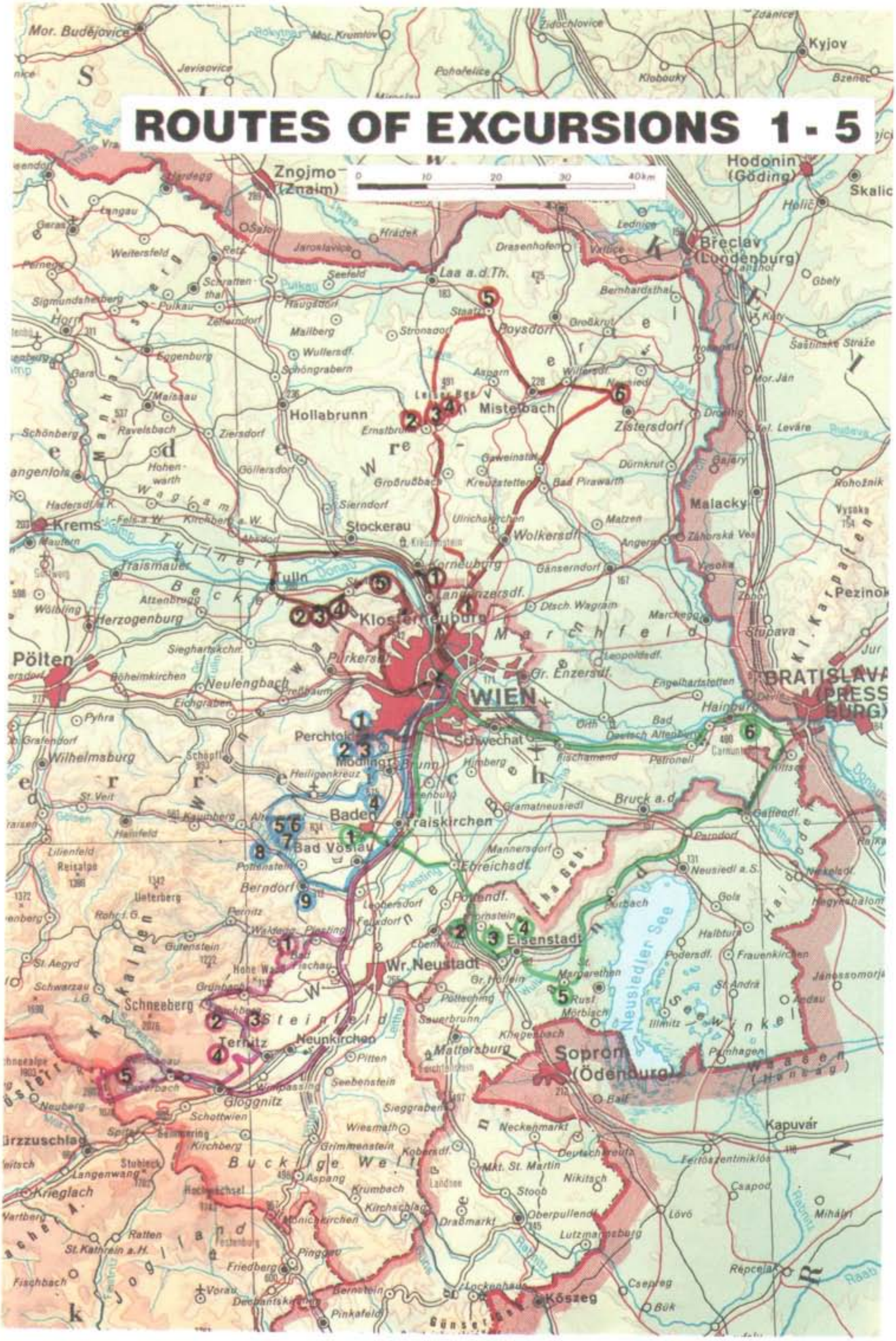
Excursions			
Mitt. Österr. Geol. Ges.	**85** (1992) Guidebook	p. 97–239 154 Abb.	Wien, September 1992

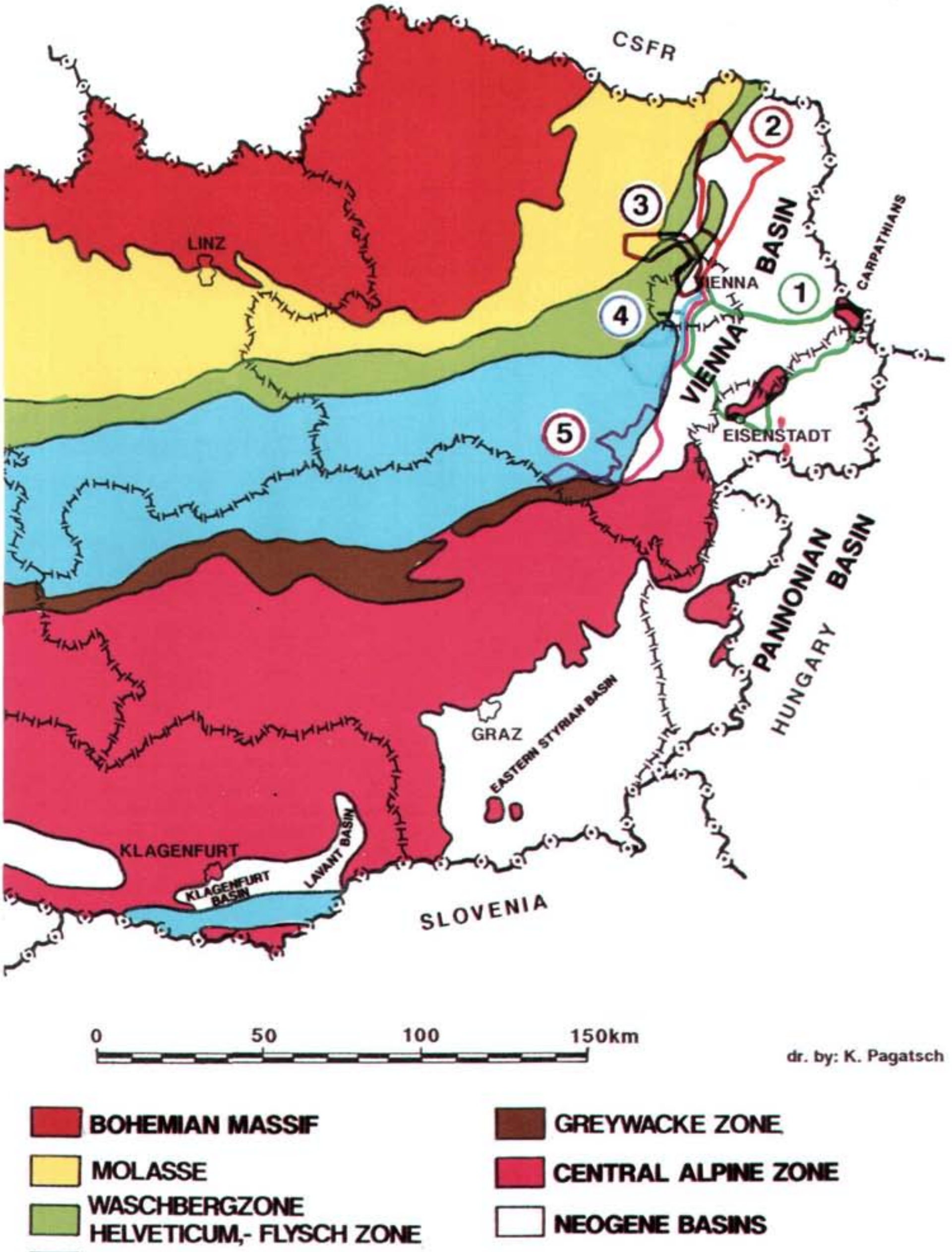
Part II

Excursions



ROUTES OF EXCURSIONS 1 - 5

GEOLOGIC FRAME OF EXCURSIONS 1 - 5



EXCURSION 1

The topic of Excursion 1 (Fig. 47) is the variety of Neogene sediments and some young tectonic features in the Vienna Basin and Eisenstadt Subbasin. The main facies types age will be examined:

For the Badenian:

- ○ marly basinal facies (Stop 1),
- ○ sandy to conglomeratic facies (Stop 4),
- ○ littoral facies of the Leitha Limestone with reef patches (Stop 3) and with a detritic development (Stop 5).

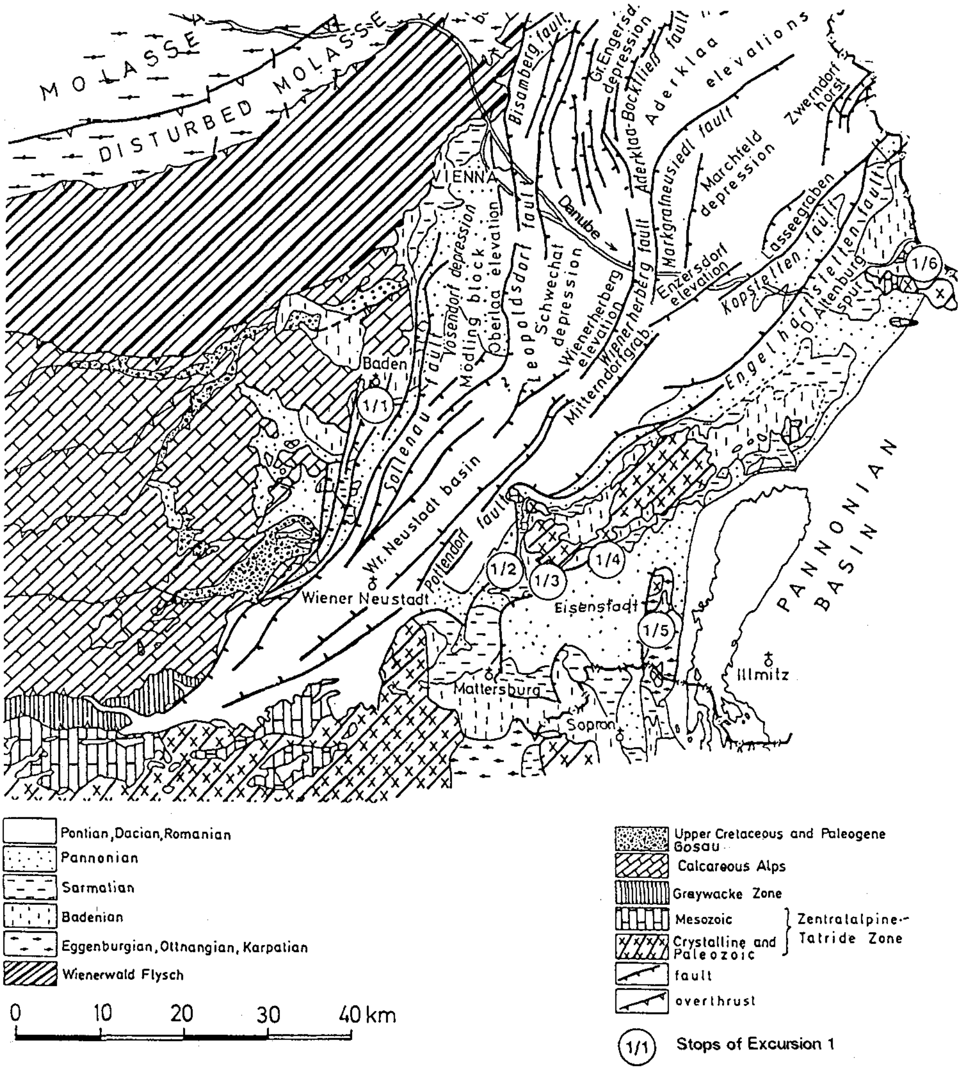


Fig. 47: Southern Vienna Basin, Stops of Excursion 1. After G. WESSELY (1988).

For the Sarmatian:
- ○ coastal facies, oolites and coquinas are typical (Stop 6),

For the Pannonian:
- ○ nearshore deposits of sandstones and marls (Stop 2).

The basinal sediments have limited surface exposure and boreholes are the main source of information. Core samples of them are shown in the core exhibition (Stop 2/1).

The main tectonic elements of the Vienna Basin are not exposed. Examples of extensional (Stops 4,5) and very young compressional features will be examined. The latter are related to strike slip movements and are minor in size, but typical.

STOP No. 1/1

LOCATION: Baden-Sooss.
Clay pit (abandoned) for brick production, 500 m south of Baden (Fig. 47).
Recent description in W. PILLER & N. VAVRA (1991).

TECTONIC UNIT: Vienna Basin.

FORMATION: Baden Tegel.
Holostratotype of Badenian stage and type locality of the Baden Tegel (PAPP & STEININGER [in:] PAPP et al., 1987, p. 138 ff.); the easternmost part consists of Sarmatian Tegel.

AGE: Badenian; Middle Miocene (Upper Lagenid Zone), the easternmost part Sarmatian.

The large clay pit has been abandoned for several years, and is several thousand m^2 in area and over 20 m deep.

The main part of the pit consists of Baden Tegel. It represents a gray-blue, plastic clay with intercalated sandy layers and lenses.

The mainly massive clays contain occasional fine laminations.

These sediments, especially the sandy layers and lenses, are extremely rich in well preserved fossils, containing calcareous nannoplankton, foraminifers, ostracods, molluscs, fish teeth and otoliths. At the lowermost level, now flooded by ground water, a layer with brachiopods (*Terebratula macrescens*) and crustaceans is present. The mollusc fauna (gastropods, bivalves and scaphopods) is characterized by infaunal elements. Axial segments of the gorgonian *Isis melitensis* and small solitary corals, e.g. *Stephanophyllia* occur very rarely.

Near the eastern margin of the pit, the clays contain a completely different and restricted fauna. The faunal association consists of cerithid gastropods and cardiid bivalves of Sarmatian age.

The Badenian is separated from the Sarmatian by a fault belonging to the marginal fault system of the Vienna Basin.

The Baden Tegel represents a quiet water environment where fine-grained clays were deposited. This soft sediment was inhabited by a diverse infauna of foraminifers (Figs. 48,49) and molluscs. The sandy layers and lenses reflect a greater terrigenous influx because the outcrop is in a marginal position. Estimates of the depositional depth of the clays vary between 50–100 m (STEININGER

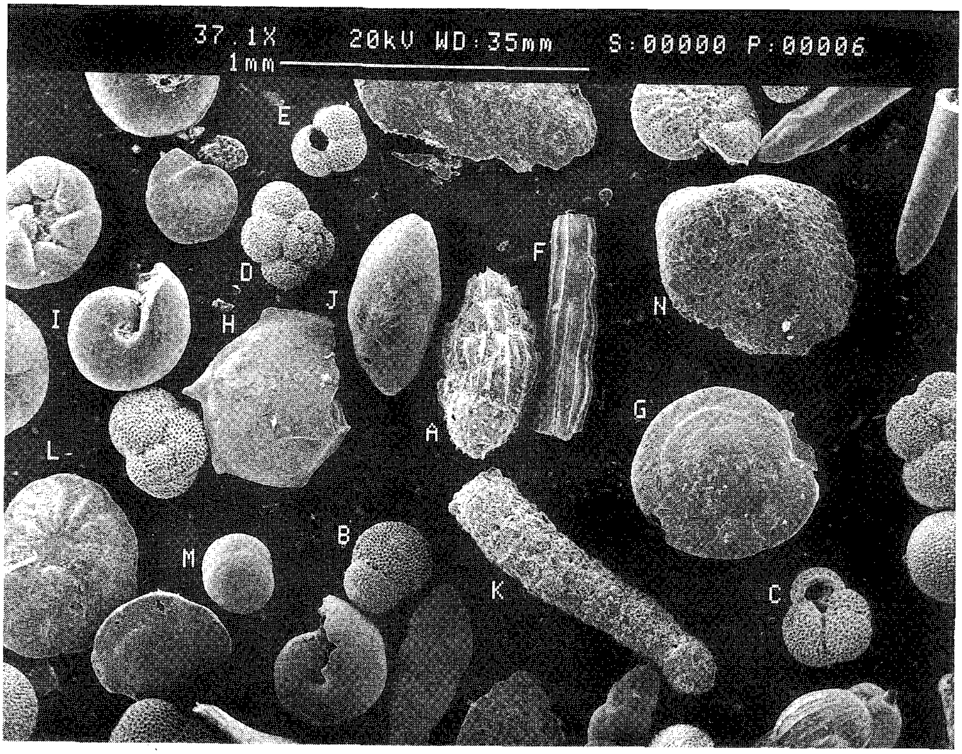


Fig. 48: Typical microfossil assemblage of the Baden Tegel.
A = *Uvigerina grilli* SCHMID; B = *Orbulina bilobata* (d'ORBIGNY); C = *Globigerinopsis grilli* SCHMID; D = *Globigerina concinna* REUSS; E = *Globigerinoides quadrilobatus* d'ORBIGNY; F = *Dentalina acuta* d'ORBIGNY; G = *Heterolepa dutemplei* (d'ORBIGNY); H = *Lenticulina calcar* (LINNÉ); I = *Melonis pompilioides* (d'ORBIGNY); J = *Bulimina pyrula* d'ORBIGNY; K = *Martinottiella communis* (d'ORBIGNY); L = *Cibicides ungerianus* (d'ORBIGNY); M = *Pullenia bulloides* (d'ORBIGNY); N = *Textularia gramen* d'ORBIGNY (det. O. SCHREIBER).

& PAPP [in:] PAPP et al., 1978) or 100–200 m (TOLLMANN, 1985). The sands originate from shallower areas, as demonstrated by the occurrence of the larger foraminifers *Amphistegina, Heterostegina* and *Borelis melo,* as well as abundant *Elphidium*. The frequent occurrence of planktonic foraminifers and calcareous nannoplankton in the clays reflect open water conditions (FUCHS, 1977). The corals here are exclusively solitary forms, adapted to soft substrates.

Near the eastern margin of the pit, the clays contain a completely different and restricted fauna. The faunal association consists of cerithiid gastropods and cardiid bivalves of Sarmatian age.

STOP No. 1/2

LOCATION: Steinbrunn sand pit (Figs. 47,50,52).
TECTONIC UNIT: Vienna Basin.
AGE and FORMATION: Lower–Middle Pannonian (Upper Miocene).

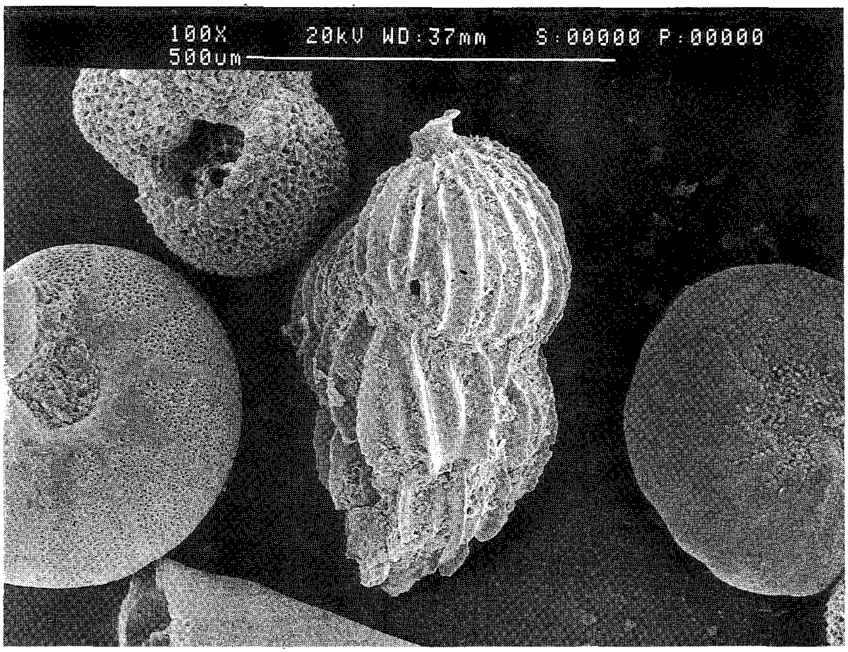


Fig. 49: Detail of *Uvigerina grilli* SCHMID, the zone index fossil of the Upper Lagenid Zone (det. O. SCHREIBER).

The sand pit NE of the village of Steinbrunn is situated on the eastern flank of the Vienna Basin near the southwestern end of the Leitha Mountains (Fig. 50), where Pannonian sandstones and marls on top of the Sarmatian and Badenian littoral sediments surround the southwestern spur of the mountains near Hornstein (F. SOHS, 1963). Towards the west deep subsidence of the Vienna Basin took place, towards the south and southeast the Eisenstadt Basin forms a subbasin of the Vienna Basin. The well Zillingthal 1 (Fig. 51) is situated in the border zone between both depressions (drilling depth 1400 m). East of the Eisenstadt Subbasin the Rust Ridge forms the boundary to the Pannonian Basin, where intensive tilting during the Pannonian and Pontian time took place.

Along the crest of the Leitha Mountains and the Rust Ridge previously deposited sediments of the Badenian were eroded down to the crystalline basement. This resulted in a large amount of redeposited Badenian microfossils, fragments of coralline algae and marlchips in younger sediments such as in the Pannonian sandstones of Steinbrunn.

Entering the outcrop (Fig. 52) from the west we see the Pannonian sequence dipping 10°–20° eastwards (Fig. 53).

From north to south (position 2 to position 3) the lithology of the sequence is characterized as follows:

Along the north wall and the northern end of the eastwall, a fine- to medium grained cyclic sandstone sequence appears. The sandstone beds show an average thickness of 18 cm (15–20 cm) and are separated by thin shale layers

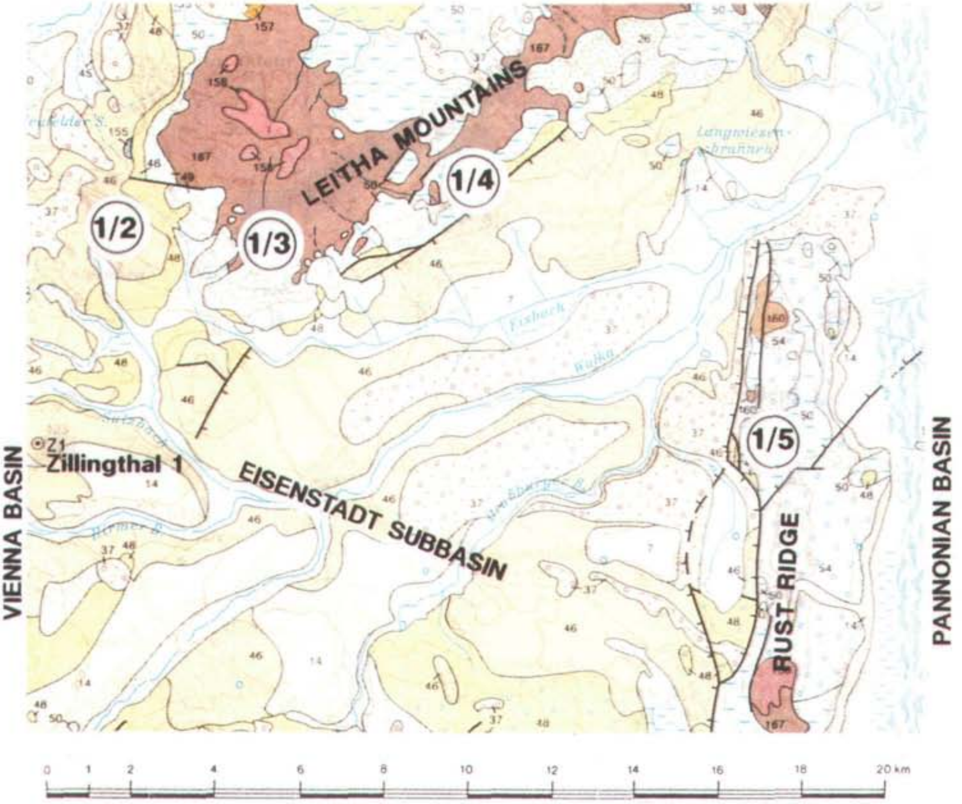


Fig. 50: Geological frame of the Stops 1/2, 1/3, 1/4, 1/5.
Section of the Eisenstadt area of the "Geologische Karte von Wien und Umgebung 1 : 200.000" (W. Fuchs & R. Grill, 1984).
7 = Postglacial to Late Pleistocene alluvial sediments
14 = Pleistocene Löss, mostly Late Pleistocene
37 = Peistocene to Upper Pliocene fluviatile gravel
45 = Pontian
46 = Pannonian
48 = Sarmatian
49 = Middle to Lower Badenian
50 = Middle to Lower Badenian Leitha Limestone, sandstones, gravel
54 = Karpatian Rust Gravel
155 = Middle Triassic carbonates
156 = Permoscythian Semmering Quartzite
158 = "Grobgneiss"
167 = Micaschist
⊙ = Well Zillingthal 1 (Z1)

(Fig. 53,54). Continental influx is documented by the reddish shale layers in the upper part of the sequence, where unconformities also occur.

The cyclic sedimentation switches to a massive bedded one in the southeastern part of the quarry, beginning south of Position 3.

It is represented by coarse grained, flaser bedded to massive sandstones with few layers of fine grained conglomerates (Fig. 57). Erosion and redeposition is

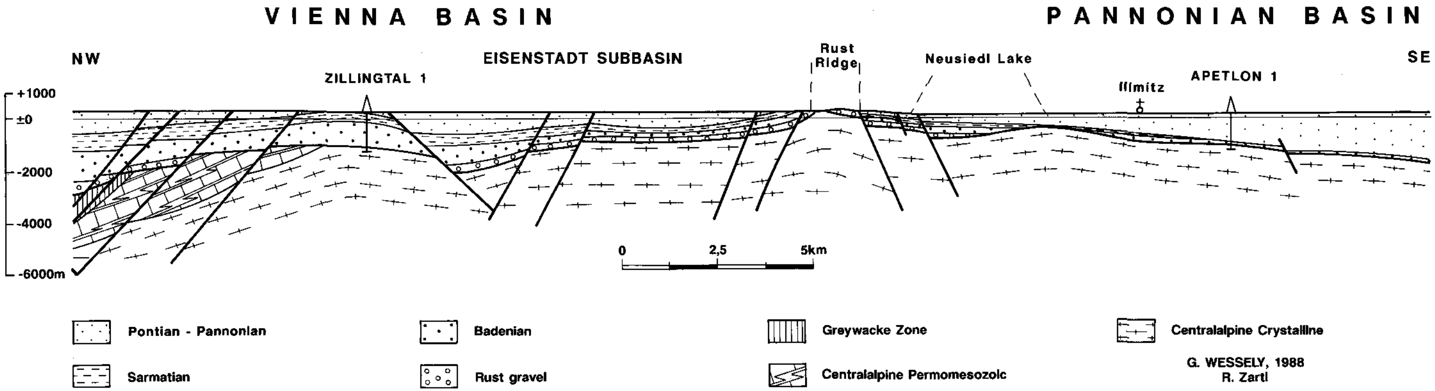


Fig. 51: Section through the borderzone between the Vienna Basin and the Pannonian Basin showing the late eastward tilting of the Pannonian Basin in comparison to the Vienna Basin and the Eisenstadt Subbasin.
After G. WESSELY (1988).

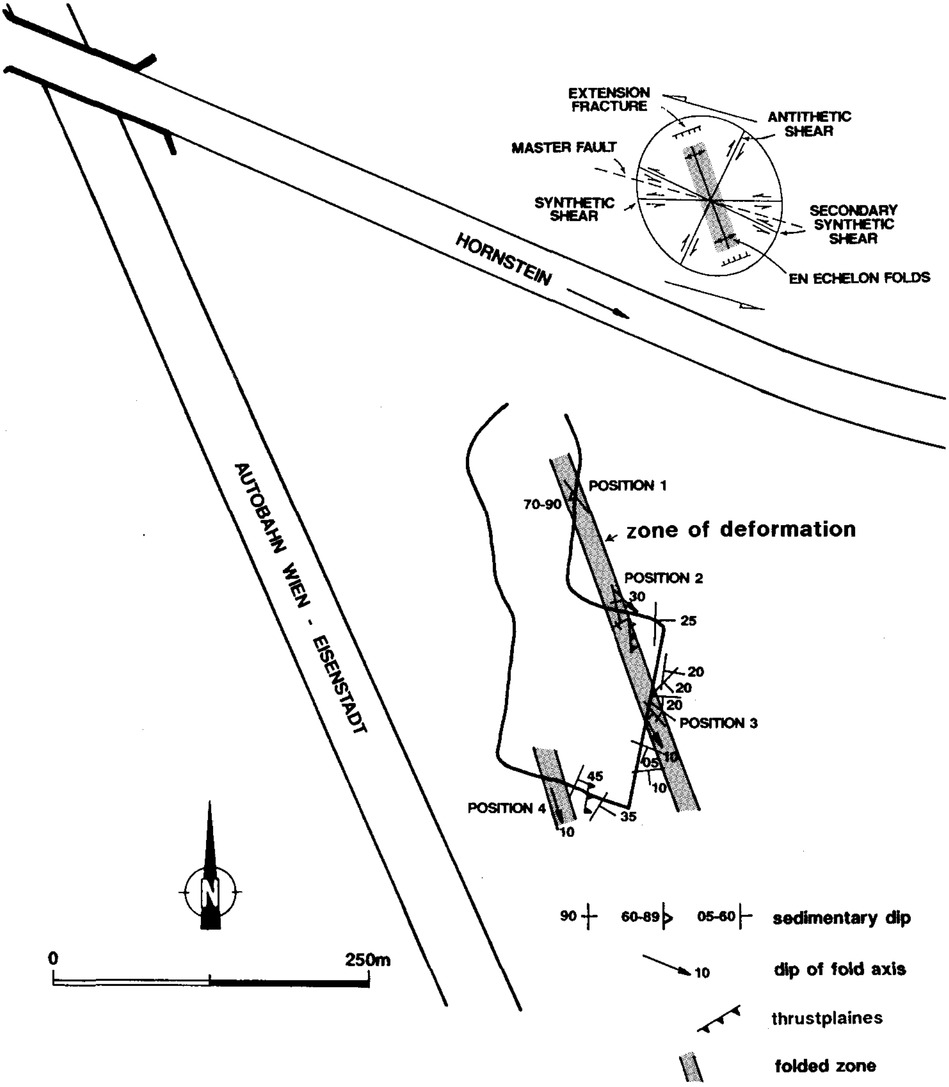


Fig. 52: Location of the Sand pit Steinbrunn and structural overview.

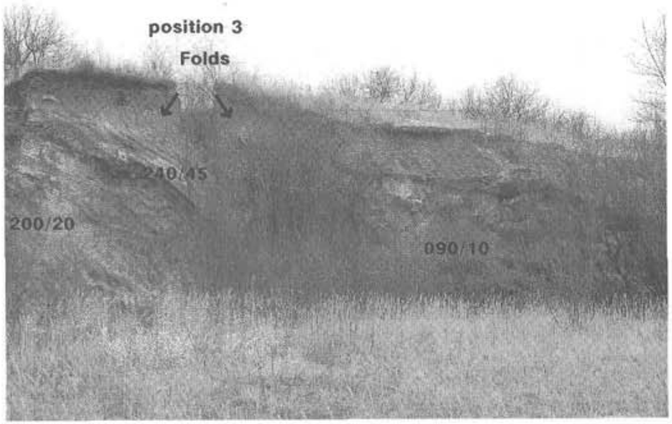
documented by the scoured base of the 30–60 cm thick beds and layers of gray Badenian marl chips. Together with a large amount of coralline algae detritus some large sole marks can be observed. The depositional environment is interpreted as a tidal influenced channel.

At the top of the sequence, mainly in the northeastern part of the sandpit, immediately below the soil, pockets of reddish Pleistocene material can be observed. This upper part shows Cryoturbation.

At the northernmost part of the sandpit (Fig. 52, position 1) a disturbed zone is exposed where the strike of the sandstone changes to WSW (240) with near vertical dip. We find the same feature at the northern wall of the outcrop (Fig 52,

Fig. 53 ▲
20° eastward dipping sequence of uppermost Lower Pannonian sandstones and marls.
Steinbrunn sand pit, northern wall.
In the left (western) part (position 2), the sequence is folded and shows steepening up to 90°.

Fig. 54 ▶
Eastward dipping beds (left side) steepen against a folded zone (position 3).
Steinbrunn sandpit, eastern wall.
Towards south again gentle eastward dip.



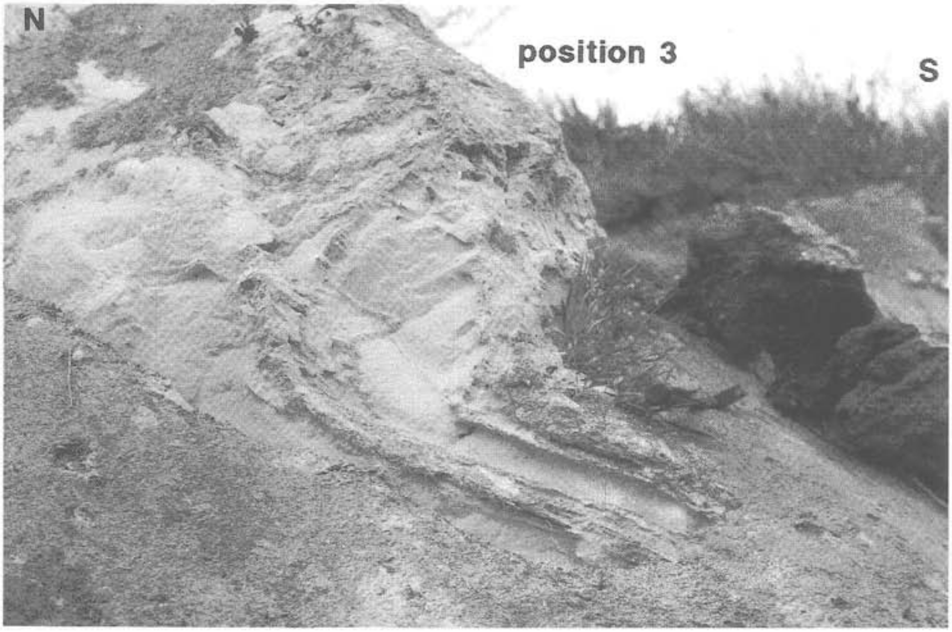


Fig. 55: Steinbrunn sandpit.
Fold of the east wall (detail of position 3).

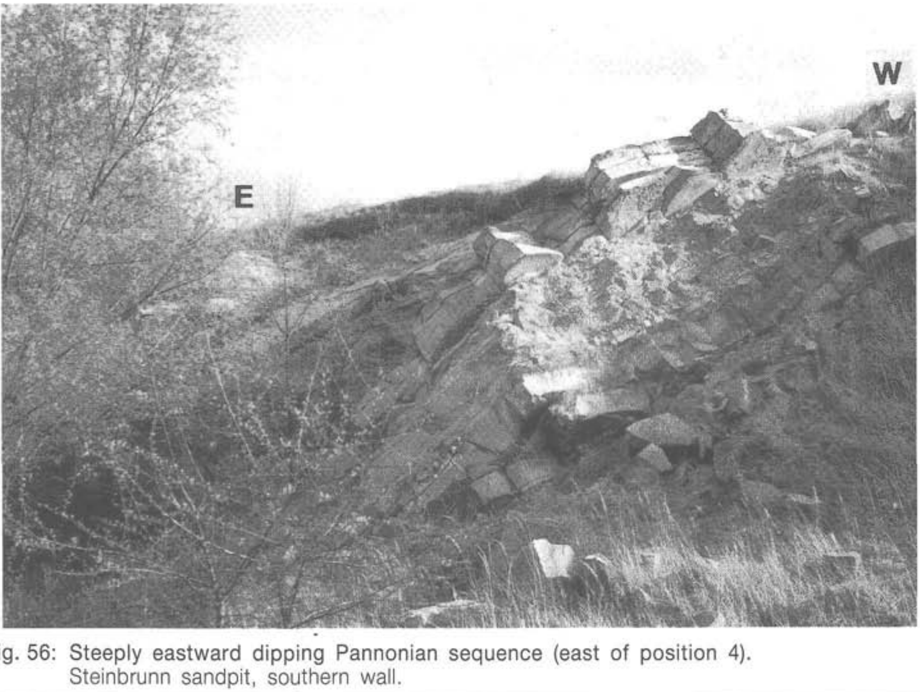


Fig. 56: Steeply eastward dipping Pannonian sequence (east of position 4).
Steinbrunn sandpit, southern wall.

Fig. 57: Massive sandstone underlain by medium-coarse grained weakly cemented sandstone with clasts of redeposited Badenian marls.
Steinbrunn sandpit, eastern wall, south of position 3.

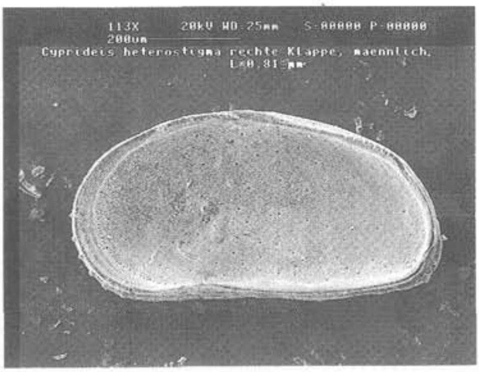
position 2). Here we can observe a narrow 5 m disturbed zone with vertical tilted beds, accompanied by another 5 m zone where folding of sediments occurs. The axis of folding dips 130/30 (Fig. 53, left side).

This feature cuts across the outcrop and is found again at position 3 (Fig. 52) in the eastern wall. Some meters north of it (Fig. 54) the gently eastward dipping beds, which show an aggredation of sediments and an increasing number and thickness of beds towars south, steepen to 45° and the strike changes to SSE, i.e. the strike approaches the strike of the fold zone of position 3 (Fig. 55). The fold axis dips 140/10°.

It seems that the folding occurred synsedimentarily. The beds return to gentle eastward dip south of this folded feature. On the southern wall (position 4) another fold can be observed. Sandstone beds of its eastern limb become steeply dipping (Fig. 56).

The narrow folded zone obliquely crosses the strike of the beds, affecting different stratigraphic levels (Fig. 52). The strong, but local tectonic effect is as-

a ▲



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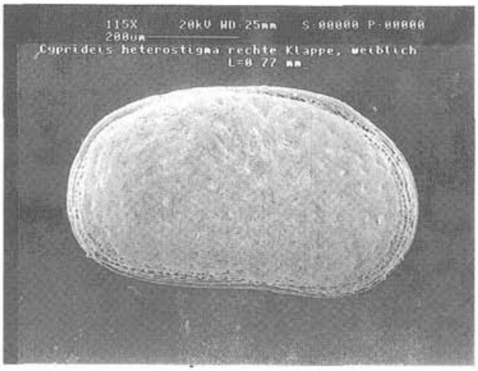

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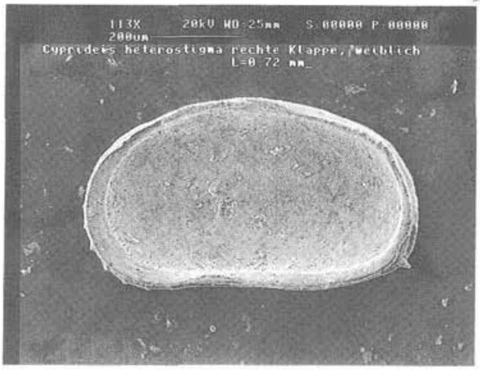
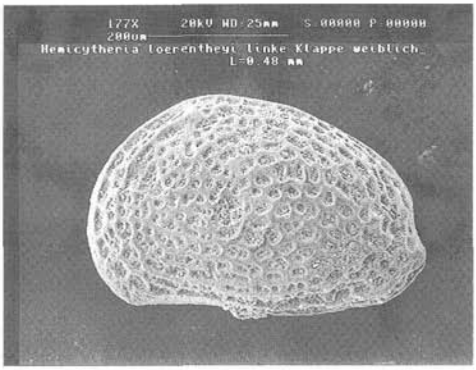


d ▲

Fig. 58: Ostracods of the uppermost Lower Pannonian age of the Steinbrunn sand pit (det. O. SCHREIBER).
a–d) *Cyprideis heterostigma.*
e) *Hemicytheria loerentheyi.*



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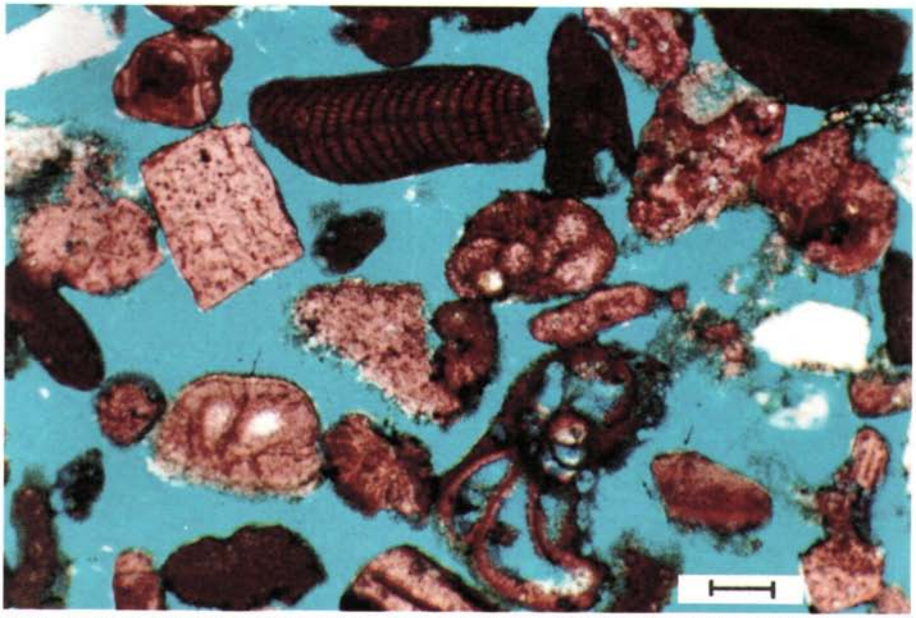


Fig. 59: Thin section microphotograph of uncemented sand with abundant reworked carbonate and bioclast grains (pores in blue color).
Steinbrunn sand pit; length of scale = 0.14 mm.

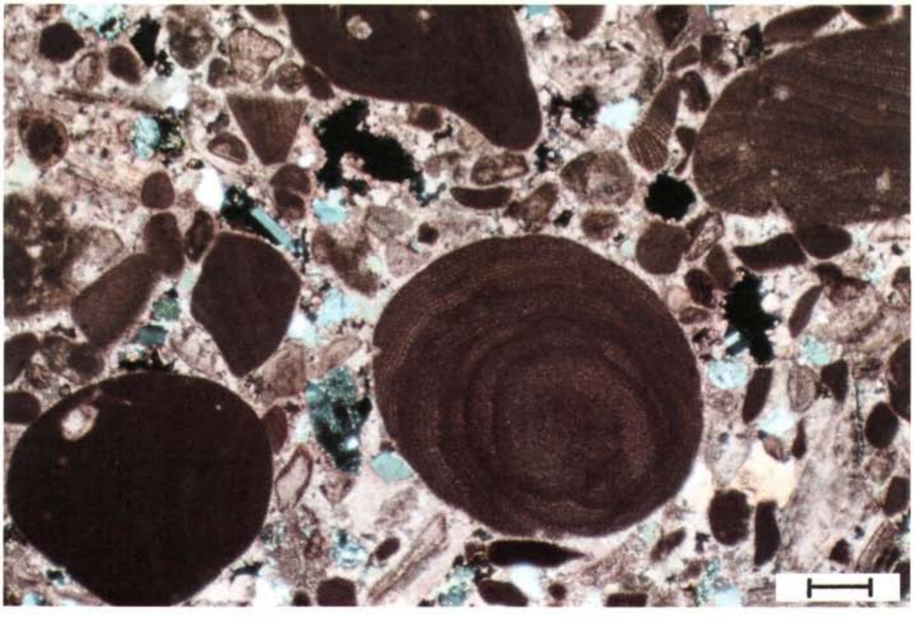


Fig. 60: Calcite-cemente sandstone bed, with abundant reorked corraline algal grains (for example 4 largest grains).
Steinbrunn sand pit; length of scale = 0.14 mm.

sumed to be the result of a compressional deformation pattern related to a strike slip fault.

Fitting the two fault zones into the pattern of strike slip deformation of the scheme of RIEDEL, they point indirectly to a left lateral WNW striking fault (Fig. 52), which may accompany the SW flank of the Leitha Mountains.

The age has been determined by ostracods (Fig. 58) found in marly layers within position 2. The ostracods indicate the brackish environment of the Pannonian. Reworked microfossils of Badenian age are abundant in some parts of the quarry (Figs. 59,60).

Pannonian Fauna (Ostracods)

Loxoconcha hastata, Aurila opaca, Cyprideis heterostigma, Hungarocypris auriculata (fragments), *Hemicytheria loerentheyi.*

Reworked Fossils

Asterigerina planorbis, Elphidium crispum, 1 *Uvigerina* cf. *pygmoides, Cibicides lobatulus,* mollusc debris, fish teeth.

Hungarocypris auriculata, Hemicytheria loerentheyi and *Cyprideis heterostigma* indicate uppermost Lower Pannonian age.

The sandstones south of position 3 are composed of: 5–16 % quartz, 3–4 % feldspar (mostly sericitised), 15–19 % micrite fragments, 20–34 % fragments of coralline algae, 5–10 % foraminifers, 3–8 % shell fragments, 4–14 % sparite, 6–14 % echinoderms, traces–2 % mica and traces of crystalline rock fragments.

The sandstones are calcite cemented, the degree of cementation varies from bed to bed (Figs. 59,60).

The heavy mineral association is characterized by predominance of garnet and epidote/zoisite:

	ZI	RU	BA	TI	TU	GR	ST	EZ	HO	AP
mean	2	2	1	1	1	62	1	20	0	11
min	0	1	0	tr	tr	47	0	10	0	7
max	5	4	4	4	1	74	2	32	1	18

Key for Symbols Used in Lists of Heavy Minerals (Stops 1/2, 1/4, 3/1, 3/5)
Zircon (ZI), rutile (RU), brookite/anatase (BA), titanite (TI), tourmaline (TU), garnet (GR), staurolite (ST), epidote/zoisite (EZ), hornblende (HO), apatite (AP), chloritoid (CD), chromium spinel (CR), monazite (MO).

STOP No. 1/3 (W. PILLER, E. KLEEMANN, F. STEININGER)

LOCATION: Großhöflein; "FENK"; quarry, Kalkofenwald approx. 1400 m NNW of Großhöflein (SW of Eisenstadt, Burgenland; Figs. 50,61).
Recent descriptions in W. PILLER & N. VAVRA (1991).

TECTONIC UNIT: Vienna Basin, Eisenstadt Subbasin.

STRATIGRAPHIC UNIT: Leitha Limestone; Faciostratotype (F. STEININGER & A. PAPP in: A. PAPP, I. CICHA, J. SENES & F. STEININGER, 1991).

AGE: Bulimina-Bolivina Zone, Upper Badenian (Middle Miocene)

The locality is situated on the southern margin of the Leitha Mountains (Fig. 50). Its litho- and biofacies has been studied recently by W. DULLO (1983)

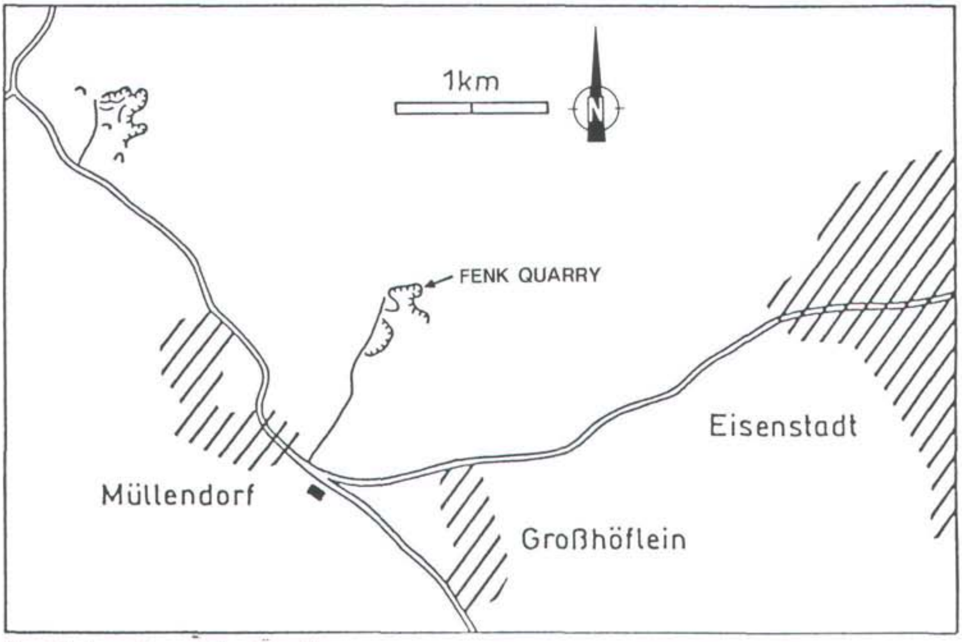


Fig. 61: Location of the "Fenk" quarry.

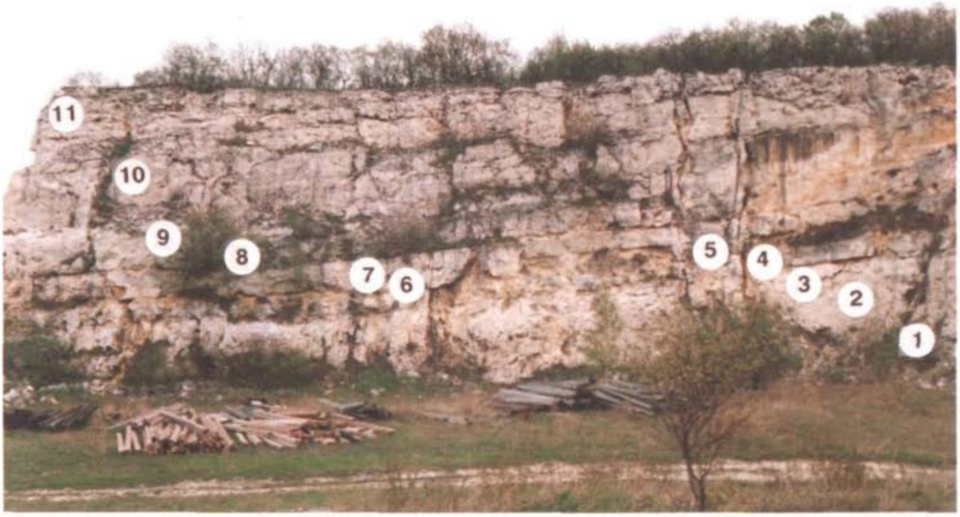


Fig. 62: Leitha Limestone, Faciostratotype.
Fenk quarry, upper level, view from South.

