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A Reconnaissance and Geomorphological Survey of Temoe Atoll, Gambier Islands (South Pacific)[1]

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ABSTRACT

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This is an account of the geomorphology, hydrology, and late Holocene evolution of the southernmost atoll in French Polynesia. A few bathymetric profiles and the use of a LANDSAT-3 satellite scene enabled a map to be made of the average water depths in the lagoon, the volume of which is estimated at 0.173 km^3. Exchanges between the closed lagoon and the ocean are very limited in normal times, but the lagoon level can quite easily be raised 1.5 m by wave set-up phenomena due to heavy austral swells. Until less than 2,000 yr B.P., when sea level was some 0.8 m higher than at present, much of the atoll rim was at water level. The following sea-level drop caused emergence, broadening of islands with vegetation and, more recently, precarious settlements of refugees from Mangareva. Since A.D. 1838, however, the atoll has been uninhabited.

ADDITIONAL INDEX WORDS: *Coastal geomorphology, coral reef, lagoon, Holocene, remote sensing, reef flat, coastal lagoon,* hoa, motu, *sea-level change.*

INTRODUCTION

Located some 50 km southeast of Mangareva (Gambier Islands), Temoe (or Timoe) (23°20'S—134°29'W) is the southernmost atoll of the French Polynesia. At present uninhabited, it is with Oeno and Ducie, which belong to Pitcairn, one of the three southernmost atolls in the world. The lagoon of Temoe is closed and landing of the reefs is usually quite dangerous owing to the rough seas.

According to traditional history, Temoe was visited by Mangarevans as early as the 16th century and since then has been inhabited from time to time by settlers or refugees from Mangareva (EMORY, 1939). The atoll was probably seen in 1687 by the Davis' ship, from a distance of a quarter of a mile; no inhabitants were observed at that time. In 1797, Captain Wilson, who called the atoll Crescent Island, reported 25 natives and did not observe a single coconut tree. BEECHEY (1831) saw forty naked inhabitants in December, 1825. Cuming, a botanist, landed on Temoe in 1827, but was very rapidly obliged to escape from the warlike attitude of the inhabitants (EMORY, 1939). Landing on the island in 1836, Captain Ebriell "found about forty persons...learned that fifty or sixty years previously their progenitors were forced to quit Mangareva on a raft...The only articles of food they could obtain were squid, and small fish taken in the holes of the coral reef, and the kernels of the nut of the pandanus" (BELCHER, 1871).

In 1838, the entire population of Temoe (82 people) was brought to Mangereva by the missionaries (LESSON, 1844) and, in 1842, LUCETT (1851) reports that there were neither inhabitants

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nor coconut trees on the island. Descendants of the people tranferred in 1838 now live in Mangareva Recently, they planted the atoll with coconuts and they visit it from time to time to make copra.

In 1902, Seale, while on a collecting expedition for the Bishop Museum of Honolulu, spent a morning ashore near the southwest point of the atoll to briefly observe some stone structures (EMORY, 1939). The first observations on the geology, fauna, and flora of Temoe are due to SEURAT (1903), a French naturalist who spent three years in Mangareva. Remains of prehistoric settlements, numerous in Temoe, were studied mostly by Emory during a two day visit in 1934. More recently, in December, 1970, four members of an expedition to Pitcairn made a dive on the outer reef of Temoe, collecting several specimens of fishes (RANDALL, 1973).

On 5 October 1982, a short period of very favourable meteorological conditions enabled me, with D. Panon and E. Sanford as volunteer guides and as-sistants, to reach Temoe from Mangareva and carry out a two-day geomorphological survey of the atoll. This was made possible by the use of a motorboat belonging to the Gendarmerie Nationale and a rubber dinghy from the yacht *Moira* for the always precarious landing and sailing operations and for surveying the lagoon. The use of a LANDSAT-3 satellite imagery was useful for preliminary mapping of the atoll and made possible the extrapolation of measurements along a few bathymetric profiles to the whole of the lagoon.

In this paper, after a discussion on the possible age of Temoe and some information on the methods used and the estimated accuracy of measurements, a bathymetric map of the lagoon is given and observations on the geomorphology and the vegetation of the atoll are reported from a number of transects and localities. Lastly, the late Holocene sea-level data obtained in Temoe are compared with the data available in other Tuamotu islands.

GEOLOGIC AGE OF TEMOE

According to the bathymetric map of MONTI and PAUTOT (1974), the volcanic basement on which the atoll of Temoe has developed rises steeply from depths of about 3,200 m. It seems to belong, together with the Gambier Islands and the Portland Bank (shown by PIRAZZOLI, in 1985, to be a submerged atoll) to the same volcanic basement, about 3,700 m deep. If this interpretation is correct, Temoe would belong to an island chain starting from a hot spot near Pitcairn and including the Gambiers, Mururoa, the Duke of Gloucester Islands and Hereheretue (Figure 1). Surface volcanic rocks have been dated between 0.45 and 0.93 Myr in Pitcairn (DUNCAN *et al.*, 1974) and between 4.8 and 6.0 Myr in the Gambiers (BELLON, 1974). In Mururoa Atoll at a depth of 438 m borings have found a volcanic basement between 6 ± 2 and 8 ± 1 Myr old (LABEYRIE *et al.*, 1969). Assuming that the rate of the horizontal movement of the Pacific plate above a fixed hot spot is about 11 cm/yr in the Pitcairn area, this would give the volcanic basement of Temoe an age about 0.5 Myr younger than that of the Gambiers.

