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Bioclastic Sedimentary Environments of Coral Reefs and Lagoon Around Mayotte Island (Comoro Archipelago, Mozambique Channel, SW Indian Ocean)

J.-P. Masse[a], B.A. Thomassin[b] and M. Acquaviva[b]

[a]Laboratoire de Stratigraphie et de Paléoécologie
Université de Provence
U.A. 1208 du C.N.R.S., Centre Saint-Charles
Place Victor Hugo
13331 Marseille cedex 3, France

[b]Centre d'Océanologie de Marseille
U.A. 41 du C.N.R.S., Station Marine d'Endoume
rue de la Batterie des Lions
13007 Marseille, et
Faculté des Sciences de Luminy, case 901
13288 Marseille cedex 9, France

ABSTRACT

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Grain-size distribution, texture (mud content) and quantitative bioclastic component analyses from outer barrier reef and lagoonal environments of Mayotte Island show that reefal and lagoonal sediments are clearly separated. Analysis of major bioclastic components allows the recognition of five sedimentary groups of "facies", each of them being significant of a particular zone. They are (1) coral-mollusc on the outer barrier reef slope, (2) coral-calcareous red algae on reef flats, (3) mollusc-coral and/or (4) mollusc-*Halimeda* at the lagoonal bottoms with coral build-ups or lagoonal plains with free living corals, and (5) mollusc-foraminifera on lagoonal plains; mollusc fragments pervade muddy substrates. In the lagoon the dominance of molluscs reflects the trophic regime related to the island terrigeneous influx. The bioclastic sediment composition generally reflects the nature of the benthic community living in this lagoon. This observation as well as textural and granulometric evidence show that the bulk of the sandy bioclastic material is *in situ* and has suffered little transport. Some relict grains are present in littoral muddy sands while probably older particles (black/green result of diagenesis) occur in the deeper parts of the lagoon. Textural parameters are more environmentally significant than granulometric ones.

ADDITIONAL INDEX WORDS: *Sedimentology, geomorphology, reefal and lagoonal communities.*

REGIONAL SETTING

General Characteristics

Mayotte Island (12°50'S and 45°10'E) is a component of the Comoro Archipelago. This volcanic island (only 374 km^2 emerged) is the largest barrier-reef island in the SW Indian Ocean, rimed by a near continuous ribbon reef (140 km in circumference), enclosing a wide lagoon with deep coastal bays (area of almost 1000 km^2) (GUILCHER, 1971; GUILCHER *et al.*, 1965; COUDRAY *et al.*, 1985).

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The barrier reefs are well developed and continuous on the southern and eastern sides where the reef flats lie close to sea level, while on the northeastern side, coral build-ups are mainly submerged (submerged barrier) and the reef rim grades into a relatively wide coral bank (Iris bank). The east important passages break up the continuity of the barrier reef while the west passages are larger. The lagoon is more than 15 km wide on the western side, narrowing to the east between the Pamanzi volcanic islet and the main island. The lagoon bed slopes gently from the barrier reef towards the central island, so that the deeper parts (commonly 30 to 40 m but in places 60 to 80 m) are near the coast line. Fringing reefs are well developed along coastal capes and rocky shores, but are also present in some bays where the terrigeneous river influx is low. Rainfall is moderate (1 m/year), occurring mainly during the four-month monsoon period (December to March). Consequently, natural land erosion was initially moderate. However, increasing human settlements, coastal management and deforestation of the island have recently increased the fine terrigeneous influx from the land, forming an important addition to sediment in coastal areas (ARNOUX *et al*, 1983).

The swell waves are controlled primarily by monsoon and trade winds with seasonal reversals, but tropical cyclones are not uncommon. The prevailing swell is from the SE. The tidal range is high (4 m) for an oceanic island. Thus from both a geomorphological and a hydrodynamical point of view, the lagoon/open sea exchanges are very important. The western lagoon is morphologically more exposed than those to the east and south.

Reef and Lagoon Physiography

Generally, the outer slope of the barrier reef exhibits a typical spur and groove system developed down to −20 m, but locally scattered unoriented coral patches are found in place of this radial pattern. In places the reef front has a vertical cliff which goes down to −30 m, followed by a steep detrital slope, and generally a narrow pre-reef platform ending near −50 m. From the pre-reef platform edge a subvertical slope surrounds the insular shelf down to at least a depth of 400 m (EHNY, 1987). Barrier reef flats may show transverse stripes formed by alternative coral growths and sand channels or bare flats with rhodolith spreads. In some backreef areas (as near the volcanic Pamanzi islet), sea grasses are well developed. Few sandy cays emerge at low spring tides on some lagoonward reef flats. The inner slope of this barrier may be marked by scattered coral growths, by subcontinuous coral frameworks enclosing pools, or locally by sand spits.

The lagoon is characterized by two sub-environments.

(1) Large areas of scattered coral pinnacles or coral patches lie on the sedimentary floor. Such areas occur in the outer mid-lagoon (*i.e.* behind the barrier), between 27 to 40 m depths, and also in the central depression of the Iris bank, a submerged coral-bank to the north of the island. Locally true lagoonal reefs, well structured, are present (isolated as La Prévoyante reef, or forming a double barrier reef system as on the south-western side; GUILCHER, 1976). They are numerous along submarine canyons at the openings of the passages.

(2) The sedimentary plain consists of a relatively flat sandy or muddy surface or of irregular thalassinoid mound-and-funnel fields; such areas occur mainly in the inner mid-lagoon. In the coastal zone and especially in bays the sedimentary plain is formed by soft terrigeneous muds, while sands or muddy sands are found farther off the coast.

