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Middle Devonian shallow marine deposits of the Graz Paleozoic: fact and fiction for deposition under ecological stress

Mitteldevonische flachmarine Ablagerungen des Grazer Paläozoikums: Daten und Interpretationen für eine Entstehung unter ökologischem Stress

by

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Abstract

Physical/chemical ecoparameters which may have prevented the creation of a flourishing reef ecosystem within a Middle Devonian fossil rich coral-stromatoporoid succession are evaluated and factors responsible for development past a biostromal pioneer stage are discussed.

Zusammenfassung

Die „Barrandeikalke" stellen die fossilreichste Formation des Grazer Paläozoikums dar. Ihr Fossilspektrum ist durch eine klare Dominanz „klassischer Riffbildner" charakterisiert. Es wird daher der Frage nachgegangen, welche Faktoren verantwortlich waren, die den Aufbau eines Riff-Ökosystems verhinderten.

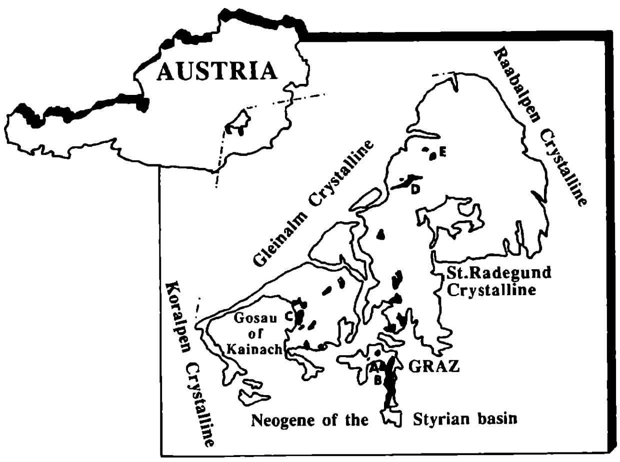

Figure 1: Geographical situation of the Graz Paleozoic and the surrounding area. In black: occurrence of the Barrandei Limestone; A–E: position of the profiles discussed in the text.

1. Introduction

The aim of the paper is to shed light on possible causes which prevented a Middle Devonian succession rich in 'potential reef-building' organisms from developing reef structures past the pioneer stage. The author is aware of the problem to evaluate important keys for an ancient ecosystem to "operate at less than optimal conditions" (COOPER, 1994:87). But, since modern reefs reduce their sizes – and even disappear! – when they are under ecological (physical and chemical) stress, it is advisable to keep in mind that similar effects may also have affected ancient environments.

The Graz Paleozoic has been the subject of over 100 years of geological-paleontological investigations. It represents a terrane of unknown style separated and removed from Pangaea and found today as a pile of nappes resting on metamorphic basement with unknown root zones. That is why scientists have difficulties in pointing out reliable paleogeographical relations with other remnants of the same age within the 'Upper Austroalpine' nappe system. Although the Graz Paleozoic has some fossil taxa in common with other Devonian areas of the Austroalpine and Southalpine, i.e. the Carnic Alps and the Karawanken mountains, the facial developments are hardly comparable: whereas reef structures are known in the latter occurrences, they are unknown (except some sparse Upper Devonian reef mounds) in the Graz area. Because of the high content of members of the 'classical reef building guild' of some formations (especially the "Barrandei Limestones") the question arises as to which of the physical/chemical ecoparameters prevented the creation of a flourishing reef ecosystem. Even though it is difficult to evaluate the causes, some clues discussed in the following point to ecological (i.e. physical-chemical) stress.

2. Geological framework

The nappes of the Graz Paleozoic consist of different facies or interminglings of several facies. Considering lithological similarities, the tectonic position, and met-

