A comparative study of the Supratidal and Basin Dolomites in the Anisian and Ladinian Carbonates of the „Hochstaufen Massif“ (Northern Limestone Alps).

By

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with

3 Tables, 2 Plates

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Mitt. Ges. Geol. Bergbaustud. Österr.	28	S. 95–108	Wien, Mai 1982

Content

Summary

Supratidal facies in the "Succession of the Wurstlkalke" of the Hochstaufen massif are characterised by the occurrence of dolomites of special morphologic as well as crystallographic features that differentiate them from those originally formed in the basin facies.

The occurrence of special forms such as Zoned Dolomites and Limpid Dolomites in the supratidal facies regarding their formation under schizohaline conditions, supply evidence that the palaeoclimatic environment was extremely arid in this case.

Crested Dolomites, occurring exclusively within the basin facies, indicate very early dolomitisation of hemipelagic muds under the influence of organic matter.

Later dolomitisation within this facies must have occurred by dissolution of the early syngenetic dolomites. Leached rhombs as well as gradual grain growth among the different dolomite generations of the basin facies support this conclusion.

Zusammenfassung

In den Flachwasserkarbonaten der anisischen „Wechselfolge der Wurstlkalke" konnten verschiedene Generationen von Dolomiten aufgrund ihrer Größe, ihres charakteristischen kristallographischen Habitus sowie ihrer Oberflächenmorphologie nachgewiesen werden, die sich deutlich von syngenetischen Dolomiten in der Beckenfazies (Reiflingerkalk) unterscheiden.

Im Korngefüge der Gesteine aus der Supratidalfazies (Wechselfolge der Wurstlkalke) wurden drei zeitlich aufeinander folgende Dolomittypen beobachtet. Spezifische Formen wie die „Zonierten Dolomite" und die besonders klaren "Limpid Dolomite" können aus schizohalinen Porenwässern entstanden sein und liefern somit Anzeichen für ein extrem arides Klima. Eine syngenetische Dolomitisierungsphase innerhalb der Beckenfazies (Reiflingerkalk) lieferte stapelartig-aggregierte, besonders feinkörnige "Crested Dolomite", die stets in dichtem Mikrit eingebettet sind. Als Bildungsbereich wird ein spezifisches Mikromilieu mit anaoerobem Zersatz von organischem Material angenommen.

Spätere Dolomitgenerationen innerhalb dieser Fazies werden als Mobilisate dieser frühen Phase aufgefaßt. Hinweise hierfür liefern angelöste Rhomboeder sowie die allmähliche Größenzunahme in den späteren Generationen.

Die letzte Generation von Dolomit mit idiomorphen Rhomboedern und Kristalldurchmessern von über 1 mm erscheint entlang von Stylolithbahnen und kann in al-

len Faziesbereichen der Flachwasser- und Beckenfazies beobachtet werden.

Introduction

The Hochstaufenmassif represents almost all members of the ternary facies model known from the Alpine Middle Triassic Series. According to the schematic representation of the facies groups displayed in table 1 three main depositional areas are documented along the vertical section: a shallow water platform, a basin and a reef platform. For the purpose of this study reference will only be made to the Anisian and Ladinian facies groups.

The lowermost Anisian rocks "the Reichenhall beds" represent a strong evaporitic platform facies. The following "Succession of the Wurstlkalke" still show restricted conditions and exhibits typical cyclic sedimentation patterns. The Steinalm limestone, however, reflects a transgressive sequence comprising a normal marine algal environment in its lower portion. The transition from the restricted to the open platform is marked by an oolitic facies. The uppermost Steinalm limestone contains crinoidal sands and calcarenitic fan deposits along the platform margin. Basin sediments of the Reifling limestone start with flaser nodular limestones, light grey pelagic limestones and bituminous limestones. They occassionaly have intercalations of cherty nodular and allodapic limestones together with small patches of reef limestones (compare HENRICH & ZANKL 1981, HENRICH 1982).

Different phases of dolomitisation have been observed in all three facies groups. In the present paper the authors try to compare dolomite occurrences in the "Succession of the Wurstlkalke" and the Reifling limestone, where the depositional environments have respectively been assigned to shallow water platform and open marine basin conditions.

