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CHAPTER 9

SEDIMENT FACIES OF THE COCOS (KEELING) ISLANDS LAGOON

BY

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ABSTRACT

Surficial sediments from the Cocos (Keeling) Islands lagoon were classified according to texture and composition using factor analysis. Six main textural facies: i) slightly gravelly coarse sands, ii) slightly gravelly medium sands, iii) gravelly sands, iv) sandy gravels, v) gravelly muds, vi) slightly gravelly fine sands; and three main compositional facies (i) coral-type sediments, ii) molluscan mud sediments, iii) coralline algae/*Halimeda* type sediments were identified, accounting for over 90% of sediment variation in the lagoon. These facies can be related to the provenance of constituent components and lagoonal hydrodynamics.

INTRODUCTION

The main atoll of the Cocos (Keeling) Islands (96°48'-56'E; 12°04'S) consists of a horse-shoe shaped reef rim, on which 26 reef islands lie, surrounding a central lagoon of approximately 190 km^2. The lagoon can be divided into two broad provinces, the deeper (8-15 m) northern basin and the shallower southern flats (0-3 m) (Fig.1). Blue holes exceeding 20m depth occur in several parts of the lagoon, but are most obvious across the shallower southern flats. A more detailed description of lagoonal marine habitats is provided by Williams (this volume), and they are mapped in Figure. 2. At the north of the atoll, deep and wide passages either side of Horsburgh Island connect the lagoon to the open ocean. Other exchange between the lagoon and ocean is restricted to 11 shallow reef flat passages situated on the eastern and southern atoll rim. Currents through these reef passages are predominantly unidirectional into the lagoon, probably driven by the persistent southeast trade winds which prevail for most of the year, and wave set-up generated by the swells which continually break over the windward reef crest. The hydrodynamics of this atoll have been examined recently by Kench (this volume).

Lagoonal infilling by sediments produced on the reef rim is generally accepted as the dominant constructional process on atolls after the reef rim has reached a stable sea level (Marshall and Davies 1982, Frith 1983, Tudhope 1989). Upward growth of the reef rim has been limited by sea level for more than 2000 years on the Cocos (Keeling) Islands (Woodroffe et al. 1990a, 1990b, this volume), and historical accounts (Darwin 1842, Guppy 1889) indicate that much of the southern part of the lagoon has been rapidly infilled. During his visit in 1836 Darwin sailed to the south of the lagoon through channels dredged through living coral. Sand sheets or seagrass meadows which are often exposed at low tides now cover these areas. Vibrocore data were used to establish the nature and chronology of longer term (mid-late Holocene) accretion in several parts of the lagoon (Smithers et al. in press).

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Sediments infilling atoll lagoons consist almost entirely of skeletal carbonate secreted by reef organisms, and facies development within atoll lagoons is governed by interaction between the supply and physical properties of the source material and the various processes which degrade, redistribute and stabilize sediments (Maxwell et al. 1964, Milliman 1974). Biogenic carbonates may consist of either rigid reef framework or unconsolidated detrital material, and may be produced and deposited *in situ* (autochthonous) or produced outside the lagoon and transported in before deposition (allochthonous). The relative contributions of allochthonous and autochthonous sediments usually varies around a lagoon, and can be determined from the texture and provenance of contributory components (Swinchatt 1965, Orme 1973). Reconciling the habitat zone of the source organism with the location of the depositional zone, and the determination of textural gradients between sediment sources and sinks, allows hydrodynamic, sediment transport, and facies development processes to be inferred.

There have been few studies of the lagoonal sediments of Indian Ocean atolls and the lagoon of the Cocos (Keeling) Islands differs in several ways from other atolls where sedimentation has been examined. Firstly, the sediment producing biota of the Cocos (Keeling) Islands appear to differ from other atolls, possibly due to its extreme isolation. Secondly, the size, bathymetry and hydrodynamics of this lagoon differ from other atolls where carbonate sedimentation has been investigated. Early studies chiefly examined sediments from the relatively large and deep Pacific atolls with lagoons which deepen towards the centre (e.g. Kapingamarangi - McKee et al. 1959, Bikini, Rongelap, Enewetok - Emery et al. 1954). Smaller atoll lagoons with complex bathymetry have more recently received some attention (Mataiva, Takapoto - Adjas et al. 1990, Henderson Reef - Chevillon and Clavier 1990, Mataiva - Desalle et al. 1985), but once again are concentrated in the Pacific. This paper reports on an examination of the surficial lagoonal sediments of the Cocos (Keeling) Islands, a moderately sized Indian Ocean atoll with a complex lagoonal bathymetry. The primary aims were to: (1) determine the textural and compositional characteristics of lagoon surface sediments; (2) identify and map textural and compositional facies; and (3) relate facies distribution to specific biotic/physiographic environments.

METHODS AND MATERIALS

The lagoon floor was examined on a series of boat and snorkel transverses. A total of 167 sediment samples were collected from the lagoon bed (Fig. 3), using a sampling strategy based on environments determined from aerial photographs and SPOT satellite imagery. Not surprisingly, the lagoonal environments delineated in this way are very similar to the marine habitat units established by Williams (this volume). Samples were collected by scooping unconsolidated sediments into plastic bags except in depths that exceeded 8m when a weighted steel dredge was used.

Seventy-six sediment samples were analysed granulometrically using the techniques of Folk (1974), making sure that several samples from each lagoonal environment were examined. Where necessary the mud fraction was first separated by wet sieving; these samples were washed with 200 ml of distilled water and approximately 1ml of 10% Calgon for each gram of estimated mud content. The mixture was left to stand overnight then mechanically stirred for 3 minutes and washed through a 4ø sieve. Sediments larger than 4ø were dried, weighed and between 50-70grams transferred to a nest of sieves ranging from -2ø to 4ø, with a 0.5ø interval. The sieves were mechanically shaken for 15 minutes and the fraction retained on each sieve (and the pan) weighed.

Mean grain size, sorting and skewness were determined using the graphic methods of Folk and Ward (1957).

The skeletal compositions of 50 sediment samples were examined. Representative subsamples were taken from sieve fractions greater that 3.5ø and grains were identified and point-counted using a binocular microscope. Approximately 100 grains were identified for each sieve fraction. Fifteen component categories were recognized: (i) coral shingle and grit; ii) *Halimeda* fragments; iii) coralline algae (principally *Spongites* rhodolith fragments); iv) *Homotrema*; v) gastropod fragments; vi) pelecypod fragments; vii) unknown molluscan fragments; viii) *Marginopora*; ix) *Amphistegina*; x) other foraminiferans; xi) echinoids; xii) annelids; xiii) alcyonarian spicules; xiv) crustacean fragments; and xv) indeterminate or unrecognisable grains. Component representation in the total sample was expressed as a weight percentage of the total sample. Granulometric and compositional data were analysed using Q-mode factor analysis (Klovan 1966, 1975, Gabrie and Montaggioni 1982, Montaggioni et al. 1986) in order to classify sediments according to their compositional and textural characteristics (Smithers 1990).

RESULTS

SEDIMENT TEXTURE

The textural characteristics of seventy-six sediment samples from the Cocos (Keeling) Islands lagoon are presented in Table 1 and descriptive statistics for each of the lagoonal environments provided in Table 2. These results indicate that the Cocos (Keeling) Islands lagoon is dominated by poorly sorted, slightly gravelly (<10%) fine to coarse sands. Several general trends in sediment texture can be identified. Mean grain size is greatest in the interisland channels and is lowest in the seagrass meadows and intertidal sand and mud flat areas. Gravel abundance appears closely related to coral outcrop proximity, the highest mean values occuring in the interisland channels where autochthonous gravels are deposited with allochthonous gravels transported from the reef flats, and in the blue hole mosaic where gravels derived from patch reefs are common. Occasional high gravel values in samples collected elsewhere in the lagoon can largely be attributed to the deposition of autochthonous carbonates. Mud content peaks at around 45% in the seagrass meadows but generally comprises 0-2% of most sediment samples. Sorting is typically poor, but improves in the exposed sandy areas in the north of the lagoon. Skewness values range from strongly fine skewed to strongly coarse skewed, and in different areas may reflect either *in situ* sediment production or else the selective removal of certain grain sizes by incident currents. The significance of variation in the textural traits of lagoon sediments will be addressed in the discussion.

Six factors were extracted from the data matrix of 14 variables (weight % of sediment in each sieve fraction) and 76 observations (sediment samples) using a Q-mode factor analysis which can account for 91.7% of the data variance. Communality values are high for all samples indicating that a good description of all samples is given by these factors. Sediment samples were classified according to the factor axis each was most heavily loaded upon; samples belonging to each class are listed in Table 3. The grain size distributions of samples with the highest loading on each factor axis are presented in Figure 4 and the average textural statistics of sediments assigned to each factor are given in Table 4.

Descriptions of the textural sediment types classified on each factor axis are provided below and their distribution is shown in Figure 5:

Factor One - Slightly Gravelly Coarse Sands. These sediments account for over one third of the samples and are chiefly composed of coarse sands with a minor gravel component (Fig. 4a and Tables 1 and 2). The grain size distribution is characterised by a primary mode in the 0ø-0.5ø range and the mean grain size is around 0.5ø. Muds usually form less than 1% of these sediments. Sorting and skewness are variable; ranging from moderately well to poorly sorted and from strongly fine to strongly coarse skewed. Slightly gravelly coarse sands occur throughout the lagoon, but appear to be most concentrated in the exposed areas of the deeper northern part of the lagoon and around the interisland channels.

Factor Two - Slightly Gravelly Medium Sands. These sediments are very similar to those defined by factor one, however the sand fraction is finer with the principle mode being between 1.5ø-2ø (Fig. 4b). Sediments represented by this factor range from moderately well to poorly sorted and show a tendency to be coarse skewed. These sediments cover much of the lagoon floor, being patchily interspersed with the slightly gravelly coarse sands in the north of the lagoon and covering large areas north of the southern passage.

Factor Three - Sandy Gravels. High gravel content is the definitive trait of these sediments, with the grain size distributions peaking in the >-2ø interval (Fig. 4c). They are typically finely or very finely skewed and range from poorly to moderately sorted. A second, smaller modal peak may occur in the sand sized range. Sandy gravel patches are sporadically distributed within the lagoon, with three distinct patches located in the centre of the lagoon and another occuring south of Horsburgh Island. Smaller pockets of sandy gravel are located just north of both Pulu Maria and the seagrass meadows behind South Island.

Factor Four - Gravelly Sands. These sediments are composed principally of sands, but also have a moderate gravel content (Fig. 4d). Grain size distributions are often bimodal, reflecting the poor sorting and variable skewness of most of these sediments. Gravelly sands are also patchily distributed over the lagoon, with a distinct band located lagoonward of the islands on the eastern rim. Several smaller patches occur towards the lagoon centre.

Factor Five - Gravelly Muds. Abundant fine sands and muds characterize these sediments, although gravels are also moderately well represented (Fig. 4e). Sorting, therefore, is typically poor and most grain size distributions coarsely skewed. Gravelly muds occur in the lee of the windward islands and in the shallow embayments locally known as Teloks.

Factor Six - Slightly Gravelly Fine Sands. Fine sands in the 2.5ø-3.0ø range dominate these sediments. The fine sands may grade into muds in some samples and they are usually coarse skewed and poorly to moderately sorted (Fig. 4f). Patches of slightly gravelly fine sands are found throughout the lagoon, however they are more common in the north central areas.

SEDIMENT COMPOSITION

The skeletal compositions of 50 samples collected from the Cocos (Keeling) Islands lagoon are listed in Table 5 and the average composition of sediments deposited in each lagoonal environment presented in Table 6. It is evident from this table that the abundance of skeletal constituents may vary markedly between different lagoonal environments. Furthermore, relatively large standard deviation values suggest that sediment composition may also vary markedly within lagoonal environments.

Nevertheless, several general statements can be made about the composition of sediments deposited within this lagoon. Coral debris clearly dominates most samples (range: 81.46% in sample 12 to 11.05% in sample 58), comprising the major identifiable component in all lagoon environments (see Table 6). *Halimeda* and coralline algae also contribute significantly to many samples (*Halimeda* >15% of samples 24, 29, 45, 48, 49, 58, 124, 171; coralline algae >15% of samples 6, 34, 58, 66, 125, 164, 165, and vibrocore cv15), particularly those collected where hard coral substrates exist, such as the blue hole mosaic and the interisland channels. Coralline algae may either encrust other constituents or consist of rhodolith debris, the later being spherical coralline algae colonies which are particularly abundant in the high energy interisland channels. The *Acropora* shingle which is widespread over the central lagoon floor is also heavily encrusted with coralline algae and represents a potential source of this material. *Homotrema* is a minor contributor to lagoonal sediments (range: 2.48% in sample 24 to 0% in many samples) but appears most abundant close to high energy, hard substrate environments. Gastropod detritus comprises around 5% of the sediment in most lagoonal environments, rising to an average of over 10% in the intertidal sand and mud flat areas, and accounting for more than 10% of some samples from the seagrass meadows (117, 122). Pelecypods comprise less than 5% of most samples, but contribute 9.8% and 9.35% of samples 108 and 38 respectively. *Marginopora* tests make up 0-4% of most samples with no clear pattern to their distribution being immediately apparent. *Amphistegina* is a widespread but locally significant component, being most prolific on the reefs south of Horsburgh Island and in the sandy lagoon floor region in the north of the lagoon. Annelida, alcyonarian spicules, crustacean debris and echiniod spines are generally present in small quantities. Crustacean detritus can, however, occasionally be quite high in areas where living crustaceans are plentiful (i.e. sample 39 from Telok Jambu - 7.85%). Alcyonarian spicules represent only a small proportion of most sediments (range: 6% in sample 50 to 0% in many) but appear most abundant in samples just lagoonward of the reef rim. Indeterminate sediments include sediments <3.5ø and those not readily recognisable because of corrosion. As outlined in the textural results, the abundance of fine sediments is greatest in the seagrass meadows and intertidal sand and mud flat areas. The -0.5ø fraction of a sheltered seagrass meadow, interisland channel, interisland channel/ sand apron and central lagoon sample is presented in Figure 10a-d.