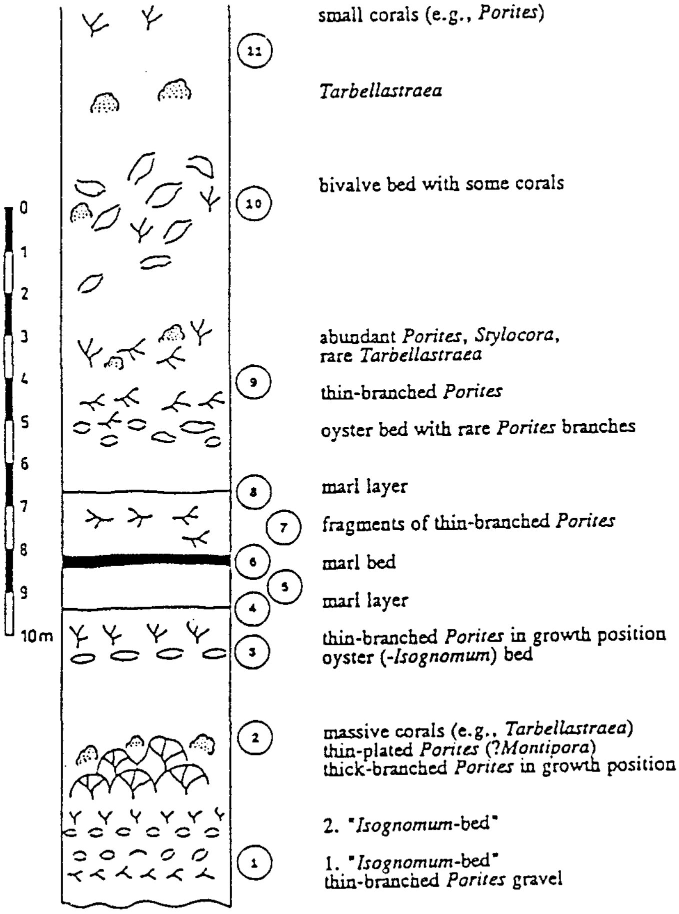


Fig. 63: Zonation of the Leitha Limestone by bio- and lithofacies. Fenk quarry, upper level. Numbers correspond to Fig. 62 and to text.

and W. PILLER & N. VAVRA (1991). The site has several quarries which were abandoned a few years ago. The main part of the large area is used as a dump. Currently only the uppermost level of the quarry area has good exposures.

The upper level shows a section of nearly 20 m height (Fig. 62). Most obvious are thick limestone beds dipping with approx. 5–10° against WNW to SW.

Lithological description (Numbers 1–11 correspond to the layers shown in Figs. 62 and 63):

1) The lowermost bed can be subdivided into several zones. At the base, a coral limestone (90 cm), characterized in the uppermost 30 cm by debris of *Porites* branches.
   It is overlain by the first "*Isognomum* bed", where large, double-valved *Isognomum* accompany double-valved ostreids. A bed of echinoidrich bioclastic limestone with large venerid bivalves (*Pitar*, Fig. 66) is overlain by the second "*Isognomum* bed" (60–80 cm). Double-valved *Isognomum* are very abundant at the base of the bed, where they occur in a more horizontal position. Above this layer, the bivalves are oriented more vertically. A coral-dominated zone tops this bivalve dominated zone. The corals are mainly branching *Porites*

Fig. 64: Coralline algae, Rhodolites.
Fenk quarry, upper level.

Fig. 65: Thin bedded limestone and marls of the facies toward the Basin.
Fenk quarry, lower level of the Fenk quarry system.

colonies of approx. 20 cm height in an upright position. In this upper part, *Isognomum* again occurs more frequently.

2) The next layer (approx. 350 cm) is characterized by thick-branched (12–22 mm) *Porites* bushes in growth position up to 90 cm in height (Fig. 67).
   They are occasionally inhabited by single *Lithophaga* specimens. Next to these bushes and especially on their tops, thin, plate-like encrusting corals are present.
   Usually these platy corals have been named *Porites incrustans*, but they may actually represent *Monipora*. Other corals include *Caulastrea* – a dendroid aviid – and *Tarbellastraea*.
3) The next layer starts with a zone of more abundant double-valved oysters and rarely also *Isognomum*; this bivalve horizon gives rise to thin-branched *Porites* preserved in upright position. The branches are encrusted by relatively thick coralline algal crusts. This coral dominated layer is overlain by a coralline algal – bryozoan arenite occasionally containing chaetetids.
4) A thin marl bed (1–2 cm) is developed on top of this arenite.
5) A bryozoan-algal bioclastic limestone with bivalves follows.
6) This limestone grades into a brown marl (25 cm) with coralline algae branches as well as rhodoliths).
7) A subsequent coralline algal-bryozoan limestone bed (130–160 cm) contains fragments of thinbranched *Porites* cf. *leptoclada* REUSS (encrusted by bryozoans and coralline algae) as well as chaetetids.
8) A thin marl layer (1–5 cm) separates this bed from a thick limestone sequence.
9) The basal (90 cm) part of the limestone sequence is characterized by the frequent occurrence of incrusting rhodoliths (Fig. 64).The coralline algae are intergrown with bryozoans and acervulinid foraminifers. A zone (90 cm) with abundant ostreids, corals, bryozoans, chaetetids, and serpulids follows. The corals are mainly represented by *Porites* branches preserved only as open moulds due to total dissolution. The oysters are frequently preserved double-valved. This zone grades into a bioclastic coralline algal limestone (70 cm); branch fragments of coralline algae dominate here, but thin branches of *Porites* encrusted by corallines are also present. The next 150–160 cm represent a coral limestone mainly with branched *Porites* or tiny, thin-branched *Stylocora exilis* REUSS. The latter occurs mainly as autochthonous rubble, sometimes several decimeters thick. Massive forms [*Tarbellastraea reussiana* (EDWARDS & HAIME)] may also be found in between. Large bivalves are also present between the corals.
10) A thick section follows (450 cm), characterized by the frequent occurrence of large bivalves and a subordinate presence of corals. In addition to ostreids, large venerids [e.g. *Pitar, Venus (Periglypta)*] and especially carditids are abundant.
11) The following sequence (400–450 cm) is subdivided very indistinctly. At the base it is dominated by rhodoliths, overlain by a coral (*Tarbellastraea*) characterized limestone and by bryozoan limestones.

The limestones of the upper levels of the quarry system are interpreted by several authors as a coral reef (e.g., TOLLMANN, 1985; STEININGER & PAPP et al., 1978; DULLO, 1983). The sequence contains clearly bedded limestones separated by marly beds. Most of the limestones are characterized by a relatively fine

Fig. 66. **Venerid bivalve.**
Fenk quarry, layer 1.

Fig. 67: **Porites colony.**
Fenk quarry, layer 2.

bioclastic fabric and corals are mainly present as rubble. However, some of the limestones contain abundant corals in growth position. One layer exhibits a sequence starting with an *Isognomum* ostreid layer on which thick-branched, 90 cm high *Porites* colonies grew.

The corals are also encrusted by coralline algal crusts, and a rich accompanying fauna is present between the corals [e.g., *Haliotis, Venus (Periglypta)*]. A similar sequence follows, being overlain by a coralline algal-bryozoan limestone. Whether this sequence represents a coral reef or a coral carpet cannot be determined due to the limited exposure in outcrop. It can, however, be interpreted as coral buildup in the broadest sense. The gentle dip of the beds points basinwards.

The short section in the lowermost outcrop of the quarry system with its thin bedded limestone–marl–sand sequence (Fig. 65), represents time-equivalent basinal deposits (reflected by organisms of an open marine environment). These are interrupted by submarine channels filled with bioclastic material derived from the buildup.

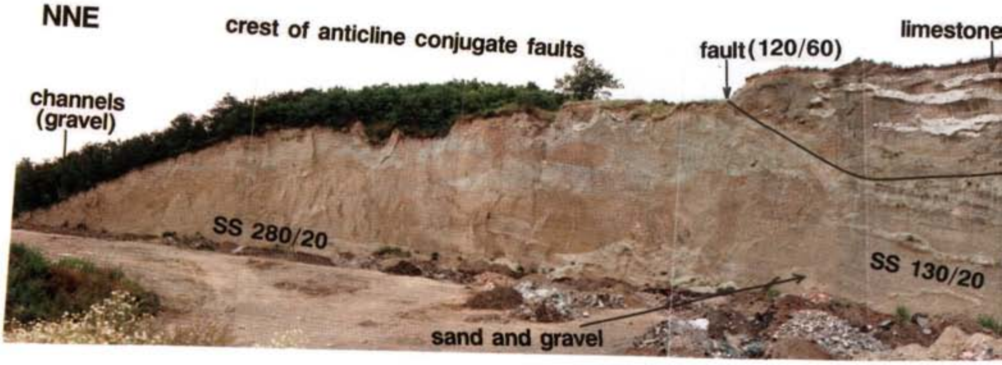
STOP No. 1/4

LOCATION: St. Georgen sandpit NE Eisenstadt (Figs. 50,68).
TECTONIC UNIT: Vienna Basin, Eisenstadt Subbasin.
FORMATION: Eisenstadt Sands.
AGE: Badenian (Middle Miocene).

The quarry is situated on the northeastern outskirts of Eisenstadt along the east flank of the Leitha Mountains.

In this northeastern part Lower Badenian sands and gravel were deposited upon the Crystalline of the Leitha Mountains, whereas along the whole southern border of the mountains Leitha Sandstone covers the basement (J. KAPOUNEK, 1938; A. TOLLMANN, 1955).

A. TOLLMANN (1955) gives a detailed description of the sediments and tectonic observations of the sandpits in this area. By consideration of the petrographic content of the sand and gravel (abundance of granite gneiss) he concluded, that the source is not the crystalline of the Leitha Mountains, but a southern (Rosalia Mountains, Ödenburg area or Rust Ridge) or even a southeastern one. The



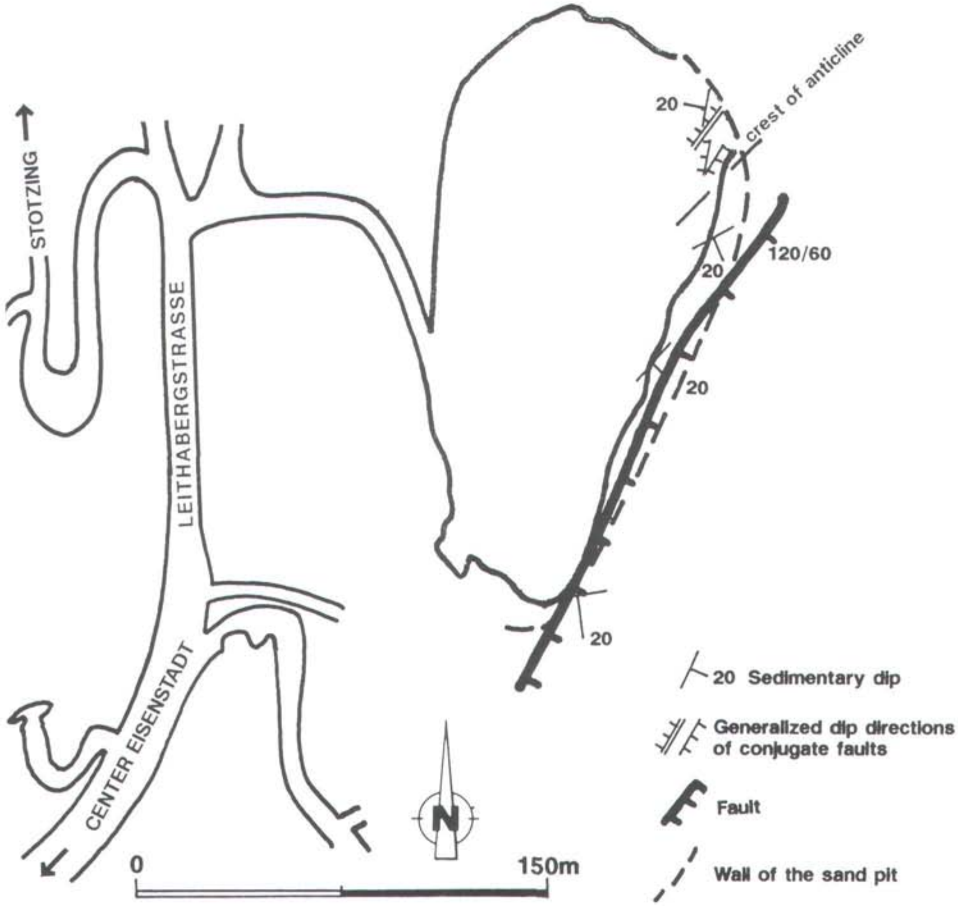


Fig. 68: St. Georgen sandpit, NE Eisenstadt.
Location and structural overview. ▲

Fig. 69: Panorama of the St. Georgen sandpit NE Eisenstadt. ▼

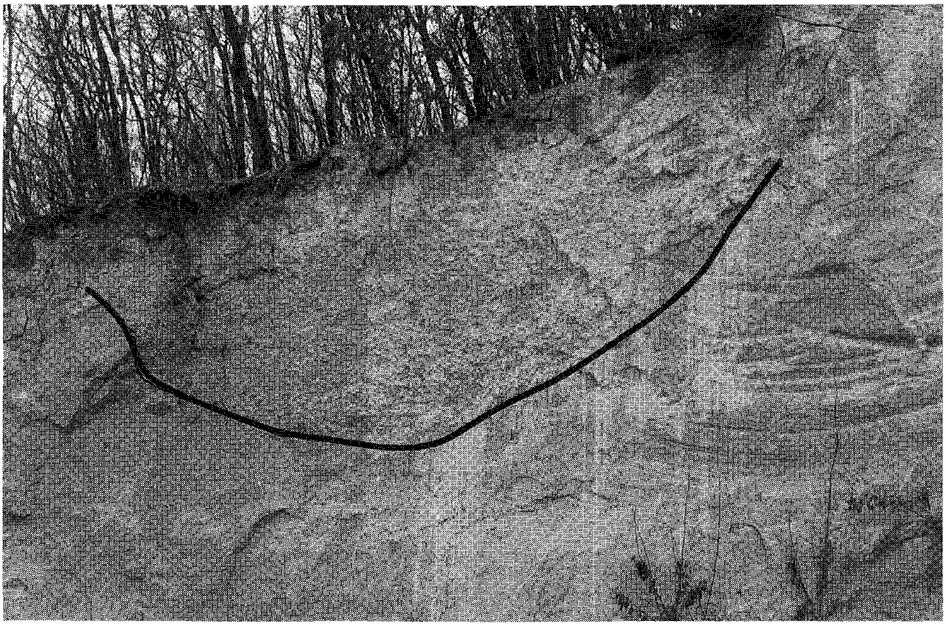


Fig. 70: St. Georgen sandpit, channel in the northern part.

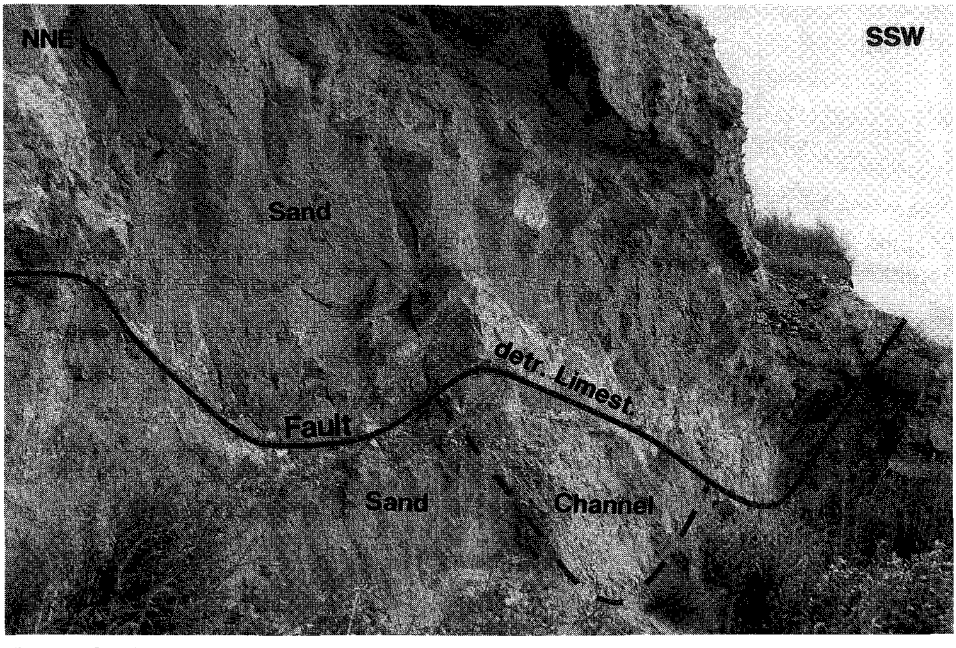


Fig. 71: St. Georgen sandpit, southern part showing the main fault.
The upthrown block contains Leitha Limestone (right), sand and a channel filled by gravel containing marl chips. The downthrown block is formed by sand and intercalations of detritic Limestone.

Fig. 72 ▲
Slickenside of the main 120/60 dipping fault.
St. Georgen sandpit.

Fig. 73 ▶
Detail of the 120/60 dipping fault.
St. Georgen sandpit.

Fig. 74: Conjugate faults in the anticline of the northern part.
St. Georgen sandpit.

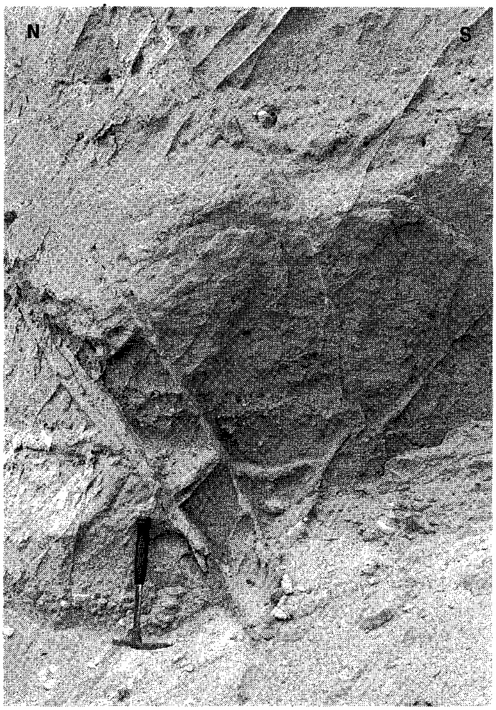


Fig. 75: Conjugate faults in the anticline of the northern part.
St. Georgen sandpit.

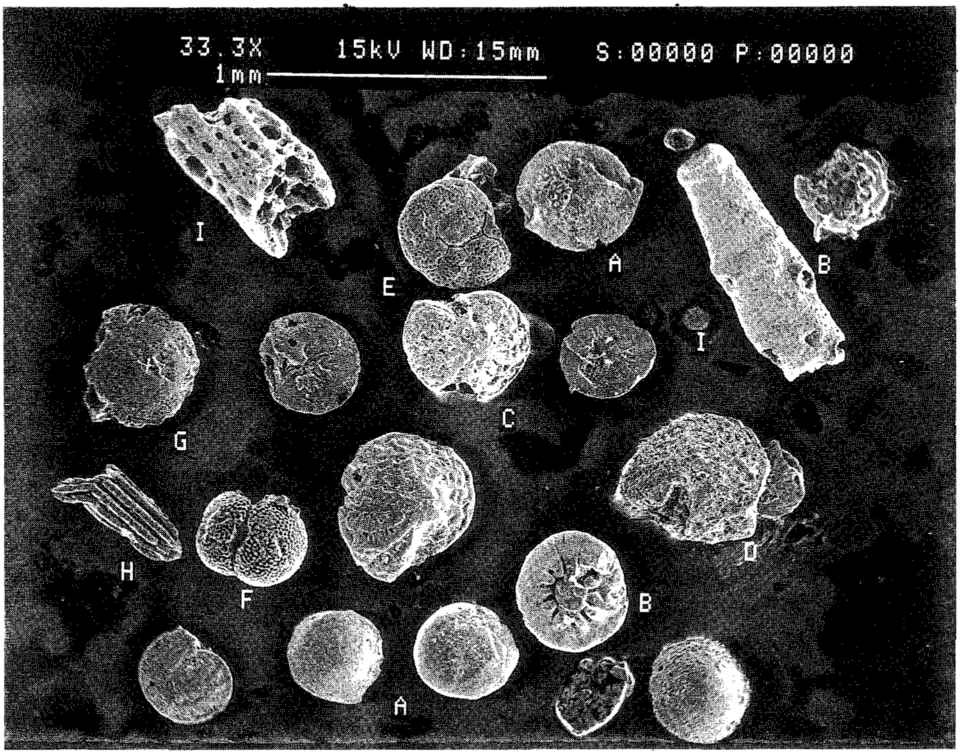


Fig. 76: Microfauna from the top of the southern channel fill (upthrown block).
A = *Asterigerinata planorbis* (D'Orbigny); B = *Ammonia beccarii* (Linné); C = *Elphidium rugosum* (D'Orbigny); D = *Elphidium crispum* (Linné); E = *Cibicidoides austriacus* (D'Orbigny); F = *Globigerinoides trilobus* Reuss; G = *Heterolepa dutemplei* (D'Orbigny); H = Seeigelstachel; I = Bryozoenrest.
St. Georgen sandpit.

material has been transported by rivers and reworked by marine processes. No pebbles of the Calcareous Alps have been found. In fact, large areas east of the Leitha Mountains and the Rust Ridge were not covered by sediments in Badenian time and tilting towards the east followed later in Pannonian and Pontian time (Fig. 51), accompanied by some faulting. One large SE dipping fault (Eisenstadt fault, Fig. 50) with a displacement of more than 80 m separates Badenian (NW) from Middle Pannonian (SE) (A. Tollmann, 1955). But because of its NW–SE direction, this fault seems to be formed by tension effects related to those in the Vienna Basin.

The sandpit which is used now as a refuse pit is up to 18 m high and 240 m long (Fig. 68). A normal fault, obviously belonging to the system of the Eisenstadt fault runs from the southern end of the pit to its mid upper edge (Fig. 69). It separates an upthrown block represented by the main part of the outcrop from a downthrown block, represented by the upper southern part.

The upthrown block consists of medium to coarse grained sandstone with frequent conglomerate layers. Channels cut the outcrop at the northern end and near the southern end and are filled by coarse gravel (Figs. 70,71). The material originates from crystalline sources. The southernmost part of the outcrop is composed of Leitha Limestone.

In the downthrown block a similar sequence of sandstones is developed, but frequently, lenses of cemented sandy limestone several feet thick containing coralline algal fragments are developed. A more continuous layer of limestone runs along the southern uppermost edge.

The structure of the upthrown block shows a gentle anticline in the northern part. At the northern end the layers dip about 20° westward. Elsewhere a uniform dip of 20° in southeastern direction dominates. Conjugate faults (130/50°, 310/60°) are visible in the anticline. The faultplanes are resistant to erosion because of greater cementation (Figs. 74,75). Their structural relationship to the mentioned larger 110–120/60° dipping normal fault is questionable. Striae on slickensides of the main fault indicate dip-slip motion (Fig. 72), greenish marly mylonite marks the faultplane in some positions (Fig. 73).

The downthrown block dips 170/20° in the southern part and gets nearly flat in the middle part of the pit.

The microfauna of the sandstone and in the coralline algal beds (thin section) contains coralline algae, echinoderms, bryozoans, mililoids, *Borelis melo, Textularia* sp., *Amphistegina hauerina.*

Badenian age can be deduced from this microfauna assemblage.

The top of the southern channel fill of the quarry contains also a Badenian microfauna (Fig. 76). The assemblage points to a shallow, nearshore facies. The sandstone composition varies considerably. The uncemented sands contain almost no carbonate grains (Fig. 77). In contrast the calcite cemented sandstone beds contain abundant reworked carbonate particles (Fig. 78).

The typical mineralogical compositions for these two types are given below:

Fig. 77: 45 % quartz, 25 % feldspar, 21 % crystalline rock fragments, 13 % mica, 2 % opaques.

Fig. 78: 5 % quartz, 16 % feldspar, 21 % crystalline rock fragments, 20 % bioclasts and carbonate particles, 37 % calcite cement.

The heavy mineral composition is predominantly of epidote/zoisite and apatite. There is no significant difference between calcite- and non cemented samples.

The heavy mineral composition is given below (5 samples; legend see stop 1/3):

	ZI	RU	BA	TI	TU	GR	EZ	HO	CD	AP
mean	2	1	2	2	1	11	55	0	0	25
min	tr	0	0	1	0	4	43	0	0	20
max	5	2	6	4	3	20	69	tr	1	31

Both the sandstone and heavy mineral composition indicate a proximal source, of low to medium grade metamorphic rocks. Taking into consideration the macroscopic observations mentioned above, a source in the eastern neighbourhood, which is now buried below the Pannonian Basin, is more probable.

Tectonic Setting of the Eisenstadt Area (L. Fodor)

The region around Eisenstadt belongs to the Middle–Late Miocene Eisenstadt Subbasin of the Vienna Basin. The basin is limited by the NE–SW-trending and SE dipping Eisenstadt fault in the north. This fault seems to diverge into several branches at its southern termination, SW of Eisenstadt. West of the town, the

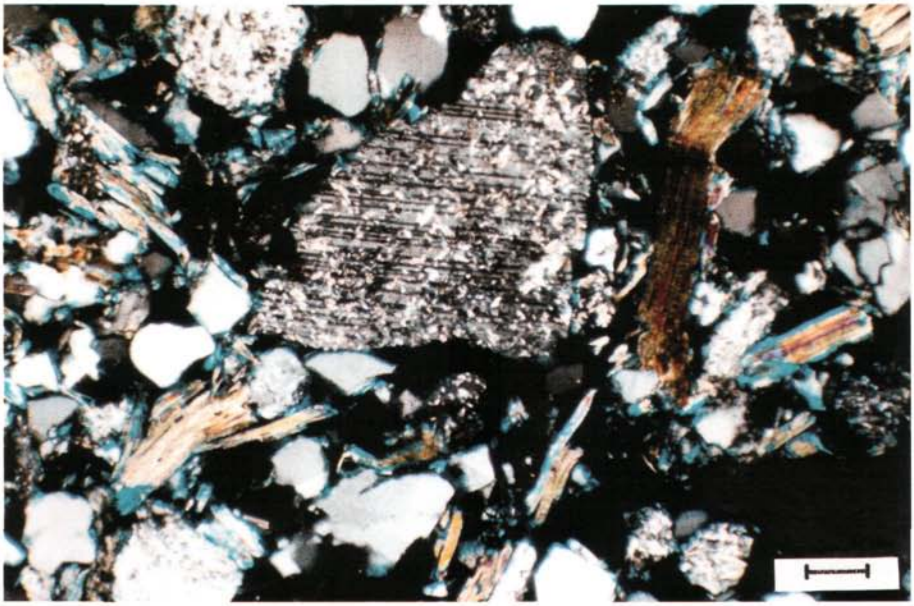


Fig. 77: Carbonate free sand with abundant quartz, mica and sericitized feldspars.
Sample 04, St. Georgen sandpit.
×Nicols; length of scale = 0.13 mm.

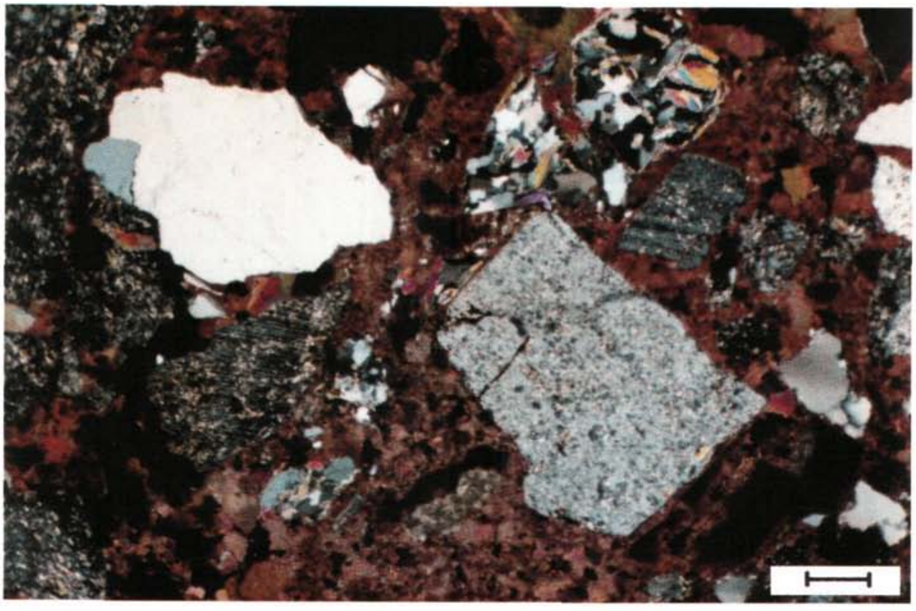


Fig. 78: Calcite cemented sandstone bed with abundant sericitized feldspars, rockfragments and grains of coralline algae.
Sample 05, St. Georgen sand pit.
×Nicols; length of scale = 0.13 mm.

main fault is associated with several smaller NS to NNE–SSW-oriented faults, which separate the crystalline basement and Badenian sediments. The main fault planes are not observable in the field. Their nature was determined by microtectonic observations.

This analysis demonstrated that during the Middle Miocene–Pliocene the basin was affected by an ESE–WNW-oriented extension, associated with a NNE–SSW directed compression. Numerous normal (micro)faults and dextral strike-slip faults resulting from this deformation affected the Badenian limestone in the quarries of Müllendorf, Kleinhöflein and Großhöflein. They are arranged en echelon with respect to the main Eisenstadt fault. This geometry, and the oblique extension suggests a left lateral component along the main border fault as well as a dip slip component.

The normal sense of displacement is clearly demonstrated in the two sandpits N of Eisenstadt (one of them is Stop 1/4). Several normal faults cut the Badenian sand sequence with displacements of 5–50 m. Between the larger faults, the blocks are fractured by small normal faults with displacements of less than 2 m. Faults dipping to the SE are 60–70°, while the conjugate faults are steeper, dipping to the WNW and ESE.

The deformation of Middle Miocene sediments suggests Late Miocene–Pliocene age for this tectonic episode. However, distribution of Middle Miocene facies, like conglomeratic or calcarenitic talus cones and shallow water carbonates, suggests that the Eisenstadt fault already controlled the Middle Miocene sedimentation.

STOP No. 1/5

LOCATION: St. Margarethen (Roman quarry) approx. 2 km east of St. Margarethen north of the main road to Rust (Figs. 50,79).

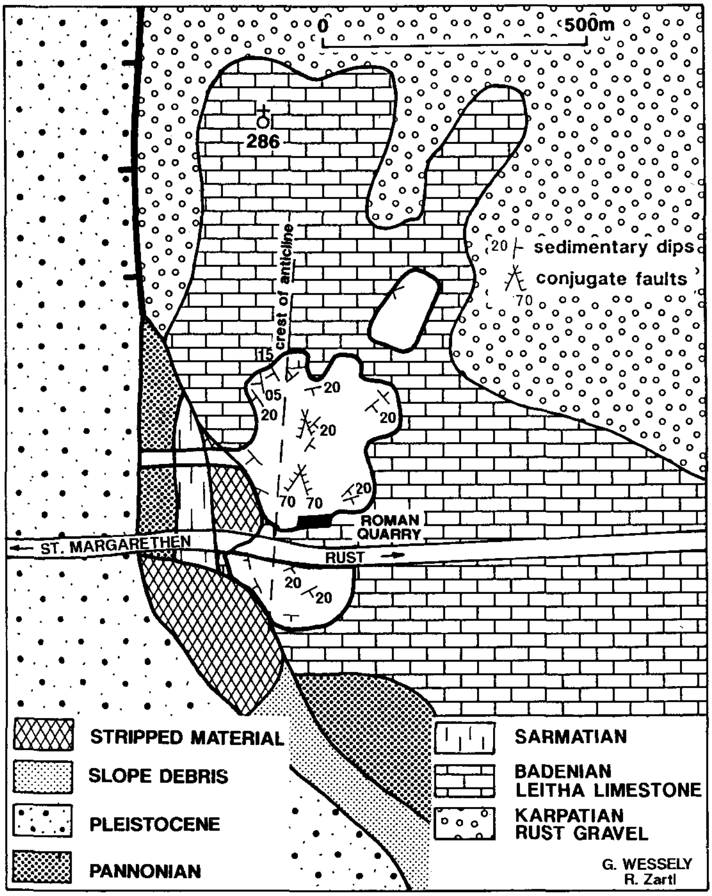
TECTONIC UNIT: Vienna Basin, Eisenstadt Subbasin.

STRATIGRAPHIC UNIT: Leitha Limestone.

AGE: Spiroplectammina to Bolivina Zone, Middle–Upper Badenian, Middle Miocene (W. FUCHS, 1965).

The Roman quarry of St. Margarethen, recently described by W. PILLER & N. VAVRA (1991), is one of the oldest and largest in Austria. The Leitha Limestone was quarried in Roman times, Roman engravations of the XV ROMAN LEGION still exist. The quarry was in its heyday during the baroque period (Fig. 84) and during the last century. The quarrystone was used for many famous baroque buildings in Vienna such as "St. Charles" church (Karlskirche) and the imperial summer residence Schönbrunn. In the last century it was also used for the construction of the larger buildings of the "Ringstraße" , for example the Opera House, Loanhall, Imperial Museum, National Theatre, etc. (A. KIESLINGER, 1949). Also St. Stephans Cathedral in Vienna is partly constructed from this material which also serves for restauration purposes (A. MENTLER, H.W. MÜLLER & B. SCHWAIGHOFER, 1986; A. ROHATSCH, 1991).

Today the quarry has limited but steady activity. Since 1959 a symposium has been held at the quarry attended by sculptors from many nations. Many of these quick works have been left on display (Figs. 82,83).



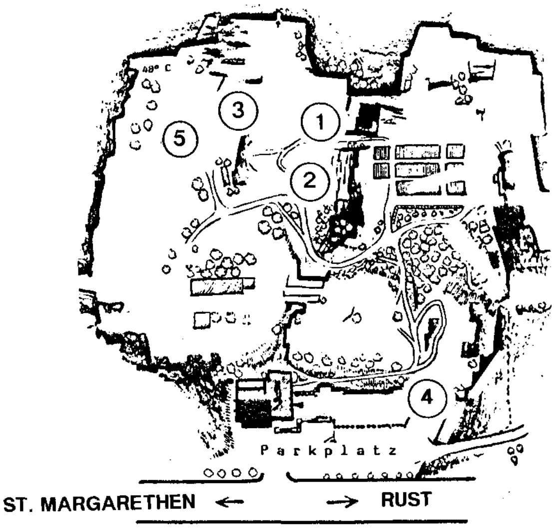


Fig. 79: Geological map of the Roman quarry of St. Margareten. Surrounding of the quarry after a geologic compilation by G. PASCHER & Ch. WIDHALM (1990). Numbers 1–5 in circles indicate position of objects in Figs. 81–85.

Fig. 80 ▲

Panorama of the Roman quarry in the Leitha Limestone of St. Magareten.

View from south to north.

Fig. 81 ▶

Conjugate faults near the crest of the anticline in the northern part (280/50–070/50).

St. Margareten, Roman quarry; position 1 in Fig. 79.

Fig. 82 ▶
"Goliath" (Achium).
St. Margareten, Roman quarry; position 2 in Fig. 79.

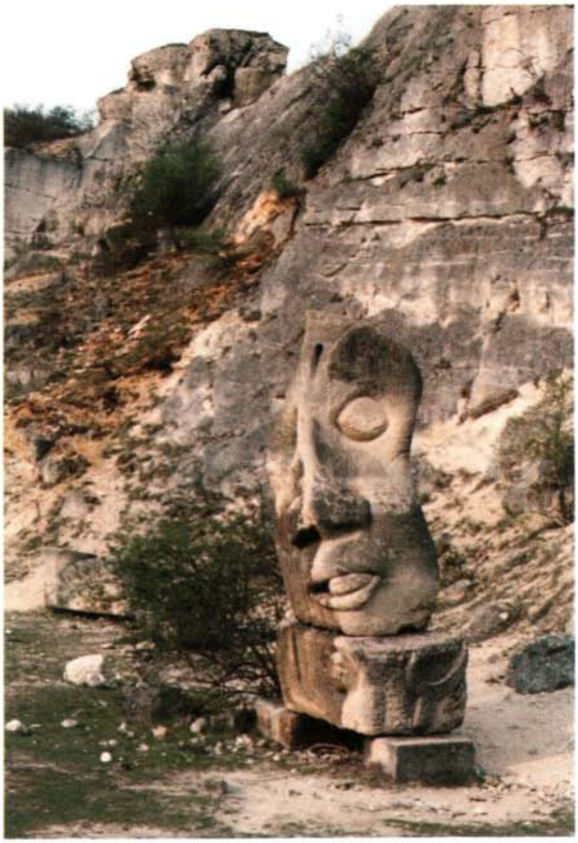


Fig. 83 ▼
Sculpture.
St. Margareten, Roman quarry; position 3 in Fig. 79.
The wall in the background shows a vertical groove (the Rille) formed by 5 Japanese artists. The groove coincides almost with the crest of the updoming exposed in the quarry.

Fig. 84.
Stonemason's Baroque relief (1761).
St. Margareten, Roman quarry; position 4 in Fig. 79.

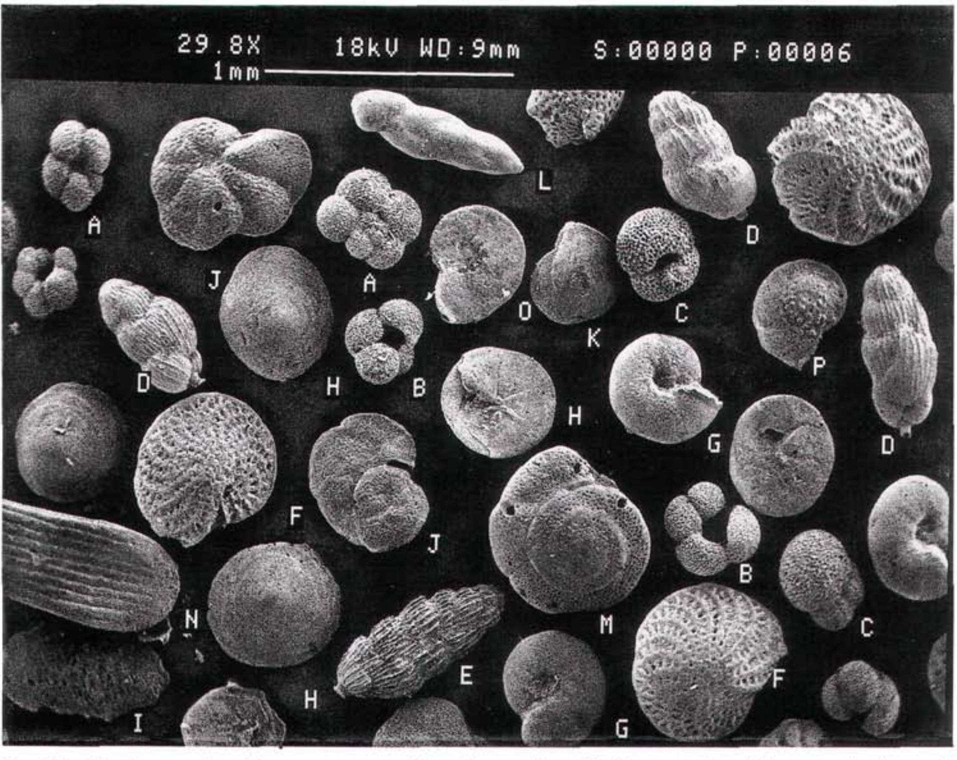


Fig. 85: St. Margareten, Roman quarry; Microfauna (det. O. Schreiber) within a marly layer at the bottom of the quarry.
A = *Globigerina concinna* Reuss; B = *Globigerina bulloides* D'Orbigny; C = *Globigerinoides trilobus* Reuss; D = *Uvigerina semiornata* D'Orbigny; E = *Uvigerina liesingensis* Toula; F = *Elphidium crispum* Linné; G = *Melonis pompilioides* (Fichtel & Moll); H = *Asterigerinata planorbis* (D'Orbigny); I = *Spiroplectinella carinata* (D'Orbigny); J = *Cibicides lobatuslus* (Walker & Jacob); K = *Lenticulina inornata* (Dorbigny); L = *Fursenkoina acuta* (D'Orbigny); M = *Heterolepa dutemplei* (D'Orbigny); N = Seeigelstachel; O = *Cibicides boueanus* (D'Orbigny); P = *Cibicides pseudoungerianus* (Cushman).
St. Margareten, Roman quarry; position 5 in Fig. 79.

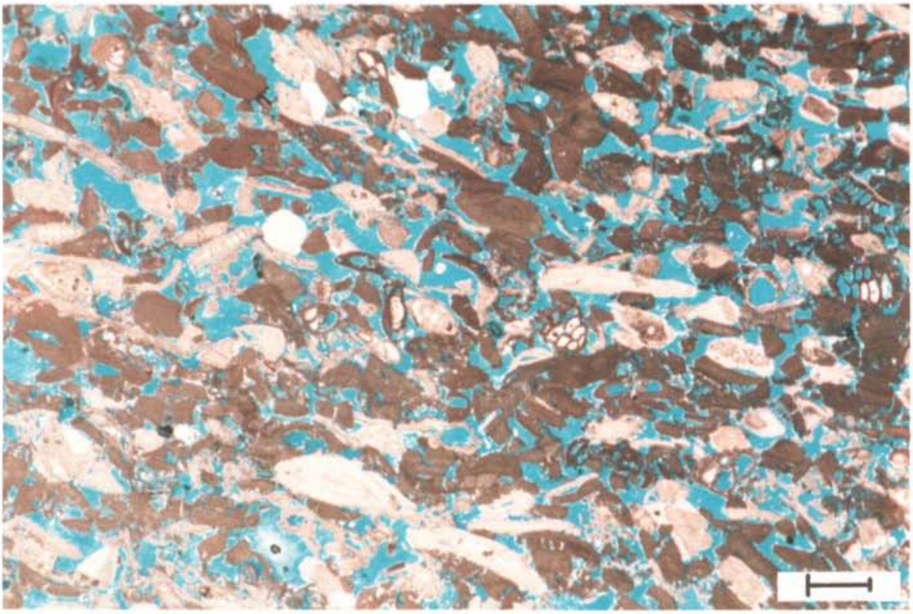


Fig. 86: Photomicrograph showing the highly porous Leitha Limestone (por. eff: 29 %; perm: 522 md).
St. Margareten, Roman quarry; length of scale = 0.69 mm.

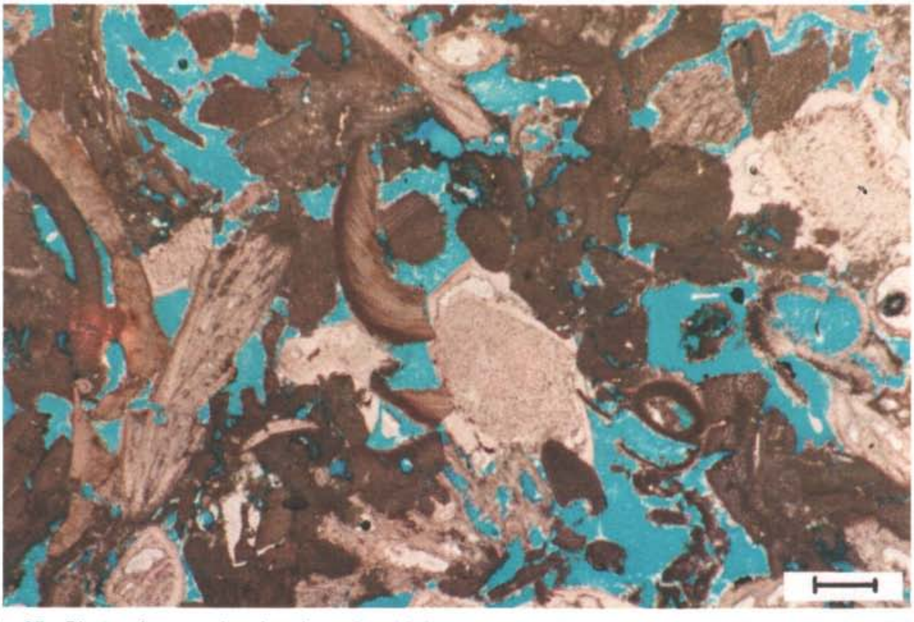


Fig. 87: Photomicrograph showing the high amount of secondary solution porosity (blue stained).
St. Margareten, Roman quarry; length of scale = 0.3 mm.

The Roman Quarry of St. Margarethen is situated on the NS-extending "Ruster Höhenzug" (Rust Mountain ridge; Fig. 50), which separates the Eisenstadt Subbasin from the Pannonian Basin (Fig. 51). Lake Neusiedl belongs to this gently eastward tilting basin.

Along the Rust Mountain ridge crystalline members of the Lower Austroalpine unit are exposed. They are overlain by (?)Karpatian Rust Gravel and by Badenian litoral sediments especially Leitha Limestones. West of the Roman quarry an old railroad cut exposes coarse Sarmatian clastics followed by Pannonian marls and sandstones to the east (W. FUCHS, 1965).

The western margin of the Rust Mountain ridge is accentuated by faults. In the Roman quarry (Figs. 79,80) the sediments show an updoming with an axis in NS direction plunging gently to the south. Conjugate pairs of faults compensate for the tension caused by the updoming (Fig. 81).

The Leitha Limestones of this quarry are characterized by poorly cemented and highly porous limestones (Figs. 86,87). According to DULLO (1983), the limestones represent several microfacies types ranging from foraminiferal facies, foraminiferal algal debris facies, foraminiferal rhodolite facies, to pavement facies. Generally, foraminifers, echinoids, bryozoans and coralline algae are the dominant sediment constituents. The pavement facies is developed in layers with rhodoliths up to 10 cm in diameter. Molluscs are represented mainly by oysters – in some layers enriched – and pectinids.

The Carbonates can be interpreted to be deposited in a shallow water environment. In shallow depressions, accumulation of rhodoliths (pavement facies) occurs.

Greenish marls, temporarily exposed at the bottom of the quarry, contain a rich microfauna (Fig. 85).

STOP No. 1/6

LOCATION: Wolfsthal, "Herrschaftsteinbruch" (Figs. 47,88).
TECTONIC UNIT: Vienna Basin.
FORMATION: Sarmatian, oolith sands.
AGE: Upper Sarmatian, Middle Miocene.

The outcrops of the "Herrschaftsteinbrüche" in Wolfsthal are located in the Hainburg Mountains (Fig. 88), which form the eastern border of the Vienna Basin, as well as the western margin of the Pannonian Basin (G. WESSELY, 1961). This marginal position results in a wide variety of facies related to coastal processes: Several phases of erosion and resedimentation took place and deposits of different ages from the Badenian to the Pontian often rest directly upon pre-Neogene rocks. The older deposits are largely in the western part of the mountain group, the younger in the eastern part. Cliffs formed by Mesozoic rocks produced coarse clastics, especially during Badenian time (mainly breccias containing a variable amount of coralline algae, Bryozoa, etc.). In contrast granitic shorelines formed sediments of smaller grain size. In Sarmatian time oolites and small buildups of reefs, formed by Bryozoans or by sessile foraminifers of the genus *Nubecularia* are common. The Sarmatian of Wolfsthal rests directly on granite. In the quarry "Herrschaftssteinbruch" (Fig. 89) these oolites form layers up to several meters thick. Intercalations of coquinas of bivalves (Fig. 90)

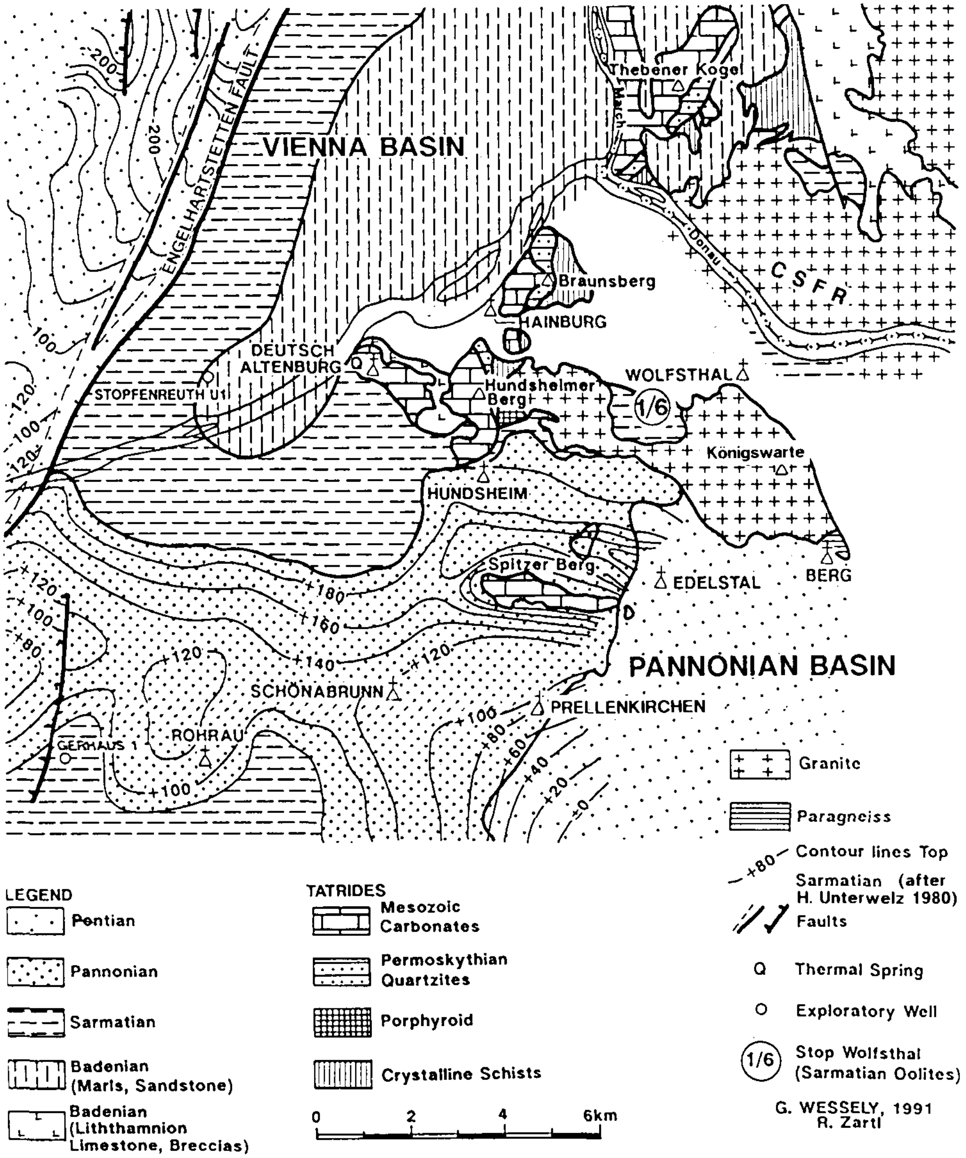


Fig. 88: Southern Carpathians and border zones of the Vienna Basin and Pannonian Basin in the area of Hainburg/Wolfsthal (G. WESSELY).

and gastropods are frequent. The sediment contains typical shallow water foraminifers and ostracods.

