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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1974/65

MARKHAM VALLEY GRAVITY SURVEY P.N.G., 1972

by

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SUMMARY

A detailed gravity survey was done on three main traverses across the Markham River Valley, PNG, by the Engineering Geophysics Group of BMR as part of the program of evaluation of the Markham Valley's groundwater resources by the Geological Survey of Papua New Guinea. The objective of the survey was to determine the thickness of alluvium in the valley. Analysis of the results shows that the river sediments may be as much as 1000 metres thick.

1. INTRODUCTION

The Markham River in New Guinea occupies, with its tributaries, a valley some 12 km wide which extends westwards 140 km from the port of Lae to the divide between the Markham and Ramu Rivers. Water bores drilled so far have failed to reach the base of the alluvium and the maximum thickness of the river deposits is expected to be greater than 120 metres. The nature of the bedrock is also uncertain.

The geological Survey, a part of the Department of Lands, Surveys and Mines in PNG is currently evaluating the groundwater resources of the Markham valley, and requested the Bureau of Mineral Resources (BMR) to carry out a gravity survey along three main traverses across the Markham valley to determine whether the gravity method could define the base of the alluvium in the valley. The field work was conducted in July 1972 by a party from the Engineering Geophysics Group, consisting of G.R. Pettifer (geophysicist) and W.J.C. Pearson (draftsman) from the BMR, and M. Zorroman (survey assistant and interpreter) and two field hands from the Department of Lands, Surveys and Mines. The assistance of G. Jacobson (Geologist) and also the staff of the Department of Lands, Survey and Mines survey branch in Lae which surveyed the traverses is gratefully acknowledged.

2. GEOLOGY OF THE MARKHAM RIVER VALLEY

The geology of the Markham Valley has been described by Best (1964), Jacobson (1971), and Grainger (1970 and in prep.), and is summarized here. The geology and location of traverses are shown in Plate 1.

The Markham River flows eastward from its headwaters on the Ramu/Markham divide at about 360 metres above sea level for 140 km along the southern margin of the Markham valley to the port of Lae. The width of the valley is 5 km wide at its headwaters, 20 km at its widest point near the junction of the Leron and Markham Rivers, and generally averages 12 km. The Markham valley, which is bordered by the Saruwaged and Finisterre Ranges to the north and the Owen Stanley Ranges to the south, forms part of a major tectonic rift 20 km wide extending over 300 km and incorporating the Ramu Valley to the west and a large submarine canyon in the Huon Gulf east of Lae. The canyon extends out into the Solomon Sea, where it eventually joins the New Britain trench.

The rift is associated with a marked change in bedrock geology between the north and south of the Markham valley. Cross-section A-B (Plate 1) shows the schematic geology to the north. The bedrock to the immediate north of the valley is uniform in character along the valley and consists of moderately folded and faulted sandstone and conglomerate of the Pliocene Leron (Ouba) Formation dipping northwards at 20° to 40°. Underlying the Pliocene are the Lower to Middle Miocene Mena Beds which are clastic sediments. The Mena Beds may subcrop beneath the Markham River Quaternary sediments to form part of the bedrock of the valley. North of the Pliocene, the Mena Beds are upfaulted, and farther north again the Upper Oligocene to Lower Miocene Mebu Beds are upfaulted against the Mena Beds. The Mebu Beds consist of clastics and volcanics. Faulting and uplift have exposed increasingly older formations towards the central core of the Saruwaged Range. Uplift of at least 4000 metres has occurred since the Late Miocene, making the Saruwaged Range area one of the most tectonically unstable areas in New Guinea. The sediments of the Saruwaged and Finisterre Range are part of the west- to northwest-trending sedimentary trough called the Northern New Guinea Basin which from gravity evidence (St John, 1967 and 1970; this report, Section 3) contains up to 13 km of sediments. Pleistocene glaciation occurred in the ranges to the north of the Markham valley, and the valley alluvial fill has largely been derived from stream erosion of the northern ranges since the Pleistocene.

The southern margin of the Markham valley is sharply faulted; bedrock to the south consists of a complex of Miocene sedimentary rocks, Mesozoic metamorphics, and some Tertiary and Mesozoic igneous intrusives. Ends of Traverses 1 and 1A cross onto bedrock of the Mesozoic Owen Stanley Metamorphics, which consist mainly of schist and phyllite.

