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GEOLOGICAL INVESTIGATION OF THE PROPOSED KUMUSI RIVER-KOKODA ROAD, T.P.N.G., JULY, 1967

by

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SUMMARY

A geological investigation of sections of the proposed route of the Kumusi River-Kokoda road was carried out in July, 1967. The investigation included an appraisal of the stability of the Oivi Hill section, an examination of the large boulders in the alluvium preserved in the Luwuni and Yodda Valleys, and an examination of possible sources of gravel and binder for use as basecourse and pavement materials.

The sections in both the Luwuni and Yodda Valleys pass over extensive alluvial deposits of piedmont-fan type. Large boulders, up to 30 cubic yards in volume, occur randomly between Jeru Creek and Sisireta village. A thin cover of weathered tuff overlies much of the area.

Oivi Hill consists of basic and ultrabasic rocks which, along the road route, are mainly norite and serpentinite. Numerous shallow slides of overburden have occurred along the interface between completely weathered bedrock and top soil: small slides at spur tips, larger slides at the junction of spurs and ridges.

Construction of the road is feasible but problems will be encountered with the piling at bridge sites owing to the presence of large boulders; instability problems will occur in the Oivi Hill section.

Discoidal and flakey gravels of quartz-sericite schist and chlorite schist, shed from the Owen Stanley Ranges, will make poor pavement material; basic and ultrabasic gravels from the Ajura Kujara Range will probably be more suitable.

It is recommended that the road formation in the Oivi Hill section be in cut wherever possible, that all overburden be stripped from fill areas located on side slopes as well as from cut faces, and that embankments be cut no steeper than 1:1. Culverts should be generously designed and peripheral ditches be constructed above the formation to intercept run-off from spurs and ridges. It is further recommended that appropriate laboratory tests be carried out on the tuff, and on the red clay of Oivi Hill, to determine their suitability as a binder.

INTRODUCTION

Work on the Kumusi River-Kokoda road forms part of the programme of upgrading the Popondetta-Kokoda road. Owing to the large number of fords, the existing road cannot be traversed after heavy rains; further, numerous small slides keep closing the Kumusi side of Oivi Hill during the wet season.

At the request of the Director, Department of Public Works, Port Moresby, a geological examination of sections of the proposed route was made on 17th and 18th July, 1967.

TOPOGRAPHY AND GENERAL GEOLOGY

The present road alignment passes westward up the Luwuni Valley from the Kumusi River, crosses Oivi Hill, a low divide between the Luwuni and Yodda Valleys, and traverses down the Yodda Valley before climbing the escarpment of an old river terrace to Kokoda, 1,100 feet above mean sea level (Plate 1).

The Kumusi and Luwuni valleys are between two and four miles wide and contain extensive piedmont deposits of unsorted angular to sub-rounded metamorphic boulders set in a sandy matrix containing very little clay. Completely weathered tuff bands are interbedded with the alluvium in places. Boulders range up to more than 30 cubic yards in volume, especially in the section between Jeru Creek and Sisireta village (Plate 1). The boulders are concentrated along present and former stream courses. As streams have covered every part of the area at some time, boulders can be expected anywhere and at any depth, although they may be concentrated near the surface as a result of compaction of the surrounding alluvium combined with, or alternatively, erosion of the surface materials, especially where later streams have incised their courses.

Most of the boulders have originated from the Owen Stanley Range to the south and southwest. The range consists of the Owen Stanley Metamorphics, a sequence of gneisses and schists probably of Palaeozoic age (Davies, 1959b). The grade of metamorphism appears to be that of the greenschist facies, quartz-sericite and chlorite schists being common.

North of the two valleys, the Southern Zone of the Ajura Kujara Complex (Davies, 1959b) contains non-feldspathic and feldspathic basic rocks, including dunite, serpentinite, norite, gabbro, and dolerite intrusions.

The southern portion of Oivi Hill consists of Mesozoic Kemp Welch Series (Davies, 1959b) - greywacke, mudstone, and sericitic siltstone with dolerite intrusions downfaulted against the Southern Zone of the Ajura Kujara Complex.

