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GEOLOGICAL RECONNAISSANCE FOR A POSSIBLE HYDRO-ELECTRIC SCHEME ON THE TORIU RIVER, NEW BRITAIN, T.P.N.G., 1962

by

E.J. Best

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SUMMARY

During November, 1962, reconnaissance traverses were made along the upper reaches of the Toriu River to obtain barometric levels and make geological notes; this information has been used to evaluate the merits of an alternative hydro-electric scheme to the Towanokoko-Pondo scheme. Two tracts of river were investigated: one is a 2-mile stretch of river near the village of Galavit, and the other is a 3-mile stretch of river near Maleseit.

The river gradient and the configuration of the river valley near Maleseit are favourable for the design of a hydro-electric project, and the geological conditions are generally favourable also. However, the power potential of the Toriu River is not known owing to the absence of regular gaugings of river flow. There are no natural large-capacity storage areas along the river valley.

The catchment of the Toriu River consists mainly of Tertiary limestone with interbedded mudstone. In the area investigated, however, the river has exposed the underlying basement of volcanic and igneous rocks, which would form good foundations for engineering structures and also be a source of construction materials. Where the limestone sequence crops out along the river, difficulties due to poor foundations and possible landslips will be encountered. High joint permeabilities are also likely in bedrock, which may give rise to leakage problems.

Seismic activity in the area is very high, and engineering structures would need to be designed to resist the effects of earthquake shocks of intensity 10 on the Modified Mercalli Scale.

INTRODUCTION

The power requirements of Rabaul and environs, New Britain, are increasing at such a rate that hydro-electric power may soon be economically competitive with diesel power. Several of the river systems within a radius of 45 miles from Rabaul have been examined within the past few years (see Plate 1 inset), but no obvious location for a hydro-electric scheme of the required capacity has been located. The Toriu River was rejected on the grounds of insufficient power potential after a cursory visual inspection.

In 1960, it appeared that an economical scheme with the required output could be designed to utilise the combined flow of the Towanokoko and Pondo Rivers. Hydrological and geological investigations were conducted during 1961, and when recent air photographs became available in 1962, a detailed feasibility investigation of alternative layouts for a scheme was undertaken, using geological and geophysical methods. During the geological investigation, which was carried out by the author, a reconnaissance of part of the Toriu River was undertaken as it seemed possible that an economic scheme could be located on this river system.

A total of six days was spent traversing along the Toriu River and one of its tributaries. Mapping of the river near the Galavit-Maleseit track crossing was carried out in the period 3rd to 7th November, 1962, from a temporary camp established at the crossing. The stretch of the Toriu River near Galavit was mapped on the 28th and 29th November while walking out from the Pondo area on completion of the geological survey of the Towanokoko-Pondo scheme.

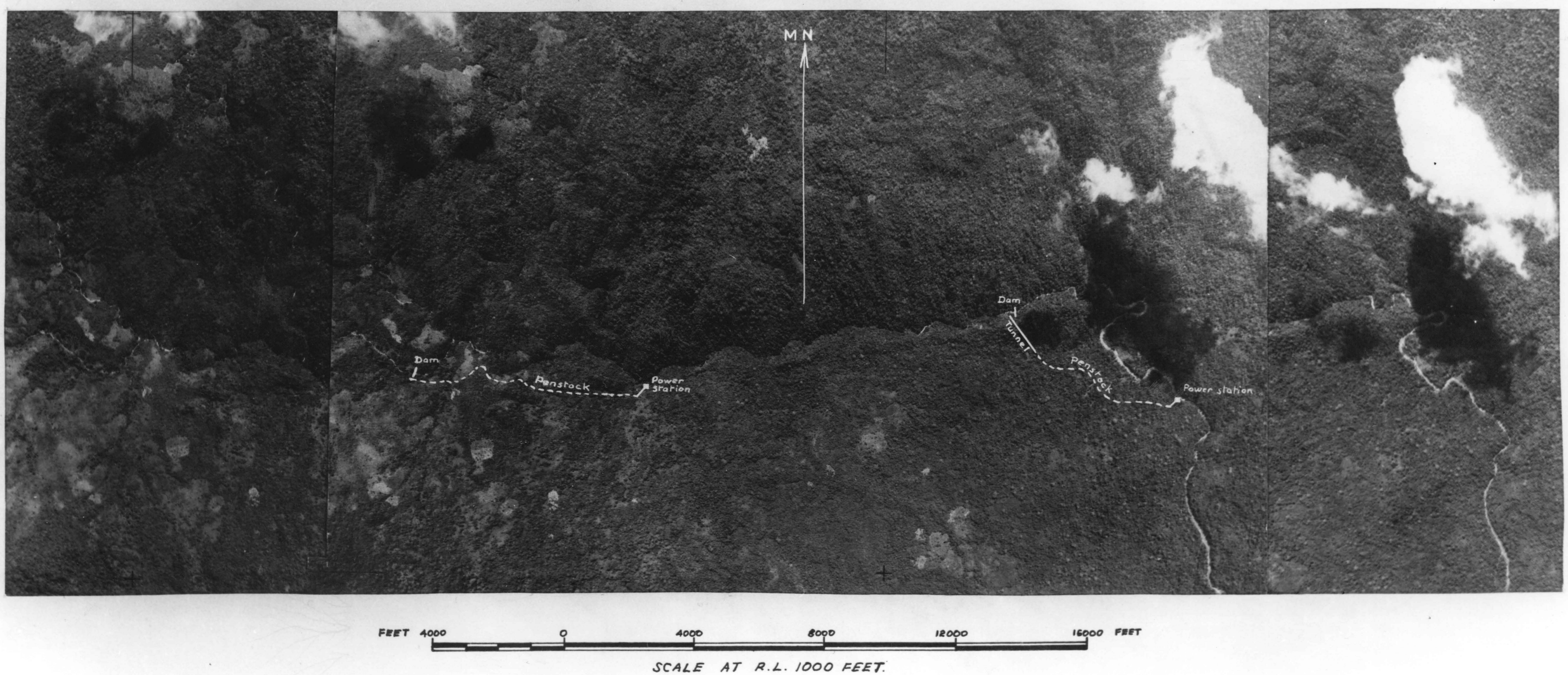

Fig. 1:- Stereoscopic pairs of photographs showing the two areas of the Toriu River under consideration and suggested scheme layouts.

LOCATION AND ACCESS

The Toriu River drains a large area of the western side of the Gazelle Peninsula, New Britain, and it enters the sea 40 miles south of Cape Lambert (see Plate 1). The proposed scheme is located at the abrupt bend in the upper reaches of the river, where the direction of river flow changes, from easterly to southerly; it is 30 air miles from Rabaul.

The area is accessible from the east via Vudal Bridge and Maleseit. At the time of the survey, Vudal Bridge was at the western limit of the road network radiating from Rabaul, access from Vudal Bridge being by a well-defined walking track only. Extension of the road to the west of Vudal Bridge was just commencing, and it was proposed that road be extended, in time, to Maleseit. The distance from Vudal Bridge to the Toriu River crossing is about 16 miles.