In the region of Traverses 2, 2A, and 3 the bedrock on the southern margin is predominantly limestone of the Middle to Upper Oligocene Omaura Greywacke. Tertiary granitic intrusives occur south of the valley near the junction of the Erap and Markham Rivers. The granite is bounded to the west by the Wampit Fault, which extends north across the Markham valley and along the Erap River.

Igneous intrusives of Tertiary age also occur southwest of the Umi-Markham river junction and may intrude the Omaura Greywacke south of Traverse 3.

The position of the actual boundary between the two types of bedrock which occur north and south of the valley is not known definitely, but it is considered that the faulted southern margin forms the boundary. In this case the bedrock beneath the Quaternary alluvial fill of the valley is predominantly Pliocene Leron Formation and possibly Miocene Mena Beds all dipping at 20° to 40° to the north. In one place the Markham River flows across the Owen Stanley Metamorphics leaving an inlier of metamorphics north of the river at Pyramid Hill near Traverse 1A (Plate 1).

The Markham River and its tributaries exhibit spectacular examples of stream deposition morphology. Rainfall throughout the Markham Valley averages 1600 mm per year, but as most of the water percolates into the ground, the valley is comparatively dry in places and heavy reliance on water bores is necessary. Rainfall in the ranges to the north and south of the valley exceeds 2800 mm per year, and the volume of water flow down the Markham River is considerable. The Markham river bed is up to 1.5 km wide in places and except at flood time, the river consists of several braided channels. The main tributaries of the Markham River - the Umi, Maniang, Leron, Rumu and Erap Rivers - flow from the northern ranges. Uplift of the northern block has caused considerable active alluvial fan deposition in the northern part of the valley, forcing the Markham River to flow against the southern margin. These alluvial fans are up to 20 km in radius, in the case of the Leron River, and contribute an estimated 80 m thickness of piedmont alluvium to the river deposits. Flood plain alluvium occurs mainly within 20 km of Lae, in thickness up to 40 m. Over 80 boreholes have been drilled in the valley, the deepest being 80 m, but all failed to penetrate bedrock. The thickness of river sediments is expected to exceed 120 m and could be in the order of 1000 metres (Grainger, in prep.).

3. PREVIOUS GEOPHYSICS

A previous gravity survey was carried out by the University of Tasmania (St John, 1967) around Lae and the Markham valley. This survey consisted of isolated road traverses and some stations established from helicopters. The results of this survey revealed a large gravity gradient across the Markham valley fault zone, leading to a -160 mGal gravity low associated with a sedimentary trough up to 13 km deep to the north. Plate 2 shows the regional gravity field contoured from the results of the present survey and the University of Tasmania stations.

Shallow resistivity depth probing has been undertaken in the Markham valley (Wainwright, 1966) at Leron Plains, near the Erap River, and at the Umi River Bridge, and the results show the river sediments to be at least 120 m thick.

4. SURVEY METHOD

The survey was carried out using a Worden gravity meter (Serial No. 140B) which was calibrated on the Port Moresby Calibration range to give a calibration factor of 0.1019 mGal per scale division. The survey was tied to the Lae Isogal station 6791-0177 (value 978 010.79 mGal).

A Toyota Scout double-cab utility was used throughout the survey. Traverses were pegged and read simultaneously and stations were located along main roads, farm and village tracks. In places the Markham River could be crossed on foot but on Traverses 1 and 1A canoes were used to cross the river. Considerable time and effort was spent in establishing stations across the faulted southern margins of the valley. Elevations ranged from 40 to 400 m above sea level over the survey area.

Traverse station spacing varied between 0.3 and 0.5 km, but where the traverse deviated in a direction parallel to the valley, larger spacings of 1½ km were adopted. Altogether, 190 traverse stations were established. In addition C.D.W. benchmarks were located along the Highlands highway through the valley, and 22 benchmarks were occupied. The benchmark stations, previous University of Tasmania stations (St John, 1967) and Traverse 1A and 2A provided sufficient control to establish the trend of the Bouguer anomalies (Plate 2) between the main Traverses 1, 2, and 3.

Station positions were plotted on airphotos in the field, with odometer readings as a check. Station locations are considered to be accurate to ± 100 m.

The gravity results were reduced to mean sea level using a Bouguer reduction density of 2.0 g/cm^3. Bouguer anomalies were then obtained by correcting mean sea level corrected, observed values to the International Ellipsoid.

