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GEOLOGICAL INVESTIGATION OF THE TOWANOKOKO - PONDO HYDRO-ELECTRIC SCHEME, NEW BRITAIN. TERRITORY OF PAPUA AND NEW GUINEA.

by

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CONTENTS

Contents (cont.)

Contents (cont.)

FIGURES AND PLATES.

TABLES

GEOLOGICAL INVESTIGATION OF THE TOWANOKOKO - PONDO HYDRO ELECTRIC SCHEME, NEW BRITAIN, T.P.N.G.

SUMMARY

A scheme to harness the Towanokoko and Pondo Rivers on the west coast of the Gazelle Peninsula, New Britain, to supply hydro-electric power for Rabaul, is under consideration. On present proposals water from the Towanokoko River, supplemented by water from the Pondo River at about 2,000 feet above sealevel, would be diverted into the Pondo River to produce an output of about 5,000 kilowatts.

The scheme is sited in steep terrain, 5 - 7 miles from the coast. Present access from the coast or the east is by foot only and provision of vehicle access will involve some steep gradients. The underlying rocks are gently dipping Tertiary limestone with some very weak mudstone interbeds. It will not be possible for engineering works to avoid the mudstone, which may affect weir foundations, tunnels and power station foundations. The limestone generally is fairly strong and competent but is strongly jointed, with extensive subterranean water movement above 2,000 feet; it is believed that large volumes of water do not move through the limestone below 2,000 feet elevation but further investigation is needed.

On geological grounds the Towanokoko - Pondo hydro-electric scheme is considered practicable but it presents a number of problems, which may raise the cost considerably, produced by the presence of soft mudstone, the absence of sand, possible high water leakage, high seismicity and difficulty of access.

Recommendations for further investigations both of the Towanokoko - Pondo scheme and of an alternative scheme on the Toriu River are given in the text.

INTRODUCTION

The power requirements of Rabaul are approaching the point where a hydro-electric source of energy is economically competitive with diesel power. Extensive searches for suitable hydraulic conditions on the river systems of the Gazelle Peninsula of New Britain failed to find suitable sites for hydro-electric projects within 30 miles of Rabaul and the Pondo-Towanokoko River systems have been selected for detailed investigation.

The first reconnaissance of the area was made in 1958. Since that time sporadic gauging of the two rivers has been carried out, a pluviometer has been installed at Wilanbengau (Wilanbemke) village, additional inspections and a geological reconnaissance of the scheme have been made. The geological reconnaissance was made and reported on by Fisher (1959).

In the three weeks immediately preceding the current geological investigation levelling and tacheometric traverses were made of portions of the Pondo and Towanokoko Rivers and a link traverse was run between the two river traverses.

The object of the investigation which is the subject of this report was to make an assessment of the practicability of the proposed scheme from geological considerations and to design a testing programme for a preliminary evaluation of the scheme. The investigation was requested by the Commonwealth Department of Works. The author spent the period 30th June to 17th July in the area and returned to Rabaul by foot to the Keravat Agricultural College site (and thence by vehicle) to ascertain geological and terrain conditions in the area through which any power transmission line from Pondo to Rabaul must pass. Mr. B.J. Fitzgerald, C.D.W. supervising engineer, accompanied the writer from 30th June to 3rd July; Mr. J. Vahala, C.D.W. hydrographer, worked in the area from 30th June to 14th July and assisted me much of the time; and Mr. G. Edwards, C.D.W. field hand, assisted me throughout the investigation.

LOCATION

The Pondo and Towanokoko Rivers, on the west coast of the Gazelle Peninsula of New Britain, drain for most of their courses west-south-westerly and enter the sea about one mile apart, 25 and 24 miles south of Cape Lambert, which is the most north-westerly point of the Gazelle Peninsula (see Plate 4). The Towanokoko River is the more northerly of the two streams and carries the greater volume of water. The proposed scheme covers the middle reaches of the two rivers from 5 to 6 miles direct distance from the coast. Distance, by straight line, from Rabaul is about 38 miles.

ACCESS

At present the area of the proposed scheme is accessible only by foot. It lies between 1,000 and 2,000 feet above sealevel, in rough terrain. An open anchorage, with deep water close to the shore, is available at Pondo Plantation beach; the anchorage is generally usable by small craft during the southeast season (May to October), but is unsheltered from the northwest monsoons and is therefore unusable for periods of up to several weeks during the remainder of the year. From Pondo and Odnop Plantations a foot track climbs from the flat coastal plain, one to two miles wide, along the ridge between the two rivers, to Wilanbengau village, six miles distant. The rise from the coastal plain begins with a sharp 500 foot rise; thereafter, although short steep rises occur, the track is generally of moderate grade. It is clearly defined but poor in places. Several foot tracks cross the ridge between the two rivers.

From the east there are no roads west of the Vudal River, although a bridge and road to the south-west are shortly to be constructed from Keravat Agricultural College site. A good foot track leads from Vunap Landing, near the mouth of the Valilie River (on Ataliklikun Bay) to Ranoulit village and beyond. It is joined by poor foot tracks from the Agricultural College site and from the Calaboose site, on the Keravat River. Around the head of the Valilie River to the village of Mainem the track is poor. From Mainem a good track passes through Evitki, Raunsepna, and Lamarang to near Galavit. An alternative route to Galavit is through Maleseit, across the Toriu River near the abrupt bend to the south (the river is not fordable after rain) and through Isingi (which has no patrol house); the track is well defined, but poor. From Galavit (elevation 2250 feet) a well-defined but indifferent track rises to cross the main divide at an elevation of 3,700 feet and then descends, over a distance of about three miles, to 1880 feet at Wilanbengau village.

Topographic information obtained in the course of the traverse is shown on Plate 4 and geological notes appear in Appendix 1.

CLIMATE AND VEGETATION

The area receives most of its rainfall during the north-west monsoon season but rain falls throughout the year, mainly in the form of storms. Days without extensive cloud cover at some time are rare. The table included here is based on rainfall records at Pondo Plantation, on the coast.

TABLE 1: Rainfall in Inches at Pondo Plantation, New Britain. (Based on 11 years' records; not continuous).

Month	Average	Maximum	Minimum	Average no. of Rain Days (1 point or more)
January	34.27	64.71	5.43	23
February	24.85	40.82	11.10	18
March	20.88	36.66	6.19	17
April	14.93	38.26	3.90	17
May	8.48	20.29	2.67	13
June	8.71	24.54	3.09	12
July	8.83	43.21	0.29	13
August	9.09	23.64	0.05	17
September	7.70	24.05	0.70	14
October	6.29	11.25	0.10	14
November	8.64	16.65	0.80	12
December	18.30	39.23	4.60	19
Year *	170.97	294.98	124.96	188

Rainfall in the mountains is considerably heavier, and there are a lot fewer rain-free days, than at Pondo. Rainfall was gauged at Wilanbengau village (altitude 1880 feet) over twelve months in 1959/60 as about 240 inches. Unfortunately the rainfall at Pondo Plantation over the same period is not known.

Day temperatures are moderate and, despite high humidity, working conditions are fairly pleasant, largely owing to the extensive cloud and vegetation cover. Nights are cool. Care needs to be exercised with optical and photographic equipment because of high humidity.

The area is covered by tropical forest with an almost continuous canopy except along the rivers. Large timbers, including the medium hardwood, Kamerere, are numerous. Ground cover ranges from dense, particularly along the creeks and rivers, to slight. The river beds (but not the banks) are generally free of vegetation. Grasses, such as kunai grass, are sparse.

TOPOGRAPHY AND DRAINAGE

From a coastal plain at Pondo one to two miles wide and with maximum relief of about 100 feet the terrain rises within 10 miles to a maximum elevation of at least 4,000 feet. Being limestone (except on the coastal plain) the country is very broken. North of the Towanokoko River karst topography appears to be well developed as little surface drainage is apparent on air photographs. A noteworthy fact is that the West Towanokoko River, which has a much larger catchment area than the East Towanokoko, is the smaller stream at the junction of the two rivers.

* Yearly figures are not arithmetic means of the monthly figures because of incomplete monthly rainfall data.

A pronounced ridge (with rough profile in places due to weathering out of joints and to sink holes) up to 750 feet high separates the Pondo and Towanokoko Rivers. The ridge has high cliff faces in places, some facing the Towanokoko River and some the Pondo. Gullies and spurs run from the main ridge to the two rivers. Sinkholes occur extensively. Up to 2,000 feet elevation they appear to be shallow and are probably not connected to an integrated sub-surface drainage system (but see below) as the floors of all sinkholes inspected are at a higher level than nearby gullies. It is, however, possible that leakage occurs below the apparent floors of some of the sinkholes. No springs were observed in rock.

Above the main falls on the East Towanokoko River extensive entry of water underground was observed through joints in the limestone bed of the river. The points of emergence of the water were not located but water probably emerges in the face of the waterfall and at the base of the high cliff which forms the southern wall of the East Towanokoko River valley.

The relief and drainage immediately south of the Pondo River is apparently similar to that between the two rivers, but karst topography predominates farther south. One of the few flat areas of more than one or two acres to be found is the site of Wilanbengau village, which is on top of a cliff between the North and East Pondo Rivers.

Apart from the leakage underground above the East Towanokoko falls no leakage was observed in the courses of the two rivers in the sections examined (i.e. between RL's 1070 and 2320 on the Pondo River and RL's 1730 and 2840 on the Towanokoko River.). Reports have been received of extensive subterranean waters from considerably farther down the Towanokoko River and of leakage underground at about R.L. 1980 before the landslide into the Towanokoko River occurred at this point in December, 1959 (see also below).

Travertine coats practically all rocks in the river and creek beds, commonly forming series of terraces with intervening deep pools. The travertine may provide a weak seal in places and prevent or reduce the movement of water from the surface to underground leakage paths.

It should not be concluded that no drainage through rock takes place: undoubtedly it does - seepages and soaks are common in landslips with exposed mudstone. All that can be said is that no evidence was found for unrestricted movement underground of large volumes of water within the area of the proposed first stage of the hydro-electric scheme.

Numerous landslides and landslips occurred in recent times along the course of the Towanokoko River. The recent slip into the possible dam storage area from the right valley slope of the Towanokoko River at R.L. 1980 (referred to above) extends up the slope for 160 feet vertical. From about RL 1780 (at river bank level) to RL 1820 - a distance of 1,000 feet - shallow landslips, mainly on the left (west) bank, extend practically without a break. About half a mile downstream from Bench Mark 3 (Plate 5) a major landslide or collapse in the last few years has dammed the river and changed its course. The area was not thoroughly examined but the distance of the existing scarp from the river, the great width of the river valley, and the huge volume of chaotic rock debris, appear to have required a series of landslides, all in recent years, or the collapse of a cave system. The presence of yellow-brown calcareous ornamentation on limestone boulders (similar to that in caves), which does not occur elsewhere in the area, supports the idea of the collapse of a cave system. If caves occurred at this point they may also occur elsewhere in the area.

Recent landslips are also common along the Pondo River between RL's 1150 and 1600 but are not as extensive as those along the Towanokoko River.

All landslips and landslides observed are associated with outcropping soft blue-grey mudstone and marl, which have very little mechanical strength.

OUTLINE OF THE SCHEME

The scheme is designed for construction in several stages; an output of 5,000 kilowatts is required from the first stage. It is proposed that initially water from the Towanokoko River, about 2,000 feet downstream from the junction of the East and West Towanokoko Rivers and at an elevation of about 1970 feet above sealevel, should be diverted into the Pondo River, at as short distance below the junction of the two Pondo Rivers as possible, by a low pressure tunnel and penstock. The diversion is the most economical means of gaining head because the Pondo River has a steeper gradient than the Towanokoko River between 2,000 and 1,000 feet above sealevel. A combined length of tunnel and penstock of roughly two and one half miles would be required. Additional capacity could be obtained by a tunnel which diverted water from the Pondo River, at the same intake level as that on the Towanokoko River, into the low pressure tunnel from the Towanokoko River.

