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Reefs and Coral Carpets in the Miocene Paratethys (Badenian, Leitha Limestone, Austria)

Bernhard Riegl
Nova Southeastern University, rieglb@nova.edu

W. E. Piller
Institut fur Palaontologie der Universitat Wien

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B. Riegl[1, 2] and W. E. Paler'[1]

ABSTRACT

Biohermal (reefs) and biostromal (coral carpets) facies were studied in the Austrian Middle Miocene Leitha Limestone. In the Vienna Basin ("Fenk quarry") non-framebuilding and framebuilding biostromal coral communities were found. In the Styrian Basin, well developed patch reefs were observed besides coral carpets. In the Fenk quarry, 2 coral carpet types, four non-framework coral communities, and one bivalve/coral community were found. In "Retznei quarry" (Styrian Basin) patch *reefs,* basal corallinacean calcarenites were followed *by•a Ponies* layer capped by marl, and the main reef-building higher diversity phase dominated by faviids *(Mantas:raea, Tarbellastraea).* In the "Tinenbacher *quarry"* no internal zonation was observed in the patch reef. The differences between reef, coral carpet, and non-framebuilding coral communities are equivalent to those in Recent systems (e.g., Red Sea). Our study therefore provides clear evidence that coral bioherms and biostromes occurred as distinct systems in the past and the Recent.

Keywords Bioherm, Biostrome, Coral reef, Coral carpet, Middle Miocene, Badenian

Introduction

In both the geological as well as the biological literature, the definition of what exactly constitutes a reef and what reefal limestones should look like has been elusive. Many studies have demonstrated that besides true reefs, other coral associations occur which can form frameworks but clearly are not reefs (Tunnel and Swanson 1976, Geister 1983, Leinfelder 1993, Kleypas 1996, van Woesik, and Done 1997, Kiessling et al. 1999). Whether these structures are incipient reefs (i.e. will necessarily turn into reefs when given enough time) or independent systems (i.e. remaining biostromal or non-framebuilding) is a matter of debate (Alegi and Piller 2000a, b). Recently, the difference between biohermal (reef) and biostromal (coral carpet) systems has been defined and described mainly from Recent systems and their geographical co-occurrence has been demonstrated (Riegl and Piller 1997, 1999, 2000a). If, as postulated by these studies, biohermal and biostromal coral systems remain distinct because of the reef building biota's different growth reaction to environmental constraints (even though systems may grade into each other), then both these systems should also co-occur as distinct units in the fossil record.

It is the aim of this paper to demonstrate this co-occurrence of both systems in Miocene coral limestones (Leitha Limestone of the Vienna and Styrian basins) and to identify other examples from earth history when both systems occurred parallel as distinct and independent ecological and sedimentary systems.

Geological setting

The Leitha Limestone is the most characteristic and widespread shallow-water carbonate unit in the Vienna and Styrian basins as well as in the entire Central Paratethys during the Middle Miocene Badenian stage (Piller and Kleemann 1991, Piller et al. 1996, Piller et al. 1997, Riegel and Piller 2000b). Its greatest thickness in the Vienna Basin is about 50 m (Tollmann 1985) and approx. 12 m at the type locality (Fenk quarry). In the Styrian Basin Friebe (1988, 1990) grouped the Leitha Limestone together with other shallow-water sediments in the Weissenegg Formation. Typically, the Leitha Limestone is characterized by coralline algae, however, in certain areas coral growth was prolific. In the Leitha Mountains (Lower Austria, Burgenland) and the Sousa' Mountains (Styria) small coral-fringed islands existed during the Badenian.

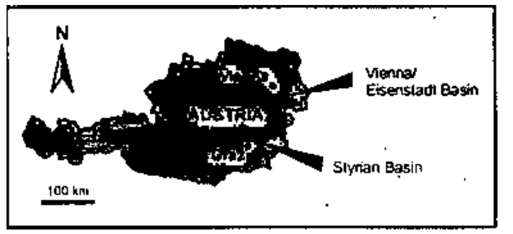

Fig. 1 Location of investigated Leitha Limestone outcrops in Austria.

