FACIES	32	195-214	Pl. 38-41	7 Figs.	--	ERLANGEN 1995

Anthracoporella Mounds in the Late Carboniferous Auernig Group, Carnic Alps (Austria)

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SUMMARY

A heretofore undocumented example of skeletal mounds formed by the dasycladacean alga *Anthracoporella spectabilis* is described from mixed carbonate-clastic cycles (Auernig cyclothems) of the Late Carboniferous (Gzhelian) Auernig Group of the central Carnic Alps in southern Austria.

The massive mound facies forms biostromal reef mounds that are up to several m thick and extend laterally over more than 100 m. The mound facies is developed in the middle of bedded limestones, which are up to 16 m thick. These limestones formed during relative sea-level highstands when clastic influx was near zero.

The mound facies is characterized by well developed baffler and binder guilds and does not show any horizontal or vertical zonation. Within the massive mound facies *Anthracoporella* is frequently found in growth position forming bafflestones and wackestones composed of abundant *Anthracoporella* skeletons which toppled in situ or drifted slightly. *Anthracoporella* grew in such profusion that it dominated the available sea bottom living space, forming 'algal meadows' which acted as efficient sediment producers and bafflers. Because *Anthracoporella* could not provide a substantial reef framework, and could not withstand high water turbulence, the biostromal skeletal mounds accumulated in shallow, quiet water below the active wave base in water depths less than 30 m.

The massive mound facies is under- and overlain by, and laterally grades into bedded, fossiliferous limestones of the intermound facies, composed mainly of different types of wackestones and packstones. Individual beds contain *Anthracoporella* and *Archaeolithophyllum missouriense* in growth position, forming "micromounds'.

Two stages of mound formation are recognized: (1) the stabilization stage when bioclastic wackestones accumulated, and (2) the skeletal mound stage when the sea-bottom was colonized by *Anthracoporella* and other members of the baffler and binder guilds, forming *Anthracoporella* bafflestones and wackestones of the mound facies.

A slight drop in sea-level led to the termination of the mound growth and accumulation of organic debris, particularly calcareous algae, fusulinids, crinoids and bryozoans, forming well bedded limestones, which overlie the mound facies

1 INTRODUCTION

Mounds are defined as biologically constructed reliefs, built by smaller, commonly delicate and/or solitary organisms in low-energy environments (James & Bourque, 1992). In the geologic record mounds are probably more frequent than reefs, for example all carbonate buildups of Mississippian to Early Triassic age are mounds (see James & Bourque, 1992).

Most Late Carboniferous to Early Permian mounds are skeletal mounds consisting of abundant calcareous algae, particularly the phylloid algae *Archaeolithophyllum, Eugonophyllum* and *Ivanovia* (Chuvashov & Riding 1984, Fagerstrom 1987, James & Bourque 1992, West 1988).

Well studied examples are reported from the southwestern United States (e.g. Choquette 1983, Dawson & Carozzi 1986, Heckel & Cocke 1969, Mazzullo & Cys 1979, Peterson & Hite 1969, Roylance 1990, Toomey et al. 1977, Toomey & Babcock 1983, Toomey & Winland 1973, Wilson 1975).

In the Carnic Alps, Boeckelmann (1985) was the first who described algal mounds from the Meledis Formation of the Auernig Group. Within the Meledis Formation small scale auloporid coral mounds are also developed (Flügel & Krainer 1992). Krainer (1990, 1992) pointed out that biostromal algal mounds are also present within the Auernig Formation. A brief description of these mounds is given by Krainer (1991). Furthermore, algal mounds are frequently

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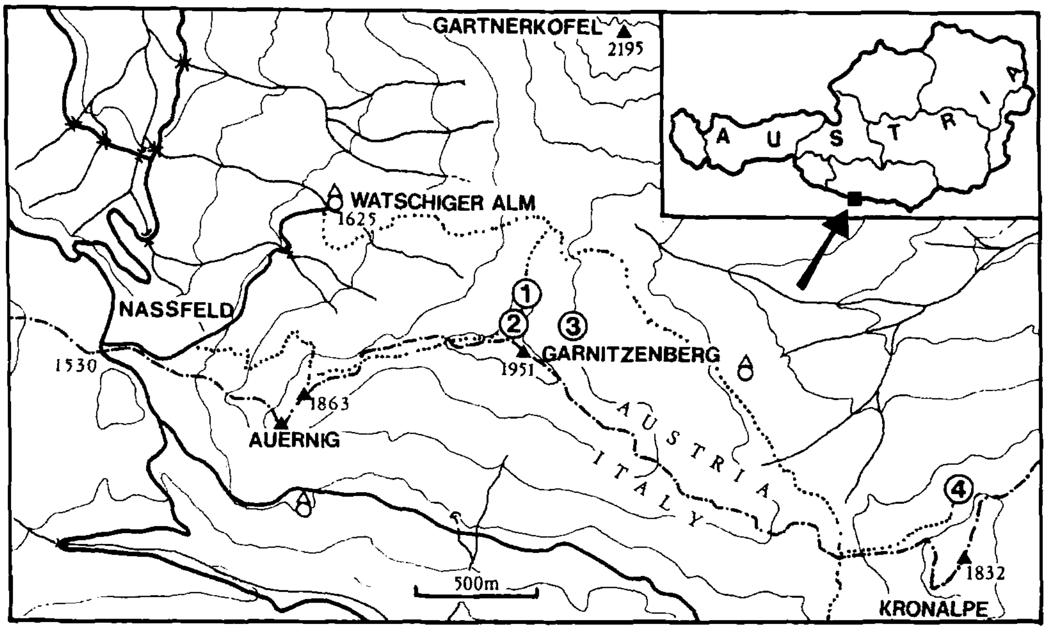


Fig. 1. Location map showing locations of the investigated sections (Figures 3 - 5).

developed within the Lower *Pseudoschwagerina* Limestone of the Rattendorf Group (Flügel 1987) which overlies the Auernig Group.

In the present study it will be shown that the algal mounds of the Auernig Formation do not fit the model for Late Paleozoic buildups proposed by Wilson (1975), and that the mound-forming organisms (algal assemblages) differ from all other described mounds of this period.

The aim of this paper is to describe the geometry, structure, mound-building organisms and composition of the mounds and intermound rocks, and to discuss the parameters which favoured mound formation.

2 LOCALITY

The study area is in the Central Carnic Alps in southern Carinthia (Austria) with outcrops located east of the Naßfeld-Pass (Passo Pramollo), at Garnitzenberg (Monte Carnizza) and Kronalpe (Monte Corona), near the Austrian/Italian border (Fig. 1). Limestones of the Auernig Formation have been investigated along the footpath to the Garnitzenberg at the Gugga (1), below the peak of the Garnitzenberg (2), NE of the Garnitzenberg (3) and at the NW-side of the Kronalpe (4).

Four sections of limestones were measured in detail and 159 samples were studied in the laboratory. More than 200 thin sections were examined using standard methods of microfacies analysis, and the proportions of bioclasts, lithoclasts, matrix and cement were obtained using the point count method. 300 points per thin section were counted.

3 GEOLOGICAL SETTING AND STRATIGRAPHY

In the Carnic Alps, which belong to the Southern Alps, the folded Variscan basement is unconformably overlain by immature clastic sedimentary rocks of the Bombaso Formation (Fenninger et al. 1976, Venturini 1990a, b, Krainer 1990, 1992). The overlying Auernig Group is a sequence of shallow-marine, clastic-carbonate sedimentary rocks with a maximum thickness of 1200 m and is divided into the Meledis-, Pizzul-, Corona-, Auernig- and Carnizza formations according to Selli (1963). According to the fusulinid assemblages the Auernig Group ranges from the Early Kasimovian to the Gzhelian (Kahler 1983, 1985, 1986, 1989) (Fig. 2).

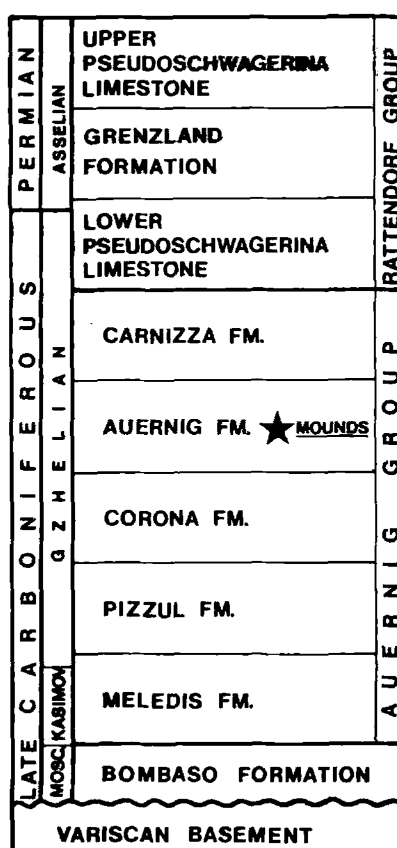


Fig. 2. Stratigraphy of the Late Paleozoic sequence in the study area. Position of *Anthracoporella*-mounds is marked by an asteriks.

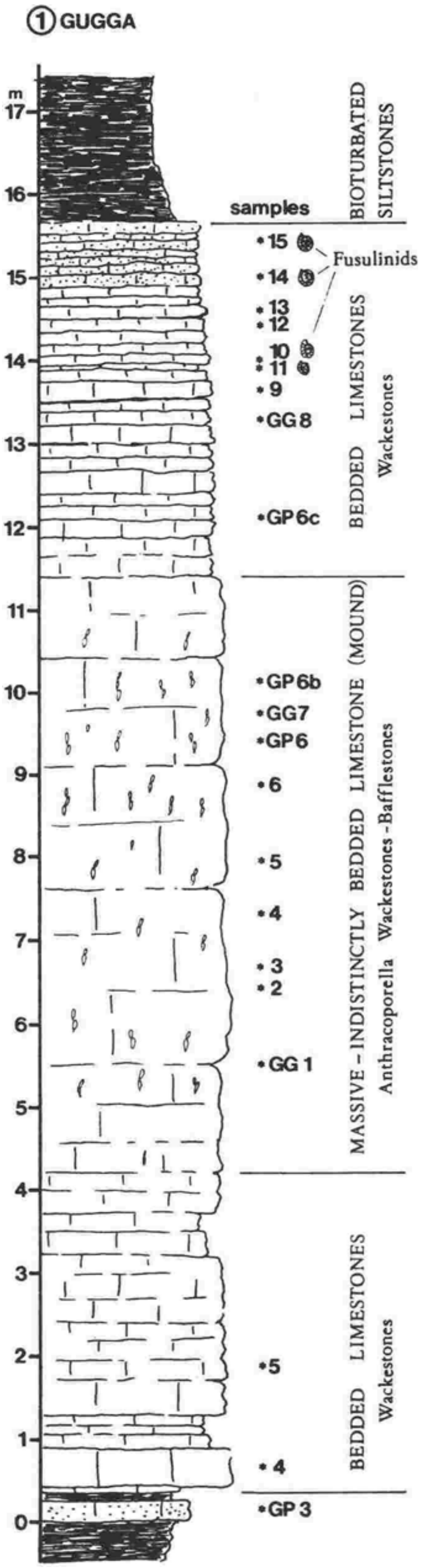


Fig. 3. Stratigraphic section through the basal limestone interval of the Auernig Formation at the Gugga locality. This interval consists of massive to indistinctly bedded limestones formed by *Anthracoporella* wackestones and bafflestones (mound facies) in the middle part, under- and overlain by bedded limestones consisting of different types of bioclastic wackestones and packstones. Asteriks indicate position of samples.

