A4 Facies development of the Eastern Alpine Paleogene with regard to algal associations

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Introduction

Only a few autochthonous relics of the once extensive Eastern Alpine Paleogene have escaped either being covered by tectonic nappes or being eroded completely. The preserved occurrences are distributed in the Northern Calcareous Alps, the eastern Central Alps (Carinthia) in the Helvetic Zone and in the "Waschberg Zone" (between Molasse and Vienna Basin). The greater part of these deposits now exists only as redeposited turbidites, olistoliths and pebbles, incorporated in different contemporary or younger sediments of the Upper Austroalpine and Helvetic nappes as well as in the Molasse: Inner-Alpine Molasse, Sub-Alpine Molasse, Foreland Molasse.

These autochthonous and allochthonous, originally littoral sediment types are partly rich in organic communities, including cyanophytes and rhodophytes, chlorophytes are generally very rare. Their environmental habitats were created during the Paleogene and contemporarily deformed by synsedimentary, tectonic strain.

1. Upper Austroalpine

1. 1. Occurrences

Numerous allochthonous and autochthonous shallow-water carbonates occur within the various tectonic units of the Upper Austroalpine region (Northern Calcareous Alps, Central Alps/Greywacke Zone); the most significant are the following (see chapter A3: Cretaceous, fig. 1):

Allochthonous occurrences:

* Sliding mass and erosional products (turbidites, olistoliths etc.) in the Paleocene to Eocene deep-water sediments of different Gosau basins, especially the basin of the Lower Inn Valley (up to Middle Eocene; HAGN 1967; HAGN et al. 1981; MOUSSAVIAN 1984), Kaisergebirge (Lower Ilerdian; ASCHAUER 1984), Gosau-Abtenau (up to Middle Eocene; WILLE-JANOSCHEK 1966), Wörschach (up to Lower Eocene; JANOSCHEK 1968; MOUSSAVIAN 1984; POBER 1984), Mooshuben-Mariazell (Lower Paleocene-Middle Paleocene; LEIN 1982) and finally Grünbach-Neue Welt and Gießhübl (up to Paleocene; PLÖCHINGER 1967, 1980; OBERHAUSER 1980; FAUPL et al. 1987; WAGREICH 1991).

* Paleogene pebbles of the Inner-Alpine Molasse (Angerberg Beds; MOUSSAVIAN 1984) and the Sub-Alpine/Foreland Molasse (ZÖBELEIN 1955; HAGN 1972, 1976, 1983, 1989; HAGN & MOUSSAVIAN 1980; HAGN & OTT 1975; MOUSSAVIAN 1984).

* Paleogene pebbles of the Miocene conglomerates near Radstadt, Pongau ("Ennstaltertiär", Central Alps; TRAUTH 1918; MOUSSAVIAN 1984)

Autochthonous Occurrences

* Transgressive Late Paleocene to Middle Eocene carbonates of the Central Alps (Carinthia; HINTE 1963, WILKENS 1985).

* Transgressive Late Eocene, (Oberaudorf Beds, Lower Inn Valley; HAGN 1960, 1967; HAGN et al. 1981; ALLERSHEIMER 1981) and Lower Oligocene (Häring Beds, Lower Inn Valley; OEXLE 1978; HAGN et al. 1981).

* Transgressive Late Eocene ("Eisenrichterstein Beds", Salzburg-Reichen-

hall basin; HERM 1957; HAGN et al. 1981; DARGA 1990; 1992).

From the facial and palaeogeographic relationships interpreted in the autochthonous and allochthonous occurrences mentioned above we may conclude that two sedimentary cycles took place in independent facies realms of the Northern Calcareous Alps:

a) The Late Austroalpine synorogenic sedimentation in the region of the Gosau basins ended in the Upper Eocene.

b) The Late Eocene and Oligocene sedimentary sequences of the western and central parts of Calcareous Alps appear to be relics of a new marine transgression, which began in Late Eocene in the northern marginal belt of the Calcareous Alps.

The relics of only one transgressional cycle occur within the Central Alps (Carinthia); their sedimentation began in Late Paleocene and lasted at least until Middle Eocene.

1.2. Tectonic and paleogeographic survey

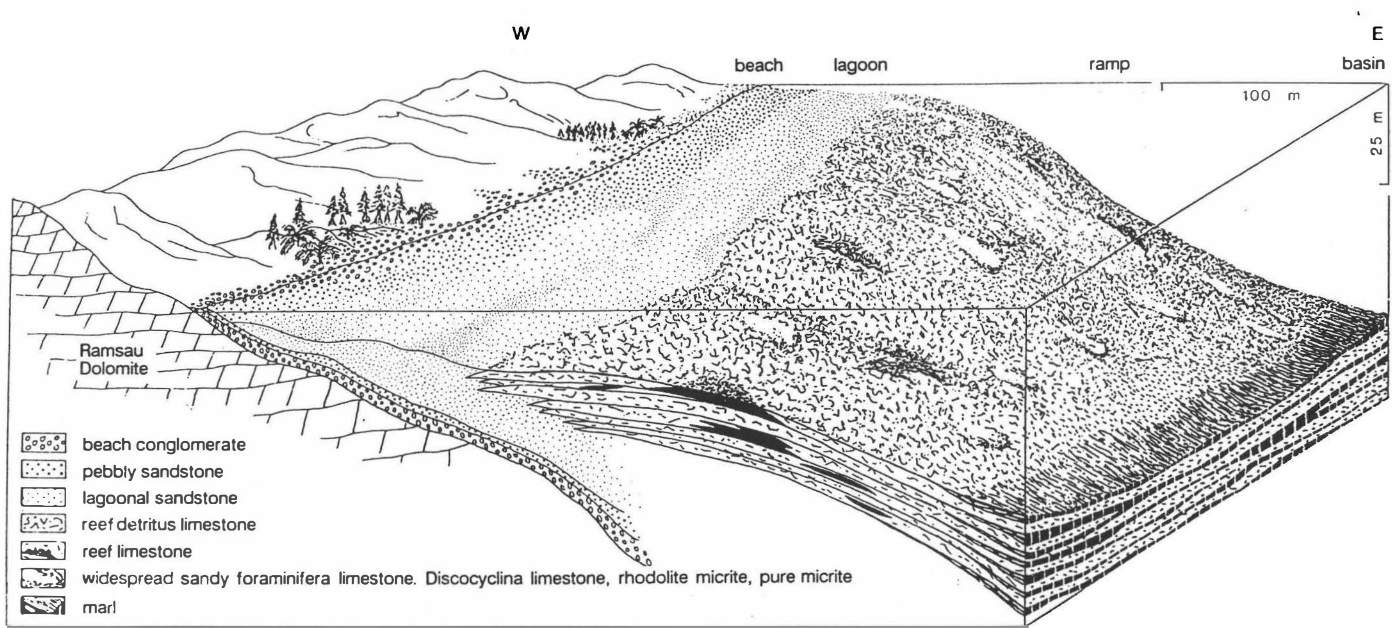
The compression of the Northern Calcareous Alps generally became stronger during the Cretaceous–Tertiary transition, so that most of the Gosau basins subsided strongly and in part sank below the CCD–level (Nierental Beds; BUTT & HERM 1978).

