On Lake Tegano, Rennell Island *

and some Remarks on the Problem of Rennell's Origin

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Abstract

Rennell Island, an emerged atoll, has in Lake Tegano a reminiscence of the former lagoon. The probable existence of a connection between the lake and the ocean – an important problem for biologists concerning fauna of Tegano – is discussed. Morphology and types of lake bottom is described on basis of echo-soundings. Finally, some general views on morphology and origin of Rennell are expressed.

Rennell Island (Polynesian name: Mugaba) is a Polynesian outlier in British Solomons lying in a position of about 11° 40' southern latitude and 160° eastern longitude. The large island (about 80 km long and 14 km wide) is rather unique in showing all signs of being an emerged atoll (average elevation appr. 110 m above sea-level). Thus the island consists of a grooved rim carrying in places relics of sandy reef-islands, the rim encloses a fairly even plain corresponding to the lagoon-bottom of the former sea-level atoll. This inner plain appears to have an eastward tilt thus allowing in the eastern part the existence of a large fresh-brackish watered lake: Tegano (fig. 1).

Visited by members of the Danish *"Galathea"-expedition* 1951, especially the biological problems of this peculiar island attracted the interest of Danish science. Quite naturally, therefore, the plans of the later *"Noona Dan"-expedition* comprised a visit to Rennell 1962 (under the leadership of dr. *Torben Wolff*, who also joined the 1951-work).

Due to some delay (repair of ship, quarantine and finally to illness) much time was not left the expedition for field work on Ren-

* Noona Dan Papers no. 11.

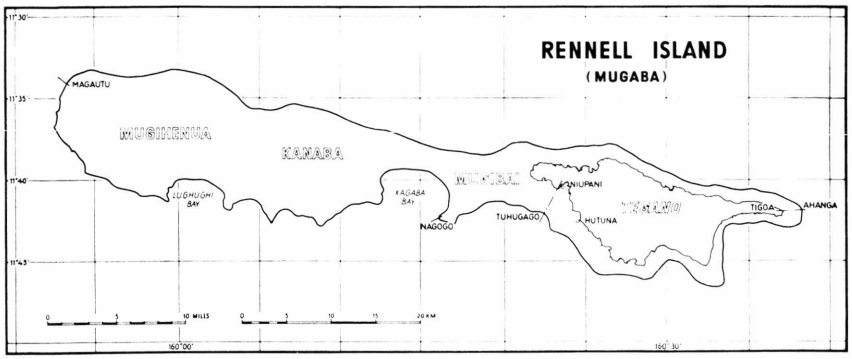

Fig. 1. Map of Rennell Island showing position of Tegano and (by broken lines) position of cliff-profiles of fig. 8.

Fig. 1. Kort over Rennell visende søen Tegano og placering af klintprofiler, der er vist i fig. 8.

nell (16th of August-1st of September). The rather detailed morphological survey, which was planned, had to be radically cut down as to extension. It was, therefore, decided to concentrate the morphological part of the expedition's work on Lake Tegano.

Lake Tegano

Tegano (pronunciation: Tenggano) is probably the largest lake of the Pacific being about 28 km and 10 km broad. Looking aside from the outline of the lake, which could be seen from an airphotograph-based map, kindly set at our disposal by the *Geological Survey of British Solomon Islands,* Honiara, not much was known with certainty about it. Our investigations should try to throw some light on the relation of the lake waterbody to the ocean and on lake-bottom configuration.

Tegano and the ocean

A probable connection between Tegano and the ocean is of major significance in understanding biological problems and has therefore given rise ot much speculation (see e.g. *Bruun* and *Nielsen* 1958, *Volsøe* 1958). *Deck* (1921) talks of the great salinity of the lake, making the water undrinkable except for the local people, and a diurnal tide with an amplitude of a few inches — both traits signs of an intimate connection with the sea. Later visitors (*Stanley, Bradley, Wolff*) have not observed any tidal variation in lake-level. 1962 the variation, if any, was completely covered by effects of the wind. The height of lake-level was measured by *Stanley* (1929) to be 21 m above sea-level; a measurement quoted in later accounts. Correctness