Three factors were extracted from the data matrix covering 15 component variables and 50 sediment samples. All samples except 153 have high communality values, suggesting that a good description of most samples is given by these factors. The lower value for sample 153 probably reflects the exceptionally high representation of *Amphistegina* in this sample, this being more than five times greater than in the sample with the next highest representation. Samples were classified according to the axis upon which they were most heavily loaded except where samples had similar loadings on more than one axis. Loadings were considered similar if the absolute difference between loadings on different axes was less than a third of the larger loading value, and where this occurred samples were deemed to be hybrids. Samples belonging to each class defined by the factor analysis are listed in Table 7 and pie charts showing the composition of the sample most heavily loaded on each factor axis are presented in Figure 6. These and the average compositional facies statistics are presented in Table 8.

Descriptions of the compositional sediment types discriminated by the factor analysis are provided below and their distribution is presented in Figure 7.

Factor One: Coral-Type Sediments. Coral-type sediments are chiefly characterised by the compositional dominance of the sample by coral debris. More than 60% of samples collected from the Cocos (Keeling) Islands lagoon are classified as coral-type sediments, conforming with the preponderance of coral evident in the raw compositional data. Skeletal material derived from organisms commonly associated with hard coral substrates (i.e. *Homotrema, Amphistegina,* annelids and alcyonarian spicules) also reach their highest representation in this facies. Most of the lagoon bed is covered by sediments most adequately described as coral-type, the main exceptions being the areas in the lee of the windward islands.

Factor Two: Molluscan Mud Sediments. A large indeterminate component is characteristic of these sediments and they contain a noticeably smaller quantity of recognisable coral debris than the coral-type sediments depicted by factor one. Gastropod debris is also found in these sediments in moderate amounts, reaching its highest representation in this facies. Crustacean debris is also significantly more abundant in these sediments than in any of the other facies, and *Marginopora* is most prolific in these sediments. Molluscan mud sediments are predominately restricted to the shallow protected parts of the lagoon, however there are outlying patches in the north and central lagoon.

Factor Three Coralline Algae/Halimeda Type Sediments. These sediments are essentially differentiated because they contain a relatively high proportion of coralline algae and *Halimeda* and a relatively low proportion of coral debris. Abundant rhodolith debris determines that sediments deposited in the lee of Pulu Maria and Pulu Siput are most heavily weighted on this factor, whilst *Halimeda* debris is responsible for sediments on the edge of the seagrass meadows in the lee of South Island being loaded on the third factor axis.

DISCUSSION

The nature and distribution of sedimentary facies in the Cocos (Keeling) Islands lagoon essentially reflects the interaction of wave and current energy on skeletal sediments derived from a range of organisms growing in different lagoon environments. The reef islands and a discontinous reef rim control the distribution of wave and current energy within the lagoon; directly controlling the entry and distribution of allochthonous sediment, indirectly controlling the distribution of autochthonous sediments by influencing biotic zonation, and controlling the redistribution of sediments within the lagoon. Three main features characterise the sedimentary facies of the Cocos (Keeling) Islands lagoon, these being: 1) the domination of the lagoon by coral derived sediments; 2) sediment sorting in areas of relatively high hydrodynamic energy and the deposition of predominantly poorly sorted sands and gravels in the centre of the lagoon; and 3) the concentration of mud deposits in the lee of the windward islands, almost exclusively in the seagrass and intertidal sand and mud flat environments.

The predominance of coral derived sediments and subsequent coverage of most of the lagoon by the coral-type compositional facies is a striking feature of the Cocos (Keeling) Islands lagoon (Fig. 7), which is even more remarkable considering the dearth of living coral presently on this atoll. Compared to other carbonate lagoons coral components comprise an inordinate proportion of the sediments deposited in this lagoon (Fig. 8). Several possible reasons exist for the high representation of coral sediments in this lagoon, including its relatively small size and shallow nature. Milliman (1974) suggested that because the ratio of lagoonal area to reef rim becomes smaller as atoll size declines smaller lagoons are more likely to receive a higher proportion of reef flat sediments, including a substantial proportion of coral material. Alternatively, because much of the Cocos (Keeling) Islands lagoon is less than 10 m deep, a depth range dominated by corals in many reef environments (Emery et al. 1954 Stoddart 1969, Milliman 1974), it is perhaps not surprising that coral sediments are abundant here. Indeed, coral outcrops are common throughout most of the Cocos (Keeling) Islands lagoon, imparting a reefal character on most lagoonal sediments. Moreover, lack of net bathymetric relief has restricted the habitat potential of this lagoon and many components and facies derived from organisms normally found in deeper water are poorly represented here (e.g. the deep water *Halimeda* facies reported from deeper lagoons like Suwarrow (Tudhope et al. 1985), Kapingamarangi (McKee et al. 1959) and Enewetok (Emery et al. 1954)).

The geomorphic history of the atoll may provide another explanation for the abundance of coral derived sediments in this lagoon. Woodroffe et al (1990a, 1990b, this volume) have established that approximately 3000 years ago sea level on this atoll was close to 1m higher than present, and that at this time a sea-level limited reef flat encircled much of the lagoon. Sea-level has subsequently fallen to its present level and most of this higher reef flat has been substantially eroded, remnants existing as the contemporary conglomerate platform. Clearly the erosion of this fossil reef flat comprises a potentially significant source of coral sediments which may have been transported around the atoll under different physiographic conditions as the atoll has developed. Prior to the consolidation of the larger islands (particularly South Island), for example, coral sediments were presumably transported into the lagoon through more numerous interisland channels and could potentially achieve a more widespread coverage of the lagoon.

Although coral-type sediments veneer most of the lagoon (Fig. 7), specific areas are covered by sediments which are more or less coral-type than others (i.e. are more or less heavily loaded on the first factor axis due to variations in the abundance of coral and other components), and textural parameters delineate two distinct source zones, the reef rim and the lagoon. Deposits formed by allochthonous material transported from the reef rim are typically most strongly defined as coral-type sediments and those composed of autochthonous material produced within the lagoon less so, reflecting a change from a strongly reefal component assemblage (i.e. coral, coralline algae, *Homotrema,* alcyonarian spicules, *Amphistegina*) to a moderately lagoonal one (reefal components less well represented, fine indeterminate sediments more abundant) (Table 6).

The sandy lagoon floor region is exposed to high levels of wave and current action due to the discontinuous nature of the reef rim at the north of the atoll and the textural traits of sediments deposited there reflect this position. Extensively rippled coarse sands which are near symmetrically skewed and well sorted dominate this area, interupted sporadically by localised seagrass patches and small coral bommies. Sediments deposited here are texturally mature; reflecting the relatively high levels of wave and current energy affecting this area and the rarity of locally generated gravels. Speculation of a peripheral reef source for these sediments is supported by high *Homotrema, Amphistegina* and alcyonarian spicule content; these components normally originating from high energy reef zones and confering a strong coral-type classification on these sediments. Ripple orientation suggests that most of this material is transported from the northeast reef rim. Unlike in much of the southern part of the lagoon these sediments remain submerged at all tidal stages and are continually affected by waves and currents, enhancing their sorting potential. Similarly well sorted and rippled sands are described from the Alacran Reef Complex, Mexico (Kornicker and Boyd 1962) and the lagoon of Enewetok atoll (Wardlaw et al. 1991) and are thought to have developed under similar environmental conditions.

Interisland channels link the high energy and highly productive outer reef flats to the lagoon along the eastern and southern atoll margin and act as a conduit for hydrodynamic energy and sediments entering the lagoon. Waves and currents forced over the windward reefs are concentrated through these channels developing relatively high levels of hydrodynamic energy which dissipates into the lagoon. The composition and texture of sediments deposited through these channels is distinctly reefal, consisting of sands and gravels derived from organisms typically located on high energy reefs such as coral, coralline algae, alcyonarian spicules, *Homotrema* and *Amphistegina*. Not suprisingly these sediments are unequivocally coral-type in composition. The relatively high levels of hydrodynamic energy which affect these channels is reflected by the mean grain size (0.02ø: the largest in the lagoon), and by the deficiency of fine sediments which are continually winnowed and transported into the lagoon. Despite the winnowing of fine sediments interisland channel deposits are generally poorly sorted and texturally immature, reflecting the heterogeneity of contributing organisms and the continual addition of variably degraded 'in-train' clasts. Three samples from the Southern Passage illustrate the coarse nature, in-train addition and textural immaturity of sediments deposited in the interisland channels, these samples (23, 24, 58) located in close proximity to each other and classified respectively as a slightly gravelly coarse sand, a sandy gravel and a gravelly sand.

Coral-type sediments dominate the slightly gravelly medium sands which extend from the interisland channels over the sand aprons and through much of the lagoon centre (Figs. 4 and 6). Despite the continuity of these facies beyond the sand apron fringe (Fig. 2), however, textural gradients in samples collected from the sand aprons and changes in minor component abundance suggest that sediments deposited over sand aprons are allochthonous whilst those deposited beyond these features are autochthonous. The evolution of analogous textural attributes in skeletal carbonate deposits due to either hydrodynamic sorting or skeletal architecture is a principal shortcoming of carbonate texture as an environmental discriminator (Stoddart 1969, Montaggioni et al. 1986) and is well demonstrated here. The redeeming usefulness of textural gradients for environmental interpretation is, however, also confirmed.

Extending into the lagoon over the sand aprons a marked decline in gravel content (24.89% to 7.94%) and an increase in the proportion of sands (74.92% to 90.97%) and muds (0.18% to 1.08%) occurs, conforming elegantly with models of lagoonal sedimentation which predict a systematic decline in mean grain size with distance from the reef rim (Frith 1983, Chevillon and Clavier 1988). Size-sorting is characteristic of backreef sand aprons on other reefs where hydrodynamic energy levels abate into the lagoon and are paralleled by a decline in mean grain size (Macintyre et al. 1987). Size-sorting generally becomes evident from around the mid-range of sand aprons extending into the Cocos (Keeling) Islands lagoon; sediments deposited at this distance from the interisland channels sufficiently removed from locally generated sediment sources to attain some degree of textural maturity. Textural gradients and composition indicate that the sand aprons predominantly comprise allochthonous sediments shed from the reef rim. Similar backreef sand deposits are described in the Pacific (Marshall and Jacobson 1985, Scoffin and Tudhope 1985, Tudhope 1989), where medium grade coral sands also dominate the lagoonward fringe. The penetration of allochthonous sand aprons in the Cocos (Keeling) Islands lagoon is similar to that reported from other reefs (Scoffin and Tudhope 1985), however at this atoll they are spatially restricted to where interisland channels link the outer reef flat to the lagoon and concentric backreef facies belts do not develop.

The systematic decline of mean grain size ceases at the lagoonward margin of the sand aprons essentially marking the limit of allochthonous slightly gravelly medium sand penetration into the lagoon. Grain component data (Table 6) support the assertion that allochthonous sediments (greater than mud-sized) penetrate the lagoon only as far as the sand apron margins, sediments deposited over the lagoonward parts of the sand aprons being generally rounded whilst those deposited beyond sand apron fringes are predominantly angular and autochthonous. The range of the coralline algae/*Halimeda* facies which extend from the interisland channels immediately east of West Island and north of South Island further supports this speculation, and demonstrates the utility of skeletal carbonates derived from habitat specific organisms as biogenic tracers of sediment transport. These facies are chiefly comprised of rhodolith debris originating from these channels which can be traced, and is size-sorted, towards the lagoonward sand apron fringe. Kench (pers. comm) has suggested that the flood tidal wave entering the lagoon from the north opposes currents flowing through the Southern Passage around the lagoonward sand apron fringe, possibly impeding the transport of allochthonous sediments beyond this point. Immediately beyond the lagoonward sand apron margins the textural trends imposed by hydrodynamic sorting are corrupted by the addition of autochthonous gravels and sands and the skeletal architecture of contributing organisms becomes the principal determinant of facies texture. The lagoonal limit of allochthonous sediments may be obscured, however, when they prograde over gravel bearing reefs such as those fringing the blue holes behind the eastern reef islands. Here a band of gravelly sands has developed when transported and sorted allochthonous sands mix with and are texturally overwhelmed by gravels derived from the lagoonal patch reefs.

The irregular mosaic of textural facies covering the central part of the lagoon suggests that sedimentation is chiefly governed by the locally abrupt bathymetric (and environmental) change imposed by the blue holes and the sporadic occurrence of patch reefs and lag gravel deposits. Formed as autochthonous material is deposited *in situ*, the textural characteristics of these facies are dependant on the grain sizes yielded as contributing organisms degrade, and the extent to which hydrodynamic conditions modify these deposits. Sediments through the centre of the lagoon are characteristically poorly sorted and coherent textural gradients are lacking, indicating the absence of significant hydrodynamic modification. Low mud values suggest, however, that fines may be winnowed from exposed deposits. The prevalence of coral debris through the centre of the lagoon is convincingly demonstrated by the distribution of the coral-type compositional facies, and the mosaic of textural facies which occurs through the same region can largely be ascribed to the variable representation of epilithic gravels derived from lagoonal patch reefs. The irregular bathymetry around the blue holes further ensures an erratic distribution for textural facies in this part of the lagoon via its control of patch reef distribution. Essentially these sediments are composed of medium to coarse coral sands supplemented with varying amounts of epilithic coral gravels to form various grades of gravelly sand and sandy gravel facies. The distribution of compositional facies other than coral-type is related to the occurrence of the definitive organisms, the presence of which may also impart distinctive textural properties. Isolated molluscan mud and coralline algae/*Halimeda* facies in the central part of the lagoon, for example, occur where the representation of their definitive components is high, and where largely intact and gravel sized mollusc shells and *Halimeda* segments respectively induce local coarsening of facies texture. Though coral detritus undoubtedly dominates most sediments through this area of the lagoon, the extent to which it does so and the representation of minor components varies considerably both within and between lagoonal environments (Tables 5 and 6), largely reflecting the diffuse and weakly zoned distribution of contributing organisms and the *in situ* deposition of derived sediments. Despite local variations in the representation of minor components, however, the overwhelming dominance of coral debris and the relative constancy of the component assemblage through the lagoon centre, which can be attributed to the lack of strong environmental and hydrodynamic gradients, has determined that except for at the extreme environments in this lagoon distinctive correlations between lagoonal environment and compositional/textural facies are difficult to define. Widespread facies-environment coincidence has been demonstrated in many carbonate emvironments (Ginsburg 1956, Swinchatt 1965, Boscence et al. 1985), however similarly poor correlations between facies distribution and lagoonal environment are reported from other lagoons where environmental/hydrodynamic condtions remain constant over most of their area (Colby and Boardman 1989).