KRAINER (1992) recognized five lithofacies:

(1) quartz-rich conglomerates of a deltaic to beach environment,
(2) trough crossbedded sandstones of the upper shoreface,
(3) hummocky crossbedded sandstones of the lower shoreface,
(4) bioturbated, sometimes fossiliferous siltstones, and
(5) bedded and massive fossiliferous limestones.

In the upper part of the Auernig Group, particularly in the Auernig and Carnizza Fms., these lithofacies form distinct clastic-carbonate, transgessive-regressive cycles with thicknesses ranging from 10 - 40 m. Algal limestones and algal mounds described in this paper occur within the Auernig Formation that corresponds to the *Pseudofusulina/ Dutkevitchia* - fusulinid zone (Gzhelian E) according to KAHLER (1986, 1989). From Late Paleozoic limestones of the Carnic Alps fusulinids were first described by SCHELLWIEN (1898). During the last decades they have been intensively studied by KAHLER (summaries in KAHLER 1983, 1985, 1986, 1989). Sphinctozoans of the limestones of the Auernig Group have been studied in detail by KÜGEL (1987). The bryozoan assemblage of the slightly silicified 'bed s' of the Auernig Formation at the Monte Auernig has been intensively studied by KODSI (1967). BECKER & FOHRER (1990) and FOHRER (1991) described a silicified ostracod assemblage from the 'bed s' of the Auernig Formation.

4 FACIES DESCRIPTION

Within thicker limestone sequences of the Auernig Formation two types of limestones can be distinguished in the field (Figs. 3 - 7): (a) well bedded limestones, and (b) indistinctly bedded to massive limestones (mound facies).

Limestone sequences of the Auernig Formation range in thickness from a few dm up to 16 m. Indistinctly bedded to massive limestones locally occur in the central part of thicker limestone sequences. They are underlain by and grade upward into well bedded limestones.

All limestone sequences of the Auernig Formation are part of well developed transgressive-regressive cyclothems and are under- and overlain by bioturbated, sometimes fossiliferous siltstones and shales (Figs. 3 and 6).

4.1 Well bedded limestone facies (intermound facies)

Thickness of individual limestone beds commonly ranges from a few cm up to 20 cm, although some beds may be as thick as 40 cm and bedding is wavy to nodular. Individual limestone beds are not laterally persistent, but pinch out over distances of less than 1m to a few m. Limestone beds are separated by dark, fossiliferous shale partings (Fig. 4; Pl. 38/3) that are composed of fossiliferous marls, containing algal fragments and/or fusulinids. They are usually a few mm, rarely up to 10 cm thick. Limestone beds are dark grey and contain abundant fossils. In some of the limestone beds the algae occur in growth position, thus forming small mounds which are termed 'micromounds' in the present paper (Pl. 38/ 3, 5). The term 'micromound' is used in a descriptive sense for small mounds in the bedded limestone facies with thicknesses of 20 - 30 cm.

Nine microfacies types are recognized in the bedded limestone facies:
(1) bioclastic wackestone/packstone,
(2) fusulinid wackestone/packstone,
(3) *Anthracoporella* wackestone/packstone,
(4) *Archaeolithophyllum* boundstone/bafflestone,
(5) *Anthracoporella* bafflestone,
(6) *Anthracoporella* packstone/rudstone,
(7) bioclastic mudstone,
(8) bindstone, and
(9) bioclastic siltstone/fine-grained sandstone

4.1.1 Bioclastic wackestone/packstone

This microfacies is very common and consists of a micritic matrix with densely packed bioclasts of different sizes (Pl. 39/2 - 4). Broken fragments of the calcareous algae *Archaeolithophyllum, Anthracoporella* and *Epimastopora* are the most frequent skeletons. Some algal fragments are encrusted by *Tubiphytes* and bryozoans. Brachiopod shells, fusulinids, bryozoans, small foraminifers, ostracodes, echinoderms, gastropods, *Cuneiphycus, Ungdarella* and *Tubiphytes* are also present. In two samples solitary corals have sporadically been observed. In a few samples high concentrations of 'algal spores' and some small spicules occur in the groundmass. Some wackestones contain abundant echinoderm remains (up to 10%; Pl. 39/ 4) and are characterized by a better degree of sorting. Small, dark micritic lithoclasts (intraclasts) occur.

In a few samples the matrix appears to be bioturbated. The matrix is locally dark coloured due to high contents of clay and organic matter. Algal fragments are frequently aligned parallel to bedding planes. Microstylolites and sutured contacts indicate diagenetic pressure solution.

Small cavities are filled with micrite and spar forming geopetal structures.

On average, the rock is composed of 32 - 46% bioclasts, 41 - 56% micrite, and up to 5% pelmicritic matrix. Spar contents are low (2-8%)and most bioclasts are present in amounts of less than 5%; only cALcareous algae, bryozoans, echinoderms and fusulinids are present in amounts up to 10%. There is no significant difference between bioclastic wackestones of the bedded limestone facies and the massive mound facies.

4.1.2 Fusulinid wackestone/packstone

Abundant fusulinid tests, some of them broken or abraded, occur in a micritic to siltitic, sometimes sparitic matrix (Pl. 39/ 5). Small bioclasts are also present within the matrix. Fusulinids in most samples are not densely packed and both adult and juvenile forms of only a few species are present. Some of the fusulinid tests were broken in situ by compaction, others were broken and abraded during transport.

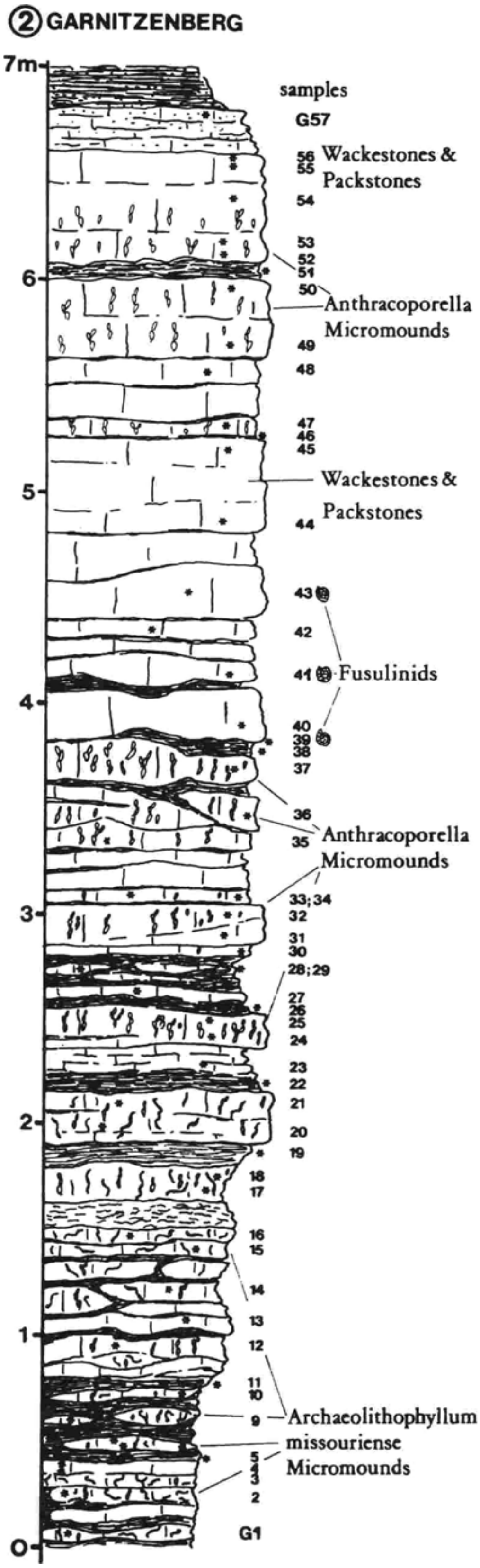


Fig. 4. Stratigraphic section through a limestone interval from the upper Auernig Formation at the Garnitzenberg locality. The bedded limestones consist of different types of bioclastic wackestones and packstones, interbedded with *Archaeolithophyllum missouriense-* and *Anthracoporella*-micromounds. Asteriks indicate position of samples.

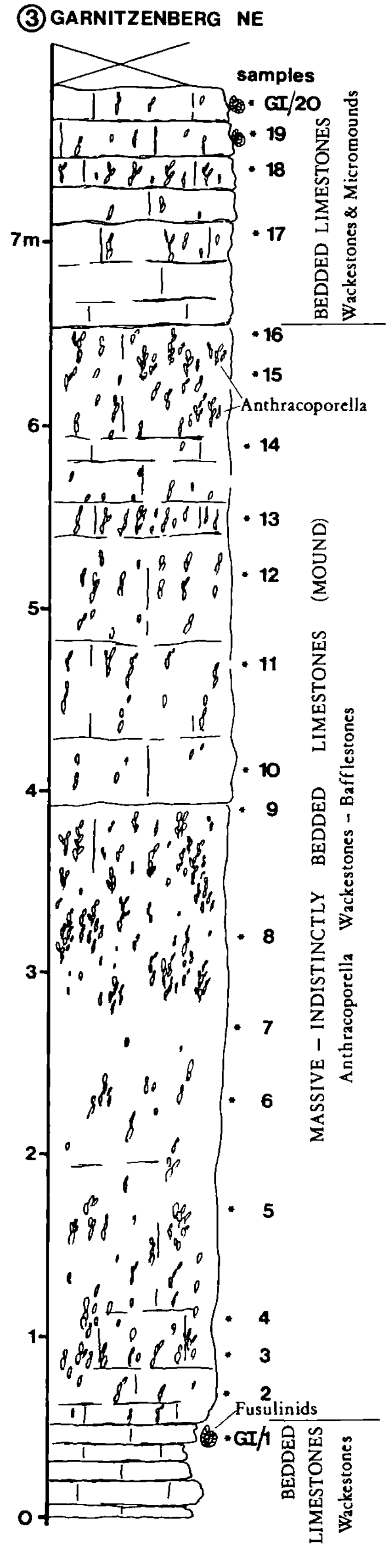


Fig. 5. Stratigraphic section through a limestone interval of the Auernig Formation northeast of Garnitzenberg. The massive to indistinctly bedded limestones are composed of *Anthracoporella* wackestones and bafflestones, representing the mound facies. Asteriks indicate position of samples.

Other bioclasts are subordinate, particularly algal fragments and sessile foraminifers. Shell fragments, bryozoans, *Tubiphytes*, echinoderm spines, ostracodes, *Ungdarella*, and *Cuneiphycus* are rare.

Clay and probably organic matter result in a dark, sometimes black matrix. In fusulinid wackestones/packstones, bioclasts average 38 - 65%. Micrite makes up 35 - 56%, pelmicrite up to 4% and spar 2 - 11% of the rock. Fusulinid tests average between 14 and 27% in wackestones and up to 55% in packstones. Fusulinid tests constitute 38 - 53% of the bioclast fraction in wackestones; in packstones up to 86% of the bioclasts are fusulinids.