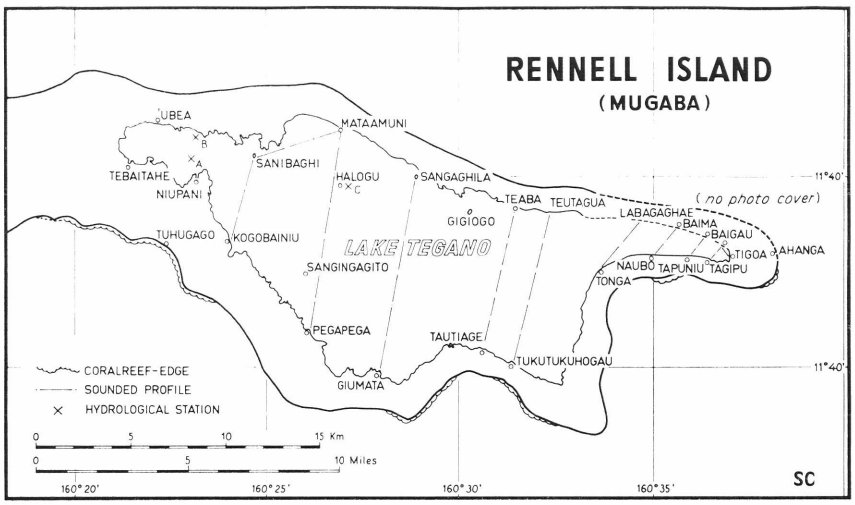

Fig. 2. Tegano with echo-sounded profiles and position of hydrological stations.
Fig. 2. Tegano med ekkoloddede profiler og stationer for hydrologiske prøver.

of this statement was, however, doubted by *Black* (1952) and the *Lairds* (1955); the measurements of last mentioned gave a height not exceeding the sea-level more than a few metres. Several repeated altimeter recordings with a Paulin instrument confirmed the view that the lake-level is at — or very close to — that of the sea. Time did not enable us to make an accurate levelling, which admittedly is necessary for a final solution of the level-problem.

Salinity of Tegano was determined by *Slevin* (1934, here cited after *Wolff)* to a total of 6.21 $^0/_{00}$ (based on a chlorinity of 3.4 $^0/_{00}$. Two samples taken by the *Galathea expedition* showed a salinity of 4.56 $^0/_{00}$ (chlorinity 2.51 $^0/_{00}$). We brought some more samples to analysis, unfortunately only from localities not too far from our base Niupani, the lake being too rough for collecting samples in the more remote and unsheltered parts. (See table below).

Station	locality	depth	salinity
A	5100 m N of Niupani	0 m	3.66 $^0/_{00}$
B	300 m from northern	0 m	4.09 -
	shore, NNE of Niupani	4 m	4.11 -
C	100-200 m E of Halogu	0 m	4.00 -
	Islet	25 m	4.09 -
	do.	0 m	2.76 -

Localities are shown on map (fig. 2). It should be noticed that the last sample was taken immediately after a heavy shower. Apart from this sample the "Galathea" and "Noona Dan" samples are very similar; the small divergence can be explained by seasonal or annual change, if it is a real one at all and not due to differences in storing and the like. We deeply regret not having sampled the deeper eastern water of the lake, especially as echograms reveal lines close to the bottom which can be interpreted as temperature or salinity boundaries.

Undoubtedly there is at Rennell a large annual excess of precipitation. No measurements are available, but vegetation a.s.o. together with general experience indicates this clearly. As the level of Tegano according to observations and local testimony only fluctuates very little, the lake must evidently be drained. The drainage is a subterranean one — probably manifested in the brackish springs found at e. g. Tuhugago beach and at other stretches of the sea-coast. Situated in the beach area around mean sea-level, the springs are probably another indication of the comparability of lake-level to sea-level. Granted the precipitation excess, the salt content of the lake can only be explained by a very recent age or by a certain influx of salt water. (If a thorough mixing between lake water and precipitation takes place, the time elapsed since segration of the lake from the sea can roughly be estimated from the formula

$$S_n = S_o\left(\frac{d_a}{d_a + p - e}\right)$$

in which S_o is the original salinity of the lake (about $35\,^0/_{00}$) and S_n the present one ($4\,^0/_{00}$), d_a is the average depth and (p—e) is the annual amount of precipitation excess over evaporation. This gives a minimum age of Tegano of a magnitude of less than 100 years at a stipulated p-e of 1 m average and a constant depth of 30 m). Evidence (from only one bottom water sample) indicates extremely intense mixing of lake water, and as ocean sea-level has not changed to any degree during the last centuries we feel an inclination to suppose a certain salt water influx. We tried to discover places in the island rim, where this could occur, but did not find evidence of it. Probably attention should be directed to the area near Tigoa, where sea and lake is only separated by a narrow and low (55 m) rim, which furthermore is severely crevassed. A Rennelese from Tigoa told us that small eel were sometimes seen in the forest of the rim; he said they regularly wandered into the lake.

