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The possible contribution of fresh water cyanobacteria to Northern Alpine Hauptdolomit sedimentation

Der mögliche Beitrag von Süßwasser-Cyanobakterien zu der Sedimentation des nordalpinen Hauptdolomites

by

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Abstract

The Upper Triassic Hauptdolomit of the Northern Limestone Alps represents the landward part of a carbonate platform that was connected to the terrestrial Keuper hinterland. In a tidal transition zone towards the marine part of the platform, marine organisms produced enough carbonate to compensate for subsidence over a period of 15 million years. Toward the hinterland, the origin of the carbonate is less obvious. Comparing modern environments, we find similar conditions in South Florida: the tidally influenced Florida Bay and extended fresh water marshes towards the hinterland, in the Everglades. There cyanobacteria produce micritic fresh water carbonates with sedimentation rates comparable to those in the Triassic Hauptdolomit. Neither sediment structures nor the stable isotope composition give clear indications for the fresh water origin of the sediments. The difficulties to prove a fresh water influence on carbonate production in a diagenetically altered carbonate rock might be the main reason that fresh water environments have never been taken into consideration for the Hauptdolomit.

Zusammenfassung

Der obertriadische Hauptdolomit der Nördlichen Kalkalpen ist Teil einer ausgedehnten Karbonatplattform, die nach Norden eine Verbindung zum terrigen dominierten Keuper Hinterland besitzt. Am Übergang zu südlichen marinen Plattformbereichen wird in den Gezeitenzonen Karbonatsediment von marinen Pflanzen und Tieren produziert und so die Absenkung über 15 Millionen Jahre kompensiert. In weiten Bereichen der Hauptdolomitfazies fehlen jedoch klare Hinweise auf die Art der Karbonatproduktion. Strukturlose Dolomikrite überwiegen.

Vergleichen wir moderne Karbonatplattformen, so finden wir in Südflorida ähnliche Ablagerungsbedingungen: marine Gezeitenzonen im Süden gegen die Florida Bay, die nach Norden in ausgedehnte Süßwassermarschen übergehen. Hier wird Karbonat von Cyanobakterien gebildet, dessen Sedimentationsrate etwa der für den Hauptdolomit geschätzten entspricht. Weder die Gefügebilder der Karbonatmikrite noch ihre isotopische Zusammensetzung weisen auf ihren Süßwasserursprung hin. Diese Schwierigkeit mag einer der Gründe sein, warum bisher für die Entstehung des Hauptdolomites noch keine Süßwassereinflüsse diskutiert wurden.

1. Introduction

According to the most abundant microfacies types, the Triassic Hauptdolomit platform in the Northern Limestone Alps is generally compared with the modern Bahama platform. The dolomitized algal laminites, making up a major portion of the Hauptdolomit sequence closely resemble the facies of the supratidal algal marshes of the Bahamas. There is, however, one major difference between the two environments. While the Bahamas are an isolated platform, the Hauptdolomit was connected to the Keuper hinterland. The influence of the hinterland on sedimentation in the Hauptdolomit has rarely been taken into account.

Most of the discussions about Hauptdolomit are either concerned with dolomitization, or with the sub- to supratidal nature of the carbonates. This discussion is important to locate those sedimentary environments on the platform in which we find obviously marine fossils. This is the case within the tidally influenced transition zone of the marine Dachsteinkalk platform into the Hauptdolomit lagoon. But over a wide area toward the north nearly no indication of marine organisms is preserved. Under which conditions were these carbonates produced and who was the main producer?

As the Hauptdolomit platform developed in a humid climate, fresh water runoff from the hinterland onto the platform was probably significant. Thus the South Florida area could possibly serve as a good modern equivalent for the Hauptdolomit platform. The hinterland to the north

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and the climatic conditions lead to fresh water runoff influencing facies distribution and sediment production. The fresh water areas were studied in detail to facilitate recognition of fossil fresh water carbonates in the Hauptdolomit.