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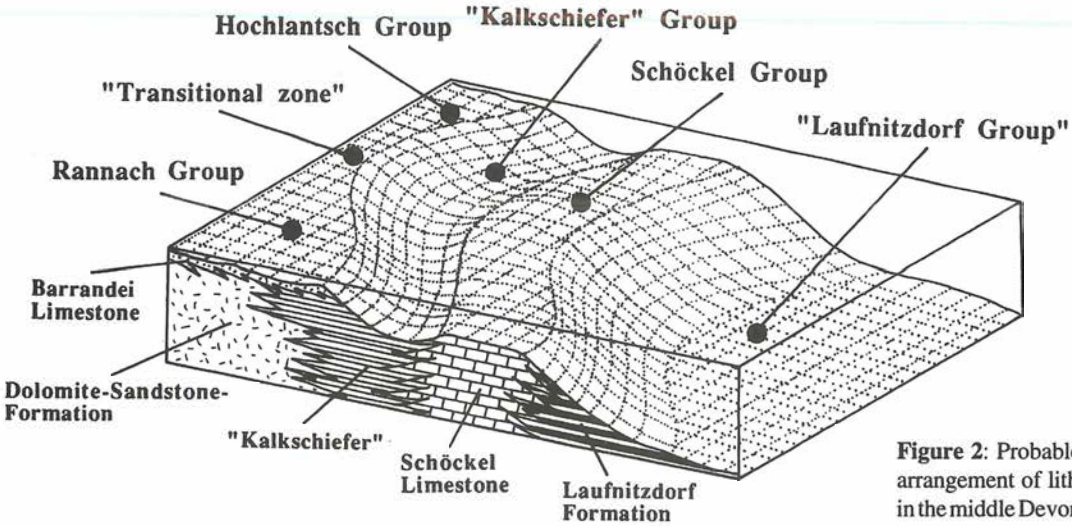

Figure 2: Probable paleogeographical arrangement of lithostratigraphic units in the middle Devonian of the Graz area.

amorphic superimposition, a lower, a middle, and a upper nappe group are discernible.
According to a paleogeographical interpretation of the entire succession, the 'Rannach- and Hochlantsch group' are interpreted as having developed nearest to shore, while the 'Laufnitzdorf group' represents the furthest from shore. The 'Schöckel group' occupies an intermediate position in this conception (Fig. 2).
The Rannach and Hochlantsch group, which belong to the high nappe group, contain very similar facial developments. A very fossil-rich formation develops in the Middle Devonian of both upper groups. This formation, the "Barrandei Limestone" (named after *Heliolites barrandei*), evolved from a supra- to shallow subtidal, barrier-surrounded lagoon, or from the sediments of tidal flats (FENNINGER & HOLZER, 1978). Nevertheless, although no previous thorough facial investigations have been carried out, the very old (MORLOT, 1847:133) concept of a reef has predominated, because of the clear dominance of classic reef-building organisms (especially stromatoporoids and corals). Recent environmental investigations (HUBMANN, 1993) show, that the formation with the greatest abundance of species and individuals of the entire paleozoic succession of the Graz area (FLÜGEL, 1975) did not develop past a "pioneer reef stage". The processes which permanently prevented the formation of wave resistant reef-structures are predominantly allogenous rather than autogenic biological ones. They will be described in the following.

3. Depositional environment

Despite the rich fossil content of the Barrandei Limestone the boundaries of the sequence are not clearly identifiable at this stage. Corals point to an Eifelian age. The appearance of several conodonts suggests that the Barrandei Limestone began in the upper Emsian and may continue into the lower Givetian (GOLLNER, 1983; HAFNER, 1983). Microfacial and geochemical investigation of the succession indicates deposition on a differentiated and

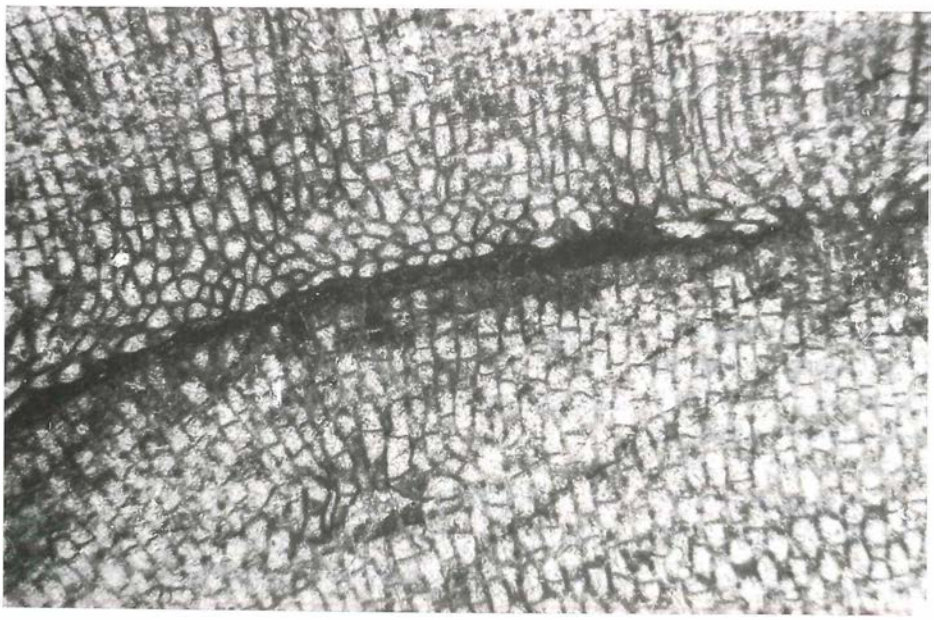

Figure 3: *Favosites* cf. *radiciformis* showing interruption of corallum growth; Magnification: 9 x.