The distribution of fine sediments within the Cocos (Keeling) Islands lagoon exhibits the strongest and most consistent textural/compositional facies and lagoonal environment correlation. In contrast to other lagoons where muds winnowed from the high energy peripheral zones accumulate in the lagoon centre (McKee et al. 1959, Roy and Smith 1971), significant mud deposits in the Cocos (Keeling) Islands lagoon are confined to the sheltered depositional environments in the lee of the windward islands. The concentration of mud facies behind windward reef islands is also described from the Tarawa atoll and Chesterfield Islands lagoons where reef islands effectively isolate the lagoon in their lee from erosional waves and currents. In the Cocos (Keeling) Islands lagoon muds are almost exclusively deposited in the seagrass meadow and intertidal sand and mud flat environments in the lee of South Island and in the West Island teloks (Figs. 2 and 4), with a marked concurrence of environment and facies boundaries. In addition to the sheltered position, the current reducing affects of benthic flora may enhance fine sediment deposition over the seagrass meadows (Ginsburg and Lowenstam 1958, Swinchatt 1965, Scoffin 1970), and intertidal periods of subaerial exposure may aid the accumulation of fine sediments in the intertidal sand and mud flat areas. Adjas et al. (1990) have demonstrated that most carbonate muds deposited in atoll lagoons are biogenic rather than chemogenic, and it is likely that the muds deposited in the Cocos (Keeling) Islands lagoon are produced by the attrition of larger skeletal carbonates (due to biological and physical action). Although some of these fine sediments are no doubt produced *in situ* it is likely that fines winnowed from elsewhere in the lagoon and transported to these sites comprise a significant proportion of these muds. In these low energy settings 'currents of delivery' rather than 'currents of removal' (Orme 1973) principally govern facies texture. The muds are deposited with autochthonous gravels and sands derived from indigenous molluscan, and to a lesser extent crustacean and coral gravels to form the gravelly mud/molluscan mud facies depicted in Figures. 3, 4, 5 and 6. Abundant molluscan and crustacean faunas presently inhabit the areas of the lagoon where muds are deposited and generate significant quantities of gravel sized sediment, however coral gravels in these deposits usually consist of lag material deposited under different physiographic conditions (i.e. prior to being isolated from the reef rim by the reef islands) or else brought to the surface by bioturbation. The skeletal remains of organisms indigenous to the seagrass meadows and intertidal sand and mud flats are particularly well represented in the recognisable fraction of these sediments (e.g. crustaceans, gastropods, *Halimeda, Marginipora*), and are normally deposited reasonably intact. The fragile tests of the epibiontic foraminiferan *Marginopora*, for example, remain relatively undamaged in these deposits but are usually fragmented in sediments deposited elsewhere. Furthermore, minor components derived from high energy reef areas (e.g. *Homotrema, Amphistegina*, alcyonarian spicules) are poorly represented.

Muds are only nominally present outside of these areas, isolated deposits of finer sediment elsewhere in the lagoon essentially developing due to local modification of the hydrodynamic regime by seagrass beds, patch reefs and bathymetric change. Isolated patches of slightly gravelly fine sand amongst the generally coarse sediments of the high energy sandy lagoon environment can be directly attributed to patches of the seagrass *Thalassodendron,* the blades of which reduce current velocity and induce the deposition of finer sediment which is then stabilised by the root system (Scoffin 1970). The association of molluscs (and molluscan debris) and seagrass evident in the *Thalassia* seagrass meadows behind South Island is also apparent in the isolated *Thalassodendron* patches, and sediments over these patches are compositionally classified as molluscan mud sediments. Muds also settle from suspension and accumulate at the base of many of the blue holes where low energy levels predominate, and pockets of muddier sediment are often deposited around patch reefs which impede current flow. These sediments are also often compositionally classified as molluscan muds, however it is the domination of fine indeterminate/mud sediments in these areas which confers this classification. The deposition of muds adjacent to patch reefs due to their modification of lagoonal currents has similarly been reported by Frith (1983) and Delasalle et al. (1985) and muds are reported to accumulate at the bottom of lagoonal 'pools' in Fanning Lagoon (Roy and Smith 1971). The concentration of fine sediments in sheltered areas behind the windward islands and their general absence elsewhere suggests that ambient lagoonal currents are sufficient to entrain and transport most fines out of the lagoon. The burrowing shrimps which inhabit areas of the lagoon bedded by sand may aid this process by resuspending sediments ejected from their burrows into the water column (Tudhope and Scoffin 1984, Scoffin and Tudhope 1985, Tudhope 1989). A sizable sediment shute extending seawards between Turk's reef and Horsburgh Island physically records the transport of sediment out of this lagoon, although the character of these sediments is not known. The purging of sands and muds outside of reef systems has, however, been well documented (Neumann and Land 1975, Roberts and Suhayda 1983, Frith 1983).

It is interesting to note that the sediments deposited in this lagoon do not appear to conform with the Sorby principle (Folk and Robles 1964) which predicts the generation of size specific grain size populations controlled by the skeletal architecture of the contributing organisms (Fig. 9). Non-conformance with the Sorby principle is not uncommon however, with several authors reporting no apparent size specificity in sediments derived from different constituent organisms (Clack and Mountjoy 1977, Flood and Scoffin 1978, Gabrie and Montaggioni 1982). The ubiquity of coral sediments at all grain sizes is apparent in Figure 9, and may possibly distort the recognition of distinctive component-specific grain size populations simply by dominating grain counts.

CONCLUSION

The lagoonal sediments of the Cocos (Keeling) Islands are principally composed of gravels and sands derived from corals with minor components such as mollusc, *Halimeda* and rhodolith debris becoming locally important. Coral-type sediments overwhelmingly dominate the lagoon, reflecting the lack of significant populations of carbonate producing organisms other than coral on this atoll. Textural and compositional trends indicate that allochthonous sediments are deposited in this lagoon only as far as the sand aprons and sandy lagoon floor environments, beyond which sediments are almost entirely autochthonous. Allochthonous coral-type sediments can be identified by the inclusion of significant quantities minor components which are of distinctly high energy reef origin and by size-sorting along established hydrodynamic gradients. The irregular distribution patttern of textural facies in the centre of the lagoon reflects the deposition of epilithic gravels and sands produced as sporadically distributed patch reefs and lag material degrades *in situ* .

The concurrent distribution of the gravelly mud textural facies, the molluscan mud compositional facies and the seagrass meadow and intertidal sand and mud flat environments is remarkable, and largely reflects the extent to which depositional conditions in these facies/environments are differentiated from the rest of the lagoon. Depositional conditions in these areas are characterised by low hydrodynamic energy levels, either as a function of position relative to the high energy interisland channels and/or as a function of the current reducing action of benthic flora. Fine sands and muds, which may be both allochthonous and autochthonous are deposited in these zones with a coarse gravel component derived from the remains of indigenous organisms such as gastropods and crustaceans

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Table 1. Sedimentological data and statistics for 76 sediment samples from the Cocos (Keeling) Islands lagoon. Key to abbreviations as for Table 2.

Sample	Grainsize Weight %														Mean	Sorting	Skewness	%Gravel	%Sand	%Mud	Environment
	-2	-1.5	-1	-0.5	0	0.5	1	1.5	2	2.5	3	3.5	4	>4.0							
11	18.5	7.5	8	26.8	9.9	18.9	7.5	1.7	0.6	0.2	0.1	0.1	0	0	-0.81	1.09 (PS)	-0.08 (NS)	34.01	65.98	0	I
12	15.1	8.9	10.4	20.2	18.3	17.7	7.4	1	0.2	0.7	0	0	0	0	-0.75	1.04 (PS)	-0.14 (CS)	34.41	65.59	0	I
22	0.9	0.9	3.1	9	21.1	5.8	18.4	17	12.8	6.5	3.1	1.1	0.3	0.2	0.70	1.09 (PS)	-0.04 (NS)	4.84	94.99	0.16	I
23	4.4	4.6	10.6	21.6	6.5	15.1	11	10.8	8.3	6.5	0.4	0.1	0	0	0.12	1.28 (PS)	0.03 (NS)	19.68	80.31	0	I
24	3.6	4.1	6.5	12.4	14.7	17.2	13.4	12	8.2	5.4	2.2	0.3	0.1	0.1	0.28	1.23 (PS)	0.01 (NS)	14.21	85.73	0.05	I
58	29.3	3.6	6.1	9.8	2.8	6.3	6.8	7.6	9.2	7.2	5.7	3.2	1.1	1.4	-0.10	1.94 (PS)	0.17 (FS)	38.92	59.62	1.44	I
152	53.7	6.8	6.8	6.5	1.7	4.4	5.1	6.2	5.2	2.3	0.8	0.3	0.1	0.1	-1.16	1.47 (PS)	0.81 (SFS)	67.27	32.59	0.12	I
153	1.5	0.1	0.1	1	1.1	31.8	17.7	26	14.5	4.6	1.2	0.2	0.1	0	0.92	0.69 (MS)	0.09 (NS)	1.74	98.25	0	I
157	20	5.7	6.9	9.1	2.9	6.8	6.1	7.9	13.3	13.8	6.3	0.8	0.4	0	0.17	1.84 (PS)	-0.13 (CS)	32.51	67.48	0	I
167	0.3	0.4	0.7	5.8	6.7	53.2	24.9	6.3	1.4	0.2	0.1	0.1	0	0	0.40	0.5 (WS)	0.08 (NS)	1.32	98.67	0	I
1	0.3	0.4	1.5	13.2	6.2	15.6	17.3	16.4	17.7	10.9	0.4	0	0	0	0.76	1.06 (PS)	-0.12 (CS)	2.2	97.8	0	II
32	0	0.8	2.4	9.8	4.6	11.8	14.4	16.4	19.9	13.6	5	0.9	0.3	0.1	1.05	1.12 (PS)	-0.18 (CS)	3.25	96.59	0.14	II
34	4.9	3.1	2.5	7.2	6.8	10.3	18.6	21	15.6	6.2	2.3	0.5	0.2	0.9	0.70	1.26 (PS)	-0.49 (SCS)	9.66	89.46	0.88	II
35	3	1.5	1.6	13.8	4.6	11.2	11.7	14.4	18.3	11.8	5.7	1.4	0.4	0.6	0.87	1.33 (PS)	-0.21 (CS)	6.12	93.32	0.55	II
38	13.6	0.4	2.9	8.2	2.8	6.9	8.2	11.5	14.9	15.6	9.3	33.5	1.2	0.9	0.86	1.73 (PS)	-0.35 (SCS)	17.01	82.06	0.91	II
114	1.1	0.6	2.9	12	4.2	9	12.7	14.9	17.9	14.3	6.8	1.9	0.7	1	1.01	1.29 (PS)	-0.20 (CS)	4.57	94.44	0.98	II
141	0.1	1.5	1.9	5.8	10.1	21.7	16	11.5	10.3	11.9	8.2	0.8	0.1	0.1	0.94	1.15 (PS)	0.15 (FS)	3.49	96.39	0.1	II
164	1.3	1.9	2.6	19	5.8	10.6	8.9	8.6	9.4	9.4	8.7	6.4	3.5	3.8	1.00	1.66 (PS)	0.09 (NS)	5.88	90.36	3.75	II
165	8.1	5.2	6	17	4.1	7.6	7.1	8.8	11.5	9.6	7.4	3.8	1.4	2.5	0.60	177 (PS)	-0.03 (NS)	19.24	78.3	2.45	II
2	4.6	4.3	5	7.9	4.1	8.2	9.6	11	14.6	13.4	8.7	3.6	2.3	2.7	1.00	1.69(PS)	-0.22 (CS)	13.97	83.32	0.27	III
3	7.5	3.6	3.7	5.6	2.6	8.1	11.6	13.3	16.2	12.6	8.1	3.7	1.7	1.7	0.95	1.67(PS)	-0.28 (CS)	14.83	83.45	1.7	III
5	17.5	9.4	9.4	15.1	4	6.8	5.9	6	7	6.1	5	3.4	2.8	1.5	-0.12	1.94 (PS)	0.34 (SFS)	36.3	62.15	1.53	III
30	4.6	4.6	9.9	18.4	8.8	9.2	9.3	10	7.4	7.3	2.8	3.5	2.2	1.9	0.40	1.59 (PS)	0.44 (SFS)	19.11	79.89	1.9	III
84	0.6	0.7	0.9	2.6	1.4	4.8	7	11.8	21	22.5	17.8	5.7	1.6	1.5	1.87	1.06 (PS)	-0.22 (CS)	2.3	96.18	1.51	III
89	9.2	2	3.3	9.4	3.5	3.5	5.9	7.8	11.2	18.3	12	9.1	4.9	0	1.20	1.78 (PS)	-0.60 (SCS)	13.76	81.01	5.23	III
117	4.9	3.1	2.5	7.2	6.8	10.3	18.6	21	15.6	6.1	2.3	0.5	0.2	0.9	0.70	1.26 (PS)	-0.49 (SCS)	15.66	41.02	43.32	III
120	10.3	4.7	6.5	7.6	1.8	3.7	4	4.2	4.4	3.7	2.5	1.3	0.5	44.8	1.76	2.45 (VPS)	-0.35 (SCS)	21.46	33.75	44.78	III
122	8.3	2.2	2.5	2.7	0.8	1.7	2.3	4	5.9	5.8	7.7	6.8	4.1	45.1	2.47	2.18 (VPS)	-0.66 (SCS)	13.02	41.9	45.07	III
142	0.1	0.1	0.3	1.9	1.2	3.6	3.9	4.5	6.4	8.6	14.8	21.3	14.8	18.4	2.90	1.27 (PS)	-0.32 (SCS)	0.51	81.09	18.38	III
147	0	0.1	0.1	0.5	0.4	1.4	2.5	4.1	5.8	11.5	33.1	30.7	9.3	0.7	2.77	0.75 (MS)	-0.27 (CS)	0.14	99.18	0.67	III
149	0.9	0.6	1.3	17.4	27.8	11.2	26.2	8.9	2.4	2.4	0.9	0	0	0	0.15	0.79 (MS)	0.16 (FS)	2.78	97.21	0	III
6	6.1	3.4	3.4	15.7	5.6	10.6	17	12.9	10.7	8.5	4.2	1.2	0.5	0.2	0.56	1.43 (PS)	-0.13 (CS)	12.91	86.92	0.16	IV
8	7.7	6.1	7.6	22.7	5.9	10.7	8.6	8.8	9.8	6.9	3.6	1.1	0.3	0.3	0.15	1.50 (PS)	0.11 (FS)	21.31	78.42	0.26	IV
10	26.6	6.9	18.3	22.9	4.5	7.3	4.8	5.3	2.5	0.7	0.2	0	0	0	-0.97	1.20 (PS)	0.18 (NS)	51.67	48.32	0	IV
29	5.5	3.4	5.3	18.4	5.9	10.3	8.3	7.7	9.7	9.4	8	3	2.6	2.5	0.71	1.71 (PS)	0.09 (NS)	14.26	83.2	2.53	IV
48	5.9	1.8	2	7.5	9.6	10	12	13.4	12.1	12.1	9.3	3.1	0.8	0.5	0.95	1.15 (PS)	-0.16 (CS)	9.71	89.82	0.45	IV
163	6.5	4	5.1	8.3	2.4	5.6	6.5	10.6	16.7	16.3	10.9	0.1	5.4	1.6	1.10	1.77 (PS)	-0.33 (SCS)	15.61	82.82	1.56	IV
169	2.7	2.44	5.4	18.4	5.1	9.8	8.6	9	10.4	8.8	9.8	5.8	2.1	1.7	0.90	1.63 (PS)	0.03 (NS)	10.55	87.79	1.65	IV

