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FORAMINIFERAL BIO- AND THANATOCOENOSES OF REEF FLATS, LIZARD ISLAND, GREAT BARRIER REEF, AUSTRALIA. NATURE OF SUBSTRATE

by

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SUMMARY

The foraminiferal communities on three reef flats of the reef complex of Lizard Island are studied by the author. The Lizard archipelago is situated in the Northern Province of the Australian Great Barrier Reef and consists of granitic islands (Lizard, Palfrey and South) linked by a reef complex. The reef flats of the « Windward » and « Southern » barriers belong to a reef « barrier » system linking respectively Lizard and South, and South and Palfrey islands. Both reef flats show comparable physiographic zonation though upon the southern flat only impoverisihed coral growth occurs. The third reef flat belongs to the fringing reef system along the East coast of Lizard Island and again shows the same zonation except for the backreef area where the microatoll zone rises up towards a sandy-gravelly beach.

The thanatocoenoses of Foraminifera found in the sand pockets, drain channels and beach accurately reflect the biocoenoses of Foraminifera living mainly upon and in a well-developed algal cover which covers large areas of the three reef flats except the algal pavement (forereef) where algal growth is reduced to the crustose coralline lithothamnioid Rhodophyta. Only smaller empty tests and finer sediment particles are transported in a leeward direction.

Highest foraminiferal abundances are reached (bio- as well as thanatocoenoses) by the Soritidae, Amphisteginidae, Calcarinidae and Elphidiidae.

The distribution of the foraminiferal communities is closely related to the distribution of the algal cover which is shown to form an ideal protecting habitat for larger as well as smaller Foraminifera. The algal composition of this cover is slightly variable but Chlorophyta, and, in particular, smaller non-encrusting Rhodophyta dominate. The foraminiferal distribution is only secondarily influenced by the biological composition and species diversity of the algal cover; the physical properties (size, shape, flexibility and surface texture of the thalli) play the primary role in this respect.

Palaeoecological applications of this algal-foraminiferal interdependance are possible but should be treated with caution.

Key-words : Foraminifera, reef flats, algal substrates.

Bio- et Thanatocoenoses de Foraminifères des Platiers récifaux de Lizard Island, Grande Barrière de Corail, Australie; Nature du Substrat

RÉSUMÉ

L'auteur a étudié les communautés de foraminifères de trois platiers récifaux de Lizard Island, île située dans la Province Septentrionale de la Grande Barrière de Corail d'Australie. L'archipel de Lizard Island est composé de trois îles granitiques (Lizard, Palfrey, South) liées entre eux et entourées d'un complexe récifal. Les platiers des barrières « Windward Barrier » et « Southern Barrier » appartiennent à un système « barrière » connectant les îles Lizard et South, resp. South et Palfrey. Ces deux platiers montrent des zonations physiographiques comparables quoique la faune des madrepores du « Southern Flat » est appauvrie. Le troisième platier appartient au système de récifs frangeant le long de la côte Est de Lizard Island; il montre une fois de plus la même zonation, sauf pour l'arrière-platier qui monte en pente douce vers une plage sableuse.

Les thanatocoenoses de foraminifères des poches de sable, des chenaux de drainage et de la plage reflètent les biocoenoses de foraminifères vivants pour la plus grande partie dans une couverture algaire bien développée, couvrant des surfaces considérables des trois platiers; sur l'avant-platier (pavement algaire) la couverture algaire est réduite à des algues rouges encroutantes.

Les familles de foraminifères atteignantes les plus hautes fréquences aussi bien dans les bio- que dans les thanatocoenoses sont les Soritidae, Amphisteginidae, Calcarinidae et Elphidiidae.

La distribution des communautés foraminiferales est étroitement liée à la distribution de la couverture algaire formant un habitat protecteur idéal. La composition algaire de cette couverture est légèrement variable mais les Chlorophyta et en particulier les Rhodophyta non-encroutants dominent.

La composition et diversité spécifique des algues au sein de cette couverture algaire n'exerce sur la distribution des foraminifères qu'une influence indirecte; les caractéristiques physiques et méchaniques (dimension, forme, flexibilité et texture de surface) des thalli sont d'une importance primordiale.

