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UNESCO/UNFPA PROJECT ON POPULATION AND ENVIRONMENT

IN THE EASTERN ISLANDS OF FIJI

(Man-and-the Biosphere Programme)

PROJECT WORKING PAPERS Nos. 1 and 2

PRELIMINARY PAPERS ON NATURAL RESOURCES

Bernard Denis; Bernard Salvat et al.

1. Bernard Denis: THE SOILS OF LAKEBA AND TAVEUNI

2. Bernard Salvat et al: THE ECOLOGY OF THE REEF-LAGOON COMPLEX OF SOME ISLANDS IN THE LAU GROUP

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THE UNESCO/UNFPA POPULATION AND ENVIRONMENT PROJECT IN THE EASTERN ISLANDS OF FIJI: A DESCRIPTION

The UNESCO/UNFPA Project was conceived within the framework of the Man-and-the Biosphere Programme of UNESCO, and forms part of Project 7, 'The Ecology and Rational Use of Island Ecosystems'. It was designed as an international project, to be one of a series in different regions of the world, both to feed into, and to provide a measure of design for, national programmes of research into man/biosphere relations. After the agreement of the Government of Fiji was obtained in 1973, the project was funded in 1974, and research began later in the same year. Field work ran through 1975 until mid-1976.

The project has had twin objectives. On the one hand its purpose is to explore the scientific study of human activity in and on specifically defined environments. On the other hand it has also had the objective of providing researched guidelines for policy aimed at optimizing, within the limits of possibility, the satisfactions of life for the people concerned, within the context of rational use of environment. The objectives are not seen as in conflict; the same research programme feeds both aims, and we have sought to demonstrate that scientific research into population and environment can equally serve both 'pure' and 'pragmatic' ends, each being the better for the incorporation of the other. The two general reports of the project, to be published in the MAB Technical Notes Series, will reflect these two faces of our work.

The research team has represented the disciplines of human and physical geography, demography, soil science, marine biology, nutrition, agronomy and agricultural economics. Topics under review have ranged from the fields of soil and vegetation ecology and the impact of natural hazards, through studies of land use and land holding, detailed community studies and the economics of farm-decision making, to regionally-comprehensive studies of production and communication, historical demography and migration. This list is not exhaustive. The emphasis given to different topics, and hence different specialisms, reflects the problems identified in the particular area. The method of research has varied; community studies are best carried out by an individual researcher, but often several specialists have lived and worked together in the field, each pursuing his own line of interest, but constantly interacting, so that almost all members of the project have become aware not only of the work of their colleagues, but also of the methods used and the problems raised.

This project has had a smaller local component than we wished or had planned. In common with many developing countries, Fiji has only a limited pool of skilled specialists, and we were not able to secure the collaboration of certain persons from

whom the project would have gained much. However, we have collaborated very extensively with the field and headquarters staff of three Ministries and have also collaborated, in a real sense, with the populations of the islands in which we have worked.

The design of the project has been governed by the resources available to us. We have carried out some general studies over the whole eastern island area, and several members of the project have been able to tour quite large areas of an oceanic region. However, we have concentrated our efforts principally on two islands, and have worked less intensively on three others. These five islands, respectively Taveuni, Lakeba, Kabara, Koro and Batiki, were chosen to reflect a range of physical types and also of economic development, and of distance - measured in the real terms of access - from the national centres.

For the most part the full evidence of integration of our work will appear only in the general reports. However, a great body of data and discussion cannot be presented in these reports, and we are thus also publishing a series of Project Working Papers, which will contain from one to three reports by individual specialists, or, in a few instances, the collaborative and integrated work of more than one. This series has limited distribution, and its primary purpose is to make our work available quickly in Fiji itself. All Project Working Papers are 'cleared' only with the Chief Technical Adviser; they therefore do not necessarily represent the views of UNESCO or UNFPA, or even of the project as a whole. Responsibility for all statements made and views expressed rests with the author.

Harold Brookfield
Chief Technical Adviser

EDITORIAL INTRODUCTION

This first issue of the Working Papers of the Project combines two basic-data papers concerning the natural resources of the islands. They present little discussion, and are essentially preparatory studies on which the final reports will expand. Because the material contained is, however, of great potential value to specialists within Fiji and in a wider scientific oecumene, they are published now in this series in order that results can be disseminated as speedily as is possible.

The first paper, by Bernard Denis, soil-scientist of the Centre ORSTOM at Noumea, presents initial data on the description and classification of the soils of Lakeba and parts of Taveuni. It is based on field work done in 1975, together with some preliminary analyses. Soil maps are not provided at this stage, since these are subject not only to the field work carried out in early 1976, but also to the results of more detailed analyses that are not even now complete. As is stated in the paper, these maps will be provided in a final report on the soil-vegetation complex of islands studied, due for completion late in 1976, and to be published in French and English by ORSTOM during 1977. However, the present report is of immediate interest not only for its own descriptions, but also as representing the first major attempt at correlation between the Wright and Tywford (1965) classification and the international (FAO-UNESCO) and French systems, and also as constituting the first comprehensive soil surveys in Fiji to be carried out on map scales larger than 1:100,000. The Wright and Twyford work is now more than twenty years old; we felt it timely that this project should contribute to the study of the natural resources of Fiji by including a soil survey incorporating the great advances in soil science made since that time.

The final report will not only elaborate this descriptive work, and present also work done on some other islands, but will be concerned also with two sets of problems in dynamic ecology. On the one hand is the effect of cultivation on soils: for this purpose the Project conducted yield measurements and soil fertility measurements, and collected land-use histories at the same sample sites. On the other is a specific dynamic problem concerning the evolution and amelioration of the barren fern-casuarina (talasiga) complex of Fiji, superbly exemplified on the island of Lakeba.

The second paper is written without data analysis, and was entirely written in Fiji itself, before the research team even left the field in April 1976. This reports a reconnaisance survey of the resources of the reef-lagoon ecosystems of a number of islands in the Lau group. It was carried out, on sub-contract to the Project, by Dr Bernard Salvat and a group of specialists engaged by him. Much is made in the literature of the Pacific about the resources of the circum-island reefs and lagoons;

clearly, they constitute a major part of subsistence resources, and are also subject to varying degrees of commercial exploitation. It was necessary to obtain some evaluation of the content and nature of these resources, and the conclusion drawn from the work of Salvat's group is one of great variability. The variability is, indeed, little if any less than the variability on land. Facile generalizations are therefore much more readily avoided.

It may be felt that the reconnaisance methods used by Salvat's group preclude any quasi-quantitative conclusions. However, a subsidiary object of this survey was to seek knowledge by relatively unsophisticated methods, without also the crudity of mass kills through the use of dynamite in order to obtain quantification. By means of a purposive visual sample, supplemented by instrumental observations, it was hoped to obtain results of sufficient precision to make possible statements concerning the nature and variability of reef-lagoon resources. With limited instrumentation, the same would be possible within the resources of most island countries. The final report will be the basis on which the success or failure of this experiment may be judged, but the preliminary report presented here is sufficiently revealing in its evidence of variability to suggest that the care needed in evaluating marine resources is no less than that required on land.

The authors acknowledge the specific help both groups have received from members of the Fiji Ministry of Agriculture, Fisheries and Forests. This has been very great, not only to these enterprises quite specifically within the domain of the Ministry, but also in all our activities. As Chief Technical Adviser of the Project, this is for me perhaps the most suitable place to acknowledge a volume and enthusiasm of collaborative interest among members of MAFF without which our project could not have achieved the half of what we have - we hope - succeeded in doing. It is therefore perhaps most appropriate that this first issue of a series of Project Working Papers should be devoted to matters entirely within their concern.

Maps accompany both reports. Those accompanying Salvat's paper have been redrawn in the Map Laboratory of the Department of Geography, Australian National University, by Mrs Val Lyon. Those accompanying Denis' report are copies of originals prepared in Noumea for an earlier version of the report in French. Being based on standard topographic sheets they also use the cumbersome orthography of Fijian names employed on those sheets. This is not the normal practice of the project, which is to use the standard Fijian orthography.

The whole of this issue has been typed and prepared for publication by Mrs Colleen Morton, assisted by Mrs Elizabeth Bray. Our debt to Mrs May Dudley for her help in arranging the cover design and printing is also most gratefully acknowledged. The cover design itself is based on a suggestion by Richard Bedford.

Both reports were prepared in French, Translation, except for a part of Denis' report, has been carried out by myself. In the case of Denis' report, this has been checked by the author and his colleague, Marc Latham. In the case of Salvat's report, it was decided to proceed directly to publication without this additional delay. The translator's apologies are therefore due both to the authors and to readers, for such inaccuracies and infelicities as quite clearly remain.

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UNESCO/UNFPA PROJECT ON POPULATION AND ENVIRONMENT

IN THE EASTERN ISLANDS OF FIJI

(Man-and-the Biosphere Programme)

PROJECT WORKING PAPER No.1

THE SOILS OF LAKEBA AND TAVEUNI:

PRELIMINARY REPORT

Bernard Denis
(ORSTOM, Noumea, New Caledonia)

Published from the Development Studies Centre,
Australian National University, Canberra, A.C.T.
July 1976

SYNOPSIS OF CONTENTS

Preamble

I LAKEBA

GENERAL REMARKS
THE SOILS OF LAKEBA
CONCLUSIONS

II TAVEUNI

GENERAL REMARKS
THE SOILS OF TAVEUNI
CONCLUSIONS

References

MAPS (in pocket at back)

1. Lakeba
2. Taveuni North
3. Taveuni South

Preamble

Following the agreement between ORSTOM and UNESCO concerning the participation of soil scientists of the ORSTOM centre in Noumea in the study of the soil-vegetation complex in the eastern islands of Fiji, three missions have been carried out. The first was a reconnaisance mission by M. Latham. The second was carried out between the end of August and the middle of October 1975, and is the subject of the present preliminary report. It had been intended to study soils on four islands, but both for practical reasons and because of their own interest, only two were retained in the programme: these were LAKEBA in the Lau islands, and TAVEUNI.

The final report will include soil maps and very complete analytical results but these latter will take some time: a completion date in November 1976 is envisaged. In order to avoid too long a gap between the mission and publication of results, this preliminary report is therefore prepared. It both presents general discussion of the geology, geomorphology and vegetation of the two islands, and also presents an account of the principal soil types encountered, together with some review of their spatial distribution and principal morphological characteristics. The account is based on field study supplemented by the use of air photographs.

Preparation of this account also facilitated design of the third mission, which was carried out between mid-January and the end of March 1976 by B. DENIS and M. LATHAM. This will be separately reported. Once we have the full results of soil analysis carried out in Suva, with the kind co-operation of the Research Division of the Ministry of Agriculture, Forests and Fisheries, and in the ORSTOM laboratories, we shall be able to refine certain aspects of the classifications, and also provide greater detail on the physical, chemical and agronomic characteristics of the soils studied. Two definitive maps will be prepared for each island (parts of the island in the case of Taveuni). The first will be a pedological map; the second will indicate the land-use potential.

Finally, I take this opportunity to thank all those who have helped in the work including Dr. Brookfield (Chief Technical Adviser), Mr. John Campbell (Project Assistant), and other members of the UNESCO/UNFPA Population and Environment Project, and equally the Fijian authorities and scientific personnel, especially those of the Department of Agriculture (MAFF).

LAKEBA

1. General Remarks

Lakeba is situated in the southeast of Fiji, in the Lau islands, at 178° East by 18° South, approximately 180 miles east of Suva. It is a rounded island with a small peninsula in the south. Its mean diameter is five miles, and its total area is 21.5 sq.miles (approx.50 km^2).

Geology Following F. Coulson, (unpublished) who has carried out the most recent survey, the island is mainly formed of a miocene volcanic complex, rocks being mainly andesitic and dacitic, with some basaltic flows. This formation is overlain by Miocene limestone on the northwest and west coasts, and in the southern peninsula. Geologically, two limestones are distinguished, the one foraminiferal, the other shelly, but this differentiation appears to have no effect on soil type. There are also quite large colluvial deposits in the valleys and sub-coastal areas, and alluvial plains in parts of marine origin.

Topography and Geomorphology Our own observations, and those of Twyford and Wright (1965) agree in describing the island as a single massif characterised by rounded summit forms. There is evidence of tilting along a north-south axis passing roughly through the centre of the island. In the western part the uplift of the airfield valley is especially notable, while in the east several valleys have been drowned, with formation of hydromorphic zones. Soil materials encountered are of colluvial and alluvial origin according to this same differentiation.

It is possible to distinguish several levels which are clearly recognisable on the ground and in aerial photographs:

(a) The central area, occupying the larger part of the island, with a highest point at 230m (720 ft). Hills are rounded mainly and their slopes overlap. Slopes are often steep (30% to 50%), falling from the two highest points directly to the sub-coastal colluvial areas in the north and south, and part of the east, and to quite extensive areas at lower altitude in the southeast and all along the west coast.

(b) Plateau areas, between 60 and 120m altitude. These occupy most of the western side between Nasaqalau and Tubou villages. There is also a smaller plateau near Waitabu, and a third, at only 20 - 30m, in the southern peninsula.

(c) Valleys, between 5 and 20 metres altitude. These are very variable in size, but extend toward the centre of the island as much as 2km or more from the sea. The largest are those of Tubou, Nukunuku and Yadrana. Materials encountered are in two classes. On colluvium of andesite material soils are often deep, and these areas are frequently occupied by coconuts. In the centre of each valley is generally found a mixture of colluvial and alluvial material in which mineral hydromorphic soils are often developed.

(d) Coastal Zones, flat topography, very gentle slopes. These cover quite a considerable area, occuring both at the foot of the hills occupying the larger part of the island, and in the mouths of valleys. The break of slope is often sharp. Both colluvial and alluvial materials are encountered. Colluvial deposits, formed from the basic rocks forming the core of the island, form a piedmont around the massif. Their extent varies from place to place, and they give place to alluvial deposits close to the shore. These alluvial deposits are sandy between Tubou and Vakano villages, but have a high clay content around the remainder of the island. These textural differences are related to the distribution of mangroves, and it seems possible that the clay-alluvial deposits represent former mangroves, subsequently elevated or stranded by a change in sea level. In the clay-alluvial areas there is an almost imperceptible gradient from colluvium, through non-hydromorphic alluvial soils, to hydromorphic alluvial soils. It is extremely difficult to draw boundaries within this zone.

Erosion seems most active on the ferralitic soils derived from andesites, the 'talasiga soils' of Twyford and Wright. Sheet flow is common, but there are also areas of strong gullying, including some coalesced gullies forming wholly eroded patches ('badlands') on the sides of some hills. These ferralitic soils are the main site of the present efforts of the Department of Forests (MAFF) in pine plantation; these have the effect of checking soil erosion, and also of ameliorating the condition of the surface horizon. Following Twyford and Wright (1965) Lakeba includes:

- 40% of steeply-sloping land
- 40% of gently-sloping land
- 20% of level ground.

Vegetation At this stage only a general discussion is provided, and greater detail will be found in accounts of particular soil types. Four main vegetal types can be distinguished:

(a) Fern-dominated treed savana. Ferns (Pteridium equisetum and Dicranopteris linearis) form the dominant ground cover, while Casuarina equisetifolia and Pandanus odorentissimus constitute the tree stratum. This formation is very widespread on the hills and on the plateau areas.

(b) Forest. Found on the hill summits, and in the heads of certain valleys.

(c) Reed-dominated savanna, with few trees. The reed-grass Miscanthus floridulus dominates this formation, ecnountered on steep slopes, and in areas of brown soils.

(d) Cyperacous bush. Encountered in the valleys on hydromorphic soils.

Climatology Twyford and Wright give the annual mean for Lakeba as 1890 mm. Only few data are available for temperature, but the regional mean for Fiji (approx. 77°F, with a seasonal range of 10° to 14°F) may be used. Relative humidity is high, of the order of 80% and 95% as extreme values, varying between seasons and between places. The following are monthly means for 22 years for Lakeba, from Twyford and Wright (1965):

	mm
January	228
February	203
March	247
April	210
May	159
June	101
July	88
August	114
September	98
October	117
November	167
December	159

There is no strongly marked dry season, but there is a notable diminution of rainfall between June and October. Droughts occur mainly in the latter season.

Land utilization Four main types may be noted in this preliminary report (much fuller accounts being available from other members of the project):

(a) food-crop cultivation in the valleys (wet and dry taro).

(b) food-crop cultivation and coconuts on the lower slopes of the reed-dominated savanna, and on the colluvial areas.

(c) coconuts with livestock on recent alluvial soils, the livestock being continuous or seasonal according to water-table fluctuations.

(d) reafforestation with Pinus Caribbea in the western part of the island. There are very few cultivated patches on the fern-dominated savanna.

2. The Soils of Lakeba

Available working materials

- Geological sketch at 1/10,000
- Aerial photograph at 1/12,500
- Draft map at 1/12,500 (watercourses, contours at 10 metres)
- Draft map at 1/25,000 (as above)

In this second section, an account is given of the different soil types encountered. For each we describe its topographic and geomorphological relationships, its principal morphological characteristics as determined in the field, and lastly its classification in the French and FAO systems. The relationships of these soil types to those identified in the Twyford and Wright survey will not be discussed here. The results of

analyses may demand certain modifications, and hence this aspect is deferred to the final report. We discuss in turn:

- soils derived from volcanic rocks
- soils derived from limestones
- alluvial soils

Soils dervied from volcanic rocks (a) Ferralitic soils, weakly or moderately leached, rejuvenated, characteristic of hilltops on andesite (C.P.C.S.); HUMIC CAMBISOLS on hill summits on andesite (F.A.O.).

