

Lagoonal to reefal ostracod assemblages from Holocene and Recent deposits, Chesterfield Islands and northern New Caledonia (southwestern Pacific)

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ABSTRACT: As part of a preliminary study on growth and evolution of Holocene reefs from northern New Caledonia and Chesterfield Islands (S.W. Pacific), micropalaeontological investigations on ostracod contents were carried out. The cored material from reef-flat and back-reef zones is composed of skeletal deposits. Bioclastic sands sediments from various reef environments contain ostracod-rich assemblages. Modern associations from the back-reef and lagoonal areas were also analyzed, to serve as ecological analogues.

Fifty-three species have been recognized, most of them already known from other areas of the Pacific and Indian Oceans. Using statistical methods, two (paleo)environmental zones can be distinguished: a) lagoonal to back-reef slope, b) inner to outer reef flat zone. In every respect, each zone is characterized by distinctive ostracod assemblages.

Autecological data available on Recent living taxa suggest some paleoecological preferences of Holocene assemblages in similar areas. Ostracod assemblages are highly diverse in modern lagoons, the main taxa belonging to Cytheracea (dominant) and Bairdiacea with a few Cypridacea; they are quite diverse in the Recent and Holocene inner reef slopes and poorly represented within the reef flat zone, probably in response to variations in physico-chemical conditions, especially wave-energy.

Considerations about relationships between composition of ostracod assemblages through time and previous data on sea-level changes are discussed.

INTRODUCTION

Studies were conducted on the growth and evolution of Holocene reefs, using cored material through reef flat and back reef zones off northwestern New Caledonia (Entrecasteaux area) and from Chesterfield Islands in the southwest Pacific (Degaugue-Michalski 1993a, 1993b).

Important and well preserved ostracod assemblages are present in Holocene to Recent samples from both these reef areas (Coll. F. Degaugue-Michalski). Studies on ostracods are extended to modern lagoonal biotopes (especially within the Chesterfield area) for comparison.

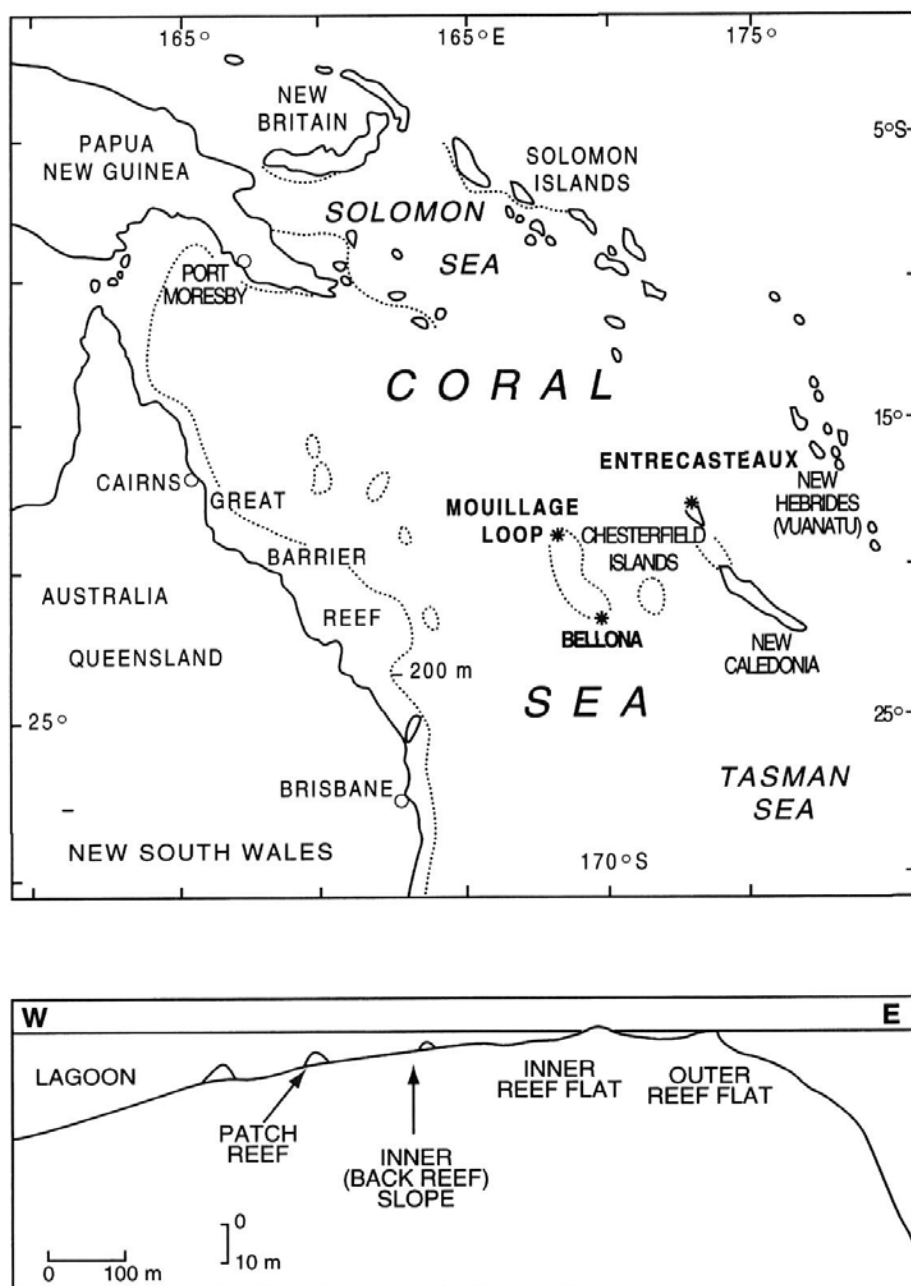
Nothing at all is known about the ostracod content of Quaternary to Recent reefal carbonate platforms from Chesterfield Islands and Entrecasteaux area. Nevertheless, some previous studies are available on recent and quaternary ostracods from New Caledonia, in the vicinity of the area studied (Apostolescu 1967; Cabioch et al. 1986; Cabioch 1988). On other hand, some papers were published on lagoonal holocene environments from south western New Caledonia (Debenay 1985) and on cores from Tenia Islet, Saint-Vincent Bay, in the same region (Coudray 1975), more generally on the local "mid-plate high volcanic islands system" (Montaggioni 1988). In the Great Barrier, Australia, it has been demonstrated a sea level rise during the Quaternary (using studies on reef growth) and then its stabilization during the Holocene from - 6000/-5500 years up to the Recent (Davies et al. 1985). Thus some stratigraphical, paleoenvironmental and diagenetic indications are available, and significant of both eustatic changes and neotectonics in the local reef growth.

