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Technical Report

CONTRIBUTION TO THE FACIES AND THE DIAGENESIS OF QUATERNARY CARBONATE SEDIMENTS OF FIJI

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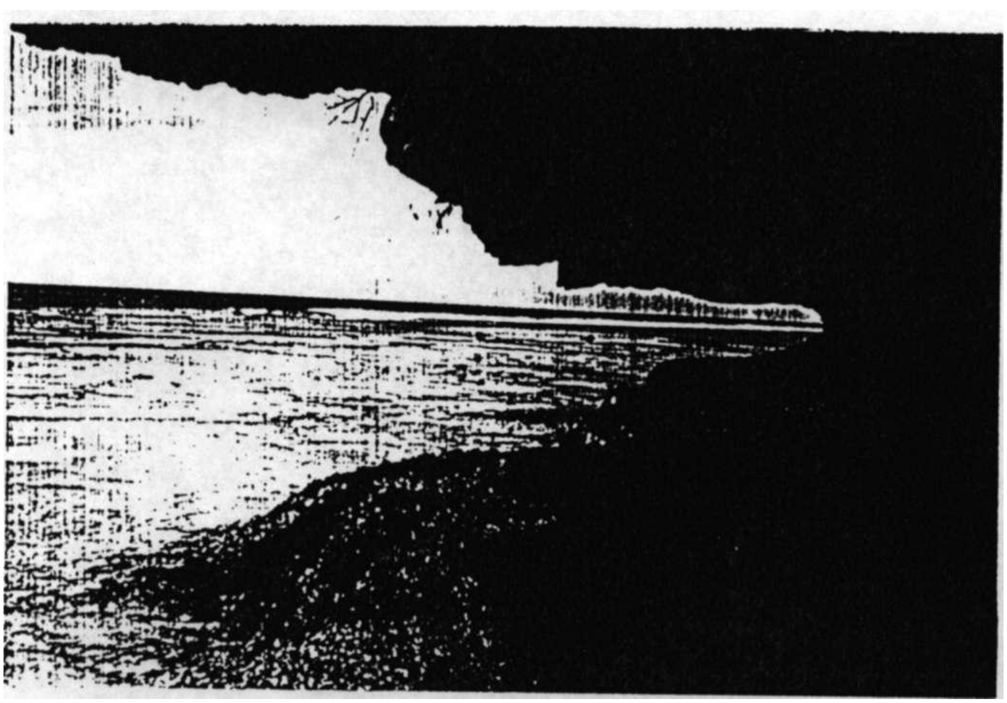

Contents

Introduction

During my sabbatical at the Institute of Marine Resources (Marine Studies Programme), University of the South Pacific, Suva which lasted from August 1992 until March 1993 sampling of surface samples was carried out along a few transects across the Fiji platform (Fig. 1).

The bio-sedimentological studies focus on

a. Facies distribution and diagenesis of modern reefs and of sediments of associated environments (basins, lagoons) as useful information for more realistic interpretation of according ancient formations.

b. Interplay of geodynamic and sedimentological processes in the realm of the fragmented Cenozoic Island Arc of Fiji (RODDA 1989, RODDA & KROENKE 1984, STACKELBERG & RAD 1990).

With regard to many modern publications on the diagenesis of reefs (SCHROEDER & PURSER 1986), it is surprising that in an area like Fiji where good field working conditions are available, there is a lack of carbonate sedimentological data of shallow water environments, whereas a broad spectrum of information of the adjacent North Fiji Basin and Lau Basin is available as provided by SONNE-cruise SO-36 (HIECH 1990).

Using the USP-research vessel "APHAREUS" and different punts respectively, surface sediments were recovered from the Laucala Bay, Astrolabe lagoon and Bligh Water by piston corer and different grabs. Onshore field work was done along the southern coast of Vanua Levu with special interest in the diagenesis and karstification of emerged Quaternary reefs.

Laboratory work at IMR included salt free washing, sieving of samples, and microscopy of grain mounts. Most of the analytical work like microscopy of stained thin sections, X-ray diffractometry, SEM and C/O-isotope studies will be carried out at TU Braunschweig for later publication.

