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REEF ISLANDS OF RAROTONGA

by D. R. Stoddart

LIST OF VASCULAR FLORA

by F. R. Fosberg

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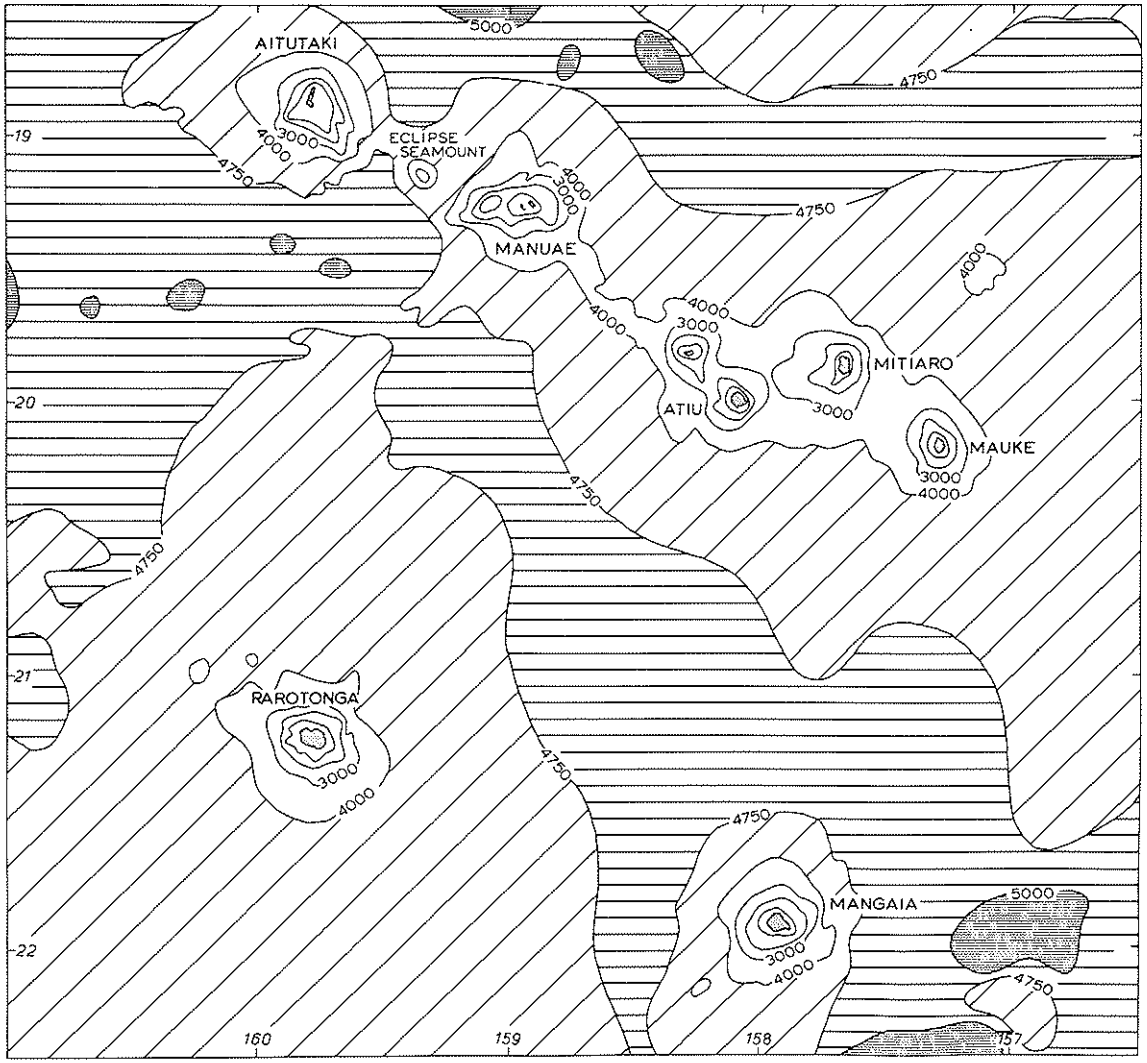

Figure 1. Bathymetry of the Southern Cook Islands. Based on Summerhayes (1967)

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INTRODUCTION

Remarkably little is known of the coral reefs of Rarotonga, southern Cook Islands. Crossland (1928a, 616-619) and Davis (1928, 407-408) gave brief descriptions following short visits, and remarks on reef structure in the context of the geological history of the island have been made by Marshall (1908, 1912, 1930) and later workers (Wood, 1967).

A marine biology party from the Cook Bicentenary Expedition to the Southwest Pacific worked on Rarotonga from 21 to 27 August 1969. The party consisted of Dr. H.G. Vevers (Zoological Society of London), Dr. P.E. Gibbs (The Marine Laboratory, Plymouth), and the author. After a reconnaissance of the coast of Rarotonga, work was concentrated at Ngatangiia Harbour on the east side of the island, though some collections were also made at other localities. Subsequently the Ngatangiia area was also visited by Prof. W.R. Philipson (Department of Botany, University of Canterbury, Christchurch, New Zealand), during floristic studies carried out on the same expedition, and some of his results are used here.

The present paper gives a general description of the reefs and environment of Rarotonga, a detailed account of the reef islands of Ngatangiia, and a list of the vascular flora of the islands determined by Dr. F.R. Fosberg (Smithsonian Institution). Other results of the Ngatangiia work will appear elsewhere. A preliminary account of coral reef studies in the Cook Islands during the 1969 expedition has already been published (Gibbs, Stoddart and Vevers, 1971).

REEF GEOMORPHOLOGY

Rarotonga (latitude 21°12'S, longitude 159°46'W) is an isolated volcanic island, now deeply dissected by erosion, with a maximum altitude of about 640 m. It rises from the ocean floor at a depth of about 4000 m (Summerhayes and Kibblewhite, 1967), at which depth the volcanic cone is 45-55 km in diameter (Figure 1). The present island has maximum dimensions of 11.5 x 8 km. The exposed volcanics consist of basaltic and phonolitic eruptives; the latter have been dated radiometrically at 2.3-2.8 million years, indicating a Pliocene age for the uppermost lavas of the cone (Tarling, 1967). The volcanics are surrounded at the coast by a low apron of gravels and sands (Fig. 2). The gravels (Nikao Gravels) were deposited first and slightly cliffed before the deposition of the more recent Aroa Sands (Wood, 1967). Swamp deposits in places occupy gaps between the gravels and the beach ridges of the Aroa Sands, particularly along the south and west coasts. Small areas of elevated reef limestone outcrop in places round the coast, and may be extensive beneath the Aroa Sands; their significance will be discussed later.