Towards the Paleogene, synorogenic sedimentation increased, shown by the deposition of olistostromes, turbidites, deep–sea fans and deep–sea fissure fillings. The enormous amounts of eroded material brought into the overs teepened troughs was derived from the topographically higher Austroalpine overthrusts in the south (Central Alps/ Greywacke zone). Synorogenic northwards–directed sediment–influx dominated the scene in the Northern Calcareous Alps until the beginning of Late Eocene.

In the western part of the Calcareous Alps, the last olistostromes and the final depositions had already taken place at the end of the Cretaceous (Muttekopf Gosau, LEISS 1990 a, b, c), whereas in the eastern and northern Gosau basins the final synorogenic sedimentation ended during the Paleocene or respectively Eocene; for example:

Kaisergebirge–Lower Inn Valley region in Late Paleocene and in Middle Eocene; Salzburg–Reichenhall basin in Late Paleocene/Eocene (compare HILLEBRANDT 1981; ASCHAUER 1988; MOUSSAVIAN et al. 1990); Wörschach Gosau in Early Eocene (POBER 1984; FAUPL et al. 1987); and finally, on the southeastern margin of the Calcareous Alps during Paleocene (compare PLÖCHINGER 1967, 1980; TOLLMANN 1976, 1985; OBERHAUSER 1980; LEIN 1982; FAUPL et al. 1987).

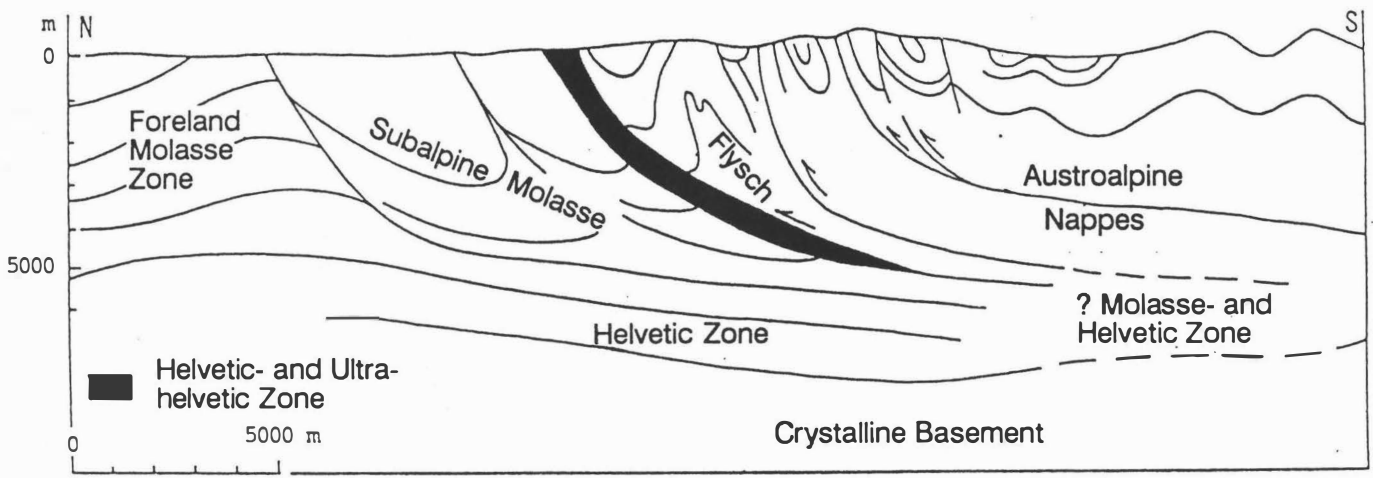
The reworked carbonates allow some insight into the geology and palaeogeography of the erosional areas in the south of the Northern Calcareous Alps during Maastrichtian to Eocene times. During sedimentation in the Northern Calcareous Alps, shallow marine archipelago environments were uplifted and soon exposed to erosion in the adjacent tectonic units to the south. The denudation processes encompassed carbonates of almost the entire older Mesozoic sedimentary sequence and even the metamorphic basement. The nappe-thrusting at the end of the Cretaceous led to the formation of extensive terrestrial environments, for example the source areas of the Muttekopf Gosau in the west and the central Alpine areas in



schematic reconstruction of the Eisenrichterstein carbonate ramp and adjacent paleoenvironments in the Lower Priabonian (after DARGA 1992).

Fig. 1

Fig. 2



Schematic N-S profile of the alpine northern marginal zone in Bavaria (after BACHMANN et al. 1979, HAUSER 1992).

the east (compare OBERHAUSER 1978, 1980; LEISS 1990 a, b, c; TOLLMANN 1985). The different Paleocene shallow–water sediment types which have been formed as the result of reworking, document the establishment of an extensive reefal facies realm which had its continuation in the western Carpathians; sedimentation began, at the latest, during the later part of Danian and ranged to the beginning of Ilerdian ("reef–belt on the southern margin of the Calcareous Alps": HAGN & OTT 1975; "Alpine–Carpathian reef–belt": MOUSSAVIAN 1984). These were not barrier reefs, but mostly small–scale locally limited red algal–coral–dominated buildups in a morphologically strongly differentiated facies realm which extended from the Calcareous Alps to the western Carpathians.

During Ilerdian and later in Early and Middle Eocene, shallow–water deposition continued in close neighbourhood to basinal sedimentation.

Apparently, renewed formation of extensive reefal areas could not become established again. Locally limited corallinacean– and corallinacean–foraminifera–bryozoan–dominated biostromes, rhodoliths and clastic carbonates represented the main facies types in the littoral zones of the mobile–sediment areas.

The termination of marine deposition in the sedimentary realms of the region to the south of the Northern Calcareous Alps, as a result of nappe-thrusting, began during Middle Eocene.