Outcrop characteristics and methods

Terminology Coral-framework consists of densely spaced coral colonies. generally in growth position in rock-forming quantities. They can form coral carpets (= biostromes) and reefs (= bioherms) (Fig. 2). Coral carpets are laterally more or less continuous, relatively thin veneers of coral framework following the existing sea-floor morphology. They do not create a distinct three-dimensionality and are therefore ecologically relatively uniform (Fig. 2A). Reefs are distinctly three-dimensional structures producing a stronger ecological differentiation of animal and plant communities than coral carpets. Framework lithologies according to Insalaco (1998). Non-framework communities are assemblages of generally well-spaced non-interlocking corals (Fig. 2C). For further details see Riegl and Piller (2000b).

Fenk quarry *The* type locality of the Leitha Limestone (Papp et al. 1978) is an abandoned quarry system near Eisenstadt (Burgenland, Fig. 1). For detailed description see Meg! and Piller (2000b). Due to the laterally limited

Institut fur Geologic and Palaontologie, Universal' Graz, Heinrichs trasse 26, 5010 Graz, Austria, wemer.piller©uni-graz.at
' NCRI, Oceanographic Center, Nova Southeastern University, 8000 N. Ocean Drive, Dania 33004 Florida, USA; riealb(a)nova.edu

outcrop situation, quantitative analyses were not performed since resultant statistics would have been arbitrary.

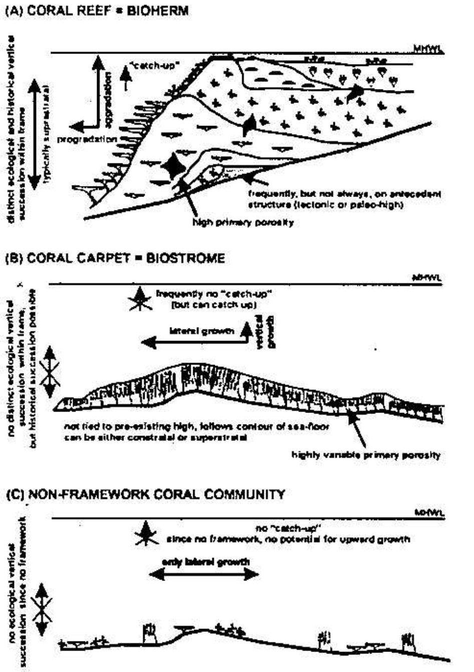

Fig. 2 Definition of framework types and coral community (non-framework carpet)

Tittenbacher quarry is an abandoned quarry between Retznei and Leibnitz, southern Styria. The outcrop is roughly 10 m high and 20 m wide and is interpreted as a patch reef (Friebe 1991b). It is a coral framestone from bottom to top without any discernible zones. The patch reef grew on a shoal within a basin influenced by fine-grained terrigenous sedimentation, evidenced by the generally marly limestone and marl layers in between. The terrigenous content allowed good preservation of the corals (in contrast to the Fenk and Retznei quarries, where most corals are dissolved). The relatively rich coral fauna in the patch reef is easily accessible and one square meter was sampled quantitatively for composition of the coral fauna.

Retznei quarry A series of quarries northwest of the village of Retznei exhibit different siliciclastic and carbonate environments. According to Friebe (1988, 1990, 1991a, b), the main outcrop is interpreted as a carbonate buildup representing coral carpets, seagrass meadows and coralline algal beds with interbedded small patch reefs. Due to the ongoing mining operations in the main quarry the outcrop situation changes constantly. The coral build-ups described in our paper are situated in the "Neuer Bruch" east of the Aflenz Creek ("Erweiterung Retznei" of Friebe 1990), where several terraces are present (outcrop situation November 1999). The coral rocks form a series of small (diameter: 10 – 20 m) patch reefs, which are surrounded by a marly calcarenite. This setting reflects a very turbid environment with abundant fine terrigenous ediments. Ongoing mining operations in this part of the quarry system may soon obliterate the studied patch reefs.

Results

Fenk quarry - biostromes

Ten coral intervals were found that are detailed in Fig. 3. Two coral carpet types were identified. Coral interval 2 is a 350 cm thick bed of columnar to branching *Porites* with thick branches in live position. Colonies up to 90 cm high and branches 12 - 22 mm wide forming a dense pillarstone (*sensu* Insalaco 1998). Almost all branching *Porites* covered by encrusting *Porites* near the contact to overlying calcarenite. Within the framestone, individual massive corals occur (*Tarbellastraea reussiana, Acanthastrea horrida*, and possibly *Caulastrea* sp.).