Reefs of foraminifers, of the species *Nubecularia caespitosa* can be found in growth position in the upper part of the quarry. In some cases, large blocks have been redeposited in a distorted position. Complete specimens of *Modiolus incrassatus* were overgrown by Nubecularians (Fig. 91).

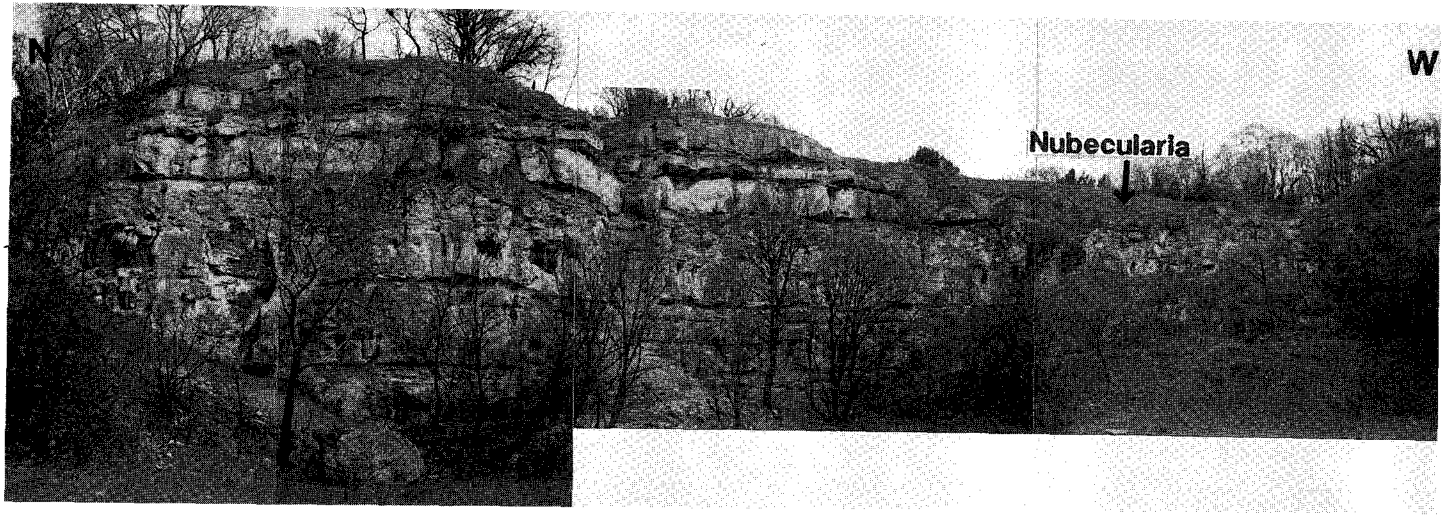


Fig. 89: Layers of oolites containing coquinas and reefs of foraminiferes (*Nubecularia caespitosa*). Quarry Wolfsthal "Herrschaftssteinbruch".

Fig. 90: Coquina of *Ervilla, Mactra, Irus* and *Cardium*.
Quarry Wolfsthal.

Fig. 91: Foraminiferal reef overgrowing whole specimens of *Modiolus*.
Quarry Wolfsthal.
Parts of the reefs are in a distorted position.

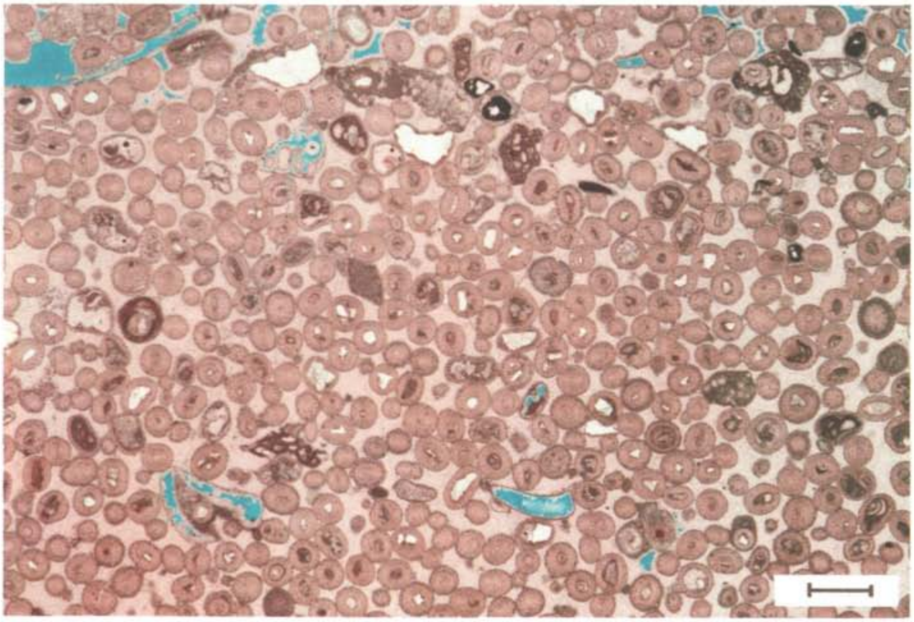


Fig. 92: Oolithic limestone (grainstone, oosparite) with some dissolved bioclasts forming molds. Quarry Wolfsthal, Herrschaftssteinbruch; Upper Sarmatian; length of scale = 0.11 mm.

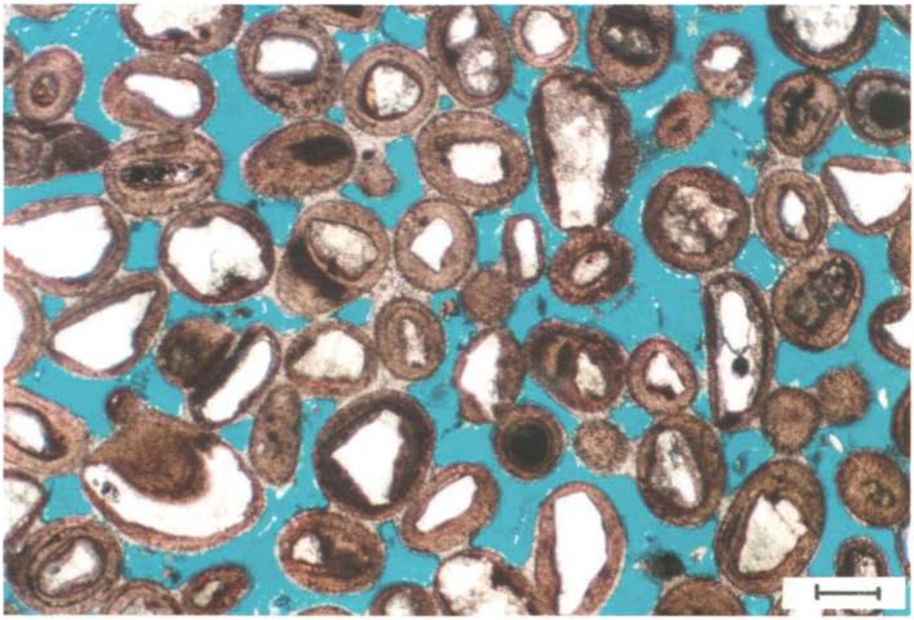


Fig. 93: Highly porous oolithic limestone.
The nuclei of most ooids consist of quartz or granite grains (pores blue).
Quarry Wolfsthal; length of scale = 0.3 mm.

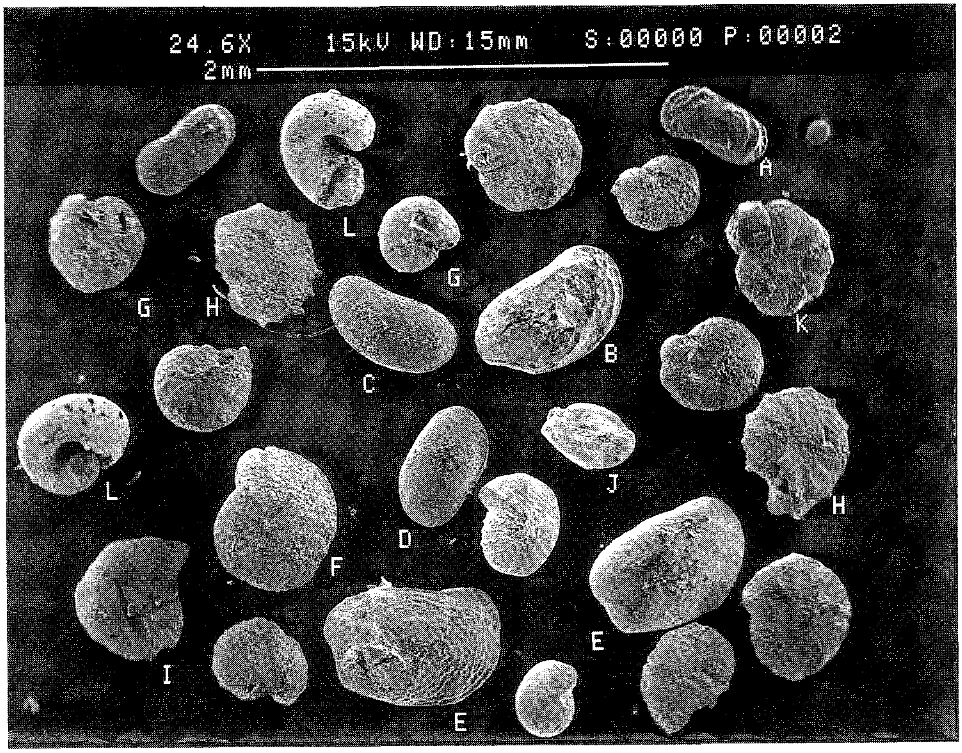


Fig. 94: Microfauna of the Sarmatian of Wolfsthal.
A = *Callistocythere egregia* (MEHES); B = *Hemicytheria omphaloides* (REUSS); C = *Bythocypris* sp.; D = *Loxoconcha* sp.; E = *Aurila notata* (REUSS); F = *Elphidium glabrum* BYSTRICKA; G = *Elphidium hauerinum* (D'ORBIGNY); H = *Elphidium aculeatum* (D'ORBIGNY); I = *Elphidium* cf. *macellum* (FICHTEL & MOLL); J = *Triloculina* sp.; K = *Anomalinoides* sp.; L = Gastropodensteinkern (det. O. SCHREIBER).

The core of the ooids is formed by quartz grains, sometimes by foraminifers (Figs. 92,93).

The fauna contains different species of *Ervilia, Mactra, Irus, Cardium, Congeria, Modiolus* and of the gastropods *Pirenella* and *Cerithium*.

The assemblage of foraminifers consists of *Quinqueloculina sarmatica, Nonion granosum* and abundant specimens of *Elphidium*. The Ostracods are represented by *Aurila notata, Leptocythere, Xestolebris* and *Loxoconcha* (Fig. 94).

EXCURSION 2

A general overview of the main sedimentary units in eastern Austria with special reference to the Autochthonous Mesozoic formations below the Molasse, the Vienna Basin and the Flysch Zone is given by the Core exhibition (Stop 2/1).

The Stops 2/2–2/5 (Fig. 52) show parts of these formations sheared off from the autochthonous cover of the eastern flank of the Bohemian Massif and transported westward within the thrust complexes of the Waschberg Zone. Stop 2/6 demonstrates the historical as well as the most recent deep exploration activities in the Zistersdorf area, from a view point on the Steinberg ridge.

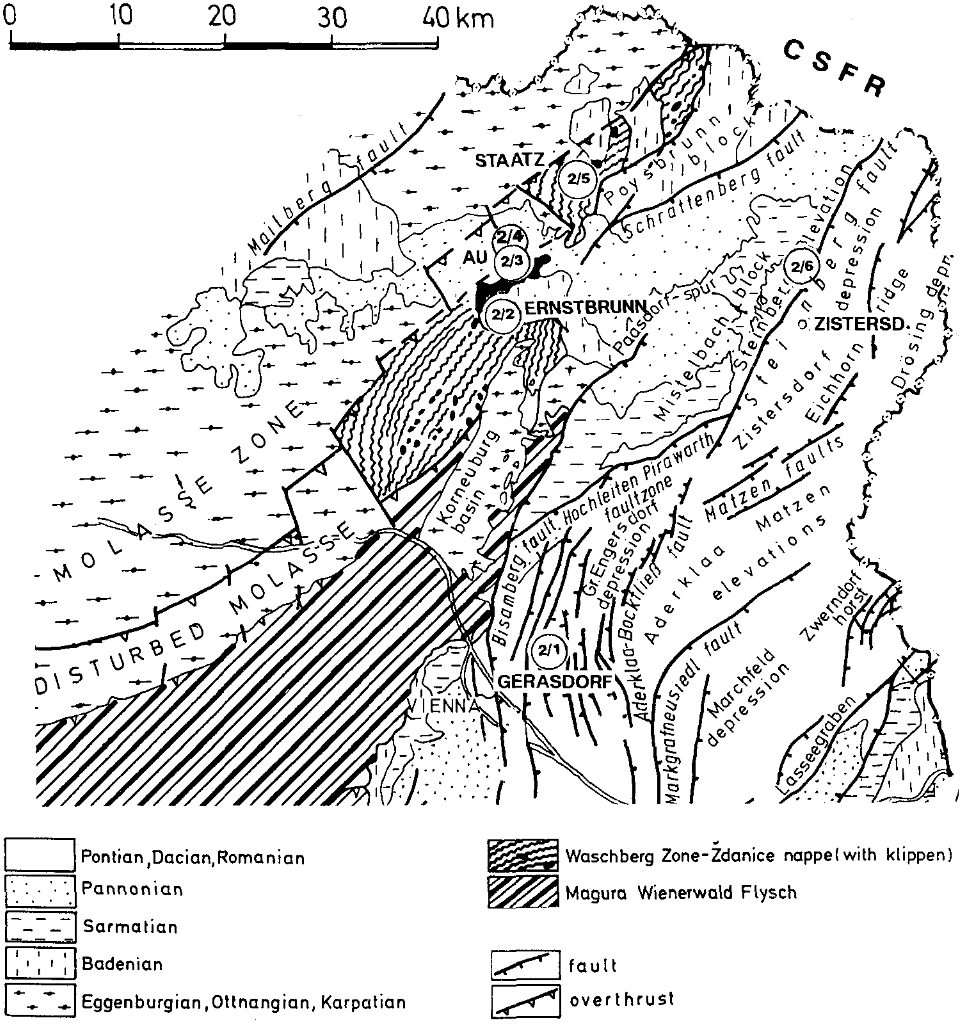


Fig. 95: Northern Vienna Basin and Waschberg Zone.
Stops of Excursion 2.
After G. WESSELY, 1988).

STOP No. 2/1

CORE EXHIBITION LOCATION: ÖMV-AG, Zentrum Gewinnung. Gerasdorferstraße 151, A-1210 Vienna.

Selected cores of all the important rocks of the Vienna Basin, its Alpine-Carpathian floor below and especially Autochthonous Mesozoic will be presented and discussed. Geological cross sections, well logs, strip logs, thin-sections and SEM photomicrographs will also be shown. The exhibition includes important key wells of the Vienna Basin such as the 8553 m deep well Zistersdorf UT2A and the 6630 m deep Aderklaa UT1a. The significance of these wells and their contribution to the understanding of the stratigraphy and hydrocarbon generation in the region, will be explained. For compilative stratigraphic and tectonic graphs explaining these topics see part I of this guide book.

Fig. 96: Example of the core exhibition.

Core fragment of Aderklaa UT1b, depth 6247 m, showing the crystalline basement overlain by Malmian limestone filling cracks within the crystalline (garnet-bearing, diaphtoritic biotite-, chlorite-, sericite-phyllite).

The well Aderklaa UT1, situated at the northern ege of Vienna encountered Neogene, the frontal parts of the Calcareous Alps, equivalents of the Waschberg Zone, Autochthonous Mesozoic and Crystalline of the Bohemian Massif. Molasse has been removed by thrusting.

STOP No. 2/2

LOCATION: Ernstbrunn quarry (Figs. 95,97).

TECTONIC UNIT: Waschberg Zone.

FORMATION: Ernstbrunn Formation, Klentnice Formation, Klement Formation.

AGE: Malmian, Upper Cretaceous.

The quarry is situated within the "Leiser Berge" in the Ernstbrunn Limestone, which is a klippen in the external part of the allochthonous Waschberg Zone (Fig. 98). The Ernstbrunn Limestone and the Klentnice beds were matter of many paleontological and geological investigations (K. JÜTTNER, 1933; F. BACHMAYER, 1958; R. GRILL, 1953, 1961, 1963; M. ELIAS, 1961, E. HANZLIKOVA, 1965, Th. HOFMANN, 1990). An extensive bibliography is documented in A. TOLLMANN (1985, p. 419).

During the last Alpidic orogenic phase the passive margin of the Bohemian Massif, covered by Middle Jurassic to Eocene shelf sediments, was turned into a foreland Molasse trough. The Alpine-Carpathian nappe system moved onto this foreland toward the NW during the last stage of its progradation in Upper Oligocene to Lower Miocene. The shaly–sandy Molasse sequence, deposited at that time, got involved in the thrust movement, together with parts of the underlying Upper Jurassic to Eocene formations. As a result we find Upper Jurassic thrust sheets bedded within the Lower Miocene sand–shale sequence (Fig. 98).

The deepest stratigraphic member is exposed in the NE (right) part of the quarry at the 3rd floor. The Klentnice Formation, dark gray detrital limestones and marls, appears below the massive white Ernstbrunn Limestone, dipping SW (230/40°) at this point. Along the northwestern, left side of the 3rd floor we see the typical development of this formation.

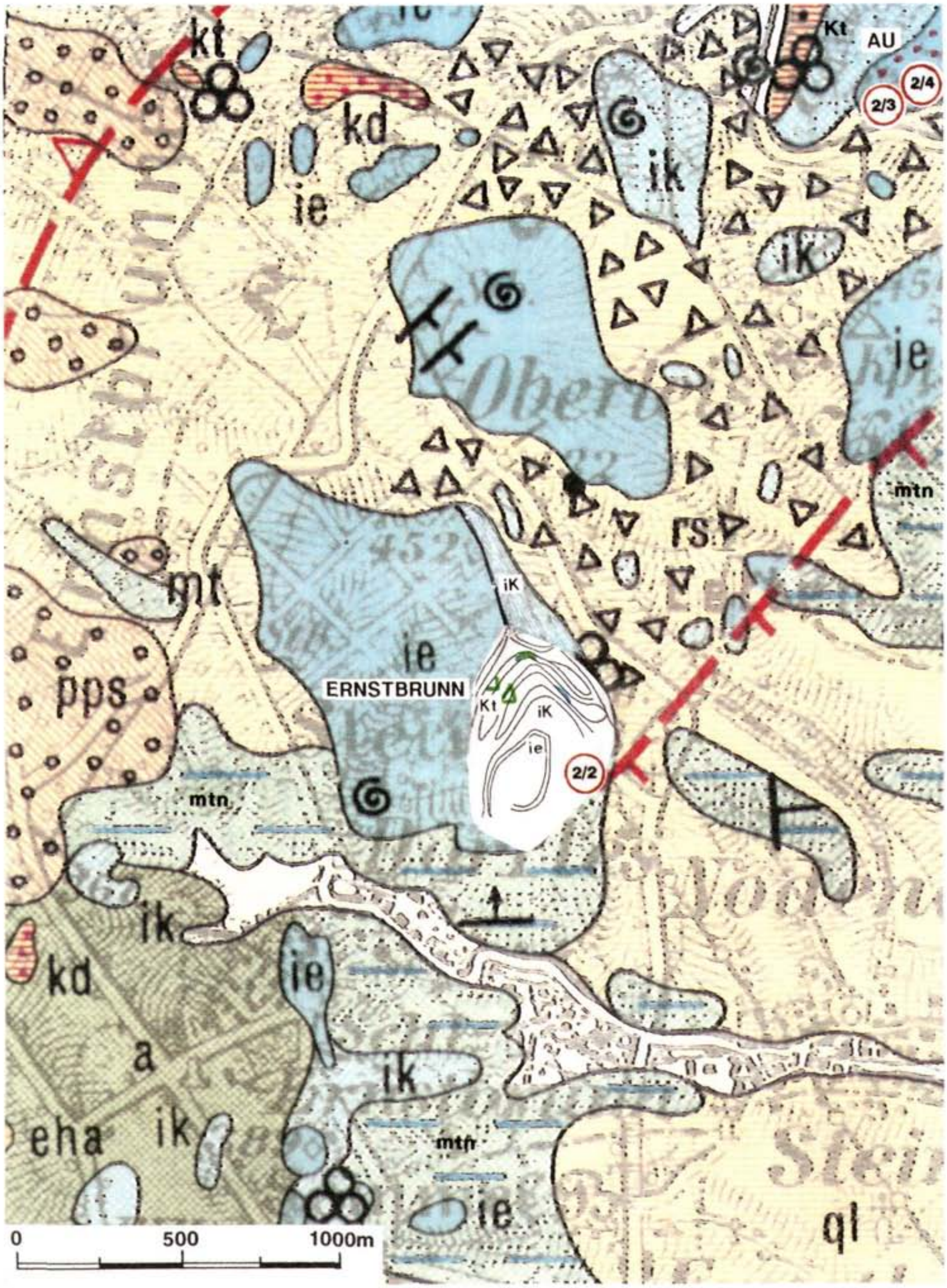
At the first floor we find patch reefs built by corals, algae etc., surrounded by detrital carbonates (Fig. 100). Typical for some parts of the Ernstbrunn limestone are "Steinkerne" of the bivalve *"Diceras"* (Fig. 102). More rare in the Ernstbrunn quarry, they are abundant in the Dörfles area (Th. HOFMANN, next chapter).

The Malmian carbonate platform was uplifted during the Lower Cretaceous. Erosion and karstification and in situ brecciation took place. In the Ernstbrunn Limestone we can observe fillings by several calcite generations and calcarenite (Fig. 101).

In the uppermost middle part of the quarry the limestone is in situ brecciated and split into blocks with some arenitic and pelitic matrix between. In the western part of the 3rd floor a deep pocket, a karstification feature, penetrates 12 m down from the surface. It is filled by greenish glauconitic marly sandstones and carbonate breccias of the Klement Formation (Figs. 103,104). Sedimentation at the Ernstbrunn carbonate platform was terminated at the end of the Malmian.

ZEISS & BACHMAYER (1989) working with ammonites and REHANEK (1987) using calpionellids, found that the deposition of the Ernstbrunn limestone started in the middle Middle Tithonian and continued to the end of the Tithonian. The stratigraphic section in the quarry is only to the lower Upper Tithonian.

Fig. 97: Geologic frame of the excursion stops 2/2, 2/3, 2/4.
Section Ernstbrunn of the "Geologische Karte des nordöstlichen Weinviertels, 1 : 75.000" (R. GRILL, 1961).



rs = debris; gl = Quarternary Löss; pps = Hollabrunn gravel fan (Lower Pannonian); mt = Badenian i.g.; mtn = Lower Badenian; a = Auspitz marls (Oligocene); om = Michelstetten Formation (Oligocene); eha = Haidhof Formation (Middle Eocene); Kd = Bruderndorf Formation (Paleocene); Kt = Klement Group (Turonian); ie = Ernstbrunn Limestone; le = Ernstbrunn Limestone, dolomitized; IK = Klentnice Formation (Malmian).

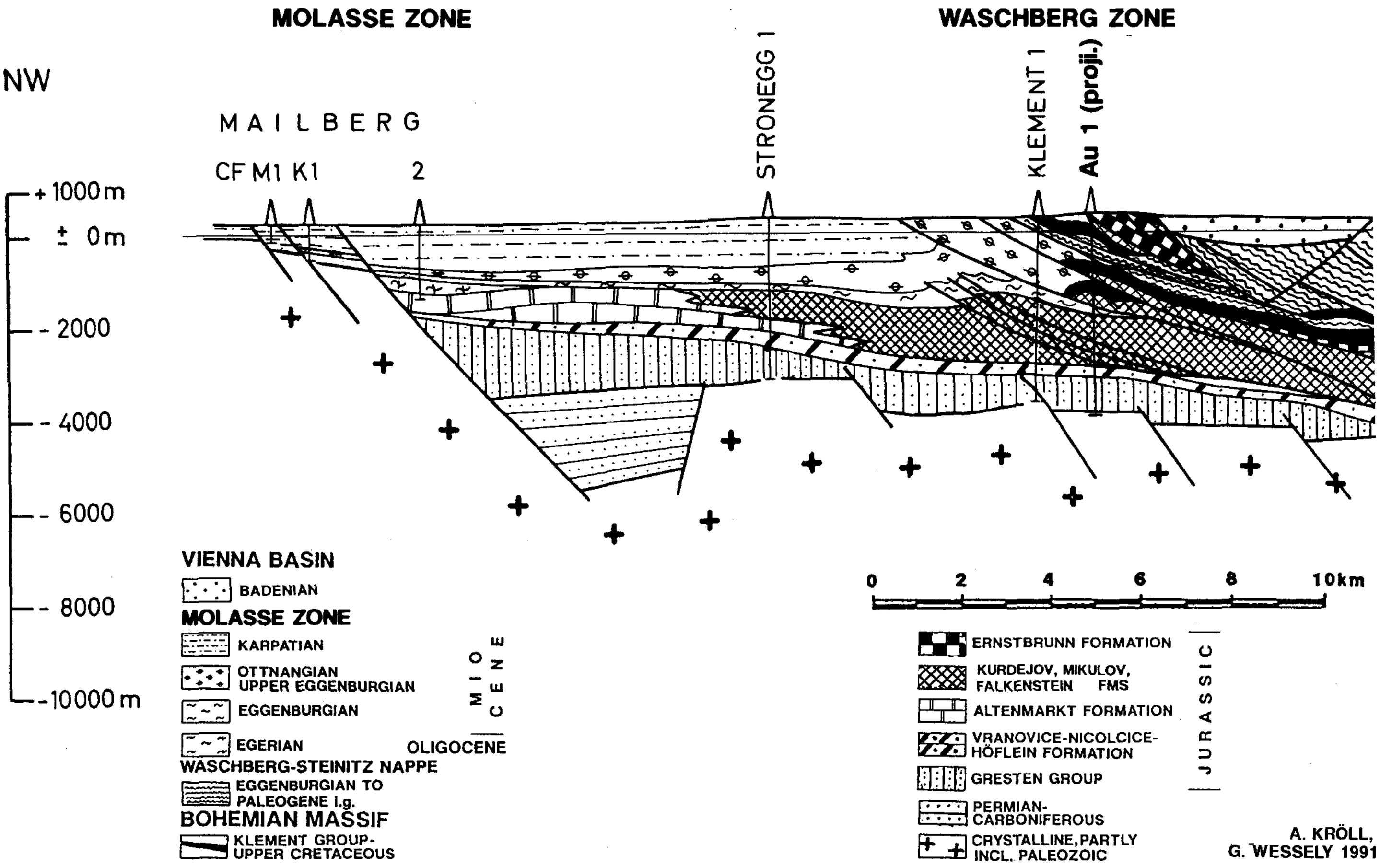


Fig. 98: Cross section through the Molasse and Waschberg Zone of the Ernstbrunn – Au area. After F. BRIX, A. KRÖLL & G. WESSELY (1977, modified).

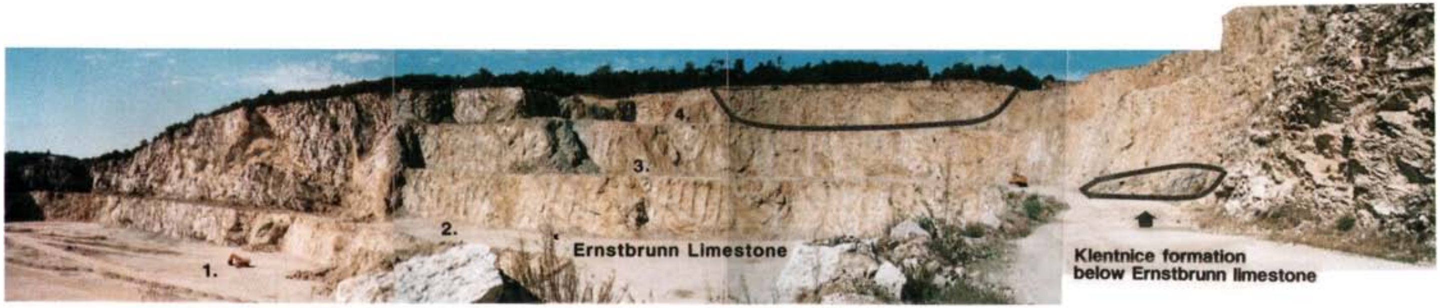


Fig. 99: Panorama of the quarry Ernstbrunn.

Facies Types and Paleoecology of the Ernstbrunn Limestone of Dörfles

(Th. Hofmann, 1990)

Six different facies types were distinguished with the carbonate classification after Dunham (1962) and Embry & Klovan (1972).

An analysis of selected foraminifera shows the abundance of certain taxa in distinct facies types (Fig. 105).

○ Wackestone facies and Transitional facies

Smooth weathered surfaces and the lack of macrofossils are characteristic. Mostly we find a micritic matrix, sometimes (transitional facies) sparitic blocky cement. The transitional facies is to a certain extent grain supported and shows similarities to the packstone facies. These two facies types are often found together. Bioturbation seems to be responsible for this. Peloids, fecal pellets, various coated grains, some algal fragments, and foraminifera are the main components of these two facies types.

Among rarely occuring foraminifers, *Trocholina* sp. is the most abundant.

○ Pack- and Grainstone facies

(Fig. 106)

A rough weathered surface is characteristic in the field. This is the result of differential weathering of components and matrix.

It is possible to distinguish between packstones and grainstones only in thin sections. Peloids, bioclasts and rarely also intraclasts occur together with many algae, which act as encrusting organisms (*Lithocodium, Bacinella*) building sometimes cm-large nodular aggregates or oncoids. Various sections of dasyclad algae give important enviromental information. Nearly all components are coated either by a thin micritic envelope or by encrusting algae.

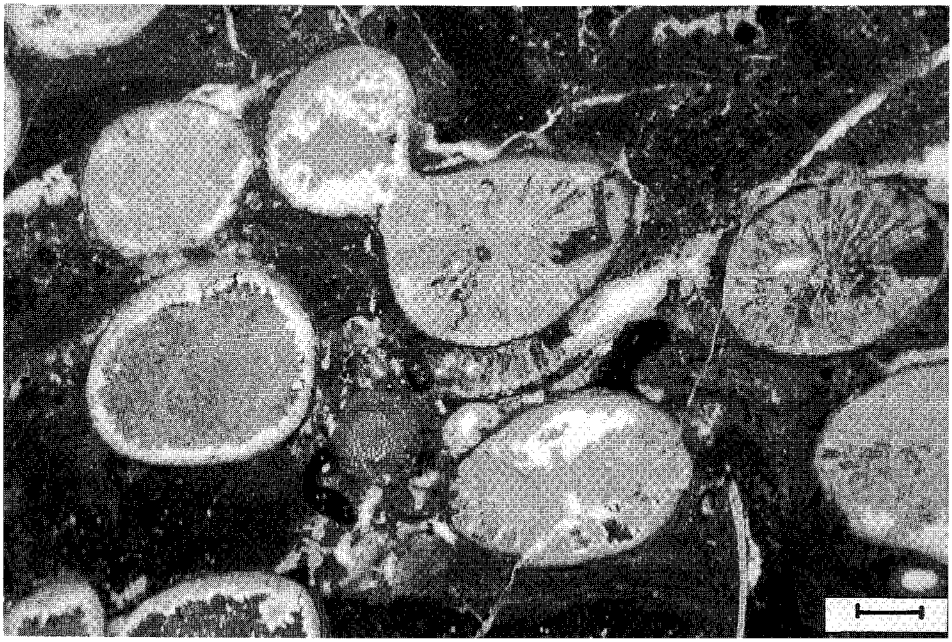


Fig. 100: Thin section of the coral Limestone (Ernstbrunn Formation).
Ernstbrunn quarry; length of scale 2.2 mm.

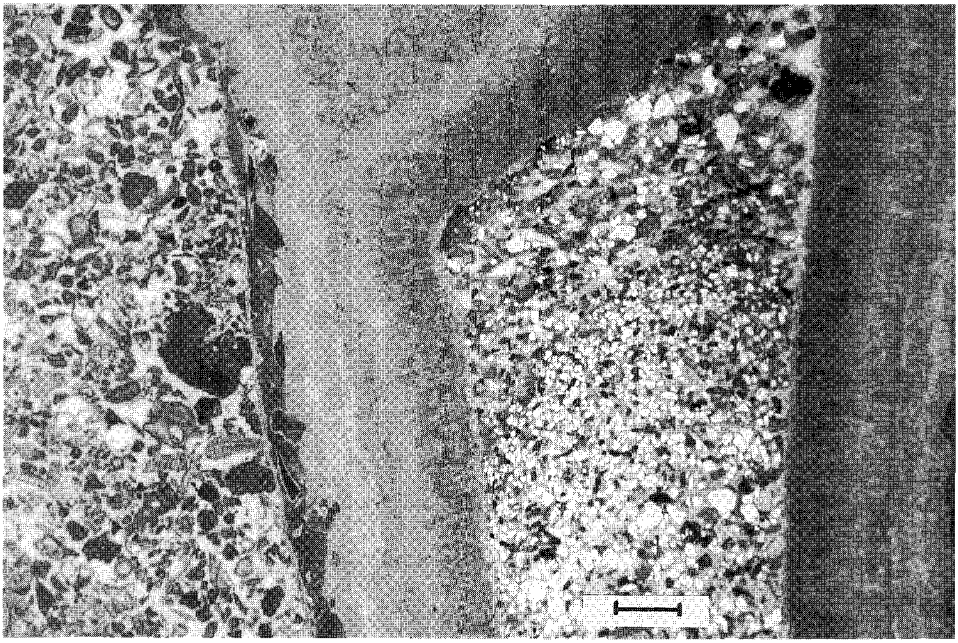


Fig. 101: Detail of cement and cavity filling in the Ernstbrunn limestone. Ernstbrunn quarry; length of scale = 1,33 mm.

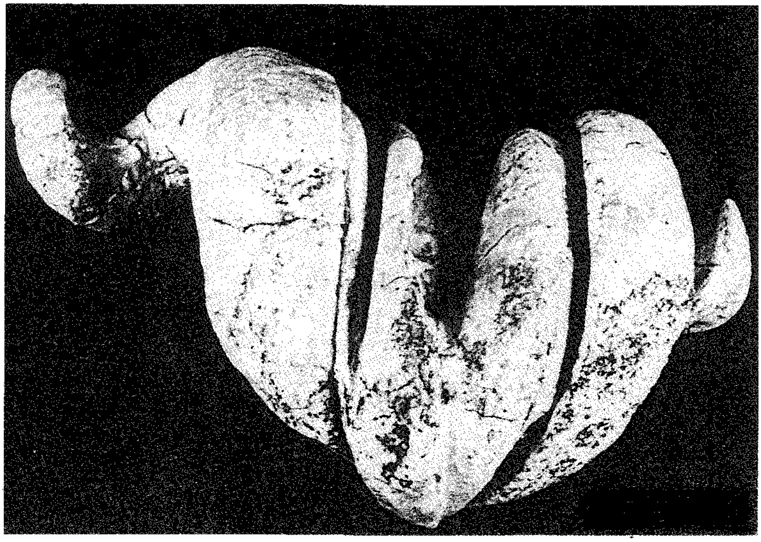


Fig. 102.
Steinkern of *Diceras arietinum*.
Ernstbrunn Limestone.
Collection Gottschling.

The packstone facies yields a great variety of foraminifers with a great diversity of taxa.

○ Algal Bindstone facies
(Fig. 107)

Encrusting algae like *Lithocodium, Bacinella, Thaumatoporella parvovesiculifera*, build large flat aggregates covering and stabilizing the sediment. A grid like sur-

Fig. 103: Ernstbrunn Limestone, pockets filled by Klement glauconitic marly sandstone.
Ernstbrunn quarry.

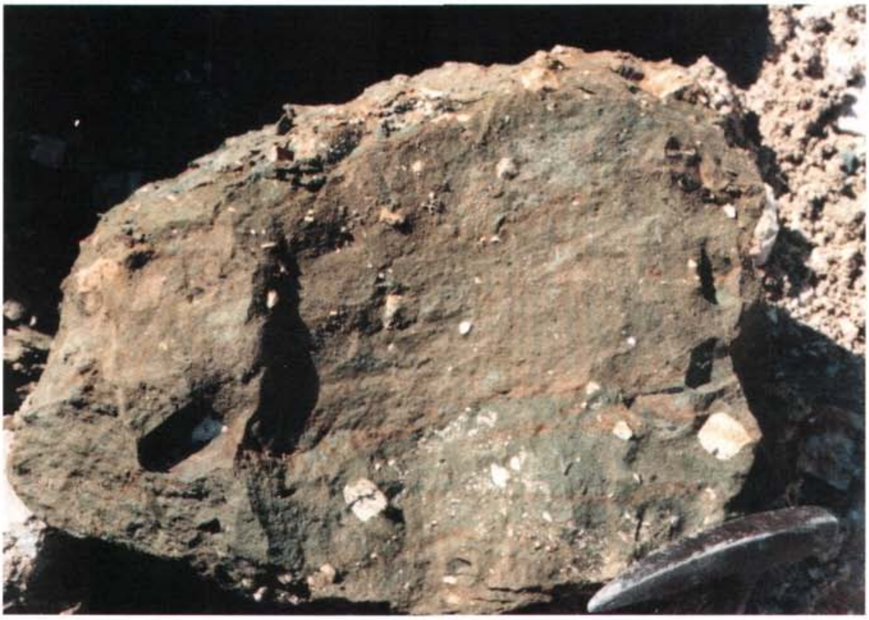


Fig. 104: Klement Group, glauconitic marly sandstone with components of Ernstbrunn Limestone.
Ernstbrunn quarry.

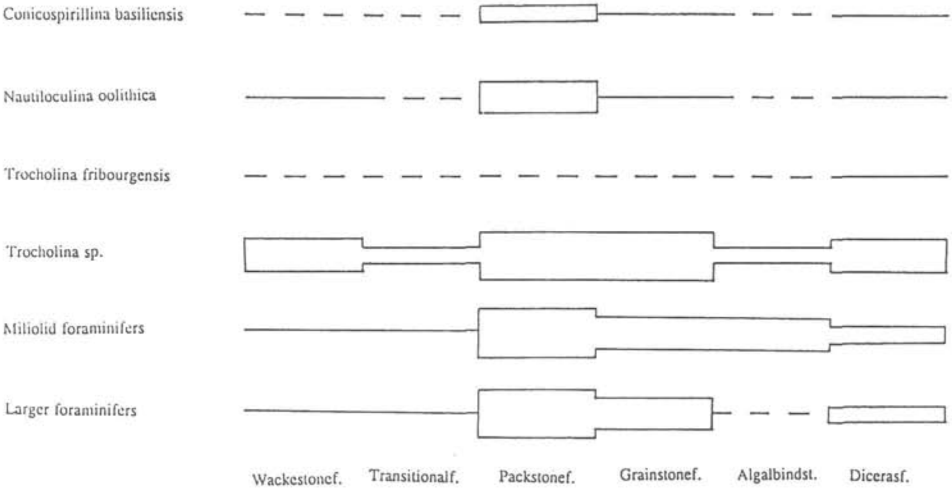


Fig. 105: Distribution of Foraminifers.

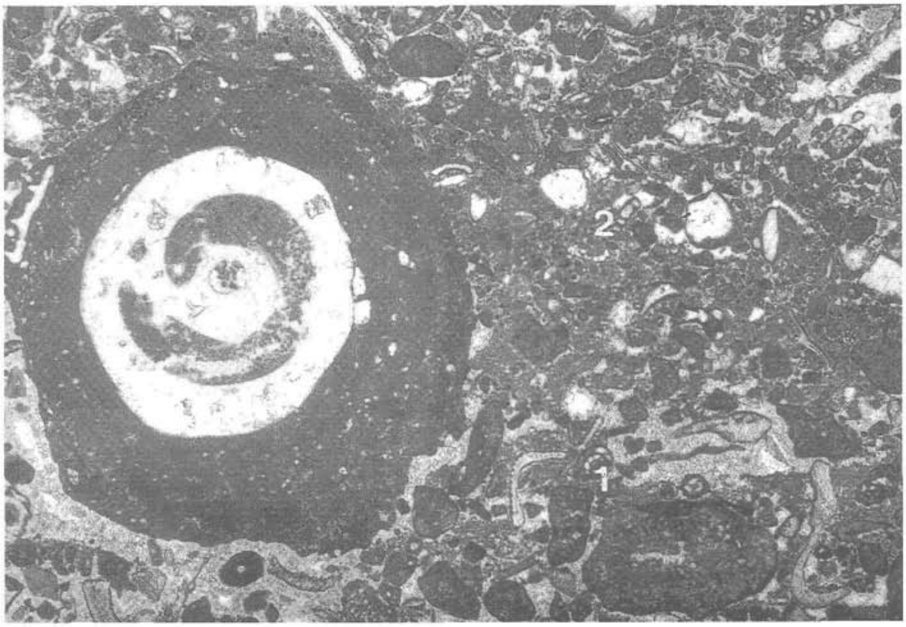


Fig. 106: Pack-Grainstone Facies (DöV/p).
Poorly sorted, grain supported sediment with two generations of sparite. The oncoid, *Nautiloculina oolithica* (1), fragments of dasyclad algae (2) and micritic encrustations provide more information about the environment.
Enlargement ≈ ×10.

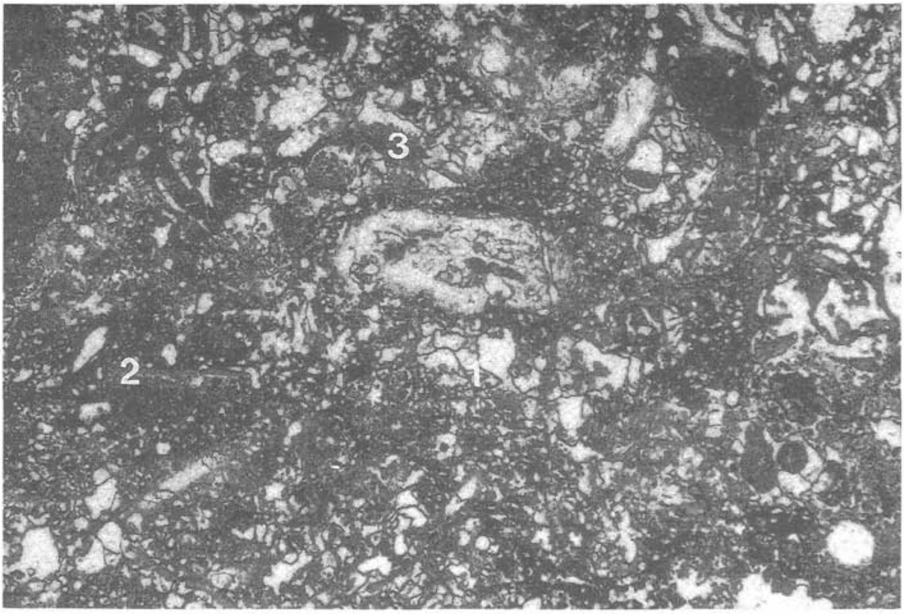


Fig. 107: Algal Bindstone Facies (Döv/10).
Binding components *Bacinella* (1) and *Thaumatoporella parvovesiculifera* (2) stabilize the surface of the sediment. Internal voids may be filled with pellets (3).
Enlargement ≈ ×10.

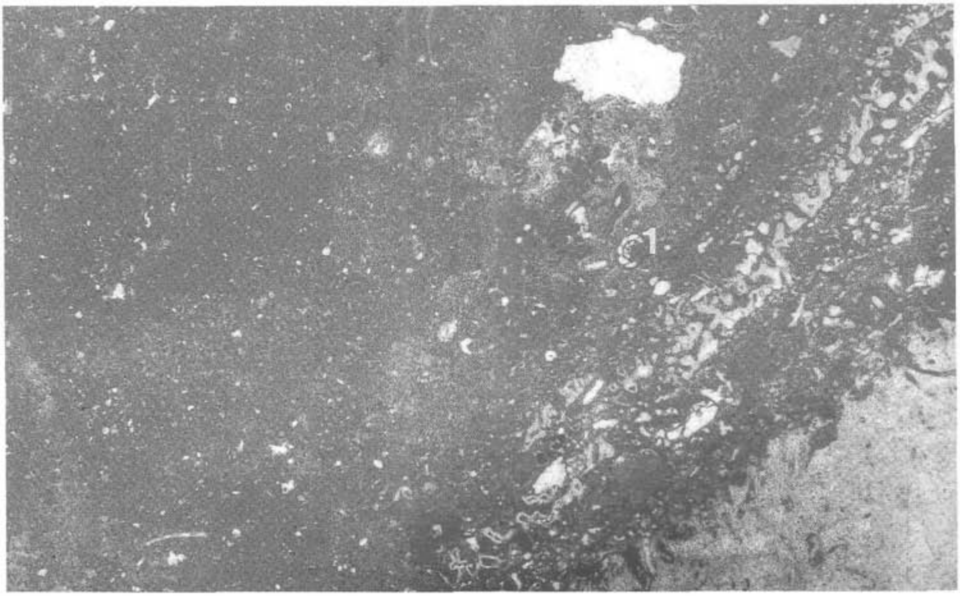


Fig. 108: *Diceras* Facies (DöIII/4).
Thick encrustations cover the bored shell of bivalve (*Diceras*?). Fine sediment, here with *Nautiloculina oolithica* (1), is found between these shells.
Enlargement ≈ × 11.

face is typical in the field. Internal vugs may be filled either totally or partly with pellets or silt, in the later case dog tooth cement is occasionally observed. Sometimes areas with pack- or grainstones are observed in between this facies. These sparitic sediments indicate a higher energy, which seems to be responsible for the origin of cm-large nodular aggregates or oncoids found in the pack- and grainstone facies. Fissures were filled synsedimentarily (Fig. 108). Miliolid foraminifers are most frequently observed followed by *Trocholina* sp.

○ *Diceras* facies (Bafflestone facies)
(Fig. 108)
Densely packed *Diceras* shells coated by encrusting organisms in association with nerineid gastropods are typical for this facies.
The "Steinkerne" of *Diceras* specimens – shells are rarely preserved – are the most common fossils in the Ernstbrunn Limestone (Fig. 102).

Paleoecology

Twenty two taxa of dasyclad algae (green algae), which are most valuable for enviromental interpretation, have been described. Typical ecological conditions for these organisms are quiet, shallow, tropical lagoons with muddy or sandy ground (WRAY, 1977).

According to FLÜGEL (1982) a high rate of encrustation occurs in water depths from 15–20 meters. Furthermore, foraminifers like *Conicospirillina basiliensis* and *Nautiloculina oolithica* are typical for limestones deposited in a shallow agitated milieu (BERNIER, 1984). Miliolid foraminifers are described from the backreef lagoonal sediments of Stramberk (Ernstbrunn) reef complex (ČSFR; ELIASOVA, 1981).

No storm deposits have been found.

The Ernstbrunn Limestone was therefore deposited in a shallow, tropical lagoon. Wackestone facies show a quiet regime, whereas grainstone facies indicate some water agitation. There is no evidence for inter/supratidal or brackish conditions. During the upper Jurassic, the investigated area belonged to the inner part of a carbonate platform (ELIAS & ELIASOVA, 1986).

STOP No. 2/3

LOCATION: Au near Klement (Figs. 95,97,109).
TECTONIC UNIT: Waschberg Zone.
FORMATION: Ernstbrunn Formation.
AGE: Malmian.

The Au outcrops are also situated in the frontal part of the Waschberg Zone (Fig. 98).

We find two types of Tithonian sediments at Stop 2/3. Small ridges of dolomitized limestone (position 1 in Fig. 109) represent the Ernstbrunn Formation (Figs. 110,111). Toward NE another small ridge (position 2 in Fig. 109) shows a rich fossiliferous limestone (Figs. 112,113).

500 m north of the dolomitized limestone the exploratory well AU1 was situated. The well penetrated a series of Klippen of Malmian Ernstbrunn limestone, Klentnice beds and Klement beds within the Waschberg zone (Fig. 98).