Kokoda township is built on a high-level river terrace, separated by a steep escarpment from a number of lower terraces above the Mambare River. The terraces consist of clay and silt interbedded with gravel bands and minor, highly weathered tuff beds.

Much of the area investigated is overlain by deposits of grey-brown, slightly vitreous-looking clay containing black ferromagnesian crystals (hornblende?), white fragments of volcanic glass, and golden mica plates; the deposits before weathering were probably of crystal-vitric tuff. Where the former tuff occurs it ranges in thickness from less than one to more than 10 feet: it is especially prominent on low ridges that lie parallel to some of the streams in the Luwuni Valley.

ENGINEERING GEOLOGY

ROAD ALIGNMENT

The incomplete traverse from Kumusi River to Kokoda is described in several sections: Kumusi River to Ilimo Creek (0-2.3 miles); Ilimo Creek to Oivi Hill (2.3-10.2 miles); Oivi Hill (10.2-12.3 miles); Oivi Hill to Mambare Creek (12.3-14.5 miles); Mambare Creek to Kokoda Escarpment; and Kokoda Escarpment. Detailed traverse notes between Oivi Hill (12.3 miles) and Komoto village (13 miles 1180 feet), are given in Appendix I.

Kumusi River to Ilimo Creek (0 to 2.3 miles)

This section was not investigated; it crosses alluvium.

Ilimo Creek to Oivi Hill (2.3 to 10.2 miles)

The section starts at Ilimo Creek (Plate 1) and runs along a low-level, slightly undulating river terrace which is incised, up to 8 feet deep, by numerous small streams. It crosses Marau No.2 and Marau No.1 Creeks near the 4-mile peg and Jeru Creek near the $4\frac{3}{4}$ mile peg. The alignment then runs parallel to Jeru Creek as far as Hangiri village, after which the road traverses a bouldery river terrace and crosses Luwuni, Chulipa, and Asua Creeks near the 8-mile peg. The boulders continue to Sisireta village, just past the 9 mile peg. From Sisireta to the base of Oivi Hill there are some gentle undulations.

The proposed bridge on Ilimo Creek is sited just upstream of a right-hand bend in the creek. The left bank stands 12 to 14 feet vertically and consists of weathered, cohesive tuff at least to water level. The face is stable and has vegetation growing on it. Two hundred yards downstream, opposite the Agricultural Officer's house, a 75-degree bend occurs in the creek. Although the full force of the creek's flow is directed at a tuff bank on this bend, only minor undercutting of the bank has occurred at water level. The remainder of the face has vegetation growing on it.

The right bank at the bridge site, on the inside edge of the bend, consists of two terraces: a vegetation-covered sandy and bouldery lower terrace, and behind this, a tuffaceous upper terrace.

Upstream the creek changes its course from time to time but at the bridge site the stream channel appears stable.

Apart from the possible need to protect the foot of the left abutment, the bridge foundations should present no problem. However, pile-driving may be difficult below the tuff, owing to the probable presence of large boulders.

Marau No.1 Creek has been diverted into Marau No.2 Creek about half a mile upstream from the proposed crossing of No.1. A 30-foot-wide gravel and boulder bar, overgrown by large trees and shrubs, separates the creeks at the point of diversion. The bar is not expected to be breached unless there is an exceptionally big flood. Some spring water runs in Marau No.1 but most of the flow sinks into the gravelly creek bed at various points along its course. One such position is 100 yards upstream of the road. Though water will flow at the crossing, large volumes are not expected.

The creek bed is a possible source of aggregate gravel as it consists of pebbles of the Owen Stanley Metamorphics between 1 and 6 inches in diameter. Some sand, consisting of crushed rock, occurs in the creek bed and lower terraces.