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The island is surrounded by a fringing reef about 400 m wide along the south and 200 m wide along the west and north coasts. In Ngatangiia Harbour the reef edge lies about 1 km from the coast. The reef edge is continuous except for steep-sided narrow inlets at Avatiu and Avaroa on the north coast, Ngatangiia on the east, and several places on the south. The reef flats are planed-rock features, rarely carrying more than 1.5 m of water even at high tide; they are covered with sand sheets, and growing corals are not common. Marine phanerogams are absent. These flats are distinguished, especially at Ngatangiia Harbour, by extremely large populations of holothurians, with densities of *Holothuria atra* reaching up to 10 per sq m. An algal ridge is only weakly developed on the reefs, though Marshall (1930) states that it is higher in the south than the north.

Crossland (1928a, 616-619) considered that the reef was originally a barrier reef converted to a fringing reef by infilling of the lagoon by the coastal sands and gravels. He said little of the composition of the reef, except to note the existence of large brain corals and also of *Porites* heads in the boulder beach at Avarua (Crossland, 1928b, 721). Davis (1928, 407-408) rather misleadingly referred to Rarotonga's "close-set and little-eroded barrier reef, from a quarter to a half mile wide, now about 15 feet above sea level, enclosing a narrow lagoon flat or swamp"; he considered that the amount of sediment produced during dissection of the island, both before and during reef growth, required considerable subsidence for its disposal, and that this overall sinking of the island was to be distinguished from the more recent 5 m uplift of what he termed the barrier reef, and the subsequent infilling of its lagoon.

Ngatangiia Harbour on the west coast forms the most pronounced coastal indentation. Rarontonga's largest river, the Avana, flows into the harbour and discharges by the deep reef gap north of Motutapu (Fig. 3). Outcrops of elevated reef limestone are found on both sides of the harbour entrance. The Harbour islands, from Motutapu southwards, continue the general trend of the coast (though Taakoka is volcanic, not detrital). Wood (1967) maps the detrital islands as Aroa Sands, and both Marshall (1930) and Wood (1967) draw attention to the absence of sands and gravels on the mainland coast of Ngatangiia Harbour, where volcanic rocks reach the sea. Marshall (1930, 19-20) proposed that the detrital islands represented fragments of a formerly continuous beach ridge breached by hurricanes, with as a result the sea flooding the swampy former back-ridge area.

ENVIRONMENT

Rarotonga lies in the South-east Trade Wind belt. There are no climatic data for the Ngatangiia area, on the windward, wetter side of the island. Avarua, on the leeward side, has a mean annual rainfall of about 2050 mm, though with considerable variation between years. Most of the rain falls during March, April and May; and the driest months, with less than 100 mm average, are July and September. Mean annual temperature is 23.6°C. Highest recorded temperature near sea level at Avarua is 33.5°C, and lowest 8.9°C (Marshall 1930; Grange and Fox 1955).

The island is frequently affected by storms of hurricane intensity, generally approaching from the northwest. Major recorded storms are those of December 1831, December 1842, March 1846 (especially damaging at Ngatangiia), December 1848, March 1926, March 1943, January 1944, January 1946, December 1948, and September 1950 (Gill, 1885; Marshall, 1930; Hutchings, 1953), but this list is clearly incomplete. Because of the open-ocean situation, storm surges associated with hurricanes are not important; most of the effects are from wind and wave activity. Tsunamis also occasionally occur. Those of May 1960 resulting from the Chilean earthquakes reached the comparatively low height in inlets at Rarotonga of 1.5 m above normal sea level, partly because the tide was low at the time and normal water level was below the outer reef edge (Keys, 1963). Both hurricanes and tsunamis, however, are likely to have been significant controls in the development of the reef islands.

Tides are semi-diurnal, with a rather pronounced diurnal inequality at and following neaps. According to predictions prepared by the Hydrographic Department, Ministry of Defence, London, for the expedition, in 1969, the range at springs is 0.85 m and at neaps 0.33 m.

DESCRIPTION OF THE ISLANDS

Motutapu (Fig. 4)

Motutapu is the northernmost and largest of the Ngatangiia islands: it is 600 m long, 360 m wide, with an area of 11 ha. The northern part of the island consists of a rough *makatea* or elevated reef limestone, well cemented, with a local relief of up to 1 m though with a rather subdued erosional topography (Plate 1); it is cliffed and undercut at intertidal levels, and its upper surface stands at 2-3 m above the sea (Plate 2). A small patch of similar rock outcrops further south on the seaward shore, and much of the northeastern part of the island is presumably underlain by this limestone. At the north point the *makatea* directly overlooks the deeper water of the harbour entrance, and similar rock outcrops on its northern side.

Apart from the *makatea* the island is a simple cay, with a gravel and cobble ridge and intertidal storm rubble forming a beach up to 5 m high on its seaward side (Plate 3), and a wide intertidal expanse of fine sand and silt forming an *Uca*-dominated flat on its leeward side. The seaward beaches are 25-30 m wide; those on the lee side are narrower as well as lower. All are aggrading except for a cliffed sector of cobble beach on the north coast.

The vegetation of the *makatea* differs from that of the rest of the cay. *Sesuvium portulacastrum* covers the floors of potholes, with a low scrub of *Wedelia biflora* and *Capparis cordifolia*. *Heliotropium anomalum* and *Ipomoea pes-caprae* are also present. Most of the characteristic strand plants of the sand cay are absent.

