

The CALSUB cruise on the bathyal slopes off New Caledonia

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ABSTRACT

The CALSUB cruise took place in 1989 off the coast of New Caledonia. The diving saucer *Cyana* enabled the exploration of the bathyal environment from the edge of the coral platform down to a depth of 3000 m. In this paper an account is given of how the study was carried out, along with the material gathered during the course of the study which may be consulted (in particular the photographs and the videos). The various sectors explored, and the principal observations made are discussed. Apart from the wide diversity of ecological niches observed, what makes this sector of the Pacific Ocean original, is the existence of bathyal benthic communities rich in "living fossils", giving us an idea of the fauna which populated the Tethys Ocean during the Mesozoic. The use of the *Cyana* diving saucer allowed direct observation of the nature of the sea beds and the associated fauna, in particular of rocky slabs, and environments affected by deep currents, where fields of hydraulic bioclastic dunes develop along fault scarps covered with dense populations dominated by Echinoderms. We were able to establish the bathymetrical distribution of the bathyal populations.

RÉSUMÉ

La campagne CALSUB sur les pentes bathyales de la Nouvelle-Calédonie.

La campagne CALSUB s'est déroulée en 1989, au large de la Nouvelle-Calédonie. Elle a permis une exploration, à l'aide de la soucoupe plongeante *Cyana*, de l'environnement bathyal, depuis la bordure de la plate-forme corallienne jusqu'à près de 3000 m de profondeur. On présente ici le déroulement de la campagne, les documents recueillis susceptibles d'être consultés (notamment les photographies et les vidéos), les différents secteurs explorés, et les principales observations effectuées. Outre la grande diversité des niches écologiques observées, l'originalité de ce secteur de l'océan Pacifique réside dans la présence de communautés benthiques bathyales, riches en "fossiles vivants" et évoquant celles qui peuplaient la Téthys au cours du Mésozoïque. L'utilisation de la soucoupe *Cyana* a donné accès à l'observation directe des fonds et des associations fauniques, et particulièrement, d'environnements sur dalles rocheuses et de ceux parcourus par des courants profonds où se développent des champs de dunes hydrauliques bioclastiques le long d'escarpements de faille couverts de peuplements très denses dominés par les échinodermes. L'étagement bathymétrique des peuplements bathyaux a pu être précisé.

INTRODUCTION

The exploration of the deep sea fauna of New Caledonia began with test cruises from 1977 to 1979 on beds ranging in depth from 200 m to 1000 m off the coast of Grande Terre, off the Isle of Pines and off the Loyalty Islands (INTÈS, 1978). As of 1985, the scope of the exploration was widened and intensified within the framework of the MUSORSTOM cruise program (RICHER DE FORGES, 1990) and the ENVIMARGES program (ROUX, 1991), which enabled sedimentologists, paleontologists and biologists to collaborate.

As the MUSORSTOM cruises developed, paleontologists began to play an important role in the study of the material gathered. The "living fossils" theme, at the forefront since MUSORSTOM 1, led by J. FOREST (1981), which set out to find new examples of the only living representative of the glypheid crustaceans, *Neoglyphea inopinata*, was reinforced when the MUSORSTOM cruises moved from the Philippines to New Caledonia. With the ENVIMARGES program, the widening of interdisciplinary cooperation was aimed at improving understanding of the ecological and geodynamic factors which, in the course of geological history, have enabled the survival of ancestral forms amongst the current bathyal fauna of the Western Pacific and, in particular, the fauna of New Caledonia.

The ENVIMARGES program, overseen by the INSU-CNRS with the support of TOTAL-CFP, concentrated primarily on a transect perpendicular to the axis of the basin of the Loyalty Islands from Thio to the west and the north-west of Lifou. Two complementary sectors were also studied: the slope situated to the south of Nouméa and the slope situated between the Isle of Pines and the large southern reef, reasonably regularly inclined towards the south-east. This program was carried out by three separate cruises: BIOCAL, BIOGECAL and CALSUB.



FIG. 1. — Recovery of SP 3000 *Cyana* at the end of a dive during the CALSUB cruise.

FIG. 1. — La SP 3000 *Cyana* récupérée à la fin d'une plongée de la campagne CALSUB.

In 1985, during the BIOCAL cruise on board the R/V *Jean Charcot* (mission led by Claude LÉVI), five sectors of the bathyal slope (SB 1 to 5) were mapped using the multibeam sounder, Sea Beam. Samples of sediment (using the Kullenberg and Usnel coring systems) and fauna (using beam trawls and Warren's epibenthic dragnet) were also taken. In 1987, the BIOGECAL cruise, on board the R/V *Coriolis* (mission led by Pierre COTILLON) enabled the

completion of the sedimentary and biological sampling of the transect on flat ground and moderate inclines. Finally, in 1989, the CALSUB cruise, on board the R/V *Suroît* (mission led by Michel ROUX) used the *Cyana* diving saucer (fig. 1) to explore the steeper and rockier beds. Moreover, a liaison with the PROPPAC program, conducted by ORSTOM (Study of the effects of climatic variation on pelagic production in the high seas of the SW Pacific) allowed us to obtain samples of plankton in order to study the current nannoflora between 20°S and 10°N by 165°E, and thereby to compare this to the fossilised calcareous nanoplankton in the Quaternary sediments of the Loyalty basin.

The principal results of the ENVIMARGES program, with special reference to the Earth Sciences, have been compiled in a special, illustrated report (LAMBERT & ROUX, co-ordinators, 1991), which biologists will be able to consult usefully.

THE CALSUB CRUISE AND RESULTING DOCUMENTATION

1. - Summary of how the cruise was carried out

The CALSUB cruise took place between 18 February and 13 March 1989 and consisted of two legs. Twenty-two dives were made (fig. 2) from the outer edge of the platforms to the abyssal zone at a depth of around 3000 m (fig. 3; table 1).

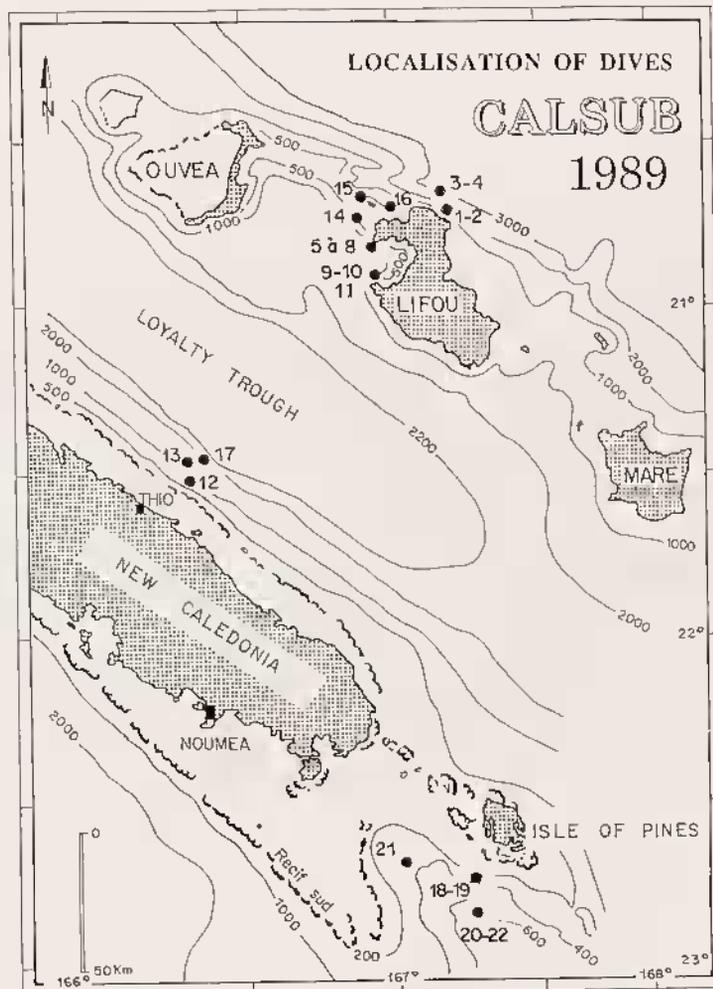


FIG. 2. — Location of *Cyana* dives conducted during the CALSUB cruise.
 FIG. 2. — Localisation des plongées *Cyana* de la campagne CALSUB.

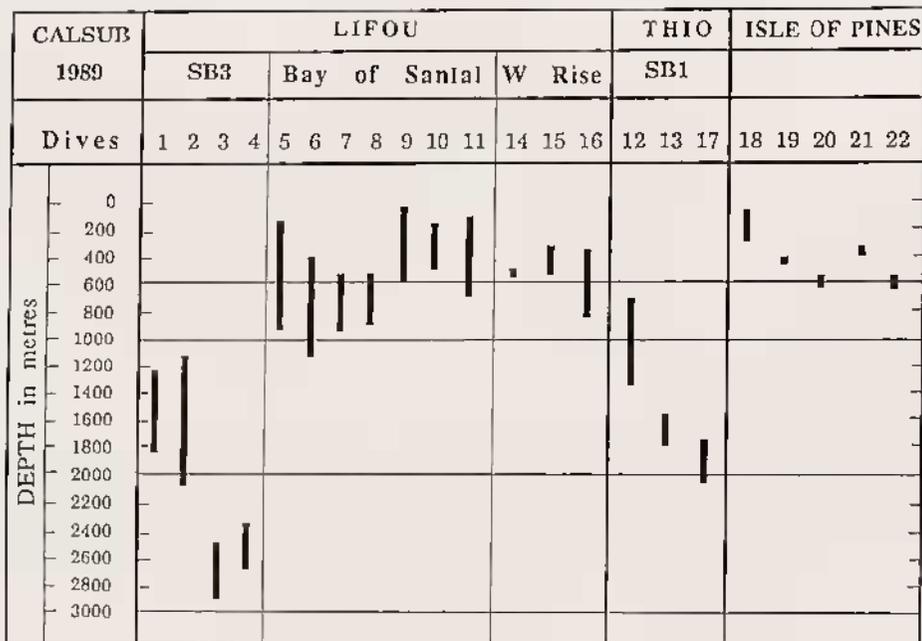


FIG. 3. — Bathymetric range of dives into different areas investigated.

FIG. 3. — Etagement bathymétrique des plongées dans les différents secteurs explorés.

Four areas had been chosen : (1) the region to the NE of Lifou, including the area shown on the Sea Beam map SB3; (2) Sea Beam map SB 1 off the coast of Thio; (3) the basin which runs between the Isle of Pines and the Great Southern Reef; (4) Stylaster Bank, a guyot situated to the SE of the Isle of Pines. As for the areas which had not been mapped during the BIOCAL cruise, we were able to benefit from readings taken by the Marine Hydrographic Service of Nouméa in Santal Bay (to the W of Lifou) and on the SE edge of the Isle of Pines.

The initial dive program was changed during the course of the cruise because of the rough condition of the sea which often only allowed us to dive in sheltered sectors. Santal Bay and the Ouvéa-Lifou rise (10 dives), as well as the basin situated to the SW of the Isle of Pines (5 dives), were explored more intensively than initially intended, whereas the number of much deeper targets was reduced (SB 1 and SB 3), and the plan to dive on the Stylaster Bank had to be abandoned. Thanks to the excellent cooperation between the crew of the *Suroît* and the technical team of the *Cyana* saucer, we were able on a number of occasions to make two dives in a single day to targets of a moderate depth.

The scientific team of each leg was composed of 6 members of the Ecoprophyce Research Group of the CNRS and one guest from the ORSTOM centre in Nouméa. Michel ROUX (Earth Sciences Laboratory, University of Reims), who led the cruise, was involved in both legs. The first leg, from 18 February until 1 March, brought together Jean-Paul BOURSEAU and Michel RIO (Centre for Earth Sciences, University of Lyon), René GRANDPERRIN (ORSTOM, Nouméa), Bernard LAURIN (Centre for Earth Sciences, University of Dijon), Claude MONNIOT (National Natural History Museum, Department of Invertebrate Marine Biology, Paris) and Jean VACELET (CNRS, Marine Station at Endoume, Marseille). The second leg brought together Philippe BOUCHET and Alain GUILLE (National Natural History Museum, Department of Invertebrate Marine Biology, Paris), Christian GAILLARD (Centre for Earth Sciences, University of Lyon), Bertrand RICHER DE FORGES (ORSTOM, Nouméa), Michel SEGONZAC (IFREMER, Brest) and Helmut ZIBROWIUS (CNRS, Marine Station at Endoume, Marseille).

Each dive produced the following documentation : (1) a complete video recording on VHS tape; (2) several hundred photographic slides; (3) a detailed report written by the diver once back on board. Umatic video sequences, which are of very high quality, were only occasionally taken; they have been converted to VHS, thereby making them easier to consult.

The sampling capacity of the *Cyana* saucer is limited, particularly when working on steep slopes. This was improved by using autonomous shuttles (lifts) and ballasted sampling cans carried aboard the saucer. The big draw-lift was only used on the first dives at the deepest site (SB 3). Its ability to carry baskets of dimensions 60 cm x 40 cm x 30 cm enabled us to collect complete specimens of some size (sponges, stalked crinoids). A double-box lift, which is more maniable, was more frequently used.

In general, this lift was placed halfway along the route : we placed in it a ballasted can full of samples taken during the first part of the dive, substituted by an empty can used during the second part. Moreover, one of the boxes is capable of keeping large specimens collected nearby. When the lift could be cast off in the evening, around 10 or 12 hours before a dive, bait (tuna, chicken) was attached to the ballast and protected from sharks by wide-meshed wire netting. It was in this way that nautilids and various crustaceans could easily be observed and, in some cases, even captured.

Since the suction system did not function properly, we were unable to collect small macrofauna, despite its abundance on certain epibathyal beds.

On board, a few samples were prepared and conserved in liquid nitrogen, with a view to performing comparative phylogenetic analyses, using information provided by ribonucleic acid (RNA) sequencing.