5. INTERPRETATION OF GRAVITY RESULTS

Plate 2 shows the regional gravity gradient across the Markham Valley. The detailed plans of Traverses 1 and 1A, 2 and 2A, and 3 are shown in Plates 3, 4, and 5. The present detailed gravity survey has shown that the gradient varies from 1 mGal per 150 metres south of Kaiapit on Traverse 3 (Plate 5) to 1 mGal per 500 metres around the Erap River area on Traverse 1 (Plate 3).

The large regional gravity gradients (Plate 6) mask the gravity effects of the alluvial valley. The complexity of the bedrock and the changes in bedrock type beneath the valley make it difficult to remove the regional gradient from the Bouguer anomaly values.

A second derivative technique has been used to estimate the maximum depth of the small amplitude, short wavelength anomalies superimposed on the long wavelength regional gradient. It is assumed that a density contrast of no more than 0.1 g/cm^3 exists between the Pliocene and Miocene clastic sediments of the valley bedrock and the overlying Quaternary alluvial fill, and that most of the high frequency anomalies arise from undulations in the bedrock/alluvium boundary. Estimates of maximum depth to the top of the bodies causing the short wavelength (high frequency) anomalies are then assumed to give estimates of the maximum depth of the river sediments.

The method used to estimate the maximum depth is based on formulae derived by Smith (1960). The second derivative of the observed gravity profile is calculated for each station, and the absolute value of the derivative gives a measure of 'sharpness' of small high frequency anomalies which are superimposed on the regional field. For a given density contrast, the higher the value of the second derivative the sharper the anomaly and the shallower the depth of the causative body. A maximum depth to the top of the body causing the anomaly can be calculated as outlined below.

If A_1, A_2, A_3, A_4, etc. are Bouguer anomalies at stations 1, 2, 3, 4, etc respectively along a straight traverse with station spacing d, then consider three functions D_1, D_2, D_3 defined as follows:

$$D_1 = A_3 - 2A_2 + A_1 \quad (1)$$

$$D_2 = A_4 - 3A_3 + 3A_2 - A_1 \quad (2)$$

$$D_3 = \tfrac{1}{2}(A_3 + A_1) - A_2 = \tfrac{1}{2}D_1 \quad (3)$$

It can be shown that

$$D_n \leqslant \tfrac{1}{2} G \rho_{max} \; d \; (J_n(\alpha) - J_n(\beta)) \quad (n = 1,2,3)$$

where G = gravitational constant = 6.68×10^{-8} c.g.s. units

ρ max = maximum density contrast assumed (g/cm^3)

$\alpha = h/d; \beta = \ell/d$

h = depth to top of causative body

l = depth to base of causative body

$J_n(\alpha)$, $J_n(\beta)$ are tabulated functions for n = 1, 2, 3

(Note $J_n(t) \rightarrow 0$ as $t \rightarrow \infty$ for n = 1, 2, 3)

If we assume in the extreme case that the body extends to an infinite depth (i.e. $\beta \rightarrow \infty$, $J_n(\beta \rightarrow 0)$ then the inequality reduces to

$$Jn(\alpha) \geqslant 2 \; Dn \; / G\rho_{max} d \qquad (5)$$

substituting Dn from field results, minimum values of $Jn(\alpha)$ are obtained which from published tables of $Jn(\alpha)$ give maximum values of α (i.e. α_{max}).

Using the relation

$$h \leqslant \alpha_{max} \; d \qquad (6)$$

and the three values (n = 1,2,3) of α_{max}, three separate estimates of maximum depth to the top of the body causing the anomaly can be obtained. The three separate cases correspond to three different geological situations and in each case an extremal body exists which satisfies the equality in equation (4). The shape of these extremal bodies suggest that the best estimates will be given by the case n = 1 for a traverse across a dyke, by the case n = 2 for a traverse across the vertical face of a step-like structure and by the case n = 3 for a survey of a roughly circular boss.

For the present survey, the method above was applied to the Bouguer anomalies at each place where the gravity stations were situated in a straight line and the spacing was equal. Out of 190 traverse stations, 92 depth estimates were made. Plate 7 shows a series of plots of maximum depth ranges (corresponding to the range of depths calculated for the three cases n = 1, 2, 3) versus station number for the five traverses 1, 1A, 2, 2A, and 3 and is intended to show a schematic cross-section of the valley in the area of each traverse and the likely maximum depths of shallow-source anomalies. The anomalies that give a narrow range of maximum depth estimates are considered to be genuine anomalies whereas the anomalies that show a large scatter in the range of maximum depth are considered to be the effect of superposition of anomalies with deep and shallow sources and therefore not associated with one density contrast interface.

