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GEOLOGICAL INVESTIGATION OF SLOPE STABILITY OF THE KASSAM PASS ROAD , NEW GUINEA, 1965 .

by

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SUMMARY

At the request of the Director, Commonwealth Department of Works, Port Moresby, a geological investigation was carried out in June, 1965 to determine the causes of landslides in the Kassam Pass area of the Highlands Highway, New Guinea and recommend remedial measures.

Rock exposed in the area consists of interbedded limestone and siltstone, indurated sandstone and siltstone and, more rarely, volcanic and intrusive igneous rocks. Rock strengths are generally low and the depth of weathering is considerable.

The major cause of the landslides was the loss of slope stability due to the removal of support as a result of roadway excavation, aggravated by (1) excavation of very steep batters in deeply weathered and unsound material, (2) existing steep slopes, (3) the presence of outward dipping strata in the underlying bedrock and (4) high rainfall and inadequate provision for drainage.

Minor realignment of the roadway and increased drainage provision have been recommended. A note on the result of a brief inspection of the Arona Valley section of the Highway is included.

INTRODUCTION

One of the most recent and important developments in the Territory of New Guinea has been the reconstruction of the Highlands Highway which connects Lae with Kainantu, Goroka and Mount Hagen (Plate 1.).

Kassam Pass, which opens into the Arona Basin of the Upper Ramu River valley, was selected as the best available route from the Markham River valley to the elevated plains of the Highland districts.

Construction of the six-mile section of roadway from Kassam camp in the Markham Valley at 2200 feet above sea level to the top of the Pass at 4,900 feet called for the excavation of about 800,000 cubic yards of earth and rock material (Plate 3). Work commenced in January, 1964 and the road was officially opened on November 19th, 1965.

During the wet season between November 1964 and March 1965 several landslides occurred at various localities along the Highway which not only interrupted construction, but also disrupted road communication between Lae and Mount Hagen.

At the request of the Director, Commonwealth Department of Works, Port Moresby, a geological inspection of the Kassam Pass area was carried out at the end of June 1965. The purpose of the inspection, on which this report is based, was to determine the causes of the landslides and seek possible methods of reducing the danger of further slides.

At the completion of the investigation a brief inspection was made of the Arona Valley section of the Highlands Highway.

GEOLOGY

REGIONAL GEOLOGY

The Markham Valley forms the eastern part of the Ramu - Markham graben It is flanked to the north by the Finisterre and Saruwaged Ranges and to the south by the south-east portion of the Bismarck Range and the Kratke Range. The Bismarck and Kratke Ranges form the major part of the Eastern and Western Highlands districts of New Guinea.

The Kassam Pass area is situated within the Miocene - Pliocene sedimentary sequence which forms the northern extension of the structural unit of New Guinea known as the Aure Trough. Upper Tertiary sediments - shale, siltstone, sandstone, conglomerate and limestone - extend to the west and south of the area into Papua where they have been dissected by the drainage systems of the Purari and Tauri rivers (Mackay, 1955).

To the north-west the Aure Trough is bordered by the Paleozoic metamorphic complex of the south-eastern part of the Bismarck Range. To the south-east lie the Mesozoic Kaindi Metamorphics and Morobe batholith which crop out in the Kratke and Herzog Ranges south of the lower reaches of the Markham Valley.

KASSAM PASS AREA

Stratigraphy: Exposures along Kassam Pass roadway (Plate 2) chiefly consist of closely-bedded sedimentary rocks - limestone, sandstone and siltstone - intruded in some areas by feldspar porphyry and granodiorite. Near the top of the Pass, interbedded volcanic rocks occur. Some of the igneous rocks have been completely weathered to considerable depths.

Interbedded limestone and siltstone is exposed along the lower section of the road between the 18-mile peg and about 19 mi. (miles) + 3000 (feet); limestone is also exposed on the U-bend between 20 mi. + 3100 and 20 mi. + 3944.

Beyond 19 mi. + 3000 and up to about 20 mi. + 5000 the limestone is increasingly, but nowhere entirely, replaced by beds of coarse-grained, brownish sandstone and medium-grained indurated sandstone. The first part of this section is extensively intruded by feldspar porphyry. Basalt overlies the sedimentary rocks beyond 20 mi. + 5000 as far as 21 mi. + 4550 except between 21 mi. + 2250 and 21 mi. + 3600 where a large body of moderately weathered granodiorite is exposed. Sedimentary rocks overlie the basalt beyond 21 mi. + 4550. Indurated sandstone with small interbeds of coarse-grained, brownish sandstone occurs from 21 mi. + 4550 but is overlain, apparently conformably, beyond about 22 mi. + 760 by soft, weathered, medium to coarse-grained arkose.