Par la suite, des applications paléoécologiques de cette interdépendance algues-foraminifères, qui ne sont pas à exclure, resteront en tout cas à traîter avec précaution.

INTRODUCTION

The name « Lizard Island » covers a small archipelago consisting of three « continental » islands linked by a reef complex and situated in the Northern Province of the Australian Great Barrier Reef, north of Cooktown and Cape Flattery (see fig. 1).

The Lizard archipelago (see Fig. 1) is composed of the granitic Lizard Island and its two granitic satellites, Palfrey and South islands. The main island is 4 km long and 3 km wide. The three islands are linked together by a reef complex consisting of :

1) a narrow fringing reef bordering the NE and E coast; this fringing reef enlarges considerably in the E, forming the first reef flat under consideration here, known as Coconut Fringing Reef flat.

2) a second reef flat belonging to the reef structure extending in the SE, between Lizard and South Islands, which was named the « Windward Barrier ».

3) a third reef flat belonging to the reef stretching out in the SW between South and Palfrey Islands. This reef was named the « Southern Barrier ».

The remaining reef structures are not dealt with in this contribution.

MATERIAL AND METHODS

The island has served as one of the activity centres and mooring places for the Belgian « De Moor »-expedition in 1967 and has been preliminarily surveyed by Dr. Monty, Liège University. During the early seventies a scientific field station (sponsored by the Australian Museum and the University of Sydney) has been

