

# GENETIC HYPOTHESIS ON THE ANCIENT AND RECENT REEF COMPLEXES IN NEW CALEDONIA

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## INTRODUCTION

New Caledonia is an island stretched NW-SE, 400 km long by 50 km wide in the South West Pacific. The whole island is surrounded by a barrier reef enclosing a very wide lagoon, especially in the south western and northern parts of the island (see fig.1). The flat reef is sub-outcropping and emerging on lowest low tide in the western part of the island ; on the other hand, in the eastern part the barrier reef is not always outcropping and then its upper part is lying some meters below the sea-level. The lagoon is representative of the new caledonian "continental shelf", the barrier reef marking the transition line before the continental slope which dips steeply to the basins surrounding New Caledonia.

The coast is surrounded by fringing reefs except in the sheltered bays where mangroves are often found. The flat parts of those fringing reefs rise up in a gentle slope, from 0.2 to 1 m above the zero of the French Navy Survey Department (1). The highest part of those flat reefs where coral growth is no longer possible, is partly covered up by the present beach. Above that one, between 2 and 4 m uplifted beaches are frequently found. Their attribution to Holocene (AVIAS, 1949 and 1953 ; ROUTHIER, 1953) has been confirmed by more recent data (LAUNAY and RECY, 1970, 1972 ; BALTZER, 1970 ; COUDRAY and DELIBRIAS, 1972). Above, that is at between 3 to 6 m,

(1) The zero of reference used in this paper is that of the French Navy Survey Dept. The highest tidal range being 1.60m in N.Cal.

sporadic traces of ancient sea levels have been radiocarbon dated. It will be shown that, these dates, attributed to a high sea level at approximately 30,000 BP (LAUNAY and RECY, 1972), must be seriously re-examined.

## I - AGES OF THE REEF COMPLEXES

### A) - Uplifted reef complexes.

A coral sample, from an undercut near Hienghene collected at an elevation of  $3.2 \pm 0.3$  m, gave a radiocarbon date of  $30,300 \pm 2,700$  years BP (1). The Uranium-Ionium date of this sample, 100,000 years BP (BERNAT et al., 1976), is very doubtful since its mineralogical composition (74 % aragonite, 26 % calcite) strongly indicates that crystallization of secondary calcite has occurred. This puts in doubt the radiocarbon age as well.

South of New Caledonia and on the Isle of Pines fringing reefs were uplifted. A Uranium-Ionium age of 118,000 years BP was attributed to a sample of coral from an elevation of 20 m on the Isle, but the sample might have been contaminated since it contains 30 % of calcite. A level of this age (BLOOM et al., 1973) at such an altitude would imply an uplift that might have been produced by the lithospheric bulge due to the underthrusting of the Australo-Indian plate beneath the Pacific plate at the level of the New-Hebrides trench (DUBOIS et al., 1973, 1974) and which is responsible of the uplift of the Loyalty Islands.

(1) Measurement made by Professor KIGOSHI's Laboratory, Kagushin University - Tokyo.

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B) - Data on the barrier reef

All the available data on the barrier reef originate from a unique borehole, 9 m deep, on Tenia Islet (Western Barrier Reef). The formations are non indurated and holocene in age. They overlay a 120,000 year old coral formations (COUDRAY, 1973). The sea-level, at that time, is assumed to be 5 or 6 m higher than the present one (BLOOM et al., 1973,1974). The resulting subsidence of the western barrier reef appears to have been about 14 m for the last 120,000 years according to the Tenia Islet data, if it is assumed that the upper parts of this formation represent a flat reef which was near sea-level, i.e. + 5 m at 120, 120,000 years B.P.

Observations carried out on the shores and in the lagoon support this hypothesis. They reveal that the living reefs are found very slightly below sea-level. The flat reefs, only partially active, are found in the tidal range. Their tops could have formed during the higher sea-levels of the Holocene, explaining why the majority now lie above current mean sea-level. On the other hand, observations made in the south east of New Caledonia, on the Isle of Pines and in the Loyalty Islands (all uplifted reefs) show they are not dismantled by erosion. They behave just as karsts ; run-off is absent and infiltration prevents surface erosion. In the context of the sea-level chronology of BLOOM et al., 1973, 1974, the resistance of the reef to erosion, implies that the ancient reef, which should be found at + 5 m, has actually subsided to -9 m.

C) - Data on the fringing reef of the eastern coast.

a) Surface samples.

Data concerning the flat fringing reef are more numerous (Table 1), but the results are not always coherent.