In the middle and upper half of interval 8 (Fig. 3), a *Porites* framework (dense pillarstone *sensu* Insalaco 1998) with individual faviids follows an underlying bivalve bank. Within the framework, bivalves (*Lima*, venerids, carditids, pinnids) are mostly in close contact with the corals.

The coral fauna in this outcrop consists primarily of branching and encrusting *Porites* (*P. leptoclada, P. incrustans*), small massive *Tarbellastraea reussiana*, and massive *Acanthastrea horrida*. Compared to the Styrian reefs, the fauna is poor.

Tittenbacher – bioherm

The entire outcrop is a coral framestone from bottom to top without internal zonation or intergrowth between adjacent coral colonies. No base or initiation sequence was observed in the outcrop. Also the top of the patch reef, described as a sandstone/oyster bed by Ebner (1972), is not cropping out anymore.

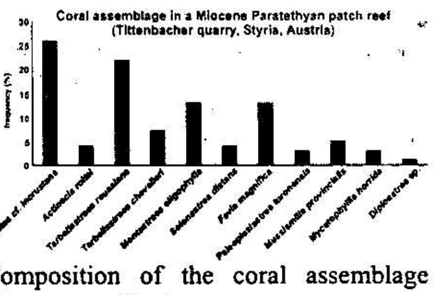

Fig 4 Composition of the coral assemblage in the Tittenbacher quarry, Styria

Nine scleractinian species were identified, the majority represents massive colonies: massive *Porites* possibly *Porites incrustans*, 26 %) and faviids (together >50%) were dominant (Fig. 4). Most common faviid species were *Tarbellastraea reussiana, Favia magnifica* and *Montastraea oligophylla*. No zonation with regard to different coral assemblages was observed. In contrast to the high diversity observed here, the Fenk quarry coral carpets were mostly made up by branching and columnar *Porites* (possibly *Porites leptoclada*) with only occasional massive corals concentrated in narrow zones.