Later stages would involve harnessing the upper reaches of the two rivers (for example the East Towanokoko River has a fall to the junction with the West Towanokoko River of about 800 feet in half a mile) and their lower stretches.

Owing to the steady normal flow of the two rivers large storage is not required - adequate pondage to cope with peak daily demand is all that is needed.

REGIONAL GEOLOGY

The scheme is set in Miocene - ?Pleistocene limestone, marl and mudstone that forms a fairly flat blanket over much of the Western Gazelle Peninsula (see Plate 4). The succession has not been measured but it is probably over 1,000 feet thick and may be considerably more. Dips up to 56°* have been measured, and wherever sufficient areas are exposed to make general observations dips are very irregular; however the overall dip in the area of the hydro-electric scheme is believed to be seaward and southward at a slightly greater gradient than that of the land surface. The wider regional structure may be a broad warp as the base of the succession is within a couple of hundred feet of sealevel at Pondo Plantation and has been observed in the Toriu River drainage area at elevations of 2530 feet half a mile east of Raunsepna and at 830 feet near the crossing of the Toriu River by the Galavit-Malesoit track. Farther north-east it also extends to within a few hundred feet of sealevel.

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* Some of the high dips measured may possibly be unrecognised large displaced boulders. Others may be depositional dips.

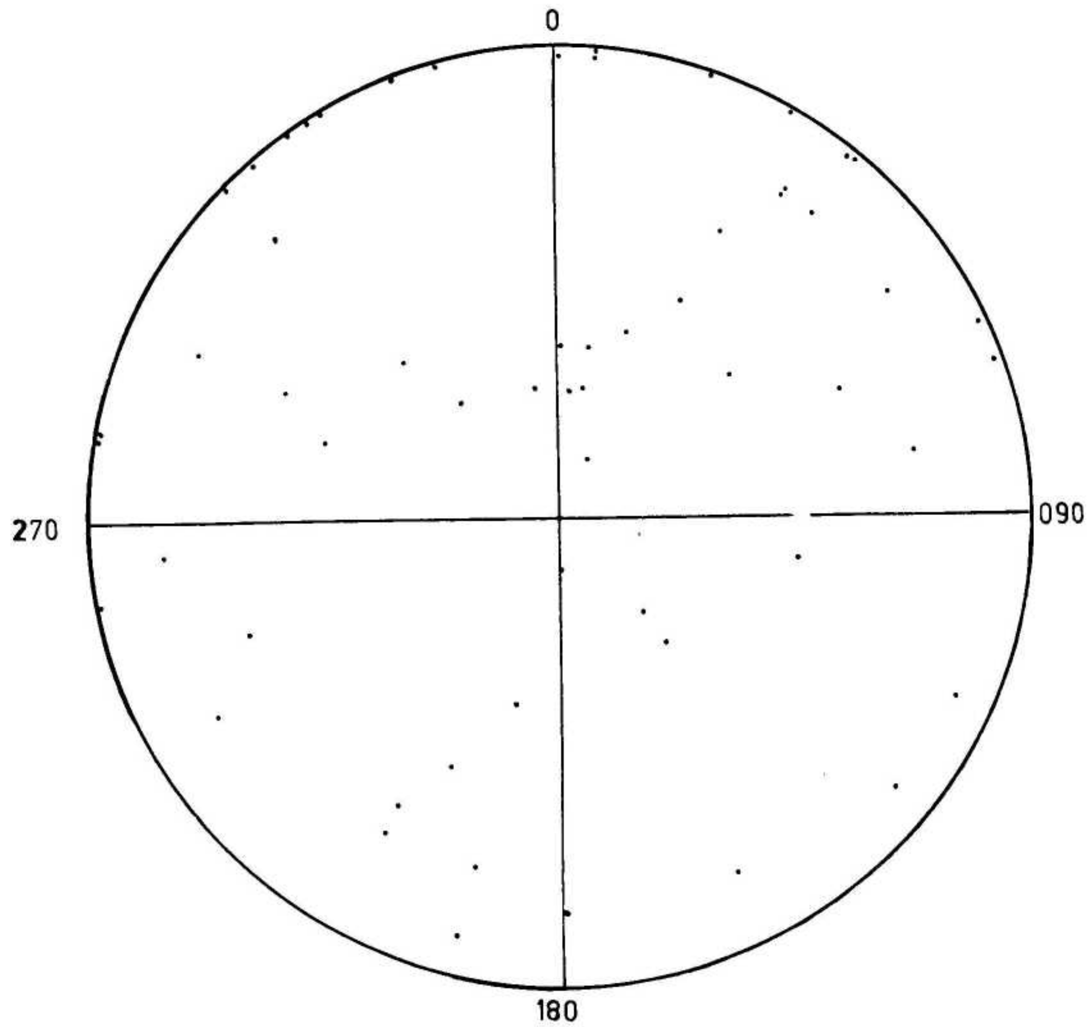

Fig.1. Stereogram showing poles of joint planes.
Bottom hemisphere projection.

BUREAU OF MINERAL RESOURCES, CANBERRA A.C.T. NOVEMBER 1961

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It is not known, however, what relief the basement had at the time of deposition of the limestone succession, nor what effect faulting has had. Fisher (1959) considers that extensive faulting has displaced the limestone east of the area of the scheme.

Neither the constituent rock type of the basement nor its depth below the limestone - mudstone succession in the Towanokoko - Pondo area is known. Pondo Plantation homestead is on lava probably andesite, and extensive pebbles and boulders of volcanic, basic intrusive and indurated sedimentary rocks were found in the Toriu, Valilie and Vudal River valleys. Some outcrops were found, revealing moderate folding. Only a few of the rocks examined could be classed as metamorphics and these were of low metamorphic grade only. Possibly all rocks observed that came from below the limestone-mudstone succession are of Lower Tertiary age.

Within the area of the hydro-electric scheme a high angle fault, which strikes roughly 030° magnetic, has been mapped along the Pondo River below Bench Mark 1 (Plate 5). It is marked by a zone, several feet thick, of brecciation in limestone and by severe contortion of mudstone. Probably other faults occur in the area, for example near the bend in the Towanokoko River 1900 feet below the junction of the West and East Towanokoko Rivers, where high bedding dips have been measured (but see footnote, p. 5). Slickensides have also been observed elsewhere.

The limestone is strongly to sparsely jointed. About sixty joint measurements were made; they are represented by stereographic projection in Figure 1. It can be seen that the strike direction 090° - 130° (pole direction 360° -040°) is the most prominent but is not strikingly so. Few joints occur at right angles to the most prominent direction.

Exposures of rock are scanty, owing to soil and vegetation cover on the slopes and valleys and to travertine in the stream course. Outcrops are confined almost entirely to cliffs and recent landslip areas, with rare exposures on low stream banks. On account of the small exposures reliable dip and strike measurements are hard to obtain as it is not possible in all cases to distinguish between outcrop and large displaced boulders (which occur extensively).

The main rock type is a cream to light buff fine-grained limestone. It is generally massive but extensive exposures, particularly along the Pondo River, are vuggy. The voids are produced by the leaching of at least two types of primary structure - coral growths and breccias (some of which, at least, are reef breccias). Some vuggy limestone has been produced by leaching along incipient joint planes and some may have formed by the recementing, in recent times, of superficial deposits of valley scree and stream rubble. Corals, and other fossils, occur widely in the limestone. Fresh limestone is hard and strong: it requires many blows from a geological hammer to break it.

Below about 1650-foot elevation on the Pondo River and 1900-foot on the Towanokoko River extensive soft, blue-grey mudstone crops out. It is not possible, owing to inadequate exposure to determine accurately the thickness of the many beds of mudstone, or whether individual beds are uniform in thickness or are lenticular.

Some beds are only a few inches thick; others are at least 30 feet thick.

In the outcrop most of the mudstone beds are soft, sticky and plastic; many may be readily worked with the fingers. Most of the landslips are associated with mudstone. It is not known what degree of rehydration has occurred near the surface, but the rock will be found to be weak wherever encountered in excavations. Fossils occur extensively in the mudstone.

Marl, generally in thin beds, is widely associated with the mudstone; a few beds also occur elsewhere. It ranges from a calcareous mudstone to a clayey limestone, and its colour, strength and hardness have corresponding ranges between those of the mudstone and limestone.

ENGINEERING GEOLOGY

The position of the diversion dam for the tunnel intake is determined by the availability of an adequate storage area. This is available on the Towanokoko River, at about the elevation required, only in the stretch of almost level valley floor extending 2000 feet downstream from the junction of the East and West Towanokoko Rivers. A topographically suitable site for a dam occurs at the head of the gorge below the level stretch. A dam 30 feet high (i.e. spillway level 30 feet above lowest river bed level) would impound roughly 55 acre feet (see Plates 7 and 8), which is ample for diurnal pondage. The river banks, 110 feet apart, rise almost vertically for about 26 feet on the right bank and 40 feet on the left bank. However this site is geologically suspect (see below); if necessary, a dam could be erected about 500 feet upstream but, for a comparable height, would impound rather less water than a dam at the lower site and would be wider.

A dam could be located without much difficulty in the Pondo River, at the same elevation as that on the Towanokoko River, to divert water from the Pondo River into the tunnel from the Towanokoko River and thereby supplement the power output of the first stage power station. However there is negligible storage capacity in the Pondo River valley around 1970 feet elevation.

It is desirable to place the power station on the Pondo River as short a distance downstream from the junction of the North and East Pondo Rivers as possible so that the water contributed from the East Pondo River may be fully utilized when the lower Pondo River is harnessed for power. A low dam could be built immediately below the junction of the two streams but would have very little storage capacity (see Plates 11 and 12). Owing to poor foundation conditions a high dam could not be built at this point. A dam could also be built in the gorge about 50 yards downstream but would have even less storage. Fair storage could be obtained with a low dam about 50 yards upstream from the lower Pondo stream gauging station, i.e. roughly 300 yards downstream from the junction of the two Pondo Rivers, at a point where a tributary enters from the right. Owing to the presence of mudstone a high dam could not be built at this point either, and the dam would have to be about 40 feet wider than the one at the junction (see Plates 9 and 10).

However the site, in addition to greater storage (roughly seven or eight acre feet for a dam 20 feet above stream bed level), has the following advantages over the junction site:

1: The waters of the tributary could be utilized for the lower Pondo development without a race line.

2: A better site for the power station is available in the right bank than at the junction site. Above ground power stations could be built at either site; in view of the terrain and rock types they are to be preferred to underground stations.

The difference in elevation of the two sites is roughly 50 feet.

Owing to poor exposures, sparse bedding and irregular dips and strikes of bedding planes it has not been possible to determine the geological structure at the proposed dam sites and alternative power station sites in more than general terms. It is considered that the tunnel line between the storage dam and the power station will encounter extensive mudstone but the extent and position of the mudstone intersection cannot be predicted with accuracy.

TOWANOKOKO PONDAGE

Topographically the best position for a dam is at the head of the gorge about 100 feet upstream from survey point a (see Profile 1, Plate 8). The main rock type is limestone but weak calcareous mudstone that dips 37°SE is exposed at the foot of the cliff forming the left abutment. The left abutment is therefore likely to be weak. Possibly better abutment conditions could be obtained by a small amount of excavation, but the left bank will require careful examination by trenching, stripping and drilling. The amount of excavation that can be done is limited by the configuration of the land surface. The bed of the river at the site is composed of limestone boulders and travertine-covered rocks of unknown lithology. Limestone is exposed sparsely in the right bank and on the spur to the west but it has not been conclusively established that the exposed limestone is in place. The abnormally high dips recorded about the site (some of the strata are definitely in place) raise the possibility of faulting. Other considerations apart, a low saddle above the right bank in the bend of the river imposes an upper limit to the height of any dam erected at this point; the saddle is at least 60 feet above the level of the water at the dam site but the depth of soil and weathered rock is not known.