This tectonic process led to the northward shift of the uplift– and trough–axes, so that great parts of the Northern Calcareous Alps also elevated and emerged (MOUSSAVIAN 1984; HAGN 1989; "Illyrian Phase": TOLLMANN e.g. 1966, 1985). The cause of this event is considered to have been the collision of the lithosphere plates (DIETRICH & FRANZ 1976; TOLLMANN 1989).

With the beginning of Lower Priabonian, a renewed transgression flooded large areas of the northern marginal belt, as a result of subsidence tendency. The Late Eocene and Early Oligocene marine sequences of the Lower Inn Valley (Oberaudorf Beds, Häring Beds etc.) and Bad Reichenhall area ("Eisenrichterstein Beds") represent the relics of this last sedimentary cycle of the Inner–Alpine realm. During this cycle small corallinacean– and coral – corallinacean – bryozoan – foraminifera–dominated biostromes/biolithites and different coated grains were formed.

Facies and algal associations

In the above chapters a survey was given of the complicated tectonically controlled distribution and evolutionary trends in the Paleogene shallow–marine facies realms of the Austroalpine nappe system. These facies have only been preserved in the form of reworked fragments and relics. In the following two case studies will be sketched.

Case study

Shallow–water sediments of Early to Middle Paleocene (Late Danian–Early Ilerdian)

A small outcrop of exclusively shallow–water sediments of Late Maastrichtian to Early Paleocene age (PLÖCHINGEN 1967) occurs at the southeastern margin of the Calcareous Alps (N of Ternitz, southern edge of Schneeberg Nappe). This is a unique occurrence for the entire region of the Upper Austroalpine. Although only having a thickness of several meters, it is apparently not an allochthonous series, but a foreign block which has been tectonically transported into the Calcareous Alps from the south (sliding mass). The investigations made by the author show, that this block consists of parts of two facies sequences which are foreign to those of the Calcareous Alps:

Late Maastrichtian

The basal sequence is a Late Maastrichtian, subtidal facies showing in part lithoclast / terrigenous influence with larger foraminifera and red algae.

Important fauna: *Orbitoides apiculata, Orbitoides media, Lepidoorbitoides minor, Omphalocyclus macroporus, Hellonocyclina beotica, Siderolites calcitrapoides, Acervulina* sp..

Important algae:

Parachaetetes asvapatii PIA,
Paraphyllum amphiroaeforme (ROTHPLETZ) LEMOINE,
Sporolithon batalleri (LEMOINE) n.comb.,
"Litho- thamnium" cuvillieri POIGNANT & CHAUFAUT,
" Lithothamnium" vilaegranis POIGNANT & BLANC
(both species belong to a new genus!) and other red algae species.

Based on investigations of unattached fragmentary parts of the section, one may conclude that the Late Maastrichtian marine facies gradually shallows upwards into supratidal (and ?non-marine) environments.

Paleocene

The Paleocene sequence ("Kambühel Limestone": TOLLMANN 1976) is composed of the following facies types: supratidal to intertidal pelmicrites (characterized by fenestral fabrics, desiccation cracks and vadose cements), intertidal pelmicrites, foraminiferal–algal–biomicrites/biosparites, and corallinacean–coral–dominated biolithites/ biostromes (pl.1/1,3; pl.3/1). The entire sequence appears to have an Early Paleocene age (Danian/Montian), based on the algal–foraminiferal composition.

Additional blocks and pebbles, respectively olistoliths, of similar marine facies occur farther westwards, namely N of Prigglitz and SE of Mariazell (compare PLÖCHINGER 1967; TOLLMANN 1976; LEIN 1982).

Thanetian may occur here also. Similar Thanetian to Lower Ilerdian carbonates, exhibiting different facies types are found especially as olistoliths at Wörschachberg (Wörschach Gosau; pl.2/1; pl.3/2,3) and also as pebbles and olistoliths in the above described deposits (e.g. Ilerdian olistostromes of Glanegg, pl.2/3; Late Oligocene Angerberg Beds, pl.2/1, pl.3/2,3). Nearly the same facies types also occur in the western Carpathians in the Myjava–Hricov–Haligovka–Zone (compare SCHEIBNER 1968; SAMUEL et al. 1972).

These allochthonous sediments which have been preserved in an enormous number of examples, can be envisioned to have been distributed in various subfacies areas of a differentiated facies realm which once extended from the Alps to the Carpathians. The small–scale biogenic buildups were mainly constructed by sheet– to mound–like red algae, corals, bryozoans and encrusting foraminifera. Columnar or dendriform corals were apparently not important. In the more or less sheltered shallow areas biomicrites and biosparites were deposited with predominantly porcelaneous foramini- fera (miliolids, alveolinids), chlorophytes, branching red algae and rhodoliths. In contrast, the deeper shallow–marine facies areas were characterized by larger foramini- fera (Nummulitidae, Discocyclinidae) and corallinacean–coral–acervulinid–dominated encrustations.

Algal associations

The most important encrusting elements of the buildups and of the coated grains belong to the red algae families Corallinaceae and Solenoporaceae. Members of Peyssonneliaceae are generally of minor importance. Cyanophytes, especially the encrusting, multispecific morphotypes, occasionally occur more frequently in some encrustations than do the red algae, but usually they are suppressed by the red algae. The chlorophytes that appear in great abundance in some facies types are almost solely limited to the order Dasycladales.

The most important algae of the Danian to Early Ilerdian are outlined below:

Cyanophytes

Multispecific morphotypes (microbial crusts): tubiphytoid forms (pl. 3/3).

Monospecific forms:

Pycnoporidium lavantinum JOHNSON.

Rhodophytes

Solenoporaceae:

Parachaetetes asvapatii PIA (syn.: *Elianella elegans* PFENDER & BASSE) (pl.2/1).

Corallinaceae:

Sporolithon cf. *batalleri* (LEMOINE) n. comb.,

Sporolithon cf. *parisiense* (LEMOINE) n.comb.,

Sporolithon gunteri JOHNSON & FERRIS n. comb.,

Sporolithon cf. *oulianovi* (PFENDER) n. comb.,

Sporolithon nongesteinensen. comb.