South of New Caledonia, at + 2 m, a continuous undercut running several kilometers can be observed in ancient uplifted reef complexes above the present flat reef. Two radiocarbon age measurements on corals which have grown in the undercut after its formation, at Tara (Tara, 1, 2, 3) and at Touaourou (69 Tou 15) gave netly different results though made on samples from nearly at the same level (LAUNAY, RECY, 1972 ; COUDRAY, DELIBRIAS, 1973). New radiocarbon measurements made on the samples Tara 2,3 exhibited younger ages and ages closer to those found by COUDRAY and DELIBRIAS (1973) for equivalent levels at Touaourou and also at Touho. The isolated coral sample 69 T 1 collected at Touho on the

flat reef, was found to have an age substantially older than core drilled samples from the upper part of that formation. This indicates that interpretations of radiocarbon ages of isolated coral samples should be made with caution. For example, the newly determined core age series in this area shows that one cannot conclude that the south eastern part of New Caledonia was uplifted during the Holocene, as previously supposed by LAUNAY and RECY (1972).

b) Core survey of the upper part of the Touho fringing reef.

1. Composition

In the Touho area, about ten core drillings from 5 to 10 m (1), were made in the fringing reef which is several hundred meters wide there (see fig. 2). In general, the flat reef elevation varies from 0.2 m to 1 m between the falling slope of the fringing reef and the shore. Some of the drillings are in shallow depressions 0.5 m deep. From the study of the cores it can be ascertained that the upper part of the fringing reef, at least to the bottom of the deepest core (-12 m), consists of organogenous sands and coral debris interspersed with continuous coral masses. These are unusual in the inner part of the reef (near the shore) and increase in number and thickness toward its outer part. Correlations between the lithological sequences of the different drillings are not easily discernable.

The following schematic descriptions of the S4 and S5 cores, made respectively in the outer and inner parts of the fringing reef (see fig. 2) show the extremes in the variation of the lithological sequences :

Touho S 5 (shore side)	
Depth	Lithology
(from surface)	
00-00.10	alluvium
00.10-02.00	sand grains and coral debris
02.00-06.50	organogenous debris
06.50-08.00	fine organogenous debris
08.00-10.40	organogenous debris
10.40-10.50	coral mass
10.50-11.10	organogenous and coral debris
11.10-12.00	coral mass

(1) The drillings were performed by OMNIUM TECHNIQUE.

Touho S 4 (lagoon side) lithological depth	
00-0.40	flat reef
0.40-0.60	debris of coral branches
0.60-0.90	indurated organogenous sand
0.90-1.00	coral mass
1.00-2.20	indurated organogenous sand and coral branches
2.30-2.40	coral mass
2.40-3.10	indurated organogenous sand
3.10-4.50	coral mass

2. Age determinations and stable isotope measurements (table II).

Samples to be radiocarbon dated were selected in the massive coral from the cores. The samples are of aragonite without any trace of calcite. Measurements of isotopic ratios of  $^{16}\text{O}/^{18}\text{O}$ ,  $^{12}\text{C}/^{13}\text{C}$  were also made. The following conclusions can be drawn from these results :

- The samples are all holocene in age. There is no continuous age variation with depth, neither among the cores nor even within any single one.

- Mineralogy shows up that non recrystallisation has occurred which would have transformed aragonite into calcite.

- The stable isotope contents can be interpreted in terms of crystallisation at or near isotopic equilibrium with the marine environment when using available values for the isotopic composition of water. The paleotemperatures equation (1) (CRAIG, 1965) :

$$t = 16.9 - 4.2 (\delta - A) + 0.13 (\delta - A)^2$$

gives temperatures ( $^{\circ}\text{C}$ ) as a function of the  $^{18}\text{O}$  content of the carbonate ( $\delta$ ) and of the water (A).

(1) The oxygen 18 values are obtained from mass spectrometric measurements of  $\text{CO}_2$  gaz. For carbonates, the  $\text{CO}_2$  is liberated by reaction with phosphoric acid at  $25^{\circ}\text{C}$  ; for water, the  $\text{CO}_2$  is prepared by equilibration with the sample also at  $25^{\circ}\text{C}$ . These values must be expressed with respect to the same working standard of gaseous  $\text{CO}_2$ . In this study, values of A and  $\delta$  are expressed with respect to a working standard which was calibrated against  $\text{CO}_2$  derived from the PDB carbonate standard.

Results shown in the following table give the extreme values :

Sample number	$\delta^{18}\text{O}$ coral/ PDB	$\text{A}^{18}\text{O}$ water/ PDB	calculated $t^{\circ}\text{C}$	Age B P
Touho S9 (1)	-3.34 (max)	-0.2*	$38^{\circ}1$	$3140 \pm 160$
		-0.7***	$35^{\circ}5$	
Touho S4 (5)	-4.64 (min)	-0.2*	$31^{\circ}3$	
		-0.7***	$28^{\circ}9$	$2660 \pm 60$

\* average isotope composition of the oceanic sea water (CRAIG, 1961).

\*\*\* isotopic composition of the Pacific sea water measured in the approaches of Noumea.