2. Fresh water micrites

The main carbonate environment in South Florida is the marine Florida Bay, which is protected to the southeast, towards the Atlantic Ocean, by the Florida Reef tract and the Florida Keys. The large swamp area of the Everglades developed north of the bay. It is characterized by strongly seasonal runoff of fresh water to the south and southeast into the Bay and the Gulf of Mexico. A mangrove belt between the fresh water area and the Bay protects the fresh water marshes from marine influence. There is no transport of marine sediments into the fresh water areas.

During and after the rainy season from about July until February the marshes are covered by several decimeter of slowly flowing fresh water. Considerably greater depths can be reached in the main runoff zones ("sloughs"). Dense cyanobacterial mats begin to develope at the beginning of the wet season, covering the sediment surface and submerged parts of plants. The dominating genera in these mats are the filamentous forms *Scytonema* and *Schizothrix*. Low Magnesium Calcite is precipitated in the gelatinous sheaths of these cyanobacteria. Precipitation is quantitavely related to bicarbonate uptake during photosynthesis and consequent hydroxyl-ion release (MERZ, 1992).

A weak lamination of the sediments caused by the seasonal developement of the mats is lost within the first few centimeter below the surface. The sediment is bioturbated, mostly by plant roots. Ponds of greater water depths can frequently be found within the marshes. Their water has a brownish colour due to a relatively high amount of humic acids. Cyanobacterial mats seem to be weakly developed or lacking in these ponds and no micrite is produced. Water level in the ponds drops during the dry season, but hardly ever they are completely dry. Fish live in the ponds as well as in the seasonally flooded marshes. Fresh water micrites crop out over several thousands of square kilometer. If their subsurface distribution is taken into account they cover even larger areas all over South Florida probably as far north as Lake Okeechobe (GLEASON et al., 1984). In most areas, however, micrite production ceased because of large-scale man-made environmental changes.

As mentioned above, the fresh water micrites are well protected from marine sediment influx by the mangrove belt which developed in the brackish water zone. The diversity of shells found in the micrites is very low as compared with marine sediments. Only a few species of fresh water gastropods are abundant, especially *Biomphalaria glabrata* (SAY 1818), *Pomacea* sp., and *Physella* sp. (determination by courtesy of R. JANSEN, Frankfurt).

The stable isotope composition of the freshwater micrites has been measured (MERZ, 1992). They are heavy in oxygen and carbon as compared with typical freshwater carbonates. The oxygen values reflect enrichment of the ^{18}O in the Everglades water because of intensive evaporation. The carbon values fall within the marine range because of preferred ^{12}C uptake during photosynthesis. Therefore ^{13}C is left behind to be precipitated in the carbonate. This leads to the precipitation of sediment 6–7 permil heavier in carbon as should be expected from the isotopic composition of the water.

3. Sedimentation rates

The carbonate in the cyanobacterial mats is precipitated during the day, while at night carbonate is dissolved. This is reflected in the rhythmic changes in calcium and carbonate concentration in the water within 24 hrs (GLEASON & SPACKMAN, 1974; MERZ, 1992). Both concentrations reach their maximum values just before sunrise when photosynthesis sets in and show minimum values in the late afternoon. The measurement minimum and maximum of Ca^{2+}-concentration and carbonate alkalinity allows to calculate the daily precipitation and dissolution. By substracting the amount of carbonate dissolved during the night from the amount precipitated the day before net production rates for 24 hrs can be calculated. As the sediment influx onto the mats is neglegible, the production rates are equal to the sedimentation rates.

From the decrease of calcium and alkalinity during the day, and the increase during the night, production rates for 24 hrs were calculated for field observations and for experiments run under field conditions (MERZ, 1992). For the field data 0.015 mmol $CaCO_3$ and for the experiments 0.080 to 0.200 mmol $CaCO_3$ were calculated. Taking into account the specific weight of calcite (2.7), a duration of the wet season of 200 days and 60% porespace thicknesses of annual laminae were estimated to be 0.018 mm (field data) to 0.1 to 0.24 mm (experiments). Especially the higher values are in good accordance with the range of sedimentation rates estimated by SCHOLL et al. (1969) from sediment thickness and ^{14}C-data from the base of the micrite sequence (1.2 to 2.8 cm/100 years).