These soils are encountered on the generally rounded summits of the hills. They also occur on the upper slopes before giving place lower down either to brown soils on steep slopes where the main vegetation is reeds, or to other ferralitic soils on andesites, on gentler slopes where there is no change in vegetation. They are covered by a more or less treed savanna with numerous Casuarina and Pandanus; the density of the ground stratum varies from one summit to another, characterised by ferns (Pteridium and Dichronopteris) and some scattered reeds (Miscanthus floridulus). In certain cases a secondary forest has developed on the summits.

The soil profile is of type A1-B-BC. The A horizon is generally organic, dark brown, clayey, with always a fine to average blocky structure. Friable and porous. In different observations, depth varies between 10 and 20cm. Many roots.

Below is a B horizon, brown in colour, often with a thin density of andesite stones and gravels: Clayey. Consistently a fine blocky-structure. Porous and friable. Roots. Depth from 10 to 30cm.

Finally is a BC horizon, more reddish in colour and always of fine texture. Structure continues that of the underlying rock. Low porosity. Friable. Some roots. This horizon is between 30 and 50cm in depth. These soils are small in area, and not always easily represented even on a scale of 1/12,500. However, they have been represented wherever possible, since these small sites are often utilized for dry taro cultivation, and other subsistence crops.

(b) Ferralitic soils, heavily leached, rejuvenated with abundant evidence of erosion, on andesite slopes and hills (C.P.C.S.) FERRALITIC CAMBISOLS on andesite hills (F.A.O.).

Together with the brown soils which we discuss below, the area occupied by these soils covers the larger part of the island. In the west they occupy the whole hillslope area, while in other areas they are found intermingled with brown soils, which are confined to the steep slopes. Erosion is almost universal on this soil type. It takes the form both of sheet erosion, with formation of a staircase landform, and also of gullies and ravines, which can sometimes coalesce into 'badlands' by regressive development. The erosion seems to be due both to the physical characteristics of the soil itself, and also to the

very sparse vegetation cover. Examples are easy to find: for example along the right-hand side of the road linking the airfield to the circum-island road, or on the slopes of hills rising to the small plateau dominating the airfield where an area of 'badlands' has developed. Even at this stage it seems certain that Pinus Caribbea plantations can only have a beneficial effect in stabilizing such soils.

Vegetation is a treed savanna of variable density, with numerous Casuarinas and a ground stratum partly formed of ferns, which provide a poor soil cover.

The soil profile is of type AB-B-C, or sometimes A1-B-C. Generally, the A horizon is shallow (less than 10cm), often having been truncated by erosion so that only a little-humified AB horizon remains. The texture ranges from silty-clay to clay; structure is very weak. This horizon is, however, porous, friable and roots are quite numerous. This is succeeded by a B horizon, often shallow but on gentle slopes attaining a depth of as much as 30 to 40cm. Rock fragments, of andesite, are often encountered. Texture is clay to clay-silt and structure is weak. Some roots.

Finally the soil passes into weathered andesite, brightly coloured red, yellow and violet. Onion-skin rock balls of 50 to 100cm diameter. Even though the physical and chemical properties of these soils seem average to good, the first need is clearly to fix the soils, so as to arrest erosion where it is already active, or to prevent it where it has just begun or is still absent. The afforestation with Pinus Caribbea already begun seems very essential not only to fix the soils, but also to ameliorate them by preventing the annual passage of fires. M. Latham's observations confirm this view.

(c) Ferralitic soils, heavily leached, clay impoverished, characteristic of the plateau areas on andesite (CPCS); RHODIC FERRALSOL on andesite, plateau situation (FAO).

The soil type is encountered on small level surfaces, plateau areas, situated around 100m altitude. These areas are always distinct, and easily identifiable on air photographs, but their location does not show any clear regularity; in general they are around the periphery of the central massif.

Vegetation is of variable density from place to place, especially the ground stratum; however the floristic composition is very similar to that of the soil types described above. Small areas have been planted with Pinus Caribbea.

Soils are always deep, and the parent rock, or even traces of the parent rock, is only encountered at a depth of about 2 metres. The topographic position has clearly played an important role in the formation of these soils; weathering has been able to penetrate deeply and the soils have not been truncated by erosion. Hence we have a profile of type A1-B1-B2 with fairly deep penetration of organic matter.

- A1 horizon, average depth 10 to 15cm, dark red, humified, sand-clay texture, weak structure. Friable, porous, permeable, with many roots.

- B1 horizon, also humified, dark red, with small ferruginous rock fragments. Sandy clay to sandy. Structure weakly, blocky to particular. Friable, very porous; fine roots. Thickness on average 30cm.

- Below this is a B21 horizon. Clayey; weakly structured subangular blocky. Friable. Poor porosity. Small black granules, most probably manganese.

- Finally a deep B22 horizon, clayey, more strongly structured than the overlying horizons. Friable, poor porosity. No roots.

It is not possible to offer a positive opinion concerning the utilization of these soils in the absence of data on their physical and chemical properties. The only advice than can be offered at this stage is continuation of the pine planting; a study of one site under two-year old pines indicates that these have a beneficial action on the structure of the A1 horizon.

(d) Brownish soils, brown eutrophic tropical in type, immature characteristic of steep slopes on andesite (CPCS); HUMIC CAMBISOLS on steep slopes in andesite (FAO).

These soils are characteristic of steep hillslopes over most of the island, with the exception of the western side where we do not find them. As we noted above, these soils are found in close association with the rejuvenated ferralitic soils of the gentler slopes around them; vegetation on these soils is totally different from that on the soil types described above. There is savanna with few trees, with a dense ground stratum composed of reeds (Miscanthus floridulus - GASAU) 2 or 3 metres tall. This sharp vegetation contrast facilitates the delimitation of these soils from aerial photographs. Essentially, the reed-savanna with few trees form a scatter of patches among the much larger areas covered by the Casuarina/Pandanus savanna which occupies the larger part of the rejuventated ferralitic soils on andesite (the TALASIGA soils of Twyford and Wright). This distinction is easily recognisable on aerial photographs, and is important; without it, separation of these two soil types would have been very difficult except where they have actually been recognised in soil pits. The profile is of type A1 (B) - (B)C:

- A1 horizon, humified, variable depth between 7 and 25cm, clayey, well structured in fine to medium blocky form. Porous. Friable. Very numerous roots.

- (B) horizon, with fragments and pebbles of andesite; clay-sand; well structured, medium to fine blocky in form. Very porous; friable; depth ranging from 15 to 35cm.

- (B)C horizon, with large areas of weathered parent rock, and numerous stones.

It would seem that the coconut groves (which extend up the hillslopes) and the food-crop gardens established on the lower reaches of these same slopes are all on such soils; the physical qualities of the soils, as observed on the ground, seem to be satisfactory. As observed in other countries, such soils generally have good chemical properties with a sufficient reserve of elements usable by cultivated plants. It therefore seems probable that these soils are capable of fuller exploitation, given adequate attention to preservation of the vegetation cover, by fallowing, in order to prevent erosion.

(e) Ferralitic soils, more or less leached, humified, formed on redeposited colluvial andesitic material, at the foot of the slopes (CPCS): HUMIC FERRALSOLS on andesitic colluvium, at the foot of the slopes (FAO).

These soils are developed at the bottom of hillslopes on material derived from the andesites. The areas are very small, and it is often not possible to map them even on the 1/12,500 scale. However, given that these soils are generally utilized, and are capable of cultivation given their physical qualities and ease of access, we are seeking to represent them on the map wherever this is possible.

These soils are related to the adjacent soil types: to the brown soils of the steep slopes; to the rejuvenated ferralitic soils on andesite; in some cases also to the sandy or clayey recent alluvial soils located along the sea coast.

Natural vegetation is often difficult to find. Much the greater part of the area occupied by this soil type is under coconuts, with a dense ground stratum covering the soil well. However there remain some trees within the coconut groves.

The soil profile is of type A-B-BC. Soils are in general deep, but there is significant variation in the depth of horizons:

- humified horizons, A1 to A3, are encountered in numerous profiles and have together a depth of from 30 to 40cm. The A1 horizon is generally 10 to 15cm deep. They are clayey, well structured of medium blocky form, sometimes of large blocky form. Porous. Friable to coherent. Very numerous roots.

- a deep B horizon, 50 to 100cm in depth. Clayey, with weak to strong structure, medium to large blocky in form; generally friable and porous. Notable are the universal clay coverings in the pores and on the aggregations. Again numerous fine to medium-sized roots.

- finally a transitional horizon to weathered parent material, BC, always deep, with large areas of altered parent material and andesite fragments. Texture is clay-silt to clay. Structure is weak. Poor porosity. Clay covering present as in the B horizon.

These soils are already well utilised; there are extensive coconut groves and areas of food-crop cultivation. Given their proximity to the villages and easy access, these areas seem likely to be used more and more in the future.

The presence of a deep humified horizon, and of numerous roots of the natural vegetation, together with the topographic situation, make these soils particularly suitable for food-crop cultivation. It is important to know if such cultivation, even with rotation, will however exhaust the mineral and organic resources of the soils after a certain time. It is not possible to be precise on this topic until analysis results are to hand.

(f) Ferralitic soils, more or less leached, characteristic of redeposited colluvium (CPCS); RHODIC-FERRALSOL on andesite colluvium (FAO).

These soils are of small extent, and were observed only at the foot of the hill above the hanging valley occupied by the airfield. They are found in pockets of varying size, always of considerable depth, confined between spurs on which rejuvenated ferralitic soils on andesite slopes give way to the deep ferralitic soils situated on the small plateau dominating the airfield.

The vegetation is very similar to that of the slope soils, i.e. a more or less treed Casuarina savanna with a very thin and patchy ground stratum. There is abundant evidence of erosion on the slopes.

Soils derived from limestone. As we noted in the introduction, limestones cover only a small part of Lakeba. They are confined mainly to the west coast and the small southern peninsula.

Three soil types have developed on this rock formation. Two are of very small extent while the third is found on the plateaux areas of low altitude which dominate the zones characterised by soils formed from coral-sand alluvium.

Vegetation on the first two types is a secondary forest; these are mineral soils associated with the brown soils of steep slopes. Vegetation on the third soil type is a more or less treed savanna of Pandanus and Casuarina, with ferns dominating the ground stratum and only few reeds. These areas are used for pine and coconut plantations. Because of its relatively large area, we describe this soil type in greater detail.

(a) Ferralitic soils, more or less leached, clay impoverished, characteristic of limestone plateau situations (CPCS); HUMIC FERRALSOLS on limestone plateaux (FAO).

The plateaus on which these soils are found lie along the west coast, where the soils lie adjacent to the hills. Soils derived from andesites (ferralitic soils) rejuvenated, essentially characteristic of slopes. These are deep soils, with a profile similar to that of the characteristically improverished ferralitic soils derived from andesites. The profile is of type

A1-A3-B2. However, morphological studies made in the field suggest that the organic matter content is higher in soils derived from limestone than from andesite. The sequence is as follows:

- A1 horizon from 10 to 15cm deep, sandy-clay, weakly structured of medium subangular polyhedric form. Permeable; friable; numerous roots.

- A3 horizon, more or less humified, without any coarse material, sandy-clay to clay, weakly structured, normally of subangular blocky form associated with a particular structure. Permeable, friable, porous. In different observations, depth ranges from 15 to 40cm.

- B horizon, thick, dark red, no large fragments, clayey, weakly structured of large blocky form. Friable; porous.

The topography of such soils is either planar, or only slightly undulating. Their extent is not negligible, and they are also characterised by fairly deep penetration of organic matter (generally to 40cm). The modification of texture between the A1 and A3 horizons, due to a diminution in the clay content, does not seem to constitute any obstacle to agricultural utilization. However, the structure is not very favourable, and might possibly be destroyed under intensive cultivation. At present some areas have been planted with pines, especially near the airfield. It seems that coconuts grow well. But without analytical data on the chemical characteristics of these soils it is difficult to be more precise about the possibilities of more extended utilization.

The alluvial soils. Among the alluvial soils, a clear distinction needs to be drawn between the non-hydromorphic and the hydromorphic sub-groups. In the first, we have soils developed on clayey alluvium and on sandy alluvium. Among the second sub-group we distinguish organic soils, partially organic soils, mineral soils and finally mangrove soils.

Non-hydromorphic alluvial soils. There are two distinct zones here. One, which extends along half the north coast, the west coast and a part of the south coast, is formed on sandy alluvium of marine origin. The other is formed on clayey alluvium, and occurs on the east coast and especially in the mouths of the Yadrana and Nukunuku valleys, and south of Waci-Waci.

(a) Immature soils, non-climatic in origin, carried on sandy marine alluvium (CPCS): CALCARIC FLUVISOLS on sandy marine alluvium (FAO).

These soils are encountered all along the shore on the three coasts listed above. For the most part they are under coconuts. The limit between these soils and the colluvial soils derived from andesites is often hard to establish, both because of some cloud shadows on the aerial photographs, and also the very faint break of slope encountered in certain places - for

example between Vakano and Nasaqalau.

The profile is of Type A1-A3-C. The whole soil is sandy in texture, and the difference between horizons is due solely to penetration of organic matter which gives a colour range from brown-black (A1) to dark grey (A3). Structure is weak, granular to particular in the A1 horizon, fine blocky to particular form in the A3. These are very porous soils, of filtering action, and their cohesion ranges from very weak to nil, notably in the C horizon.

Generally, the organic matter penetrates to a depth of over 30cm before pure grey sand with shells is encountered. These soils are very suitable for coconuts, but should not be put under any other form of use, except for certain types of pine and eucalyptus, which are able to maintain their vegetative habit on such soils.

(b) Soils of marine clayey-alluvium; EUTRIC FLUVISOLS (FAO).

These soils bear close relationship to the soils under present mangroves, and most probably are derived from clayey material forming ancient mangroves, subsequently uplifted.

It is often difficult to determine the limit between colluvial and alluvial soils, because of the very slight break of slope in these coastal zones. Another cartographic problem arises in separating these non-hydromorphic soils from the hydromorphic soils found at the lowest levels on the edges of the present mangrove. Villagers have planted coconuts on these soils,and also maintain cattle on them. This is particularly the case in a zone several hundred metres wide in front of Yadrana. For these reasons, it has been necessary to combine the clayey-alluvial soils with the colluvial soils derived from andesite in preliminary mapping. In the final report, after verification on the ground, an attempt will be made to separate these soils, which are of considerable agricultural importance, and describe them in greater detail.

Hydromorphic soils. The area occupied by these soils is quite small, but they are often used, especially for irrigated taro. They have a very special significance from an agricultural point of view. They occur in a number of valleys between Tubou and Yadrana.

(a) Hydromorphic soils, organic, semi-fibrous, oligotrophic, on marine alluvium (CPCS); DISTRIC HISTOSOLS (FAO).

The main areas of this soil type are at the mouth of the Tubou-Levuka valley. To a depth of one metre, the profile is formed exclusively of organic matter, partly decomposed, with total absence of mineral elements. These latter, of fine texture, are encountered between 100cm and 280cm; they are sands containing numerous shells of all kinds, which increase in number with depth.

The entire profile is very wet, and the top 30cm are permanently saturated in spite of the fact that the water table may be at a lower level. Such soils are no longer used, and in the present state of decomposition of organic matter it would seem very difficult to bring them into use, even with a system of drainage; the absence of mineral matter suggests a serious disequilibrium in elements assimilable by plants.

(b) Hydromorphic soils, moderately organic, with acid humus on colluvio-alluvium (CPCS): HUMIC GLEYSOLS (FAO).

This soil type is encountered in the bottom of the Tubou valley, between hills on which are developed Humic Ferralsols on andesite colluvium, and Humic Cambisols on steep slopes in andesite. The secondary vegetation that arises is a thick, low bush, with ferns, convolvulus and cyperaceous plants. After drainage, these soils are used for irrigated taro cultivation.

The profile is formed of an A1 horizon (above water table), of partially fresh organic matter, silty in texture, granular in structure which is very weak. Below this is a gley horizon, bluish-grey in colour, clay-silt texture, and showing very many traces of hydromorphism; some andesite pebbles are encountered, and make it possible to determine the origin of colluvial and alluvial infilling material. Structure is quite strong, medium blocky in form; there are numerous very fine live roots. Finally, below 100-120cm the parent material is encountered, silty-clay in texture, marked with traces of vivid colour.

The use of these soils after drainage is easily explained. The organic material is in large measure decomposed, and the mineral elements impart cohesion and structure to the whole. The elements forming these soils are different from those of the organic soils; despite the very close topographic relationship of the two, their evolution and morphology are not identical.

(c) Hydromorphic mineral soil, weakly gleyed, on alluvial clays (CPCS); EUTRIC GLEYSOLS on alluvial clays (FAO).

These soils are encountered in the lower parts of valleys, such as those of Nukunuku and Yadrana. They are found in relation to colluvial soils or non-hydromorphic soils on alluvial clay, at slightly higher elevation. Vegetation is a savanna with very few trees, characterised by the SEKARAWA and the Rhizophora micronata typical of hydromorphic soils. These soils have the following profile:-

- A1 horizon, humiferous, red-brown, clayey, strongly blocky structured of form very fine to granular; porous; permeable; friable; very many roots.

- below this is a horizon with a mixture of orange-red iron hydroxide and deep grey stains (BG. G). Wet, clayey, massively structured, sticky. Some roots penetrate into this horizon.

- finally is a gley horizon (BG) wet, dark brown in colour, clayey; massively structured, very sticky, plastic. The water table is reached at 70cm.

Our information suggests that the water table fluctuates seasonally and that these areas may sometimes be submerged for varying periods of time. Certainly the water table may rise very close to the surface. Given good physical and chemical qualities, these soils are probably suitable for irrigated taro cultivation, at least over small areas with sufficient drainage to avoid soil-saturation when the level of the water table rises very close to the surface. An examination of these water table fluctuations would probably assist in establishing the scale of drainage required.

3. Conclusions

This first report on the soils of Lakeba has three principal objectives;

(a) to present an inventory of the soil-types present,

(b) to give a more precise impression of their distribution than is possible from the Twyford and Wright map, which is on a smaller scale, and

(c) to correlate the French and FAO classifications in order to facilitate relationships with maps made by other pedologists and agronomists.

