the stratified facies bioherms were built by sediments-trapping siliceous sponges and blue-green algae in low-energy environments. Formation of reefs started during the Oxfordian at the boundaries of submarine ridges. Water depth may have been about 100 - 150 m. At the beginning small and low patch reefs were formed with higher calcium carbonate contents than the neighbouring sediments (fig.C 10). Up to the Middle Kimmeridgian, following to this first phase "Großkuppel-Riffe"(large dome-shaped structures) with Ø up to 500 m and with dips up to 50^{0} can rise more than 50 m about the "Schichtfazies" (fig. C 11). The relief within reef-facies and "Schichtfazies" is due to growth of reef-building organisms together with sediment binding algae as well as to compaction and differential settlement.

By laterally intergrown dome-shaped reef-structures large reef-complexes can be developed (fig. C 9, right), which create the main part of the sponge-facies in Franconian.

Polished sections show dark coloured hexactinellid and lithistid siliceous sponges with saucer- and cone-shaped forms. Mainly the siliceous skeleton is tranformed into calcite.

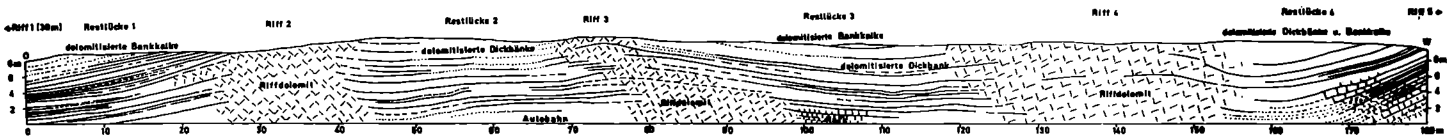
Fig. C 10 Dolomitizised sponge reef, embryonal stadium. Oxfordian; Autobahn near Neumarkt, Oberpfalz;(after MEYER 1974).

Fig. C 11 Dolomitizised "Großkuppel"sponge reef (domed-shaped structure). Hohllochberg near Velburg. Middle Kimmeridgian. STOP 1 . - (after MEYER 1974).

Erlanger geol. Abh. 96, 1974 (Meyer)

Sämtliche Profile sind nicht überhöht!

Fig. 1: Malm Beta



C 10

Fig. 2: Malm Beta

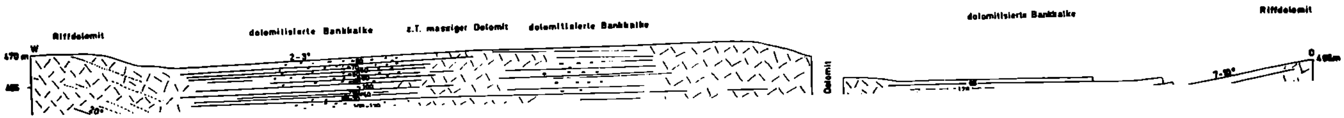
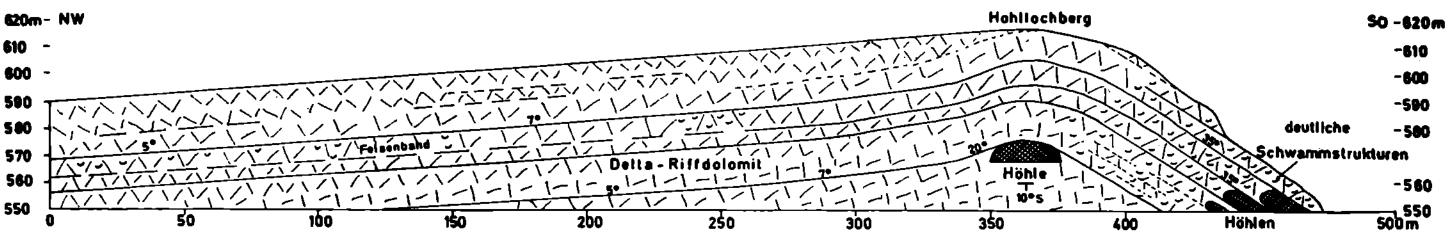


Fig. 5: Malm Delta



C 11

Epiphytes (crusts and pellets made by blue-green-algae) can be found together with sessile foraminifera on the surface of the sponges. Epizoans (serpulids, bryozoans, brachiopods, rarely calcareous sponges and lamellibranchs) grew at the lower side of the sponges (fig. C 12).

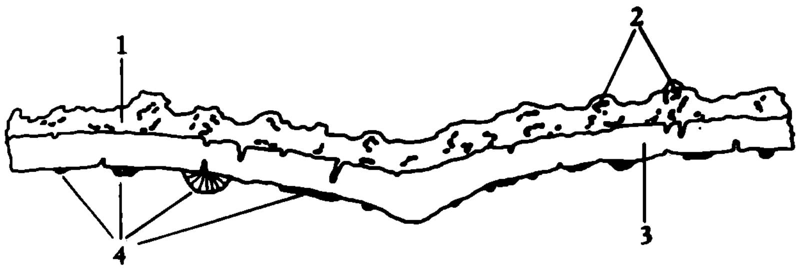


Fig. C 12 Epifauna and-flora of a siliceous sponge (after GAILLARD 1971). 1 - micrite crusts (algal products), 2 - sessil foraminifera, 3 - siliceous sponge, 4 - epizoans (serpulids, bryozoans, brachiopods, calcareous sponges, lamellibranchs).

According to B.ZIEGLER (1964) overgrowth was possible after the mazeration of sponges only.

During Oxfordian and Middle Kimmeridgian the sponge - algal crust - facies, (sponge biolithite) mentioned above, dominates in the Franconian sponge reefs. The open framework consisting of siliceous sponges (10-15%) and algal crusts without fine laminations (40-60%) covers 50-70% of the total rock volume. Matrix is made up of micrite with pellets. Strikingly, no oncoids and intraclasts have been found.

Beginning with the uppermost Middle Kimmeridgian (uppermost Malm delta), the thick algal crusts are replaced by stromalithic crusts, built up of well-defined layers of micrite pelltes. These algal products are cemented by blue-green algae (see Abstract BEHR & BEHR). Abundance of stromatolithic algal structures may indicate shallowing of sea level but there are no hints to supratidal or intertidal conditions. An.upper subtidal environment seems to be probable.

In the transition area towards the "Schichtfazies" the frequencey of sponges diminishes, tiny algal crusts can be found only, and brachiopods together with echinoderms become more frequent.

2.1.2.3 Well-bedded Sponge-Biostromes ("Treuchtlinger Marmor")

Starting in the Middle Kimmeridgian sponges do not only settle in the bioherms but also in the environment of the "Schichtfazies", thus developing a biostrome facies which is exploited in large quarries as "Treuchtlinger Marnor". Laterally this facies interfingers with reefs. In the relatively thick limestone beds mm - and cm-sized biogene particles can be seen.

The microfacies is characterized by : a) oncoids made by incrusting nubecularoid foraminifera, visible in rock-specimens as white flames (10 - 20% of the total rock volume); b) rarely incrusted filaments probably juven-ile mollusk shells (up to 5%); c) sponges (up to 5%) which are considerably scarce as compared with the reef-facies. Encrusting algae are missing mostly. Frequently free algal crusts can be found together with nubecularoid foraminifera (up to 20%). Some of these particles may be algae of the Tubiphytes-group. Up to 10% small intraclasts (fragmented sponges and algal crusts) contribute to the composition of the rock. The particles show no sorting.

Associated benthonic organisms are represented by serpulids, brachiopods, echinoderms, and bryozoans.

No reef-framework, made by sponges and algae, can be recognized in the "Treuchtlinger Marmor". Most types of this limestones are mudstones or wackestones according to the mud-support of about 50-70% of the grains. Uniform bedthickness for more than 50 km indicates a calm deposition environment.

2.1.2.4 Indistinct bedded Sponge Biostromes

The basement of the Tithonian "Wannen" often is formed by thick, indistinctly bedded limestones with cherts. Together with siliceous sponges (up to 5%) sessile nubecularoid foraminifera, serpulids, brachiopods, echinoderms, bryozoans, and lamellibranchs can be found.

The microfacies is characterized by dense stromatolithic algal crusts upon siliceous sponges in thick beds, and mainly by oncoids (10-30%) together with bioclasts with dark micrite envelopes, and some siliceous sponges (5-10%) in thin beds. Grain-support can be seen.

Some ooids (up to 4%), micrite envelopes, and stromatolithic algal crusts may indicate shallowing which was favourable for sponge growth.

2.1.2.5 Spongiomorphid - Coral - Bioherms

In the Kelheim area the sponge-reefs are followed by spongiomorphid-coral-reefs beginning with the uppermost Middle Kimmeridgian. They form reef-complexes of some Km in diameter and are surrounded all sides by zones of detritus up to 2 km wide. These detrital limestones are called Diceras-Kalk, Kelheimer Kalk, or Breistein. No differentiation in fore- and back-reef can be seen.

The detrital limestones interfinger with platy limestones of the "Wannen". Spongiomorphids sometimes are similarly to the sponges overgrown by stromatolithic algal crusts. Within the micrite matrix white flames of nubecularoid foraminifera can be recognized.

For the composition of the detrital limestones see STOP 2, Excursion Route.

2.1.2.6 Frankendolomit

The predominant part of the sponge-bioherms and the thick-bedded biostromes are dolomitizised epidiagenetically.

Most dolomites are characterized by xenotypic textures. Crystal varies between 0,1 and 0,5 mm (up to 1 mm). Zonar dolomite crystals are known.

Chemical composition of the Frankendolomit varies. Pure dolomites have between 45 to 51 Mol.% $MgCO_3$ (RAZAIAN 1972). These differences may be due to zonar dolomites with Mg-rich cores. According to BAUSCH & HOEFS (1972) dolomites are isotopically lighter than limestones. Dedolomitization and recalcification are common (BAUSCH 1965 a). By this "Braunkalke" and saccharoidal limestones are formed.

Since most biogenes of the dolomites have been destroyed, microfacies can only be investigated in syndiagenetically formed cherts (R.MEYER 1976 b).

Within the dolomite sponges are clearly to be seen on joint planes only as horizontally orientated flat cuts. Correlations within the Frankendolomit can be made by exact investigations of facies units (R.MEYER 1972, 1974 b).

2.2 Solnhofen Lithographic Limestones (H.KEUPP)

Stratigraphy

In the Southern Frankenalb platy limestones (Plattenkalke) occur from the Upper Kimmeridgian (Malm delta) to Lower Tithonian (Malm zeta 3). A migration of facies took place from East to West (ZEISS 1968; see fig. C 8). Stratigraphically the "Solnhofener Schichten" are dated as Lower part of the Lower Tithonian (Malm zeta 2). The facies transition between the "Röglinger Bankkalke" (Malm zeta 1) and the typical Lithographic Limestones during Malm zeta 2a is gradually. This is indicated by interstratification of micro-bedded limestones(latent-geschichtete Bankkalke) with thin-platy marly layers. At the base and at the top of the Lithographic Limestones in the region of Solnhofen-Eichstätt submarine slumping units ("Krumme Lage") are developed.