Fringing reefs, growing on the mainland coast or around landward volcanic islands, are frequently flourishing with narrow living or dead reef flats, sometimes with a sea-grass growths on coral rubbles. Their reef fronts are often steep (down to −6 m) and made of scattered coral patches embedded in or lying on muddy substrates. Behind such reefs narrow sandy beaches and/or mangroves rim the shore. Mangroves and silty sand beaches occur also in coastal embayments.

LIVING CORAL REEF AND LAGOON BENTHIC COMMUNITIES

Benthic organisms are important as sediment producers, and therefore the composition and distribution of the main benthic communities need to be briefly described. The following data are from ARNOUX *et al.* (1983), PAYRI (1983), FAURE *et al.* (1984), GOUT (1984), and include personal observations and unpublished data from one of our team (B.A.T.).

Living Coral Reef Communities

The barrier reefs. On the upper parts of the outer slopes, Scleractinian cover is relatively low (15 to 30%) and is dominated by branched and tabular Acroporids associated with scattered massive forms (Poritids and *Pocillopora*). Soft corals may cover up to 40%, and with soft algae and *Halimeda*, they may colonize up to 60% of the whole surface. On the deeper slope the sessile benthos is composed of Agaricids, sponges, alcyonarians, antipatharians and some Stylasterids (in crevices or under the overhangs). In associated sediment patches or sand pockets, the typical "coarse and medium sand infaunal community" is present of which molluscs form about 20% (64 indiv./m^2 for example in the Longogori Pass). Bare, flat, hard surfaces, with crustose coralline algae and clumps of soft *Asparagopsis* algae trapping sands, are observed on the outer reef flat. Thus, this zone where only rare small coral colonies are present has no boulder tract. The mid reef flat is occupied by dead, corroded tabular coral knolls intensely bored by Echinoids (*Echinostrephus molare* and *Echinothrix diadema*). The inner reef flat has an active coral frame (*Acropora palifera*) surrounding small size sandy depressions (to 1 m deep) in a reticulate pattern. The sandy substrates are inhabited by an infaunal mollusc community in which gastropods dominate bivalves. On the inner slope of the barrier, large polygenetic coral patches (*Acropora, Porites, Goniopora, Platygyra, Montastraea, Goniastraea, Halomitra* and *Fungia*) cover 55 to 65% of the surface, associated with algae.

Coastal and fringing reefs. Coral assemblages show a high diversity, especially near the edges of steep slopes and cliffs. Scleractinians cover 7 to 27% of the surface, and soft corals are abundant. On the corresponding reef flats, hard substrates predominate with sparse living or dead corals and some algae; sediments (muddy sands) occur as limited and local pockets. In sheltered areas, "rooted" *Halimeda (H. macroloba)* meadows are characteristic. As in the lagoon, *Pycnodonta* is relatively abundant, attached to coral fragments.

Living Lagoon Communities

On outer lagoon sandy bottoms, scattered coral patches are recorded. In this instance however, build-ups are polygenetic, with living coral coverage relatively low (about 30%); soft corals, antipatharians, large sponges (*Petrosia testudinaria* especially), encrusting bivalves (*Pycnodonta* and *Spondylus*) and *Halimeda* are well represented. Sandy substrates belonging to the "pure carbonate facies" are occupied by an infaunal assemblage belonging to the "coarse and medium sands under bottom current effects community," defined by THOMASSIN (1978) in the SW malagasian coral reef complexes. This community shows different aspects according to the local development of some groups: foraminifera epifauna, thalassinoid (*Thomassinia*) infauna or free living *Heteropsammia michelini* coral assemblage (in some channels). Molluscs are not abundant (3 to 20%) and are dominated by bivalves.

When the sands are contaminated by terrigeneous silts ("impure carbonate facies"), meadows of large rooted *Halimeda* develop. The infaunal community changes and belongs to the less silt-clogged aspects of the "sheltered muddy sediments community" of THOMASSIN (1978). Lagoonal sandy-muddy bottoms are heavily bioturbated by the large callianassids that create mounds-and-funnels fields.

On the muddy bottoms of the inner lagoon, molluscan infauna decreases (to an average 3%) but clumps of the epifaunal *Avicularia* are encountered on small isolated hard substrates. Locally, a typical coral community is initiated on these bivalve shells. Characteristics forms are *Euphyllia, Cycloseris* and *Mycedium*, associated with some lenticular *Blastomussa* carpets, and the resulting biostromal build-ups are of the mud-mound type.

MATERIAL AND METHODS

Surface sediments samples were collected during the 1977 "Benthedi" cruise of vessel "N.O. Suroît" and during the 1983 "Acanthaster" survey, in association with field observations (both snorkeling and S.C.U.B.A. diving down to 40 m) in lagoon, reef flats and reef front areas. Following previous work and after a regional reconnaissance sampling, some localities were selected to exemplify the most typical environments (see Figure 1).

Texture and grain size distributions were analysed by sieving for about 60 samples. Percentages of mud (material finer than 60 μm) were measured as grain size distribution curves were constructed for the sandy fraction (greater than 60 μm) of all samples. Mean size and sorting index (see MASSE *et al.*, in press) were calculated. Granulometric data from GUILCHER *et al.* (1965) were also considered. Insoluble residues were measured on the finer fraction to determine the terrigeneous influence.