Since the calculated temperatures are reasonable, with respect to the present temperature of the coral environment, it appears that the coral carbonate crystallised under conditions near equilibrium with dissolved carbonate. If one considers the general evolution of the  $^{18}\text{O}$  content of the carbonate as a function of radiocarbon age, one finds (table II) that this change was on the order of 1 % between 6000 and 1500 years BP. The resulting apparent thermal change would about  $4.2^{\circ}\text{C}$ . This represents a maximum variation since, during this period an influx of water derived from polar ice and having a very low oxygen 18 content, may have still occurred.

The effect of the rise in temperature can thus be added to the effect of the lowering of the isotopic composition of since it appears from the paleotemperature equation that both effects influence the heavy isotope contents of the carbonates in the same sense. The corals, therefore, seem to have recorded a logical and reasonable change of the holocene climatic conditions. This supports the significance of the isotopic record of the coral samples.

The  $^{13}\text{C}$  contents show no particular tendency, however they suggest the corals to be free from isotopic exchange after the death of the organisms.

D) - Data on the fringing reef of the western coast.

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a) Core drillings from Poya.

In the Prowy bay area (Poya), not very far from the Croix-Haute cape, a series of continuous core drillings were made to determine a place to build a wharf (1) (see fig. 3).

These drillings showed (see fig. 4) the existence of an ancient rise modeling thin and more or less indurated detrital materials (sands and sandstone).

When submerged, the depressions of this rise were filled with primarily clay material, while the upper parts gave bases for coral growths.

Core S 9, particularly rich in well preserved coral material, has been chosen for a more detailed study.

That core, located on the flat reef side and isolated from the fringing reef by a channel, encountered 8.70 m of coral formation (see detailed section fig. 5). This formation consists alternately of massive coral banks and of detritic layers containing shell and coral debris. The samples studied come from both these levels (see fig. 5).

b) Age determinations and stable isotope measurements (table III).

The age profile is roughly coherent with depth and deals with the interval 5,400 to 1,300 BP corresponding to the growth of approximately 7 meters of coral. The lowest sample, S 9 (H) at -24,9 m, is older than the radio-carbon detection limit. The oxygen 28 content variation is on the order of 0.5 %. Calculated temperatures fall within the same range as the preceding samples. The carbon 13 contents as well as the mineralogical assays of coral, containing exclusively aragonite, show that the original isotopic compositions has been conserved.

## II - DISCUSSION

A general tendency for age to correspond with depth may be observed in the cores from the Touho and Poya fringing reefs. But the lack of a rigorous chronological order as a function of the sample depth is characteristic of reworkings and of allochthonous inputs, which may occur during the construction of a coral flat. Age anomalies in the coral mass proper may be explained by the growth of re-

(1) Drillings were performed by the BACHY Company for De ROUVRAY's firm.

cent coral in the depressions in older coral flats e.g. Touho S 4 (6), and also by the accumulation of shell material from above which is trapped in crevasses in the coral, e.g. Poya S 9 (F).

The growth of a reef complex takes place during several thousand years. During this period significant reworking may occur in the solid phase or even in the liquid phase (bi-carbonate produced by the dissolution of pre-existing material). Thus coral is a marker not easily used in the study of sea level changes during the Holocene. Since coral growth occurs at various depths, it is apparent that only ages found for samples of the highest elevations should be considered in sea-level studies of the Holocene. Nevertheless it is a good marker in the age determination of ancient high sea levels. In this case the inaccuracy due to the mixing of coral of different ages is of the same order as the error in radiometric dating.

At Touho a level which dates from 5.000 years BP at the bottom to 1.500 years BP at the top is found between -8 m and the surface at +0.8 m. These same ages are found between -13.3 m and the submerged surface of the reef at -6.3 m. Thus the dated holocene profiles at Touho S 4 and Poya S 9 are of virtually the same thickness and correspond to the same range of ages. The profiles are not found on the same level at these two locations since core S 9 is from the slope of the reef.

The flat reef surfaces are of dead coral. The present profiles of the flats reefs were formed about 1500 years ago. Thus it appears that sea-level has slightly decreased since then. This agrees with the drop in sea-level of one to two meters between approximately 500 to 1500 years BP from by previous authors (BALTZER, 1970 ; LAUNAY and RECY, 1970, 1972; COUDRAY and DELIBRIAS, 1972).

Six thousand years ago, the fringing reef was still growing at approximately -8 m. In light of the velocity of the holocene sea-level rise before 6000 years BP, it is improbable that reef growth began long before this date and at a far lower level. Drillings and observations made by divers show the outer side of the fringing reef on the east coast of New Caledonia is thicker than 15 m.