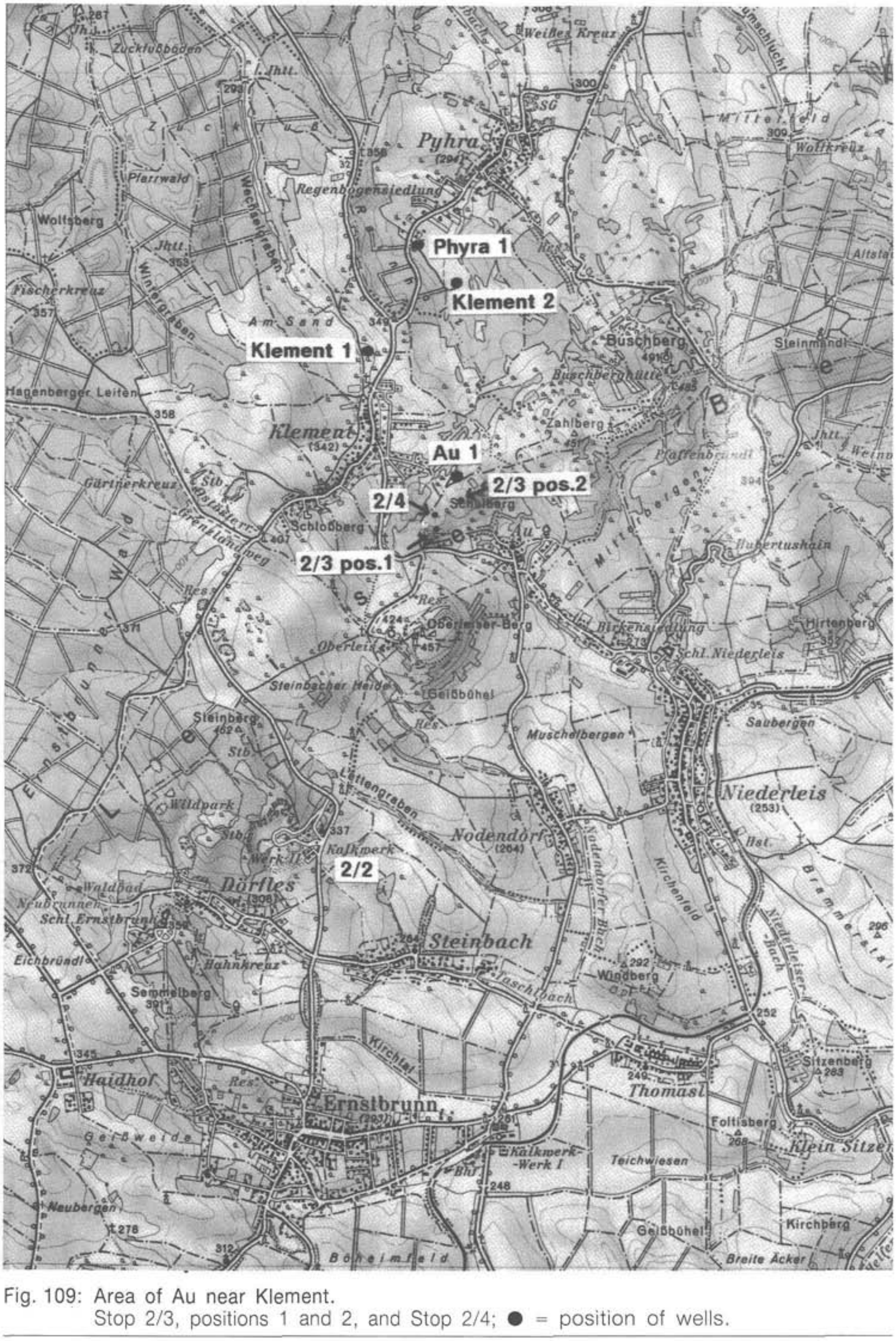


Fig. 109: Area of Au near Klement.
Stop 2/3, positions 1 and 2, and Stop 2/4; ● = position of wells.

Fig. 110: Dolomitized limestone.
Au, Ernstbrunn Formation.

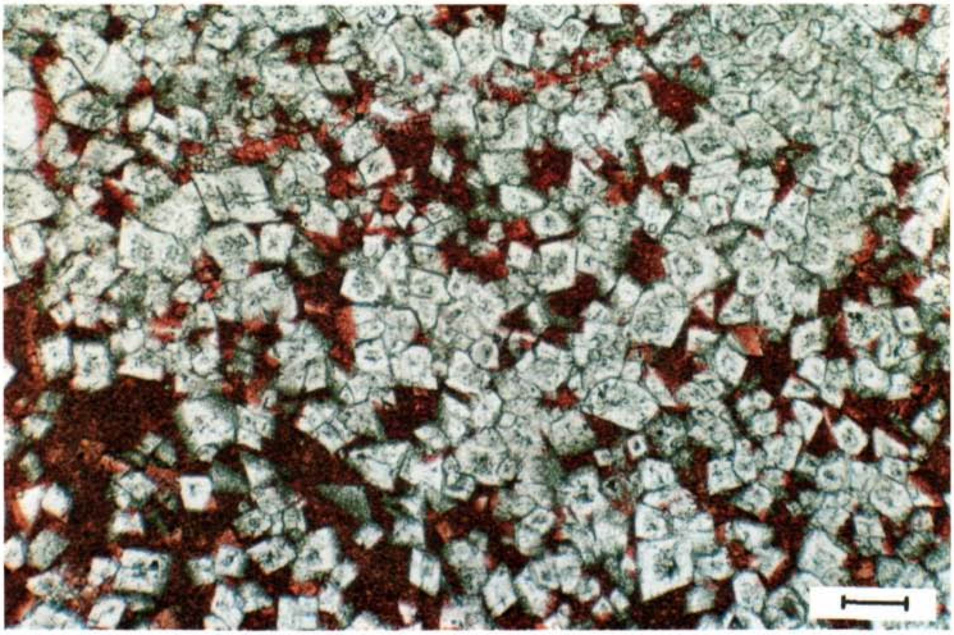


Fig. 111: Thin section of dolomitized limestone.
Au, Ernstbrunn Formation; length of scale = 0.13 mm.

Fig. 112: Fossiliferous limestone.
Au, Ernstbrunn Formation.

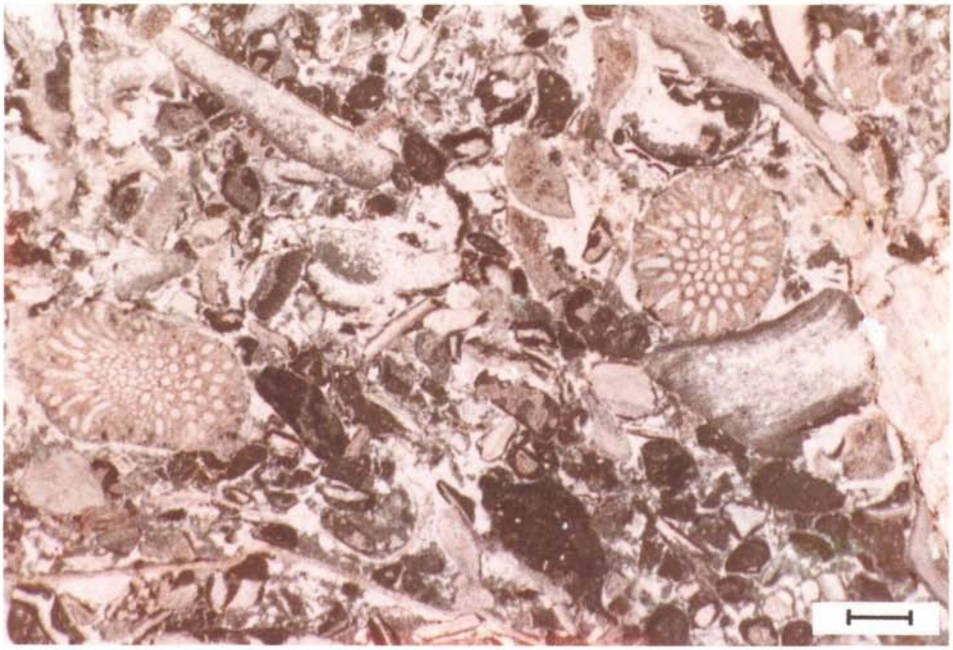


Fig. 113: Thin section photomicrograph of the fossiliferous limestone (packstone).
Au, Ernstbrunn Formation; length of scale = 0.7 mm.

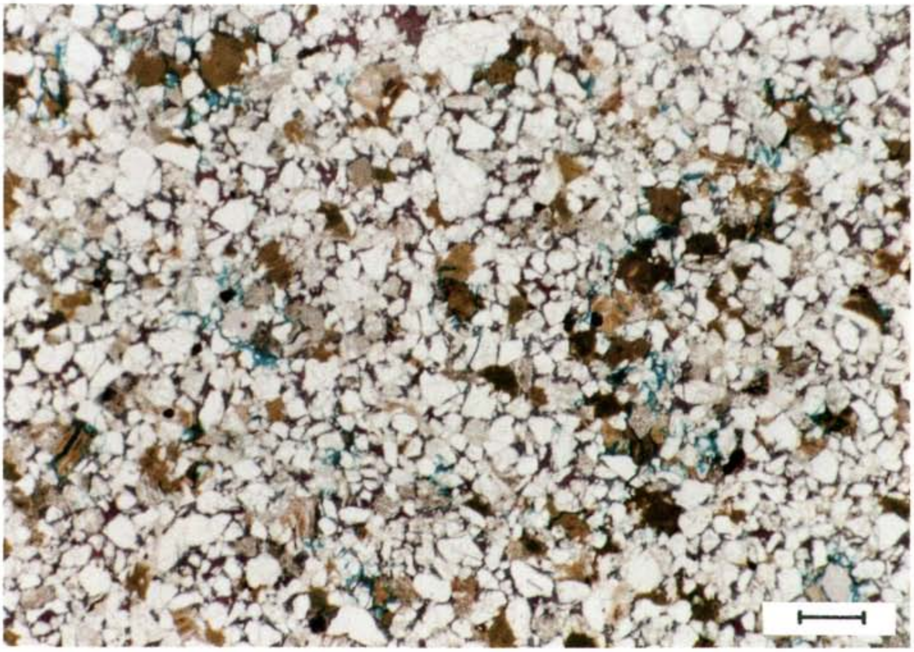


Fig. 114: Thin section photomicrograph of the sandstone.
Typical are the high glauconite content and calcite cementation.
Au, Klement group; length of scale = 0.5 mm.

Finally Autochthonous Malmian, Dogger and Crystalline of the Bohemian Massif has been encountered. The upper section of the neighbouring Klement 1 well differs by a replacement of the Mesozoic klippen by deformed Lower Miocene–Oligocene sediments of the Waschberg Zone. The wells Klement 1 and 2 produced some oil and gas from autochthonous Dogger deltaic sandstones. Their final depths were 4034 m and 4065 m respectively. The well Pyhra 1 penetrated undisturbed Neogene, Waschberg Zone and Molasse of Ottnangian–Eggenburgian age (final depth 1700 m).

STOP No. 2/4

LOCATION: Au (Figs. 97,109).
TECTONIC UNIT: Waschberg Zone.
FORMATION: Klement Group.
AGE: Upper Cretaceous.

Near the road, 100 m north of position 1 we find the Klement Group in a shallow excavation. These glauconitic sandstones (Fig. 114) unconformably cover the Ernstbrunn Formation. It represents an outer shelf sediment. The Klement group has been a matter of investigation by H. KOLLMANN, F. BACHMAYER et al. (1978). The stratigraphy and paloegeography according to drilling informations has been documented by R. FUCHS & G. WESSELY (1977) and R. FUCHS, G. WESSELY & O. SCHREIBER (1984).

STOP No. 2/5

LOCATION: Staatz, castle rock (Fig. 95).
TECTONIC UNIT: Waschberg Zone.
FORMATION: Ernstbrunn Limestone.
AGE: Malmian, Tithonian.

The klippe of Staatz is situated in the outer part of the Waschberg Zone (Fig. 115). The castle rock forms a prominent hill located in soft sediments of Paleogene to Lower Miocene (Fig. 116). These are highly deformed sediments of the Waschberg Zone. The site and some wells around have been described by R. GRILL, J. KAPOUNEK & A. PAPP in R. GRILL et al. (1968).

The quarry on the SW side of the castle rock exposes limestones composed of reef detritus including corals, sponges, algal fragments, etc. On the western side of the quarry breccias of Miocene age are cutting the limestone.

The first time the autochthonous Jurassic and Cretaceous cover of the Bohemian massif was encountered in Austria, was in 1959 by the well Staatz 1. This finding promoted further exploration below the Molasse Zone, the Vienna Basin and the eastern part of the Alps, which resulted in the discovery of Höflein, Roseldorf, Klement, Pottenhofen and Neuruppersdorf fields.

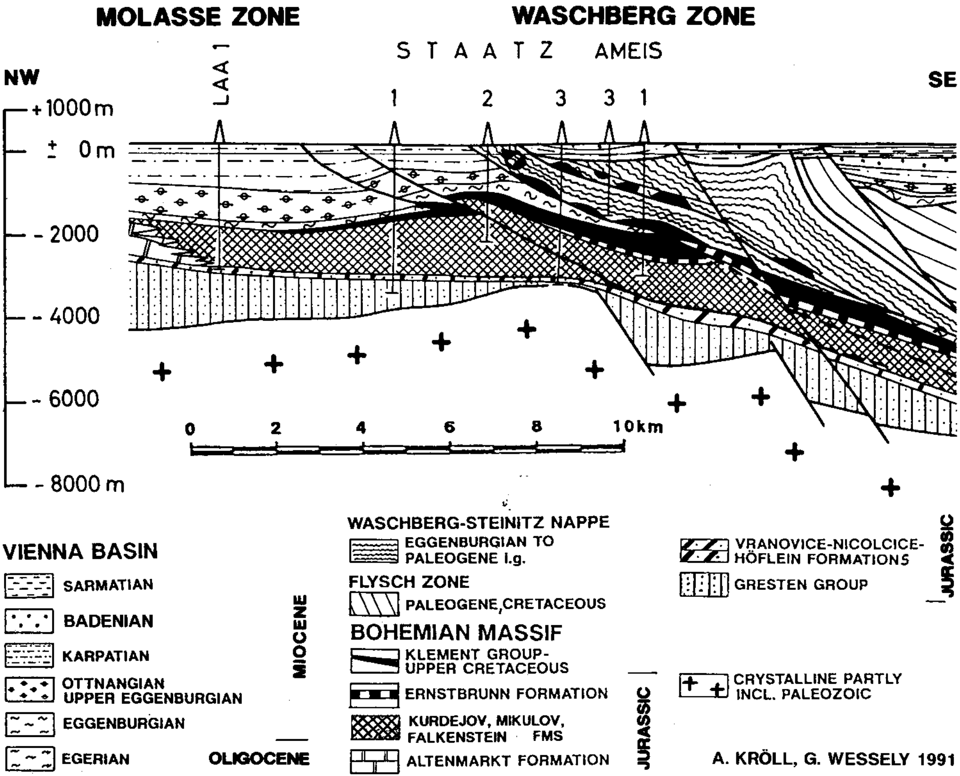


Fig. 115: Cross section through the Molasse and the Waschberg Zone in the area of Staatz. A. KRÖLL et al. in G. WESSELY (1984).

Fig. 116: Klippen of Malmian Ernstbrunn Limestone rising above the soft landscape of the Waschberg Zone seen from south. Staatz, castle rock.

Ernstbrunn Formation in autochthonous position but not in a reefoidal facies has been found on top of the Malmian sequence in Staatz 3 and in a dolomitized development in Ameis 1 (Fig. 115).

STOP No. 2/6

LOCATION: Steinberg ridge, NW Zistersdorf.
TECTONIC UNIT: Vienna Basin, 1st–3rd floor:
Neogene, Flysch, Autochthonous Mesozoic.

The morphology of the Steinberg area reflects its geologic setting: A prominent elevation within the northern Vienna Basin. The Steinberg High is separated toward the east from a deep depression by the Steinberg Fault. The displacement of the fault between the Preneogene Top at −200 m and the Zistersdorf depression (Preneogene Top at about −5800 m) is about 6000 m. The fault is synsedimentary and has been active since the Badenian time (Figs. 117–120).

The Neogene section of the upthrown block is very thin and the facies is a shallow water one. For example, coralline algal limestones in Badenian time and oolitic limestones or coquinas in Sarmatian time, form a morphologically resistant ridge. Erosion removed Pannonian and Pontian sedimentation on top of the ridge.

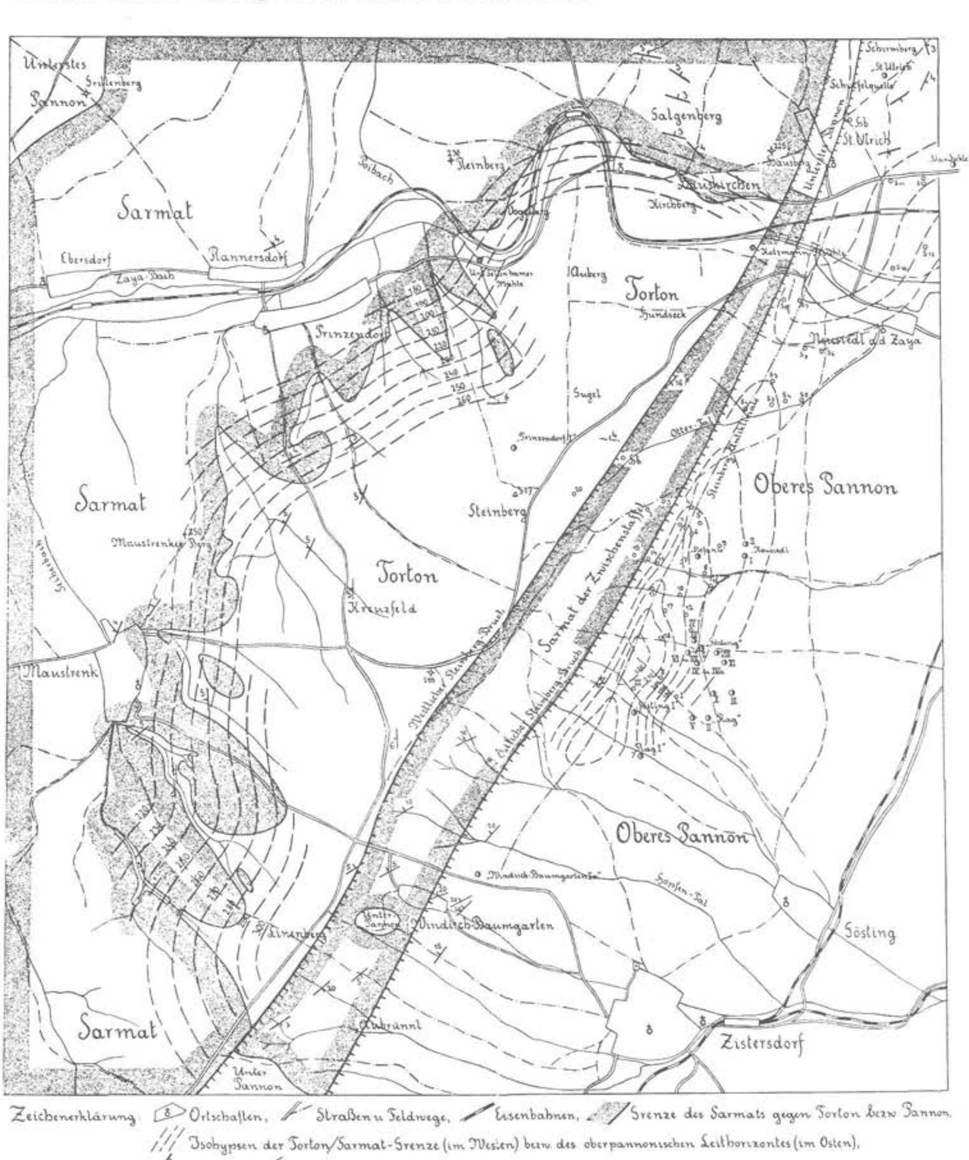
The thickness of time equivalent sediments on the downthrown block is several times greater than on the upthrown block. The facies is a basinal one, from Badenian up to Pontian time consisting of marls and sandstones. Besides the dip slip displacement of the fault, a distinct component of horizontal movement may have occurred, as the right stepping en echelon fault arrangement in the southern continuation of the dying out Steinberg Fault indicates. This arrangement points to a left lateral transtension. The fault shows no flattening in its upper part till 5000 m, but dipping of sediments (including rollover features) and the pattern of faults, indicate its listric character. The subhorizontal part of the fault plane may coincide with a thrust below the Waschberg Zone or within the overpressured Malmian marls below.

The Preneogene base in the Steinberg area is formed by Flysch nappes (L. PONGRACZ, 1983; N. KREUTZER, 1984; M. RAMMEL, 1988), the Raca Nappe (Harrersdorf subunit), the Greifenstein Nappe (Gösting- and Zistersdorf subunits) and the Kahlenberg Nappe (Sulz subunit) (Fig. 120). Oil production derives from the Gösting and Zistersdorf subunits. Enhanced production was achieved by the horizontal well Steinberg 20 (W. GRÜN, 1992). The wells Zistersdorf Übertief and Maustrenk Übertief, encountered Waschberg–Steinitz-Zone below the Flysch.

In the well Zistersdorf Übertief, an autochthonous Molasse containing Oligocene conglomerates with components of Malmian carbonates and olistolithes of Upper Cretaceous glauconitic sandstones were encountered.

Below this a 140 m thick carbonate sequence was penetrated. The upper part contains blocks of different carbonate facies encased in carbonate muds. It is either uppermost Tithonian or Lower Cretaceous age. The lower part consists of limestone of the Ernstbrunn Formation. Many dissolution cavities of small size are visible. They have been filled with cement and sediments of Upper Cretaceous age. Below the carbonate sequence, is a thick complex of Mikulov marls (final depth at 8553 m). Besides being an excellent source, the marls have up to 7 % matrix porosity.

Karl Friedl: Der Steinberg-Dom bei Zistersdorf und sein Ölfeld.



Tektonische Übersichtskarte des Zistersdorfer Ölfeldes.

Auf Grund eigener Aufnahmen und der Bohrergebnisse entworfen von Karl Friedl.

Fig. 117: Map of the Steinberg dome (K. FRIEDL, 1937).

Karl Friedl: Der Steinberg-Dom bei Zistersdorf und sein Ölfeld.

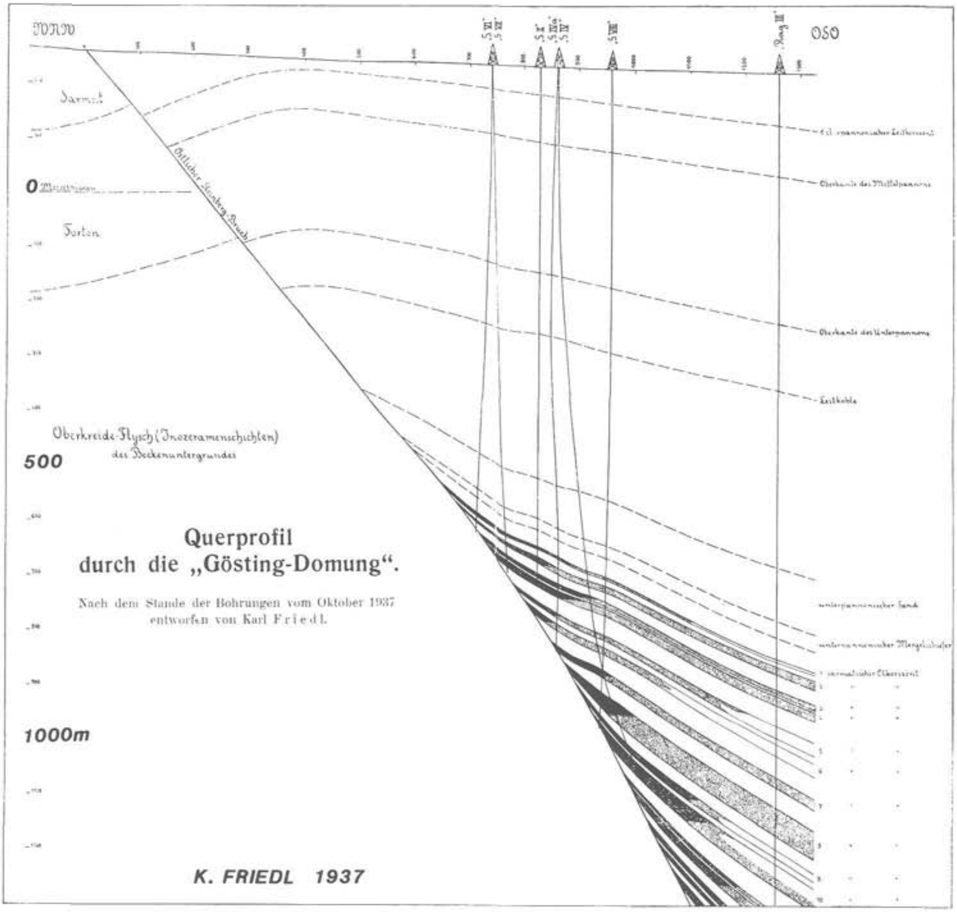


Fig. 118: Cross section through the oilfield Gösting in the Sarmatian of the downthrown block of the Steinberg dome (K. FRIEDL, 1937).

The high zone of the Steinberg region led to the first exploration activities within the basin. The area was mapped by K. FRIEDL (Fig. 117) in the year 1925 (K. FRIEDL, 1937). The first well, Windischbaumgarten 1, drilled in 1930, encountered only Pannonian and reached the Flysch, where some oil was found.

The first economic production came from Gösting II, 1934, of Sarmatian sandstones (Fig. 118). The fields Mühlberg, Gösting, Zistersdorf and Gaiselberg were found. They produce from the downthrown block, in onlapping and rollover structures along the Steinberg fault (K. FRIEDL, 1957). Some of them have produced more than 4 Mill. tons of oil. Oil was also found in the upthrown block in the Lower Miocene basal clastics, consisting of Flysch material (Hauskirchen) and in the Flysch itself. The Neogene deposits produce, but with a high water cut. Secondary and tertiary recovery production methods have been performed.

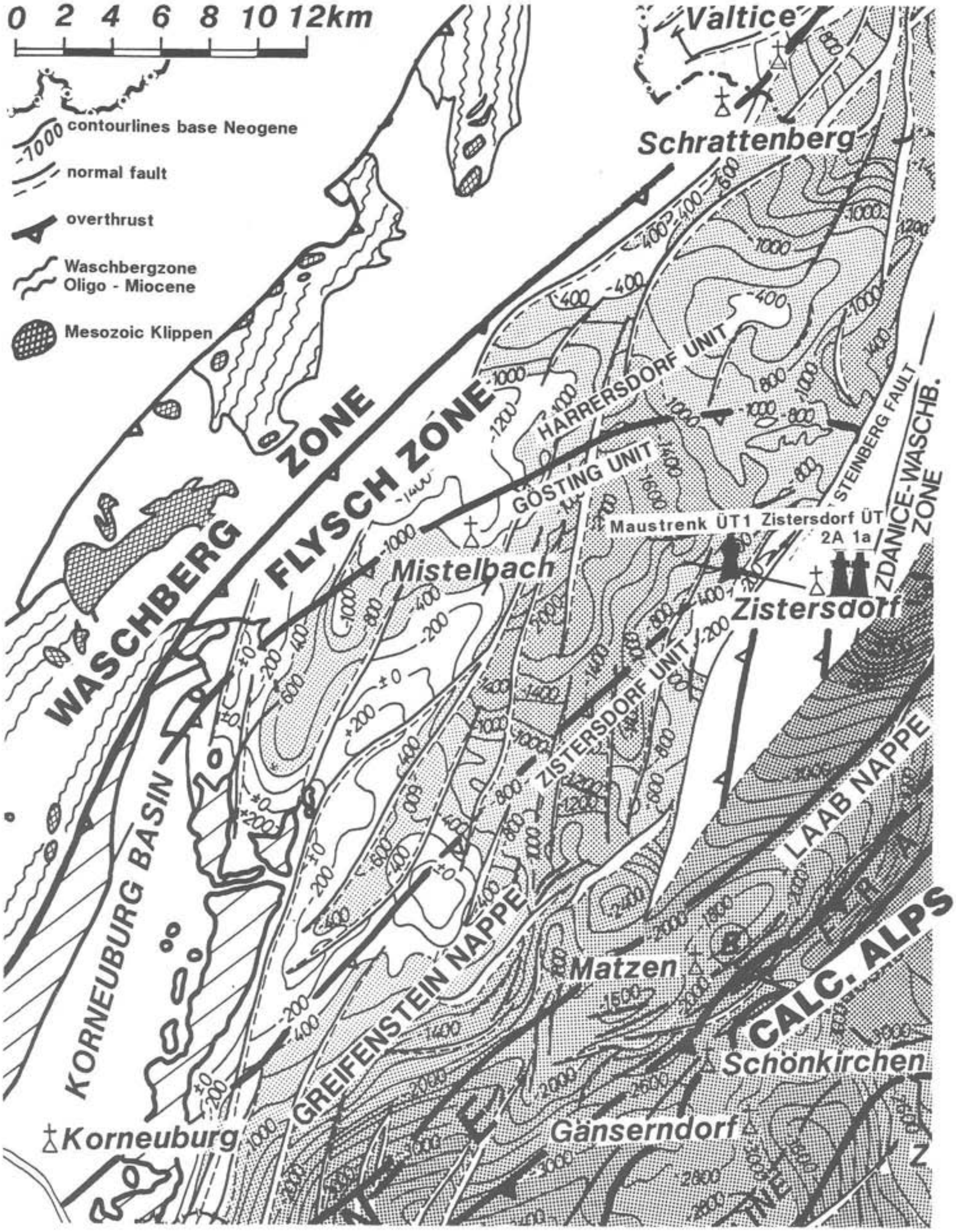


Fig. 119: Contour map of the base Neogene of the Vienna Basin showing the dimension of the Steinberg fault in the Zistersdorf area.
After W. HAMILTON, R. JIŘIČEK & G. WESSELY (1990).

The last stage in exploration activity started in 1977 with the well Zistersdorf ÜT1a (Figs. 119,120). Situated 5 km east of the outcropping Steinberg fault. Neogene was drilled down to 5 km and the Steinitz Waschberg Zone was pene-

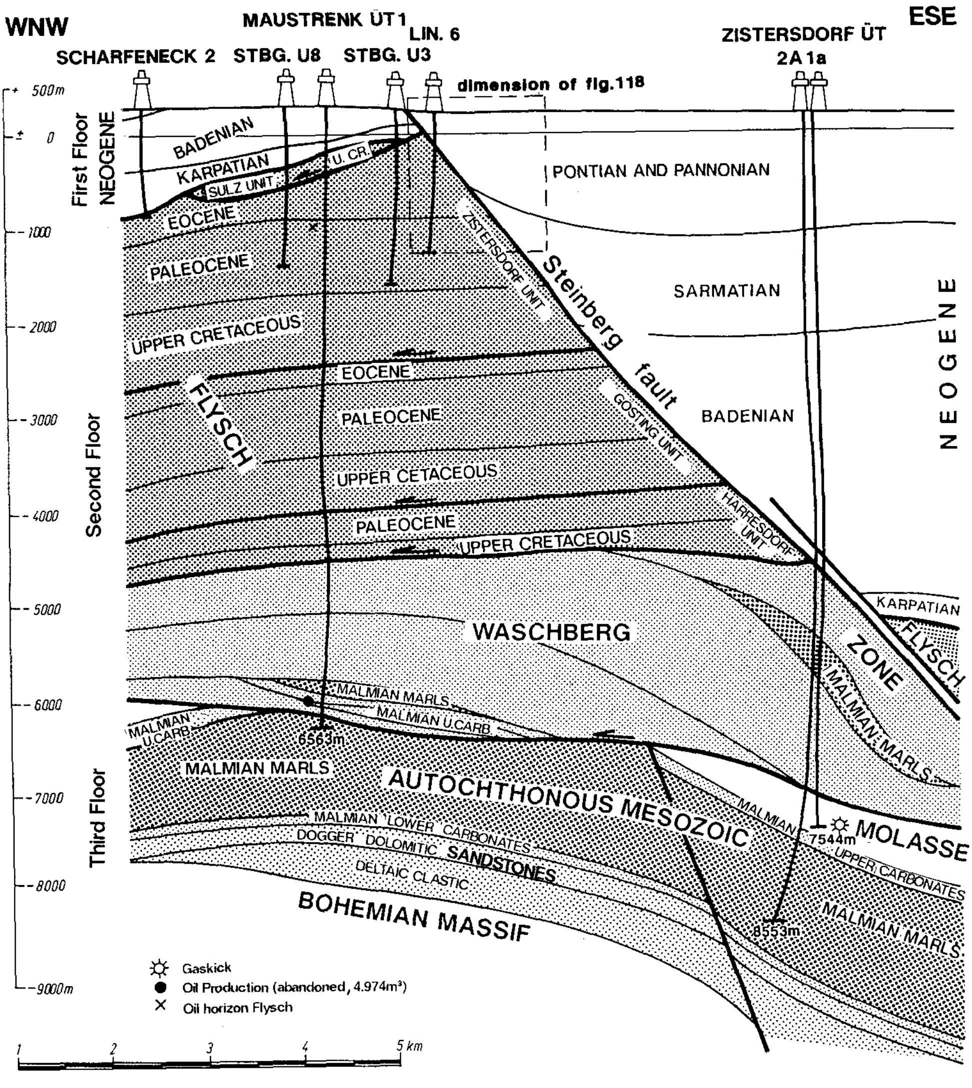


Fig. 120: Cross section Maustrenk – Zistersdorf.
G. WESSELY (1990).

trated (G. WESSELY, 1990). After a gas kick at a depth of 7544 m out of the basal breccia of the Molasse (about 1,3 Mill m^3/dry Methan/day) the well collapsed and the replacement well Zistersdorf ÜT2a was drilled to 8553 m 1981–1983. Tests in the Malmian carbonates and in Molasse breccias brought only shows of dry gas probably coming out of the Malmian marls below. The pore pressure is rather high (1500 bar at 7,5 km depth), the temperature was 240°C.

The Maustrenk well, drilled directly on the Steinberg high produced 4974 m^3 oil out of a high pressured (1385 bar at 6300 m) thrust zone with a limited reservoir volume.

EXCURSION 3

Examples of typical Molasse sediments (Stop 3/2) with "Sandstreifenschlier" and orogene-related block conglomerates (Stop 3/3) are shown.

Characteristic Flysch Formations of the Greifenstein and Kahlenberg Nappes are included covering the uppermost Lower Cretaceous (Stop 3/4), Upper Cretaceous (Stop 3/1) and Paleogene (Stop 3/5).

The gas condensate field Höflein which produces from the Autochthonous Dogger below Molasse and Flysch is passed along the route.

STOP No. 3/1

LOCATION: Bisamberg Quarry, Rehgraben (Figs. 121,122).

TECTONIC UNIT: Flysch Zone, Kahlenberg Nappe.

FORMATION: Kahlenberg Formation.

AGE: Upper Campanian to earliest Maastrichtian.

The quarry (Fig. 123) has been investigated by A. MÜLLER, 1987. It exhibits typically sediments of the Kahlenberg formation in the NE–SW extending Kahlenberg Nappe (Fig. 122).

Biostratigraphy

Calcareous nannoplancton indicates an age of Upper Campanian to earliest Maastrichtian (CC22a–CC23b).

Lithology and Facies

Within the quarry four types of lithofacies can be distinguished:

○ Classical turbidites

Mainly incomplete BOUMA sequences Tbcde, Tcde, rarely with Ta are developed. Facies C2.2, C2.3, D2.1 (PICKERING et al., 1986) respectively C2, D1, D2 (MUTTI & RICCI LUCCHI, 1975).

Depositional mechanisms: low and high density turbidity currents.

They are primarily fine-grained sandstones. Occasionally medium- to coarse-grained sandstones, siltstones, marls and marly limestones occur in the basal parts of the sequences. In general the carbonate content of the sediments is very high.

Sedimentological features: graded bedding (Ta), even horizontal laminations (Tb, Td), convolute and wavy bedding (Tc), flute casts, obstacle marks and groove marks.

○ Genetically independent calcilutite beds of turbiditic origin (Te)

Facies E1.1 (PICKERING et al., 1986) resp. D3 (MUTTI & RICCI LUCCHI, 1975).

Depositional mechanisms: low density turbidity currents.

The calcilutite beds are mudstones (micrites or spicule-micrites). They can be characterized as limy marls to limestones ($CaCO_3$ up to 90 %).

Gradations within these beds can be detected with SEM analysis. Very thin, even laminated intervals with higher content of siliciclastics, siltstones (Td or E1 interval) are sometimes developed at the base of the beds.

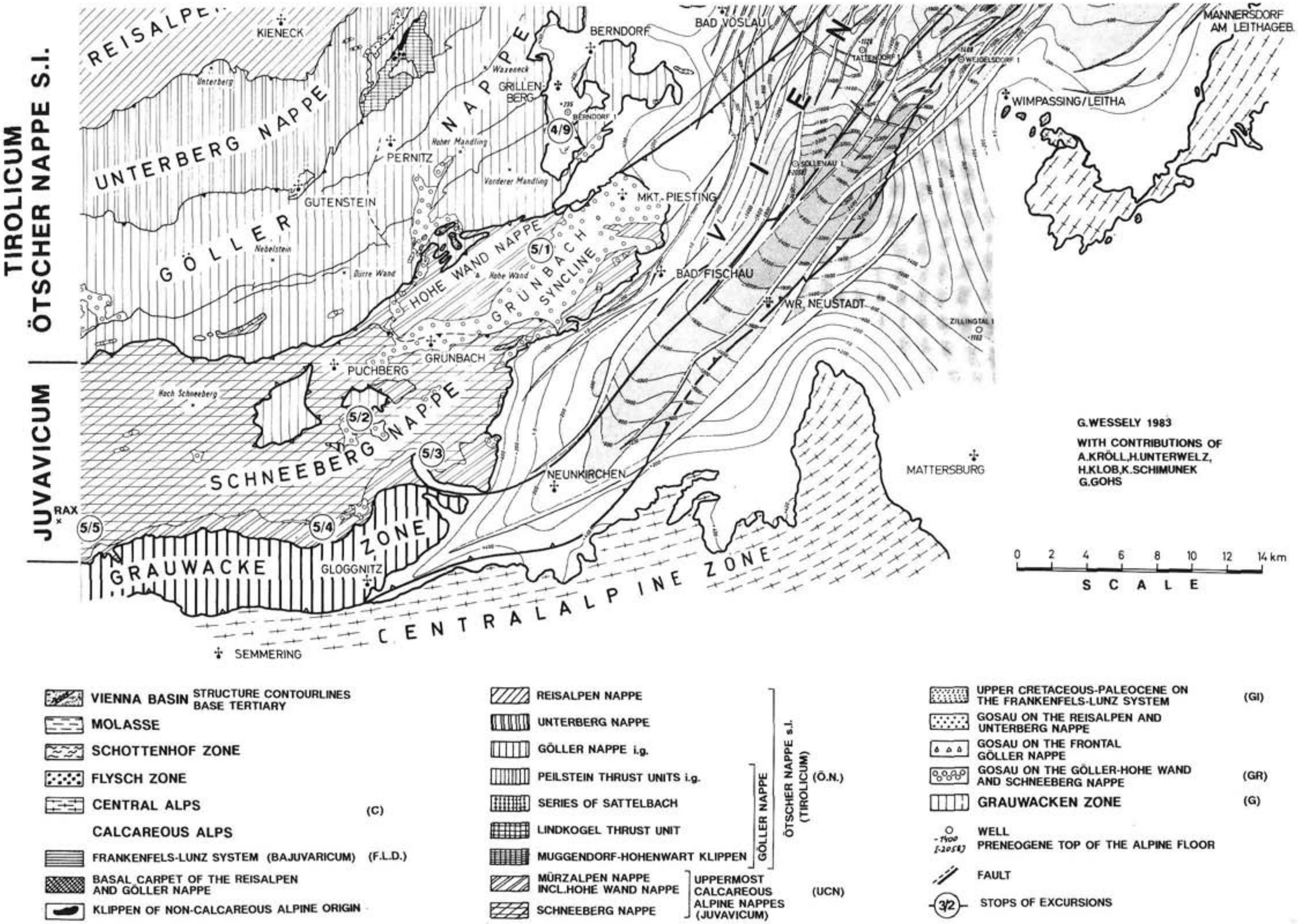

TIROLICUM
ÖTSCHER NAPPE S.l.
JUVAVICUM
REISALPEN
KIENECK
BERNDORF
BAD VÖSLAU
MANNERSDORF AM LEITHAGEB.
UNTERBERG NAPPE
Unterberg
Waxeneck
GRILLENBERG
BERNDORF 1
TATTENDORF 1
WEIGELSDORF 1
WIMPASSING/LEITHA
N A P P E
Hoher Mandling
PERNITZ
Vorderer Mandling
4/9
MKT. PIESTING
SOLLENAU 1
V I E N
GUTENSTEIN
G Ö L L E R
Nebelstein
Dürre Wand
HOHE WAND NAPPE
Hohe Wand
5/1
G R Ü N B A C H SYNCLINE
BAD FISCHAU
WR. NEUSTADT
ZILLINGTAL 1
PUCHBERG
GRÜNBACH
Hoch Schneeberg
5/2
SCHNEEBERG NAPPE
5/3
NEUNKIRCHEN
MATTERSBURG
G.WESSELY 1983
WITH CONTRIBUTIONS OF A.KRÖLL,H.UNTERWELZ, H.KLOB,K.SCHIMUNEK G.GOHS
RAX
5/5
5/4
GRAUWACKE ZONE
GLOGGNITZ
CENTRALALPINE ZONE
SEMMERING
0 2 4 6 8 10 12 14 km
S C A L E
VIENNA BASIN STRUCTURE CONTOURLINES BASE TERTIARY
MOLASSE
SCHOTTENHOF ZONE
FLYSCH ZONE
CENTRAL ALPS (C)
CALCAREOUS ALPS
FRANKENFELS-LUNZ SYSTEM (BAJUVARICUM) (F.L.D.)
BASAL CARPET OF THE REISALPEN AND GÖLLER NAPPE
KLIPPEN OF NON-CALCAREOUS ALPINE ORIGIN
REISALPEN NAPPE
UNTERBERG NAPPE
GÖLLER NAPPE i.g.
PEILSTEIN THRUST UNITS i.g.
SERIES OF SATTELBACH
LINDKOGEL THRUST UNIT
MUGGENDORF-HOHENWART KLIPPEN
GÖLLER NAPPE
ÖTSCHER NAPPE s.l. (TIROLICUM) (Ö.N.)
MÜRZALPEN NAPPE INCL.HOHE WAND NAPPE
SCHNEEBERG NAPPE
UPPERMOST CALCAREOUS ALPINE NAPPES (JUVAVICUM) (UCN)
UPPER CRETACEOUS-PALEOCENE ON THE FRANKENFELS-LUNZ SYSTEM (GI)
GOSAU ON THE REISALPEN AND UNTERBERG NAPPE
GOSAU ON THE FRONTAL GÖLLER NAPPE
GOSAU ON THE GÖLLER-HOHE WAND AND SCHNEEBERG NAPPE (GR)
GRAUWACKEN ZONE (G)
WELL
-1400 [-2058] PRENEOGENE TOP OF THE ALPINE FLOOR
FAULT
3/2 STOPS OF EXCURSIONS

Fig. 121: Northeastern Alps and southern Vienna Basin. Tectonic units and contour map of the Base of Neogene (G. Wessely, 1983). Stops of Excursions 3–5.

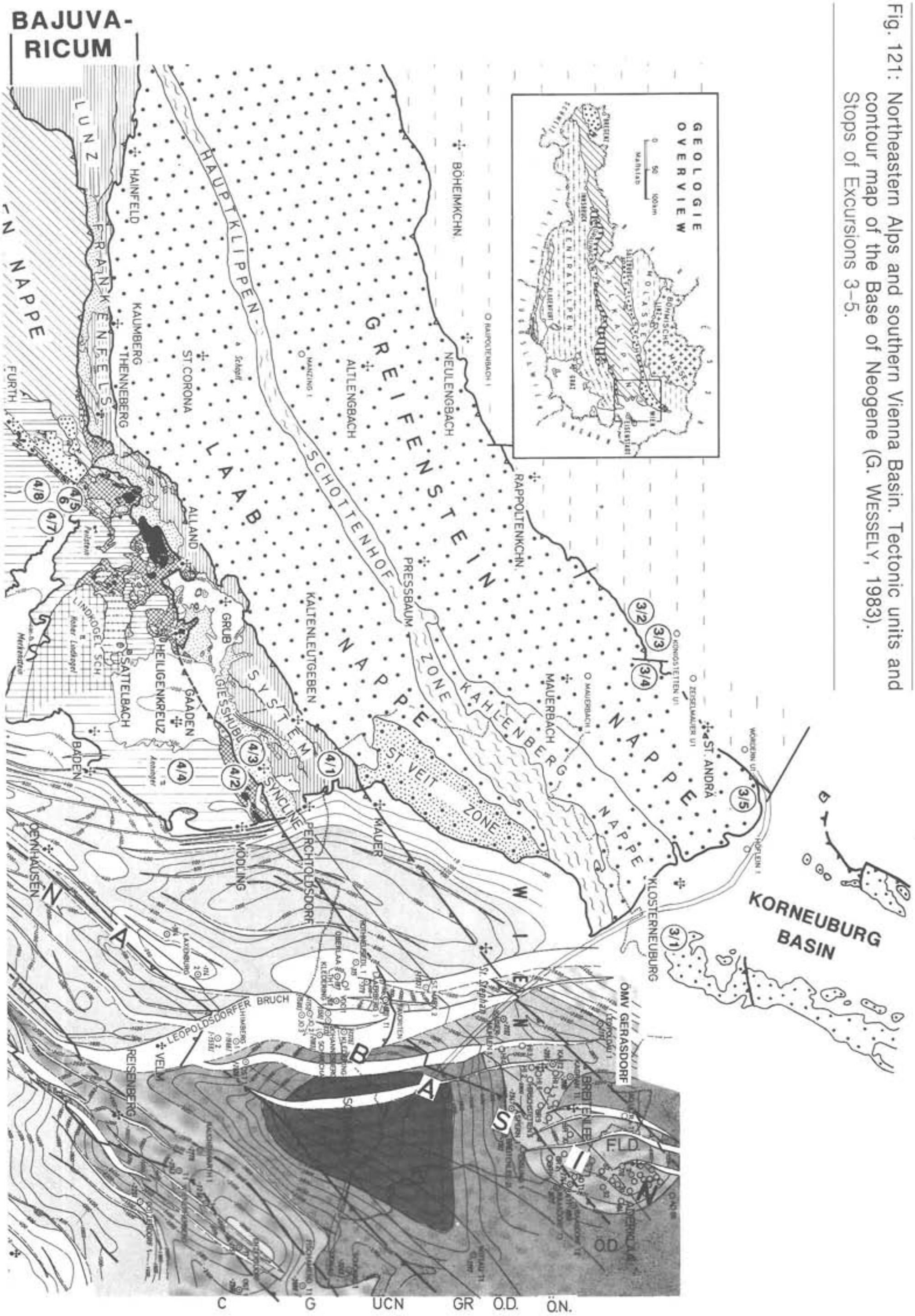
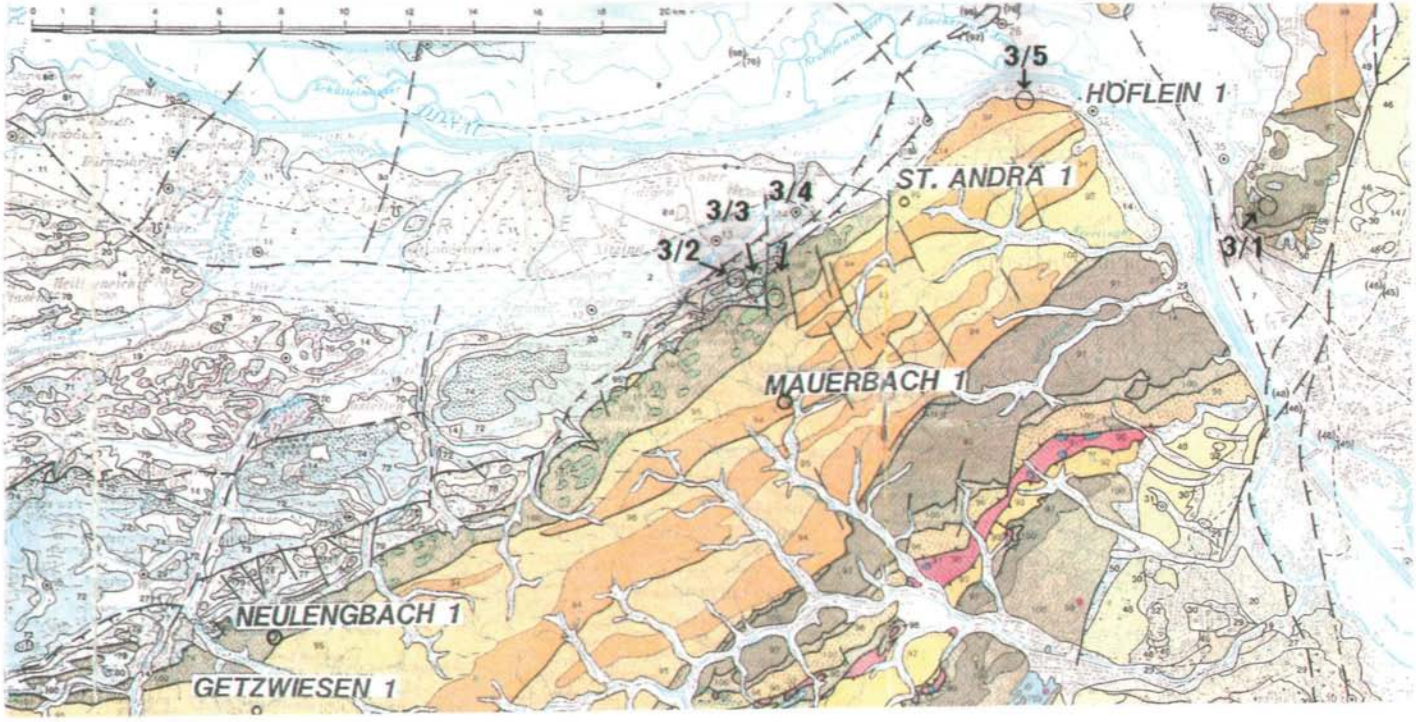


Fig. 122: Geological frame of the excursion route 3.
Section of the area NW of Vienna of the "Geologische Karte von Wien und Umgebung, 1 : 200.000" (W. Fuchs & R. Grill, 1984).