The constituent particle identity of 45 selected samples was studied, corresponding to the main types of the bioclastic sedimentary environments. Major and minor constituents of fractions coarser than 0.10 mm were identified

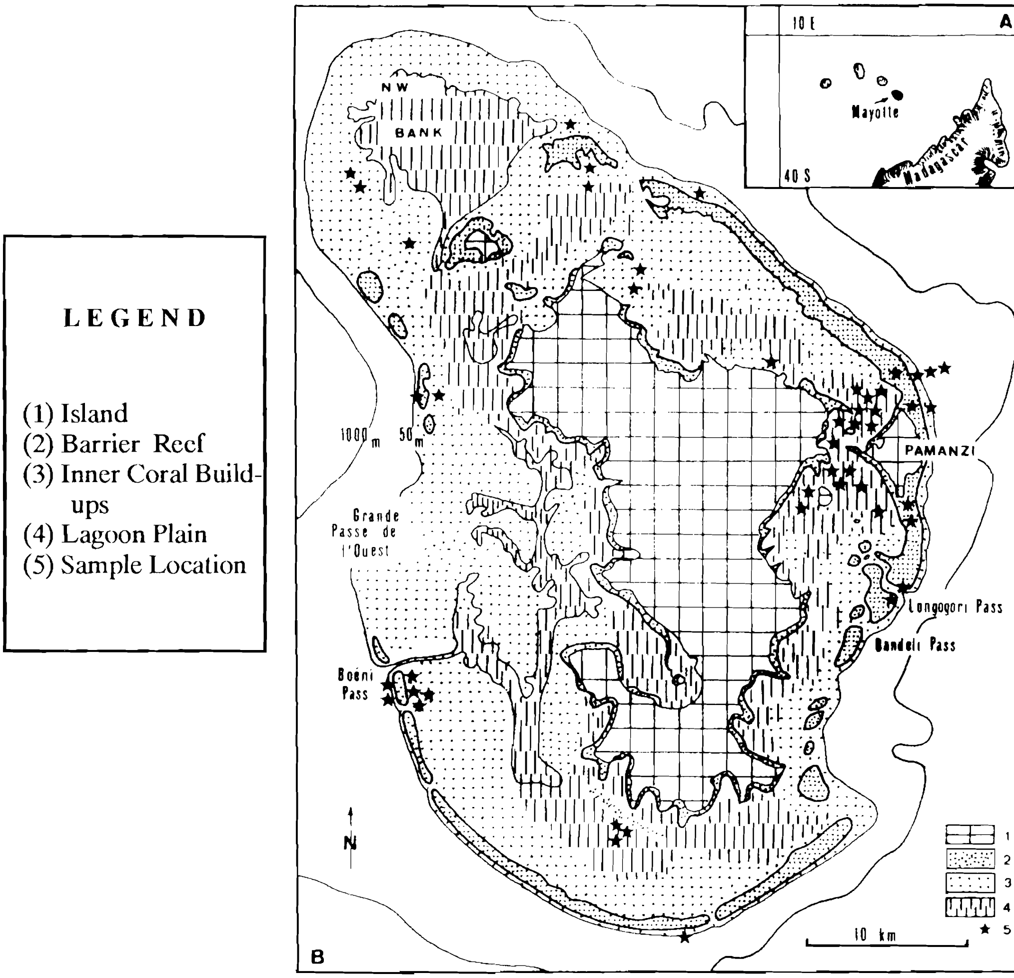


Figure 1. Map of Mayotte area and its situation in the SW Indian Ocean. (A) Location of Mayotte I. within the Comoro Archipelago. (B). Physiographic map of the Mayotte I. and surrounding reefs and lagoon.

and counted using a binocular microscope. For each sample 100 grains were examined for each size population, results were converted to weight percentages according to the amount of the corresponding size fraction. Thus total constituent percentages were calculated (for more information concerning the calculation processes, see MASSE, 1970).

Identified components have been separated into two groups:

(1) major components: benthic foraminifera, molluscs (gastropods and bivalves may be recognized separately in the coarser fractions, while in the finer one they can only be listed as "molluscs"), corals (in the coarser fractions debris of colonial forms have been separated from often complete, solitary forms), red calcareous algae, and the green Udoteacea (*Halimeda*);

(2) minor components: crustaceans (macroforms and ostracods), bryozoans, echinoderms (mainly echinoids), serpulid worm tubes, sponge and alcyonarian spicules, altered grains (brown, green-black or black particles of unknown biological origin), lithoclasts and grain aggregates. Volcanic derived grains are

sometimes recorded in the sandy fraction but are also, in the sample examined, of minor importance.

Unknown bioclastic particles correspond to small or medium sized grains altered by abrasion or microborings.

RESULTS: THE BIOCLASTIC SEDIMENTARY ENVIRONMENTS DESCRIPTION (Figure 2 and Table 1)

Barrier Reef

Outer reef slope. Sheet sands within grooves, sand pockets and aprons on the reef front lack a fine fraction, the mean size is moderate (mean = 1.1 mm) and the sorting is excellent (=1). Coral fragments dominate (mean = 37%) but molluscs are important (mean = 19%). Calcareous red algae play a significant role (mean = 11%), the highest values are recorded on the outer pre-reef platform. *Halimeda* and foraminiferas are poorly represented (5% each). Among the minor components Alcyonarian spicules reach their highest values here (mean = 4%) (Figure 3).

Reef flat. Although the mean size ranges from medium sand (mean = 1.5 mm) to gravel/boulder grade, sediments from sandy pools and channels are relatively well sorted (mean = 1.5) and, as the outer reef sediments, lack a fine fraction. The mean values of coral fragment are identical to those of the outer reef, calcareous red algae are abundant (mean = 28%) and molluscs remain important (mean = 15%). Foraminifera and *Halimeda* reach their lowest values here (respectively 2% and 1%).

Passages. Textural parameters and component composition are very similar to those of the outer slope sediments, nevertheless sorting is not so good and mollusc fragments are more frequent (mean = 30%). Sediments from the passes are characterized by high quantities of unknown bioclastic grains resulting from biological alteration and/or mechanical abrasion.