1. Petrography and sedimentological framework

1.1 Reichenhall Beds

The evaporitic platform facies of the Reichenhall beds comprises two main lithologies. The first is of dark bituminous dolomites and dolomitic limestones with high fluorite content. They posses low energy sedimentary structures such as flaserbedding, microchanelling and rare bioturbation. Early diagenetic degasification structures and shrinkage pores together with high bitumen content could be considered as indications of sapropelic conditions. Further indications are given by their very restricted faunal assemblage, comprising only few species of gastropods and pelycopods.

The second lithology consists of light coloured dololaminites, rauhwackes, and stromatolites. Stromatolites and dololaminites often show dissolution casts of evaporites.

Dololaminites were found to pass laterally into beds with small-scale slumping and finally into rauhwackes. Thus the rauhwackes are thought to have been formed by a combined process of dissolution of evaporites and subsequent slumping and collapsing of sediment.

The environmental interpretation depicts a restricted platform, which was surrounded and intersected by hypersaline, supratidal mud flats.

1.2 "Succession of the Wurstlkalke

Table 2 provides a representation of the "Succession of the Wurstlkalke" showing

Table 1: MIDDLE TRIASSIC CARBONATE SEQUENCE HOCHSTAUFEN MASSIF

Stage	Formation	thickness		Environment
KARNIAN	WETTERSTEIN LIMESTONE	350 m	REEF PLATFORM	dasycladacean banks lagoonal cycles with vadose pisolitic crusts
		300 m		central reef
		100 m		fore reef breccia
	REIFLING LIMESTONE (upper group)	80 m	BASIN	fore slope
	PARTNACH MARLS	50 m		basin subdivided in ridges and throughs
LADIN.	REIFLING LIMESTONE (lower group)	150 m		basin
				platform margin
ANISIAN	STEINALM LIMESTONE	30 m	SHALLOW-WATER PLATFORM	open platform
	Sucession of the WURSTLKALKE	150 m		oolite bars restricted platform cycles
	REICHENHALL BEDS			platform evaporitic facies