"Krumme Lage"

These two subaquatic slides (O.REIS 1909) ca be traced with alternating thickness approximately over both "Wannen". While many locally limited slumps may be due to relief differences within the sedimentation region, the interpretation of KRUMBECK (1928) for the "Hangende Krumme Lage" and the "Trennende Krumme Lage" is more likely: he postulated a large-scaled collapse of the sediment from east to west caused (after FESEFELDT 1962 in direction to the Wannen centre) by earthquakes. According to ROLL (1933) and FESEFELDT (1962) theorigin of the "Krumme Lage" may be caused by differential settlement in the Wannen facies and in the reef facies. EDLINGER (1964) emphasizes facial alterations which should influence the extent of the sliding horizons since thicker beds show more sliding structures than fine-stratified platy limestones.

Besides bed thickness and resedimentation structures caused by the subaquatic slides, no material difference can be recognized between the crumpled layers and non-influenced platy limestones in the Solnhofen-Eichstätt region. In shallow basins like the Kehlheim Wanne and Painten Wanne, however, the locally limited sliding horizons are characterized by reef detritus (STOP 2 - Hennhüll, STOP 3 - Kapfelberg).

Paleogeography

The deposition of platy limestones took place in "Wannen" (FESEFELDT 1962), that means depressions on the surface of the reef facies. While the underlying bedded limestones (Bankkalke) of the Malm epsilon and zeta 1 laterally interfinger with algal-sponge-reefs ("Restlücken-Stadium" ROLL 1934), the dead reefs are covered disconformably by platy limestones ("Schüssel-Stadium"). These limestones gradually fill up the relief.

No sound answer can be given to the question about the relations between the area of platy limestone deposition and a southern reef-chain respectively a northern and/or eastern mainland because of the total erosion of the Solnhofen beds north of Solnhofen and due to the steep plunge below the Alpine Molasse south of the Danube. While ROLL (1933) is claiming for a north-western and southern mainland, v.FREYBERG (1968) supposes a migration of the Central-German ridge from north to south. He regards the platy limestones as off-shore shelf deposits which are limited by reef barriers towards the open sea (back-reef-position). Hints for a progressive shallowing of the sedimentation area in the north are:

(1) increase of thickness of the Tithonian sediments towards south;
(2) distribution of shales and platy limestones; the dominance of shales in the northern region may indicate shallow water;
(3) predominance of land-derived fauna and flora in the northern and eastern region.

HÖCKEL (1974) postulates near-shore conditions too according to high amounts of kaolinite in the clay fraction.

Nevertheless there are arguments against the assumption of a northern mainland: Paleozoogeographical studies by ZEISS (1968) show that intermarine streets must have been existed between north western Germany and Southern Germany for the migration of ammonites.

In contrast to ENE-ESW directed facies boundaries, postulated by v. FREYBERG (1968), are large-scaled facies changes which indicate a gradual deepening of the sedimentation base from east to west. Thus the platy limestones of the Painten-Kelheim area, characterized by shallow-water detritus, (SEILACHER 1963,, JANICKE 1967, ZEISS 1968) gradually pass on to the Solnhofen platy limestones which may indicate sedimentation below wave-basis;these limestones show transitions to the fine-grained Zementmergel of the Ries area.

Facies

Different facies can be recognized within different "Wannen" filled with plate limestone (see fig. C 13): The "Eichstätter Fazies" is characterized by a small thickness (20-25 m) and by mm- to cm-bedding ("Schiefer"). The "Solnhofener Fazies" has a total thickness between 30 and 60 m, the platy limestones show cm- to dm-bedding. To what extent bed thickness is dependend on the water depth (v.FREYBERG 1968) or only from different subsidence intensities is not yet clear.

According to v.FREYBERG (1968) a distinction can be made between "Bankkalken", "Plattenkalken" and"Schiefern" due to the thickness of the Flinz beds. For facies analysis it seems more effective to separate

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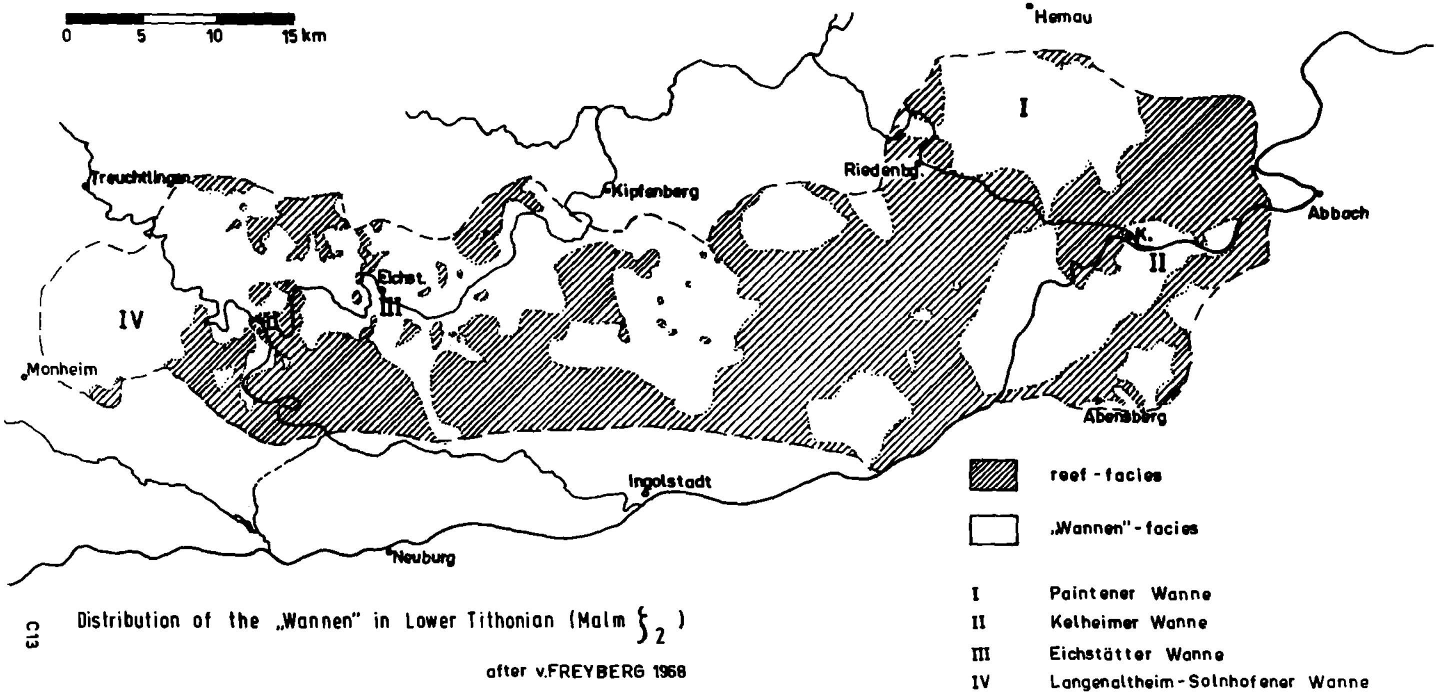
Fig. C 13 Distribution of the "Wannen"- and reef-facies, Southern Frankenalb ;(after v.FREYBERG 1968).



C13

Distribution of the „Wannen" in Lower Tithonian (Malm ζ_2)

after v. FREYBERG 1968

platy limestones (Plattenkalke) with even-layered textures and with frequent micro-bedding ("Latentschichtung" v.FREYBERG) form bedded limestones (Bankkalke) with uneven surface planes without micro-bedding.

In comparison with the Eichstätt area only in the Solnhofen area textural uniform fine-grained limestones are developed which can be used as lithographic stone. Here the limestones (by the quarrymen called "Flinz") are irregularly intercalated with very fine-layered calcareous marls (called "Fäulen" because of its uselessness for the quarry industry). Only small amounts of the platy limestones can be used as lithographic stones. Nevertheless textural and microfacial criteria of the platy limestones corresponds with the definitions of lithographic limstones as given by HADDING (1958).

Macroscopally the platy limestones are dense and evenly surfaced. The colour is white to yellow. Only some stratigraphically deep layers are developed as blue-gray limestones. The colour of these limestones is caused not by pyrite (BARTHEL 1964) but by increased C-content (GÜMBEL 1891, HÜCKEL 1974).

The "Flinze" consists of 97-99% $CaCO_3$, the "Fäulen" show carbonate contents between 80 and 90%. The insoluble residue is made by 25-30% kaolinite, 20-45% illite, about 5-12% montmorillonite, and vestiges of quartz (HÜCKEL 1974). The grain-size of the calcite crystals of the Flinz varies between <1 and 6 microns, most grains have diameters $<$ 4 micron (E.FLÜGEL & H.E.FRANZ 1967).

After GÜMBEL (1889)has already interpreted the Flinz as recrystalizised coccolith mud, FLÜGEL & FRANZ (1967) could recognize coccoliths in Flinz samples from the Maxberg quarry electronmicroscopally. These limestones fit the definition of nanomicrites (NOEL 1967). According to recent investigation by H.KEUPP abundant coccoliths and coccospheres can be found in samples from the "Fäulen" using SEM equipment.

Fauna and Flora

Generally the platy limestones are poor in fossils. The associations are very heterogenous since ecological ghost faunas and floras with marine and terrestrial elements have been found. Terrestrial organisms are represented by less than about 1% of the forms. Detailed fossil lists are given by FRISCHMANN 1853, J.WALTHER 1904, and O. KUHN 1961. Non regarding unique discoveries the following ecological groups can be recognized:

Plancton: coccolithophorids, radiolarias, echinoderms (Saccocoma), scyphozoan and hydrozoan medusae
Pseudoplancton: seaweed with gastropods, lamellibranchs
Necton: ammonites, teuthoideans, belemnites,some crustaceans, fishes, some reptiles
Vagile benthos: foraminifera, ostracods, crustaceans, lamellibranchs, annelids
Terrestrial organisms: land plants, insects, Pterosauria, Archaeopteryx.

Except for "Mesolimulus" and Mecochirus there are hardly any trace fossils in the Solnhofen platy limestone. Even these arthropods are frequently found at the end of the trail. This implies a hostile bottom environment (J.WALTHER 1904, O.ABEL 1922). MONCH (1955) and BARTHEL (1964) postulated a stagnating milieu at the sea bottom; many authors have accepted this theory. Contrary to this interpretation obviously is the abundance of rich benthonic microfauna (GROISS 1967) which seems to be autochthonous.