Near the Pass the arkose is overlain by a volcanic rock, possibly trachyte or rhyolite, which has been almost completely decomposed by weathering to considerable depths: not even moderately fresh exposures of this volcanic were located. The weathered remains show a pronounced flow structure formed by phenocrysts of mafic minerals set in a fine-grained matrix of sub-parallel feldspar crystals.

Structure: The sedimentary rocks, apart from massive arkose near the top of the Pass, are closely bedded; most of the beds are 1-6 inches thick. Some of the limestone is more massive, but banding is well-developed.

Along the first 1¼ miles of road (from 18 mi.) the strike is slightly west of north; every where else the dominant strike of all strata is east-north-east with dips to the southeast. Minor variations were recorded but most of them, particularly in the limestone, are the result of minor warping within the overall fold pattern.

ENGINEERING GEOLOGY

When freshly excavated the interbedded limestone and siltstone, and also the closely-bedded indurated sandstone near 22 mi., are quite hard and sound, but after exposure readily disintegrate to form a scree which consists of small, augular fragments and sand-size particles. Soil cover is deep, up to 30 feet thick in many places, and there is a sharply defined interface between overburden and bedrock which is roughly parallel to the surface topography. With removal of support and entry of water into the overburden and along the interface, the soil and scree tend to slide away over bedrock, expecially where the dip of rock strata is nearly parallel to the interface.

The indurated sandstones beyond 20 mi. + 2500 are very hard and, unlike the sedimentary rocks described in the preceeding paragraph, are not susceptible to weathering after exposure. Soil cover is generally thinner than elsewhere and the slopes appear to be fairly stable.

The feldspar porphyry intruding the sediments between 19 mi. + 3000 and 20 mi. + 2500 has been moderately to highly weathered: the rock can be crumbled to a powder in the hand and is easily washed out by running water. By contrast, the basalt exposed beyond 20 mi. + 5000 is very hard and unweathered, but it has a tendency to split along joints into large blocks. The granodiorite, although slightly to moderately weathered, is quite sound. The arkose which extends from 22 mi. + 760 to near the top of the Pass is deeply weathered and very soft. The material lacks cohesion, has a low strenght, has been deeply incised by running water, and samples can easily be crushed by hand. The volcanic rock at the top of the Pass has also been completely weathered; it has formed a plastic clay which turns into a quagmire when wet. When slope support is removed the clay fails, mainly along preferred faces within the mass and large quantities of clay slide down the batter. Even small embankments of this material will slump.

CONCLUSIONS

Landslides will continue to occur along the Kassam Pass road for some time, but in decreasing number and size as the present unstable slopes approach stability. Although the road will be blocked on occasion during the next two or three wet seasons, there are few instances where the stability of the road will be endangered.

The principal cause of the landslides has been the removal of support as a result of roadway excavation. Other factors which have combined to produce the landslides are:-

1. Existing steep slopes.
2. Excavation in earth and deeply weathered, unsound rock material.
3. Excavation of very steep batters - slopes generally have a grade of 1:1.
4. Unfavourably inclined strata i.e. bedding inclined approximately parallel to the slope of the soil profile.
5. Excavation across previous landslides creating unstable conditions which have re-activated old slips.
6. Heavy rainfall in the wet season.

Treating the major landslide areas individually, slips L5, L6 and L21 (Plate 4) can be classified as previous landslide and scree slope areas which have been re-activated during road excavation. None is serious although a fair quantity of scree is likely to come down L21 in the future.

In areas L7, L18, L19 and L20 landslides have exposed bedrock on the lower two-thirds of the batter and left an overhang of soil and scree on the upper one-third. The causes are typical of the entire Kassam Pass area - removal of support, aggravated by the cutting of very steep batters, followed by heavy rainfall and consequent sliding of the weakened, unsupported overburden over bedrock. The process has been aided at L9, L19 and L20 by strata inclined almost parallel to the natural slope of the hillside and soil profile.