TOPOGRAPHY AND DRAINAGE

The upper reaches of the Toriu River are in steep limestone country, and the gradient of the river in this area is steep. The downstream limit of the reconnaissance mapping is at an elevation of 680 feet; this is only about 8 miles from the source of the river (at an elevation of well over 3,000 feet), though the river flows for about 45 miles before reaching the sea. In the area traversed, the valley sides are steep, and in several places the river has incised a narrow gorge up to 100 feet deep in the valley floor. There are no natural high-capacity reservoir areas; consequently, any scheme would possibly have to rely on diurnal pondage only. Stereoscopic pairs of air photographs of the areas mapped are shown in Fig.1, while Plates 3 and 4 show the topography of the areas traversed. Only form-lines are plotted, as the maps were drawn from the aerial photographs using a simple stereoscope only.

MAPPING

The location of all geological observations along the river courses were noted directly on air photographs. The scale of the prints used in the field is about 1 inch to 4,000 feet, but for plotting purposes, scales of 1 inch to 2,000 feet, 1,000 feet, and 500 feet were used.

Barometric levels were taken at intervals along the river courses; corrected levels are plotted on Plates 3 and 4. It was not possible to obtain values of diurnal variation during the reconnaissance, and so diurnal variation curves obtained under similar weather conditions at the Pondo base camp were used for corrections; this is a possible source of error in the corrected levels.

REGIONAL GEOLOGY

The catchment of the upper reaches of the Toriu River consists mainly of Tertiary limestone. In the area investigated, however, the river has cut down through the limestone and exposed the underlying basement of volcanic and intrusive rocks. The approximate boundary between the limestone and the basement rocks is shown in Plate 2. The Tertiary limestone is believed, on structural evidence, to overlie the basement rocks unconformably.

LIMESTONE

Specimens from the limestone succession were submitted for palaeontological examination, and the results (Lloyd , 1963) indicate a Middle to Lower Miocene age-range for the sequence; the limestone is therefore part of the "Neogene Series" of Noakes (1942). Thickly bedded limestone is the main rock type, but interbeds of marl, mudstone and conglomerate are commonly present throughout the series. In the area traversed downstream of the Galavit-Maleseit track crossing, interbeds of calcareous sandstone have also been mapped.

The limestone is generally cream to buff coloured, and is uniform in appearance. Structure is seldom evident in the thick beds, but interbeds of marl and mudstone clearly show the attitude of bedding in many places. Measured dips generally range from 30° to 45°, with occasional dips of less than 30°; the beds dip in a south-easterly to east-south-easterly direction (see Plates 2 and 6).

A basal limestone containing fragments of volcanic rock has been located along one of the tributary streams of the Toriu River near Galavit (see Plate 5). Insufficient time was available to locate exactly the base of the "Neogene Series" along the Toriu River in this area, and the boundary is not visible in the Toriu valley near Maleseit owing to lack of outcrop.

BASEMENT ROCKS

The basement rocks of the Gazelle Peninsula (the "Baining Series" of Noakes, 1942) consist mainly of metamorphosed shale, siltstone and mudstone. Regional metamorphism has resulted in the development of slate and phyllite, and widespread granitic and porphyritic intrusions have locally produced quartzite and typical contact metamorphic rocks.

These pre-Tertiary rocks were subsequently affected by intrusive and extrusive activity which seems to have persisted over a long period of time in the early Tertiary epoch. Intrusions of acid to intermediate porphyritic rocks have been noted, together with subordinate basic lavas. In addition, basalt flows interbedded with tuffaceous sediments have been found along the north coast of the Gazelle Peninsula.

The inlier of basement rocks exposed by the Toriu River consists mainly of banded volcanic rocks. In the area traversed near Galavit, lithic tuff is the predominant rock type with some interbanded flows of andesine basalt (see Plate 5 for distribution of rock types). Volcanic agglomerate,

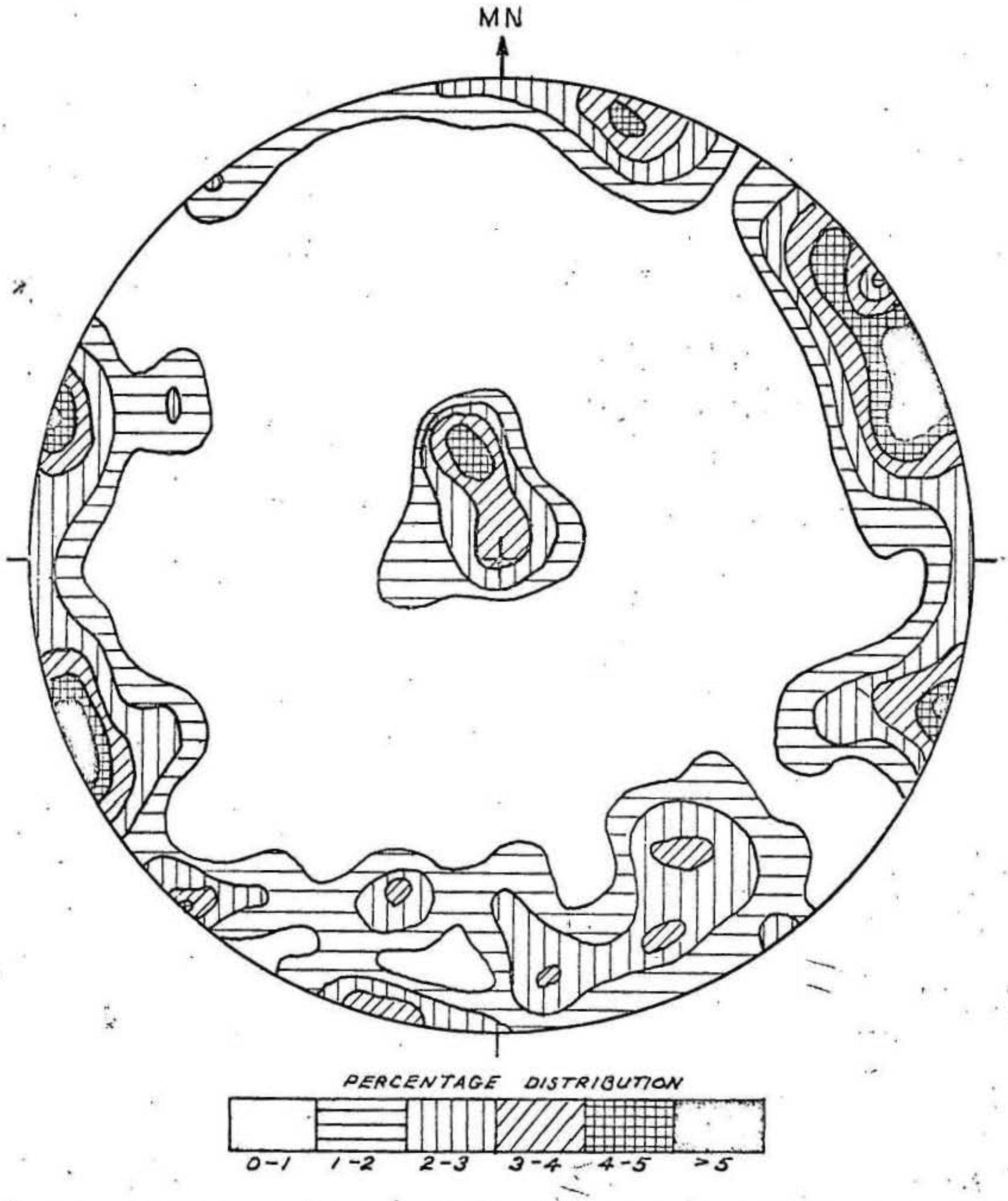

Fig. 2 :- Contoured joint plane stereogram. Poles of 105 joint measurements are projected onto the lower hemisphere, using an equal area net.

which is commonly associated with the "Baining Series" in other areas of New Britain, has been mapped in the upstream tracts of the river close to the boundary with the overlying "Neogene Series". In addition to these rock types, dykes of dolerite and augite andesite have been mapped.