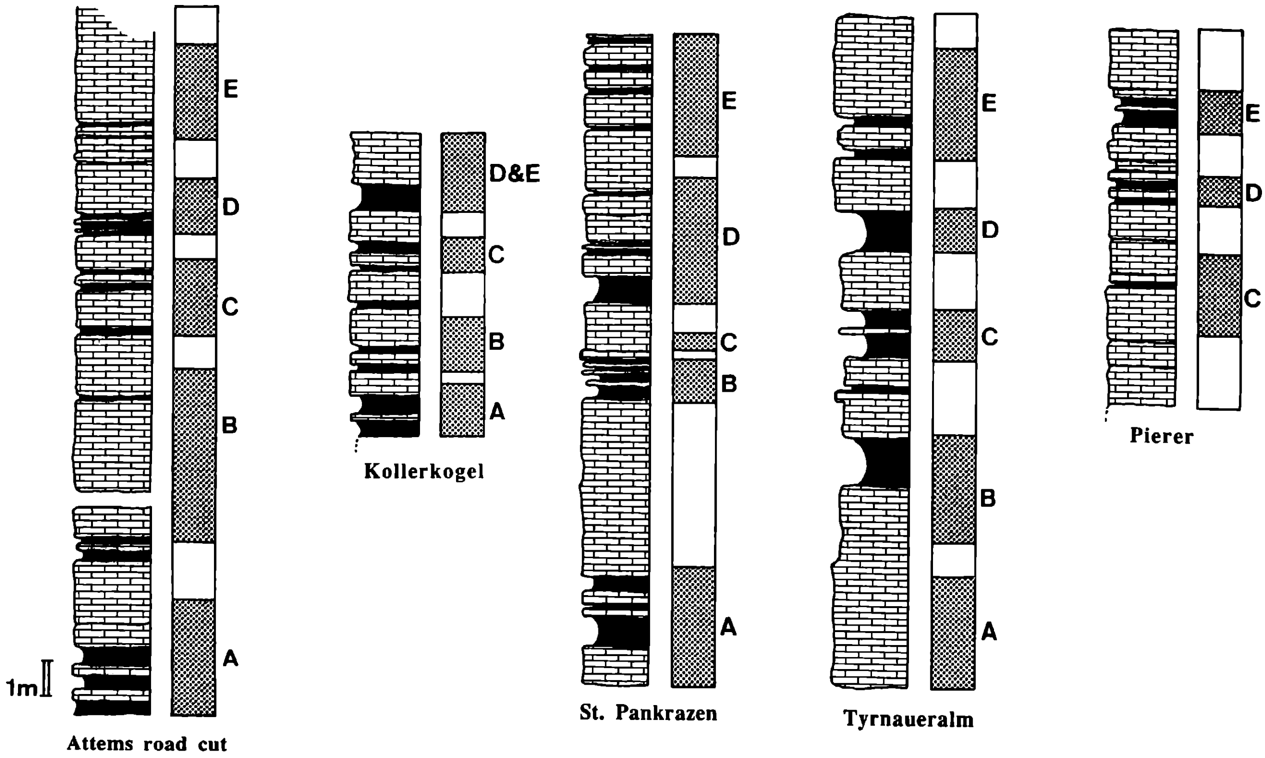

Figure 4: Profiles of the Barrandei Limestones with cycles of higher insoluble residue (the dotted sections represent these cycles; A–E)

gently inclined carbonate platform (HUBMANN, 1993). Considering the following facts:

- rarity of in situ organisms
- intermittent high supply of clayey sediments (marl-limestone intercalations)
- intermittent high supply of lime mud
- temporary influx of high amounts of continental phytoclasts
- storm impacts (several tempestite sequences within the profiles)
- rapid sea level changes (erosional unconformities due to emersion)

and, especially, the effects they had on the depositional environment, the substrate produced was hardly suitable for the creation of reef structures.