Within different "Wannen" diversity, frequency and preservation of organisms vary. On the whole, the mega-fauna (mostly on bedding surfaces; Saccocoma, Leptolepis, locally Geocoma, some ammonites) is poor in individuals and rich in the number of species. The wellknown excellent preservation of many fossils seem to be due to the extremely fine-grained sediment, the high rate of deposition (BANTZ 1967, JANICKE 1969) and perhaps to stagnating conditions (BARTHEL 1964, BUISONJE 1972).

Genetic aspects of the Solnhofen limestone

For almost 300 years paleontologists and geologists are in search for a genetical concept of the Solnhofen lithographic limestone. Until now no generally accepted interpretation theory has been found.

Fig. C 14 shows different environmental models proposed for the Solnhofen limestone:

One of the first interpretations was given by BAIER (1730). He explained the distortion of many fish fossils by a violent unnatural death caused by a sudden burst of water- and mud-masses following the deluge.

For the very first time all known fossils were tabulated by FRISCHMANN (1853). By doing this, he got the opinion that the platy limestones are of marine origin, deposited in quite near-shore waters.

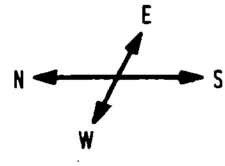
In 1887 Solnhofen was compared with recent lagoons of barrier-reefs by NEUMAYR. He believed in a transport of fine carbonate particles from the land to an extremely shallow basin which had no communities with the open sea. By this mechanism the thin-layered shales should have been formed (fig. C 14, modell I).

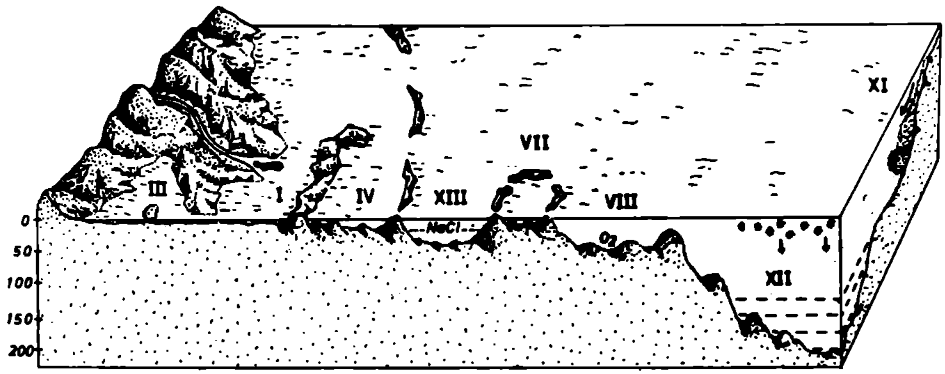
Contrary to this GÜMBEL (1889, 1891) followed FRISCHMANN claiming a normal-marine environments of deposition. The sedimentation took place in quiet bays bordered by reefs; coccolith detritus is of main importance. Due to a misinterpretation of "Mesolimulus" a short dessication is considered as possible (fig. 2, modell IV).

Beginning with J. WALTHER (1904) a new period of Solnhofen research started. He recognized the differences in facies and fossil content between different areas. Considering that most fossils are found on bed surfaces, insects generally show good preservation, and the "Fäulen" contain relatively much detritus, WALTHER developed the model of permanent alterations with overflowing (Flinz) and drying-up together with an aeolian transport of terrigenous dust (Fäule).

Fig. C 14 Different models of the Solnhofen environment.

Different models of the
Solnhofen environment

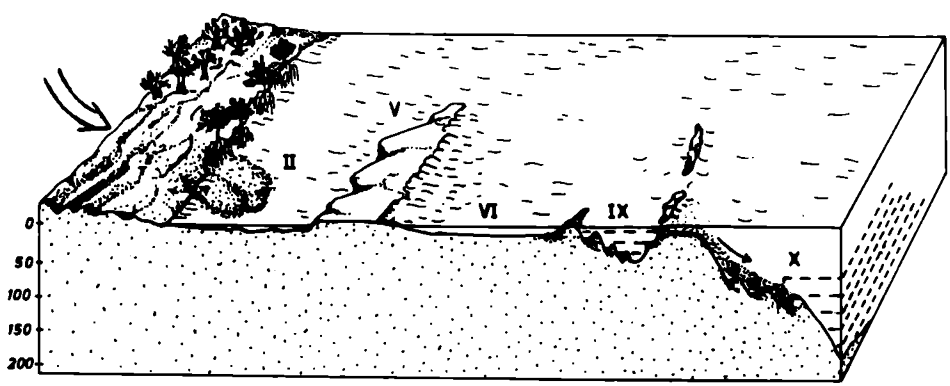




I NEUMAYR 1887 VII BARTHEL 1964 XII BUISONJE 1972

III SCHWERTSCHLAGER 1919 VIII GROISS 1967, BANTZ 1969 XIII JORDAN 1974

IV GÜMBEL 1891, v.FREYBERG '68 XI GOLDRING & SEILACHER 1971 phytoplankton



II WALTHER 1904, ABEL 1922 VI FESEFELDT 1962 X v. STRAATEN 1971

V WILFARTH 1937 IX BARTHEL 1970 H_2S-water

H. Keupp 1975

According to this model the platy limestones would have been formed in a lagoon which silted up during a regression period. Only larger floods were able to get over the reef barries. These floods brought organisms and calcareous mud to the hostile area. During dry periods tropical rains caused the freshening of water. In this way calcite cements could conservate fragile fossil structures like insects.

After ROTHPLETZ (1909) had tried to prove the aeolic origin of the "Flinz" by a calculating the amount of sediment, and SCHWERTSCHLAGER (1919) had introduced the comparison with tidal flats (see fig. C 14, model III), ABEL (1922) summarized the modified dune-theory. According to him, from nearby dunes, fine particles were blown out by lee-side winds.The cementation of the eolian Flinz is explained by freshwater-cementation (fig. C 14, model II).

M.WILFARTH (1937) rejected eolian origin as well as the interpretation as tidal flats. He postulated "Großgezeiten", which washed in mud and organisms from erosion areas between the open sea and the deposition area of the platy limestones (fig. C 14, model V).

CASTER (1940) weakened the main arguments for an extremely shallow water environments. He proves, that the supposed vertebrate tracks (OPPEL 1862, FIGUIER 1866, ABEL 1911, NOPCSA 1923) can be explained as "Mesolimulus" trails.

According to HADDING (1958) the Solnhofen limestones can be explained like other lithographic limestones as lagoonal deposits of the litoral zone. The carbonate mud is formed biochemically by algae and bacteria.

In connection with geological mapping of the southern Frankenalb by B.v.FREYBERG and his co-workers , FE-SEFELDT (1962) recognized that the platy limestones have been deposited within depressions in the reef surface area (="Wannen"). Calm, marine shallow-water is postulated for the Solnhofen region. Drying-up in some places seems possible (see fig. C 14, model VI).

In 1968 v.FREYBERG summarized the results of geological mapping in different parts of the southern Frankanalb. He still believes in an sporadic drying-up (see MAYR 1967) caused by the irregularly migration of the Central-German ridge towards south.

Many publications about the genesis of the platy limestones are offered at present:

BARTHEL (1964) developes the model of very shallow atoll-lagoons with stagnating conditions (fig. C 14, model VII). In later publications he argues strongly against dessication regarding the results of fossilisation experiments (BARTHEL 1966, 1970, 1972); a water depth of about 30-60 m is postulated. This theory has been supported by JANICKE (1969), HÖCKEL (1974), and other authors but there are important arguments against this model:

Regarding the rich autochthonous micro-fauna GROISS (1967) believes, that the lack of mega-fauna is caused not by euxinic conditions but rather by a soft substrate. Similar to BARTHEL a constant water regime is postulated. According to GROISS water depths was about 50 m (see fig. C 14, model VIII), according to ZEISS (1968) the distribution of ammonites would indicate water depths of about more than 30 m.

BANTZ (1969) also argues for a deeper, normal marin environment because of the relief of the "Wannen"; the Flinz should represent a phase of quick sedimentation whereas the Fäulen represent low sedimentation rates.

JANICKE (1969) recognized some structures formerly interpreted as decission cracks as synaeresis structures.

JORDAN (1974) has again discussed the stagnating conditions postulated by BARTHEL (1964) but he believes in different salinity layers of the water caused by leaching of salt-bearing rocks (fig. C 14, model XIII).

GOLDRING & SEILACHER (1971) using the "Mesolimulus" trails transfer the turbidity-theory, established by TEMMLER (1964),for platy limestones near Nusplingen/Württemberg to the Solnhofen environment (fig. C 14, model XI). In 1971 van STRAATEN modified this turbidity-model postulating that storms had stirred up the water of the shallow shelf sea and suspension was pushed above the margins of the "Wannen". Owing to gravitation this suspension was deposited as turbidity current of mostly rather low density and small velosity (fig. C 14, model X). The lack of benthos within the Fäule is explained by low O_2-content caused by only weak circulations with water of the open Tethys. Water depths about 100 m are postulated (see fig. C 14, model X).

The last model has been offered by BUISONJE (1972): Periodical fluctuations of coccolithophorids may have resulted in carbonate sedimentation and continuous stagnating conditions near the bottom. Red tides lead to poisoning of water (fig. C 14. model XII).

3. Algae and Algal Products (E. FLÜGEL)

Algal products have been supposed by many authors for micrite crusts and pellets of Upper Jurassic Sponge-reefs. Stereoscan electronmicroscope studies (BEHR & BEHR, in press) show, that some reefs are constructed quantitatively by cyanophycean algae (Rivulariaceae, Oscillatoriaceae) - see STOP 7b of the excursion. Further studies will deal with micro- and ultrafacies of "stromatolihtic" crusts and of "oncoids", and other micrite components of the reef facies.

Benthic calcareous algae have been described from the Franconian Upper Jurassic by GÜMBEL (1873, 1891), PIA (1924), SCHAIRER (1968), BARTHEL (1969), SCHAIRER & LUPU (1969), BERNIER (1971), JANICKE (1971), and FISCHER & THIERRY (1971). The Middle Tithonian flora, found in spongiomorphid-coral-reefs, corresponds with associations known from the Tethyan region.

Table 1 shows the distribution of calcareous algae according to the authors mentioned above and according to own studies of allochthonous associations from the Lower Tithonian of the Southern Frankenalb.