N° CALSUB	N° CYANA	DATE 1989	LOCATION New Caledonia	DEPTH in metres	OBSERVER
N of Lifou SB3					
01	1016/22	19/2	20°38'S/167°13'E	1863 à 1228	C. Monniot
02	1017/23	21/2	20°37'S/167°14'E	2191 à 1130	M. Roux
03	1018/24	22/2	20°36'S/167°13'E	2885 à 2465	M. Rio
04	1019/25	23/2	20°35'4S/167°12'E	2697 à 2380	J. Vacelet
W of Lifou and N of the Bay of Santal					
05	1020/26	24/2	20°47'S/167°01'E	954 à 130	R. Grandperrin
06	1021/27	24/2	20°48'S/167°02'4E	1150 à 400	B. Laurin
07	1022/28	25/2	20°48'S/167°05'E	970 à 489	J.P. Bourseau
08	1023/29	26/2	20°48'3S/167°05'E	880 à 516	B. Laurin
W of Lifou and S of the Bay of Santal					
09	1024/30	27/2	20°53'S/167°03'E	602 à 70	J. Vacelet
10	1025/31	28/2	20°53'S/167°03'E	480 à 170	C. Monniot
11	1026/32	28/2	20°52'5S/167°03'E	681 à 120	J.P. Bourseau
Thio SB1					
12	1027/33	3/3	21°28'S/166°21'5E	1265 à 700	H. Zibrowius
13	1028/34	4/3	21°26'S/166°22'7E	1807 à 1567	M. Segonzac
Between Lifou and Ouvéa					
14	1029/35	5/3	20°38'S/166°56'6E	570 à 494	B. Richer de F.
15	1030/36	6/3	20°37'1S/166°58'E	545 à 317	A. Guille
16	1031/37	7/3	20°37'8S/167°2'7E	825 à 365	M. Roux
Thio SB1					
17	1032/38	8/3	21°25'S/166°24'E	2049 à 1753	C. Gaillard
S. to SW of the Isle of Plinee					
18	1033/39	9/3	22°46'S/167°20'E	290 à 50	P. Bouchel
19	1034/40	10/3	22°46'S/167°20'E	416 à 404	M. Segonzac
20	1035/41	10/3	22°52'7S/167°23'E	616 à 555	A. Guille
21	1036/42	12/3	22°45'S/167°09'E	344 à 330	B. Richer de F.
22	1037/43	13/3	22°53'S/167°23'E	627 à 563	M. Roux

TABLE 1. — *Cyana* dives during the CALSUB cruise.

TABLEAU 1. — Ptongées de *Cyana* lors de la campagne CALSUB.

2. - Documentation available for consultation

The video and photographic documents, along with the reports of the dives can be consulted at the Earth Sciences Laboratory at the University of Reims. The biological specimens have been listed and sent out to specialists by the CENTOB (IFREMER - Brest). The samples of sediment or rock have been listed and sent out for study by the Centre for Earth Sciences at the University of Lyon. Copies of slides and a video of the cruise (produced by FR3 Champagne-Ardenne and available only for strictly scientific or pedagogic purposes) are available by request to the head of the mission.

The data chamber which appears on the slides (fig. 4) and video films, indicates the depth, bearing, time and numerical order of the photograph (or, on the videos, the number of the dive). For the lesser depths, the bathymetric readings tend to be overestimated and must be corrected by reckoning that from 500 m up to the surface, the overestimation of the depth varies progressively from 0 to 30 m.

depth (1850m)
 /
 1 5 2 7 <--- *photo number* (527)
 8 0 1 2 <--- *hours* (12h)
 5 6 5 5 <--- *minutes* (55mn)
 0 5 1 3 <--- *seconds* (13s)
 /
course (065)

FIG. 4. — Data chamber printed on the lower left side of pictures taken by *Cyana* during CALSUB cruise.

FIG. 4. — Chambre de données apparaissant en bas et à gauche sur les photographies prises par *Cyana* lors de la campagne CALSUB.

The reports of the dives include :

- detailed maps of the route taken and its position in the study zone (for example, figs 5, 6 and 7);
- diagrams indicating the main substrates and environments observed;
- a list of the useful photographs, with a brief commentary and sometimes preliminary names for organisms;
- a selection of the dive's more striking photographs;
- the list of the samples taken with the corresponding video sequences and photographs;
- a summary of the dive, written following the course of the VHS tape, with a temporal guide from the data chamber; here the observations and interpretations have the advantage of having been written 'on the spur of the moment' by the observer;
- complementary information provided, once on board, by the members of the scientific team, or after the mission by specialists who had examined the documents.

Video and photographic documentation gathered during cruises such as this, is often underused. This is probably partly due to the fact that not enough information is available as to its nature and content, and partly to its mere bulk, which means that a thorough preliminary study is necessary before the required information can be found. We have attempted to facilitate the work of specialists interested by the extremely diverse documentation gathered by the CALSUB mission and hope that it will be frequently consulted.

3. - The different sectors explored

3-1. - Around the island of Lifou

The Loyalty Islands, of which Lifou is one of the three largest, are ancient atolls, raised up by the lithospheric bulge which affects the Pacific Plate, before its subduction at the Vanuatu Trench. There is no platform at the

island's edge, and very rapidly we reach depths in the thousands of meters. The three sectors explored off the coast of Lifou (fig. 5) correspond to (1) a sheltered bay, (2) a rise and (3) the flank of an ancient underwater volcano.

3-1-1. - In Santal Bay

Santal Bay is situated on the western coast of Lifou. A narrow projecting edge supports coral pinnacles. The bed of the bay is deep, around a thousand meters, and is reached by a moderate to steep ramp covered in coral sands. By the headlands which enclose the bay to the north and south, the slope is much steeper, even abrupt in places, and rocky beds are predominant. The morphology of this bay might indicate that it is the scar of a collapse which affected Lifou as it rose.

To the north, near cap Aimé, four dives explored the talus between 1150 m and 130 m. The first two (dives 5 and 6) were carried out in the mouth of the bay, in an area swept by currents, and the following two (dives 7 and 8) on the side of a more sheltered spur.

To the south, near the mouth of the bay at cap Lefèvre, three dives (9 to 11), at between 600 m and 700 m, studied the external flanks, often abrupt, of a small coral group, the Shelter reef (fig. 6).

Coral or algal material, and even blocks of rock loosened by erosion, are in constant movement on these steep epibathyal slopes (RIO *et al.*, 1991).

The benthic fauna only develops beyond areas frequently affected by these sedimentary movements. On the whole, the density of benthic fauna observed in Santal Bay was rather low.

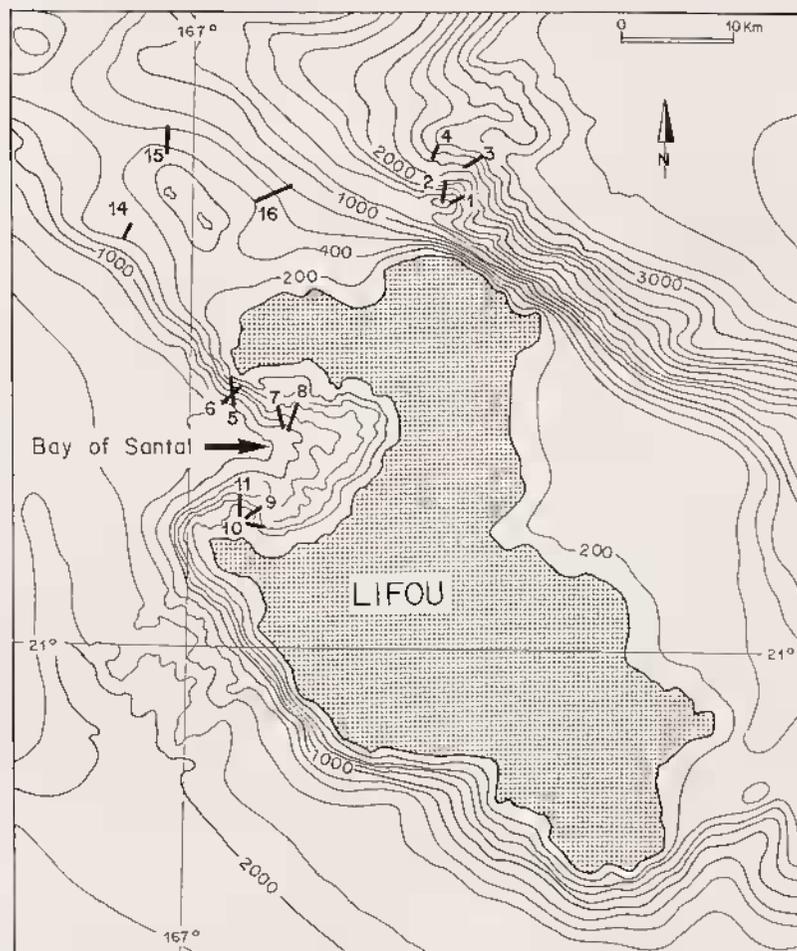


FIG. 5. — Location of dives conducted off Lifou island.

FIG. 5. — Localisation des plongées menées au large de l'île de Lifou.

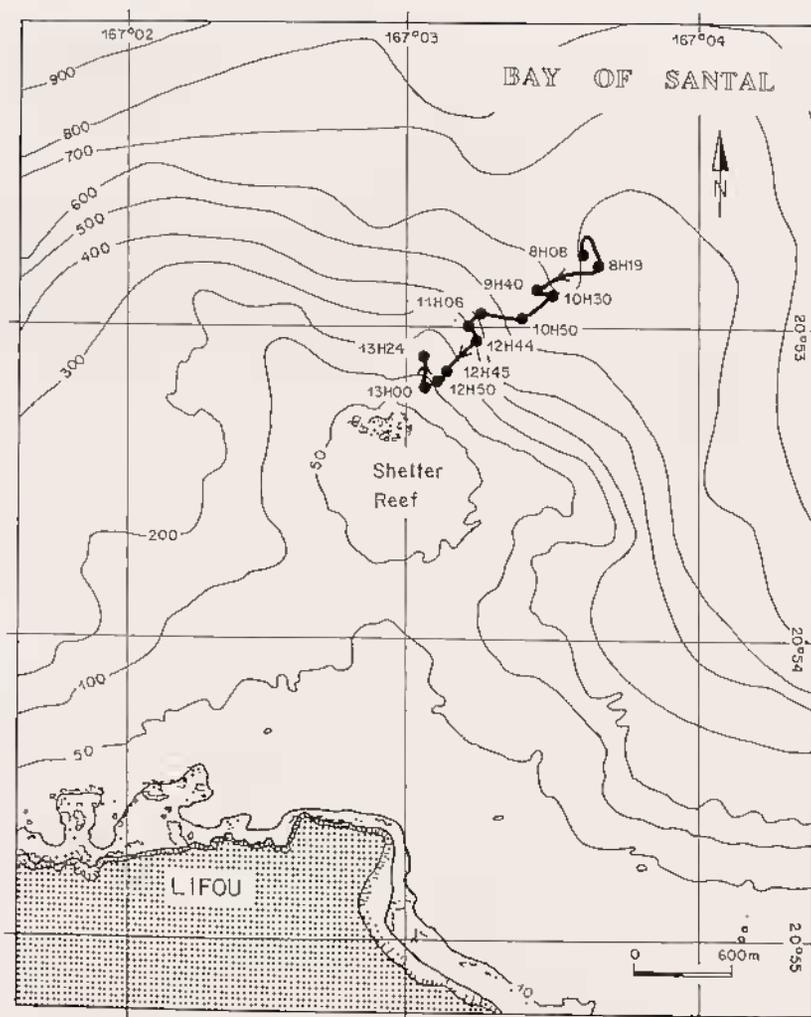


FIG. 6. — Map with the location of dive 9 on the NE flank of Shelter reef. This type of map is available for each dive in Santal Bay.

FIG. 6. — Carte avec la plongée 9 effectuée sur le flanc NE du récif Shelter. Ce type de document existe pour chacune des plongées en baie du Santal.

3-1-2. - On the Ouvéa-Lifou rise

Dives 14, 15 and 16 explored, between 900 m and 400 m, the flanks of the Ouvéa-Lifou rise, just to the west of the Jouan reef, a small coral outcrop. At around 500 m, the first two dives discovered a very peculiar submarine morphology, probably linked to ancient hydrothermal activity (VANNEY, 1991; VANNEY *et al.* 1992), containing indurated ferromanganiferous rock, dissected by erosion into "mushroom rocks". The other hard ground beds are, for the main part, large calcareous surfaces, often suffering biocorrosion or covered in a thin film of pteropod shells. The flanks of the rise are affected by faults which form the limit of the sedimentary channels swept by currents and which are bordered by subvertical walls (even overhangs in some places). Dive 16, near to Jouan reef, observed substantial quantities of rocks and algal gravel, at times covering the entire bed for around 400 m or 500 m, limiting the benthos to a predominantly vagile fauna. Dive 15, to an area more sheltered from the effects of neritic sediments, observed an abundant fauna attached to the hardened beds.

3-1-3. - In the deeper zone to the North of Lifou

The Sea Beam map SB3 (fig. 7) allowed us to accurately plan four dives (1 to 4), between 1100 m and 2900 m in depth, on the flank of a volcanic seamount with a summit at around 1000 m deep, and slightly detached from

the talus situated to the north of Lifou. Here, rocky slabs or rather coarse volcanic breccia are predominant. In those areas where the slope is less steep and on the few flattish ledges, accumulations of sediment are seen to develop.

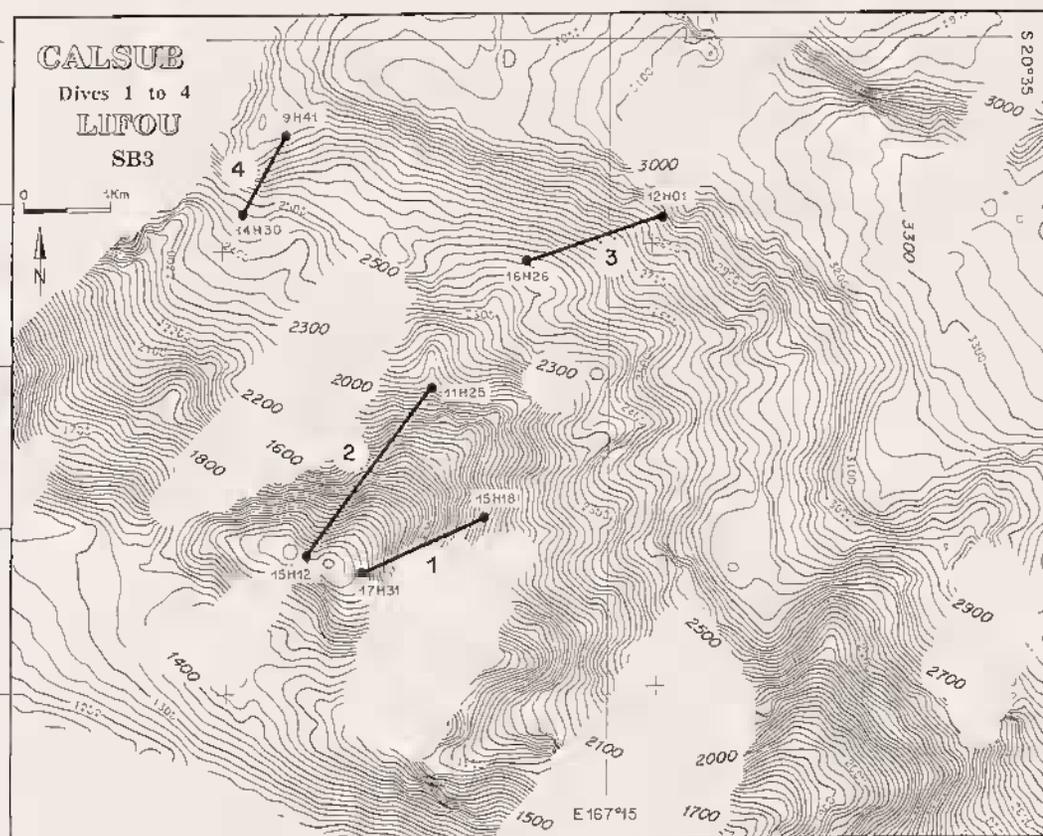


FIG. 7. — Location of dives 1 to 4 off the North of Lifou island. Map without extrapolation, from multibeam sounder of R/V *J. Charcot*.