4.1.3 *Anthracoporella* wackestone/packstone

This microfacies is characterized by the occurrence of large, mostly unbroken thalli of *Anthracoporella*, some still in growth position, some toppled in situ with minimal movement by currents after toppling (Pl. 39/ 6). The micritic, in most cases inhomogenous matrix in some samples contains abundant algal spores and also small spicules, and is locally bioturbated and pelmicritic. Other bioclasts are small and rare, mostly below 3%: small fragments of calcareous algae, shell fragments, echinoderms, bryozoans, ostracodes, small foraminifers, *Tubiphytes*, *Ungdarella*, *Cuneiphycus*, fusulinids, solitary corals, *Girvanella*, ?*Mizzia*, and ?phylloid algae (recrystallized).

Anthracoporella is encrusted by *Tubiphytes*, micritic algae (*Girvanella*), *Archaeolithophyllum missouriense* and sessile foraminifers. In a few samples abundant sediment-binding organisms are present, particularly sessile foraminifers (*Calcitornella*, *Calcivertella*, *Tuberitina*), algae (*Ungdarella*), and *Tubiphytes*, such that the wackestones/packstones locally grade into bindstones.

Voids within brachiopods, gastropods and *Anthracoporella* thalli, as well as pores in the matrix between *Anthracoporella* thalli, are filled with micrite and spar, frequently forming geopetal structures.

This microfacies grades into bioclastic wackestones and *Anthracoporella* bafflestones. Generally, *Anthracoporella* wackestones are composed of 50% micrite on an average, 9 - 21% spar, and 34 - 39% bioclasts. *Anthracoporella* is the dominant skeletal element, making up about 20% of the rock and up to 70% of the bioclasts. Other bioclasts are present in amounts up to 5% (bryozoans, fusulinids), but mostly below 3%.

4.1.4 *Archaeolithophyllum* bafflestone/bindstone

The inhomogenous, micritic to pelmicritic matrix contains different amounts of small skeletons. In the matrix well-preserved, sometimes branching thalli of several cm long *Archaeolithophyllum missouriense* occur in growth position (Pl. 40/ 1, 2). The growth position is either upright to oblique or parallel to the bedding plane. Thus, *Archaeolithophyllum missouriense* acted as a sediment baffler as well as a sediment binder. In one sample, large thalli of *Archaeolithophyllum missouriense grew* upright and are bent in the same direction, probably by currents. The toppled thalli formed spectacular umbrella sturctures filled with spar (Pl. 40/ 1, 4).

Many thalli of *Archaeolithophyllum missouriense* are encrusted by 'micritic algae', sessile foraminifers, *Tubiphytes*, and rarely by thin crusts of *Archaeolithophyllum lamellosum*, all of which also acted as sediment binders.

Other calcareous algae, particularly *Anthracoporella* and small fragments of *Epimastopora* are also present, although in small amounts.

Small skeletons in the matrix are mainly brachiopods, ostracodes, echinoderms, bryozoans, sessile and mobile foraminifers, and gastropods; although spicules and *Tubiphytes* also occur. Small cavities formed by compaction are filled with spar.

Archaeolithophyllum bafflestones/bindstones contain large amounts of micrite (42 - 56%) and skeletons of *Archaeolithophyllum missouriense* (21 - 32%). Encrusting organisms (particularly sessile foraminifers and *Tubiphytes*) contribute up to 12 % of the rock (10% of the bioclasts on average). Total bioclasts average around 34% with *A. missouriense* skeletons making up 63% of the bioclasts on average. Spar cement makes up 3 - 11%, and up to 7% of the rock is pelmicrite.

4.1.5 *Anthracoporella* bafflestone

This microfacies type is composed of a 'framework' formed by the dasycladacean algae *Anthracoporella spectabilis* (Pl. 40/ 5, 6; Pl. 41/ 1). Almost all thalli occur in growth position; they grew upright to heights of several centimeters. In most samples, the thalli are very well preserved, although in a few samples they are recrystallized. The interior of the thalli is either filled completely with micritic to pelmicritic sediment, sometimes containing a few small bioclasts, or with micrite and spar forming geopetal structures, or completely filled with spar.

Space between the *Anthracoporella* thalli, which in most cases seem to have lived in loosely packed associations, is filled with micrite and pelmicrite. When the algae grew closer, some open pore space remained which was filled with spar.

Small bioclasts (grain size below 1 mm) in varying amounts are also present: fragments of *Epimastopora*, *Anthracoporella*, *Archaeolithophyllum missouriense*, brachiopods, echinoderms, spicules, bryozoans, sessile and mobile foraminifers, ostracodes, and sporadically fusulinids.

Several mm to several cm large bioclasts, particularly algae, are encrusted by *Tubiphytes*, micritic algae (*Girvanella*), bryozoans, and sessile foraminifers.

In a few samples *Archaeolithophyllum missouriense* is also present in small amounts, in growth position and as small broken fragments.

Borings on *Anthracoporella*-thalli, probably produced by boring algae, are very rare.

Differences exist in the rock type found within algal thalli and between the algae: the interior of algal thalli is filled with micrite which is finer in grain size, darker in colour and contains fewer bioclasts than the matrix between the algae.

Two types of inhomogenous matrix occur:
(1) grey, pelmicrite or micrite, locally laminated and inversely graded matrix, and
(2) brownish-grey, slightly recrystallized micrite. The boundary between these two types is sharp. Small bioclasts (< 1 mm) in varying amounts occur in both types.

On average, micrite forms 50 - 60% of the rock, spar cement 9 - 18% and bioclasts 35 - 38%. *Anthracoporella* skeletons constitute 15 - 30% of the rock; other bioclasts are present in very small amounts (less than 2%) or completely absent.

4.1.6 *Anthracoporella* packstone/rudstone

Densely packed fragments of *Anthracoporella* constitute this microfacies (Pl. 40/ 3). Pore space between the skeletons is filled with spar and in some places with small patches of pelmicrite. Other bioclasts are very rare (< 2%): shell fragments, echinoderms, small foraminifers, bryozoans,

Plate 38 — *Anthracoporella* Mounds in the Late Carboniferous Auernig Group, Carnic Alps (Austria)

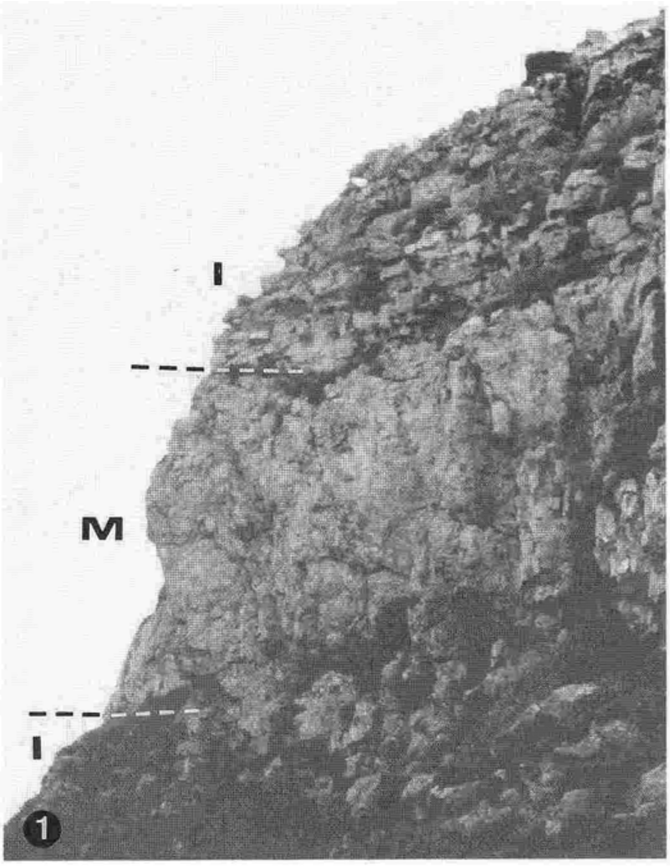
Fig. 1. Limestone interval of the basal Auernig Formation at the Kronalpe locality (see section fig. 5) with a well developed, 2 m thick massive to indistinctly bedded mound facies (M) in the center, composed of *Anthracoporella* wackestones and bafflestones. The massive mound facies is under- and overlain by bedded limestones of the intermound facies (I).

Fig. 2. *Archaeolithophyllum missouriense* bafflestone from a micromound, composed of large, unbroken thalli of *A. missouriense* in growth position and micritic matrix (Garnitzenberg). Each band on the scale is 1 cm wide.

Fig. 3. Bedded limestones at the Garnitzenberg locality (see section fig. 4), composed of intercalated bioclastic wackestones and packstones, and micromounds.

Fig. 4. *Anthracoporella* bafflestone from a micromound with large *Anthracoporella*-thalli in growth position and micritic matrix (Garnitzenberg). Each band on the scale is 1 cm wide.