Corallinaceae gen. et sp. indet. (pl.3/1),

Palaeothamnium kossovense MASLOV (pl.1/4; pl.2/4),

Palaeothamnium iorii MASLOV,

Lithothamnion andrusovi (LEMOINE) n. comb.,

Lithothamnion cf. *guatemalense* (LEMOINE) n. comb.,

Lithothamnion contraversum (LEMOINE) n. comb.,

Mesophyllum ramosum LEMOINE,

Mesophyllum tropicale (LEMOINE) (pl.2/3),

Lithophyllum quadrangulum LEMOINE,

Lithophyllum mengaudi var. *carpathica* LEMOINE (pl.1/4),

"Lithophyllum" densum LEMOINE,

Distichoplax biserialis (DIETRICH) PIA,

Pseudoamphiroa propria (LEMOINE) MOUSSAVIAN (pl.2/2),

Corallina abundans LEMOINE,

Jania nummulitica LEMOINE.

Peyssonneliaceae:

Peyssonnelia praean- tiqua MOUSSAVIAN (pl.1/3),

Peyssonnelia taeniiformis MOUSSAVIAN,

Peyssonnelia antiqua JOHNSON (pl.3/3),

Peyssonnelia bistrata MOUSSAVIAN (pl.1/4),

Pseudolithothamnium album PFENDER.

Chlorophyta:

Broeckella belgica MORELLET & MORELLET (siehe auch OTT in TOLLMANN 1976: 450),

Dactylopora sp.,

Digitella sp.,

?*Rostrporella* sp.,

Neomeris sp.,

Cymopolia elongata (DEFRANCE) MUNIER–CHALMAS,

Uteria sp.,
Frederica sp.,
Terquemella globularis ELLIOTT,
Acicularia ssp.

Case study

Late Eocene shallow–water carbonates of Eisenrichterstein (Hallthurm, Salzburg–Reichenhall basin): "Eisenrichterstein Beds" ("Eisenrichterstein-Schichten", nov. nom.)

The steeply dipping shallow–marine Priabonian carbonates of Eisenrichterstein in the Nierental area between Untersberg and Lattengebirge representrelics of a transgressional sequence, which has been sandwiched–in tectonically and thus has escaped erosion (compare HERM 1957, HILLEBRANDT 1962; DARGA 1992).

Simultaneous to with the shallow–marine sedimentation in the Nierental area, the basinal sedimentation continued in the north (Kühlbach), in the south (Tongraben) as well as in the east (HERM 1957, 1993: pers. comm.; HILLEBRANDT 1981).

This transgressional development did not start, as generally supposed, in the realm of the Calcareous Alps on top of a previously formed, dry, terrestrial environment, but on an archipelago–like, topographic high, which began subsiding during Early Priabonian.

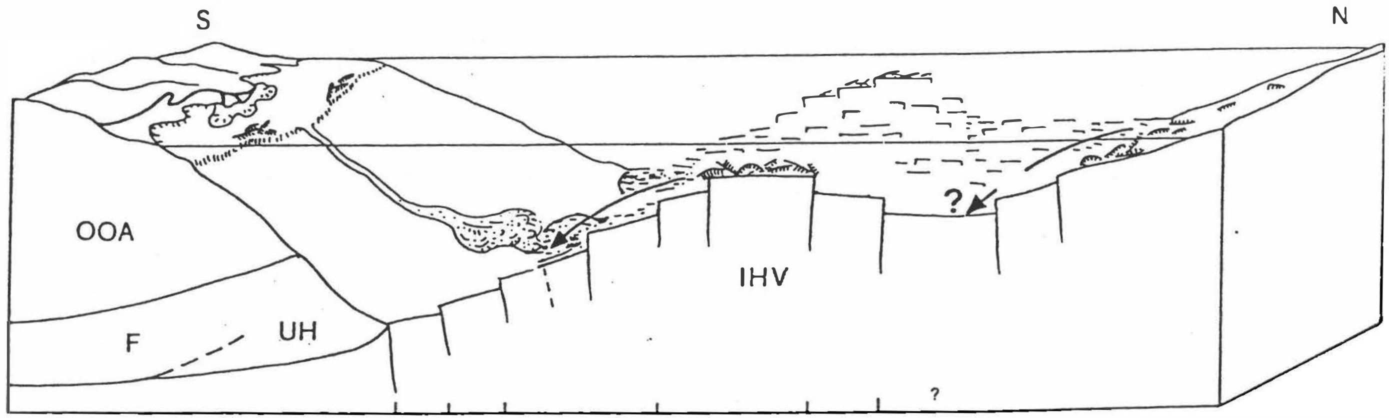
The carbonate sequence is dismembered tectonically into numerous homogeneous parts (DARGA 1992). Nevertheless, the facies development in the sedimentary column is recognisable: sedimentation begins with a coarse to medium–grained clastic deposit which towards the top gradually changes to a more and more biogenic–carbonate facies. Within this predominantly bioclastic environment mollusc pavements, coated grains, encrustations and biostromes occur, which were mainly formed by red algae, corals, encrusting foraminifera and bryozoans. In spite of the occasional dense growth of diverse corals (coral tufts), a true reef system never developed because of the instability and transient existance of the "insular shelf", on which they were formed. This carbonate sequence can be designated as "Eisenrichterstein Beds" ("Eisenrichtersteiner Schichten"). DARGA (1990, 1992), who investigated the deposits of Eisenrichterstein interprets the different facies types as representing the various environments of carbonate ramp embayment ("beach conglomerates", "lagoonal sandstones", "patch reefs" etc.; fig.1). The ramp hypothesis is founded by this author as follows: "The absence of real, large scaled coral frameworks...", and "the fairly well–defined bedding (in places indistinct) of the whole reef complex as well as of the near-basin sediments..." (DARGA 1990: 24; 1992: 32–36, 109–110).