Ostracod assemblages must be analyzed firstly on a systematical point of view (qualitative and quantitative data) and then on their ecological significance in order to characterize some (paleo)geographic domains. Another interest is as follows: in the area studied, are Holocene to Recent ostracods going to be interpreted to tell us about such sea-level changes?

GEOLOGICAL SETTING

New Caledonia and the Chesterfield Plateau are located in the Coral Sea (tropical zone of the southwest Pacific), between longitudes 155°E-170°E and latitudes 15°S-25°S, east of the Australian continent (text-fig. 1). Reefal barriers from Entrecasteaux and Chesterfield were prospected (1985, 1987) by Coralmin Co., Australia (research of potential carbonate sands and phosphate-fields); in the LAGON program, O.R.S.T.O.M., France (Office de Recherche Scientifique dans les Territoires d'Outre-Mer) collaborated in order to better understand the reefal lagoonal sedimentation. Program LAGON I (1985) provides cored material obtained from rotary drillholes originated from a) inner reef flats at Huon and Leixour (Huon-Surprise Plateau) (HN1, HN2, LX) which extends northwards from New Caledonia High (Collot et al. 1988). Program LAGON II explored back-reef slopes of Loop and Mouillage Islands (Chesterfield Platform) (from S.W to N.E, cores CH 01, CH 05, CH 18, CH 22, CH 24) and reef flat areas (Caye de l'Observatoire, southeastern reefs) from Bellona Platform to the south (OB 2, BSE 2), located 350 km north-west of New Caledonia (text-figs. 1, 2).

The material is mainly composed of limestones including corals, red algae, large benthic foraminifera, molluscs, echinoderms, sponges etc. There are some bioclastic sandy deposits interca-



TEXT-FIGURE 1

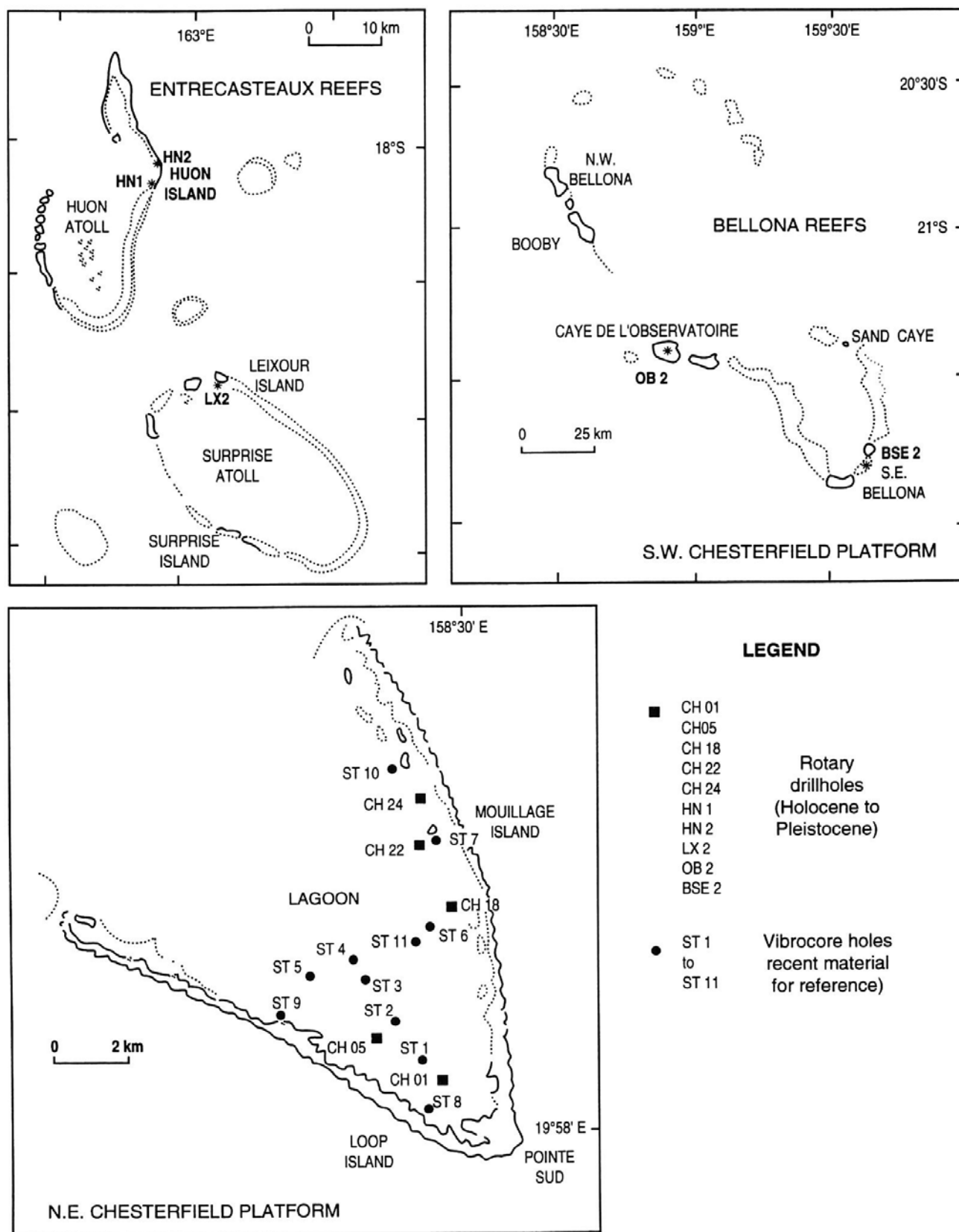
Location map (stars indicate the geographical position of the cored material) and summarized transect through the reefal complex of Mouillage Islands (Chesterfield platform) giving the position of the studied zones (morphological terms).

lated, the bioclasts being derived from these organisms. Coarse-grained sands are dominant as thin layers at Entrecasteaux and Bellona Islands (text-fig. 3) within thick and dominant carbonate lithology, whereas medium to fine sands occur predominantly at the Chesterfield Islands (lagoonal zones) (text-fig. 4).