On the seaward coast of the sand cay section there is a long narrow zone of *Scaevola taccada*, with some scattered bushes of *Tournefortia argentea* and a patch of *Lantana camara*. Outpost vegetation is restricted to small areas of *Vigna marina* and *Cassytha filiformis*. The *Scaevola*, in places up to 4 m tall, is replaced inland by a dense woodland of *Hibiscus tiliaceus* 6-8 m tall, with some *Guettarda, Morinda, Casuarina*, and occasional conspicuous tall coconuts. The interior of the cay is occupied by a higher woodland, dominated by coconuts, with *Hernandia sonora, Leucaena insularum, Morinda citrifolia, Carica papaya* and other species. On the low-lying, partly waterlogged lee shore there are areas of grass and sedge marsh dominated by a sterile grass (possibly *Paspalum)* and inhabited by *Uca*.

Oneroa (Fig. 5)

Oneroa, south of Motutapu, is slightly smaller; it lacks the *makatea* but is otherwise similar in topography and vegetation. The island is 500 m long and 200-250 m wide, with an area of 10.6 ha.

The seaward beach (Plate 4) consists of sand, gravel and cobbles, with broken coral rubble at its foot and strewn across its surface; the coarser sediments are more common in the southeast. The beach is 20 m wide and 2-3 m high. The leeward beach is low and sandy, with a sand spit 100 m long extending lagoonward in the north. This spit encloses, as at Motutapu, a wide intertidal flat of sand and fine gravel with large numbers of *Uca*. Cemented rubble forms a low shelf at the foot of the seaward beach towards the north, but otherwise there is no beachrock.

The main vegetation of the island is a mixed woodland dominated by *Casuarina*, broadleaf trees and coconuts. *Hibiscus tiliaceus* is an important component, together with *Hernandia sonora, Pisonia grandis, Morinda citrifolia* and *Leucaena insularum*. Several species of ferns

form a ground cover. *Casuarina* reaches the shore in several places, and is locally being undermined by beach erosion. *Scaevola taccada* forms an interrupted beach-crest scrub up to 4 m tall, with some *Tournefortia* and *Guettarda*, on the seaward shore. Inland from the narrow *Scaevola* belt is a zone of taller *Pisonia* and *Hernandia* woodland 40-50 m wide, largely growing on coarse beach-crest coral rubble with no other ground cover. At the abrupt inner edge of the rubble spread, on sand and fine gravel, the vegetation changes to a mixed woodland dominated by *Casuarina* with a ground cover of ferns and grasses. The *Scaevola* belt is wider and more continuous on the lagoon shore, again with occasional *Tournefortia; Sophora* and *Suriana* are represented by isolated bushes. Outpost species on the beach outside the *Scaevola* zone include *Cassytha, Cenchrus* and *Triumfetta*.

Koromiri (Fig. 6)

Koromiri, the smallest of the cays (320 m long, 120 m wide, area 3 ha) strikingly resembles Oneroa in its topography, with a prominent northern sand spit. The beaches are narrower, however, and on the southeast coast cliffed and retreating. The island is distinguished by its relict beachrock extending up to 120 m seaward of the cay.

Apart from patches of *Hernandia, Hibiscus, Morinda* and *Guettarda* woodland, the island is covered with *Casuarina* woodland. Beach-crest scrub of *Scaevola taccada*, with some *Tournefortia argentea*, is most continuous on the lagoon shore, where *Cassytha* is abundant. Outpost vegetation is very limited, with some *Vigna marina* and *Triumfetta procumbens*.

Taakoka

Taakoka, the southernmost island, set well back from the reef edge, is not a sand cay but a low hill of basalt forming an island half the size of Koromiri. The island may be described in two parts. First, a central plateau, consisting of a jumble of large angular and sub-rounded basalt blocks, encrusted with lichens and covered with bryophytes, and surrounded on its seaward margins by large spreading trees of *Barringtonia asiatica* 10-15 m tall. In the centre of the plateau there are some 50 coconut trees 15-25 m tall, with *Morinda, Hernandia* and ferns. The plateau stands about 6 m above sea level. Second, there is a "tail" lagoonward of the plateau, of basalt blocks up to 1 m long. This has an outer zone of *Casuarina* up to 20 m tall, with *Vigna marina* and *Ipomoea macrantha* beneath, and an inner zone of *Hernandia*, 10 m tall, with *Morinda*, coconuts and ferns.

Scaevola grows abundantly among the basalt blocks of the seaward coast, with *Wedelia biflora, Vigna marina* and *Ipomoea pes-caprae*. Along the north and south shores *Barringtonia* approaches close to the beach, with thickets of *Hibiscus tiliaceus* and outpost *Vigna marina* and *Ipomoea macrantha*.

Several species are clearly introduced, though the island is not inhabited. These include not only the coconuts, but cultivated *Hibiscus* and *Hippeastrum*, and a single banana plant.

It is clear that Taakoka, so different physiographically, has little in common with the other three islands, and is only linked with them by proximity. Along the north shore there is a thick outcrop of beachrock, consisting of angular basalt cobbles in a red clayey matrix which is presumably a decomposition product of the basalt. The beach sands, as on the other islands, are, however, reef-derived.

DEVELOPMENT OF THE ISLANDS

From these surveys of the cays, it is not possible to confirm Marshall's proposal (1930, 19-20) that the islands form part of a formerly continuous ridge of Aroa Sands fragmented by storm action. This could be so, but equally the islands have all the characteristics of ordinary sand cays, and they show no obvious signs of major erosion or dissection. Nor is there any evidence between the islands, e.g. in relict beachrock, of formerly more continuous land. The islands, other than Taakoka, consist of successive increments of storm-deposited rubble and cobbles of reef origin on the seaward beaches, with infill and spit-growth of fine gravel and sand to leeward. It seems likely that these processes of aggradation are still active. The islands in their present form are not therefore directly related to the occurrence of raised reefrock remnants in the *makatea* of Motutapu and the mainland coast. There are also two small islands on the northern reef flats of Rarotonga: one near Avatiu has been much altered by land reclamation on the reef flat, but the other, Motu Toa, has probably also originated by sediment accretion to form a discrete island on the reef flat.

Some data are available on the absolute chronology of late Pleistocene and Holocene events at Rarotonga. Schofield (1970) has published C^{14} dates on *makatea* samples: a sample from Ngatangiia Harbour, elevation 3.05 m, is dated at 28,200 ± 850 yr B.P., and one at Te Ara Vaka, elevation 1.83 m, at more than 48,900 yr. A sample from 3.2 m elevation at Matavera could not be dated. Schofield suggests that the reef from which these samples were taken (equivalent to the Motutapu *makatea)* was formed during an interstadial at 32,000–35,000 yr B.P.; it is perhaps more probable, in view of the difficulty of dating such material, that it correlates with the *makatea* of Mangaia, for which Veeh (1966) obtained a uranium-series age of 110,000 ± 50,000 yr.