Fig. 3. Our canoe with echosounder and outboard motor in Hutuna. This particular day the lake was calm, but the sounder out of function!

Fig. 3. Vor kano med ekkolod og påhængsmotor i Hutuna. Det var den eneste dag, søen var helt rolig. Netop denne dag fungerede ekkoloddet ikke!

The lake-bottom

Very few ciphers on depths (and very divergent as to a maximum) have previously been published. Thus *Deck* (1921) talks of a depth of 7 fathoms in the shallow western end, but "else where no bottom was found with 30 fathoms (55 m) of line". *Bradley* (1955) suggests a depth of more than 60 fathoms (110 m), while *Wolff* (1955) more cautiously mentions Deck's cipher of 55 m.

Of course above mentioned scattered and inharmonious information gives no picture of what the lake-bottom is like. We, therefore, decided to pick up more recordings by means of the expedition's portable Atlas Supergraph echosounder. The apparatus, driven by a car-type battery, had proved to be very reliable and was mounted on the sturdiest and biggest canoe we could hire on the lake. To ensure a nearly constant speed and a satisfying range of action we used an outboard motor on the canoe (fig. 3); sails are now practically out of use on lake canoes. Method of sounding was hereafter simply to steer straightlined courses between identifiable landmarks — athwart the lake to make deviations as small as possible. A few positions of the course were fixed by taking crossbearings underway; an accurate hand ocmpass was used to this purpose. By the used

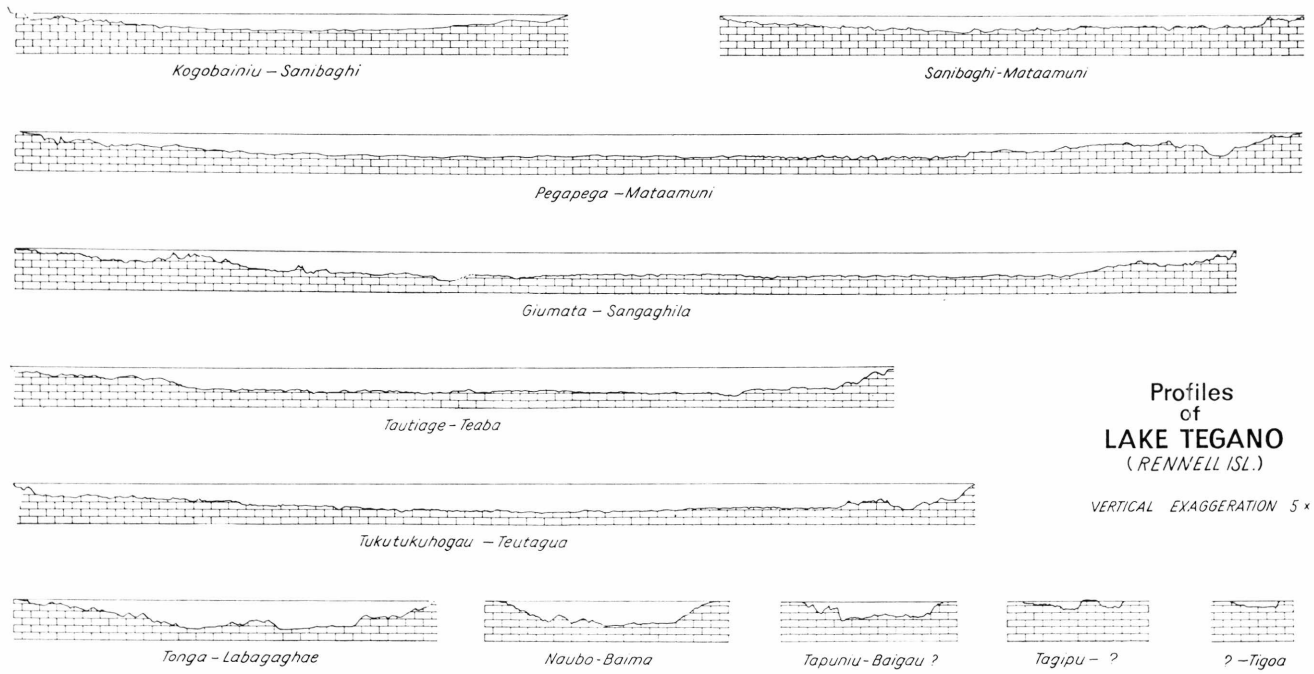

Fig. 4. Sounded profiles of Tegano, corrected as to variations in speed. Positions of profiles can be seen in fig. 2.