Further bio-sedimentological and diagenetic studies in the South Pacific are intended in cooperation with the Institute of Marine Resources, USP Suva.

Preliminary Results

LAUCALA BAY

High siliciclastic fluvial input, increasing pollution by the towns Suva and Nausori as well as intensive agriculture in the Rewa delta which is, over extended parts, covered by dense mangrove forests (PILLAI 1990), have become alarming factors to ecologists and to communities with special regard to the water quality worsening in both river channels and Laucala Bay.

Sediment samples were recovered along two transects running from the coastline to the barrier reef (Fig. 2 A) in order to analyze grain size distribution patterns and the mineralogical composition of the lagoonal sediments. These data will give ideas on controlling factors of deposition. The western transect comprises 20 stations, the eastern transect 23 stations. Both reveal lagoonal environments of varying water depth, the barrier reef margin and platform as well as two passages through the reef.

North of an E/W-running depression (foul ground) the western part of the Laucala Bay displays **Cora**-rich dark silty-sandy oozes whose provenance mainly concerns the Rewa river (SHORTEN 1992). South of the foul ground reef-dominated calcarenites and calcirudites abruptly occur in approach to the barrier reef which, itself, allowed sampling of biolithites.

The eastern part of the Laucala Bay which is more affected by the Rewa delta than the western part and therefore morphologically more complex, reveals characteristic Corg--rich, very fine grained clayey-silty oozes. Endobenthic brachiopod species Lingula displaying a high number of individuals in the tidal flats, significantly underlines the brackish character of this environment. Marine conditions become fully dominant when ascending to the barrier reef platform and into the passages where the mixed sediments (siliciclastics, carbonates) of the lagoon are replaced by reef debris (calcarenites, calcirudites).

Triangular diagrams of diverse grain size groups (Fig. 3) demonstrate that the river sediments revealing low mean values at the delta front are deposited under low energy conditions (eastern transect), whereas currents and waves cause the increase of grain size towards west by reworking and sorting processes. Thus the coarsest sediments can be found in the passages and in vicinity of the barrier reef near to the breaker zone.

The interplay and admixture of both low energy deltaic deposits and high energy carbonate elastics of the breaker zone are mainly controlled by sorting processes initiated by wave activity and currents (Fig. 4) which is confirmed by profound grain size analysis (KYAW 1982). Fig. 5 compiles the controlling sedimentological processes where carbonates and siliciclastics represent the end members of a continuous mixed facies spectrum. Thereby, pelagic and storm-induced processes play a subordinate role.

As Fig. 6 shows, facies and grain size distribution of Laucala Bay sediments correlate with the mineralogical composition of the sand fraction. Heavy minerals (mainly pyroxenes, amphiboles) of fluvial provenance are enriched in the higher energetic environments of the western Laucala Bay by reworking processes (coastal longitudinal transport, waves). Their content is diminishing with increasing distance to the delta channels and in approach to the barrier reef where carbonate particles completely dominate. The light/heavy mineral-ratio shows the same trend.

X-ray diffractograms to be run are expected to reveal the carbonate minerals-ratio of samples in order to evaluate the skeletons provenance from the diverse groups of organisms. Furthermore, the clay mineral assemblage of the Rewa delta sediments is to be analyzed.

As adjacent part of the barrier reef, Makuluva Island, displays slightly consolidated oolites (beach rocks) on its eastern beach where apparently the conditions for the formation of recent ooids are favorable. These samples like others of the outer reef flank have to be analyzed by microscopy of stained thin sections, X-ray diffractometry, SEM and C and 0-isotopes as well, in order to understand the occurring early diagenetic processes.

For extending the western Laucala Bay transect beyond the Suva barrier reef towards the off reef three other samples were recovered at 108 metres, 180 metres, and 405 metres. High portions of the clay fraction correlating positively with water depth, represent detrital input from the Rewa delta and transect through the reef passages. Bimodal grain size distribution at 108 metres gives evidence of recent/subrecent slumping processes at the steep reef flank.