There is some evidence from Rarotonga for much more recent high stands of the sea. A raised reef at Avarua on the north coast, at 1 m above present low water level, with corals in the position of growth, has been dated at 2030 ± 60 yr B.P., and soil samples from beach ridges of Aroa Sands age have been dated at 1235 ± 57, 2470 ± 63, and 3510 ± 50 yr B.P. (Wood 1967; Schofield 1970). Schofield also reports a beachrock at Titikaveka at 1 m above present high water level. He suggests that these recent dates indicate sea stands at +2 and +1 m above the present, and that the Aroa Sands beach ridges, which rise to about 8 m above present sea level, were formed during these higher stands. There is no evidence of such stands in the topography of the Ngatangiia reef islands, and indeed large parts of the islands would be submerged with such higher sea levels. It should be noted that the much older Motutapu *makatea* is tidally notched at present intertidal levels, and there are no apparent signs of higher notches.

The Ngatangiia islands can thus be assumed, from their own characteristics, to have had a simple aggradational history, punctuated by hurricane events, accumulating on reef flats partially formed by the erosion of older elevated reef limestone. It is possible that they are younger than the sea-level events described by Schofield, or that the evidence of such events in the physiography of the islands has been erased by later storm action.

SUMMARY OF VEGETATION

The vegetation of the islands is relatively simple. Essentially it comprises a broadleaf woodland of *Hibiscus, Guettarda, Morinda, Pisonia* and *Hernandia,* with coconuts and *Casuarina,* the latter apparently spreading at the expense of broadleaf trees; a beach-crest scrub of *Scaevola taccada* with some *Tournefortia argentea;* and an outpost or pioneer strand vegetation, very patchily developed, of *Triumfetta, Ipomoea, Vigna* and other species. The Motutapu *makatea* has its own distinctive vegetation of *Wedelia biflora, Ipomoea, Heliotropium,* and *Capparis cordifolia.* Ill-drained leeward sand flats have a low vegetation of grasses and sedges. This restricted range of vegetation types reflects the limited range of habitats and the

small size of the islands, as well as floristic poverty. Some types, notably *Barringtonia* woodland, are found only on Taakoka and not on the sand cays.

There is no mangrove vegetation, and sea-grasses are absent, not only on Rarotonga but throughout the Cook Islands. Some species, especially littoral shrubs, are surprisingly rare, particularly *Suriana maritima*, which is extremely common on Aitutaki on similar cays. Wilder (1931) recorded this species as occurring only on Motutapu; it was not seen there in 1969, but a single specimen was growing on Oneroa.

ACKNOWLEDGEMENTS

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LIST OF VASCULAR PLANTS

by F.R. Fosberg

Plants collected in 1969 and determined by Dr. F.R. Fosberg, together with those collected on the cays by Prof. W.R. Philipson, comprise 2 bryophytes (not determined), 1 lichen (not determined), and 49 species of vascular plants, including 4 species of ferns. Some earlier records, usually without precise location, are given in the floras of Cheeseman (1903) and Wilder (1931). One species recorded on Motutapu by Wilder, *Myoporum sandwicense* A. Gray, was not collected in 1969.

Of the plants in the following list, excluding ferns, 26 species are recorded from Motutapu, 17 from Oneroa, 14 from Koromiri, and 18 from Taakoka. Seven of the Taakoka species, plus one fern, are recorded only from that island and not from the three reef islands, bringing the number of species from the latter down to 41.

The list is interesting for its omissions, compared with other Cook Island reef islands, particularly those of Aitutaki. There are no pandans; *Pemphis acidula*, elsewhere abundant, is missing; and there are no species of Euphorbiaceae, though on similar islands on Aitutaki *Euphorbia chamissonis* is an important component of the vegetation.

Some aspects of the floristics of Rarotonga are discussed by Philipson (1971).

Almost complete sets of the specimens cited are deposited in the U.S. National Herbarium, Washington, D.C. and in the herbarium of the Botany Division, Dept of Scientific and Industrial Research, Christchurch, New Zealand.

POLYPODIACEAE

Asplenium nidus L.
Oneroa: *Stoddart 2118.* Koromiri: *Stoddart 2154.*

Davallia solida (F. f.) Sw.
Oneroa: *Stoddart 2119.* Taakoka: *Stoddart 2167.*

Nephrolepis hirsutula (Forst. f.) Presl
Taakoka: *Stoddart 2169.*

Polypodium scolopendria Burm. f.
Oneroa: *Stoddart 2121.* Koromiri: *Stoddart 2157.* Taakoka: *Stoddart 2168.*

GRAMINEAE

Cenchrus echinatus L.
Oneroa: *Stoddart 2158.*

Lepturus repens R. Br.
Taakoka: *Philipson 10349.*

Stenotaphrum secundatum (Walt.) O. Ktze. ?
Oneroa: *Philipson 10354.*

Thuarea involuta (Forst. f.) R. Br. ex R. and S.
Motutapu: *Stoddart 2135.*

CYPERACEAE

Fimbristylis cymosa R. Br.
Motutapu: *Philipson 10364.*

PALMAE

Cocos nucifera L.
Motutapu: Stoddart, sight record. Oneroa: Stoddart, sight record. Koromiri: Stoddart, sight record. Taakoka: Stoddart, sight record.

AMARYLLIDACEAE

Hippeastrum puniceum (Lam.) Voss
Taakoka: *Stoddart 2159.*

MUSACEAE

Musa sapientum L.
Taakoka: Stoddart, sight record.

CASUARINACEAE

Casuarina equisetifolia L.
Motutapu: Stoddart, sight record. Oneroa: *Stoddart 2115.* Koromiri: Stoddart, sight record. Taakoka: Stoddart, sight record.