Fig. 4. Loddede profiler korrigeret m. h. t. variationer i sejlhastighed. Profilernes placering fremgår af fig. 2.

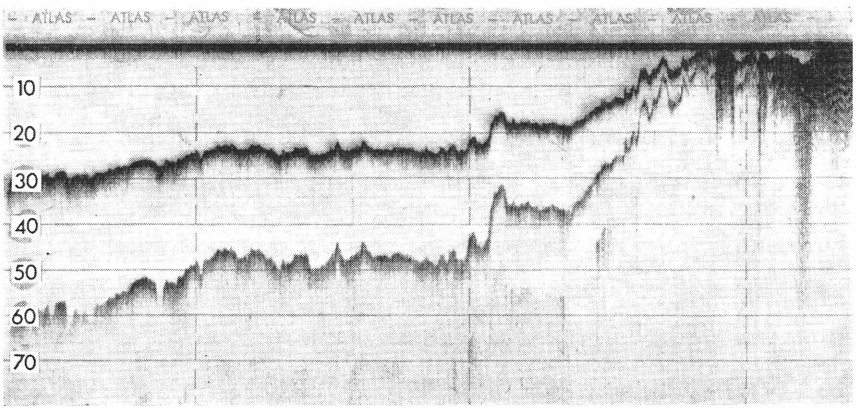

Fig. 5. The step-like transition from the deeper eastern part of the lake to the shallow western one. Depths in metres.

Fig. 5. Overgangen fra den dybe østlige til den lavvandede vestlige del af Tegano. Dybder i meter.

method positions will of course not be determined with an exactness comparable to that of the sounding itself, but nevertheless the accurate soundings are of considerable value because they render an impression of bottom-type, which would have been difficult to obtain otherwise. In the rough weather with short, sharp-crested waves often met with in Tegano, the canoe was rather unwieldy by our relatively high speed. Our Rennelese helmsman, "*Steven*" from Niupani, did his utmost and saved us from board-filling (which would have been disastrous) more than one time.

The echosounded profiles were afterwards redrawn, corrected for inevitable changes in speed. Their localization is shown in fig. 2 and the corrected profiles are given in fig. 4. It was intended to make all sections parallel and approximately equally spaced, with no big success however, as the map shows. Some sounded lines: Niupani-'Ubea and 'Ubea-Tebaitahe are not shown in fig. 4 as the recorded depths did not exceed 4 m.

Description of profiles

The most striking feature of Tegano's bottom is the flatness. Generally the central part of the lake forms a nearly unbroken plain with a depth rarely exceeding 40 m; the recorded maximum amounted to only 43 m (130 ft.). Around the central zone two bordering zones are found, marked by their depth and generally more jagged profiles. The profiles' transition into the shore area is often very abrupt as usually found by coasts of living corals, which those of

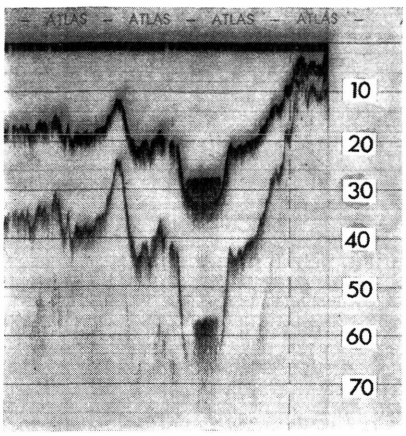

Fig. 6

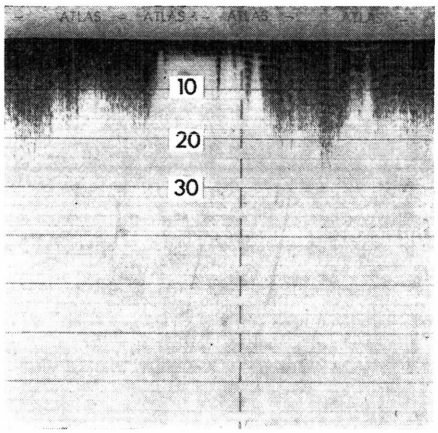

Fig. 7

Fig. 6. One of the "pockets" of the lake bottom. This one near Mataamuni was probably filled with jelly-like detritus.
Fig. 6. En lomme i søbunden nær Mataamuni fyldt med næsten flydende detritus.