Table 1. continued

170	2.8	3.5	6.1	12.8	3.8	8	8.6	9.5	11.2	11.8	8.8	6.6	4	2.6	1.10	1.74 (PS)	'-0.11 (CS)	12.36	85.04	2.58	IV
9	0	2.4	3.2	4.6	3.9	9.8	12.3	14.5	17.9	15.8	11.8	3.2	0.5	0.1	1.35	1.21 (PS)	'-0.21 (CS)	5.62	94.26	0.11	V
50	1.2	3.7	5.7	9.9	5.3	17.7	20.3	17.1	14	4	0.7	0.1	0	0	0.51	1.11 (PS)	'-0.21 (CS)	10.59	89.4	0	V
60	0	0.1	0.1	7.1	0.6	1.8	2.5	4.2	7.6	11.9	21.9	21.1	12.7	8.4	2.66	1.30 (PS)	'-0.33 (SCS)	0.24	91.38	8.37	V
124	13.2	25.8	25.5	15.4	3.1	3.5	2.5	2.8	3.8	1.9	0.9	0.9	0.3	0.3	-1.03	1.16 (PS)	0.44 (SFS)	64.46	35.22	0.31	V
125	27.1	21.7	8.8	1.9	4.7	4.3	4.7	4.8	7.2	5.3	5.6	2.3	1.5	0.2	-0.49	1.85 (PS)	0.72 (SFS)	57.15	41.91	0.94	V
128	11.2	15.1	13.8	3.4	3.2	4.5	9.9	10.3	12.2	5.8	4.9	3.3	2.5	0.4	0.17	1.78 (PS)	0.17 (FS)	39.01	58.46	2.53	V
130	1.3	0.1	0.6	1.7	2.7	5.6	10.4	15	15	14.6	14.5	9.6	5	4	1.92	1.24 (PS)	'-0.03 (NS)	1.91	94.1	3.97	V
171	3.2	4.8	8.6	15.7	4.4	9.4	9.1	10	12.5	10.3	6.9	0	3.8	1.3	0.70	1.64 (PS)	0.00 (NS)	16.64	82.12	1.23	V
21	1.7	1.7	2.7	15.3	7.8	16.2	18	13.5	6.9	5.5	4.4	2.3	1.9	2.3	0.66	1.36 (PS)	0.11 (FS)	6.07	91.65	2.26	VI
39	7.8	2.2	3.3	7.6	17.9	5.2	3	2.1	5	4.4	6.1	7.3	10.9	17.2	1.44	2.19 (VPS)	'-0.12 (CS)	13.3	69.47	17.23	VI
161	8	3.2	1.1	6.7	5.7	10.3	11.8	10	6	3.2	3.1	2.3	1.5	27.2	1.47	2.14 (VPS)	'-0.05 (NS)	12.35	60.44	27.21	VI
15	1.1	0.5	0.5	3.9	4.7	32.4	31.9	11.2	4.3	2.8	3.9	2.1	0.3	0.2	0.69	0.83 (MS)	0.23 (FS)	2.13	97.71	0.16	VII
16	2.6	1.8	1.9	8.3	5.5	28	18.2	5.9	4.4	3.8	5.5	8.3	3.7	2	0.99	1.55 (PS)	0.32 (SFS)	6.33	91.7	1.96	VII
57	0	0.2	1.2	7.9	2.3	4.2	4.8	6	8.9	12	17.8	21.3	10.7	2.7	2.18	1.43 (PS)	'-0.47 (SCS)	1.35	95.96	2.67	VII
65	0	0.1	0.1	0.3	0.8	11.3	18.7	19	18.1	14.9	11.5	4.4	0.7	0.4	1.55	0.92 (MS)	0.08 (NS)	0.11	99.49	0.39	VII
66	52.8	17	13.2	0	8.5	1.9	2.8	3.8	0	0	0	0	0	0	-1.60	0.96 (MS)	0.98 (SFS)	81.57	18.43	0	VII
70	0	0	0.1	4.1	5.1	17.1	16	14.4	13.7	12.5	9.5	4.4	1.7	1.4	1.34	1.15 (PS)	0.09 (NS)	0.07	98.51	1.4	VII
79	1.4	2.6	4.4	13.5	4.8	11.4	10.9	12	14.6	11.6	7	3	1.1	1.7	0.90	1.46 (PS)	'-0.11 (CS)	8.41	89.88	1.7	VIII
132	22.7	0.2	0.2	0.8	1.2	5.1	8.5	11.9	15.1	15	13.1	5.2	0.8	0.3	0.65	2.03 (VPS)	'-0.46 (SCS)	23.11	76.54	0.33	VIII
134	3.4	1.9	5.6	8.2	13	15	15.4	13.3	10	7.6	4.5	1.2	0.3	0.4	0.60	1.29 (PS)	'-0.01 (NS)	10.99	88.62	0.37	VIII
136	0	1.8	2.4	7.3	6.3	8	14	9.7	5.5	1.3	0.6	39	2.3	1.9	0.68	1.33 (PS)	0.65 (SFS)	8.02	89.11	2.88	VIII
145	7.4	5.9	6.1	11.7	15.2	13.9	8.3	9.5	14.2	6.6	1.1	0.1	0	0	0.19	1.41 (PS)	0.00 (NS)	19.39	80.55	0.04	VIII
148	3.7	1.9	3.5	13.4	7.2	19.7	18.5	14.6	10.7	4.6	1.9	0.2	0	0	0.45	1.16 (PS)	'-0.11 (CS)	9.13	90.84	0.01	VIII
150	1.8	1.8	2.6	11.8	5.9	18.8	16.8	12	11.4	11.9	5	0.2	0	0	0.73	1.23 (PS)	'-0.02 (NS)	6.21	93.78	0	VIII
156	0	0	0.1	5.7	5.5	20.5	22.8	14.7	8.2	5.7	7.1	6.7	2.5	0.3	1.18	1.20 (PS)	0.30 (SFS)	0.14	99.58	0.27	VIII
13	2.8	3	4.2	19.8	13.1	33.1	12.1	4.1	3.6	2.5	1.2	0.4	0.1	0.1	0.03	0.95 (MS)	'-0.06 (NS)	9.92	90	0.07	IX
14	5.4	2.4	2.5	9.5	21	28.8	12.7	3.4	2.7	4.2	5.2	1.6	0.4	0.2	0.24	1.21 (PS)	0.10 (FS)	10.29	89.5	0.2	IX
45	0.6	0	0.4	3.4	2.8	10.6	16.5	23.1	26.6	13.7	2	0.1	0	0.1	1.25	0.82 (MS)	'-0.20 (CS)	1.07	98.85	0.06	IX
46	0	0	0.2	3.9	1.5	1.8	0	6.5	19.2	25.6	22.3	13.1	5.9	2.8	2.41	0.82 (MS)	0.04 (NS)	0.23	96.92	2.84	IX
49	2.9	2.9	3	8	2.6	4.7	6.4	6.7	13.5	20.3	19	7.7	1.4	0.9	1.42	1.60 (PS)	'-0.47 (SCS)	8.85	90.25	0.89	IX
104	2.2	1.6	1.7	6.3	2.5	5.8	6.8	7.8	10.3	9.7	14.2	18.3	8.7	4.1	1.94	1.59 (PS)	'-0.32 (SCS)	5.53	90.39	4.06	IX
143	0	0	0	0.1	0.3	1.7	7.7	25.4	45.1	18.4	1.14	0	0	0	1.63	).50 (MWS	'-0.13 (CS)	0.06	99.93	0	IX
144	0.7	1.2	2.2	13.2	8.2	23	21.9	17.3	8.9	2.6	0.7	0.1	0	0	0.46	0.92 (MS)	'-0.08 (NS)	4.14	95.85	0	IX
146	0.1	0.1	0.1	1.7	1.9	10.3	21.4	24.8	13	13.7	10.6	1.9	0.2	0	1.40	0.89 (MS)	0.15 (FS)	0.27	99.69	0.03	IX
151	5.4	7.4	11.1	15.3	3.2	10.1	18	21	1.4	0.2	6.7	0	0	0	0.11	1.38 (PS)	'-0.16 (CS)	23.95	76.04	0	IX
154	1.1	1.6	3.9	12.8	4.6	13.7	19.6	25	14.6	2.6	0.4	0.1	0	0	0.58	1.02 (PS)	'-0.30 (SCS)	6.61	93.38	0	IX
155	0	0	0.1	0.1	0.1	0.8	2	5.6	14.2	36.9	38.3	1.8	0	0	2.31	0.54 (MS)	'-0.25 (CS)	0.1	99.89	0	IX

Table 2. Summary of textural statistics for each lagoonal environment. (n) denotes number of samples per environment.

	Lagoonal Environment								
	I	II	III	IV	V	VI	VII	VIII	IX
(n)	(10)	(9)	(12)	(8)	(8)	(3)	(6)	(8)	(12)
Mean (Ø)	0.02 (0.68) Coarse Sand	0.87 (0.15) Coarse Sand	1.34 (1.02) Medium Sand	0.56 (0.70) Coarse Sand	0.72 (1.22) Coarse Sand	1.46 (0.02) Medium Sand	0.83 (1.20) Coarse Sand	0.74 (0.24) Coarse Sand	1.05 (0.89) Medium Sand
Sorting (Ø)	1.28 (0.45) PS	1.37 (0.27) PS	1.54 (0.53) PS	1.52 (0.24) PS	1.41 (0.30) PS	2.17 (0.04) VPS	1.23 (0.26) PS	1.39 (0.30) PS	1.00 (0.34) MS
Skewness	0.08 (0.28) NS	-0.15 (0.20) CS	-0.21 (0.35) CS	-0.04 (0.17) NS	0.05 (0.39) NS	-0.09 (0.05) NS	0.23 (0.67) FS	0.03 (0.35) NS	-0.10 (0.15) NS
Gravel %	24.89 (20.71)	7.94 (6.19)	12.82 (10.46)	18.55 (13.86)	24.45 (25.59)	12.81 (0.68)	2.03 (2.68)	10.98 (6.14)	6.90 (7.93)
Sand %	74.92 (20.83)	90.97 (6.78)	73.35 (23.10)	80.29 (13.38)	73.36 (24.47)	65 (6.40)	96.63 (3.26)	88.13 (5.96)	92.58 (7.79)
Mud %	0.18 (0.45)	1.08 (1.24)	13.70 (19.16)	1.15 (1.07)	2.18 (2.84)	22.19 (7.03)	1.33 (0.94)	0.88 (1.16)	0.61 (1.35)

Key

Sorting

PS	Poorly Sorted
VPS	Very Poorly Sorted
MS	Moderately Sorted
WS	Well Sorted
MWS	Moderately Well Sorted

Skewness

NS	Near Symmetrical
CS	Coarse Skewed
SCS	Strongly Coarse Skewed
FS	Fine Skewed
SFS	Strongly Fine Skewed

Environment

I	Interisland Reef Flats
II	Sand Aprons
III	Seagrass Meadows
IV	Variable Coral and Algal Flat
V	Blue Hole Mosaic
VI	Intertidal Sand and Mud Flats
VII	Algal Covered Acropora Rubble
VIII	Massive Corals Interspersed with Sandy Patches
IX	Sandy Lagoon Floor

Table 3. Sediment sample textural classification based on factor analysis. Bold numbers represent samples with the highest loading on each factor axis.