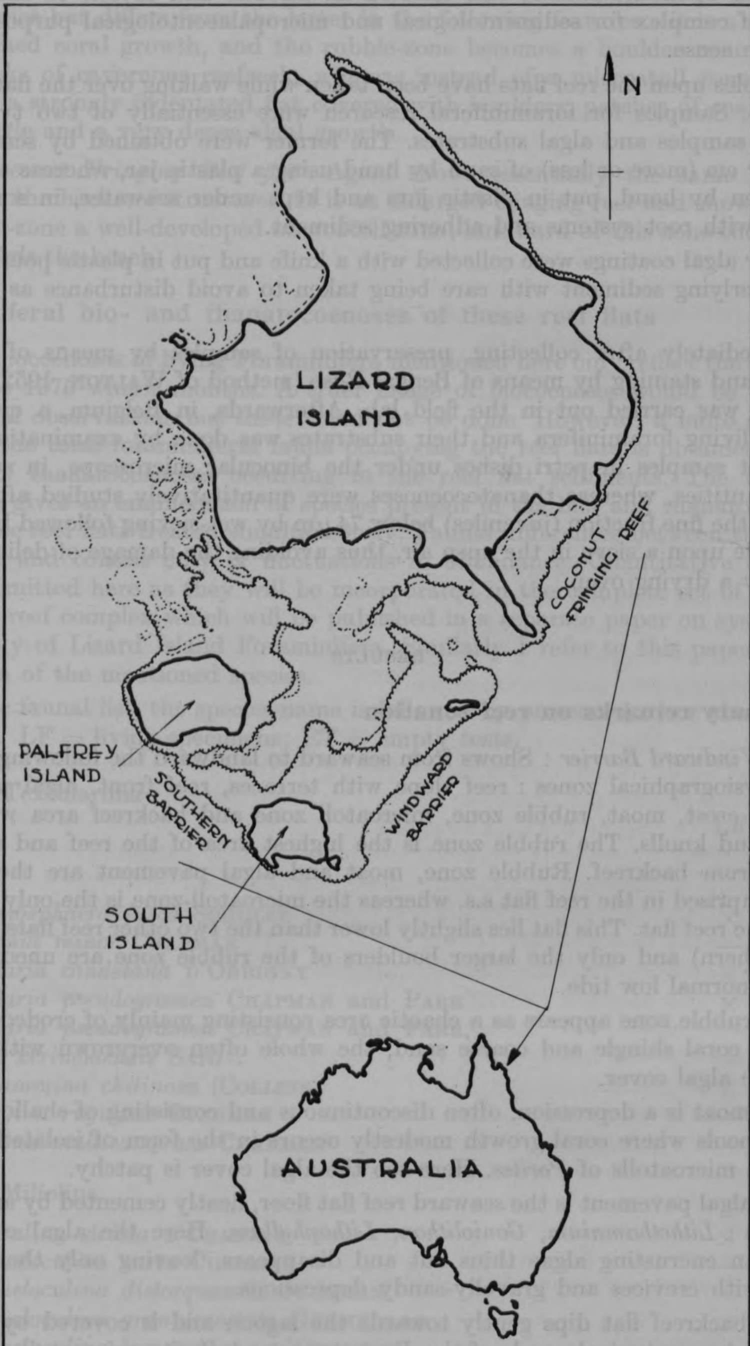

Fig. 1. — Map showing the location of the Lizard Archipelago, its gross topography and the position of the three reef flats dealt with in the present article.

established upon the island; this enabled E. SEGERS and myself to sample the entire reef complex for sedimentological and micropalaeontological purposes in an actualistic sense.

Samples upon the reef flats have been taken while walking over the flats during neap tide. Samples for foraminiferal research were essentially of two types, viz. sediment samples and algal substrates. The former were obtained by scraping off the upper cm (more or less) of sand by hand using a plastic jar, whereas the latter were taken by hand, put in plastic jars and kept under seawater, in some cases together with root systems and adhering sediment.

Finer algal coatings were collected with a knife and put in plastic pots together with underlying sediment with care being taken to avoid disturbance as much as possible.

Immediately after collecting, preservation of samples by means of buffered formalin and staining by means of Bengal Rose (method of WALTON, 1952, slightly modified) was carried out in the field lab. Afterwards, in Belgium, a qualitative study of living foraminifera and their substrates was done by examination of the entire wet samples in petri dishes under the binocular microscope, in successive small quantities, whereas thanatocoenoses were quantitatively studied after elimination of the fine fraction (juveniles) below 74 μm by wet-sieving followed by drying the sample upon a sieve in the open air, thus avoiding the damage of delicate tests caused by a drying oven.

RESULTS

Preliminary remarks on reef zonation

— *Windward Barrier* : Shows from seaward to landward the following recognisable physiographical zones : reef slope with terraces, reef front, algal pavement with reef crest, moat, rubble zone, microatoll zone and backreef area with coral patches and knolls. The rubble zone is the highest area of the reef and separates forereef from backreef. Rubble zone, moat and algal pavement are the forereef zones comprised in the reef flat s.s. whereas the microatoll-zone is the only backreef zone of the reef flat. This flat lies slightly lower than the two other reef flats (Coconut and Southern) and only the larger boulders of the rubble zone are uncovered by water at normal low tide.

The rubble zone appears as a chaotic area consisting mainly of eroded reefrock boulders, coral shingle and coarse sand, the whole often overgrown with a thick and dense algal cover.

The moat is a depression, often discontinuous and consisting of shallow sandy-gravelly pools where coral growth modestly occurs in the form of isolated colonies and some microatolls of *Porites*. Here too the algal cover is patchy.

The algal pavement is the seaward reef flat floor, neatly cemented by encrusting red algae : *Lithothamnium*, *Goniolithon*, *Lithophyllum*. Here the algal coating of other than encrusting algae thins out and disappears, leaving only the denuded bottom with crevices and gravelly-sandy depressions.

The backreef flat dips gently towards the lagoon and is covered by a sandy substrate, hemispherical corals of the *Favia*-type, and *Porites*-microatolls. An algal coating is present except on the nude sandpockets and in the drain channels normal to the reef elongation.

— *Southern Barrier* : Shows a zonation essentially comparable to the Windward Barrier but differs from the latter in the following features : it is a reef with impoverished coral growth, and the rubble-zone becomes a boulder zone showing large blocks of cavernous reefrock, whereas instead of a microatoll zone we find here only a strongly indentated flat covered with boulders, patches of coarse sand, coral shingle and a very dense algal growth.

— *Coconut Fringing Reef flat* : Again shows essentially the same zonation except for the backreef structures. It is an enlarged fringing reef and shows behind the rubble-zone a well-developed microatoll-zone; landward of this zone the bottom rises towards the beach.