Ostracods occur abundantly in the Holocene sandy lagoonal zones of the Chesterfield area, but are more scattered in other areas studied. A Holocene age of 7000 to 2500 yrs B.P. is given (C14 dating of cores) by O.R.S.T.O.M. (unpublished data);

lagoonal sands with mainly aragonitic bioclastic debris (*Halimeda* algae) are dated from 5000 to 600 yrs B.P. (Cabioch 1988).

The ostracod content of the lagoonal zone of Chesterfield platform have also been explored in order to study the overall composition of modern well preserved assemblages (ST samples), giving as expected an ecological model for further interpretations of Holocene deposits. Substrates obtained by vibrocoreing are mainly composed of fine to medium-sized sandy deposits (text-fig. 2).



TEXT-FIGURE 2

Detailed maps with location of rotary drillholes (Holocene deposits) and vibrocore holes (in the Recent) in the Entrecasteaux reefs and Chesterfield platform.

OSTRACOD ASSEMBLAGES

Fifty sand samples were studied, among them twenty originating from modern inner slope and lagoonal biotopes (ST samples). Forty-four samples (text-figs. 2-4) contained ostracod carapaces and valves. Fifty-two different species (a rather low diversity) were identified. This rather low diversity may be explained by the small recover rate of sediments. With the exception of several species in open nomenclature (poorly preserved and/or scarce) all the species are already known and described from other areas of the Pacific and Indian Oceans.

Considerations about the composition of the whole associations related to the local sedimentary facies and (paleo)geographic settings are presented, using some quantitative studies, especially multivariate analysis methods.

Principal components analysis

An analysis has been undertaken in order to study the relationships between elements of both Recent and Holocene samples.

A classic methodology for granulometric analysis of sands was used first: sieving of weighed sediments through the meshes of a sieve-column (AFNOR NF-501) between the range 0.063mm (very fine sands) and 4mm (gravels). Granulometric parameters and indexes (Folk and Ward 1957; Krumbein 1936) are obtained (see text-fig. 5 and legend).

Then, a factor analysis (R-mode principal components analysis) was also performed on a normalized data set using the MacMul Multivariate Analysis Software (Thioulouze 1989, 1990), taking into consideration the following: size of grains, percentages of granulometric classes and their values (8 indexes) and percentages of all bioclastic categories. The examination of such factor analysis (see text-fig. 5, A) shows that F1 to F4 axis may be considered as principal with about 80% of the total inertia percentage. F1/F2 is the better factor plan (58% of inertia) and related to grain-size. F1/F3 (50%) led to better understand the distribution of granulometric indexes. Lastly, F3/F4 (20.5%) give some records on the distribution of different bioclasts into the sandy sediments. In this case, corals and molluscs are the principal bioclastic categories linked to the principal F3 axis; foraminifers and coralline algae are related to the F4 axis. Concerning ostracods, we can observe their median position, quite related with benthic foraminifers, serpulids and green calcareous algae (*Halimeda*) and rather within medium to fine detritic sediments.

On the other hand, F1/F2 shows the location of ostracods on the median part towards the lagoonal zone and the inner slope (text-fig. 5, A4).

Cluster analysis

Another quantitative technique is the hierarchical cluster analysis, which is a convenient way of graphically illustrating relationships among variables or stations, in order to obtain accurate data for descriptions. Values were binary (presence/absence data, without any consideration about the total number of specimens). Q-mode (samples) and R-mode (ostracod species) cluster analysis were performed on non-standardized data sets, using the classical euclidean distance and the hierarchical algorithm (Methodology "des voisins réciproques") (Roux 1985, 1991).

Cluster analysis of samples (Q-mode)

This demonstrates the existence of sample groups with similar ostracod assemblages. The subdivision is given by samples which are probably located in the margin of different physiographic zones (text-fig. 5 B).

By this means, we found two sample groups. From this evidence, we hypothesize the existence of two habitats, each with a distinctive ostracod fauna, corresponding to the following environmental areas:

group 1 : lagoonal zones, including all sands from the modern Chesterfield platform (ST samples for reference). Linked with ST samples are Holocene cored materials from the Chesterfield platform (CH samples).

group 2 : back reef (slope) to outer reef-flat; limits of environmental zones are not easy to distinguish. Samples from Huon - Leixour and Bellona platforms (samples HN, OB, BSE) are located in this area.

Cluster analysis of ostracod species (R-mode)

The cluster diagram obtained is projecting relationships in 53 species-space into two dimensions. The subdivision of ostracod species into well defined subgroups appears to be questionable. However, we can propose two main ostracod-assemblages, from a) lagoonal and inner (back reef) slope, and b) without any precise distinction between them, shallow inner to outer reef flat (text-fig. 6). The proposed paleogeographic interpretation of these two groups of close-spaced branches that join the stem of diagram are directly deducted from the position of close-spaced branches from the cluster diagram of samples. This is also the case for benthic foraminifers with many taxa characteristic of each zone (Degaugue-Michalski 1993a).