ASTROLABE REEF DRAVUNI

A transect was run across the Astrolabe Reef and the lagoon nearby Dravuni by "APHAREUS". It comprises both Herald Passage and Usborne Passage as well as the fore reef and off reef on both western and eastern side (Fig. 2 B).

Dravuni Island Field Station served as base during the four days cruise. A base line study (MORRISON & NAqASIMA 1992) provides geomorphological, geological and biological results to the newcomer; even first mineralogical and chemical data are represented as well (MORRISON& NAIDU 1992).

This work focus as on sedimentary facies distribution and early diagenetic processes of reefs and beach rocks along the transect, where 38 stations were sampled.

Both reef flanks steeply slope down to the adjacent 2000 metres deep Suva Basin and Astrolabe Basin. Nevertheless, fine grained carbonate-bearing oozes could be recovered on the western side at water depths of 108 metres, 216 metres, and 486 metres, whereas recovery of samples was not successful on the eastern side despite several attempts. The reason seems to be extreme steepness of the reef.

Calcarenites and calcirudites alternate with biolithites within the lagoon where average water depths of some 30 metres dominate. Two or three samples were generally taken by diving (F. MANUELI, J. WORTZ) from the different reef types (RYLAND 1979) down to 30 metres water depth.

As Fig. 3 shows the almost pure carbonate sediments of the Astrolabe lagoon are generally coarser grained and therefore energetically higher deposited than the mixed sediments of the Laucala Bay. The high portion of clay/silt-fractions of the latter is caused by the siliciclastic input of the Rewa delta; the reef-dominated carbonate portions of the sediments of both study areas display comparable grain size distribution which is represented by poorly sorted calcarenites and calcirudites of low maturity initiated by continuous production of debris from the adjacent reefs, patch reefs, and coral knobs.

Volcano-detrital input from the volcanic island core of Dravuni (HOWORTH and CARMAN 1992) plays quite an unimportant role as part of the adjacent lagoonal sediments. Grain mounts display just a few light minerals (feldspars) and heavy minerals (pyroxenes; amphiboles, opaques). Among the carbonate constituents benthic foraminifera to be analyzed more in detail have been encountered. X-ray analysis of different grain size fractions will provide qualitative and quantitative data about the portions of carbonate minerals (calcite, Mg-calcite, aragonite) of the sediments with regard to their skeletal provenance.

According to the Suva barrier reef samples, the early diagenetic pattern will be studied by using stained thin sections, scanning electron microscopy (SEM), and C and O-isotopes.

These methods concern also several beach rock samples recovered around the islands of Dravuni, Oasibale, and Yaukuvelevu. Their sedimentological setting has to be brought in connection to changing sea level and Island uplifting (comp. MIYATA et al.. 1990, NUNN 1992).

MALAKE PASSAGE (VITI LEVU) - BLIGHWATER - YASAWA ISLAND

The campaign of "APHAREUS" was run from Suva along the eastern coast of Viti Levu to the Malake Passage where the first sample was recovered (Fig. 1). The striking of the transect was fixed with regard to alternating highs (platforms, Charybdis reef, Tivolei reef) and adjacent basins (Bligh Water) in order to obtain a significant facies discrimination dependant on relief, and water depth. In total 33 samples (including dives at Charybdis reef) were recovered along some 100 kilometres.

Grain size decreases from Malake Passage (calcarenites) towards the neighbouring basin where greenish clayey sediments are abundant. The southeastern slope of the Charybdis reef is mainly covered by calcarenites. The atoll-like reef complex itself displays a fairly continuous reef growth in its northeastern part whereas the southwestern part is characterized by reef patches. Major parts of the Charybdis reef seem to be dead, related to subsidence, though several patch reefs are still alive within the lagoon. Running across the Charybdis reef by a dinghy, grab samples reveal monotonous calcareous algae debris (Halimeda) without remarkable portions of coral fragments that might indicate the beginning overburden of the predominantly dead reef complex. No other samples except dive samples from the northwestern reef flank could be recovered because of reef steepness and lack of unconsolidated sediments.

The sediments of Bligh Water are generally described as rough and affected by strong currents (Captain BLIGH and even modern fishermen have been driven out through the Round Island Passage up to the Solomon Islands) and are uniformly characterized by greenish clayey oozes whose carbonate contents increase in approach to the Tivolei reef.