This first mission has made possible an understanding of the importance of topography in soil distribution; a more precise account will be presented in the final report with the aid of certain representative soil-successions. The classification itself will also be made more exact once the results of physical and chemical analysis are available; it should be remarked that in the FAO-UNESCO classification some of the differentiations between diagnostic horizons call for statistical data. In the final report, we will also present correlation between the French (CPCS), FAO and UNESCO and Twyford and Wright classifications, in order to relate the work done by Twyford and Wright to our own. Analysis results will also make it possible to present the characteristics of each soil in precise terms, and will make possible corresponding information on their agronomic value. The second mission was carried out in January-February 1976. Physical and chemical measures carried out in the field, or to be undertaken in the laboratory, will permit the measurement of changes in the soil which result from cultivation; the soils chosen for this purpose are those mainly under food crops. During the second mission the soil map was verified in the field.

The mission of M. Latham (February-March) has been concerned with the problem of the Talasiga soils (FERRALITIC CAMBISOLS on andesite hills), and also with the effect of pine plantation in fixing and eventually ameliorating these soils. Physical and chemical measures were carried out of the same type as those undertaken on soils used for food-crop cultivation.

TAVEUNI

1. General Remarks

Taveuni is the third largest island in Fiji. It is situated directly on the 180th meridian and lies between latitudes of 16°40' and 17° south. It is separated by Somosomo strait (9km wide at the narrowest point) from the large island of Vanua Levu. The island is 42km long (26 miles) by 11.5km (7 miles wide): the total area is approximately 430km^2 (168 sq.miles).

Although a detailed geological survey of Taveuni has been carried out, its results have not been published. Only reconnaisance accounts are available. Twyford and Wright (pp.26-7) provide an adequate summary. The island is composed almost entirely of basic volcanic rocks, described by Rickard, (1965, p.20) as 'very young and fresh, highly vesicular, coarse augite-olivine basalts'. The volcanics of the northeastern sector are older, and the country here is quite heavily dissected; elsewhere the slopes approximate closely the natural slopes of the volcanoes, only slightly dissected.

A chain of approximately 120 craters and vents lies along the main axis of the island from SW to NE, and a subsidiary line with 6 major craters parallels this on the eastern side. While the origin of Taveuni may be in the Pliocene, the island is essentially a product of the Pleistocene. The older vents probably ceased activity in the late Pleistocene, but others continued into recent and very recent times (one to four thousand years), producing large areas of pyroclastics - scoria and basic volcanic ash, and vesicular lavas. The south of the island is largely covered by a mantle of volcanic ash, overlying very young basic volcanic rocks. These ash beds have a depth of 1 to 2 metres in the central-south, but diminish to a depth of a few centimetres near the coast. A number of very recent ash cones seems to be the origin of this mantle. Elsewhere, along the high central chain, the recent pyroclastics remained confined to the vicinity of the vents, although soils in this whole area are very deep.

The highest point of the island is the crater ULUIQALAU (1241m), one of the highest mountains in Fiji. A chain of craters with intervening small plateaux at an altitude around or above 1000m extends some 10km northeast from this point, terminating in the caldera-like basin of TAGIMAUCEA Lake. The present survey covered the north and the south of the island, but not the central area lying between a line joining Somosomo (west coast) and Pagai (east coast) on the north, and the Waimaqera-Salialevu road on the south. The two areas have very marked differences in topography and geology. The northern area is formed of older volcanics with little or no ash; the only remaining evidence of recent vulcanism in the soil is provided by residual blocks of scoria and lava which litter the surface and are found in the soil to varying depths. These originate from volcanic cones of the central chain, and are variable in distribution; other than by very meticulous ground survey it is very difficult to determine their pattern of distribution.

The southern area, by contrast, experienced vulcanism to a much later date; the ash mantle, and the alternating bands of lapilli and volcanic sand noted in certain profiles bear clear evidence of recent activity. We also encountered numerous blocks of lava and scoria pebbles, and vesicular lavas, all in much greater density than in the north. On the slopes of the ash cones themselves these unweathered elements are found within the soil, intermingled with ash, but almost never at the surface. On the shield-like slopes between the foot of the recent cones and the coast, by contrast, they litter the surface of the soil almost everywhere. It is, for this reason, much simpler to delimit the distribution of soil types in the south than in the north.

Geomorphologically and topographically there are also very marked contrasts between north and south. In the centre of the island there is a very regular slope from about 700 metres to the coast. Above this, an area of gentler slope separates the steep coastal fall from the more precipitous central chain. As we go northward, the height of the central chain diminishes, and some plateau-like areas emerge, at heights descending northward, to occupy the axis of high ground. Below these we encounter the same steep and regular slopes of the coastal fall as in the central part of the island. Toward the northern point, north of NARATA hill (410m), slopes become gentler.

However, while the upper portions of the eastern and western slopes have the same order of steepness, there are great contrasts in the coastal zone. On the western side the slopes continue uninterrupted to the sea, while in the east there is much more dissection higher up, and along the shore itself are some areas of low topography, such as the area between QELENI village and VUNIVASA estate. The only mangroves encountered on the Taveuni coast are developed here.

In the south of the island three principal zones can be distinguished:-

(a) recent volcanic cones, occuring as isolated hills or as groups of steep sided hills, ranging from 300 to 420m in altitude. The majority lie along the SW-NE axis.

(b) a piedmont zone around these cones, with a mixture of scoria and ash, but without rocks at the surface. Altitude is variable, but extends from the feet of the cones down to about 130-100m. In the extreme south, however, this landform continues to the coast.

(c) around this, beginning about an equal distance from the line of cones on both sides, is a zone of gentler slopes (a little steeper on the eastern side than on the western side), in which the whole surface is littered with volcanic rocks, often in very great density. Rocks are also found in the soil, often in such high density as seemingly to exclude all possibility of cultivation. An attempt to delimit the distribution of rock-density formed part of the work during the second mission.

Forest or traces of forest are found over the entire island, but dense high forest is now confined mainly to the centre of the island, and the whole central part of the eastern coast (RAVILEVU) which is extremely rugged, and uninhabited. Elsewhere we encounter:-

(a) coconut plantations, on estate and Fijian land, extending right around the northern coast and up to an altitude of 150-200m and sometimes higher than this. In the south, where slopes are gentler, coconut planting extends much further inland.

(b) food crop cultivation, extending more and more deeply into the interior to elevations as high as 520m along and beyond new roads.

(c) areas of former clearing, under secondary bush of various ages.

(d) areas under grass, and used for grazing cattle, at the back of large estates in the north and south of the island.

Survey was concentrated on the occupied areas and the adjacent forest margin. There are strong climatic contrasts, as demonstrated by the following table derived from Twyford and Wright.

Stations	Alt.	Situa.	No. Yrs.	J	F	M	A	M	J	Jl	A	S	O	N	D	Total
SALIALEVU	100 feet = 30m	Zone South and East Coast	33	401	474	437	521	587	483	386	400	517	539	488	485	5720
VUNA POINT	25 feet = 8m	Zone South and West Coast	35	327	341	302	311	272	183	183	185	195	275	230	315	3119
WAIYEVO	175 feet = 53m	Zone North and West Coast	49	294	312	300	277	221	129	80	113	122	179	212	278	2517
MUA	175 feet = 53m	Zone North and West Coast	35	311	355	335	335	256	138	115	143	153	191	254	315	2900

Table: Rainfall at some Taveuni stations (in mm).
(for Twyford, Wright 1965).

It is clear that:-

(a) there is no marked dry season

(b) there is, however, a notable reduction in mean rainfall in the June-September period on the western coast, and down the full length of this coast

(c) the contrast between the east and west coasts in total rainfall is very great: thus SALIALEVU has double the rainfall of VUNA POINT.

Available working materials

- published topographic map, contoured at 50 ft. (15.24m) intervals (Vanua Levu, sheets 15 and 16).
- aerial photography at 12,000ft (3650m) for 1967,
- geological work done but not published.

2. The Soils of Taveuni

In this preliminary report, we present a soil classification, using first field and analytical records, the major characteristics of each main soil group and their land uses. Some modifications may occur in the final report when the analyses will be completed.

Classification. As for Lakeba, FAO-UNESCO legend (1968-1974) will be taken as reference. It is shown in parallel with the French classification and Twyford and Wright in a following table. Two points will be developed:

- the choice of the Andosols as a major group,
- definition of the lower units.

(a) Choice of the Andosol great group. From a morphological point of view we have found some diagnostic characteristics, already observed in other recent volcanic areas. They concern mainly the B layer and are:

- a weak structure and cohesion of this horizon which forms a continuous and fragmented mass;
- a strong and very fine porosity;
- a smeary touch giving the appearance of a loamy texture;
- aggregation very poorly developed.

In order to confirm these observations, we carried out the Fieldes and Perrot (1966) test which permits one to identify the presence of Allophane*, a clay characteristic of andosols. It emerged that, while all soils in the south gave a strong positive reaction, results among the northern soils were variable, but almost never negative.

Taking geological, climatic and morphological considerations into account, it seems certain that the majority of Taveuni soils are in the Andosols or at least that andosolic character must

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X This occurrence is confirmed by mineralogical analysis carried out by Twyford and Wright in 1959 in New Zealand.

occupy a relatively high level in the classification. However the physical and chemical analysis will allow us to go further into details in this classification. These soils are characterised by:

- a thick, well structured, humiferous horizon;
- a high organic matter level;

which set them into two first subdivisions of the Andosols, the MOLLIC and the HUMIC. The separation between Mollic and Humic Andosols rests on base saturation criteria, above or below 50%. According to the analytical records we obtained, we thought that the shallower soils could be saturated and so Mollic or Humic. The thicker and more weathered ones should be desaturated and so Humic.

(b) Definition of lower units. The major divisions of the FAO legend are of very little use in representing the differences in the soils of this island. So we used the lower division; the textural and the slope classes and the phases.

For the textural classes we took into account the presence of gravels in some soils, made of lapilli, so as to distinguish them from the fine textured soil form on basaltic flows.

The slope classes permitted us to distinguish level to gently undulating, rolling to hilly and strongly dissected to mountainous landscapes.

Distinctions were also made between a deep phase, a petric phase (soils showing the occurence of hard rock in the first 50cm) and stony phase (soils having big blocks of rocks in the profile and mostly up to the surface).

(c) Key for the soils of Taveuni.

Mollic or Humic Andosols.

- Coarse textured, rolling to hilly, on lapilli.
- Fine textured, steeply dissected, petric phase, on basaltic flows.
- Fine textured, gently undulating, deep phase, on basaltic flows.

Humic Andosols.

- Fine textured, steeply dissected, deep phase on lapilli.
- Fine textured, rolling to hilly, deep phase, on lapilli and basaltic flows.
- Fine textured, rolling to hilly, deep phase, on basaltic flows.
- Fine textured, rolling to hilly, petric phase, on basaltic flows.
- Fine textured, rolling to hilly, stony phase, on basaltic flows.
- Fine textured, gently undulating, stony phase, on basaltic flows.

(d) Correlation between the FAO legend and the French classification and the Twyford and Wright legend.

FAO-UNESCO Legend	French Classification	Twyford and Wright Legend
1. MOLLIC or HUMIC ANDOSOLS Coarse textured rolling to hilly on lapilli	ANDOSOLS, peu différenciés humiques, sur lapilli, de pentes et glacis de cones volcaniques	LATOSOLIC SOILS, without dry season, steep land or silt loam.
2. MOLLIC or HUMIC ANDOSOLS fine textured steeply dissected petric phase on basaltic flows	ANDOSOLS, peu différenciés, humiques, sur coulees basaltiques, de pentes de collines	LATOSOLIC SOILS, with weak dry season, steep land
3. MOLLIC or HUMIC ANDOSOLS fine textured gentle undulating deep phase on basaltic flows	ANDOSOLS, différenciés, saturés, chromiques, sur coulées basaltiques de zones peu vallonnées sans éléments grossiers	LATOSOLIC SOILS, with weak dry season, silt loam, and recent soils
4. HUMIC ANDOSOLS fine textured steeply dissected deep phase on lapilli	ANDOSOLS, différenciés, désaturés, chromiques, sur lapillis de pentes de cones volcaniques	LATOSOLIC SOILS, without dry season, steep land
5. HUMIC ANDOSOLS fine textured rolling to hilly deep phase on lapillis and basaltic flows	ANDOSOLS, différenciés désaturés, chromiques sur lapillis et coulées basaltiques, de zones peu vallonnées	LATOSOLIC SOILS, without dry season, steep land and with weak dry season
6. HUMIC ANDOSOLS fine textured rolling to hilly deep phase on basaltic flows	ANDOSOLS, différenciés, désaturés, chromiques, sur coulées basaltiques, de pentes de collines. sans éléments grossiers.	LATOSOLIC SOILS, with weak dry season, steep land
7. HUMIC ANDOSOLS fine textured rolling to hilly petric phase, on basaltic flows	ANDOSOLS, différenciés, désaturés chromiques, sur coulées basaltiques, de pentes de collines, avec éléments grossiers (inferieur a 30%).	LATOSOLIC SOILS, without dry season, steep land
8. HUMIC ANDOSOLS fine textured rolling to hilly, stony phase, on basaltic flows	ANDOSOLS, différenciés, désaturés, chromiques, sur coulées basaltiques de pentes de collines, avec éléments grossiers abondants des la surface	LATOSOLIC SOILS, with weak dry season, silt loam
9. HUMIC ANDOSOLS fine textured gentle undulating stony phase on basaltic flows	ANDOSOLS, différenciés, désaturés, chromiques, sur coulées basaltiques, de zones peu vallonnées, avec éléments grossiers abondants.	LATOSOLIC SOILS, without dry season, (middle north and East coast in south) With dry season (West coast in south).

Soil Distribution. Except for some very restricted areas of the sandy coastal plain and the mangrove, soils of Taveuni derive from volcanic material. Some places, especially in the south, are covered with a thick lapilli layer.

In the following section, the approximate localisation and extension of every soil are given. These often show some difficulties because the phases are distributed in a very heterogeneous way in the field and in the soil profile.

These characteristics do not seem to be linked to a topographical pattern but more to the recent volcanic activity. However, as we have not been able to consult the most recent geological studies, the soil boundaries are sometimes rather imprecise.

Description of the major soils. (a) Mollic and Humic Andosols, coarse textured, rolling to hilly, on lapilli.

They are mainly located on the southern part of the island, on slopes of recent volcanoes (1,000 to 4,000 years) and on some of their piedmonts. The original material is lapilli. These are unconsolidated rock made of gravel size elements. Natural vegetation is a dense forest. It has been cleared in many places for coconut plantation or gardens. Soils are normally shallow and are characterised by A-AC-C profile with:

- an A humiferous, loamy, well structured horizon of about 20cms;
- an AC, still humiferous, gravelly, poorly structured, very permeable horizon of 20 to 60 cms;
- a C, unstructured horizon, made of lapilli gravels.

As for similar New Hebridian soils, these seem well drained and resistant to erosion. Their water retention capacity is good despite the youth of the soil. From a chemical point of view, these soils look rich.

The deeper soils can be planted with arborescent crops such as coconut and the shallower ones with field crops such as yaqona, taro, cassava and kumala. Special attention will have to be given to these latter so as to prevent the exhaustion of the soils when they are under continous cultivation without fertilisers. On the steeper slopes erosion danger must be taken into account.

(b) Mollic or Humic Andosols, fine textured, petric phase, on basaltic flows.

Very few profiles of this type have been seen. They are located on steep slopes on the coastal plain in the southern part of the north zone. Natural vegetation is a secondary forest. Boulders may occur at the soil surface. The profile can be characterised by:

- its shallowness (30 to 40cms before reaching weathered rock, in joints;
- a humiferous, fine textured, porous horizon of about 10cms;

- the occurence in the following horizon (10 to 30cms) of coarse fragments, stones and gravels more or less weathered.

From a utilisation point of view, the major handicap is the generally steep slope and the presence of boulders from place to place. The weathered coarse rock fragments which occur in the profiles do not seem to be a constraint on root crops which do not penetrate too deeply. Coconut trees are sometimes also planted on these soils.

(c) Mollic or Humic Andosols, fine textured, deep phase, on basaltic flows.

These soils have been observed on the East coast (by Qeleni) and in the extreme north of the island on both sides of the air strip. They cover large areas used mainly for coconut plantation but also for root crops. Mean slopes are about 10% and the landscape is undulating. The soil profile is characterised by:

- a depth of 90 to 130cm before the weathered rock;
- the absence of coarse fragments in the whole soil profile;
- a humiferous penetration of 20 to 30 cms;
- a good general porosity.

The absence of coarse fragments, the depth of the pedon and the topographical situation are very favourable factors for cultivation on these soils. The chemical characteristics should reinforce this first favourable impression.

(d) Humic Andosols, fine textured, deeply dissected, deep phase, on lapilli.

These soils have been observed in juxtaposition with the (a) soil on the upper part of some volcanic hills on slopes of about 50%. Natural vegetation is a secondary forest. A savannah has developed in some cleared areas. They are characterised by:

- the depth of the pedon (deeper than the soils of the 3.1 unit);
- a humiferous, fine textured, porous horizon of about 20cms;
- a poorly structured with friable aggregate, porous underlayer;
- the absence of coarse material in their profiles.

Their use possibilities are similar to those of the (a) soil but they are deeper.

(e) Humic Andosols, fine textured, rolling to hilly, deep phase, on lapilli and basaltic flows.