The Traverse 1 results indicate a belt of anomalies with maximum depths in the range 600-1000 metres whereas near Pyramid Hill on Traverse 1A, anomalies appear to arise from shallower than 500 metres and probably shallower than the depth range 100-300 metres. Moreover, on the southern end of Traverse 1 at station 7210/1039 a single anomaly of maximum depth 200 metres is traversed. The gravity thus suggests a shallowing of bedrock around Pyramid Hill and possibly to the west, south of Chivasing village. Bedrock across the valley in the area of Traverse 1 may be as deep as 1000 metres.

Traverse 2 crosses the Leron Plains, the widest part of the Markham valley. In the plot of the Traverse 2 results a belt of anomalies originating from depths less than the range 400-800 metres is evident. Between stations 7210/2030 and 7210/2035 a consistent belt of anomalies from a very shallow source (less than 100 metres) is present. These anomalies may arise from coarse boulder gravels of the alluvial outwash fan of the Leron River. Resistivity results (Wainwright, 1966) have indicated up to 80 metres of coarse gravel in the region of these gravity stations. Traverse 2A results show a large scatter of maximum depths with bias toward a band of anomalies with maximum depths ranging from 800-1600 metres. The plots of Traverses 2 and 2A also suggest that around station 7210/2010 near the northern margin of the valley the anomalies with shallow sources have maximum depths in the range 300-700 metres, and that farther south around station 7210/2040 to 7210/2055 (i.e. near the intersection of Traverses 2 and 2A) the maximum depths are more in the range 500-1000 metres. This fact could be evidence for a thickening of the Markham valley sediments towards the southern margin of the valley in the Leron Plains area.

The Traverse 3 maximum depth plots show less scatter, with all but two anomalies originating from depths of less than 1000 metres. There is a bias toward anomalies with maximum depths in the range 300-600 metres.

Certain limitations must be placed on the depth estimates made in this report. The assumption of 0.1 g/cm^3 as a maximum density contrast between Tertiary bedrock and Quaternary fluvial sediments has been made in the absence of any reliable density data. St John (1970) estimates a density contrast of 0.05 g/cm^3. If the density is halved in equation (5), Jn(α) doubles and for the ranges of Jn(α) encountered, if Jn(α) is doubled, the maximum depths from the published tables (Smith, 1960) decreases by approximately one-third. Then the maximum depth ranges calculated in this report using 0.1 g/cm^3 are approximately

1½ times as great as the maximum depths using 0.05 g/cm^3 as a density contrast. In this sense, as 0.1 g/cm^3 is probably an over-estimate of the true density contrast then the maximum depths calculated are probably over-estimates. It is stressed that all values quoted for depth are extremal. In one area, near Pyramid Hill, on Traverse 1A the bedrock is Mesozoic metamorphic rock and probably has a density contrast higher than 0.1 g/cm^3 with the overlying alluvium. In this area the true depth may be larger than the maximum depths quoted.

6. CONCLUSIONS AND RECOMMENDATIONS

Estimates of maximum depth suggest that in the region south of Kaiapit the maximum depth of the river sediments is in the range 300-600 metres. Farther downstream in the Leron Plains area, the gravity results show maximum depths to bedrock in the range 300-700 metres in the northern margin of the valley, with indications of deepening on the southern Lerons plains to 500-1000 metres. Shallow anomalies (depth less than 100 metres) in the central Leron Plains may arise from coarse boulder gravels from the Leron River alluvial fan. Traverse 1 gravity results suggest that in the region west of the Erap River the river sediments may be as thick as 600-1000 metres. There are also indications of shallower bedrock around Pyramid Hill and south of Chivasing village, but the interpretation is complicated by the possible presence of Mesozoic metamorphic bedrock.

The results suggest that the valley bedrock may be up to 1000 metres deep, much deeper than present economic recovery depths for bore water. It is recommended that one or more deep seismic probes be carried out to verify the thickness of the valley fill and that further investigation then be confined to deep or shallow resistivity surveying in specific areas as outlined by future objectives of groundwater resource assessment in the Markham valley.

