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DEPARTMENT OF NATIONAL DEVELOPMENT.
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GEOLOGY OF A POSSIBLE HYDRO-ELECTRIC SCHEME ON THE LOWER
WARANGOI RIVER, NEW BRITAIN, T.N.G.
PRELIMINARY INSPECTION MARCH 1964.

by

E.K. Carter and J.P. MacGregor

The information contained in this report has been obtained by the Department of National Development, as part of the policy of the Commonwealth Government, to assist in the exploration and development of mineral resources. It may not be published in any form or used in a company prospectus without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.

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SUMMARY

A four-day inspection of the Lower Warangoi River, Gazelle Peninsula, New Britain, to determine the suitability of sites for a hydro-electric power scheme involving water storage and to ascertain what additional geological investigation would be needed, was made in March 1964. Only one suitable site exists; it is near Clifton Plantation, about $2\frac{1}{2}$ river miles below the junction of the Warangoi and Kavavas Rivers.

The site for the dam is formed by a constriction in the river, about 400 feet wide; the walls of the defile are of basaltic agglomerate, basalt and a basaltic dyke, overlain by coral limestone. The banks at the damsite rise steeply to a minimum height of about 240 feet and appear to be fairly strong; they therefore appear to be suitable for a dam at least 120 feet high. Leakage may possibly occur through the abutments and through other points, particularly the southern ridge and the divide between the Warangoi and Sigule Rivers; the possibility requires careful checking.

Other points to be considered in evaluating the feasibility of the project are:

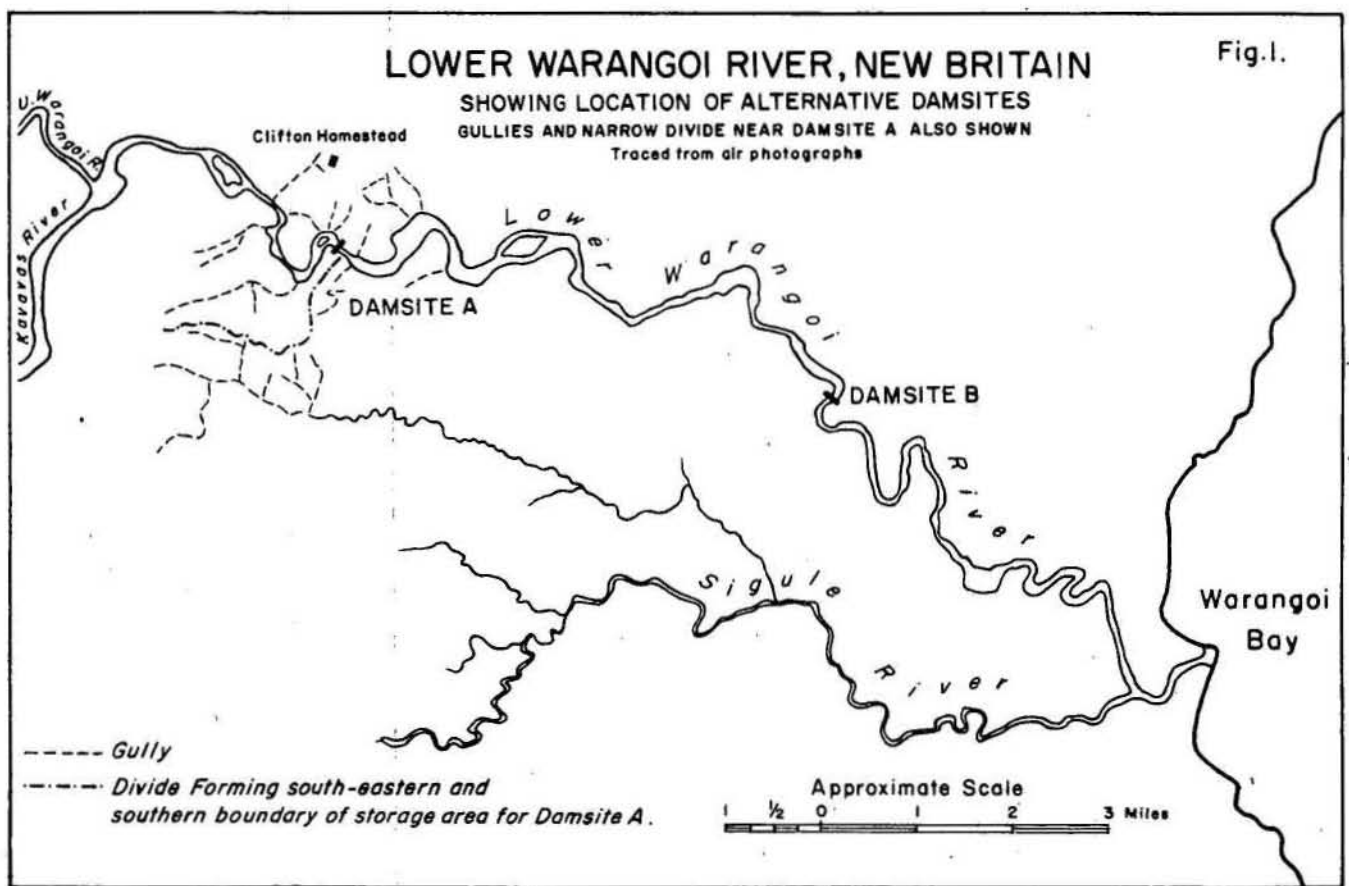
The site is in a region of extremely high seismicity and is just within the limits of historical volcanic ashfall.

Storage characteristics of the proposed reservoir appear good; normal siltation rate is probably high but should not seriously prejudice the scheme.

Extremely heavy siltation, due mainly to slope failure in the upper catchment area, could result from a severe earthquake. Volcanic activity, though a lesser hazard, could also reduce the effective life of the reservoir.

The river contains extensive banks of gravel composed, entirely or mainly, of durable pebbles and cobbles. Sand and impervious earth material may not be readily available.

Recommended additional work includes normal geological mapping, costeaming and drilling; geophysical testing of the abutments and possible zones of leakage; establishment of a sediment-sampling programme and installation of seismic ground-response recording instruments.



To accompany Record No. 1964/105

INTRODUCTION

Future electricity supply requirements for Rabaul, New Britain, make the early development of a source of hydro-electric power desirable. The hydraulic characteristics of the streams of the Gazelle Peninsula appear to limit the available energy, at economic cost, to the Towanokoko - Pondo River system and the Warangoi River. Geological investigations show that the Towanokoko - Pondo project would be very expensive and that it might not be possible to guarantee the integrity of the scheme against landslides. (Fisher, 1959; Carter, 1962 and Best in prep.).