Algal associations

Besides cyanophytes crusts within the buildups, the predominant algal flora consists almost completely of red algae which serve as the most common element of the encrustations (biostromes, mono/multispecific rhodoliths). Some of the more important forms are:

Corallinaceae:

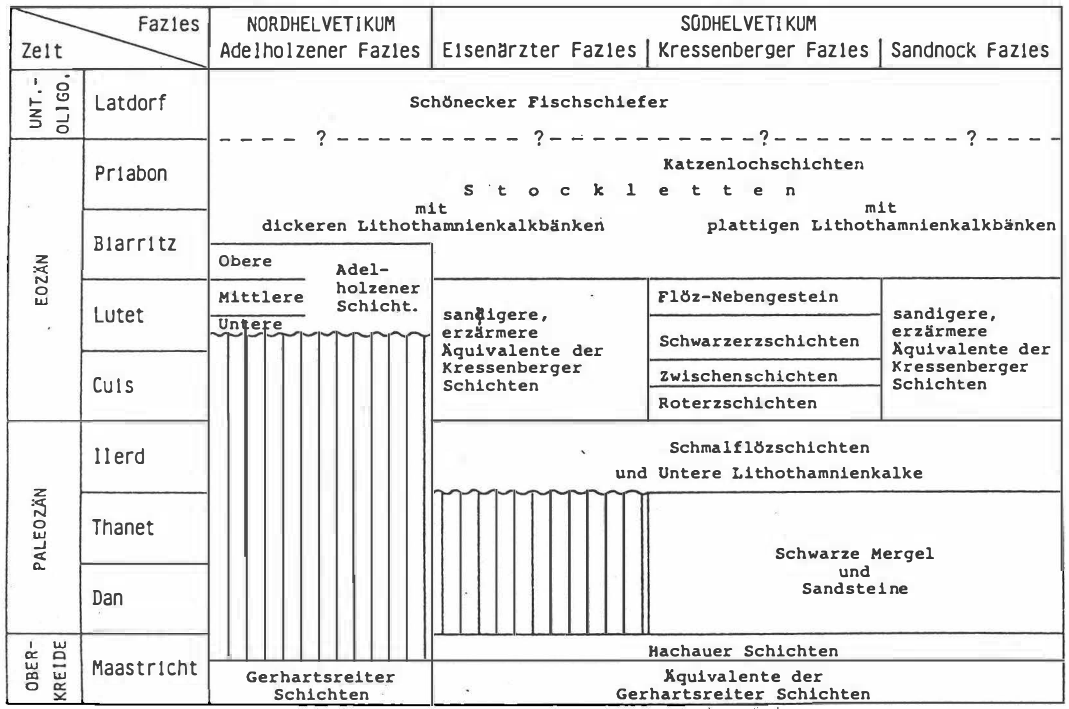
Sporolithon nummuliticum (GÜMELBELI) n. comb.,
Sporolithon aff. *oulianovi* (PFENDER) n.comb.,
Sporolithon cf. *boggiolense* (MASTRORILLI) n.comb.,
Lithothamnion torulosum (GÜMEL) n. comb.,



Hypothetic paleogeographic relations between the basement of the Molasse Zone and the advancing front of the alpine nappes during Upper Eocene. Approximate width of deposition area at least 200 km (after WAGNER et al. 1986).
OOA = Upper Austroalpine, F = Flysch-Z., UH = Ultrahelvetic Z., IHV = Intrahelvetic High

Fig. 3

Fig. 4



Paleogene of the Helvetic Zone in SE Bavaria, stratigraphy, facies distribution and facies zones (compiled by HAUSER 1992).

Corallinacean-dominated, allochthonous and autochthonous carbonates ("Lithothamnienkalke") are restricted to the Southern Helvetic Zone during Paleocene. From Middle to Upper Eocene they occur in the Northern and Southern Helvetic Zone.

A4

Mesophyllum mazzapiedense MASTRORILLI,
Mesophyllum roveretoi CONTI (sensu MASTRORILLI 1968),
Mesophyllum vaughani (HOWE) LEMOINE (sensu MASTRORILLI 1968; pl.4/3),
Lithoporella melobesioides (FOSLIE) FOSLIE,
Melobesia minus JOHNSON,
Lithophyllum intumescens (MASTRORILLI) (pl.4/1),
Lithophyllum contii MASTRORILLI (pl.4/2), *Lithophyllum embergeri* MASTRORILLI;
Lithophyllum prae- lichenoides LEMOINE,
"Lithophyllum" cf. *albanense* LEMOINE,
"Lithophyllum" anguineum CONTI.

Peyssonneliaceae:
Pseudolithothamnium album PFENDER (pl.4/4);
Peyssonnelia rara MOUSSAVIAN,
Peyssonnelia reposita MOUSSAVIAN.

2. Helvetic Zone

2.1. Tectonic and palaeogeographic survey

As a result of a regression which ended during the Late Maastrichtian, extensive areas of the northern margin of the Helvetic Zone were emerged, whereas contemporaneously shallow-water sedimentation commenced along the southern margin of the Bavarian-Salzburg Helvetic Zone and lasted here beyond the Cretaceous-Tertiary boundary (compare TRAUB 1953; GOHRBAND 1963; VOGELTANZ 1970; HAGN 1967; HAGN et al. 1981; KUHN 1992). In contrast to this, continuous deep-water sedimentation dominated the Ultrahevetic facies zone. A number of archipelago-like highs are supposed to have accentuated the geomorphology: "Cetic Ridge" (between Ultrahelvetic and Flysch Zone: HAGN 1960, HAGN et al. 1981), "Pre-Vindelician Island Chain" (between Helveticum and Ultrahelveticum: Traub 1953; VOGELTANZ 1970) and "Intrahelvetic sill" (between the southern and northern facies regions: HAGN 1954; 1960, HAGN et al. 1981). Corallinacean-foraminifera-bryozoan-dominated encrustations (as rhodoliths, local biostromes, etc.) developed in the littoral environments of Middle Ilerdian.

Marked sand influx beginning already during the Ilerdian, led to the formation of iron-rich, siliciclastic carbonate deposits in the Bavarian-Salzburg region. Facies differentiation took place in the southern Helvetic Zone with the development of some terrestrial areas.

Beginning with Middle Eocene, a zone of subsidence gradually moved northwards, caused by the approaching Austroalpine Nappe pile. The resulting transgression, coming from the south, reached the northern margin of the Helvetic Zone by late Middle Eocene, thereby inundating this area which had been dry land since the end of the Cretaceous (HAGN 1960, 1978, HAGN et al. 1981; WAGNER et al. 1986; HAUSER 1992). In Priabonian, at the time when the Helvetic realm was extensively a deep-water environment, increased turbiditic and olistostromatic deposition took place. The redeposited material originated, for the most part, from the old topographic highs in the south as well as from the newly formed shallow-water areas in the north (fig.1). These new subtidal areas as well as those of the south were characterized by rhodoliths and local corallinacean-dominated buildups. Small-scale coral-algal-dominated biostromes appear to have been far less common. A continuous barrier reef, as postulated by BUCHHOLZ (1986) on the "northern Prae-Molasse edge", or by HAGN & DARGA (1990), DARGA (1992; see stop 1,2) on the "northern edge of Intrahelvetic High" (South Helvetic Zone) cannot be substantiated in the investigations done for this paper. The facies analysis of all this sediment types and the palaeogeographic relationships suggests a comparison with modern environmental conditions of the Mediterranean Sea (MOUSSAVIAN 1988).