The holocene growth probably rests on an ancient reef whose age is not known. The similarity of the Tenia islet to the barrier reef would suggest that this ancient fringing reef was formed 120,000 years ago corresponding a high sea level of +5 m (BLOOM et al., 1973).

Neglecting the effect of erosion on the coral elevation it seems that the subsidence of approximately 14 m in the last 120,000 years is not confined to the area of continental flexture seen on the barrier reef, but would have affected all of New Caledonia. This would not include the southern part and the Islet of Pines which were uplifted. Such an interpretation would not agree with the age of 105,000 years measured at +3.2 m on the coral from a remnant flat reef at Hienghene, but this result is questionable, as discussed above. Only a drilling survey on the fringing reef and the determination of ages with Ionium-Uranium on the lower levels would solve this problem with more accuracy.

### CONCLUSIONS

This study, which needs further informations on several points, suggests the following hypotheses :

- A general subsidence of approximately 14 m may have affected the entire continental plateau of New Caledonia during the last 120,000 years. This subsidence represents the last part of a general quaternary episode of 200 m which could have the formation of the barrier reef, the inundation of the lower valleys and major coast line retreat (phase III of the physiographic model of ROUTHIER, 1953).

- The holocene reef, 15 m in thickness, is underlain by a subsided ancient reef platform.

- Although the holocene deposits are found or 2 meters above the current sea-level, there is no evidence which proves that these deposits have undergone significant vertical displacement since they may have been formed during the period of high sea-level which came to a close near 1.500 BP.

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TABLE I

Mineralogic, isotopic and radiometric radiocarbon data, on the fringing reef of the New Caledonia South Eastern Coast.

Sample n° Place Nature	Altitude zéro S H en m	Calcite- Aragonite		$\delta^{18}O/$ P D B	$\delta^{13}C/$ P D B	Age mesuré 14 <sub>C</sub> (ans BP)	Référence
		C %	A %				
69 Tou 10 coral Touaourou in growth position	+1.8±0.2					4380±110 (A)	COUDRAY et DELIBRIAS 1973
Tara 2 coral sub in situ	+1 ±0.3	0	100 (D)	-3.10(C)	-0.72(C)	7340±140 (B) 4970±120 (C)	
Tara 3 coral in growth position	+0.6±0.2	0	100 (D)	-4.03(C)	-0.75(C)	6300±140 (B) 5470± 90 (C)	
Tara 1 coral in growth position	+2.1±0.2	0	100 (D)	-3.53(C)	+0.59(C)	7360±170 (B)	LAUNAY et RECY, 1972
69 Tou 15 Touaourou coral sub in situ	+2 ±0.2					3970±110 (A)	COUDRAY et DELIBRIAS 1973
69 T 1 Touho coral apparently in situ	+1 ±0.5					5400±120 (A)	COUDRAY et DELIBRIAS 1973

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T A B L E II

Sample n°	Depth in m of the sample in the drilling	Level in meter	% Calcite % Aragonite	$\delta^{18}\text{O}/\text{PDB}$	$\delta^{13}\text{C}/\text{PDB}$	Age $^{14}\text{C}$ years BP
TOUHO S4 (1) coral	0.08	+ 0.18	O C 100 A	- 4.69	- 0.73	1540 $\pm$ 120
TOUHO S4 (2) coral	0.35	- 0.09	O C 100 A	- 4.38	- 1.02	2580 $\pm$ 90
TOUHO S4 (3) coral	0.95	- 0.69	O C 100 A	- 4.25	- 1.99	2110 $\pm$ 140
TOUHO S4 (4) coral	2.15	- 1.89	O C 100 A	- 4.04	- 1.15	2200 $\pm$ 130
TOUHO S4 (5) coral	3.15	- 2.89	O C 100 A	- 4.64	- 1.50	2660 $\pm$ 90
TOUHO S4 (6) coral	4.20 to 4.30	- 3.94 to - 4.04	O C 100 A	- 4.42	- 0.45	2170 $\pm$ 120
TOUHO S4 (7) coral	7.70	- 7.95	O C 100 A	- 3.64	- 0.29	6025 $\pm$ 200
TOUHO S6 (1) coral	1.00 to 1.50	- 0.40 to - 0.90	O C 100 A	- 3.57	+ 0.34	5730 $\pm$ 150
TOUHO S6 (2) coral	3.10	- 2.50	O C 100 A	- 3.97	+ 0.14	4070 $\pm$ 100
TOUHO S6 (3) coral	3.95	- 3.35	O C 100 A	- 3.89	- 1.56	5470 $\pm$ 130
TOUHO S8 (1) coral	7.95	- 8.43 (+0.5 -0.1)	O C 100 A	- 3.85	- 0.39	5500 $\pm$ 110
TOUHO S9 (1) coral	0.20	- 0.98 (+0.7 -0.1)	O C 100 A	- 3.34	- 0.05	3140 $\pm$ 160
TOUHO S9 (2) coral	2.90	- 3.68 (+0.7 -0.1)	O C 100 A	- 3.95	- 1.35	3190 $\pm$ 200