Lagoonal to inner slope assemblages

Twenty-seven species occur within the first cluster group, belonging mainly to the following ostracod families (classification after Hartmann and Puri, 1974):

Cytherellidae *Cytherella* sp. aff. *textum* Holden 1976,

Bairdiidae: *Paranesidea fracticorallicola* Maddocks 1969, *Neonesidea michaelsoni* Hartmann 1982, *N. aff. schulzi* (Hartmann 1964), *N. cf. parilihamata* Maddocks 1969,

Cytheridae: *Kotarocythere inconspicua* Brady 1880,

Leptocytheridae: *Leptocythere keiji* Hartmann 1978,

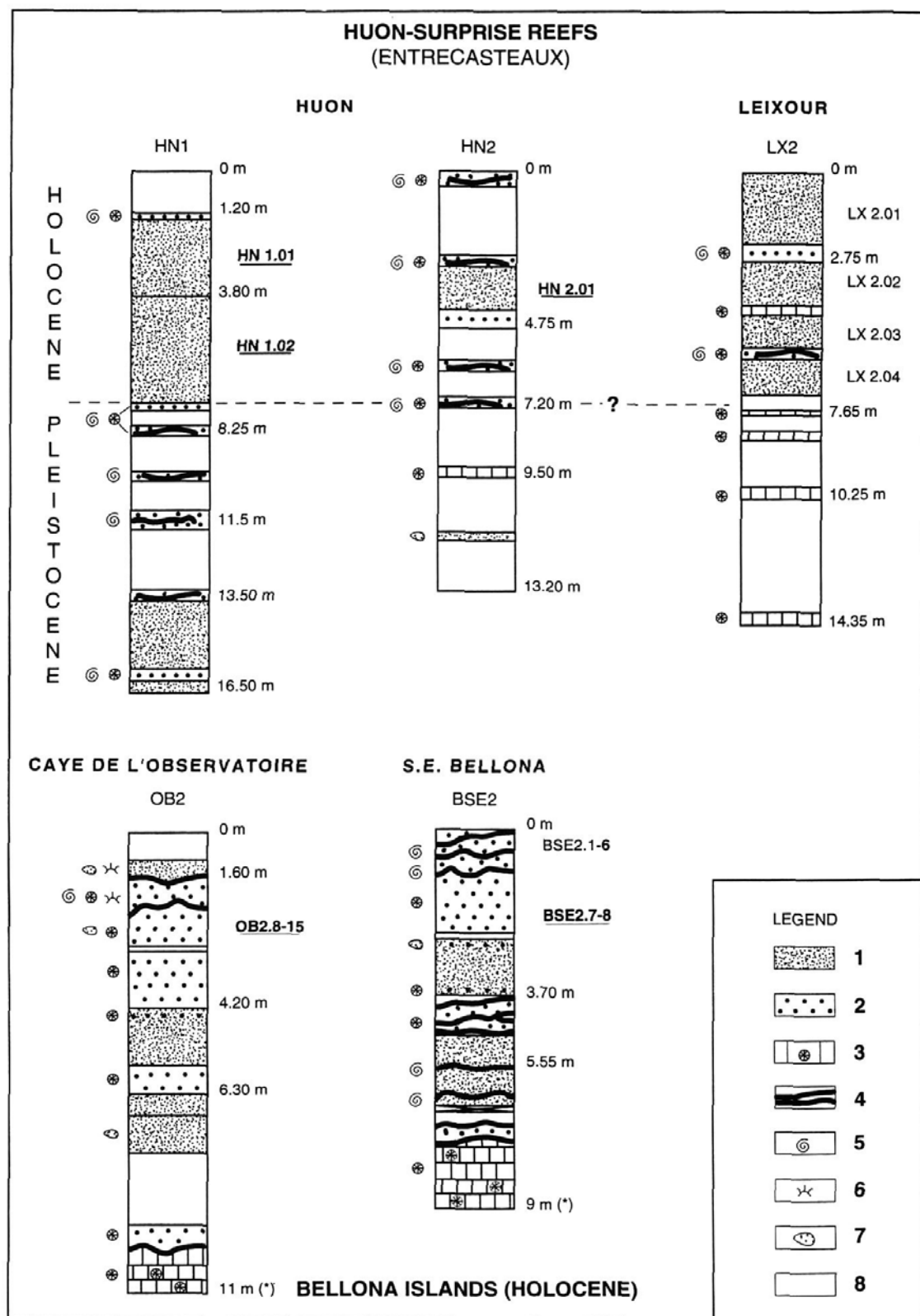
Trachyleberididae: *Ponticocythereis manis* Whatley and Titterton 1881, *Neocaudites* sp.,

Loxoconchidae: *Loxoconcha* sp. aff. *australis* (Brady 1880), *L. insulaecapricornensis* Hartmann 1981, *L. huahineensis* Hartmann 1984, *Loxoconchella honoluluensis* (Brady 1880), *L. anomala* (Brady 1880),

Hemicytheridae: *Quadracythere (Tenedocythere) deltoides* (Brady 1880), *Jugosocytheris* sp. a, *Hermanites* sp., *Mutilus* sp.

Xestoleberididae: *Xestoleberis* sp., *X. tigrina* (Brady 1866), *X. datelinensis* Holden 1976, *X. cf. variegata* Brady 1880,

Cytheruridae: *Hemicytherura* sp.,



TEXT-FIGURE 3

Lithostratigraphy and paleontological contents of cored material from Huon-Surprise (Entrecasteaux area) and Bellona Islands (Chesterfield Plateau). Samples with ostracods are underlined.

1 = bioclastic sands, 2 = bioclastic sands with corals, 3 = carbonates with corals, 4 = calcareous algae, 5 = gastropods (vermetids) 6 = octocorallids, 7 = pebble gravels, 8 = no sediments available.

Paracytheridae: *Paracytheridea* sp. aff. *remani* Hartmann 1964.

Cyprididae: *Macrocyprina* sp. 1, M. sp. 2.

Pontocyprididae and Paracypridinae are very scarce, their systematical determination very uncertain; thus, they were arbitrarily excluded.

All these species were collected in back reef, protected zones. They characterize sandy deposits especially those of the central area and nearest slopes of the Chesterfield lagoon (subsurface sediments of stations ST 1 to ST 6). We observed an overall decrease in diversity from the central part (about 20-40 m depth) up to the inner slopes. As predictable before the study began, water energy seems therefore to be the main environmental controlling parameter.

b) Shallow inner slope to outer reef flat assemblages.