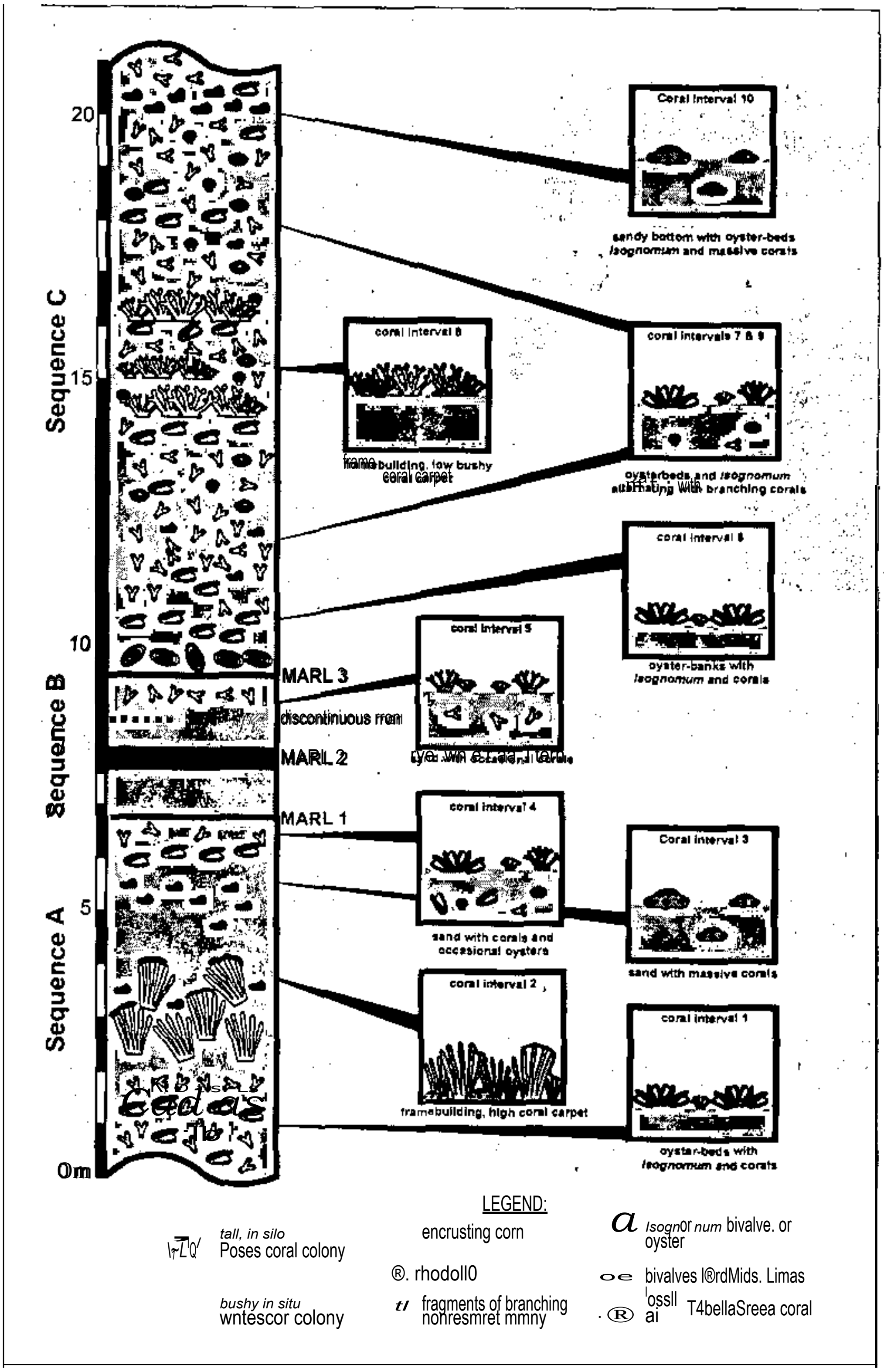

Fig 3 Stratigraphic column in the Burgenland study area (Fenk quarry, from Riegl and Piller 2000b)

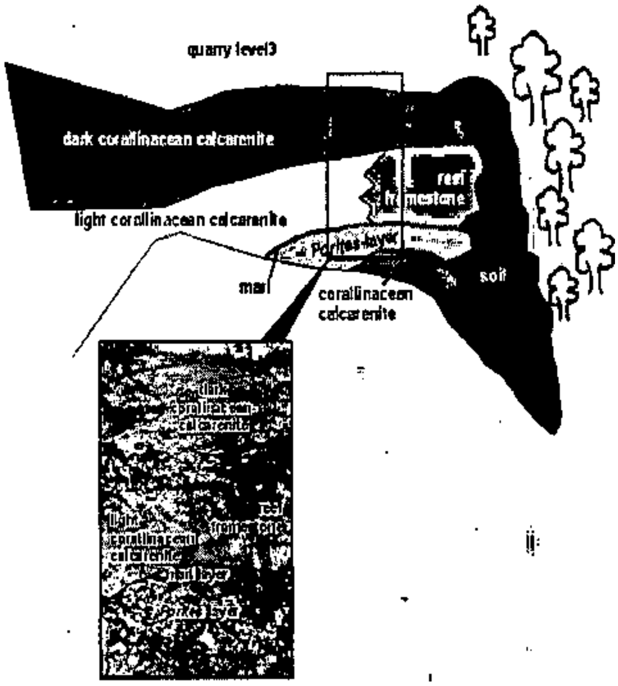

Fig 5 A patch reef from the Styrian Basin ("Neuer Brach" of Retznei quarry system) which shows all features necessary to call a continuous framestone sequence a reef: internal ecological zonation and clear separatidn of the framestone against surrounding calcarenites. Height of insert: approx. 5 m

Retznei —bioherms

The patch reefs in this cluster of small bioherms show a clear primary relief with a coral framestone in the center and a surrounding light corallinacean calcarenite (Fig. 5). The patches are covered by a dark gray corallinacean calcarenite. Similar coral species as in the nearby Tittenbacher quarry occur. The reefs' bases are,made up by gray corallinacean calcarenite similar to that capping the reefs. This is followed by a layer of massive and platy *Porites,* which terminates in a 1 cm thick marly layer. The marl is followed again by a coral framestone consisting of branching and platy *Porites* as well as *Montastraea, Tarbellastraea,* and *Mussismilia.* The uppermost layer of the framestone is mainly made up *by Porites.*