T A B L E III

Sample n°	Depth of the sample in the drilling	Level in meter	% Calcite % Aragonite	$\delta^{18}\text{O}/\text{PDB}$	$\delta^{13}\text{C}/\text{PDB}$	Age $^{14}\text{C}$ years BP
Poya S9 (A) coral	1.05	- 6.30	O C 100 A	- 3.92	- 0.65	1315 $\pm$ 170
Poya S9 (B) coral	1.30	- 6.55	O C 100 A	- 3.84	- 1.08	1680 $\pm$ 50
Poya S9 (C) shell tests	1.60 to 2.70	- 6.85 to 7.95	O C 100 A	- 1.29	- 1.06	1955 $\pm$ 165
Poya S9 (D) coral	3.05	- 8.30	O C 100 A	- 2.58	- 0.48	1635 $\pm$ 220
Poya S9 (E) shell tests	3.25 to 6	- 8.50 to 11.25	O C 100 A	- 0.84	- 1.64	1995 $\pm$ 165
Poya S9 (F) shell tests	6.5 to 7.25	-11.75 to 12.50	O C 100 A	- 1.77	- 1.54	515
Poya S9 (J) coral	7.30	- 12.55	O C 100 A	- 3.57	- 1.09	5330 $\pm$ 300
Poya S9 (F) coral	8.05	- 13.30	O C 100 A	- 3.70	- 0.06	5410 $\pm$ 110
Poya S9 (H) indurated sand	19.65	- 24.90	O C 100 A			