Twenty-six species belong to the second cluster group, but they are generally represented by few specimens; this may be a sampling artefact rather a meaningful association of species that share habitat-preferences. On other hand, both rare and ubiquitous species cluster together. In the stations with Recent reference material (e.g. ST 7 to ST 11, Chesterfield subsurface sediments) the following taxa are dominant: species of the genera *Paranesidea*, *Neonesidea*, *Mydionobairda* (M. *schyroconcha* Maddocks 1969) *Triebelina*, and *Quadracythere* sp., *Pontocythereis spinosa* Whatley and Titterton 1981, *Anchistrocheles fumata* Brady 1880, *Mutilus parallelucostatus* Hartmann 1978, *Ornatoleberis* sp., *Tanella gracilis* Kingma 1948, *Parakrithella* sp. This is probably an odd list of species because some live on the reef front, some are interstitial or algal, some are robust or fragile (R. Maddocks, pers. comm.); sampling considerations explain also the lack of structure in the ostracode cluster analysis and the association may be an artefact of the cluster method. Nevertheless, taking into account their geographic setting, they are probably controlled by two main factors: shallow depth and high energy.

PALEOECOLOGY OF HOLOCENE ASSEMBLAGES - EVOLUTIONARY SIGNIFICANCE

Some well established records are available concerning the ecology of modern reefal and lagoonal associations in the tropical Pacific. Moreover, quantitative criteria and in particular assemblages patterns related to environment give some indications about the paleoecology of Holocene assemblages in similar zones.

3.1. Huon-Leixour platform

In the Huon atoll deposits, the following species are abundant in the higher levels: *Neonesidea schulzi*, *N. michaelsoni*, *Quadracythere* (T.) *deltoidea*, *Anchistrocheles fumata*, *Loxoconcha huahineensis* and *Tanella gracilis*. At Nosy-Bé, north Madagascar, *N. schulzi* is often the most representative species in the epifauna of algae, grasses, sponges, corals and dead coral fragments in coral reefs and submerged platform habitats; in subfossil distribution, the same species is moderately common in shallow-water sands, especially near reefs (Maddocks 1969). *N. michaelsoni* occurs in sandy deposits near patch reefs and zones with accumulations of coral debris, just above the tidal flat areas and in beach sands (Hartmann 1982, 1984; Maddocks 1969). *Anchistrocheles fumata* has been observed in intertidal flats and pools on sandy beaches in the Samoa and Hawaii Islands (Brady 1890; Holden 1967). *Loxoconcha huahineensis*

occurs in the Tuamotu Islands (Hartmann 1984) in zones with high water energy level (seaweeds with *Turbinaria* in Rangiroa Islands, for example). *Tanella gracilis* is an ubiquitous species which tolerates a large salinity range (Hartmann-Schroeder and Hartmann 1978-1981). These data strongly suggest a more or less disturbed area in a back reef environment with colonization by calcareous algae.

Chesterfield platform

Mouillage Islands

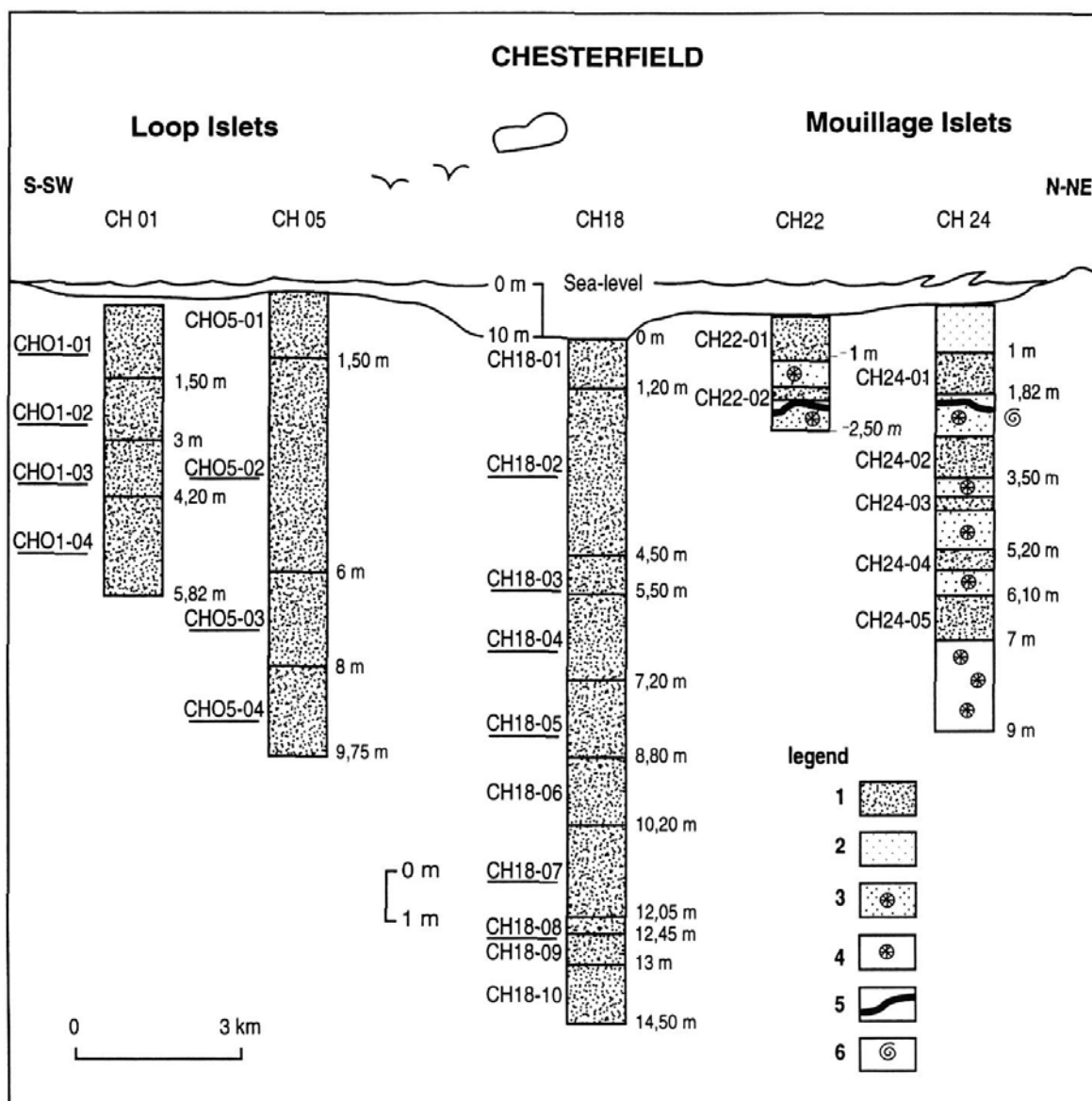
Samples from Holocene deposits (CH 18, CH 22, CH 24) contain different ostracod assemblages but the high diversity level of the modern central lagoonal zone is never observed. The samples in core CH 24 yielded only one level with three ostracod species: *Macrocyprina* ? sp. 1, *Xestoleberis variegata* and *Microcytherura* sp.; *Macrocyprina* may occur in the holdfasts of seaweeds (Maddocks, pers. comm.). In sample CH 22, 2 species were collected: *Paranesidea fracticorallicola* which is common on calcareous and non-calcareous algae and accumulations of dead coral fragments near low tide level on the back reef platform and lower beach at Nosy-Bé, Madagascar (Maddocks 1969), and *Xestoleberis tigrina*, living on beaches or platform zones subject to a high hydrodynamic level (Teeter 1975; McKenzie et al. 1990).