PIPERACEAE

Peperomia leptostachya H. and A.?
Motutapu: *Stoddart 2140.*

Peperomia pallida var.
Oneroa: *Philipson 10360.*

NYCTAGINACEAE

Pisonia grandis R. Br.
Oneroa: *Stoddart 2114.*

AIZOACEAE

Sesuvium portulacastrum L.
Motutapu: *Stoddart 2105; Philipson 10365.*

PORTULACACEAE

Portulaca lutea Sol. ?
Motutapu: *Stoddart 2106.*

LAURACEAE

Cassytha filiformis L.
Motutapu: Stoddart, sight record. Oneroa: *Stoddart 2117.* Koromiri: Stoddart, sight record.

HERNANDIACEAE

Hernandia sonora L.
Motutapu: *Stoddart 2137.* Oneroa: *Stoddart 2124.* Koromiri: *Stoddart 2148.*
Taakoka: *Stoddart 2164.*

CAPPARIDACEAE

Capparis cordifolia Lam.
Motutapu: *Stoddart 2141; Philipson 10361.* Koromiri: *Stoddart 2155.*

LEGUMINOSAE

Canavalia sericea A. Gray
Motutapu: *Stoddart 2133.*

Leucaena insularum (Lam.) Dan.
Motutapu: *Stoddart 2139.* Oneroa: Stoddart, sight record.

Mucuna gigantea (Willd.) DC.
Taakoka: *Philipson 10351.*

Sophora tomentosa L.
Oneroa: *Stoddart 2127.*

Vigna marina (Burm.) Merr.
Motutapu: *Stoddart 2112.* Koromiri: *Stoddart 2146.* Taakoka: *Stoddart 2165.*

SURIANACEAE

Suriana maritima L.
Oneroa: *Stoddart 2123.*

RHAMNACEAE

Colubrina asiatica (L.) O. Ktze.
Oneroa: *Stoddart 2131; Philipson 10356.*

TILIACEAE

Triumfetta procumbens Forst.
Oneroa: *Stoddart 2132.* Koromiri: *Stoddart 2147.*

MALVACEAE

Hibiscus sp. (cultivated variety)
Taakoka: *Stoddart 2161.*

Hibiscus tiliaceus L.
Motutapu: *Stoddart 2104.* Oneroa: *Stoddart 2130.* Koromiri: *Stoddart 2150.*
Taakoka: *Stoddart 2166.*

CARICACEAE

Carica papaya L.
Motutapu: *Philipson 10363.*

LECYTHIDACEAE

Barringtonia asiatica (L.) Kurz
Taakoka: *Stoddart 2172.*

MYRSINACEAE

Ardisia elliptica Thunb.
Motutapu: *Stoddart 2142.*

CONVOLVULACEAE

Ipomoea macrantha R. and S.
Taakoka: *Stoddart 2163.*

Ipomoea pes-caprae subsp. *brasiliensis* (L.) v. Ooststr.
Motutapu: *Stoddart 2108.* Taakoka: Stoddart, sight record.

BORAGINACEAE

Heliotropium anomalum H. and A.
Motutapu: *Stoddart 2113.*

Tournefortia argentea L. f.
Oneroa: *Stoddart 2128.* Koromiri: *Stoddart 2152.*

VERBENACEAE

Lantana camara L.
Oneroa: *Stoddart 2122.*

Lantana camara var. *aculeata* (L.) Mold.
Motutapu: *Stoddart 2110.* Taakoka: *Stoddart 2160.* Koromiri: *Philipson 10352.*

Stachytarpheta urticifolia Sims
Koromiri: *Stoddart 2153.*

Vitex trifolia L. var. *bicolor* (Willd.) Mold.
Motutapu: *Philipson 10362.*

RUBIACEAE

Guettarda speciosa L.
Motutapu: *Stoddart 2136.* Oneroa: *Stoddart 2116.* Koromiri: *Stoddart 2151; Philipson 10352.*

Morinda citrifolia L.
Motutapu: *Stoddart 2144.* Oneroa: *Stoddart 2126.* Koromiri: *Stoddart 2149.* Taakoka: *Stoddart 2170.*

GOODENIACEAE

Scaevola taccada (Gaertn.) Roxb.
Motutapu: *Stoddart 2145.* Oneroa: *Stoddart 2129.* Koromiri: Stoddart, sight record. Taakoka: *Stoddart 2171.*

COMPOSITAE

Bidens pilosa L.
Koromiri: *Stoddart 2156.*

Elephantopus mollis HBK.
Motutapu: *Stoddart 2143.*

Emilia sonchifolia (L.) DC.
Motutapu: *Stoddart 2134.*

Sonchus oleraceus L.
Motutapu: *Stoddart 2111, 2138.*

Wedelia biflora (L.) DC.
Motutapu: *Stoddart 2107.* Taakoka: *Stoddart 2162.*

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Cheeseman, T.F. 1903. The flora of Rarotonga, the chief island of the Cook Group. Trans. Linn. Soc. London II. Bot. 6: 261-313.

Philipson, W.R. 1971. Floristics of Rarotonga. Bull. Roy. Soc. New Zealand 8: 49-54.

Wilder, G.P. 1931. Flora of Rarotonga. Bull. Bernice P. Bishop Mus. 86: 1-113.