Foraminiferal bio- and thanatocoenoses of these reef flats

The biocoenoses of living Foraminifera mentioned here only reflect the situation during the 1975 winter months. A truer image of biocoenoses would be obtained by seasonal observations but these could not be done. However, a more complete image of the total foraminiferal fauna occupying the reef flats is obtained by the analysis of thanatocoenoses occurring in the reef flat sediments. The following faunal list gives an enumeration of species present in the bio- and thanatocoenoses of the three reef flats treated simultaneously. Faunal differences between these flats are minor and consist only of fluctuations in abundance. Quantitative data are however omitted here as they will be incorporated in the complete set of data for the entire reef complex which will be published in a separate paper on systematics and ecology of Lizard Island Foraminifera. Similarly I refer to this paper for the illustration of the mentioned species.

In the faunal list, the species name is followed by presence (×) or absence (—) indication. LF = living specimens; ET = empty tests.

	LF	ET
Suborder Textulariina		
1. *Psammosphaera fusca* Schulze	×	—
2. *Haddonia minor* Chapman	—	×
3. *Textularia candeiana* d'Orbigny	×	×
4. *Textularia pseudogramen* Chapman and Parr	×	×
5. *Textularia pseudogramen* Chapman and Parr, subsp. *kerimbaensis* Said	—	×
6. *Rotaliammina chitinosa* (Collins)	×	—
7. *Gaudryina rugulosa* Cushman	—	×
8. *Clavulina multicamerata* Chapman	—	×
Suborder Miliolina		
9. *Vertebralina striata* d'Orbigny	×	×
10. *Quinqueloculina curta* Cushman	—	×
11. *Quinqueloculina distorquaeata* Cushman	—	×
12. *Quinqueloculina granulocostata* Germeraad	×	×
13. *Quinqueloculina lamarckiana* d'Orbigny	—	×
14. *Quinqueloculina lamarckiana* d'Orbigny, subsp. *queenslandica* Collins	×	×

	LF	ET
15. *Quinqueloculina neostriatula* Thalmann	—	×
16. *Quinqueloculina oblonga* s.s. (Montagu)	×	×
17. *Quinqueloculina oblonga* (Montagu), subsp. *segersi* (new name)	—	×
18. *Quinqueloculina oblonga* (Montagu), subsp. *eburnea* (d'Orbigny)	—	×
19. *Quinqueloculina pittensis* Albani	×	×
20. *Quinqueloculina poeyana carinata* Albani	—	×
21. *Quinqueloculina quinquecarinata* Collins	—	×
22. *Quinqueloculina montyi* n.sp.	—	×
23. *Massilina corrugata* Collins	—	×
24. *Massilina inaequalis* Cushman	—	×
25. *Spiroloculina communis* Cushman and Todd, subsp. *attenuata* Cushman and Todd	—	×
26. *Spiroloculina corrugata* Cushman and Todd	×	×
27. *Spiroloculina samoaensis* s.s. Cushman	—	×
28. *Spiroloculina samoaensis* Cushman, subsp. *acescata* Cushman	—	×
29. *Triloculina costifera* Terquem	—	×
30. *Triloculina earlandi* Cushman	—	×
31. *Triloculina irregularis* (d'Orbigny)	×	×
32. *Triloculina bicarinata* d'Orbigny	—	×
33. *Triloculina linneiana* s.s. d'Orbigny	—	×
34. *Triloculina linneiana* d'Orbigny, subsp. *subgranulata* Cushman	—	×
35. *Triloculina littoralis* Collins	—	×
36. *Triloculina trigonula* s.s. (Lamarck)	—	×
37. *Triloculina trigonula* (Lamarck), subsp. *tricarinata* d'Orbigny	—	×
38. *Triloculina trigonula* (Lamarck), subsp. *bertheliniana* (Brady)	—	×
39. *Triloculina trigonula* (Lamarck), subsp. *terquemiana* (Brady)	×	×
40. *Miliolinella baragwanathi* (Parr)	—	×
41. *Miliolinella australis* s.s. (Parr)	×	×
42. *Miliolinella australis* (Parr)	×	×
43. *Miliolinella australis* (Parr), subsp. *labiosa* (d'Orbigny)	×	×
44. *Miliolinella australis* (Parr), subsp. *bradyi* (Millett)	—	×
45. *Hauerina circinata* Brady	—	×
46. *Nevillina coronata* (Millett)	—	×
47. *Peneroplis pertusus* s.s. (Forskal)	×	×
48. *Peneroplis pertusus* (Forskal), subsp. *planatus* (Fichtel and Moll)	×	×
49. *Sorites discoideus* (Flint)	—	×
50. *Sorites orbiculus* Ehrenberg	×	×
51. *Marginopora vertebralis* Blainville	×	×
Suborder Rotaliina		
52. *Fissurina laevigata* Reuss	—	×
53. *Fissurina marginato-perforata* (Seguenza)	×	—