FIG. 7. — Localisation des plongées 1 à 4 au Nord de Lifou. Carte sans extrapolation, levée avec le Sea-Beam du N/O *J. Charcot*.

These are the dives which best demonstrate the New Caledonian abyssal benthos on hard substratum. Dive 2 (fig. 8) provides us with the clearest picture of the fauna and of its distribution. However, the navigational difficulties we faced with the saucer during dive 3 (the deepest) meant we were unable to localise the route it took, which involved, in part, the sedimentary beds at the foot of the talus.

3-2. - Off the coast of Thio

This is a mesobathyal area, dominated by sedimentary beds in the process of being eroded, and therefore generally much less stable than those in the SB3 area. Weather conditions only allowed us to carry out three dives (12, 13 and 17) on the bathyal talus. It was not possible to explore the fringe of the reef immediately below the barrier reef situated off the coast of Thio. Sea Beam map SB1 (fig. 9) shows a series of trenches and edges parallel to the slope. The dives were performed in stages along the same edge in each case. It would appear that this morphology is dominated by the effects of regressive erosion starting from the base of the talus, since the trenches become less marked towards the top of the talus. This would primarily come about as the result of erosion processes in a sedimentary material that has undergone little or no lithification.

We may consider then that the fauna observed is able to adapt to an unstable bed where erosion is active on most surfaces, with a substratum ranging from crumbly to compact, containing slightly more resistant,

ferromanganiferous layers. We only observed more indurated sites on dive 12 near the epibathyal region. Ancient or indeed current bioturbation affects the compact sediments as much as the crumbly sediments; we were able to analyse this in greater detail during dive 17 (GAILLARD, 1991 a and b). The second half of dive 12, which included more indurated substrates, merits a comparison with dives 1 and 2 of SB3.

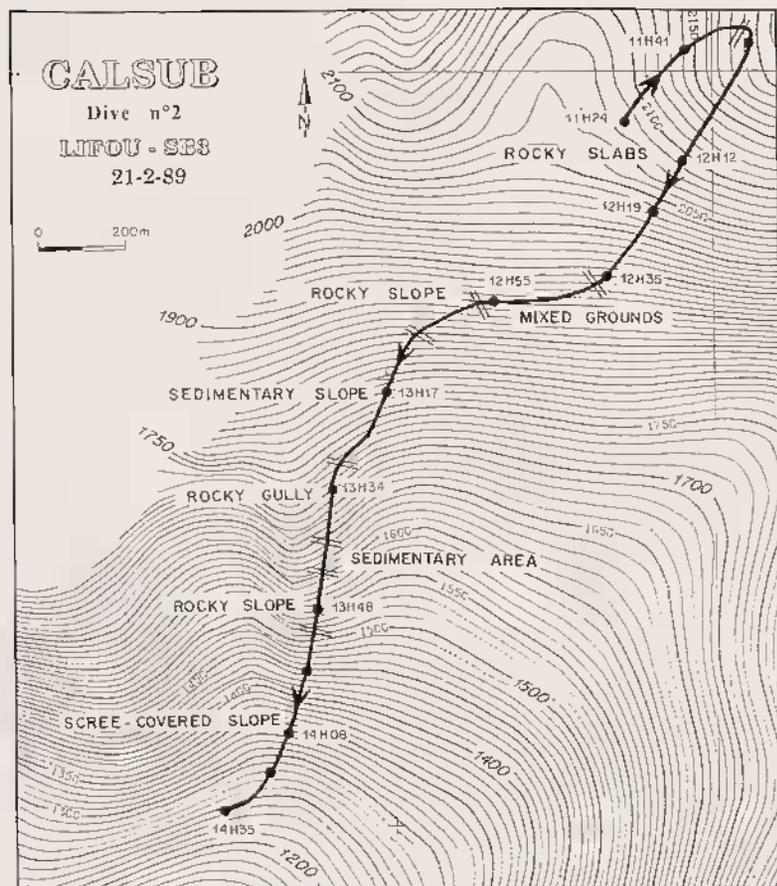


FIG. 8. — Map of the area of dive 2 with the different substrates observed on the north slope of Lifou.

FIG. 8. — Carte de la zone parcourue par la plongée 2 avec les principaux types de fonds observés.

3-3. - Between the Isle of Pines and the Great Southern Reef

Five dives (18 to 22) allowed us to describe the environment of this epibathyal gully (fig. 10).

Dives 18 and 19 examined the slope which links the outer edge of the coral platform with the Isle of Pines between 60 m and 450 m deep. There is no barrier reef in this place, and the carbonate ooze which accumulates at the edge of the platform leads to mass slides at those areas where the slope becomes steeper.

The ramp which slopes towards the SE and which forms the bottom of the gully is periodically swept by substantial currents, which create bioclastic hydraulic dunes in areas of sedimentary accumulation, and types of "reg" covered by rocky particles which are a result of the loosening of indurated ferruginous crusts in the non-deposit zones (RIO *et al.*, 1991).

Dive 21, at around 350 m depth, showed some relatively stabilised dunes, separated by rather wide gaps of the "reg" type, rich in well-diversified sessile and vagile benthos.

Dives 20 and 22, between 575 m and 620 m, demonstrated an interesting biosedimentary ensemble, linked to a fault escarpment which channels the currents (figs 11 and 12). Detailed cartography of the area was undertaken using a 3.5 kHz sounder and the bathymetric data collected during the *Cyana* dives. The dunes, in this area, are active with very soft sediment, devoid of sessile epifauna, even in the gaps between dunes. At the foot of the scarp,

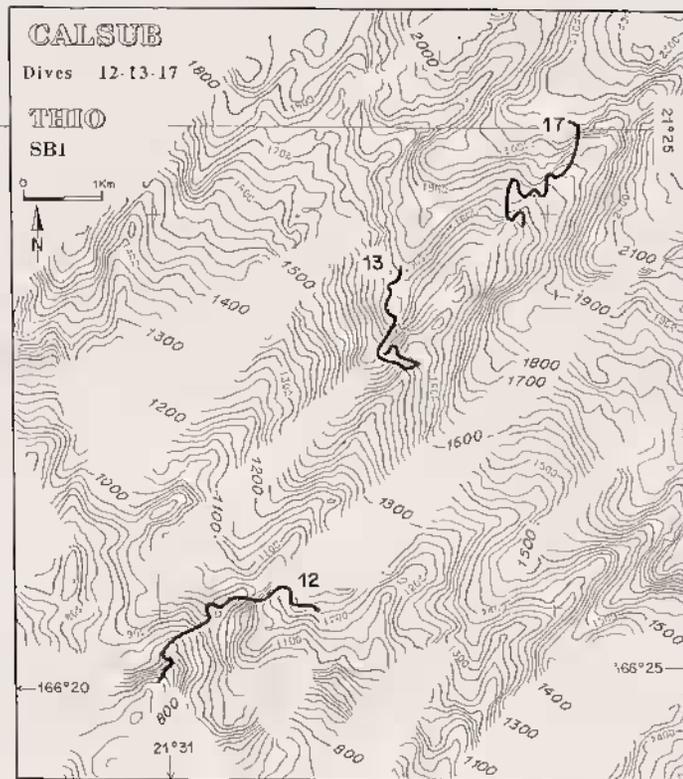


FIG. 9. — Location of dives 12, 13 and 17 on the bathyal slope off the north east of Thio. Map without extrapolation from multibeam sounder of R/V *J. Charcot*.

FIG. 9. — Localisation des plongées 12, 13 et 17 sur le talus bathyal situé au NE de Thio. Carte sans extrapolation, levée avec le Sea-Beam du N/O *J. Charcot*,

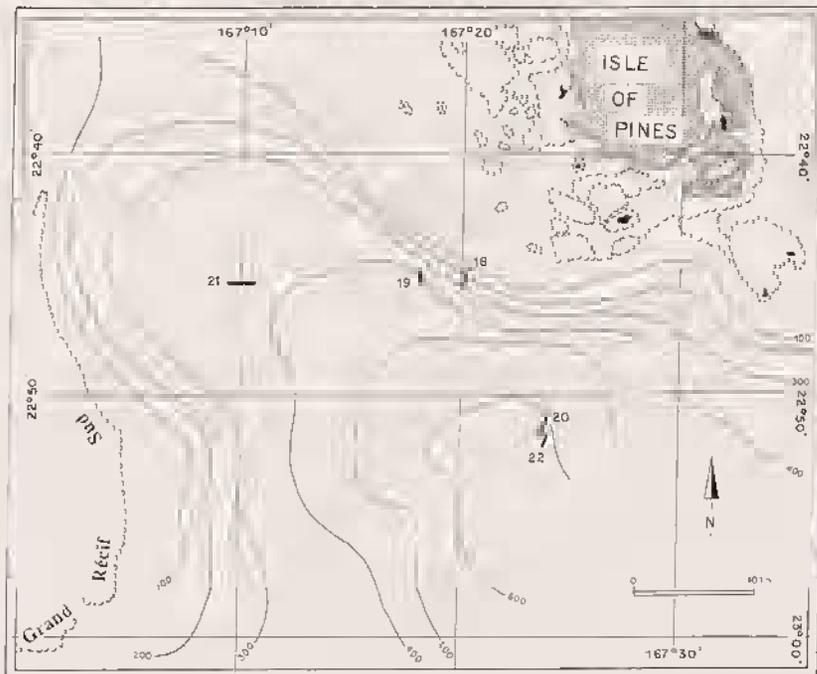


FIG. 10. — Location of dives 18 to 22 on the epibathyal gully between the Isle of Pines and the Great Southern Reef.

FIG. 10. — Localisation des plongées 18 à 22 dans la gouttière épibathyale entre l'île des Pins et le Grand Récif Sud.

The stronger force of the current excavates a depression several meters deep, covered with blocks of rock, pebbles and very crude bioclastic sediments. The upper end of the subvertical wall is a hardened ferruginous layer, slightly overhanging, which supports a very dense population of suspension-feeders, predominantly Echinoderms (ROUX *et al.*, 1991 a and b).

3-4. - Stylaster Bank

Stylaster Bank is a guyot situated to the southeast of the Isle of Pines, 23°38' S, 167°43' E. Since the high swell prevented us from using the *Cyana* saucer, we carried out instead a series of bathymetric profiles using the 3.5 kHz sounder, in order to gain a precise idea of the morphology and cartography. This guyot is rooted to surrounding beds situated at a depth of around 1000 m (fig. 13). Its flanks are relatively regular and very steep. The summit rises to between 450 m and 500 m depth, and has a very irregular and dissymmetric topography. This type of morphology would seem to lend itself well to testing the possible effects of currents on the density of benthic populations and the resulting halieutic resources.

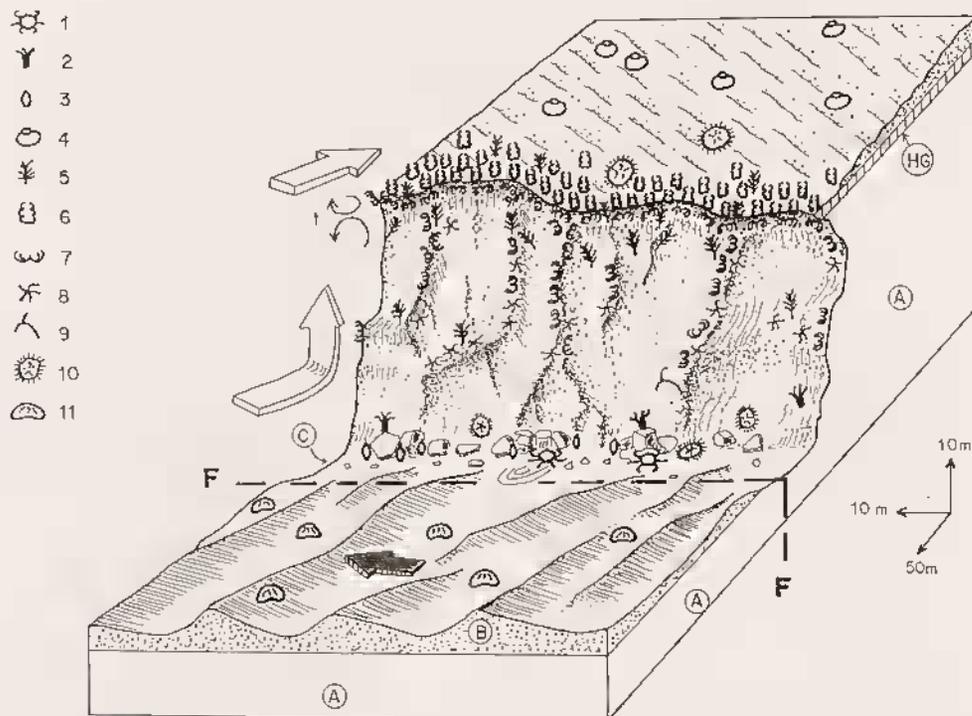


FIG. 11. — The fault escarpment environment observed off the South of the Isle of Pines with its benthic fauna.

A : hemipelagic pliocene chalk; B : bioclastic sand; C : "reg" at the foot of the fault escarpment; F : fault; HG : ferruginous hard ground.

1 : crab (*Geryon*); 2 : actinian; 3 : large bivalve (*Acesta*); 4 : spherical siliceous sponge; 5 : zoantharian; 6 : ophiacanthid brittle stars with uplifted arms; 7 : suspension-feeding sea stars (Brisingiidae); 8 : ophiacanthid brittle stars with arms crawling on the substrate; 9 : bourgueticrinid stalked crinoid (*Porphyrocrinus*); 10 : regular soft sea urchin (*Phormosoma*); 11 : spatangid sea urchin (*Taimanawa*). Arrows indicate direction of currents.

This site is also illustrated in fig. 22-2 to 4 and fig. 25-6.

FIG. 11. — L'escarpement de faille observé au sud de l'île des Pins et sa faune benthique.