Discussion

We were able to identify several distinct coral facies and framework types: (I) patch reefs (bioherms), (2) coral carpet frameworks (biostromes), (3) non-framework coral communities (Fig. 2). This clearly demonstrates the co-occurrence of different constructional framework types in different environments during the same lime interval, similar to recent examples (Riegl and Piller 1997, 1999, 2000a). In the Vienna/Eisenstadt Basin, two coral carpet types could be differentiated according to the height of the framework: an up to 2 m high framestone (dense pillarstone, *sensu* Insalaco 1998) of mainly thick-branched *Porites* with individual thinly branched and rare massive colonies interspersed and a variety of framework settlers (coral interval 2, Fig. 3) and a low (50 cm) bushy framework (dense pillarstone, sensu Insalaco 1998) of thin-branched *Porites* with interspersed platy and massive *Porites,* as well as faviids with a rich fauna of framework settlers (coral interval 8, Fig. 3). Each interval formed a framestone of laterally uniform thickness (as far as the we were able to judge from the limited outcrop), but with no internal, growth-related assemblage succession. This satisfies the definition of a coral carpet (biostrome) as proposed by Riegl and Piller (2000a).

Besides frameworks, several intergrading non-framework communities were observed in the Fenk outcrop which we interpreted as lateral variations of basically the same patchy coral community *(sensu* Geister 1983) of thinly branched *Porites,* preserved as float- or rudstone. Also patchy coral communities of massive faviids (mainly *Tarbellastraea)* in a generally sandy environment were found forming a floatstone in a calcarenite matrix.

It is unclear why the Fenk quarry coral carpets did not develop into a proper reef. In analogy with other high-latitude coral systems characterized by coral carpets and a general absence of reefs (Arabian Gulf), Riegl and Piller (2000c) speculated that the area may have been situated in waters at the very limit of the temperature tolerance of framework formation, which would have led to repeated disruption of the framebuilding process, never allowing more than a carpet to form (see also Riegl 2001). Alternatively, water depth might have been too shallow to allow development of an ecological sequence leading to the formation of a coral reef.

True patch reefs with a distinct relief were found in the Styrian Basin. While the Retznei reefs show a clear internal zonation, the Tittenbacher reef does not. Since in the latter the contact to the basal facies, on which this reef grew, does not crop out, we assume that the early ecological sequence is buried. In similar Upper Miocene patch reefs in Spain (Sant Pau d'Ordal, Purchena, Granada Basin) Alvarez et al. (1977), Martin et al. (1989), and Braga et al. (1990) described comparable coral zonations. In times of higher sediment input, only *Porites* survived, while under lower sediment stress *Tarbellastraea* and other faviids became dominant. While in Spanish examples both coarse and fine-grained silicilastics influenced the development of coral communities, the studied small patch reefs in the Styrian Basin did not receive any coarse clastic sediment. In Retznei, the investigated patch reefs show an initial stabilization phase (mounded corallinacean calcarenite) and a zonation into a basal *Porites* layer which is capped by a marly horizon followed by a diverse reef limestone containing *Montastraea, Mussismilia, Tarbellastraea,* and several *Porites,* which most likely represents an era of better environmental conditions. This zonation is roughly comparable to that observed in Upper Miocene Patch reefs in Catalonia (Alvarez et al. 1977). This ecological differentiation within the framestone satisfies the criteria in Riegl and Piller (2000a, b) to define a framestone as a reef (bioherm).

Wider Implications

The results show clearly that in the Austrian Middle Miocene both reefs and coral carpets are found (filler and Kleemann 1991, Friebe 1991b, Piller et al. 1996, Riegl and Piller 2000b). This is equivalent to the Recent situation described from the Red Sea by Riegl and Piller (1999, 2000a) and also from the Great Bather Reef by Kleypas (1996) and van Woesik and Done (1997), although these authors used the term incipient reef instead of coral carpet. .McManus (1997) shows the wide distribution of coral md- or floatstone-type sediments in Recent SE-Asia, which allows to speculate about the importance of biostromes in these vast areas, where no reefs occur. It is now evident that both systems, reef and carpet (i.e. bioherm and biostrome), have been repeatedly present synchronously but in different environmental settings during earth history. Leinfelder (1993, 1994), Leinfelder et al. (1996) and Kiessling et al. (1999), clearly demonstrate that biostromal as well as biohermal scleractinian coral systems were common in the Triassic, the Jurassic, and the Cretaceous, reflecting a different inventory of frame-building species and their reaction to the environment in each system. Kershaw (1994, 1998) discussed the geological significance of biostromes in general. This study shows that care needs to be taken when applying terminology to framestones since bioherms (= reefs) and biostromes (= carpets) and non-framebuilding coral communities are distinct sedimentological units.

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