Oxfordian	Kimmeridgian	Lower Tithonian	Middle Tithonian	
			x	Gymnocodium sp.
			x	Permocalculus leptothallus BARTHEL
		x		Solenopora sp.
		x		Marinella lugeoni PFENDER
			x	Acicularia elongata CAROZZI
			x	Actinoporella podolica (ALTH)
			x	Clypeina catinula CAROZZI
		x		Clypeina jurassica (FAURE)
			x	Clypeina parvula CAROZZI
			x	Cylindroporella arabica ELLIOTT
x				Conodictyum striatum MONSTER)
		x	x	Likanella bartheli BERNIER
			x	Munieria sp.
		x	x	Salpingoporella annulata CAROZZI
		x		Salpingoporella pygmaea (GÜMBEL)
			x	Uragiella suprajurassica (GÜMBEL)
		x		Cayeuxia anae DRAGASTAN
		x		Cayeuxia kurdistanensis ELLIOTT
		x		Cayeuxia moldavica FROLLO
		x		Cayeuxia piae FROLLO
		x		Lithocodium aggregatum ELLIOTT
		x	x	Lithocodium morikawai ENDO
		x	x	Consinocodium japonicum ENDO
		x	x	Thaumatoporellavpar ovesiculifera(RAINERI)
		x	x	Baccinella
			x	Prochara cf. maxima(DONZE)
			x	Clavator cf. reidi GROVES

Table 1.: Calcareous algae in Upper Jurassic limestones of the Frankenalb.

4. Appendix - The R i e s - Story (J.-Th. GROISS)

Topography: The R i e s, which name comes from the Roman Raetia, is nearly a circular basin (diameter 21-24 km), marking the border between the Swabian adn Franconian Alb. The marginal hills lift up to about 150 m above the basin floor.

The origin of the Ries in general is now considered as sure: in the late Tertiary, in the period between the Tortonian (=Badenian) and Sarmatian the Ries basin was formed by an impact of a meteorite.

Evidences of the impact theory

- circular structure of the basin
- high-pressure minerals (coesite, stishovite)
- crushing of the rocks in place, down to a depth of about 1000 m
- overthrusting on the margin of the basin and ejected material ("Bunte Bresche")
- dissolution of rocks ("Suevit").
- the energetic problems con only be explained by a meteoritic impact
- the hole of the impact is wide (21-24 km) but not deep (about 300-400m)
- slight thickness of the rocks in place.

If it had been an iron meteroite, the caldera would have had a Ø of approximately 300-600 m only. The flight patch was flat, coming from NE (Moldavites of CSSR), the high velosity was not reduced by the atmosphere. During touching the ground, shock waves modified quartz into high-pressure minerals coesite and stishovite. The meteroite itself became completely evaporated. Parts of the original rocks in place became dissolutes ("Suevit") and the great mass of material was crushed and dislocated ("Bunte Bresche"). Grain sizes of the ejected material extend from millimeter up to kilometer (surface slides).

The Lake

After the impact the basin was filled up with water to a freshwater lake. In the basin lacustrine clay was deposited (more than 300 m). On the lake shore and on small elevations in the basin (mostly allochthonous blocks of the basement (over 10 m), lacustrine limestone grew up biogenetically.

The general vertical zonation of the fresh water limestones:

- limestone, mostly compact (up to 1 m)
- conglomerate, built up by components of the basement (diameter from mm up to dm; thickness of the conglomerat up to some meters)
- compact limestone, in most cases poor fauna (Cypris Hydrobia) (some decimeter)
- algal limestone constructed by cone-shaped algal structures which look like turnips. Hight of the algal cones less than 1 m
- belt with small algal cones (10 - 15 m) (very good exposed in Hainsfarth)
- compact limestone (in some places Hydrobia or Cypris abundant; some dm only)
- big algal-cone reefs (diameter and hight of about some meters); interspaces between the reef bodies are filled up with layers made by Hydrobia or Cypris; Cepaea in some localities frequent
- thin limestone belt (50 cm)
- algal cones (hight up to 50 cm)
- basement

F a u n a

The fauna is very rich in individuals but extremely poor in species:

- Cypris risgoviensis SIEB: abundant, rock-forming, mostly in interspaces between the reef bodies
- Hydrobia trochulus SANDBERGER: abundant, rock-forming, mostly in interspaces between reef-bodies
- Cepaea sylvestrina (SCHLOTHEIM (land snail): infloated, in some localities very rich, sometimes colours can be seen.
- Bones of mammalia, even bird bones, feathers and complete layings.
- Tortoise, one species only.

F l o r a

- Algae, rock-forming
- fragments of wood, branches, most encrusted (probably carried by water).

Older theories and hypotheses on the origin of the Ries

Volcanism: SCHNITZLEIN & FRICKHINGER 1848; FRAAS 1877;
glacial origin: DEFFNER & FRAAS 1857; KOKEN 1894;
volcanism and explosion of vapour: BRANCE & FRAAS 1900; KRANZ 1912;
tectonic(in connection with nappe tectonics): REGELMANN 1911; SEEMANN 1937;
impact of a meteorite: WERNER 1904; STUTZER 1936; CHAO, SHOEMAKER & MADSEN 1960.

Remarks on the Algal Flora (E.FLOGEL)

According to REIS (1926) most of the algae belong to Cladophorites. - Thin-sections show the following microfacies types:

a) inhomogenous biomicrite with abundant ostracods (Cypris),with high interparticle porosity.

b) layered algal-micrite, consisting of micrite and recrystallizised zones, up to 1 mm. 10-15 laminations can be recognized within one layer

c) zoned algal-biolithite, composed by vertical orientated, tangled tufts of Cladophorites.

Conclusions

The extreme poor fauna (except some localities which must be considered as the debouchures of creeks) indicates a very anormal biotop.Fishes, pelecypods and other fresh-water animals are lacking;therefore we must assume that just for limnic animals there were unfavourable conditions, probalby caused by beginning hypersalinity.

5. Excursion - Route

See figs. C 1 - C 4 and C 9!

Bus drive Erlangen - Nürnberg - Altdorf - Neumarkt - Velburg.

From Erlangen the excursion is passing the Nürnberg Keuper basin with sandstones and varigated clays and argillaceous marls. During the Pleistocene sanddunes developed,today mostly covered by pine-wood.

Near Altdorf Liassic dark clays, clay marls and some limestones are forming the plateau of the Alb foreland. Following the low-dipping beds we reach the Dogger near Gnadenberg.

Near Neumarkt the ascent on the Alb begins within Dogger sandstones, followed by a peneplain with oolithic limestones and clays of Bajocian to Callovian age. This again is followed by marls, white limestones and dolomites of the Malm. Here the development of sponge reefs started already during the lower Oxfordian.

At the right side of the high way small dolomitizised reef embryos within the Schichtfazies can be seen (fig. C 10).

From the Albplateau the "Kuppenalb" formed by irregularly shaped dolomite hills with soft slopes are clearly recognizable.

STOP 1 (fig. C 11)

Locality: Hohllochberg near Velburg,
Top.sheet 6736 Velburg, R 4477 500, H 5456 000.

Stratigraphy: Middle Kimmeridgian (Malm delta).

Facies: "Frankendolomit", dolomitizised "Großkuppel-Riff" (large dome-shaped sponge-reef).

The small Oxfordian reef embryos develop up to the Middle Kimmeridgian to "Großkuppelriffen" with considerable horizontal and vertical extension.

The dome-shaped reef structure has a Ø of more than 500 m. The relief is characterized by slopes of 5-7^{o} and up to 20^{o} in the northwestern part, and 35^{o} in south-west. Differences within the relief can reach about 60 m.

The topography of the Hohllochberg itself and of the other dolomite hills near Velburg corresponds with the original forms of the reefs. The sediments deposited originally between the reef were eroded. Today karst depressions can be seen.

Now the excursion is directed to southeast following the Parsberg - Kelheim reef chain which is developed beginning with the lower Oxfordian. South of Willenhofen we leave the "Kuppenalb" and reach the Tertiary peneplain of the Südalb with the "Wannen"facies of the Tithonian. Near Höfen we are in front of the margin of the "Paintener Wanne" (see fig. C 13).

STOP 2

Locality: Hennhüll, Harteis quarry,
Top.sheet Hemau, R 4484 300, H 5431 450.
Stratigraphy: lower part of Lower Tithonian (Malm zeta 1).
Facies: Platy limestones with "Krumme Lage".

Due to the vicinity of small coral reefs (about 500 m in the north), which were formed upon large sponge-reef-complexes, these limestones show different textures in comparison with the lithographic platy limestones of Solnhofen. The fine-grained micrite limestones have a relatively high amount of reef detritus.

Shallow medium- to high-energy environment is indicated by variation of thickness of single beds, unconformity structures,and lumachelles with crinoids, echinoids, lamellibranchs, and algal nodules. Graded bedding structures may be caused by turbidity currents which transported detritus from adjacent coral reef.

Submarine slumping and sliding is represented by the "Krumme Lage" which contains grain-supported oncoids, hydrozoan colonies, and other fossils.

Oscillation ripple marks (distance of the crests 5 mm, heigh up to 0,5 mm) are rare. South of Hennhüll near Painten current ripple marks have been found which indicate east-west directed currents. Ammonite roll marks show southeast-northwest directions parallel to the reef margin. Infauna trace fossils and resting traces of arthropods can seldom be found.

Polygonal patterns on bedding planes are due to syneresis cracks (JONGST 1934).

Microfacies of the "Krumme Lage" is characterized by medium- to coarse-grained calcerenites (biomicrites) with fragments of corals (*Microsolenia*, *Thamnasteria*),hydrozoans, echinoderms, mollusk shells, and many thalli of *Cayeuxia* *C.moldovica* FROLLO and other species.

Thin-section of detrital limestones show biosparites with many partly circumcrusted colonies of Cayeuxia and Marinella together with circumcrusted gastropods, lamellibranch fragments, echinoderms, and some hydrozoans. Large globular hydrozoan colonies belong to Ptychochaetetes globosus KOECHLIN ,and Actinostromaria sp.