The road between 22 mi. + 969 and 22 mi. + 1500 has been constructed in the very weak, soft, weathered arkese and this section, together with slide areas L2, L3, and L4, will be unstable in wet weather. Similarly, the road between 20 mi. + 1900 and 20 mi. + 2260 has been constructed on overburden, which is slowly being undermined by a slump in area L8, and will also be unstable in wet weather.

Between 19 mi. + 3000 and 20 Mi. + 1900 four successive levels of highway are stacked one on top of the other, each separated by a steep, narrow batter with average slopes of 1:1. The batters have been formed in weathered sedimentary rock and intrusive porphyry, and show considerable signs of landslide activity which, if allowed to continue, will completely destory the stability of the road at each level. Further deterioration will primarily be caused by water entering the rock behind the steeply battered, sidecuts resulting in an increase in mass density and the sharp reduction of what little cohesion and strength the overburden and rock possess. Tests to gauge the degree of saturation of the rock behind the side cuts are recommended below.

RECOMMENDATIONS

1. In most of the landslide areas - L1, L5, L6, L7, L9, L18, L19, L20 and L21 - there appears to be no practical way of preventing further slide action. In fact, it is considered that in these areas it would be best to allow the slides to take place. Once the overhanging sections have collapsed the slopes will have become as stable as can be expected. Although road will be blocked from time to time it is not though that there will be any damage to the stability of the road.

2. Realignment is recommended for the sections from 20 mi. + 1900 to 20 mi. + 2260 and from 22 mi. + 969 to 22 mi. + 1500. In both cases realignment farther into the hillside will locate the road on moderately freash bedrock away from the present unstable slide-prone areas. Some protection of the newly exposed bedrock against weathering and erosion should be considered.

3. Extensive drainage control is recommended between 19 mi. + 3000 and 20 mi. + 1900 and also in both the sections mentioned in paragraph 2. above. As already pointed out further deterioration in all these areas will primarily be caused by water entering the batters. As a preventive measure the water must be controlled by the provision of adequate drains on both the inside (uphill side) and outside of the road. Particular care should be taken to provide adequate drainage outlets which will not allow haphasard release of the collected water back into the wet areas, as at 20 mi. + 603 (slide area L13). Outlet drains should be directed towards natural waterways and the run-off contained within these limits.

4. In addition to the surface drainage recommended above, the degree of saturation of the rock behind the side cuts between 19 mi. + 3000 and 20 mi. + 1900 should be checked. It is suggested that a number of near-horizontal jackhammer holes be drilled near the base of side cuts in critical areas. The holes should be flushed out and if necessary surged using - compressed air and water, to remove caked clay in the hole, and the rate of flow from each hole systimatically recorded under all climatic conditions. As a general rule it is considered that if a sustained flow of water is obtained from a hole the adjoining ground is not adequately drained. If water emerges under pressure an adequate, permanent, system of drainage, using near-horizontal holes, should be installed as soon as possible.

5. Any surface drainage system in the realignment area between 22 mi. + 969 and 22 mi. + 1500 should be carried at least as far back as 22 mi. to keep water out of the steep narrow batter and slide area L4.

6. The recommendation for adequate drainage control applies in principle for the whole of the Kassam Pass area. Most of the landslides have taken place during the wet season, which underlines the part played by water in creating the landslides; provision of adequate drainage is the simplest and most effective way of minimising its effect.

ARONA VALLEY ROADWAY

The Arona Valley section of the Highlands Highway passes across the Pleistocene lake sediments preserved in the Arona Basin. The sediments consist of fine sand, silty sand, silt and clay. Bedding is predominatly horizontal.

The sediments are extremely weak and lack cohesion; they are consequently extremely prone to slumping and soil creep action. Excavation appears to initiate almost immediate failure followed by slumping, particularly when the ground is wet.

Control of the slump areas is likely to be both difficult and costly, particularly as the road has been routed over many existing slump and creep areas.

Methods which will prove successful in combating ground movement are difficult to contrive. However, it was noted during the inspection that the movement is a shallow-seated gravity slump effective to a maximum depth of about 10-15 feet. Excavation for the road could be carried into the sediments below the base of the slump and then back-filled to the required level. Such an operation would help to key the roadway into firmer ground and has already been attempted with some measure of success by the Commonwealth Department of Works.

An attempt must also be made to provide adequate drainage in the Arona Valley section of road although this may prove difficult owing to the low permeability of the clays.