Fig. 7. A flat-topped coral-knoll revealed through the thick bottom-deposits by the echo-sounder. Western part of the lake near Tebaitahe.
Fig. 7. En fladtoppet koralknold afsløret gennem de tykke bundaflejringer af ekkoloddet. I nærheden af Tebaitahe i søens vestlige del.

Tegano were evidently not. While the eastern trench-like part of the lake has a character very like that of the central, the western islet-filled part obviously definitely belongs to the border-zone (fig. 4). The general features pointed out above are easily found in the Kogobainiu-Sanibaghi profile. Carrying a lot of islets, among which Sanibaghi, the northern shore-terrace is very marked (also shown in fig. 5). As it is seen from the Sanibaghi-Mataamuni profile the northern part of the lake is usually relatively deep, looking of course aside from the shore-terrace. In the Pegapega-Mataamuni section the northern shore terrace is separated from the shore by a sink-hole depression, deemed to be of local extension only by its content of material. Seaward from the shore-terrace the lake-bottom is jagged, this type gradually emerging into the usually smooth central bottom. Giumata-Sangaghila is quite a "normal" profile. A local sinkhole south of the middle is not recorded accurately in its northern part, because of a technical mishap. The two next profiles Tautiage-Teaba and Tukutukuhogau-Teutagua show a high degree of conformity. Position of Tautiage (central) islet was inaccurately shown on the used map, wherefore that profile was run too easterly for an equal spacing of profiles. Unfortunately the weather prevented us from making an extra travers to fill the gap. Profiles

from the eastern narrow part of Tegano show that this part of the lake has a trench-like appearance, especially the northern shore with a rather precipitous slope. Although the lake in this region is relatively deep, it must, however, be stressed, that depths are far from approaching the magnitude of previous findings and suggestions. Of course we do not pretend having recorded the maximum depth, but the relative evenness and conformity of profiles indicates that chances for finding depths exceeding 50 m must be very faint.

Type of bottom

With some caution bottom-type met with can be roughly determined from the echograms. At least two types can be safely discerned; soft and hard bottom-types. By dredging a few places it was found that soft bottom seems to be of organic, quite recent origin. In some inspected samples, the organic material had decayed to a brown jelly, which filled the cavities of the coral-bottom. This seems to be the case in the big pocket of the Pegapega-Mataamuni profile, too, a detail shown in the echogram fig. 6. Hard coral bottom was present in the largest part of the lake. This type often penetrated soft deposits as is clearly seen from the echogram-detail fig. 7. Often the hard bottom evidently was developed to a type very similar to the "Makatea"-surface, which dominates the dry land except where pockets of clayey soils prevail. It is, however, doubtfull if a true "Makatea" type (developed through subaerial solution) can be discerned in echograms from certain growth forms of coral-bottom. The question whether Tegano's plain bottom was derived mainly by marine abrasion by growth or simply by sedimentation can only be solved by extensive borings.

Tegano's significance for hypotheses on Rennell's origin

From unpublished depth-recordings in the Bismarck Archipelago as well as from sea-level atolls off the eastern coast of New Ireland it appeared that bay and lagoon maximum depths seem to be very uniform (about 45 m = 140 ft.) in the named region. When Tegano showed the same depth, we naturally looked for more similarities. Attention was called to the remarkable terraces found along nearly any Melanesian coast — on Rennell, too. Usually 4—5 very marked terraces were found at the coasts of the Bismarck Archipelago in an altitude interval up to about 120 m (360 ft.). *Grover's* report on Rennell Island comprises some sketch-profiles which could

be interpreted as variations of the general type. Fig. 8 shows Grover's profile from Magautu as well as other profiles sketched during our stay on a basis of altimeter-readings, plotted on R.A.F.-photos. Although lack of material prevents us from making too fixed statements, it should be pointed out that our views diverge from Grover's as to the nature of the island rim. Grover finds this of nearly uniform height with a prominence at Labagu (estimated to 600 ft.). However, the height of Labagu Hill will probably be found to be the "normal" height of the rim only, as its conspicuousness apparently stems only from the fact, that the larger part of the island rim is missing in the Kagaba section. The rim-section from Tigoa-Ahanga sketched in fig. 8 gives rise to questioning of the statement of uniformity of height in the island rim. Has the rim an easterly tilt? Observations from the lake and inspection of aerial photographs gave us the impression of the eastern island rim lying one step lower than the rest. This interpretation is supported by the incurved form of the upper part of the rim, seen on air-photographs. Fig. 8 illustrates by the ciphered terraces a possible explanation of the morphology of this part of the island: the upper terraces are missing!