Near the 4-mile 3196-foot peg, the alignment is on a terrace, 8 to 10 feet above the Luwuni River. The terrace is composed of 5 feet of bouldery alluvium with an open silty-sand matrix, underlying 3-5 feet of fine-grained, weathered tuff with poor cohesion. South of the road alignment, Jeru Creek runs parallel to the Luwuni River. If exceptional floods occur, Jeru Creek may breach its bank and flow across the proposed road into the Luwuni River.

Numerous boulders of foliated metamorphics, some more than 30 cubic yards in volume, occur along the alignment between Jeru Creek and Sisireta village. They are concentrated along present and former stream courses and probably occur at any depth in the alluvium along this section. The most common rock types are quartz-sericite and chlorite schists. Fractures parallel to the foliation are much more common than cross fractures. Some smaller boulders (about 5 cubic yards in volume) were broken with explosives when the first road was built. They have parted along both the foliation and incipient fractures normal to the foliation, forming near-equidimensional blocks up to one cubic yard in volume.

Where such boulders are to be removed, they will have to be drilled and blasted. They will split along their foliation planes, forming plates; where cross fractures are present, more nearly equidimensional blocks may be formed.

As the large boulders are concentrated along stream courses and banks, many difficulties in piling are expected. If steel piles are to be driven, a number of alternative pile groupings will have to be used as some piles will undoubtedly strike boulders close to the surface. Such a situation is likely to be encountered at the Luwuni Creek bridge site, where boulders of foliated chlorite schist, up to 15 by 10 by 6 feet, occur along the river bank. The boulders have discontinuous fractures parallel to the foliation, together with a number of cross fractures.

In the area between Hangiri village and position A (Plate 1) 70 to 80 percent of the pebbles and boulders consist of Owen Stanley Metamorphics. Pebbles and cobbles average 2 to 12 inches in diameter with boulders up to 4 by 3 by 3 feet. Some boulders of dolerite, norite, and serpentinite also occur.

Spurs up to 20 feet high, with 10-foot-thick tuff cappings overlying gravel, occur on both sides of Asua Creek. In places, tuff extends below the present stream level. Blocks part along vertical joints but generally the tuff has a good cohesion and is not very susceptible to erosion. Abutments at the new bridge site, which consist of tuff overlying gravel, are stable.

Gravel bars downstream of the present crossing of Asua Creek are a possible source of base-course material. Another possible source occurs upstream of the new bridge site where at least 4 feet of gravel is overlain by tuff. However, in both sources the pebbles are mainly of metamorphic rock.

Oivi Hill (10.2 to 12.3 miles)

From chainage 10.2 miles at the head of the Luwuni Valley the proposed alignment generally follows the present road across Oivi Hill into the Yodda Valley. Construction of the road will require extensive side-cuts around hill-slopes and spurs and some box-cuts through larger spurs.

Numerous small surface slides have occurred on side cuts along the existing road. The slides mainly involved the movement of overburden along the interface between completely weathered bedrock (generally norite or serpentinite) and top soil. At spur tips, especially where they have been truncated by the road, small slides, 3 to 5 feet in depth, occur. Large slides have occurred at the 'root' of spurs, where the spur joins to the ridge. In these positions there is normally a deeper soil cover than elsewhere and seeping water is often noticeable. The depth of the slides ranges from 10 to 30 feet and their area is up to 100 by 60 feet.

Between pegs, T2709 and T3002 on the Kumusi side of the ridge, ten slides have occurred, at least four within the last two years. In parts of this section the face of the cut may be 150 to 200 feet high.

The scar slopes range from 32 to 70 degrees, and average 45 degrees. Observations have shown that batters no steeper than 1:1 should be constructed for cuts greater than 10 feet high, and that cuts higher than 40 to 50 feet should be benched.

From 11 mile 4125 feet to 11 mile 4400 feet the proposed alignment follows the base of a sheared serpentinite ridge with swampy ground on the south side. A moderate-sized slide has occurred at the root of a spur in this section. The slide, which is still active, has much water draining from it and will need artificial draining to help stabilize it.