The Tivolei reef complex which is also not easily accessible by ships because of its patch reefs, can be compared to the Charybdis reef complex with regard to water depth and sediment type (calcareous algal rudites). Numerous sunken coral knobs are mentioned on the bathymetric chart.

Extending northwestward, an extremely narrow and steep trough 230 metres in depth does not display any sediments, though several attempts by grabs were made. It has to be assumed that strong currents remove immediately settling sediment on the canyon bottom towards the Round Island Passage and leave a blank basement of volcanics or carbonate rocks.

Approaching Yasawa Island calcirudites of calcareous algae composition dominate the carbonate platform occupied by many patch reefs, whereas poorly sorted calcarenites and calcisiltites indicate decreasing energy within Enene Bay. The northwestern Yasawa platform shows similar sediment types and energy conditions like its southeastern pendant.

Contrary to Laucala Bay and Astrolabe Lagoon, the calcareous shallow water sediments of this transect reveal lower portions of coral reef debris, but higher portions of calcareous algae while having a comparable grain size distribution. This significant difference characterizes the stage of the relating reefs of the study areas. X-ray analysis of the carbonate minerals ratio will confirm these macroscopic observations. Slight siliciclastic input of volcanic minerals (plagioclase, pyroxenes, amphiboles, opques) are present in Malake Passage and Enene Bay.

The basinal marls and clays have to be analyzed granulometrically and claymineralogically. The results can be used for facieB discrimination along the transect and for distinguishing them from the marly oozeB of the Suva basin. In the further course of the campaign samples of consolidated carbonate rocks of varying Cenozoic age were recovered from Islands of the Yasawa Group and Mamanuca Group in order to compare the diagenetic history of both recent and ancient formations.

The first concerns Holocene and subrecent beach rocks (Sava-I-Lau, Yaqeta, Yanuya, Monoriki) encountered as calcarenites and calcirudites. Even oolites have been found on Yanuya and Monoriki beaches where classic conditions for ooid formation occur. All these rock types inform about the kind and sequence of marine and meteoric cement precipitation and increase our knowledge about porosity history with regard to reservoir properties for hydrocarbons.

Secondly, additional sample recovering of late upper Miocene carbonate rocks will enhance Buch diagenetic studies. On Sava-I-Lau (RODDA 1989) andesites are overlain by a bank facies (Verona F.) and that, in turn, by massive reef facies (Sava-I-Lau Limestone). EASTON (1973) describes the transformation of aragonite to calcite and the complete cementation of the limestones. Finally, on Yanqeta late Miocene/Pliocene massive calcarenites overlying subaerial basalts (RODDA 1989) represent other useful samples.

All the samples recovered have to be analyzed by microscopy of stained thin sections, X-ray diffraction, SEM as well as by C and O-isotopes with regard to their diagenetic history.

PLEISTOCENE CORAL REEFS OF VANUA LEVU

Pleistocene reefs and related sediments of the Lau Group known as Uncuna Limestone as part of the Tokalau Limestone Group (WOODHALL in press) also occur along the southern coast of Vanua Levu at many places where they emerge up to 30 metres above sea level (WODDHALL 1976, RODDA 1989). Other occurrences of Uncuna Limestone are known from Viwa (TAYLOR 1978) and from Viti Levu (RODDA 1977).

My studies focus on outcrops on Vanua Levu (Nasewa, Naidi, Savasi, Naweni) and on Viti Levu (south of Sigatoka).

These Quarternary fringing reefs are of complex origin. Along the Hibiscus Road they display notches 1.52-1.65 metres and 2.22-3.30 metres above low tide level. Their recent platform shows Holocene coral incrustations and microatolls revealing 8^{14}C-ageS of 6000^{+200} 3400^{+170}a. B.P.(MIYATA) et al.. 1990) and of 4560^{+170} a. B.P. (MC LEAN 1979), (Fig. 7) (see also front cover).
The top portions of the reef complexes are strongly affected by karstification and host plenty of caverns, vugs, joints and even intraskeletal pores filled with lateritic internal sediments (Fig. 8). Since onset of growing they have been undergone marine and meteoric influence under subtidal, intertidal, and supratidal conditions. That makes evident how difficult the analysis of ancient reefs is since long periods have impact on such reef complexes which are growing both vertically and laterally.