However, Temoe can also be considered to form an island chain with Oeno, Henderson, and Ducie. At least the two latter islands must be much older than Pitcairn. Henderson, in particular, is an elevated atoll that seems to have been raised isostatically by a flexuring of the lithosphere due to

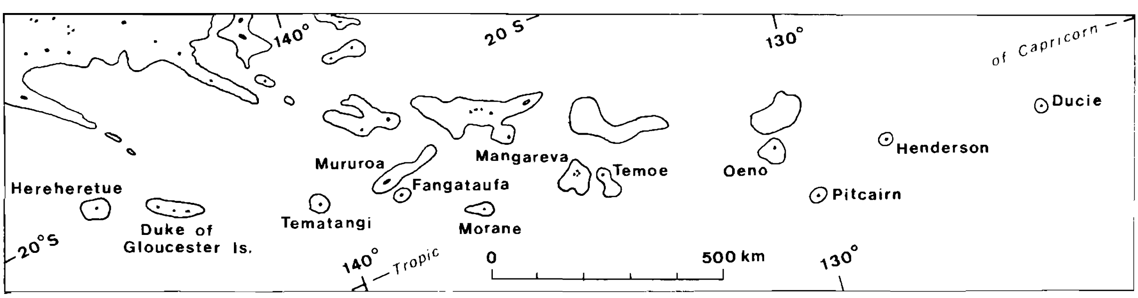

Figure 1. Contours of the 3,000-m isobath in the south Tuamotu-Gambier-Pitcairn area and location of the islands mentioned in the text, according to the Southeast Quadrant of the Geographic map of the Circum-Pacific region (scale 1:10,000,000) compiled by the U.S. Geological Survey (1978).

the load of Pitcairn (McNUTT and MENARD, 1978). If the volcano of Temoe was formed near the East Pacific Ridge, as is likely for at least Henderson and Ducie, then its age would be of the order of 15 Myr.

MEASUREMENTS OF HEIGHT, DEPTH, AND AGE

In spite of the lack of tide gauge data in Temoe Atoll, estimates of tide levels have been deduced from the station of Rikitea (Mangareva), where the average spring tidal range is 0.7 m and daily predictions are available (SHOM, 1980), under the very likely assumption that the tides in Mangareva and Temoe are the same.

In the field, altitudes have been measured by means of a spirit level and a folding ruler, in relation to the water level at the seaward reef margin, corrected for the tide, or in the lagoon. According to the direction of currents through *hoa* (shallow channels) and to the difference in level between the sea and the lagoon in different parts of the atoll rim at various tide situations, it may be concluded that the water level stood between MSL (mean sea level) and +10 cm in the southern part of the lagoon and between +10 and +20 cm in the northern part, throughout the survey. This slight difference in level is probably due to wind set up caused by a weak, but contiuous, south wind. On the reef flat, the water level in moats was found most often at intermediate levels between that of low tide and 10 to 20 cm above MSL. Later on, all the elevations measured were decreased by 5 cm, in order to take into account the sea level anomaly in this part of the Pacific in October, 1982 (K. WYRTKI, personal communication). According to these procedures, the accuracy of the elevations given in this paper (in relation to MSL) is estimated to be ± 10 cm in most cases and better than ± 20 cm in all cases.

In the lagoon, continuous bathymetric profiles were measured using a Koden echosounder, with an accuracy estimated at about ± 1 m.

Radiocarbon dating was carried out in Hannover, under the direction of M.A. Geyh, assuming for ^{14}C a half life of 5,570 years. The results were corrected for the isotope fractionation effect ($\delta^{13}C$). In order to take into account the apparent older age of the surface ocean water, 400 years have been deduced from the age obtained for samples collected near the open ocean. For samples collected from the closed lagoon, however, where the ^{14}C activity of the water can be considered in equilibrium with that of the atmosphere, this 400 yr correction is no longer necessary, as shown by PIRAZZOLI *et al.* (1987a) in Reao Atoll.

THE LAGOON

Previous to our survey, the only information available on the depths of the lagoon of Temoe was that reported by SEURAT (1903): "a shallow coastal zone, extending rather far, and a central part where the depth is less than fifteen fathoms."

Four continuous bathymetric profiles were measured in 1982 along transects covering distances of 13 km (Figure 2). The profiles obtained are given in Figure 3. The floor, usually less than 23 m deep, is studded with pinnacles, some of which reach the water surface, especially in the northwest part of the lagoon.

The transects measured were located on computer listings of the LANDSAT-3 satellite scene (0326-18131), taken on 25 January 1979, where Temoe Atoll is visible and devoid of clouds. Each bathymetric profile was divided into a number of sections equal to the number of pixels crossed by the transect. In each section, the average depth of water was calculated and this value was assumed to represent the average depth in the corresponding pixel of the LANDSAT-3 scene.

This is of course only a preliminary approximation. The values of radiance recorded by the satellite are integrals of all the topographical uneveness existing on the 6,240 m^2-wide pixel surfaces and in a lagoon studded with pinnacles the water depth may wary appreciably in the same pixel along transects carried out at some distance from the measured one.

At the next stage, following a method that has been described in more detail in previous papers (PIRAZZOLI, 1984, 1985), the average values of the water depth in each of the 149 pixels studied have been compared with the digital values read in the tape of MSS-4 of the LANDSAT scene, which penetrates deeper into the water (Table 1). The comparison shows that increasing MSS-4 values correspond clearly to decreasing average water depths. Groups of MSS-4 values can be used therefore as an approximation for bathymetric scale, and thus allows bathymetric mapping of the whole lagoon. The dimensions of the atoll as represented in Figure 4 are the emerged surface of the atoll rim (6.9 km^2), surface of the lagoon (13.1 km^2), volume of the lagoon (0.173 km^3), and