Lagoon

Lagoon plain. Sediments from the inner lagoon plain, close to the island, show a high fine fraction content (mean = 62%) the main part of which is terrigeneous. The insoluble residue ranges from 63 to 79%. The sandy fraction of these mud-bottom sediments is dominated by mollusc fragments (mean = 45%) and coral, calcareous red algal fragments and foraminifera

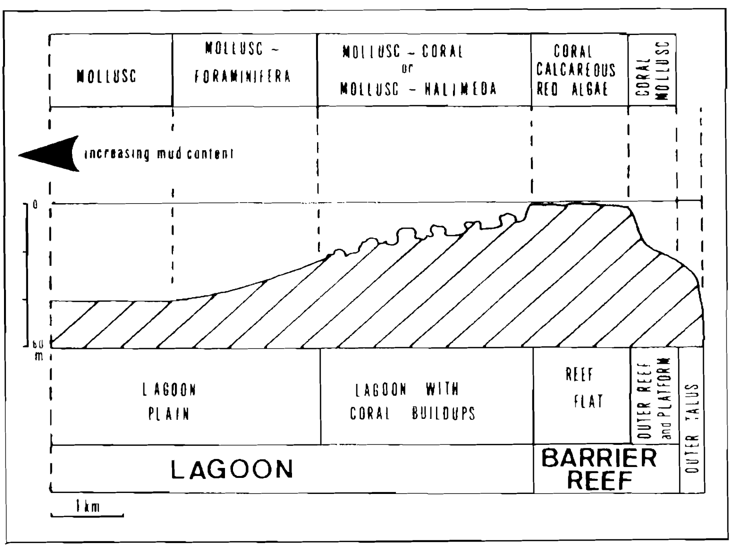


Figure 2. Idealized section through the lagoon/reef system from Mayotte showing the relationships between physiography and sediment constitution (*i.e.* main bioclastic components).

Table 1. *Principle components of the sandy fraction textural and granulometric parameters (mean values) in the bioclastic sedimentary environments. Values in brackets correspond to "relict" particles. Unidentified particles have not been listed here.*

BIOCLASTIC SEDIMENTARY ENVIRONMENTS			TEXTURE AND GRANULOMETRY			% BIOCLASATIC COMPONENTS							
			FINE FRACTION < 63 µm	MEAN SIZE mm	SORTING	CORAL	CALCAREOUS RED ALGAE	FORAMINIFERA	MOLLUSC	HALIMEDA	BRYOZOA	ALCYONARIAN	ECHINODERM
BARRIER REEF	OUTER REEF AND PASSES		< 1	1.1	0.9	37	11	5	19	4	2	4	2
BARRIER REEF	REEF FLAT		< 1	1.5	1.5	37	28	2	15	1	< 1	< 1	< 1
LAGOON	LAGOON WITH CORAL BUILDUPS		2	0.8	2	18	13	10	22	17	2	<1	< 1
LAGOON	LAGOON PLAIN	Muddy sands with corals	20	1.6 6.9	> 2	21	2	6	31	15	1	< 1	2
LAGOON	LAGOON PLAIN	muddy sands	9	0.8	2.1	6	3	20	37	2	2	1	3
LAGOON	LAGOON PLAIN	mud	62	0.15 2.6	2.1.	(7)	(4)	6	45	1	(3)	(2)	(3)

play minor roles (7% each). The mean size of the coarse fraction is extremely variable but sorting remains relatively good (mean = 2.1). A recent increase of fine terrigeneous influx from the land (linked to human activities and settlement) has significantly modified the nature of the bottom of the inner lagoon and quite pure terrigeneous muds now spread out over large areas. Nevertheless, as such muds only thinly cover the previous veneer, muddy sand samples collected include both. Consequently, except for the main part of the mollusc content (small thin shelled forms dominant), the main bioclastic components seem to belong to the muddy sands community, and need to be considered as "relict" (in the sense that they do not correspond to present day conditions).

The main part of the lagoon plain (central and outer parts of the lagoon) is covered by muddy to almost clean, pure bioclastic sands. The average mud content is moderate (mean = 9%), the mean size of the sandy fraction is low (mean = 0.8 mm) as the sorting is similar to that of the corresponding fractions of mud bot-

Figure 3. Main types of coral reef and lagoon bottoms with the corresponding bioclastic facies.

(1a) Barrier reef outer slope, coral patches with scattered sandy pockets (20 m deep, Grand récif du Nord-Est, st. TR7, June 1983).