MOLASSE

66	Hollabrunner Schotterkegel (kreuzgeschichteter Sand, feinkörniger Quarzschotter; nördlich der Donau); *Unterpannon (Zonen C–B)*
67	Tonmergel, Sand; *Baden (Obere Lagenidenzone)* der Äußeren Molasse
68	Laaer Schichten (Tonmergel, Sand); *Karpat*
69	Flyschkonglomerat vom Haberg (jetzt Heidberg); *Karpat*
70	Oncophora-Schichten, Eisenschüssige Sande und Tone; *höheres Ottnang*
71	Eichbergkonglomerat (Flysch- und Kristallingerölle); *höheres Ottnang*
72	Robulus-Schlier s. l. (Tonmergel mit Sandlagen); *tieferes Ottnang*
73	Blockmergel von Königstetten (Flysch- und Kristallingerölle); *tieferes Ottnang*
74	Prinzersdorfer Sande, *tieferes Ottnang*
75	Blocksande von Königstetten, Blockschichten vom Heuberg (Flysch- und Kristallingerölle), *tieferes Ottnang*
76	Schieferiger Tonmergel, lokale Einschaltungen von Blockschichten (Flysch- und Kristallingerölle); *Ottnang bis Eggenburg*
77	Aquivalente des Haller Schliers (Tonmergel mit Sandlagen); *Eggenburg*
78	Buchbergkonglomerat (Flysch-, Kalk- und Kristallingerölle); *Eggenburg*
79	Älterer Schlier (Ton, Schieferton); Jüngerer und Älterer Melker Sand; Pielacher Tegel (Quarzsand, Ton mit Kohleführung); *Eger*
80	Ollersbacher Konglomerat (Quarz- und Kristallingerölle), lokale Einschaltungen im Älteren Melker Sand; *Eger*

1-50 Quartar und Inneralpines Tertiar

HELVETIKUM

90	Buntmergelserie i. a. (roter, grüner und grauer Schieferton, Mergel und Fleckenmergel); *Mitteleozän bis Alb* Sedimentärer Untergrund der Ablagerungen der Inneren Molasse südlich der Donau
91	Klippe der Buntmergelserie: Aptychen-Schichten, Fleckenmergel (*Neokom/Tithon*); Radiolarit, Hornstein führender Kieselton (*Malm*); Posidonienschichten (sandig-kieseliger Kalk, Ton, Mergel; *Dogger*); Grestener Schichten (Sandkalk, Mergelschiefer, Schieferton mit Kohle, Arkose, Konglomerat; *Lias*), konglomeratischer Sandstein beim Forsthaus in Neuwaldegg (*Keuper*); *Neokom bis Obertrias* Sedimentärer Untergrund der Gesteine der Buntmergelserie

FLYSCHZONE, NORDPENNINIKUM

92	Laaber Schichten: Agsbachschichten (Schieferton- und Feinsandsteinlagen), *(Obereozän) Mitteleozän bis Paleozän*
93	Laaber Schichten: Hoisschichten (vorw. Sandstein); *höheres Paleozän*
94	Greifensteiner Schichten (Schieferton mit grobkörnigen, Nummuliten führenden Einschaltungen von Greifensteiner Sandstein), *Mitteleozän bis Paleozän*
95	Altlengbacher Schichten (Kalk- und Mürbsandstein, grauer Mergel, grauschwarzer Tonschiefer), *Paleozän bis Maastricht*
96	Sieveringer Schichten (Kalk- und Mürbsandstein, grauer Mergel, grauschwarzer Tonschiefer); *Paleozän bis Maastricht*
97	Kahlenberger Schichten (Kalksandstein, Mergel), *Campan bis Santon*
98	Kaumberger Schichten (bunte Schiefertone und Tonmergel, Sandstein); *(Maastricht) Campan bis Coniac*
99	Pikrit, -tuff (Hörndlwald, Spiegelgrundgasse, Sulz, etc.), anstehend oder sekundär verfrachtet; *(?Apt) Alb bis Cenoman (Turon)*
100	Reiselsberger Sandstein, Bunte Schiefer, Gaultflysch, Wolfpassinger Schichten, Aptychen-Schichten, nicht differenziert, *Mittel- bis Unterkreide*
101	Neokomkalk
102	Klippen von St. Veit und W Baunzen (Aptychen-Schichten, Radiolarit; Posidonienschichten; dunkler Kalk, Ton- oder Konglomeratschiefer in „Grestener Fazies", quarzitische Arkose), *Neokom bis Obertrias (Keuper)* Sedimentärer Untergrund der Gesteine der Kahlenberger Decke s. l.

These beds seem to be composed of lime muds with only small amounts of siliciclastic material. These muds have large amounts of spicules and could be from regions of the upper slope, whith minor terrigeneous influx.

○ Sandstone facies in which BOUMA's divisions are not applicable

Facies B1.1, A1.4 (PICKERING et al., 1986) resp. B, A1 (MUTTI & RICCI LUCCHI, 1975).

Depositional mechanisms: high density turbidity currents, liquified flows, density modified grain flows or transitions between them.

Mainly friable sandstones, partly fine-conglomeratic with high content of clay, mica and organic material and much lower $CaCO_3$ content than in facies 1 are developed. Sometimes clayey or marly clasts occur within the sandstones beds.

Sedimentological features: rip up clasts (erosional features) parallel lamination (shear lamination) combined with multiple grading, coarse-tail grading, channel-like structures (see Fig. 124), load casts, frondescent structures.

○ Non-turbiditic claystones

Facies G2 (PICKERING et al., 1986) resp. G (MUTTI & RICCI LUCCHI, 1975).

The thin claystone intervals between the turbidite units are interpreted to be hemipelagic in origin. They are almost carbonate-free.

In consideration of the carbonate-poor to carbonate-free hemipelagic mudstones it is suggested that the whole clastic deep-water development was deposited below the calcite compensation depth (CCD).

Thickness and Frequency of the Sedimentation Units

The relative frequency of the turbiditic events has been estimated based on the overall formation thickness and frequency of the sedimentation units. With an estimated sedimentation time of 7–9 million years (nannofossil stratigraphy) the average frequency would be 1 turbiditic event per 3500–4000 years. This coincides very well with calculations from the Polish Karpat Flysch where a frequency of 4000 years per cycle is indicated.

A sedimentation rate of 2–3 cm/1000 years has been estimated for the "normal" nonturbiditic clays. A reduction of the thickness during compaction by the factor 3 and a denudation rate of 50 % has been assumed in this calculation.

Facies 1 and 2

In the upper part of the profile section where mainly facies 1 and 2 are developed, thinning upward cycles are visible. Normally this kind of cycle indicates the possibility of channelized sedimentation mechanisms. In comparable facies 1 sequences of the Kahlenberg Formation, only monotonous sequences have been recorded. Thus, a "relative proximal" position of the Bisamberg profile compared with other locations is indicated. This trend is also confirmed by other features like the thickness of turbiditic units, the distribution of the facies, grain-size of the sediments and the paleogeographic situation.

Facies 3

In the lower part of the profile section where facies 3 is dominating, a multiple thinning upward sequence is developed. The thickest beds ("coarse divisions") within these sequences show a thickening upward trend. This thickening upward trend can be interpreted as an indication of progradation within a channelized environment.

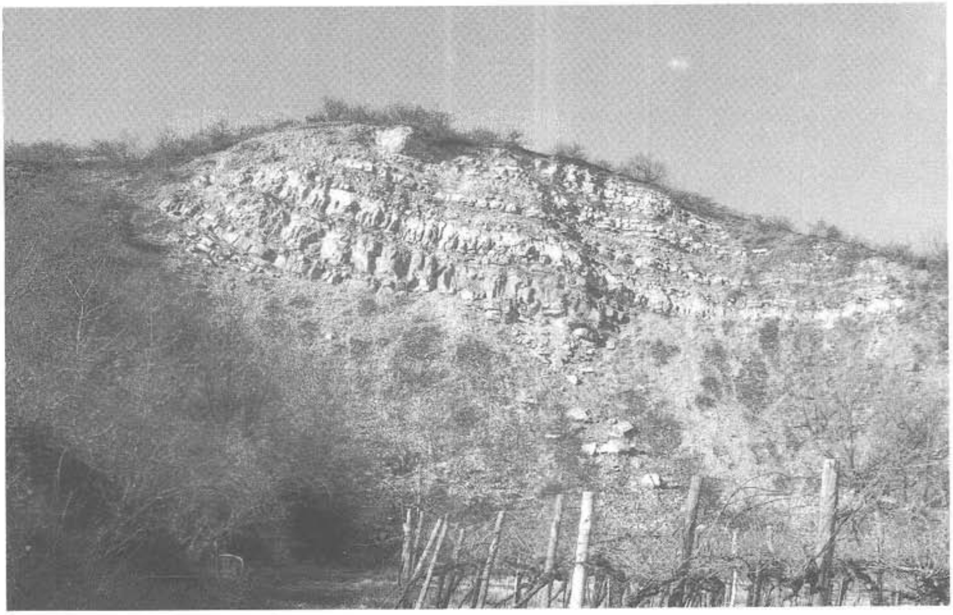


Fig. 123: Overview of the Kahlenberg Formation.
Quarry Bisamberg.

Fig. 124: Example of a sandstone sequence in facies 3 with a cannel-like structure filled with coarse-grained sandstone with fine breccia of the base of the carbonate-rich bed.
Quarry Bisamberg.
White or black units on the scale: 1 dm.

Petrological composition

Thin-section analysis of some sandstones from both facies 1 and 3 are given below (legend see part I, chapter 3.4.1.):

	MG	PG	CH	FSP	RF	L+B	DOL	MI	GL	OP	CLAY	CC
mean	30	18	1	6	12	5	+	4	+	2	6	16
max	38	24	1	10	21	16	1	8	2	4	15	27
min	15	8	0	2	4	0	0	+	+	0	1	3

The mineralogical composition of the sandstones can be characterized as sublithic arenites and calcareous sandstones. They are hybrid sandstones with an appreciable amount of detrital carbonate as well as of calcareous matrix (sparitic and irregularely dispersed micritic material).

It is clearly visible that the total carbonate content of the sandstones in facies 1 is much higher than in facies 3. On the other hand the amount of noncalcareous clayey groundmass and of the detrital mica minerals is lower in the sandstones of facies 1 compared with those of facies 3.

Heavy Mineral Composition

The results of the heavy mineral analysis are shown below (33 samples; legend see stop 1/3):

	ZI	TU	RU	AP	GR	ST	CD	CR	HO
mean	5	10	3	12	66	4	+	0	+
max	25	28	8	30	79	10	2	1	1
min	1	1	+	4	28	0	0	0	0

Garnet is clearly dominant and of stratigraphic importance. It is very characteristic for the Kahlenberg Formation as well as for the Upper Cretaceous sediments in the East Alpine Flysch Zone in general. In the Palaeogene parts of the Flysch Zone zircon is always predominant.

Clay Mineral Composition

Analysis of the fraction <2 µm indicates a difference between the nonturbiditic pelites (F) of facies 4 and the turbiditic pelites (Te) of facies 1. The first show higher content of kaolinite than the latter. This trend is also observed in other parts of the Kahlenberg Formation.

In conclusion, it is possible to distinguish between the turbiditic and the "normal" sediments based on their mineralogical composition.

STOP No. 3/2

LOCATION: Königstetten, Hollow way SSW church of Königstetten (Figs. 121,122).

TECTONIC UNIT: Molasse Zone.

FORMATION: Sandstreifenschlier.

AGE: Eggenburgian/Ottnangian (NN3/NN4), Lower Miocene; according to S. PREY (1974) Eggenburgian; according to W. FUCHS & R. GRILL (1984) Lower Ottnangian (Robulusschlier).

Micaeous shales, interbedded with thin siltstone and fine-grained sandstone beds, can be observed along the walls of the hollow way (Fig. 125). The sandstone beds frequently exhibit lenticular and flaser bedding.

The microfossil content is poor and is mainly comprised of fish remains, sponges spicules and mollusc fragments and rarely foraminifers (*Elphidium* sp.). Only the nannoflora is useful for an age determination of Eggenburgian/Ottnangian (NN3/NN4). Reworked nannoplankton esp. from the Eocene, Paleocene and Cretaceous is abundant.

Two samples taken within a vertical distance of 1 m show this fact (det. R. BRAUNSTEIN).

Sample 1/02

Nannoflora of Upper Middle Eocene (NP 16, NP 17)
Ericsonia ovalis, Ericsonia formosa, Chiasmolithus grandis, Reticulofenestra hillae, Reticulofenestra umbilica, Reticulofenestra bisecta, Reticulofenestra scrippsae, Cyclicargolithus floridanus, Toweius cf. *crassus, Toweius* sp., *Semihololithus kerabyi, Lanternithus minutus, Nannotetrina swasticoides, Sphenolithus* sp., *Pontosphaera* sp.

Nannoflora of Upper Paleocene
Ellipsolithus macellus, Heliolithus riedeli, Discoaster mohleri, Chiasmolithus bidens.

Nannoflora of the Cretaceous
Reinhardtites levis, Quadrum sissinghii, Arkhangelskiella cymbiformis, Prediscosphaera grandis, Micula decussata, Quadrum gartneri, Stradneria crenulata, Watznaueria barnesae.

Fig. 125: "Sandstreifenschlier".
Königstetten, hollow way (Stop 3/2).

Sample 1/03

Nannoflora typical for Eggenburgian/Ottnangian NN3/NN4

Coccolithus pelagicus, Coccolithus eopelagicus, Coccolithus sp., *Cyclicargolithus floridanus, Sphenolithus heteromorphus, Sphenolithus* sp., *Helicosphaera ampliaperta, Triquetrorhabdulus milowii.*

Middle Eocene to Upper Oligocene

Reticulofenestra bisecta.

*

The sandstones can be classified as calcilithites.

A typical sandstone composition of two samples from this location is given below: monocrystalline quartz 36–41 %, polycrystalline quartz 1 %, feldspar 4–6 %, traces of crystalline rock fragments, limestone and bioclasts 8 %, dolomite fragments 11 %, mica (muscovite + biotite + chlorite) 4–6 %, opaques 1 %, heavy minerals 1 %, clay matrix 9–10 %, calcite cement 8–21 %.

This composition (i.e. with abundant dolomite and limestone fragments) is typical for many Neogene sandstones in the Molasse and in the Vienna Basin.

The heavy mineral composition is characterized by a predominance of garnet with significant amounts of epidote, green hornblende and staurolite. An analysis of a fine-grained sandstone sample from this location is given below:

Zircon 2 %, rutile 4 %, brookite/anatase 2 %, traces of titanite, monazite and tourmaline, garnet 67 %, staurolite 3 %, epidote/zoisite 8 %, hornblende 8 %, apatite 5 %.

The source area for the terrigeneous material was situated in the south. Sediments of the Northern Calcareous Alps, Flysch Zone and the Crystalline of the Central Alps are assumed.

These cyclic sediments were deposited in a slightly brackish environment, at a depth of about a hundred meters.

STOP No. 3/3

LOCATION: Königstetten, Marleitengraben, beside Grabenhof (Figs. 121,122).

TECTONIC UNIT: Molasse Zone.

FORMATION: Königstetten Blocksands (G. GÖTZINGER in G. GÖTZINGER, R. GRILL et al., 1954; S. PREY, 1974; W. FUCHS & R. GRILL, 1984).

AGE: ?Upper Eggenburgian/Ottnangian, (NN3/NN4), Lower Miocene.

The Königstetten Blocksands represent sediments which were deposited in front of the northward advancing flysch nappes. These sediments were probably deposited by small rivers having their source in the local hinterland. They consist of successions of coarse clastics (block sands, conglomerates and coarse sands) (Fig. 126), which are dipping 20° SSE.

Several, partial lenticular, sandy conglomerate beds intercalated with coarse-grained sand beds are visible. Occasionally, very thin (mm–cm) coal seams and silty shales can be observed.

Fig. 126: Coarse clastics of the "Königstetten Blocksands".
The components are mostly Flysch, sometimes components of the Calcareous Alps. The source of a Middle Eocene Sandstone is questionable.
Königstetten, Marleitengraben (Stop 3/3).

The conglomerate beds are poorly sorted with a sandy matrix. The grain size of the partially rounded pebbles is in the order of several cm, but some blocks can reach 70 cm in diameter.

Most of the pebbles are intensely weathered and are often macroscopically difficult to identify. With the aid of thin-sections, heavy mineral analyses and partial micropaleontological analyses, the source of the pebble components can be identified.

Components

○ Flysch Zone, Zementmergel Formation
(comprising the largest portion of the pebbles)
Most of these components are gray, fine-grained carbonates, mainly silty biomicrites and spiculites containing a microfauna of Upper Cretaceous age. The heavy mineral assemblage is characterized by a predominance of garnet. Calcitic siltstones and calcite cemented, fine-grained calcilithic arenites are less common.

○ Flysch Zone, probably Greifenstein Formation
(less frequent)
Fine- to medium-grained sandstones, glauconite bearing, calcite or quartz cemented. The heavy mineral assemblages are rich in zircon, rutile and tourmaline. These components are probably of Paleogene age.

○ Flysch Zone, Wolfpassing Formation
(rare)
Grainstones, biopel- to biointrasparites with small amounts of siliciclastics and a Lower Cretacous microfauna.

○ Flysch Zone, probably Altlengbach Formation
(Upper Cretaceous to Lower Paleocene) (rare)
Dark shale clasts containing a rich microfauna of arenaceous foraminifers.

○ Calcareous Alps
(very rare)
Dolomite, probably Hauptdolomit (very rare in pebble form), but more significant in the sand fraction.

○ Questionable
Coarse-grained sandstone (calcilithite) with abundant micrite fragments,coralline algae, echinoderms and nummulites indicating Middle Eocene age.
The heavy mineral assemblage shows a predominance of garnet.
The source for these rarely occuring components is questionable.

○ Neogene (shale clasts)
Marine dark shale clasts containing a nannoflora of Upper Eggenburgian to Lower Ottnangian age (NN3/NN4, det. R.BRAUNSTEIN).
Coccolithus miopelagicus, Coccolithus pelagicus, Coccolithus eopelagicus, Reticulofenestra pseudoumbilica, Reticulofenestra hesslandii, Reticulofenestra gelida, Cyclicargolithus floridanus, Helicosphaera ampliaperta, Orthorhabdus serratus, Cyclococcolithus leptoporus, Pyrocyclus hermosus, Pontosphaera japonica, Triquetrorhabdulus milowii, Helicosphaera scissura, Helicosphaera euphratis, Discoaster cf. *druggii.*

*

These data give the maximum age of the sediments in this outcrop. These marine clasts are reworked and deposited in a fluvial environment therefore a slightly younger age of the Königstettener Blocksands is possible.

Many reworked nannofossils of Lower Cretaceous/Jurassic, Upper Cretaceous, Paleocene and Eocene to Oligocene also occur.

The fine- to coarse-grained sandstones and the sandy matrix of the conglomerates consist of weakly calcite cemented lithic to calcilithitic arenites. The sand grains are mainly composed of quartz, quartz-feldspar fragments, micrite and sparite particles. Lesser amounts of dolosparite, siltstone, chert, glauconite, spiculite and small shale fragments are found.

The heavy mineral assemblage is characterized by very high garnet contents (between 80–90 %).

STOP No. 3/4

LOCATION: Dopplerhütte, SSE Königstetten, abandoned quarry (Figs. 121,122).

TECTONIC UNIT: Flysch Zone, Greifenstein Nappe.

FORMATION: Wolfpassing Formation.

AGE: Lower Cretaceous (Neocomian, Aptian to Albian).

In this quarry, which has been described by H. BERTLE (1970), the Wolfpassing Formation, the deepest formation within the Greifenstein Nappe is exposed near the overthrust of the Alps over the Molasse.

The quarry exhibits strongly folded calcarenites and thin shale beds with sporadically intercalated sandstone and micrite beds (Fig. 127). The fine- to

Fig. 127: Intensively NNW vergent folded Wolfpassing Formation.
Quarry Dopplerhütte.

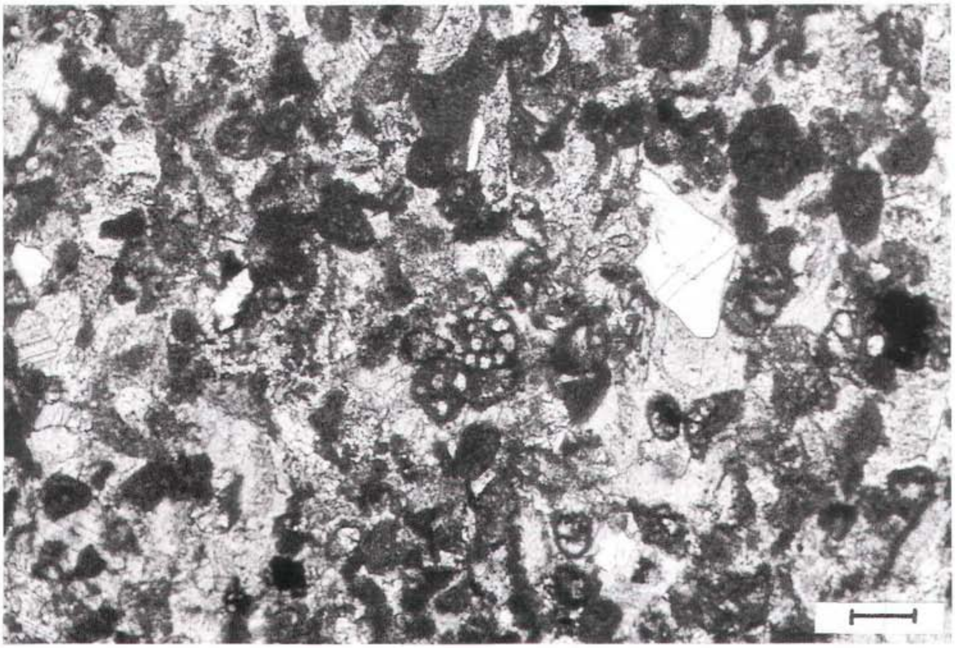


Fig. 128: Typical photomicrograph of the calcarenite of the Wolfpassing Formation.
Quarry Dopplerhütte; 1 cm = 0,3 mm.

medium-grained calcarenites contain occasional chert layers. The thickness of single calcarenite beds ranges from 15–50 cm, the shale intercalations attain 15–30 cm.

The exposed thickness of the formation is 9–10 m. The calcarenites can be classified as grainstones (biopelsparites) with small amounts of siliciclastic particles (quartz, feldspar, glauconite, etc.) (Fig. 128).

Occasionally irregularly dispersed, silicified spots can be observed. Frequently clay enrichments around stylolithes are visible.

The shale beds contain fucoids and plant debris. The microfauna found in the calcarenites is composed mainly of arenaceous foraminifers (Textulariids, Recurvoids, Verneuilinids, Ammodiscids, Trochamminids, Eggerellinids, Cornuspirids, Lagenids, *Stomiosphaera* cf. *echinata, Cadosina fusca*, echinoderms, etc.).

Hedbergella, Trocholina and Radiolarians have been referred by S. PREY (1974). The nannofossils (H. STRADNER in F. BRIX, 1961) indicate Lower Cretaceous age.

The heavy mineral composition is generally characterized by a predominance of zircon and smaller amounts of rutile, tourmaline, brookite/anatase and garnet.

The results of two analysed samples from this quarry are given below:

Zircon 54–55 %, rutile 10–18 %, brookite/anatase 4–9 %, monazite 4–8 %, tourmaline 4–14 %, garnet 3–9 %, epidote/zoisite 1 %, apatite 1–3 %, traces of chromspinell.

STOP No. 3/5

LOCATION: Greifenstein quarry, Strombauamt between the villages Höflein and Greifenstein (Figs. 121,122).

TECTONIC UNIT: Flysch Zone, Greifenstein Nappe.

FORMATION: Greifenstein Formation.

AGE: Lower Eocene, Lower Cuisian.

The quarry, which is the locus typicus for the Greifenstein Formation, is several hundred meters long. The SE-dipping rocks show a bisection in a lower, thick bedded, and an upper, thinner layered part (Fig. 129).

The quarry has been investigated by K. HÖSCH (1985), who also gave a complete bibliography.

The upper part consists of intensely bedded sandstones, separated by shale layers. The shales contain a fauna of arenaceous foraminifers. The following nummulites could be identified by A. PAPP (1962) in the sandstones:

Nummulites globulus, N. praecursor, N. atacicus, N. pernotus, N. planulatus, N. sparsiseptatus, N. aff. *planulatus, N. ficheuri.*

Their maximum occurrence was during Lower Cuisian, but the age of the exposed rocks could be younger because of resedimentation.

From outcrops north of the river Danube we know that the Greifenstein Formation reaches from NP8 (*Heliolithus riedeli*) up to NP14 (*Discoaster sublodoensis*), Upper Paleocene–Middle Eocene.

Within the whole series several facies of deepwater clastics can be observed:

Graded, reverse graded or ungraded conglomerates (Fig. 130). They were only found in an old part west of todays quarry. Their shaly matrix plays a minor role because the conglomerates are clast supported. Their main components are: quartz, feldspars, granites, granodiorites, phyllites, gneiss, shales, sandy shales,

Fig. 129 ▲
Greifenstein Formation.
Multiple fining upward cycle in the upper level of the quarry.
Quarry Strombauamt Greifenstein.
Length of scale = 0.5 m.

Fig. 130 ▶
Conglomerate of the Greifenstein Formation.
Beside crystallinic components it contains fragments of Autochthonous Mesozoic (Malmian dolomites and limestones).
Quarry Strombauamt Greifenstein.

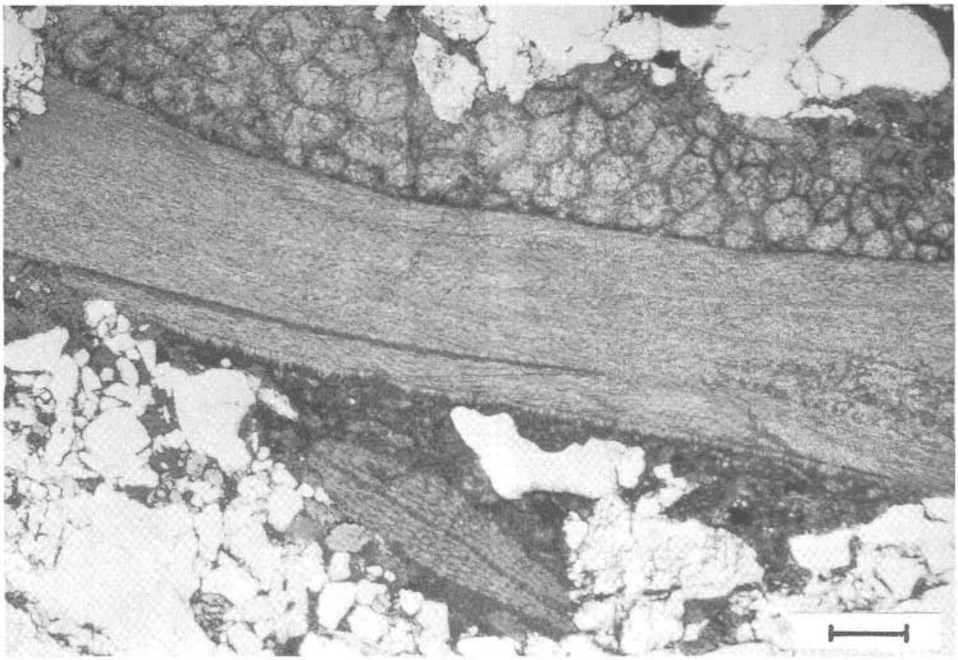


Fig. 131: Thin section photomicrograph of a coarse grained sample of the Greifenstein Formation with crystalline rock fragments and with components of *Discocyclina* and shell fragments encrusted by bryozoans.
Quarry Strombauamt Greifenstein; length of scale = 0.8 mm.

sandstones, limestones, chert, dolomites, fossil fragments and frequently biolithites composed of coralline algae, bryozoans, foraminifers, echinoderms etc. (Fig. 131). The conglomerates, seem to be the product of turbulent dispersion flows and are interpreted to be proximal channel-fill deposits, comparable to facies A of MUTTI & RICCI LUCCHI (1978).

The lower part of the quarry consists of rather coarse-grained, glauconitic quartz sandstones without any grading or cross bedding. Amalgamation is very common. Rip up clasts are found throughout the whole section. This facies is also considered to represent channel-fill deposits. Equivalents have been described by MUTTI & RICCHI LUCCHI as fazies B1.

The sandstones contain heavy mineral associations with zircon domination. Tourmaline, garnet and rutile are found in considerable amounts, 14 samples (legend see stop 1/3):

	ZR	TU	AP	RU	GR	BA	MO	ST
mean	55	23	4	6	5	4	2	1
max	77	50	36	16	26	15	5	1
min	31	10	+	1	+	0	+	0

As mentioned above, the upper part consists of thin layered sandstones, with frequent sole marks and ichnofossils, intercalated with shales. They can be described by the Bouma Model and are interpreted therefore as the results of turbidity currents or similar processes. The thin interbedded turbitic mudstones show a clay mineral composition characterized by kaolinite and illite and varying proportions of mixed-layer minerals. No hemipelagic layer could be identified.

Although the Bouma Cycles are not fully developed and marly beds start with interval Tb, these members are considered to be overbank and interchannel deposits.

From the analysis of rock particles, sedimentary structures and grain orientation, a paleocurrent direction perpendicular to the E–W-striking sedimentary basin is indicated. The material was derived from the Bohemian Massif and its Autochthonous Mesozoic and Paleogene cover.

Lithologic facies and facies associations suggest that the Greifenstein Formation was deposited in the lower part of an inner submarine fan, to the upper part of a middle fan.

EXCURSION 4

The main stratigraphic and facies members of the Mesozoic to Paleogene sequence will be demonstrated along the eastern border of the Calcareous Alps (Fig. 121):

Upper Triassic, Jurassic and Lower Cretaceous of the Bajuvaricum, the Uppermost Cretaceous to Paleogene of the Gießhübl syncline (below the Vienna Basin an important caprock) and Middle and Upper Triassic of the Tirolicum.

The facies change of Mesozoic sediments from north to south with special attention to the upper Middle Triassic and to the Upper Triassic is considered. This is demonstrated by the following changes:

1) Low thickness of basinal Reifling and Partnach limestones, in the northern nappe systems.
2) Large thickness of the platform deposits of the Wetterstein Limestone and Dolomite visible from the well Berndorf 1 southward.
3) Increasing thickness of the Upper Triassic Hauptdolomit southward.
4) The development of the Hauptdolomit from a lagoonal, partly continental influenced facies to a reefoidal and finally to a basinal one as to be seen in excursion 5.

The complex tectonic structure is strongly influenced by the facies and thickness. Narrow folds and schuppen predominate in the North, in contrast to the rigid behaviour of tectonic units in the south. An example for dating thrusts is shown. The importance of dolomites and fractured limestones as reservoir rocks is demonstrated.

The desriptions of Stops 4/1–4/8 are based on investigations of G. WESSELY during mapping of the geological sheets 1 : 50.000 "58 Baden" and "57 Neulengbach" and neighbouring areas ("75 Puchberg", H. SUMMESBERGER, 1991, including data of G. HERTWECK). In Stop 4/9 results of the well Berndorf 1 (G. WACHTEL & G. WESSELY, 1981) are referrred.

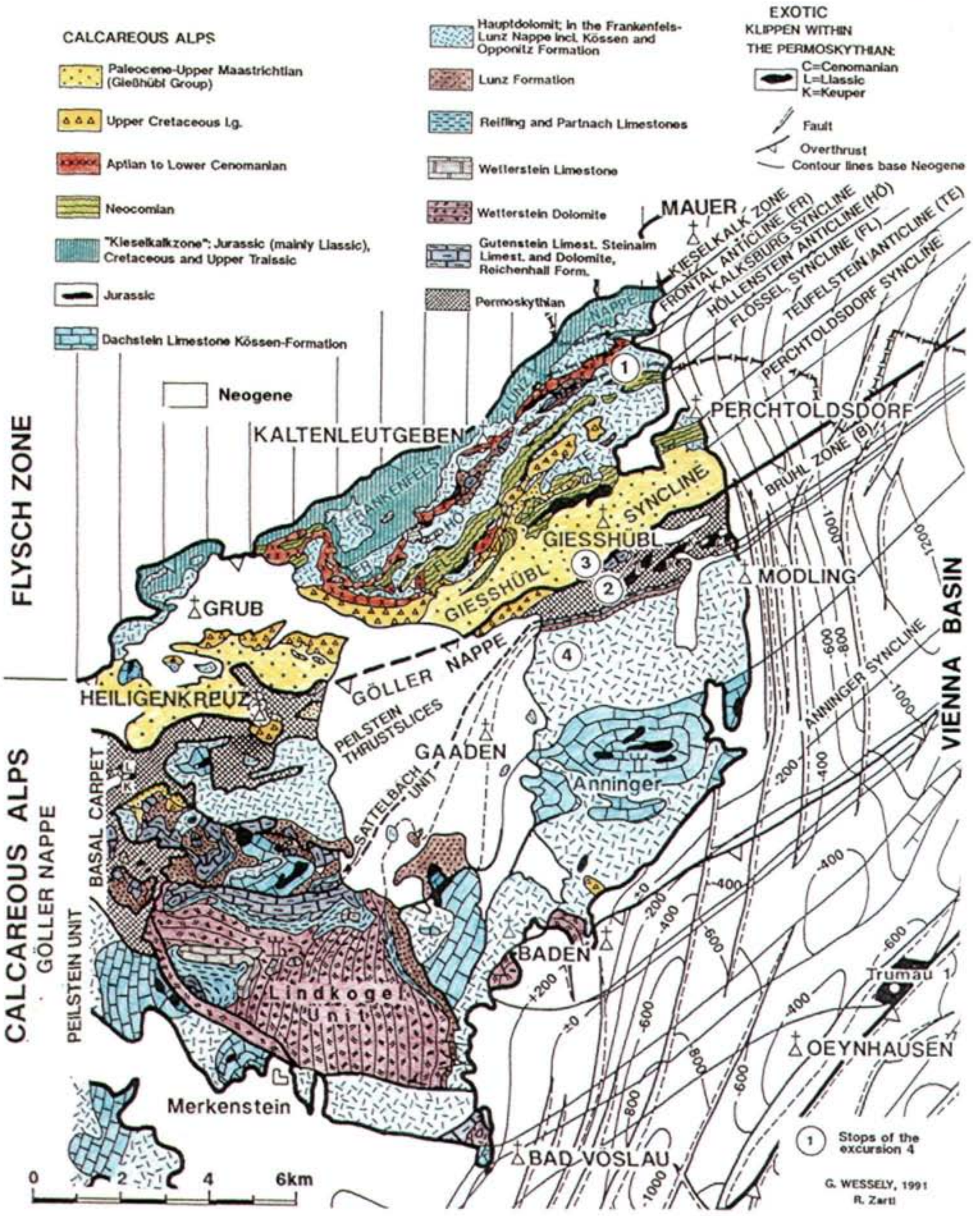


Fig. 132: Northern part of the Calcareous Alps, geologic overview (G. WESSELY).
Stops 1–4 of Excursion 4.

STOP No. 4/1

LOCATION: Neumühle "Kritsch" quarry (Figs. 132,133,134).
TECTONIC UNIT: Calcareous Alps, Bajuvaricum, Frankenfels-Lunz Nappe.
FORMATION: Hauptdolomit, "Rodaun Limestone", Kössen Formation, Klaus Formation, Saccocoma Limestone, Calpionella Limestone, Neocomian.
AGE: Upper Triassic, Middle to Upper Jurassic, Lower Cretaceous.

The quarry Neumühle (Figs. 135–138) is located in the Kaltenleutgeben valley southwest of Vienna. The tectonic position within the Bajuvaricum is the southern limb of the Höllenstein Anticline and the northern limb of the Flössel Syncline (Figs. 133, 134). The quarry has been subject of many investigations, the most extensive made by G ROSENBERG (1965 a,b), L. KRYSTYN (1970, 1972) and G. WESSELY (preparation of the geological sheet "58 Baden" 1 : 50.000).

The quarry exhibits a section from Upper Triassic to Lower Cretaceous characteristic for the development and thickness of the eastern Bajuvaricum. In the lower part of the sequence an Upper Triassic limestone is exposed. G. ROSENBERG (1965) designated it as "basal Norian limestone". However, it forms an about 150 m thick intercalation within the Hauptdolomit, which has its typical thick development north of the Kaltenleutgeben valley (Fig. 133). Transitions of the limestone to the Hauptdolomit below are already visible in the quarry, in the lowest part of the exposed sequence. The limestone replaces a rather higher part of the Hauptdolomit. It consists of dark mudstones and packstones (Fig. 139). Interbedded dolomite is common even within one layer. Lamination and sometimes intraclasts can be observed. Layers of dark shale cause bedding. Abundant ostracods in the dark limestone are typical (Fig. 140). For this sequence the new term "Rodaun Limestone" may be used.

The "Rodaun Limestone" is followed by gray to brownish Hauptdolomit which is partly laminated (Fig. 141). The low thickness and layers of green or dark gray shales are significant for the frontal facies of the Hauptdolomit. The shales represent a continental influence ("Keuper beds") in the lagoonal environment (Fig. 142).

The same fractured Hauptdolomit that is exposed here, forms the reservoir rock of the Aderklaa gasfield below the Vienna basin fill.

The Hauptdolomit is covered by the Kössen Formation. Layers of limestone alternate with dolomite beds at the base.

Dark bioclastic and oolithic limestones and dark marls and marly limestones rich in macrofossils are developed up section (Fig. 143,144). Signs of slumping can be observed (Fig. 145). The top of the Rhätian is composed of a dark limestone with corals. Sheet cracks within the limestone are filled with reddish or brownish or red limestone (Figs. 146,147). It is assumed that the filling is of Liassic age, because of the abundance of crinoids. Liassic, as represented by the pink Crinoidal or "Hierlatz" Limestone on the northern flank of the Flössel Syncline, is missing in the quarry section. Dogger forms a hardground on Rhaetian coral limestone (Fig. 146). The massive, few meter thick brown to reddish Dogger limestone "Klauskalk" (Fig. 146) is characterized by an enrichment of filaments (tiny shells of Bositra) (Fig. 150). L. KRYSTYN (1972) described ammonites of the Klauskalk in a now removed part of the quarry. In the uppermost part of the massive limestone the microfacies changes to a packstone, rich in

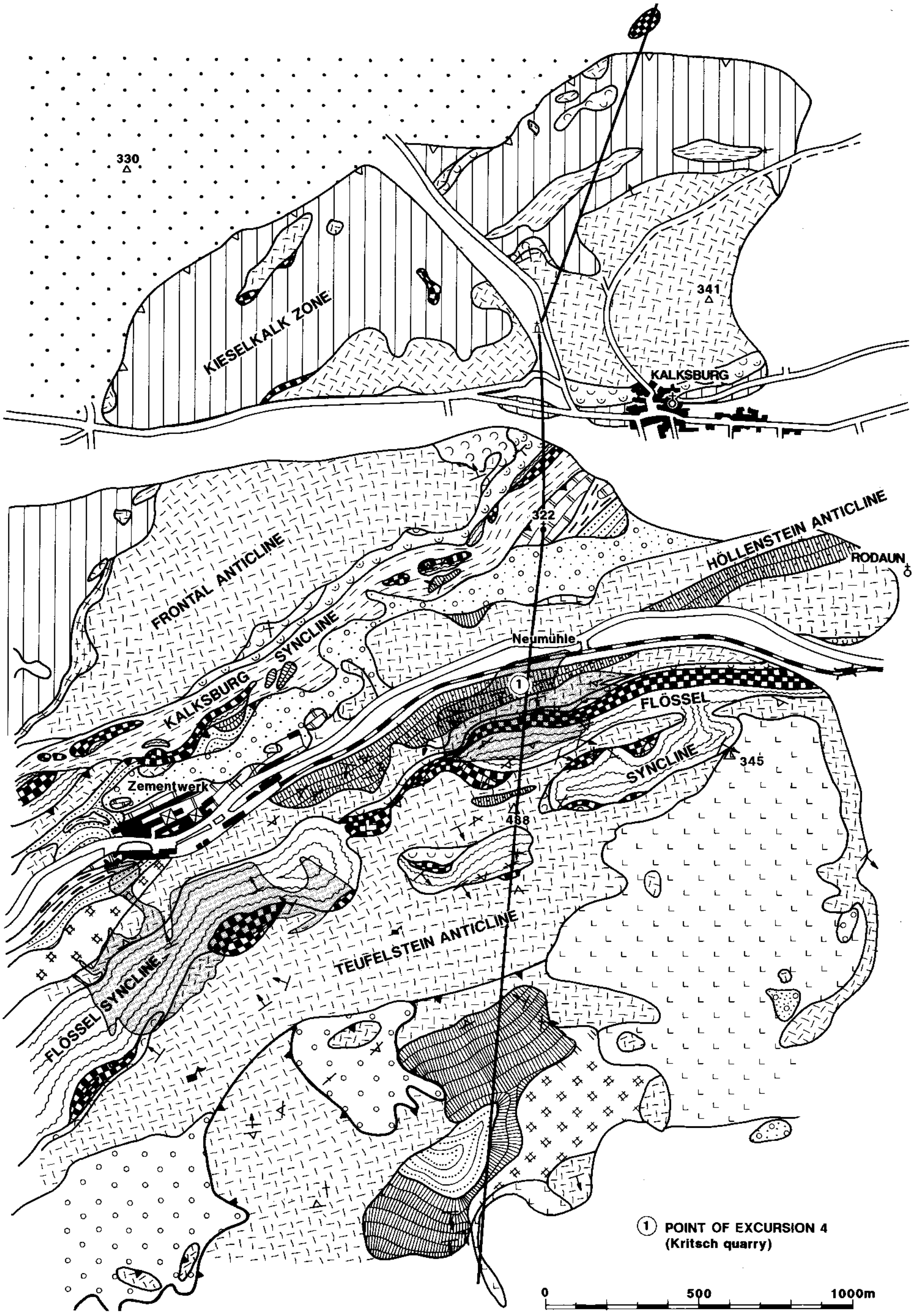


Fig. 133: Calcareous Alps of the Kalksburg-Kaltenleutgeben area (G. WESSELY).

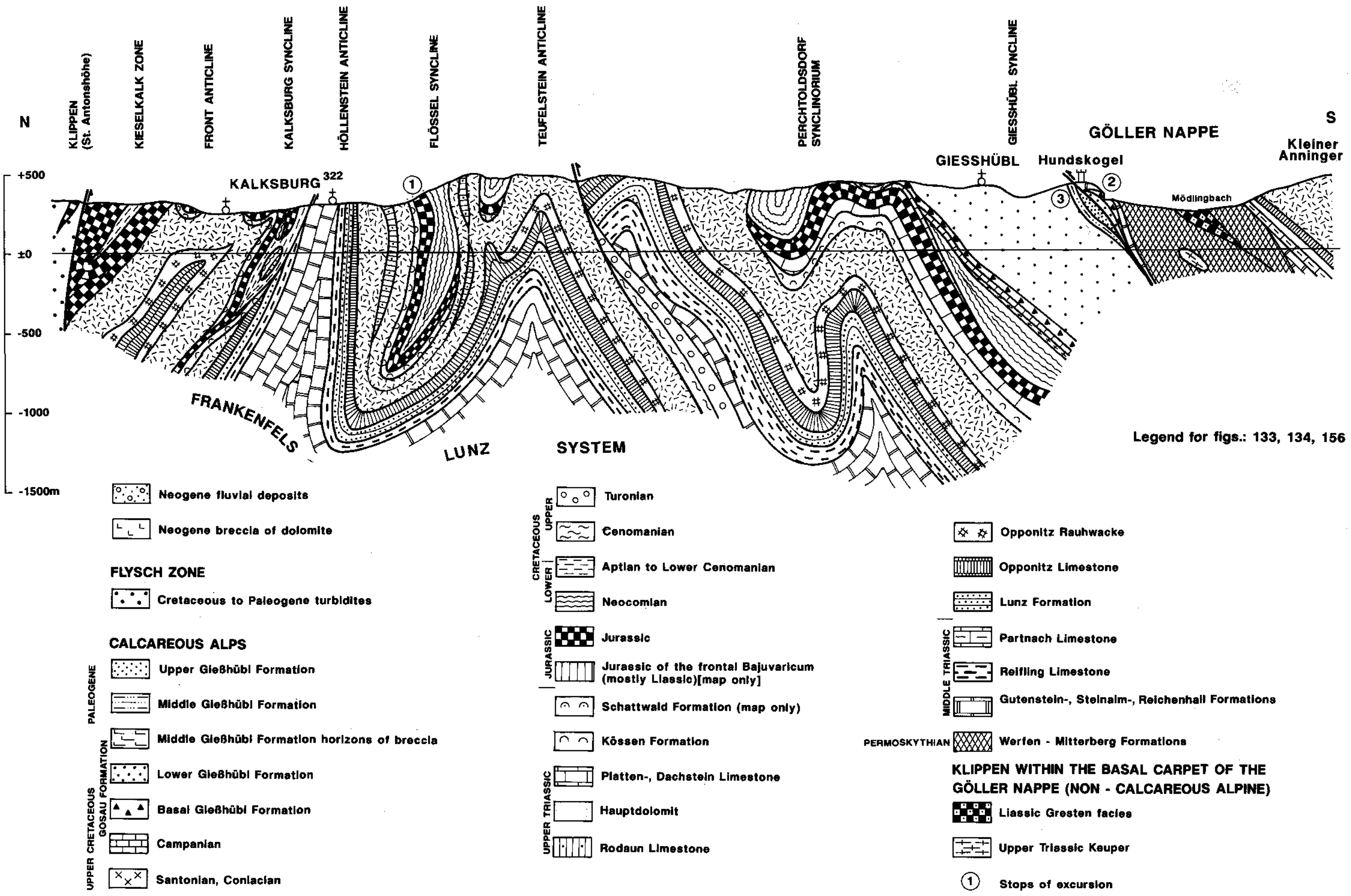


Fig. 134: Cross section through the northernmost Calcareous Alps SW of Vienna (G. WESSELY).

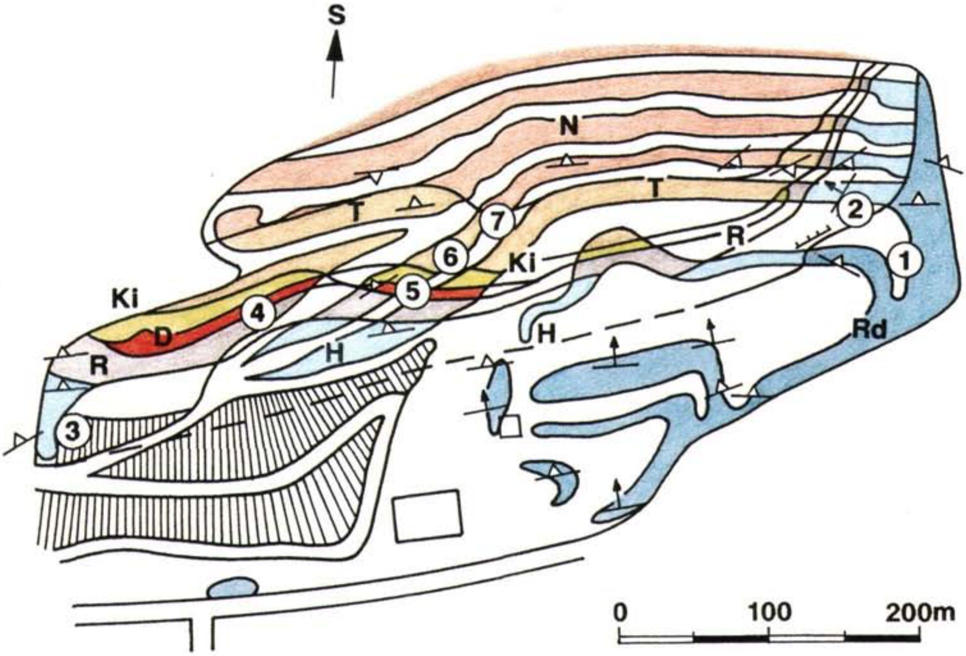


Fig. 135: Kritsch quarry Neumühle.
Geologic overview.
N = Neocomian spotted marly limestones and marls; T = Tithonian light gray bedded limestones and red conglomeratic limestones, Ki = Kimmeridgian conglomerates and nodular limestones; D = Dogger (Klaus Limestone); R = Kössen Formation, in the uppermost part with coral beds; H = Hauptdolomit; K = Intercalation of Keuper in the Hauptdolomit; Rd = Rodaun Limestone. Dark, thin bedded limestones, shales and dolomite.
1–7 = positions of details in the figures 139–155.
Dipping: long arrow = 40–60; short arrow = 61–90.

Globigerinas. In similar stratigraphic positions of this area additionally an oolithic development is common ("Gobigerina oolite"). Possibly this part represents already Lower Malmian (Oxfordian). Radiolarites, normally on top of the Klauskalk, *are missing, probably eroded. The massive limestone is followed by a red nodular* limestone of Kimmeridgian age (Fig. 150). Fragments of Saccocoma dominate the microfacies (Fig. 152). This Saccocoma Limestone is conglomeratic at the base and contains components of the uppermost horizon of the massive limestone, rich in Globigerinas (Fig. 151). The Tithonian is characterized by reddish and pale thin bedded limestones (Fig. 154), partially brecciated at the bottom (Fig. 153), with abundant Calpionellids (Fig. 155). The youngest beds are Neocomian, thin bedded, gray spotted marly limestones (Fig. 154, right side).

The quarry gives evidence of the steep to overturned structures near the front *of the Calcareous Alps formed by compression of the Calcareous Alps against* the Flysch. The steep southward dip of the beds in the eastern part of the quarry changes to a steep northern one on the west side caused by differential thrusting. This is indicated by thinning out of the black Kössen beds (Fig. 137). The Hauptdolomit and "Rodaun Limestone" return to a southward dip after another fault. Intense folding is visible in the Tithonian beds, possibly caused by submarine gliding.

Fig. 136: Panorama of the Kritsch quarry. ▼
Symbols see Fig. 135.

Fig. 137: **Western part of the Kritsch quarry.**
Upper Triassic Formations to the right separated by Kössen Formation (black shales) from Tithonian–Neocomian beds.
Symbols see Fig. 135.