More significant are the CH 18 samples cored in Holocene bioclastic sands with, from base to top, a relative decreasing in diversity. CH 18-08 (base) contains *Trachyleberis* sp., *Ornatoleberis* sp., *Xestoleberis datelinensis*, *Xestoleberis* sp., *Tanella gracilis*, *Cytheropteron* aff. *alabarda* Bonaduce, Masoli and Pugliese 1978, *Loxoconcha australis*. The latter species has been described from sandy accumulations in swash zones (Brady 1880; Hartmann 1979; McKenzie et al., loc. cit.), but generally it colonizes seaweeds, such as *Posidonia*, on inner shallow slopes (Hartmann 1979, 1980). In the higher part, *L. australis* is associated with other species which have been recorded as living within the same biotopes: *Loxoconcha insulae-capricornensis* (CH 19-07), *Neonesidea michaelsoni* (CH 18-03) and *Tanella gracilis* (CH 18-02) (Hartmann-Schroeder and Hartmann loc. cit.; Hartmann, 1984). Bairdiidae occur at all levels.

A bathymetric evolution seems to be demonstrated from an inner reefal slope domain up to a supratidal and/or beach zone. The cluster diagram cannot accurately represent gradational assemblages, though one may interpret this evolution to conclude that the lagoon filled.

Loop Island

Within CH 05 and CH 01 samples, the same tendencies are detected, with decreasing diversity through time. In CH 01, for example, the base contains *Xestoleberis tigrina*, *Trachyleberis* sp., *Triebelina sertata* Triebel 1948, *Quadracythere* (*Tenedocythere*) *deltoidea*, *Paranesidea* sp., *Neonesidea schulzi*. This association occurs on inner slopes (shallow platforms) (Teeter 1975; Whatley and Keeler 1989; McKenzie et al., loc. cit.); the higher part belongs to inner slopes with coral reefs and algal tufts, just below the low tide-levels with *Xestoleberis variegata* and *Kotoracythere inconspicua* (Kingma 1948; Hartmann 1984; Witte and Van Harten 1991).



TEXT-FIGURE 4

Lithostratigraphy and paleontological contents of cored material (Holocene) from Loop to Mouillage Islands (Chesterfield platform). Samples with ostracods are underlined.

1 = bioclastic sands, 2 = beach-rock, 3 = bioclastic deposits with corals, 4 = corals, 5 = calcareous algae, 6 = gastropods (vermetids).

Bellona reefs

Ostracod assemblages from *Bellona* reefs (Caye de l'Observatoire, samples OB 2 and reefs from Southeastern *Bellona*, samples BSE 2) are generally poorly diverse with only a few Bairdiidae (*Triebelina sertata*, *Paranesidea* sp., *Neonesidea schulzi*), *Xestoleberis* species and a few specimens of *Anchistrocheles fumata*. In sample BSE 2-6, many *Paranesidea*, especially *P. cf. algicola* occur; some authors emphasize the frequency of fossilization of such species in sandy deposits of beaches (Whatley and Titterton 1981; Cabioch 1988; Titterton and Whatley 1988a). On other hand, it seems that only robust shells survive the pounding of surf to be recognizable in a beach sand.

PALEOENVIRONMENTAL IMPLICATIONS

Two main Holocene paleoenvironments can be distinguished:

Lagoon to back-reef slope

Assemblages are diverse and abundant. They are characteristic of a quiet marine environment; carapaces are generally well preserved, a feature which indicates a biocoenosis with in situ deposition; the biotope is characterized by a high carbonate content with organic matter (Degaugue-Michalski, loc. cit.), which explains the proliferation of some taxa. Species belong mainly to super-families Cytheracea (dominant) and Bairdiacea (among them Bairdiidae indicative of normal salinities).

The inner slope being transitional, it is usual to observe both lagoonal and reefal taxa. Material is less preserved.

Inner to outer reef flat zone

Due to hydrodynamic control (intertidal zone) and occasional changes in salinity, ostracod assemblages are sparse. Many of the species are ubiquitous.

In summary, the back reef (slopes) and lagoonal bottoms in Chesterfield Islands are favourable for the development of ostracod-rich associations: quiet waters, stability of the salinity. Generally, the taxa are rather phytal and coralline species (proliferation of seaweeds with *Halimeda*).