The Commonwealth Department of Works therefore requested the Bureau of Mineral Resources in a letter dated 31st December, 1963, to carry out a geological investigation of two possible sites for a dam and power station on the Lower Warangoi River. This report is the result of a four-day inspection by the authors, in the company of Mr. H. Berg, Commonwealth Department of Works Engineer, carried out from the 7th to 11th March 1964, and contains recommendations for further investigations.

Of the two sites selected for inspection the lower site (see Figure 1) proved to have a very low right abutment, an inadequate left abutment, and to be composed of soft, gently dipping siltstone, pebble beds and probably permeable conglomerate. The upper site was found to be a very suitable site on grounds of topography, reservoir capacity, and geology. No further suitable site was found between the junction of the Kavavas and Upper Warangoi* Rivers and the sea. The remainder of this report is therefore concerned only with the upper site shown in Figure 1 as Damsite A.

Location

The Warangoi River and its tributaries drain a large part of south-eastern and central Gazelle Peninsula, and discharge into the sea on the east coast of the Peninsula, 24 air miles south-east of Rabaul and 13 miles south-south-east of Kokopo (Plate 3 and Figure 1). Dam site A is about 8 air miles from the mouth of the river and about 2 air miles - $2\frac{1}{2}$ river miles - below the junction of the Upper Warangoi and Kavavas Rivers. It is about one mile south of Clifton Plantation Homestead.

* Also known as the Nengmukta River.

Fig. 2.

CLIMATIC STATISTICS FOR RABAU

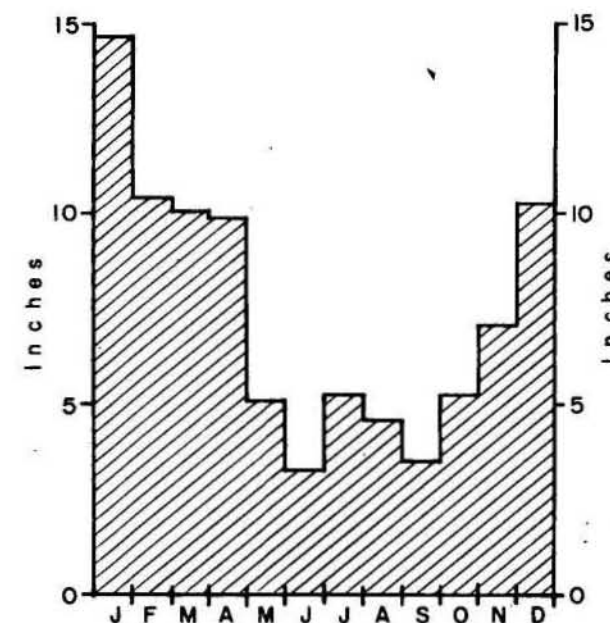
Average Daily Maximum Temp. 90.2°F
Range of Monthly A.D. Max.Temp. 89.4 - 91.6°F

Average Daily Minimum Temp. 73.0°F
Range of Monthly A.D. Min.Temp. 72.4 - 73.2°F

Average Daily Humidity 9 am 82%
 " " " 3 pm 72%

Highest Temperature recorded 100.2°F
Lowest Temperature recorded 64.0°F

Average Annual Rainfall 89.03 inches



Information from: - Climatic Averages of Australia - Commonwealth Bureau of Meteorology, Canberra 1956.

Access

Access from Rabaul is by the coast road to Kokopo and Cape Gazelle, a distance of 19-20 miles i.e. about one mile past Kokopo, where the Upper Warangoi Road via Tobera is taken for seven miles - about one mile past the war-time Tobera airstrip. Plantation roads are then followed for five miles to Clifton Homestead. The turn-off from the Upper Warangoi Road is indicated by a sign bearing a number of plantation names, headed by Wonga-Wonga (and not including Clifton). On the plantation roads the left hand road is taken throughout ignoring minor tracks except where a sign indicates the Clifton Homestead to the right or straight ahead. From Clifton Homestead access may be obtained by plantation road with gravel surface to the river about one river mile upstream from the damsite. The north abutment may be approached within about a quarter of a mile by plantation tracks. No tracks to the south of the river approach within usable distance of the southern abutment of the damsite. The only practicable way to approach the southern abutment is by boat or by swimming across the river. All public roads are serviceable at most times, and plantation roads are generally maintained except after heavy rain.

Climate, Topography and Vegetation

The Warangoi area is subject to two seasonal influences : the north-west monsoon from the months of November to April, and the south-east monsoon from April to November. Consequently, the area has a constant high temperature and humidity but judging from statistics for Rabaul (see Figure 2), most rain falls during the north-west monsoonal season. Details of rainfall are not presently available. The average annual rainfall at Rabaul is 89 inches and at Kokopo is 83½ inches. These figures are lower than for most parts of New Britain and it may be assumed that the rainfall in the catchment area is rather higher than 90 inches. The Lower Warangoi River and its tributaries drain the east-central portion of the Gazelle Peninsula, east from the nearby 8,000 foot-high Mount Sinewit. The dam site is about 100 feet above sea level at river level and is formed by two steep spurs about 400 feet apart at river level. In this area the Warangoi valley is approximately 2 miles wide and falls from country 500 to 4,000 feet high, in a series of dissected gullies and ridges. Relief is moderate but some of the gullies are extremely steep, and deeply incised. The fall of the river above the damsite is fairly gentle; for example,

the fall from the junction of the Kavavas and Upper Warangoi Rivers to the damsite, a distance of about 2½ river miles, is only about 20 feet. A 120-foot high dam would probably impound water back some eight or ten miles. The damsite therefore has excellent storage characteristics.

Natural vegetation consists of tropical rain forest with tall timber and extensive undergrowth. Much of the northern side of the Warangoi Valley has, however, been planted with cocoa and coconut. Minor portions of these would be inundated by the proposed dam.

Hydrology

No satisfactory gauging has been carried out on the Warangoi river*. A stream gauging station with float recorder and gauge stick was established in October 1955 at Kamarere on the Upper Warangoi River (see Plate 1) but the section proved to be most unstable and the station was abandoned in September 1959. The maximum flow measured during the period of operation was 1157 cusecs (cubic feet per second) and the minimum flow was 45 cusecs. The station gauged only a small part of the river system.