Fig. 138: **Eastern part of the Kritsch quarry.**
From left to right Rodaun Limestone, Hauptdolomit, Kössen Formation (sequence with black shales), Middle Jurassic to Neocomian.
Symbols see Fig. 135.

Fig. 139: Rodaun Limestone with intercalations of dark shales.
Position 1 in Fig. 135.
Kritsch quarry, western part.

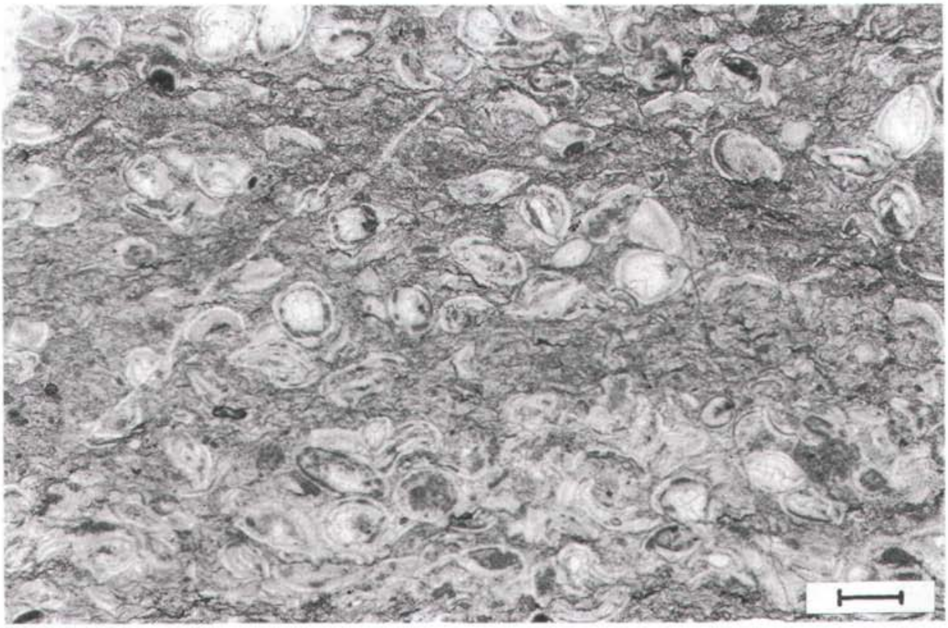


Fig. 140: Thin section photomicrograph of an ostracod packstone, typical for Rodaun Limestone.
Position 1 in Fig. 135.
Kritsch quarry; length of scale = 0.43 mm.

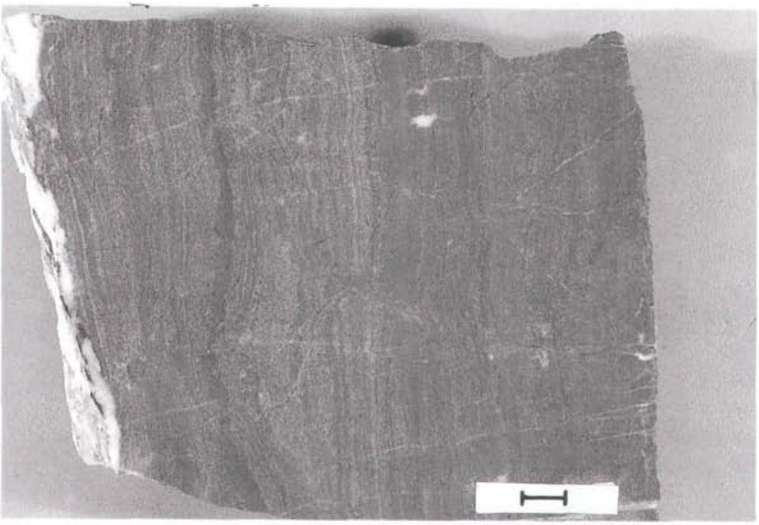


Fig. 141 ▲
Hauptdolomit bed with algal mat lamination.
Position 2 in Fig. 135.
Kritsch quarry; scale 1 cm.

Fig. 142 ▶
Fractured Hauptdolomit with an intercalation of green shales ("Keuper bed").
Position 3 in Fig. 135.
Kritsch quarry, eastern part.

Fig. 143: Photomicrograph of bioclastic Kössen Formation, Packstone with corals.
◄ Kritsch quarry; length of scale = 2.1 mm.

Fig. 144: Kössen Formation, coquina, matrix of mudstone.
► Kritsch quarry; length of scale = 2.1 mm.

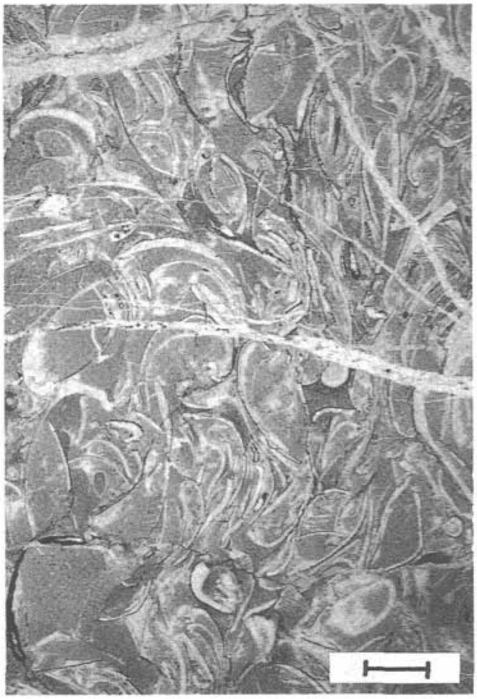


Fig. 145 ▲
Slumping of Rhätian sediments.
Position 4 in Fig. 135.
Kritsch quarry, eastern part.

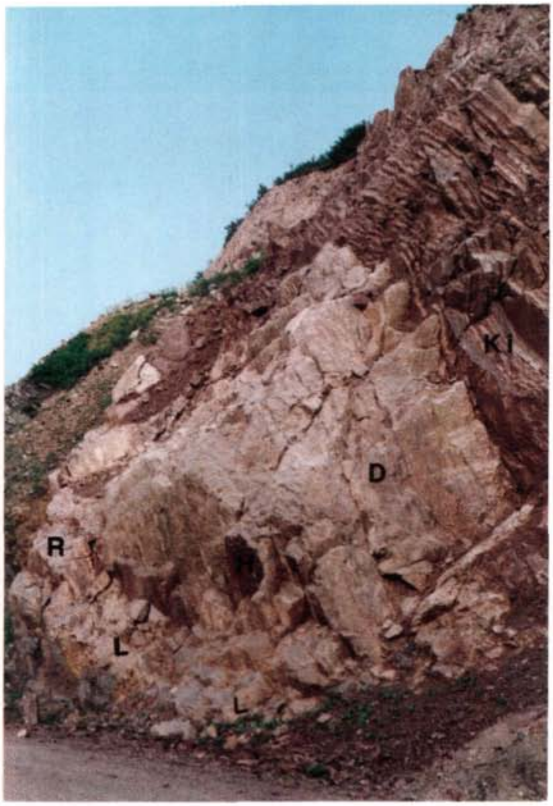


Fig. 146 ▶
Kössen Formation (R) and Klauskalk (D), Hardground in between (H), on top Kimmeridgian.
Liassic (?) cavity fillings (L) within the Kössen Formation (coral limestone).
Position 5 in Fig. 135.
Kritsch quarry.

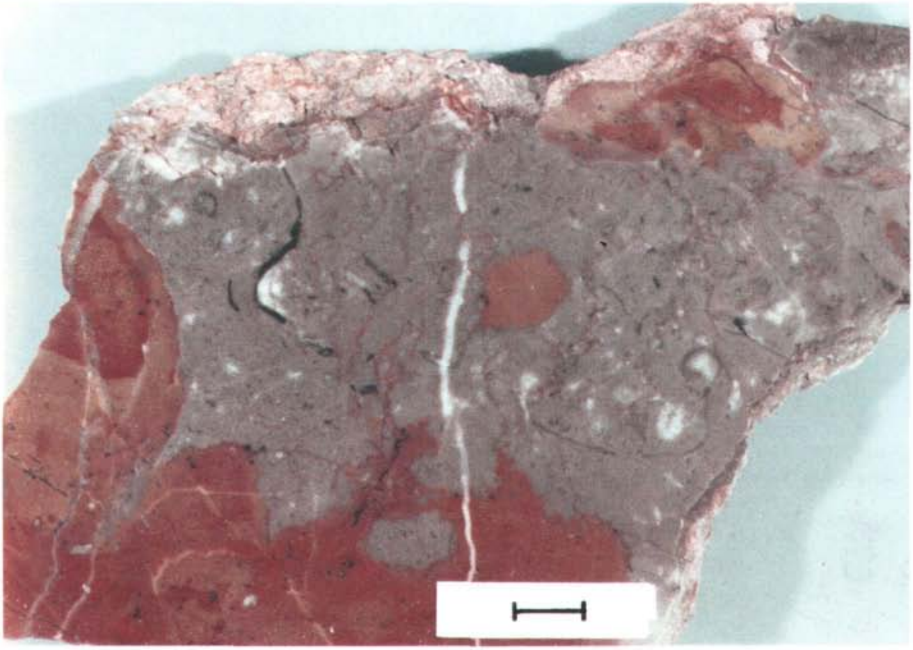


Fig. 147: Slabbed sample of coral limestone with Liassic (?) cavity fillings (reddish).
Kritsch quarry.

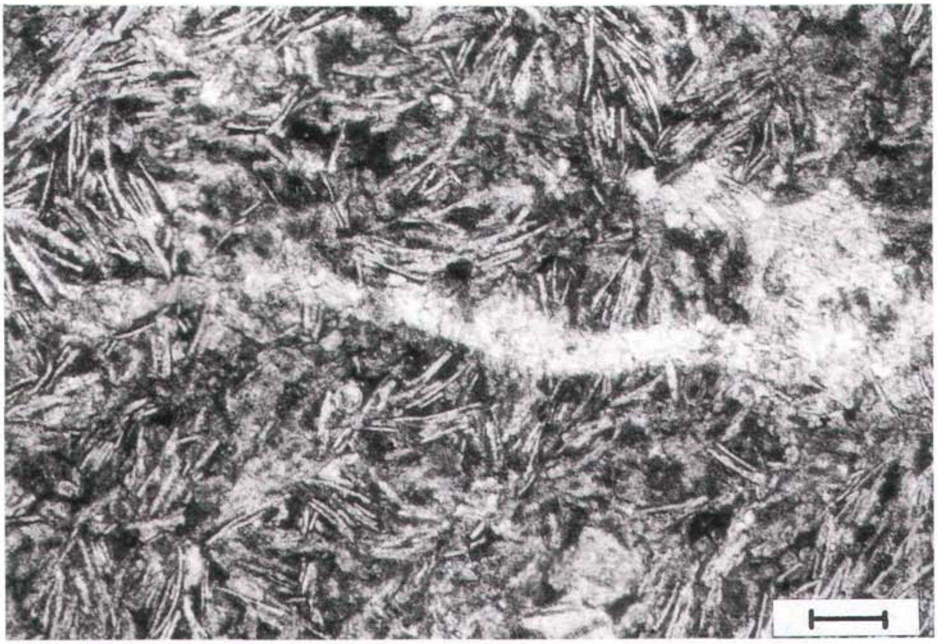


Fig. 148: Thin section photomicrograph of filament packstone (Dogger).
Position 5 in Fig. 135.
Kritsch quarry; length of scale = 0.25 mm.

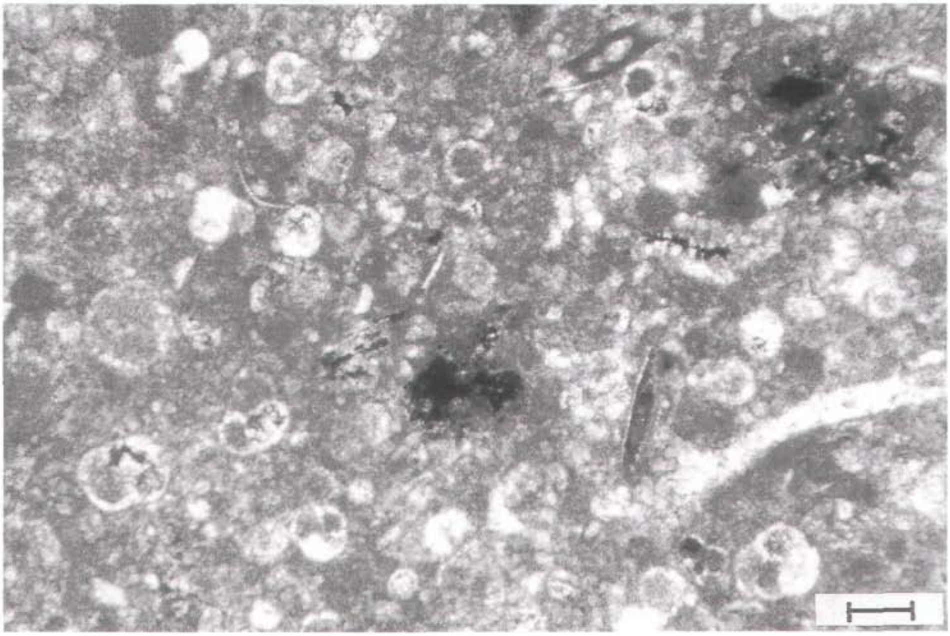


Fig. 149: Thin section photomicrograph of Globigerinid Limestone (Dogger–?Lower Malm).
Position 5 in Fig. 135).
Kritsch quarry; length of scale 0.14 mm.

Fig. 150: Detail of Kimmeridgian nodular limestone.
Position 5 in Fig. 135.
Kritsch quarry.

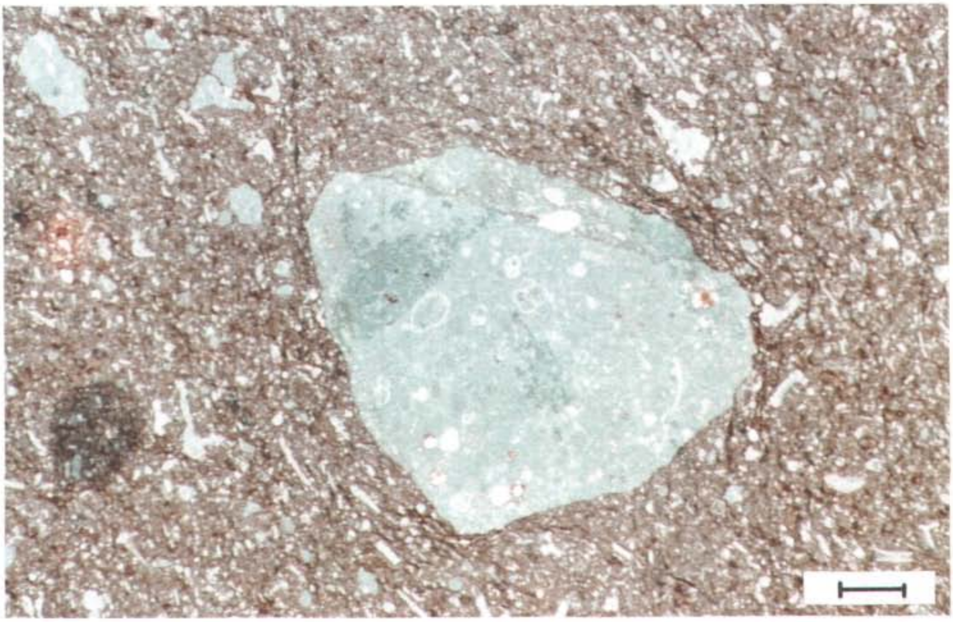


Fig. 151: Limestone clast with Globigerina in a Saccocoma limestone (Kimmeridgian).
Position 5 in Fig. 135.
Kritsch quarry; length of scale = 0.43 mm.

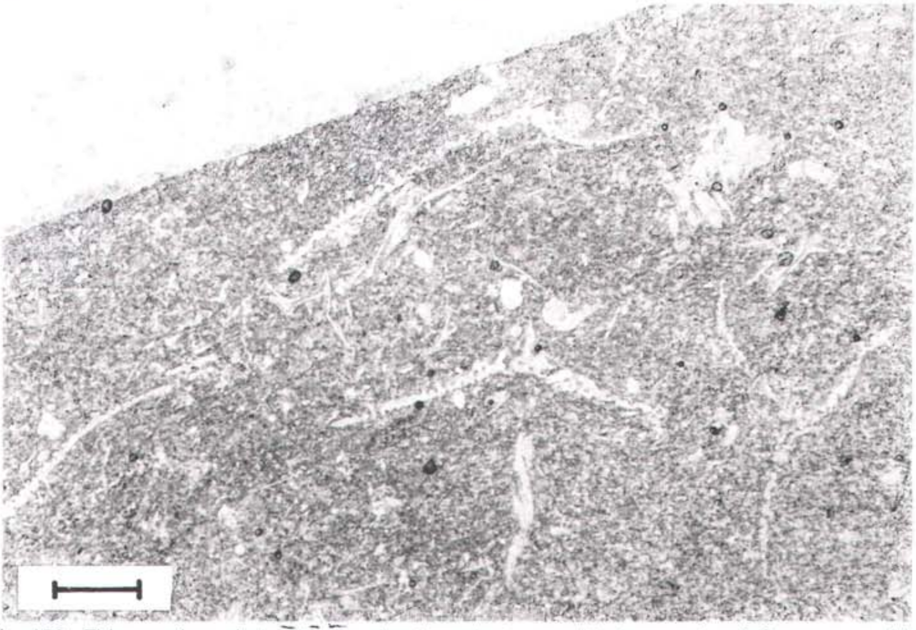


Fig. 152: Thin section photomicrograph of wackestone with fragments of Saccocoma (Kimmeridgian).
Kritsch quarry; Position 5 in Fig. 135; length of scale 0.15 mm.

Fig. 153 ▶
Tithonian brecciated limestone.
Position 6 in Fig. 135).
Kritsch quarry.

Fig. 154 ▼
Tithonian to Neocomian limestone (left to right).
Position 7 in Fig. 135).
Kritsch quarry.

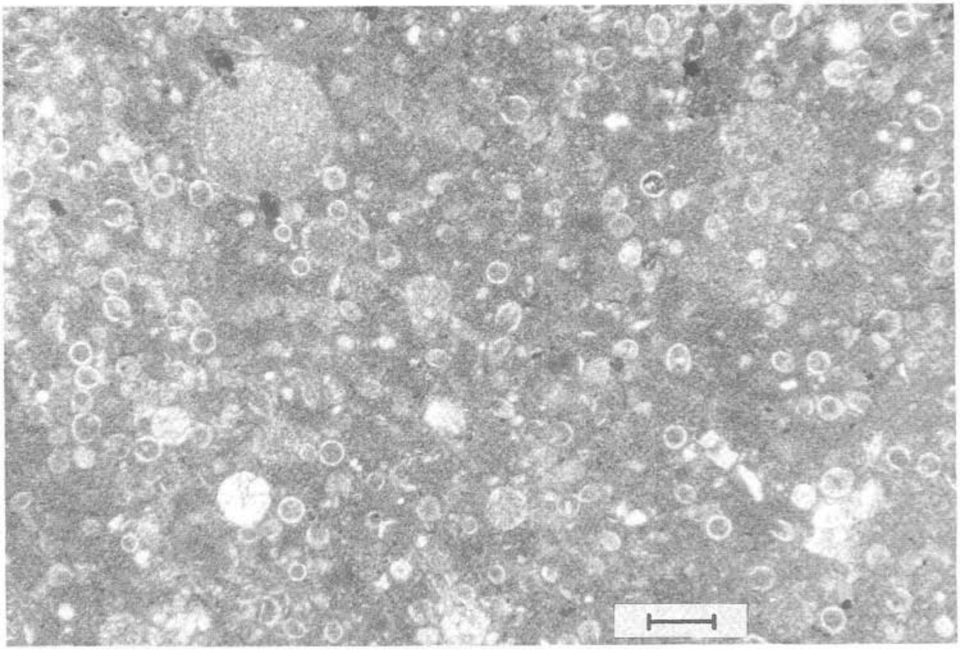


Fig. 155: Thin section photomicrograph of Tithonian limestone with abundant Calpionellids and Radiolarians.
Position 7 in Fig. 135.
Kritsch quarry; length of scale = 0.14 mm.

STOP No. 4/2

LOCATION: "Wertheim" quarry, Hinterbrühl (Figs. 132,156).
TECTONIC UNIT: Tirolicum, Göller Nappe.
FORMATION: Permoscythian Werfen Formation s.l., Anisian Reichenhall Formation and Steinalm Limestone, Gutenstein Limestone, Upper Maastrichtian to Paleocene Gießhübl Group.
AGE: Permian, Middle Triassic, Upper Cretaceous to Paleogene.

The "Wertheim" quarry below the view point "Hundskogl" is situated on the northern flank of the Mödling valley, south of the village Hinterbrühl.

The quarry exposes the frontal part of the Tirolicum (Fig. 157). This outcrop is near the contact of the Göller Nappe with the underlying Maastricht–Paleogene Gießhübl Group of the Bajuvaricum (B. PLÖCHINGER, 1974).

The frontal part of the Göller Nappe called the "Brühl Zone" consists of strongly deformed, tectonically incompetent sections of Permoscythian shales, evaporites and klippen-like rigid complexes of Middle Triassic limestones and dolomites. It also contains isolated exotic shear bodies. These consist of Keuper, Liassic Gresten beds, Upper Jurassic and Neocomian pelagic limestones as well as Cenomanian marls including exotic boulders, uplifted from a northern Alpine-Carpathian tectonic unit (probably Klippen belt or Manin Zone).

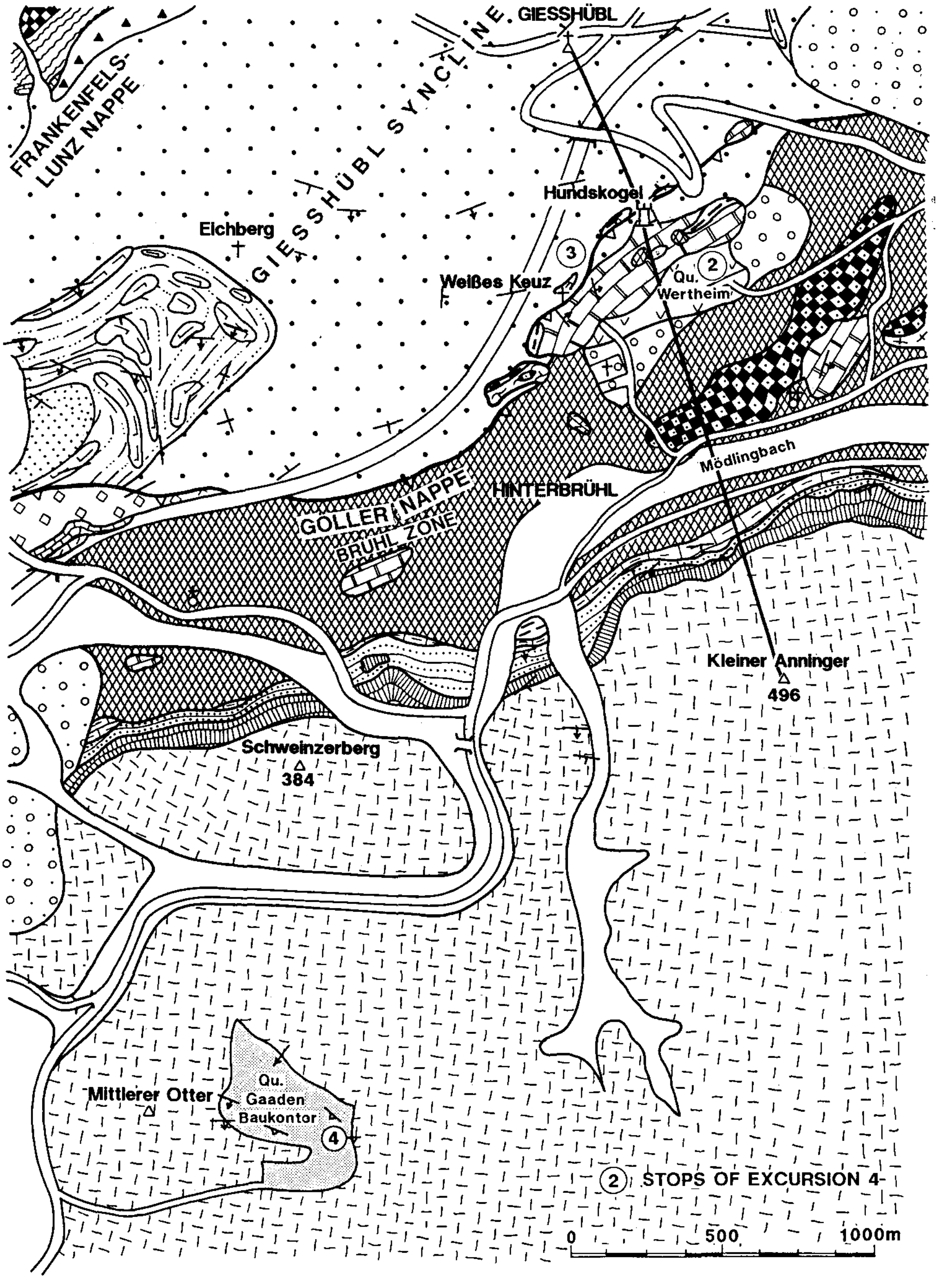


Fig. 156: Calcareous Alps of the Hinterbrühl area southwest of Vienna (G. WESSELY).
Line between Gießhübl and Kleiner Anninger marks southern part of cross section in Fig. 134.
Legend see Fig. 134.

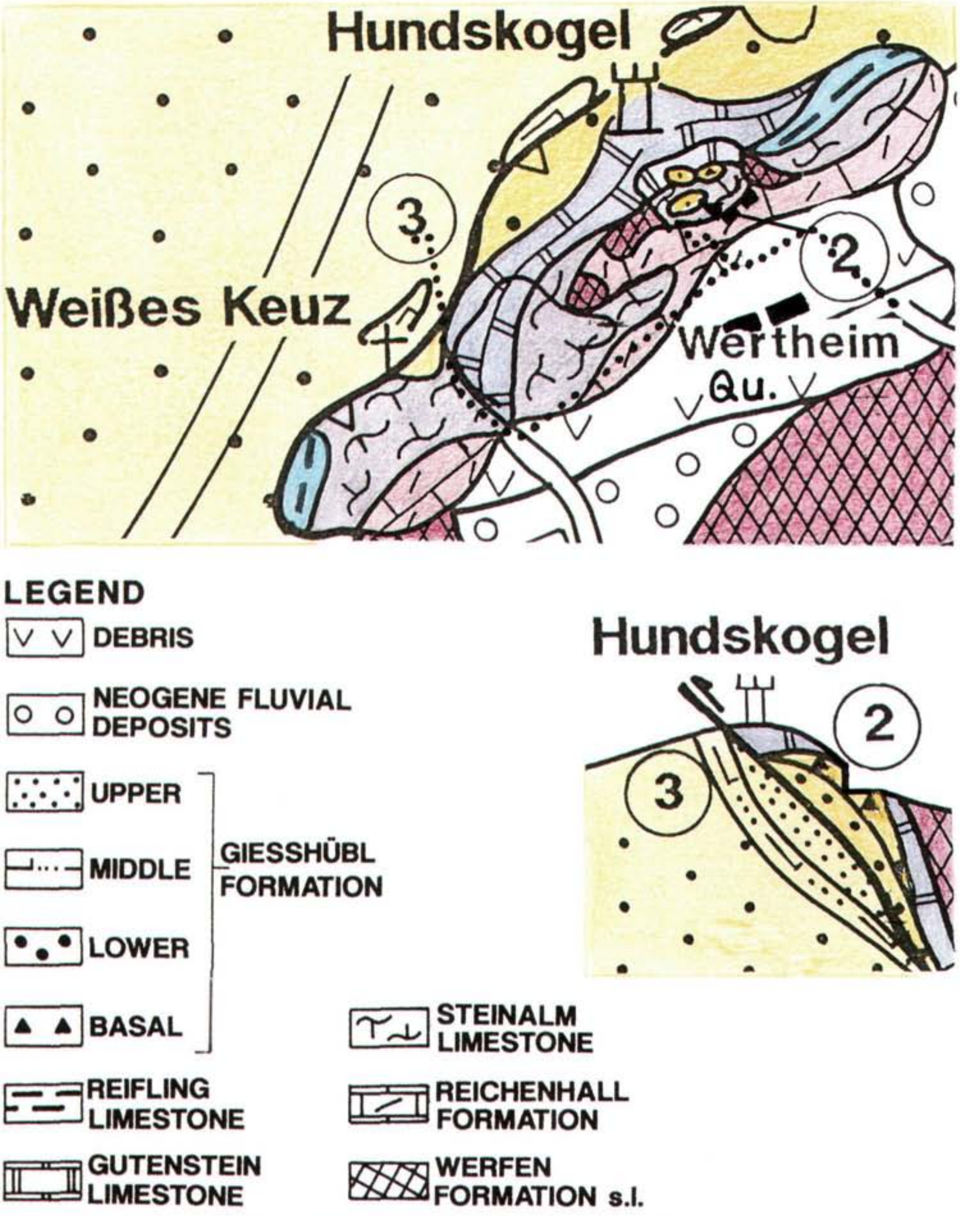


Fig. 157: Wertheim quarry: Location and schematic profile (G. WESSELY).

These have been incorporated in the basal thrust carpet of the Göller Nappe. This frontal element roughly forms a twofold recumbent anticline. Permian gypsum was mined in the "Seegrotte", now a famous tourist attraction because of a large underground lake. On the top of the frontal "Brühl Zone"; a rigid Upper Triassic complex, with a thick section of Hauptdolomit and Dachsteinkalk follows

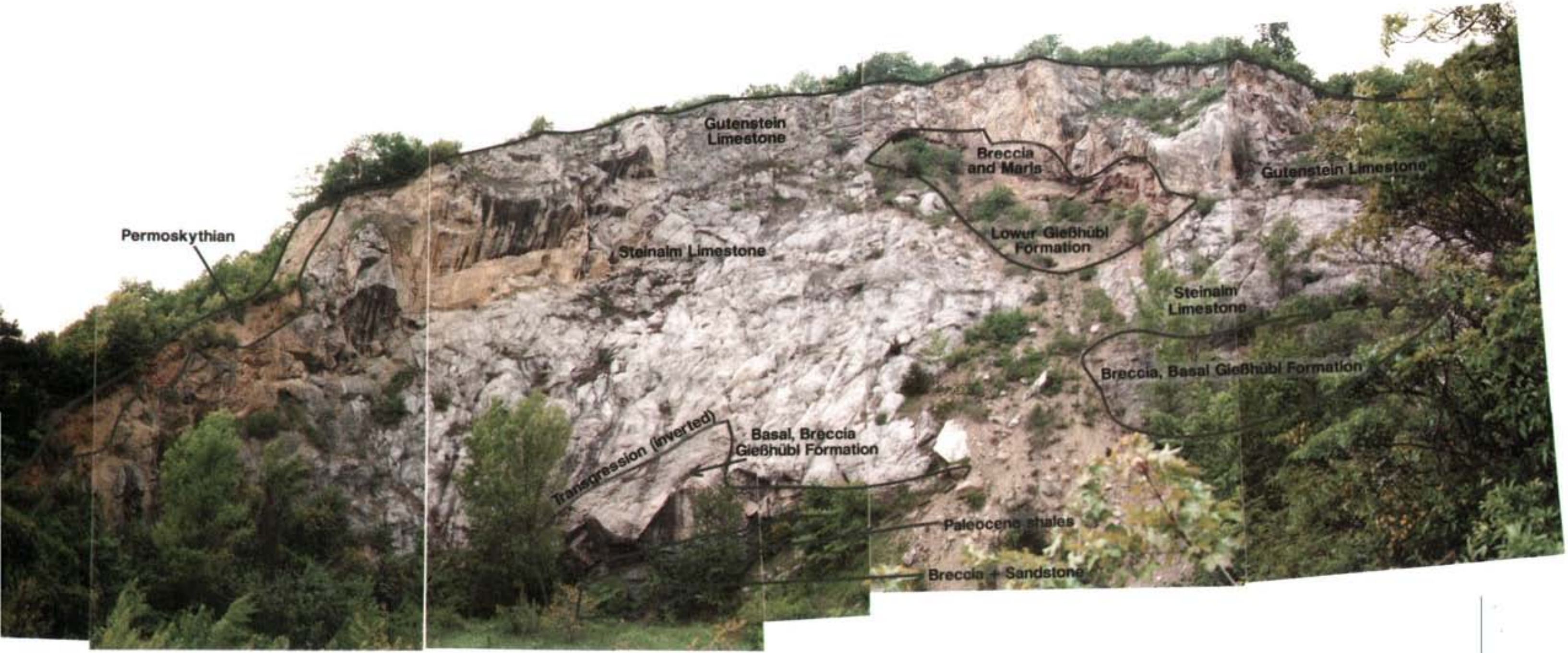


Fig. 158: Inverted section of Permoskythian beds (brown weathered zone of the upper left margin), gray Middle Triassic limestone and transgressive Gießhübl beds (central part).
Wertheim quarry.

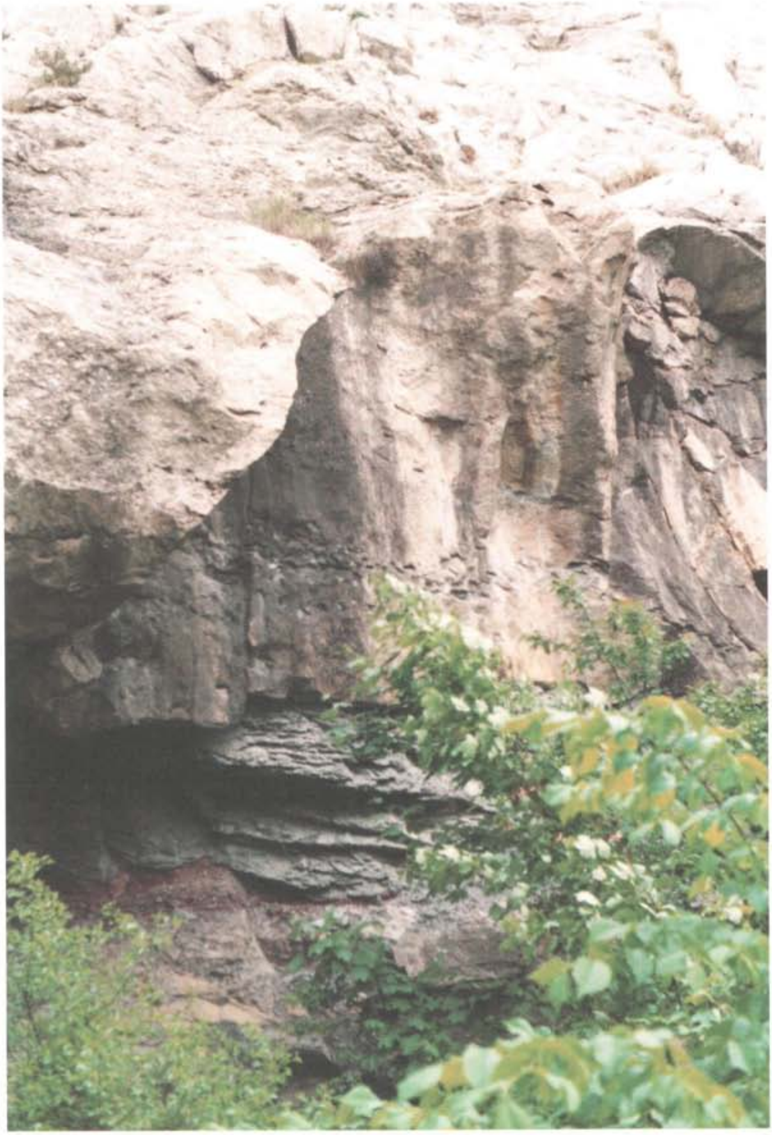


Fig. 159: Inverted section of (from top to bottom) Steinalm limestone, polymict breccias (chips horizon) and variegated shales of Lower Gießhübl Formation.
Wertheim quarry.

to the South. It forms a broad syncline, containing Jurassic sediments in its innermost part (Anninger syncline) (Fig. 132).

The "Wertheim" quarry is situated in the inverted limb of the lowermost recumbent fold of the frontal zone. Along the upper rim of the western and the eastern wall (Fig. 158) a totally mylonitized and weathered Permoskythian member marks the innermost core of the fold. It consists of brownish rauhwacke with green and

Fig. 160: Chaotic breccia of the Lower Gießhübl Formation.
Wertheim quarry.

violet shale clasts. The Reichenhall Formation is also composed of rauhwacke (southeasternmost end of the quarry, not in the figure). The dominant rock types are the gray Middle Triassic (Anisian) massive Steinalm Limestone and the bedded Gutenstein Limestone. The inverted series is followed by a transgression of breccias of the Lower Gießhübl Formation. Initially these are monomict and difficult to distinguish from the host rock. Later they become polymict and contain horizons of green and dark shale chips. These breccias are exposed in some "window-like" parts of the quarry. The best one is in the lowermost part of the northern wall (Fig. 159), where green, gray and red shales appear below the breccias. Breccias within the shales are composed of a chaotic mixture of shales, fragments of carbonates and sandstones (Fig. 160). The shales are dated as Danian–Montian. Folding within this series may be caused by tectonics or by slumping. A detachment plane is not visible. This leads to the conclusion that these sediments are the primary synorogenic cover on the front of the Göller Nappe. They were deposited during its advance over the Gießhübl Group and are now inverted. The thrust plane is below the quarry on the Middle Gießhübl Formation as it was mapped north of the quarry (Fig. 157).

This situation, which documents the age and succession of the thrust event, can be observed by drilling in the Vienna basin, in the Aderklaa–Raasdorf area: Above Lower Gießhübl Formation, frontal parts of the Göller Nappe were emplaced by sliding. Sedimentation of turbiditic Upper Gießhübl Formation followed, covering this advancing frontal part. Thrusting of the main part of the nappe occurred after deposition of the Upper Gießhübl Formation (well Raasdorf T3; Fig. 17).

The route continues westward by foot to Stop 3. Another quarry similar to Stop 2 is passed, with an inverted series of Permoscythian (right above), Reichenhall Formation (lowermost eastern portion), Steinalm- and Gutenstein Formation (main part). Looking eastward from the western upper rim steep dipping red and green marls and breccias of the Lower Gießhübl Formation (North) deposited on the Middle Triassic (South) confirm the interpretations made in Stop 2.

STOP No. 4/3

LOCATION: Weißes Kreuz NE, near Hinterbrühl (Fig. 156,157).
TECTONIC UNIT: Bajuvaricum, Gießhübl Syncline.
FORMATION: S: Middle to Lower Gießhübl Formation.
AGE: Paleocene (Montian to Thanetian).

A steeply southward dipping graded turbidite bed (carbonate breccia to sandstone in an upright position) is exposed, about 150 m NE of Weißes Kreuz, along a small valley. Later, on the eastern flank of the valley, a small outcrop exposes one cycle of typical Lower Gießhübl Formation, showing part of a southward concave fold (Fig. 161). The turbiditic member starts with a basal breccia (Fig. 162), which grades southward into a sandstone and finally into a gray marl. The base of sandstone exhibits flute casts.

The term "Gießhübler Schichten" has been established by B. PLÖCHINGER (1964) for the flysch-like Gosau beds in which R. OBERHAUSER determined a Paleocene microfauna. Later on (G. WESSELY, 1975) the range of the Gießhübl beds has been widened by uppermost Maastrichtian and a subdivision in Upper–Middle and Lower Gießhübl beds has been made, mainly in wells of the Vienna Basin on the base of lithological criteria and of microfauna and nannoflora, determined by H. STRADNER. Detailed sedimentological studies have been carried out by R. SAUER (1980).

Fig. 161: Lower Gießhübl Formation with a graded trubidite bed. The top of the cycle toward the south (right).
N Hinterbrühl, Stop 4/3.

Fig. 162: Turbidite bed with graded bedding at the base.
Lower Gießhübl Formation, Stop 4/3; length of scale = 1 cm.

In the Vienna Basin the Gießhübl Formation is an important caprock for gas accummulations in Calcareous Alpine internal traps.

STOP No. 4/4

LOCATION: quarry Baukontor east of Gaaden (Figs. 132,156).
TECTONIC UNIT: Tirolicum, Göller nappe.
FORMATION: Hauptdolomit.
AGE: Upper Triassic, Norian.

The quarry runs east of the hill "Mittlerer Otter".

The Hauptdolomit belongs to the northern part of the Göller Nappe. It forms the northern limb of the "Anninger" Syncline on top of the complicated frontal zone of Hinterbrühl (Fig. 134). The Hauptdolomit (Fig. 163) is composed of mudstones, doloarenites and sometimes breccias. Its colour is primarily light to medium gray. Sometimes thin black intercalations occur. The texture of the bedded Hauptdolomit shows algal laminated layers, concentrations of birdseyes and burrowed sections.

The dolomite has moderate to steep dips towards the SSW. It is strongly fractured. The faults are characterized by zones of mylonite. Some directions of motion are favoured, but no significant displacements are observable. A fold in the

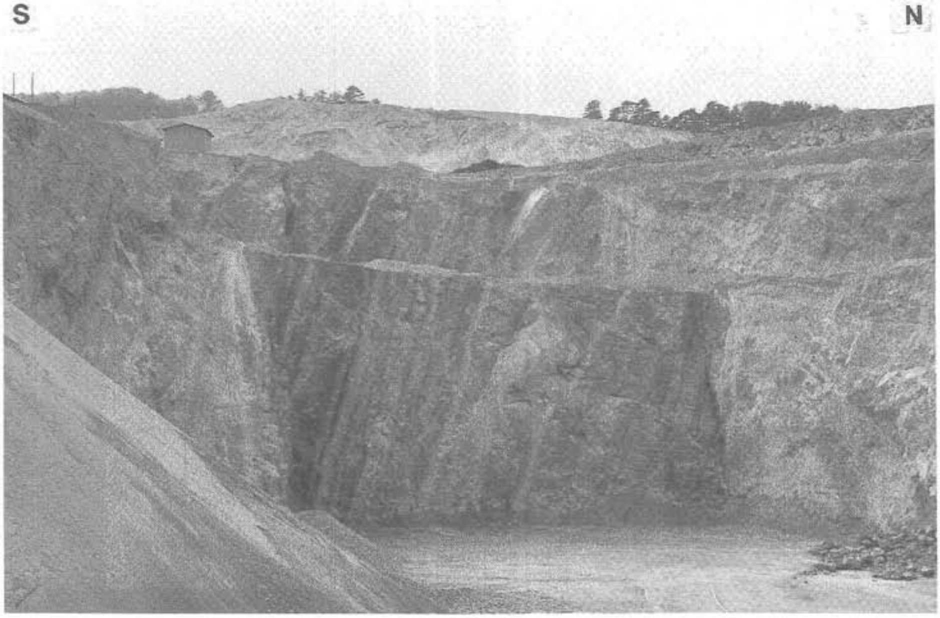


Fig. 163: Steep SSW dipping Hauptdolomit.
Quarry Baukontor east Gaaden.

Fig. 164: Fold with a SSW dipping axis within the Hauptdolomit. The faults are marked by mylonitic, cemented zones.
Quarry Baukontor.

NE-part of the quarry (Fig. 164) with an axis dipping toward SSW is displaced by faults. The dolomite is high in porosity and permeability and is comparable with the reservoir rock of the oil- and gasfields of Schönkirchen and Prottes below the Neogene of the central Vienna Basin.

The route (Figs. 132,121) continues in the small Neogene basin of Gaaden (depth about 200 m) and enters the frontal zone of the Tirolicum again near Heiligenkreuz (Campanian breccias and slope sediments on top of Permoscythian basal complex overthrusting Middle Gießhübl Formation on the northern road cut). Leaving Heiligenkreuz the same Campanian breccias are seen along the left side of the road. The route then moves within an extended "basal carpet" of the Tirolicum with deformed and mylonitized Permoscythian beds including gypsum deposits, Reichenhall beds and on top with klippen like bodies of isolated, sometimes inverted parts of north trending partial nappes of the Tirolicum (Buchberg S Alland). An extended inverted part is represented by the Sattelbach unit. Within the "basal carpet" shear bodies like in Hinterbrühl not belonging to the Calcareous Alps occur. The following shear bodies are comparable with the Inner Carpathian klippen belt or related zones: Keuper, Liassic in Gresten facies, pelagic limestones of Upper Jurassic and Neocomian. They are enveloped by Permoscythian beds. The route passes the largest one of these shear bodies: Liassic sandstones and marls rich in Microfauna and with Gryphaea arcuata between Alland and Groisbach. Along road cuts north and west of Groisbach, Campanian Gosau beds are exposed. These consist of varigated marly limestones, shales and coarse clastics.

STOP No. 4/5

LOCATION: Talhof, road cut (Figs. 165,121).
TECTONIC UNIT: Tirolicum, Göller Nappe, Peilstein unit.
FORMATION: Anisian (to Scythian?) Reichenhall Formation, Anisian Steinalm Limestone.
AGE: Middle (to Lower) Triassic.

The Peilstein unit is a partial nappe of the Göller Nappe. West of the Peilstein region a basal carpet of Permoscythian shales and evaporites extends northwestward over the Gießhübl Group. Massive Cretaceous breccias form the front of the nappe (Figs. 165,166).

The main complex of the Peilstein unit, especially the Middle Triassic carbonate platform complex, is exposed along the road cut (left side of the road Nöstach – Neuhaus) beginning at the farm house Talhof.

The basal formation is the Reichenhall Formation (Fig. 167). It consists of dolomites and dark, partly laminated shallow water limestones. It is unconformably overlain by breccias, consisting mainly of dolomites and some particles of Permoscythian green shales.

The most significant rock is the Steinalm Limestone. It forms the southern Peilstein walls (Fig. 168) and is frequented by climbers. Its lower part is composed of algal fragments, frequently Tubiphytes (Fig. 169). The upper part of the Steinalm Limestone contains abundant reefal debris (dasyclad algae, echinoderms, etc.) (Fig. 170).

Further along the profile are folded Gutenstein Limestones which are also exposed in the next Stop.

STOP No. 4/6

LOCATION: Quarry Aegydigraben S of Talhof (Fig. 165).
TECTONIC UNIT: Tirolicum, Göller Nappe, Peilstein unit.
FORMATION: Anisian Gutenstein Limestone.
AGE: Middle Triassic.

The Anisian basinal facies exposed here (Fig. 171) is a continuation of Stop 4/5. Two different developments are exposed: The lower part shows typical Gutenstein Limestones, thin bedded, dark gray, with some thin intercalations of dark gray to brownish marls. Small spheres of dark chert are concentrated in some layers ("Kugelkalk").

The attitude of the formation is nearly flat. In the Gutenstein Limestones, some well developed kink folds can be seen , like along the road cut south of the quarry (Fig. 172).

The upper part of the quarry is medium gray to brownish with nodular beds that are generally thicker and contain brownish gray shale intercalations (Fig. 173). Conodonts place this limestone in the Anisian (information by L. KRYSTYN & R. LEIN). A definition of this formation is in preparation. The microfacies of the Gutenstein Limestone is characterized by the ocurrance of radiolarians in the lower part (Fig. 174) and filaments and spicules in the upper part (Fig. 175).

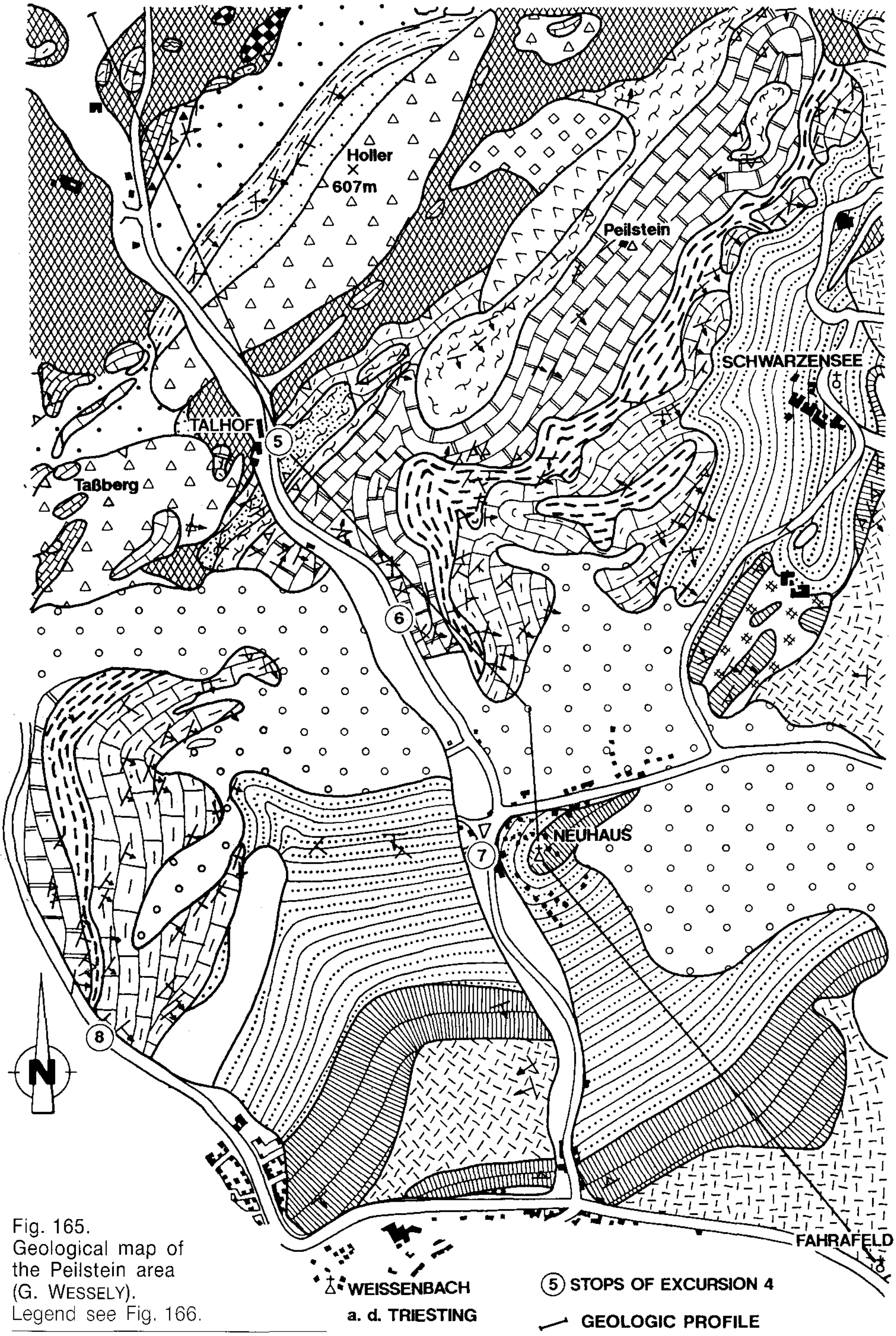


Fig. 165.
Geological map of the Peilstein area (G. Wessely).
Legend see Fig. 166.