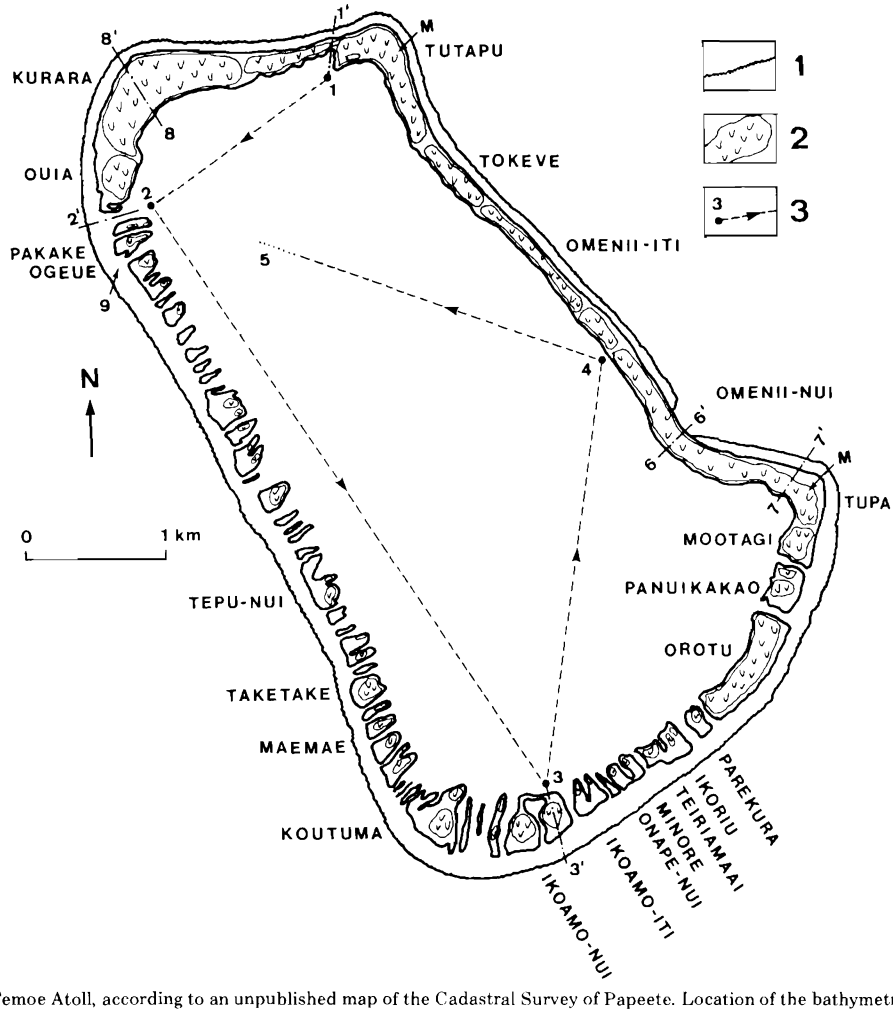

Figure 2. Temoe Atoll, according to an unpublished map of the Cadastral Survey of Papeete. Location of the bathymetric profiles of Figure 3 and of the transects studied. (1) seaward reef margin; (2) *motu* with vegetation; (3) bathymetric transects; and (M) *marae*.

average depth of the lagoon (13.2 m).

THE REEF RIM

The only maps of Temoe Atoll published previously are those of Wilson, with place names added by EMORY (1939), where the shape of the atoll is nevertheless very approximate, and the very small map of chart number 6692 of the French SHOM (scale 1:574,000).

In this paper, Figure 2 was prepared from a 1958 cadastral survey. This map locates the edge of the seaward reef margin and delimits the *motu* (emerged low islands). The border of the lagoon is not indicated, but it coincides most often with the inner edge of *motu*. Elongated basins, delimited laterally by sand bars, often penetrate deeply between *motu*, but are usually interrupted on the reef flat by conglomerate flagstones and do not extend to the ocean, with the exception of a few active *hoa*.

Generally, the northern and eastern parts of the atoll rim, exposed to short-period waves of trade winds from east and northeast, show a narrow reef flat and a continuous *motu*. On the west and south sides, on the other hand, which are exposed to

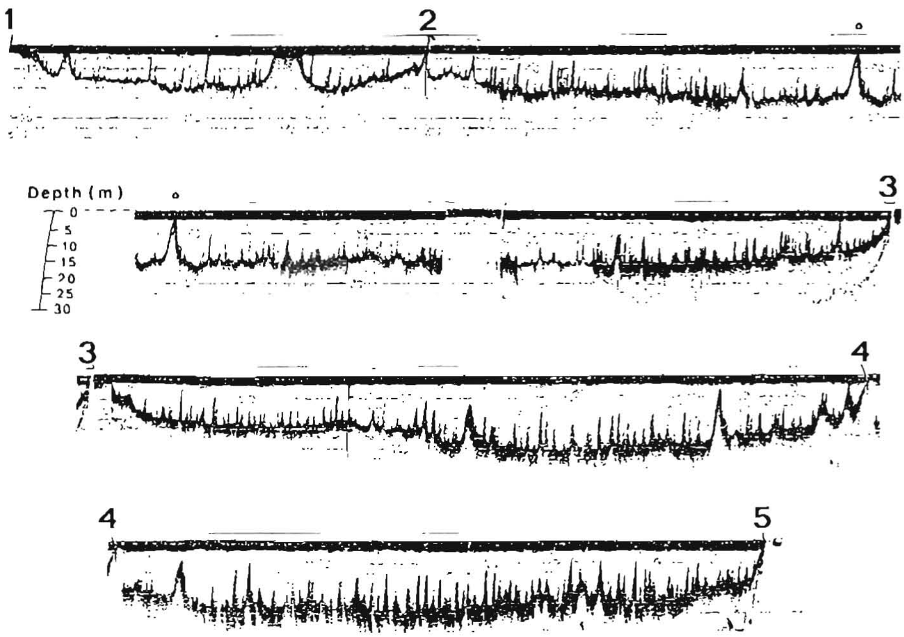

Figure 3. Bathymetric profiles measured in the lagoon of Temoe Atoll. For location of the profiles see Figure 2.

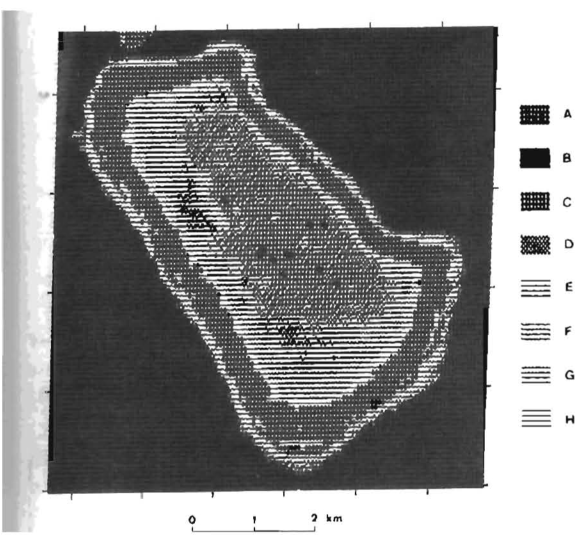

Figure 4. Map of average water depths in the lagoon of Temoe Atoll. (A) emerged areas or clouds; (B to H) water depths (see Table 1).