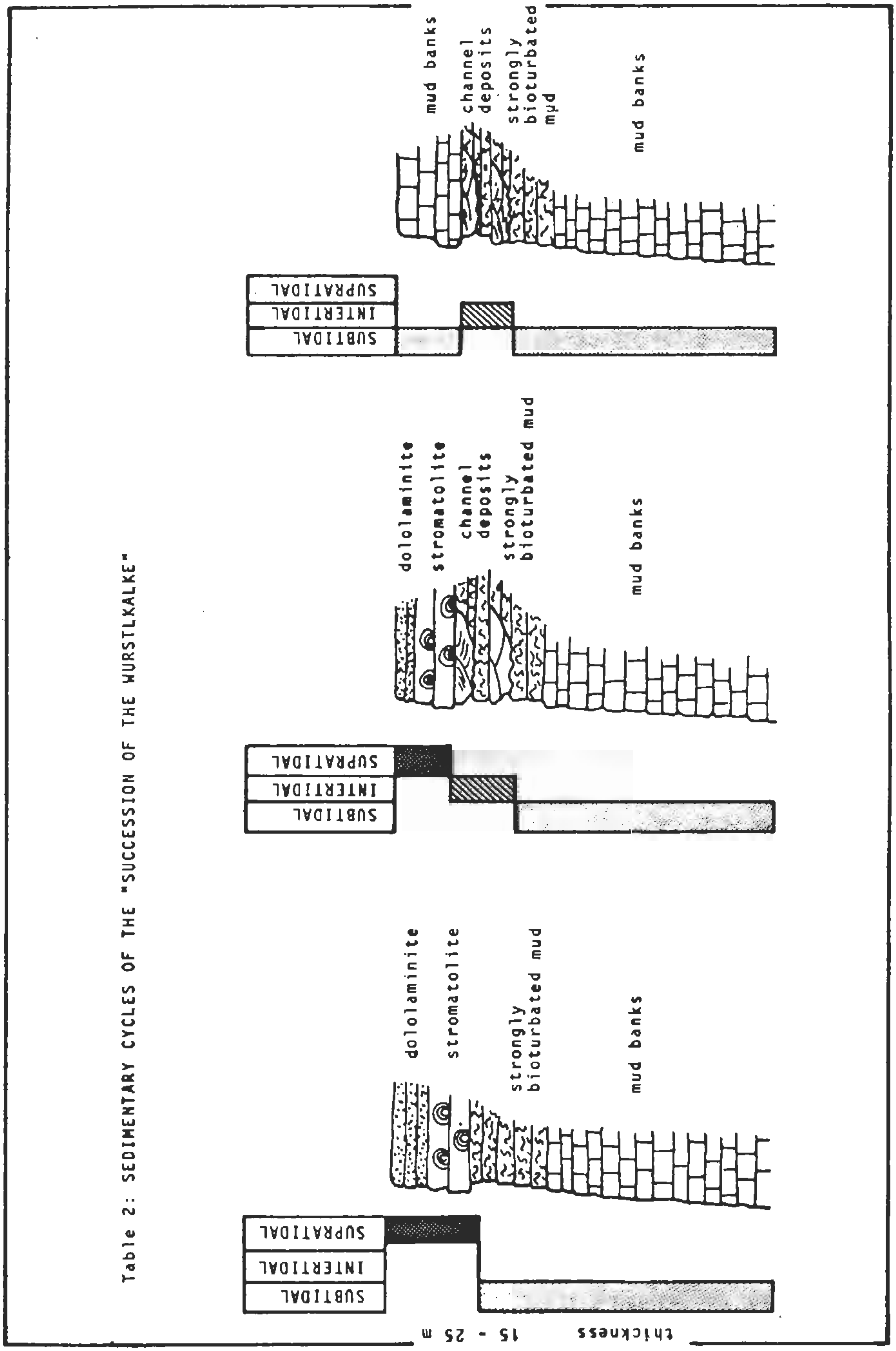


Table 2: SEDIMENTARY CYCLES OF THE "SUCCESSION OF THE WURSTLKALKE"

typical sedimentary cycles (thickness 15–25 m). A complete cycle consists of subtidal mud banks, normally strong bioturbated in the higher portions of the sequence, and intercalated by intertidal channel deposits. The supratidal part is composed of dololaminites and stromatolites.

In many cases incomplete cycles can be observed.

Complete cycles, however, seem to be restricted to the lower part of the section. The absence of supratidal sediments in higher parts of the entire sequence supports the idea of a general transgression.

The cyclic sedimentation being presumably a result of cyclic change of the water energy and lateral shifting of facies belts, seems to have taken place on a calm shelf extending over a wide area. Facies differentiation on this shelf includes subtidal mud flats with locally strong bioturbation interrupted by hypersaline supratidal areas. This muddy environments were irregularily truncated by tidal channels (Table 3). Original sedimentary structures in the form of shrinkage fissures, and brecciation together with calcitic pseudomorphs of gypsum or anhydrite indicate rather arid conditions.

The millimeter scale rhythmic manner of micritic and silty layers of the dololaminites is thought to have been originated by repetitive storm activities on the sabkha planes. Reworked algal mats that must have been subjected to several phases of weathering should be attributed to shallow intertidal positions in the surroundings of the sabkha planes. Furthermore, the occurrence of lenghth-slow calcite within the fenestral fabrics indicates fresh water seepage into the supratidal planes.

The subtidal sediments mainly consisting of monotonous pelloidal mud suggest a restricted environment. They show indications of strong bioturbation.

The lense shaped tidal channel deposits are consisted largely of biogenic debris, mainly shell fragments and crinoidal sand, algal lumps, pelloids, intraclasts, and mud pebbles. They erosively cut into the underlying mud bed, and show horizontal stratification in the lower portion and cross bedding in the upper portion of the accretion.