A : craie hémipélagique d'âge pliocène; B : sable bioclastique; C : "reg" en pied d'escarpement; F : faille; HG : surface durcie ferrugineuse.

1 : crabe (*Geryon*); 2 : actinie; 3 : bivalve limidé (*Acesta*); 4 : éponge siliceuse globuleuse; 5 : zoanthaire; 6 : ophiure ophiacanthidée aux bras dressés; 7 : astérie brisingidée; 8 : ophiure ophiacanthidée aux bras plaqués sur le substrat; 9 : crinoïde pédonculé (*Porphyrocrinus*); 10 : échinide régulier (*Phormosoma*); 11 : échinide irrégulier (*Taimanawa*). Les flèches indiquent le sens des courants.

Ce site est également illustré fig. 22.2 à 4 et fig. 25-6.

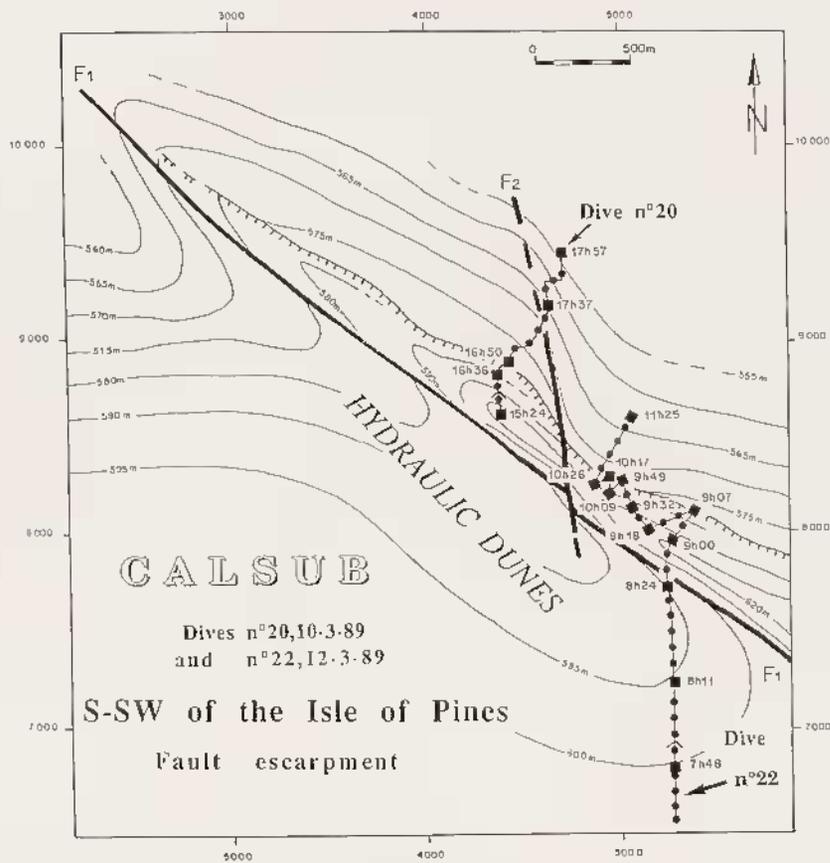


FIG. 12. — Map of the fault escarpment with hydraulic dunes area off the South of the Isle of Pines, and location of dives 20 and 22.

FIG. 12. — Carte du relief de faille et de la zone à dunes hydrauliques situés au sud de l'île des Pins, et localisation des plongées 20 et 22.

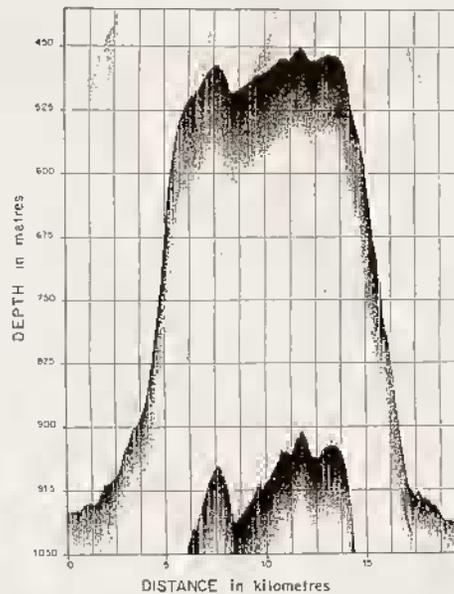


FIG. 13. — Bathymetric profile of the Stylaster Bank (3.5 kHz sounder).

FIG. 13. — Profil bathymétrique du banc Stylaster (sondeur 3,5 kHz).

MAIN OBSERVATIONS AND REMARKS

1. - Remarks on climate and hydrology

During the austral summer, New Caledonia is subject to the influence of equatorial depressions and may at times suffer from tropical cyclones which arise in the Coral Sea and to the north of the arc formed by Vanuatu and the Salomon Islands.

The violent winds and the strong rainfall which go hand in hand with tropical depressions and cyclones are particularly strongly felt by the marine environment, causing strong swells, drop in salinity, serious perturbations of the currents, homogenisation of the shallow sea water layer, exceptionally high tidal ranges, and resuspension of sediments from the bed, with a consequent strong increase in the turbidity of the sea water. They probably also have consequences, for the environment at a much deeper level, as we shall see later. Depressions such as these, which result in fierce storms, pass close to Grande Terre on average once or twice a year (ROUGERIE, 1986).

New Caledonia is set within the hydrological context of the Coral Sea, which is very open to the great oceanic currents running through the central and southwestern Pacific. The hydrology in the basin of the Loyalty Islands during the winter of 1981 was analysed by D. GUEVEL (1983). In addition, the *Cyana* diving saucer recorded temperature contours at the time of the CALSUB dives at the end of the summer of 1989 (fig. 14).

The vertical thermohaline structure in winter (fig. 14C) shows a salinity maximum of 35.68 ‰ between 150 and 170 m, thereby separating the southern layer of subtropical water from the superficial layer of water

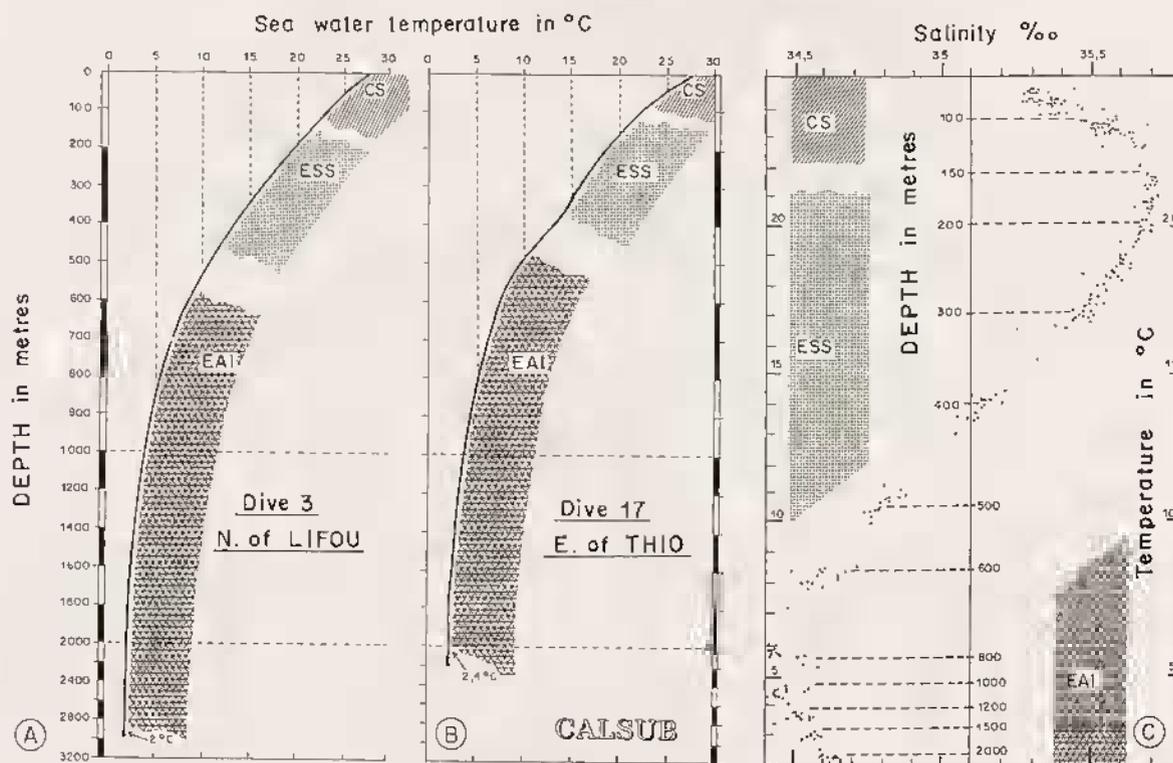


FIG. 14. — Vertical hydrological profiles near the east edge of Loyalty ridge (A) and basin (B and C).

A and B : data recorded by the diving saucer *Cyana* during CALSUB cruise ; C : modified from GUEVEL, 1983.

CS : shallow water layer; ESS : southern subtropical water layer; EAI : intermediate deep antarctic water layer.

FIG. 14. — Profils hydrologiques au large de la Nouvelle-Calédonie. Structure thermique et thermohaline verticale à l'est de la ride (A) et dans le bassin des Loyauté (B et C).

A et B : données enregistrées par la soucoupe *Cyana* lors de la campagne CALSUB; C : modifié d'après GUEVEL, 1983.

CS : couche superficielle; ESS : eau subtropicale sud; EAI : eau antarctique intermédiaire.

which is saltier to the South (subtropical influence) than to the North (equatorial influence). The intermediate antarctic water, which is travelling north, has an average 34.50% salinity and a 5°C temperature in this area. Minimal salinity values occur between 700 m and 1100 m. Its upper limit has been defined at nearer 600 m close to the barrier reef off the coast at Nouméa (ROUGERIE, 1986). This conclusion is also suggested by the CALSUB thermal readings (fig. 14 A and B) and it may even rise further towards the end of summer off the coast of Thio, which would explain the rapid fall in temperature between 400 m and 500 m.

The cartography of the water masses in the Loyalty basin (GUEVEL, 1983) demonstrates the following : (1) a superficial frontal zone to the west of Maré which separates warmer and less salty water in the north from that in the south; (2) between 0 to a depth of 200 m, a geostrophic current running towards the SE, which dominates the NW drift resulting from the trade winds; (3) at a depth of 1000 m, a geostrophic current running towards the NW.

Seasonal changes in the principal surface currents are more noticeable on the western edge of Grande Terre, as well as to the S and SE of the Isle of Pines. The strength of the currents observed between 300 m and 650 m by the CALSUB dives between the Isle of Pines and the Great Southern Reef may be due to seasonal conditions which could cause to the upper part of the antarctic water layer to rise, channelled by the morphology of the gully. It may also be due to the effect of internal waves being propagated along the upper limit of the antarctic water layer. The moving hydraulic dunes observed during dive number 22, as well as the presence of Echinoderms which we would normally expect to encounter much deeper (see later) all indicate the frequent, if not almost permanent influence of antarctic water at a depth of around 600 m. The more stabilised dunes observed at around 350 m during dive 21, are probably due to a more exceptional activity of deep currents likely to give rise to them (fig. 15).

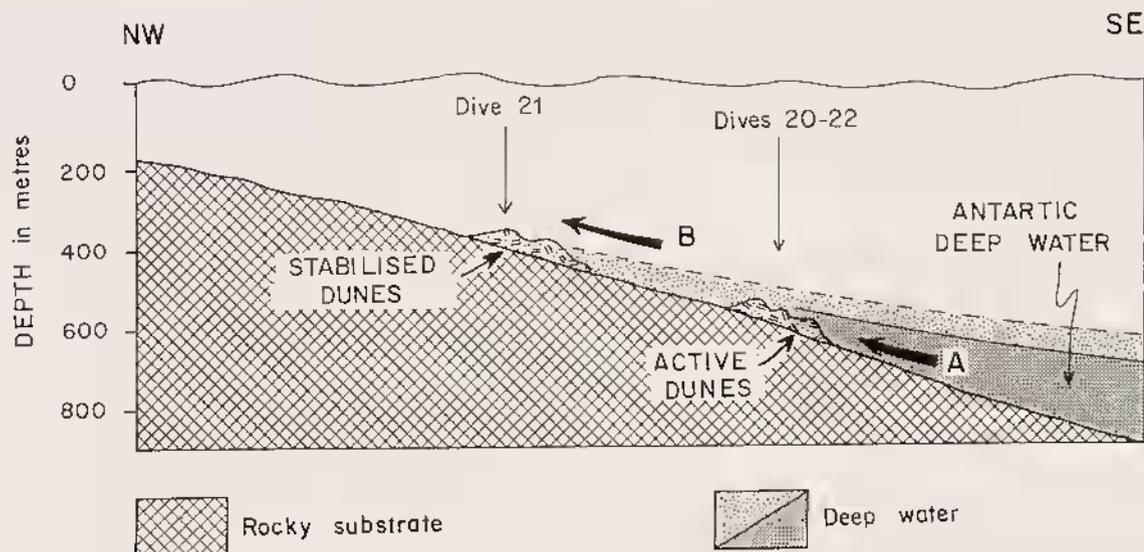


FIG. 15. — Axial profile of the epibathyal gully between the Isle of Pines and the Great Southern Reef.

A : frequent upwellings of antarctic water explaining active hydraulic dunes. **B** : exceptional upwellings of antarctic water allowing the formation of stabilised hydraulic dunes and development of a diversified benthic fauna.

FIG. 15. — Profil axial de la gouitière épibathyale située entre l'île des Pins et le Grand Récif Sud.

A : remontées fréquentes de l'eau antarctique intermédiaire entretenant des dunes hydrauliques vives. **B** : remontées exceptionnelles permettant la stabilisation des dunes hydrauliques et la colonisation par une faune benthique diversifiée.

2. - Bathymetric distribution of communities

Because these results have already been presented and discussed in some detail elsewhere (ROUX *et al.*, 1991 a and b), we shall restrict ourselves to a summary of the main aspects here. In the bathyal domain of New Caledonia, it appears that the changes in fauna, as we head deeper down into the ocean, are closely linked to the limits of the different water layers.

It is at depths of around 100 m to 150 m that the break in the slope limiting the platform usually occurs, and that the fall in luminosity is most noticeable. In Santal Bay, encrusting green algae, of the *Palmophyllum*-type, are associated with rhodolites at around 110 m, whereas *Melobesia*-type algae are found as deep as 145 m. Compact algal structures, supporting a rich fauna of large gorgonians, sponges and antipatharians (figs 21-1 and 21-2), develop between 60 m and 100 m. Algal slabs with scoriaceous surfaces tend to lose their blanket of sessile megafauna, particularly when the incline becomes steeper, at around 80 m to 100 m (fig. 21-3). Beyond 100 m, algal balls dominate, together with a primarily vagile epifauna (fig. 21-4). The substratum's biological cover becomes more dispersed and its bathyal character becomes evident from 150 m downwards, when the layer of southern subtropical water is entered.