These soils have been noticed mostly in the south of the island around the volcanic cones. But we have also found some of them in the northern part. On the soil surface, scattered boulders and stones from the basaltic flows may be seen. These soils are already very cultivated either with taro gardens or coconut plantations. The natural vegetation which must have

been forest has disappeared. The soil profile shows:

- a depth of about 80cms without coarse fragments. Under this, a mixture of lapilli and fragments from basaltic flows can be observed;
- a humiferous penetration of 30 to 50cms;
- a good porosity with fine pores;

These soils seem to have a high organic matter level. They are very permeable, very porous and the root penetration can be noticed down to 40cms. Their original material is indicative of a high mineral reserve. Their agricultural possibilities are very wide.

(f) Humic Andosols, fine textured, in rolling to hilly landscapes, deep phase, on basaltic flows.

These soils have been observed in two main zones; one around Qeleni village from Waibula creek near Pagai to the north of Qeleni road; the other one on the west coast in the Nasilasila and Tuvurega estates. Some of the Vione road soils go into this unit. They are located on slopes ranging mainly from 15 to 30% but reaching sometimes 50% near the thalwegs. They are characterised by:

- the absence of coarse fragments in the whole profile;
- a humiferous, well structured, porous, permeable horizon of 15 to 20cms;
- a B, fine textured, with friable, very porous underlayer;

From an agronomic point of view, the restricting factor for this unit would be mainly the slope. Actually this does not seem likely to embarrass the users who plant taro gardens even on the steeper slopes. The soil preparation and the cultivation can only be manual and no signs of erosion have been seen. The vegetative state of plants appears very good and the yields obtained high according to informants. In the second mission, not reported here, we have investigated a possible depressive effect on the soil mineral reserve and on the physical state after years of continuous cultivation.

(g) Humic Andosols; fine textured, on rolling to hilly landscapes, petric phase, on basaltic flows.

They are located in the centre and the west coast of the northern part of the island. They cover an area limited by Qila road, Nasarata (Vione) road and the northern part of the Lagiloa plateau. In the south of the island they can be seen on undulating areas which extend by the volcanic cones.

They are very similar to the previous one; the main difference lies in the occurence of coarse material from basaltic flows under 30 to 40cms;. However these fragments represent rarely more than 30% of the soil volume.

This characteristic presents rather few constraints for the development of these lands as most of it must be cultivated manually because of the slope.

(h) Humic Andosols, fine textured, on rolling to hilly landscapes, stony phase, on basaltic flows.

These soils can be seen on hillslopes and are located in the northern part of the island at two major points:

- one on an area limited by the northern boundary of the Lagiloa plateau, the Nakaute creek on the east coast and the Nasilasila (Mua) estate on the west coast. It is surrounded by three zones without coarse material in the entire soil profile.
- a second area has been observed by Welagi village, including Nambeka estate on the west coast.

Their altitude ranges from 400 metres to sea level. Slopes vary between 10 and 25%. In most cases boulders can be observed on the soil surface. Their density is variable but always very high. The soil profile is characterised by:

- the occurence of coarse fragments, mostly of stone size (2 to 20cms) in the whole profile. Their concentration is very important, generally more than 50% in volume.
- a humiferous, fine textured, well structured, horizon of 15 to 20 cms. The coarse fragment percentage in this layer is at least 25%.
- a B horizon, well rooted in spite of the coarse fragment richness. This layer is highly porous with fine to very fine pores.

From a land development point of view, the major constraint for these soils is the high coarse material percentage, that occurs in the superficial layer as well as in the whole profile. This prevents any mechanical cultivation and restrains also manual cultivation in view of the enormous work demanded in land preparation. Only some soils, which have a coarse material percentage of less than 25%, can be used for field crops, if they are accessible and if their other characteristics are fair. Some coconut plantations can be seen but few field crops. At present, it seems better to leave these soils covered with the natural vegetation as there are plenty of other unused soils with little or no coarse material in them.

(i) Humic Andosols, fine textured, on gentle undulating landscapes, stony phase, on basaltic flows.

We have observed these soils in the north of the island on an undulating area above Qeleni road under secondary forest and in the south of the island on large undulating zones, on the west coast (Vuna Point) and on the east coast (Salialevu). These two places are almost entirely occupied by coconut plantations.

Soils have the same characteristics as the previous one except the topographical location.

This favourable location does not allow field crop cultivation because of the high coarse material level. But the cattle breeding under coconut trees are of a very high economic interest and could be expanded. This ultilisation may increase the sinking of the upper layer and so restrict the macroporosity.

Soil utilisation possibilities. As a summary of the remarks given for each soil unit, we have drawn up a table showing the soil utilisation possibilities of both parts of Taveuni. Agological value allows us to give a first approximation on the soil value. It is chiefly made on morphological and topographical criteria at the present stage.

The following table gives only indications and is only related to present crops cultivated in Taveuni. In the final report we shall try to suggest other crops which could fit into these ecological conditions.

3. Conclusions

It must be stressed again that the work reported here is only preliminary, and that the aim of this report is simply to give an account of the principal elements of the soils of Lakeba and Taveuni. The final report will take account of subsequent work, including:

(a) verification during the second mission (Jan-Feb 1976), especially on the delimitation of soil types on the map.

(b) analytical results, both physical and chemical. These will not only permit refinement of the classification, but will also provide an indication of the agronomic qualities of the soils, yielding numerical data which will be interpreted in relation to morphological and topographic criteria, and also to the present agricultural use of the soils.

For each island, this final report will be accompanied by a soil map, a map of land-use potential, and diagrams to facilitate understanding of the distribution of soil types.

However, the principal aim of the second mission was to study the evolution of soils under cultivation. Measures in the field, and samples for subsequent laboratory analysis, were taken at parallel sites, so far as possible identical in terms of soil type and topography, but representing cultivated and uncultivated plots. The location of these sites followed the earlier selection by Haynes and Brookfield of sites for the measurement of taro yields (October 1975 and January 1976). It will therefore be possible to compare sites on the basis of soil evolution under cultivation, given a comprehensive backgroun of data on recent land-use history and present productivity. All this work, however, will be separately reported.

SOIL UTILISATION POSSIBILITIES

Agological Value	Soils	Topographic Criteria	Morphological Critera	Major Constraints	Utilisation Present	Utilisation Suggested
Very good	C and E	Soil C: Slopes average 10%. Soil E: Slopes from 10 to 25%.	Deep soils. Sparse coarse fragments. none in top 80cm of profile. Humiferous penetration 20 to 35cm. Structure: good, porosity: good.	Nil	Coconuts Taro Yaqona Cassava	Best to retain food crops in these areas. Avoid soil exhaustion by use of fallow rotation.
Medium	A	Medium slope usually about 10% (base of hills and undulating zones), but in places up to 50%.	Depth varies, with topography. About 35cm as pedon. Humiferous, well structured, porous horizon.	Some steep slopes. Good structure only in upper layer.	Coconuts on steeper slopes. Taro, Yaqona, Cassava, Sweet potatoes in undulating zones.	Avoid steep slopes; fallow rotation desirable.
Good	F and G	Hillslope areas. Usually 15 to 30% but steepening to 50% on slopes of thalwegs.	Deep soils belonging to unit 7. Coarse material less than 30% of whole column. Humiferous, well structured, A horizon.	Some steep slopes.	Some coconuts but mainly gardens planted after clearing secondary forest.	Fallow rotation desirable; avoid steep slopes.
Weak	B and D	Steep slopes (above 30%)	Shallow (soil D) to medium depth (soil B) soils. Humiferous, porous, A horizon. Sometimes coarse fragments on surface (soil B).	Steep slopes. Inaccessibility.	Soil D: food crops. Soil B: sparse coconuts.	Leave natural vegetation undisturbed.
Bad	H and I	80% of area covered by coarse fragments. Soil H: slopes less than 10%. Soil I: slopes 15 to 30%.	Coarse fragments account for 50% of soil volume throughout depth of profile. In some locations only 25 to 30% coarse fragments in first 20cm. Humiferous horizon: 15 to 20 cm.	Coarse fragments in profile and on surface.	Coconuts: especially in South of island.	Leave natural vegetation on soils with greater than 25% coarse fragments in first 20cm undisturbed.

Soils A to I refer to soil descriptions (a) to (i) at pages 20 to 23.

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UNESCO/UNFPA PROJECT ON POPULATION AND ENVIRONMENT

IN THE EASTERN ISLANDS OF FIJI

(Man-and-the Biosphere Programme)

PROJECT WORKING PAPER No. 2

THE ECOLOGY OF THE REEF-LAGOON COMPLEX OF SOME ISLANDS IN THE LAU GROUP: PRELIMINARY REPORT

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(Ecole Pratique des Hautes Etudes,
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SYNOPSIS OF CONTENTS

I PLANNING AND EXECUTION

PREPARATION OF THE MISSION

OBJECTIVES OF THE MISSION

PARTICIPANTS IN THE MISSION

RECORD OF THE MISSION
- Preparations in Suva
- Chronological account of the mission
- Islands visited and studied
- Events during the mission

NATURE AND NUMBER OF STUDIES, COLLECTION AND OBSERVATIONS
- Study of Benthos
- Study of Plankton
- List of studies completed

II PRINCIPAL OBSERVATIONS AND PRELIMINARY CONCLUSIONS FOR EACH ISLAND

LAKEBA
- Morphological types
- Benthos
- Fish
- Environment

AIWA
- Benthos
- Fish
- Environment

TAVUNA SICI
- Benthos
- Fish
- Environment

KABARA
- Benthos
- Fish
- Environment

NAMUKA
- Benthos
- Fish
- Environment

YAGASA CLUSTER
- Benthos
- Fish
- Environment

NAVATU REEF
Benthos
Fish
Environment

III TRANSLATOR'S NOTE

MAPS (at end of paper)

1. FIJI, showing the area of research

2. SOUTH-CENTRAL LAU, showing islands visited and dates

3. LAKEBA

4. AIWA

5. KABARA

6. YAGASA CLUSTER

I - PLANNING AND EXECUTION

PREPARATION OF THE MISSION

Following the preliminary mission of B. Salvat from 29 May until 12 June 1975 (unpublished report dated 15 September 1975), a programme for the study of the reef lagoon system of certain islands of the Lau group was developed. This programme formed part of the UNESCO/UNFPA Population and Environment Project and was specified in the project document as sub-project B3: Reef Lagoon Complex.

The proposed programme was discussed in Suva with Dr Brookfield and the Fijian authorities (Ministry of Fijian Affairs and Ministry of Agriculture, Fisheries and Forests) and also at UNESCO in Paris between Salvat and Glaser. The research programme was finally scheduled for the period 15 March to 30 April 1976, with the intention to study the reef lagoon systems of the islands of LAKEBA, AIWA, KABARA and YAGASA, all situated in the south of Lau.

A contract was established between UNESCO (Paris) and the Association Naturalia et Biologia acting on account of Dr Salvat. In this contract it was specified that three reports would be furnished:
a) an account of activities at latest by 15 May 1976,
b) a detailed intermediate report at latest by 15 June 1976,
c) a final report at latest by 31 October 1976.
The present report combines the activities statement and the intermediate report. It was decided in Suva to make this change partly in order to make descriptive results available more quickly, and partly in order to clear our own minds in preparation for writing up the final report.

OBJECTIVES OF THE MISSION

The absence of any scientific work on the reefs and lagoons of the Fijian islands was remarked upon in Salvat's report on his preliminary mission in 1975. This present mission was asked to describe the reef lagoon systems of certain islands in the Lau group, and to indicate their richness or poverty in resources for human use and also their potential for exploitation. Two pairs of islands, in each case comprising one inhabited and one uninhabited island, were chosen. The first pair was formed of a volcanic island surrounded by a barrier reef (Lakeba) and an uplifted limestone island, uninhabited but close enough to Lakeba to be used by the people of Lakeba for fish (Aiwa). The second pair comprised a raised atoll (Kabara, which is inhabited) and the Yagasa Cluster (uninhabited) some way removed from inhabited islands, and reputed to be rich in marine resources. The research method chosen was by transects running from the shore to the ocean, selected after the study of aerial photographs. This made possible a very rapid study of sections of the reef lagoon complex, each relatively homogenous in character. In

addition to these transects various particular habitats were also studied (mangroves, bays, etc). At each site the following studies were pursued:

a) the benthic (bottom-living) fauna and flora;
b) the fish;
c) the plankton, the seston and primary productivity;
d) certain hydrological characteristics of the lagoon and oceanic floor.

PARTICIPANTS IN THE MISSION

There follows a list of names of the principal participants with their official titles, functions, professional addresses and specialities. Two members of the Division of Fisheries, Ministry of Agriculture, Fisheries and Forests, Fiji accompanied the party. These were Mr Surendra SEWAK, Fisheries Officer, and a Field Officer who, in the first part of the mission was Mr Jope KAVOA, and in the second part of the mission Mr Manasa TUIDAMA.

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RECORD OF THE MISSION

Preparations in Suva.

These occupied from 16 - 19 March and proceeded as planned in discussions with the Division of Fisheries (Chief Fisheries Officer, Mr R. Stone), the University of the South Pacific, and other members of the project. As stated in the contract of the mission, the Ecole Pratique des Hautes Etudes supplied all the scientific equipment necessary (Fluorimeter, Secchi Disc, Analyser, etc.) A vessel was provided by the Division of Fisheries (with the basic expenses of the voyage paid by this mission. This was used for inter-island transport and also for quite a significant part of the mission activity, which was based at sea. The Division of Fisheries also provided necessary small material including two boats and three outboard motors, nets, lines, hooks etc. The University of the South Pacific provided some indispensable chemicals, and permitted us to study their biological collections. It was unfortunately not possible to obtain from the University, as earlier anticipated, scuba diving equipment, but this was not of major consequence since the whole plan of the mission was based on the use of equipment of relatively unsophisticated order, so that its methodology could be adapted for use by organizations having only limited resources.

Chronological account of the mission.

In all essentials this followed the predetermined plan. Certain minor modifications were made, including the visit of certain supplementary islands, and changes in date of movement from one island to another. We were transported initially on the 'Dauqoli' (Captain Paula) and later on the 'Gonedau' (Captain Delana). This latter vessel was with us for the whole period we were at Aiwa and Yagasa. Remarkably in the South Pacific, the ships were always available exactly on the pre-determined dates. Very good relations were established with the two captains and crews. It should however be noted that no sleeping berths were available on either vessel for any member of the research team. This made it impossible to base work at sea for any long period and this is the reason why time spent based on shore was greater than had originally been proposed.

Islands visited and studied.

Following the programme the islands of Lakeba, Aiwa, Kabara and Yagasa were the object of study. During our movements around the group we took the opportunity however to visit three other islands: Tavuna Sici to the North of Kabara, Namuka between Kabara and Yagasa, and Navatu Reef between Yagasa and Suva.

These short visits made it possible to obtain a much better impression of the general characteristics of the marine resources of the Lau islands, and also the differences between islands. To our great regret from a scientific point of view it was not possible to visit the island of Vuagava which has an inland lake used for the raising of turtles. This was due to a prohibition on our visiting this island imposed locally without stated reason. This was the only time such a check occurred.

Lakeba	21 March to 5 April)	18 days
	9 to 10 April)	
Aiwa	6 to 8 April)	3 days
Tavuna Sici	Passage on 11 April	
Kabara	12 to 19 April)	8 days
Namuka	Passage on 20-21 April	
Yagasa	22 to 23 April)	2 days
Tavuna Sici	Second passage on 24 April	
Navatu Reef	Passage 24 April	

Events during the Mission.

Three outboard motors and two wooden boats were embarked on board the 'Dauqoli' for our mission. Although these had been put into good order by the Engineer of the Division of Fisheries they quickly gave trouble. For a mission of this nature it is absolutely indispensable to have new or almost new material available. Difficulties which arose, particularly with the outboard motors, caused delays in the programme in the early part of the mission, at Lakeba. Ultimately new motors were provided, one being purchased by the mission and being donated to the Division of Fisheries in lieu of repair costs which otherwise would have been charged to the expedition. It must be recorded however that a certain loss of time was suffered due to these purely logistic and mechanical problems.

Use of time.

March
16 Arrive in Suva.
17 Preparations for the mission: MAFF; UNESCO.
18 Preparations for the mission: MAFF; University of South Pacific.
19 Departure Salvat and Ricard for Lakeba by air. Establishment Lakeba.
20 Departure Dauqoli from Suva to Lakeba (Richard, Galzin, Toffart).
21 Installation at Lakeba, Tubou.
22 Lakeba. Waciwaci.
23 Lakeba. Albert Transect (Reef S.W. of island).
24 Lakeba. Albert Transect.
25 Lakeba. Beatrice Transect (Reef south of Great Lagoon).

26 Lakeba. Nukunuku (Mangrove).
27 Lakeba. Nukunuku.
28 Lakeba. Analysis. Discussion of field notes. Programme for coming week.
29 Lakeba. Nukunuku.
30 Lakeba. Complete Albert Transect.
31 Lakeba. Yadrana hole.

April
1 Lakeba. Waciwaci, Nukunuku, Tubou.
2 Lakeba. Tubou (south of island)
3 Lakeba. Tubou, Celine Transect.
4 Waciwaci.
5 Lakeba. Delphine Transect (East side of great lagoon).
6 Aiwa. Stations and Transects, A, B & C.
7 Aiwa. Stations and Transects, D & E.
8 Aiwa. Stations and Transects, F, G & H.
9 Lakeba. Vakano Transect (North of island).
10 Lakeba. Nasaqalau Transect.
11 Departure for Lakeba and Kabara; stop at Tavuna Sici.
12 Kabara, northeastern sector.
13 Kabara, Stations A, B, C & D (Eastern coast, windward).
14 Kabara, Stations E, F, G & H (Western coast, leeward).
15 Kabara, Stations I, J,K,L,M,N,O & P (East coast).
16 Kabara, Discussion; completion of notes.
17 Kabara, Tokalau and Naikeleyaga.
18 Kabara, Station E (Outer reef west of island; open sea sector).
19 Kabara, Discussion, Preparations for departure.
20 Departure from Kabara for Namuka. Outer reef south of Namuka.
21 Namuka, south coast and bay; departure for Yagasa.
22 Yagasa, Transects A and E, outer reefs on windward side; Stations B, C & D.
23 Yagasa, transect F, outer reefs on leeward side, departure and arrival at Kabara.
24 Departure from Kabara for Suva, with stops at Tavuna Sici and Navatu Reef.
25 Arrive Suva.
26 Cleaning of equipment; Preparation of report; MAFF.
27 Packing of scientific and biological material for despatch; U.S.P.
28 Completion of report.
29 Despatch of scientific and biological material; departure from Suva.