In the area near Maleseit, dolerite is the main rock type, with interbanded flows of rhyolite, tholeiite, augite andesite and lithic tuff (see Plate 6 for distribution of rock types). Towards the top of the exposed sequence of interbanded volcanics, i.e. close to the contact with the overlying limestone sequence, devitrified rhyolitic flows become the dominant rock type. The individual rhyolite flows show small-scale banding resulting from weathering and alteration.

The marked banding of the volcanic rocks is consistent throughout the two areas examined; in the Galavit area the banding dips at between 5° and 15°, while in the Maleseit area measured dips range between 7° and 20°. The direction of dip in both areas ranges from south-east to south, which is similar to the dip of bedding of the "Neogene Series". This affinity, together with the proximity to the base of the "Neogene Series", suggests that the volcanic rocks exposed in the Toriu valley may be a separate sequence from the "Baining Series".

Two minor fault zones were mapped in the Maleseit area, one in rhyolite and the other in dolerite. Both have a northerly strike and dip steeply to the west, and both have been recemented by calcite.

Regular jointing is common in the basement rocks. Sheet jointing is in places well-developed, with spacings ranging from 12 inches down to 1 inch or less in closely jointed zones. Rectangular jointing is also common, and in some places three prominent sets of joints are developed. The distribution pattern of joint planes measured along the Toriu River is shown in the contoured stereogram (Fig.2). Three main concentrations of vertical joints are indicated; two sets are perpendicular to each other (with strikes of 108°* and 199°) while the strike of the third set (154°) bisects the angle between the other two. There is also a concentration of joints dipping gently to the east-south-east, representing jointing parallel to bedding and banding.

Apart from these main sets of joints, there are several smaller concentrations of joints with dips ranging from 65° to 80° in a north-north-westerly to northerly direction. Inspection of the field data reveals that each of these sets is perpendicular to the banding in the particular area; the strike of the joints corresponds closely to the strike of banding.

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* All bearings in this report are magnetic.

HYDROLOGY

Very little hydrological information is available from the Toriu catchment, and continuous records of rainfall and run-off over a period of at least two years would be necessary to evaluate the hydro-electric potential of the river. The only relevant information obtained to date consists of intermittent rainfall records at the village of Raunsepna, and several sporadic gaugings of river flow in the Toriu River (see Appendix 1).

From the limited records available, the annual rainfall at Raunsepna is of the order of 150 inches. It appears to be spread fairly evenly throughout the year, the monthly rainfall being usually between 10 and 18 inches. January and February , 1963 were particularly dry, however, with a rainfall of only 1.06 and 2.82 inches respectively. The river gaugings on the Toriu River were carried out after this prolonged dry period, and the figures must be abnormally low. During the geological traverses, the flow of the Toriu River at the Maleseit track crossing was estimated to be at least 200 cusecs, probably more. The gauged flows, however, ranged between 65 and 80 cusecs only. The flows of the Towanokoko and Pondo Rivers dropped to 43 and 13 cusecs respectively for several weeks during this dry period, i.e. lower than the minimum flows necessary to generate the required power; this was in spite of much higher rainfall (13 inches in the two months) than in the Toriu catchment.

ENGINEERING GEOLOGY

Possible Scheme near Maleseit

The most obvious location for a hydro-electric scheme on the upper reaches of the Toriu River is near the Galavit-Maleseit track crossing; here, the river makes a sharp change in direction and meanders considerably. Over the 3 miles of river investigated, the fall in elevation is 300 feet (from 983 to 681 feet), while the direct horizontal distance between the two ends of the traverse is only 1½ miles.

At the upstream end of this section of the river, there are no obvious high capacity storage areas. The best reservoir area available would be upstream of the slight curve in the river at elevation 961 feet (Plate 4); here the river valley widens noticeably, although the valley sides are still steep. The bedrock at the site consists of very hard and strong dolerite, which would form ideal foundationsfor a concrete dam.

For power generation, the water would be diverted by a 1500-foot long tunnel through the narrow ridge forming the southern bank of the river, and then a surface race or penstock would carry the water to a suitable point above the river downstream of the track crossing (see Fig.1). The length and route of the race or penstock would depend upon the choice of power station site, which in turn would depend on the head of water required to generate the desired amount of power. If the power station is sited at an elevation lower than 750 feet, the penstock or race would have to traverse the steep western bank of the river downstream of this point; this could be difficult from an engineering point-of-view, as the bedrock in this area is limestone. The high pressure penstock and the power station would also be sited on limestone.

Near the right-angle bend in the Toriu River just upstream from the track crossing, two deeply incised tributaries join the main river. At the time of the investigation, there did not appear to be much water in these streams, but it may be economical to collect the water available and divert it to the proposed reservoir by means of a surface race around the hillside.

POSSIBLE SCHEME NEAR GALAVIT

The section of the Toriu River between Galavit and the confluence with the Warangi River was investigated on the advice of Mr.D. Ryan of the Department of Works office at Port Moresby. He had previously been into this area and noted a substantial volume of water in the river, flowing in a deep gorge with several major falls. The gorge starts ¼ mile downstream from the confluence with Lambrian Creek and continues to 1,000 feet downstream from the confluence with Warangi River (see Plate 3). In this one-mile stretch of the Toriu River, there is only one place where it is possible to get down to river level. Generally the river flows in a vertical sided gorge, from 30 to 100 feet high, incised into hard and strong, jointed, volcanic rocks. The fall of the river over this one-mile section is 370 feet, (from 1534 feet to 1160 feet above sea level).

The Warangi River was seen to enter the Toriu River over what is virtually a 200 foot waterfall - there are two breaks in the fall where the river flows horizontally for 100 feet or so before plunging down again. The banding in the volcanic rocks is clearly evident in the rock face.

Upstream from the head of the gorge, the river gradient is still high; the river falls 240 feet in the one-mile stretch above the gorge (1770 to 1534 feet). From 1770 feet to 1690 feet (see Plate 3) the river valley is wide with gentle slopes. Below 1690 feet the valley narrows and steepens until just downstream of the junction with Lambrian Creek. From here to the head of the gorge, the river is again wide, with gently sloping banks. Thus a dam could probably be built at an elevation of about 1680 feet, from which a race surface penstock or tunnel could run along the southern side of the valley to an appropiate point above a possible power station site lower on the Toriu River (see Fig.1). There is no suitable site for a surface power station above the 1160-foot point on the Toriu, so the head available would be at least 520 feet. The water from Lambrian Creek could be diverted into the diversion dam on the Toriu River by a surface penstock or race.

The bedrock exposed in the area consists of hard, strong, igneous and volcanic rocks which would provide good foundations for engineering structures. Regular tight jointing is evident in most outcrops, and veins of calcite are commonly present.