The spur on which the saddle occurs also provides a potential leakage path from the pondage as there is a difference in elevation of river level on either side of the spur of about 60 feet and with a 20-foot high dam the leakage path would be only about 300 feet.

In the course of the investigation no information was obtained about possible leakage from the floor of the storage, other than that reported on p. 4 . The question of leakage will require close investigation; it will require observation bores along the spur to the right of the weir site.

Resistivity testing by a geophysicist along the spur and the banks of the river may provide useful information on ground water level and on the existence of cavities in the bedrock to the storage area.

POWER STATION SITES

A level to gently sloping area large enough for a power station and switch yard, and free of serious danger from landslips, is available above the right bank at the lower Pondo gauging station site. Ground level is estimated to be roughly 50 feet above river level; the surface is of soil, of unknown depth, and is covered by secondary growth.

Limestone and mudstone probably underlie the site. Any mudstone near the surface is probably thin but foundation conditions would have to be examined by drilling, possibly supplemented by seismic and resistivity testing.

If provision of storage at the head of any future development of the lower Pondo River is considered important the dam site and pondage area should be proved at the same time as the power station site is tested. The site near the gauging station is considered satisfactory for a low dam but will require testing for strength of foundations, in view of the presence of mudstone, and for water leakage. Stripping, drilling and geophysical testing are recommended.

The right bank near the junction of the two Pondo Rivers is not considered as suitable for a power station site as the area near the gauging station because:

1: The area of level ground is smaller.

2: The surface is very irregular, probably due to the leaching out of joints in limestone, in which case open joints may persist well below water level.

It is not clear whether mudstone that appears in the North Pondo River bank a short distance upstream underlies the site but measured dips suggest that it is stratigraphically above the exposed limestone. The area is heavily timbered and was not closely examined; possibly more suitable sites occur nearby.

A low dam just below the junction of the two Pondo Rivers should present no great difficulty but would require testing for foundation and abutment soundness and water leakage.

The river below the lower gauging station site was examined only to the next bend downstream. An informed opinion cannot therefore be expressed as to the danger to any power station site by the damming of the river by landslips, but the danger is thought to be slight. As the gorge below the junction site falls sharply a major landslip would be required to jeopardise by flooding a power station at this point. Mudstone occurs in the left valley wall but no evidence was seen for substantial recent slips. Further examination would be necessary when airphotographs become available if it is proposed to use the junction site.

The possibility of an underground power station below the intake area, and using a long tail race tunnel is considered on p. 11 .

TUNNEL LINE AND PENSTOCK

Owing to the absence of suitable airphotography or survey a provisional route for the tunnel line has not been selected. It is therefore not possible to comment with any precision on difficulties likely to be encountered. No geological mapping was undertaken between the intake area and the possible power station sites. In any case outcrop is likely to be extremely rare.

However it may be expected that a low pressure tunnel, with a minimum gradient needed for the required flow, would pass through mudstone, with alternating limestone and marl, for a considerable distance at the intake end as the overall dip of the strata is probably not much more than 5° to the west and south. The mudstone is mechanically weak and, except for thin beds, probably will require total support. Attempts should be made at an early stage to obtain specimens of fresh mudstone on which to carry out compressional and shear tests. When further information is available the location and gradient of the tunnel should be so designed that the distance that it passes through mudstone is kept to a minimum. It is not possible at this stage to determine the length of tunnel line that would require support.

The limestone through which the tunnel passes should be strong and fairly hard and should provide good tunnelling ground. Except in closely jointed or fractured ground it should stand well. Open jointing, with strong flow of water, may be encountered during mining. Such joints will have to be sealed. In some cases grouting ahead of mining may be necessary It may be found advisable to seal limestone surfaces, e.g. with gunite, to reduce solution along joints and incipient joints. On the other hand precipitation of travertine may effectively seal minor openings. Experiments into the behaviour of the carbonate-charged waters of the Towanokoko River, both under low and high pressures appear desirable. (see p. 12).

Owing to poor outcrop the tunnel line will need to be tested largely by drilling and geophysical methods, particularly at the portals. Geophysical methods may not be applicable under the main ridge, owing to excessive cover.

Further topographical information will be necessary before advice can be tendered on the site of the penstock line. It is thought that a suitable route could be found, free of the dangers of rock falls and landslips, for a surface penstock. Topographic and geological conditions appear to favour a surface penstock rather than an underground high pressure line. Depth of soil, boulders and weathered rock along the route will have to be determined by costeaning, augering, drilling and, or, geophysical methods to determine suitable sites for anchor blocks. No information is available at present on likely depths to sound foundations.

In the foregoing discussion it is assumed that a low pressure tunnel will be constructed on the most direct practicable route to serve a power station on the Pondo River.

Other possibilities are :

1: A combination of race lines and tunnel. The possibility of such a combination can be properly evaluated only when more detailed survey data are available. In general, it would be unwise to place race lines in areas where mudstone occurs at or near the surface or in steep terrain, since the danger of dislocation by falling blocks or landslides, particularly as a result of earthquakes, would be high.

2: A power station at depth below the Towanokoko intake, and a long tail race tunnel to the Pondo River. With such a layout mudstone would probably be avoided in the upper part of the tunnel but would presumably be encountered at the lower end. The power station would probably be in strong massive, well-jointed limestone but could possibly be in underlying metamorphic rocks (a possible source of aggregate and sand by crushing). This arrangement for the power station may provide economies in the further development of power from the upper Pondo and Towanokoko Rivers but would add considerably to exploration costs; further a deep underground power station is probably undesirable in an area of high seismic hazard.

SEISMICITY

The Gazelle Peninsula is one of the most highly seismic areas in the world. The foci of most of the major shocks are at moderate to great depths and therefore are likely to affect wide areas. The position is stated by Fisher (1959). Major shocks are likely to have a periodicity measured in decades rather than months or years and can be expected to produce widespread landslips. No evidence was found for recent movement on the various slickensided surfaces and the one pronounced fault mapped. No earthquake shocks were experienced in the course of the investigation.

The effect on engineering structures is not related simply to magnitude of the shock but is dependent also on the time the shock lasts, wavelength of the shock and the natural period of the structure. In some circumstances a design factor of greater than 0.2g (suggested by Fisher, 1959) may be necessary. It is suggested that the matter be referred to the Chief Geophysicist, Bureau of Mineral Resources, for further advice.

CONSTRUCTION MATERIALS

The current investigation did not significantly affect the appraisal of the availability of construction materials made by Fisher. It is considered that early tests should be made on drill core specimens of limestone to determine the suitability of the limestone as concrete aggregate since the importation into the area of concrete aggregate would add very substantially to the cost of the project. Sand would certainly have to be brought in. If sand and aggregate had to be imported from the west coast of the Gazelle Peninsula access from the coast would be needed. The nearest source of suitable rock to the east is in the upper Toriu River valley. Apparently no suitable material crops out upstream of Galavit village but "floaters" of igneous and metamorphic rocks were observed in a creek half a mile north-east of Raunsepna village; igneous and metasedimentary rocks also extend upstream from the crossing of the Toriu River by the Galavit - Maleseit track.

Extensive gravel deposits form the bed of the Toriu River at the Galavit-Maleseit track crossing but a great variety of rock types is present. As the catchment consists mainly of limestone the gravels would need close examination to determine whether they would provide satisfactory aggregate. It is not known whether any deposits of suitable sand exist. Possibly both aggregate and sand would have to be obtained by quarrying and crushing suitable material.

WATER QUALITY

Analyses of water from the Towanokoko and Pondo Rivers are given below:

TABLE 2 : Stream water analyses.

	Towanokoko River		Pondo River	
	1	2	3	4
Date collected	20/11/61	6/12/61	21/11/61	5/12/62
Gauge height, feet	2.51	3.5	2.62	3.70
Stream flow, cusecs	71 (low stream flow)	160 (Medium)	27.4 (Low)	143 (Medium)
Results				
pH	7.30*	7.24*	7.44*	7.44*
Total soluble salts (conductimetrically)	150 ppm	148 ppm	147 ppm	161 ppm
Cations				
Potassium	0.4 "	nil	nil	nil
Sodium	4.1 ppm	3.5 ppm	5.3 ppm	4.8 ppm.
Calcium	40.2 "	39.0 "	37.2 "	39.8 "
Magnesium	3.8 "	4.4 "	6.4 "	2.9 "
Anions				
Carbonate	3.0 ppm	5.1 ppm	4.6 ppm	5.1 ppm
Bicarbonate	143.3 "	136.0 "	133.6 "	144.6 "
Sulphate (qualitative)	Negative	Negative	Negative	Negative
Chloride	3.6 ppm	1.1 ppm	6.0 ppm	2.6 ppm
Alkalinity				
Carbonate (gm $CaCO_3$ per litre)	0.005	0.009	0.008	0.009
Bicarbonate " " "	0.118	0.112	0.110	0.119
Hardness (mgm $CaCO_3$ per litre)				
Calcium hardness	100.5	97.5	93	99.5
Magnesium "	15.5	18.0	26.5	12.0
Total	116.0	115.5	119.5	111.5

1. Towanokoko River, at gauging station GS61.
2. Towanokoko River, 15 feet downstream from GS61.
3. Pondo River, 10 feet downstream from GS63.
4. Pondo River, 15 feet downstream from GS63.

Analyses by Commonwealth Department of Works.

* In view of the presence of carbonate the pH values appear to be too low.

For streams that drain limestone country exclusively and have formed very extensive travertine deposits in their beds, the carbonate content appears unusually low. A possible explanation is that most of the stream water does not pass through limestone but consists of ground run-off and seepage through soil.

Despite the low content of dissolved solids (for a limestone terrain), in view of the copious formation of travertine, it is considered that the effect of the carbonate-bearing water on engineering works and machinery should be examined.

ROUTE OF THE TRANSMISSION LINE AND ACCESS ROAD.

The most direct line from the Pondo area to Rabaul passes across high, rough country to the north of the Toriu River. This route also provides the best overall gradient. In the course of a traverse from Wilanbengau to Keravat the direct line was crossed only twice, but the route from the Pondo River to the Valilie River would be over Tertiary limestone - the same succession as that in which the hydro-electric scheme is set. Experience in the Pondo - Towanokoko area and the divide between the coastal drainage and the Toriu River suggests that in detail the country will be found to be very rough and broken, and that construction costs would be high.

As the region is one of high seismic activity transmission line towers or pylons would need to be very securely anchored, and should not be placed on steep slopes where either seismic activity or excavations associated with engineering works may initiate landslips. The catenary of the power lines between towers should be designed to allow for substantial sway of towers during earthquakes.

Any access route from the east would have to service the transmission line, may have to pass through or close to a source of aggregate and sand, and would serve as a development road for the populated areas of the Toriu valley. A direct route from the Valilie River below Ranoulit village, along the divide between the heads of the Valilie and Tavalue Rivers, in the north, and the Toriu River in the south would not serve the last two purposes. On the other hand the route across the Toriu River, following the present track between Maleseit and Galavit, involves very steep grades to cross the Toriu River and to cross the divide south-west of Galavit. The most satisfactory route appears to be south of the head of the Valilie River to the Mainem - Evitki - Raunsepna track (which has excellent grades and is a wide path) and thence over the coastal divide west of Raunsepna. The ascent of the coastal divide may provide serious difficulties, but these will be encountered on practically all routes and would not be greater than the difficulties of access from Pondo Plantation to the area of the scheme.

The transmission line and access route would cross at least one zone of major faulting and seismic epicentres; particular care in design and layout would be needed here. Further work is required to define the critical areas.

POSSIBLE ALTERNATIVE LOCATIONS FOR A HYDRO-ELECTRIC PROJECT

In view of the difficulties, of access and of engineering owing to geological conditions, associated with the Pondo-Towanokoko scheme it is considered that a further examination of the possibilities of the Toriu River should be made.

It is noted that :

1: The normal flow of the Toriu River, where the Malaseit - Galavit track crosses it, is substantial - possibly several hundred cusecs.