GENETIC HYPOTHESIS ON THE ANCIENT AND RECENT REEF COMPLEXES IN NEW CALEDONIA

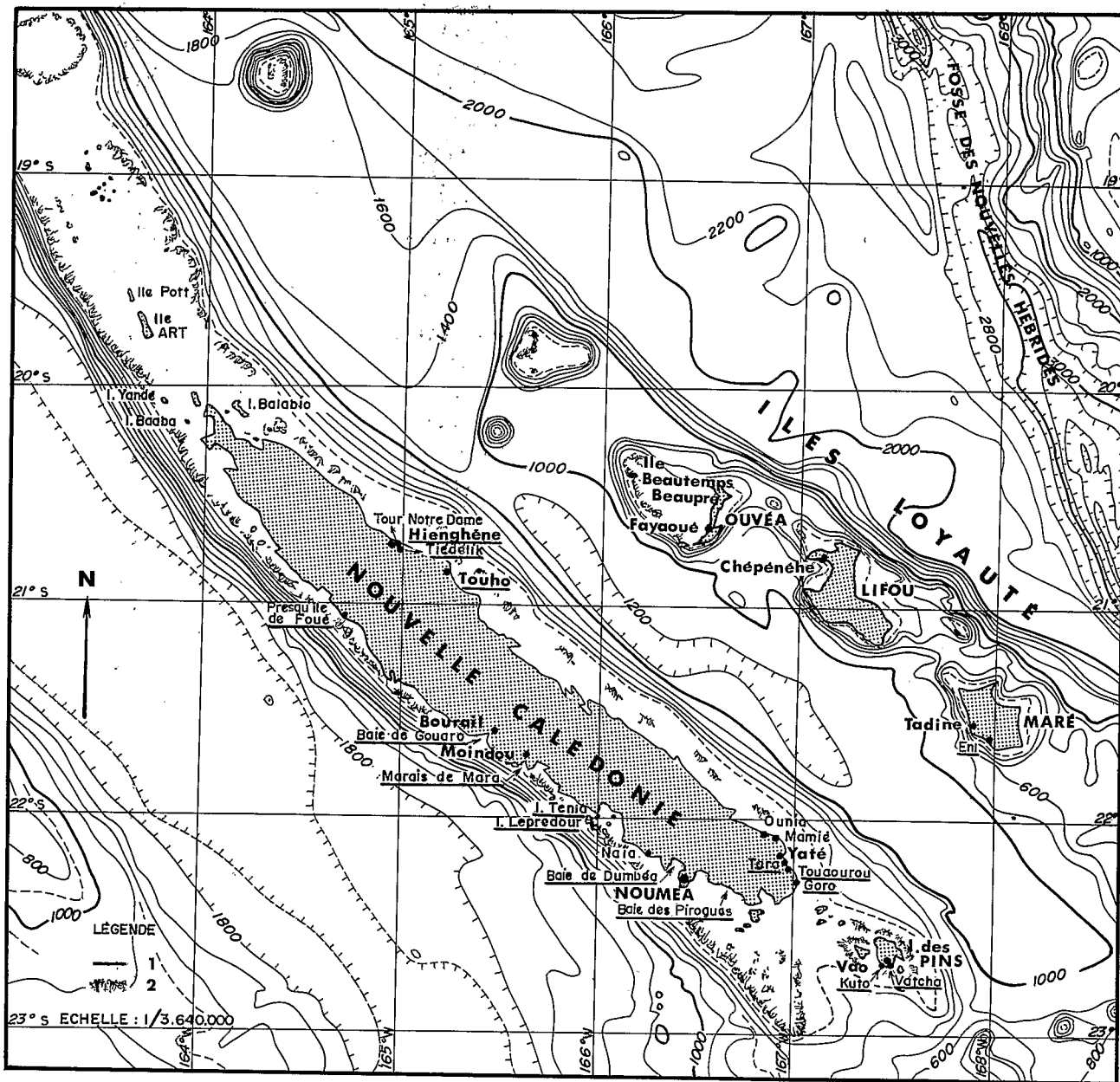


Fig. 1 - Locality map.



GENETIC HYPOTHESIS ON THE ANCIENT AND RECENT REEF COMPLEXES IN NEW CALEDONIA

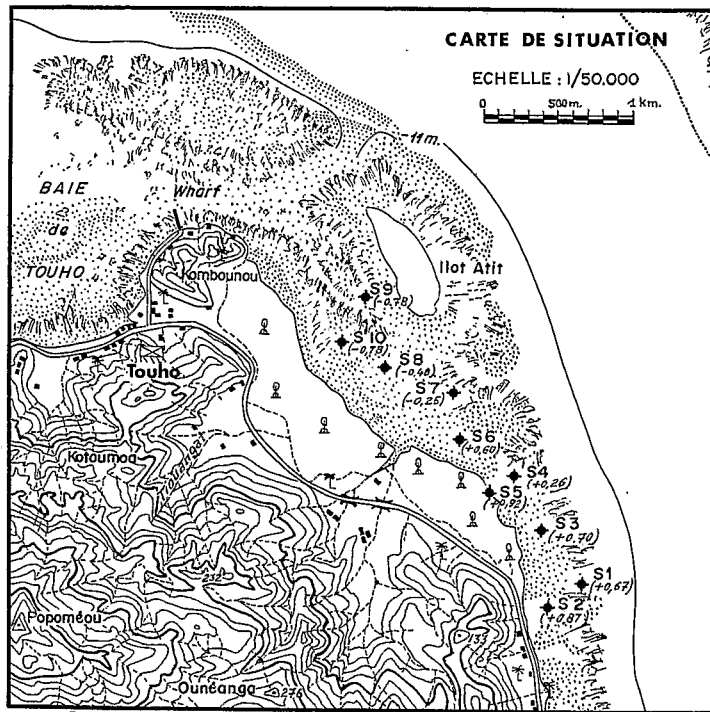


Fig. 2

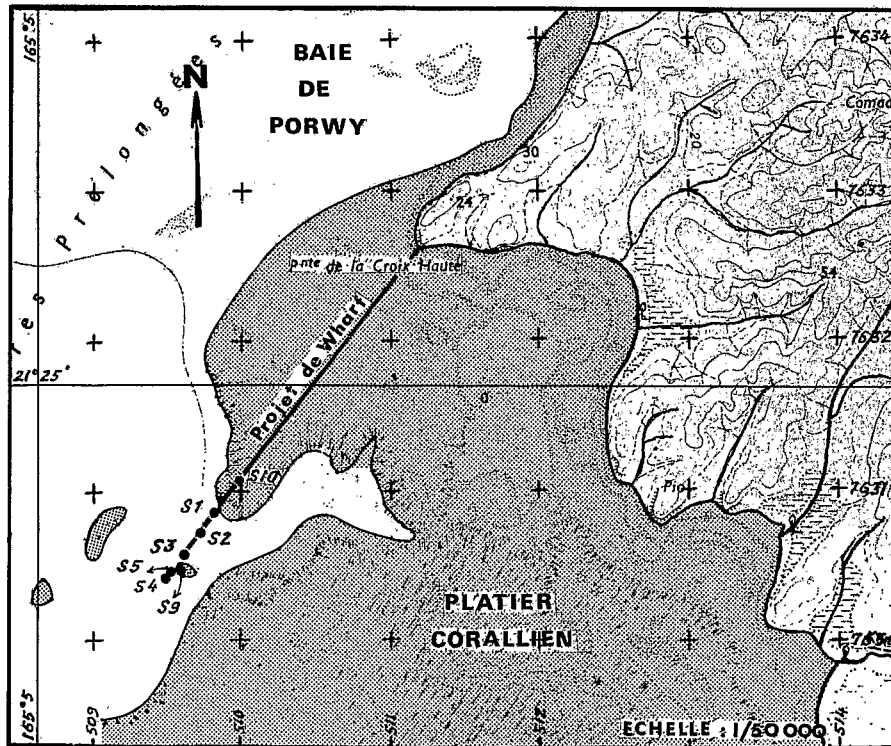


Fig. 3

Fig. 2 and 3 - Settlement of the drillings.