Fig. 5. Micromound from bedded limestones of the Garnitzenberg locality with several *Anthracoporella* bushes, all in growth position, i.e. no toppling, re-orientation or transportation. Pencil for scale (photo by J.A. Fagerstrom).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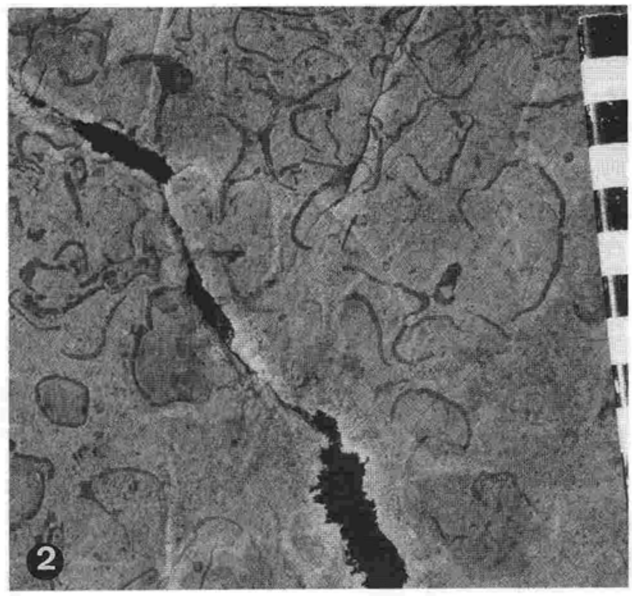
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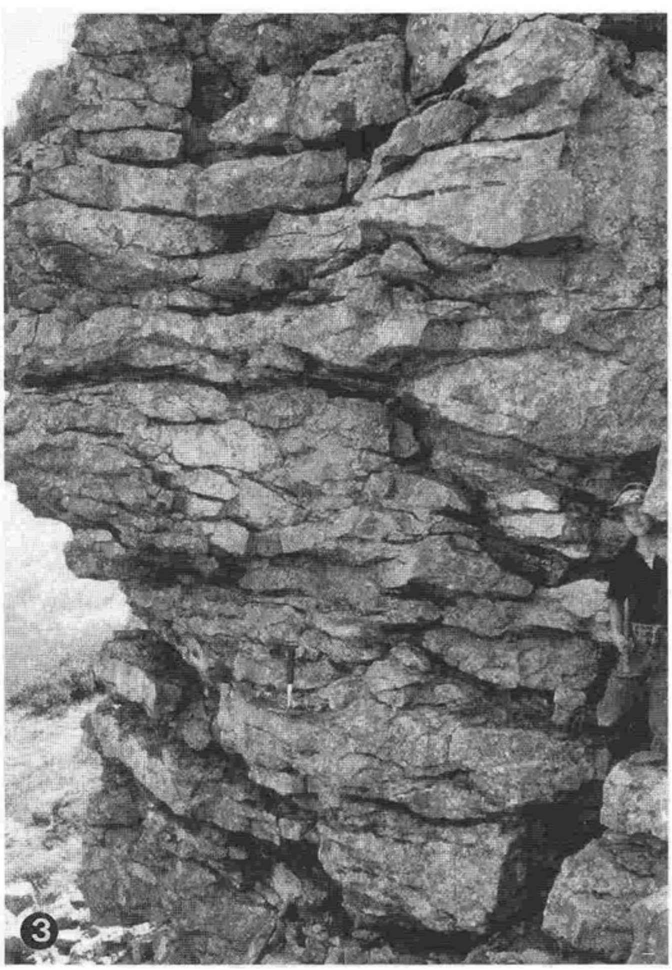
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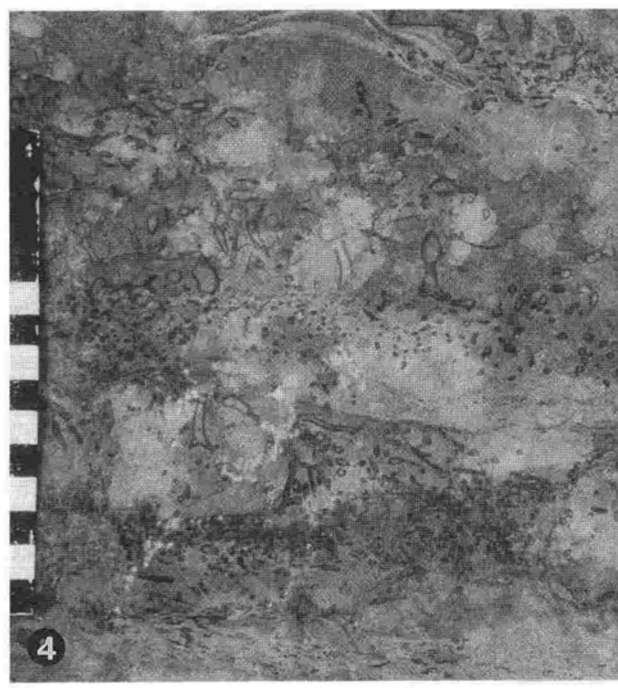
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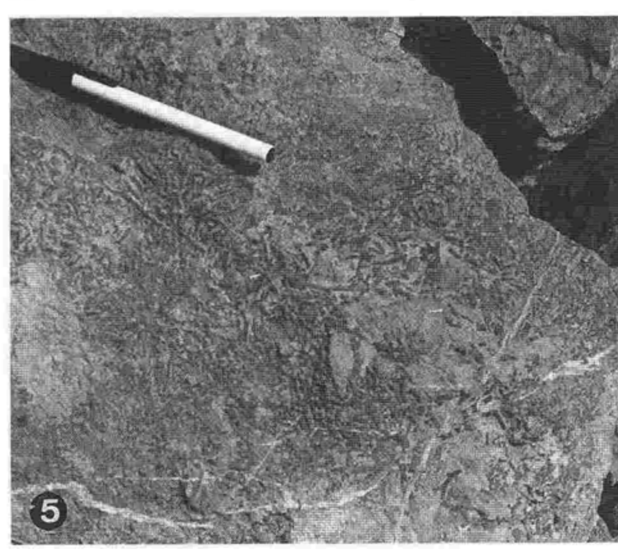
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Epimastopora, and *Archaeolithophyllum missouriense*.

A few *Anthracoporella* fragments are encrusted by *Tubiphytes*. *Anthracoporella* fragments are commonly oriented parallel to bedding planes. Sutured contacts between individual thalli indicate pressure solution caused by compaction.

Anthracoporella packstones contain up to 55% *Anthracoporella* skeletons, which are responsible for more than 90% of the total bioclast content. Other bioclasts are either completely absent or present in very small amounts (<2%). The content of matrix ranges between 31 - 43%, and of spar between 2 - 10%.

4.1.7 Bindstones

Within mudstones and wackestones/packstones thin layers of bindstone are locally developed, particularly at locality 4 in the Kronalpe.

One type is formed of algal crusts several mm thick, composed of *Archaeolithophyllum lamellosum, Girvanella?, Tubiphytes*, and sessile foraminifers (Pl. 41/3). This type frequently occurs on larger bioclasts, particularly on large thalli of *Anthracoporella* and *Archaeolithophyllum missouriense*, but also on bryozoans and directly on the substrate.

Another type occurs as oncoid-like encrustations, up to several cm thick, around bioclasts, especially calcareous algae. These encrustations are also composed of *Archaeolithophyllum lamellosum, Girvanella, Tubiphytes*, and sessile foraminifers. Bryozoans and *Cuneiphycus* are rarely found within the crust. Pore space between individual laminae of the crust is filled with micrite or spar. *Anthracoporella*, in growth position, sometimes occurs attached to the algal crusts.

4.1.8 Mudstone

Massive to indistinctly laminated micrite to pelmicrite containing a few brachiopod and echinoderm skeletal fragments and small foraminifers occurs as thin layers within wackestones/packstones. Coarser laminae are pelmicrite and contain more bioclasts; finer laminae consist of micrite with only a few bioclasts.

4.1.9 Bioclastic siltstone - fine-grained sandstone

At the base and top of thicker limestone sequences are beds of bioclastic siltstones to fine-grained sandstones, up to several decimeters thick. They are indistinctly laminated, moderately to poorly sorted, locally bioturbated, and composed of angular quartz grains, detrital mica and micrite. Within the siliciclastic-calcareous groundmass skeletons of calcareous algae (*Epimastopora, Archaeolithophyllum miss., Anthracoporella*), shell fragments, echinoderm remains, gastropods, ostracodes, foraminifers, *Cuneiphycus*, and *Tubiphytes* occur. Bioclasts range from less than 1 % up to somewhat more than 20 % (Pl. 39/ 1).

4.2 Massive mound facies

The mound facies is represented by massive to indistinctly bedded, light grey limestones, which are developed in the central part of thicker limestone intervals of the basal Auernig Formation at Garnitzenberg and Kronalpe (Figs. 3, 5, 6 and Pl. 38/ 1). Limestones of the mound facies are up to about 4 m thick and extend laterally over several tens of meters; on the western side of the Kronalpe the mound facies extends over more than 100 m, forming very flat, biostromal buildups with a thickness of 2 m.

Plate 39 *Anthracoporella* Mounds in the Late Carboniferous Auernig Group, Carnic Alps (Austria). Thin section photomicrographs illustrating microfacies types of the bedded intermound facies. All under plane polarized light, scale bar 2 mm.

Fig. 1. Bioclastic siltstone. Skeletons of calcareous algae, brachiopods, echinoderms, gastropods, and others are embedded in a matrix composed of angular quartz grains, detrital mica and micrite.

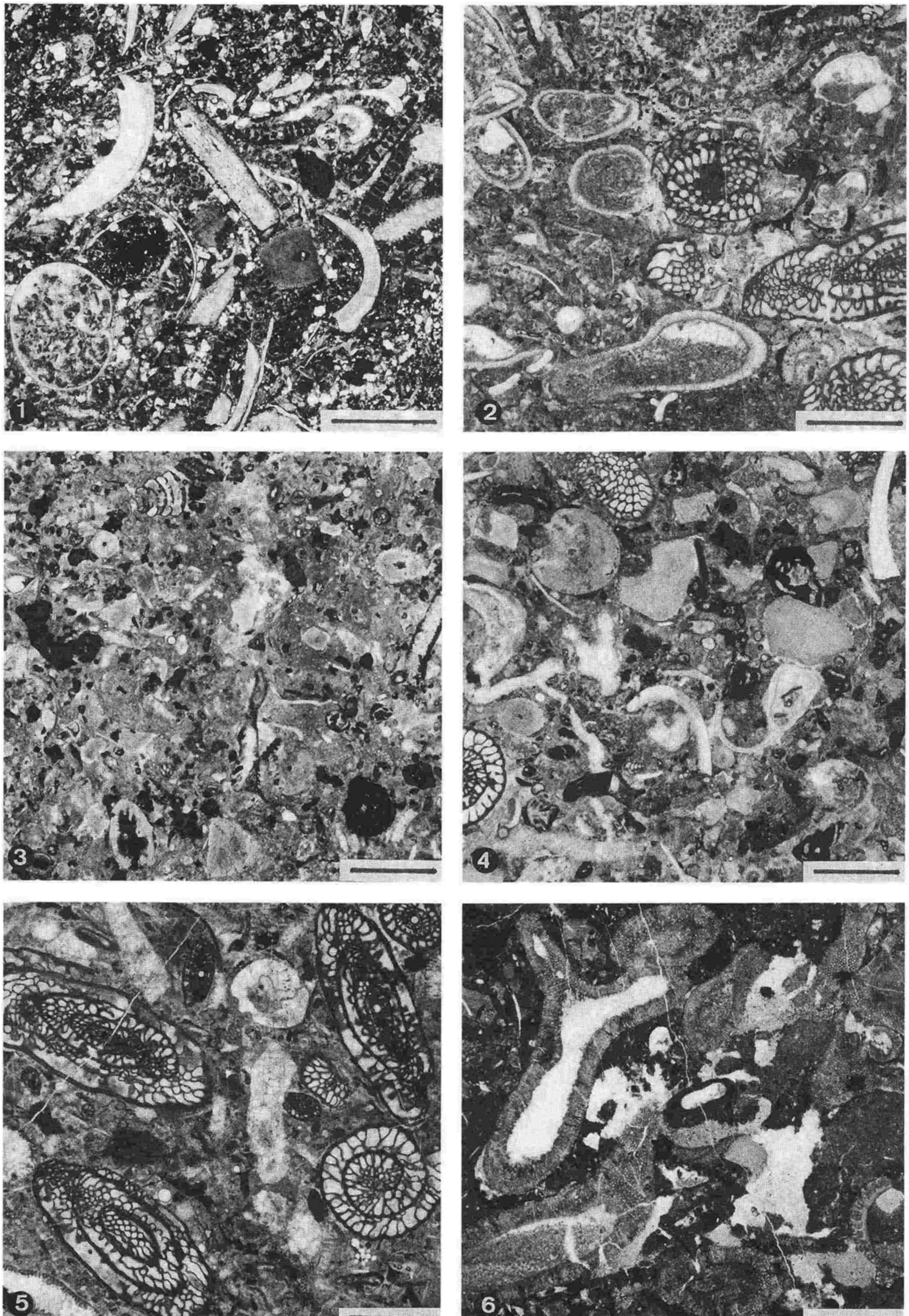
Fig. 2. Bioclastic wackestone composed of abundant calcareous algae (*Anthracoporella, Epimastopora*), fusulinids, gastropods, small foraminifers, and other bioclasts. The matrix consists of micrite and pelletal micrite (sample AF 5).