Table 1. *Average water depths in the lagoon of Temoe Atoll corresponding with 90% probabilities to the digital values read on the CCT of the MSS-4 (LANDSAT-3, 25 January 1979).*

Digital MSS-4	Number of pixels studied	Water depth (m)	Symbols in Fig. 4
36-41	1	≥ 18	B
42-47	43	16.5 ± 3.5	C
48-49	25	15.2 ± 2.0	D
50-55	46	13.5 ± 1.5	E
56-59	14	10.6 ± 1.6	F
60-69	13	9.8 ± 0.9	F
70-81	4	8.5 ± 4.7	G
82-91	1	unreliable	H
92	2	$5.5\ ^{+9.5}_{-5.5}$	H

heavy austral swells, the reef flat is larger and only small inlets have developed, consisting mostly of conglomerate flagstones, with scattered sand cays and vegetation inland.

In transect 6-6′, the detrital origin of the *motu* material is shown clearly (Figure 5). Oceanwards, at the end of the reef flat (a), in the zone exposed continuously to waves and tide, an heterometric conglomerate, pitted by erosion, extends over a width of several metres, reaching locally the elevation of about +1 m (b). Behind the conglomerate, a beach of some thirty metres wide, consisting of white sand and coral gravels (c), corresponds to recent storm deposits. Farther inland (d, e, f, g) the ground consists of an accumulation of coral boulders piled up chaotically, the surface of which

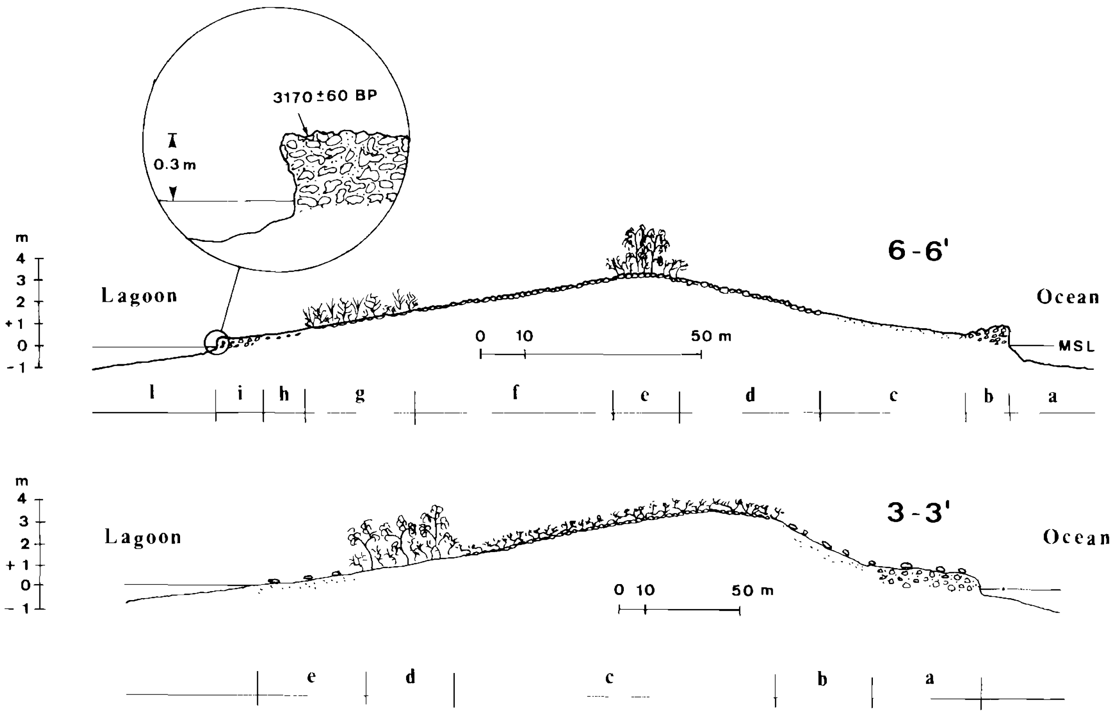

Figure 5. Transects 6-6′ and 3-3′. For the meaning of a, b, *etc.*, see the text.

has been blackened by Cyanophycean algae (Photo 1). On the top of the ridge (e) the only vegetation is *Suriana maritima* and *Pandanus*, whereas father inland (g) *Suriana*, *Scaevola* and *Pemphis acidula* are found. Towards the lagoon, after a detrital zone without any vegetation (h), an almost horizontal conglomerate flagstone (i), consisting of a calcirudite with corals and Soritides, lithified in the marine phreatic zone, has developed up to about +0.3 m above the lagoon level. A coral-algal pebble collected slightly below the surface of the conglomerate has been dated 3,170 ± 60 yr B.P. (Hv-12266). Assuming that the lagoon was not yet closed at that time, this may be assumed as a maximum age for a MSL about 0.7 ± 0.2 m higher than at present.

In transect 7-7′ the rampart of coral blocks starts from the low tide level and the top of the ridge, about 3.5 m high, is only a dozen metres distant from the shoreline (Photo 2). Behind the ridge a heap of blackened coral blocks, over which walking is hard, form a terrace up to one hundred metres wide, without any vegetation, with the exception of scattered blobs made by creeping *Triumfetta procumbens*.

On the terrace, ruins of prehistoric stone structures built by former inhabitants are in evidence (Photo 3). Further remains are located on the northeast and north sides of the atoll. On the atoll, EMORY (1939) counted about 80 stone structures (*marae*, platforms, pavements, tombs), and described in detail the most interesting ones. Other traces of ancient inhabitants consist of series of flat topped coral blocks placed over the rough coral ground, which were used as footpaths making it easier to walk in several parts of the atoll (*e.g.* across the ridge of transect 6-6′).

Transect 1-1′ corresponds to an emerged *hoa* where a conglomerate flagstone projects about 0.5 m over the reef flat. Near the outer limit of the conglomerate heterometric remains reaching +1.9 m locally probably correspond to an exceptional accumulation of storm deposits at the time of a cyclone, which are now lithified and strongly attacked by erosion. Two coral pebbles collected from the conglomerate, at +1.5 m and at +0.6 m, have been dated 3,405 ± 85 yr BP (Hv-12267) and 2875 ± 75 yr BP (Hv-12268) respectively.