At the damsite the river normally runs strongly, and in time of spate a very considerable volume of swiftly-moving, turbulent, silt-and debris-laden water passes through the defile.

Itinerary of Investigation

Two and one half days were spent inspecting the abutments and environs of the damsite, and noting suitable construction materials. In the course of a 50-minute charter flight by Piper Aztec the site, including most of the storage area, was inspected from the air, and on the final day a dinghy trip was made from the Warangoi (Nengmukta) Bridge to below the alternative damsite to form some opinion as to the geology of the storage area, availability of construction materials, and to ensure that no other suitable damsites were available.

Previous Investigations

No previous investigations of the engineering geology of the area have been carried out. A general account of the geology of the area is included in Noakes (1942), which presents the geology of New Britain.

REGIONAL GEOLOGY

The following account of the regional geology is drawn from Noakes (1942) and Fisher (1939), supplemented by the observations in the immediate vicinity of the damsite, including particularly an examination of river gravels. Most of the western part of the catchment area appears to consist of Baining 'Series' - metamorphics and intrusives - together with, presumably Lower Tertiary, volcanic rocks. Gravels in the vicinity of the damsite consist mainly of intrusive igneous and volcanic cobbles and pebbles with some quartzite and jasper. The Miocene limestone, marl and mudstone which is a feature of the Pondo - Towanokoko area, and which were referred to by Noakes as the Neogene Series, appear to be absent in the catchment and storage area of the Warangoi damsite. At least no pebbles of limestone and mudstone were observed.

* Since the site inspection was made a gauging station was installed a few hundred feet upstream from the damsite.

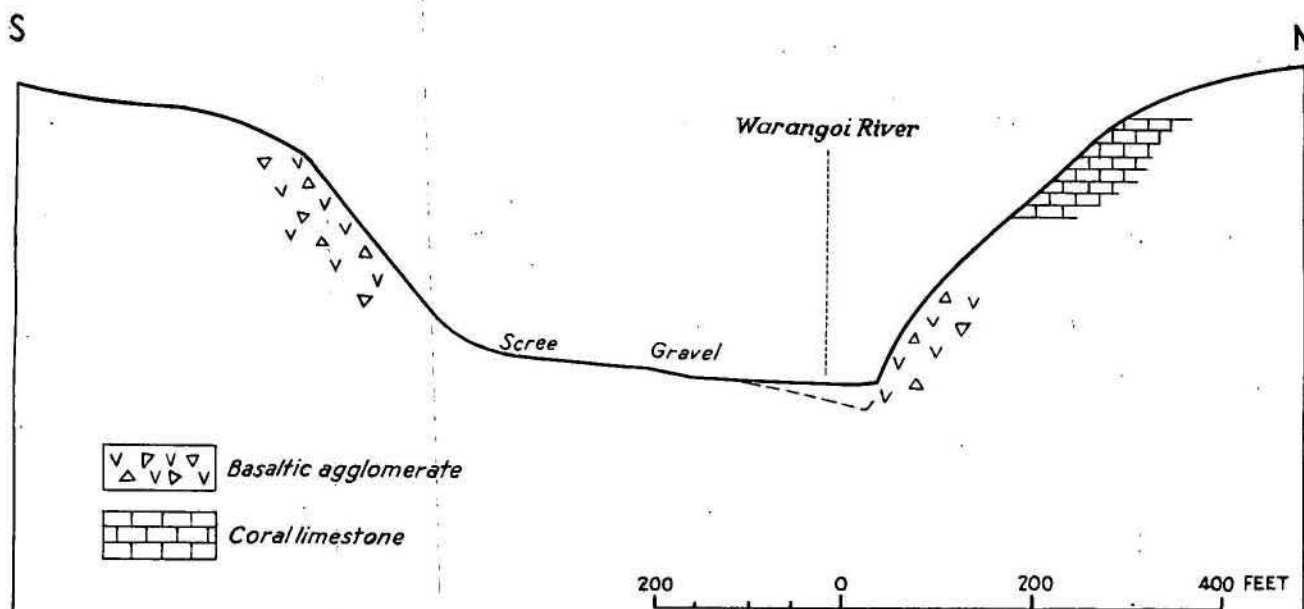
The abutments of the damsite consist of basic, largely fragmental, volcanics, presumably of Lower Tertiary age, overlain in part by Upper Miocene coralline limestone (see Appendix 2). These strata appear to be gently dipping to flat-lying and have possibly been faulted. Upstream from the damsite the valley of the river contains exposures of flat-lying silts, gravels and some minor conglomerate. Some of the silts are probably limey and near the damsite contain fragments of both coral limestone and volcanic rocks. They dip off the volcanics and coral of the abutments, and elsewhere are flat-lying to gently folded. Downstream from the damsite similar sediments, although generally perhaps more marly, occur widely; one cliff appeared to be about 60 feet high. These presumably form part of Noakes' 'Lamogai Series'. At alternative damsite B the 'Lamogai Series' is overlain by poorly consolidated conglomerate. Noakes regards the 'Lamogai Series' as Pleistocene in age and presumably the conglomerate is sub-Recent.

ENGINEERING GEOLOGY

DAMSITE

Plates 1 and 2 are photographs of the damsite. Figure 3 shows a schematic profile through the abutments. The section is based on an approximate measurement between abutments at river level, several barometric readings, and some abney level readings of slopes. The river channel at the site is approximately 150 feet wide and is probably more than 20 feet deep in places. The right bank of the river is formed by a narrow gravel shingle, beyond which is a vegetation-covered soil and scree slope. Geological observations in the vicinity of the damsite are shown in figures 4 and 5. As no survey control was available these should be regarded as schematic only.