4. Discussion

A fresh water/marine transition zone developes on a marine carbonate platform connected with a hinterland in a humid climate. Carbonate can be produced in both, marine as well as fresh water. A modern example of such an environment exists in South Florida. Similar conditions are proposed here for the Hauptdolomit platform on the northern margin of the Late Triassic Tethys which was connected to the Keuper hinterland. Several indications of fresh water influence have been documented. Marls ("Bunter Keuper"; in TOLLMAN, 1976) seem to contain fluvially transported material from weathered Keuper rocks. ZANKL & MIRSAL (1983) found characeans in the Hauptdolomit of the Steinplatte, and GORJANOVIC-KRAMBERGER (1905) determined Keuper fish.

Fresh water carbonates such as travertines or lacustrine marls are of limited spatial distribution compared with marine sediments. The micrites of South Florida show, however, that under suitable conditions fresh water carbonates may have significant extension and sedimentation rates, so that they might well be of geological importance. In the Hauptdolomit, however, carbonate sediments actually precipitated from fresh water have so far not been described, probably because their occurence was unexpected and therefore overlooked.

In the Hauptdolomit deposited in the southern parts of the platform within the tidal zones, the marine influence is obvious. In the north, however, there are dolomitized structureless micrites in which fossils are rare. By FRUTH & SCHERREIKS (1982) these dolomicrites were described as "non-laminate, sparry (intraclast) dolomite mudstone" and "homogenic to intermittently laminated dolomite mudstones"

According to MÜLLER-JUNGBLUTH (1968, 1970) the laminae in the middle part of the Hauptdolomit formation have a thickness of 0.080 to 0.1 mm and in the Lower Hauptdolomit of 0.1 to 5 mm. Although the time span represented by a single lamina is not known, the thicknesses of the laminae compare well with the annual sedimentation rates measured for the Everglades micrites. These measurements show that large scale fresh water carbonate accumulation could keep up with sedimentation on the marine influenced parts of a platform.

As can be seen from the isotopic data of the Everglades, the isotopic composition of a fresh water micrite does not neccessarily give fresh water signals. Evaporation and carbonate precipitation as a consequence of photosynthesis in a CO_2-poor environment may lead to carbonates that are heavy with respect to both, oxygen and carbon. So, even if the original isotopic composition is preserved, this micrite could not be distinguished from a marine carbonate. The influence of the cyanobacteria on isotopic carbon composition of the micrite could be recognized only, if the original shell composition of gastropods could be measured for comparison. For the Hauptdolomit, however, this is not the case, because of complete recrystallization of sediments and fossils. Isotopic composition, therefore, may not be a suitable indicator of fresh water carbonates in the Hauptdolomit.

The fossil content may be a good indicator, providing the species can be determined and their fresh water occurence is known. Otherwise, the lack of marine fossils together with generally low species diversity suggests a fresh water origin of a micrite, at least for platforms which were protected against marine influence. By Triassic times the developement of the flora certainly allowed the occurence of a mangrove-type biotop protecting the Hauptdolomit platform. Indicators for a rich flora adjacent to the carbonate deposition are the plant remains and coal, frequently found in the Hauptdolomit. The Keuper fish found in the Hauptdolomit might have lived in ponds in the fresh water marshes, surrounded by carbonate producing, seasonally dessicating cyanobacterial mats.

5. Conclusion

We suggest, that the influence of cyanobacteria on Hauptdolomit sedimentation was not restricted to the role of sediment binders, but they also might have produced a considerable amount of fresh water carbonate. This activity would be recorded as meter-scaled micrite beds, lacking marine fossils. They may contain a fauna of only a few species, but many individuals, especially gastropods. The isotopic composition would not nesseccarily reflect the fresh water origin of the carbonate sediment. These fresh water micrites should occur in the landward areas of a platform, in the case of the Hauptdolomit towards the Keuper hinterland.

In addition to the widely discussed sub- to supratidal environments for Hauptdolomit sedimentation (CZURDA & NICKLAS, 1970; MÜLLER-JUNGBLUTH, 1970; FRUTH & SCHERREIKS, 1982) we suggest a fresh water environment in which landward parts of the Hauptdolomit have been produced. This stimulates not only a better understanding of carbonate production on platforms with a hinterland but brings additional arguments into the discussion on dolomitization.

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