Profiles

Five profiles (locations see Fig. 1: A–E) illuminate the heterogenous depositional spectrum of the succession characterized by the intercalation of marls/slates and limestones of different carbonate concentrations. The influx of fine grained terrigenous sediment certainly had no significant influence on the faunal assembly of the profile succession, but always represented drastic interruptions in the faunal spectrum: in general only favositids, along with brachiopods and trails of *Scalarituba* are found in the marly layers. The favositids in these horizons, which are globular in growth form, very precisely illuminate the sedimentology and ecology of these layers. However, the corals suffered from the influx of terrigenous sediment into their habitat and mostly they totally were buried and killed by excessive amounts of clayey sediment. Although they survived the influx, their coralla show interruptions in growth and rejuvenescence of the colonies (Fig. 3).

After deposition of marly sediments the 'Barrandei fauna' regenerated itself quickly. The layers below and above the marls feature very similar collections of organisms. This can be explained by the fine-grained siliciclastic material not affecting the entire depositional environment, and so with a return to normal (sedimentary) conditions, the resettlement of the entire area proceeded quickly.

4. Allogenic controls and paleoecology

The often relatively high amount of fine-grained siliciclastic material, as well as the high micrite content point to poor light conditions. It may have represented correspondingly unfavorable effects on the permanent settlement of reef-building benthic organisms (especially the ?photoautotrophic corals were affected) although it is difficult to prove if the water column was either permanently or episodically turbid. Nevertheless, five periods of higher deposition of fine-grained terrigenous siliciclastics in the sedimentation area are recognizable when studying the insoluble residue of the succession bed by bed (Fig. 4). They could be caused by the five transgressional phases during the upper Emsian to the lower Givetian sealevel fluctuations in Euroamerica (KREBS, 1979; JOHNSON et al., 1985).

Additionally, episodically occurring storms and the resulting tempestites had negative results on the permanent

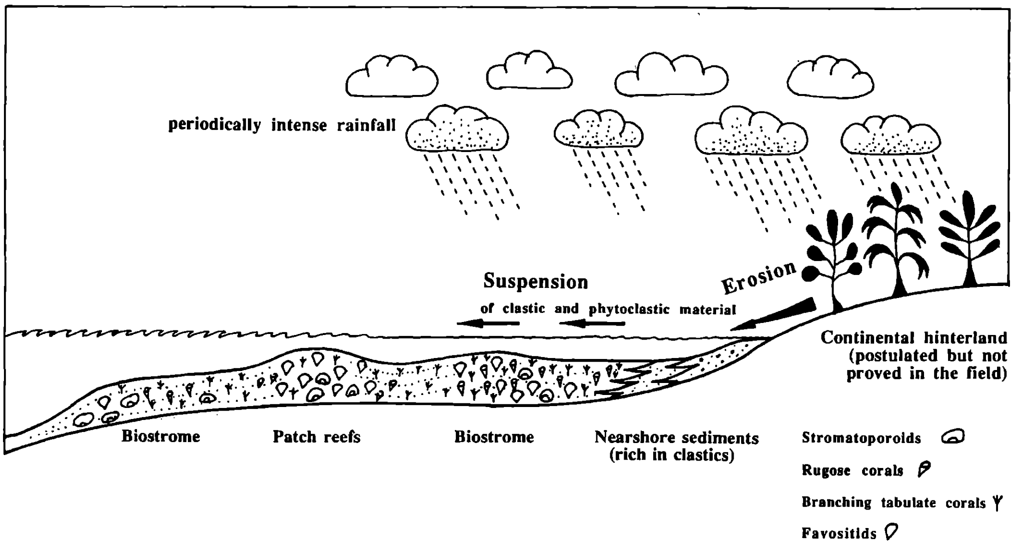

Figure 5: Processes driven by the continental hinterland that had negative effects on biostromal growth, as on benthic organisms (modified after WILDER, 1994). Clayey-silty detritus as well as plant material was carried into the depositional environment from a (hypothetical, though in the area unprobable) partly plant-covered hinterland through periodically intense rainfall. This material, carried in suspension in rivers, spread over the entire depositional environment. The deposition of the fine-grained clastic components thus covered the benthic organisms and suffocated them. The plant material, remaining longer in suspension, provided an overabundant food supply for bacteria, causing eutrophication in stagnant areas through its decomposition.

settlement of benthic organisms: On one hand, the sediment surfaces were completely recast by the deep erosive-abrasive storm waves, while on the other hand, the living, sessile organisms were completely covered and "suffocated" by the deposition of considerable amounts of transported organic detritus.