Fig. 3. Bioclastic wackestone consisting of micritic matrix and skeletons of echinoderms, calcareous algae, small foraminifers, *Tubiphytes* (dark), bryozoans, and other bioclasts (sample AF 11).

Fig. 4. Bioclastic wackestone/packstone composed of densely packed echinoderms, shell fragments, calcareous algae, *Tubiphytes*, fusulinids, small foraminifers, and a few other bioclasts in a micritic matrix (sample G 40).

Fig. 5. Fusulinid wackestone consisting of abundant fusulinids and minor amounts of algal skeletons (mostly *Anthracoporella*), small foraminifers, and some other bioclasts. The matrix is composed of micrite (sample KR 42).

Fig. 6. *Anthracoporella* wackestone composed of large, unbroken *Anthracoporella* thalli, some are in growth position, and micritic groundmass. The interior and pore space between the algal thalli is partly filled with spar and, partly with pelletal matrix. In the matrix only a few small bioclasts are present (sample G 52).



Laterally, the mound facies grades into the bedded limestone facies (intermound facies) and is also under- and overlain by dark grey, fossiliferous bedded limestones of the intermound facies.

Limestones of the mound facies are composed of the following microfacies types:

(1) *Anthracoporella* bafflestone,
(2) *Anthracoporella* wackestone/ bindstone,
(3) *Anthracoporella* grainstone (rare),
(4) bioclastic wackestone (rare) and
(5) fusulinid wackestone/packstone (very rare)

Anthracoporella bafflestones and wackestones are by far the most common sediment types of the mounds.

4.2.1 *Anthracoporella* bafflestone

This microfacies is very similar to the *Anthracoporella* bafflestones in the bedded limestone facies (intermound facies), although the alga *Archaeolithophyllum missouriense*, a common constituent of the micromounds in the intermound facies, is lacking in the massive mound facies.

The inhomogenous micrite to pelmicrite contains large, unbroken thalli of *Anthracoporella spectabilis*, mostly in growth position, although some toppled in situ. The interior of the algal thalli is filled with dark micrite and a few small bioclasts, particularly ostracodes and foraminifers (Pl. 41/ 2, 4, 5).

In the matrix only a few larger bioclasts (fusulinids, brachiopod shells) occur; smaller bioclasts are also not conspicious. *Anthracoporella* bafflestones are therefore characterized by a relatively low taxonomic diversity compared to all other microfacies, particularly compared to the bedded limestones of the intermound facies. Sessile foraminifers, particularly *Calcitornella*, and *Tubiphytes* locally were abundant (up to 7%), encrusting sediment as well as *Anthracoporella* thalli. Locally, *Archaeolithophyllum lamellosum*, *Girvanella*, and *Ungdarella* occur as sediment binders and as encrustations on skeletons of *Anthracoporella*.

When *Anthracoporella* lived in more densly packed associations, they formed a 'framestone' with open pore space between the algal thalli which was filled with spar or indistinctly laminated pelmicrite.

Micrite makes up 44 - 50%, spar 9 - 21%, bioclasts 29 - 33% of the rock. The most frequent bioclast type is *Anthracoporella*, averaging 13 - 22 % of the rock (45 - 67% of the bioclasts). Encrusting organisms (sessile foraminifers and *Tubiphytes*) comprise 15 - 22% of all bioclasts.

The terms 'bafflestone' and 'framestone', introduced by EMBRY & KLOVAN (1971), are highly interpretative. Framestones contain large in-place fossils that construct the supporting and rigid framework. According to KLEMENT (1967) cementation appears to be very important in the resulting structure, and many framestones thus are characterized by high contents of cement.

Bafflestones, on the other hand, are defined as autochthonous boundstones formed by stalk-shaped and dendroid organisms which acted as bafflers for accumulation of fine sediment (see EMBRY & KLOVAN 1971, WILSON 1975). Bafflestones therefore are characterized by high amounts of micrite whereas cement is rare or completely absent.

As *Anthracoporella* could not provide a rigid framework resistant to water turbulence, also when it grew in more densly packed associations forming framestone-like structures, the main function was baffling micritic sediment. Therefore the term *Anthracoporella* bafflestone is preferred in the present paper.

Plate 40 — *Anthracoporella* Mounds in the Late Carboniferous Auernig Group, Carnic Alps (Austria). Thin section photomicrographs of microfacies types from the bedded intermound facies. Figures 1, 2, 4 and 6 are from micromounds. Plane polarized light, scale bar 2 mm.

Fig. 1. *Archaeolithophyllum* bafflestone with cm-large, branching thalli of *A. missouriense* in growth position, thus acting as sediment bafflers, trapping fine carbonate mud with a few small bioclasts. Pore space is filled with spar. Note the well developed umbrella structure filled with spar at top (sample G 11/2).

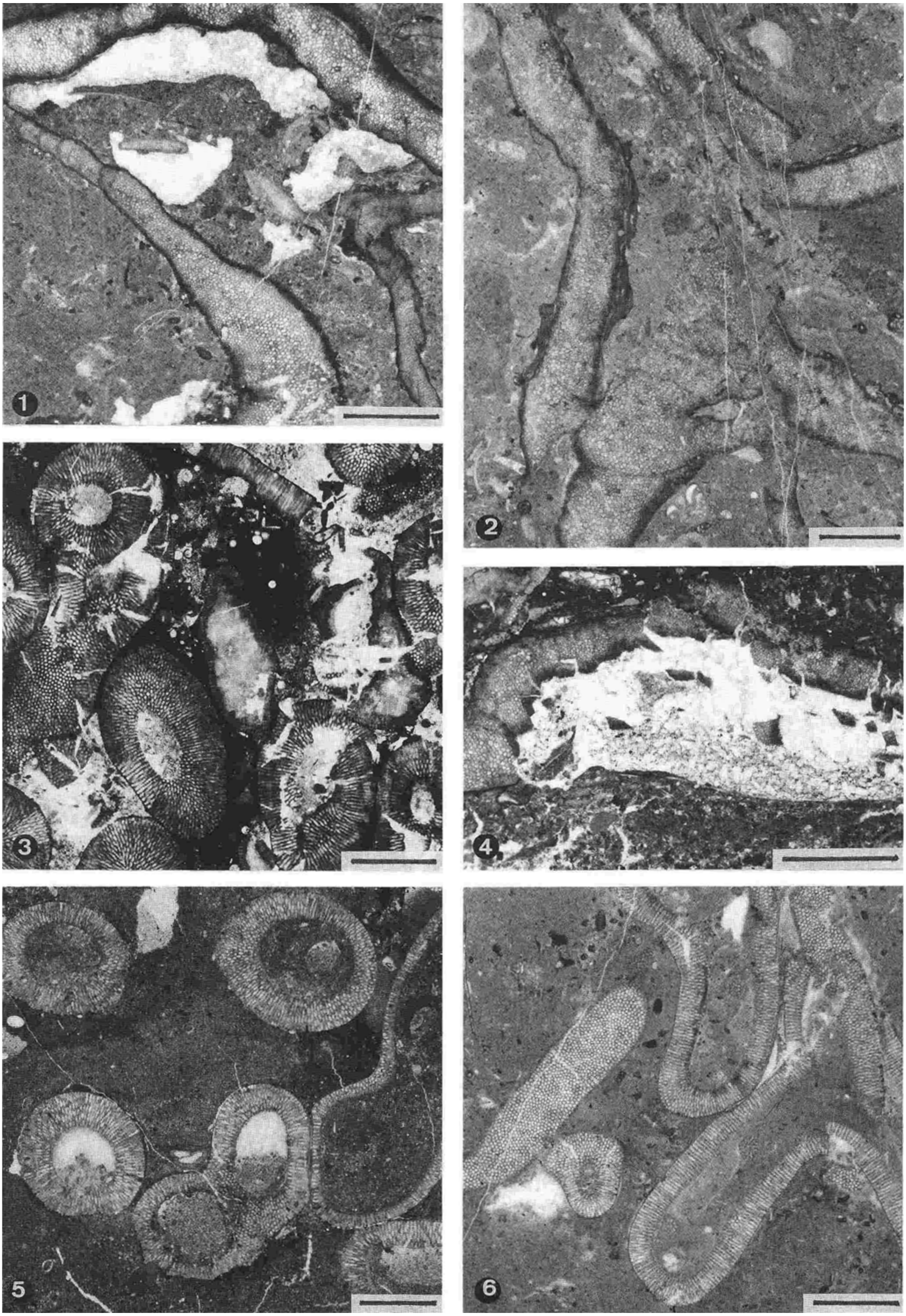
Fig. 2. *Archaeolithophyllum* bafflestone consisting of cm-large thalli of *A. missouriense*, encrusted by *Tubiphytes*, micritic algae, and sessile foraminifers. The algal thalli are still in growth position, they grew upright and acted as sediment bafflers (sample G 15).

Fig. 3. *Anthracoporella* packstone with densly packed *Anthracoporella* fragments. Some algal thalli were broken during compaction. In the micrite and spar only a few other small bioclasts occur (sample KR 5b).

Fig. 4. Well preserved umbrella structure below an algal thallum of *Archaeolithophyllum missouriense*, which grew attached to the substrate and acted as sediment binder (sample G 11).

Fig. 5. *Anthracoporella* bafflestone with unbroken thalli of *A. spectabilis*, mostly in growth position, embedded in a micritic, locally pelletal matrix. In the matrix only a few other, very small bioclasts are present. Note the well developed geopetal structures in the interior of the algal thalli, which are partly filled with pelletal micrite, partly with spar (sample G 53).

Fig. 6. *Anthracoporella* bafflestone from a micromound, composed of unbroken thalli of *Anthracoporella spectabilis*, most are in growth position. These algae acted as sediment bafflers trapping carbonate mud which contains only a few small bioclasts, particularly small encrusting foraminifers. Remaining pore space is filled with spar (sample G 37).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4.2.2 *Anthracoporella* wackestone/bindstone

The matrix of this microfacies type is inhomogenous micrite to pelmicrite with small pores filled with microspar and spar. Skeletons of *Anthracoporella* are the most conspicious bioclast with many *Anthracoporella* thalli toppled in situ and slightly transported, which is indicated by tilted geopetal structures in the interior of the algal thalli. Locally many *Anthracoporella* thalli are still in growth position, resulting in a bafflestone.

Other bioclasts are present in small amounts. Some micritic intraclasts up to 5 mm in diameter, composed of micritic matrix and a few small bioclasts also occur.

Sediment and skeletons (particularly of *Anthracoporella*) locally were heavily encrusted by sessile foraminifers, *Tubiphytes*, algal crusts (*Girvanella*), and *Ungdarella*, forming bindstones. Sometimes thin algal crusts were developed on the substrate.