2: Difference in altitude between this point and the Toriu River at the Galavit - Lamarang crossing is about 1340 feet and between the same point (the Galavit - Malaseit crossing) and the Warangi River near Evitki is about 1520 feet. The upper Toriu and the Warangi Rivers at the points mentioned have, however, only small flows.

3: Two substantial tributaries enter the Toriu River near where the course of the latter changes abruptly from east to south. They apparently fall rapidly from the ranges to the north.

4: Upstream from the Galavit - Maleseit crossing the Toriu River runs through a deep gorge and probably falls rapidly. Possibly there is (a) sufficient volume of water and head in the two tributaries referred to in 3,

or (b) in the Toriu River between the Galavit - Maleseit crossing and the head of the gorge roughly one mile upstream (supplemented if necessary by the water from the two tributaries from the north) to provide for the power requirements of Rabaul. At a later stage it might also be possible to harness the water from some of the other tributaries of the Toriu River.

A power scheme at this point would have the following advantages over the Pondo-Towanokoko scheme:

Access would be easier.

Foundation conditions are probably better, being sited on igneous or metamorphic rocks.

Sources of sand and aggregate should be available close at hand.

The seismic hazard may however, be greater.

CONCLUSIONS

1. The Towanokoko - Pondo hydro-electric scheme is, on geological grounds, practicable but presents a number of problems occasioned by the presence of soft mudstone, the absence of sand, possible high water leakage, high seismicity and difficulty of access.

For these reasons it is considered worthwhile to examine further the potentialities of the Toriu River before a firm decision is made to carry out a detailed investigation of the Towanokoko - Pondo scheme.

2. If the Towanokoko-Pondo scheme is proceeded with a great deal more hydrological and geological work will be required. Specific matters having a bearing on the scheme as a whole, which require attention are :

(a) More detailed information is needed about rainfall and run-off characteristics of the catchment area in general and of the four main watercourses in particular, to aid in evaluation of sub-surface leakage.

(b) The whole of the Pondo and Towanokoko river courses need geological mapping.

(c) More complete survey data, including airphoto cover and a slotted template compilation of photography, are required.

3. The proposed pondage and dam on the Towanokoko River (shown on Plate 5), to provide diurnal storage, appear practicable from the geological viewpoint but foundations and abutments would probably not support a high dam. The site needs further testing by detailed geological mapping of the surface and exploratory trenches or stripping, by drilling, by geophysical testing, and by laboratory testing of drill core, to ascertain strength and soundness of foundations and abutments; groundwater conditions with particular reference to water tightness of the dam environs and pondage area require systematic study.

Configuration of the storage area should permit the tunnel intake portal to be placed in the left bank well clear of the dam abutments.

If the proposed weir site proves unsuitable a dam could probably be constructed about 500 feet farther upstream.

4. A site suitable for a surface power station can be found near the junction of the North and East Pondo Rivers. The preferred site is on the right bank near the lower gauging station. The site requires testing for soundness of foundations by stripping, drilling and geophysical testing.

If pondage is required near the power station site when the lower Pondo River is developed for power at a later stage, the suitability of the area for a dam should be tested at the same time as the power station site is proved.

5. As an alternative proposal, an underground power station below the intake and with a long tail race tunnel appears practicable but would require thorough testing by drilling. It would probably be in massive limestone but might possibly be in underlying unknown rocks. If similar to the underlying rocks in other parts of the Gazelle Peninsula any underlying rocks encountered might provide a source of aggregate and sand by crushing.

6. Any tunnel line between the Towanokoko pondage and a discharge point into the Pondo River would be in limestone for much of its length but would also pass through very weak mudstone. The limestone should provide good tunnelling conditions except for possible heavy flows of groundwater. It should stand well without support but may require local sealing to prevent solution along joints. The mudstone, at least where thick beds occur, may require total support; the tunnel should be lined wherever mudstone is exposed in it. Stripping, drilling and geophysical testing at, and near, each portal of the tunnel may make it possible to predict conditions along much of the remainder of the tunnel.

7. The location and length of tunnel and race/s (if any) can only be decided after more detailed information is available on topography, depth of soil, and foundation conditions.

8. If a surface power station is decided upon a surface penstock is preferred to a high pressure tunnel penstock. The route of any penstock can only be determined after further survey information is available. A penstock can best be located after a geophysical survey followed by trenching and augering or drilling.

9. In general care should be exercised in making surface excavations, including road cuttings, where slopes are steep and particularly where mudstone occurs at or near the surface, as landslides and slips may be initiated. Under the worst conditions cuts may have to be drained by lined drains to prevent saturation of potentially unstable material.

10. Construction materials, apart from road materials, may be difficult to obtain. The limestone may be suitable for concrete aggregate but sand will have to be imported into the area unless material suitable for crushing is found in the course of exploration for an underground power station (see Conclusion 5).

11. Seismicity of the area is high. Further information should be obtained on necessary allowances in the design of structures and consideration should be given to the installation of a seismograph and/or accelerometer to determine frequency and intensity of earthquake activity.

12. The practicability of the scheme as at present envisaged depends in the first instance on the dam and pondage on the Towanokoko River. These should be tested first.

13. The best access route from the east appears to be, on present information, south of the head of the Valilie River and north of the Toriu River through, or north of, the villages of Evitki and Raunsepna.

14. The location of the transmission line may be determined by accessibility. Care will be needed in siting cable towers. Further work will be necessary on tower location.

RECOMMENDATIONS

1. The possibilities of a hydro-electric project on the Toriu River should be examined before detailed investigation of the Towanokoko - Pondo scheme is undertaken.

2. Assuming that it is decided to proceed with the Towanokoko - Pondo scheme the following measures are recommended:

(a) Urgent steps should be taken to obtain air photography, as ordered from Adastra Airways, and a slotted template compilation for the whole area of the scheme.

(b) Additional continuous recording pluviometers and stream-gauging instruments should be installed to enable the proportion of rainfall that runs off through the branches of the Pondo and Towanokoko Rivers to be evaluated, as a guide to sub-surface water leakage.

(c) A request should be made at an early date to the Chief Geophysicist, Bureau of Mineral Resources, for seismic and resistivity surveys to test proposed dam sites, pondages, tunnel line (including any alternative proposals) and penstock route. A substantial amount of clearing and of detailed topographical surveying would be required in association with the geophysical work.

(d) A detailed topographic survey should be made of the Towanokoko diversion weir site, the ridge on the right bank above the weir site, and the intake area. Permanent reference points should be established.

(e) Drilling and trenching should commence on the Towanokoko diversion weir site. If necessary a drilling programme can be laid out as soon as a detailed survey is available but a more economical programme could probably be designed when geophysical results and a detailed geological map are available.

(f) Two vertical holes should be drilled on the spur extending from the right abutment of the Towanokoko pondage dam to enable regular observations of groundwater fluctuations under the spur to be made, as a guide to water leakage.

(g) It is most important that in drilling core loss should be kept to a minimum as the location of all mudstone must be accurately known. The use of triple-barrel, bottom-discharge barrel with spring-loaded retractable lead piece (as used by the Snowy Mountains Hydro-Electric Authority) is therefore recommended for drilling through the mudstone. All holes should be water pressure tested.

(h) Representative specimens of unweathered limestone, marl and mudstone from drill holes should be subjected to compression and shear tests to determine the design loads that they can carry without non-elastic deformation. Limestone from cores should also be tested for suitability as concrete aggregate.

(i) When air photography is available the whole course of the Towanokoko and Pondo Rivers should be geologically mapped to provide further information on the stratigraphical succession, geological structure and underground water leakage.

In particular the West Towanokoko River should be examined carefully to determine whether it is practicable to eliminate any of the water loss which undoubtedly occurs.

(j) A search for sand and further investigation of access route and transmission line route will be necessary but can await firm decisions on the project. For the purpose of estimates it may be assumed that sand will have to be brought into the area from either the west coast of the Gazelle Peninsula or the Toriu River.

(k) The likely effects of the carbonate-bearing stream water on tunnels, penstocks and machinery should be examined.

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The hospitality of the manager of Pondo Plantation, Mr. Balt and his wife, and Mr. J. Cooper was also greatly appreciated.

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PLATE 1.

Figure 1: Possible storage area for diurnal pondage on Towanokoko River, looking upstream.

Figure 2: Possible weir site, Towanokoko River, looking downstream to gorge below the site.

PLATE 2

Figure 1: Possible storage on Pondo River just above lower gauging station. Looking upstream.

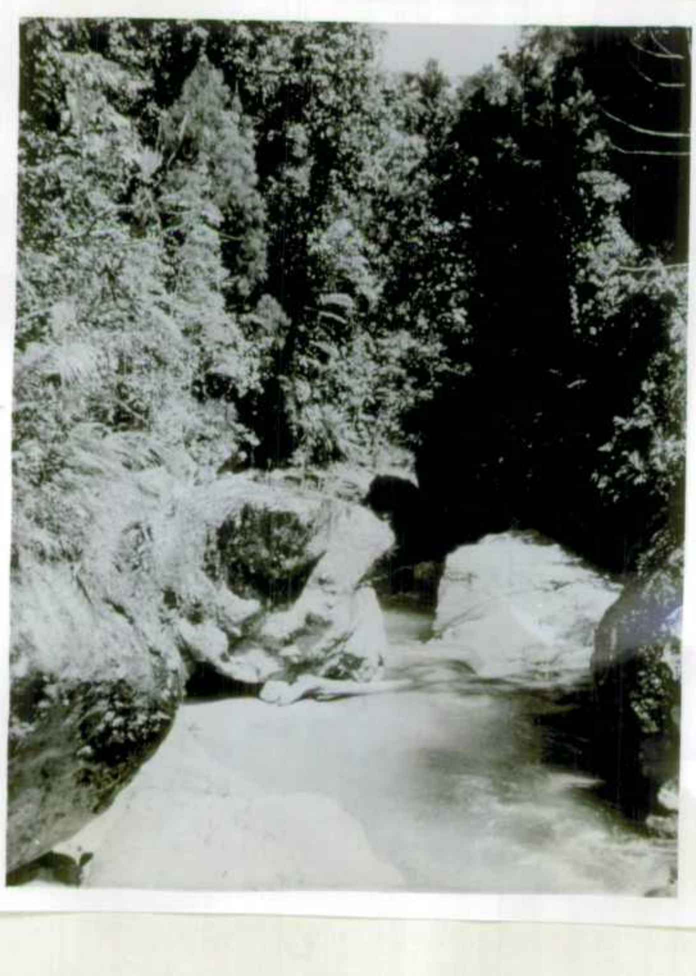

Figure 2: Possible weir site just below junction of North and East Pondo Rivers, looking downstream.

Figure 1: Head of 250-foot fall on East Towanokoko River.

Figure 2: Toriu River at the Galavit - Maleseit track crossing. Looking upstream.

APPENDIX 1.

Notes on Traverse from Wilanbengau Village to the site of Keravat Agricultural College, 17th-22nd July, 1961.

E. K. Carter

The traverse was carried out to obtain information on the geology and relief of the terrain over which any power transmission line and access road from the Towanokoko - Pondo area to Rabaul would pass. No attempt was made to follow the most direct route, such as the power line would probably follow, and tracks were rarely left. Air photo cover was not available and the course and observations were plotted by estimating position from rate of travel, time elapsed and general direction of travel. Corrections were applied to fit the topography (particularly drainage) shown in the military one-mile maps and by compass bearings to recognisable features. Two aneroid barometers were used to measure spot heights, and readings were corrected by use of a standard diurnal variation curve and by spreading drift according to the most probable error. The observations between the Keravat and Vudal Rivers were made on 25th July.

Palaeontological and petrological determinations of specimens collected are given in Appendices 2 and 3, by A.R. Lloyd and K.R. Walker respectively.

Topographical and Geological Observations.