	LF	ET
54. *Spirillina vivipara* s.s. EHRENBERG	—	×
55. *Spirillina vivipara* EHRENBERG, subsp. *revertens* RHUMBLER	×	×
56. *Spirillina* sp. 1 (cf. *S. spinipapillata* MCCULLOCH)	—	×
57. *Alliatina translucens* (CUSHMAN)	—	×
58. *Buliminoides madagascariensis* s.s. (D'ORBIGNY)	—	×
59. *Buliminoides madagascariensis* (D'ORBIGNY), subsp. *parallela* (CUSHMAN and PARKER)	×	×
60. *Buliminoides madagascariensis* (D'ORBIGNY), subsp. *spicatus* (CUSHMAN and PARKER)	—	×
61. *Buliminoides williamsonianus* (BRADY)	×	—
62. *Bolivina compacta* SIDEBOTTOM	×	×
63. *Bolivina rhomboidalis* (MILLETT)	×	×
64. *Bolivina spinea* CUSHMAN	—	×
65. *Brizalina pacifica* (CUSHMAN and MCCULLOCH)	×	—
66. *Rectobolivina raphana* (PARKER and JONES)	—	×
67. *Reussella simplex* (CUSHMAN)	—	×
68. *Neoconorbina terquemi* (RHEZAK)	×	×
69. *Discorbis mira* CUSHMAN	×	×
70. *Discorbis subvesicularis* COLLINS	—	×
71. *Rosalina orientalis* (CUSHMAN)	×	×
72. *Poroeponides lateralis* (TERQUEM), subsp. *cribrorepandus* ASANO and UCHIO	—	×
73. *Glabratella patelliformis* (BRADY)	×	×
74. *Angulodiscorbis quadrangularis* UCHIO	×	×
75. *Epistomaroides polystomelloides* (PARKER and JONES)	×	×
76. *Siphoninoides echinatus* (BRADY)	—	×
77. *Amphistegina lobifera* LARSEN	×	×
78. *Amphistegina radiata* (FICHTEL and MOLL)	—	×
79. *Cibicides aravaensis* PERELIS and REISS	—	×
80. *Cibicides pseudolobatulus* PERELIS and REISS	—	×
81. *Planorbulina acervalis* BRADY	×	×
82. *Planorbulinella larvata* (PARKER and JONES)	—	×
83. *Gypsina globulus* (REUSS)	—	×
84. *Cymbaloporella tabellaeformis* (BRADY)	—	×
85. *Cymbaloporetta* gr. *bradyi* (CUSHMAN)	×	×
86. *Cymbaloporetta squammosa* (D'ORBIGNY)	×	×
87. *Asterorotalia gaimardii* (D'ORBIGNY)	×	×
88. *Rotalia* sp.	×	×
89. *Ammonia tepida* (CUSHAMN)	×	×
90. *Calcarina calcar* D'ORBIGNY	—	×
91. *Calcarina spengleri* s.s. (GMELIN)	×	×
92. *Baculogypsina sphaerulata* (PARKER and JONES)	×	×
93. *Parrellina milletti* (H. ALLEN and EARLAND)	—	×
94. *Elphidium advenum* s.s. (CUSHMAN)	—	×
95. *Ozawaia* (?) sp. aff. *O. tongaensis* CUSHMAN	—	×
96. *Elphidium batavum* HOFKER	—	×
97. *Elphidium craticulatum* (FICHTEL and MOLL)	—	×
98. *Elphidium crispum* (LINNÉ)	×	×

	LF	ET
99. *Elphidium jenseni* CUSHMAN	—	×
100. *Elphidium limbatum* (CHAPMAN)	×	×
101. *Elphidium poeyanum* (D'ORBIGNY)	×	×
102. *Heterostegina depressa* D'ORBIGNY	×	×
103. *Sigmavirgulina tortuosa* (BRADY)	×	×
104. *Anomalinella rostrata* (BRADY)	×	×

Rotaliina is the most frequently represented suborder. At family level the highest diversity is shown by the Miliolidae although in the Rotaliina the Bolivinitidae, Discorbidae and Elphidiidae are also well-diversified.