NATURE AND NUMBER OF COLLECTIONS, STUDIES AND OBSERVATIONS

As noted above the Reef complex of each island was studied by transects and by the investigation of certain particular sites for work on the bottom-living life (benthos), while for work on the plankton, a series of collections were made in order to measure the richness of the water in plankton and other primary production.

Study of Benthos.

The transect studies can be grouped into three types:
i) those proceeding from the shore to the outer slope of the reef crossing the reef and lagoon,
ii) those proceeding from the shore of the lagoon across fringing reef,
iii) those limited to the barrier reef, that is to say to the outer section of the coral reef tract only.
The population and the sub-strata were recorded along each transect in order to establish the geomorphological profile and also the biological associations and dominant species. For each island a minimum of two reef-lagoon sectors were studied: one on the windward and one on the leeward side of the island. Particular attention was paid to the following groups: fish, corals, molluscs, algae, and to a secondary degree to the echinoderms and the crustaceans. These latter are of relatively minor importance in the reef-lagoon systems of Fiji. Each transect was chosen to represent a pre-determined segment of the reef-lagoon system. Particular environments studied were mangroves, bays, lagoon basins (holes), transverse lagoon reefs (Kabara), a secondary lagoon (Yagasa).

Study of Plankton.

These studies were both quantitative and qualitative and physico-chemical measures were also taken. Wherever it was possible nets were used in both lagoon and ocean in order to obtain as complete as possible a sample of the phyto-and zoo-plankton, with the object of making systematic lists of species and types. Most of these net collections were made in the ocean because of the difficult topography of the lagoons where a net would rapidly become torn on the coral.

Measures of the chlorophyll and pheophytine content were made in order to evaluate the biomass of phytoplankton. Also the primary production of the system was measured by means of evaluating the carbon dioxide produced by the chlorophyllic vegetation under the action of light and diffused in the water. Pigmentation levels were measured using a Torwer 111 fluorimeter, and primary production measures were made by use of a C^{14} cube in situ. These measures were completed by filtering sea water in order to extract the seston - that is to say the whole body of micro-organisms and mineral particles in suspension in the water. Comparison between the seston and the chlorophyll levels provided an indication of the relationship existing between the mineral mass and the biomass present in the water. Finally, measures of salinity, temperature, dissolved oxygen and turbidity (using a Secchi disc) provided us with certain basic data on the physico-chemical characteristics of the environment.

List of studies completed.

The following table lists the nature and number of collections, studies and observations made at each island. It will be noted that we were able to work more widely than in the original plan of only four islands. For the Benthos (the

	BENTHOS				PLANKTON					
		Number of transects		Stations	Number of collections/observations					
	No of Days	Barrier Reef	Shore to outer slope	Lagoon Shore	C^{14}	Chloropa.	Seston	Net	Secchi	Physico Chemical
LAKEBA	18	2	5	1	13	32	8	9	5	16
AIWA	3	2	-	4	3	5	2	2	2	5
TAVUNA SICT	1	-	1	-	-	5	2	-	1	-
NAMUKA	2	1	-	2	1	5	1	1	-	4
KABARA	8	-	3	-	6	14	1	1	1	8
YAGASA	2	3	-	1	1	8	1	2	1	4
NAVATU REEF	1	1	-	-	-	3	1	1	-	-

Table 1: Nature and Number of Collections and Observations

bottom-living life) 26 transects were studied (nine on the barrier reef, nine complete transects from the shore to the outer slope, nine on the fringing coral formations of the lagoon shore). For the plankton measures 72 chlorophyll and pheophytine measures were taken together with measures of acidification, 16 collections of seston, and 16 net hauls were made to collect zoo-and phyto-plankton, and 24 measures of primary production were made. The hydrological stations, where measures of temperature, dissolved oxygen and salinity were made, numbered 37, and ten observations were made of turbidity using the Secchi disc. The islands most thoroughly studied were those at which we spent the longest time: Lakeba and Kabara.

II - PRINCIPAL OBSERVATIONS AND PRELIMINARY CONCLUSIONS FOR EACH ISLAND

LAKEBA

Lying at latitude 18° 12' south and longitude 178° 47' west, Lakeba island has an almost circular form, diameter varying between 8 and 9.6 km. It is a relatively low volcanic island (maximum altitude 230 metres) surrounded around the western and south coast by uplifted coral limestone. The island is surrounded by a barrier reef which spreads out a considerable distance from the coast on the eastern side enclosing a large lagoon which is relatively deep in its eastern part.

Morphological types.[1]

One can distinguish the following morphological types in the reef-lagoon complex of Lakeba:

(1) The western sector of the lagoon, approximately 600m wide, where we worked along the Albert Transect, is a shallow complex divisible into four zones.

(a) the beach.
(b) eroded coral flagstone with different algal facies close to the shore, then coral colonies further out.
(c) a zone of small coral patches built on the flagstone; these growths anastomose to form small reefs aligned at right angles to the shore.

[1] For translation of terms describing parts of the coral reef tract, I have relied so far as possible on the special supplement of Tethys presenting a comprehensive list of definitions in both French and English (M.Clausade et al, Morphologie des récifs coralliens de la région de Tuléar [Madagascar]: éléménts de terminologie récifale. Tethys, supplément 2, 1971: p.1-76.) I am grateful to Roger McLean for introducing me to this source (Ed.)

(d) a detritic zone of algae of the species Caulerpa and Halimeda.
(e) a zone where the flagstone is eroded into pot holes at the bottom of which sea urchins (Echinometra) nest.
(f) the outer slope with a first terrace at 5 to 7 m, and after a slope of 70°, a second terrace at about 17 m.

(2) The northern sector of the island where the reef lagoon system is dominated by loose sediments covered with sea-grasses and algae, (Transects: Nasaqalau and Vakano).

(3) The south of the island is more open to the ocean as a result of the existence of the harbour entrance at Tubou. Together with the morphology of the island, this provides a sandy bay which is rich in sea-grass.

(4) In front of the villages of Waci waci and Yadrana are two 'holes' or 'enclosed lagoons' about 5-6 m deep, with very turbid water. It seems highly probable that these large basins are the result of karstic erosion during a period of low sea level, or a relative emergence of the island rather than that they arose from enclavement of the areas in the course of reef growth. These specialized environments, specialized from the geomorphological as well as the biological point of view, were studied particularly closely.

(5) The eastern shore of the island is occupied by an extensive area of mangroves which reaches a width of 900 m in front of the village of Nukunuku. Between the Rhizophora the coral flagstone is lightly covered with sediments in most cases, and the sediments themselves colonised by algaes and marine phanerogams. The rarity, almost absence of fine and silty sediments is remarkable, and frequently the mangroves rest directly on the flagstone.

(6) Some distance from the island is the outer reef bounding the great lagoon on the eastern side. This was prospected on the south at Transect Beatrice and the east at Transect Delphine. There is an outer reef flat on the oceanic side lying approximately 20 or 30 cm below water level at low tide, carrying a population of encrusted algae and chlorophyllic plants (Caulerpa). These facies are modified on the inner reef flat by the addition of loose stones and the development of living coral colonies. The inner slope of the reef is relatively rich in coral, falling to a depth of about 4 to 5 m where the sandy inner slope of the lagoon commences. On this inner slope the presence of several coral patches is noteworthy: sometimes their summits reach the surface. This barrier reef and inner slope are quite similar morphologically to Navatu Reef.

(7) The eastern side of the great lagoon was too deep to be studied for Benthos by the means at our disposal.

Benthos.

Lakeba is a relatively diversified complex from the geomorphological point of view. We attempted to select sites within each type and examine them. It is the only island which we studied that has large areas of sea-grass, lagoons occupied entirely by sea-grasses and algae, and also mangrove.

Corals. There was great diversity on Lakeba in the distribution of corals. Although the reefs do not lie close to the coast around much of the island they are nonetheless well developed and form very large fringing reefs in the western sector, with living corals growing on from 5 to 70% of the sub-stratum.

The majority of the coral reefs of Lakeba however are in the form of barrier reefs, extending a considerable distance from the coast to enclose the great eastern lagoon. It is in this eastern zone that the barrier reef is richest, with 20 to 80% of the sub-strata formed of growing corals. On the corresponding coast of the island, mangrove extends over a very poor fringing reef (less than 10% of growing corals) in which the living portion is dominated by the genera Porites and Millepora.

The northern sector of the island is the poorest from the point of view of coral fauna. The sandy platform is almost bare of coralline colonies, living or dead, and one finds living corals only on the outer slope.

The enclosed lagoons at Waciwaci and Yadrana show comparatively poor coral conditions. The only living corals were encountered on the upper slopes of the basins and the percentage of area covered never exceeded 15%. The outer slopes of the reef, where observed, were relatively rich in comparison to the other islands. The percentage of living corals here reaches 70 to 80%. We also note that the madreporic population of Lakeba is very heavily dominated by colonies of the species Acropora. There is great diversity in the distribution of coral colonies and the reefs seem to be relatively rich.

Molluscs. In our studies at Lakeba we collected 210 species
52/ distributed among ~~[illegible]~~ families. The Gastropods Prosobranca dominated very heavily, with 179 species, whereas the Cephalopods and Polyplacophora were almost non-existant. Best represented families were the Mitridae with 27 species (their demographic explosion is very well known in Fiji) then come the Conidae (26) and the Cypraeidae (16) and the Terebridae (16), the Cerithiidae (15) and then the Muricidae (14); these are families with food and habitat needs very different from one another. This fact underlines the great variety of environments, very well colonized by this enormous group of molluscs on Lakeba.

(a) In the west sector (Albert Transect) Cypraea annulus colonizes a good part of the reef flat, together with the Conidae, often in company with Trochidae and Turbinidae, while the sandy areas abound in Mitres and Cerithes.

(b) The northern sector (Vakano) also has numerous Cypraea annulus among the algaes in association with Columbella and the Cerithes. It is the same in the southern sector, however with rather more Conus and also Terebrus, as also in front of the mangrove zone and close to the enclosed lagoons of Waciwaci and Yadrana.

(c) In mangroves the vegetation is colonized by Littorina scabra and some Nerita, while the sub-stratum shelters Cerithiidae and the Veneridae principally. The mangrove sector is poor both quantitatively and qualitatively.

(c) The loose sediments in the south and south-east are very rich with a whole range of Mitridae, Olividae, Terebridae and Conidae. It is possible that the great lagoon exhibits similar richness but it was not possible to test this. Only the edges of the lagoon were investigated; these resembled the western sector very closely. On the island scale the most abundant species are perhaps Fragum Fragum and Gufrarium, both edible, among the endofauna, with Cypraea annulus (Porcelain coils) and Littorina scabra among the epifauna. Other than the species mentioned above the local population consumes Tridacna crocea, Strombus gibberulus, Lambis lambis and Trochus niloticus, among about a dozen species in all. Finally Trochus and pearl shell are bought and sold on a very small scale.

Fish.

There is a great diversity in the fish species around Lakeba doubtless in consequence of the very great diversity of biotopes in the waters surrounding the island. However it is necessary to note that in each one of the areas studied, fish of the family Pomacentridae were numerous. An area-by-area description follows:

(a) As throughout the island the Pomacentridae were found all along the Albert transect in the west sector of Lakeba. At the beginning, on the coral flagstone, these Pomacentridae were accompanied by Blennidae and Serranidae. Once the coral patches were reached Serranidae, Lutjanidae and Scaridae became dominant, later giving place to the Acanthuridae. The outer slope of the reef was also relatively densly populated, the dominant species being the Scaridae, Labridae, Acanthuridae and Lutjanidae.

(b) The Northern sector of the island (Vakano and Nasaqalau) is the poorest zone in fish fauna. We used fish poisoning methods on the large areas which are uncovered at low tide.

(c) To the south of the island are the extensive sandy areas covered by large banks of Kanace (Crenimugil crenilabis). These mullet shoals are exploited by the local population using nets. The fish are encountered especially close to the reef pass at Tubou where are encountered large speciments of Scaridae, Acanthuridae and Labridae.

(d) The basins at Waciwaci and Yadrana are very poorly populated. On the edges invaded or colonized by sea grass one encounters just a small number of fishes on the sandy bottom.

The only important populations are located at the coral heads where we encountered Pomacentridae, Serranidae and Acanthuridae.

(e) The mangrove area is also extremely poor in fish. Attempts at net fishing here were very unproductive. Collections using poisoning yielded very few species. We were however able to note the growing number of species as one went out along the transect from the mangrove toward the lagoon.

(f) The Great Lagoon. It was only possible to study the great lagoon close to the reef border and this only at two points, Transects Beatrice and Delphine. We encountered the greatest fish concentration close to the pass between the great lagoon and the sea.

In conclusion certain general points may be made.

(a) The presence all around the island of very numerous Pomacentridae which seem to colonize all habitats.

(b) Poverty of the mangrove, sandy areas and the algal areas.

(c) Relative richness of the outer slopes and great concentration of fish near the passes.

(d) Exploitation by the local populations of the important shoals of Kanace. It would be very interesting to study the dynamics of the population of the species; this would probably teach us a great deal about the evolution of the stock of fish.

Environment

Lakeba is characterised by the juxtaposition of several different biotopes in which richness in phytoplankton is closely correlated with the turbidity of the water, the reason being the great density of particular organisms in suspension.

It is possible to find five different biotopes: the mangroves, the 'enclosed lagoons' or holes at Yadrana and Waciwaci, the lagoons, the passes where oceanic water is in contact with that of the reef, and the great lagoon. The richest biotopes are those of Nukunuku, Waciwaci and Yadrana with 0.050 mg/m^3 of chlorop-A on an average, and 0.1 mg/m^3 at Nukunuku (maximum value), and the poorest are those of the lagoons with 0.0070 mg/m^3 on the average. The salinity of the lagoon is between 32.8 and 33.1 but at Nukunuku the level of salinity is only 32.2 gr/1. Concentrations of dissolved oxygen are variable in accordance with different biotopes but it was not possible to obtain any saturation values running through a 24 hour period. The most turbid water is that of Nukunuku where the Secchi disc disappeared at 4 metres and after this the basins at Yadrana and Waciwaci (4.5m).

AIWA

Aiwa is a group of two small islands, almost identical in size, each almost 1.6 km in length, and aligned east-west. The islands are formed up uplifted limestone, to a maximum elevation

of 60m. Heavily forested, they are now occupied only by goats, but seem to have been inhabited at some time in the remote past. The two islets are protected on the southern side by a submerged barrier reef which extends a great distance to both east and west, having a total length of around 12 km.

Between the two islets and the southern reef is a small, rather shallow lagoon. The western island extends onto the barrier reef itself, but the eastern island is linked to the barrier only by a submerged reef. Ocean currents enter this small lagoon across the barrier reef, and are very violent in the passage between the two islands (minimum depth 5m) and across the submerged reef. To the north, largely open to the ocean, is a very large and deep lagoon limited only to east and west by submerged reefs.

Benthos.

The coasts of the two islands are cliffed, and do not have true fringing reefs.

Coral. Coral is only weakly developed on the island shores. At the foot of the cliffs, and on the fringing zone along the northern shores, the percentage of ground covered with living corals nowhere exceeds five percent. The narrow passage between the two islands is the richest area. Here certain species cover as much as 100 percent of the substratum over wide areas: these species belong to two different genera, Acropora and Merulina. On the barrier reef, the internal reef flat is poor, with less than ten percent of living corals. The submerged reef linking the eastern island to the barrier reef is much more populous; living corals, dominated by Acropora, cover 40 percent of the substratum. The outer slope, on the other hand is rich; living corals, again dominated by Acropora, occupy as much as 75 percent of the surface.

Molluscs. There were 62 species of molluscs, heavily dominated by Conidae and Muricidae, in our collections on Aiwa. Two main population groups can be distinguished. On the barrier reef Trochidae, Turbinidae, Cypraeidae and Conidae dominate, with some mitres in lenses of sand in the detritic zones. On the island fringes below the cliffs, Littorinidae, Neritidae, Muricidae and Conidae are the only families well represented. The richest part of the whole complex in bivalves is the eastern submerged reef; Pinctada margaritifera, Chama imbricata, Tridacna maxima and Tridacna crocea are particularly numerous. People come quite regularly to Aiwa from Lakeba to collect giant clams (Tridacna) for food, which are therefore abundant only at depths below 2.5 - 3m. Taking the complex as a whole, the most abundant molluscs at Aiwa are Cypreaea annulus, Vermetus sp. and Morula granulata.

Fish.

The fish fauna is best discussed in terms of four distinct environments:

(a) the outer slopes on the ocean side of the barrier reef are thickly populated. Beyond the spurs and grooves zone, in a depth of 15m, Scaridae alone form up to 50 percent of all fish

encountered. Just beyond the wave-break zone, by contrast, the fauna is dominated by Acanthuridae.

(b) the inner reef flat of the barrier reef is uniformly very rich in fish. Dominant species are the Lutjanidae, Holocentridae, Serranidae and Mullidae; these are fished every weekend by parties from Lakeba.

(c) the inshore area below the cliffs seems to have a very homogenous fauna.

(d) the strait between the two islands is the most richly colonized zone in all Aiwa. Unfortunately, the very violent currents which run constantly through this deep passage (in many places more than 15 m) make any exploitation of these large stocks almost impossible.