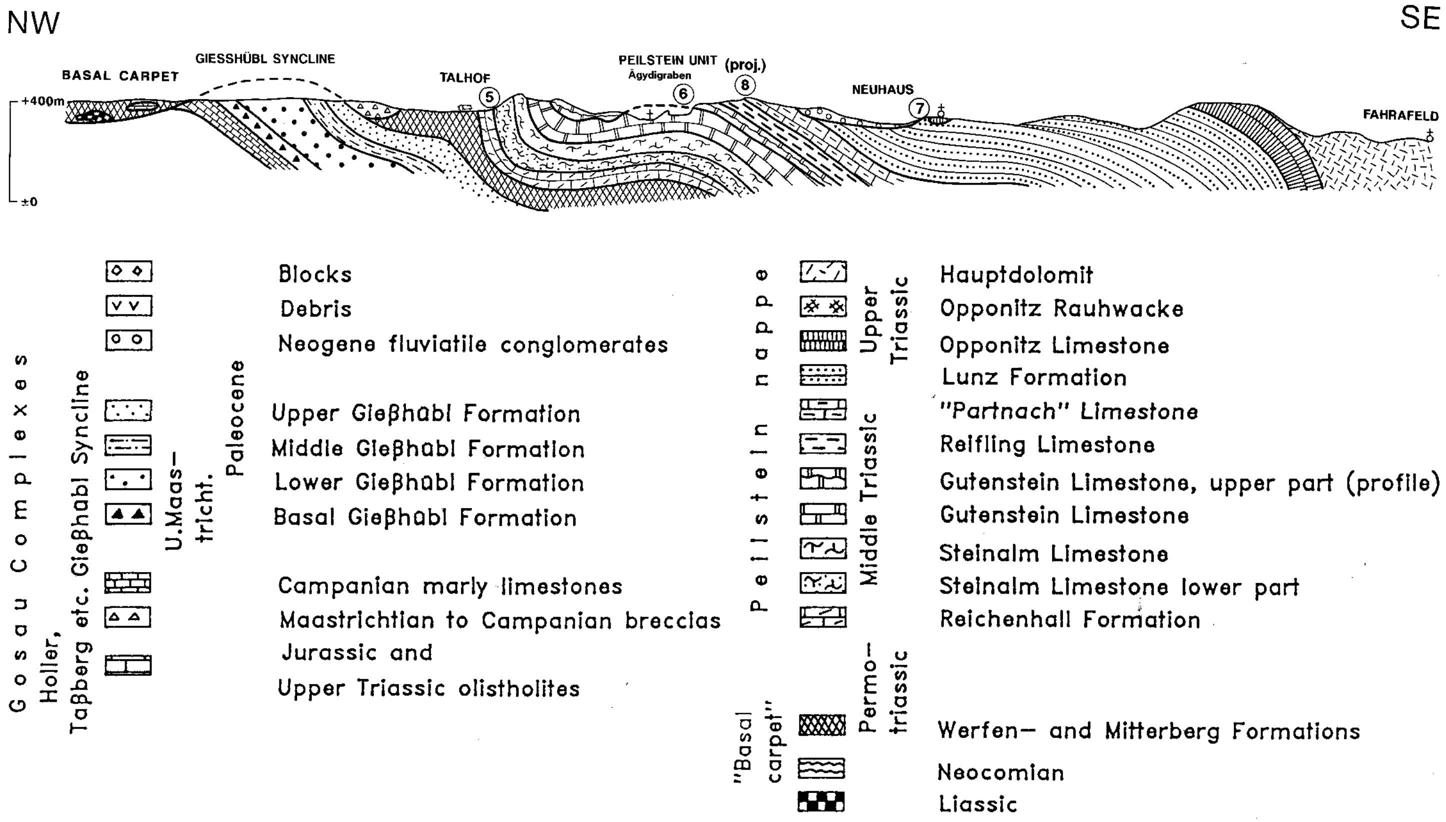


Fig. 166: Cross section through the Peilstein Unit and its overthrust over the Gießhübl syncline W of Peilstein (G. WESSELY).

Fig. 167: Reichenhall Formation of the Peilstein Unit.
D = dolomite; L = laminated limestone; B = breccia. Dipping: 100/80.
Road cut at Talhof.

STOP No. 4/7

LOCATION: Neuhaus (Fig. 165).
TECTONIC UNIT: Tirolicum, Göller Nappe, Peilstein unit.
FORMATION: Carnian Lunz Formation.
AGE: Upper Triassic.

A small outcrop of steeply eastward dipping Lunz Formation is exposed in the village Neuhaus near the war memorial. It consists of brown weathered, fine grained sandstones with ripple structures and flute casts. Some gray shales are intercalated. The Lunz Sandstone can be petrographically classified as a subarkose to arkose (44 % monocrystalline quartz, 5 % polycrystalline quartz, 4 % chert, 21 % feldspar, 2 % crystalline rock fragments, 1 % mica, 21 % clayey matrix + ironoxide). The heavy mineral fraction is characterized by predominance of apatite and zircon. A typical heavy mineral composition of this outcrop is: 39 % zircon, 1 % rutile, 5 % tourmaline, 13 % garnet, tr chloritoid, 40 % apatite, tr chromianspinel. This petrography is common for the whole vertical and lateral extent of the Lunz beds in the Calcareous Alps and the Central Carpathians (BEHRENS, 1973). The depositional environment of the Lunz Formation was assumed primarily to be a shallow water, because of the presence of coal layers, which are locally developed (for example in the Lunz area). The presence of a turbidite facies in regions of pre-existing Pre-Upper Triassic relief or areas of

Fig. 168: Southern part of the Peilstein walls formed by Steinalm limestone.

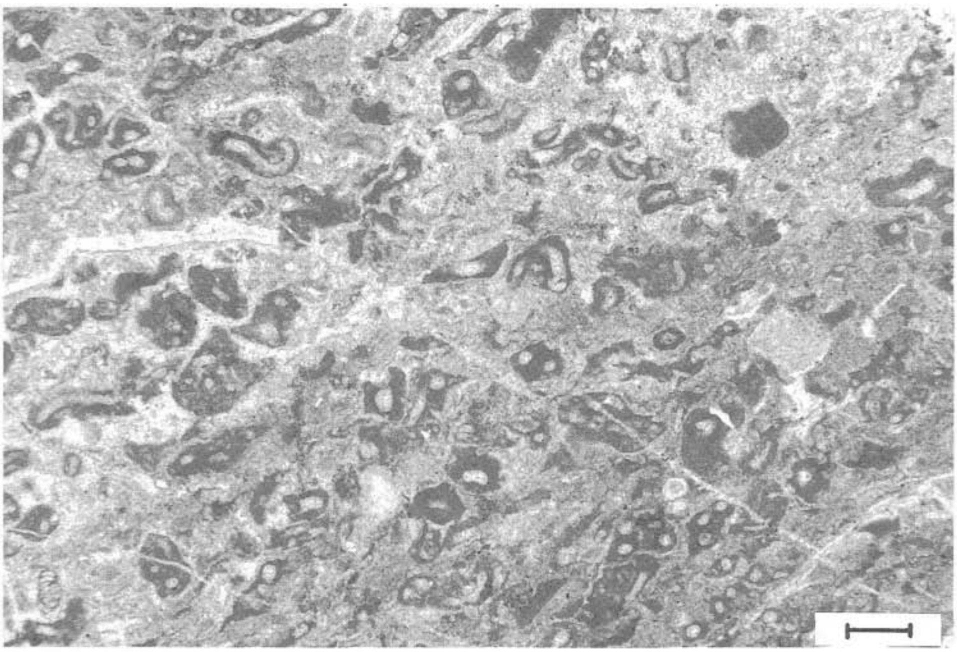


Fig. 169: Packstone with frequent Tubiphytes.
Thin section of the Steinalm Limestone (lower part) south of Stop 4/5; scale = 0.34 mm.

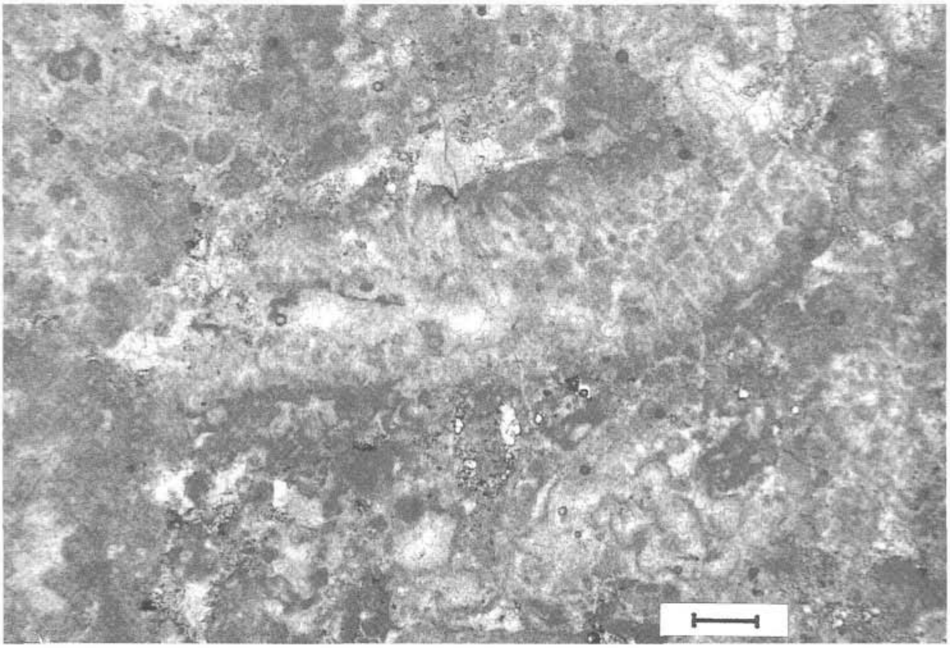


Fig. 170: Algal rudstone with Dasycladacea.
Thin section of the Steinalm Limestone (upper part) south of Stop 4/5; scale = 0.43 mm.

Fig. 171: Anisian Gutenstein limestone, typically thin bedded in the lower part, thicker, nodular beds in the upper part. Quarry Aegydigraben.

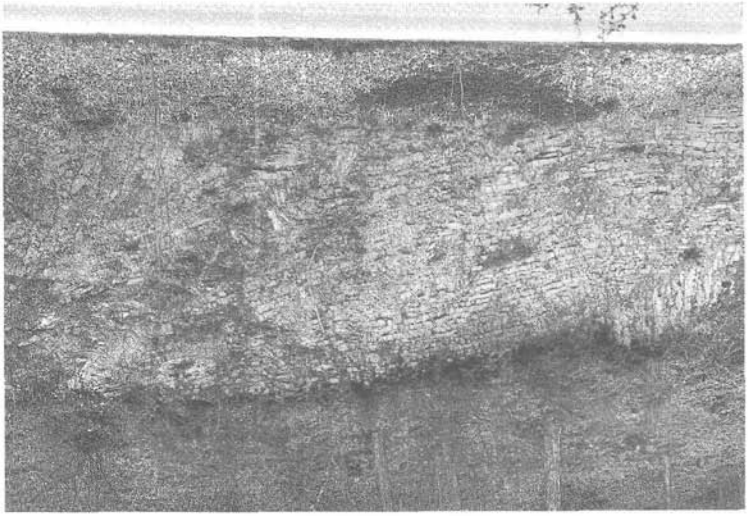


Fig. 172 ▲
Gutenstein Limestone with kink folds.
Road cut S of the quarry "Aegydigraben".

Fig. 173 ▶
Nodular limestone in the upper part of the Gutenstein limestone.
Quarry Aegydigraben.

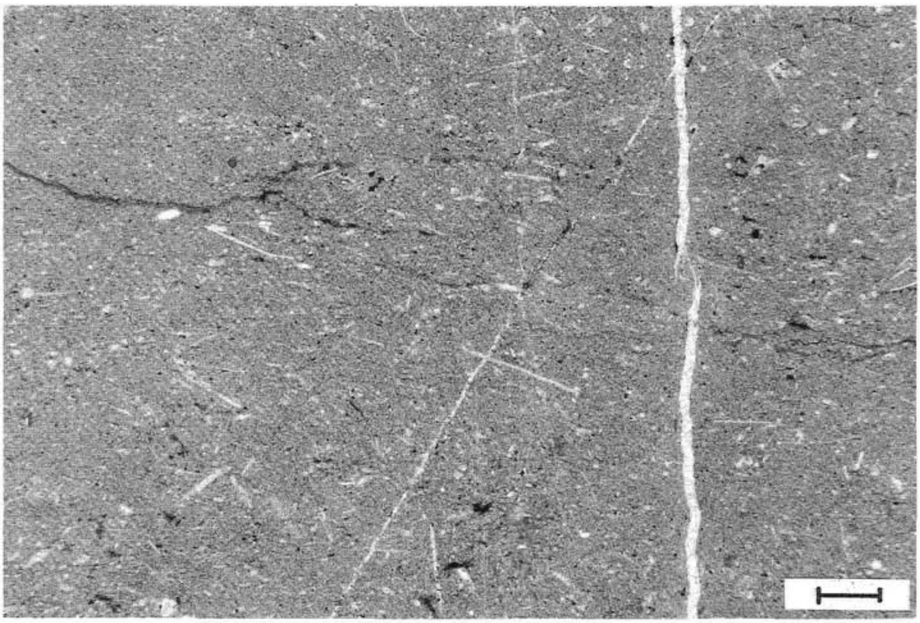


Fig. 174: Thin section of the Gutenstein limestone (lower part).
Mudstone with radiolarians and few spicules.
Quarry Aegydigraben; scale = 0,43 mm.

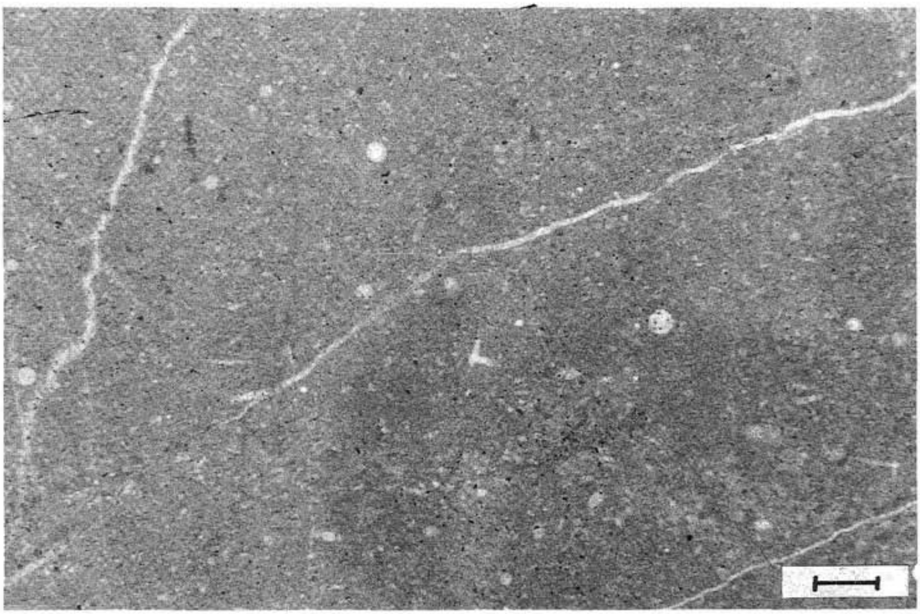


Fig. 175: Thin section of the Gutenstein limestone (upper part).
Mudstone with filaments and spicules.
Quarry Aegydigraben; scale = 0,43 mm.

larger subsidence is difficult to reconcile with this interpretation. The source of the terrigeneous material is also an area of discussion. The assumption of a Middle to Eastern European provenance contradicts the paleogeographical position of the Calcareous Alps south of the central alpine region with its wide spread Keuper facies (TOLLMANN, 1976).

STOP No. 4/8

LOCATION: Road cut NW of Weißenbach (Fig. 165).
TECTONIC UNIT: Tirolicum, Göller Nappe, Peilstein unit.
FORMATION: Ladinian Upper Reifling Limestone, "Partnach" Limestone.
AGE: Middle Triassic.

The profile at Stop 4/8 (Fig. 176) exposes 45° SE dipping uppermost Middle Triassic pelagic limestones on the northeastern side of the road, NW of Weißenbach.

The lowermost part is composed of light coloured, bedded, partly nodular Upper Reifling limestones with reddish cherts (Fig. 177). This section is followed by a light, thick to massive bedded limestone, currently called the "Partnach" limestone. One noteworthy attribute are the sheet cracks, filled with calcite or red limestone (Fig. 178). Nodular habit and red "flaser" intercalations are very pronounced on the boundary between the Reifling and the "Partnach" limestones. Thin sections contain large quantities of filaments deriving from thin shells of molluscs, and radiolaria (Figs. 179,180). According to information of L.

Fig. 176: Ladinian Upper Reifling Limestone overlain by "Partnach limestone". Road cut NW Weißenbach.

Fig. 177: Reifling limestone with red cherts.
Road cut NW Weißenbach.

Fig. 178: "Partnach limestone" with cavity fillings of red mudstone.
Road cut NW Weißenbach.

KRYSTYN and R. LEIN who investigated conodonts from the Reifling Formation they recognized a Ladinian age.

The Middle Triassic of the Peilstein Nappe is the southernmost pelagic facies observed in the Tirolicum of this area. In the well Berndorf 1 (15 km southeast) the pelagic development changes into a carbonate platform facies, represented by Wetterstein Limestone and Wetterstein Dolomite.

Along the route to the well Berndorf, Lunz beds cross the valley, followed by Opponitz beds N of Weißenbach and finally Hauptdolomit which forms all outcrops between here and the well.

STOP No. 4/9

LOCATION: Well Berndorf 1 (Fig. 121).

TECTONIC UNIT: S: Calcareous Alps, Flysch Zone, Molasse Zone, Bohemian Massif.

The well Berndorf 1 (G. WACHTEL & G. WESSELY, 1981) is situated in the Tirolicum of the Eastern part of the Calcareous Alps, 35 km from the Alpine thrust front (Fig. 3).

In the complex of the Calcareous Alps 3 main thrust slices, down to a depth of 5,640 m were encountered (Fig. 181). The uppermost unit consists only of

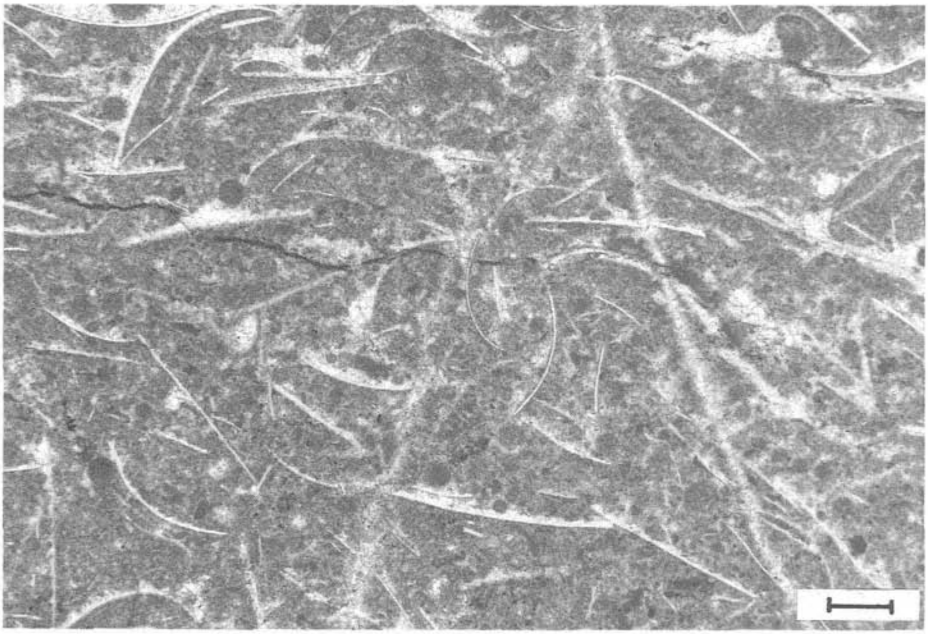


Fig. 179: Thin section of a packstone with abundant filaments and radiolarians of the Partnach limestone; note the geopetal indications.
Road cut NW Weißenbach; scale = 0.43 mm.

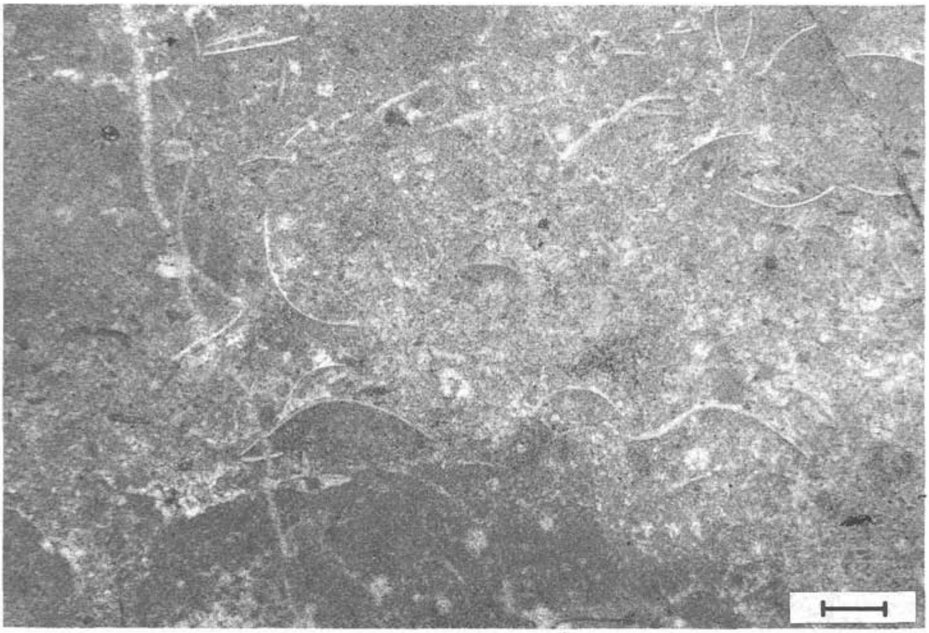


Fig. 180: Thin section of a wackestone with filaments and radiolarians of the Reifling limestone.
Road cut NW Weißenbach; scale = 0.55 mm.

Hauptdolomit. It is underlain by Dachstein Limestone, Hauptdolomit, Opponitz Formation, Lunz Formation, Wetterstein Dolomite and Reichenhall Formation of the intermediate unit. The large thickness of the Middle Triassic Wetterstein Dolomite is noteworthy and indicates that the basinal facies, which is developed in the northern part of the Tirolicum (Peilstein unit, Stop 4/8) has changed into a platform facies. The lowermost unit is represented by Middle Triassic and Permoscythian. Lower in the Middle Triassic the Wetterstein Dolomite and Wetterstein Limestone are replaced by Reifling facies. Reichenhall Formation with anhydrite beds follows and finally the Werfen Quartzite, forms a basal fold.

The Berndorf 1 well penetrated only 200 m of Flysch below the Calcareous Alps. These were distal turbiditic sandstones and marls of Cretaceous age. This is typical of other wells, which penetrated the Flysch.

Molasse is overthrust by Flysch at a depth of 5840 m and is comprised of conglomerates, sandstones and some marls. These are of Upper Oligocene age and contain *Miogypsina* and a Nannoflora of NP24 (det. R. Braunstein). The components are derived mainly from the Calcareous Alps and Flysch Zone.

The section through the Calcareous Alpine is a good reservoir due to its fracturing. This reservoir is filled by fresh water. Relatively low temperatures (70° Celsius at the 5,640 m deep bottom of the Calcareous Alps) point to a continuous flow of water from surface recharge areas to low positions in the Vienna basin. This circulation effect is important for thermal anomalies and hot springs. Below the Calcareous Alps the temperature increases rapidly. This is due to tight Flysch sediments isolating this section and functioning as a caprock. Gas has been tested within the disrupted basal Molasse providing encouragement for the possibility of hydrocarbon accummulations also in this area in the case of an existing reservoir.

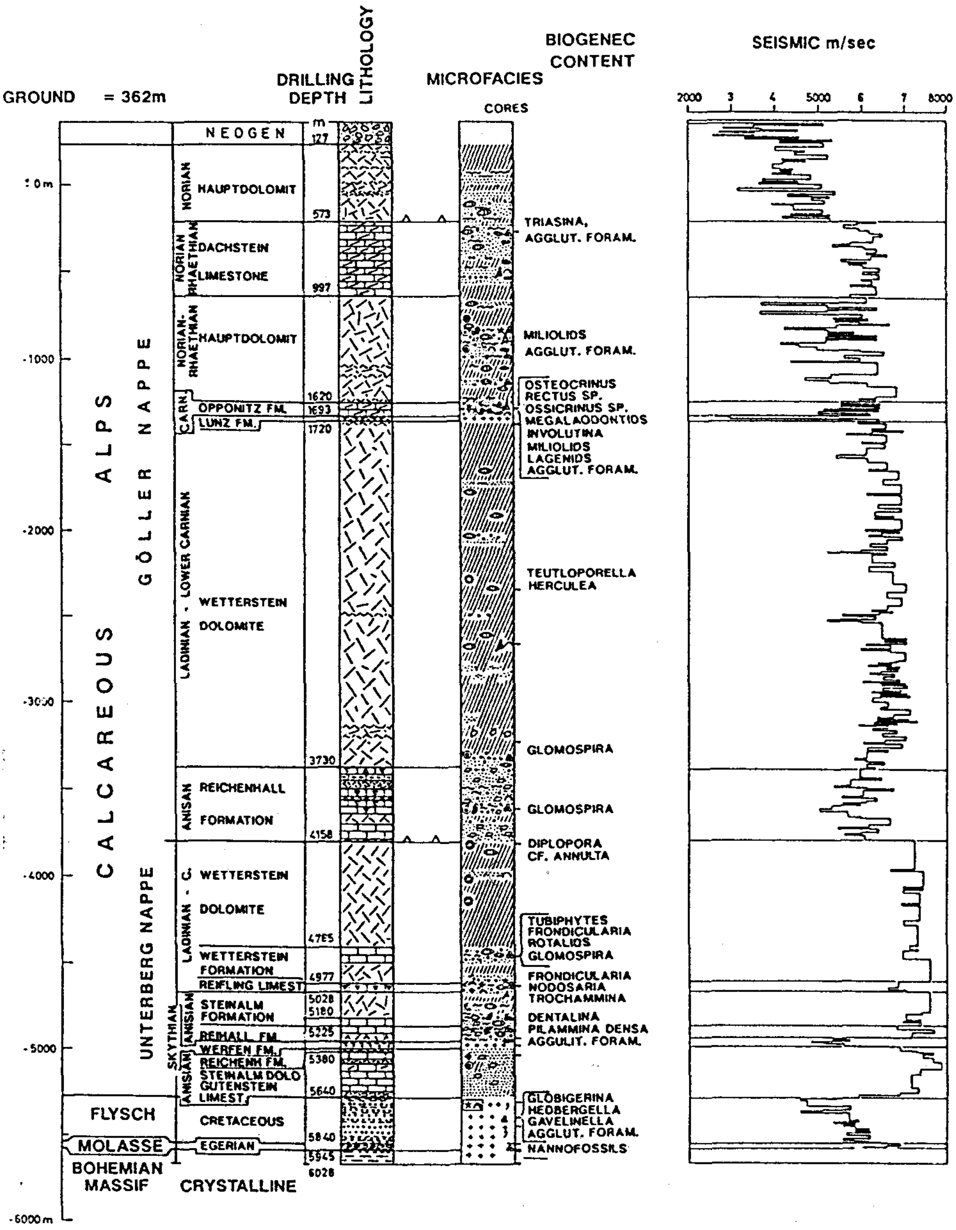
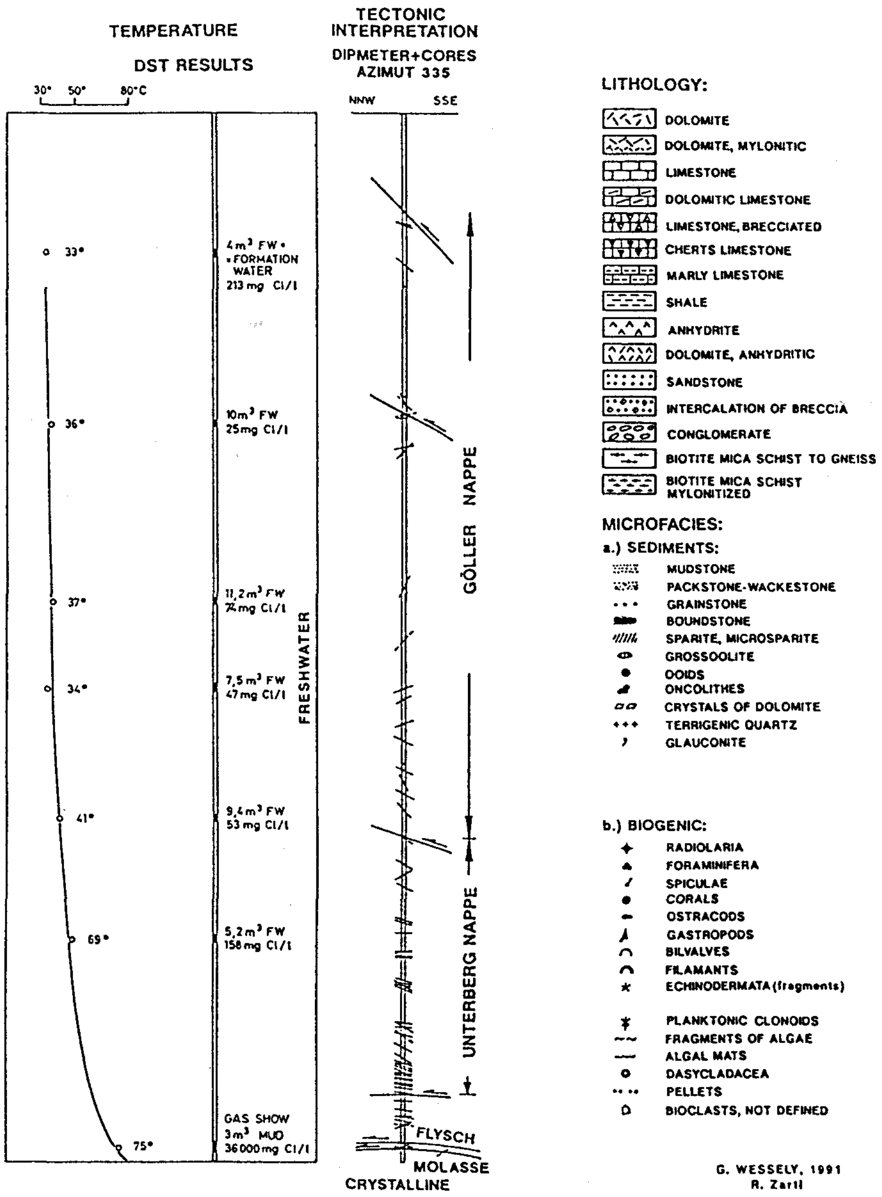


Fig. 181: Well Berndorf 1.
Stratigraphy, tectonic interpretation, formation tests.
G. WACHTEL & G. WESSELY (1981).



G. WESSELY, 1991
R. Zartl

EXCURSION 5

Continuing the route along the eastern margin of the Calcareous Alps the main topics are the stratigraphy and the facies succession of the Triassic sediments from north to south.

In the Middle Triassic the Wetterstein Formation with its large thickness and variety differs from northern Calcareous Alpine sections (facies change between stops 4/8 and 4/9).

The Upper Triassic facies turns from a continentally influenced and lagoonal one (Hauptdolomit and Dachstein Limestone) in the northern and middle sections of the Calcareous Alpine nappes to a reefoidal and basin facies in the southern nappes.

Finally, remains of a deep water development have been detected recently, pointing to an oceanic environment towards the south. These are additional arguments that the sediments of the Calcareous Alps originally have been deposited south of the Central Alps with their continental Keuper facies in the Upper Triassic.

The tectonics of uppermost Calcareous Alpine units is further under discussion, but in connection with results from the subsurface of the Vienna Basin (part I of this guidebook) solutions may be expected.

STOP No. 5/1

LOCATION: Hohe Wand, road cut between Kohlröserlhaus and Herrgottschnitzer-Hütte (Figs. 182,121).

TECTONIC UNIT: Calcareous Alps, Juvavicum.

FORMATION: S: Norian carbonate platform "Wandkalk".

AGE: Upper Triassic.

The Hohe Wand is composed of Triassic rocks (Fig. 182,183). Investigations and compilations of this area have been made by E. KRISTAN (1958), B. PLÖCHINGER (1963, 1964b, 1967). Newest works have been done during mapping of the geological sheet "75 Puchberg" (H. SUMMESBERGER, 1991). Especially in its northwestern part the Hohe Wand shows a complex tectonical mosaic of Middle Triassic Steinalm Dolomite, Reifling limestone, Carnian shales and limestones and Norian to Rhätian Pedata beds and Zlambach beds overthrusted to the Upper Triassic Hohe Wand carbonate platform. Most significant are light gray or reddish Norian carbonates that developed as lagoonal patch reefs (SADATI, 1981). They form the main ridge and the southeastern walls of the Hohe Wand. Evidence for a lagoonal environment is indicated by the low diversity of reef patches, low sedimentation rate (abundant open space structures), particular foraminiferal associations and by interfingering of a biolithe facies and a grapestone facies. SADATI assumes, that the postulated lagoon, with its patch reefs, might have been separated from a southern basin by a reef belt, which is now eroded. In southwestern parts coquinas consisting of *Daonella* and *Halobia* (PLÖCHINGER, 1967) point to a pelagic incursion. The detailed stratigraphical relations between lagoonal, reefal and pelagic facies are still a matter of discussion.

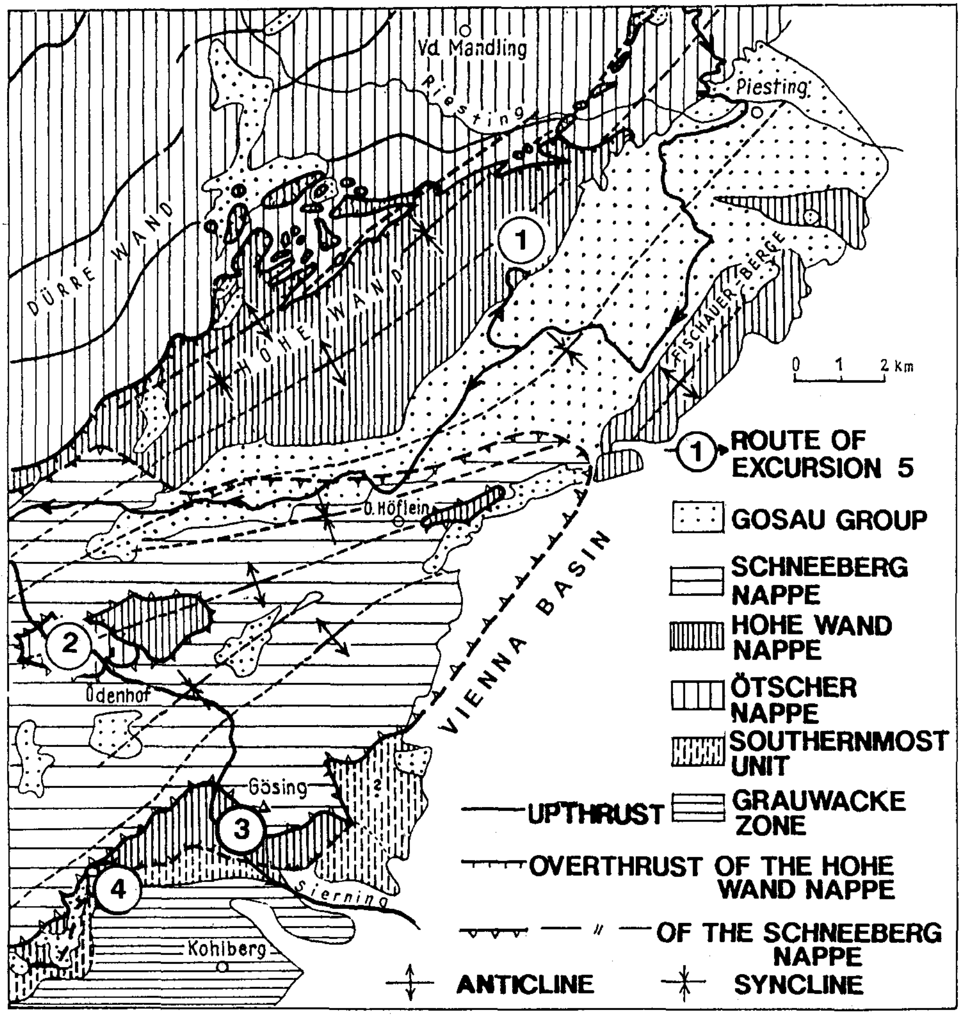


Fig. 182: Tectonic overview over the Hohe Wand-Ödenhof area (B. PLÖCHINGER, 1967).

The reef development, as it is visible in Stop 4/10 between Kohlröserlhaus and Herrgottschnitzerhütte is rich in corals, sponges (Fig. 184), algae, etc. Open space structures are frequent (Fig. 185) and several types are distinguished. They are interpreted as submarine features. The reef development may pass into the Rhaetian.

The Hohe Wand complex overlies Liassic basinal sediments to the NW. Below the ridge to the SE Gosau beds were transgressively deposited on the Triassic limestone. They form a deep syncline, intensively investigated by former coal mining.

From the Hohe Wand there is an excellent view over the Grünbach syncline, the Fischau Mountains, the Southern Vienna Basin to the Leitha Mountains (Fig. 187).

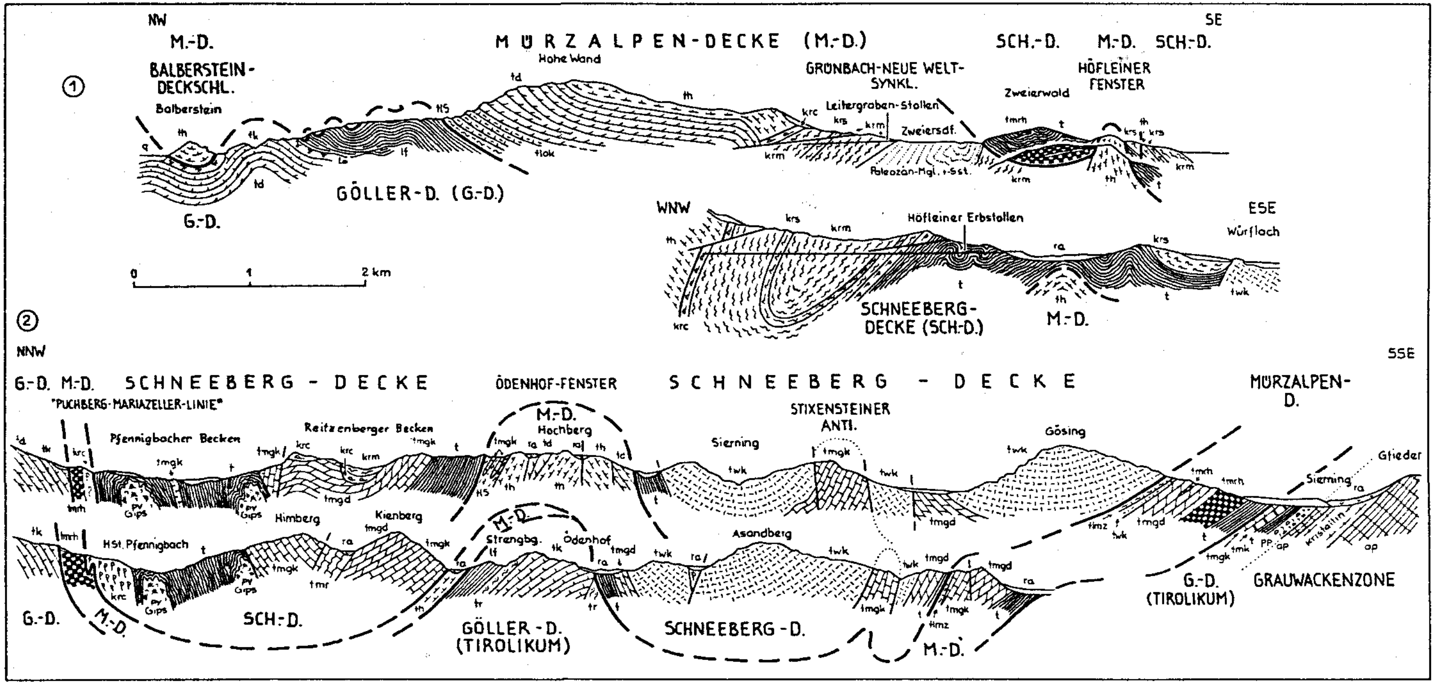


Fig. 183: Cross sections through the upper Calcareous Alpine Nappes (Mürzalpen and Schneeberg Nappe) in the area of the Hohe Wand and the Ödenhof window (B. PLÖCHINGER, 1967, in A. TOLLMANN, 1976).
q = Quaternary; va = Alluvium. **Cretaceous:** krm = Gosau marl; krs = Gosau sandstone; krc = Gosau conglomerate. **Jurassic:** lf = Allgäu beds (Liassic–Dogger). **Triassic:** tr = Kössen beds; th = Hallstatt Limestone; tk = Dachstein Limestone; td = Hauptdolomit, tlmz = Mürztal beds (Carnian–Norian); tls = Lunz Sandstone; twk = Wetterstein Limestone; twd = Wetterstein Dolomite; tmk = "Muschelkalk", tmr = Reifling Limestone; tmgk = Gutenstein Limestone; tmgd = Gutenstein Dolomite. **Permotriassic:** tmrh = Reichenhall beds; t = Werfen beds; py = "Haselgebirge", gypsum; pp = Prebichl beds. **Paleozoic:** ap = Lower Paleozoic.

Fig. 184: Weathered surface of a reefoidal limestone (Wandkalk) with cavity filling. Hohe Wand, road cut SW Herrgottschnitzer Hütte.

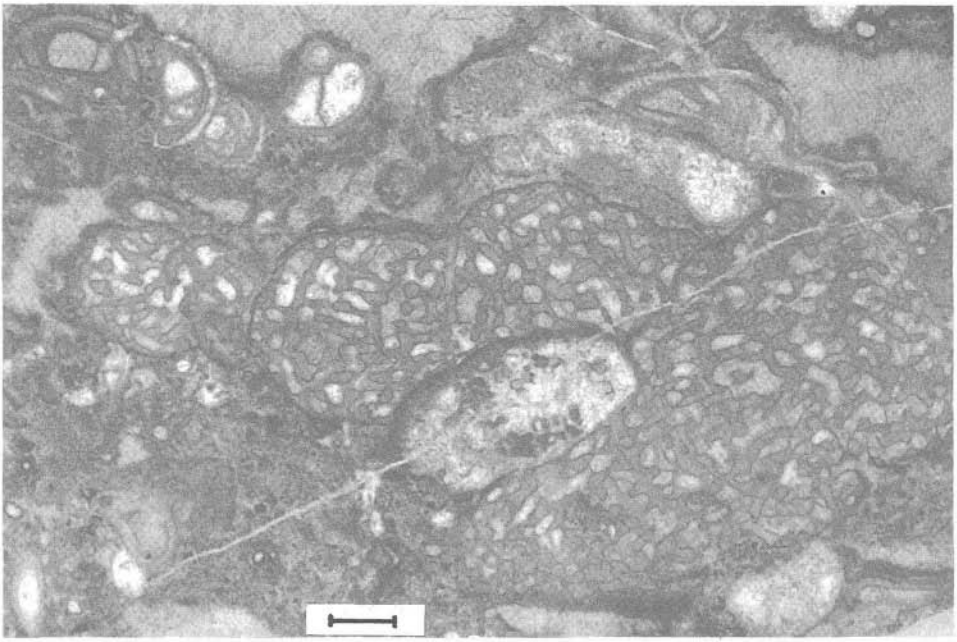


Fig. 185: Thin section of reefoidal limestone ("Wandkalk") with sponge fragments. Hohe Wand, road cut SW Herrgottschnitzer Hütte; scale = 1,1 mm.

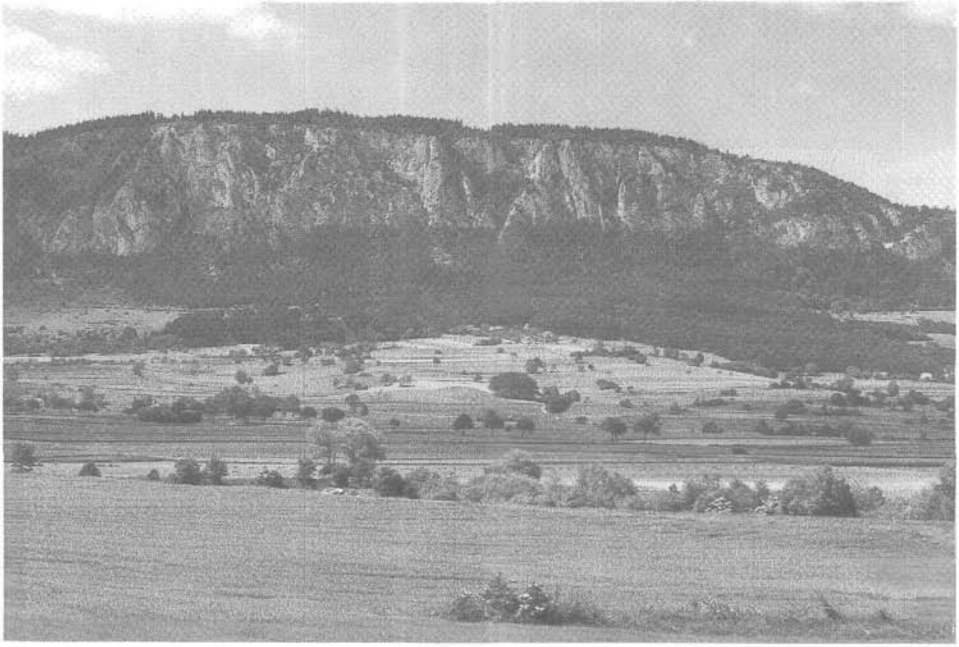


Fig. 186: Hohe Wand, south-eastern showing wall of the "Wandkalk", a lagoonal patchreef limestone.
In the foreground the soft terrain of the Grünbach Gosau sediments ("Neue Welt").

The route to Stop 5/2 (Fig. 182) goes westwards along the Gosau syncline of Grünbach (Fig. 188). The syncline consists of basal Santonian conglomerates, breccias and rudist reefs, Campanian Actaeonella beds and coal bearing marls and sandstones, Maastrichtian clastics with two Orbitoid horizons and Inoceramus marls, and finally, in Zweiersdorf, Paleocene turbidites (B. PLÖCHINGER, 1961, 1964, 1967). The Permoscythian base of the Schneeberg Nappe contains a large gypsum deposit within the area of Pfennigbach. Driving southward from Puchberg the walls of Middle Triassic carbonates of the Schneeberg Nappe (left side) are exposed. Together with Werfen beds they form the western border of the Oedenhof window.

STOP No. 5/2

LOCATION: Oedenhof NW, Sierning valley, 2 km SE Puchberg (Fig. 182).
TECTONIC UNIT: Window of the Göller Nappe (southernmost part of the Ötscher Nappe system) below the Schneeberg Nappe.
FORMATION: Dachstein Limestone.
AGE: Upper Triassic.