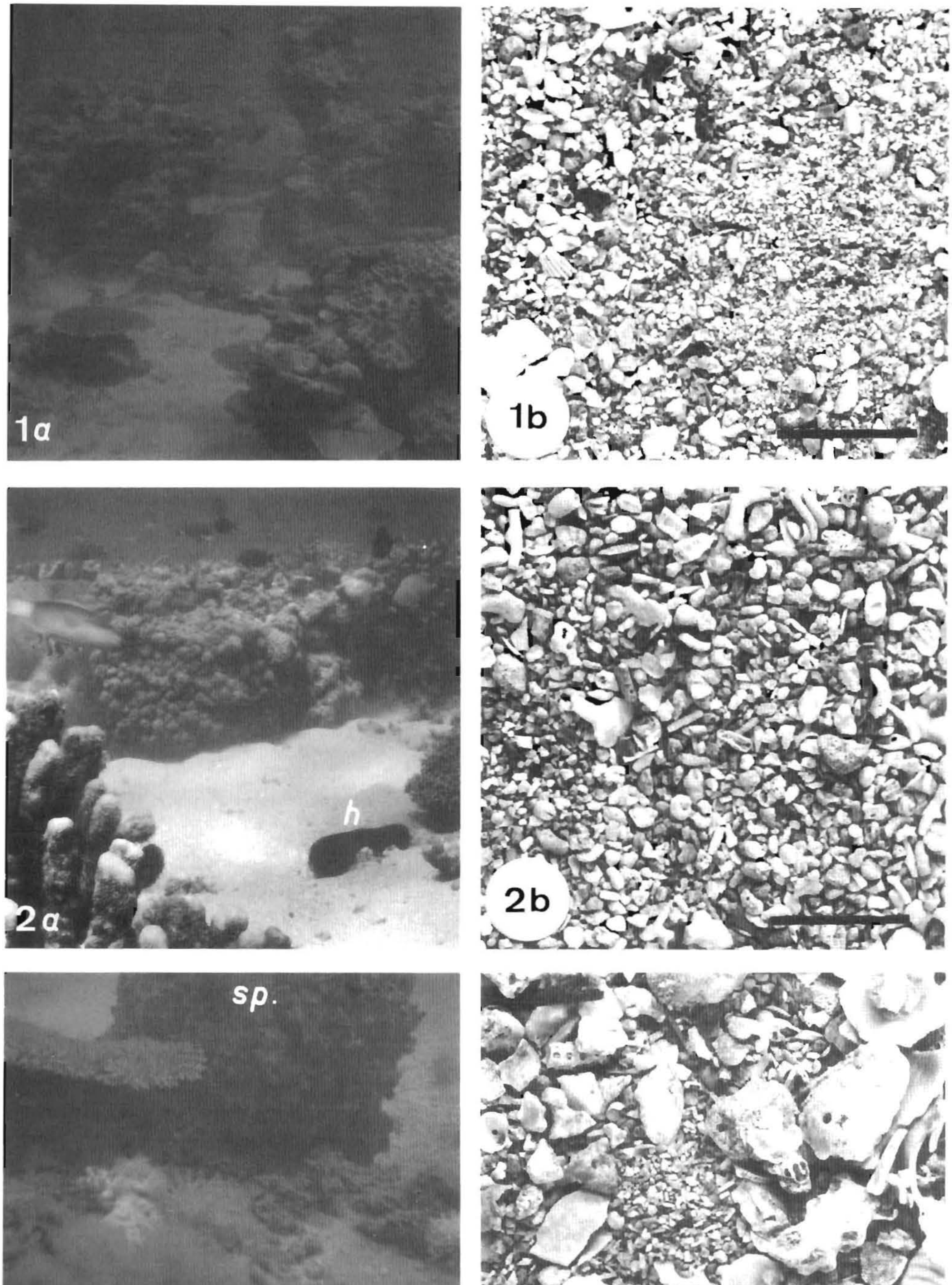
(1b) Coral-Mollusc sediment facies.

(2a) Barrier reef flat, sandy pool (h: Holothurian) (1,5 m deep, S. Pamanzi barrier reef, st. P, June 1983).

(2b) Coral-Algal sediment facies.

(3a) Lagoonal reef slopes, gravelly sands at the basement of a coral growth (x.n. = *Xenia* alcyonarian) (18 m deep, Andrema Island, SE corner, May 1983).

(3b) Mollusc-Coral sediment facies. (Facing Page)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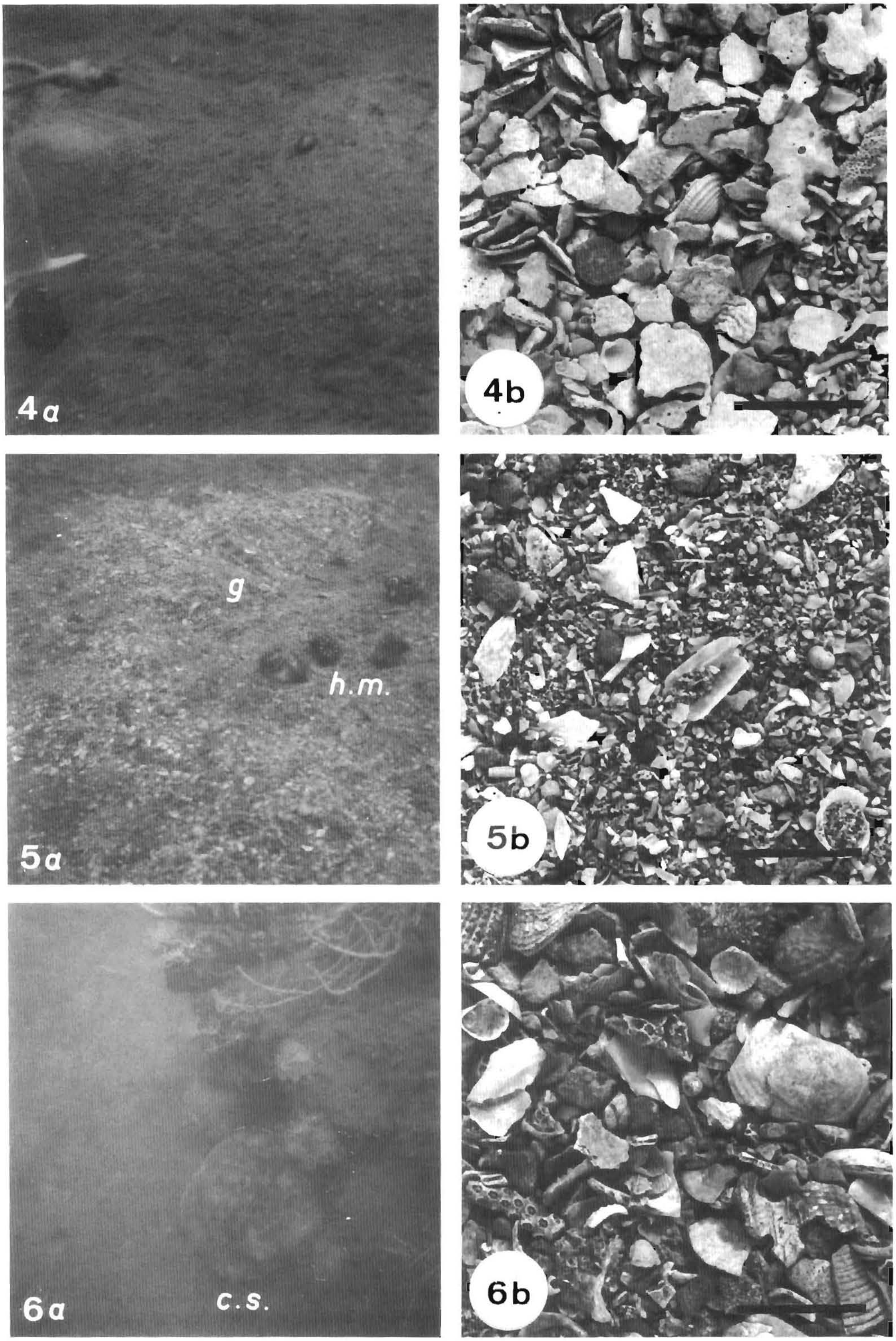
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tom deposits. Molluscs debris dominate (mean = 37%) but foraminifera reach their highest percentages here (mean = 20%). Coral, calcareous red algae and *Halimeda* fragments are poorly represented. Locally free living corals may grow on the muddy sands, consequently coral content may rise (mean = 21%), local *Halimeda* give the same result. The occurrence of these relatively large *in situ* sediment producers results in the coarsening of the sandy fraction up to gravel size while sorting reaches its poorest values. Locally (near Pamanzi islet) sand size volcanic grains are mixed with the bioclastic fraction.