Eustatism and ostracod assemblages

Eustatic changes during Holocene time may be inferred from changes of reef morphologies. In the area studied (Entrecasteaux and Chesterfield-Bellona platforms) three separate phases of eustatic changes (Baltzer 1970; Coudray and Delebrias 1972; Peltier 1988) characterise the Holocene time from 7000 to 2500 yrs B.P. The eustatic phases are correlated with rapid and/or stunted growth of local reefs (Montaggioni 1988; Michalski 1989; Degaugue-Michalski 1993b). The biosedimentological record (Ehny 1987; Degaugue-Michalski, loc. cit.; Laborel 1986) and geophysical data confirm such dynamical evolution: a) from 7000 to 6000 yrs B.P., the previous reefal colonization stopped with a first stabilization of the marine level (between -7 and -9m. in the cores), b) a highest ratio of reef-growth occurs at -6000 to 4000 yrs. B.P. related to a transgressive tendency, with external carbonate progradation, whereas important detritic input occurs within the frontal zones, c) an important lagoonal infilling (second stabilization phase) started between 4000 and 3000 yrs B.P.; external reefal zones are eroded and detritic material flooded into the lagoonal zones, d) new phase of reef-growth related to an eustatic positive change (3000 to 2500 yrs B.P.), e) eustatic stabilization (2500 yrs. B.P.) with detritic sedimentation, the marine level reaching to its recent position.

The paleoecological evolution of Holocene ostracod assemblages (particularly cores CH 01, CH 05, CH 18 of Loop and Mouillage Islands) through time shows a general decrease in both qualitative and quantitative composition from about -9m up to -3, -1 m. This evolution may be related to the generalized infilling of lagoonal zones with changes of the local bathymetry and biotope diversity. The recent stabilized phase at about 2500 yrs B.P. (relative drowning phase) and development of fine sandy substrates seems to better explain the proliferation and spatial distribution of various Recent ostracod assemblages, especially into the lagoonal domain (ST samples).

SOME BIOGEOGRAPHIC INDICATIONS

Ostracod assemblages from Entrecasteaux area and Chesterfield Islands show strong affinities with associations already described from analogous reefal or perireefal areas of the Pacific provinces: West Pacific (mainly New Caledonia, Great Australian Barrier, South-Australian lagoons) (Brady 1890; Apostolescu 1967; Cabioch et al. 1986; Hartmann-Schroeder and Hartmann 1978-1981; Hartmann 1979, 1980; McKenzie et al. 1990), Indo-Pacific Realm (Java, Sumatra, Kalimantan, Fiji and Solomon Islands) (Brady, loc. cit., Kingma 1948; Titterton and Whatley 1988a-b; Whatley and Zhao 1987, 1988; Zhao and Whatley 1989a-b), Central Pacific (Hawaii, Society and Tuamotu Islands) (Keij 1954, 1975; Holden 1976; Hartmann

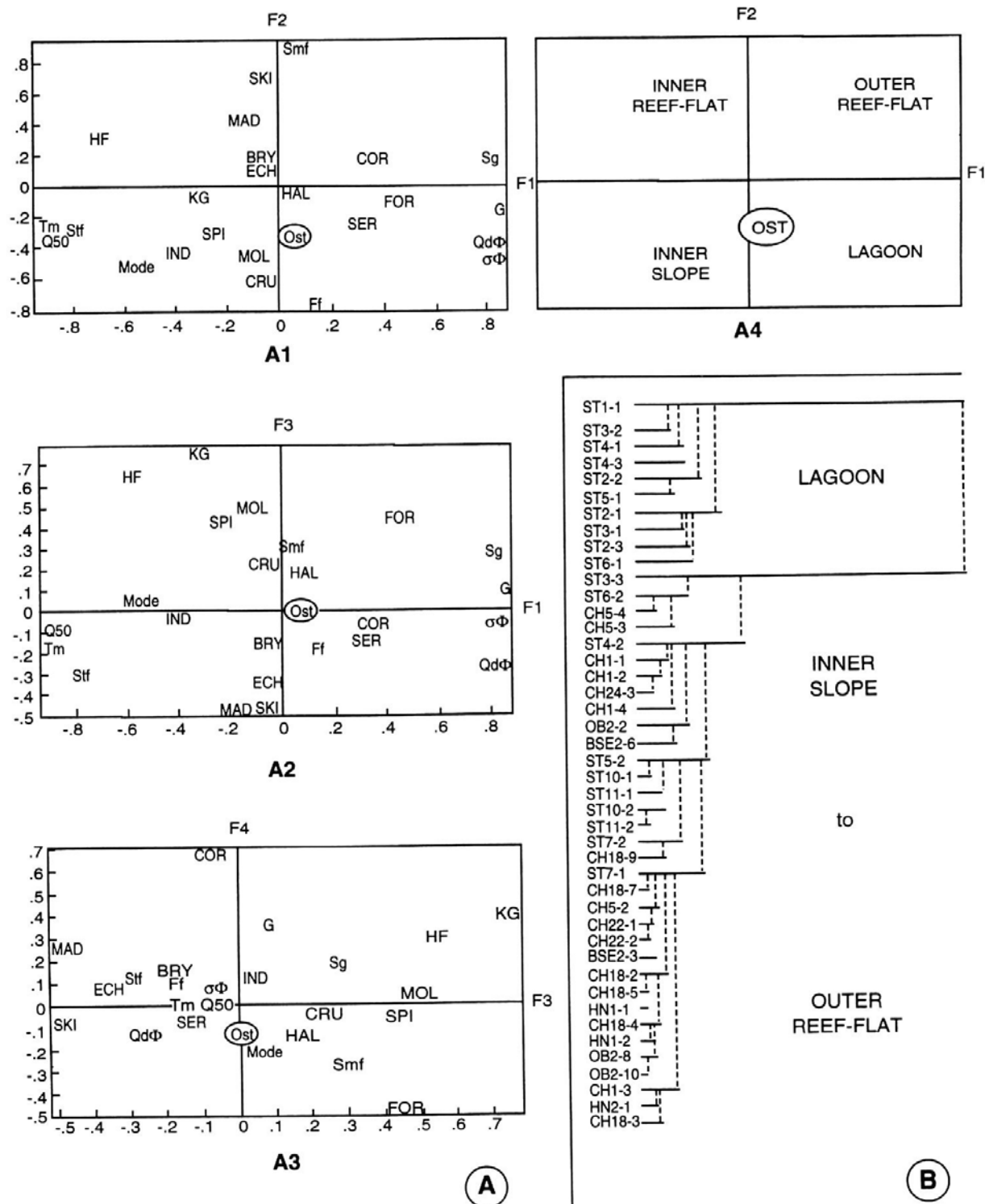
1984). Relationships with the Indian Ocean are less marked (Maddocks 1966, 1969, 1991; Hartmann 1974; Bonaduce et al. 1983; Whatley and Keeler 1989; Babinot and Kouyoumontzakis 1995). The few species which have previously been described from the Caribbean are found mainly in the carbonate platform of Belize (Teeter 1975). In all the areas, some cosmopolitan species occur: *Quadracythere* (T.) *deltoidea*, *Tanella gracilis*, *Neonesidea schulzi*, *Kotoracythere inconspicua*, *Triebelina serrata*... with a worldwide distribution in circumtropical carbonate platforms.