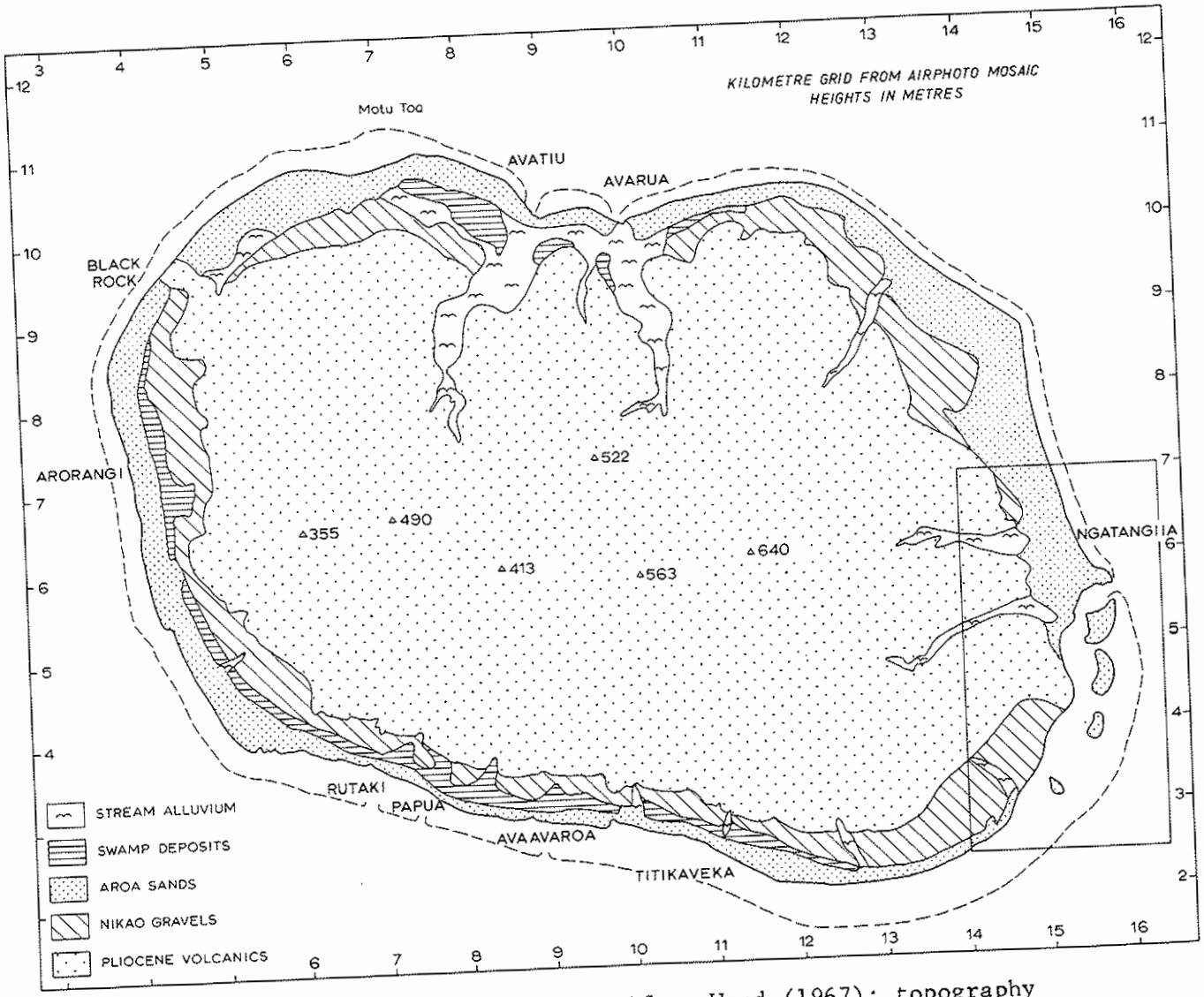

Figure 2. Geology of Rarotonga. After Wood (1967); topography reduced from air photograph mosaic