Lagoon bottoms with coral patches and lagoon patch reef talus. Sand sheets with only scattered coral heads or sand pockets associated with the coral framework are found between −9 to −40 m depths. These sands have a variable mean size but the fine fraction is low (mean: 2%), sorting is moderate (mean = 2). As in other lagoonal environments molluscs dominate (mean = 22%), nevertheless the other major components, coral and *Halimeda* (means are 18% and 17% respectively) and calcareous red algae and foraminifera (means are 13% and 10% respectively) are well represented. Among the minor components bryozoa reach their highest values (mean = 4%).

DISTRIBUTION OF SEDIMENT COMPONENTS (SANDY FRACTION)

Major Components

Molluscs. This is the most important group for sediment production in the lagoon. The mollusc content increases with increasing mud as in the SW New Caledonia lagoon (MASSE *et al.*, in press). On the flat lagoon floor bivalves dominate over gastropods but the two groups are of almost equal importance on lagoon bottom with coral build-ups and lagoon patch reef talus. Molluscs are less important on the barrier reef although higher values are found on the outer reef slope and in passages, the lowest values occur on reef flat sand sheets where gastropods dominate bivalves. The change in dominance between the two groups reflects their relative importance in the corresponding benthic communities.

Corals. This group including both Scleractinian and Milleporid Cnidaria is the most important on the barrier reef with a rich fauna developing on the outer reef, the reef flat and in passes. Free-living corals are also important gravel size sediment producers on lagoonal muddy-sand substrates. Significant coral debris is produced near lagoonal patch reefs or local minor build-ups as the result of bioerosion and gravity displacement. On the lagoon plain coral fragments only occur in minor quantities but are always present. In such environments, where living corals are absent, coral grains might originate either from lateral transport, from lagoonal build-ups (or even barrier reef?) or *in situ* production. We favour the last hypothesis and consider this material as partly relict, especially on muddy substrates, as no mechanical features are observed on particles while microbiological alteration is important.

Calcareous red algae. The highest values are recorded on reef flats where small branching Corallinacaea are common ("false maerl" type in the sense used by THOMASSIN, 1971). On the outer reef and in passes, fragments of articulate forms are frequent whereas thin encrusting forms are also observed in significant amounts on coarse coral debris. True rounded rhodolites of centimeter-size have not been found within these zones as it was said from many other reefs areas (WEYDERT, 1973, 1974; BATTISTINI *et al*, 1976; MONTAGGIONI, 1979). Fragments of small articulate calcareous red algae are frequent on lagoon bottoms with coral build-ups and patch reef talus, they are rare on flat lagoon floors.

Foraminifera. The barrier reef system is poor in foraminifera (mean = 2 to 5%). The highest percentages are found in fine sands of the outer reef and the lowest in reef flat sands.

Figure 3 Continued.

(4a) Lagoon plain, fine-medium sandy bottoms with thalassinoid mounts (small free living coral: *Heteropsammia michelini*) (15) m deep, northern Pamanzi lagoon, st. I, May 1983).

(4b) Mollusc-*Halimeda* sediment facies.

(5a) Lagoon plain, sandy bottoms (h.m. − *Heteropsammia michelini* corals, g = Gobiid fish living in association with burrowing alpheid shrimp) (20 m deep, channel between Dzaoudzi almost-island and Mogne Amiri islet, June 1986).

(5b) Mollusc-Foraminifera sediment facies.

(6a) Inner coral patches in coastal bay (c.s. − *Culcita schmideliana* starfish (9 m deep, Anse Choa in front Mamoudzou village, st. A, May 1983).