The epibathyal domain (from approximately 150 m to 700 m) is characterized by a wide variety of beds. Rocky slabs, covering soft sediment, undermined by the burrowing of crustaceans or fish, conserve caverns sheltering a number of sessile and vagile organisms (figs 22-1 and 23-4). The hard beds alternate with sedimentary beds of varying stability and granulometry (ranging from masses of fallen rock to hemipelagic ooze). They are frequently covered by vegetal debris, at times of some considerable size. This debris becomes rarer as we go deeper; however, we did observe a tree, probably uprooted during a cyclone, at a depth of about 2000 m (fig. 23-6).

On the upper part of the talus, the rocky surfaces are often swept by avalanches of sediment, which is at times quite crude, coming from the outer edge of the platform (fig. 23-2). On these unstable substrates, only a vagile or semi-vagile fauna develops (holothurians, sea stars, comatulid crinoids, gasteropods). Those surfaces better sheltered from these movements of sediment (figs 21-5 and 23-5) show a great diversity of siliceous sponges, some of which (fistulous sponges, clionids) seem to participate in the cupulate erosion of the substratum (GAILLARD, 1991 a).

Between 300 m and 700 m, large steep indurated surfaces support different communities of suspension-feeders (gorgonians, echinoderms, sponges) (fig. 22-5). On the Ouvéa-Lifou rise, each community is clearly dominated by one or two species, and it is possible to observe groups consisting of a single species, particularly the echinoderms (fig. 23-3). In the area to the SW of the Isle of Pines, the richness and abundance of the macrofauna reaches high levels. Between 320 m and 410 m, in the zone of the relatively stabilised dunes (fig. 22-6), the epifauna is extremely diverse (brachiopods, gasteropods, *Stylaster* corals, sponges including lithistids, echinids, stalked crinoids, crustaceans), with a regular and fairly homogeneous spread. At around 600 m, the fault scarp, at the foot of which moving hydraulic dunes develop (fig. 25-6) demonstrates, in a relatively reduced space, how the intensity of the currents and the nature of the substrate can affect the composition of benthic communities (fig. 11). The summit of the scarp supports very dense communities of suspension-feeders, dominated by echinoderms (fig. 22-2 to 4). A large part of this fauna, particularly among the echinoderms (*Phormosoma* and brisinginds, for example), is in great abundance, and normally more characteristic of depths below 1000 m. In fact, this site marks the beginning of the transition zone between the beds washed by subtropical water and those washed by intermediate antarctic water.

This transition generally occurs between 700 m and 1000 m. The communities in this zone, which are often rather peculiar, may still be quite dense. What singles them out is the presence of hexactinellid sponges, notably the abundance of *Monorhaphis* (figs 24-1 and 24-2). These communities already contain taxa which, as we shall see, dominate the deepest areas explored (e. g. hyocrinid crinoids, *Euplectella*, *Hyalonema*, *Iridogorgia* -fig. 16A-, xenophiophorids, etc.).

Beyond 1000 m, the macro- and megafauna become definitely more scarce, while remaining quite diversified. Individual specimens are apt to grow very large, in some cases over one metre. The stalked hexactinellid sponges become very diversified (fig. 24-6). The sponges and dead branches of gorgonians frequently support suspension-feeders (comatulid crinoids, sea stars, brittle stars, actinians), at times in thick bunches (fig. 24-3). Between 1000 m and 1600 m, the megafauna on the rocky surfaces is characterised by the simultaneous presence of three forms: two homeomorphic stalked crinoids (*Proisocrinus* and *Guillecrinus*) (figs 24-4 and 24-5) and a gorgonian of the genus *Metallogorgia* (fig. 16B). At around 2000 m, we see the first examples of large *Euplectella*, attached to the gently sloping rocky beds. In the sedimentary zones, the relative importance of bioturbation increases with depth (fig. 26-1), and different ichnofacies are the distinguishing markers for lower or upper beds at a depth of around 1800 m (GAILLARD, 1991).

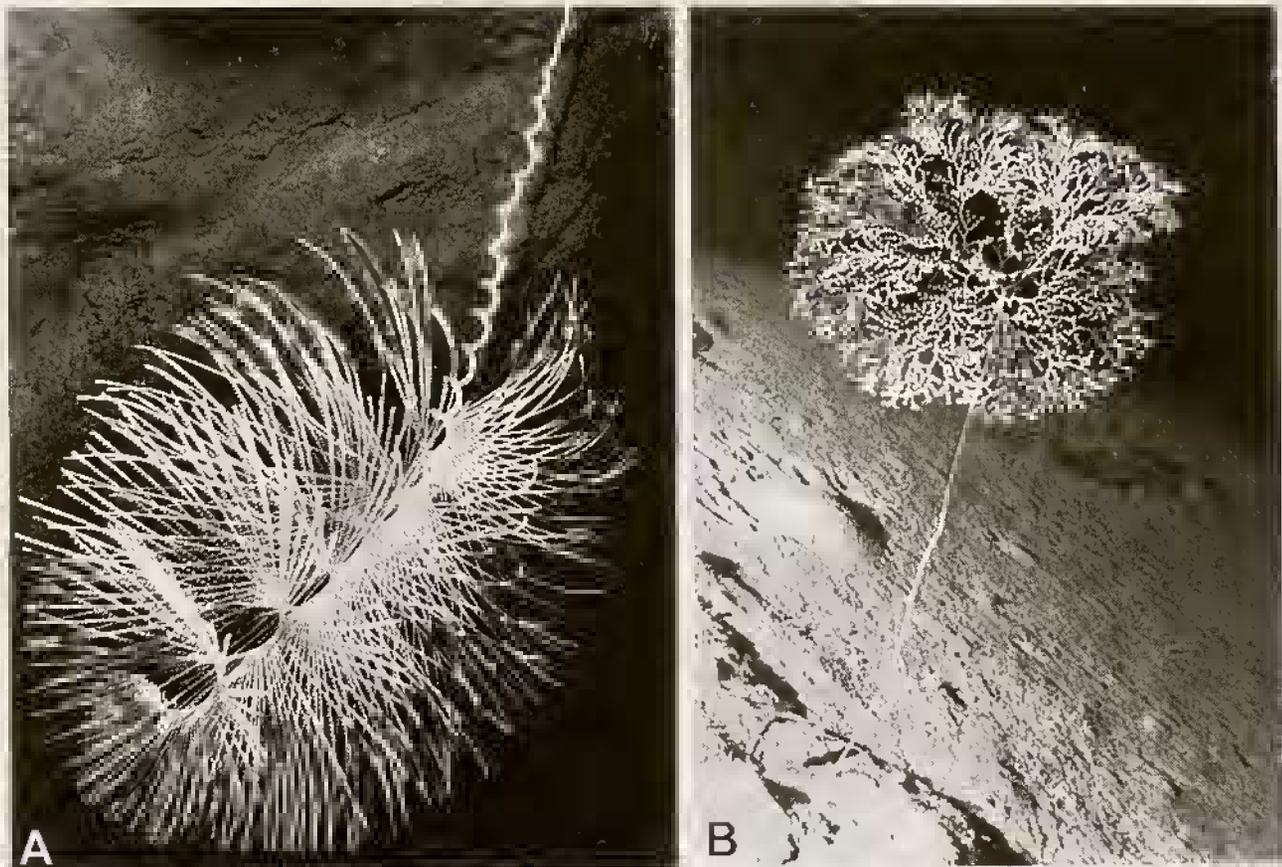


FIG. 16. — Two bathyal gorgonians with a typical morphology.

A : a large specimen of the genus *Iridogorgia* on the slope off Thio (dive 12, depth 880 m, observer H. ZIBROWIUS);
 B : a specimen of the genus *Metallogorgia* on the mesobathyal slope off Thio (dive 13, depth 1766 m, observer M. SEGONZAC).

FIG. 16. — Deux gorgones bathyales avec une morphologie typique.

A : un grand individu du genre *Iridogorgia* sur le tatus au large de Thio (plongée 12, profondeur 880 m, observateur H. ZIBROWIUS); B : un individu du genre *Metallogorgia* sur le tatus mésobathyal au large de Thio (plongée 13, profondeur 1766 m, observateur M. SEGONZAC).

3. - Notes on a few particular taxa

3-1. - Behaviour of the cephalopods

Solitary specimens of the New Caledonian nautilus (*Nautilus macromphalus*) were encountered several times between 300 m and 545 m during dives carried out during the day around the Loyalty Islands. A piece of bait (chicken), placed on the sea bed 10 to 12 hours prior to dives 19 (413 m) and 22 (610 m), to the SW of the Isle of Pines, attracted a group of around fifteen nautilus specimens during dive 19 (fig. 23-1); only crustaceans (*Geryon* and *Heterocarpus*) came to the bait for dive 22. Our observations of the bathymetric distribution of the nautili confirm the data acquired through use of lobster pois between 1976 and 1978 (INTÈS, 1978; RANCUREL, 1990).

The specimens encountered by the *Cyana* saucer were very active and swam efficiently, without crashing against the rocky walls. Their speed can reach between 20 and 30 cm/s (ROUX, 1990), which indicates that their physiological optimum would seem to be superior in an epibathyal environment, rather than under experimental conditions on the surface, where their ability to oxygenate does not seem to allow them to exceed a speed of 16 cm/s (WELLS & WELLS, 1985; WELLS, 1987 and *in litt.*).

Two very different types of behaviour were noted in the cirrates (Cirroctopoda). The most spectacular recorded and photographed sequences were those of dives 3 (*Cirrothauma*) and 16 (*Opisthoteuthis*).

At a depth of 2880 m, a specimen (which may belong to the genus *Cirrothauma*), when touched by the claw of the *Cyana*, quickly inflated his interbrachial membrane into a turgescient balloon, reminiscent of a pumpkin (figs 17A and 17B) (BOLETZKY *et al.*, 1992). This may be a means of capturing prey which, once spotted, would be engulfed in the brachial ensemble. However, in an environment where light does not penetrate, tactile stimuli are likely to be important and the ballooning response might have a stunning or disorientating effect on a potential predator in a first (possibly accidental) contact with the cirrate. This could thus be a defense mechanism.

At a depth of 812 m, a specimen of the genus *Opisthotheutis* demonstrated that it was able to pass unnoticed on a sloping rocky substratum by retracting itself into the form of an hemisphere (figs 17C and 17D). These two octopods are capable of "gliding" by stretching out their arms and interbrachial membranes, thereby moving like a parachute between two active phases of swimming.

3-2. - Behaviour of some of the fish encountered

B. SÉRET gives a list (table 2) and pictures (figs 18 and 19) of the main species of fish observed during the course of the CALSUB cruise and of which we have photographs or video sequences taken aboard the *Cyana* saucer. Here he also gives additional observations and remarks on the behaviour of a few kinds of fish we observed.

Numerous pictures of fish were taken during the *Cyana* dives, but only about sixty could be identified to species, genus or family from the morphological characters observed. The identifications of taxa are listed in table 2, with doubts remaining for a few attributions because of the difficulties of basing determinations on photographs only. However, two specimens were photographed and collected by A. GUILLE during dive 20 : one specimen (362 mm LT) of the macrourid rat-tail fish *Coelorhynchus anatirostris* (photo 023, collection MNHN 1989-965) and one specimen (613 mm LS) of the trichiurid silver scabbardfish *Lepidotus caudatus* (photo 061, collection MNHN 1989-966).

We have selected the following remarks on the behaviour of a number of species observed from *Cyana*.

Numerous sharks, mainly the shortnose spurdog *Squalus megalops* (fig. 18D) and the kitefin shark *Dalatias licha* (fig. 18E) were observed. These observations are corroborated by the shark specimens frequently collected during recent investigations on several seamounts off New Caledonia. Photograph 385 of dive 19 is a good illustration of the opportunistic scavenging behaviour of the kitefin shark *Dalatias licha* : attracted by a bait, they wait for the *Nautilus* to finish feeding (fig. 23-1) without attacking any of them. Another observation of interest is that of the behaviour of *Squalus megalops* : this demersal shark was resting on the sea floor, evidence that its respiration is not dependent on permanent movement as had frequently been assumed. Specimens of a new species of cat shark belonging to the genus *Galeus* or the genus *Halaelurus* were observed, two genera never before recorded in New Caledonian waters. During dive 22 at a depth of 613 m, a specimen of the skate genus *Notoraja* was photographed (photo 093) resting on the flank of a bioclastic sandy dune; this is probably a new species, a few juvenile specimens of which were collected during BIOGEOCAL cruise.

FIG. 17. — Behaviour of two cirrate octopods.

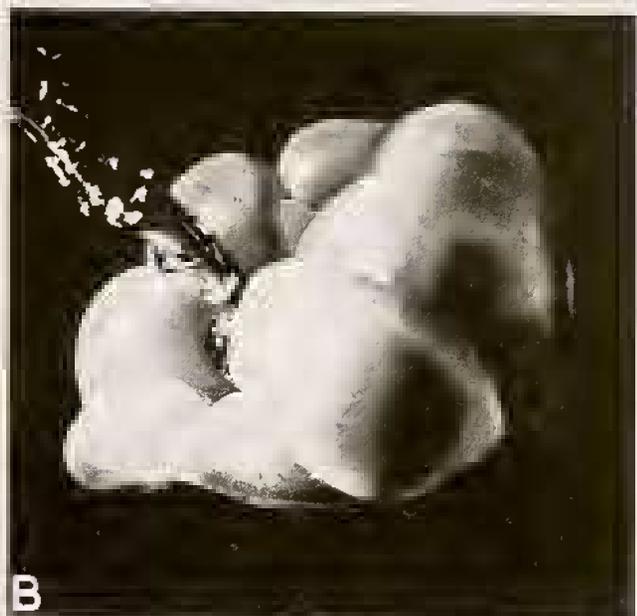
A : just before contact with *Cyana's* claw, a specimen having affinities with the genus *Cirrothauma* gliding through the water, arms outstretched and showing the well-developed interbrachial membrane. B : the same specimen reacting to contact with the claw by inflating its interbrachial membrane into a turgescient balloon (dive 3, depth 2880 m, observer M. RIO).

C : a specimen of the genus *Opisthotheutis* swimming. D : the same specimen several minutes after the previous shot, rolled into a ball on the rocky substrate (Dive 16, depth 813 m, observer M. ROUX).

FIG. 17. — Comportement de deux octopodes (Cirrates).