Progressive overthrusting of the Austroalpine nappes during Early Oligocene led to increased restriction of the northern Tethys ("Paratethys"), where boreal and anoxic depositional conditions began ("Schōnecker Fischschiefer"; compare HAUSER 1992). The final and complete tectonic elimination of the Helvetic sedimentary realm began in the Late Oligocene, with the result that the Helveticum, in a number of slices, was transported over subduced Molasse; the Helvetic Nappe in turn was buried under the Flysch Nappe in the Miocene ("Pyrenean Phase"-"Savian Phase": TOLLMANN e.g. 1985; fig.2).

2.2. Facies development

The Paleogene sequence of the South Helvetic Zone in the Bavarian-Austrian region begins with dark-coloured marls and sandstones of the Early and Middle Paleocene ("Oiching Beds", see fig.4) which then pass into limonite-rich, often biota-rich layers of Ilerdian age. Lateral changes in facies character occur in this rapidly differentiating depositional region: sandy limestones, mollusc-banks, corallinacean-acervulinid-dominated biolithits / rhodoliths ("Unterer Lithothamnienkalk") as well as corallinacean-foraminifera-dominated packstones and grain/rudstones ("Lithothamnienschuttkalke", "Fossilschuttkalke").

The siliciclastic and biogenic carbonate facies become generally more and more clastic and iron-rich towards Middle Eocene, so that iron-ore-bearing special facies characterize the time period of Early Eocene to early Middle Eocene ("Roterzschichten", "Schwarzerzschichten" etc.; fig.4).

The following pelagic sediments ("Stockletten" - clays) with turbiditic or olistostromatic intercalations indicate the final subsidence of this depositional realm which spreads northwards. In the northern Helvetic Zone the transgressive siliciclastic and nummulitid-bearing beds (Adelholzen Beds), that were deposited initially, soon were followed pelagic sediments ("Stockletten"). The Priabonian turbidites and olistostromes contain in especially high abundance corallinacean-dominated biolithites and rhodoliths, which were transported into the basin from the shallow marine areas (submarine topographic highs; fig.3).

Interesting case studies for algae-bearing carbonates are given by the Late Paleocene rhodoliths of the southern Helvetic Zone of Haunsberg (N of Salzburg) and the Late Eocene turbidites and olistostromes of the northern Helvetic Zone in the area of Rohrdorf/Neubeuern (Upper Bavaria; see chapter B1, stops 1,2).

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Plate 1

Algal associations of the Eastern Alpin Paleogene:
Allochthonous carbonates of Upper Danian – Thanctian

Plate 2

Algal associations of the Eastern Alpine Paleogene:
Allochthonous carbonates of Thanetian – Early Ilerdian

Plate 3

Algal associations of the Eastern Alpine Paleogene:
Allochthonous carbonates of Upper Danian – Thanetian

Plate 4

Algal associations of the Eastern Alpine Paleogene:
Autochthonous carbonates of Priabonian – Lower Oligocene

Plate 1

Fig.1:
Red algal-coral-dominated thicket consisting mainly of encrusting corallinaceans. The allochthonous occurence of this facies type represents the once extensive Early Paleocene reefal facies in the South of the Northern Calcareous Alps. Stratum: "Kambühel limestone". Locality: Kambühel N Ternitz, Niederösterreich (Austria). Age: Early Paleocene. x 7.

Fig.2:
Coral-corallinacean encrustation with scleractinian (Poritidae (a), *Cladocora* sp.(b)) as well as *Mesophyllum* sp. (c). Stratum: Reworked biolithite within the Angerberg Beds (Late Oligocene; compare MOUSSAVIAN 1984, pl.2/5).Locality: Angerberg, Lower Inn Valley (Austria). Age: Thanetian. x 7.

Fig.3:
Peyssonnelia praeantiqua MOUSSAVIAN overgrown by *Acervulina* sp. (= "*Solenomeris*", foraminifera). Stratum: "Kambühel limestone". Locality: Kambühel N Ternitz, Niederösterreich (Austria). Age: Early Paleocene. x 80.

Fig.4:
Corallinacean-dominated encrustation composed of *Palaeothamnium kossovense* MASLOV (a), "*Lithophyllum*" *carpathicum* LEMOINE (b) and *Peyssonnelia bistrata* MOUSSAVIAN (c). Stratum: Reworked biolithite within the Angerberg Beds (Late Oligocene). Locality: Angerberg, Lower Inn Valley (Austria). Age: Thanetian. x 14.