Grover (1960) supposes a post-pliocene development of Rennell by an intermittent uplift of a doming sea-floor, dating of event derived from determinations of fossils from the island rim by *J. Crespin*. Grover remarks that eustatic changes in sea-level may have assisted in the forming of the island. On basis of the similarity in number, height and character of many nearly horizontal terraces of the coasts on the continental side of the Andesite-line of the Western Pacific we feel that further investigations of these will be justified. If terraces are of eustatic origin (even if possibly combined with crustal movements) they could be used as a basis for studies of development of the conspicuous tectonic features in this region. For Rennell the explanation of origin would be greatly simplified as no pulsations in uplift need to be considered. The heights of rim and terraces fits fairly nice into the scheme of post-pliocene changes of sea-level as it is exposed e.g. in *H. Valentin's* work (1954).

Even a general explanation of Rennell's morphology will, however, still leave us with open questions. Among these the question of the coastal configuration should be noticed. The northern coast-line of Rennell has a nearly rectilinear shape, whereas the southern one is characterized by bays and points. Are these different forms related to subsurface configurations, or are they only products of different effects of actual forces?

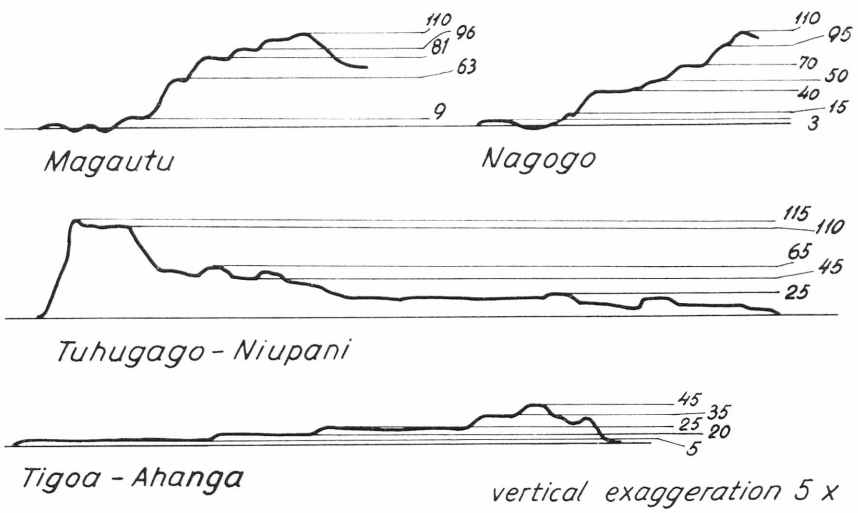

Fig. 8. Some of the terraced cliffs of Rennell. The Magautu-profile after J. C. Grover (1960). All heights in metres and approximate.

Fig. 8. Nogle terrasserede klintprofiler fra Rennell. Magautuprofilet er fra J. C. Grover (1960). Alle højder i meter, tilnærmet.

Fairbridge (1950) relates the big outer concavities in atoll shapes to landslides, while *Emery, Tracey* and *Ladd* (1954) for Bikini and other atolls demonstrated a correlation between foundations and atoll shape. Landslides leaving small concave bays can actually be seen at Rennell, breaking the continuation of coastal terraces, but it is very doubtful if landslides can be responsible for the origin of e.g. the big horseshoe-formed Kagaba Bay on the southern coast. May be this can be registered among the "refraction-bays" of *R. Russell* (verbal information).

These last questions are, however, minor ones. It would be by far more important if the question of terrace-forming in Melanesia by big comparative investigations including a dating of all occurrences could be solved. A lot of work remains to be done in this field.