Gradients on the foot track between Wilanbengau and the upper Toriu River valley are steep. From the village to the top of the divide the track rises over 1800 feet in about 4½ miles. The track generally follows spurs and ridges and climbs steadily to the summit with only minor descents into gullies. Gradients approaching 1:2 and involving unbroken climbs of several hundred feet were encountered. Water-courses are generally deeply incised and any vehicle track would generally have to be routed around the heads of the gullies. Outcrop along the track is poor but a few limestone boulders were seen and sink holes are common. The soil is generally a heavy clay to red clayey loam except where intimately mixed with vegetable matter. Provision of a road from the Toriu valley to the Towanokoko-Pondo area would involve many difficulties. The track crosses the watershed at a low point (elevation 3,700 feet).

Similar terrain was seen to extend to the north and south and along both sides of the east-draining upper Toriu River valley. No easy ascent from the Toriu River valley to the coastal divide is apparent though a couple of persistent spurs were noted which might provide reasonable grades.

The upper Toriu River where it flows generally eastwards has a moderate gradient; it falls from 2160 feet at the Galavit - Lamarang crossing to 820 feet at the Galavit - Maleseit crossing - a fall of about 220 feet per mile. The distribution of fall along the river between these two points is not known but there is a deep gorge, less than a mile upstream from the lower crossing, where the fall is probably very sharp.

The tributaries of the upper Toriu River have even steeper gradients than the river and are deeply incised, thereby producing steep interfluves. In places small marshy patches of level ground occur. The track from Galavit to Maleseit is generally sharply undulating with a few steep gradients. From the village of Isingi to the crossing of the Toriu River it descends about 670 feet in 1½ miles; beyond the Toriu River it climbs 900 feet in about 2 miles. The track, though clearly defined, has a very poor, commonly muddy, surface. The track between Galavit, Lamarang, Raunsepna and Evitki has much gentler gradients. Between Raunsepna and Evitki it is wide and well-formed and existing gradients over much of the route are suitable for vehicles.

Outcrops are poor throughout the Toriu Valley but sufficient outcrops and 'floaters' were seen to indicate that most of the area is underlain by gently-folded 'Neogene Series' limestone and mudstone similar to that in the Pondo-Towanokoko area. A dip of 30° was measured in a creek bed at Maleseit, where blue-grey shell-bearing mudstone and cream limestone crops out. Similar mudstone was seen at Raunsepna and in the Toriu River above the Galavit-Lamarang track crossing, but dips here and in other places are 10° or less. The elevation of the base of the 'Neogene Series' limestone and mudstone has a wide range - from 2530 to about 900 feet was observed or inferred. It is not known whether the variation is due to depositional, or later tectonic, features.

Between Isingi and the Toriu River crossing en route to Maleseit 'floaters' of a friable light-brown sandstone were observed. Similar material, as indicated in Plate 4, was found in a number of places farther east and north-east. Generally it was not found in place but occurred in creeks and gullies, in some cases with 'Neogene Series' limestone floaters on the higher ridges. It was therefore concluded that the sandstone underlies the 'Neogene Series' limestone, either as a basal bed or as an older sequence. The existence of outcropping similar rock in the hill that bears the survey point to the south-east of Mainem does not accord with this interpretation but the ridge of which the hill is a part rises so abruptly and has such a steep northerly aspect that it may be bounded by a fault. A specimen of sandstone (WK5, R11388, Appendix 2) from near the survey point contained a single foram (Elphidium sp.) which indicates a Tertiary age but does not establish the relationship to the 'Neogene Series'.

In the upper Toriu River catchment area rocks older than the 'Neogene Series' limestone and the sandstone were recorded in seven places; outcrops were observed in four of the localities. Many of the rocks are of igneous origin - volcanics or basic intrusives. The volcanics were related in the field to the 'Baining Series' of Noakes (1942), following Noakes' and later maps, but may belong to the Tertiary Volcanics that Noakes records (see below), Of the outcrops examined only one, which has a pronounced fracture cleavage, could be described as a metamorphic rock. 'Floaters' of slate, quartzite and ?hornfels were found. An outcrop of steeply (50°) dipping sediment, probably calcareous siltstone (Specimen R11387, Appendices 2 and 3), contains Globigerina spp. and Globoritalia sp. and its age is Tertiary. Its relationship to the volcanics was not established; further it is not known whether the outcrop forms part of the 'Baining Series' (establishing a Tertiary age for them) or is younger.

A full list of rock types recorded from below the 'Neogene Series' is as follows (see Plate 4 for location):

Raunsepna - Evitki track, creek about ¾ mile from Raunsepna:
Basic lava (some porphyritic in feldspar)*
Crystal and lapilli basic tuff (WK1b - Appendix 3)*
Dolerite or microgabbro*
Hornfels?* (WK1a - Appendix 3).

Rise on Raunsepna - Evitki track about ¼ mile east of creek referred to above: Basic lava.

Tributary of Warangi River 150 yards north of Raunsepna - Evitki track:
Basic volcanics*
Basic volcanic breccia (see below).*

Warangi River north of Evitki Village: Coarse, spheroidally weathered, basic rock.
Dolerite?*
Basic lava, some porphyritic* including porphyritic basaltic andesite* (WK2, R11247, Appendix 3)
Quartzite or siliceous hornfels*
Fine-grained breccia or conglomerate with volcanic components.*

Galavit - Maleseit track, 300 yards west of Toriu River crossing:
Slate*
Quartzite
Basic tuff and lava?*
Blue mudstone*
Dolerite and gabbro (WK3a & b, R11248 & 9, Appendix 3).*

Galavit - Maleseit track, Toriu River crossing:
Fossiliferous green-blue calcareous siltstone? (Spec. R11387, Appendices 2 & 3)
Assorted igneous rocks.*
Fine conglomerate with wide variety of angular fragments.*

Galavit - Maleseit track, large creek 2-300 yards east of Toriu River crossing:
Blue-green slate; dip 35°; plunge of fold based on bedding - cleavage relationship, 28°NE
Angular conglomerate (as above)*
Fine conglomerate, possibly agglomerate, with quartz veinlet*
Quartzite*
Slate*
Basic lavas with abundant feldspar*
Basic intrusives*
Grey-green basic greywacke.*

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* Not in place.

From Mainem the track generally descends gently to Ranoulit but crosses some gullied ground with watercourses (some boggy) and a few steep ascents between a point about 2 miles from Mainem and the coconut palms (RL1150 on Plate 4). The descent from Mainem is moderately steep then follows undulating country until a rather boggy area and small steep gullies, which apparently represent the head of a drainage system, is reached. The ascent to the coconut palms referred to above (probably an old village site) is a fairly steep climb for 150 feet or more. Beyond this point to Ranoulit the walking track is good and gradients are suitable for vehicles.

No outcrops were observed along the track from Mainem to Ranoulit but 'floaters' of 'Neogene Series' limestone and the friable sandstone recorded earlier were observed at several points. The sandstone boulders are confined to the gullied area 2-3 miles from Mainem. About half a mile north-west of the old plantation a boulder of well-bedded sandstone stands to the left of the track. It is soft, but not friable, and contains pellets of clay and dark minerals. Its stratigraphic position is not known.

In the creek about 200 yards west of the patrol house near Ranoulit soft red sandy siltstone and a fine conglomerate crop out. They are gently but irregularly folded (5^{o}) and are probably Tertiary in age. Their relationship to the 'Neogene Series' has not been established. There are a number of 'floaters' up to boulder size; they include:

Grey crystalline limestone, probably in the age range Eocene-Oligocene (see R11389, Appendix 2)

Several varieties of breccia - conglomerate, generally with a varied assortment of fine-grained ill-sorted fragments set in a limey or sandy matrix.

Other medium-grained sediments

Blue-grey porphyritic dacite (Spec.WK6c,R11252)

Amygdoloidal, and other, basalt (Spec.WK6d,R11253)
(Appendix 3)

The larger tributary of the Valilie River about ½-mile north-north-west of Ranoulit village contains similar outcrops and transported material. In addition a specimen of ?soda rhyolite (Spec.WK 7, R11254, Appendix 3) was collected. Specimen WK 8 is from a small gully which contains numerous boulders of similar rock. As the gully is very small apparently dolerite or gabbro (see Appendix 3) occurs in place a short distance to the south-west.

The terrain west of Ranoulit village has strong relief. The ridge between the east branch of the Valilie River and the village is about 450 feet above the river bed and slopes are steep. Just above the junction of its two branches the Valilie River falls sharply and has small waterfalls and rapids in its course.

Coarse and medium-grained tuff in greywacke (Spec.WK9, R11256, Appendix 3) crops out extensively in both branches of the Valilie River where examined. Dips of 38^{o} and 35^{o}N were measured.

Transported material includes a wide variety of tuff or greywacke, polymict conglomerate, breccia-conglomerate and basic lavas and intrusions. No acid intrusive or acid lava 'floaters' were observed.

From Ranoulit the track north to Vunap Landing is well-defined, wide and firm. It descends gently, with minor undulations, for about 3 miles, at which point a poor, muddy, in part ill-defined, foot-track leaves the Vunap Landing track. The track to the north-east and east leads to a vehicle track in the Keravat Agricultural College area, east of the Vudal River. No outcrops were seen on the Vunap Landing track and only one or two, which were probably of Sub-Recent origin, on the Keravat path.

On 25th July a traverse, for the most part along Forestry Department survey clearings, was made from the prison compound on the Keravat River (see Plate 4) west to the Vudal River past an abandoned village site and a Forestry Trig. Point. For the most part the tracks used follow spurs with gentle to moderate gradients; there is a moderately steep descent from the Trig. Point to the Vudal River. Very few 'floaters' or outcrops were seen. In the watercourse about ½-mile west of the Calaboose pebbles of porphyritic basic or intermediate lava, greywacke, breccia-conglomerate with sedimentary inclusions, a cherty (silicified limestone?) rock, and a soft light brown greywacke which appears to be from a younger succession than the other transported material.

At the Trig. Station rubble of soft brown sandstone, similar to that seen near the Trig. Point south-east of Mainem, was dug up during erection of the Trig. Point. Similar material was found on the western flank of the hill and in a small creek draining the area.

In the east branch or tributary of the Vudal River an outcrop of light buff, fine-grained limestone which breaks with a conchoidal fracture contains, amongst other fauna, ?Austrotrillina howchini (Schlumberger) which suggests a possible Lower or Middle Miocene age (Spec. WK10a, R11390, Appendix 2); the limestone strikes 020°mag. and dips 25°W. Transported material includes:

Magnetite-bearing black sand.

'Neogene Series' limestone.

Highly fossiliferous grey limestone containing gastropods, pelecypods and ?barnacles of post-Palaeozoic age (Spec. WK 10b, R11391, Appendix 2).

Soft brown sandstone, as at the Trig. Ststion.

Medium-grained acid to intermediate igneous rock with white euhedral feldspar phenocrysts.

Quartz-biotite rock (?intrusive).

Metamorphosed greywacke, some bedded.

Basic to acid volcanics.

APPENDIX 2

Palaeontological Determinations of Specimens from between Pondo and Keravat, Gazelle Peninsula, New Britain.

by

A.R. Lloyd

Eleven samples from the Gazelle Peninsula, New Britain were examined for fossils. The samples, collected from scattered localities and containing mainly non-diagnostic faunas, did not permit the erection of a stratigraphic sequence. Diagnostic 'larger' and pelagic forms are very rare and most of the benthonic 'smaller' forams are probably new species and did not permit accurate age determinations. Some of the samples are rich in ostracods and forams, the forams are characteristic of a brackish water environment. Each sample is treated separately in numerical order and not in stratigraphic sequence.

R11381 (P1) Cream Limestone: Abundant bryozoa. Rare foraminifera which include *Globigerina* spp., ?*Orbulina* sp., *Globorotalia* sp., *Amphistegina* sp., *Textularia* sp. and ?*Austrotrillina howchini* (Schlumberger).

Age: ?Middle Miocene.