A : juste avant le contact avec la pince de *Cyana*, un individu proche du genre *Cirrothauma* "planant" entre deux eaux, les bras étendus et montrant la membrane interbrachiale bien développée. B : le même individu réagissant au contact de la pince en gonflant sa membrane interbrachiale en un ballon turgescient (plongée 3, profondeur 2880 m, observateur M. RIO).

C : un individu du genre *Opisthotheutis* nageant. D : le même individu, quelques minutes après la vue précédente, posé sur le substrat rocheux et rétracté en boule sur lui-même. (Plongée 16, profondeur 813 m, observateur M. ROUX).



Taxa	Slide ref.	Depth	No.
CHONDRICHTHYANS			
Squalidae			
<i>Centrophorus</i> sp.	S16-036	818 m	1 ex.
<i>Dalatias licha</i> (Bonnaterre, 1798)	S19-233	415 m	1 ex.
	S19-270	416 m	1 ex.
	S19-331	409 m	1 ex.
	S19-369	561 m	1 ex.
	S19-385	413 m	1 ex.
	S20-102	609 m	1 ex.
	S20-105	609 m	1 ex.
	S20-370	561 m	1 ex.
<i>Squalus megalops</i> (Macleay, 1881)	S19-114	412 m	1 ex.
	S21-126	342 m	1 ex.
	S21-372	337 m	1 ex.
	S21-450	332 m	1 ex.
	S21-454	332 m	1 ex.
<i>Squalus</i> cf. <i>melanurus</i> Fourmanoir, 1978	S11-081	493 m	1 ex.
Scyliorhinidae			
<i>Galeus</i> sp. or <i>Halaeturus</i> sp.	S12-507	796 m	1 ex.
	S16-178	821 m	1 ex.
Rajidae			
<i>Notoraja</i> sp.	S22-093	613 m	1 ex.
TELEOSTEANS			
Synaphobranchidae			
? <i>Synaphobranchus</i> sp.	S07-009	973 m	1 ex.
Congridae			
? <i>Conger</i> cf. <i>cinereus</i> (Rüppel, 1828)	S17-130	2033 m	1 ex.
Unidentified congrid	S07-149	945 m	1 ex.
Halosauridae			
	S06-302	874 m	1 ex.
Chlorophthalmidae			
<i>Bathypterois</i> cf. <i>guentheri</i> Alcock, 1889	S16-207	823 m	1 ex.
	S02-155 à 163	2015 m	1 ex.
<i>Chlorophthalmus</i> sp.	S05-06	959 m	1 ex.
Neoscopelidae			
<i>Neoscopelus</i> cf. <i>macrolepidotus</i> (Johnson, 1863)	S08-134	840 m	1 ex.
Moridae			
	S03-119	2809 m	1 ex.
Macrouridae			
<i>Coelorhynchus anatrostris</i> Jordan & Gilbert, 1904	S20-023	616 m	1 ex.
<i>Coelorhynchus</i> cf. <i>anatrostris</i>	S12-339	1020 m	1 ex.
	S12-340	1020 m	1 ex.
? <i>Ventrifossa</i> sp.	S06-314	831 m	1 ex.
	S07-152	934 m	1 ex.
	S11-038	616 m	1 ex.

Trachichthyidae			
<i>Hoplostethus cf. mediterraneus</i> Cuvier, 1829	S15-377	373 m	1 ex.
Lophiidae	S22-023	601 m	1 ex.
Ateleopodidae			
? <i>Ateleopus</i> sp.	S08-194	678 m	1 ex.
Serranidae			
<i>Epinephelus morrhuu</i> (Valenciennes, 1833)	S18-408	142 m	1 ex.
<i>Epinephelus octofasciatus</i> Griffin, 1926	S15-454	356 m	2 ex.
	S15-460	356 m	2 ex.
Apogonidae			
<i>Apogon</i> sp.	S14-612	495 m	1 ex.
Carangidae			
? <i>Pseudocaranx dentex</i> (Bloch & Schneider, 1801)	S18-535	71 m	8 ex.
Lutjanidae			
<i>Etelis carbunculus</i> (Cuvier, 1828)	S16-664	359 m	1 ex.
<i>Etelis coruscans</i> Valenciennes, 1862	S15-358 à 360	379 m	1 ex.
	S16-576	512 m	1 ex.
	S16-577	512 m	1 ex.
	S16-586	512 m	1 ex.
<i>Pristipomoides argyrogrammicus</i> (Val., 1831)	S05-267	295 m	1 ex.
Gempytidae			
<i>Rexea prometheoides</i> (Bleeker, 1856)	S06-050	1137 m	1 ex.
Trichiuridae			
<i>Lepidotus caudatus</i> (Euphrasen, 1788)	S20-061	616 m	1 ex.
Tetraodontidae			
? <i>Lagocephalus</i> sp.	S18-214	276 m	1 ex.

TABLE 2. — Identification of fishes from photographs taken by *Cyana* during the CALSUB cruise (listed by B. SÉRET).TABLEAU 2. — Liste des poissons identifiables photographiés par *Cyana* lors de la campagne CALSUB (déterminations par B. SÉRET).

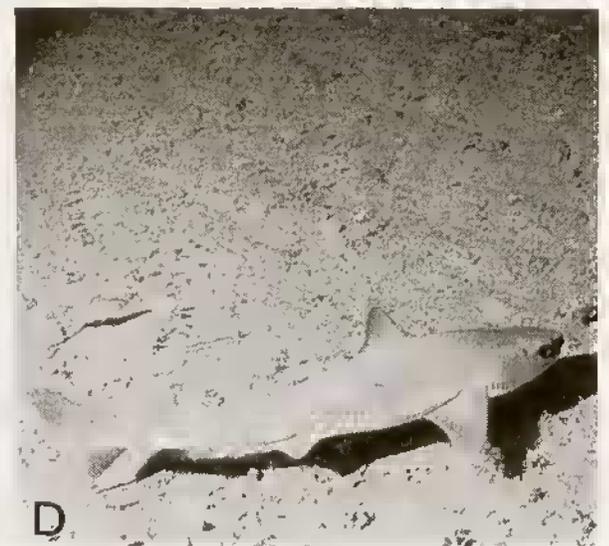
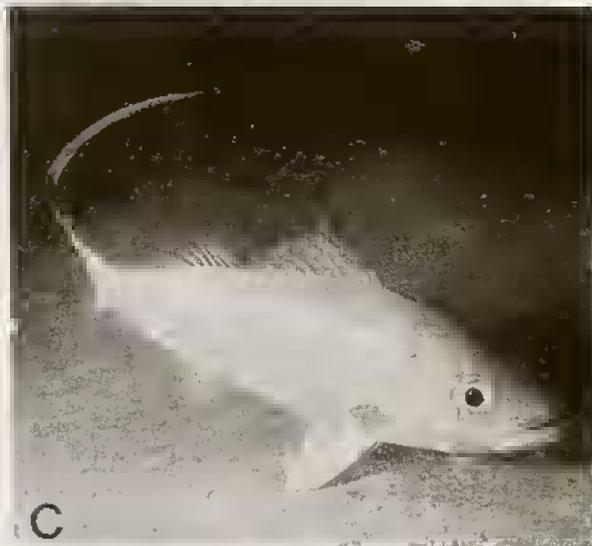
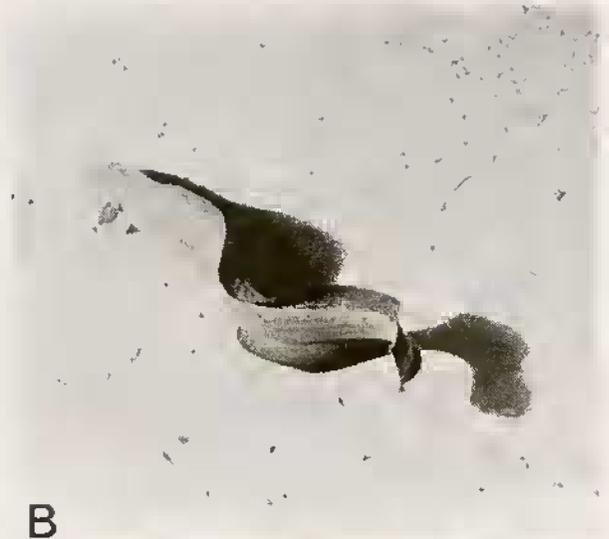
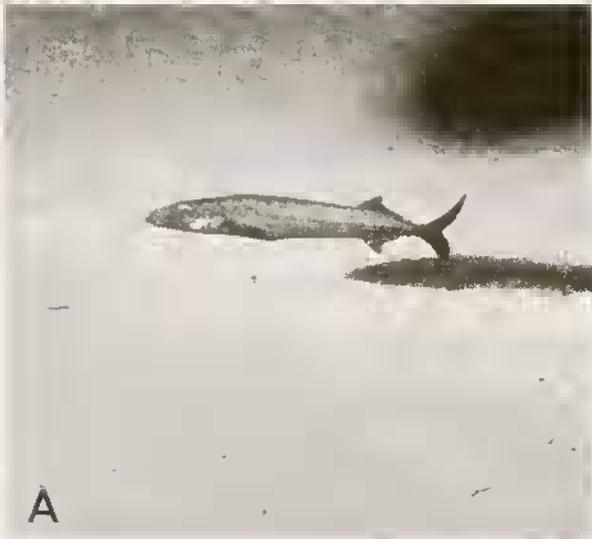
Among the teleostean fishes, several individuals of about three species were observed. The first example in New Caledonia of *Coelorhynchus anatrostris* was photographed and collected during the CALSUB cruise, a species which was only previously known from Japanese waters and the China Sea.

FIG. 18. — A few fishes observed during the CALSUB cruise.

A : oilfish belonging to the genus *Rexea* (dive 06; depth 1137 m; observer B. LAURIN). **B** : conger eel attributable to *Conger* cf. *cinereus* (dive 17; depth 2033 m; observer C. GAILLARD). **C** : ruby snapper of the species *Etelis coruscans*, circling the saucer before coming to rest on the sea bed within range of the spotlights (dive 16; depth 512 m; observer M. ROUX). **D** : spurdog of the species *Squalus megalops*, resting on the sea bed (dive 21; depth 332 m; observer B. RICHER DE FORGES). **E** : kitelin shark, *Dalatias licha*, lurking around the manipulating arm of the saucer (dive 19; depth 415 m; observer M. SEGONZAC).

FIG. 18. — Quelques poissons observés durant la campagne CALSUB.

A : individu attribué au genre *Rexea* (plongée 6, profondeur 1137 m, observateur B. LAURIN). **B** : congre attribuable à *Conger* cf. *cinereus* (plongée 17, profondeur 2033 m, observateur C. GAILLARD). **C** : vivaneau de l'espèce *Etelis coruscans*, tournant autour de la soucoupe avant de s'immobiliser, posé sur le fond dans le champ des projecteurs (plongée 16, profondeur 512 m, observateur M. ROUX). **D** : requin de l'espèce *Squalus megalops* se reposant sur le fond (plongée 21, profondeur 332 m, observateur B. RICHER DE FORGES). **E** : requin de l'espèce *Dalatias licha*, rodant autour du bras manipulateur de la soucoupe (plongée 19, profondeur 415 m, observateur M. SEGONZAC).



The two wonderful species of rufy snapper observed exhibit very different behaviour on the approach of the saucer. We were only able to take photographs of *Etelis carbunculus* on exceptional occasions because it swam off rapidly every time the saucer came close. By contrast, *Etelis coruscans* moves more slowly and willingly circles around the saucer. During dive 16 at a depth of 512 m, one individual came to rest just in front of *Cyana* and remained motionless, as if immobilised by the spotlights (fig. 18C).

During dive 23 at a depth of 2015 m, a beautiful example (fig. 19) of the tripodfish *Bathypterois* cf. *guentheri*, a species typical of the abyss, was filmed swimming and coming to rest in its classic position, perched on its long pectoral fins and caudal fin, like a tripod, lying in wait for its prey.



FIG. 19. — An abyssal tripodfish attributable to *Bathypterois* cf. *guentheri* about to come to rest on a sedimentary bed (dive 02; depth 2015 m; observer M. ROUX).

FIG. 19. — Un poisson abyssal "tripode" attribuable à *Bathypterois* cf. *guentheri* prêt à se poser sur un fond sédimentaire (plongée 2, profondeur 2015 m, observateur M. ROUX).

Numerous fish, of all sizes, burrow in the sediment and are therefore agents of bioturbation. Some, generally of small to medium size, were seen to dig head-first into the sand, or to work the sand along a stretch of several decimetres (fig. 25-5); it is clear that they feed on the superficial endofauna in this way. Others, often slightly larger (groupers, rufy snappers) shelter in niches dug by the movement of soft sediment under an indurated level. This burrowing can lead to the creation of cavernous substrates which are home to a rich, vagile fauna (VANNEY, 1991).

3-3. - The importance of bioturbation and biocorrosion

An inventory of the principal biogenic tracks has been drawn up (fig. 25 and 26) (GAILLARD, 1991 a and b). It is at depths of between 1800 m and 2000 m that bioturbation seems to be at its most diversified (fig. 20). The most original discoveries were the observation of the ichnogeni *Paleodictyon* and *Urohelminthoidea*, exceptional in this area, and that of a new track ("track FC"), which was very common and characteristic of the bathymetric level between 1600 m and 2000 m (fig. 26-6 and 26-8). The bioturbation of the soft sediment is variable since it depends to a large extent on the rhythm and the degree of external elements, particularly turbiditic faecal elements. Biocorrosion of the rocky substrata is substantial towards the top of the slopes, but is more difficult to evaluate in the semi-indurated oozes of the talus, since the numerous cavities witnessed here may be of recent origin (biocorrosion) or former burrows in the process of being eroded (bioturbation). Fish and crustaceans sweep soft sediment away from under indurated surfaces, thereby contributing to the formation of cryptic ecological niches. Whatever the answer, it is certain that the action of organisms plays a role in the general process of erosion.