Sediment Classification	Samples
Factor One	1, 6, 12, 13, 14, **15**, 16, 21, 24, 34, 50, 70, 134, 136, 141, 144, 148, 149, 150, 151, 153, 154, 156, 167.
Factor Two	2, 3, 9, 32, 35, 38, 45, 46, 48, 49, 84, 89, 114, 128, 130, **143**, 155, 163.
Factor Three	5, 10, 58, 66, 125, **152**.
Factor Four	8, 23, 29, 30, 164, 165, 169, 170, 171.
Factor Five	39, **117**, 120, 122, 161.
Factor Six	57, 60, 104, 142, **147**.
Variable Mixtures	11, 65, 79, 124, 126, 132, 145, 146, 157.

Table 4. Textural characteristics of sediment types discriminated by factor analysis. Abbreviations as per Table 2. Standard deviations in parentheses.

Factor	1	2	3	4	5	6
(n)	25	19	6	9	5	5
Var. %	37.7	23.4	12.3	6.8	5.8	5.3
Cum. Var.%	37.7	61.1	73.4	80.2	86	91.3
Mean (ø)	0.55 (0.44)	1.31 (0.55)	-0.74 (0.60)	0.63 (0.35)	1.82 (0.42)	2.49 (0.41)
Sorting (ø)	1.11 (0.24)	1.26 (0.45)	1.56 (0.42)	1.61 (0.15)	2.27 (0.14)	2.72 (0.32)
Skewness	0.03 (0.23)	-0.14 (0.23)	0.53 (0.35)	0.07 (0.15)	-0.34 (0.26)	-0.33 (0.54)
Gravel %	8.02 (7.89)	8.32 (9.51)	55.48 (17.20)	15.45 (5.10)	15.16 (3.74)	1.55 (2.27)
Sand %	91.51 (7.82)	90.29 (10.12)	43.84 (16.62)	82.83 (4.21)	49.32 (14.97)	91.60 (6.86)
Mud %	0.46 (0.84)	1.25 (1.46)	0.67 (0.72)	1.82 (1.19)	35.52 (12.66)	6.83 (7.05)

Table 5. Skeletal composition of 50 sediment samples from the Cocos (Keeling) Islands lagoon.

Sample	3	6	9	10	12	24	29	30	32	34	38	39	45	48	49	50	56
Coral	58.13	44.53	58.51	61.32	81.46	44.92	39.95	40.91	75.60	55.64	66.32	24.50	27.58	50.86	27.58	62.67	59.67
Halimeda	0.66	4.11	9.57	20.71	1.75	27.42	19.82	13.66	5.71	11.33	2.13	3.22	18.80	18.56	18.80	12.55	4.58
Coralline Algae	14.37	29.93	15.20	5.06	1.26	6.31	9.37	2.31	11.36	15.54	6.89	0.00	2.97	12.25	2.97	1.90	0.00
Homotrema	0.00	0.00	0.00	0.00	0.20	2.48	0.00	0.00	0.57	0.81	0.60	0.00	0.00	0.00	0.00	0.71	0.00
Gastropods	3.94	6.82	2.58	6.70	8.50	1.82	9.45	7.08	1.91	2.39	1.08	11.80	5.47	6.14	5.57	3.41	7.88
Pelecypods	0.54	2.33	2.00	1.40	0.12	1.18	0.78	0.17	1.38	1.83	9.35	0.00	0.79	0.65	0.79	0.40	2.66
Unknown Molluscs	0.99	6.59	3.86	2.55	1.61	3.82	5.19	4.88	0.49	0.94	4.02	6.54	2.12	4.73	2.12	3.65	3.78
Marginopora	0.40	1.31	0.97	0.33	0.00	3.75	1.92	2.64	1.40	3.06	1.36	3.25	3.14	1.45	3.14	0.00	3.01
Amphistegina	1.48	0.38	0.00	0.00	1.65	2.58	0.00	0.00	0.93	1.13	0.43	0.00	0.06	0.27	0.06	0.92	0.00
Unknown Foraminiferans	2.61	2.89	0.62	0.30	0.00	0.56	1.41	1.18	2.38	3.46	2.35	2.45	5.02	1.49	5.02	0.39	2.15
Annelida	1.39	0.00	0.00	0.42	0.20	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.07	0.00
Alcyonarian Spicules	1.09	0.54	0.73	0.00	1.95	0.28	0.64	0.58	0.95	1.43	0.91	0.00	0.69	0.37	0.69	6.00	0.00
Crustaceans	0.27	0.00	0.50	1.06	0.98	0.00	1.63	1.55	0.43	0.58	0.11	7.85	2.33	0.13	2.33	0.09	1.67
Echinoids	0.00	0.57	0.31	0.15	0.43	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	1.35	0.00
Indeterminable	14.13	0.00	5.14	0.00	0.10	2.12	9.84	25.05	1.26	1.24	5.51	40.41	30.99	4.30	30.99	0.12	14.61
Environment	III	III	IV	IV	I	I	V	III	II	II	II	VI	VIII	V	V	IV	VIII

Sample	57	58	60	65	66	77	79	84	89	104	108	114	117	120	122	124	125
Coral	44.27	11.05	39.05	55.68	80.77	63.62	51.22	68.61	52.48	77.34	31.01	50.07	14.88	51.65	3.55	57.06	56.97
Halimeda	13.87	16.41	5.08	13.89	0.00	4.18	9.85	6.58	2.32	1.05	14.76	5.69	6.94	12.14	3.79	17.95	6.00
Coralline Algae	3.53	44.95	0.11	1.98	19.23	0.00	1.98	0.41	1.25	0.00	12.71	8.29	0.00	1.50	0.00	7.77	18.80
Homotrema	0.00	0.53	0.82	0.28	0.00	0.00	0.12	0.00	0.00	0.91	0.00	0.92	0.00	0.00	0.00	0.03	2.43
Gastropods	6.80	7.14	0.64	6.47	0.00	3.57	8.99	3.49	6.83	3.81	5.93	6.57	12.53	18.69	14.21	8.56	2.78
Pelecypods	3.58	0.83	4.14	2.11	0.00	0.00	4.30	0.90	0.00	2.78	9.80	2.61	3.20	6.30	3.69	4.31	1.86
Unknown Molluscs	4.31	5.87	0.93	2.22	0.00	2.67	3.71	2.30	0.81	3.08	3.70	1.41	2.10	3.24	1.58	1.33	1.32
Marginopora	1.35	2.98	0.66	2.37	0.00	1.76	8.42	1.17	4.00	0.98	1.19	9.70	3.68	0.24	0.19	0.00	3.50
Amphistegina	0.00	0.61	0.03	0.00	0.00	0.00	0.69	0.26	0.00	7.51	0.08	1.29	0.00	0.16	0.12	0.00	1.21
Unknown Foraminiferans	0.96	0.00	2.27	3.00	0.00	2.63	1.32	4.03	4.74	1.15	2.23	0.00	1.53	0.22	4.65	0.04	0.00
Annelida	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.19	1.93	0.00	0.07	0.21	0.00	0.04	0.31	0.12	2.76
Alcyonarian Spicules	0.49	0.67	0.00	0.40	0.00	0.46	0.00	2.07	0.00	1.98	0.25	1.19	0.00	0.11	0.00	0.08	0.00
Crustaceans	0.95	0.97	0.43	0.17	0.00	0.00	3.40	0.67	3.05	0.00	1.84	3.90	2.83	1.02	2.99	0.24	0.00
Echinoids	0.11	0.00	0.04	0.27	0.00	0.00	0.80	0.52	0.83	0.00	0.09	2.83	0.00	0.17	0.00	0.92	0.62
Indeterminable	19.77	8.00	44.99	14.10	0.00	21.11	5.21	8.29	21.75	0.49	16.36	5.33	52.30	3.90	64.66	1.57	1.74
Environment	VII	I	IV	VII	VII	VII	VIII	III	III	IX	V	II	III	III	V	IV	IV

Table 5. continued

Sample	130	132	136	138	143	144	147	153	156	157	161	163	164	165	171	CV15
Coral	54.31	77.25	63.91	64.75	66.63	69.46	36.25	54.72	66.80	74.67	30.27	49.73	34.21	46.79	48.86	34.26
Halimeda	8.31	5.95	2.41	8.09	11.27	8.55	6.72	12.11	6.58	7.07	8.79	14.02	10.69	12.15	24.68	6.58
Coralline Algae	3.15	4.17	0.67	2.02	10.89	3.30	0.15	1.56	2.76	0.65	12.47	12.87	23.81	21.89	7.48	17.04
Homotrema	0.75	0.24	0.00	1.45	0.37	0.00	0.57	1.72	0.12	1.16	0.00	2.05	0.11	0.08	0.00	0.72
Gastropods	8.82	1.88	1.77	4.24	0.06	1.35	1.57	11.86	1.74	3.78	8.75	5.28	6.09	3.66	4.80	4.19
Pelecypods	1.21	0.73	4.27	0.55	0.63	2.76	0.79	0.02	1.14	0.59	0.37	2.81	1.30	0.11	1.38	11.77
Unknown Molluscs	2.83	2.43	3.16	5.65	3.05	2.08	5.40	3.46	2.48	5.03	1.67	4.51	6.49	3.85	4.66	7.46
Marginopora	4.68	0.15	6.19	1.27	0.13	2.22	1.35	0.58	0.40	1.27	3.19	0.23	0.00	0.21	0.91	8.91
Amphistegina	0.00	0.13	1.49	2.48	2.20	3.83	0.19	33.87	0.40	1.50	0.00	0.00	0.00	0.00	0.00	0.00
Unknown Foraminiferans	2.45	1.50	1.92	0.00	1.45	0.00	7.02	0.64	0.47	1.70	0.00	0.00	2.66	0.08	0.00	0.00
Annelida	0.00	0.01	0.00	0.86	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.08	0.30	0.09	0.34	0.00
Alcyonarian Spicules	0.00	0.37	0.00	0.00	1.75	1.16	0.69	2.63	3.24	1.26	0.00	0.00	0.97	0.47	0.00	1.09
Crustaceans	0.00	0.06	1.51	1.73	0.00	1.89	1.18	0.00	0.09	0.06	5.95	0.22	0.15	2.32	1.46	3.76
Echinoids	0.59	0.00	0.00	1.13	1.47	3.40	0.10	0.32	0.13	0.15	0.00	1.20	0.28	0.76	0.43	0.72
Indeterminable	12.90	6.28	12.72	5.79	0.05	0.00	38.04	0.26	9.45	0.88	28.56	7.44	13.71	7.31	5.06	2.79
Environment	IV	VIII	VIII	IX	IX	IX	III	IX	VII	IX	VI	V	III	II	IV	V

Table 6. Summary of the proportion of skeletal components in samples from each depositional environment (Mean [S.D.]).

	Lagoonal Environment.								
	I	II	III	IV	V	VI	VII	VIII	IX
(n)	3	5	9	7	8	2	4	6	5
Coral (%)	45.8 [35.1]	58.1 [10.7]	44.7 [15.7]	33.7 [15.9]	55.4 [8.2]	27.4 [4.1]	61.1 [15.3]	63.0 [9.1]	65.4 [12.9]
Halimeda (%)	15.2 [12.9]	7.4 [4.3]	7.1 [4.4]	13.7 [6.3]	13.2 [7.2]	6.0 [3.9]	8.0 [7.0]	5.9 [2.5]	7.5 [3.9]
Coralline Algae (%)	17.5 [23.9]	12.7 [6.1]	8.2 [11.6]	9.6 [6.0]	7.5 [6.5]	6.2 [8.8]	6.2 [8.8]	4.1 [7.5]	3.0 [4.5]
Homotrema (%)	1.1 [1.2]	0.6 [0.3]	0.1 [0.2]	0.4 [0.8]	0.6 [0.8]	0	0.1 [0.1]	0.5 [1.0]	1.1 [0.4]
Gastropods (%)	5.8 [3.5]	3.1 [2.2]	7.5 [5.3]	7.3 [3.4]	4.8 [3.0]	10.3 [2.2]	4.2 [3.2]	4.2 [3.3]	4.3 [3.4]
Pelecypods (%)	0.7 [0.5]	3.0 [3.6]	1.7 [2.0]	4.3 [4.6]	2.1 [1.4]	0.2 [0.3]	1.4 [1.8]	2.5 [1.5]	0.9 [1.1]
Unknown Molluscs (%)	3.7 [2.1]	2.1 [1.7]	3.6 [2.3]	4.3 [2.0]	2.7 [1.4]	4.1 [3.4]	2.3 [1.8]	2.8 [0.9]	3.9 [1.3]
Marginopora (%)	2.2 [2.0]	3.1 [3.8]	1.6 [1.5]	2.4 [3.0]	1.4 [1.7]	3.2 [0.1]	1.4 [1.0]	3.6 [3.2]	0.8 [0.5]
Amphistegina (%)	1.6 [1.0]	0.8 [0.5]	0.3 [0.5]	0.1 [0.1]	0.3 [0.5]	0	0	0.7 [0.6]	8.2 [11.0]
Other Foraminiferans (%)	0.2 [0.3]	1.6 [1.5]	3.0 [2.1]	2.1 [2.0]	0.8 [1.0]	1.2 [1.7]	0.9 [1.2]	1.2 [0.8]	1.0 [0.7]
Annelida (%)	1.0 [1.6]	0.1 [0.1]	0.4 [0.7]	0.1 [0.1]	0.5 [0.9]	0	0	0.5 [1.1]	0.2 [0.1]
Alcyonarian Spicules	1.0 [0.8]	1.0 [0.4]	0.7 [0.7]	0.4 [0.4]	0.9 [2.2]	0	0.3 [0.2]	0.6 [1.4]	1.4 [0.9]
Crustaceans (%)	0.7 [0.6]	1.5 [1.6]	1.2 [1.1]	1.8 [1.4]	0.5 [0.5]	6.9 [1.3]	0.3 [0.5]	1.1 [1.4]	0.4 [0.8]
Echinoids (%)	0.1 [0.3]	0.8 [1.2]	0.3 [0.3]	0.3 [0.5]	0.6 [0.5]	0	0.1 [0.1]	0.3 [0.4]	0.6 [0.7]
Indeterminate (%)	3.4 [4.1]	4.1 [2.8]	19.7 [16.8]	19.5 [22.2]	9.0 [15.3]	34.4 [8.4]	13.8 [9.7]	8.4 [4.9]	1.5 [2.4]
Grain Presentation	Angular/fresh.	Variable, some show evidence of rounding.	Variable, some organic stained, others fresh and appearing unaffected.	Variable, some fresh and angular, others worn and corroded.	As for IV.	As for IV.	As for IV.	Angular/fresh near reefs, rounded with distance.	Macroscopic sediments angular, some with corroded surfaces.