R11382 (P2) Grey lignitic calcareous mudstone : Abundant ostracods and foraminifera, common mollusca and rare bryozoa. Foraminifera identified are :-

Globigerina mayeri (Cushman and Ellison) - juvenile form.
Ammonia aff. *beccarii* Linne
Baggina inflata LeRoy
Nonion aff. *victoriensis* Cushman
Amphistegina aff. *gibbosa* d'Orbigny
Quinqueloculina sp.
Bolivina spp.
Pavonina sp.
Reusella spinulosa (Reuss)
Chrysalidinella sp.
Elphidium cf. *tumidum* Natland
E. cf. *crespinae* Cushman
E. aff. *chapmani* Cushman
E. *craticulatum* (Fiehtel & Moll)

Age: ?Upper Miocene

R11383 (P3) Shelly Calcareous Mudstone: Abundant mollusca, common foraminifera and ostracods. The ostracods consist of two species which are also present in P2. The foraminifera are *Elphidium* cf. *tumidum* Natland, Nonion aff. *victoriensis* Cushman and *Ammonia* aff. beccarii Linne.

Age: ?Upper Miocene, possibly close to that of P2.

R11384 (P4) Cream Limestone: Rare forams, poorly preserved, including *Elphidium* sp., *Nonion* sp, and *Bolivina* sp. which is also present in P 2.

Age: Tertiary, possibly same as for P2 and P3.

R11385 (T1) Marly Limestone: Abundant ostracods and foraminifera. The ostracods include two species which are also present in P2 and P3.

Foraminifera identified are :

Globigerina mayeri (Cushman and Ellison) - juvenile form
Elphidium cf. tumidum Natland
E. cf. jexceni Cushman
Ammonia aff. beccarii Linne
Bolivina cf. uniforminata LeRoy.
Nonion aff. victoriensis Cushman
Miliolinella sp.
Pseudoclavulina sp.

Age: ?Middle or Upper Miocene, close to P2 but possibly older.

R11386 (T2) Cream Limestone: Rare fragmentary mollusca, algae and forams. The forams include Textularia sp. and ?Alveolinella guoyi (d'Orbigny) the presence of which suggests an Upper Miocene age.

R11387 (WK4) Dark Grey Limestone: Rare pelagic forams including Globigerina spp. and Globorotalia sp. Tertiary in age.

R11388 (WK5) Sandstone: One small foram. Elphidium sp. Tertiary in age.

R11389 (WK6a) Grey Crystalline Limestone: Specimen of a hydrozoa close to Axopora sp. which belongs to the family Axoporidae ranging from the Eocene to Oligocene, suggesting an Eocene or Oligocene age for the sample.

R11390 (WK10a) Buff Limestone: Abundant algae, rare mollusca and foraminifera. The forams include ?Austrotrillina howchini (Schlumberger) which suggests a possible Lower or Middle Miocene age.

R11391 (WK10b) Grey Fragmental Limestone: Abundant Gastropods, Pelecypods and ?Barnacles; age post - Palaeozoic.

APPENDIX 3

Petrography of Specimens from between the village of Raunsepna and the Keravat River, Gazelle Peninsula; New Britain.

by

K.R. Walker.

Twelve rocks were submitted to the laboratory by E.K. Carter for naming and comment on interesting features, including alteration. They are from the Gazelle Peninsula, New Britain, T.N.G.. Details of the thin sections and the petrographic determinative results are as follows :

R11245 (WK1a) Thin Section No.8634.

Locality: ¾ mile north-east of Raunsepna R.C. Mission, on track to Evitki.
Name : Dolerite or microgabbro.
Texture : Subophitic.
Mineral Constituents : Plagioclase - laths of calcic variety, strongly zoned.
Augite - Grains between and penetrated by plagioclase laths. Moderate positive 2V.
Mesostasis - Fine and, in places, coarse (micropegmatitic) intergrowths of turbid sodic feldspar and quartz.
Accessories - Opaque iron ore, apatite.
Secondary - Hornblende, green and brown varieties.

Uralite

Chlorite, including some penninite.

Carbonate.

Rock alteration : Hydrothermal or autometamorphic.

R11246 (WK1b) Thin Section No.8635.

Locality: ¾ mile north-east of Raunsepna R.C. Mission, on track to Evitki.
Name : Crystal and lapilli basic tuff.
Texture : Bombs and lapilli are welded in a turbid matrix that contains numerous crystal fragments.
Alteration: Most crystals are severely cracked, and incipient alteration is indicated by a turbid base dusted with opaque iron mineral and flecks of sericite. Plagioclase is slightly saussuritized. The base was probably glassy originally.

R11247 (WK2) Thin Section No.8636.

Locality: ½ mile north-north-east of Evitki village (in Warangi Creek).
Name : Porphyritic basaltic andesite.
Phenocrysts: All fresh, some are severely cracked.

Plagioclase - euhedral crystals, strongly zoned.

Olivine - euhedral crystals, elongated along the vertical axis and terminated by domes. Faintly pleochroic, moderate to high negative 2V, i.e. Fe-Mg variety of olivine.

Augite - euhedral crystals, moderate positive 2V.

Opaque iron mineral.

Groundmass: Mostly aphanitic and turbid, but contains plagioclase microlites and is dusted with iron ore.
Includes very minor amounts of potash feldspar.

Alteration: Negligible.

R11248 (WK3a) Thin Section No. 8637

Locality : Creek 200 yards west of crossing of Toriu River by Galavit-Maleseit track.

Name : Dolerite.
Texture : Subophitic and porphyritic. Phenocrysts are exclusively euhedral, zoned plagioclase.
Mineral Constituents:
Plagioclase - laths and phenocrysts, are mostly turbid and extensively cracked.
Augite - partly chloritized, especially in marginal zones against plagioclase.
Opaque iron mineral - granular - some grains skeletal.
Mesostasis - few patches with quartz.

Alteration : Slight hydrothermal or autometamorphism.

R11249 (WK3b) Thin Section No.8638.

Locality : Creek 200 yards west of crossing of Toriu River by Galavit - Maleseit track.
Name : Gabbro (on the basis of texture).
The rock is fresher and the ferromagnesiam mineral is a little more abundant than in WK3a. The rocks are essentially similar, however.

Texture : Porphyritic, most grains are densely cracked. All phenocrysts are euhedral zoned plagioclase crystals.

Mineral Constituents:
Plagioclase - mostly labradorite forming phenocrysts and a few laths. Zoning strong.

Augite - many fresh grains; some are altered to chlorite and a serpentine-like mineral.

Opaque iron mineral.

Quartz - feldspar mesostosis and micropegmatite.

Alteration : Slight hydrothermal or autometamorphic, has resulted in formation of calcite, turbid plagioclase, serpentine-like mineral and chlorite.

R11387 (WK4) Thin Section No.8639

Locality : Toriu River, right bank at crossing of Galavit-Maleseit track.

Name : Calcareous siltstone?

Very little can be identified in the thin section. Even with high magnification only a few minerals can be resolved, but this is partly due to the turbid alteration that has made the section almost opaque. A few small patches of silica can be identified, together with feldspar, chlorite and numerous small carbonate patches. No quartz shards were found.
In one part of the thin section, there are recrystallized micro fossil tests (see Appendix 2).

R11251 (WK6b) Thin Section No.8640.

Locality : Creek about 200 yards west of patrol house, near Ranoulit village.

Name : Lithic conglomerate (poorly sorted).

The conglomerate is composed of sub-rounded lithic fragments (mainly feldspar-quartz aggregates) in a fine, poorly-sorted base that contains quartz and feldspathic fragments. Much of the base is turbid, and dusted with iron oxide minerals. Pebbles are free from iron ore, though iron oxides are concentrated in cracks and against margins of pebbles.

R11252 (WK6c) Thin Section No, 8641.

Locality : Creek about 200 yards west of patrol house near Ranoulit village.

Name : Dacite.

Texture : Porphyritic (euhedral plagioclase phenocrysts only); aphanatic base with a few feldspar microlites.

Minerals : Plagioclase.

Potash feldspar.

Pyroxene - diopsidic augite - present in small amount only.

Opaque iron mineral - a few discrete grains evenly distributed throughout.

Silica - fairly abundant spherulitic chalcedony and some patches of tridymite.

Calcite.

Sphene.

Groundmass: Turbid, apparently aphanitic, but feldspar microlites can be recognised.

R11253 (WK6d) Thin Section No.8642.

Locality : Creek about 200 yards west of patrol house, near Ranoulit village.

Name : Amygdaloidal basalt.

Texture : Pilotaxitic, porphyritic and amygdaloidal.

Phenocrysts: Plagioclase - euhedral and zoned. Most of the crystals are turbid with alteration whose products include calcite and sericite.

Minerals : Plagioclase - laths and microlites form a large proportion of the groundmass.

Opaque iron minerals (including a hydrous form) dusts the groundmass.

Silica - occurs in a few small patches.

Groundmass: Was probably originally glassy.

Amygdules : These are well-layered. The mineral layering from outside to inside is generally - calcite, emerald green chloritic mineral, iron-stained siderite and calcite core.

R11254 (WK7) Thin Section No. 6843

Locality : Creek about ½ mile from Ranoulit village.

Name : Soda rhyolite (This name is not entirely satisfactory as quartz and alkali feldspar have not been recognised, though they may be occluded in the groundmass).

Texture : Porphyritic - euhedral plagioclase phenocrysts are set in a very fine-grained to aphanatic groundmass.

Minerals : All the plagioclase phenocrysts are oligoclase, twinned and turbid in part. Much of the groundmass is feldspathic.

There are no ferromagnesian minerals.

Opaque iron mineral grains are rare; they include magnetite, ilmenite and hydrous iron oxide.

Apatite forms rare needles.

Groundmass: Too fine to be completely resolved; the extent of turbid alteration suggests much of the groundmass is feldspathic.

R11255 (WK8) Thin Section No.8644.

Locality : Small creek 50 yards west of Specimen WK7.

Name : Dolerite or gabbro.

Texture : Subophitic

Minerals : Primary - Plagioclase, turbid from alteration.
Augite, most grains are unaltered; commonly adjacent to the pyroxene grains, however, are patches of a serpentine-like mineral. As the pyroxene grains are fresh, possibly the serpentine has replaced olivine.

Opaque iron mineral, unaltered.

The magnetite has ilmenite lamillae.

Apatite.

Secondary- Uralite
Calcite
Epidote
Prehnite
Sericite.

Alteration: Hydrothermal (saussuritized).

R11256 (WK9) Thin Section No.8645.

Locality : Valilie River, East branch, just above junction.

Name : Crystal and lithic tuff?

Alteration undergone by the rock makes accurate naming difficult. The thin section contains many plagioclase crystals, euhedral and fragmental, and rock fragments, most of which are probably andesitic in composition. Calcite is abundant and some quartz grains are present. Epidote is another secondary mineral. The result is that the rock is extremely heterogeneous (poorly sorted?) even though it shows a crude banding in hand specimen.

R11256 (WK9) Thin Section No.8645 (cont.)

Crystal and rock fragment boundaries have become diffuse as a result of alteration (mostly hydrothermal). The base has also been thoroughly altered to form chlorite, uralite and calcite; it displays an overall turbid appearance, Most of the iron mineral is in a hydrous form. The disturbing part in naming the rock is the apparent flow features vaguely preserved in the base. The feldspar microlites are partly responsible; possibly the apparent flow banding is accentuated by the micaceous minerals present. Apart from these features the rock resembles a lithic or volcanic greywacke.

PLATE 4

Geological & Topographical Observations made on Traverse from Wilanbengau Village to Site of Keravat Agricultural College July 17th to 22nd 1961.

TOWANOKOKO-PONDO HYDRO ELECTRIC SCHEME, GAZELLE PENINSULA, NEW BRITAIN, T.P.N.G.

Plan showing Geological Observations July 1961

GEOLOGY BY E.K.CARTER

BASE ADAPTED FROM COMMONWEALTH DEPARTMENT OF WORKS (P.N.G. BRANCH) DRAWING Nº RS 723.

Note: Stations along the two rivers were marked in red paint subsequent to the survey; reduced levels given above (except for bench marks) are of water level at the time of survey and are not the height of the marked points.