In times of normal carbonate (shallow marine) background sedimentation, ecologically unfavorable conditions arose for sessile benthic organisms, through increased production of organic material: Continental detrital plant material (in the form of phytoclasts; cf. HASENHÜTTL & RUSSEGGER, 1992) was transported into the sedimentation area and caused at least locally and temporarily eutrophication through the following chain of events (WILDER, 1989, 1994; cf. to Fig. 5):

> permanent land plant settlement – overproduction of phytoclasts – transport into the marine environment – overabundance of plant nutrients – eutrophication caused by the activities of bacteria and other microbes when dissolving the organic material

Such conditions set in, when the depositional area was constricted from the open marine environment thus preventing the influx of fresh, oxygen-rich seawater. These episodes may also be related to sealevel fluctuations mentioned above. However, the cnidarians and especially the stromatoporoids were sensitive to the plentiful presence of organic substances in their habitat: they reacted with stunted specimens and growth interruptions. Favositids, apparently more resistent to environmental factors, deposited the undigestable organic material against the skeletal wall (Fig. 6), but also they were hardly in the state to build larger colonies.

Organisms

A frequency distribution, reduced to the most important 'reef-builders' and 'reef inhabitants' of the Barrandei-fauna results in the following picture (Table 1):

Profiles		Stromatoporoids	Rugosa	Tabulata	Gastropoda	Brachiopoda
(A)	Attems / Road cut	22.0	9.1	39.0	4.6	25.3
(B)	Kollerkogel	16.2	8.6	30.4	15.6	29.2
(C)	St. Pankrazen	11.0	8.8	29.1	12.8	38.3
(D)	Tyrnaueralm	15.2	6.9	27.2	18.3	32.4
(E)	Pierer	46.1	9.2	25.1	7.9	11.7

Note: The most frequent remains of organisms consist of crinoid stem fragments, which can occupy up to about 50 % of the organic portion of the rock in the profiles. Since they are easily transportable because of their high porosity, and allow no statements about autochthony, specifically the transport distances and points of origination, they are not mentioned here.

Table 1: Frequency distribution of most important reef-builders and -inhabitants of profiles A–E.

Figure 6: Cross-Section (dark field microphotograph) of *Favosites* showing organic material deposited against skeletal elements (wall, septal spines, tabules); Magnification: 6.5 x.

In the "reef-building guild", or "constructor-guild" the dominance of tabulate corals is noticable. Representatives of the genus *Thamnopora* predominate and suggest a great importance for current reduction and 'baffling' of fine-grained sediment. The similarly species- and individual-rich Rugosa fauna points to settlement of narrow ecological niches. A suppression of the stromatoporoids in favour of the corals, caused by climatic factors or temperate currents (WOLOSZ, 1992) cannot be considered together with the evidence of an individual-rich, autochthonous algae-flora (HUBMANN, 1990) and paleomagnetic data (FLÜGEL & HUBMANN, 1993). Stromatoporoids were the dominant organisms worldwide in contemporaneous shallow marine beds. They are nevertheless found in the Barrandei Limestone facies, because the discussed environment, although unfavorable, contained a minimum of factors allowing their survival. The small size of their coenostea, their often dendroid growth forms, and the small fraction of the entire fauna that they occupy also indicate unfavorable conditions.

5. Environmental Concept

Following the classification schemes for organogenically-controlled successions lacking topographic relief, parts of the Barrandei Limestones would represent an "auto-parabiostrome", according to the emended definition of biostrome (CUMINGS, 1932) by KERSHAW (1994).

(Auto-)Biostromes can only grow when the sensitive balance of subsidence, light, aeration, water chemistry, nutrient supply (from land and ocean), and long term stable faunal associations exist (WILDER, 1985). Thus biostromes react sensitively to wide-ranging events like increased sedimentation from the continental hinterland, stronger turbulence, tidal waves, high precipitation, etc. Unlike bioherms, most of the biostromes obviously cannot survive deepenings of the environment with 'compensatory vertical growth' (KÜHLMANN, 1991). These factors may also explain why large portions of the Barrandei Limestone formation are typical "pioneer reef communities" (characterized by *Thamnopora* associations).

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