Table 7. Component classification based on factor analysis. Bold numbers represent samples with the highest loadings on the three factor axes.

Sediment Classification	Samples
Factor One:	3, 9, 10, **12**, 24, 29, 32, 34, 38, 48, 50, 56, 65, 66, 77, 79, 84, 89, 104, 114, 120, 124, 125, 130, 132, 136, 138, 143, 144, 153, 156, 157, 163, 171, cv15.
Factor Two:	39, 45, 49, 60, 147, 161, 117, **122**.
Factor Three:	**58**, 164.
Hybrid: Factors One and Two	30, 57.
Hybrid: Factors One and Three	6, 165.
Hybrid: Factors Two and Three	108.

Table 8. Component facies statistics. Bold values denote representative component types.

Factor	1	2	3	Hybrid	Hybrid	Hybrid
Var. %	69.9	20.6	9.5			
Cum. Var. %	69.9	90.5	100			
Sediment-type (samples)	*Coral -type*	*Molluscan Muds*	*Coralline Algae/ Halimeda Type*	*Coral- Molluscan Mud Hybrid.*	*Coral-Coralline Algae/ Halimeda Hybrid*	*Molluscan Mud-Coralline Algae/ Halimeda Hybrid*
Coral	**59.9 (11.5)**	27.21 (11.97)	29.84 (11.97)	**42.59 (2.38)**	**45.72 (1.68)**	31.01
Halimeda	9.38 (6.86)	9.54 (6.08)	**10.38 (6.16)**	13.76 (0.15)	**8.14 (5.71)**	**14.76**
Coralline Algae	6.47 (6.02)	2.33 (4.02)	**32.84 (10.96)**	2.92 (0.87)	**25.94 (5.65)**	**12.71**
Homotrema	0.52 (0.71)	0.16 (0.32)	0.21 (0.28)	0	0.04 (0.06)	0
Gastropods	4.97 (3.70)	**7.51 (4.77)**	0.67 (0.57)	**6.94 ((0.20)**	5.25 (2.73)	**5.93**
Pelecypods	2.15 (2.57)	**1.55 (1.65)**	1.48 (0.77)	**1.88 (2.41)**	1.22 (1.57)	**9.80**
Unknown Molluscs	2.97 (1.62)	**3.04 (2.0)**	6.30 (0.38)	**4.60 (0.40)**	5.23 (1.93)	**3.70**
Marginopora	2.19 (2.60)	2.36 (1.28)	1.43 (1.49)	2.0 (0.91)	0.76 (0.78)	1.19
Amphistegina	1.71 (4.70)	0.05 (0.07)	0.33 (0.31)	0	0.19 (0.27)	0.08
Unknown Foraminiferans.	1.19 (1.28)	3.24 (2.29)	1.84 (1.60)	1.07 (0.16)	1.48 (1.97)	2.23
Annelida	0.33 (0.74)	0.04 (0.1)	0.1 (0.17)	0	0.04 (0.06)	0.07
Alcyonarians	0.92 (1.26)	0.3 (0.35)	0.72 (0.22)	0.54 (0.06)	0.5 (0.5)	0.25
Crustaceans	0.88 (1.14)	3.05 (2.37)	0.37 (0.52)	1.25 (0.42)	1.16 (1.64)	1.84
Echinoids	0.55 (0.78)	0.02 (0.03)	0.28 (0.29)	0.06 (0.08)	0.67 (0.13)	0.09
Indeterminate	5.88 (6.02)	**39.62 (12.83)**	7.20 (6.84)	**22.41 (3.74)**	3.66 (5.18)	**16.36**

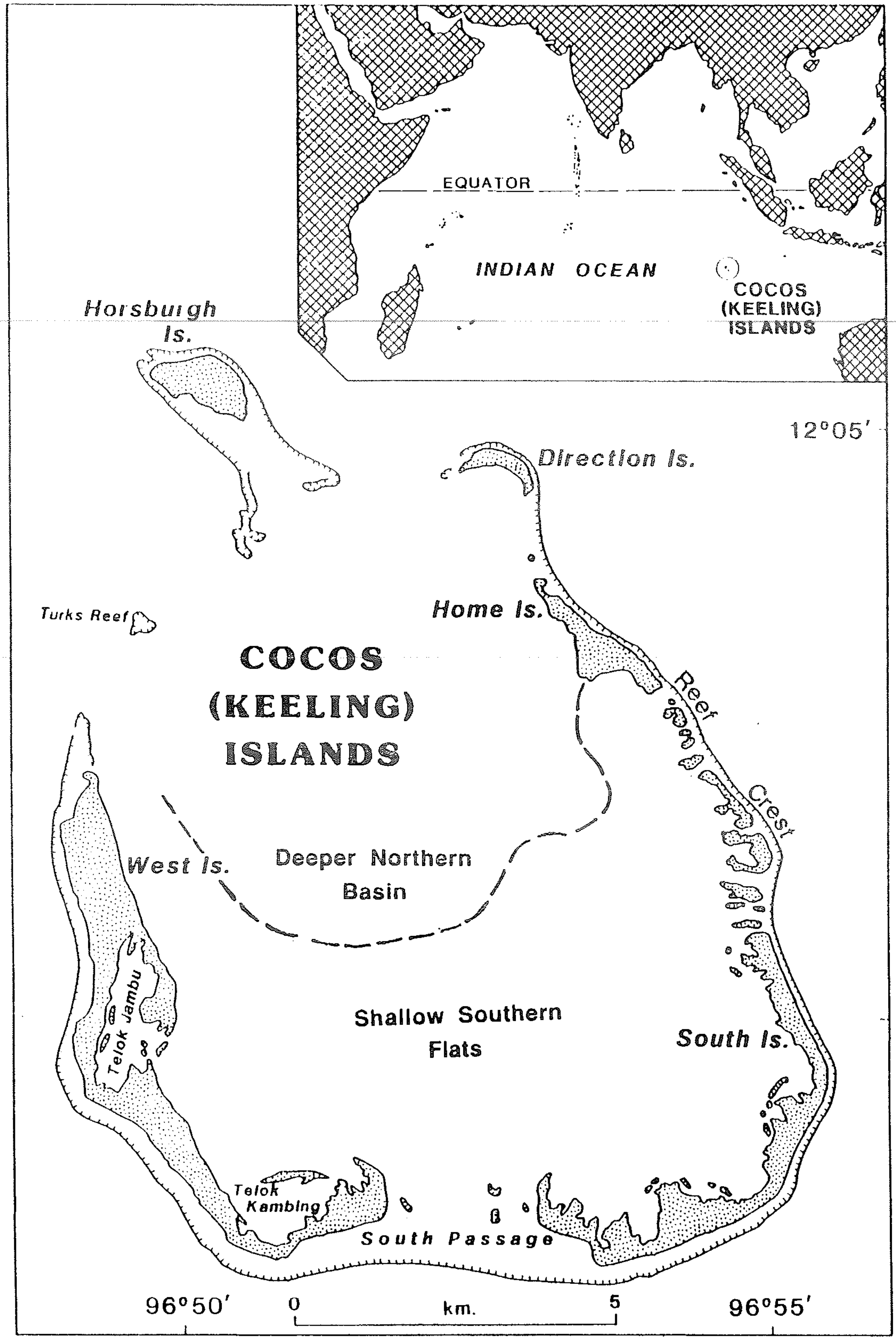

Figure 1. Location map of the Cocos (Keeling) Islands, showing bathymetric precincts.

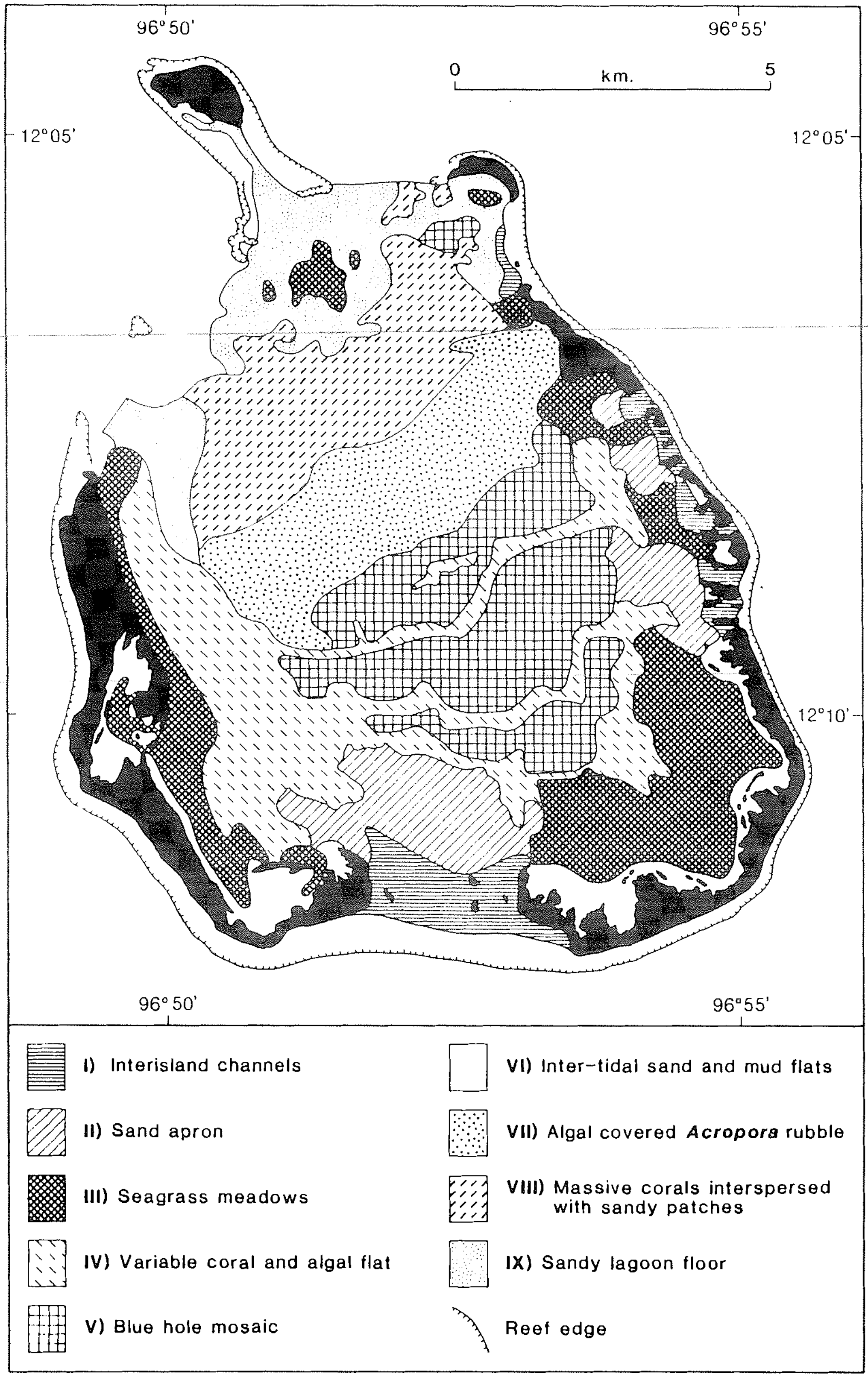

Figure 2. Lagoonal environments of the Cocos (Keeling) Islands.

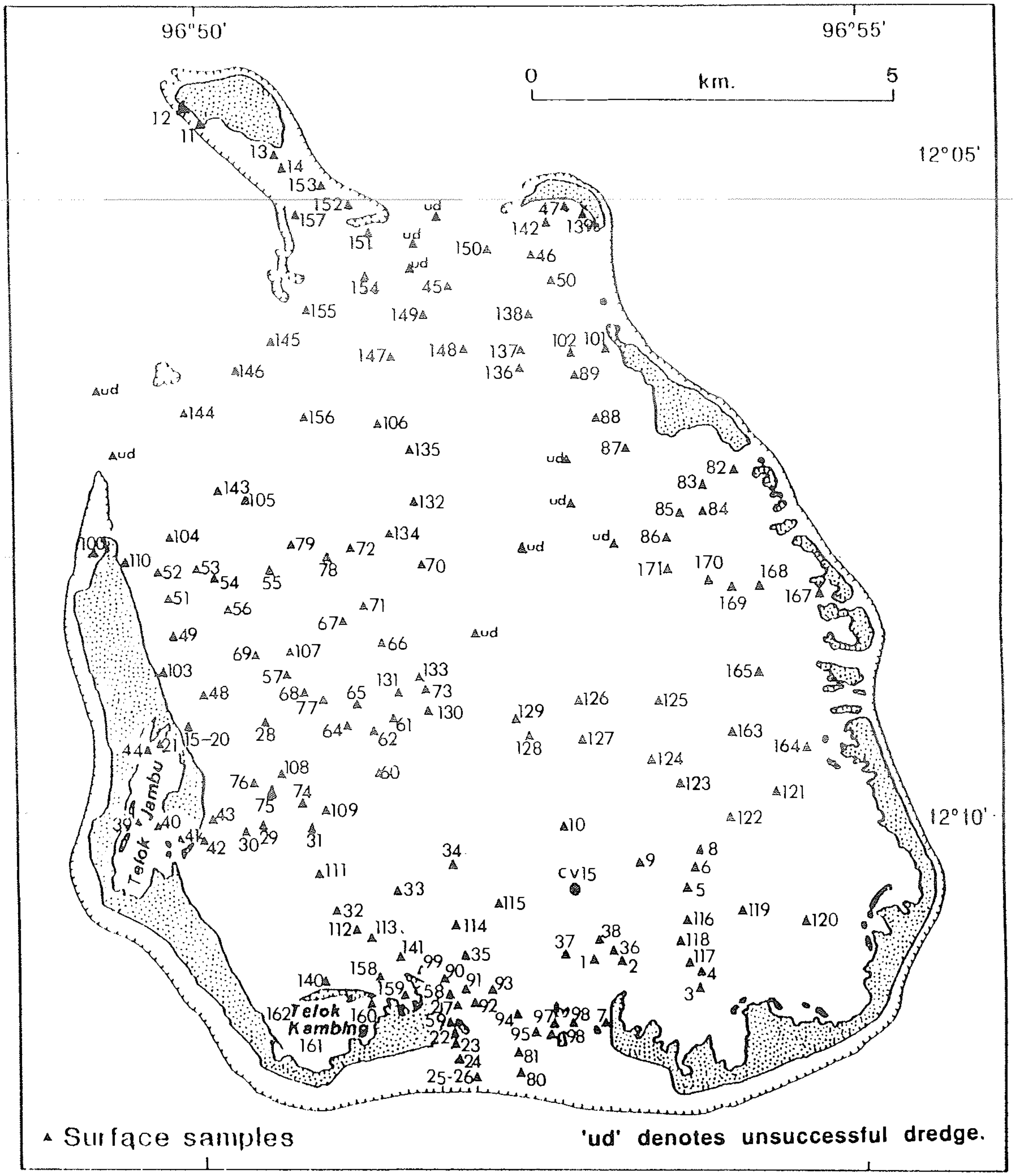

Figure 3. Sediment sample locations.