The areas of serious slumping appear to be restricted to several horizons of highly plastic clay within the sedimentary sequence in the valley. A preliminary investigation of soil types and shear strength would have revealed this problem and enabled a more stable road level and alignment to be chosen.

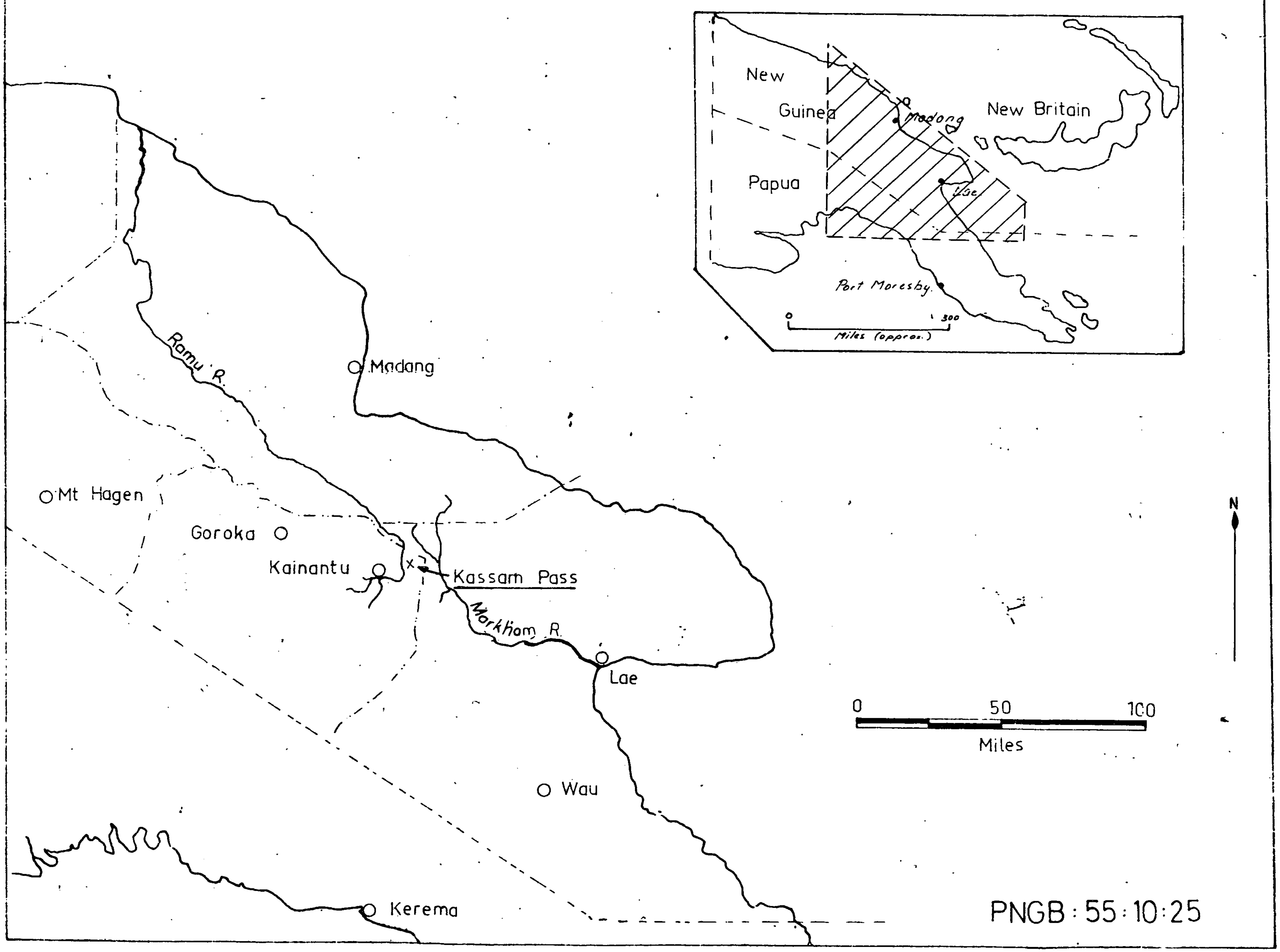
REFERENCE

Mackay, N.J., 1955 - Geological report on a reconnaisance of the Markham and Upper Ramu drainage systems, New Guinea. Bureau of Mineral Resources Australia Rec. 1955/25.