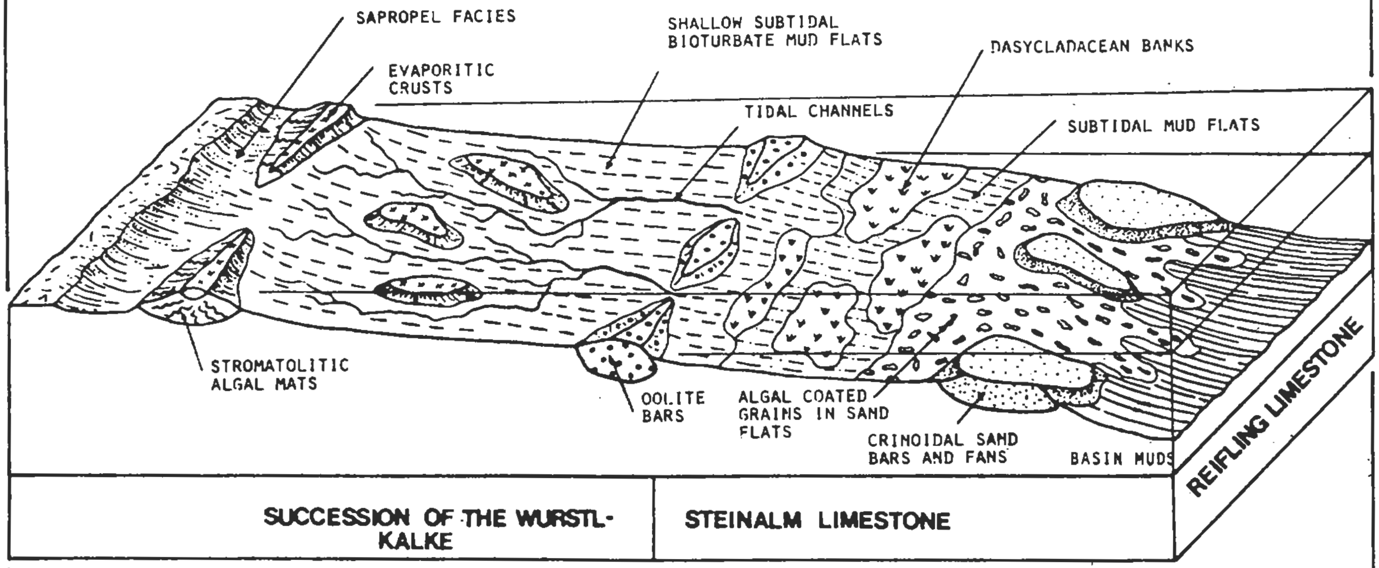
The cyclic sequence is covered in the uppermost parts of the "Succession of the Wurstlkalke" by oolite beds whose origin is to be sought in the shallow intertidal zone.

1.3 Basin Facies – Reifling limestone

The upper member of the alpine Muschelkalk (Reifling limestone), representing a basin environment in general, contains different dolomite occurrences. The most striking of these are the successive dolomitisation phases taking place in the light grey "stromatactis limestones". Consequently, reference will only be made to these beds.

The facies of the stromatactis rich limestones is composed of mudstones containing calcitised radiolarian and siliceous sponge spicules, as well as pelagic foraminifera and echinoidal fragments. Pelloids are the most important allochmes. Sedimentary structures display a wide range of phenomena. Of these, the most important are bioturbation, small scale slumping and void structures filled with different cement generations and/or geopetal sediments. The void structures as revealed by thin section analysis are of different genetic types, occurring as a result of differential compaction, sediment collapse and bioturbation (BECHSTÄDT, 1974).

Table 3: ENVIRONMENTAL MODEL OF MIDDLE AND UPPER ANISIAN CARBONATE FACIES OF THE HOCHSTAUFENMASSIF.



2. Diagenetic history and Dolomitisation processes

2.1 The Wurstlkalk shelf facies

Early lithification in this member is indicated by the occurrence of reworked lithified stromatolitic fragments that were reassembled by later generations of algal mats. The diagenetic history as revealed by thin section analysis would indicate an evolution of a bioturbated mud, whose burrows must have been lithified at a very early stage. Primitive algae living under the surface of the sediment must have caused cementation through their mucilaginous surfaces, and induced carbonate precipitation by raising the pH of the environment. Final lithification of this member is preceeded by differential compaction and dewatering. This has given rise to various systems of fissures and fine fractures.

Petrographic investigation revealed following dolomite types:

a) Zoned Dolomite (Pl. 1/b). Zoned Dolomite was described by many authors as indicating salinity fluctuations during deposition (KATZ, 1971 and LONGMAN & MENCH, 1978). Zoned Dolomites in this sense in our study area display growth zones of irregular thickness unlike the regular varves described by LONGMAN & MENCH (1978).