LANDSLIDES

Interbedded limestone and mudstone crops out only in the area downstream of the track crossing; therefore only the low and high pressure pipelines and power station site of the Maleseit scheme are likely to be affected by landslides. A large area of landslide debris is present on the east bank from elevation 792 feet to 740 feet, and small landslips are evident on the west bank from 692 feet to downstream of 681 feet. Difficulties may therefore be encountered should it be necessary to locate the pipelines and power station in this area. On the other hand, mudstone interbeds are not as frequent as in the Pondo area, and the limestone is more thickly bedded; difficulties due to landslides should not be as serious as in the Pondo area.

SEISMICITY

The Gazelle peninsula is a highly seismic area, and a summary of all recorded seismic data from the area is given in Brooks (1963). During the past 50 years, eight earthquakes with a recorded magnitude of 7 or greater have been recorded within a radius of 75 miles from the scheme area. Brooks predicts that an earthquake of intensity 9 on the Modified Mercalli Scale could be expected once every 25 years, and an earthquake of intensity 10 once every 100 years. These are very severe conditions, and earthquake-resistant design for engineering structures would be necessary, despite the good foundation conditions of the basement rocks.

CONSTRUCTION MATERIALS

The basement rocks exposed along the Toriu River would be a good source of concrete aggregate and rockfill (if necessary). No natural sources of sand have been located, but suitably-sized material could be produced by crushing the basement rocks. Construction materials are much more suitable and readily available than in the environs of the Towanokoko-Pondo scheme.

CONCLUSIONS

1. Geological conditions are favourable for the construction of a hydro-electric scheme.

2. The river gradient and the configuration of the river valley near Maleseit are favourable for the development of hydro-electric power.

3. The hydro-electric potential of the Toriu River is unknown because of the absence of regular gaugings of river flow.

4. There are no natural large-capacity storage areas along the sections of the Toriu River traversed.

5. Basement volcanic rocks of the "Baining Series" crop out along much of the river valley; these would provide strong foundations for any engineering structures.

6. In the downstream area of the river (below the Galavit-Maleseit track crossing), a sequence of thickly bedded limestone, with a few mudstone interbeds, crops out in the river valley; this sequence, which unconformably

overlies the basement rocks is part of the "Neogene Series". Similar problems to those of the Towanokoko-Pondo scheme would be encountered in siting and founding engineering structures on the limestone sequence.

7. Engineering structures would need to be designed to resist the effects of earthquake shocks of up to intensity 10 on the Modified Mercalli Scale.

8. Construction materials are readily available from the basement rocks which crop out extensively along the river. Sand would be obtained by crushing suitable rock.

RECOMMENDATIONS

1. Continuous recording pluviometers and stream-gauging instruments should be installed along the Toriu River to enable the power potential of the river to be evaluated. Suggested locations for regular gaugings of river flow are (1) close to Galavit, (2) downstream of the confluence of Warangi River, and (3) close to the Galavit-Maleseit track crossing. No further work can be justified unless regular gaugings of river flow indicate that there is sufficient potential to meet the required output.

2. Of the two areas investigated, the stretch of river near Maleseit is the more suitable for the development of hydro-electric power. If the power potential of this area is found to be adequate, the following measures are recommended:-

(a) Aerial photographs of the area should be obtained by flying at a lower elevation than during the previous survey flights, i.e. at 15,000 feet or lower. Prior to the aerial survey, reference survey points should be clearly established on the ground to enable a reasonably accurate topographic map of the area to be compiled,

(b) Dumpy level or stadia traverses will be necessary to obtain accurate levels along the river.

(c) Detailed geological mapping of all rock outcrops in the area will be required in order to design a scheme layout to suit the geological conditions.

(d) When the preliminary work outlined above has been carried out, it should be possible to design one or more layouts for a hydro-electric scheme. More detailed work, such as pitting and trenching, diamond drilling, geophysical traverses, accurate topographic surveys, search for suitable quarry sites, laboratory testing of rock samples, can then be planned.

ACKNOWLEDGEMENTS

All necessary arrangements for messing, labour force, and local native carriers were made by the Commonwealth Department of Works, who were represented in the field by Mr. R. Jensen, the surveyor for the Towanokoko-Pondo project. His ready cooperation in allocating competent native assistants for the Toriu River traverses was greatly appreciated.

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APPENDIX 1

HYDROLOGICAL DATA FOR THE UPPER REACHES OF THE TORIU RIVER

The following information was recorded by the Commonwealth Department of Works, Port Moresby.

1. Monthly rainfall readings at Raunsepna for 1961-1964 (records incomplete)

Year	Month	Rainfall (points)	Year	Month	Rainfall (points)
1960	Jan.	1456	1963	Jan.	106
	Feb.	1131		Feb.	282
	Mar.	1390		Mar.	750
	May	1076		Apr.	1307
	June	1524		May	640
	July	567		June	737
	Sept.	1232		July	1448
1961	Oct.	1827		Aug.	1754
	Nov.	2409		Sept.	1082
1962	May	930	1964	Apr.	1030
	June	641		May	1020
	July	1009		June	669
	Aug.	1217		July	537
	Sept.	1924		Aug.	689
	Oct.	1781		Sept.	561
	Nov.	1197		Oct.	817
	Dec.	789		Nov.	1136

No readings taken since Nov. 1964.

2. Gauging of river flow in the Toriu River

(a) Upstream from the Lambrian Creek junction
27/2/63 50 cusecs
27/2/63 50 cusecs

(b) Downstream from the Lambrian Creek junction
27/2/63 55 cusecs
27/2/63 53 cusecs

(c) At possible damsite (elevation 961 feet)
27/2/63 79 cusecs.

(d) 1500 feet upstream from Galavit-Maleseit track crossing
25/2/63 84 cusecs
26/2/63 71 cusecs

(e) At Galavit-Maleseit track crossing.

24/2/63	73 cusecs
24/2/63	66 cusecs
24/2/63	76 cusecs
25/2/63	71 cusecs
25/2/63	80 cusecs
25/2/63	65 cusecs
26/2/63	70 cusecs
26/2/63	68 cusecs
28/2/63	67 cusecs
1/12/63	185 cusecs
21/10/64	126 cusecs
7/11/64	153 cusecs
25/3/65	359 cusecs

APPENDIX 2

PETROLOGICAL DESCRIPTIONS OF ROCK SPECIMENS FROM THE BASEMENT ROCKS

by

Celia Newbigin

Field No: T19. Slide No:10155 Rock No: 13811

Flow-brecciated quartz andesite.

The rock consists of laths and angular grains of feldspar and quartz, set in a groundmass of welded brecciated glass fragments; a few grains of pyroxene are also present. The glass fragments contain vesicles stretched by flow, infilled vughs, and fragments showing laths oriented by flow. The glass shows incipient devitrification. Xenoliths are common.

The feldspar is plagioclase with a composition in the andesine-labradorite range where fresh. Most feldspar grains are altered and have a more sodic composition - some are albite. Most fresh grains have an albitic rim. Alteration to clay minerals and chlorite is evident in most grains. Quartz occurs as rounded grains and as vesicle fillings; the minor amounts of pyroxene present are of fresh augite.