RESUMÉ

Øen Rennell i Solomongruppen (fig. 1) er en hævet atoll at dømme efter mange karakteristika, f. eks. en høj koralkant kransende en næsten vandret slette. I den østlige del ligger en brakvandssø, Tegano (fig. 2), der blev gjort til genstand for en undersøgelse af *Noona Dan ekspeditionen* 1962. Hensigten var oprindelig at undersøge hele øens morfologi, men på grund af den meget korte tid, der stod til rådighed, måtte omfanget

nedskæres til ekkolodning af Tegano og rekognosceringer i den østlige del af Rennell.

Af betydelig biologisk interesse er det, om der eksisterer en forbindelse mellem Tegano og havet eller ikke. Nyere målinger (*Laird* 1955 og *Noona Dan* 1962) viser tydeligt, at søens vandspejl er i niveau med eller højst nogle få meter højere end havets. Det ferskvandsoverskud, der efter vegetation m. m. at dømme forårsages af nedbøren, må afdrænes subterrant fra søen. Forudsat 1 m nedbørsoverskud over fordampningen på søfladen kan det antages, at søen på mindre end 100 år ville afsaltes til nuværende saltindhold (4.9 $^{0}/_{00}$), når opblanding finder sted. Måske er det derfor rimeligt at antage, at de porer, der er virksomme ved afstrømningen, også muliggør en vis saltvandsindstrømning. Formodentlig finder denne sted i området ved Tigoa, hvor atollranden er lav og stærkt forkløftet, hvis den ikke generelt – som afstrømningen synes at gøre det – finder sted i en zone langs kysten nær havspejlet. Der kunne ikke konstateres noget tidevand i søen, men vandspejlet synes genstand for vindstuvningseffekt.

Teganos bund kan deles i følgende områder:

1) en vestlig lavvandet, næsten plan bund, der går jævnt over i
2) breddernes terrasse. Denne har ofte en markeret kant mod
3) den centrale søbund, der har en jævnt flad skålform (se fig. 4), der viser profiler udtegnet på basis af ekkolodninger). Langs den nordlige bred findes ret store dybder i et begrænset område, der kan minde om en grav. Denne må ikke forveksles med de lokale sænkninger, der formodes at være jordfaldshuller.

På ekkogrammerne er det muligt at skelne mellem hård og blød bund (fig. 6 og 7). Den bløde bund forekommer oftest i »lommer« og iøvrigt udbredt i den centrale del af søen. Prøveoptagning på enkelte lokaliteter viste, at det bløde materiale ofte er et flydende humøst stof. Visse afsnit af den hårde bund er ekstremt ujævne og ligner de af *Wiens* (1962) omtalte »makatea«-overflader, der er terrestrisk udformet karst. Det er dog næppe muligt at afgøre, om deres form er dannet på omtalte måde eller blot er koralvækstens former, måske modificeret ved opløsning. Der forekommer også en jævn, hård bundtype, af form som en abrasionsflade, men uidentificerbar som sådan.

Teganos dybder synes ikke nær at andrage de tidligere publicerede tal (*Deck, Bradley* o. s. v.). Maksimaldybden er antagelig ca. 45 m. Forbavsende synes bundfladen at ligge i en dybde, der omtrent svarer til lagune- og bugtdybder i det nordligere Bismarck Arkipel. En anden lighed med dette områdes kyster fandtes i det forhold, at disse lige som Rennell fremviser skarpt udformede terrasser. Fig. 8 viser de på Rennell forekommende hovedterrasser, hvoraf det bemærkes, at de øvre (?) mangler ved Tigoa.

Den udstrakte udbredelse af kystterrasser vest for Andesitlinien i Stillehavet – kystterrasser, der synes uniforme i højde over store områder – kan ses på baggrund af enten vældige vertikale blokforskydninger eller svingninger i havspejlets højde – evt. en kombination af begge. En nærmere undersøgelse, specielt med datering, af de omtalte terrasser synes

lønnende. Måske kan det foreløbig antages, at en regional hævning har udspillet sig under glacio-eustatiske svingninger i havspejlet. Dersom dette er rigtigt, vil terrasserne efter en datering kunne tilvejebringe et interessant materiale til belysning af geologiske stor-strukturers udvikling.

Også mindre landformers opståen på Rennell er gådefuld. Som eksempel er omtalt sydkystens næsten halvcirkulære bugter. Er de udformet ved skred, som antaget for andre atoller af *Fairbridge* (1950), eller er de snarere et eksempel på *Russell's* »refraction-bays«, der skyldes en regelmæssig variation i bølgernes nedbrydende virksomhed som følge af bølgefronternes bøjning?

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