4.2.3 *Anthracoporella* grainstone

In one sample a thin layer of *Anthracoporella* grainstone/packstone has been observed (Pl. 41/ 6). This layer is formed of mostly broken, transported *Anthracoporella* skeletons, which are sometimes encrusted by algae, *Tubiphytes*, and sessile foraminifers. *Anthracoporella* skeletons are frequently recrystallized, the interior of the algal thalli in most cases is filled with spar. The groundmass consists of spar and small patches of pelletal micrite. Other bioclasts like fusulinid tests and shell fragments are rare (< 2%).

Anthracoporella grainstones are characterized by a high content of spar cement (63% on average). Pelmicritic matrix constitutes 10% and bioclasts 27% of the rock (average values). *Anthracoporella* skeletons are 16% of the rock (60 % of the bioclasts).

Thin layers of bioclastic wackestones and fusulinid wackestones/packstones as described from the bedded limestone facies are present in the mound facies.

5 BIOTA

The most frequent biotic constituents of the bedded limestone facies and mound facies are calcareous algae.

The dasycladacean alga *Anthracoporella spectabilis*, which Pia (1920) first described from Late Paleozoic limestones of the Carnic Alps, is the most important type. This unsegmented, cylindrical to subcylindrical, straight or slightly indented branching tube (see also Bebout & Coogan 1964; Johnson 1961; Pia 1920), occurs as excellently preserved specimens both in growth position and as toppled and transported, broken fragments. Indivudual tubes more than 4.5 cm long have been observed in thin section. In some samples skeletons of *Anthracoporella* are partly or completely recrystallized. The wide stem is not preserved, being filled with micrite and/or spar, sometimes forming geopetal structures (Pl. 40/ 5, 6; Pl. 41/ 1, 2).

Less abundant is the dasycladacean alga *Epimastopora*, which occurs only as broken fragments, never in growth position. In bioclastic wackestones *Epimastopora* fragments may be aligned parallel to bedding planes.

Of some importance is the ancestral coralline alga *Archaeolithophyllum missouriense*, which has an irregularly shaped, blade- and leaf-like, calcified, branching thallus. Specimens measuring more than 5 cm long have been observed. *Archaeolithophyllum missouriense* may be very well preserved (Pl. 40/ 1, 2), or recrystallized. They appear as toppled and broken fragments or in growth position. Growth form is either free on the substrate (straight or oblique) thus acting as a sediment baffler, or attached on the substrate, acting as a sediment binder (see

Plate 41 — *Anthracoporella* Mounds in the Late Carboniferous Auernig Group, Carnic Alps (Austria). Thin section photomicrographs showing microfacies types of the intermound facies (Figs. 1 and 3, Fig. 1 is from a micromound) and massive mound facies (Figs 2, 4-6). Plane polarized light, scale bar 2 mm.

Fig. 1. *Anthracoporella* bafflestone from a micromound with large, unbroken *Anthracoporella* thalli in growth position. Algal thalli are encrusted by bryozoans and other sessile organisms. Interior of the algal thalli filled with dark carbonate mud containing a few very small bioclasts (sample G 9/2).

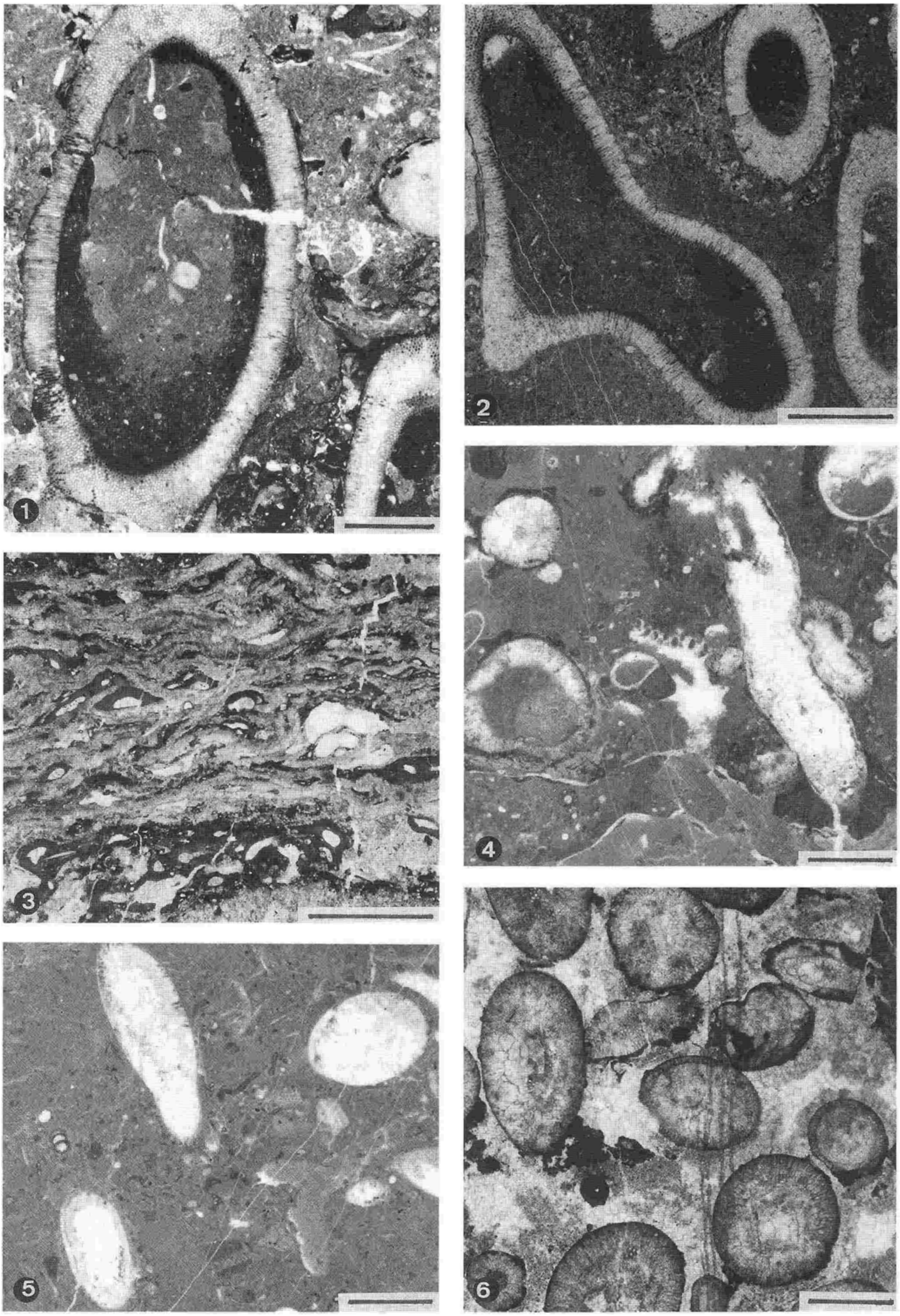
Fig. 2. *Anthracoporella* bafflestone from the mound facies at the Gugga section, composed of well preserved *Anthracoporella* thalli in growth position. The micritic to pelletal matrix contains only a few very small bioclasts and was trapped by the algae, which acted as sediment bafflers (sample GP 7).

Fig. 3. Thin bindstone-layer composed of *Archaeolithophyllum lamellosum*, *Tubiphytes*, and sessile foraminifers (sample AF 8a).

Fig. 4. *Anthracoporella* bafflestone composed of large *Anthracoporella* thalli in growth position. Most of the algal thalli are recrystallized and encrusted by *Tubiphytes*, micritic algae, and sessile foraminifers. A few bioclasts are present in the micritic matrix (sample GI/13).

Fig. 5. *Anthracoporella* bafflestone composed of recrystallized thalli of *A. spectabilis*. The micrite contains a few bioclasts, particularly small foraminifers and ostracodes (sample GI/16).

Fig. 6. *Anthracoporella* grainstone composed of broken, transported skeletons of *A. spectabilis*. Some of the algal thalli are recrystallized and encrusted by algae, *Tubiphytes*, and sessile foraminifers. The pore space between the algal thalli is filled with spar and small patches of pelletal micrite (sample KR 9a).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also JOHNSON 1956, 1961, WRAY 1964, 1977).

Other algae are subordinate: *Eugonophyllum* (codiacean), ?phylloid algae (strongly recrystallized), *Cuneiphycus, Ungdarella, Vermiporella, Girvanella, Archaeolithophyllum lamellosum*, and others.

Tubiphytes is present in all studied samples; it may be abundant in the mound facies and in *Anthracoporella* - wackestones, encrusting the substrate as well as skeletons, particularly of *Anthracoporella* and *Archaeolithophyllum missouriense* (Pl. 40/ 2; Pl. 41/ 4).

Fusulinids are a frequent constituent of bioclastic wackestones/packstones, particularly of fusulinid wackestones/packstones (Pl. 39/ 5). Individual fusulinid tests are also found in other microfacies types, even in the mound facies.

Fusulinids are the most important fossils for the biostratigraphy of limestones of the Auernig Group as well as the overlying Rattendorf and Trogkofel Groups.

Smaller foraminifers are very common in all microfacies. The foraminiferal assemblage consists of calcareous and agglutinated, tubular and chambered, sessile and mobile species. The most common genera are *Ammovertella, Bradyina, Calcitornella, Calcivertella, Climacammina, Endothyra, Eolasiodiscus, Eotuberitina, Polytaxis, Tetrataxis*, and *Tuberitina* (see also EBNER 1989). The most frequent encrusting genera are *Calcitornella, Calcivertella, Eotuberitina*, and *Tuberitina*, encrusting substrate as well as skeletons, particularly calcareous algae.

Some samples contain fragments of sphinctozoans (calcisponges). In the micritic groundmass of many samples, particularly in *Anthracoporella* wackestones and bafflestones, small spicules of calcisponges are present.

Small solitary corals are absent in most samples, they have been recognized sporadically in two samples.

Bryozoans, mostly fenestellid species, are present in all limestones and occur as broken fragments. Some encrusting forms have been observed on skeletons of calcareous algae.

Brachiopods, bivalves and gastropods are found in all microfacies, commonly as broken shell fragments.
Ostracodes are a common bioclastic constituent, particularly in micritic limestones.

All limestones contain echinoderm fragments. They are particularly abundant (up to 7%) in bioclastic wackestones/packstones with crinoid fragments most conspicious, but some echinoid spines are also present.

6 GUILD STRUCTURES

According to the guild concept presented for reef communities and other organic buildups by FAGERSTROM (1987, 1988, 1991), algal mounds are formed of organisms of the baffler guild, the binder guild, the destroyer guild, and the dweller guild.

6.1 Baffler guild

According to FAGERSTROM (1988: 219) 'the chief function of members of the baffler guild is current baffling'. Bafflers are poorly skeletonized or non-skeletal and therefore seldom remain in life position after death. Members of the baffler guild are characterized by firm attachment to the substrate, erect growth and are smaller and more delicate than constructors. Organisms of the baffler guild were solitary, gregarious, or colonial.

In the algal mounds of the Auernig Formation, *Anthracoporella spectabilis*, the most frequent algae, clearly fulfills the criteria for membership in the baffler guild. *Anthracoporella* is an amazingly well skeletonized alga, frequently occurring in growth position, indicating that they grew as cylindrical to subcylindrical branching tubes. The relatively thick and stable thalli of *Anthracoporella* grew upward to heights of several centimeters, acting as current bafflers so that fine-grained sediment and small skeletons were trapped between the individual branches (Pl. 40/ 5, 6; Pl. 41/ 1, 2, 4, 5).