PLATE I

KASSAM PASS ROAD

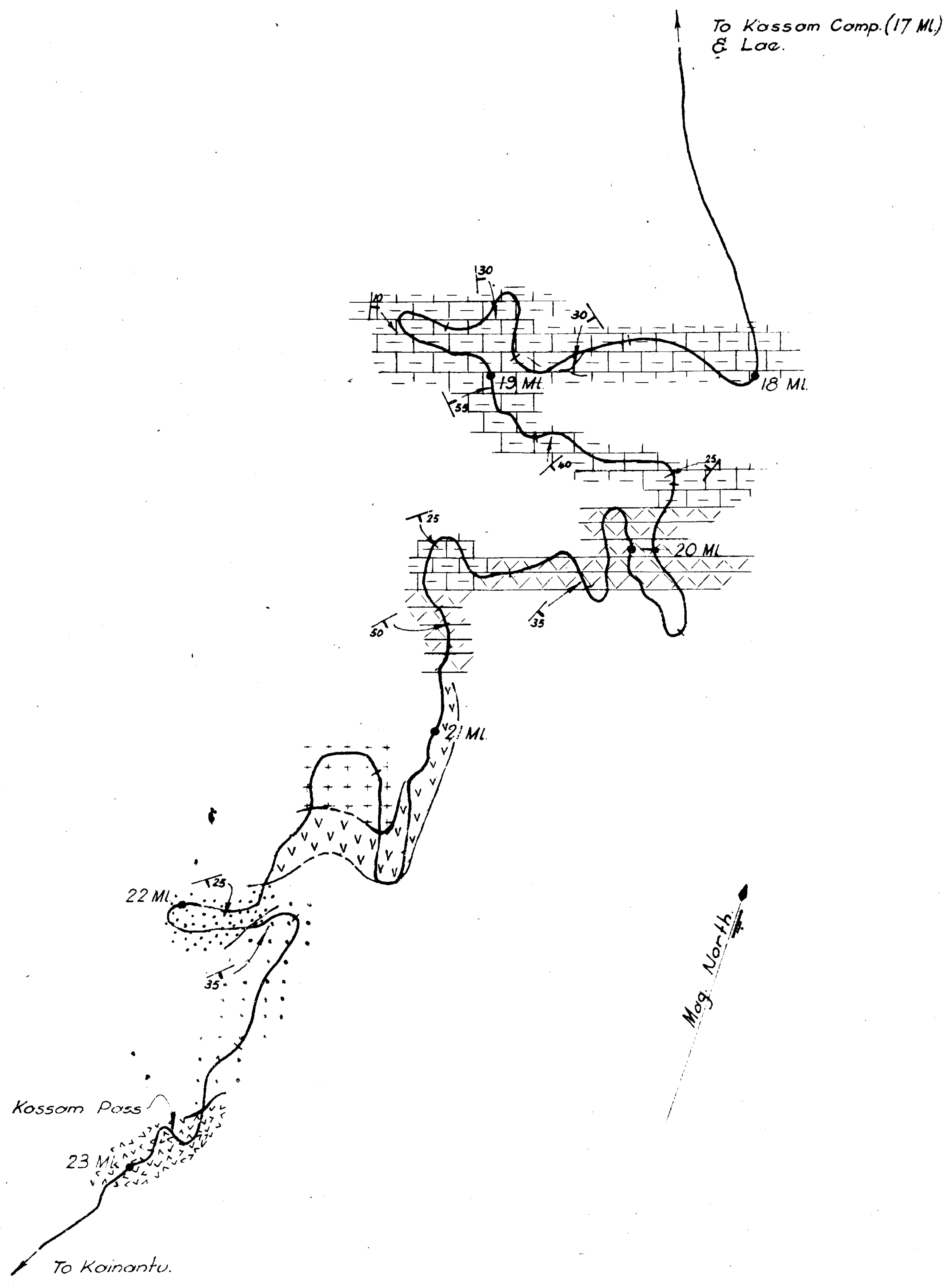
LOCALITY MAP



Geological Office, Port Moresby   *To accompany record 1966/31*   J.R.L. Read   December 1965   B55/A10/23

PLATE 2

KASSAM PASS ROAD.
GEOLOGICAL PLAN.