Aspects such primary and secondary porosity, cement precipitation, dissolution directed by karstification, residual formations like lateritic soils and diaspor as internal sediments, dolomitization and reprecipitation of calcite are so complex that a broad spectrum of methods (microscopy, X-ray diffraction, SEM, cathodoluminisence, C and O-isotopes) has to be applied.

Such studies give useful information on the diagenetic history of carbonate rocks, which is relevant for a better understanding of them as potential reservoir rocks for hydrocarbons migrating from adjacent basins.

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Figure on front cover:

Emerged Qua ternary reefs displaying subrecent notches some 1.5 to 3.3 metres above recent low tide level. Naidi, Hibiscus Road, Vanua Levu.

Fig. 1:

Study areas across Fiji. A Laucala Bay, B Astrolabe lagoon, Dravuni, Kadavu-Group, C Malake Passage-Bligh Water-Yasawa.

Fig. 2A:

Echo sounding profile running from the Institute of Marine Resources wharf to the Nukumbuthu Passage, Laucala Bay.

Fig. 2B:

Echo sounding profile running from Dravuni Village to the Usborne Passage, Astrolabe Lagoon.

Fig. 3:

Triangular diagram of grain size groups of the sand fraction showing energy distribution in between river- and reef-dominated environments of the Laucala Bay, Astrolabe Lagoon, and Malake-Bligh Water-Vasawa transects.

Fig. 4:

Distribution of sediment-controlling factors at Laucala Bay.

Fig. 5:

Interrelationship of sediment-controlling factors at Laucala Bay.

Fig. 6:

Triangular diagram showing carbonate, light mineral, and heavy mineral assemblages of the sediments at Laucala Bay.

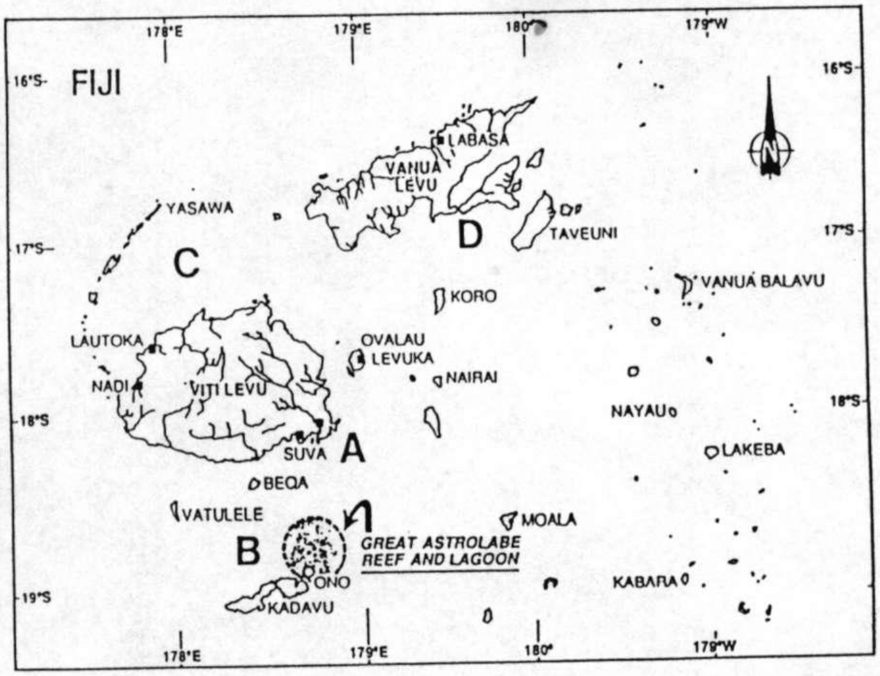
Fig. 7:

Schematic profile through emerged subrecent reef complexes along the Hibiscus Road, Vanua Levu.