A4

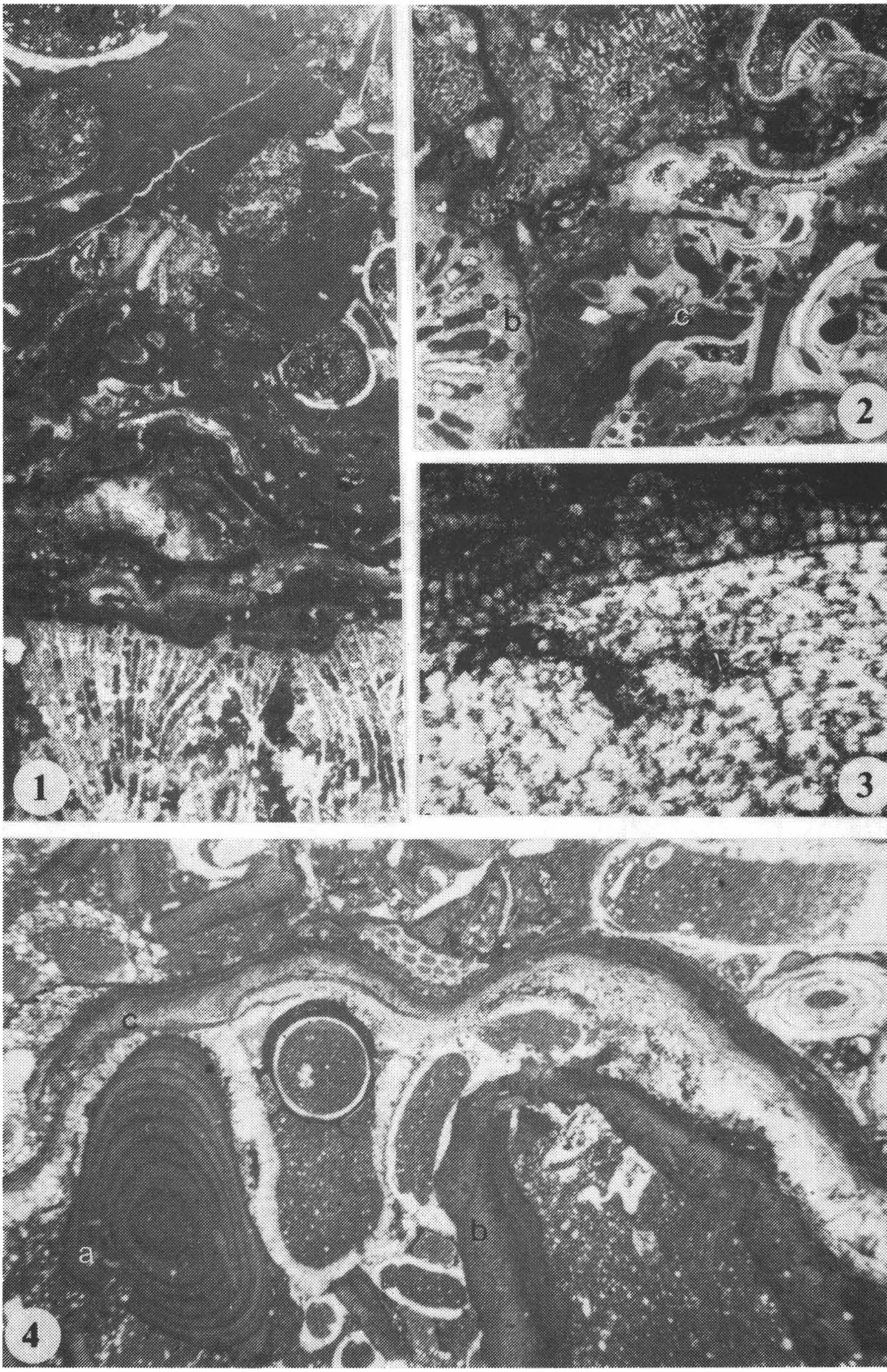

Plate 2

Fig.1:
Parachaetetes asvapatii PIA (syn.: *Elianella elegans* PFENDER & BASSE). Stratum: Reworked biolithite within the Early Eocene olistostromes of Wörschach Gosau Basin. Locality: Wörschachberg, Steiermark (Austria). Age: Thanetian. x 7.

Fig.2:
Pseudoamphiroa propria (LEMOINE) MOUSSAVIAN; Note the monosporangial reproductive organs (left edge). Stratum: Reworked biolithite within the Angerberg Beds (Late Oligocene). Locality: Angerberg, Lower Inn Valley (Austria). Age: Thanetian. x 80.

Fig.3:
Mesophyllum ramosum LEMOINE (a) and *Lithothamnion contraversum* (LEMOINE) n.comb. (b). Stratum: Reworked corallinacean-biomicrite within the olistostromes (Early Ilerdian) of the Gosau basin of Salzburg-Reichenhall. Locality: Glanegg, near Salzburg (Austria). x 23.

Fig.4:
Palaeothamnium kossovense MASLOV with sporangial conceptacles. Stratum: Reworked biolithite within the Angerberg Beds (Late Oligocene). Locality: Angerberg, Lower Inn Valley (Austria).
Age: Thanetian-Early Ilerdian. x 80.

A4

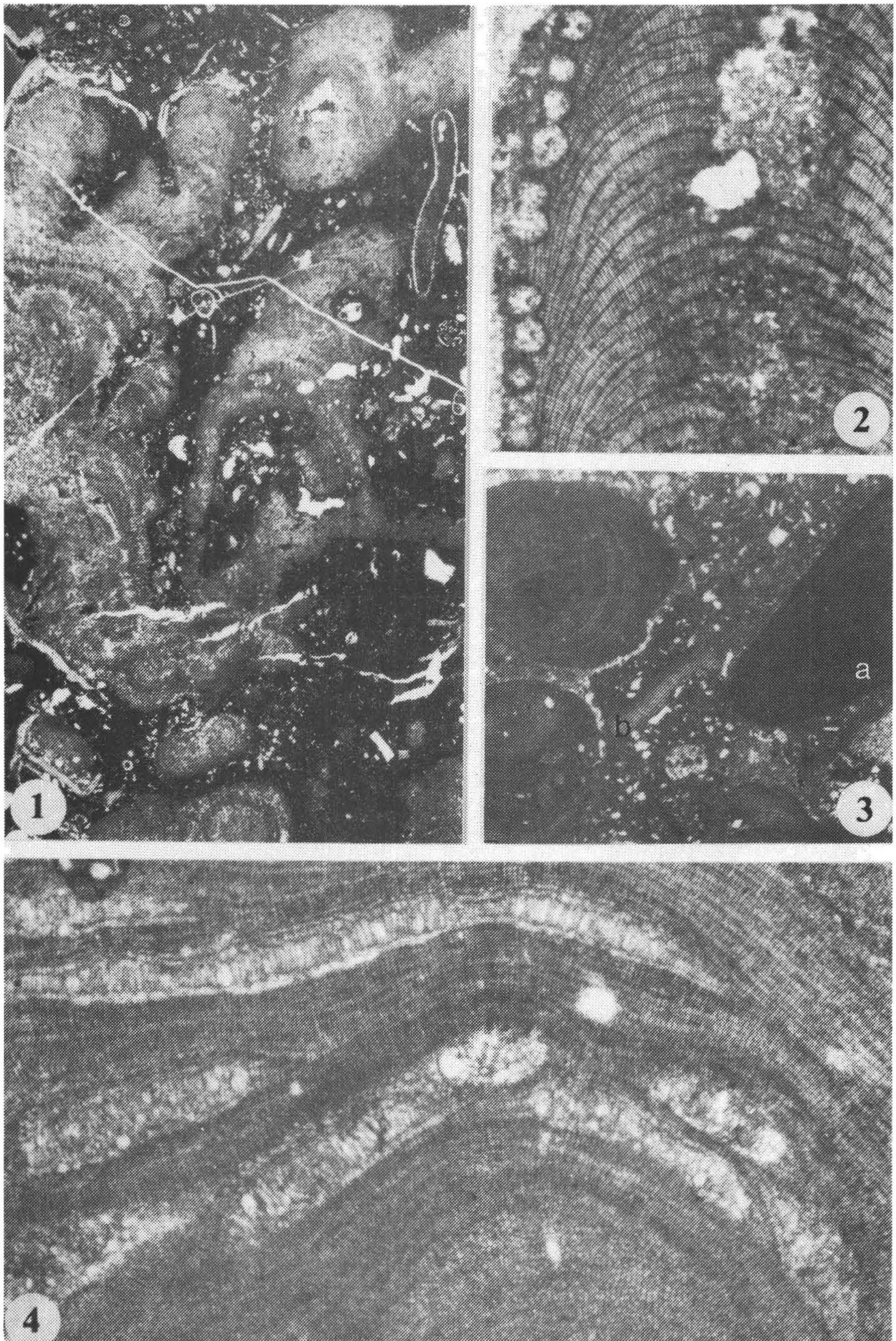

Plate 3

Fig.1:
Corallinaceae gen.et sp.indet, with monoporate and monosporangial reproductive organs. Stratum: "Kambühel limestone".Locality: Kambühel N Ternitz, Niederösterreich (Austria). Age: Early Paleocene. x 30.