Figure 3



Bureau of Mineral Resources, Geology and Geophysics, June 1964

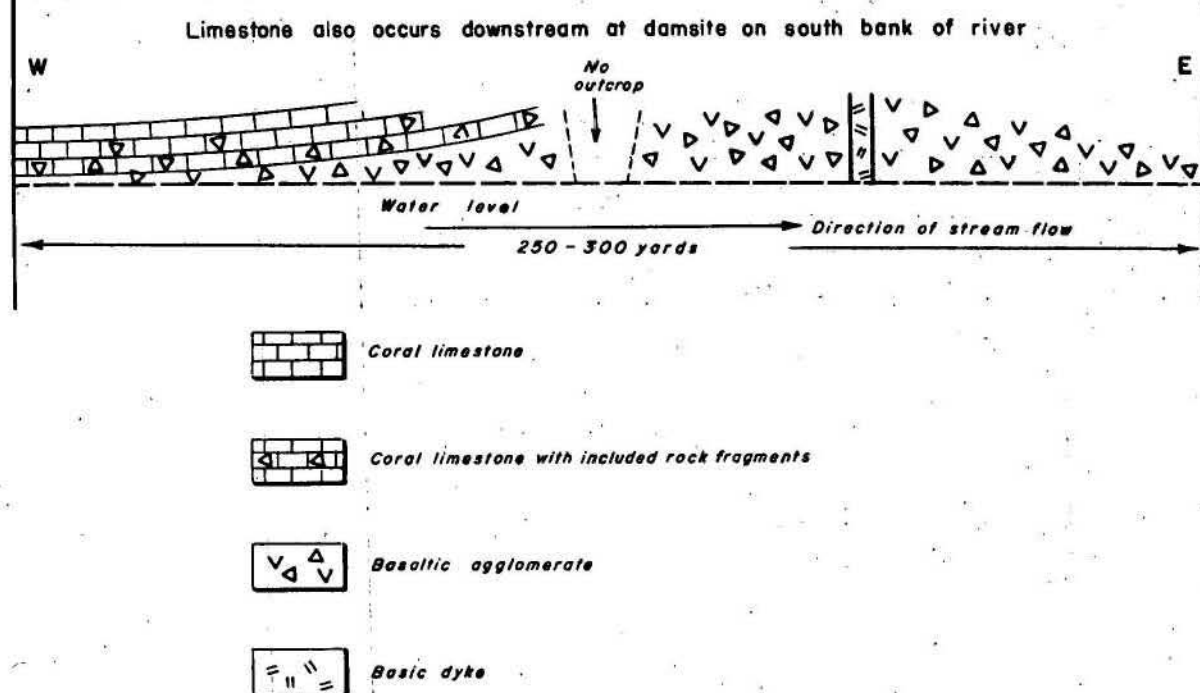
To accompany Record 1964/105

Schematic profile through abutments of Damsite A, Lower Warangoi River, New Britain. View looking upstream.

B56/A2/25

Figure 4

**Schematic section along river at north abutment of Damsite A,
Lower Warangoi River, New Britain.**



Bureau of Mineral Resources, Geology and Geophysics. June 1964 To accompany Record 1964/105 B56/A2/23 JK

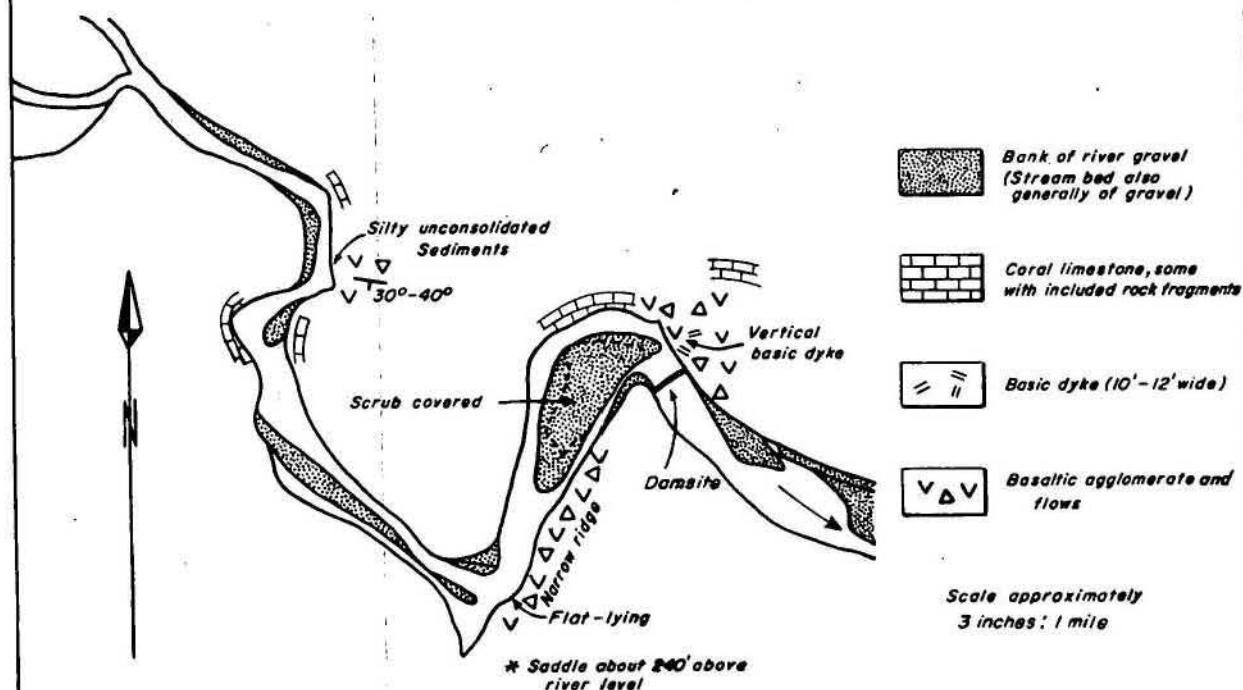
The north abutment consists of a steeply descending ridge with a narrow crest and is flanked by two or three steep gullies more or less parallel to the crest. On descending the spur from the cocoa plantation coral outcrops are first observed near the edge of the plantation, and within it, at an elevation of about 350 feet above river level. The highest observed occurrence of volcanic material, possibly not in place, was noted about 150 feet above river level. Coral occurs a short distance above this but the contact was not seen. The section along the north bank of the river in the vicinity of the damsite shows that the coral is 'draped' over the volcanics and also exposes a near-vertical dyke, 10-12 feet wide and closely jointed. The dyke is composed of a basaltic rock (see Appendix 1). It intrudes a mantle of volcanic agglomerate consisting of large angular and rounded fragments of rock, apparently of similar composition to that of the dyke, and with a fine-grained well-compacted matrix. The agglomerate appears to be a strong rock but will require further testing. Its permeability is not known. The opinion was formed that the agglomerate is not highly permeable but as the feasibility of the scheme depends on the abutments and flanking spurs being strong and water-tight, testing, involving drilling, water-pressure testing, and possibly laboratory tests of samples, will be necessary.