Vughs are filled in three stages: firstly chlorite, then quartz with hematite dust, and finally quartz. The second and third stages are not everywhere present.

The glass contains opaque material and chlorite. In places where devitrification has advanced, large areas of clay minerals and calcite have developed. The xenoliths are of volcanic and plutonic material, and are mostly opaque except for microlites of feldspar.

Field No: T20. Slide No:10156 Rock No: 13812

Hyalopilitic andesite.

In this rock, feldspar microlites and sub-angular to sub-rounded quartz grains are set in a groundmass of glass which shows only slight devitrification. There are a few larger grains of feldspar present, and some structures are evident which appear to pseudomorph former phenocrysts. These pseudomorph structures are filled with chlorite, calcite and, in some places, prehnite.

The feldspar microlites are composed of andesine, but larger grains are more sodic; some are possibly potash feldspar. The groundmass contains opaque material, calcite and chlorite; the opaque material is mainly pyrite with some hematite.

Field No: T22. Slide No: 10157 Rock No: 13813

Altered rhyolite.

Irregular euhedral to subhedral crystals of feldspar, some of them bent, occur in a groundmass of devitrified and altered glass. Flow texture is still visible in the pattern of alteration and the granules of opaque material; also, a slight degree of preferred orientation is evident in the phenocrysts.

Both alkali and plagioclase feldspars are present, and together they make up 25% of the rock. Crystals of orthoclase and albite are altered to sericite and clay minerals; the plagioclase is so altered that the original composition cannot be determined. In one grain, there is an intergrowth of plagioclase and alkali feldspar.

The glass, which comprises 70% of the rock, has been altered to zeolitic material with chlorite and calcite also present. A few minor xenoliths are present; they are composed of igneous material which is opaque, except for microlites arranged in a trachytic texture and some fragments of relatively fresh glass.

Minor amounts of quartz and magnetite are present.

Field No: T23 Slide No: 10158 Rock No: 13814

Augite andesite.

Phenocrysts of feldspar, many enclosing tiny grains of pyroxene, are set in a groundmass of interlocking plagioclase laths and pyroxene granules. The feldspar phenocrysts have a maximum length of 5mm; the average size of grains in the groundmass is between 0.5 and 0.8mm.

Zoning is evident in the phenocrysts, the average composition being labradorite. The alteration is also zonal, and kaolinisation is generally evident. Some of the phenocrysts have been altered to calcite and prehnite. The feldspar laths in the groundmass are more sodic than the phenocrysts, and are only slightly kaolinised. Secondary chlorite and prehnite is commonly present. The pyroxene in the groundmass is titaniferous augite, partly altered to chlorite. Magnetite and ilmenite grains are also present in the groundmass.

Field No: T24 Slide No: 10159 Rock No: 13815

Altered andesitic welded tuff.

Both angular and rounded resorbed fragments of minerals, glass and lava are present in a groundmass of devitrified and altered glass. The groundmass contains vesicles and displays a distinct streakiness.

Plagioclase feldspar, in the range oligoclase to andesine, has been altered extensively to albite, kaolin and prehnite. Angular, anhedral and resorbed grains of quartz are present, together with augite which appearsas tiny, rounded and unaltered granules. The glassy groundmass is devitrified and has been altered to chlorite, clay minerals, prehnite and zeolites. Most vesicles are filled with chlorite, but some contain quartz. The composition of the microlites in the groundmass could not be determined. Epidote is present as a secondary mineral, extensively altering the groundmass and the feldspar. A few xenoliths of feldspar and iron-rich glass are also present.

Field No: T26 Slide No: 10160 Rock No: 13816

Devitrified Rhyolitic Flow.

Euhedral to anhedral grains (average grain size 0.02mm) of quartz and feldspar occur set in a devitrified and altered groundmass. Vesicles 6 to 10 mm in diameter are present and are filled with secondary minerals.

The quartz grains which constitute 10% of the rock, contain cavities and inclusions of acicular crystals. The feldspar, which is albite, is fresh and shows irregular twin planes; the average grain size is 0.03mm, and the feldspar forms 15% of the rock. Calcite occurs as a vesicle filling and as an alteration mineral. The bulk of the rock is a groundmass of devitrified glass; chlorite and clay minerals are abundant, and were formed by the alteration of microlites, probably of feldspar. Granules of unidentified opaque minerals are scattered throughout the groundmass.

Field No: T30 Slide No: 10161 Rock No: 13817

Albitised tholeiite.

This is an even medium-grained rock consisting of interlocking laths of feldspar, interrupted by larger grains of quartz. Quartz also occurs interstitially with small rounded grains of pyroxene and angular grains of opaque material.

The feldspar was originally zoned plagioclase, but it has been altered to albite and, in some grains, to prehnite. The pyroxene is pigeonite, partly altered to chlorite, and the opaque material is mostly magnetite, with some pyrite. Calcite is present as an alteration product of the plagioclase.

Field No: T33 Slide No: 10162 Rock No: 13818

Tholeiitic dolerite.

The rock consists of tightly packed, irregular, subhedral phenocrysts of feldspar (average length 2mm) and anhedral, resorbed phenocrysts of pyroxene (1.5mm). Some pyroxene phenocrysts show a sub-ophitic relationship with the smaller laths of feldspar (0.8-1.0mm) which comprise the groundmass. Skeletal grains of ilmenite and a secondary amphibole are distributed throughout the slide.

The feldspar is labradorite which occurs as zoned crystals mostly fresh but with some alteration to chlorite. The pyroxene is sub-calcic augite which is generally altered to actinolite and chlorite. In some cases a second chlorite forms rims around pyroxene grains. Quartz occurs in minor amounts in the groundmass, along with apatite and ilmenite.

Field No: T34 Slide No: 10163 Rock No: 13819

Flow-brecciated andesite.

Euhedral crystals, mineral fragments and rock fragments are set in a groundmass of welded glass fragments and glass.

Plagioclase feldspar, in the range andesine- labradorite, forms 40% of the rock; it is extensively altered to zeolitic material and a fibrous amphibole. Fresh euhedral crystals of sub-calcic augite form 2-3% of the rock, and rock fragments make up to 6%. The rock fragments are mostly opaque, except for microlites arranged in either a trachytic or flow texture; some consist of glass peppered with opaque material. The remaining 50% of the rock is a groundmass consisting of devitrified glass, partly altered to chlorite and zeolites. A distinct flow texture is evident in the groundmass.

Field No: T35 Slide No: 10164 Rock No: 13820

Dacite.

The rock is banded with coarse and fine bands 5 to 10mm in thickness. The fine bands contain microlites in a semi-devitrified groundmass, while the coarse bands contain phenocrysts 0.1 to 0.4mm long,as well as microlites.

The microlites are feldspar, and the groundmass is altered to granules of opaque material, chlorite, calcite and sericite. The phenocrysts are mostly quartz and feldspar, though a few altered augite phenocrysts are also present. The quartz grains are embayed and angular. Vughs of (?) tridymite and crystobalite occur in the fine bands, and veins of quartz and calcite transect the rock as a whole.

Field No: T40 Slide No: 10165 Rock No: 13821

Altered dacite.

Broken, resorbed phenocrysts occur in a devitrified and altered groundmass in which microlites define a flow texture and perlitic structures are visible. Xenoliths with a trachytic texture commonly occur in the groundmass.