On the lagoon side, near location 1, at least seven stepped shorelines have been modelled on

Photo 1 Omenii-nui, transect 6-6'. View from the top of zone f (see Figure 5) towards the lagoon. In the background, note scattered *motu* in the southwest part of the atoll rim.

the sand of the beach between the water level and 1.5 m above it (Photo 4). Much drift wood is scattered near the bighest shoreline, which seems to correspond to the uppermost level reached in the lagoon by a recent wave set-up phenomenon. The lower shorelines, which are devoid of drift wood, probably mark stages in the gradual draining of the lagoon through *hoa*. If each shoreline corresponds to a high-tide standstill in the ocean, then more than three days are necessary to reach a normal level in the lagoon again, after the storm surge.

On the northern side of the atoll rim there is no coral rubble rampart. A white sandy gravel beach forms a gentle slope between the reef flat, locally delimited by a narrow fringe of exposed conglomerate, and the zone covered with vegetation, which has developed over a distance of more than 350 m near the northwest tip of the atoll (transect 8-8'). Here in the *motu*, the ground consists, as usual, of coral boulders without any apparent soil, colonized mostly by *Scaevola* and *Pandanus* (Photo 5). Near the lagoon coconut trees can be found. The lagoon shore consists most often of a strip of white sandy gravel beach.

Some 200 m north of location 2, remnants of a former reef developed near the lagoon shore can be seen slightly emerged (Photo 6). Here a specimen from a *Porites lobata* coral microatoll, collected in a growth position at about 0.2 to 0.3 m above MSL, has been dated 1,385 ± 65 yr BP (Hv-12273). It is difficult to ascertain whether the lagoon was closed or open at that time. If it was already closed, as it is likely, some 400 years should be added in order to take into account the difference in ^{14}C activity between a closed lagoon and the ocean (PIRAZZOLI *et al.*, 1987a). In this case, the corrected age would be 1,785 ± 65 yr BP.

On the western side of the atoll rim many digitate basins prolong the lagoon between the *motu* as far as the reef flat, where however a coral conglomerate flagstone most often obturates them. Even where the conglomerate has been eroded,

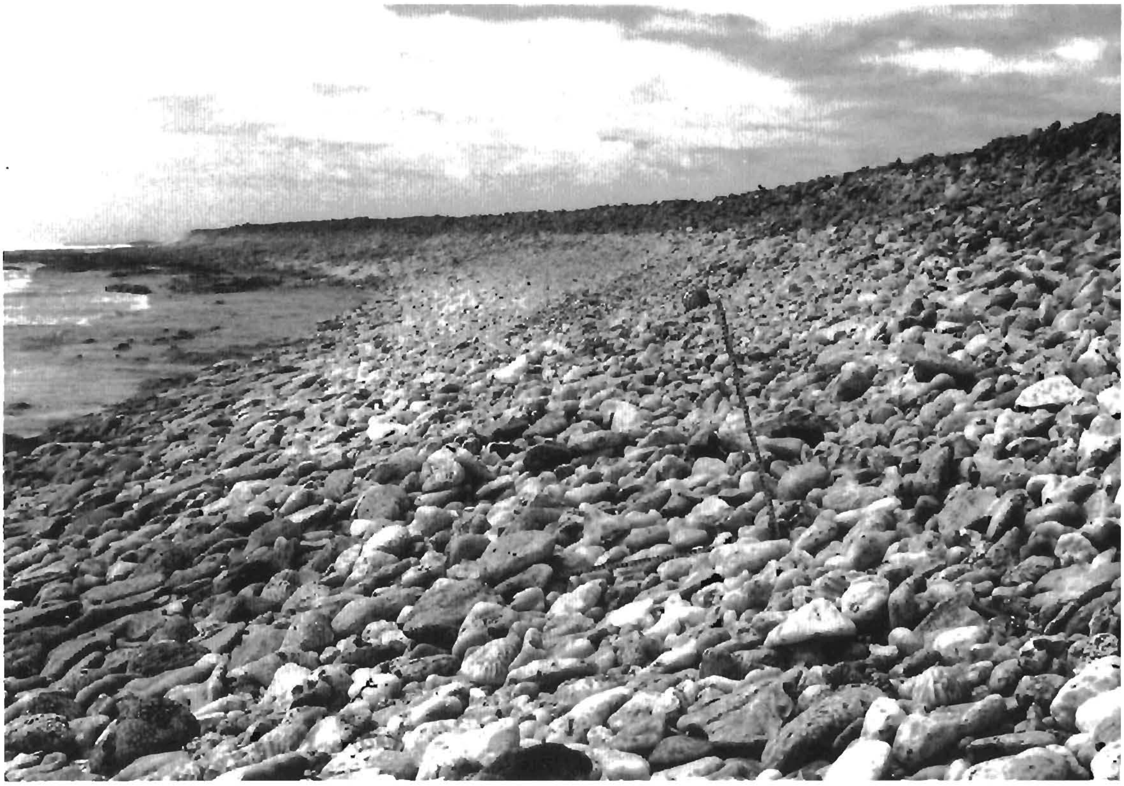

Photo 2. Tupa, transect 7-7'. A steep rubble rampart, 3.5 m high, starts abruptly from the inner edge of the reef flat. White boulders on the lower part of the rampart indicate recent storm deposits. Scale is 1 m. Low tide, view towards the southeast.

remnants of a former reef flat have emerged sufficiently to make the exchanges between the lagoon and the ocean almost no existent in the absence of strong wave set-up phenomena.

Near transect 2-2', for instance, where a series of digitated *hoa* is obturated on the reef flat by an almost continuous conglomerate flagstone reaching +0.7 m, a sample consisting of coral and coralline algae *in situ*, collected near the present MSL, has been dated 2,695 ± 55 yr BP (Hv-12270). In the same section, a reworked *Tridacna* shell, collected from the conglomerate at +0.5 m, has shown a slightly older age (3,145 ± 95 yr BP: Hv-12269). This seems to indicate, as for the ages obtained in transect 1-1', that detrital material can be displaced on the reef flat for several hundred years before being lithified into a conglomerate.