The south abutment appears to consist entirely of volcanic material. Coral limestone is exposed farther downstream. The abutment is actually the end of a narrow ridge half a mile long. The top of the ridge is only 30-40 feet wide, but is everywhere at least 240 feet above river level. A saddle at the southern end of the ridge forms the lowest point. There may be some structural reason for this saddle, and the geological conditions require close investigation; on the other hand the sharp deflection of the river below the saddle appears to indicate that the rock is sound and strong. Along the upstream face of the ridge volcanics, including flat-lying lavas, are exposed. The main rock type is coarse agglomerate similar to that in the northern abutment. Because of the narrowness of the ridge careful testing for water tightness will be necessary (see previous paragraph). It is not, however, expected that the ridge will be structurally weak. Outcrop is sparse but the exposed rock appears to be fairly fresh. Because of the narrowness of the abutments and the poor outcrop it may be expected that considerable stripping back to form dam abutments will be necessary.

A narrow divide between drainage systems extends southwest and west from the southern end of the ridge for a distance of nearly 2 miles. This divide also is potentially a zone of leakage and will require careful examination. A study of aerial photographs indicates that there are no low points which could be overtopped by water stored by a 120-foot high dam.

Figure 5

Geological observations along Warangoi River, New Britain, near Damsite A.
Based on aerial photograph.



No evidence was found for any structural control of the river course at the centre line of the damsite. The foundations at this point will, of course, have to be tested; the material of which they are composed is unknown. The remarkably sharp line of the north-west side of the southern ridge suggests some structural control. This view is re-inforced by the absence of volcanics on the opposite, left hand, bank of the river. If this is indeed a fault lineament it would appear to pre-date the coral which overlies the volcanics, as the impression was gained that the coral was draped over the volcanics, without dislocation. Outcrop, however, is discontinuous. An alternative interpretation is that the southern ridge forms the north-western arm of a syncline.

Owing to lack of time and poor exposures no opinion was formed of the geology to the north of the northern abutment and to the south of the southern ridge. Mr. J. Dunbar-Reid, partowner and manager of Clifton Plantation, reports that near the homestead the following near-surface succession occurs: 1 foot of black soil, underlain by 4 feet of pumice, which in turn is underlain by an unknown thickness of red clay. The red clay is described as generally silty, not very plastic, and is stated to dry to a very hard, severely cracked, surface.

Both the volcanics and the reef limestone by their nature are probably irregularly distributed. It will therefore be necessary to investigate thoroughly their distribution where possible leakage paths exist. The volcanics are expected to have highly magnetic properties and to have high seismic velocities than the surrounding coral limestone and unconsolidated sediments, and should therefore be amenable to delineation by geophysical methods.

STORAGE AND CATCHMENT AREAS

The geology of the storage area is described in general terms under regional geology. No limestone other than the reef limestone described above was observed; however, little of the storage area has been examined. No pumiceous material was seen below top water level for the proposed dam although some of the sediments may contain volcanic debris. The reconnaissance inspection did not indicate any grounds for anticipating leakage problems from the storage area, other than through the southern ridge and divide, and possibly around the north abutment, as described above. More detailed examination of the geology of the storage area is required.

In general the land surface in the storage area has quite gentle slopes and it is not expected that slope stability will prove a serious problem. Undoubtedly minor slope failures will occur but this should not result in any serious diminution in the volume of the storage nor jeopardise the dam structure. Fisher (1944) reports only minor cracking and slipping as a result of the very strong January 1941 earthquake.

The upper part of the catchment area (which was not visited) is in steep terrain and probably minor land slips occur quite frequently. Fisher (1944) records damming of the Upper Warangoi River by the 1941 earthquake. Large-scale slope failure in steep parts of the catchment area during earthquakes could result in serious siltation of the storage area.

The possibility of serious siltation due to seismic or volcanic activity is discussed further in a later section (p. 10).

CONSTRUCTION MATERIALS

Concrete Aggregate and Sand

A most impressive feature of the Warangoi River course both above and below the damsite is the extensive gravel banks (see Plate 1, Fig.1, and Figure 5). The cobbles and pebbles in these banks generally do not exceed 8 inches in length and most of the pebbles appear to be between 1 and 3 inches in diameter. They are well-rounded and consist of hard, durable material. Most appear to be of igneous origin - both intrusive and volcanic; some quartzite was seen and a few jasper pebbles also were noted. Pebbles and cobbles appear to consist of material suitable for concrete aggregate, but opaline or cryptocrystalline silica may possibly occur in some of the volcanic pebbles and normal reactivity tests would have to be conducted. Some sand banks were observed but sand does not appear to be as abundant as gravel. The gravel banks appear to consist only of coarse material at the surface but probably extensive finer material occurs between the pebbles at depth. The greatest thickness of gravel observed was about five feet but it is probable that greater thicknesses exist.

Impervious Core Material

Extensive occurrences of flat-lying, soft, silty sediments immediately upstream and downstream from the damsite appear to offer possibilities for impervious core material. Strata examined proved to be non-plastic silts; the compactability and permeability of the sediments is not known. Further, the variability in lithology and thin bedding make the material unattractive. If an earth-cored rock-fill dam is considered the red clays reported by Mr. Dunbar-Reid should also be examined. These clays, judging by Mr. Dunbar-Reid's description, may not in themselves be suitable but may provide useful blending material.

Rock-fill

The shingle banks described above contain a very large volume of rock material. Surface material appears to lack adequate fine-grained components, but augering or pitting may reveal a considerably higher proportion at depth. In view of the high seismicity of the area (see below) very thorough testing of the compactability and shear strength of the gravels will be necessary before they could be accepted for rock-fill.

Only small quantities of other material suitable for quarried rock-fill, other than that in the abutments, was observed. Presumably other volcanic materials are present in the vicinity and, failing any near source, Mount Varzin, 7 miles distant, might provide suitable material.