Figure 4

SONDAGES DE LA BAIE DE PORWY (POYA)

ESSAI D'INTERPRÉTATION

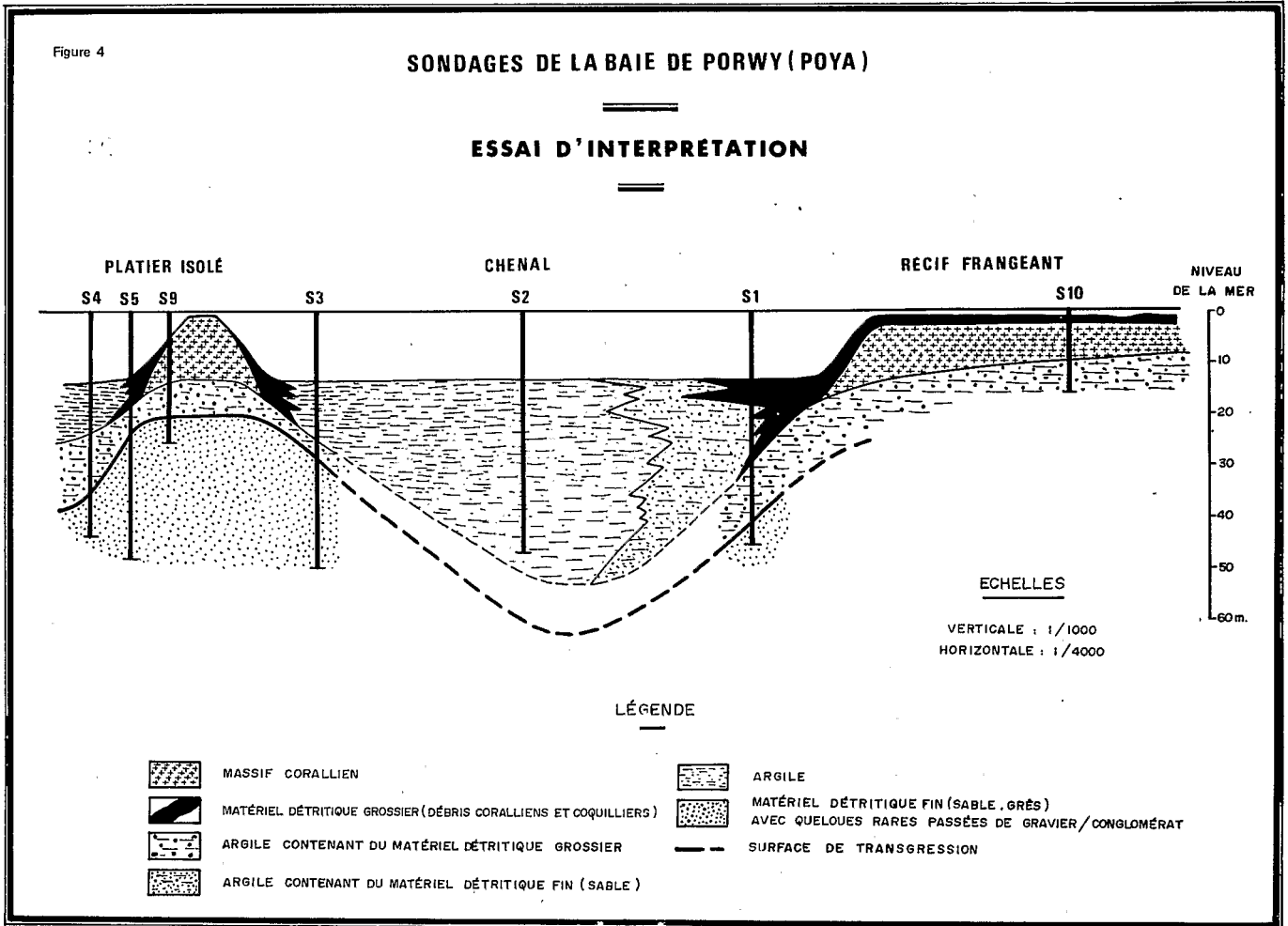
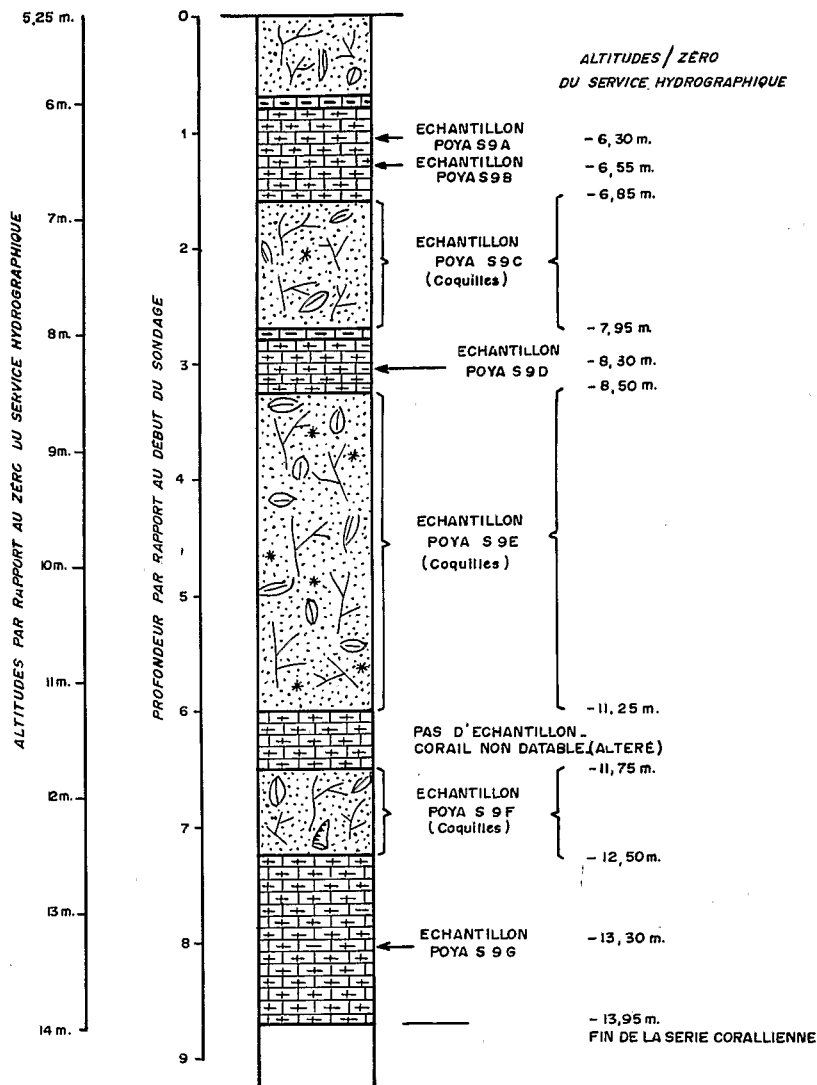