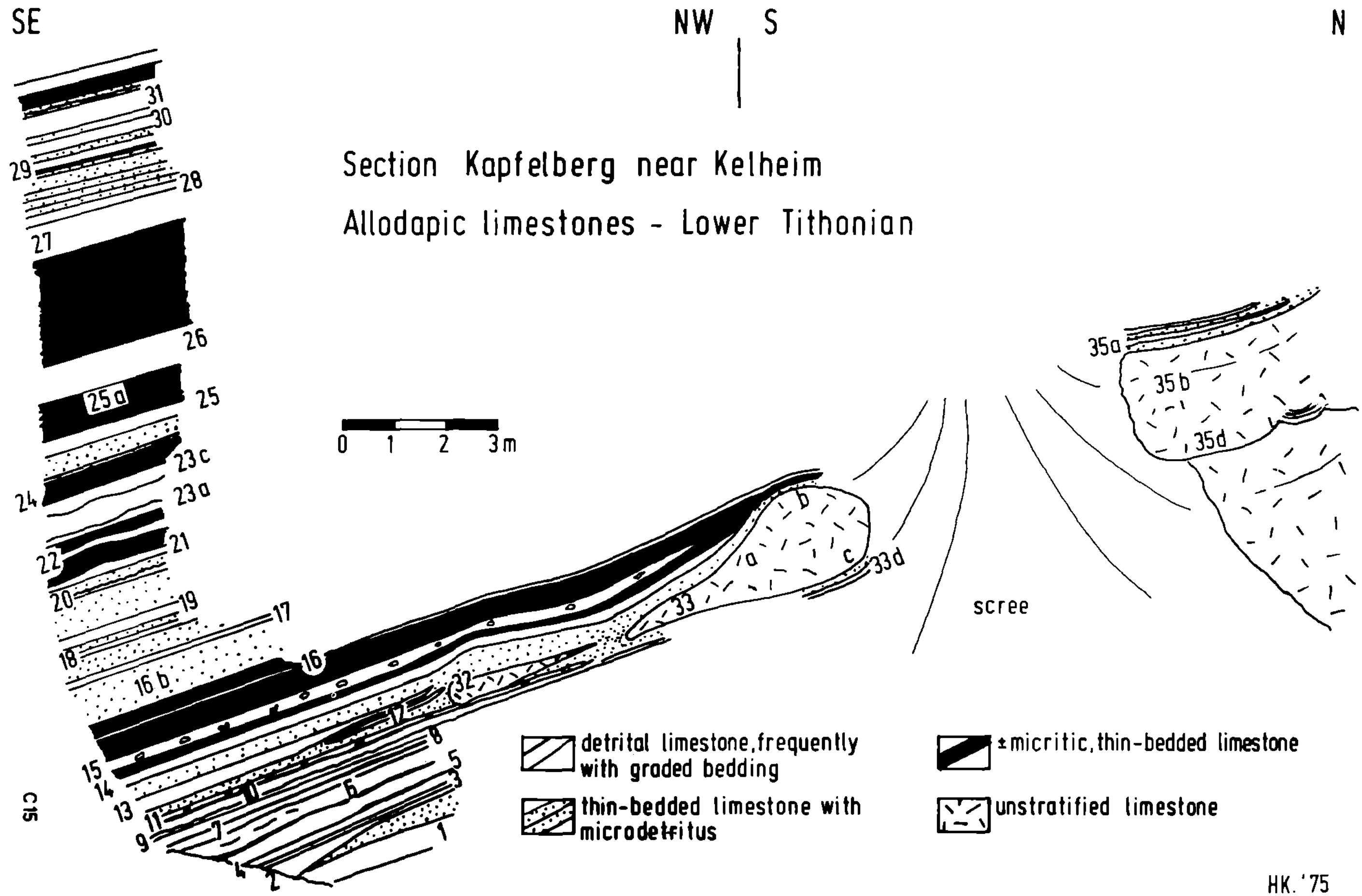
The excursion proceeds in direction to Kelheim. The "Paintener Wanne" goes up to Walddorf. In the wooded area , however, the platy limestones are covered by Cretaceous and Tertiary deposits. In the narrow valley, following Ihrlerstein, we pass a reef-chain and reach the "Kelheimer Wanne" which has been excavated by the Danube river. At the right we see the "Befreiungshalle" (memorial for the end of the Napoleonic wars), built on the western reef margin of the "Kelheimer Wanne".

STOP 3 (figs. C 15, C 16, C 17)

Locality:	Western Wall of the Quarry Kapfelberg, SW Kapfelberg Top.sheet 7037 Kelheim, R 4498 100, H 5420 800.
Stratigraphy:	lower part of Lower Tithonian (Malm zeta 2).
Facies:	Allodapic detrital limestones within platy limestones; small coral patch reefs.

The outcrop is situated at the northeastern boundary of the "Kelheimer Wanne" close to the reef margin. The section shows 20 m lower Tithonian micrite limestones with intercalated beds with reef-derived biodetritus, and about 12 m upper Cenoman Regenburger Grünsandstein. Most of the Upper Jurassic sediments are allochthonous; this is proved by frequent gradding bedding str-uctures, low sorting of bioclastic components and by the nearly complete lack of infauna. Within coarse detrital layers brachiopods, lamellibranchs, gastropods, and some ammonites can be found. Land-derived plants have been described by R.MEYER (1974).
Many detrital layers are composed by overturned thalli of Cayeuxia, Marinella, and (mainly in the upper part of the section) some dasyclads (Salpingoporella). A first investigation of the microfacies was made by SCHAIRER & LUPU (1969). According to new studies by E.FLÜGEL. besides many lituolid foraminifera the following algae can be recognized in thin-sections:

Fig. C 15 Kapfelberg section near Kelheim, Lower Tithonian. Allodapic limestones within platy limestones; small patch reefs (nos. 33 and 35). STOP 3.



SE
NW
S
N
Section Kapfelberg near Kelheim
Allodapic limestones - Lower Tithonian
0 1 2 3m
31
30
29
28
27
26
25a
25
23c
23a
24
22
21
20
19
17
18
16
16b
15
14
13
11
9
10
7
6
8
5
3
1
4
2
17
32
33
a
b
c
33d
35a
35b
35d
scree
detrital limestone, frequently with graded bedding
thin-bedded limestone with microdetritus
± micritic, thin-bedded limestone
unstratified limestone
HK. '75

C15

Cayeuxia anae DRAGASTAN
Cayeuxia kurdistanensis ELLIOTT
Cayeuxia moldavica FROLLO
Cayeuxia piae FROLLO
Marinella lugeoni PFENDER
Solenopora sp.
Actinoporella sp.
Clypeina jurassica (FAVRE)
Salingopora annulata CAROZZI
Salingoporella pygmaea (GÜMBEL)
Baccinella sp.
Consinocodium japonicum ENDO
Lithocodium aggregatum ELLIOTT
Lithocodium morakawai ENDO
Thaumatoporella parvovesiculifera (RAINERI)

Two small patch reefs (33 and 35, fig. C 15) show abundant Lithocodium together with Baccinella, encrusting hydrozoans (Burgundia cf. trinochii MUNIER-CHALMAS), corals, and globular hydrozoans (Baueina multitabulata) (DENINGER).

Fig C 16 shows the differences in the composition of patch reefs and allodapic limestones (turbidites).

Lit.: R.MEYER (1974); RUTTE (1962); SCHAIRER & LUPU (1969).

Fig. C 16 Microfacies, fauna and flora of the allodapic Tithonian limestones and of the patch reefs, Kapfelberg near Kelheim. Matrix: I. micrite, II sparite, a- pellets + oncoids, b- ooids, c- foraminifera, d- corals + hydrozoans, e- shells (brachiopods + lamellibranchs) f- gastropods, g- serpulids, h- echinoderms. A: Cayeuxia, B: Lithocodium, C: Solenopora + Marinella + Thaumatoporella, D: Salpingoporella, E: Clypeina + Actinoporella, F: Organisme multicellulaire, G: Baccinella.

beds	Matrix		Allochems		Fauna						Flora						
											Codiac.		Reda.	Dasyclads		Problem.	
	I	II	a	b	c	d	e	f	g	h	A	B	C	D	E	F	G
35a		x	x		x		x			x	x	x	x				
31		x	x		x		x	x	x				x	xx			
30		x	x		x		x	x					x	x			x
29	x	x	x		xx				x				x				
28 ↓		x	xx		x		x	x	x				xx	xx			
27	x						x										
26	x				x		x										
25 ↓	x			x			xx	x		x			x			x	
24	x				x		x										
23c ↓	x	x	x	x	x		xx			x	x					x	
23a ↓	x						xx	x								xx	
22 ↓	(x)	x	x		x	(x)	x	x		x	x		x			x	x
21 ↓		x	x		x		x	x		xx	x						
20 ↓	x	x	x	xx			x	x	x	x	xx		x				
19 ↓	x	x	(x)	xx	x		x		xx	x	xx						
18 ↓		x		xx					x		xx						
17 ↓		x	x		x		x				xx						
16b	x												x				
16 ↓		x	x				x			x	xx						
15 ↓		x	x				x	x		x	x						
14 ↓		x	x	x		x				x	x		x		x		
13 ↓		x	x	x		x	x	x		x	xx		x				
12 ↓		x	x	x			x	x		x	xx				x		
11 ↓		x	x	x	x		x			x	xx						
10 ↓		x	x	x			x				x						
9 ↓		x	xx		x		x	x		x	xx		x				
8 ↓		x	x	x	x		x				xx						
7 ↓		x	x		x		x				xx						
6 ↓		x	x	x	x		x	x			xx						
5 ↓		x	x					x	x		xx		x				
4 ↓		x	x								xx						
3 ↓		x	x								xx			x	x		x
2		x	x	x		x					xx			x	x		x
1 ↓		x	x		x							x					
	Unstratified facies																
35b	x		x			x	x			x	x		x				
35d	x		x		x	x	x			x	x			x			
33	x				x	x		x	x	x		x					
33a	x		x		x	xx	x	x	x	x		x	x				x
33b	x		x		x		x		x		x	x		x			
33c	x					x		x		x							
32	x	x	x	x	x		x	x		x	x	x	x	x			
32u	x		x	x	x	x	x		x		x	x			x	C18	x