Environment

There are clear contrasts between the northern and southern lagoons. The poorest waters are those on the inner side of the reef flat (0.026 mg Chlor.a/m^3), but while those in the southern lagoon reach 0.47 to 0.82 mg/m^3, those in the northern lagoon range only from 0.44 to 0.54 mg/m^3. The difference between the two lagoons may be explained by a higher acidification level in the southern lagoon (1.47 to 1.56) than in the northern (1.33 to 1.43), and also by the greater turbidity of the northern lagoon, where the Secchi disc vanished more quickly than in the south and there is a higher concentration of mineral and organic particles in suspension.

TAVUNA SICI

Some 30km northwest of Kabara is the tiny island of Tavuna Sici, only some 800m in diameter and surrounded by a barrier reef which has only two small high-tide passages on the northern side. Within the barrier reef is a lagoon of width varying from 400 to 800m. The shoreline consists of low cliffs, of coral-sand beaches or of beach rock. The inner part of the lagoon is quite shallow, generally about 3m and exceptionally 5-6m with basins dropping to 7-8m, and is covered in loose sediments; there is no sea-grass cover, and algae do not form dense colonies. Some higher parts of the lagoon are occupied by colonies of live or dead coral, and by eroded detritus. The outer part of the lagoon resembles a barrier reef almost at sea level (with some rubbly banks above water), and the proportion of living corals increases as the reef edge is approached. In summary, then, there is a shallow lagoon, essentially sandy in the north, with a hard substratum and living corals in the rest of the lagoon; a very wide reef flat is more dead than alive.

Benthos.

Corals. There is a wide diversity among living coral in the lagoon. But while on the outer slope of the large barrier reef the percentage of living corals is as high as 40 to 50 percent of the

whole, on the inner reef flat not more than 15 percent of the surface is occupied by living corals. Most species belong to the genus Acropora, but there is a narrow bank of Porites around the shore, as at Kabara.

Molluscs. Twelve species of molluscs were collected along the Tavuna Sici transect, and a thirteenth (Cypraea tigris) was observed in branching Acropora at the southeast of the island. The endofauna is poor, and a large part of the lagoon is occupied only by sediments. Only Strombus gibberulus was collected in abundance, and Conus virgo here and there in the sand. The epifauna is dominated by Cypraea annulus and Vasum turbinellum among the several small algal colonies near the shore, and by Cypraea moneta and Cymatium gemmatum on the barrier-reef level. Chitons (Polyplacophora) and Tridacnes (Bivalves) are the only non-gastropods collected among the molluscs.

Fish.

Our study in this lagoon was very superficial. The radial that we prospected, which passes over an area dominated by sediments and lying opposite the northern reef-passage, seems to be the most poorly populated part of the lagoon. On the southern side, quite large banks of Scaridae, Mullidae and Carangidae could be seen. The outer slopes seemed to us very rich in Scaridae, Carangidae and Acanthuridae.

Environment.

Comparison of measures taken within the lagoon and outside the reef at Tavuna Sici provides clear evidence of the richness of the oceanic water (0.086 to 0.115 mg/m^3) by comparison with the water of the lagoon (0.030 to 0.056 mg/m^3). This difference is underlined by the contrast in acidification levels (average 1.55 outside the reef; 1.46 inside the lagoon). The oceanic waters are also much clearer at Tavuna Sici than at any other place seen in the course of the mission. The limit of visibility of the Secchi disc was 45 m, against only 30 m outside the reef at Tubou, Lakeba.

KABARA

Located at 178°57'S, Kabara is in the main an uplifted limestone island, sub-circular in form; the plateau everywhere dominates the lagoon with cliffs up to 57 m in height. The diameter of the island varies from 7.3 to 4.8 km. A continuous barrier reef, with no passage, delimits a lagoon 500 m in average width, except in the northwestern one-seventh of the island's circumference. This lagoon is shallow, generally only 2-3 m in depth, exceptionally 4-6 m, and is dominated by loose sediments which occupy four-fifths of a transect from shore to outer slope; the remaining one fifth is composed of a tabular reef of dead coral. This barrier zone emerges at low tide along the east coast, but is submerged along the west coast, supporting there a relatively dense algal zone rich in Caulerpa and Microdyction. A well-developed spurs and grooves zone characterizes the outer

slope of the reef, which then plunges at 70-90° to a terrace at 20 m, only some 40 to 50 m wide. This outer slope is the only important living part of the whole reef-lagoon coral complex of Kabara.

Within the lagoon, a series of transversal reefs running from the shore to the barrier edge are a very distinctive feature. There are 11 of these, and they are made up for the most part of small coral patches and microatolls. The present hydro-dynamism of the lagoon is certainly not without relevance to the formation of these transveral lagoon reefs. In effect the Kabara lagoon fills at high tide with water flowing over the barrier reef. When the tide falls, this water is entrapped, and can only escape in the northern sector of the island, where the barrier is non-existent. The prevailing southeasterly winds aid the flow of water within the lagoon in a northerly direction, and well-marked northerly currents are encountered within the lagoons on both sides of the island.

The open-sea sector is a zone of collapse. A very narrow fringing reef of living coral (0.5 to 5 m only in width) borders the cliffs. Beyond this, over a width of 500 m, is a terrace at about 7 m on which stand more or less rich patches of coral. This zone is well-known for its toxicity.

Kabara thus offers a reef-lagoon complex dominated by sand (covering four-fifths of the area), without sea-grass or algal colonies, and of shallow depth. The absence of any algal covering in the lagoon is particularly significant. This is a lagoon in course of being filled by sand, a type not uncommon in southern Lau, where the most remarkable example is the great lagoon of Ono-i-Lau (Ed.) Geomorphological and bionomic evidence both suggest very recent uplift and this is presumed to be the cause of the death of the outer reef, most notably the barrier reef along the eastern side of the island.

Benthos.

Corals. The coral reefs occupy only one fifth of the coastal zone. It is interesting to note the presence of a band of small colonies of living Porites, very sparse, on the edges of the beach. There are no fringing reefs except on the open coast, and the major part of the barrier reef forms a platform, emergent at low tide; 98 percent of this is dead. The only important concentrations of living coral within the lagoon are on the face of these tabular reefs, and on the transversal lagoon reefs (respectively 40 and 60 percent). The outer slope is also poor (30 percent only of living corals on the east coast reef), a long way from reaching the 100 percent cover of living coral normal in French Polynesia. The open-sea section is the only one which is reasonably rich (60 percent of living coral), and this area also has a small section of fringing reef.

Molluscs. The sum of our collections at Kabara yielded a harvest of 122 species belonging to 43 families. The best represented families are the Conidae (15 species), the Muricidae (13 species),

and the Cypraeidae (12 species). In the open-sea sector, the littoral is better colonized (Nerita, Astraea, Chiton) than the coral heads (Lambis, Trochus), but not as well as the sedimentary floor (Oliva, Cerithium, Conus, Terebra). In the barrier-reef sector, only the hard substratum is well colonized (Cypraea, Trochus, Turbo); the only significant endofauna representatives in this place are Strombus gibberulus, Cardium fragum and one Pyrenidae. The transversal reefs are rich in Cypraeidae (8 species), Vasidae, Conidae and Opistobrancus (especially at night). On the external slope of the reef, the molluscal fauna is limited to some Trochidae, Turbinidae and Muricidae of the spurs and grooves zone. The lack of any mangroves, or muddy substrata with algal colonies, prevent us from finding here anything comparable with the range of species encountered abundantly at Lakeba.

Fish.

In fish, Kabara is without question the poorest of the islands studied. Except for the Pomacentridae, the lagoon is very sparsely populated. Taken as a whole, the fish fauna is concentrated close to the transversal lagoon reefs. There is a certain species homogeniety, but it disappears where certain families become dominant. The outer slopes of the reef, on both sides of the island, are less populated than the slopes around Lakeba and Aiwa. Species diversity on the one hand, and number and size of individuals on the other, enables us to differentiate between the windward and leeward sectors. The open-sea sector in the northwest is almost as populated as the outer slopes, but is not exploitable because of the toxicity that characterizes this area.

In conclusion, the poverty of the lagoon, the fish-toxicity in the open sea, and the difficult working conditions along the outer slopes make this island economically of small value for fish exploitation.

Environment.

The waters of Kabara are homogenous. Concentrations of chorophyll varied from 0.045 to 0.100 mg/m^3 in the lagoon, and from 0.060 to 0.160 in the open sea. Acidification levels are indicative of populations that are quite dynamic and have few degraded pigments. The inshore waters are charged with detritic particles, and the limit of the euphotic layer lies at about 60 m depth. Both lagoon and oceanic littoral waters are averagely oxygenated, and the values for dissolved oxygen do not fall below saturation except during the night and early morning. Net collections were poor in zoo-and phytoplankton. The water temperature varied from 28.4° to 30.5°, and salinity showed only small variation between levels of 32.9 gr/1 and 33.2 gr/1.

NAMUKA

Eighty kilometres south-south-east of Lakeba, the limestone island of Namuka lies east and west with a length of about 8 km. It is never more than 2 km wide, and the southern coast is broken

by a large shallow bay (maximum depth 5 m), almost completely closed from the open sea, and seemingly forming the submerged part of a central basin similar to that of other limestone islands. There is a long barrier reef, without breaks on the southwestern, southern and eastern sides. Most of the north coast, however, is not protected. Between the south coast and the southern reef is a lagoon whose depth reaches 20 m in places. The south coast itself is formed of a cliff, bordered by a narrow fringing zone, with the inner slope of the lagoon beginning at eight or nine metres below sea level.

Benthos.

The morphology of the barrier reef is analagous with that encountered on the other islands. The following zones are successively encountered going from the ocean towards the land: (a) outer reef flat rich in corals, (b) zone of dead corals with dead colonies of Acropora, (c) boulder and detritus zone, (d) zone of small coral patches and microatolls, (e) sandy accumulation, (f) inner slope. This barrier reef is dominated by a small sea-urchin (Echinometra mathaei) found in extraordinary density.

The bay is sandy, and one quarter of its surface (in the western part) is occupied by algaes, which there attain a 100 percent coverage. The genera Caulerpa, Halimeda and Dictyota are dominant and shelter rich populations of large Foraminifera. In the southwestern part of the bay, quite a large area is covered by a chlorophyllous algae, forming a kind of 'felt' mat about 20 to 30 cm deep over a sand with Halimeda. This facies recalls eutrophisation phenomena to mind.

Corals. This island is quite rich in living coral. It is the only place where we encountered an 80 percent cover of the substratum on the outer reef flat. A peculiarity of Namuka is the existence of three distinct zones in the lagoon; an ill-developed fringing reef below the cliffs (living corals 10 percent); a channel (living corals - 0 percent); a barrier reef where the living coral cover ranges from 20 to 80 percent, with important species diversification. On the reef flat, at the edge of the wavebreak zone, we found large fields of Acropora broken up by detritic zones without living corals. It should also be noted that the inner bay on the south coast has no coral, living or dead.

Molluscs. Collections at Namuka included 40 species of Molluscs, dominated by spiny Gastropods. The inner part of the barrier reef is colonized mainly by Turbinidae, Cerithiidae and Conidae. The fringing reef at the foot of the cliffs shelters several species of Neritidae, a Chiton and a Patella, just as in similar situations at Aiwa and Kabara especially. In the sedimentary areas areas we collected Olives and Terebres; on the Alcyonaires we found Ovulidae, and on the flagstone Conidae. The area is well diversified, and the population density is considerable even in the intertidal zone. By contrast, the bay houses only eight or ten species, among which Strombus gibberulus in the sediments, Columbella sp. on the Caulerpa, and Cypraea annulus among the

Halimeda are the only species found in significant numbers.

Fish.

Although our study of Namuka was very incomplete, it was sufficient to provide an impression of the rich fish fauna of this island. The southern lagoon contains all the species characteristic of a coral reef tract (Pomacentridae, Acanthuridae, Labridae and Mugilidae), but there were no representatives of the larger fish (Scaridae, Lutjanidae) and Chaetodontidae are not numerous. Though less rich, the population of the cliff-foot zone resembles closely that of Aiwa. The bay is very poor in species, and the few present were represented only by young individuals (Mugilidae, Lutjanidae, Scaridae, Serranidae) -- a phenomenon doubtless significant for the fish ecology of the whole coral reef tract outside.

Environment.

The waters of Namuka are rich in chlorophyll a. The levels measured in the lagoon are comparable with those of the 'holes' at Yadrana and Waciwaci, and of the mangrove at Nukunuku in Lakeba. We recorded 0.148 mg Chl.a/m3 on average. The lagoon is more saline than the bay (32.9 g/l against 32.4 g/l, and the water temperature ranges between 28.8° and 29.1°. Oxygen levels are close to saturation in the early morning, then rise very rapidly during the day, especially in the bay.

YAGASA CLUSTER

This extensive lagoon, lying at 18°58'S by 178°25'W, contains four principal islands, all composed of upraised limestone. Except on the northwestern side, where there is a wide open entrance, the barrier reef is continuous. The great lagoon is relatively deep, and we could not prospect it with the means at at our disposal. Between the southern reef and the islands of Navatu-i-ra and Yuvuca there is, however, a small lagoon the depth of which is not greater than 16-17m.

Benthos.

Corals. The barrier reef was investigated at two points, on the windward and leeward sides respectively. There is, however, little difference between the two sites in terms of structure. In each case we encountered a small inward fall behind the outer algal rim, descending in the form of a staircase to a reef flat with Caulerpa. The inner reef flat has many colonies of living coral, with density increasing toward the lagoon. The outer slope, regularly at 30°, reaches a terrace covered with sand and detritus at 30 m below sea level. On the lagoon side, the inner edge of the reef system is composed first of a dead reef covered by a sandy accumulation, within which lie isolated dead and living coral alignments, then a closer density of coral alignments separated by two or three metres of water. The inner slope of the reef, between the islands of Navutu-i-ra and Yuvuca, is composed of a coral substratum of which 95 percent is dead. The

small lagoon between these islands and the barrier reef is filled by several hundred coral patches, rising ten to 16 m above a sandy floor without sea-grass or algae. This group of islands appears to be very poor in coral life. Although the outer slope may have up to 50 percent live corals, the inner reef flat has a live cover generally less than 20 percent. On the leeward side of the Cluster, the outer slope is relatively rich (50-60 percent of living corals), but the inner reef flat has only about 0.1 percent of live growth. The dominant genus is Acropora, which represents from 50 to 90 percent of all coral on the outer slopes and outer reef flats on both windward and leeward sides. On the inner slope, it is interesting to note the gradual diminution of Acropora without replacement by another dominant genus.

Molluscs. More than 60 species of Molluscs were collected in two short days of work, indicating the presence of very rich resources of molluscs, especially in the sediments. The barrier reef shelters the same Trochidae, Turbinidae and Muricidae as at the other islands, and has nothing of particular interest except an abundance of Tridacnidae not encountered elsewhere. The rocky littoral of the islands seems very rich in Neritidae and Chiton, but a very large number of species are encountered each in very small quantity, and the dead material lying on the shore gives evidence of very great richness in the adjacent lagoons. The white sand bottom behind the barrier reef is very rich in Cerithiidae (2 species), Olividae (2 species), Mitridae (2 species) and Terebridae (3 species). The Cypraeidae family must also be abundant, notwithstanding the limited harvest in our collections, if account is taken of the shore deposits and also the existence of large areas of an environment particularly suited to this genus in several parts of the Cluster.

Fish.

By its abundance and diversity, the fish fauna of Yagasa is very different from that of the other islands studied. On the outer slope we remarked two species as particularly noteworthy: Acanthurus lineatus by the large number of individuals; Naso rigoletto by the large size of its representatives. Two types of population are found in the lagoon. First is the characteristic population of all coral reef tracts, here dominated by Ballistoides; second is an open-sea fauna (Sardinella). Our studies of a coral patch on the northern reef flat revealed the presence of a minimum of 50 different species around this one patch, and especially a great number of Lutjanus kasmira. This group of islands is very rich in fish, due to the presence of two different populations in the lagoon -- those of the coral reef tract, and those of the open sea.

Environment.

The richest concentrations of chlorophyll a. are at Navutu-i-loma (0.130 mg/m^3), then those at Yagasa Levu (0.110 mg/m^3) and finally those at Navutu-i-ra (0.088 mg/m^3). Acidification and chlorophyll levels at Navutu-i-loma and Yagasa Levu are comparable

with those at Namuka, while those at Navutu-i-ra compare with those obtained at Lakeba.

The average salinity is 33.2 gr/1, and the temperature range recorded was from 28.6° to 29.2°. Oxygen levels lie within the normal range, except at Navutu-i-loma where levels fall very sharply close to the sandy bottom.

NAVATU REEF

The opportunity of a near passage en route back to Suva enabled us to make a brief exploration of this submerged reef, lying in the open ocean at 18°40 S by 179°35'W. Given the circular form of the shallow submerged reef, over which waves break, and the greater depth of the central 'lagoon', it would seem that this reef is in fact a submerged atoll. Our short stop here enabled us to make some essays at comparison with situations where there is a volcanic or limestone island within the reef, and also to examine a situation where there seems never to have been any exploitation by man, certainly in modern times.

We were able to study three stations along a transect taken from the lagoon toward the ocean, in the northwestern sector (leeward) of the reef. The reef is under one or two metres of water at low tide. For the most part (95 percent) it is dead, but the outer edge has a sparse algal rim with Caulerpa, similar to that observed at Lakeba, Namuka and Yagasa. On the inner ('lagoon') side, a 90°fall gives way directly to the beginning of the inner sandy slope at six metres below the surface. On the outer side, both the slope and the wavebreak zone are rich in coral colonies. This outer face comprises first a gently-sloping reef flat declining from -1m to -5m and about 30 to 40 m wide at the point studied, then an 80° slope falling to a terrace at 15 m below the surface, covered with sand and rubble.

Benthos.