On the three reef flats 104 species and/or subspecies have been registered altogether. The most frequently represented families are the Soritidae in the suborder Miliolina and the Amphisteginidae and Calcarinidae in the Rotaliina.

The Soritidae are represented by four (sub-) species : *Peneroplis pertusoplanatus*, *Sorites orbiculus* and *Marginopora vertebralis* (crenulated form).

The Amphisteginidae are represented by one particularly abundant species : *Amphistegina lobifera.*

The Calcarinidae are represented by two abundant species : *Calcarina spengleri* s.s. and *Baculogypsina sphaerulata.*

In the Elphidiidae the abundance of *Elphidium crispum* is to be noted.

Further common species are, among the Miliolidae : *Spiroloculina corrugata*, *Quinqueloculina lamarckiana queenslandica*, *Q. oblonga* and variants and *Triloculina irregularis.*

Among the Rotaliidae : *Discorbis mira*, *Tretomphalus bulloides*, *Glabratella patelliformis*, *Epistomaroides polystomelloides*, *Cymbaloporetta bradyi* and *C. squammosa*, and the small variant of *Heterostegina depressa.*

The preceding faunal list shows a strong correspondance between bio- and thanatocoenoses which is particularly demonstrated by the common and abundant species. This is one of the arguments showing that there is little or no allochtonous transport from outside these reef flats (except perhaps for floating *Tretomphalus bulloides*) and only restricted sediment transport. The surplus of empty tests resulting from high foraminiferal productivity is either eroded and fragmented in place (after which the finer fragments are either transported towards backreef areas or beaches), or concentrated upon the reef slope terraces and in the sandpatches, drain channels and beaches.

Differences between foraminiferal faunas of the respective reef flats are only minor and are exemplified by some particular distribution anomalies of e.g. *Q. oblonga* s.s., *Q. neostriatula* and *Discorbis mira.*

Observations on the zonal distribution of foraminifera

Except for the occasional appearance of rare and very rare species in separate samples, it can be seen that the variations between fore- and backreef samples are to a great extent quantitative and not qualitative.

Samples taken on the forereef (sand pockets, algal pavement) mainly consist of coarse foraminiferal sands and contain sorted and heavily eroded empty tests of larger Foraminifera such as *Marginopora* fragments, *Amphistegina* and particularly *Calcarina spengleri* and *Baculogypsina sphaerulata*. Finer material is washed out of the sediment and is transported in a mainly leeward direction, towards backreef areas and the lagoon in the case of the Windward and Southern reef flats, and towards the beach in case of Coconut reef.

In all environments, be it forereef (rubble zone, moat and to a minor extent algal pavement) or backreef (microatoll zone) an often thick and dense algal coating or algal cover is present; observations have made it clear that it is this algal cover that serves as a substrate for most living Foraminifera. This cover overgrows everything : reefrock, boulders, gravel, coral shingle, shells of living Gastropoda and bivalves such as *Tridacna*, *Arca* etc. The cover consists of often densely interwoven and intergrown species of calcareous algae showing themselves a kind of zonation parallel to the coastline although the algal species composition of the cover seems to show only a moderate variation. As there are only few sandpatches on the forereef (algal pavement), the *Laurencia* - *Palythoa* band seems to be poorly developed at Lizard Island, and mainly encrustation by *Lithothamnium* and allied forms persists here, as well as species of the cyanophytes *Lyngbya* and *Phormidium*. The zoanthid *Palythoa* only occurs in significant quantities at Lizard Island on the reef flat of the Windward Barrier. [Compare with the algal zonation observed in the Southern Province of the Great Barrier Reef : Wilson Island (CRIBB, 1965), Heron Island (CRIBB, 1966).]