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PLATE 1

Reference

- Geological boundary
- Facies boundary
- Anticline showing plunge
- Syncline showing plunge
- Overturned anticline
- Plunge of minor anticline
- Plunge of minor syncline
- Fault (D, U indicate relative movement down, up)
- Fault showing relative horizontal movement
- Normal fault

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, folds are dotted, faults are shown by short dashes

- Strike and dip of strata
- Vertical strata
- Strike and dip of strata, facing not known
- Dip < 5°
- Dip 5 - 15°
- Dip 15 - 45°
- Dip > 45°
- Strike and dip of overturned strata, dip 5-15°
- Horizontal strata
- Trend of bedding
- Lineament

(Dip < 5° to Lineament: air-photo interpretation)

- Strike and dip of foliation
- Vertical foliation with plunge of lineation

- Macrofossil locality
- Microfossil locality
- Plant fossil locality
- Sample locality for age determination

(number refers to data in Explanatory Notes)

- Diamond drill hole
- Percussion drill hole

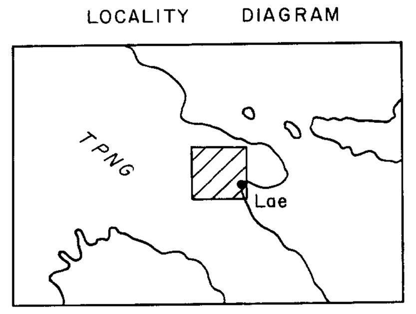
(drill holes of PNG Mines Division; number refers to authors reference)

- Minor mineral occurrence
- Unworked deposits
- Mine, not worked
- Prospect
- Alluvial workings
- Au Gold
- Cu Copper
- Pb Lead
- Py Pyrite
- Zn Zinc

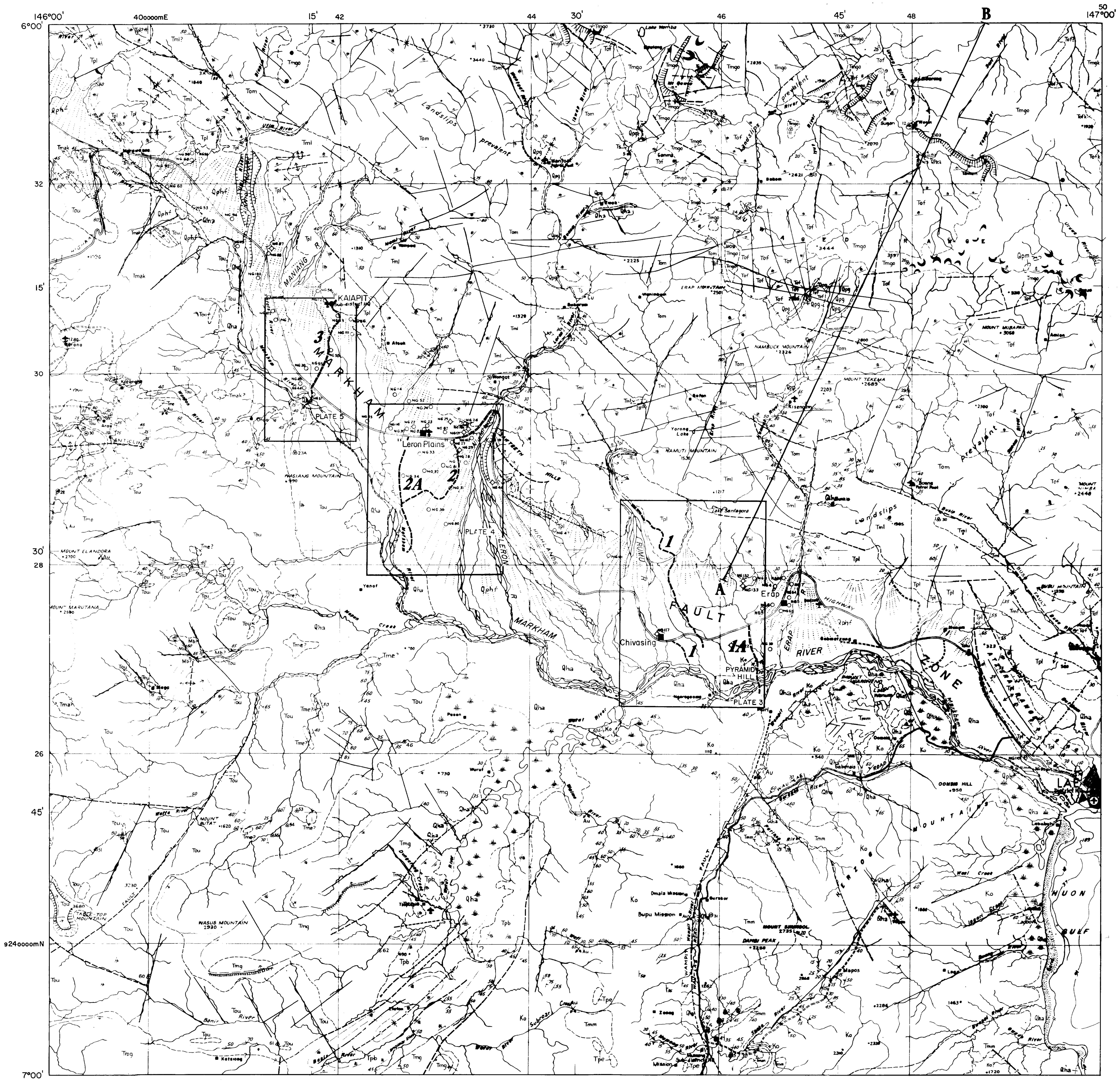
- Bore
- Abandoned bore
- N653 Reg No (Geological Survey of Papua New Guinea)
- Sink hole
- Swamp
- Bathymetric contour in metres, approximate