Fig.2:
Peyssonnelia antiqua JOHNSON in encrustation with corallinaceans. Stratum: Reworked biolithite within the olistostromes (Early Eocene) of the Wörschach Gosau Basin. Locality: Wörschachberg, Steiermark (Austria). x 100

Fig.3:
Tubiphytoid crusts grown on a coral. Stratum: Reworked biolithite within the Angerberg Beds (Late Oligocene). Locality: Angerberg, Lower Inn Valley (Austria). Age: Thanetian. x 180.

A4

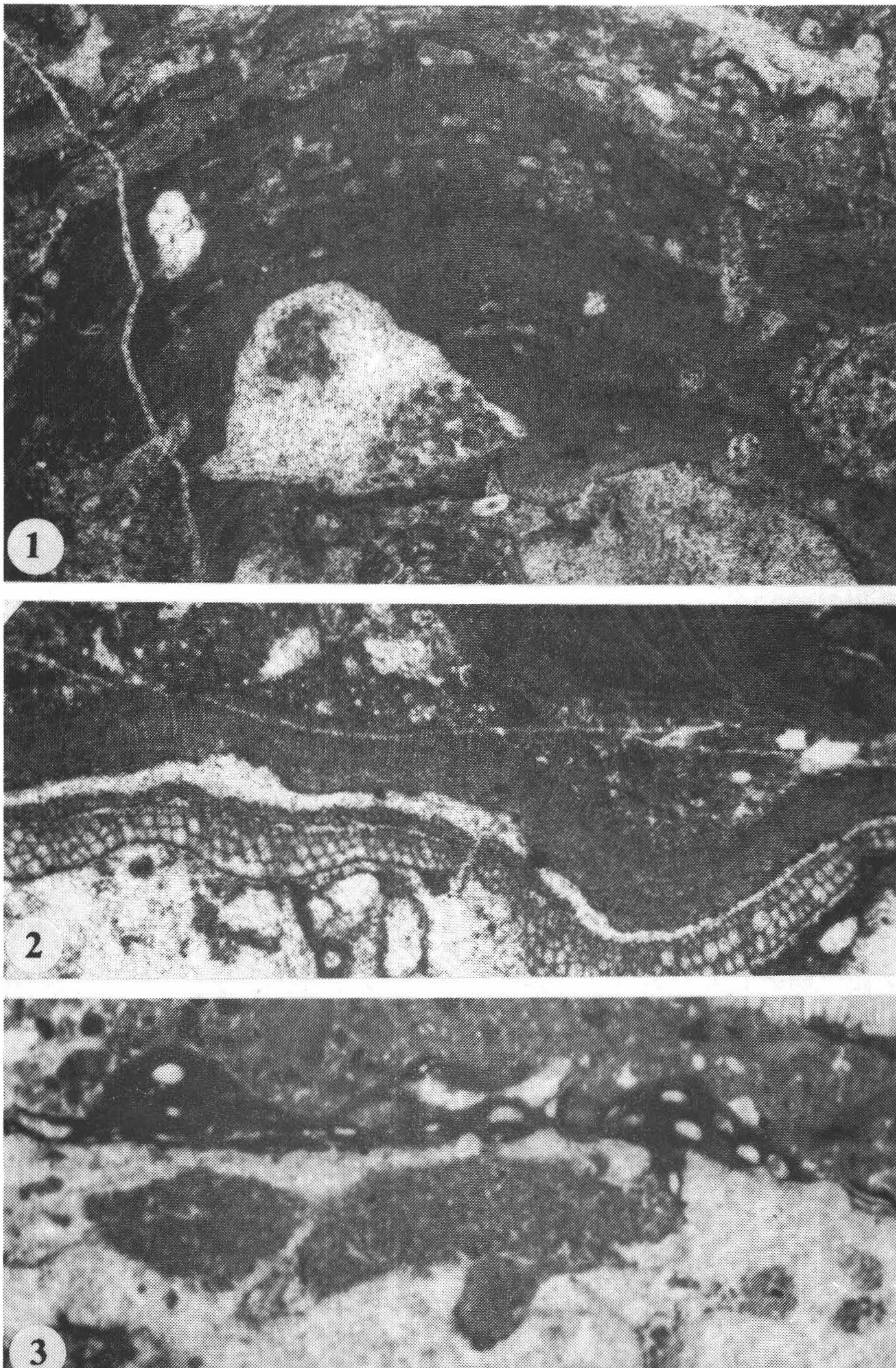

Plate 4

Fig.1:
Lithophyllum intumescens MASTRORILLI showing monoporate conceptacles. Stratum: "Eisenrichterstein Beds". Locality: Hallthurm near Bad Reichenhall (Germany). Age: Priabonian. x 35.

Fig.2:
Lithophyllum contii MASTRORILLI. Stratum: Eisenrichterstein Beds". Locality: Hallthurm near Bad Reichenhall (Germany).Age: Priabonian. x 80.

Fig.3:
Mesophyllum vaughani (HOWE) LEMOINE (sensu MASTRORILLI 1968) with multiporate conceptacles. Stratum: Eisenrichterstein Beds".Locality: Hallthurm near Bad Reichenhall (Germany).Age: Priabonian. x 45.

Fig.4:
Pseudolithothamnium album PFENDER. Stratum: Eisenrichterstein Beds". Locality: Hallthurm near Bad Reichenhall (Germany). Age: Priabonian. x 80.

Fig.5:
Neogoniolithon raripunctatum MASTRORILLI in association with corals. Stratum: Håring Beds. Locality: Lower Inn Valley (Austria). Age: Lower Oligocene. x 6.

A4