Further leeward the algal cover is composed of a whole array of algae; thin, flexible and filamentous species are interwoven with thicker, vesicular ones or more rigid, articulate, calcareous ones. Several species of the codiacean *Halimeda* appear in the moat and become more numerous and even dominant towards the microatoll zone and near the beach of Coconut reef. The most common of these is *H. cylindracea* with narrow, rounded thallus segments.

Further components of the algal cover are, [main nomenclatural sources : YALE DAWSON (1962a, b); WRAY (1977)] among the Chlorophyta : *Codium spongiosum*, *Chlorodesmis*, *Caulerpa*, *Boodlea* and *Boodleopsis* spp., rare *Struvea* and others; *Phaeophyta* seem to be less important, whereas a considerable number of species belong to the non-encrusting Rhodophyta with several species of *Laurencia*, *Hypnea*, *Amphiroa*, *Gelidiella*, *Liagora*, *Herposiphonia* and many others in minor relative abundances. Cyanophyta like *Phormidium* are present in variable quantities whereas phanerogames are very rare or virtually absent.

This algal cover forms a spongy, elastic surface layer over all hard and sandy surfaces and serves as a perfect protecting substrate for Foraminifera which find here humidity during low-tide exposures, a solid anchorage in higher-energy conditions (wave impact) and plenty of nourishment in the microhabitats of relatively quiet interstitial seawater. The fixation of this algal cover upon sedimentary surfaces is extremely solid, by means of deep root systems of, *e.g.*, *Halimeda*. The interface between algal coating and sediment is never abrupt : largest algae generally have the deepest fixation in sediment whereas smaller algae are often mixed with sand grains in variable quantities. In vertical section we obtain the image shown in Fig. 2 :

In the uppermost layer the largest thalli are found (*e.g.*, *Halimeda*), with the largest and more robust Foraminifera attached to them by means of their pseudopodia (*Amphistegina*, *Calcarina*, *Baculogypsina*, *Marginopora*).

In the middle layer, these larger thalli are mixed with a coating of finer algae and sediment grains which are often detached empty foraminiferal tests. Here most of the medium-sized and smaller living Foraminifera are to be found, their pseudopodia interwoven with the thalli.

In the lowermost layer, the algae become scarcer and only the sediment persists, which is often a foraminiferite consisting of the larger and medium-sized specimens in the thanatocoenosis.

It is to be seen that there is a gradual transition from the algal cover towards the sediment, which results in a high degree of mutual fixation.

CONCLUSIONS

The algal cover constitutes the most important substrate for the living Foraminifera on the reef flats. This cover provides anchoring possibilities for these Foraminifera as well as protection against dessiccation and physical stress in higher-energy environments, and against chemical stress such as salinity fluctuations which can be expected in marginal intertidal conditions upon reef flats. The microenvironments in the cover provide plenty of nourishment (*e.g.*, diatoms) and shelter for reproduction activities.

The distribution of bio- and thanatocoenoses of Foraminifera upon these reef flats is, as a result, highly conditioned by the composition and extent of this algal cover. Further observations confirmed that this is a statement which is valid in the entire reef belt of Lizard Island, and to a certain degree may also be applied to the perireefal environment if some supplementary conditions are taken into account. This foraminiferal distribution is only secondarily influenced by the biological composition and species diversity of the algal cover; the physical properties (size, shape, flexibility and surface texture of thalli) are of foremost importance.

Therefore, it is clear that foraminiferal distributions in fossil reefs can yield information about the physical properties of the algal substrates occurring in these reef systems. This information should, however, be treated with caution and it may be dangerous to link the presence of certain Foraminifera to certain algal species as the latter may perfectly well be replaced by similar or convergent ones possessing comparable physico-mechanical properties.

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Fig. 2. — Schematical vertical section through an algal cover with underlying sediment on the reef flats.

A = Zone where larger thalli and larger living Foraminifera predominate. B = Transitional zone at the base level of larger thalli, where smaller algal thalli are densely interwoven and where the majority of intermediate — and smaller living Foraminifera occur together with empty foraminiferal tests and occasional sediment grains of non-foraminiferal origin. C = Upper centimeters of sediment fixed by root systems of larger algal thalli; a few living foraminiferal specimens occur in the uppermost cm of this layer but are rapidly replaced by mostly large empty tests below. This sediment is generally very coarse sand or sandy gravel.