Oivi Hill to Mambare Creek (12.3 to 14.5 miles)

From 12.3 miles to Mambare Creek the alignment passes over a gently undulating river terrace which is shallowly incised (up to 6 feet) by occasional streams and crossed by a few low spurs; the streams will require box culverts and the spurs box cuts. The river alluvium is covered by a layer of weathered tuff which is at least 6 feet thick in places. Small areas of water-logged, black, silty soil occur. Depths of this material will have to be determined.

Along the west bank of the present ford on Mambare Creek, 4 feet of tuff overlie at least 4 feet of river gravel. Up and downstream of the crossing, there are bars, at least 100 feet long by 30 feet wide, composed of metamorphic pebbles that average 1 to 4 inches in diameter. The pebbles are mainly of mica schist and tend to be elongate or discoidal in shape. Finely crushed metamorphics have formed small deposits of gravelly sand.

Mambare Creek to Kokoda Escarpment

This section was not investigated, but is known to cross alluvium.

Kokoda Escarpment

Kokoda is situated on a high-level river terrace at the eastern edge of which is a 100-foot escarpment. Below the escarpment two or three lower terraces rise above the valley floor. There are two possible routes into Kokoda: one, (a) on Plate 1, crosses Fiawani Creek and joins the existing road near the base of the northern end of the escarpment; the second, (b), crosses Fiawani Creek and climbs the escarpment from a position near Hansen's new rubber factory, following the existing access road. The material exposed along this road consists of bands of river gravel in a succession of red, plastic, slightly micaceous clay, and silty, grey-brown, micaceous beds, probably tuff. In this, ¼:1 faces 8 to 10 feet high are stable and have a thin vegetation cover; but 15-foot faces have minor slides. Route (b) is expected to be stable provided cuts are not greater than 30 feet high and drainage is adequate. Seepage will probably occur along gravel bands and may need special attention.

The Department of Public Works has pegged a further access road alignment running from near Hansen's rubber factory towards the airstrip. This alignment crosses an embayment within the terrace where a number of shallow slides, both old and recent, have occurred. Near centre-line peg 8703.5 feet, a recent slide has formed a 15-foot-high bank with a 45-degree slope in red clay. Water seeping out of a low gravel bed probably triggered this slide. As the embayment will tend to concentrate drainage of the water table, any alignment across this position will be unstable and is therefore not recommended.

PAVEMENT MATERIALS

Gravel and Sand

Boulders in all creeks draining from the Owen Stanley Ranges consist mainly of quartz-sericite and chlorite schists. The fragments, which range in thickness from 1 to 12 inches but may be 4 feet or more across, tend to be discoidal in shape. If crushed, they will tend to form platey or elongate, flakey pieces, not desirable as pavement materials.

Only small volumes of sand, consisting of crushed metamorphic rock fragments, occur in scattered areas. No extensive sand deposits are likely to be found.

Possible gravel sources are: gravel bars in Marau No.1 and Asua Creek beds; or the 3 to 4 feet thick gravel terraces in the banks of the Mambare, Efu and Asua Creeks.

Better pavement material is shed from the Ajura Kujara Complex which consists of basic and ultra-basic rocks: dunite, serpentinite, norite, gabbro, and dolerite. Detrital deposits of these materials may occur at the head of the Upper Mambare River, 1½ to 2 miles north of Komoto village, but access to the area may be difficult. On crushing, these rocks will form equidimensional fragments.

Binder

Much of the proposed alignment is overlain by a grey-brown, cohesive, weathered, crystal-vitric (?) tuff, probably of intermediate composition. The tuff is up to 10 feet thick in places and is very noticeable as cappings of low spurs, e.g. near Ewo Mission, and Ilimo and Mambare Creeks. Under normal weathering conditions tuff alters to montmorillonite, (Grim, 1962, p.43), but under tropical leaching conditions, kaolinite is a more likely product. Cohesion of re-moulded tuff appears to be moderate to high. Appropriate soil tests will be needed to determine its suitability as a binder.