Figure 6

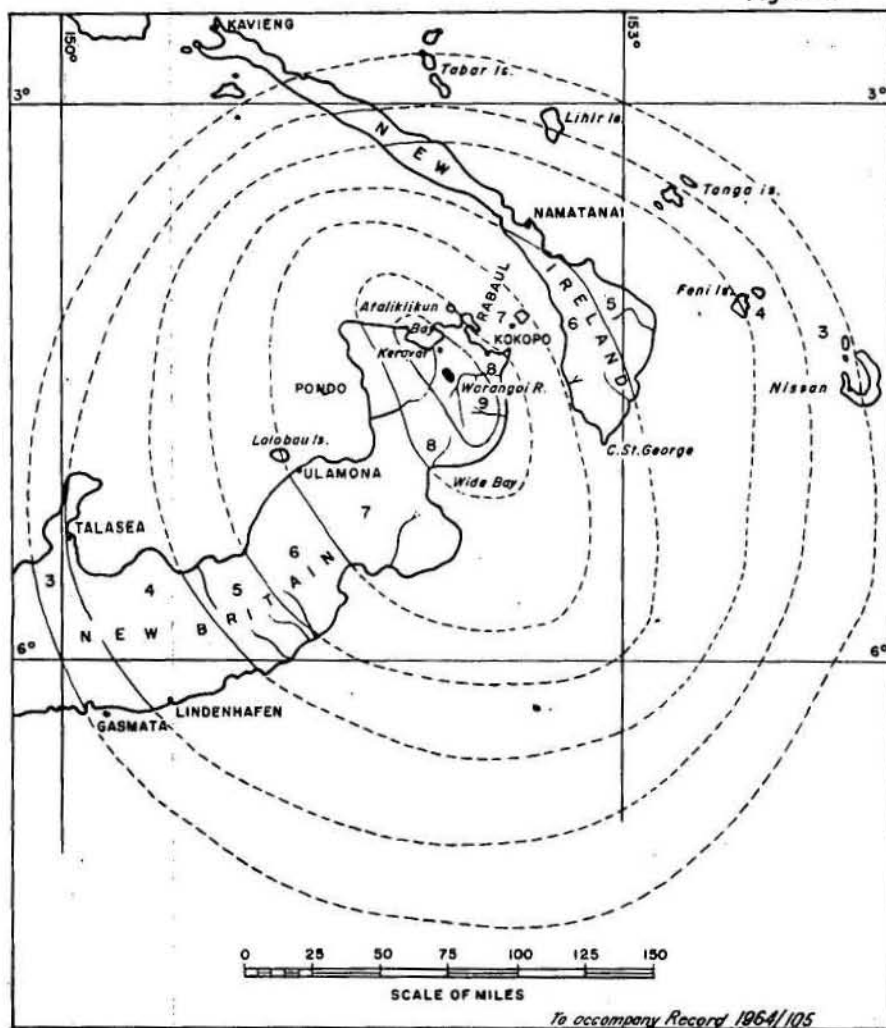


Fig.6. Isoseismal map of area affected by the earthquake of January 14, 1941. Numbers refer to intensity on Rossi-Forel Scale. Shaded area indicates probable position of epicentre. (From Fisher, 1944.)

SEISMICITY AND VULCANICITY

All earthquakes of magnitude 5 (Richter scale) or greater* recorded by, or reported to, the United States Coast and Geodetic Survey for the years 1958-1963, that have occurred within the latitudes 4° and 5° S. and longitudes $151^{\circ}30'$ and $152^{\circ}45'E$, are shown in Plate 4.

Brooks (1963) has studied the available records of seismicity in the New Guinea Islands and has produced maps showing the probability of occurrence of an earthquake of given intensity in those areas. One map -reproduced in this report as Plate 5 - shows that the Warangoi damsite lies within a zone in which earthquakes of intensity 9 (Modified Mercalli scale) can be expected within a 25-year period; another shows that an earthquake of intensity 10 can be expected in a 100-year period. Any hydro-electric project erected in the area would therefore have to be designed for high accelerations. Fisher (1944, Figure 2; reproduced as Figure 6) indicates that the damsite was subjected to an intensity of 9 (Rossi-Forel scale) in the January 1941 earthquake (see also Fisher, 1946). Damage along the Lower Warangoi Valley was reported to be slight: some incipient land slipping and cracking. It therefore appears that structures suitably designed and positioned would not sustain damage from land slides except in very exceptional circumstances. The inspection failed to reveal any structural elements within the damsite along which fault movement in the course of an earthquake could be expected.

As detailed seismic data, particularly about ground response to earthquakes of various magnitudes, are needed for the design of installations, steps should be taken to install simple ground-response instruments on volcanics, coral limestone and soil as soon as possible (see Brooks, 1963). Model studies will be needed later to ascertain the hydraulic effects of earthquake-induced waves in the reservoir.

Plate C1 of Fisher (1939) shows that the Warangoi damsite is just within the limit of ashfall in the 1937 eruption of Vulcan and Matapi (Tavurvur). This eruption was the most violent in the Blanche Bay area in historic time and is considered by Fisher to have been the most violent for a very considerable time.

Mount Varzin, 7 miles distant, is part of the Blanche Bay volcanic complex (Fisher, 1939). There is, however, no historical record of activity or present signs of thermal activity and therefore the possibility of eruption need not be considered seriously.

* The Richter scale is a measure of the energy released at the focal point in the form of elastic waves. The greatest recorded magnitude is about $8\frac{1}{2}$. Two scales are used to indicate the intensity of an earthquake at any given point on the earth's crust: the Rossi-Forel scale has a range of 1-10 and the more commonly used Modified Mercalli scale has a range of 1-12. In each scale value 1 represents a tremor which is barely perceptible by human senses under the most favourable conditions and the upper figure represents an earthquake that produces total, or almost total, destruction.

SILTATION

Residents report that the Warangoi River is extremely dirty when in spate but it is apparently no more so than is normal in New Guinea rivers. Undoubtedly, as evidenced by the extensive shingle banks, the river has a very heavy bed load at times of high flow. A study should therefore be made of the volume and nature of sediment that would be brought into the reservoir in the course of normal seasonal variations of flow.

A greater hazard of siltation arises from the likely incidence of earthquakes and volcanic eruptions that would affect the catchment area. The probability of a major earthquake occurring within the economic life of the scheme appears very high. Such an earthquake could result in massive landslides in the steep terrain in the western and southern part of the catchment area; these could provide a source of easily-eroded material that would be rapidly transported to, and deposited in, the reservoir. Fisher (1944) records temporary damming of the Upper Warangoi River by landslides initiated by the 1941 earthquake. The siltation resulting from a major earthquake could greatly exceed the normal silt accumulation over the economic life of the project.