(6b) Mollusc dominant sediment facies. (Facing Page)

In the lagoon, foraminiferal contents are significantly higher (mean 6%) especially on muddy sand bottoms where they reach a maximum (mean = 20%) but local contents may be up to 40%.

As mentioned by LE CALVEZ (*in* GUILCHER *et al.*, 1965) high foraminiferal contents represent a small number of genera. *Operculina* and *Amphistegina* are particularly important. *Operculina* is the most important sediment producer on the lagoonal areas below 10 m deep on muddy or clean sands. A similar distribution has been demonstrated in many lagoonal or protected outer reef areas (MASSE, 1970; HÖTTINGER, 1980; DEBENAY, 1985; BOICHARD *et al.*, 1985; MASSE *et al.*, in press).

Amphistegina is widespread and the highest relative frequencies are recorded on the outer reef as in the case of the Mascarene reef province (MONTAGGIONI, 1978), certain atoll lagoons (CHEVALIER *et al.*, 1969) and various coral reef banks (BATTISTINI *et al.*, 1976).

Close to these genera, relative to their sediment production are *Marginopora*, a very common form, and *Alveolinella* found in lagoonal areas, except on substrates where the mud content is high.

Halimeda. The highest values occur on lagoon bottoms with lagoon reefs where whole flakes dominate the coarser sand fraction of sandy substrates. In these environments, the *Halimeda* content may be up to 35% and seems to be derived from hard substrate species. High values are also observed locally on muddy substrates where the algal debris seems to originate from soft bottom species.

Although there are few *Halimeda* fragments, they are always present in other environments. Significant amounts may occur locally on some outer reef areas. GUILCHER *et al.* (1965) mentioned local *Halimeda* flake concentrations on reef flats (lagoonal reef, inner barrier, fringing reef flats and barrier reef flats from the northern part of the reef rim).

Minor Components

Bryozoa. The highest values (mean = 4%) are found on lagoon bottoms with coral buildups and lagoon reef talus. Fragments are of encrusting or branching sessile forms derived from hard substrates. Similar forms are also present in smaller quantities on the outer reef zone. One some parts of the lagoon free living forms such as *Cupuladria* may contribute to the sediment coarse fraction.

Echinoderms. Fragments are widely distributed, but mean contents never exceed 3%. These values occur on muddy and muddy-sand bottoms from the lagoon plain where they derive mainly from infaunal irregular echinoids, while hard substrate echinoderms play a minor role.

Alcyonarian spicules. The highest contents are found on outer reef areas with a rich alcyonarian community.

EARLY DIAGENETIC ASPECTS OF THE SANDY FRACTIONS

Early diagenetic features include grain modification prior to lithification. Grain alteration results from microborings (made by blue-green algae and fungae) but these frequently remain empty (EHNY, 1987) thus true "micritisation" (*i.e.* micropores filled with micritic material) is totally absent as was observed in some reefal systems (BOICHARD *et al.*, 1985). Microbiological grain modification is important, in lagoonal areas the alteration of bioclastic particles is frequently followed by the blackening and/or the deposition of a black to green void filling. The void filling is very similar to some chloritic products also found on bioclastic components (BUROLLET *et al.*, 1979; BOICHARD *et al.*, 1985) or verdine facies (a chlorite family mineral) found in tropical coastal areas (ODIN, 1985). It must be noted that this type of authigenesis is mainly found on *Miliolacea* foraminiferal tests, especially on *Marginopora* and *Alveolinella*. It has not been observed on perforate genera such as *Operculina*) in the same environments. Thus a significant "substrate control" is involved in this black/green diagenesis as well as in other environmental parameters. Further studies are needed of this type of mineral formation (especially for the length of time needed for its genesis, which might be relatively important) and consequently its possible "relict" significance (see MASSE *et al.*, in press).

Grain aggregation is common in intraskeletal "micritic" fillings especially on coral fragments derived from lagoon build-ups. Some packstone-wackestone millimeter size lithoclasts have also been found in lagoon sediments. Their foraminiferal/mollusc debris content seems to indicate that they may be derived from some lithified lagoon deposits, but lagoonal hardgrounds such as those in the Nouméa lagoon, SW New Caledonia (THOMASSIN and COUDRAY, 1982), have not been recorded in the studied area.

DISCUSSION

An ordered arithmetic association of the five major components: coral, molluscs, foraminifera, calcareous red algae and *Halimeda* can lead to twenty binomial theoretical possibilities, the majority of which are effectively recorded in reef systems. Among these, only five groups or "facies" are observed in the area investigated, each being related to a specific environment. These facies and their environmental significance are as follows: (1) coral-mollusc: outer reef; (2) coral-calcareous red algae: reef flat; (3) mollusc-coral and/or; (4) mollusc-*Halimeda*: lagoon bottoms with coral build-ups or free living corals on the sediment: and (5) mollusc-foraminifera: lagoon plain.

As in many other reef systems (MAXWELL, 1973; MAIKLEM, 1970; MASSE, 1970; MONTAGGIONI, 1978; GABRIÉ, 1982; MASSE *et al.*, in press) the mollusc-foraminifera sedimentary assemblage and the coral-calcareous red algal assemblage tend to be mutually exclusive. They correspond respectively to extreme physiographic patterns, to sediment sheets in protected areas, and to reefal build-ups in relatively high energy environments. In the Mayotte reef and lagoon system the first group characterizes most lagoon sedimentary bottoms and the second one the barrier reef flat. In addition to these two major groups the "coralgal" and "foramol" of LEES (1973, 1975), a coral/mollusc assemblage is associated with the outer reef slope and mollusc/algal (red calcareous and/or *Halimeda*) group is mainly linked to lagoon bottoms with coral build-ups.