Corals. Where seen, the coral fauna is very poor. On the inner side (reef flat and inner slope) the cover of living coral never exceeds five percent. On the outer slope, where the Agropora are dominant, the cover is about ten times greater than this. Except here, and unlike the other reefs studied, the dominant genus is not Acropora but Porites, together also with Goniopora, Stylophora and Lepitora in significant quantity. It is surprising to find such poverty in living coral on a submerged reef with significant hydrodynamism.

Molluscs. Nothing unusual was encountered among the molluscal fauna of this reef. Five species were collected, all typical of the semi-dead reef flat situations encountered elsewhere in Lau. These were Turbo chrysostomus, Tectus pyramis, Tridacna maxima, Turbo argyrostomus and Latyrus smaragdulus; this is an entirely epigentic fauna, very abundant everywhere in Lau, but here rather sparse.

Fish.

At first sight, the outer slope seems less rich than comparable situations at Yagasa, Lakeba and Aiwa. Naso and the Acanthuridae predominate. The reef flat, also poor, resembles that of other islands. The inner slope is the richest part of this reef, both in large specimens (Matsuwomus pelamis, Naso rigoletto, Plectorhynchus punctatissimus) and in number of individuals (Lutjanus kasmira, Epinephelus mera, and the Scaridae). In this same sector we were able to witness the evolutions of three large Cheilinus undulatus (Daguva), a spectacle sufficiently rare to warrant special remark.

Environment.

Observations indicate that the water at Navatu Reef is rich in chlorophyll with a concentration of 0.090 to 0.120 mg ch.a/m^3, a value equivalent to that recorded in the open sea close to Tuvuna Sici. Acidification levels are average -- 1.45 to 1.52. Waters are turbid, and heavily charged with small organisms carried away from the substratum by wave action. The yields obtained in net hauls occasion no particular remark.

TRANSLATOR'S NOTE

Zoological names are given in the text in both Latin and French forms; so far as possible I have endeavoured to standardize these in the Latin form, but some discrepancies remain, and there may be errors. That these appear is due to the need to get this report published quickly, and is not the fault of the authors. The French version of the report also contains a conclusion that presents a factual recapitulation of items for each island under the headings: Corals, Molluscs, Fish, Plankton. This is not reproduced here.

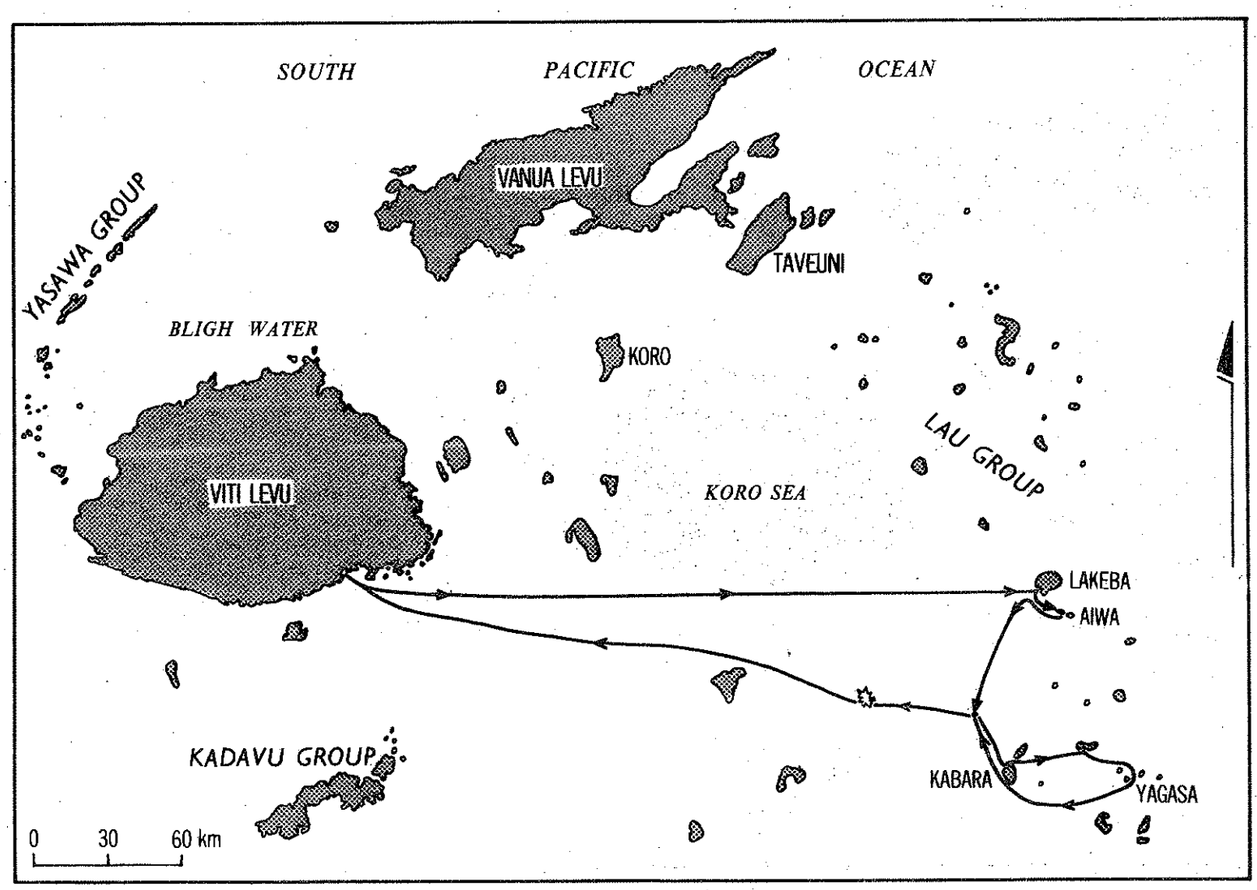


Fig 1 FIJI ISLANDS (showing route of the expedition)

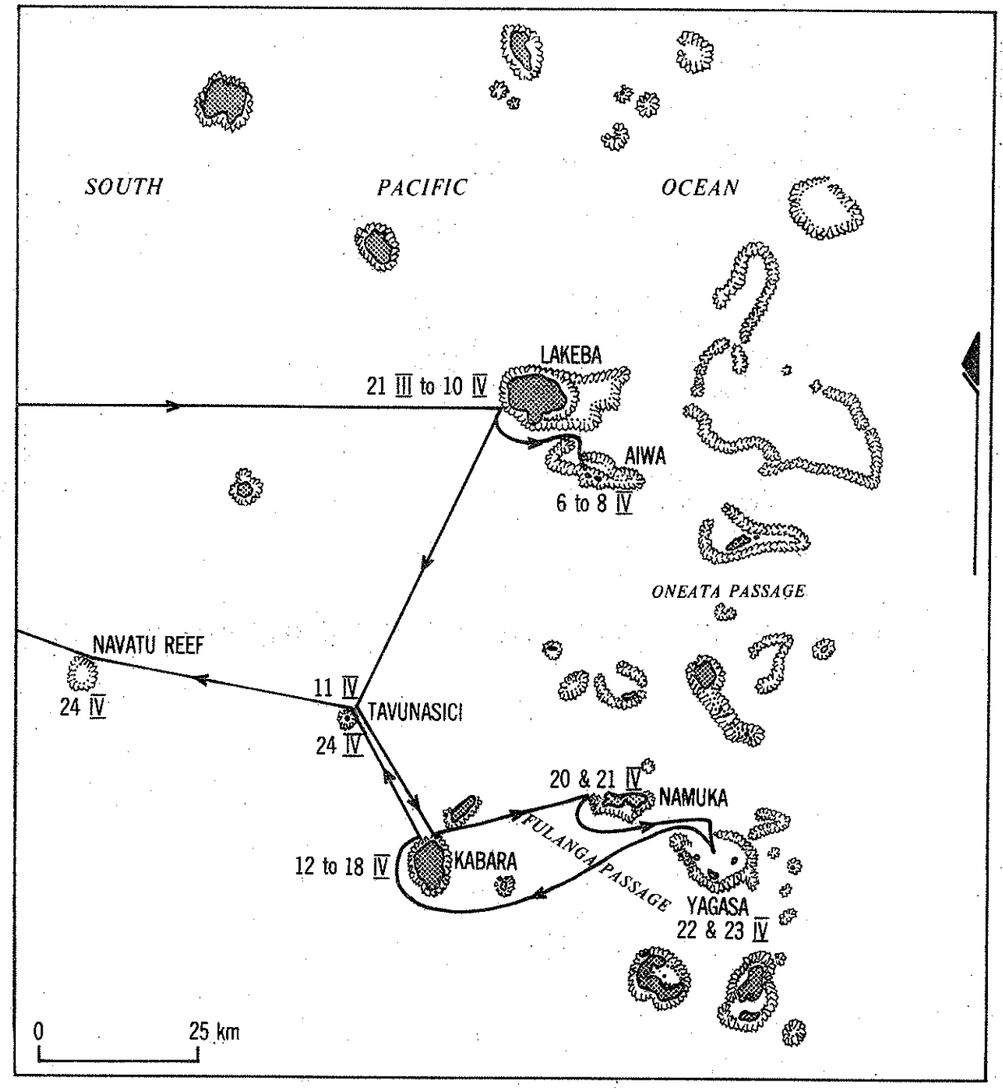
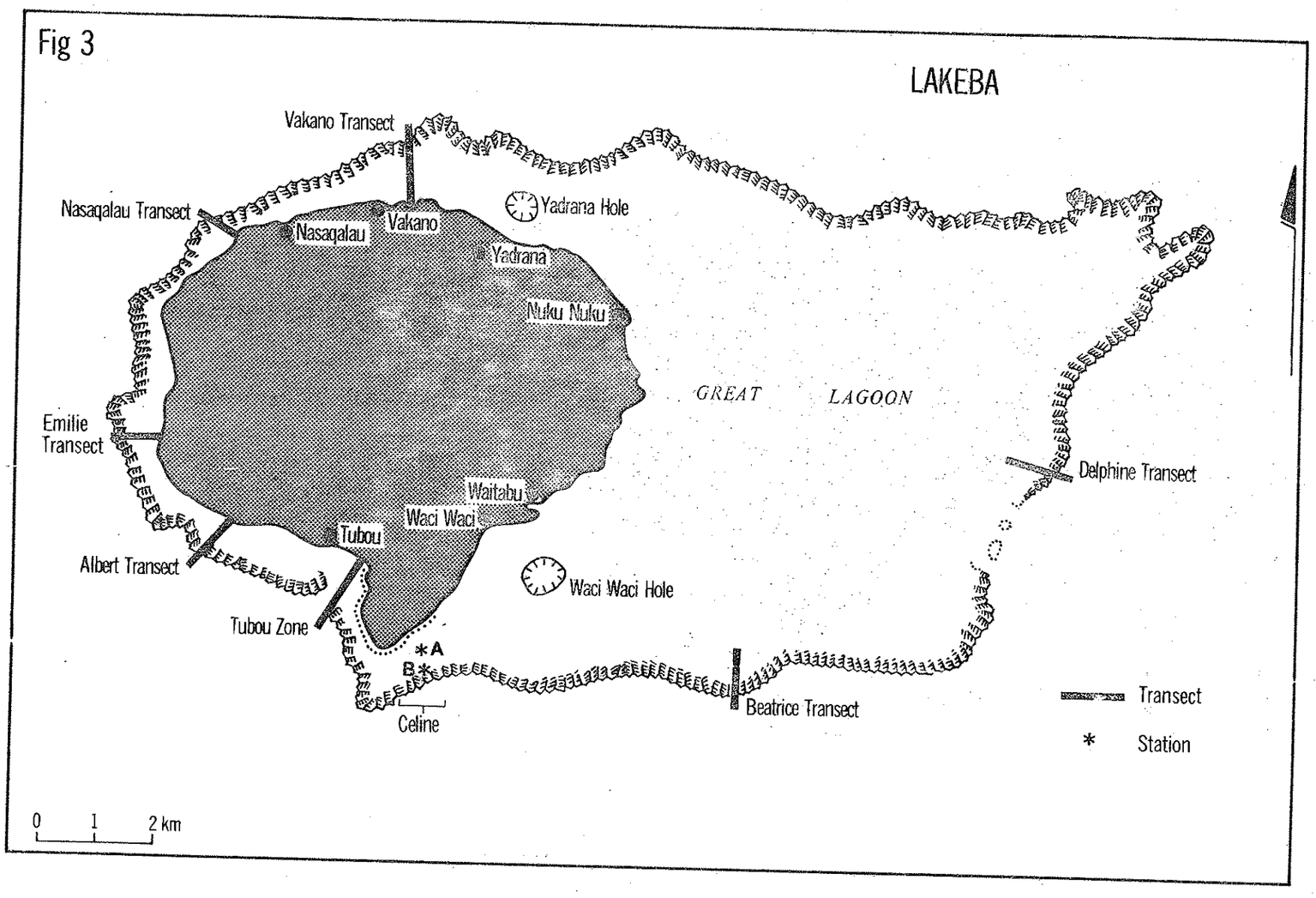


Fig 2 SOUTH CENTRAL LAU (showing route of the expedition)

Fig 3


LAKEBA
Vakano Transect
Nasaqalau Transect
Nasaqalau
Vakano
Yadrana Hole
Yadrana
Nuku Nuku
GREAT LAGOON
Emilie Transect
Delphine Transect
Waitabu
Waci Waci
Tubou
Albert Transect
Waci Waci Hole
Tubou Zone
*A
B*
Celine
Beatrice Transect
Transect
* Station
0 1 2 km

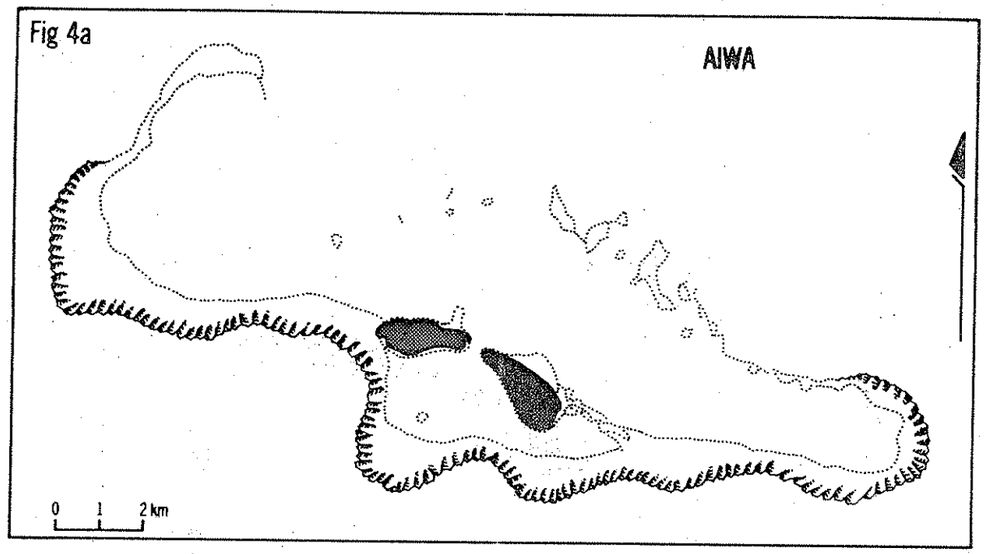


Fig 4a
AIWA
0 1 2 km

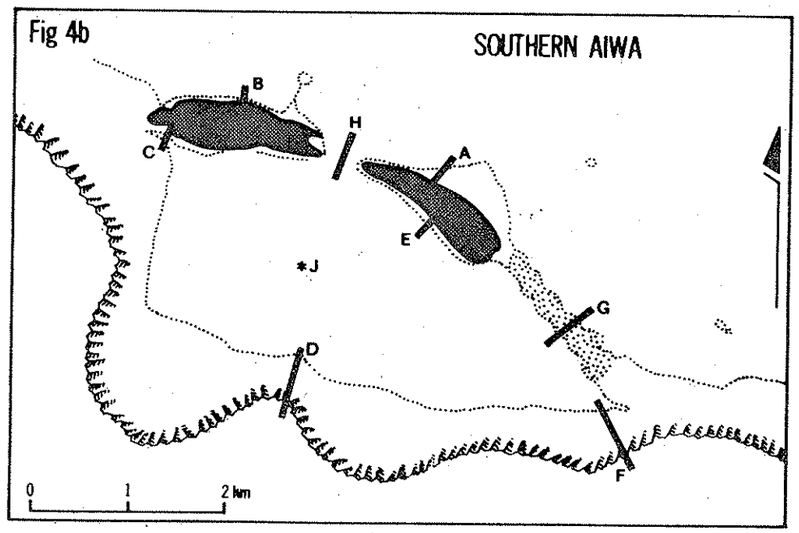
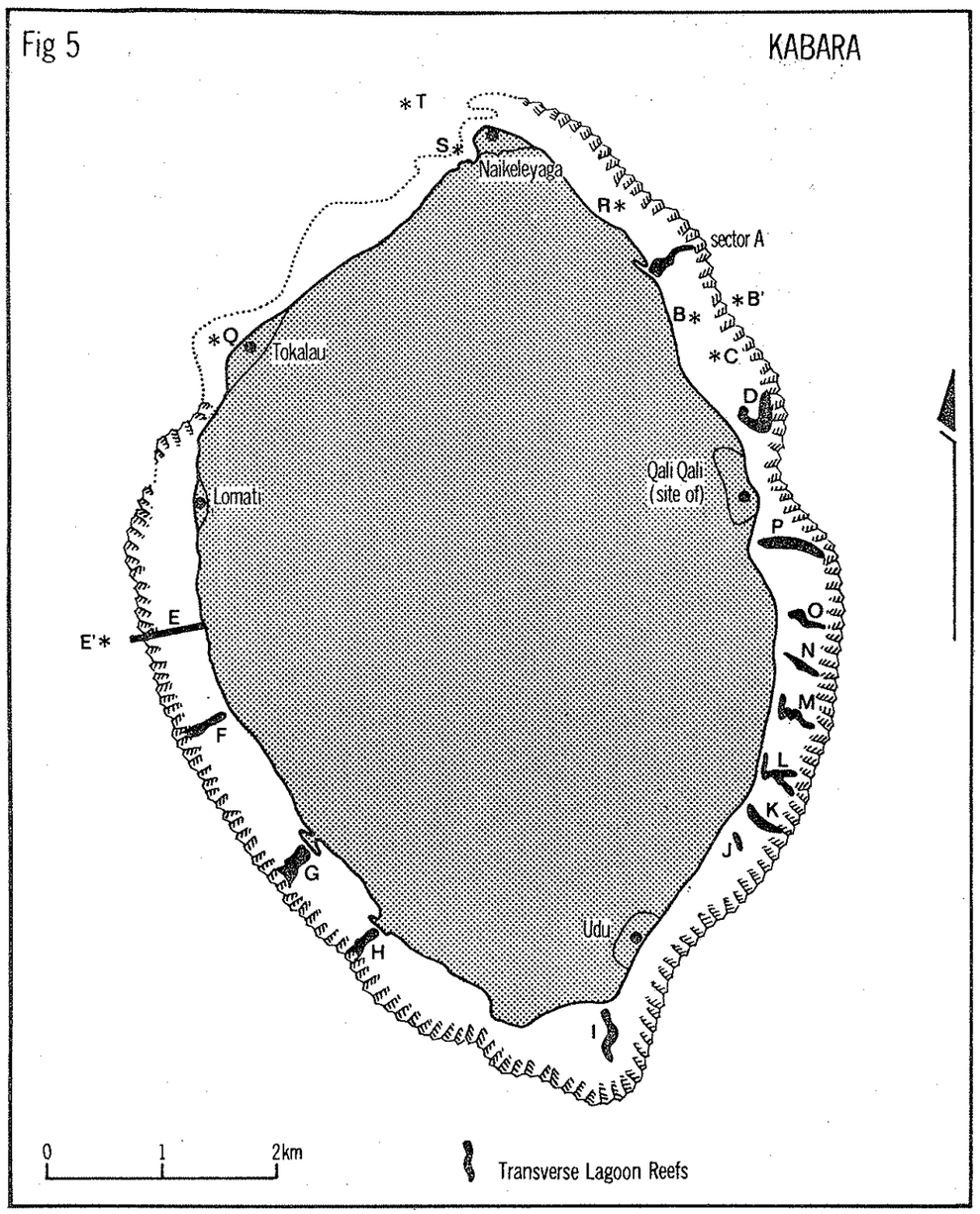