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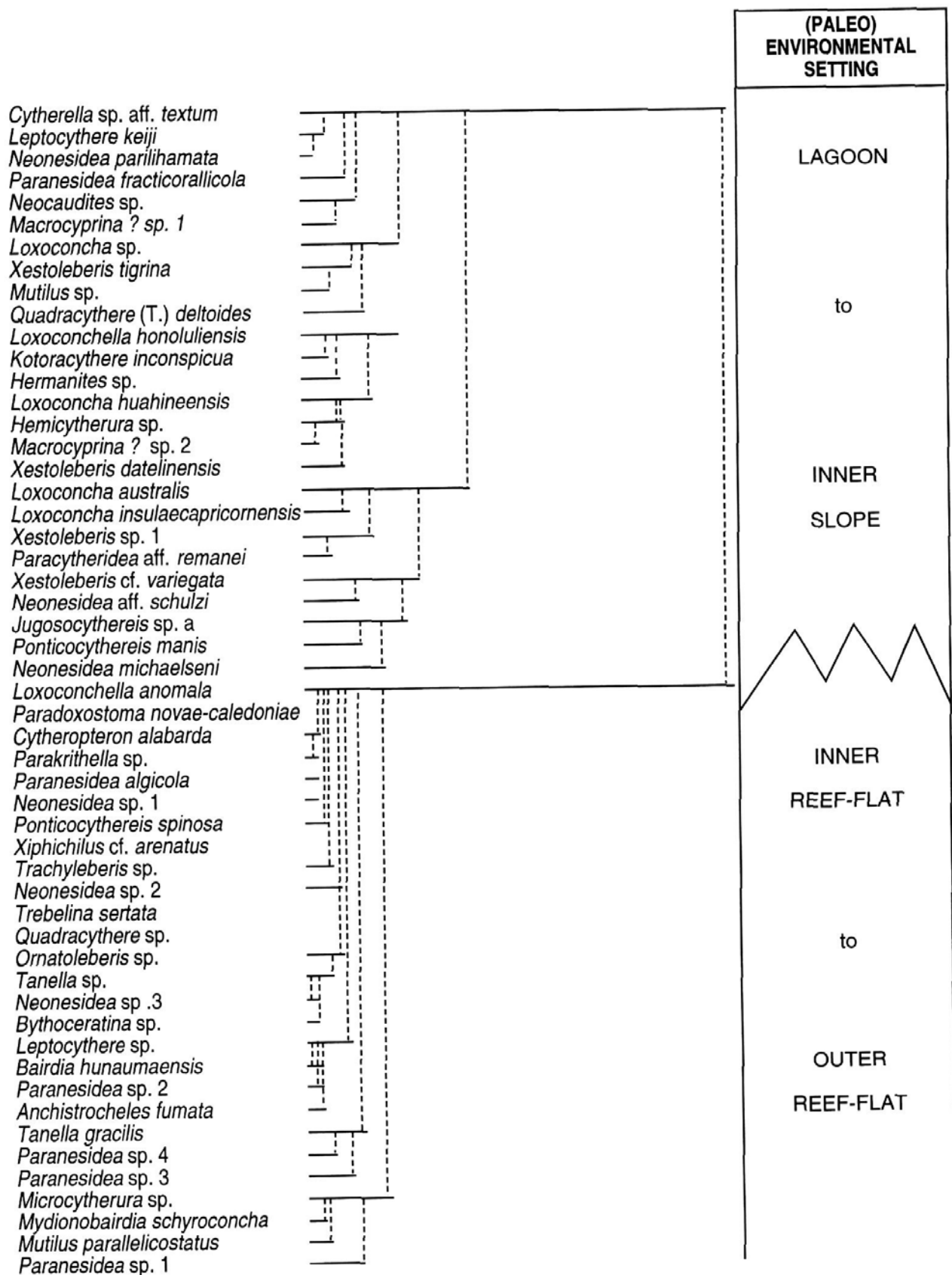
TEXT-FIGURE 5

A 1 to A 3 : Normalized principal components analysis (R-mode) using sedimentological data and bioclasts from soft sediments. G = granules, Sg = grain-sized sands, Smf = medium to fine sands, Stf = very fine sands, Tm = medium-sized sediment, Ff = fine sized sediment, Q50 = median, QdΦ = sorting, σΦ = selecting, SKI = asymetry, KG = normality, HF = hydrodynamic factor, BRY = Bryozoa, COR = Red algae (Corallinaceae), CRU = Crustaceans (except Ostracods), ECH = Echinoderms, FOR = benthic Foraminifers, HAL = Green algae (Halimeda), MAD = Corals (Madrepores), MOL = Molluscs, OST = Ostracods, SER = Serpulids, SPI = Sponges (spicules), IND = unidentified taxa.

A 4 : Environmental interpretation inferred from factor plan F1/F2 (principal components analysis).

B : R-mode classical euclidean distance dendrogram on overall samples, illustrating the physiographic setting (for discussion, see the text).

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TEXT-FIGURE 6

R-mode classical euclidean distance dendrogram on overall ostracod species illustrating the (paleo)environmental setting (for discussion, see the text).

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