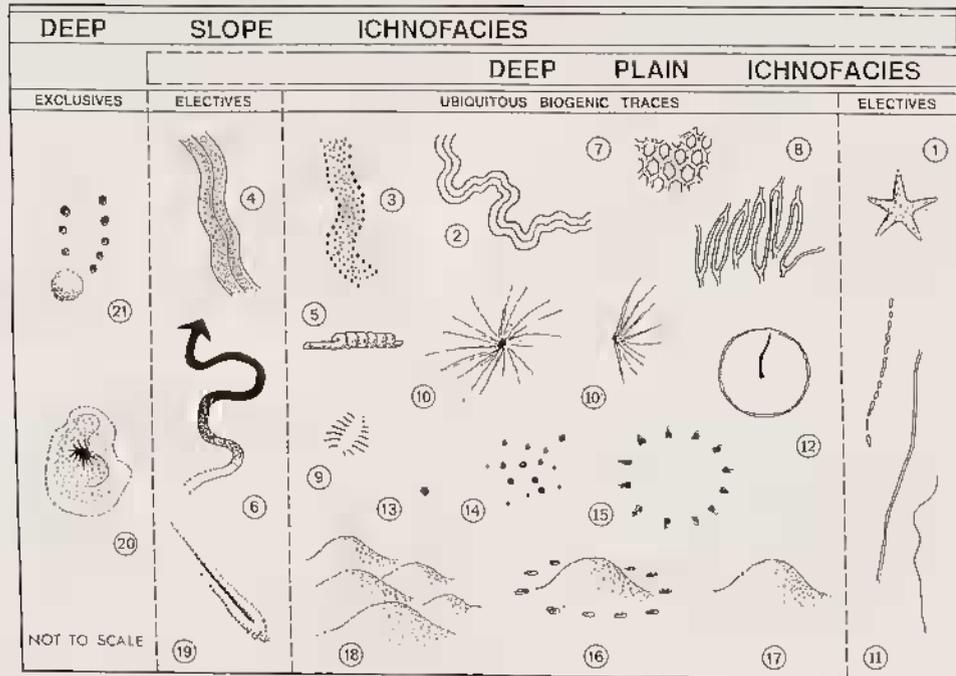
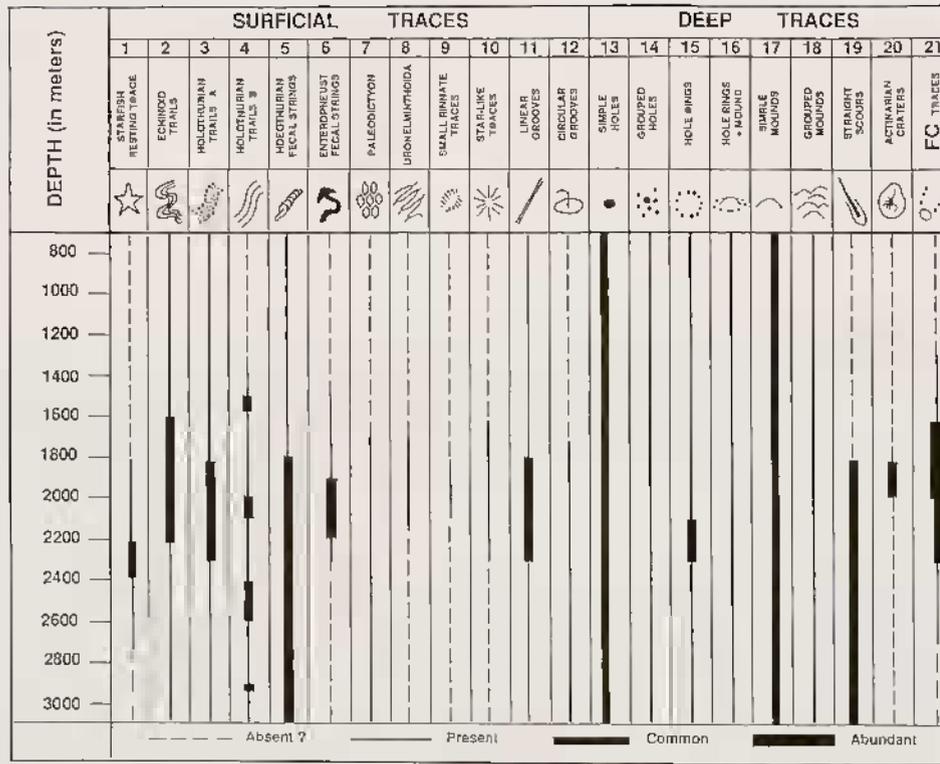


FIG. 20. — Diversity and bathymetric range of traces and burrows off New Caledonia (from GAILLARD, 1991b).

FIG. 20. — Diversité et distribution bathymétrique des traces et terriers au large de la Nouvelle-Calédonie (d'après GAILLARD, 1991b).

Generally speaking, the role played by both biocorrosion and bioturbation would seem to be essential to the sedimentary dynamics of the zones we explored, and to the evolution of benthic populations, particularly as regards to the relative importance of the sessile epifauna.

4. - A word about "living fossils"

One of the most interesting aspects of the bathyal fauna of New Caledonia is the apparently high number of taxa with what we might call an "archaic" stamp to them, "living fossils", relics of the fauna of the Jurassic and Cretaceous Tethys Ocean. This phenomenon is particularly spectacular among the stalked crinoids (AMÉZIANE-COMINARDI *et al.*, 1987 and 1990; BOURSEAU *et al.*, 1991) (figs 24-4 and 24-5), among the sponges, with the presence of sphinctozoans (VACELET *et al.*, 1992) (fig. 21-6) and among the pterobranchs. The pterobranch species *Cephalodiscus graptoloides*, collected during the CALSUB cruise, and identified as a specimen of interest by H. ZIBROWIUS, has an astonishing resemblance to graptolites, a group considered to have been extinct since the Carboniferous (DILLY, 1993; RIGBY, 1993). Note also the discovery of a new line of evolution among the deep sea ascidians, *Fimbrora calsubia*, which shows a new type of adaptation to macrophagy (MONNIOT & MONNIOT, 1991)

Up until the Lower Cretaceous, New Caledonia formed part of the eastern edge of Gondwana. When Gondwana broke up, New Caledonia separated from Australia and then drifted towards the lower latitudes which, from a climatic point of view, may have in some way made up for the very noticeable cooling during the second half of the Cenozoic, which was to cause the Quaternary glaciation. During the most recent glacial maximum, the level of the sea dropped by 120 m, causing the New Caledonian lagoon to emerge completely and destabilising the upper portion of the bathyal slope. In any case, it is difficult to imagine that conditions in the New Caledonian environment have remained unchanged since the Mesozoic.

The CALSUB cruise demonstrated that there is a great variety of ecological niches, but also a relative instability (both sedimentological and hydrological) in the epibathyal zone of New Caledonia (LAMBERT & ROUX, 1991). From 1000 m downwards, the environment seems to be more stable and the populations more homogeneous, as in the Central Pacific.

When we talk of "living fossils", we may be talking of two things; on the one hand, they may be veritably panchronic forms (slow or imperceptible evolution), or, on the other hand, forms that have undergone a more recent paedomorphic evolution, leading to a phenotypic convergence with ancient forms (AMÉZIANE-COMINARDI & ROUX, 1994). Only a certain permanence in the conditions of the environment allows us to assume the first possibility, unless we are dealing with extremely opportunist taxa, capable of surviving great environmental changes.

In fact, the conditions for survival of ancestral forms depend a great deal on the autecology of each taxon and we must therefore beware of making generalizations on the basis of the analysis of a single group of organisms.

CONCLUSION

The bathyal domain of New Caledonia is currently one of the best known in the Pacific, as much in terms of the inventories of fauna as in terms of the direct observation of its populations by submersible. The CALSUB cruise has shown the great diversity of the ecological niches, particularly on the epibathyal beds, of which it explored only a very small portion. It remains to explore in more detail the populations of fauna which develop at the summit of guyots.

In spite of the considerable exploration efforts made, and given the diversity of the substrate and of the environmental conditions, our knowledge of the New Caledonian bathyal fauna and its ecology still remains very sketchy, particularly in regard to the rocky beds, where only the use of a submersible allows significant progress. We see therefore how difficult it is to gain an idea of the real originality of the fauna in this region of the Western Pacific. Its apparent originality is due in part to the absence or rarity of similar data from other areas of the same ocean. The "living fossils" aspect, however spectacular it might seem, is probably more a reflection of a lack of knowledge about the current bathyal benthos and of gaps in paleontological records, than an indication of the existence of a New Caledonian sanctuary for fauna directly descended from the most distant geological eras. However, we must not exclude from our study the unusual historical and climatic factors. It remains now for further cruises to demonstrate these things, cruises which will be better targeted thanks to the invaluable direct observations made by the CALSUB cruise.

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FIGURE 21

1. — Algal bed supporting large gorgonian communities. S of Santal Bay, W of Lifou. Depth 80 m. Dive 11; observer J.-P. BOURSEAU.
1. — Trottoir algair supportant une prairie de grandes gorgones. Sud de la baie du Santal à l'ouest de Lifou. Profondeur 80 m. Plongée 11; observateur J.-P. BOURSEAU.
2. — Algal bed covering a dome and supporting lithistid sponges, gorgonians and anthipatharians. SW of the Isle of Pines. Depth 60 m. Dive 18; observer P. BOUCHET.
2. — Dôme couvert d'une construction algair supportant des éponges lithistides, des gorgones et des antipathaires. SW de l'île des Pins. Profondeur 60 m. Plongée 18; observateur P. BOUCHET.
3. — Algal bed. S of Santal Bay. Depth 80 m. Dive 11; observer J.-P. BOURSEAU.
3. — Trottoir algair. Sud de la baie du Santal. Profondeur 80 m. Plongée 11; observateur J.-P. BOURSEAU.
4. — Large holothurian (about 80 cm long) on a slope with algal balls and bioclastic sand. S of Santal Bay. Depth 130 m. Dive 11; observer J.-P. BOURSEAU.
4. — Grande holothurie (environ 80 cm) sur une pente à boulets algaires et sable bioclastique. Sud de la baie du Santal. Profondeur 130 m. Plongée 11; observateur J.-P. BOURSEAU.
5. — Large coniform sponges on an escarpment encrusted with small sponges (biocorrosion?). N of Santal Bay. Depth 380 m. Dive 05; observer R. GRANDPERRIN.
5. — Grandes éponges en cornet sur une paroi incrustée de petites éponges (biocorrosion ?). Nord de la baie du Santal. Profondeur 380 m. Plongée 5; observateur R. GRANDPERRIN.
6. — Small decimetrical structure of sphinctozoan sponge (*Vaceletia*) observed at a depth of around 240 m in Santal Bay (photograph taken by J. VACELET).
6. — Petit massif décimétrique construit par les sphinctozoaires (*Vaceletia*) observés vers 240 m dans la baie du Santal (cliché J. VACELET).

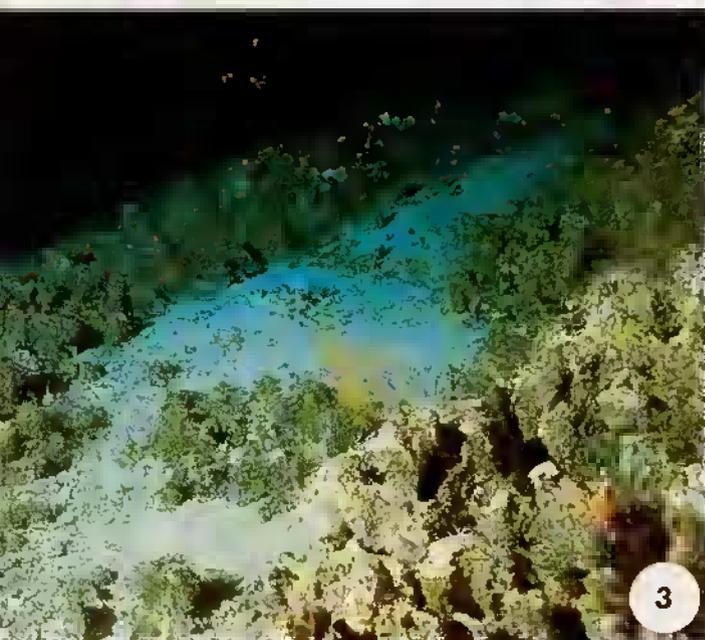


FIGURE 22

1. — Cavern carpeted with gorgonians, bryozoans and comatulid crinoids, home to a dense shrimp population of the genus *Plesionika*. Santal Bay. Depth 180 m. Dive 10; observer C. MONNIOT.
1. — Grotte tapissée de gorgones, bryozoaires, comatules et abritant une population de crevettes du genre *Plesionika*. Sud de la baie du Santal. Profondeur 180 m. Plongée 10; observateur C. MONNIOT.
2. — Overhang at the top of a fault escarpment (see fig. 12) - side view. On the lower surface, zoantharians; on the edge, brisingid sea stars; on the upper surface, ophiacanthid and euryalid brittle stars. S of the Isle of Pines. Depth 584 m. Dive 20; observer A. GUILLE.
2. — Surplomb au sommet d'un escarpement de faille, vue de profil (cf. fig. 12). En dessous : zoanthaires ; à l'extrémité : astérides brisingidées ; au-dessus : ophiures ophiacanthidées et euryales. Sud de l'île des Pins. Profondeur 584 m. Plongée 20; observateur A. GUILLE.
3. — Dense echinoderm population at the top of the same fault escarpment (see fig. 12). Same location. Depth 597 m. Dive 22; observer M. ROUX.
3. — Agrégat d'échinodermes au sommet d'un escarpement de faille (cf. fig. 12). Même lieu. Profondeur 597 m. Plongée 22; observateur M. ROUX.
4. — Upper surface of the same escarpment entirely covered by ophiacanthid brittle stars. Same dive. Same depth.
4. — Même lieu, population d'ophiures ophiacanthidées sur le replat sommital. Même profondeur, même plongée.
5. — Slab of rock covered at regular intervals by small gorgonians (in the background), and, in the foreground, a large gorgonian of the genus *Calyptrophora* supporting an euryalid brittle star with partially retracted arms (on the left). N slope of the Ouvéa-Lifou rise. Depth 355 m. Dive 15; observer A. GUILLE.
5. — Dalle régulièrement couverte de petites gorgones (en arrière-plan) et de plus grandes du genre *Calyptrophora* (au premier plan) supportant une euryale aux bras en partie rétractés (à gauche). Versant nord du seuil Ouvéa-Lifou. Profondeur 355 m. Plongée 15; observateur A. GUILLE.
6. — Lithistid sponge (*Corallistes undulatus*), diameter 30 to 40 cm. The sea floor is covered by terebratulid brachiopods (small shadows). SW of the Isle of Pines. Depth 330 m. Dive 21; observer B. RICHER DE FORGES.
6. — Eponge lithistide (*Corallistes undulatus*), 30 à 40 cm de diamètre, sur un fond riche en brachiopodes (térébratules) dont la présence est ici soulignée par leur ombre. SW de l'île des Pins. Profondeur 330 m. Plongée 21; observateur B. RICHER DE FORGES.