REFERENCE :

Trachyte

Medium grained feldspathic sandstone

Indurated sandstone

Granodiorite

Basalt

Interbedded medium grained sandstone, indurated sandstone, & limestone, intruded by feldspar porphory

Interbedded limestone & indurated siltstone

Bedding.

0 ¼ ½ ¾

Miles.

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To accompany record 1966/31

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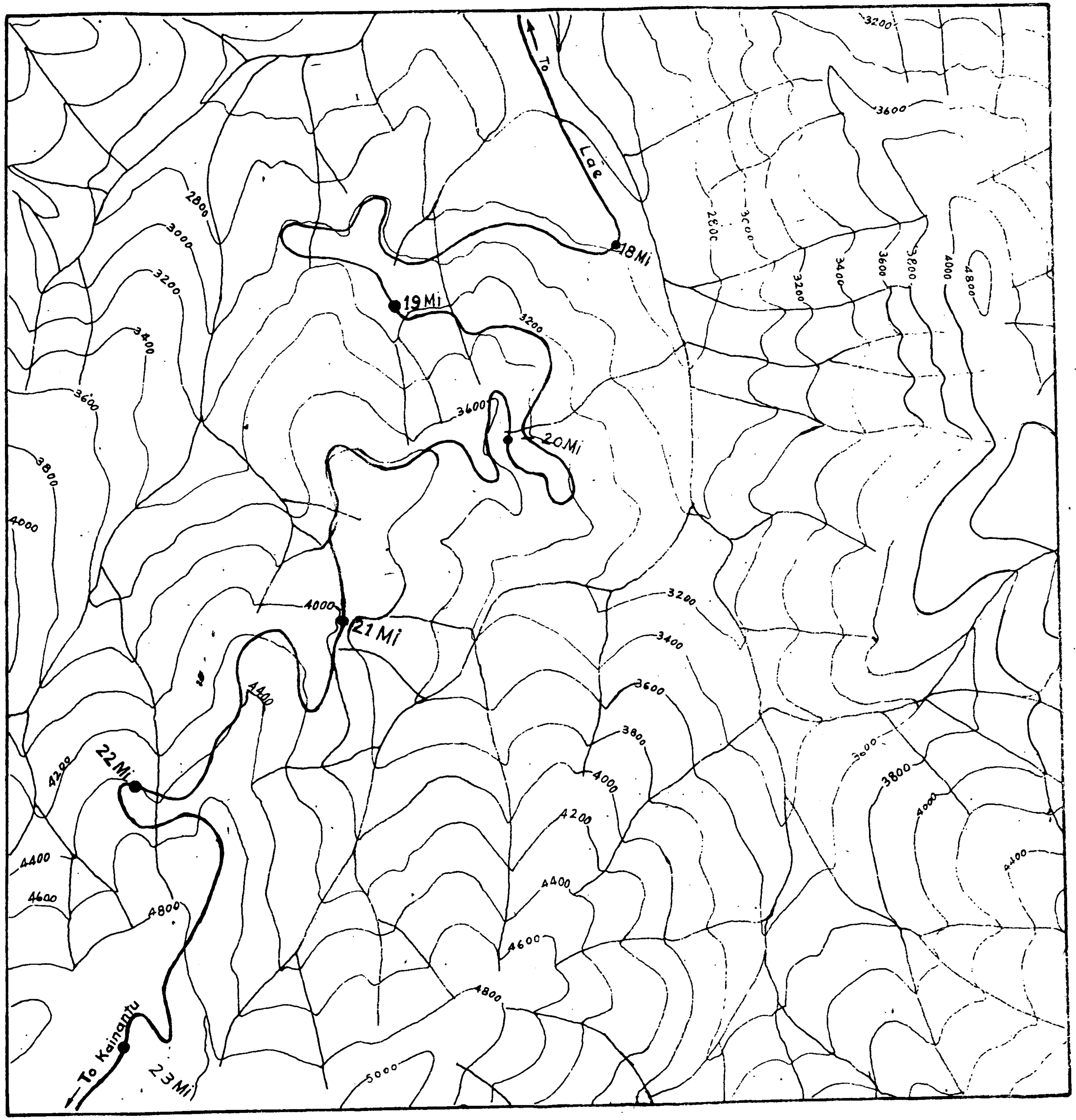
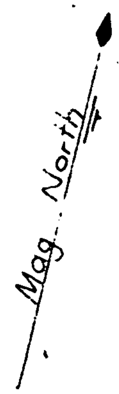
PLATE 3



KASSAM PASS ROAD.