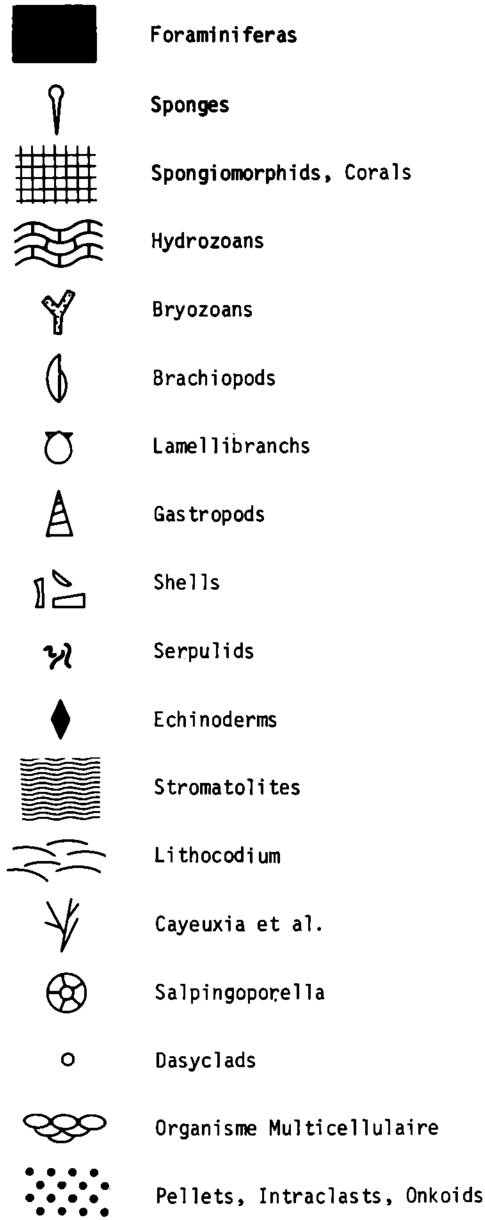
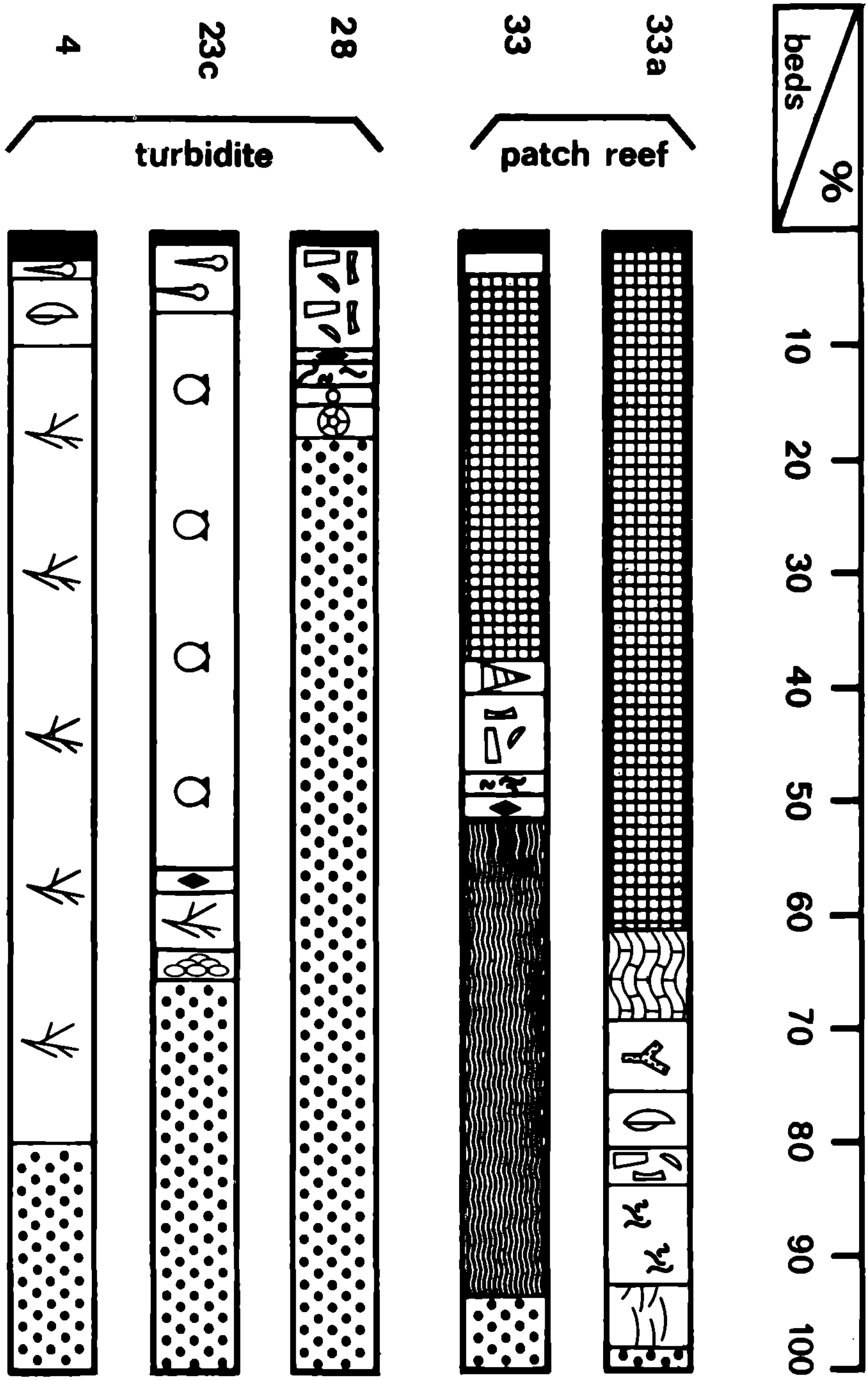


Fig. C 17 Kapfelberg, Lower Tithonian, Quantitative composition of allodapic limestones (4, 23c, 28) and patch reefs (33, 33a) according to point-counter analysis.



4
23c
28
33
33a
beds
%
turbidite
patch reef
10
20
30
40
50
60
70
80
90
100

STOP 4 a

Locality: Quarry Saal, Top.sheet 7137 Abensberg, R 44 95500, H 54 16500.
Stratigraphy: Upper Kimmeridgian (Malm epsilon).
Facies: Margin of spongiomorphid-coral-reefs at the southern boundary of the "Kelheimer Wanne".

Between large coral colonies growing on reef detritus , we find a brachiopod fauna rich in individuals, in other areas algal-circumcrusted gastropods. Rarely graded oobiosparites can be seen.

The microfacies is charaterized by pelsparites with micrite pellets, stromatolithic pellets (cf. Tubiphytes MASLOV), encrusted shells, foraminifera and some mollusk fragments. In some places biocalcarenites (biopelsparites) can be seen, dominated by brachiopods and/or corals, together with echinoderms, lamellibranchs, bryozoans, and many micrite pellets. Oobiosparites are rare. Biogene encrusting and borings are abundant.
Lit.: SCHLOSSER (1881)

STOP 4 b

Locality: Approach to the "Befreiungshalle" W Kelheim. Top.sheet 7037 Kelheim, R 4489 600, H 5420 300.
Stratigraphy: Upper Kimmeridgian (Malm epsilon).
Facies: Reef-detritus limestones and spongiomorphid-coral reefs.

Detrital reef limestones (dip 30^{O}N) consists of coarse bioclasts and autochthonous coral colonies. An abundant fauna with thick-walled lamellibranchs (Diceras, Ostrea, Lima), gastropods (Nerinea), and brachiopods has been found (SCHLOSSER & BÖHM 1881). Echinoderm detritus is quite common. Besides hydrozoans and calcareous sponges there are some siliceous sponges too. The matrix mainly consists of pelmicrite, sometimes of sparite. Ooids are present.

Micritic reef limestone with fine-detritus is exposed in the turn of the road. The frame-work of the reef is built up by spongiomorphids and tabular microsolenid corals, sometimes together with stromatolithic algal crusts (see STOP 5).

When leaving the locality the reef detritus area around the spongiomorphid-coral reefs can be seen at the opposite side of the valley.

STOP 5

Locality: Teich quarry (Oberau) near Esslingen.
Top.sheet 7036 Riedenburg, R 4487 700, H 5421 000.

Stratigraphy: Upper Kimmeridgian to the lower part of Lower Tithonian (Malm epsilon to Malm zeta 1).

Facies: Spongiomorphid-coral-reef.

Large sawn quarry walls give the opportunity to see the central reef area with spongiomorphids, corals and siliceous sponges in pelmicrite matrix.

Quantitative tabulation (BAUSCH & ZEISS 1966) yields the following results: Matrix (and fine detritus) - 73-85%, Spongiomorphids and microsolenid corals as main reef-building organisms, sometimes with algal crusts - 14-25%, other corals up to 1%, crinoids- up to 1%, siliceous sponges - 1% or more; rarely brachippods and gastropods.

Microfacies: Biopelmicrites with thamanasteriod and microsolenid corals, spongiomorphid hydrozoans and siliceous sponges, all characterized by tabular growth forms. Reef-building organisms show borings and sometimes pelleted micrite crusts caused by algae. Low water energy is indicated by winnowed biopelmicrites yielding micrite pellets and oncoids together with some foraminifera and echinoderm fragments.

Lit.: BAUSCH & ZEISS (1966)

The excursion continues upstream the Altmühl river. On both sides of the valley steep rocky cliffs made, by spongiomorphid-coral-reef limestone, (e.g. Neu-Essing) Upper Kimmeridgian to Lower Tithonian age can be seen.

Beginning at Riedenburg we are again concerned with the dolomitizised Middle to Upper Kimmeridgian sponge reefs. North of the Flügelsberg the reef facies is replaced by thick-bedded biostrom dolomites at the base of the "Dietfurter Wanne". From Kinding to Pfahldorf we are passing the sponge-reef dolomite zone of Kipfenberg (see fig. C 9), followed by the "Wannen" around Eichstätt (see fig. C 13).

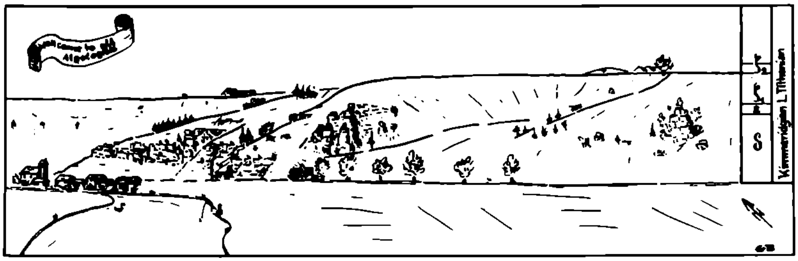


Fig. C 18 Obereichstätt, geological sketch. STOP 6 a.

STOP 6 a

Locality: Obereichstätt
Top.sheet Dollnstein, R 4437 000, H 5418 000

Geology of the "Obereichstätter Wanne": STOP 6 is situated right in the center of the "Obereichstätter Wanne". The basement of the "Wanne" can be seen at the northern slope of the valley. Above the top of thick-bedded limestones ("Treuchtlinger Marnor", Malm delta) follow biostrom-dolomites (Upper Malm delta) exposed in rock cliffs. Than the relief degrees (Malm epsilon and zets 1). A planation plain with trees indicates the top of Malm zeta 1.

Than an ascent is notable caused by the harder rocks of Malm zeta 2 a. With the white spoil areas of the lithographic Solnhofen platy limestones (Malm zeta 2 b) the profile has its end.

STOP 6 b

Locality: Old quarry Obereichstätt, Schöpfel company.
Top.sheet 7132 Dollnstein, R 4437 000, H 5418 000.
Stratigraphy: "Trecuhtlinger Maronr" (Kimmeridgian, Malm delta).
Facies: Well-bedded sponge biostromes.

The section is built up by relatively thicklimestone layers of algal-sponge facies, sometimes intercaltated with marls. These marls can be found in the same position over a distance of 70 km. The strikingly uniform sequence is widely distributed in the southern Frankenalb (SCHMIDT-KALER 1962, ZEISS 1964). The biofacies has been studied by BANTZ (1969).
Lit.: BANTZ(1969);

The excursion continues towards the reef chain of Dollnstein (white reef limestones, Malm delta to zeta).

STOP 7 a

Locality: Altmühl valley, road between Dollnstein and Solnhofen, near the railway tunnel east of Esslingen.
Top.sheet 7132 Dollnstein, R 4429 100, H 5417 000
Stratigraphy: Kimmeridgian, Malm delta.
Facies: Algal-sponge bioherm

The locality is of interest because of well developed algal crusts upon saucer-shaped siliceous sponges.

STOP 7 b (K.BEHR)

Locality: 12-Apostelfelsen, Altmühl-valley,
Top.sheet 7132 Dollnstein, H 5417 700, R 4428 100
Stratigraphy: Kimmeridgian, Malm delta
Facies: Algal-sponge-bioherms, built by abundant Rivulariaceae.