Two aspects of the lagoon/reef sedimentary composition warrant further mention. First, most Mayotte lagoon sediments lack the large amounts of *Halimeda* fragments recorded in many atoll lagoons (EMERY *et al.*, 1954; TUDHOPE *et al.*, 1985) and in back-reef areas and bays (GINSBURG, 1956; EBANKS and BUBB, 1975). In the Mayotte lagoon, *Halimeda* sand sheet production is limited and only local. Disregarding some substrate control (such as mud content) the dominance of molluscs (mainly bivalves) among *Halimeda* may be the result of the trophic regime: the former group is favoured by suspended fine organic particulate nutrients carried from the islands, as the latter may develop in waters where only dissolved nutrients are present (*i.e.* oceanic waters) as for some atolls (TUDHOPE *et al.*, 1985).

A second feature is the paucity of red calcareous algae and foraminiferas on the outer reef. These two components are common on many exposed outer reefs (MONTAGGIONI, 1978; GABRIÉ and MONTAGGIONI, 1982; MASSE and FROGET, 1984) but although they increase on the outer platform of Mayotte, they do not reach the dominance found elsewhere. This might be linked to the high energy resulting from the narrowness of the pre-reef platform, where lateral sediment transfer from the spur and groove or reef front talus is important.

Generally, the sediment component reflects the nature of the community living in close vicinity to the area of deposition. Skeletal particles derived from soft bottom communities are therefore considered as *in situ*. Similarly the distribution of most foraminifera is not, as it was thought by LE CALVEZ (*in* GUILCHER *et al.*, 1965), controlled by bottom currents, but by the ecology of the organisms themselves.

Some components of the sandy fraction of lagoonal areas are considered "relict". This is the case for most of the sandy fraction of inner lagoon "muds", but here the "relict" character is very recent (perhaps 20 years). This probably also applies to some black-green altered grains from the deeper parts of the lagoon, but the age of this material is problematic and further study needs to be undertaken.

Textural parameters such as the fine-fraction content are more significant in terms of environmental discrimination, than granulometric ones such as the mean size and sorting of the sandy fraction. The fine fraction is absent on the barrier reef areas. In the lagoon, mud content increases towards the island coast.

The relative importance of the terrigenous material in the fine fraction associated with the sandy material from lagoonal areas reminds of many other lagoon systems in settings near to a land mass or an island (coastal lagoons of Madagascar and New Caledonia for instance). As in New Caledonia (MASSE *et al.*, in press) there is a possible relationship between this terrigeneous influence and the large content of molluscs (mainly bivalves), but this phenomenon is also controlled by depth and littoral morphology.

The mean size of the sandy fraction is extremely variable and values are not typical of particular environments. Variations are more important in lagoon environments than in the barrier reef, reflecting a higher physiographic diversity. Sorting is significantly better on the barrier reef (especially on the outer reef) than in the lagoon where mean values are always >2. These differences are linked to the relative importance of hydrodynamic control, which is significantly lower in the lagoon than on the barrier reef. In the lagoon, sorting is poorer with mean size, this phenomenon clearly reflects the *in situ* origin of most of the bioclastic sandy fraction. Similar conclusions concerning the relationship of sorting variations between reef and lagoon areas have also been drawn for other reef complexes (MAIKLEM, 1970; GARRETT *et al.*, 1971; BATTISTINI *et al.*, 1976; MASSE *et al.*, in press), for atolls (STODDART, 1971; CHEVALIER *et al.*, 1969), and for reef/carbonate platform complexes (GINSBURG, 1956; PURDY, 1963).

The lack of significant amounts of carbonate mud associated with the sandy fraction of lagoonal areas is reminiscent of many other lagoonal systems occurring near a land mass or an island.

CONCLUSIONS

The study of texture, grain size and components of sediments from the barrier reef and lagoon of Mayotte island leads to the following conclusions:

lagoon and barrier reef sediments are clearly separated according to the considered parameters;

among the twenty possibilities of the ordered arithmetic association of the five major components only five are observed: (1) coral-molluscs, (2) coral-calcareous red algae, (3) mollusc-coral, (4) mollusc-*Halimeda* and (5) mollusc-foraminifera. Each has a particular environmental distribution: groups 1 and 2 on the outer reef and reef flat respectively, groups 3 and 4 on lagoon bottoms with coral build-ups and group 5 on the lagoon plain.

The coral-calcareous red algae and mollusc-foraminifera groups which are respectively typical of reefal build-ups and sedimentary bottoms are well separated off Mayotte Island, but the *Halimeda*-mollusc and *Halimeda*-foraminifera groups are absent here, while they have been recognized in some other lagoons.

Mollusc fragments always dominate *Halimeda* as the result of a possible trophic regime linked to lateral influence of the island. The relatively high content of terrigeneous mud and associated organic matter occurring in the lagoon is considered to be an important factor for mollusc development as infered for other coastal lagoons. The outer reef mollusc-foraminifera facies and red calcareous algae-foraminifera facies are lacking due to the narrowness of the outer or pre-reef platform.

The bioclastic composition of the sediments reflects the nature of the benthic community living on the corresponding substrate, or on hard (bioconstructed) substrates close to the area of deposition; moreover, especially in the lagoon, sorting is poorer with a mean size, thus both bioclastic composition and granulometric parameters indicate an *in situ* origin for most of the sandy fraction.

In situ relict bioclastic grains are also found in the lagoon. Some have very recently become relict as the result of an increasing mud influx in the inner lagoon, while possibly older altered grains from the deeper parts of the lagoon are also present.

Textural parameters such as the fine fraction content are more significant than granulometric ones from an environmental point of view, but sorting (of the sandy fraction) is more significant than mean size.

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