TOPOGRAPHY

CONTOUR INTERVAL 200 feet



Based on CDW Plan PC 4411/C

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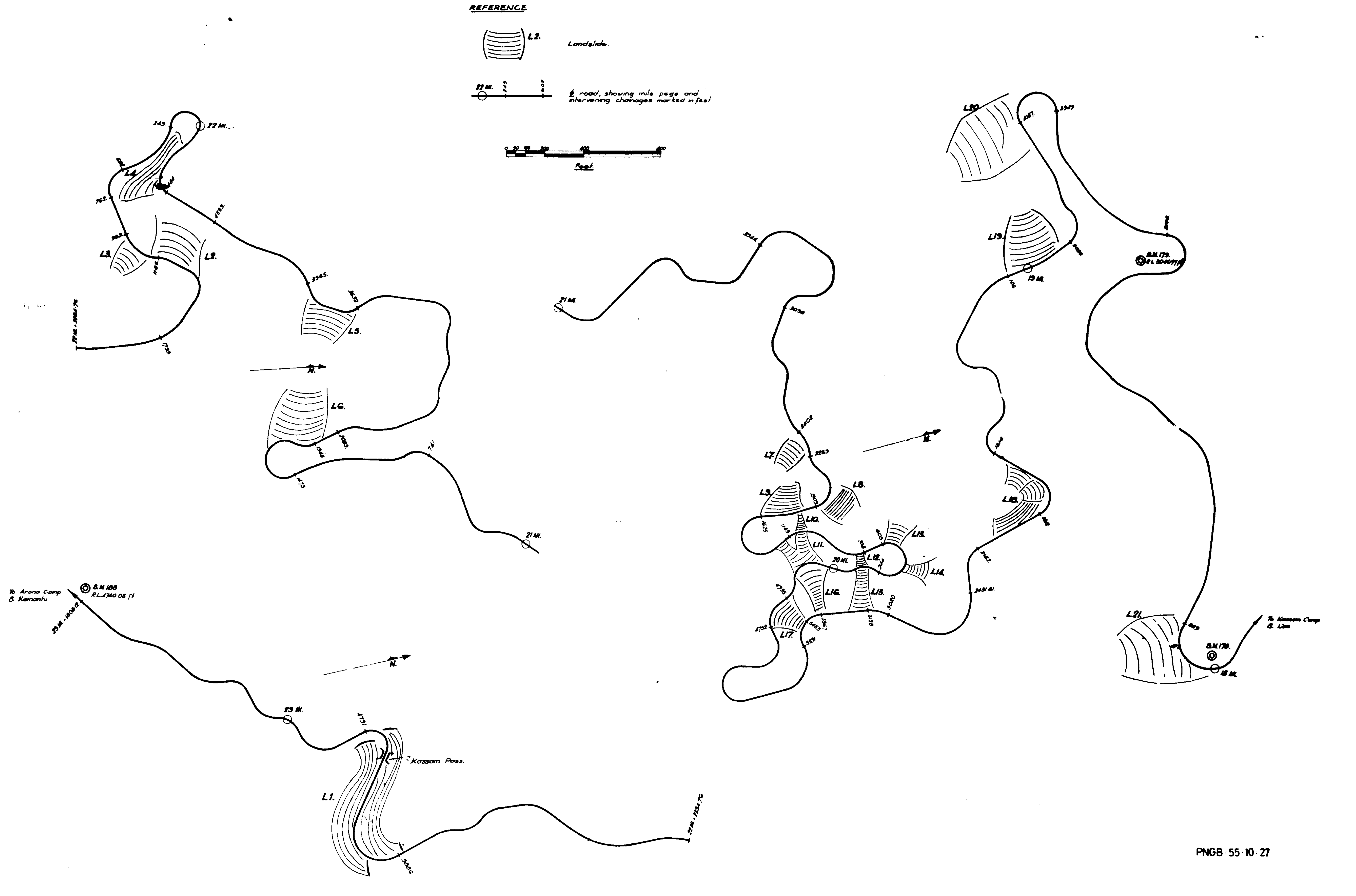
To accompany record 1966/31

— KASSAM PASS ROAD. —

PLAN SHOWING LOCATIONS OF LANDSLIDES.

PLATE 4



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