As indicated in the previous section the danger of the damsite and catchment area being blanketed by ash from any known volcanic source is considered slight. The 1937 eruption occurred during the south-east monsoon season; had it happened during the north-west monsoon season (Fisher, 1939) the fall-out would have extended into the catchment area. As an ash-fall of average thickness of only one inch over the catchment area would result in a substantial accumulation of sediment in the reservoir the possibility, even though slight, of massive siltation as a result of vulcanicity must be taken into account.

It will not be possible to define the maximum siltation hazard for the suggested Warangoi reservoir. A basis for the study of the problem could be provided by immediate implementation of a regular stream-sediment sampling programme to determine normal sedimentation under various stream flows; should a substantial earthquake shock be experienced in the area sampling should be augmented promptly to record the added silt load. The storage of the reservoir will need to be large enough to accommodate, without impaired efficiency, normal siltation during the assumed economic life of the project plus a very considerable reserve for the effects of an earthquake or volcanic eruption at least once in every twenty-five years.

CONCLUSIONS AND RECOMMENDATIONS

It is concluded that:

1. the Warangoi River damsite near Clifton Homestead is, on the available evidence, and subject to the qualifications given below, suitable for a 120-foot high dam with power station.
2. the abutments appear to be strong and configuration is suitable for a concrete dam; the abundance of apparently suitable gravels also favours the construction of a concrete dam rather than an earth and rock-fill structure, though sand may be scarce.
3. because of the narrowness of the abutments, particularly of the ridge that forms the southern abutment, the narrowness of the divide to the south-east of the storage area, and the lack of outcrop in places, possible leakage from the proposed reservoir in these areas will require careful investigation, including drilling and testing, before the scheme can be considered feasible.
4. storage characteristics of the reservoir are good and such slope failure as may normally occur should not seriously affect the reservoir.
5. the area is one of extremely high seismicity and any structures would have to be designed accordingly. Methods are available for measuring the ground response to an earthquake at a particular site and in view of the high incidence of earthquakes in this region consideration should be given to the immediate installation of suitable instruments on the several types of earth and rock materials at the dam site, to enable an estimate to be made of the effect of a large earthquake. The damsite defile does not appear to represent a line of structural weakness that might be affected by fault movement.
6. the damsite lies just inside the area affected by historic volcanic eruptions and the risk of damage by volcanic activity is considered negligible (but see 7, below).
7. at times of high flow the volume of transported material in the river is probably large. The reservoir would probably serve as an adequate settling pond to protect the turbines but the nature of suspended material and the rate of siltation under normal conditions should be investigated; gauging should start as soon as possible. A much greater siltation hazard arises, however, from the likely disruption of the land surface by a major earthquake. Added to this probable source of sediment is the less likely, but possible, contribution of ash from a volcanic eruption. Calculation of the volume of sediment likely to accumulate in the reservoir during the economic life of the project is not possible but the original capacity of the reservoir should greatly exceed requirements to allow for substantial siltation.

The opinions expressed above are the result of a brief inspection only and substantial additional geological investigation, supplemented later by augering and drilling, are necessary. Before systematic geological mapping can be undertaken substantial support facilities will be needed, including:

- (a) secure means of transport or passage from the north to south abutments,
- (b) stripping of undergrowth on the north and south abutments with some pitting or stripping of soil to expose bedrock. Trees should be left standing.
- (c) close survey control about the north and south abutments, with lesser control along the southern ridge and the divide shown in Figure 1.
- (d) because of the extensive area that must be examined for possible leakage paths systematic geological mapping would be expedited by large-scale air photography (which will, in any case, be needed for reservoir storage computations) at an early stage of the investigation.

Owing to the ~~security~~^{scarcity} of outcrop the geological mapping should be supplemented by geophysical surveys. The contrasting properties of soil, coral limestone and volcanics should enable excellent results to be obtained by seismic, magnetic and resistivity methods.

Steps should be taken as soon as possible to set up, operate and maintain ground response measuring instruments to give information on likely foundation and embankment behaviour during earthquakes. It is provisionally suggested that instruments should be installed on the volcanics, limestone, soil (e.g. at Clifton homestead) and, if practicable, on a gravel bank.

It is reported that a Japanese defensive line was established in the area during World War II. Enquiries should therefore be made of military authorities as to the danger of unexploded devices such as grenades, bombs and land mines being present, and if necessary the area should be checked by mine detectors operated by a bomb disposal unit.

As an investigation is at present under way to select a site for future development of a settlement that would form a satellite township to Rabaul, consideration should possibly be given to the use of any reservoir constructed on the Warangoi River as a town water supply.

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APPENDIX 1

PETROGRAPHIC DESCRIPTION OF THREE BASALT SPECIMENS FROM DAMSITE A, LOWER WARANGOI RIVER, NEW BRITAIN

by

W. Oldershaw

The following petrographic descriptions are of three basalt specimens from the Warangoi River which were submitted by E.K. Carter.

R. 17701

TS 14001

FN. CA.

Porphyritic Vesicular Augite Basalt

The specimen is a porous granular rock composed of white crystals of feldspar and olive-green crystals of augite set in a dark grey vesicular matrix. There is no shearing or foliation, and the rock has a rough irregular fracture. The rock has a bulk specific gravity of 2.57 which compared to the specific gravity of 2.73 of solid basalt shows it to have a porosity of 6 percent. This porosity is high for a basalt and is due to the vesicular matrix.

Under the microscope, the rock is seen to consist of phenocrysts of plagioclase and augite 1 to 2 mm. across, comprising 60 percent of the rock, set in a matrix of small laths of plagioclase and grains of magnetite with interstitial brown basaltic glass.

The phenocrysts of plagioclase consist of euhedral crystals of labradorite, most of which are well zoned and show growth lines. Some phenocrysts consist of two interpenetrant euhedral crystals in the form of a cross. Many of the crystals are strongly zoned from cores of labradorite to margins of oligoclase. The growth lines are marked by inclusions of dust and basalt glass along the old crystal faces. The laths of plagioclase in the groundmass consist of euhedral crystals of labradorite-andesine about 0.1 mm. long.

The mafic minerals, augite and magnetite, occur in groups. The augite consists of fresh, roughly prismatic crystals, some of which are slightly leached and corroded around their margins.

The matrix of the rock consists of minute laths of fresh plagioclase, minute octahedra of magnetite which comprise about 6 percent of the matrix, and interstitial brown basaltic glass which comprises about 10 percent of the matrix.