A discontinuity, consisting of an almost horizontal fissure developed on the lower part of the conglomerate flagstone, between +0.3 and +0.6 m, is often clearly visible (Photo 7). This fissure is interpreted as being the boundary between the former bioconstructed reef and the conglomerate capping it. A sample of *in situ* aragonitic *Acropora* coral and high-Mg calcite coralline algae collected from the former reef flat at +0.3 m, beneath the level of the fissure, has been dated 3,610 ± 105 yr BP (Hv-12271) (Photo 8). This apparent age might be made slightly younger (or older) by reef material trapped in the algal framework. Near location 9, a sample of aragonitic *Acropora* cf. *hyacinthus*, *in situ* at +0.3 m, has been dated 3,740 ± 55 yr BP (Hv-12272).

In the south and west parts of the atoll rim, behind the *Porolithon* ridge (Photo 9) and the reef flat, most of the islets shown in Figure 2 consist essentially of bare conglomerate flagstones. Vegetation has developed only in small spots near the lagoon side of the conglomerates. Contrary to the east and north sides of the atoll, where the sediments forming the *motu* come directly from the outer part of the reef, on the west and south sides,

Photo 3. Tupa, transect 7-7'. An almost horizontal terrace consisting of boulders blackened by Cyanophycean algae has developed at the level of the rampart ridge. A stone structure (platform with a step at one face) left by former inhabitants is visible. In the background, Omenii.

sand and gravel deposits are rapidly swept away from the reef flat and the conglomerate flagstone by heavy austral swells and tend to accumulate in the lagoon (this is shown clearly by the distribution of shallow-water zones in Figure 4). After each storm surge however, when the lagoon empties through the *hoa*, sediments may move from the lagoon towards the reef flat and are left on the sides of the *hoa* and above the flagstone. This to-and-fro movement of the sediments is considered the main cause of the frequent occurrence of sand and gravel bars at the lagoon mouth of the *hoa* and also of the sparse vegetation on the *motu* restricted in this part of the atoll to the inner part of the rim, at a good distance from the west and south reef fronts.

Transect 3-3' (Ikoamo-nui) is shown in Figure 5. The outer part of the islet consists of a bare conglomerate flagstone, almost horizontal at +0.9 m (a), followed by a sloping beach of white coral sand (b). Blackened coral pebbles are scattered above (a) and (b). A thick cover of *Scaevola* starts abruptly in the upper part of the sandy slope and extends over most of the islet surface (c). *Pandanus*, with a few coconut trees, can be seen only in the easternmost part of the *motu*. Towards the lagoon, a final zone of thick vegetation with *Pandanus*, *Suriana*, and *Pemphis* (d) precedes the gentle slope of a white coral sand beach capped by scattered blackened coral pebbles. The *motu* crossed by 3-3' is delimited to the east by an active *hoa* and to the west by a filled-in *hoa*, the sides of which have been chosen by several red-footed boobies *(Sula sula)* for nesting on bushes of *Suriana* (Photo 10).

On the whole, the vegetation of Temoe is very poor. In addition to *Suriana*, *Pandanus*, *Scaevola*, *Pemphis*, and *Triumfetta*, mentioned above, SEURAT (1903) reported *Lepidium*, *Cassytha filiformis*, *Barringtonia speciosa*, and, imported from Mangareva, *Polypodium* and *Calophyllum inophyllum*. In addition, *Messorschmidia argentea*,

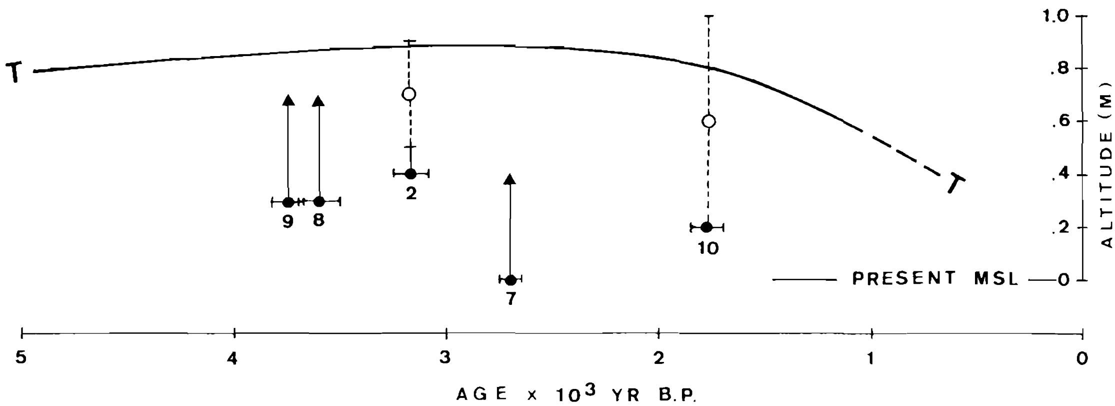

Figure 6. Comparison between the sea-level data available in Temoe Atoll and the T-T MSL (mean sea level) curve obtained in the northwest Tuamotus by PIRAZZOLI and MONTAGGIONI (1986). Full circles, position of samples; triangles, reconstructed minimum MSL positions; open circles, reconstructed MSL positions; dotted lines, vertical uncertainty limits.