Feldspar phenocrysts constitute 15% of the rock, plagioclase occurring more commonly than orthoclase. The plagioclase feldspars are in the range oligoclase-andesine, and occur as broken and resorbed crystals, mostly unaltered. The orthoclase is also generally fresh, and occurs as both rounded and angular fragments. Angular and resorbed quartz amounts to 10% of the rock; the minor amounts of augite present are fresh and unresorbed. The xenoliths are generally opaque; some consist purely of glass, while others contain microlites. The groundmass of devitrified glass accounts for 65% of the rock; it is powdered with opaque material and is extensively altered to chlorite with patches of calcite and clay minerals.

Field No: T41 Slide No: 10166 Rock No: 13822

Andesite.

Feldspar phenocrysts up to 10 mm. long occur in a groundmass showing a sub-ophitic texture. The phenocrysts account for 45% of the rock and most are composed of zoned andesine. They have been albitised, kaolinised, chloritised, and veined by a late stage mineral (zoisite?). They also contain resorbed and altered fragments of pyroxene, many of which have been altered to chlorite. Plagioclase constitutes a further 25% of the rock in the form of laths of oligoclase which exhibit a sub-ophitic texture with sub-calcic augite. Pyroxene also occurs interstitially with the plagioclase phenocrysts; it is commonly altered to chlorite and tremolite-actinolite. Opaque material (10% of the rock) occurs as irregular and skeletal grains dispersed through the groundmass.

Field No: T42 Slide No: 10167 Rock No: 13823

Tholeiitic dolerite.

Only a few phenocrysts (3% of the rock) occur, set in a trachytic groundmass. Plagioclase feldspar constitutes 45% of the rock, and has a composition in the range andesine-labradorite. The phenocrysts and groundmass plagioclase have the same composition, and are altered to chlorite and sericite. Pyroxene amounts to 20% of the rock, and is mainly composed of sub-calcic augite occurring as rounded grains (0.1-0.2mm) and laths (maximum length 0.4mm); some pigeonite occurs also. The pyroxene is generally slightly altered to iron-stained fibrous material and chlorite; one or two unaltered phenocrysts were observed. Chlorite, which comprises 25% of the rock, occurs interstitially and as an alteration product. Minor amounts of quartz, calcite and opaque material are scattered through the groundmass.

Field No: T43 Slide No: 10168 Rock No: 13824

Augite andesite.

Angular broken grains and laths of feldspar and augite are set in a groundmass of chlorite. The groundmass was probably originally glass, but alteration to chlorite has destroyed most of the primary glass structures.

The feldspar is plagioclase with a composition in the range oligoclase-andesine. It has been kaolinised, prehnitised, and in part chloritised. The augite occurs as anhedral, broken but unaltered grains. Opaque fragments of lava are present as xenoliths, and these contain unaltered microlites of feldspar.

Field No: T44 Slide No: 10169 Rock No: 13825

Indurated marl:

This is an extremely fine-grained carbonate-rich rock with a high clay content; it also contains foraminifera and other shelly fragments, volcanic and mineral fragments, and pelletal material. Banding in the rock is caused by variations in grain size of the carbonate material, which ranges between 0.005 mm. and 0.01mm.

The carbonate is intergrown with colourless and brown clay minerals, and pale green chlorite is scattered throughout as a secondary mineral. The fossil fragments are generally unaltered, but most of them contain secondary chlorite and clay minerals. The pelletal material is mostly glauconite, some of which is outlined by a colourless material, and the mineral fragments are sub-hedral to euhedral fresh grains of feldspar and minor augite. The volcanic fragments consist of brownish glass, containing feldspar crystals.

Field No: T48 Slide No: 10172 Rock No: 13828

Lithic tuff.

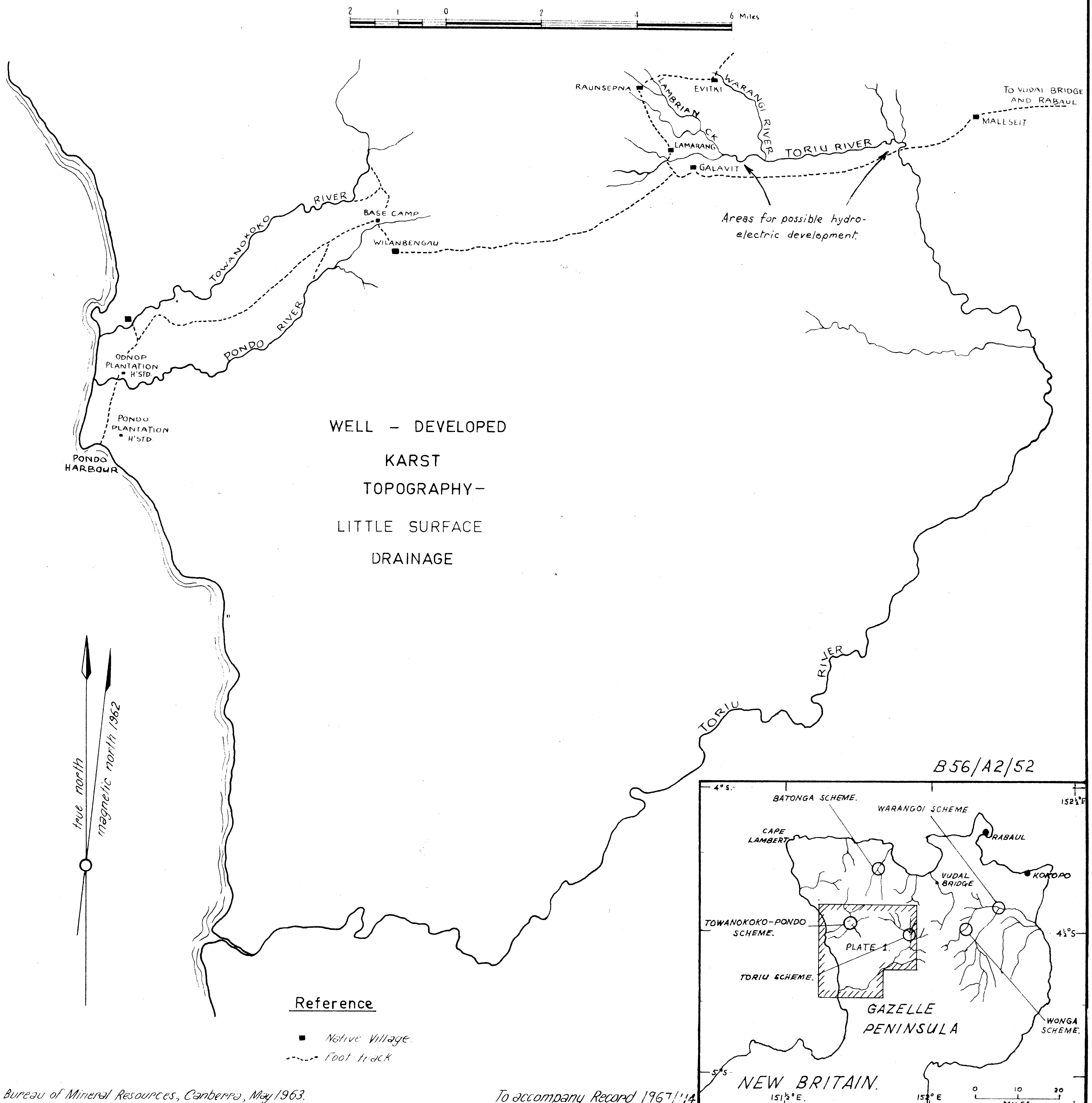
Rock fragments, mineral fragments, and glass shards occur set in a groundmass which was originally glassy, but is now devitrified and extensively altered. Some rock fragments are trachytic, feldspar laths occurring in a devitrified groundmass which has been converted to iron oxides; other fragments are devitrified shards of volcanic rock, showing vesicular and flow structure. The vesicle fillings are mainly iron-rich chlorite, with some quartz, while the glass has generally formed microlites on devitrification and been altered to chlorite, calcite and limonite.