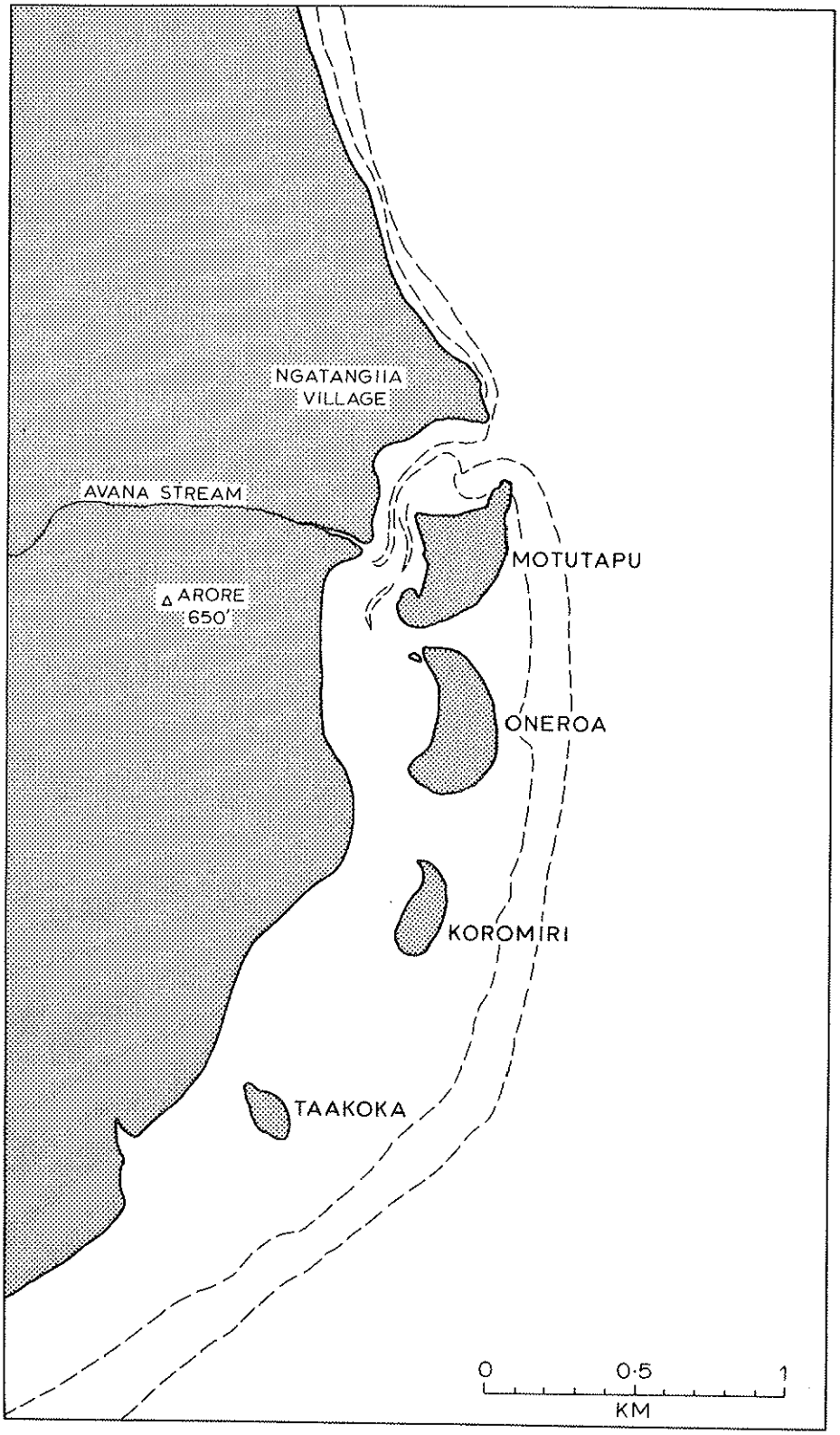

Figure 3. Reef islands of Ngatangiia Harbour. For location, see Figure 2

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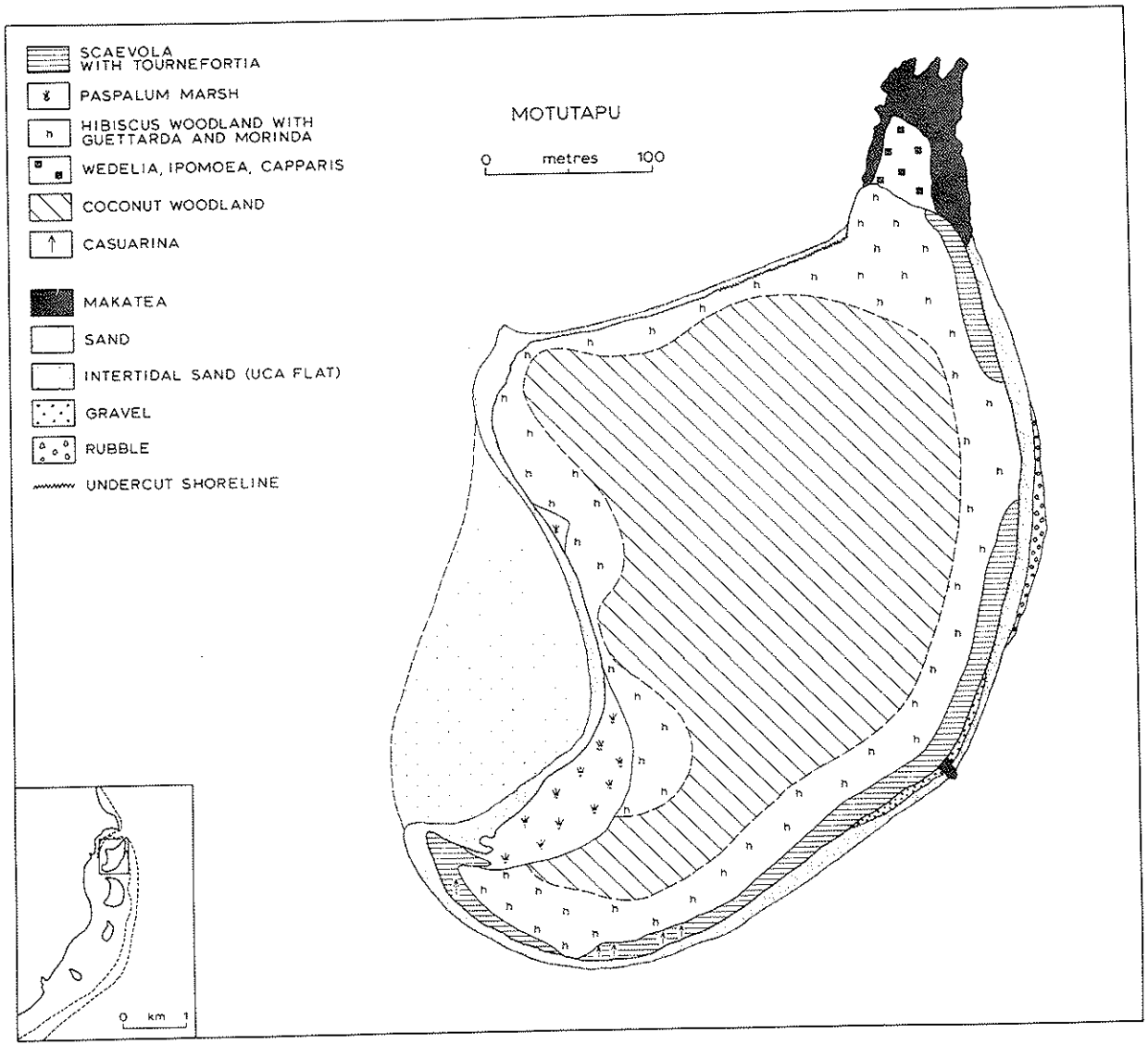