Table 2. *Radiocarbon ages of reef samples collected from Temoe Atoll.*

Loc. (Fig. 2)	Sample	Material(1)	Elevation (m above MSL) Sample	Paleo MSL	Corrected Age(2) (yr B.P.)	Laboratory No.	$\delta^{13}C$ ‰	Minerology(4) A %	HMC %	% $MgCO_3$
1'	2TE4	coral pebble (d)	+1.5		3,405±85	Hv-12667	+0.4			
1'	2TE5	coral pebble (d)	+0.6		2,875±85	Hv-12668	+0.9			
N of 2	2TE10	*Porites lobata* coral (g.p.)	+0.2	+0.6 ± 0.4	1,785±65 (3)	Hv-12273	+2.4	100	—	
2'	2TE7	coral (g.p.) + coralline algae	±0.0	≥+0.4	2,695±55	Hv-12270	−0.2	65	35	19
2'	2TE6	*Tridacna* shell (d)	+0.5		3,145±95	Hv-12269	+3.7			
2'	2TE8	Coralline algae + *Acropora* coral (g.p.)	+0.3	≥+0.7	3,610±105	Hv-12271	+2.0	35	65	14
6'	2TE2	coral-algal pebble (d)	+0.4	+0.7 ± 0.2	3,170±60	Hv-12266	−0.7	70	30	12
9'	2TE9	*Acropora hyacinthus* coral (g.p.)	+0.3	≥∓0.7	3,740±55	Hv-12272	+0.2	100	—	

(1) d, displaced; g.p., in a growth position.
(2) Corrected ages are calculated taking into account the $\delta^{13}C$ correction and an apparent age of 400 yr for surface ocean water.
(3) Only the correction has been applied to this sample.
(4) A, aragonite; HMC, high-magnesian calcite.

Lepturus repens, Portulaca, orinda citrifolia, Guettarda speciosa, Hedyotis romanzoffiensis, and *Boerhaavia* have been recorded by EMORY (1939). Coconut trees, "extremely rare" in 1903, were much more frequent in 1982.

SEA LEVEL CHANGES

The sea-level data recorded in Temoe are summarized in Table 2 and plotted in Figure 6. For aragonitic corals in a growth position, it has been assumed that the ^{14}C age obtained corresponds to that of a former mean low water spring level equal or higher than the surface of the sample dated. Although the data available are not numerous or precise enough to draw a curve of local sea-level variations, they seem consistent with the T-T sea-level curve obtained in the northwest Tuamotu Islands (PIRAZZOLI and MONTAGGIONI, 1986). Similar results have been found in the atolls of Reao and Vahitahi (PIRAZZOLI *et al.*, 1987a, 1987b), in the eastern Tuamotus. It can be said therefore that if the slow subsidence of the atoll due to the gradual cooling and thickening of the oceanic crust is not taken into account, Temoe Atoll was tectonically stable during the late Holocene. Thus the same T-T curve is representative of the eustatic situation over distances as great as 1,700 km in the Tuamotu and Gambier Islands, the only exceptions being found in areas

Photo 4. Tutapu. Several stepped shorelines have been left on the beach by recent higher water levels in the lagoon. View towards location 1 from the east.

located near hot spots, where reheating and isostatic flexuring of the oceanic lithosphere may occur (MCNUTT and MENARD, 1978; LAMBECK, 1981; PIRAZZOLI and MONTAGGIONI, 1985).

No evidence could be found in Temoe of Pleistocene raised coral reefs *(feo)*.

CONCLUDING REMARKS

Temoe Atoll developed on a volcanic foundation which is either 4.0 to 4.5 Myr or about 15 Myr old. During the late Holocene and until less than 2,000 years ago, most of the west and south parts of the atoll rim were at water level, when sea level was some 0.8 m higher than at present. At that time, coral pebbles and boulders projected by storm waves were building ramparts on the reef flat, giving rise gradually to the earliest islands with vegetation *(motu)* on the windward east side. The subsequent drop in sea level enabled the whole atoll rim to emerge, the *motu* to widen and, more recently, even some precarious settlements of refugees from Mangareva from time to time.

Remote, difficult of access, uninhabited for the last 150 years, Temoe Atoll has still to be explored in detail. In this paper, detailed maps and new data on the bathymetry, the geomorphology, and the Holocene evolution of the atoll are published

Photo 5. Kurara, transect 8-8'. The vegetation in the outer part of the *motu* consists mostly of *Pandanus* trees and *Scaevola*.

for the first time.

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Photo 6. Ouia, lagoon shore. Emerged corals in a growth position. The *Porites* microatoll in the foreground has been dated 1,775 ± 65 yr BP.

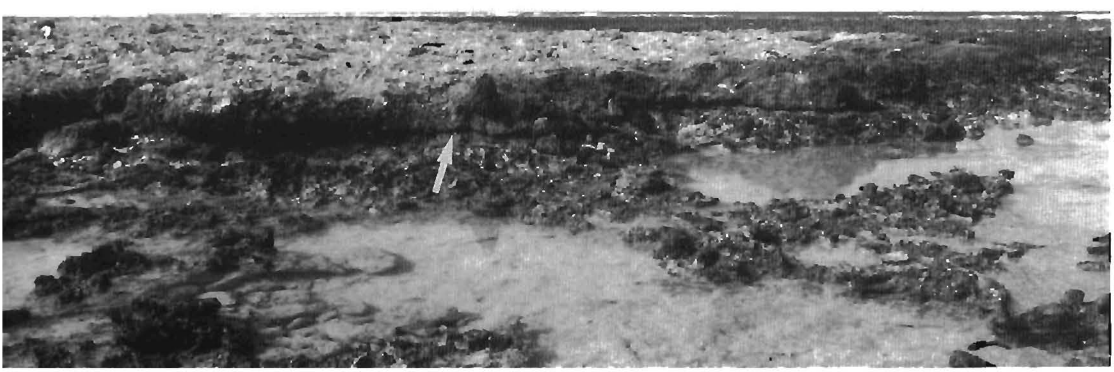

Photo 7. Pakake (near location 2'). A continuous fissure at about +0.5 m (arrow) marks the boundary between an ancient reef flat with corals emerged *in situ* and a conglomerate flagstone developed above them.