The red, cohesive clay on Oivi Hill is another possible source of binder material, especially from sections between pegs T3670 to T3976, T4226 to T4453, and 12 mile 675 feet to 12 mile 1770 feet. Appropriate soil tests and quantity surveys will be required.

Completely weathered and bleached norite is probably kaolinitic and so may have suitable properties for use as a binder. Another possibility is the mixture of tuff and silty clay present in the Kokoda escarpment. However, as many layers are rich in mica, cohesion and shear strength may be insufficient for use as a binder.

CONCLUSIONS

1. Very little moderately weathered to fresh rock will be encountered in the Oivi Hill section. Some will be present in the section T2709 to T2800 and at 11 mile 4125 feet. In both places the rock is mainly serpentinite.

2. All the slides in the Oivi Hill section have been caused by overburden, consisting of rock fragments and top soil, sliding along the interface between completely weathered bedrock and top soil.

3. Small slides occur at the truncated tips of spurs, larger slides occur at the roots of spurs. Roots of spurs have a thicker cover of overburden and many are seepage sites.

4. In general, the angle of the slide scar (i.e. of the apparently stable slope) decreases as the height of the slide increases.

5. Slopes of 45 degrees and less in completely weathered norite are easily eroded by running water.

6. Tuff has good <u>in situ</u> cohesion, will stand vertically to at least 15 feet, and resists scour by fast-running water.

7. Large boulders occur randomly in the alluvium, especially between Jeru Creek and Sisireta village. The boulders are concentrated along present and former stream courses and will cause problems where bridge abutments are piled.

8. When blasted by explosives, boulders of metamorphic rock will break along their foliation planes. Where cross fractures are present, near equidimensional fragments will be formed.

9. Natural stream deposits consisting of elongate and disc-shaped pebbles and boulders of metamorphic rock will make poor pavement material. If crushed, they will tend to form flakes and discoidal pieces.

10. Natural stream deposits shed from the Ajura Kujara Range are believed to have more nearly equidimensional boulders and pebbles than those from the Owen Stanley Ranges, and should produce angular, cuboid fragments when crushed.

11. Sand is unlikely to be found in extensive deposits. Any sand will consist essentially of finely-crushed rock fragments, which have been little sorted and rounded by water action.

12. Because of tropical weathering conditions, clays in the area are expected to be kaolinitic. Some illite may be present in the red clays.

RECOMMENDATIONS

1. Any swampy or waterlogged section of the alignment should be augered to determine the depth of silty material.

2. As there is a high rainfall with no dry month, (Kokoda has an annual rainfall of 143 inches with the lowest rainfall of 7 to 9 inches per month in July-August-September), culverts should be generously designed to prevent a backing-up of water after heavy rain. Ponded waters could saturate the fill and reduce the factor of safety of built-up sections of the road.

3. Where culverts drain onto embankments the embankment area should be protected against erosion. Drains should be lined to prevent undercutting of slopes and surface, peripheral interceptor ditches should be constructed above the proposed road to intercept run-off from spurs and ridges.

4. Because of the steep side-slopes on the Kumusi side of Oivi Hill, the alignment in this section should be in cut wherever possible.

5. Wherever practicable, all top soil (mostly red clay) should be removed from side slopes above the road to prevent shallow slides. Where

the road is to be on fill on a side slope, all overburden should be removed from the slope prior to placement of the fill.

6. If deep box cuts are made, the formation width should be increased so that if slope failure should occur, the road will not be completely blocked or can be easily cleared. This will probably apply to section T3203 to T3512.

7. Batter slopes should be no greater than 45 degrees in completely weathered bedrock and cuts greater than 40 to 50 feet deep should be benched; appropriate laboratory soil tests should be conducted to obtain information for designing deep cuts, especially in the section T2709 to T3002.

8. Where large cuts and fills are proposed, the exposed slopes should be topdressed and/or seeded to provide a protective vegetation cover.

9. At chainage 11 mile 4125 feet, the road should by-pass the unstabilized slide and should be sited on fill in the swampy area. The depth of silty material in the swamp should be determined.