The distribution of *Anthracoporella* within the mounds is uneven (Pl. 38/ 5). In the massive mound facies, and even in the micromounds, *Anthracoporella* frequently forms small 'algal colonies'. Within these colonies, the packing density between individual *Anthracoporella* thalli is higher than between the colonies, commonly ranging from 20 to 38 %. Distances between individual algal thalli commonly range from 1 mm up to several mm. Distances between individual colonies commonly measure several cm, and the packing density of individual *Anthracoporella* thalli between the colonies is significantly lower, mostly below 15%.

The high packing density within individual colonies may cause a framestone-like structure. In this case, *Anthracoporella* may be a baffler that functioned like a constructor, by what FAGERSTROM (1987, 1988, 1991) called 'guild overlap'. But because the main function of *Anthracoporella* was baffling fine sediment, even in densly packed associations, this alga is suggested to be member of the baffler guild, but by guild overlap may locally be member of the constructor guild as well.

Another member of the baffler guild is *Archaeolithophyllum missouriense*. This alga is also relatively well skeletonized, but less stable than *Anthracoporella*. *Archaeolithophyllum missouriense* is also frequently found in upward growth position, indicating a leaf-like growth form, thus also acted as a baffler (Pl. 40/ 1, 2).

Sponge spicules and other fragments of calcisponges (sphinctozoans) indicate that poorly skeletonized calcisponges were also present and members of the baffler guild. Fenestellid bryozoans and probably also crinoids, although only found as broken fragments, could have been baffling organisms of the mounds, but much less important than the calcareous algae.

Among the algal bafflers, *Anthracoporella spectabilis* was the most rigid because of its morphology. It is also the most abundant alga and thus the most important member of the baffler guild, forming *Anthracoporella*-mounds.

Concerning the packing density there are no significant differences between *Anthracoporella* bafflestones of the massive mound facies and the micromounds of the

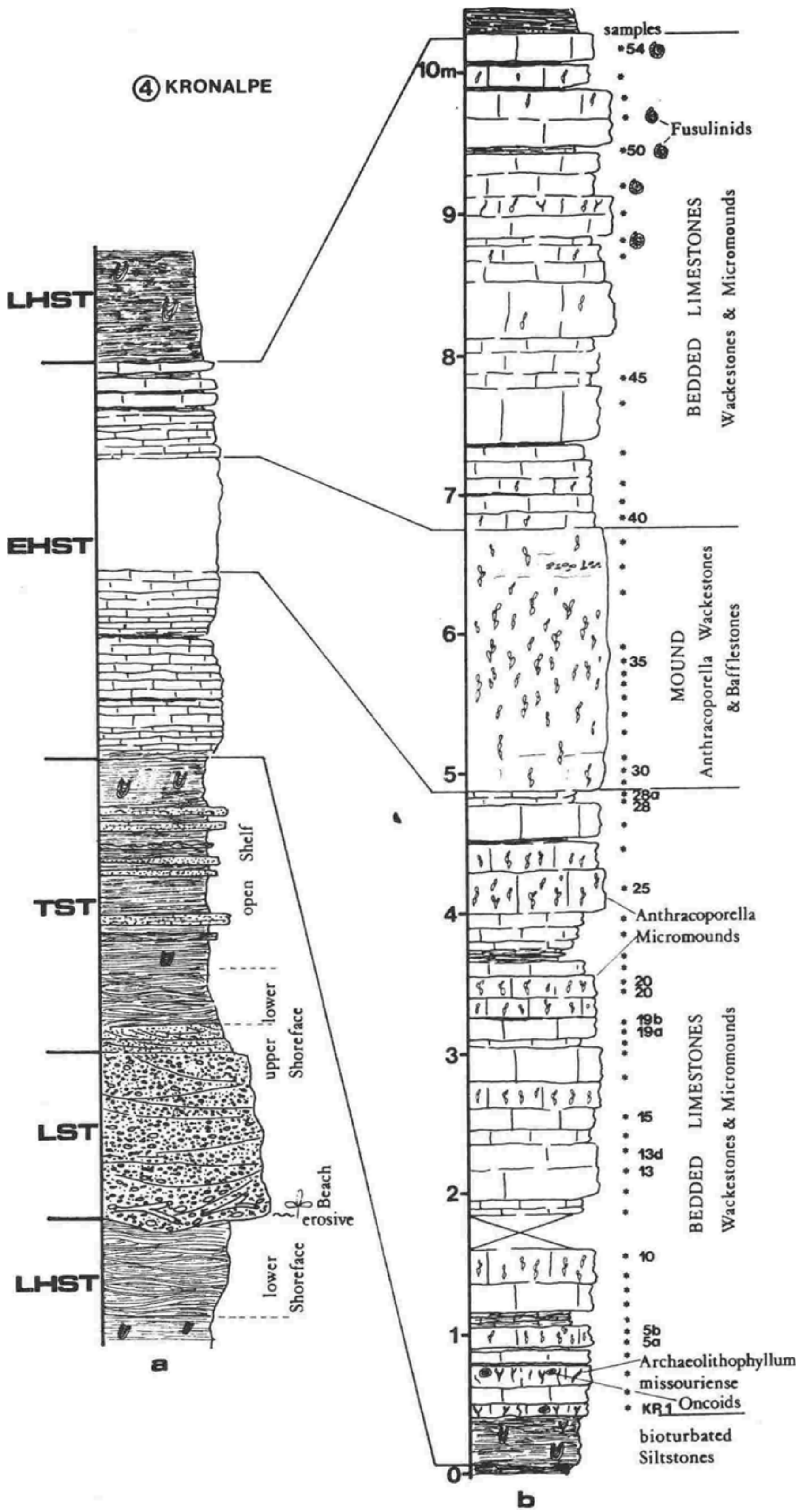

Fig. 6. (a) Stratigraphic section through a transgressive sequence of an 'Auernig cyclothem' at the Kronalpe locality in terms of sequence stratigraphy, showing position of the limestone interval.
LST = lowstand systems tract,
TST = transgressive systems tract,
EHST = early highstand systems tract,
LHST = late highstand systems tract.
(b) Detailed section through the limestone interval (basal Auernig Formation). In the center a 2 m thick mound facies consisting of *Anthracoporella* wackestones and bafflestones is developed, under- and overlain by bedded limestones composed of bioclastic wackestones and packstones and intercalated *Anthracoporella*-micromounds. Asteriks indicate position of samples.

intermound facies. But differences exist concerning the baffler (and binder) guild. In contrast to the massive mound facies, in which *Anthracoporella* is the only alga, *Archeolithophyllum missouriense* is a common, locally dominating alga in the micromounds forming *Archaeolithophyllum* bafflestones and wackestones. *Archaeolithophyllum missouriense* grew in less dense associations than *Anthracoporella spectabilis*, with distances between individual thalli commonly measuring a few mm up to about 2 cm.

6.2 Binder guild

Members of the binder guild are characterized by lateral growth of organisms along the surface of the substrate that encrust sediment as well as skeletons. Within the mound facies several encrusting organisms occur, all belonging to the binder guild.

Archaeolithophyllum missouriense occurs in growth position attached to the substrate, trapping and binding sediment, sometimes forming prominent umbrella structures (cavities) which later were filled with spar (Pl. 40/4). *Archaeolithophyllum lamellosum* not only forms thin crusts on the sediment but also encrusts skeletons, particularly of calcareous algae (*Anthracoporella* and *Archaeolithophyllum missouriense*).

Other members of the binder guild are cyanobacteria (especially *Girvanella*), *Tubiphytes*, encrusting foraminifers (particularly *Tuberitina*, *Calcitornella*, and *Calcivertella*), *Ungdarella*, *Cuneiphycus* and some bryozoans (Pl. 41/3, 4).

All these organisms are characterized by their sessile mode of life, encrusting sediment as well as skeletons, particularly larger skeletons of calcareous algae.

6.3 Destroyer guild

Reefs, and perhaps also algal mounds, could be destroyed rapidly, almost as soon as they were formed. Destruction occurs by physico-chemical processes (storm waves and currents) and biological processes. Destroying organisms bore into, rasp or bite the mound or reef framework and the individual members of the baffler guild in the reefs and mounds.

Destruction results in the formation of micritic sediment and broken fragments of organisms, which are then found in the internal sediment of the reefs and mounds. It is suggested that destruction played an important role in algal mounds, although it is not known, which organisms were members of the destroyer guild. Destruction by rasping and biting organisms, particularly by fishes, gastropods and echinoids, was probably a very significant destroying process in the algal mounds.

6.4 Dweller guild

Members of the dweller guild are those organisms that are neither actively building nor destroying the reef or mound framework. In general, the number and diversity of organisms that belong to the dweller guild is large. In the algal mounds particularly foraminifers, some other fishes, brachiopods, gastropods, bivalves and solitary corals were members of the dweller guild.

7 DISCUSSION

7.1 Limestones and sea-level changes

The lithofacies types of the Auernig Formation - conglomerates, sandstones, siltstones and limestones - are vertically arranged to form prominent transgressive-regressive cycles termed 'Auernig cyclothems' (Fig. 6). Within the Auernig cyclothems the conglomerates, deposited in a nearshore environment, formed during relative sea-level lowstands, and the limestones formed during relative sea-level highstands. Carbonate production and mound formation, therefore, was highly controlled by eustatic sea-level changes.

In terms of sequence stratigraphy, the limestones were formed during a stillstand phase of a highstand systems tract and therefore represent early highstand systems tracts (EHST) (see KRAINER 1991, 1992; MASSARI et al. 1991). In this respect the Auernig mounds differ from many Late Paleozoic mounds which formed during a regressive phase. In New Mexico for example, they occur near the middle of a regressive phase, and are overlain by high-energy deposits, particularly grainstones. Many Late Paleozoic mounds were subject to subaerial exposure resulting in vadose diagenetic processes and the formation of secondary porosity (e.g. WILSON 1967, 1975; TOOMEY et al. 1977; MAZZULLO & CYS 1979; CHOQUETTE 1983; HECKEL 1983; DAWSON & CAROZZI1986; ROYLANCE 1990).

During the early highstand, clastic influx was near zero and the sea-bottom near or below active wave base was colonized by different carbonate producing organisms, particularly calcareous algae. The biotic assemblage of the limestones indicates water depths of not more than a few tens of meters and low energy marine conditions with normal salinity.

Initial regression during the late highstand systems tract (LHST) caused increase in water turbulence and clastic influx, termination of the mounds and cessation of carbonate production. The limestones were overlain by bioturbated siltstones, which graded upward into hummocky crossbedded sandstones of the lower shoreface and trough crossbedded sandstones of the upper shoreface. These clastic rocks represent the late highstand systems tract and are separated by an erosional contact from the overlying conglomerates of a lowstand systems tract.

Thickness of the Auernig cycles, which represent small-scale, high-frequency sea-level fluctuations, ranges from 10 - 40 m. Cycle duration is in the order of 100.000 years or less. Cycles are interpreted to be caused by glacio-eustatic sea-level changes related to Gondwana glaciation in the southern hemisphere (see KRAINER 1991, 1992; MASSARI et al. 1991).