They presumably owe their origin to salinity fluctuations caused by freshwater influx on supratidal planes.

b) Leached Dolomites. Leached Dolomites indicate both external and internal leaching processes. Dolomite rhombs showing external leaching were found to display the so called flame structures (Pl. 1/d) described early by LONGMAN & MENCH (1978). They also possess pitted surfaces with overgrowths on the corners suggesting that these were more susceptible to leaching than the faces (Pl. 1/c). Internal leaching on the other hand is indicated by hollow rhombs (Pl. 1/b).

c) Limpid Dolomites. Smooth faced crystals of Limpid Dolomite (Pl. 1/e, Pl. 1/f) as described by FOLK & LAND (1975) were found to grow in the open spaces, where micrite was absent, suggesting its leaching before the dolomitisation. The occurrence of the limpid dolomite in the study material indicates dolomitisation under schizohaline conditions, where extreme fluctuation between fresh water and hypersaline brines must have taken place (FOLK & LAND, 1975). This upholds our early conclusion of salinity fluctuations in an arid region due to intermittant periods of freshwater influx followed by long periods of aridity.

2.2 Basin facies (Reifling limestone)

This beds are thought to have been deposited as hemipelagic muds containing planctonic nanno and microfossils.

The diagenetic history of the sequence as revealed by thin section and scanning electron microscope study, indicate the following diagenetic phases:

1. Early compaction and lithification leading to dewatering and void formation. Sediments filling the voids and burrows were selectively dolomitized shortly after their lithification.
2. Part-compaction of the voids combined with fracturing preceeding the final lithification.
3. Deep burial resulting in pressure solution together with stylolitisation. Along the stylolites pyrite impregnations indicate a shift of the chemical environment towards higher pH values.

Dolomitisation processes in this member can be chronologically classified into three generations or phases. These are (1) a syngenetic phase represented by very minute rhombs (2–3 μ) of Crested Dolomite (Pl. 2/a) (2) a relatively early phase within the void-filling sediments represented by pitted rhombs of about 30 μ and (3) a very late stage represented by rhombs of sizes up to 1–2 mm, whose faces are pitted.

Crested Dolomite have been reported from different sites of the "Deep Sea Drilling Project", mostly in association with hemipelagic muds on the outer ridge of the Blake plateau (Initial Report of the Deep Sea Drilling Project, Vol. 11). There, dolomite was found to occur regularly as well developed rhombs in presence of calcareous nanoplancton and some foraminifera. Siliceous organisms were almost absent. The dolomite occurrence in the mud was refered to replacement of the microfossils.

Crested dolomites were also reported from the deep water facies on the eastern side of Andros Island by Bourrouilh-Le Jan (1973), who described dolomite rhombs of flakey habit with a long diameter of about 1–2 microns. The rhombs were accumulated on each other in bundles attaining a thickness of about 5–6 microns.

In our material flakey crystals of crested dolomites having long diameters of 2–3 microns were observed (Pl. 1/a). These are thought to be of a syngenetic origin. This view is supported by the fact that the flakes were always found to be sporadically burried within the micrite. Such a mode of occurrence suggests dolomitisation by replacement of the microfossils. Another feature of these dolomites is the concomittent occurrence of magnesite in the same samples (Pl. 2/b). If this magnesite was to be assigned a syngenetic origin like the dolomite, which is probably the case, one would have to account for the elevation of the pH to the point allowing precipitation. This might either be explained by the occurrence of natural gases held as hydrates at the top of the mud during the early burial phase (BOURROUILH-LE JAN, 1973) or by anaerobic bacterial action, which is capable of elvating the pH to values above 9 (FAIRBRIDGE, 1967, p. 67).

We assume that both cases might have prevailed during the precipitation of the crested dolomite and the accompynying magnesite.

b) Dolomite occurring within the void-filling sediments

Dolomite in the void-filling sediments (Pl. 2/c) were presumably formed in the early burial stage, shortly after the partial lithification of the sediments filling the voids and the burrows. Anaerobic bacterial action must have largely contributed to creating the chemical conditions (pH 9) required for their formation.

The pitted surfaces of this dolomite together with the occurrence of hollowrhombs (Pl. 2/c, Pl. 2/d) suggest a dissolution that presumably supplied the material required for the late diagenetic dolomite that grew along the stylolites.

c) Late diagenetic Dolomite

This late phase of dolomitisation represented by idiomorphic rhombs of crystal sizes attaining length of about 1 mm along the long diameter seems to have been brought into existence during the anadiagenetic stage.

KUBANEK (1969, 1970) revealed that the dolomite formed in this phase was not a stoechiometric but rather more calcium rich one – a conclusion which is also supported by our work. We assume however that pressure solution of the early dolomites must have supplied the required magnesium for the precipitation of the late ones. The mechanism proposed by KUBANEK (1969, p. 152) according to which the late diagenetic dolomite was formed after pressure solution of low magnesium calcite, under temperatures of about 200° C, is regarded by the present authors as less probable.