10. As the alignment from Hansen's rubber factory to the Kokoda airstrip, pegged by P.W.D., is over unstable ground, a realignment following the existing road is recommended.

11. Deposits on the Upper Mambare River, north of Komoto village, should be investigated as a possible borrow area for pavement material.

12. If crushing is proposed, a trial sample of the material should be crushed first.

13. Suitable laboratory soil tests should be carried out on the tuff, on the red clay of Oivi Hill, and on the soils of the Kokoda escarpment. If any of these prove to be suitable for use as a binder, volumes available should be ascertained by augering.

REFERENCES

Davies, H.L., 1959a - A note on the geology of the Aewo-Sirorata area. Bur. Miner. Resour. Aust. Rec. 1959/31 (Unpubl.).

Davies, H.L., 1959b - The geology of the Ajura Kujara Range. Bur. Miner. Resour. Aust. Rec. 1959/32, (Unpubl.).

Grim, R.E., 1962 - APPLIED CLAY MINERALOGY. McGraw-Hill; New York.

APPENDIX 1

GEOLOGICAL TRAVERSE NOTES, OIVI HILL TO KOMOTO VILLAGE

T638.8 to T1134	Side cut in low spur; cut 3 to 6 ft high in red-brown, clayey tuff: stable.
T1134 to T1350	Alignment truncates three gently sloping spurs covered with red, moderately plastic clay.
T1350 to T1433	Box cut; highly weathered bedrock may occur in base of cut. 6 to 8 ft cut has minor slips. Run-off water incised 1 ft into drainage channel.
T1433 to T1920	Alignment truncates small spurs forming 6 to 10 ft cuts in orange-red clay. Minor slips at spur tips; scar slope 55°.
At T1700	Slip of overburden at spur tip, 10 ft high (h) by 20 ft wide (w) by 3 to 4 ft deep (d).
At T1801	Small slip of overburden, scar slope is 70° in completely weathered norite and serpentinite. Random white clay seams at 1-inch intervals; one set, $023^{\circ}/60^{\circ}$NW, dips into face; another, $155^{\circ}/73^{\circ}$SW, dips out of face.
At T1921	Slip of overburden, (20h x 20w x 14d) ft. Back and side walls in completely weathered bedrock containing many clay seams. Scar slope 36°.
T1920 to T2008	Side cut along low ridge; many small slips of overburden with back faces in completely weathered bedrock.
At T1976	Slide of overburden extends to top of ridge, (20h x 15w x 3-10d) ft. Side and part of back wall in completely weathered rock. Slope of slide scar: in weathered rock, 42°; in red, structureless clay, 36°.
T2008 to T3203	Formation truncates short spurs; many slides, small at spur tips, e.g. at T2038, T2050, and T2104; larger at root of spurs, (i.e., junction between spur and ridge).
At T2114	Batter of fill, 47° and stable.
T2188 to T2240	Slide of overburden at end of truncated spur, (14h x 50w x 4d) ft. Back face in completely weathered bedrock.
At T2290	Shallow slide of overburden. Back face stands 52° in completely weathered bedrock which is criss-crossed by white clay seams. A series of clean fractures strike and dip $000^{\circ}/60^{\circ}$E.
At T2543	Slide of overburden, (20-25h x 50W x 10-15d) feet, between two close, small, truncated spurs. Back face in completely weathered rock with 35° slope.