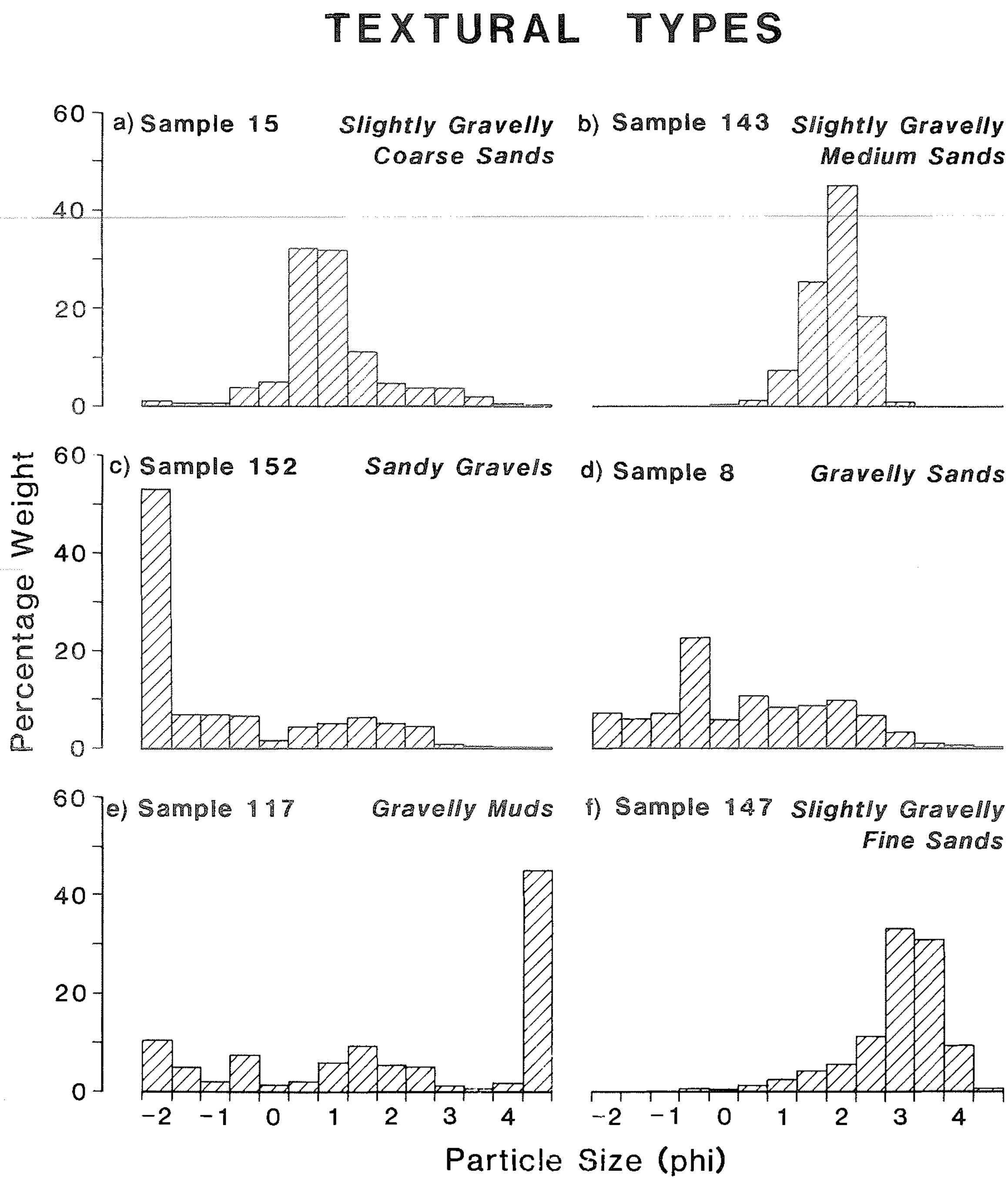

Figure 4. Grain size histograms of samples with the highest loadings on a) factor 1; b) factor 2; c) factor 3; d) factor 4; e) factor 5; f) factor 6.

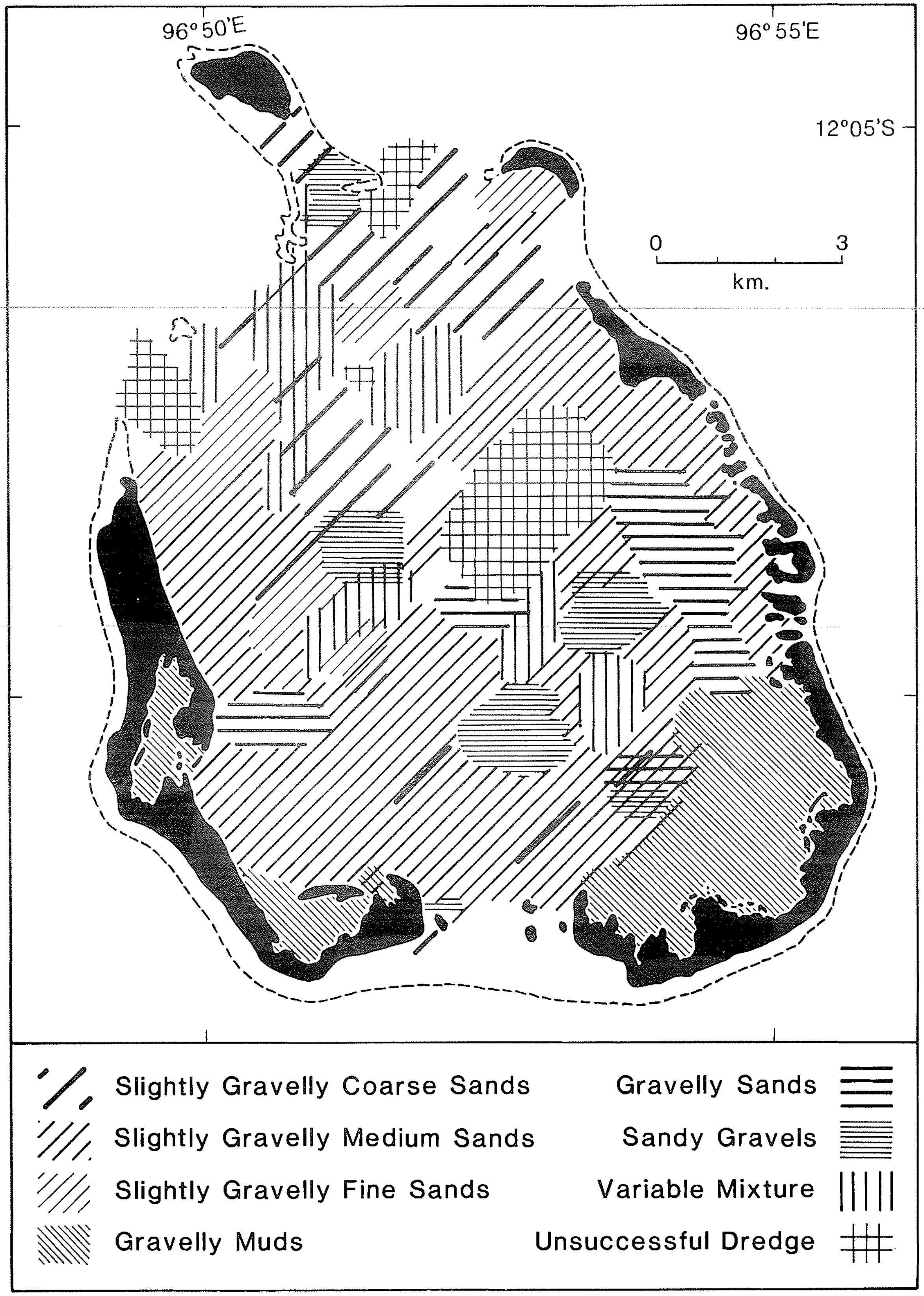

Figure 5. Textural facies distribution, Cocos (Keeling) Islands lagoon.

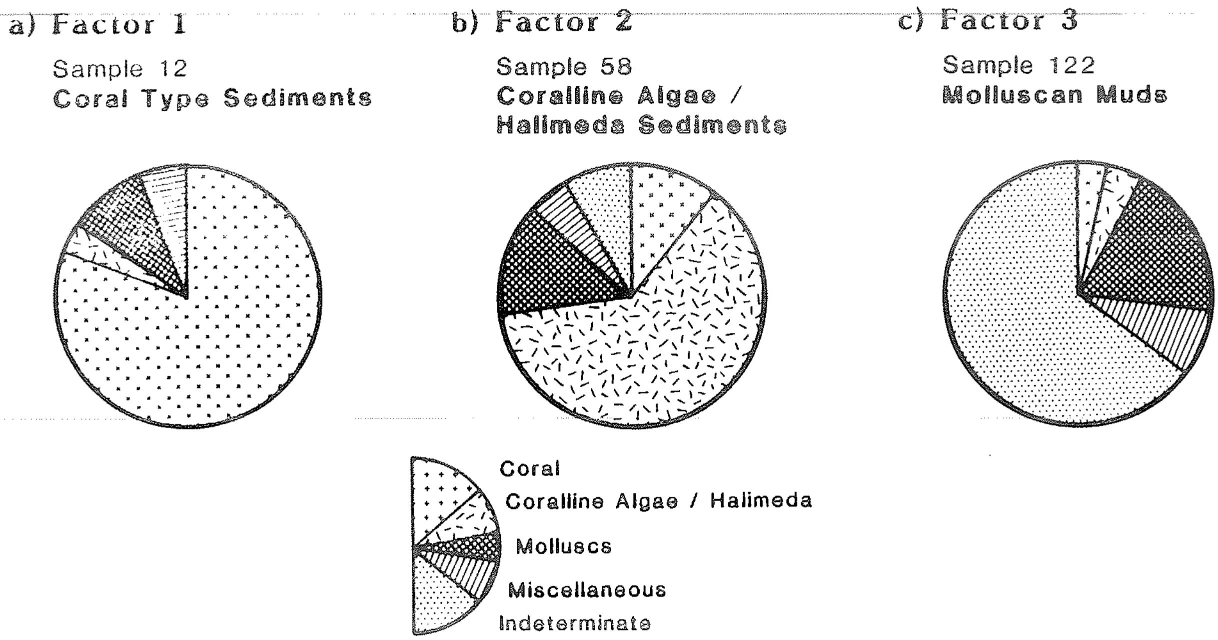

Figure 6. Pie charts showing sediment composition of samples with the highest loadings on a) factor 1; b) factor 2; c) factor 3.