Figure 4. Motutapu

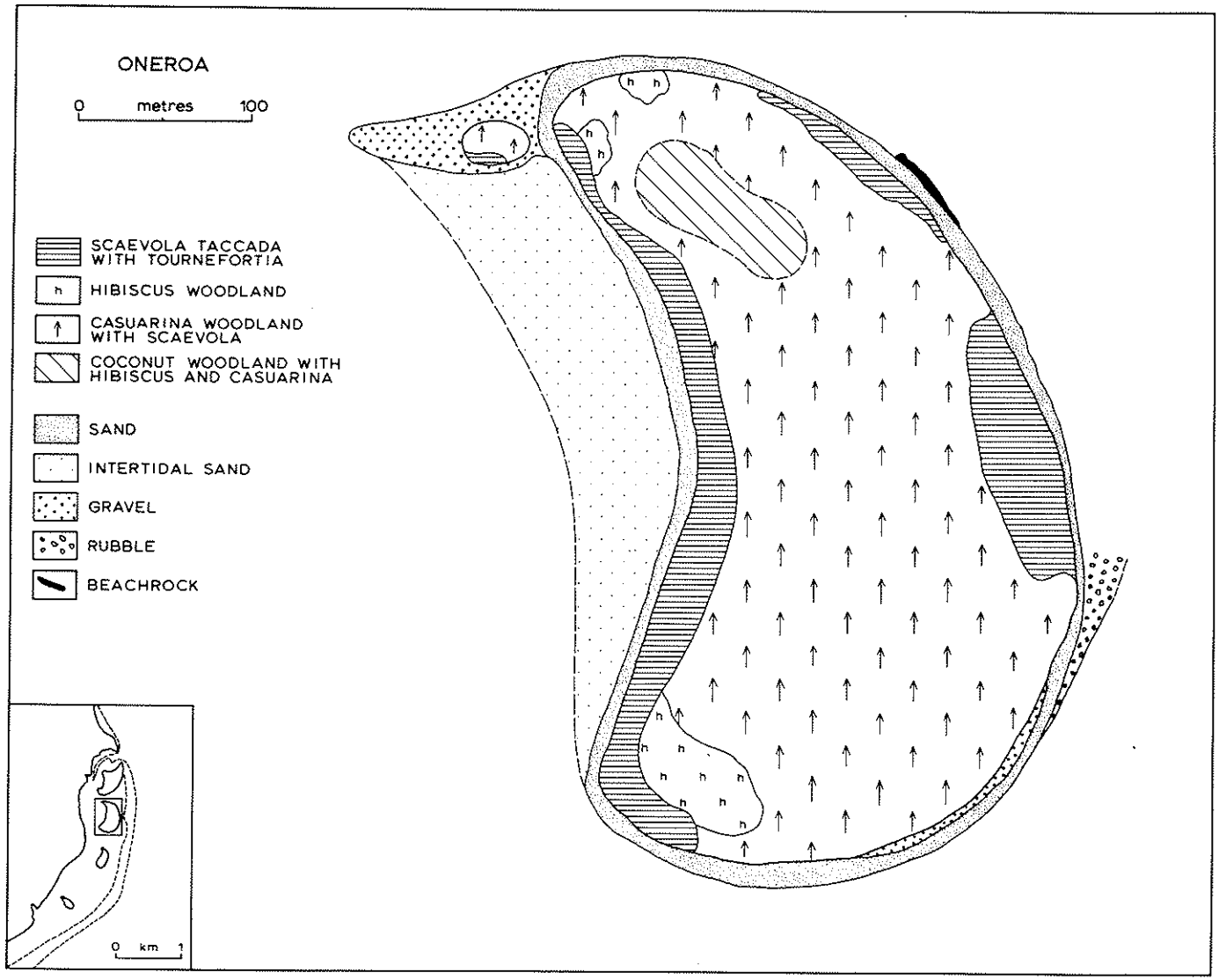

Figure 5. Oneroa

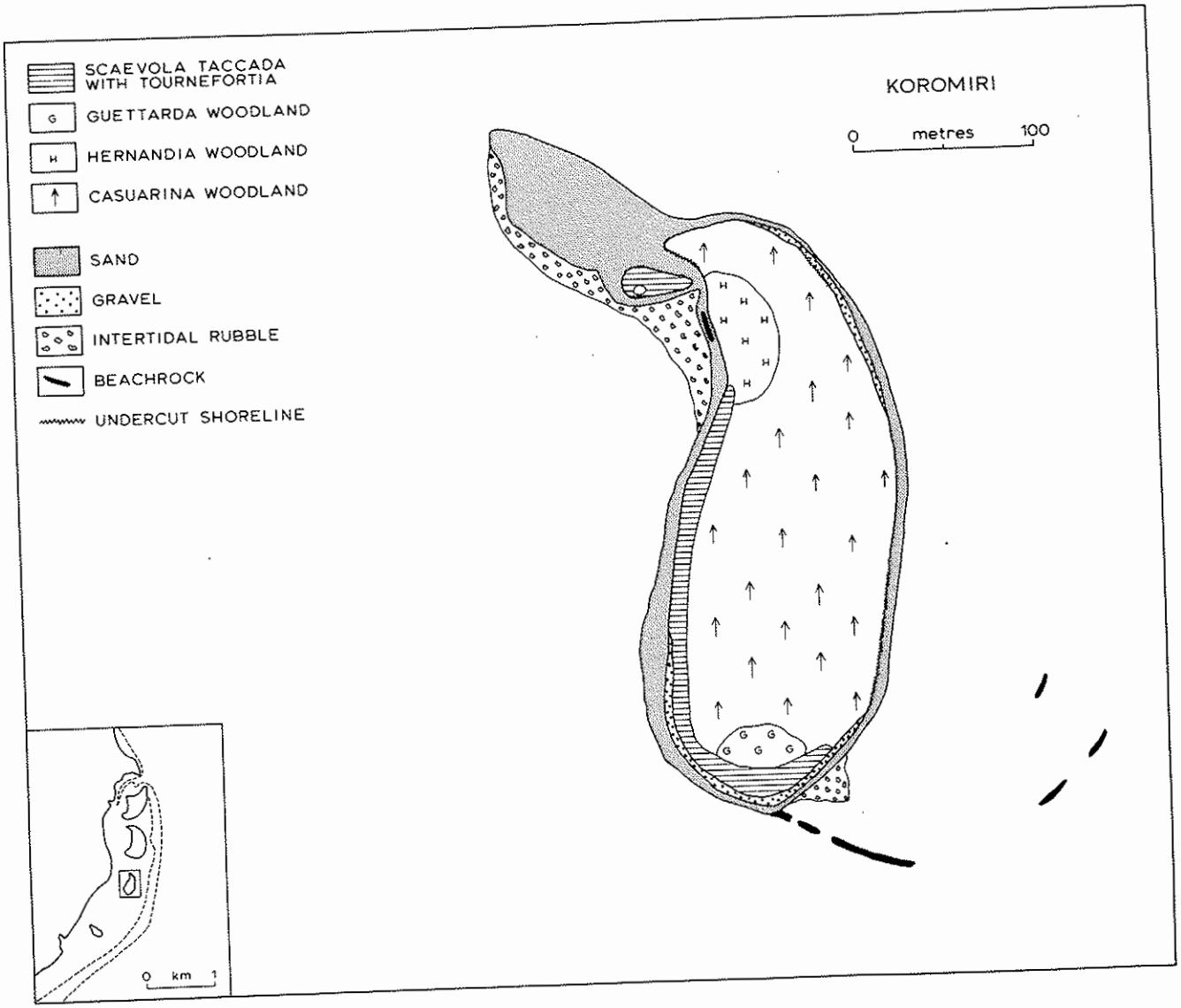

Figure 6. Koromiri

Plate 1. Dissected makatea surface on Motutapu

Plate 2. Makatea outcrop at the northeast point of Motutapu

Plate 3. Seaward cobble beach with littoral *Scaevola* scrub, Motutapu

Plate 4. Storm rubble on the southeast beach of Oneroa