B56/2/6

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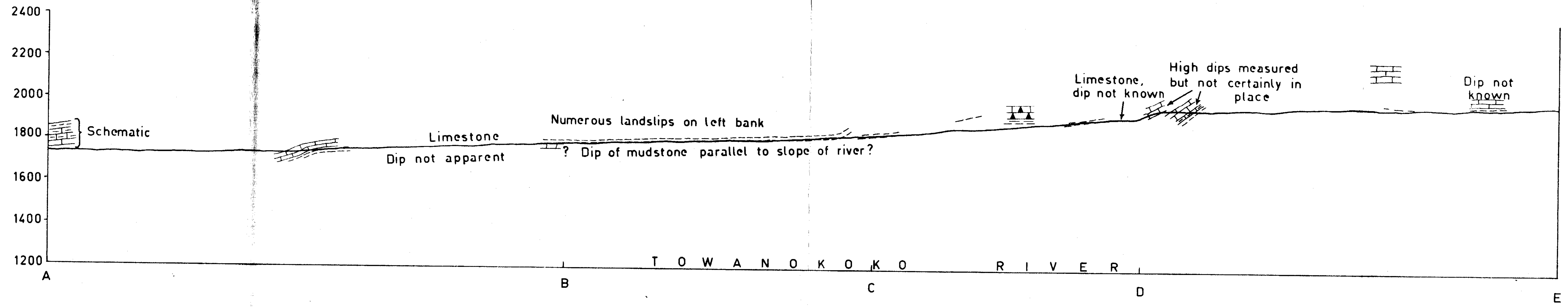
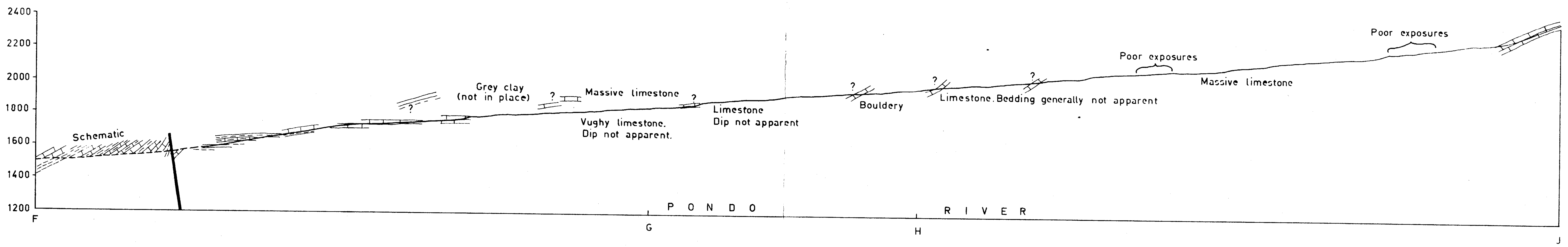
To accompany Records 1962/120





TOWANOKOKO-PONDO HYDRO ELECTRIC SCHEME, GAZELLE PENINSULA, NEW BRITAIN, T.N.G.

Profiles along Towanokoko and Pondo Rivers, looking North-west.

Surface is water level.

Lines on to which River levels and Geology are projected are shown in Plate 5.

Horizontal and Vertical Scale

200 0 400 1000 Feet

TOWANOKOKO-PONDO HYDRO ELECTRIC SCHEME

20' CONTOUR OF POSSIBLE STORAGE ON TOWANOKOKO RIVER

Datum: Point 0 of Profile 1 (see Plate 8)

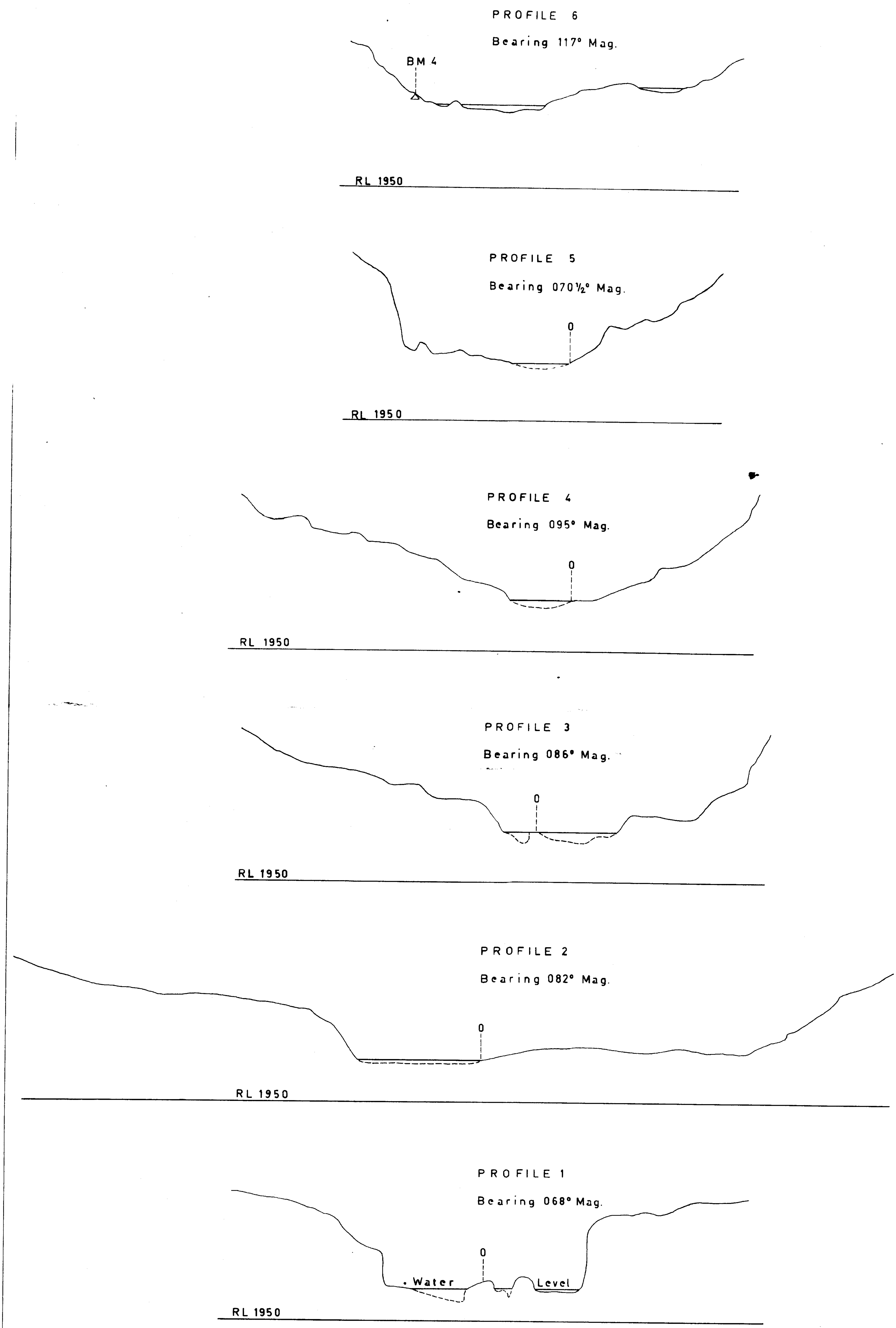
Positions of profiles approximate

Scale

40 0 40 80 120 Feet

Dumpy Level traverse by J. Vahala,
Commonwealth Department of Works, July 1961. B56/2/7

BUREAU OF MINERAL RESOURCES, CANBERRA, A.C.T. OCTOBER 1961.



TOWANOKOKO – PONDO HYDRO-ELECTRIC SCHEME, NEW BRITAIN

Profiles through Possible Storage Area, Towanokoko River, Looking Upstream.

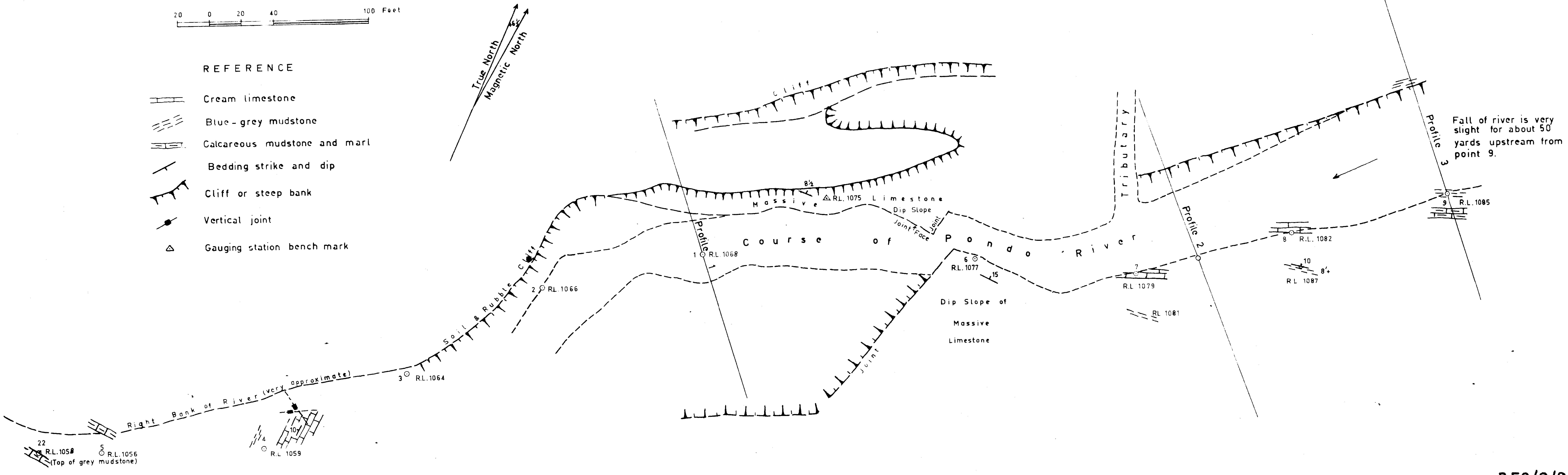
Locations shown on Plate 7. Compass, tape and Abney level survey by E.K. Carter, July 1961.

40 0 40 80 100 Feet

TOWANOKOKO-PONDO HYDRO-ELECTRIC SCHEME

GAZELLE PENINSULA, NEW BRITAIN

ROUGH SKETCH OF PONDO RIVER ABOUT LOWER GAUGING STATION SITE.
TAPE, COMPASS AND ABNEY LEVEL SURVEY BY E.K. CARTER JULY 1961.
R.L. OF BENCH MARK ESTABLISHED BY BAROMETER REFERRED TO UPPER PONDO RIVER GAUGING STATION BENCH MARK (R.L 1767'). FOR PROFILES SEE PLATE 10.