Fig 4b
SOUTHERN AIWA
B
H
C
A
E
J
G
D
F
0 1 2 km

Fig 5

KABARA


*T
S*
Naikeleyaga
R*
sector A
B*
*B'
*C
D
*O
Tokalau
Qali Qali
(site of)
Lomati
P
O
N
M
L
K
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E
E'*
F
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Udu
0
1
2km
Transverse Lagoon Reefs

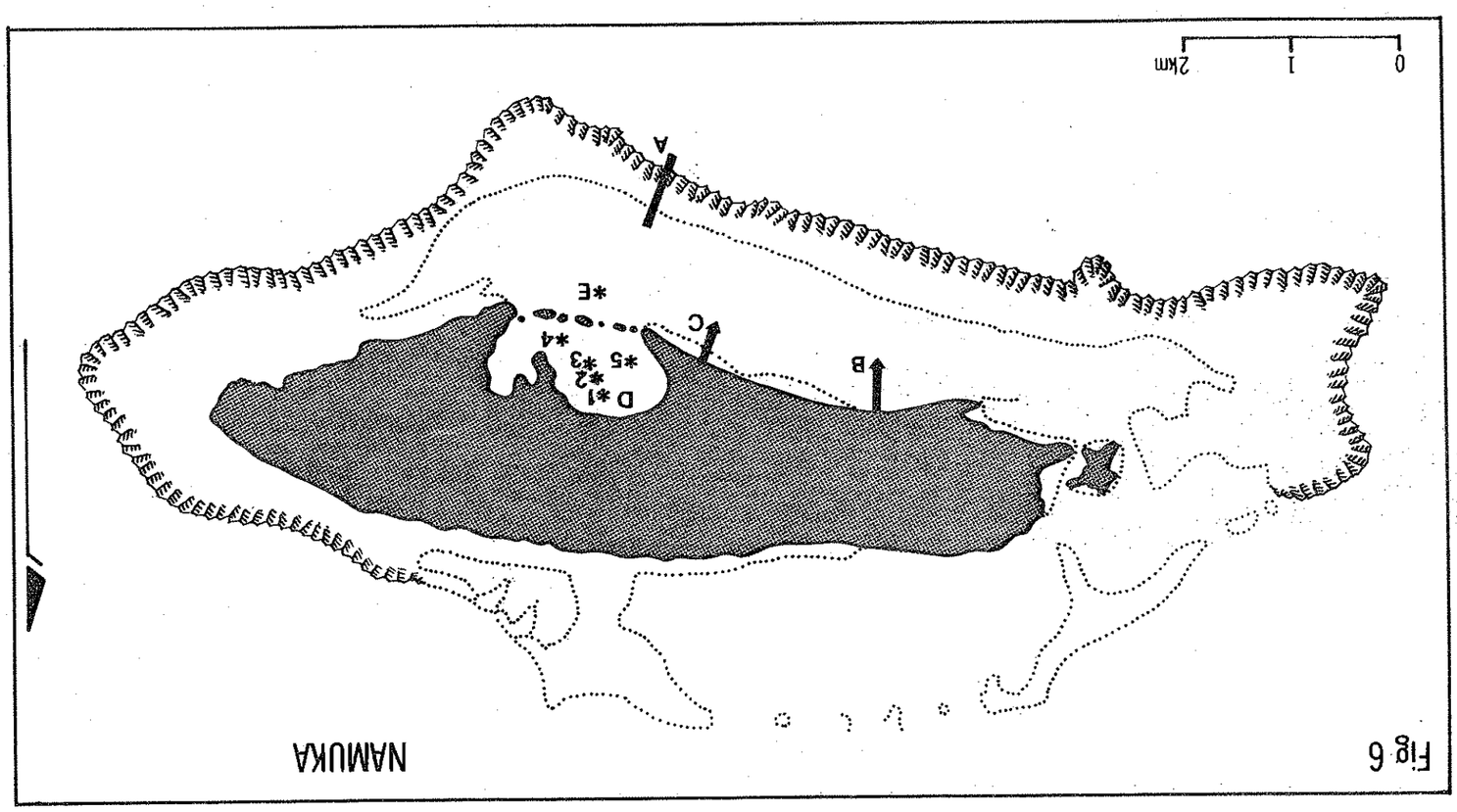
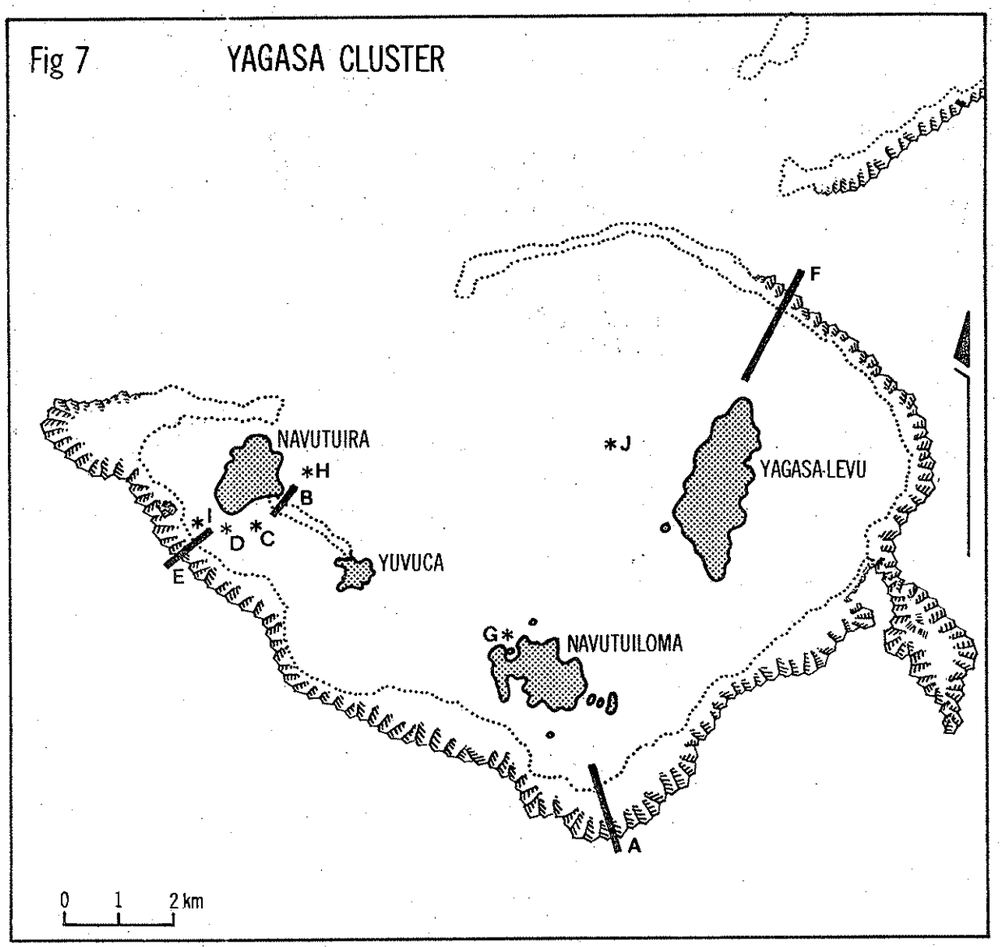


Fig 6

Fig 7 YAGASA CLUSTER



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CARTE DE SITUATION DES PROFILS

LÉGENDE

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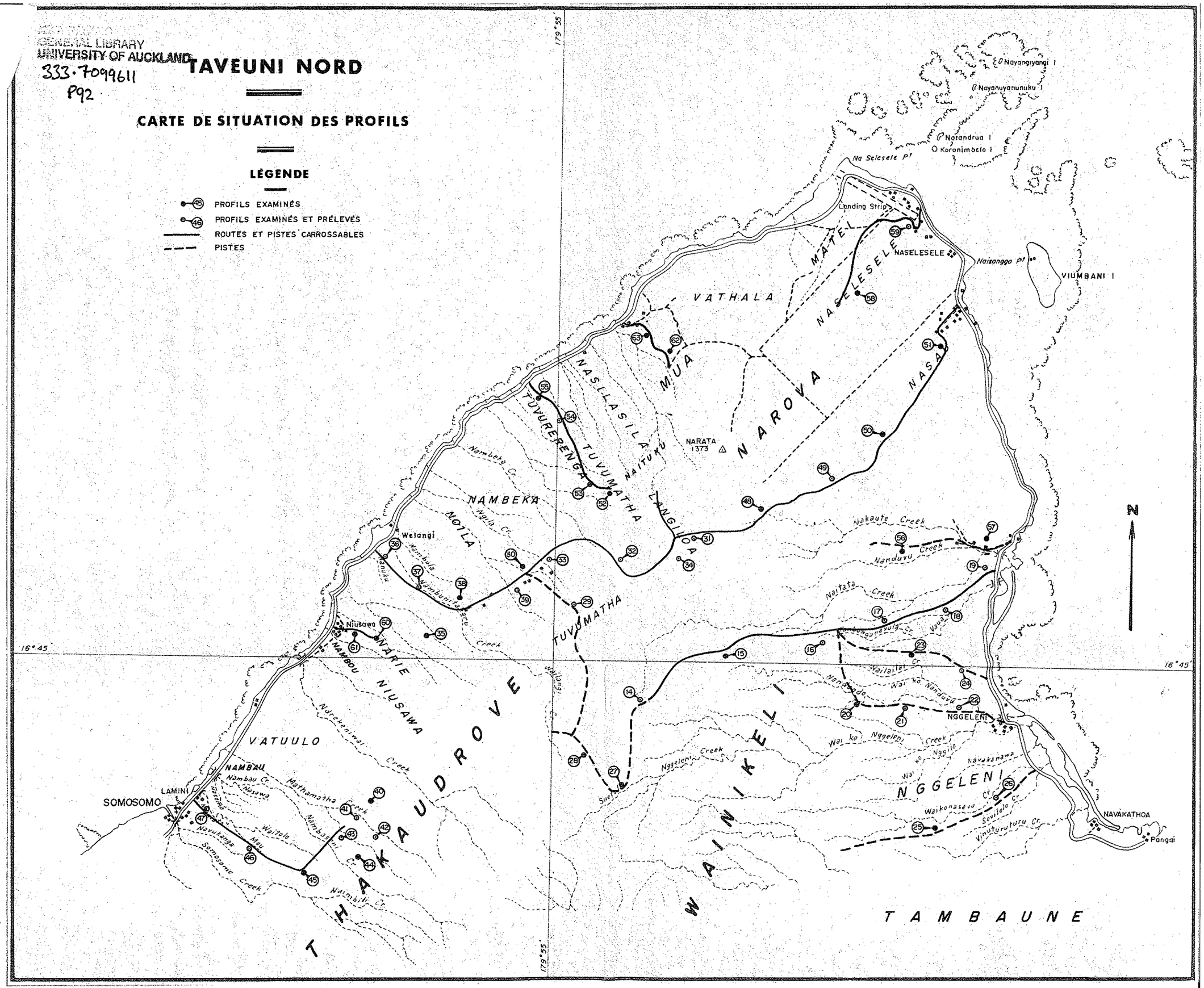
- (46) PROFILS EXAMINÉS ET PRÉLEVÉS
- ROUTES ET PISTES CARROSSABLES
- PISTES



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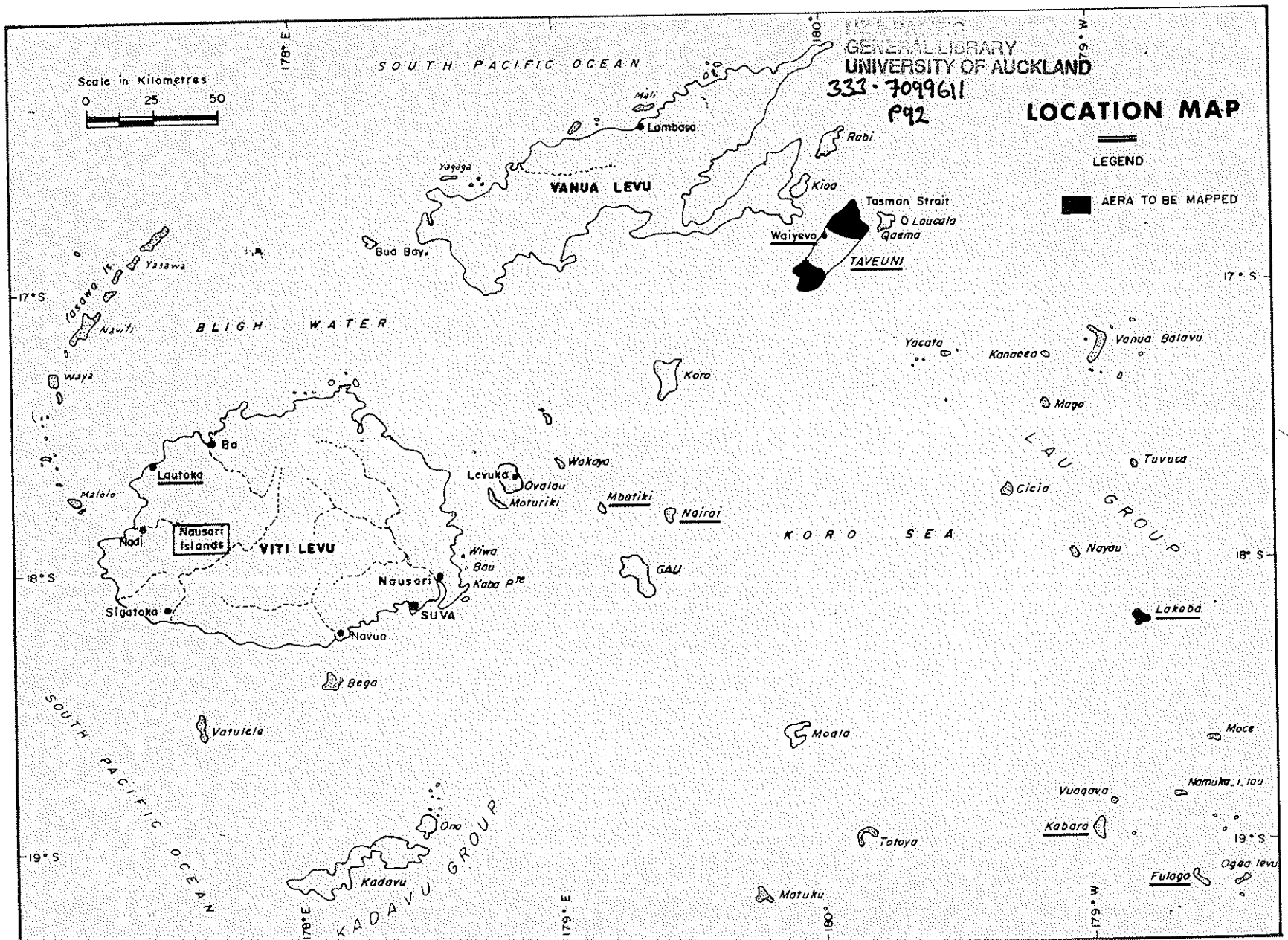

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LAKEBA

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120 000 119 000 118 000 117 000 16 000 15 000 14 000

NASAGALAU
VAKANO
YANDRANA
NUKUNUKU
TUBOU

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