Fig. 8:

A: Platform, cliff and notch of subrecent emerged reefs which are karstified. The dark masses are lateritic internal sediments with diaspar (A1O OH) weathered out. Mrs. D. TOSHIKO PFAELTZER; Savasi Island, Vanua Levu.

B. Karstified reef limestone showing a network of fissures and vuqs displaying laterlile internal sediments, Savasi Island. Vanua Levu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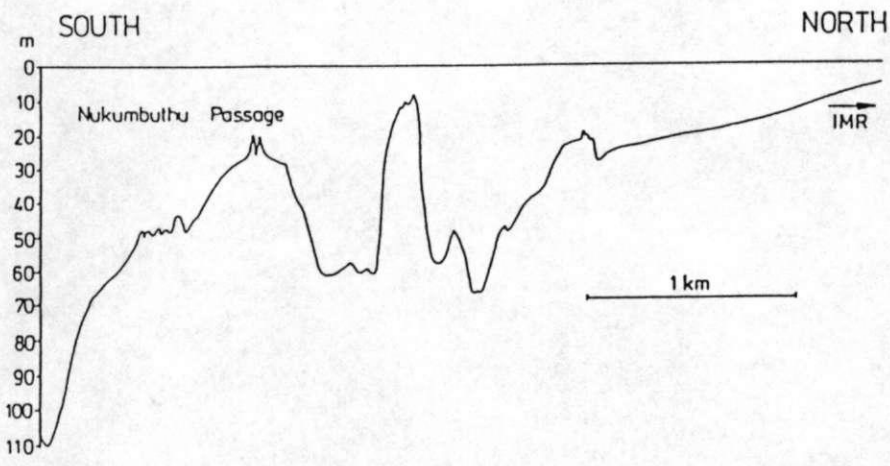
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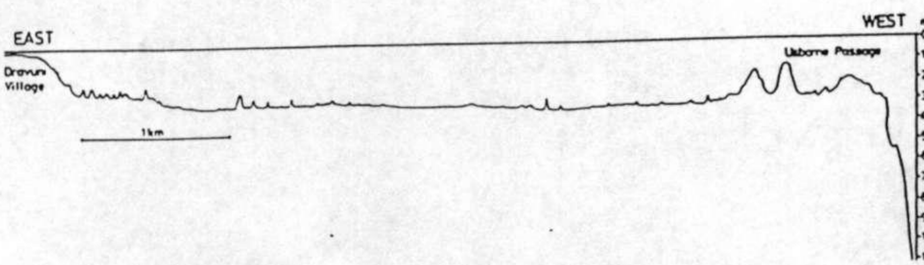
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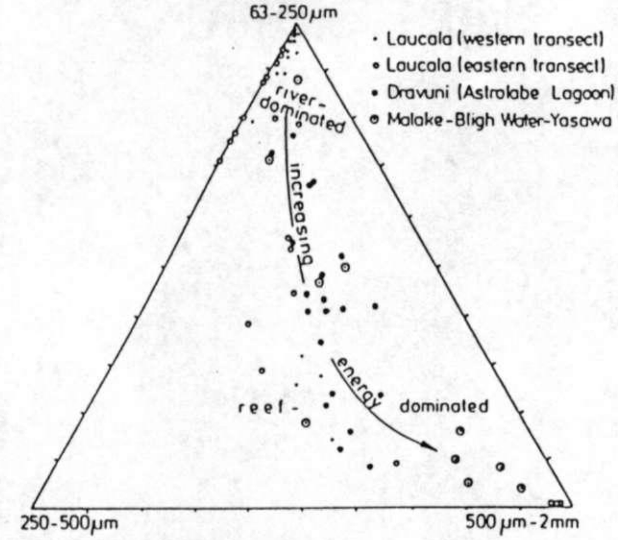
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Laucala (eastern transect)
Dravuni (Astrolabe Lagoon)
Malake-Bligh Water-Yasawa
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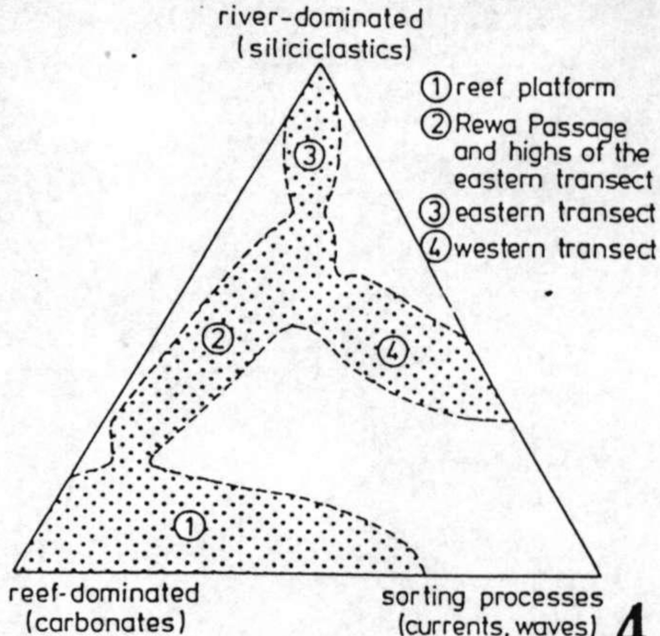
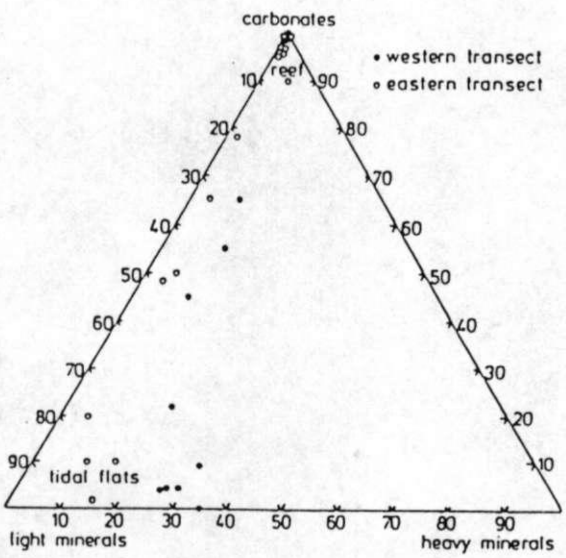
increasing
energy
reef-
dominated
250-500µm
500µm-2mm