The mineral fragments are predominantly broken, euhedral, zoned grains of plagioclase which are commonly sericitised and albitised. Some broken, rounded grains of aegirine augite occur also; these have been altered along fractures to chlorite, calcite and an amphibole.

The groundmass of the rock is a devitrified glass which has altered in a fashion similar to the rock fragments, but with a greater proportion of calcite.

PLATE I

LOCALITY MAP



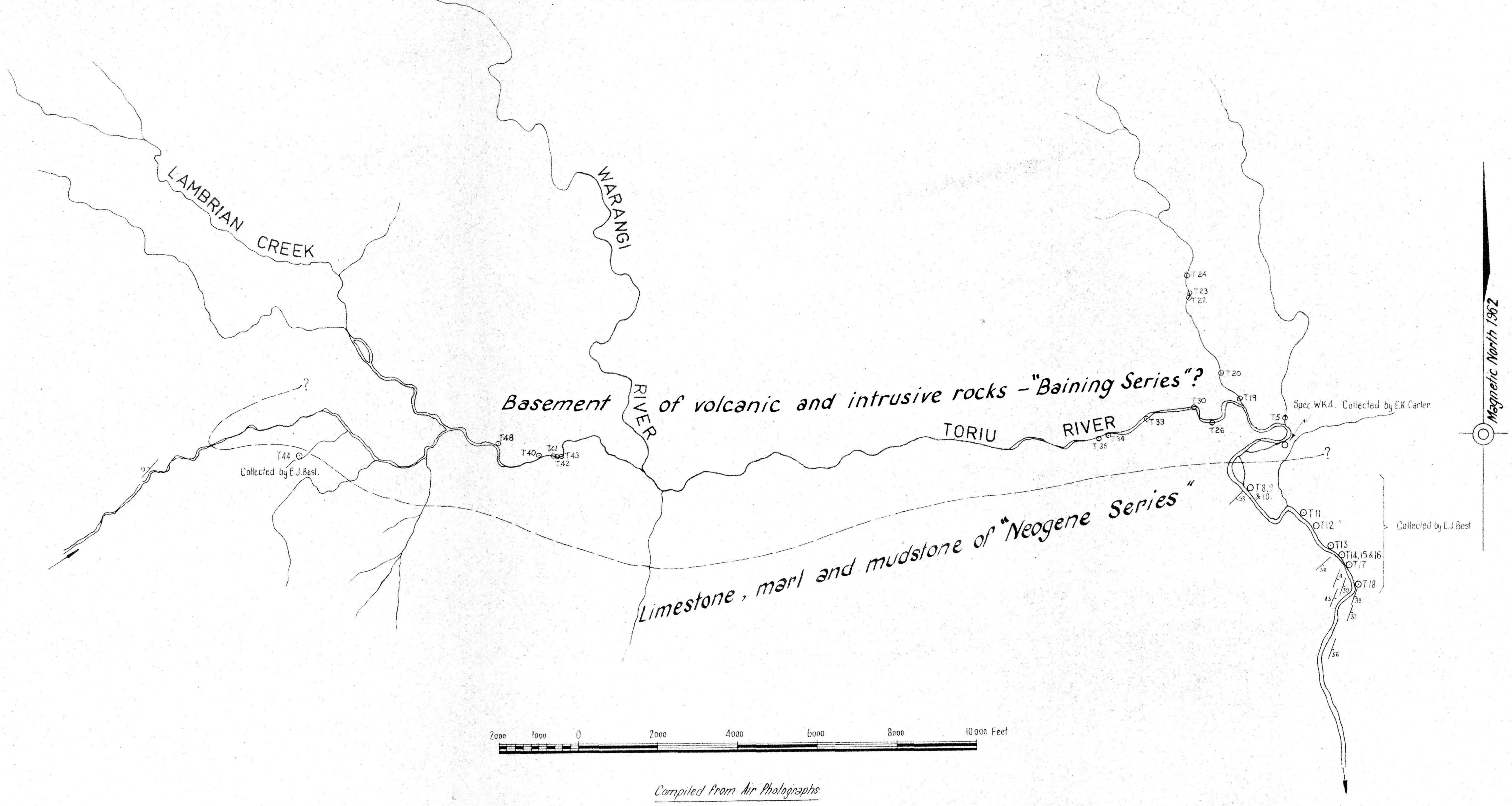
Bureau of Mineral Resources, Canberra, May 1963.