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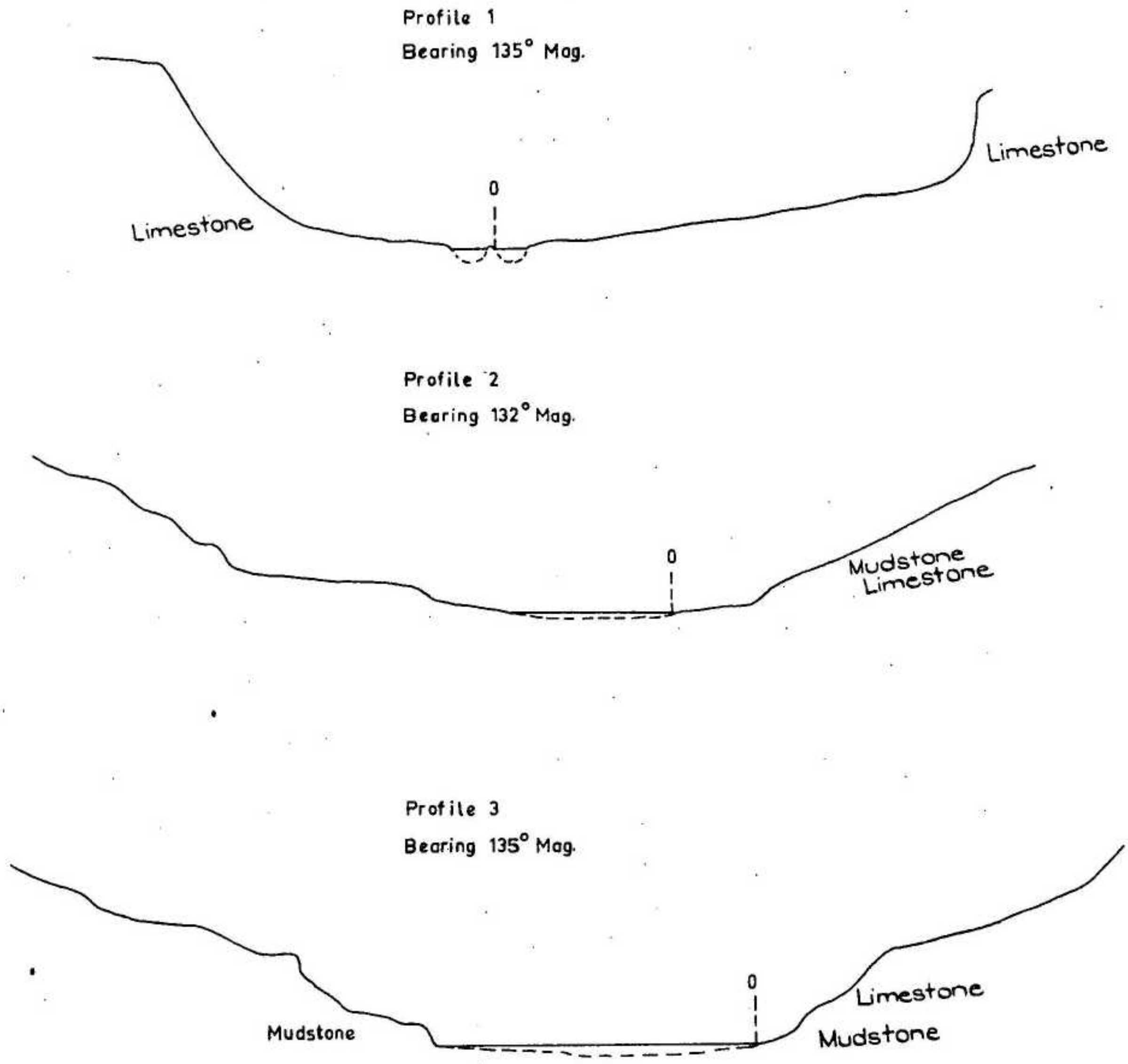
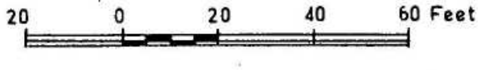
To accompany Records 1962/120



PROFILES THROUGH POSSIBLE STORAGE AREA NEAR LOWER GAUGING STATION, PONDO RIVER, LOOKING UPSTREAM. LOCATIONS SHOWN ON PLATE 9. COMPASS, TAPE AND ABNEY LEVEL SURVEY BY E.K.CARTER, JULY 1961.



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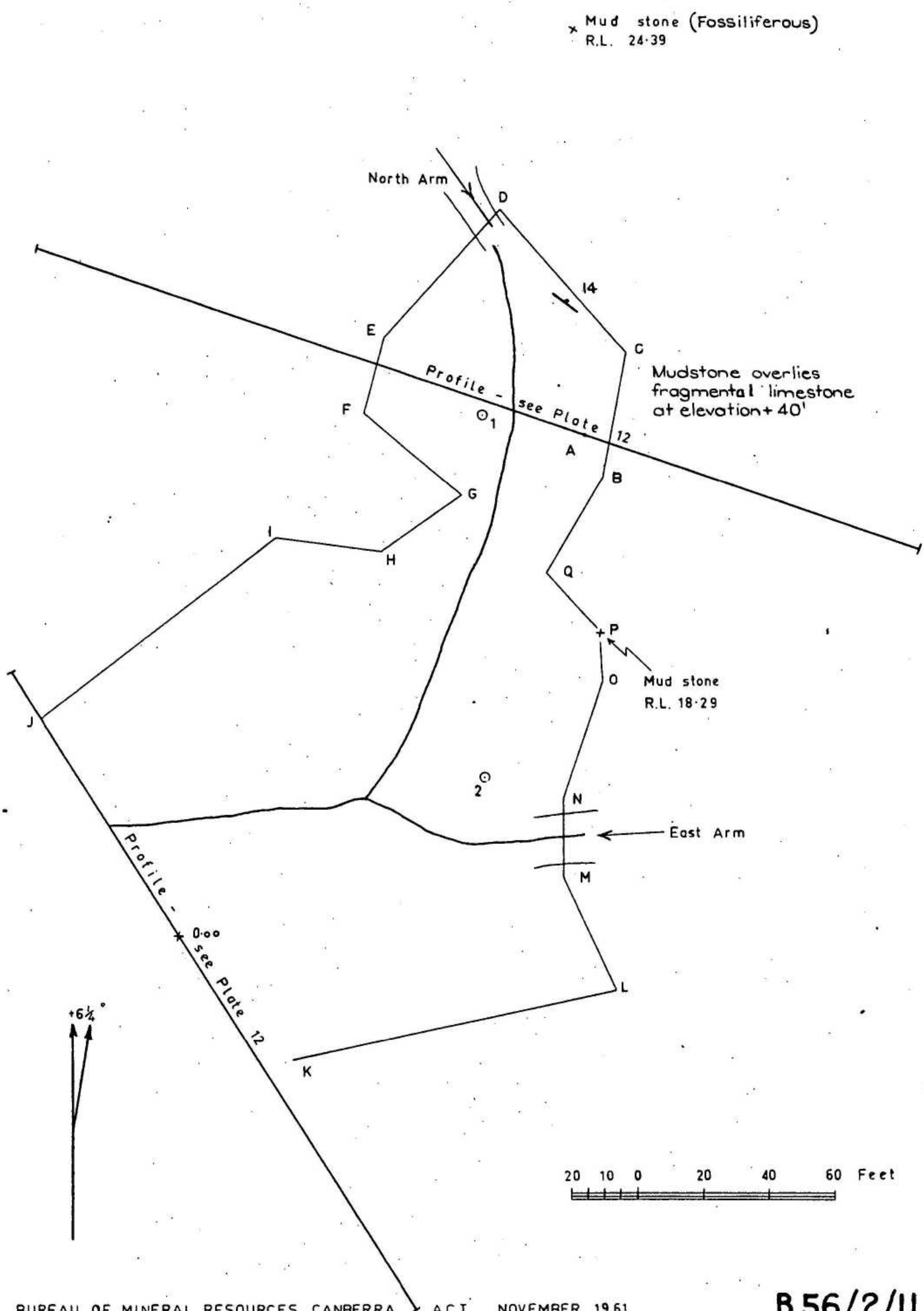
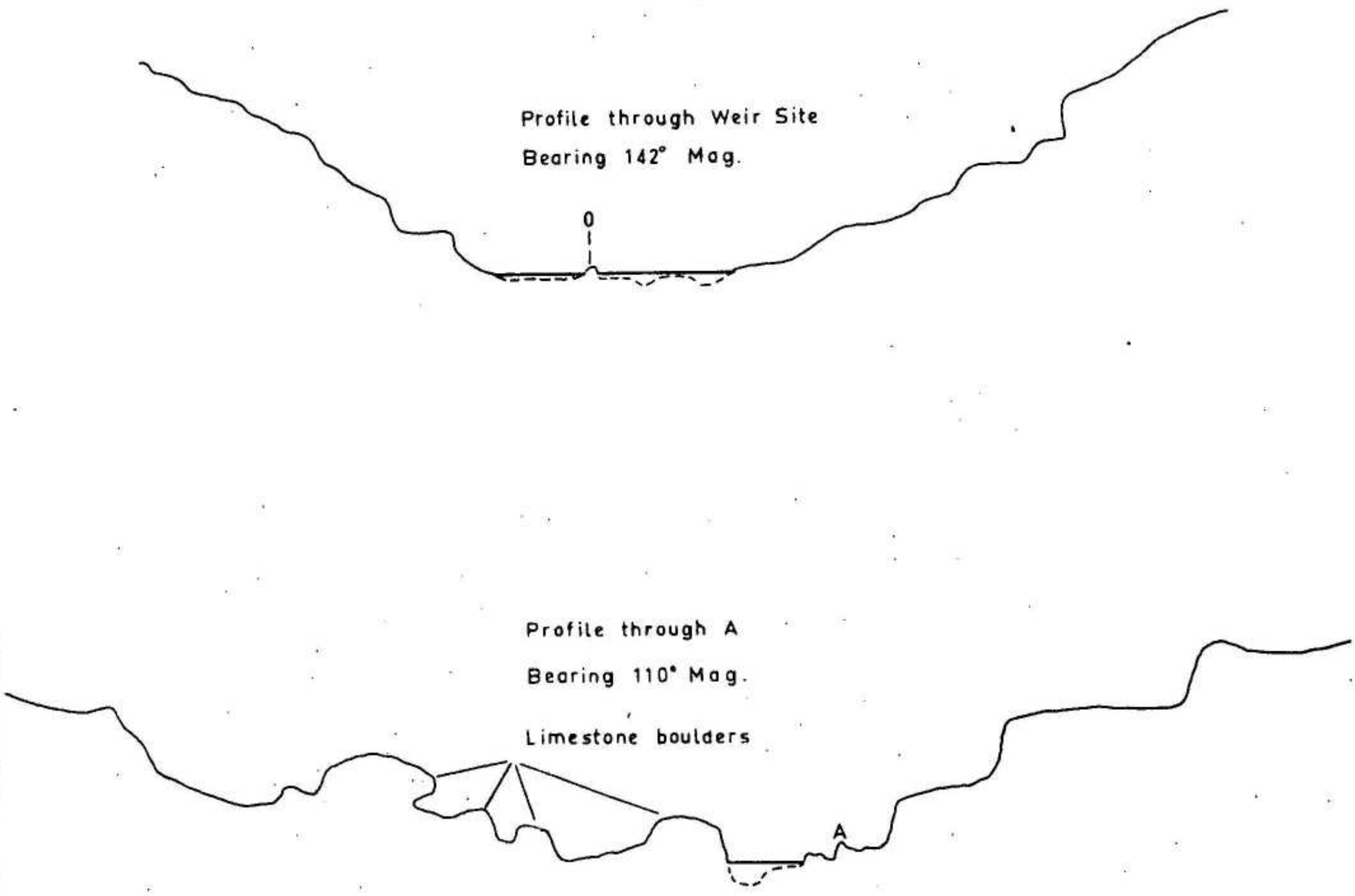
B56/2/10

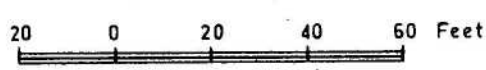
TOWANOKOKO-PONDO HYDRO-ELECTRIC SCHEME NEW BRITAIN, T.N.G.

20-FOOT CONTOUR OF POSSIBLE STORAGE AT JUNCTION OF NORTH AND EAST PONDO RIVERS. DATUM: POINT 0 OF PROFILE THROUGH WEIR SITE (SEE PLATE 12). DUMPY LEVEL TRAVERSE BY T.VAHALA COMMONWEALTH DEPARTMENT OF WORKS JULY 1961.





PROFILES THROUGH POSSIBLE STORAGE AREA, AT JUNCTION OF NORTH AND EAST PONDO RIVERS. LOOKING UPSTREAM. LOCATIONS SHOWN ON PLATE 11. COMPASS, TAPE AND ABNEY LEVEL SURVEY BY E.K. CARTER JULY 1961.



BUREAU OF MINERAL RESOURCES, CANBERRA ACT. NOVEMBER 1961

B55/2/12

To accompany Record 1962/120