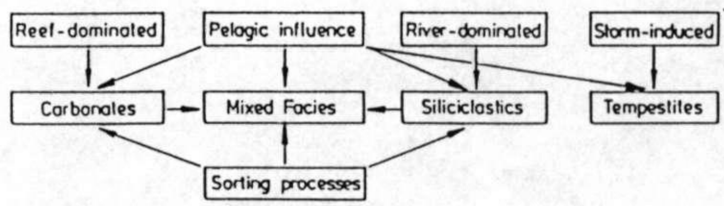
3


river-dominated
(siliciclastics)
① reef platform
② Rewa Passage and highs of the eastern transect
③ eastern transect
④ western transect
reef-dominated
(carbonates)
sorting processes
(currents, waves)

4


carbonates
western transect
eastern transect
reef
tidal flats
light minerals
heavy minerals

5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Pelagic influence
River-dominated
Storm-induced
Carbonates
Mixed Facies
Siliciclastics
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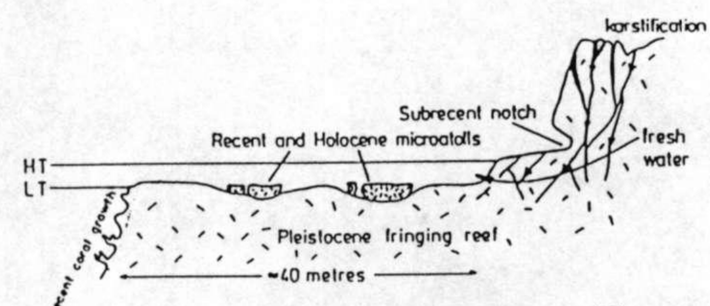
Sorting processes

6


karstification
Subrecent notch
Recent and Holocene microatolls
fresh water
HT
LT
recent coral growth
Pleistocene fringing reef
~40 metres

7