To accompany Record 1967/14

PLATE 2

MAP OF UPPER REACHES OF TORIU RIVER

SHOWING DIPS AND STRIKES OF BEDDING AND SAMPLE LOCALITIES



Compiled from Air Photographs

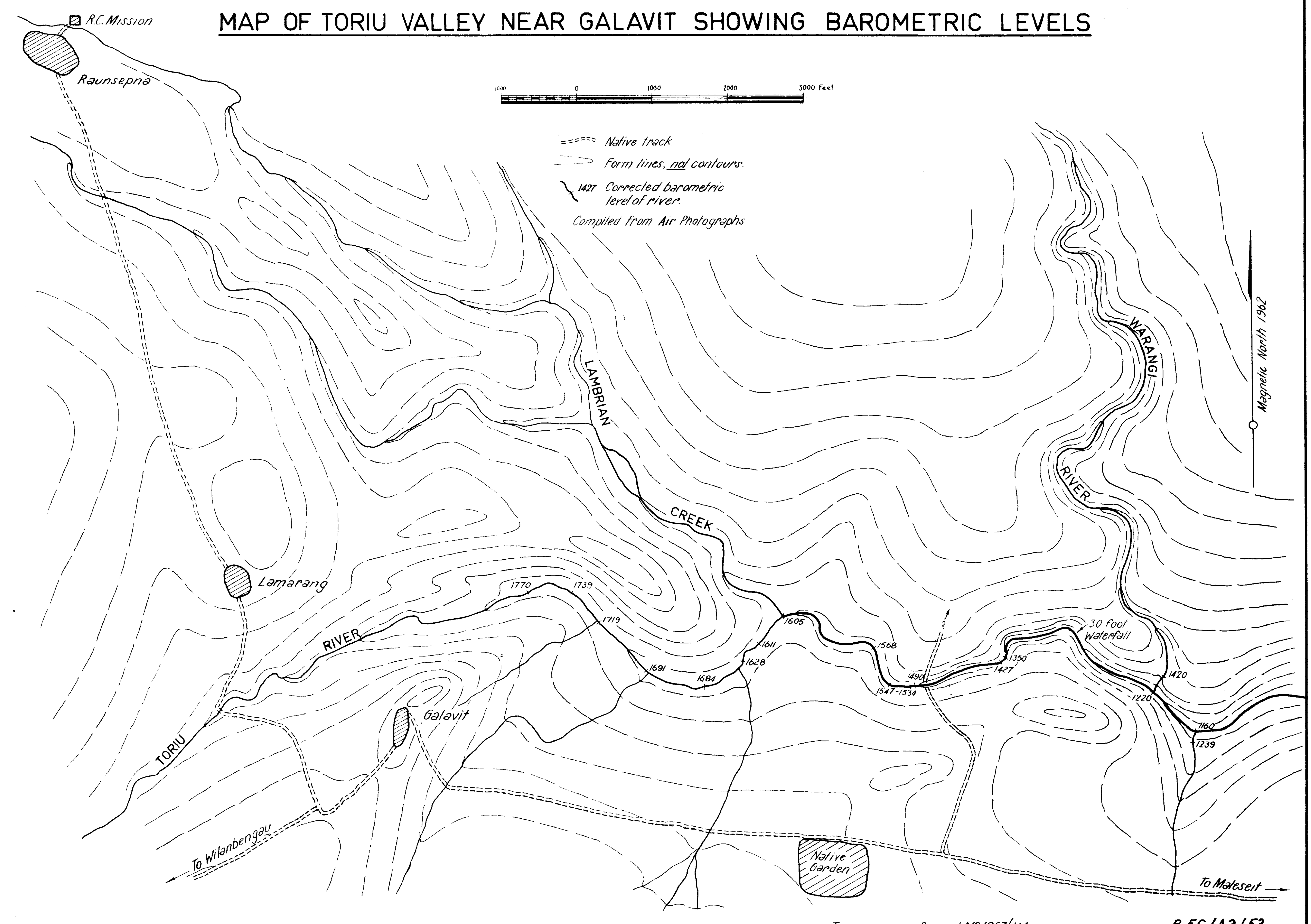
Bureau of Mineral Resources, May 1963.

To accompany Record No. 1967/114

B56/2/16

PLATE 3

MAP OF TORIU VALLEY NEAR GALAVIT SHOWING BAROMETRIC LEVELS



Bureau of Mineral Resources, Canberra, May 1963.

To accompany Record No 1967/114.

B 56/A2/53

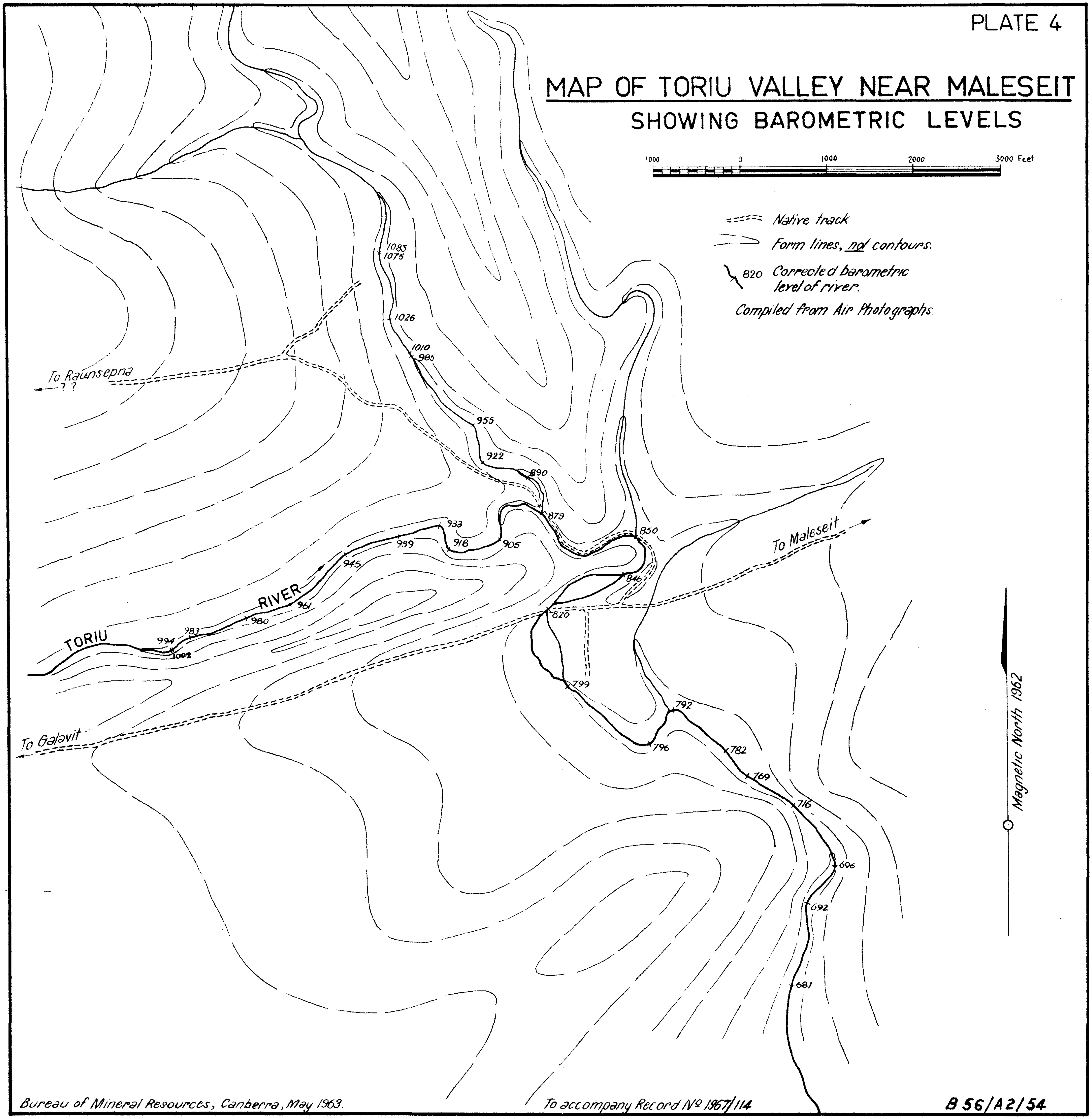


PLATE 4
MAP OF TORIU VALLEY NEAR MALESEIT
SHOWING BAROMETRIC LEVELS
1000 0 1000 2000 3000 Feet
Native track
Form lines, not contours.
820 Corrected barometric level of river.
Compiled from Air Photographs.
To Raunsepna ??
To Maleseit
To Galavit
TORIU RIVER
1083
1075
1026
1010
985
955
922
890
879
850
933
939
918
905
945
961
980
983
994
1002
846
820
799
792
796
782
769
716
696
692
681
Magnetic North 1962
Bureau of Mineral Resources, Canberra, May 1963.
To accompany Record No 1967/114
B 56/A2/54

PLATE 5

GEOLOGICAL OBSERVATIONS ALONG TORIU RIVER NEAR GALAVIT

Bureau of Mineral Resources, Geology & Geophysics, Canberra, May 1963.

To accompany Record No 1967/114

B 56/A2/55

GEOLOGICAL OBSERVATIONS ALONG TORIU RIVER NEAR MALESEIT