Figure 5

**BAIE DE PORWY (POYA)**  
**SONDAGE S9**  
**COUPE PARTIELLE**

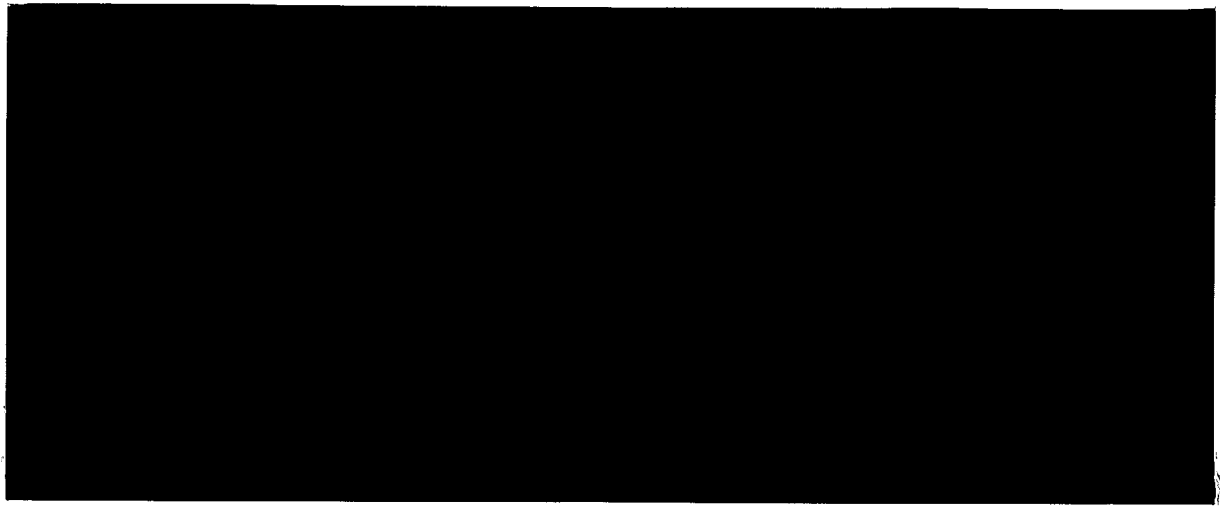


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