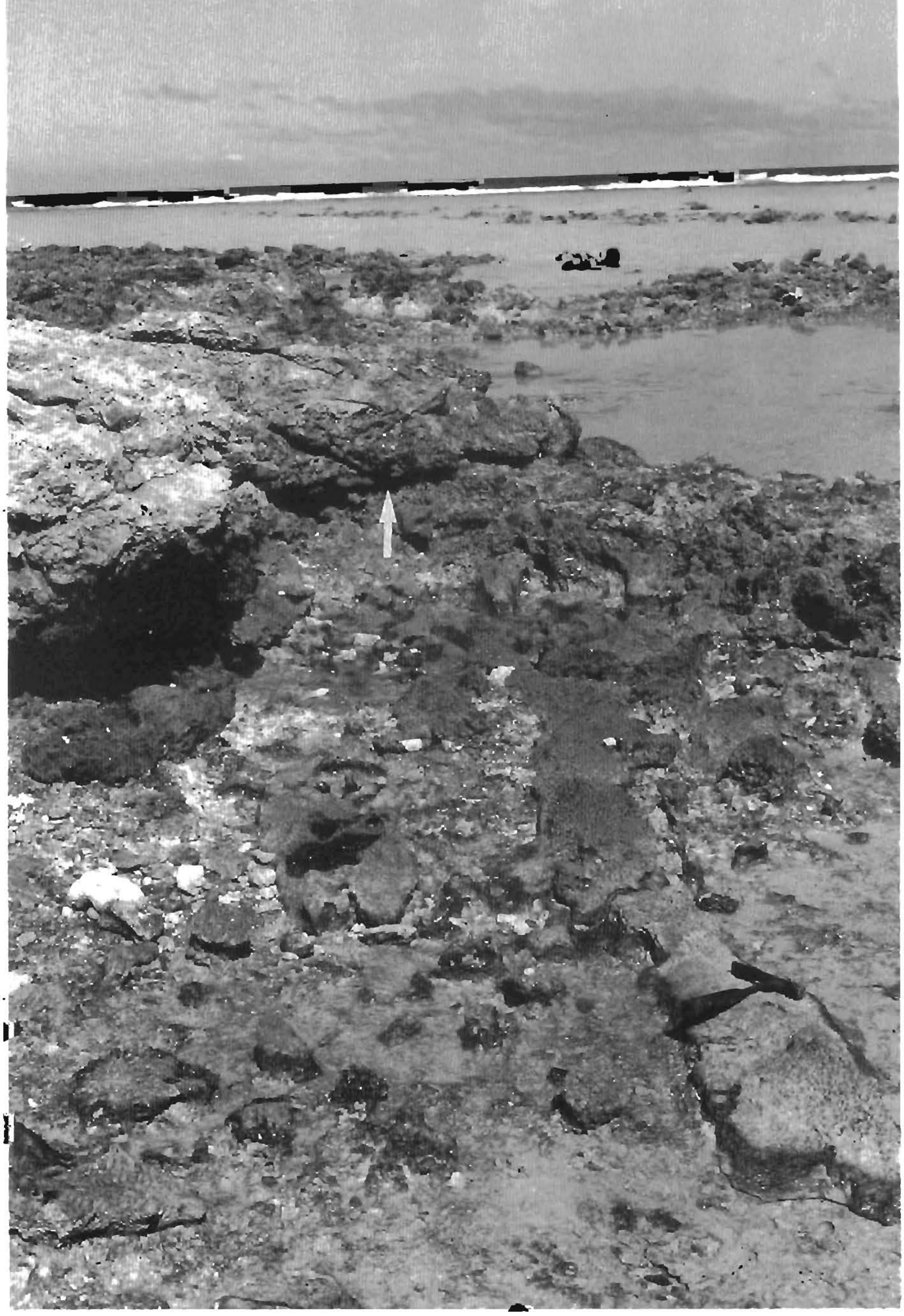

Photo 8. Pakake. Emerged biolithites *in situ* are visible below the level of the fissure (arrow). A specimen of *Acropora* and coralline algae collected at +0.3 m, beneath the hammer, has been dated 3,610 ± 105 yr BP.

Photo 9. The seaward reef margin near Taketake at low tide. Waves break on the algal ridges *(Porolithon)* cut by surge channels even when the sea is calm. This makes landing on the reef unsafe at any time.

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Photo 10. Red-footed boobies *(Sula sula)* nesting on bushes of *Suriana maritima* on the east side of the filled-in *hoa* between the two *motu* of Ikoamo-nui (near transect 3-3'). Left, a dark-phase adult booby. Right, two young birds, six weeks old (identification by R. Schreiber).

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□ ZUSAMMENFASSUNG □

Hier folgt ein Bericht der Geomorphologie, Hydrologie und spätholozänen Entwicklung vom südlichsten Atoll französicher Polynesiens. Mit ein Paar bathymetrischen Profile und der Benutzung eines LANDSAT-3 Satellitbilds, wurde eine Landkarte der Durchschnittstiefe der Lagunengewässer erschaffen. Das Lagunenvolumen ist auf 0,173 km^3 abgeschätzt. Der Wassertausch zwischen die Lagune und den Ozean ist sehr begrenzt; Wellenerrichtungerscheinungen, die schweren sülichen Dünungen gebühren, können leicht das Lagunenniveau 1,5 m heben. Bis 2.000 Jahre B.P. liegte der Atollrand auf dem Wasserspiegel, als der Meersspiegel 0,8 m höher als heute war. Der folgende Meeresspiegelniedergang bewirkte das Auftauchen, der Verbreitung der Pflänzen über den Inseln und (sehr neulich) Flüchtlinge von dem Inseln Mangareva. Seit 1838 A.D. ist das Atoll unbewohnt.--*Stephen A. Murdock, CERF, Charlottesville, Virginia, USA*

□ RÉSUMÉ □

Rend compte de la géomorphologie, de l'hydrologie et de l'évolution tardi-Holocène de l'atoll le plus au Sud de la Polynésie frannçaise. Quelques profils bathymétriques combinés à des donées de LANDSAT 3 ont permis de réaliser une carte des profondeurs moyennes du lagon, dont le volume est estimé à 0,173 km^3. Les échanges entre le lagon fermé et l'océan sont faibles, mais le niveau du lagon peut s'élever de 1,5 m par ensachage dû aux déferlements des vagues provenant de Sud. Jusqu'à-2.000 BP, lorsque le niveau de la mer était quelque 0,8 m au dessus de l'actuel, la plupart de l'atoll était submergé. La descente du niveau qui a suivi, a provoqué l'émersion, l'élargissement des îles avec végétation et, plus récemment, l'implantation d'établissements précaires de réfugiés de Mangareva. Pourtant l'atoll était resté inhabité depuis 1838.--*Catherine Bressolier, EPHE, Montrouge, France*