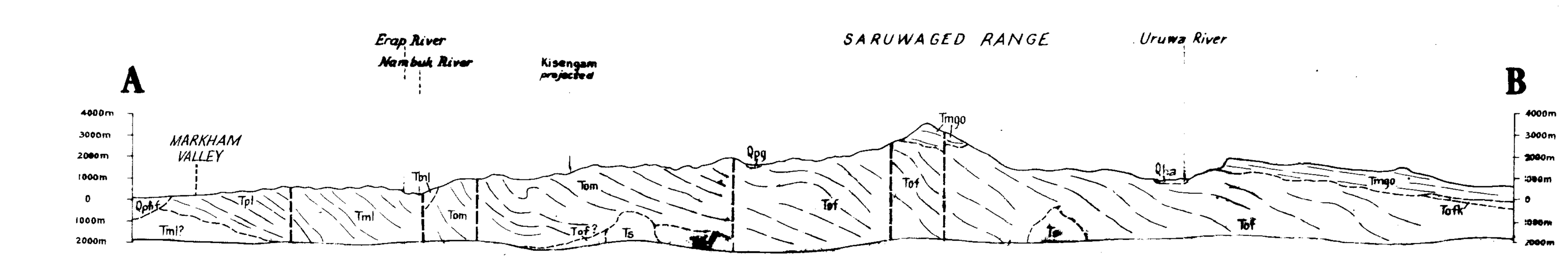
- Escarpment
- Cirque
- Alluvial fan
- Highway
- Road
- Vehicle track
- Airport
- Landing ground
- Leron Plains Homestead
- Town
- Settlement
- 689 Elevation in metres, approximate
- **Traverse line (Gravity)**