The specimen is a porous granular rock with numerous vesicles which would greatly reduce its strength. The vesicles are empty and unlined. There is no foliation or shearing. The rock is fresh and shows no sign of weathering or alteration. Ten percent of the matrix consists of basaltic glass, but this is not known to be deleterious.

R. 17702

TS. 14002

F.CB

Porphyritic Vesicular Augite Basalt

The specimen is a porous crystalline rock with a few crystals of white feldspar and olive-green augite, 1-2 mm. across, set in a dark grey vesicular groundmass. There is no shearing or foliation and the rock has a rough hackly fracture. The rock has a bulk specific gravity of 2.57. This is less than the specific gravity of most basalts (2.73) and is due to the vesicles which comprise 6 percent of the rock.

Under the microscope the rock is seen to consist of euhedral crystals of plagioclase, comprising 60 percent of the rock, and groups of roughly prismatic crystals of augite set in a very fine-grained matrix of minute laths of plagioclase, octahedra of magnetite and sparse interstitial basaltic glass.

The phenocrysts of feldspar consist of euhedral, strongly zoned crystals of plagioclase with bytownite-labradorite cores and oligoclase margins. The crystals contain bands of inclusions of dust, gas vugs and pods of basaltic glass along the growth lines marking old crystal faces.

The mafic minerals - augite, magnetite and a little olivine - occur in groups. The augite shows little alteration and little corrosion.

The matrix of the rock is finer-grained and darker than in specimen R. 17701 and consists of minute laths of plagioclase and octahedra of magnetite set in a sparse brown basaltic glass.

Most of the numerous vesicles in this rock are lined with a thin layer (0.1 mm. thick) of a pale brown, non-pleochroic, highly birefringent colloform mineral, parts of which show a layered structure and parts show an aggregate structure.

Some of the smaller vesicles are full of this mineral. It appears to be one of the montmorillonite group of clay minerals and was probably formed by deuteritic alteration of the basaltic glass in the matrix around the vesicles.

The specimen is a porous vesicular rock. There is no foliation or shearing. The rock is fresh and shows no signs of weathering and only a little alteration. The numerous vesicles in the rock account for its high porosity of 6 percent and would tend to reduce its strength. The basaltic glass around some of the vesicles has been altered to montmorillonite. This is one of the "swelling clays", but as it only forms a thin lining to the larger vesicles and fills a few of the smaller vesicles, it comprises about one percent of the rock and its effect would be quite small.

R. 17703

TS.14003

FN. CC

Augite Basalt

The specimen is a compact crystalline black rock with a few crystals of grey feldspar, black augite, and small pods of brown clay minerals scattered through it. The sample has a rough hackly fracture. No shear planes, joints or foliation were found. The sample has a specific gravity of 2.67 and a porosity of 1 percent. The sample is not weathered or stained. It was collected from the vertical dyke in the north bank of the Warangoi River, near the proposed axis for Damsite A.

Under the microscope, the rock is seen to consist of euhedral and subhedral phenocrysts of plagioclase, which form 60 percent of the rock, and a few prisms of augite and a few grains of magnetite set in a fine-grained matrix of minute laths and prisms of plagioclase and octahedra of magnetite.

The phenocrysts of plagioclase are strongly zoned and consist of bytownite-labradorite with oligoclase margins. The cores of the phenocrysts are crowded with inclusions of groundmass, part altered to clay, magnetite and dust, but the marginal zones are clear. Some of the growth lines are marked by bands of inclusions. Some grains are cut by parallel cracks, a few of which are filled with a brown clay.

The mafic minerals - augite and magnetite - occur in clots. The augite forms euhedral to subhedral prisms and shows no alteration.

The matrix of the rock consists of minute laths and prisms of plagioclase (0.05 mm. long) and octahedra of magnetite. The magnetite comprises 10 percent of the matrix. There are a few small vesicles comprising 1 percent of the rock; they contain a brown, banded colloform, highly birefringent mineral which is probably nontronite, one of the "montmorillonite" groups of clay minerals. The matrix in a few places has been altered to irregularly shaped masses of brown montmorillonite. There are a few veinlets filled with brown clay.

The rock is a hard compact augite basalt. It contains few vesicles and there is no foliation or shearing. The rock is not weathered and the minerals show no alteration. In a few places, comprising less than 1 percent of the rock, the glassy part of the matrix has broken down into one of the montmorillonitic group of clays.

APPENDIX 2

UPPER MIOCENE FORAMINIFERA IN SPECIMEN FROM DAMSITE "A" LOWER WARANGOI RIVER, NEW BRITAIN.

by

A.R. Lloyd

A specimen of coralline limestone was submitted by E.K. Carter from the north bank of the Warangoi River, two miles down-stream from the junction of the Warangoi and Kavavas Rivers, Gazelle Peninsula, New Britain, T.P.N.G., The specimen was collected upstream from the proposed Damsite A. A number of foraminifera and rare ostracods and gastropods were obtained from the washing. The following forams were identified:

Orbulina universa d'Orbigny
Globorotalia menardii (d'Orbigny)
Globigerinoides triloba (Reuss)
Globigerina duterteri (d'Orbigny)
Globoquadrina venezuelana (Hedberg)
Pulleniatina obliqueloculata (Parker & Jones)
Amphistegina gibbosi d'Orbigny
Lenticulina sp.
Cibicides mediocris Finlay
C. spp.
Cassidulina spp.
Eponides repandus (Fichtel & Mall)
Baculogypsina sphaerulata (Parker & Jones)
Bassina inflata LeRoy
Cancris sp.
Elphidium craticulatum (Fichtel & Mall)
?Cycloclypeus sp.
Planorbulinella larvata (Parker & Jones)

Pulleniatina obliqueloculata ranges from the Upper Miocene to the Recent but may extend down into the Middle Miocene (Todd, 1958, p.281), and Globoquadrina venezuelana has not been recorded above the Upper Miocene. It is therefore considered that the fauna indicates an Upper Miocene age. The fauna differs from the fauna found on the western side of the Gazelle Peninsula (Lloyd, 1963) which is Lower Miocene in age.

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Figure 1: Aerial view of Damsite A, Warangoi River, New Britain. View from downstream.



Figure 2: Damsite A from gravel bank in river upstream of proposed axis.



Figure 1: Left abutment of Damsite A - volcanic agglomerate with jointed basaltic dyke near left hand of photograph.



Figure 2: Gravel bank near Damsite A.