At present this locality is studied by K.BEHR. In an outcrop of approximately 1 km the reef facies is exposed as conspicious erosion-cliffs called "Rocks of Twelfe Apostles".

Contrary to STOP 1 the intergrown dome-shaped reef-structures are very flat.

Main reef-building organisms are blue-green-algae together with lithistid and hexactinellid sponges with saucer- and cup-shaped forms. According to submicroscopic investigations Rivulariacean blue-algae are of predominant importance for the construction of these small bioherms. Macroscopally these algae can be seen only as dark mm-thin crusts; thin-sections show micrite pellets and "oncoids" which in fact correspond to agglomerations of Rivulariacean colonies (see lecture by BEHR & BEHR, Symposium).

STOP 8 a

Locality: Horstberg near Mörnsheim,
Top.sheet Monheim, r 26480, h 15280
Stratigraphy: Lower Tithonian, Malm zeta 2b and Malm zeta 3.
Facies: Solnhofen platy limestones; "Krumme Lage".

The quarry is situated within the "Solnhofener Wanne" (see fig. C 13). The following section can be seen: 11 m platy limestones (Malm zeta 2b), 6 m slumping horizon of the "Hangende Krumme Lage", the top of which is the stratigraphical boundary to Malm zeta 3. Above this follows 16 m siliceous bedded limestones with uneven bedding-planes (Malm zeta 3 = Mörnsheimer Schichten).

STOP 8 b

Locality: Oberer Maxberg near Solnhofen. Quarry of the Solnhofener Aktienverein.
Top.sheet Dollnstein, r 27250, h 16700

Stratigraphy: Malm zeta 2 b

Facies: Lithographic Solnhofen platy limestones.

The quarry exposes a monotonous sequence of micrite limestone beds (= Flinz) and irregularly intercalated calcareous marls (= Fäule). Here this stratigraphic unit reaches its max. thickness of about 50 m. From here the thickness decreases quickly, causing correlation difficulties.
Lit.: see chapter C 2.2

STOP 9 (fig. C 19)

Locality: Quarry Bonhof NE Treuchtlingen,
Top.sheet 7130 Treuchtlingen, R 4423 900, H 5426 900

Stratigraphy: Kimmeridgian, Malm delta.

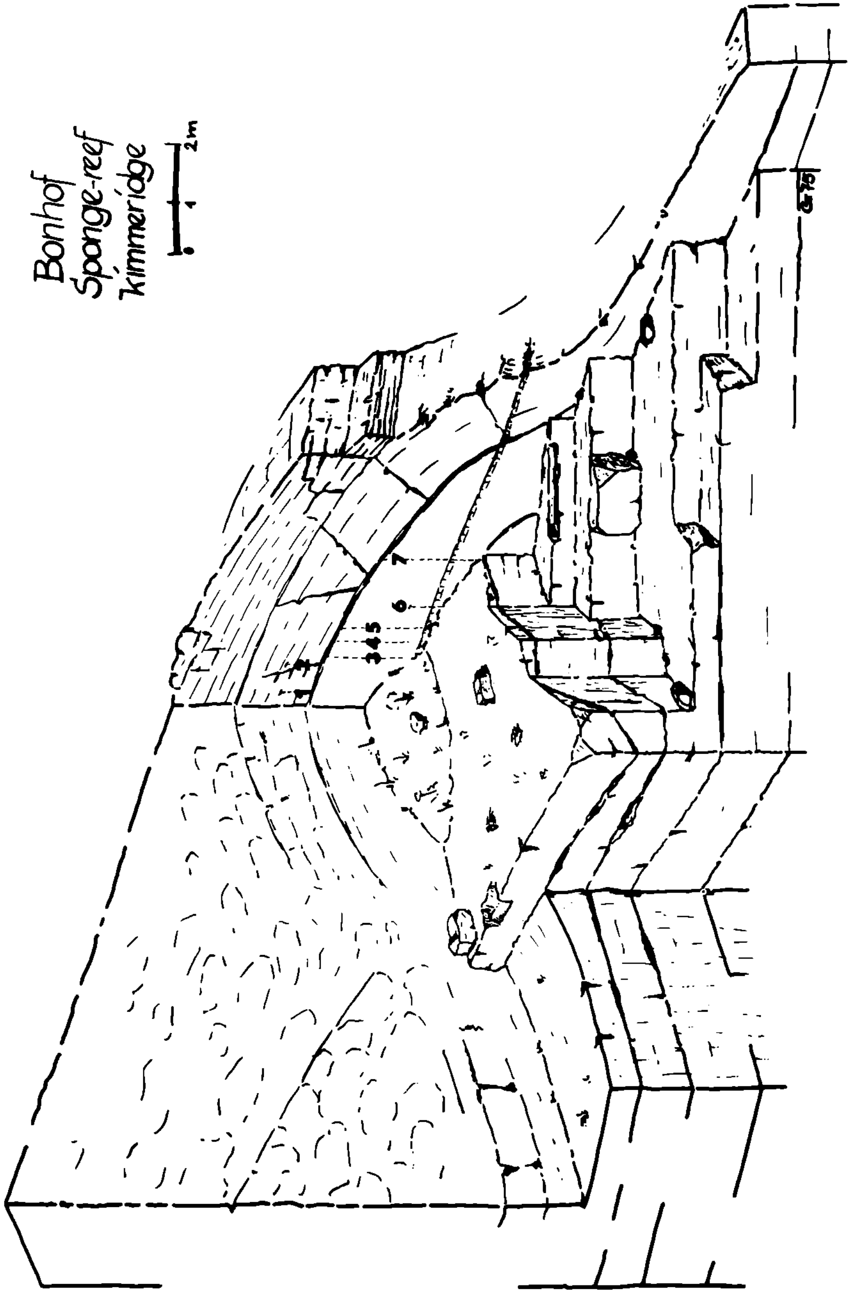
Facies: Algal-sponge-bioherm.

This bioherm is characterized by very dense sponge sequences. On a joint plane siliceous sponges are weathered quite clearly. Tabulation in different part of the reef show differences in the density of sponge generations. Within the centre of the bioherm up to saucer-shaped sponges in one m can be recognized.

Fig. C19ashows the distribution of sponge generations in different parts of the reef. Sponges are acting as sediment-trapping agents within mud mounds.

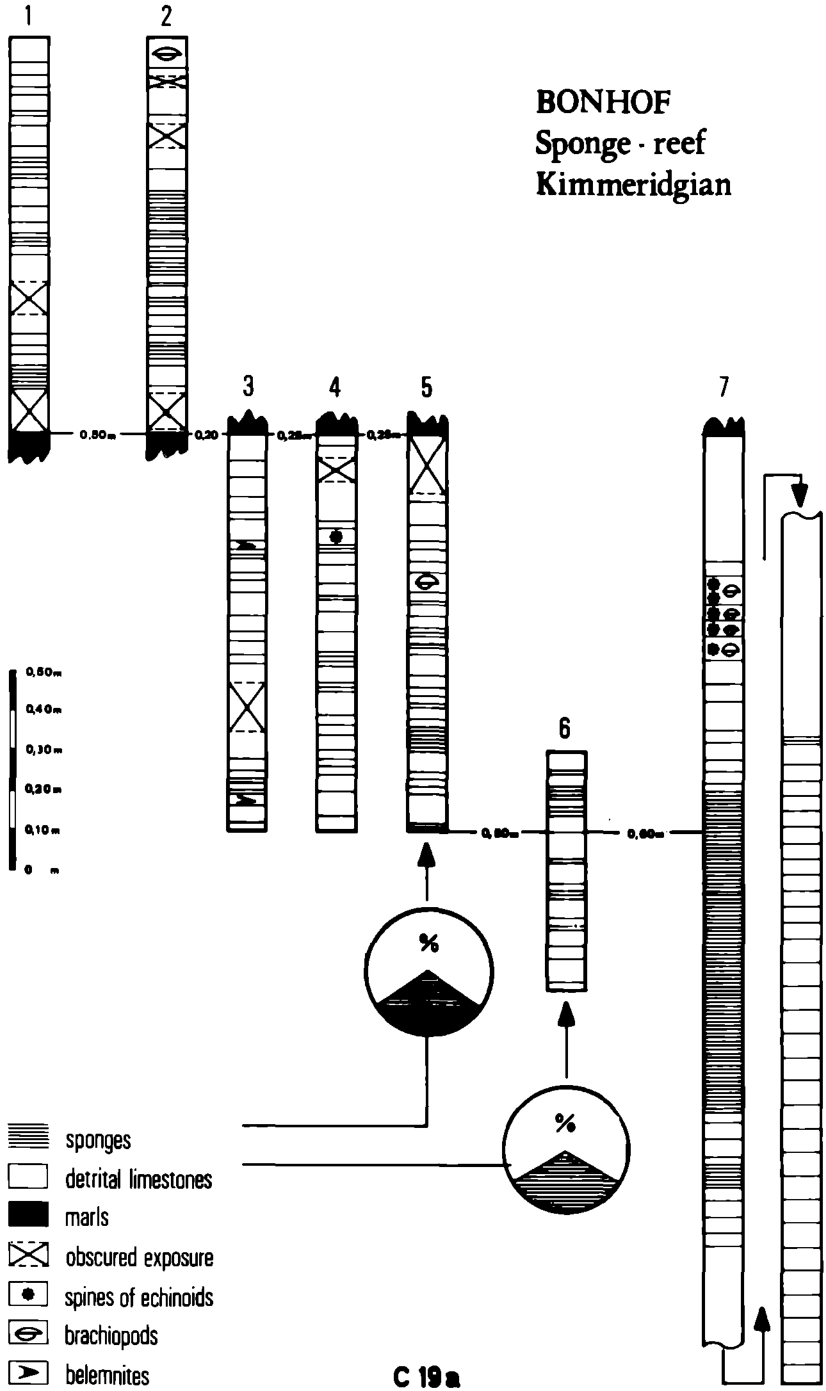
Fig. C 19 Algal-sponge bioherms, Kimmeridgian. Bonhof NE Treuchtlingen. Quantitative distribution of sponges (see fig. C 19 a). STOP 9.

Fig. C 19 a Quantitative distribution of sponges in the centre of the bioherms (= nos. 3 - 6) and bioherm margins (= nos. 1,2 and 7). STOP 9.