FIGURE 23

1. — Group of *Nautilus macromphalus* attracted to a bait. SW of the Isle of Pines. Depth 413 m. Dive 19; observer M. SEGONZAC.
1. — Groupe de *Nautilus macromphalus* attirés par un appât. SW de l'île des Pins. Profondeur 413 m. Plongée 19; observateur M. SEGONZAC.
2. — Allochthonous blocks and pebbles from a collapsed algal bed mixed with a group of autochthonous nautilus shells. Northern slope of the Ouvéa-Lifou rise. Depth 360 m. Dive 16; observer M. ROUX.
2. — Blocs éboulés et graviers provenant d'un trottoir algairé mélangés à une concentration de coquilles de nautilus autochtones. Versant septentrional du seuil Ouvéa-Lifou. Profondeur 360 m. Plongée 16; observateur M. ROUX.
3. — Population of cidarid sea-urchins on a steeply inclined slab of rock. Same location. Depth 370 m. Dive 15; observer A. GUILLE.
3. — Population de cidaridés (échinides réguliers) sur une dalle pentue. Même lieu. Profondeur 370 m. Plongée 15; observateur A. GUILLE.
4. — Dense macrofauna in a sheltered area (bryozoans, sponges, scleractinians, ascidians, etc.). S. of Santal Bay. Depth 525 m. Dive 09; observer J. VACELET.
4. — Macrofaune plus dense dans une zone abritée (bryozoaires, éponges, scléactiniaires, ascidies, etc...). Sud de la baie du Santal. Profondeur 525 m. Plongée 09; observateur J. VACELET.
5. — Hexactinellid sponge attached to a slab of rock by a thick cushion of spicules. Northern slope of the Ouvéa-Lifou rise. Dive: 16; observer M. ROUX.
5. — Eponge hexactinellide sur une dalle rocheuse fixée par un coussin de spicules. Versant septentrional du seuil Ouvéa-Lifou. Plongée 16; observateur M. ROUX.
6. — Tree uprooted by a storm lying on the sea floor at a depth of 1834 m. Notice the galatheid shrimps (*Munidopsis*) grasping the roots. NE of Thio. Dive 17; observer C. GAILLARD.
6. — Epave d'un arbre déraciné par un cyclone. On distingue des galathées (*Munidopsis*) accrochées aux racines. NE de Thio. Profondeur 1834 m. Plongée 17; observateur C. GAILLARD.

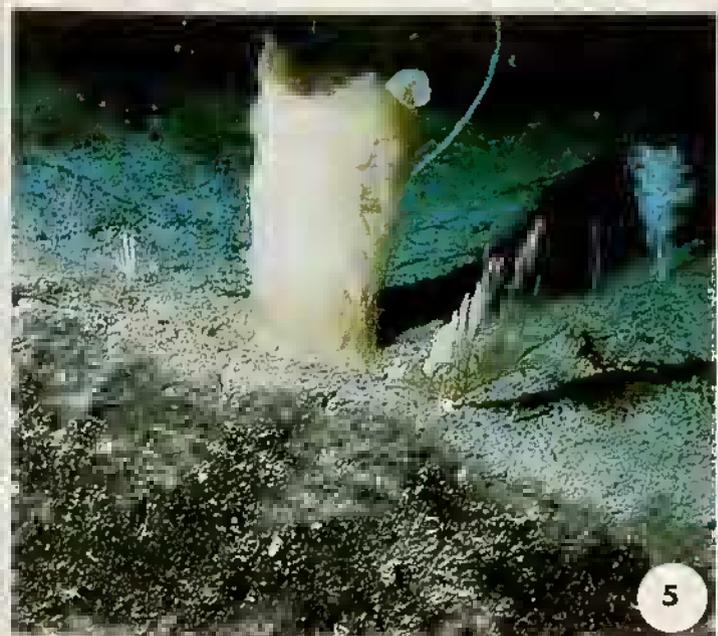
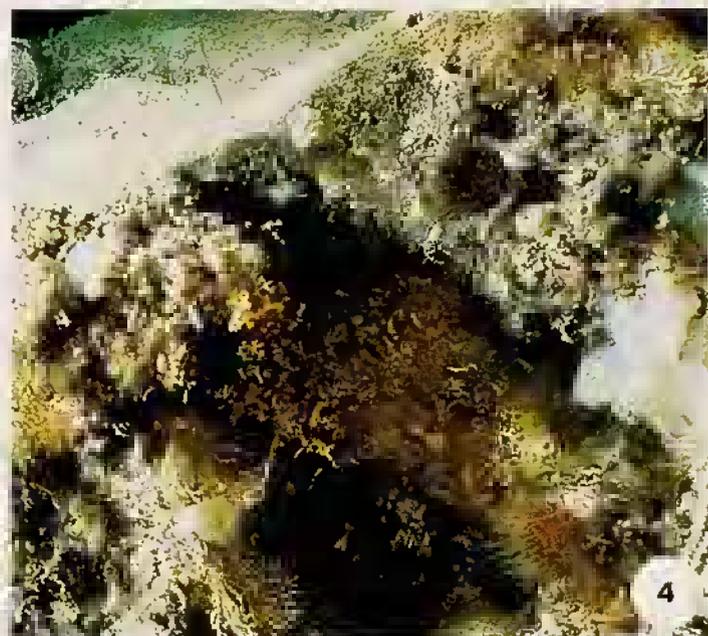


FIGURE 24

1. — Hexactinellid sponge (*Monorhaphis*), 50 to 80 cm long. N of Santal Bay. Depth 875 m. Dive 08; observer B. LAURIN.
1. — Eponge hexactinellide (*Monorhaphis*), longueur 50 à 80 cm. Nord de la baie du Santal. Profondeur 875 m. Plongée 08; observateur B. LAURIN.
2. — Dense population of *Monorhaphis*. The spicule of a number of dead specimens is covered by epibiotic macrofauna. Depth 816 m. Same dive.
2. — Champ de *Monorhaphis*, comportant de nombreux individus morts dont le spicule est couvert par les épibiontes. Profondeur 816 m. Même plongée.
3. — Ophiacanthid and euryalid brittle stars perched on the axis of a dead gorgonian. NE of Thio. Depth 1627 m. Dive 13; observer M. SEGONZAC.
3. — Ophiures (ophiacanthidées et euryales) perchées sur un axe de gorgone morte. NE de Thio. Profondeur 1627 m. Plongée 13; observateur M. SEGONZAC.
4. — Stalked crinoid with jurassic affinities (*Proisocrinus ruberrimus*). N of Lifou. Depth 1254 m. Dive 02; observer M. ROUX.
4. — Crinoïde pédonculé d'affinités jurassiques (*Proisocrinus ruberrimus*). Nord de Lifou. Profondeur 1254 m. Plongée 02; observateur M. ROUX.
5. — Stalked crinoid with paleozoic affinities (*Guillecrinus neocaledonicus*). Depth 1276 m. Same dive.
5. — Crinoïde pédonculé d'affinités paléozoïques (*Guillecrinus neocaledonicus*). Profondeur 1276 m. Même plongée.
6. — Hexactinellid stalked sponge (*Hyalouema*) with a comatulid crinoid attached to the upper part of the stalk. N of Lifou. Depth 1820 m. Dive 01; observer C. MONNIOT.
6. — Eponge hexactinellide pédonculée (*Hyalouema*) avec une comatule fixée au sommet du pédoncule. Nord de Lifou. Profondeur 1820 m. Plongée 01; observateur C. MONNIOT.
7. — Euplectellid sponge (Hexactinellid sponge) about 1,5 m in height. N of Lifou. Depth 2116 m. Dive 02; observer M. ROUX.
7. — Euplectelle (Eponge hexactinellide) d'environ 1,5 m de haut. N. de Lifou. Profondeur 2116 m. Plongée 02; observateur M. ROUX.



FIGURE 25
(from GAILLARD, 1991a, courtesy of the author)

1. — Two heavily eroded beds at the top of a cliff. The cavities are in part ancient burrows, but may also be recent borings, testifying to active bioerosion. Hemipelagic semi-indurated calcareous ooze. Thio slope. Depth 1871 m. Dive 17; observer C. GAILLARD.
1. — Deux bancs en sommet de relief soumis à une intense érosion. Les cavités sont pro parte des anciens terriers, mais peut-être également pro parte des perforations récentes témoignant d'une biocorrosion active. Boue calcaire hémipélagique semi-indurée. Pente de Thio. Profondeur 1871 m. Plongée 17; observateur C. GAILLARD.
2. — Rocky cliff showing a dense sponge community and traces of bioerosion. Santal Bay. Depth 376 m. Dive 09; observer J. VACELET.
2. — Paroi rocheuse montrant un peuplement dense d'éponges incrustées dans la roche et des traces de biocorrosion. Baie du Santal. Profondeur: 376 m. Plongée 09; observateur J. VACELET.
3. — Part of a high cliff (around 20m) with well stratified semi-indurated calcareous oozes. Note the abundance of biogenic cavities on vertical walls. Slope off Thio. Depth 1886 m. Dive 17; observer C. GAILLARD.
3. — Vue partielle d'une falaise importante (environ 20m) dans des boues calcaires semi-indurées bien stratifiées. Noter l'abondance des cavités d'origine biologique sur les parois verticales. Pente au large de Thio. Profondeur: 1886 m. Plongée 17; observateur C. GAILLARD.
4. — Collapsed semi-indurated blocks, settled on hemipelagic muds. Note the numerous biogenic cavities on these blocks and the actinian attached to the smaller one. Echinoids (?) trails are visible on the muddy area. Slope off Thio. Depth: 1726 m. Dive 13; observer M. SEGONZAC.
4. — Blocs semi-indurés écroulés, isolés au sein des boues hémipélagiques. Noter les nombreuses cavités d'origine biologique qu'ils renferment et l'actinie fixée sur le plus petit d'entre eux. Des pistes d'échinides (?) sont visibles dans la zone boueuse. Pente au large de Thio. Profondeur: 1726 m. Plongée 13; observateur M. SEGONZAC.
5. — A crab at the entrance of its burrow. S of Santal Bay. Depth 603 m. Dive 09; observer J. VACELET.
5. — Crabe devant l'entrée de son terrier. S de la baie du Santal. Profondeur 603 m. Plongée 09; observateur J. VACELET.
6. — Sea urchin belonging to the genus *Taimanawa* at the end of its track. Megaripple covered with ripple-marks. Gully off SW of Isle of Pines. Depth 596 m. Dive 22; observer M. ROUX.
6. — Oursin irrégulier du genre *Taimanawa* à l'extrémité de sa piste. Mégaride couverte de ripple marks. Gouttière au SW de l'île des Pins. Profondeur 596 m. Plongée 22; observateur: M. ROUX.

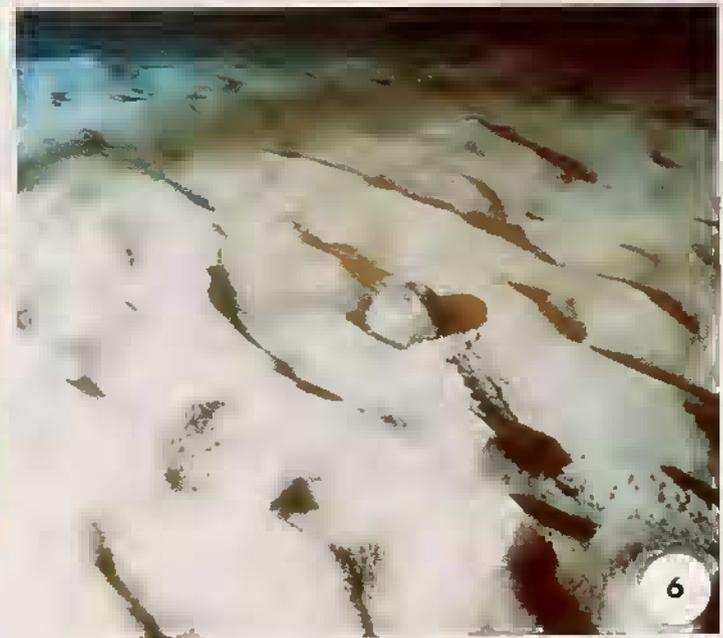


FIGURE 26

(from C. GAILLARD, 1991a, courtesy of the author)

1. — Superficial muddy sediment wholly bioturbated by holothurians (approximate width 10 cm). North-Lifou slope. Depth 2459 m. Dive 3; observer M. RIO.
1. — Sédiment superficiel boueux entièrement bioturbé par des holothuries (largeur des pistes 10 cm environ). Pente N. de Lifou. Profondeur 2459 m. Plongée 03; observateur M. RIO.
2. — Tumulus encircled by burrows (approximate total diameter 30 cm). Slope off Thio. Depth 1851 m. Dive 17; observer C. GAILLARD.
2. — Tumulus entouré de terriers (diamètre total 30 cm environ). Pente de Thio. Profondeur 1851 m. Plongée 17; observateur C. GAILLARD.
3. — Holothurian trail (approximate width 6-10 cm). Slope off Thio. Depth 1663 m. Dive 13; observer M. SEGONZAC.
3. — Piste d'holothurie (largeur approximative 6-10 cm). Talus de Thio. Profondeur 1663 m. Plongée 13; observateur M. SEGONZAC.
4. — Circle of holes (approximate diameter 30 cm). Slope off Thio. Depth 2032 m. Dive 17; observer C. GAILLARD.
4. — Terriers en cercle (diamètre 30 cm environ). Talus de Thio. Profondeur 2032 m. Plongée 17; observateur C. GAILLARD.
5. — Straight groove (approximate length 50 cm). Slope off Thio. Depth 1865 m. Dive 17; observer C. GAILLARD.
5. — Souille rectiligne (longueur environ 50 cm). Talus de Thio. Profondeur 1865 m. Plongée 17; observateur C. GAILLARD.
6. — FC trace ichnofacies. Hemipelagic calcareous ooze. Slope off Thio. Depth 1798 m. Dive 17; observer C. GAILLARD.
6. — Ichnofaciès à traces FC. Boues calcaires hémipélagiques. Talus au large de Thio. Profondeur: 1798 m. Plongée 17; observateur C. GAILLARD.
7. — Cluster of tumuli (approximate diameter of one tumulus 10 to 20 cm). Slope off Thio. Depth 1693 m. Dive 13; observer M. SEGONZAC.
7. — Tumulus groupés (diamètre de chaque tumulus 10 à 20 cm environ). Pente au large de Thio. Profondeur 1693 m. Plongée 13; observateur M. SEGONZAC.
8. — Trace FC (approximate total length 20-30 cm). SW slope of New Caledonia (BIOGEOCAL, CB 203, depth 2000 m).
8. — Trace FC (longueur hors-tout 20 à 30 cm environ). Pente SW Nouvelle-Calédonie (BIOGEOCAL, CB 203, profondeur 2000 m).
9. — Enteropneust (?) on muddy hemipelagic bed (approximate length of the body 15-20 cm). Lower SW slope of Lifou (BIOGEOCAL, CB 320, depth 2050 m).
9. — Entéropneuste (?) sur fond de boue calcaire hémipélagique (longueur du corps 15-20 cm environ). Bas de la pente SW de Lifou (BIOGEOCAL, CB 320, profondeur 2050 m).



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