Acknowledgments

Special thanks to Prof. H. Zankl (Marburg) for reading the paper and giving fruitfull comments. We are particularly grateful to Mr. Fecher (technical support on the scanning electron microscope) and to Mrs. Preiß (typewriting). Our studies were carried out with the generous financial support provided by the Deutsche Forschungsgemeinschaft (DFG-project Za 22/21).

Conclusions

Different textural and morphologic aspects correlate with facies differences among the Anisian and Ladinian carbonates of the Hochstuafenmassif.

Within the supratidal facies, Zoned and Limpid Dolomites indicate formation under schizohaline conditions reflecting extremely arid climate.

Very early dolomitisation of the basin sediments is demonstrated by Crested Dolomites indicating dolomitisation of hemipelagic muds under the influence of organic matter.

Dissolution of the early syngenetic dolomites must have supplied the material required for the formation of the late generatious.

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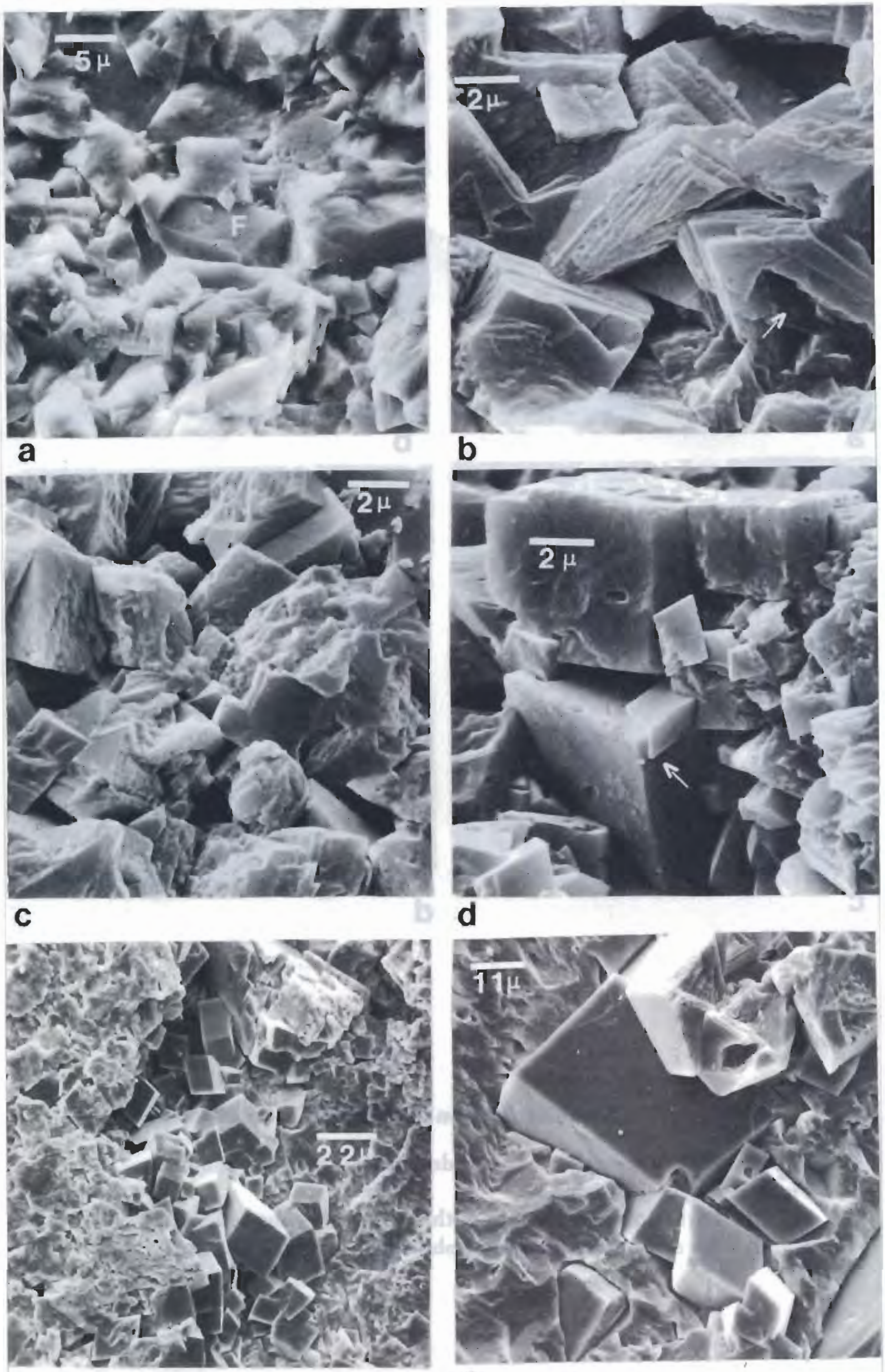
Plate 1