C19

BONHOF
Sponge - reef
Kimmeridgian



C 19a

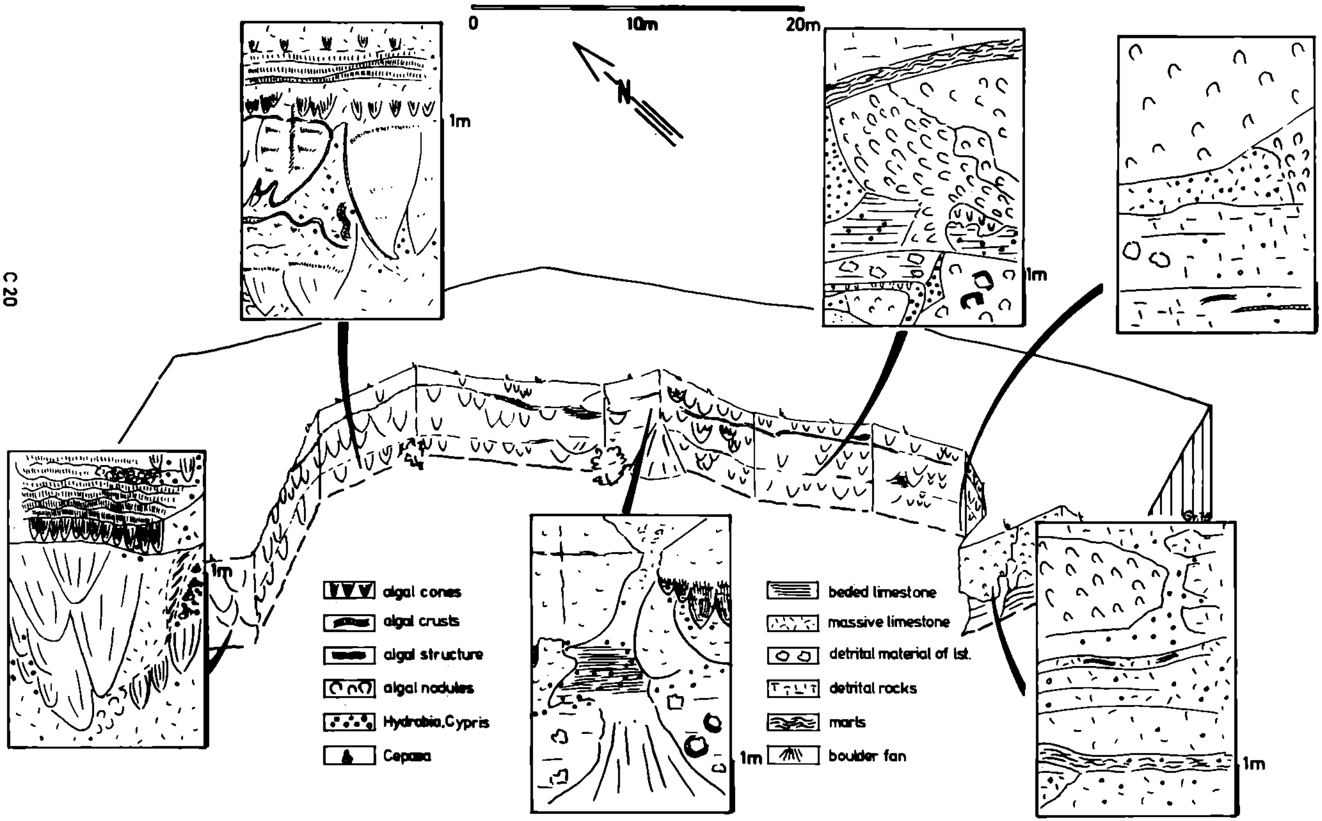
STOP 10 (see fig. C 20, C 21)

Locality: Hainsfarth, Büschelberg quarry;
Ries, top.sheet 7029 Öttingen, R 44oo 34o / H 5424 790.
Stratigraphy: Sarmatian, Miocene.
Facies: Lacustrine algal-reef.

At the northern rim of the Ries basin a basis conglomerate (granite fragments, Jurassic and Tertiary limestones) is covered by lacustrine carbonate deposits which have been formed by blue-green-algae (see Guide Book, Appendix).

Fig. C 20 Lacustrine Algal Reef, Miocene. Büschelberg near Hainsfarth, Ries. STOP 10.

Tertiary "Algal Reef" Hainsfarth/Ries



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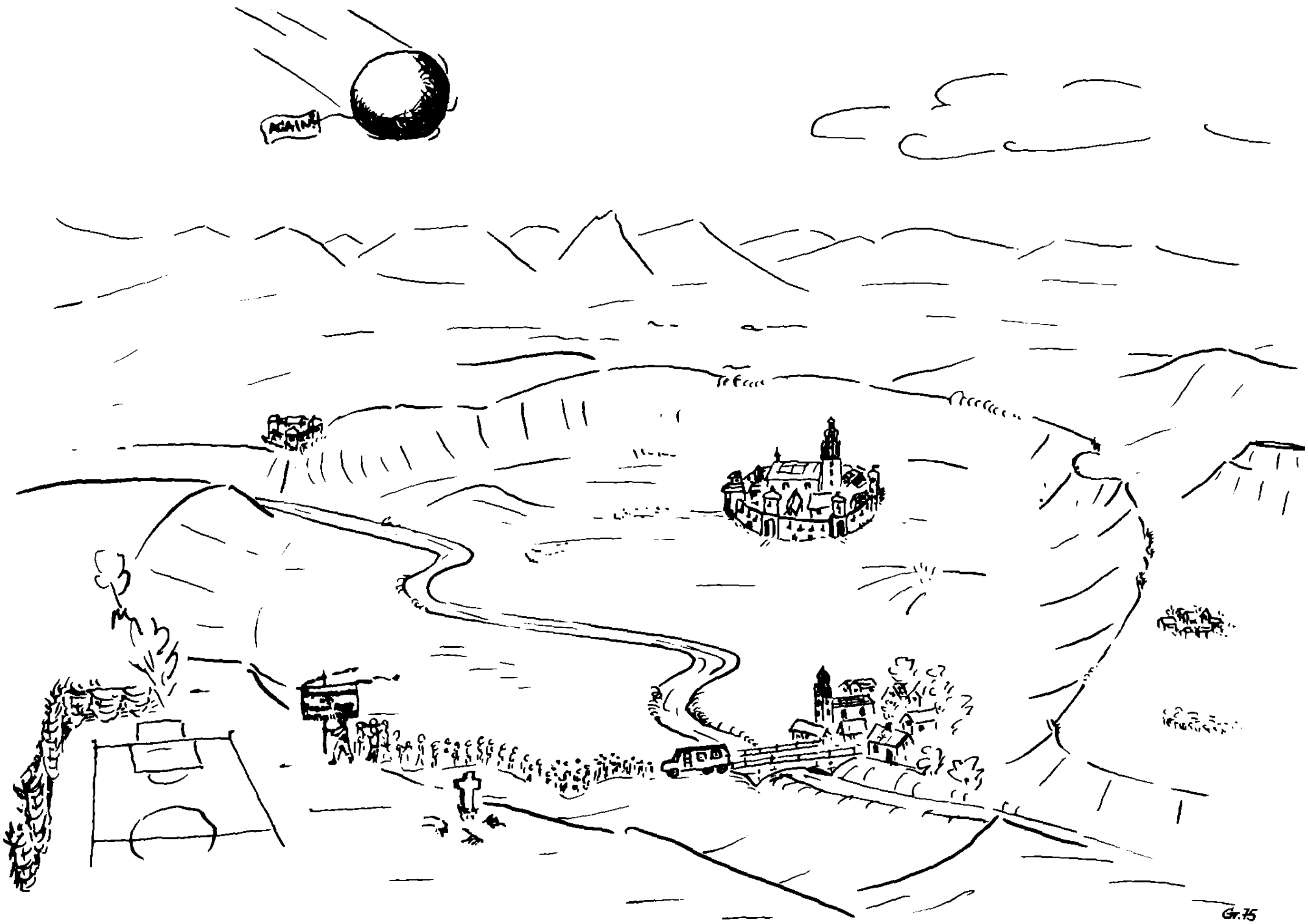
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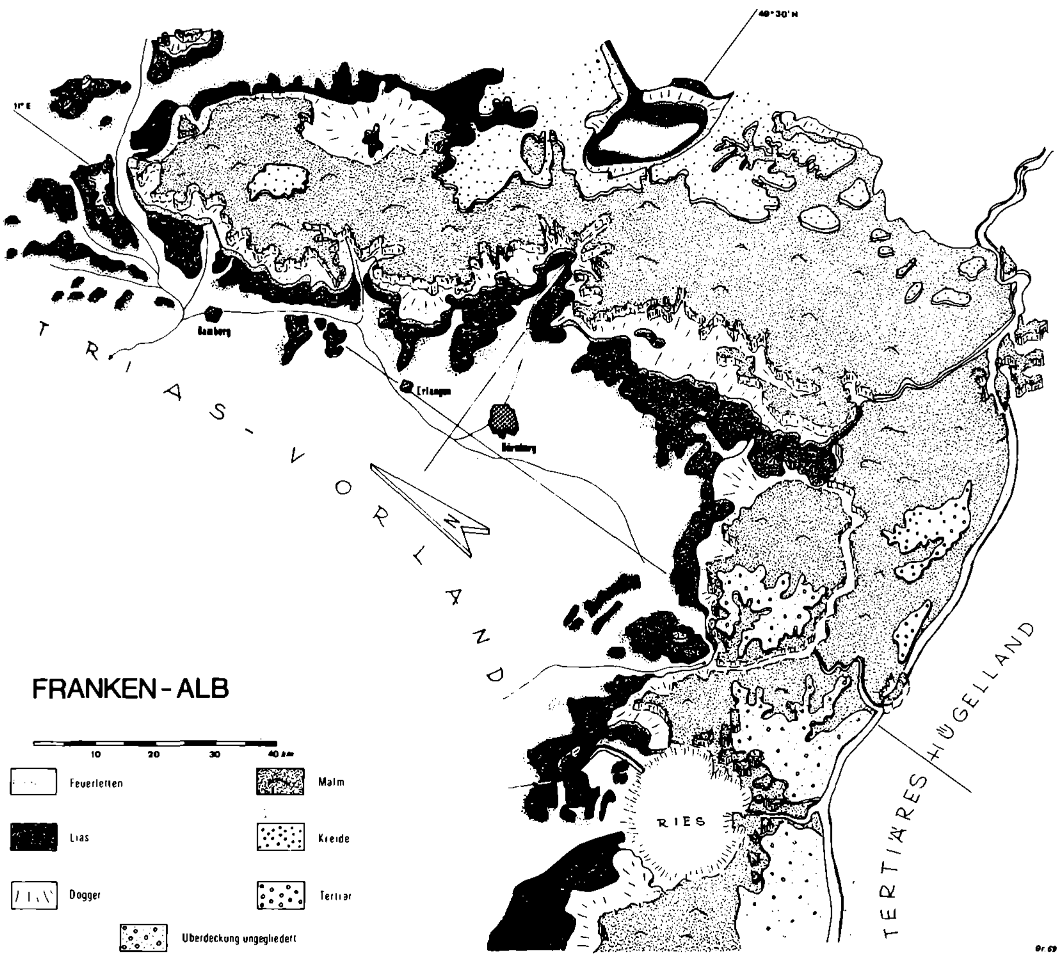
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