Norian Dachstein limestone and Jurassic rocks of the Göller Nappe appear in the Ödenhof window. They are surrounded by Permotriassic and Middle Triassic

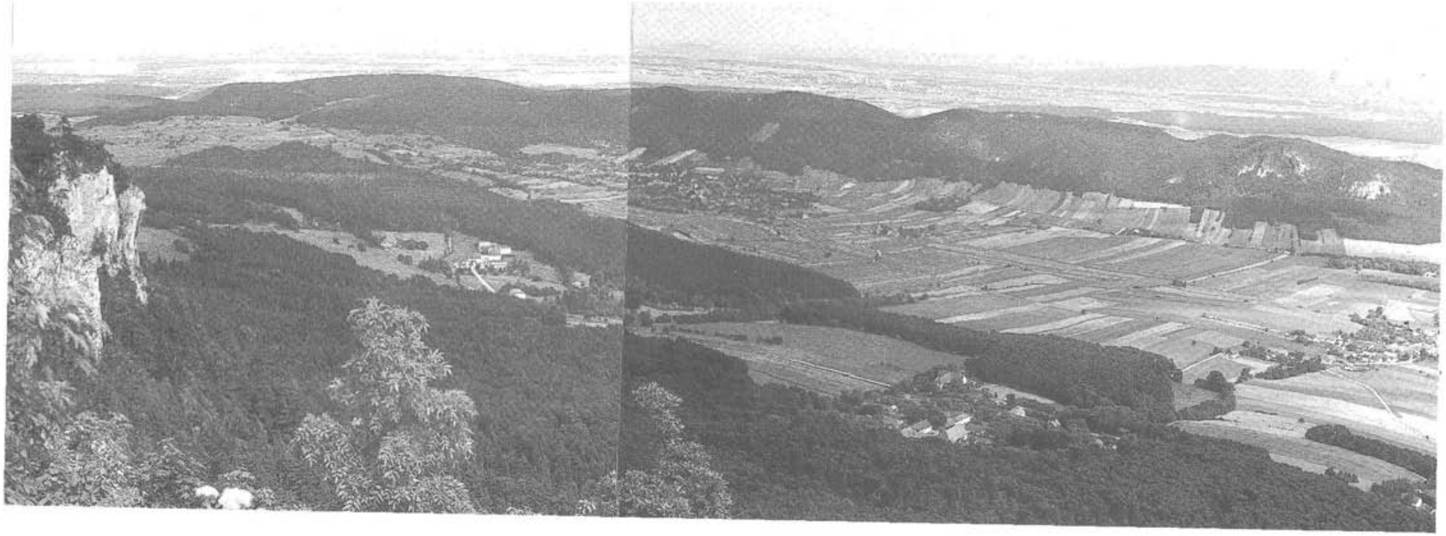
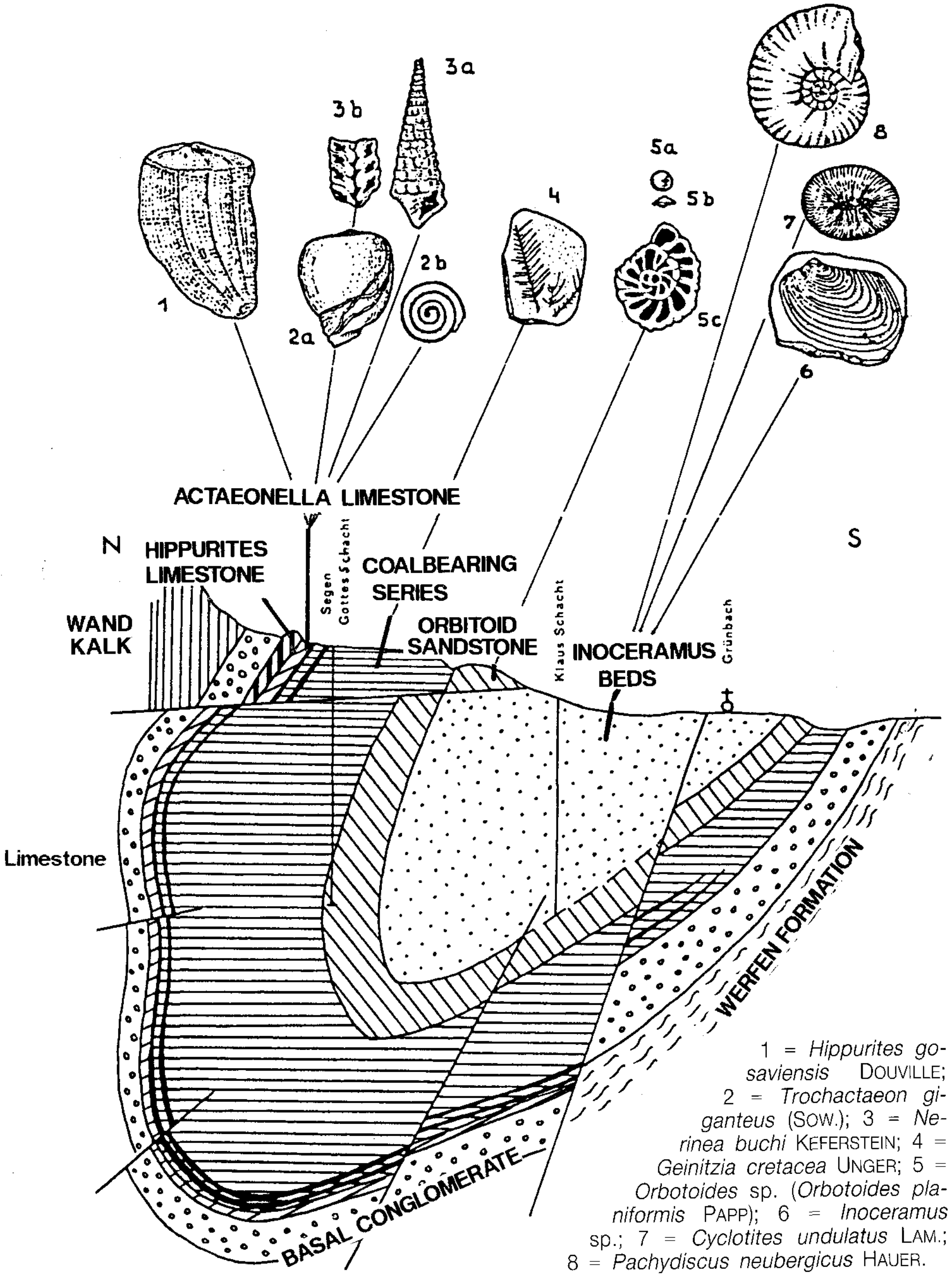


Fig. 187: View from the Hohe Wand in eastern direction.
Below the Wandkalk (visible left) and the Fischau Mountains (woody range) the Grünbach Gosau in extending (fields and meadows). East of the Fischau Mountains the southern Vienna Basin and along the horizon the Central Alps (Leitha- and Rosalia Mountains) are visible.



1 = *Hippurites gosaviensis* DOUVILLE; 2 = *Trochactaeon giganteus* (SOW.); 3 = *Nerinea buchi* KEFERSTEIN; 4 = *Geinitzia cretacea* UNGER; 5 = *Orbotoides* sp. (*Orbotoides planiformis* PAPP); 6 = *Inoceramus* sp.; 7 = *Cyclotites undulatus* LAM.; 8 = *Pachydiscus neubergicus* HAUER.

Fig. 188: Cross section through the Gosau syncline of Grünbach.
All fossils drawn diminuished; only 5c is enlarged.
After LEIN (1984), according to PLÖCHINGER (1961) and THENIUS (1962).

Fig. 189: Bedded Dachstein Limestone with Lofer cyclothemes.
Members A and B between 2 members C in foreground.
Ödenhof Window.

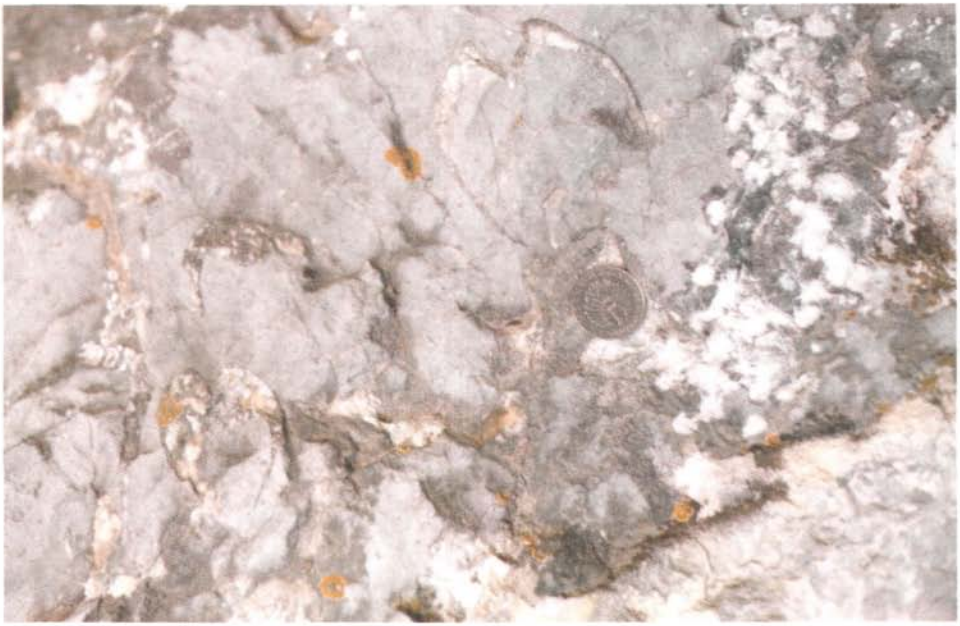


Fig. 190: Dachstein limestone; member C with megalodonts.
Ödenhof Window, detail of Fig. 189.

Fig. 191: **Dachstein limestone; above member C follow the members A (red horizon) and B (laminated part).**
Ödenhof Window, detail of Fig. 189.

rocks of the Schneeberg Nappe. Also the Hohe Wand Nappe is exposed in the same window to the Northeast (Figs. 182,183).

In this location, NE dipping Dachsteinkalk (Fig. 189) is exposed on both sides of the Sierning river. Typical members of the Lofer cyclothemes (after A.G. FISCHER, 1964) can be identified: The supratidal member A shows breccias and shaly reddish remains which are the result of dissolution (Fig. 191). It is followed by laminated dolomitic Algal mats of the intertidal member B and finally by member C, thick beds of subtidal limestones, rich in organic detritus and with large Megalodonts (Fig. 190). Near the top sheet cracks are filled with calcite or material of member A.

South of the Ödenhof, past the Ödenhof window and the Permoscythian base of the surrounding Schneeberg Nappe, Wettersteinkalk of this nappe can be seen.

STOP No. 5/3 (G.W. MANDL)

LOCATION: Sieding E (Fig. 192).
TECTONIC UNIT: Calcareous Alps, Juvavicum (Hohe Wand Nappe system), Geyerstein slices.

FORMATIONS: Gutenstein Dolomite, Steinalm Limestone, Hallstatt Limestone, Raming Limestone, Carnian shale/limestone sequence, Pötschen limestone.
AGE: Middle Anisian to Lower Norian.

The impressive rocky cliffs at the western slope of Mt. Gösing near the village of Sieding expose some of the best sections of the Geyerstein slices. These slices are arranged along a main overthrust plane and separate the Permoscythian siliciclastics of Werning zone ("Südrandelement"; PLÖCHINGER, 1967) below from the Middle Triassic carbonates of Schneeberg Nappe above.

Despite tectonical fragmentation the complete sequence from Anisian to Upper Carnian can be reconstructed, all carbonates are visible in good outcrops.

The section (Fig. 193/section 16)) starts with about 100 meters dark grey Gutenstein dolomite. It shows occasionally lamination and birdseye structures of a shallow water environment, fossils are lacking. At the top the dolomite becomes light-coloured and grades into Steinalm limestone of about 10 meters thickness. Its common microfacies is a dasycladacean grainstone with *Physoporella dissita, Physoporella pauciforata pauciforata, Physoporella pauciforata undulata, Oligoporella pilosa, Teutloporella peniculiformis* and a few foraminiferas as *Meandrospira dinarica* and *Glomospirella semiplana*. The fossil content points to an anisian age. After questionable block tilting and an erosional discordance the pelagic sedimentation of Hallstatt facies starts with lightgrey and yellowish thickbedded pelmicritic limestones. At the boundary often decimeter sized lenses of a yellow crinoidal wackestone occur, rich in ostracodes, holothuroidean sclerites, echinid spines, radiolarians and "filaments". This basal horizon is proved by conodonts as Upper Anisian. The total thickness is affected by tectonics but should exceed 15 meters. The following 6 meters consist of violet nodular limestones with chert nodules and green tuffitic intercalations. Due to strong recristallisation the primary micritic microfacies is mostly not preserved. Only a coarse grained mosaic of calcite and beginning dolomitization is visible. According to conodonts this nodular facies is of Langobardian age. Still in uppermost Langobardian an evenbedded lightgrey limestone with thin yellow marly layers is following. It contains fine-grained carbonate turbidites which become macroscopically visible after about 10 meters. Chert nodules and layers are frequent. Thickness is strongly affected by folding, it will be in the range of 40 m. According to its allodapic character this limestone refers to Raming limestone. It represents mainly Cordevolian time.

The Julian sequence is composed of two horizons of black shales with a few thin biodetritic limestone layers and an interbedded horizon of 18 meters dark allodapic limestones. Characteristic bioclasts are fragments of calcisponges. The age is proved by conocont samples, containing *Gondolella auriformis*.
The sequence is finished by Tuvalian black micritic limestones.

The lower Norian shown in Fig. 193/section 16 is a poorly exposed tektonized limestone near the overthrust of Schneeberg Nappe. The Norian is much better exposed at the Geyerstein cliff near the village Payerbach. Also the Middle Triassic to Carnian is visible there. It differs from the sequence described above in its lack of allodapic intercalations. The Cordevolian is represented there by Hallstatt-type grey and pinkish thickbedded micritic limestone.

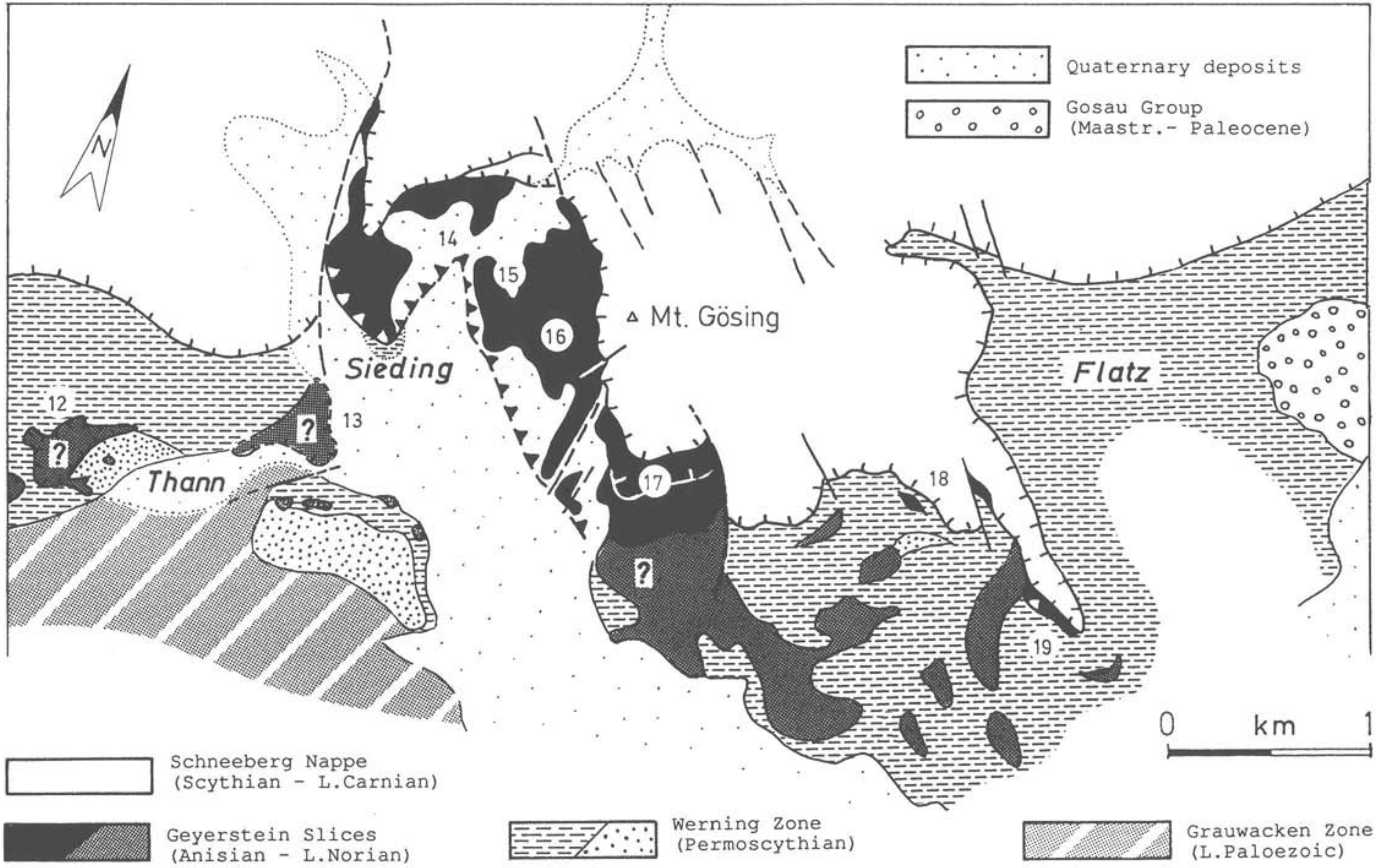


Fig. 192: Tectonic sketch of the Geyerstein slices (Juvavicum) near the village of Sieding (G.W. MANDL).

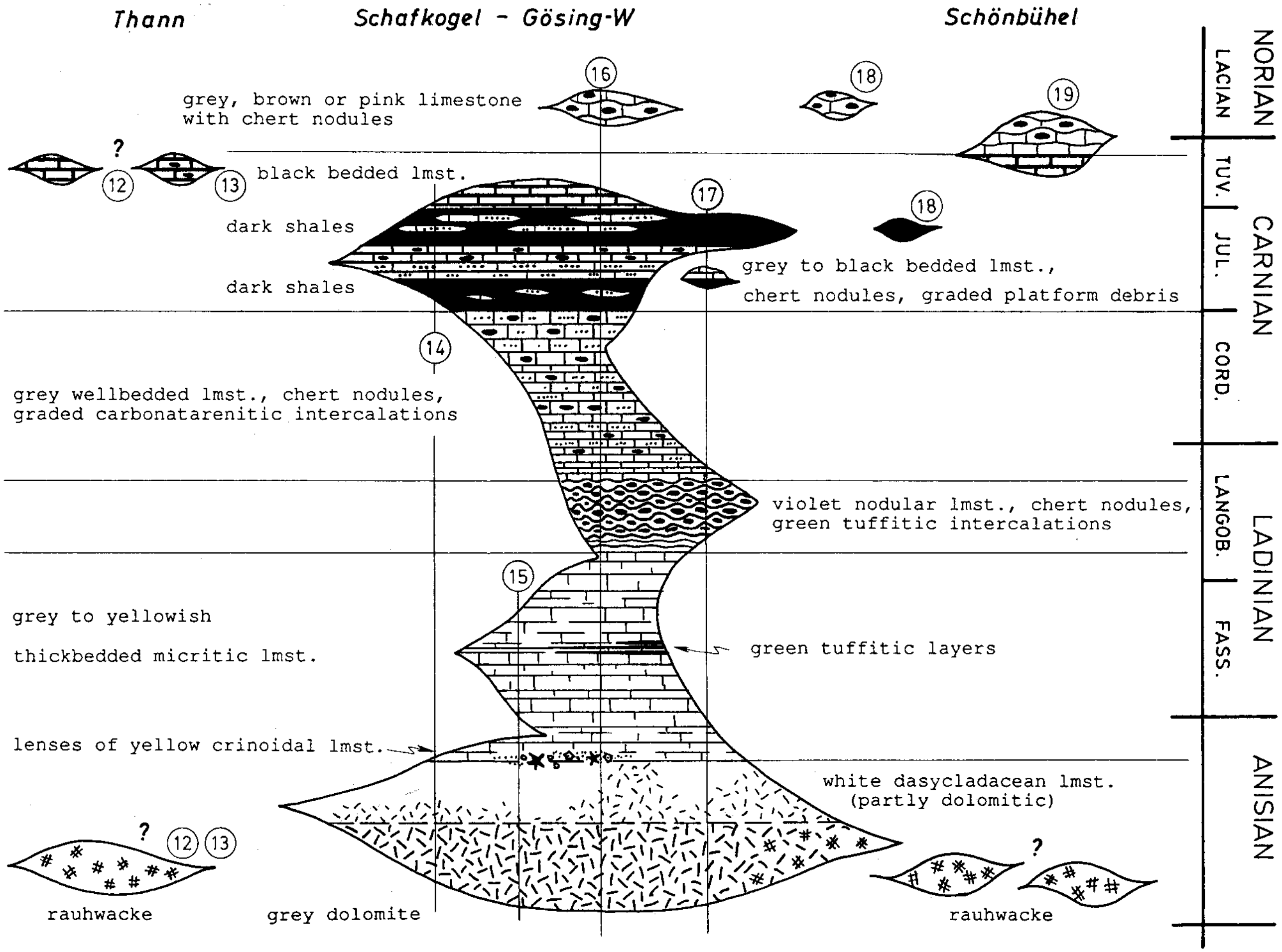
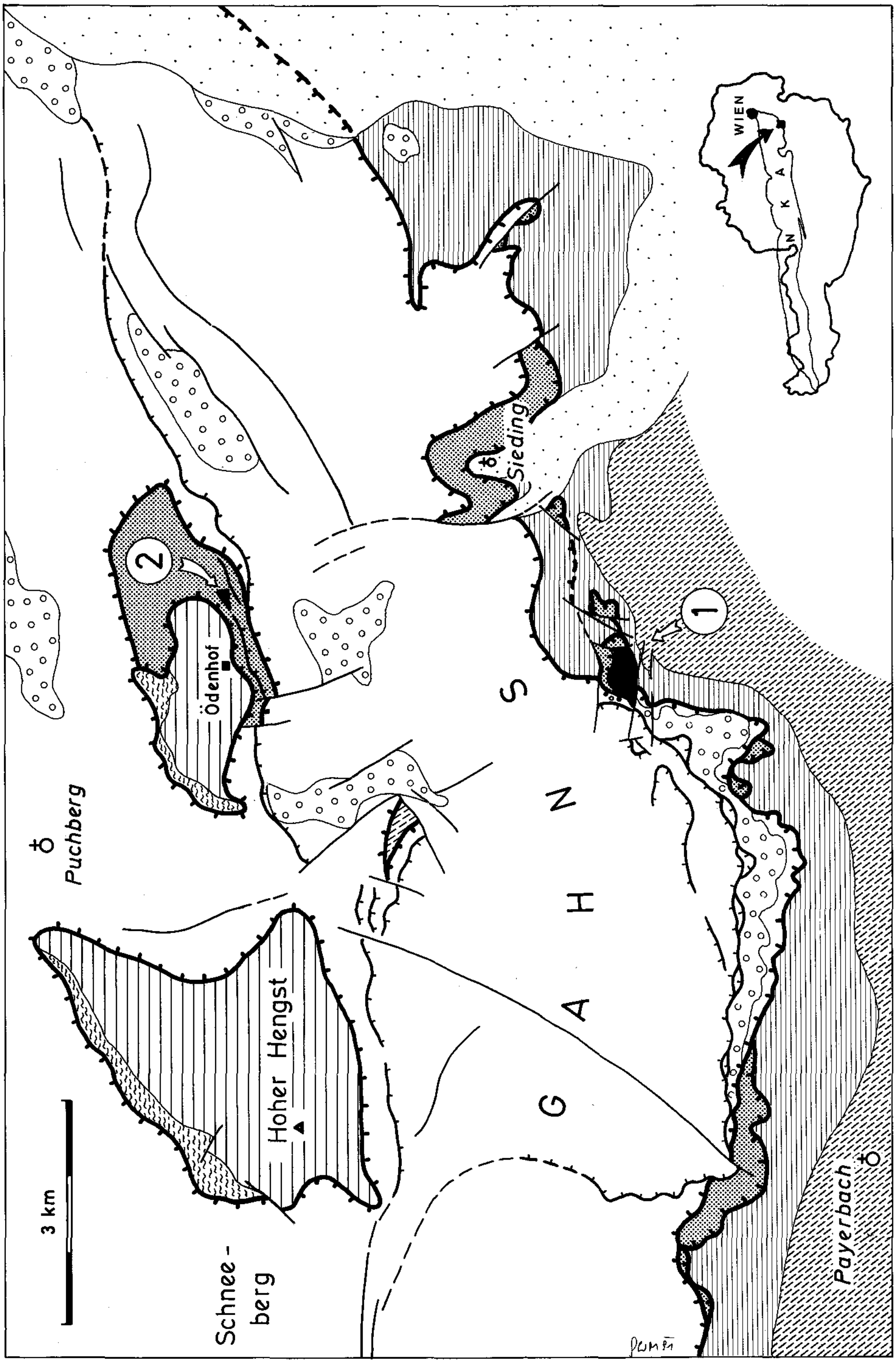


Fig. 193: Lithological sequence of Geyerstein slices (Juvavicum; G.W. Mandl).
Location of numbered sections see Fig. 192.


3 km
Schnee-
berg
Hoher Hengst
Puchberg
Ödenhof
2
G A H N S
Sieding
1
Payerbach
WIEN
N K A

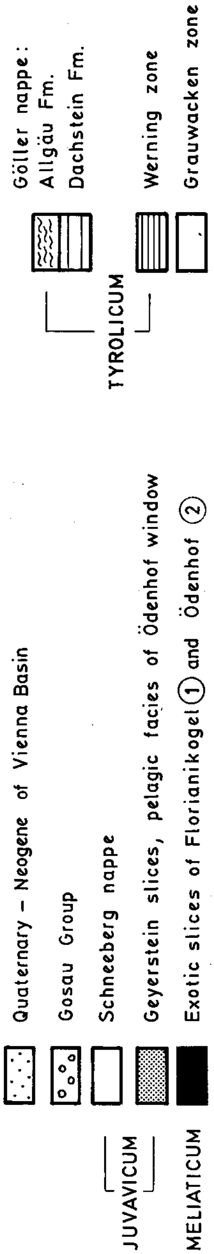


Fig. 194: Tectonical sketch of south-eastern Schneeberg area (G.W. MANDL & A. ONDREJIČKOVA, 1991).

STOP No. 5/4 (G.W. MANDL)

LOCATION: Florianikogel (Fig. 194).
TECTONIC UNIT: Calcareous Alps, Meliaticum.
FORMATION: "Floriani Olistolite Group".
AGE: Triassic olistolites in Jurassic matrix.

Recently two occurrences of radiolarite and associated carbonates have been proved to be of Middle Triassic age (MANDL & ONDREJIČKOVA, 1991; KOZUR & MOSTLER, 1991/92). This was the first proof of Triassic deepwater facies in the Eastern Alps, comparable with the Meliaticum of Western Carpathians.

Contrary to the first interpretation as a stratigraphic sequence (Fig. 195) of Anisian limestone, Ladinian radiolarite and Upper Triassic shales with local olistolites KOZUR & MOSTLER have shown a Jurassic age of the black and the greenish cherty shales by means of rich radiolarian faunas. Therefore all Triassic rocks are olistolites from centimeter size up to several meters.

The sequence is tectonically embedded between Permian Prebichl conglomerates of the Werning zone below and the Schneeberg Nappe above, having the same tectonical position as the Geyerstein slices (see Fig. 194). Anisian so called "Flaser limestone" and rauhwackes on the northern slope of Florianikogel may be part of the Schneeberg Nappe or Geyerstein slices, the latter interpretation is favoured in Fig. 194.

The contrast in Triassic facies between Geyerstein slices, Floriani Group and Schneeberg Nappe points at the significance of the overthrust plane between Werning zone and Schneeberg Nappe. It can not be interpreted as a local and secondary, post-Cretaceous backthrusting within a primary sedimentary succession.

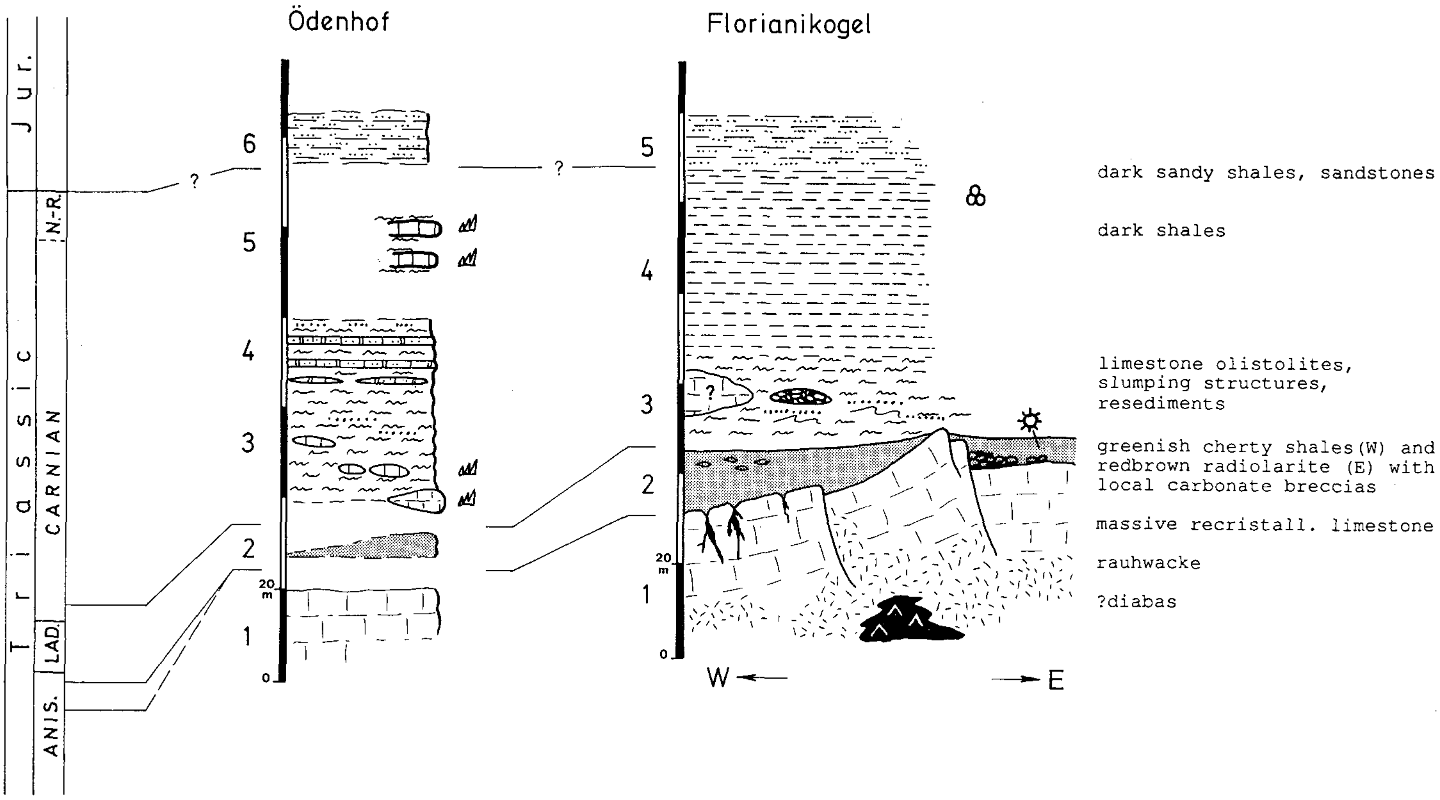


Fig. 195: Lithological sequence of Meliaticum in Northern Calcareous Alps (G.W. MANDL & A. ONDREJIČKOVA, 1991).
Due to current investigations of KOZUR & MOSTLER (in press) the greenish part of radiolarite (2) and the whole sequence of dark shales (4) are of Jurassic age – prooved by radiolarians. Therefore all Triassic rocks are large olistolite bodies in Jurassic matrix.

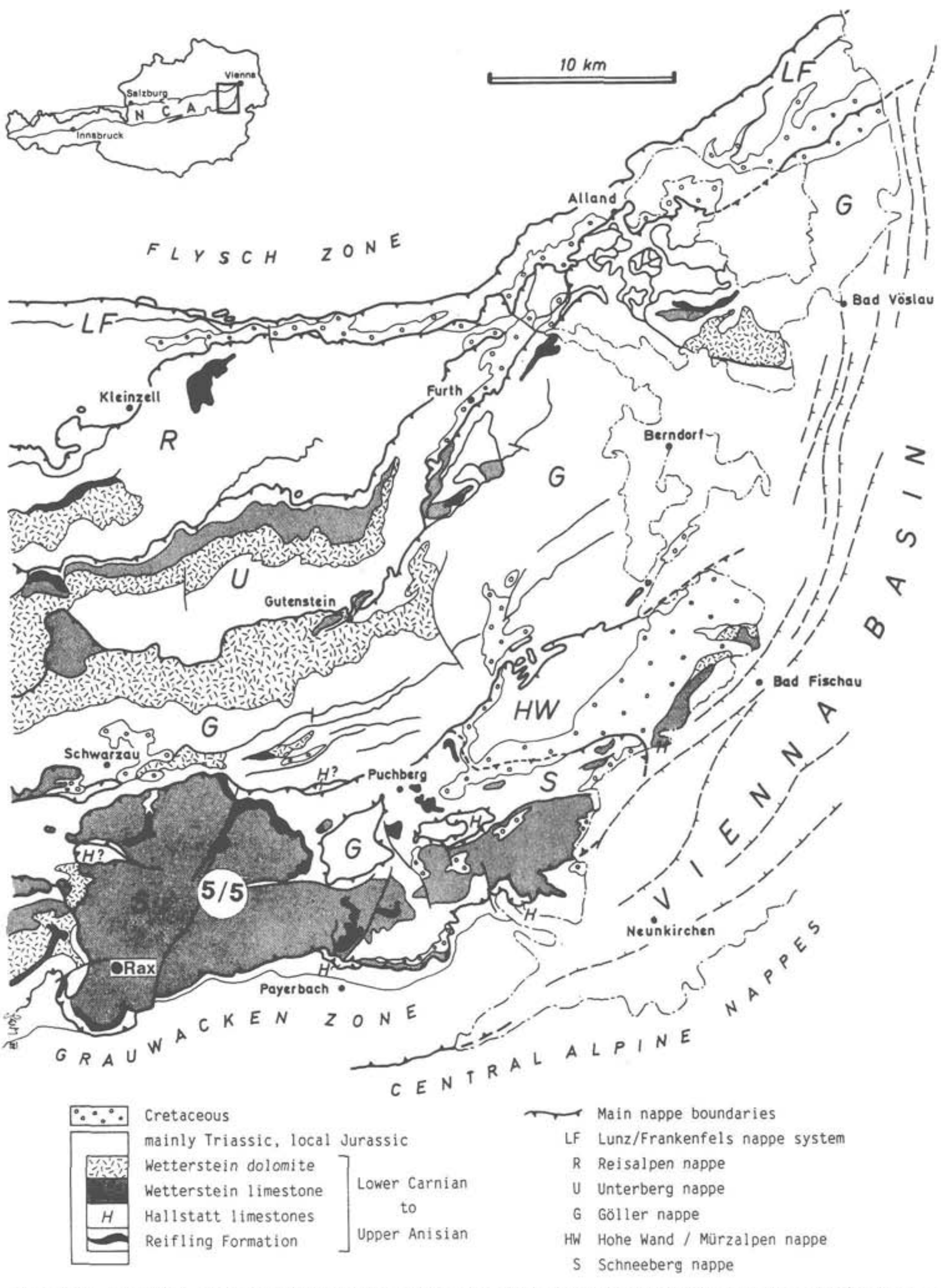


Fig. 196: Location map of Wetterstein carbonate platforms and coeval basin deposits in the eastern part of the Northern Calcareous Alps.
Compiled from AMPFERER & SPENGLER (1931), CORNELIUS (1936), BRIX & PLÖCHINGER (1982), TOLLMANN (1976b), WESSELY (1983), FUCHS & GRILL (1984) and own mapping (G.W. MANDL, 1983–1986, unpubl.).

STOP No. 5/5 (H. LOBITZER, G.W. MANDL)

LOCATION: Rax Mountain (Fig. 197).
TECTONIC UNIT: Calcareous Alps, Juvavicum, Schneeberg Nappe.
FORMATION: Wetterstein Limestone.
AGE: Middle Triassic to Lower Upper Triassic.

The Rax Mountain (Fig. 196), belongs to the Schneeberg Nappe which is the uppermost nappe in the eastern Calcareous Alps. To the south, the Schneeberg Nappe is underlain by north dipping Lower Calcareous Alpine elements, whose tectonic range is currently under discussion. They are connected with Greywacke Zone overthrusting Middle and Lower Austroalpine units (Fig. 196).

This massif forms the highest mountains of the eastern Calcareous Alpine section having elevations of over 2000 m. It also has the largest exposure of Wetterstein Limestone, as seen in the overview (Fig. 197).

Lower Middle Triassic formations appear along some parts of the tectonic boundary, surrounding the Ladinian Wetterstein Limestone massif of the Schneeberg Nappe. These are Gutenstein Limestone and -Dolomite and, to the east, also the Steinalm Limestone (Figs. 198, 199).

The Rax Plateau provides an excellent exposure of a prograding carbonate platform over slope sediments (LOBITZER, MANDL, MAZZULLO & MELLO, 1990). In the southwest, an extensive platform edge reef (the Heukuppe-Predigtstuhl reef complex) interfingers towards the south with upper slope limestones and towards the northeast with near-reef lagoonal sediments, which are in part peritidal limestones. The slope sediments are comprised of various allodapic limestones and variegated micrites. These often have pronounced deeper water biota, including ammonites, conodonts, "filaments" and radiolarians. The "reefbelt" stretches from the uppermost slope well into the platform. In the field the intensive cementation by radiaxial fibrous calcite, often of grossolithic character, is noticeable. Larger biota are scarce, the maximum being in the decimeter size range. A variety of calcisponges (inozoans and sphinctozoans), Tubiphytes and, to a lesser extent corals predominate. Brachiopods are the most important reefdwellers. Small lenses of pinkish micritic limestone of Hallstatt-type, occasionally with "zebra"-neptunian dykes or stromatactis-shaped fabrics occur within the reef. They clearly indicate deeper-water biota and also contain stratigraphically valuable conodonts and foraminifera (LOBITZER, 1986; LOBITZER et al., 1988). Northward or to the northeast, the reef belt interfingers with grainstones or with birdseye limestones. Both contain the characteristic dasycladacean alga *Teutloporella herculea* and often abundant solenoporaceans and/or porostromate algae and sphinctozoans. Corals may also occur. Patchy dolomitization affects the reef as well as the lagoonal sediments. The stratigraphic and facies arrangement of the Middle Triassic and lowest Upper Triassic is illustrated by two schematic sections (Fig. 199).

Different sedimentary facies of the Middle Triassic depositional system in this area have been identified in detail: peritidal, lagoonal, reef and grossoolite facies. A depositional (Fig. 200) and diagenetic model has been reconstructed.

The main environments can be observed along the E–W lenght of the Rax Plateau. Zones of dolomitization and considerable karstification contain large water reserves important for supplying the city of Vienna with drinking water.

Fig. 197: The Rax ridge from south showing the route of excursion (Stop 5/4) from east (station of the cable car) to west (platform below Heukuppe).
In the foreground the soft terrain of the Greywacke Zone.

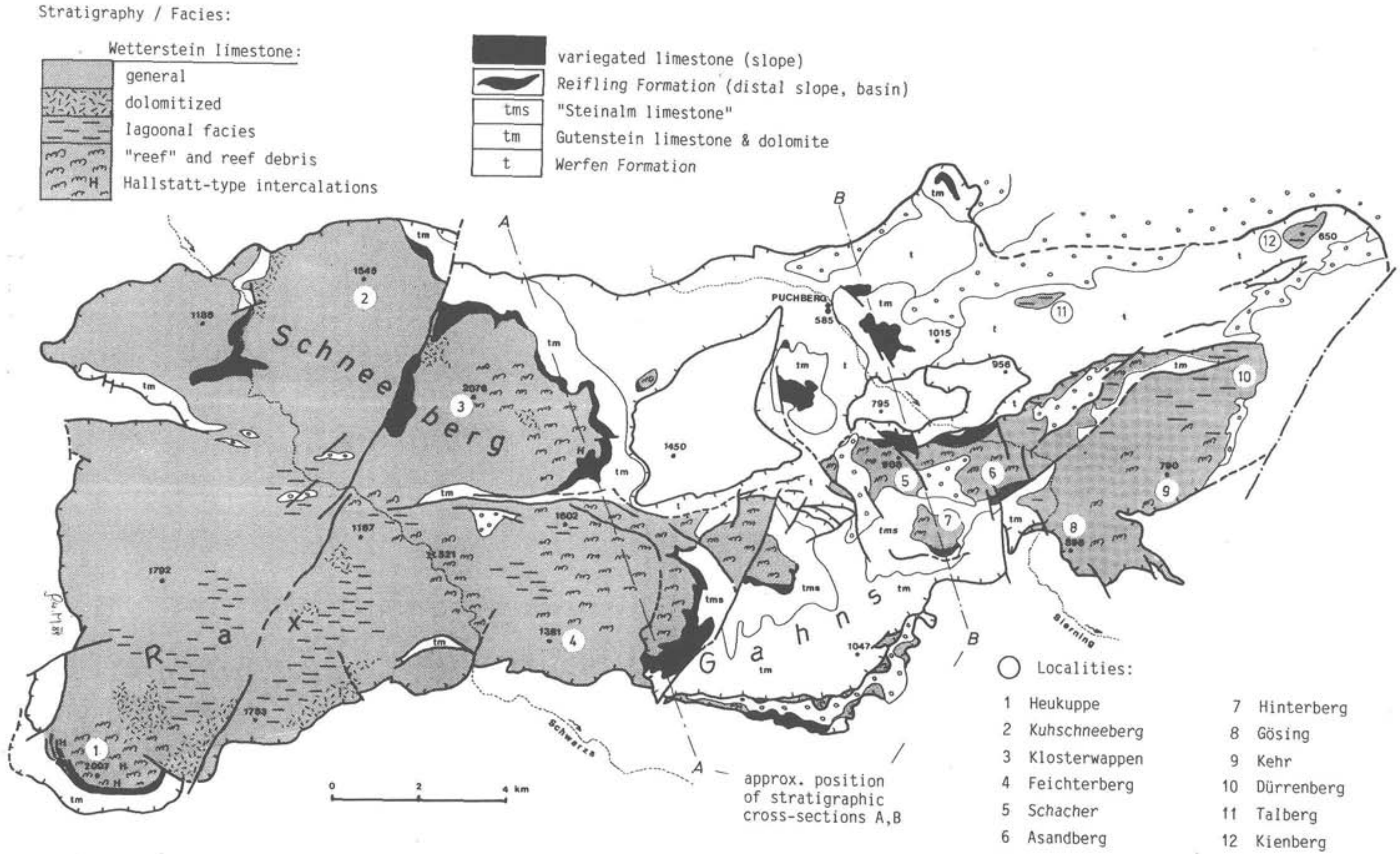
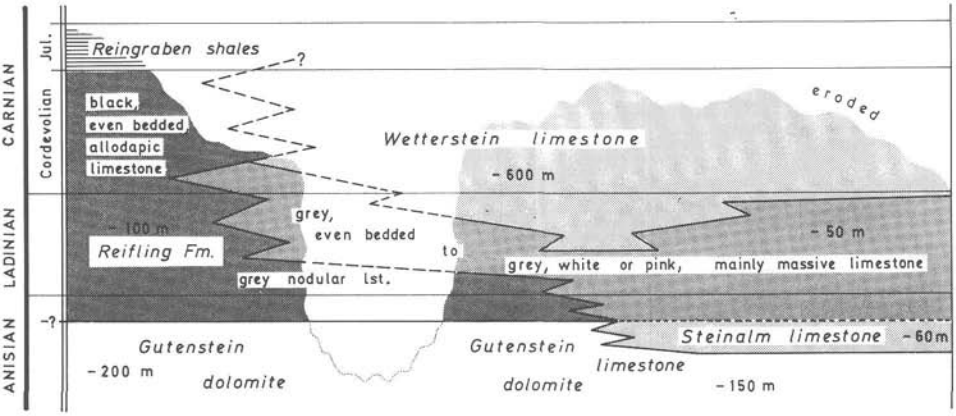


Fig. 198: Facies distribution within the Wetterstein limestone of Schneeberg nappe.
H. LOBITZER, G.W. MANDL, S. MAZULLO & J. MELLO (1990); compiled after CORNELIUS (1939, 1951), LOBITZER (1971–1988) and G.W. MANDL (1984–1987).

Section B



Section A

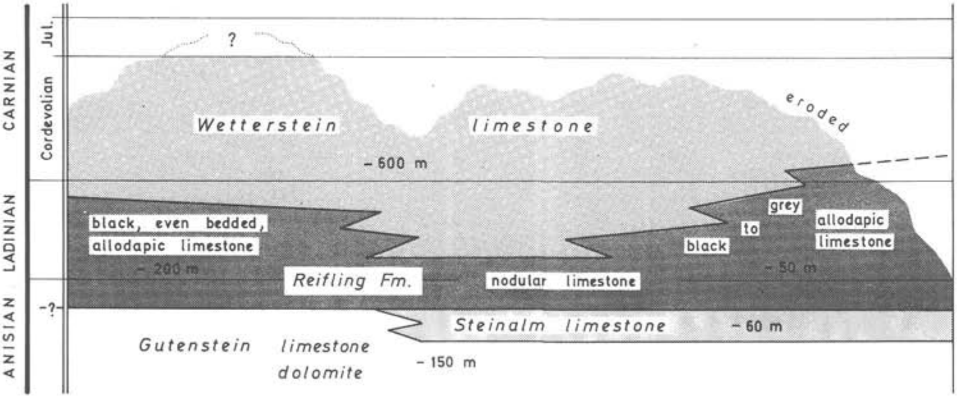
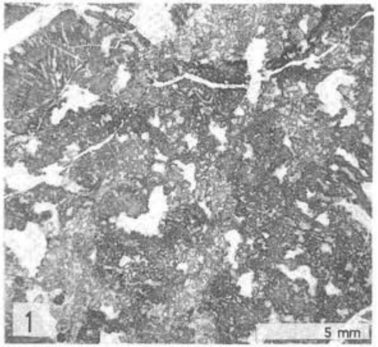


Fig. 199: Stratigraphic scheme (Anisian to Lower Carnian) of Schneeberg nappe.
Note lateral variability of platform to basin transition.
For location of cross section A, B see textfigure of facies distribution (H. LOBITZER, G.W. MANDL, S. MAZULLO & J. MELLO, 1990).

Remains of a Miocene river system "Augensteinschotter" indicate to the elevated position of the southern Calcareous Alps, relative to the Vienna Basin (H.P. CORNELIUS, 1936).

Descending the "Schlangenweg" from the Plateau south of the Heukuppe, the slope limestones can be seen. The base of the Calcareous Alps is passed and the route finishes in the Greywacke Zone at the Preiner Gscheid.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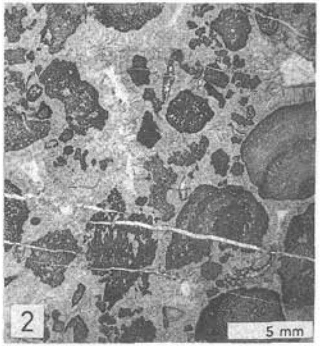
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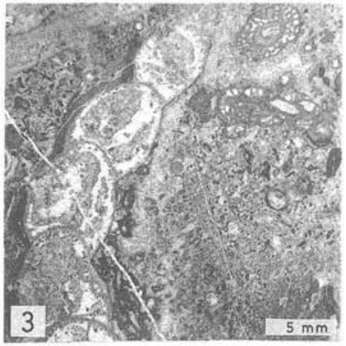
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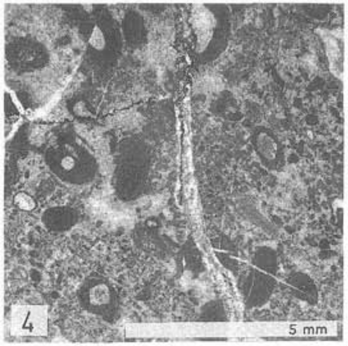
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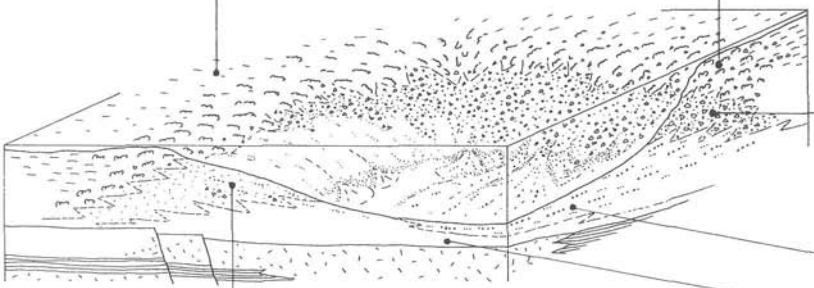
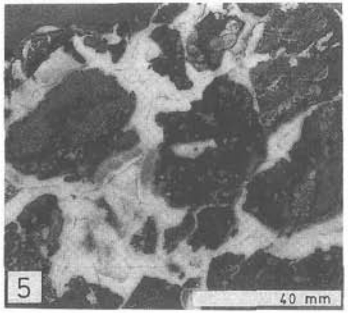

LAGOON
"REEF"
proximal SLOPE
(type A)
"grossoolithic" breccias
distal slope to BASIN
not to scale
proximal SLOPE
(type B)
distal slope to BASIN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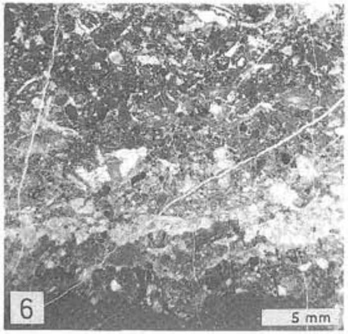
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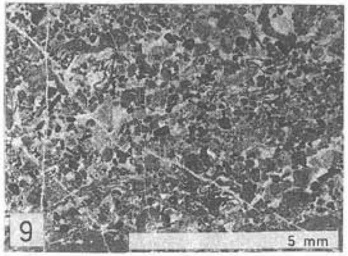
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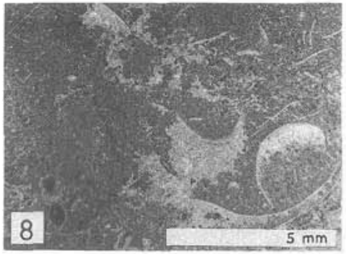
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Fig. 200: Deposition model of the Middle Triassic (H. Lobitzer, G. Mandl, S. Mazullo & J. Mello, 1990).
1) Near-reef lagoonal Wetterstein Limestone in birdseye facies with solenoporaceans.
Between Friedrich-Haller-Haus and Feichterberg.
2) Lagoonal Wetterstein Limestone with abundant solenoporaceans.
South of Haslitz-Adriganbauer.
3) Wetterstein Limestone in reef facies with sphinctozoan sponges, "tubes in the reef debris" sensu Ott. Strong biogenic encrustation.
Schacherberg.
4) Wetterstein Limestone in reef facies with abundant *Tubiphytes obscurus*.
Asandberg, top plateau.
5) Großoolite facies of Wetterstein Limestone. Clasts (dark) composed of marine-cemented calcispongal reef lithology.
Schneeberg plateau.
6) Grafensteig Limestone: graded allodapic intercalations of platform-derived debris within black micritic basinal limestone.
Himberg.
7) Reifling Limestone. Light grey nodular limestone of pelmicritic composition, abundant filaments and sparse platform debris (*Tubiiphytes*).
Himberg.
8) Variegated limestone, arenitic layer of platform debris.
Himberg.