7.2 Mound Formation

Late Carboniferous - Early Permian mounds described in the literature are rich in phylloid algae (*Archaeolithophyllum*, *Eugonophyllum*, *Ivanovia*) and/or the enigmatic platy organism *Paleoaplysina*, and they are characterized by well defined vertical zonation and near absence of lateral zonation (JAMES & BOURQUE 1992, WILSON 1975). These mounds generally formed on slopes and ramps, and on the inner parts of platforms. In shelf and upper slope environments skeletal mounds dominate. They generally

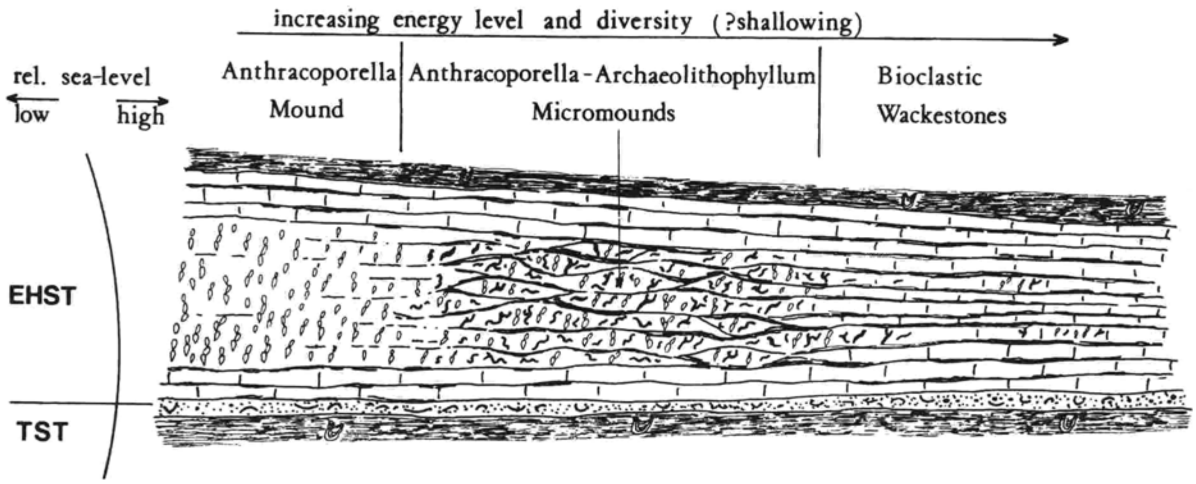

Fig. 7. Cross-section through a hypothetical *Anthracoporella*-mound. The mound formed in a quiet, shallow water environment below wave base during an early highstand systems tract (EHST). Laterally the mound grades into bedded limestones consisting of micromounds and intercalated bioclastic wackestones and packstones, and finally into bedded limestones composed of bioclastic wackestones and packstones without intercalated micromounds. This lateral relationship is suggested to be caused by increasing water turbulence from the mound towards the bedded limestones, suggesting development on a ramp.

formed below the wave base in a relatively low energy environment.

The most common algae in Late Paleozoic mounds of the Central - and SW-USA are the codiaceans *Eugonophyllum, Ivanovia,* and *Anchicodium*, which grew upright as blades, sheets and cups, thus acting as bafflers, and two species of *Archaeolithophyllum. A. lamellosum* was an encrusting form, whereas *A. missouriense* grew attached on the surface as well as upright (see CHOQUETTE 1983, DAWSON & CAROZZI 1986, HECKEL & COCKE 1969, PETERSON & HITE 1969, TOOMEY & BABCOCK 1983, TOOMEY & WINLAND 1973L, TOOMEY et al. 1977), therefore being a member of both the baffler and binder guild .

The quantity of algal skeletons in many mounds indicates that the in situ density of the mound forming algae during lifes was apparently so high, that they nearly excluded all other skeletal organism (FAGERSTROM 1987, TOOMEY 1976). Many Late Paleozoic mounds are characterized by high original porosities; the pores are now filled with carbonate cement (CHOQUETTE 1983, MAZZULLO & CYS 1979, TOOMEY & WINLAND 1973, ROYLANCE 1990)

Many of the Late Paleozoic algal-dominated mounds are biostromes with well developed baffler and binder guilds (CHOQUETTE 1983, FAGERSTROM 1987).

According to WILSON (1975) and JAMES & BOURQUE (1992), Late Paleozoic platy algal mounds are characterized by 3 successive stages: (a) a basal accumulation of bioclastic muddy sediment, (b) a core of lime-mud rich in platy algal bafflestone ('skeletal mound stage') built below wave base in relatively quiet water, and (c) a crestal boundstone of encrusting skeletal organisms when the mound grew into turbulent water (above the active wave base). Many of these mounds are overlain by grainstones of a sand shoal facies.

FAGERSTROM (1987) pointed out that in the geologic record in-situ algal bafflestones are rare as the algae are easily broken, and that bafflestones composed of abundant dasycladaceans in growth position are virtually unknown.

FLÜGEL (1987) was the first to describe *Anthracoporella*-dominated mounds from the Lower *Pseudoschwagerina* Limestone (Rattendorf Group) of the Carnic Alps. These mounds are different from those of the Auernig Formation described in this paper, as they are mainly composed of bioclastic wackestones and packstones containing abundant *Anthracoporella* skeletons. *Anthracoporella* in growth position, forming *Anthracoporella* bafflestones, has not been reported by FLÜGEL (1987).

Mounds of the Auernig Formation display the following features:

(1) they form biostromes which are only a few m thick but show great lateral extent (more than 100m),
(2) the massive mound facies is under- and overlain by fossiliferous bedded limestones (mostly wackestones), formed by the accumulation of organic debris,
(3) the massive mound facies does not show any vertical or horizontal zonation,
(4) the massive mound facies is formed by well developed baffler and binder guilds,
(5) the dominating mound forming organism is the dasycladacean alga *Anthracoporella spectabilis*, which is frequently found in growth position, forming *Anthracoporella* bafflestones, and
(6) pore space between the algal thalli is almost completely filled with micrite.

The crestal boundstone facies and capping grainstones as proposed in the model of WILSON (1975) are not developed, the mound formation cannot be explained by the model proposed by WILSON (1975).

Microfacies analyses revealed that *Anthracoporella spectabilis* was by far the most important mound-building organism. Broken fragments of other skeletal algae, particularly *Epimastopora*, are found only in very small amounts. Quite remarkable is the almost complete absence of phylloid algae, which are the dominating mound forming organisms in most Late Paleozoic mounds.

Broken fragments of fenestellid bryozoans and sponge spicules indicate that these organisms may also have contributed to mound formation, but were of minor importance.

Members of the binder guild, particularly sessile foraminifers, *Tubiphytes* and encrusting algae (*Archaeolithophyllum missouriense, A. lamellosum, Girvanella, Cuneiphycus*) encrusted sediment as well as skeletons of the mound forming organisms, thus contributing in the stabilization of the mound.

It is assumed that the micritic and pelmicritic groundmass of the mound, filling the pore space between the baffling organisms, was formed mostly in-situ by the fragmentation and disintegration of baffling organisms. Areas of high algal density probably grew faster upwards producing skeletal mounds, and sediment between the algae accumulated faster due to the high production of fine carbonate mud by the algae.

For the mounds in the Auernig Formation the following model is proposed (Fig. 7):

During the first stage, bioclastic muddy sediments (wackestones) accumulated, forming bedded limestones ('basal bioclastic wackestone pile' according to WILSON 1975).

During a relative sea-level highstand and absence of clastic influx the sea bottom was colonized by carbonate-producing organisms, particularly by calcareous algae. Subsequent mound formation was strongly controlled by the energy level. In slightly turbulent water the formation of bedded limestones continued. Laterally, towards areas of reduced water energy, 'micromounds' in individual limestone beds composed of *Anthracoporella* and/or *Archaeolithophyllum* bafflestones formed. As the mound formation was frequently interrupted by slight currents, 'shale partings' and different types of wackestones and packstones developed, which are intercalated with the 'micromound' beds, under these conditions thicker mounds could not develop. Laterally, these bedded limestones containing the 'micromound' beds grade into a massive mound facies composed dominantly of *Anthracoporella* bafflestones and *Anthracoporella* wackestones, which formed in a low energy environment.

It is suggested that *Anthracoporella*, due to the high reproduction rate (like phylloid algae) grew in such profusion and dominated the available sea-bottom living space, formed 'algal meadows' and excluded almost all other organisms except epiphytic organisms, particularly encrusting foraminifers, *Tubiphytes*, and encrusting algae (*Girvanella, Archaeolithophyllum lamellosum, Cuneiphycus*) (see TOOMEY 1976). Therefore the taxonomic diversity in the mound facies, particularly in the *Anthracoporella* bafflestones, is lower than in other microfacies.

The upright growing thalli of *Anthracoporella* could not have provided a substantial 'reef framework' and could not have withstood current and wave turbulence, thus indicating formation below active wave base. Phylloid, and perhaps also dasycladacean, algae are believed to have lived in water depths not greater than about 30m (HECKEL & COCKE 1969, JOHNSON 1961, KONISHI & WRAY 1961, ROYLANCE 1990, TOOMEY 1976, TOOMEY & WINLAND 1973). According to JOHNSON (1961) dasycladacean algae are restricted to water depths of not more than 12 m.

This lateral zonation - bedded limestones, bedded limestones with 'micromound' beds and massive mound facies - is energy dependent and probably indicates that the mounds formed on a ramp. The bedded limestones, composed mostly of different types of wackestones, were deposited in shallower, more agitated water, the mounds formed in deeper, less agitated water, and the bedded limestones with the micromounds formed between these depositional environments on a gently inclined ramp.

8 CONCLUSION

1) Mounds within the Auernig Formation formed during relative sea-level highstands, when clastic influx was near zero.
2) Mounds formed in a shelf environment, probably on a gently inclined ramp.
3) The dominant and representative mound-forming organism is the dasycladacean alga *Anthracoporella spectabilis*, which is frequently found in growth position, forming *Anthracoporella* bafflestones.
4) The mounds are characterized by well defined baffler and binder guilds.
5) Mounds form biostromes, which are up to a few m thick and extend laterally over distances of more than 100 m.
6) The mounds formed in the photic zone below the active wave base under quiet water conditions.
7) Mound formation does not follow the model proposed by WILSON (1975). Two stages of mound formation are recognized. During the first stage ('stabilization stage' according to JAMES & BOURQUE 1992) a basal bioclastic wackestone pile accumulated. During the 'skeletal mound stage' the sea-bottom was colonized by baffling and binding organisms, particularly by the dasyclacean alga *Anthracoporella spectabilis*, forming a massive mound facies composed of *Anthracoporella* bafflestones and wackestones.
8) The horizontal zonation from the bedded limestones to the bedded limestones with micromounds and finally to the mound facies resulted from different energy regimes across the ramp going from shallower to deeper water.
9) Mound growth was stopped by a slight drop of the sea-level, causing more agitated water, in which bedded limestones composed mainly of different types of bioclastic wackestones accumulated.

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