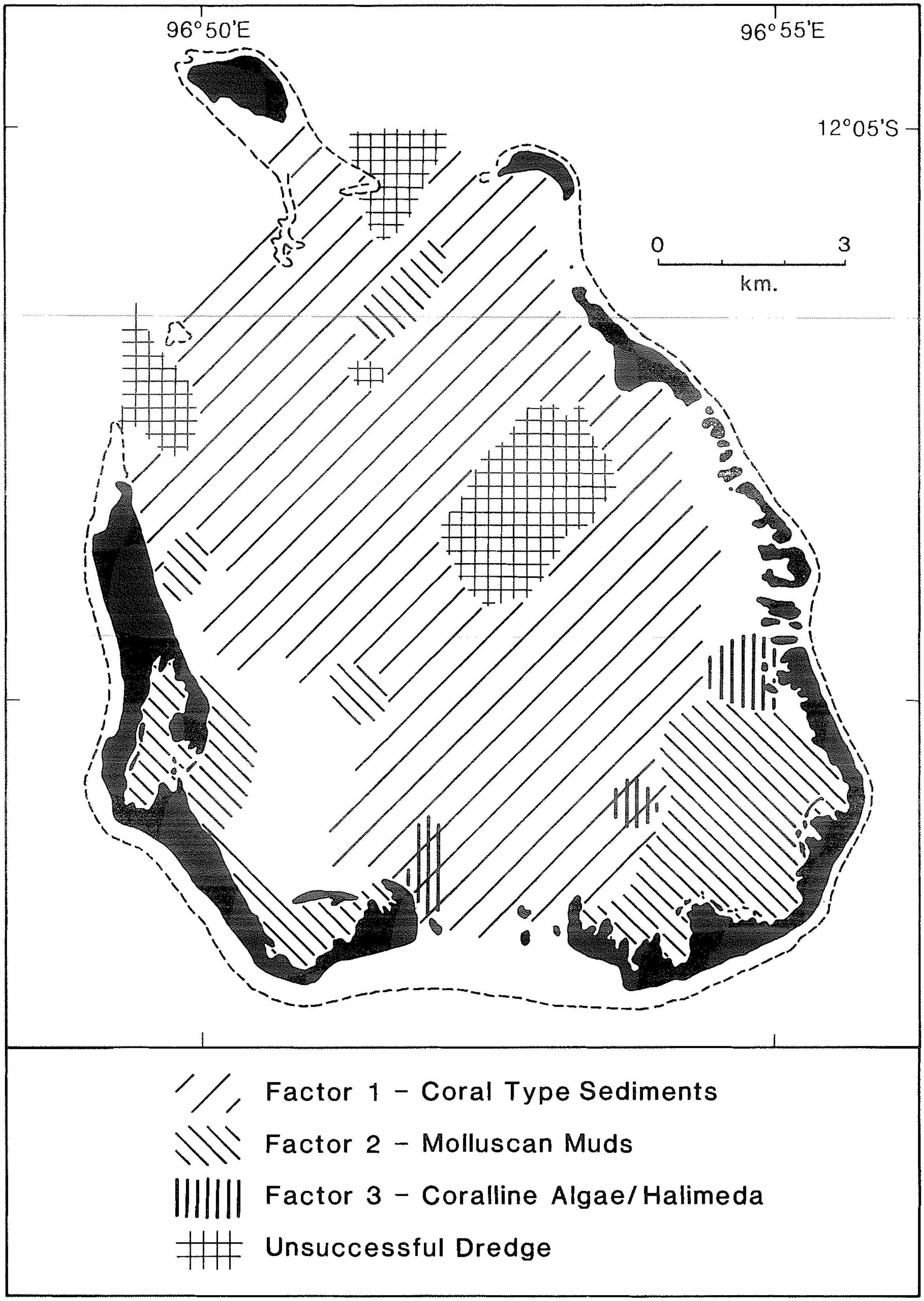

Figure 7. Compositional facies distribution, Cocos (Keeling) Islands lagoon.

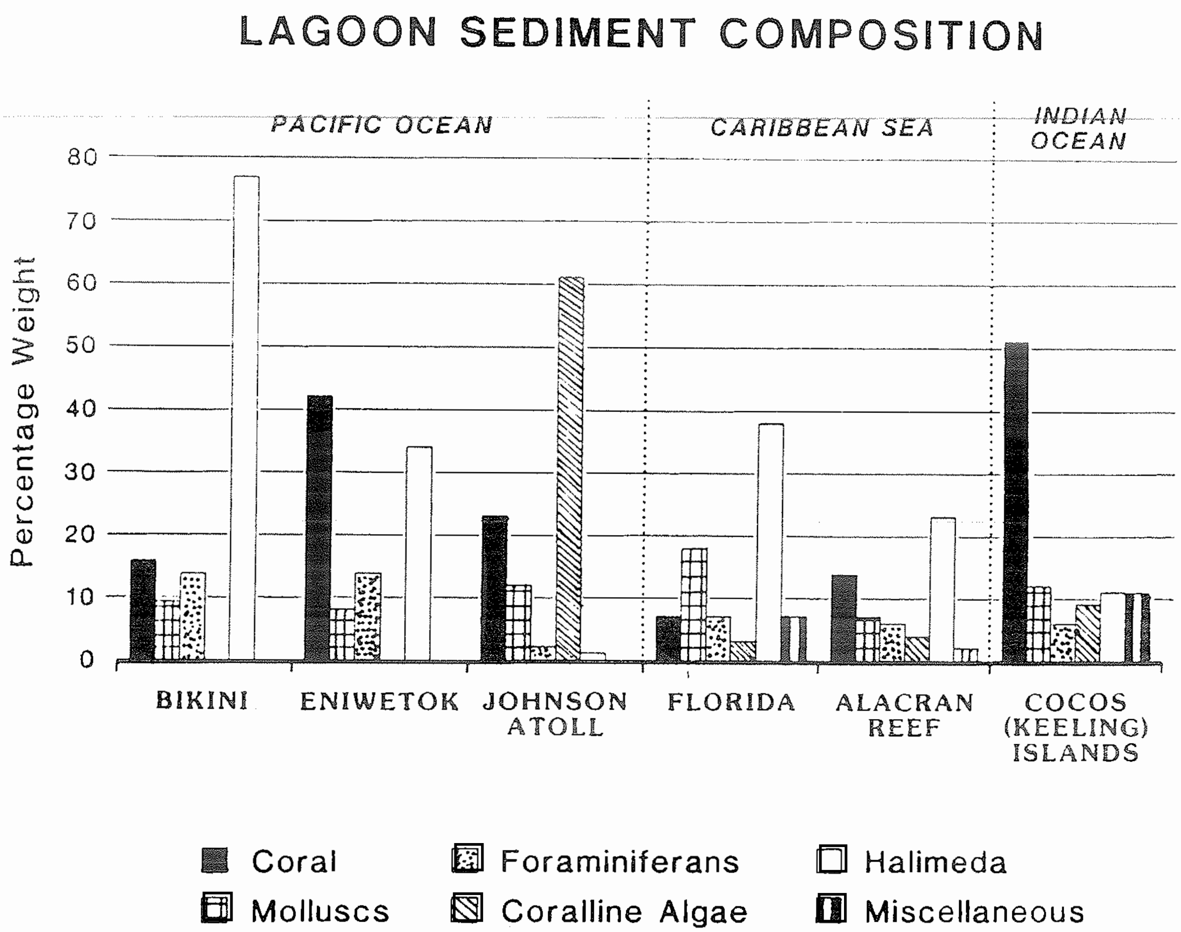

Figure 8. Histogram comparing of skeletal composition of the Cocos (Keeling) Islands lagoon to other carbonate lagoons. Data for other lagoons from: Bikini - Emery et al. 1954, Enewetok - Emery et al. 1954, Johnson Atoll - Emery 1962, Florida - Ginsburg 1956, Alacran Reef - Hoskin 1966.

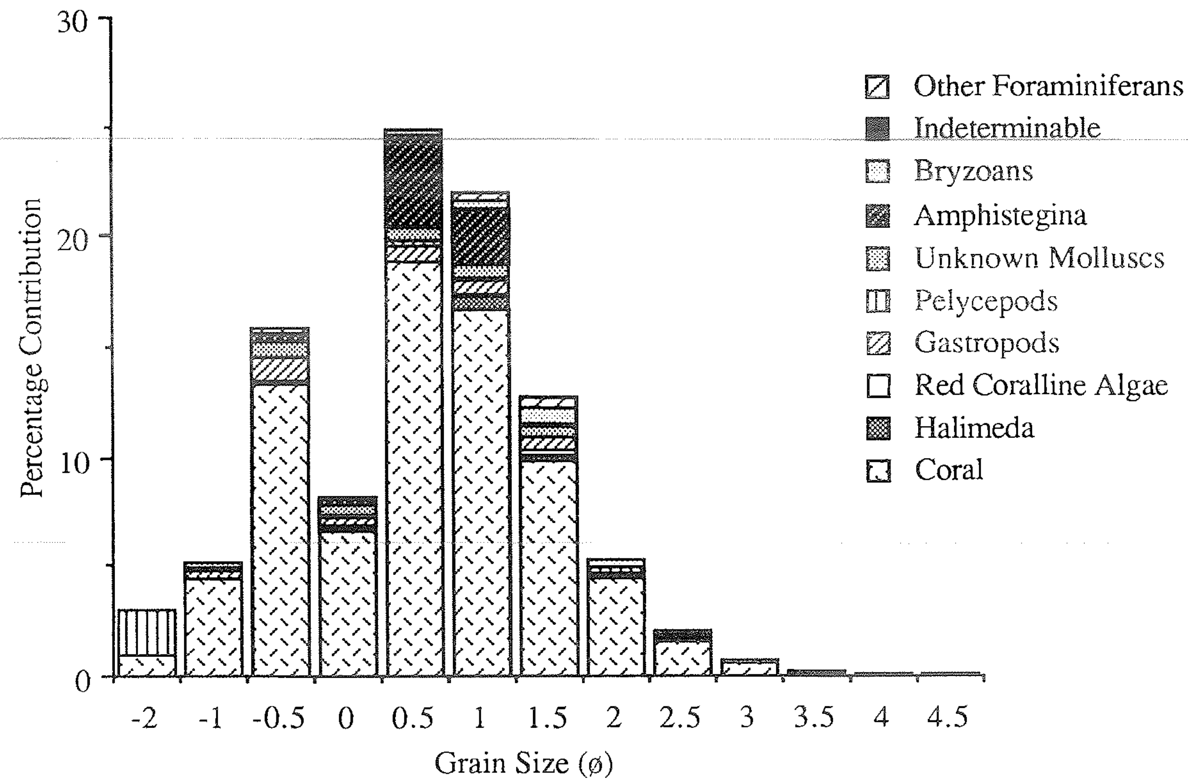

Figure 9. Histogram showing grain size distribution of sample 104 and the size distribution of skeletal components.

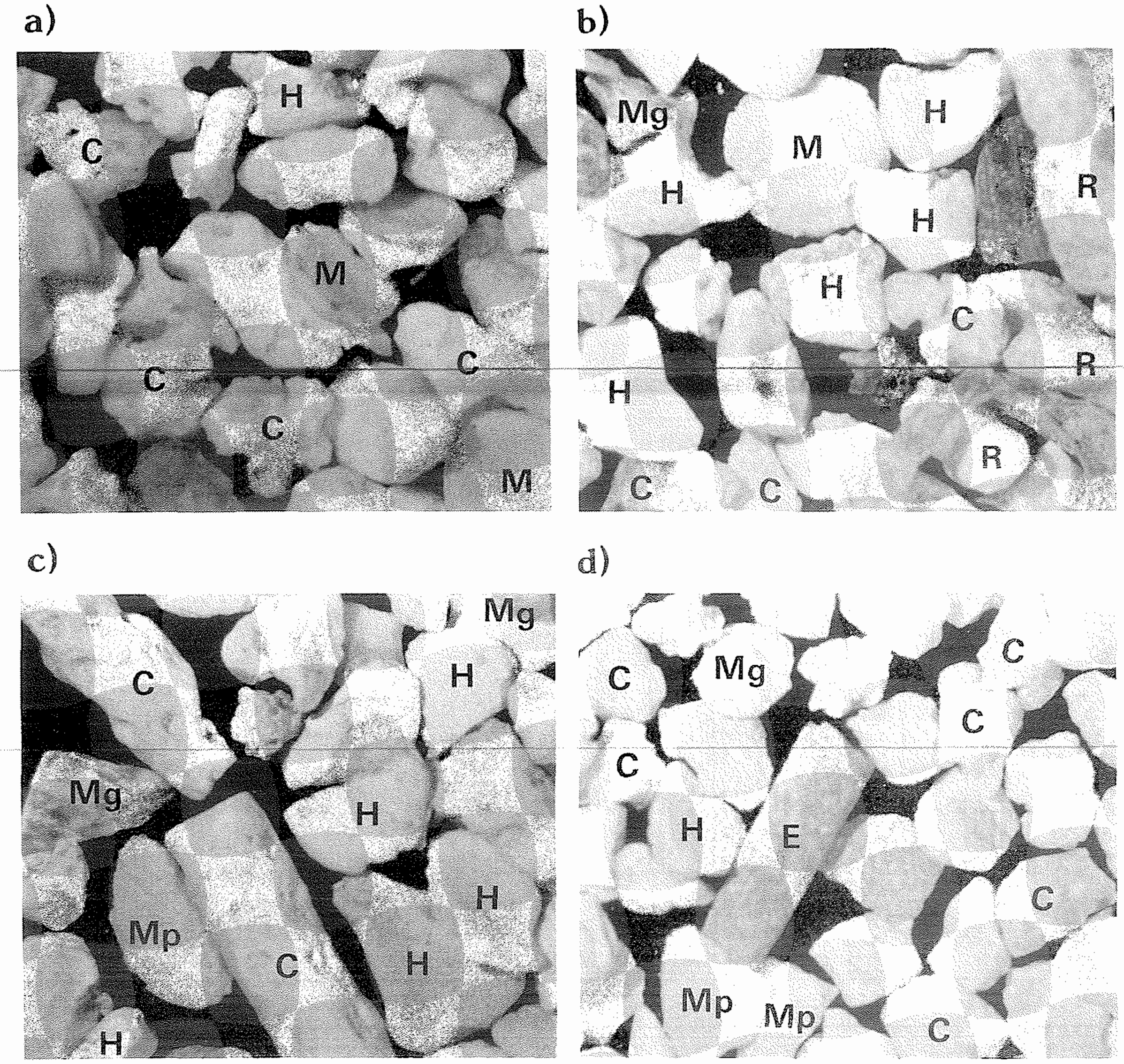

Figure 10. -0.5ø fraction of sediments from various parts of the Cocos (Keeling) Islands lagoon. (a) Sample 24 from the interisland channel. Note the dominance of coral components. Mixed rounded and angular sediments indicative of texturally immature deposit. (b) Sample 58, collected from the lagoonward margin of the interisland channel. Samples predominantly rounded, reflecting the high levels of hydrodynamic energy through this zone. Note rhodolith debris. (c) Sample 120, collected from the seagrass meadow behind South Island. Note the abundance of molluscan material and *Halimeda* flakes. Angular fragments common. (d) Sample 70 collected from the centre of the lagoon. Note the dominance of coral which is variably rounded and encrusted with coralline algae. *Halimeda* flakes, mollusc debris, echinoid spines also apparent. Key: C - coral; E - echinoid; H - *Halimeda*; M - *Marginopora*; Mg - gastropod; Mp - pelecypod; R - rhodolith.