Scanning electron micrographs of supratidal samples

Fig. a) Diagenetic potasch Feldspar (F) in micritic calcite matrix as revealed by microanalysis by EDAX
Fig. b) Zoned dolomite, showing leached centres (arrow).
Fig. c) Leached dolomite rhombs with pitted surfaces and overgrowths on the corners (arrow).
Fig. d) Leached dolomite rhombs with flame structures.
Fig. e) Limpid dolomite lining a cavity.
Fig. f) Limpid dolomite rhombs.

Tafel 1



Tafel 2

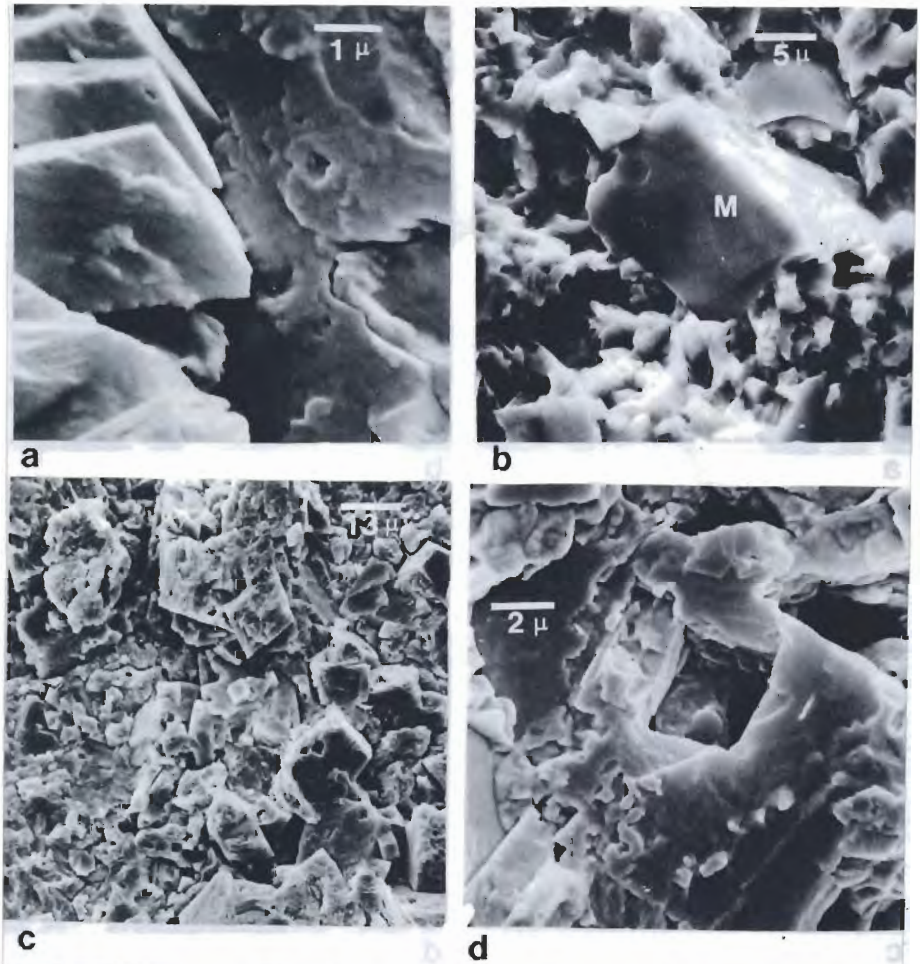


Plate 2

Scanning electron micrographs of basin samples

Fig. a) Flakey crystals of crested dolomite growing in bundle.
Fig. b) Magnesite grain (M).
Fig. c) Early dolomite rhombs within the void-filling sediments.
Fig. d) An early dolomite rhomb showing secondary leaching.