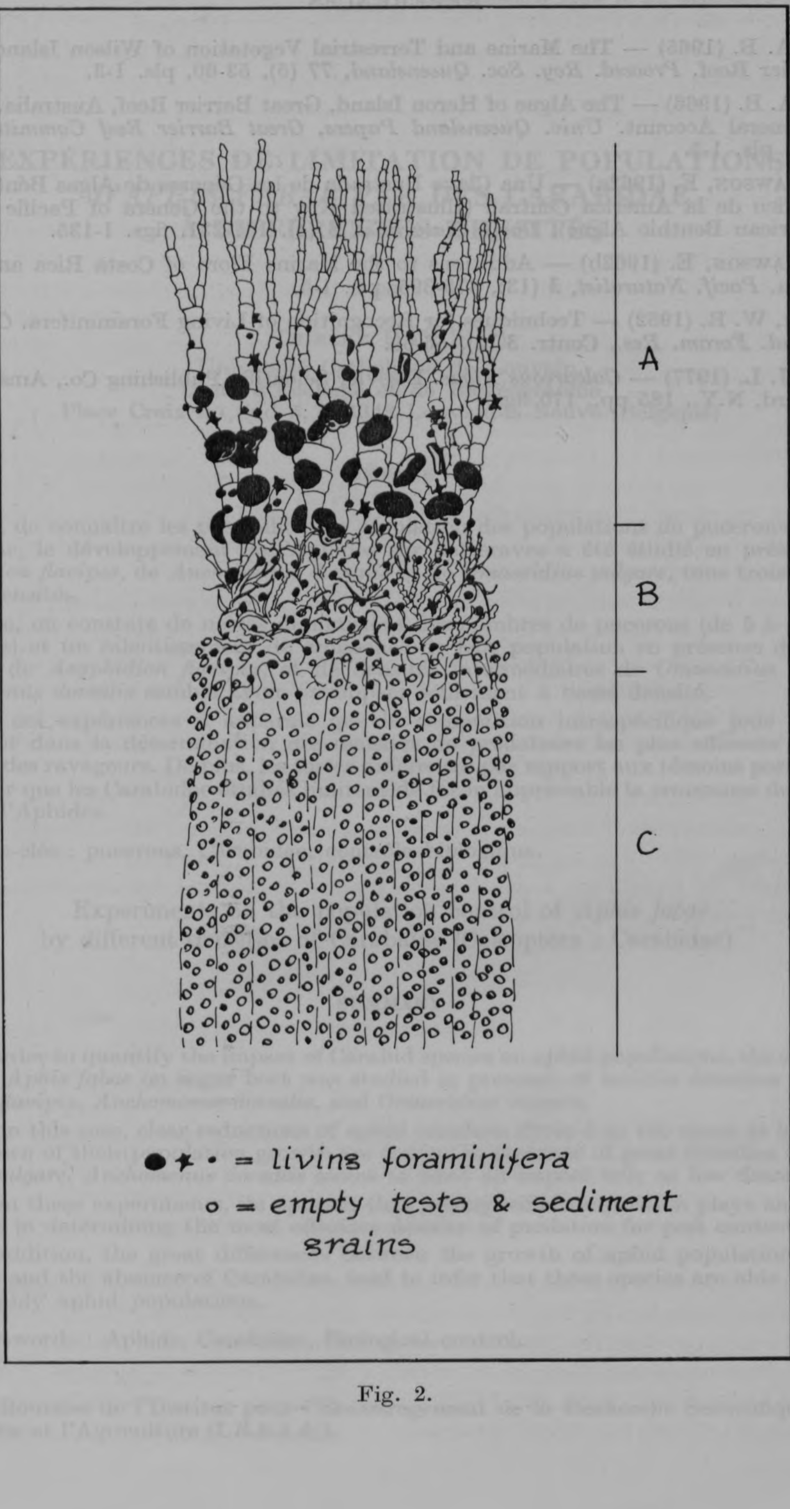

Fig. 2.

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