At T2620	Slide of overburden, (15h x 25w x 4-5d) ft, reaches to top of spur.
At T2709	Recent slide of overburden, (15-20h x 35w x 5d) ft, over weathered, sheared and fragmented serpentinite (?), now a chloritic schist with slightly contorted foliation dipping out of face at $015^\circ/28^\circ$W. A prominent fracture set has orientation, $080^\circ/65^\circ$N. Seepage occurs along foliation planes. Back face stands at 60°.
At T2745	Recent slide, (about 100h x 50-60w x 30d) ft, occurs above old, stabilized slide at the root of two spurs. Moderate to highly weathered norite (?) and sheared, bleached serpentinite occur at formation level. A strong foliation strikes and dips $075^\circ/47^\circ$N. The rocks are moderately strong to strong and will require some blasting. The high slope above the road is unstable and will require stripping of overburden and benching.
At T2800	Two slides of overburden, (25h x 30w x 5d) ft, on either side of spur tip. Back face in completely weathered bedrock containing many ramifying, white clay seams.
At T2880	Three shallow slides of overburden at spur tip. Back faces stand at 45° and are in completely weathered norite underlain by a fine-grained, schist-like rock. Water running down these faces has cut runnels up to 1 ft deep.
At T3002	A large, shallow slide of overburden at the root of the spur, extending to top of ridge. Overall slope of the completely weathered bedrock back face is 38°.
At T3113	Large slide at root of spur, extends to top of ridge. Back face in red clay with slope of 32°; some seepage out of slide material; side slopes in completely weathered norite. Toe of slide was probably excavated during construction.
T3203 to T3512	Box cut through spur of completely to highly weathered norite; no blasting expected. Possible failure planes will dip out of up-hill face at shallow angle, therefore up-hill side of cut may have to be benched, also recommended that width of cut be over-designed.
T3512 to T3670	Side cut along ridge of red clay underlain by completely weathered norite. Fracture planes partially control some small block slides. Cut may be unstable.
T3670 to T3976	Shallow box cut through spur of completely weathered norite overlain by red clay. Prominent fracture, oriented at $105^\circ/33^\circ$S, with seeping water; may be potential failure surface in up-hill side of cut. Red clay is very plastic and may be possible source for binder material, will need soil tests.

T3976 to T4226	Proposed alignment passes along spur of completely weathered norite, then crosses stream; latter requires box culvert.
T4226 to T4453	Shallow box cut to top of hill through spur of red clay; latter is possible binder material.
T4453 to 11 m 725	Top of hill; flat section over cover of weathered tuff.
11m 725 to 11m 1100	Gentle, undulating down grade with minor cut and fill in red clay, (probably weathered tuff). Shallow box cut at 11m. 1100 ft.
11m 1100-11 m 3700	Gently undulating section over a shallow cover of weathered tuff.
11 m 3700-11m 4125	Alignment truncates low spurs of red clay overlying completely weathered bedrock.
11m 4125-11m 4400	Side cut along base of ridge with red clay and serpentinite fragments overlying sheared serpentinite; swampy ground on the south side.
At 11m 4125	At root of spur, slide of overburden along sheared-serpentinite/clay interface, lubricated by seeping water. Slide, (50h x 30-40w x 15d) ft, very unstable. Alignment should by-pass slide and be over fill in flat swampy section below slide; depth of black silt will have to be determined.
11m 4475-11m 4700	Small spur of sticky, orange-brown clay passes into low side slope.
11m 4700-12m 675	Gently undulating section over shallow cover of weathered tuff. Bridge at 11m 4907 ft.
12m 675-12m 1770	Side cut along ridge in red-brown, cohesive, vitreous clay which breaks up into small, hard lumps when dry. 8 ft vertical cuts have minor slips. Possible source of binder material.
12m 1770-13m 4650	Gently undulating river terrace crossed by occasional low spurs and overlain by weathered tuff. Some sections of poorly drained, silty material. Streams, incised up to 6 ft in tuff have stable, vertical banks.
12m 2430-12m 2550	Small box cut through spur of brown, clayey tuff. 8 ft vertical banks are completely stable.
13m 1115-13m 1180	Waterlogged area of black, silty material. Determine depth of silt.

KUMUSI RIVER — KOKODA ROAD

PLATE 1

GEOLOGICAL MAP
SHOWING LOCATION OF PRESENT AND PROPOSED ALIGNMENTS

BASE MAP COMPILED FROM WILLING AND PARTNERS SHEET No 1. GEOLOGY BASED ON FIELD WORK BY H.L. DAVIES (1959 a & b). & J.C. BRAYBROOKE.