LOCALITY DIAGRAM



5 0 5 10 15 20 25 KILOMETRES





Reference

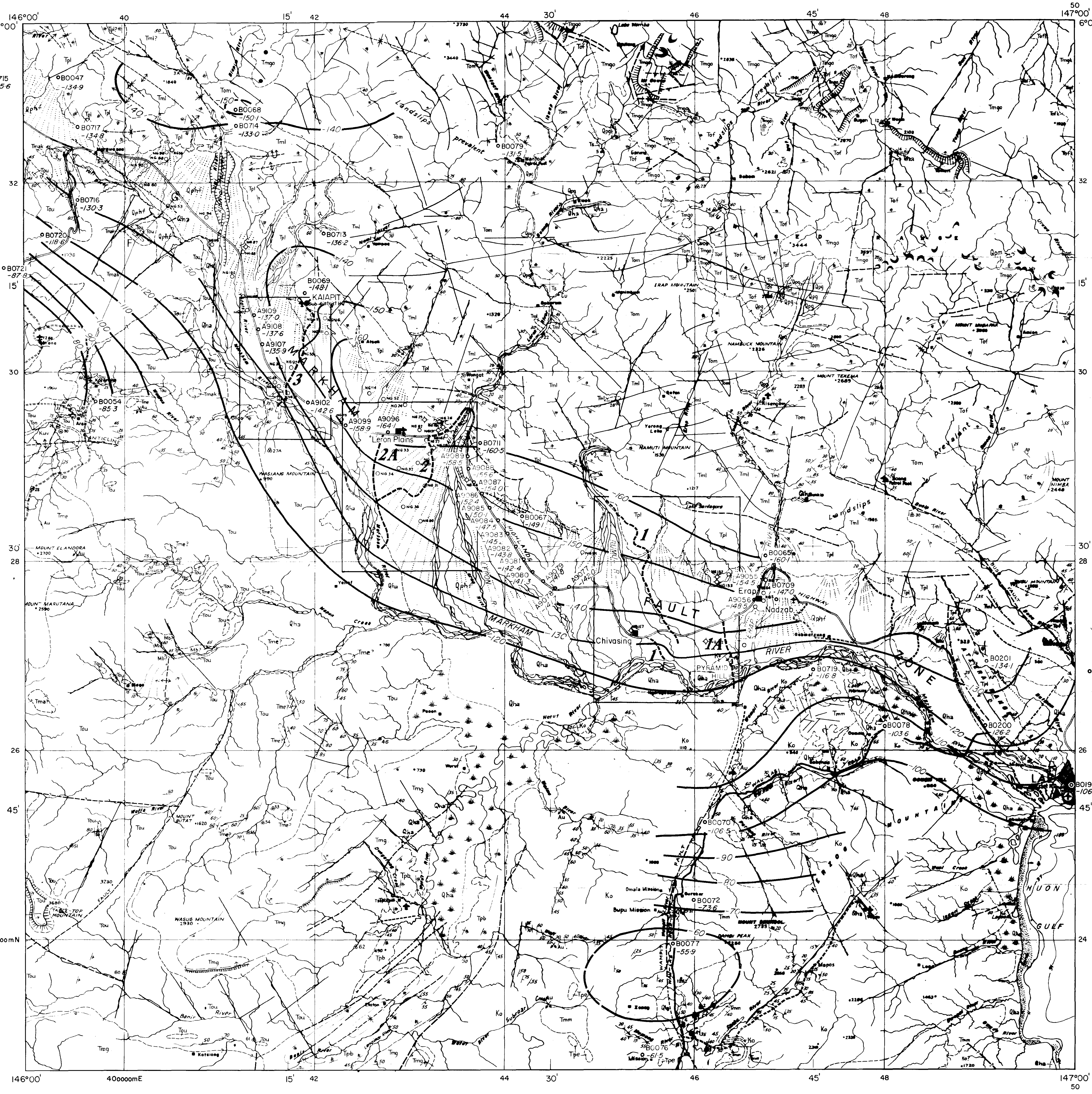
QUATERNARY	HOLOCENE		Qha	Gravel, sand, silt, clay, organic remains: alluvium and swamp deposits
QUATERNARY	HOLOCENE		Qhl	Gravel, sand, silt: lacustrine deposits
QUATERNARY	PLEISTOCENE TO HOLOCENE		Qphf	Conglomerate, gravel, sand, silt piedmont-slope deposits
QUATERNARY	PLEISTOCENE	Kainantu Beds	Qpg	Sand, gravel, silt, boulder beds: fluvioglacial deposits
QUATERNARY	PLEISTOCENE	Kainantu Beds	Qpm	Boulder beds, gravel, sand, silt, clay: moraine deposits
QUATERNARY	PLEISTOCENE	Kainantu Beds	Qpn	Conglomerate, silt, sand, clay: lacustrine deposits
QUATERNARY	PLEISTOCENE	Kainantu Beds	Qpa	Tuffaceous and calcareous sand and gravel: lacustrine deposits
QUATERNARY	PLEISTOCENE	Kainantu Beds	Qvy	Dacitic and andesitic lava, crystal tuff, agglomerate
CAINOZOIC / TERTIARY	PLIOCENE ?	Babwaf Conglomerate	Tpb	Conglomerate, sandstone, siltstone
CAINOZOIC / TERTIARY	PLIOCENE * Th	Leron Formation	Tpl	Bedded sandstone, pebbly sandstone and conglomerate, siltstone; minor lignite. Minor limestone lenses
CAINOZOIC / TERTIARY	PLIOCENE	Edie Porphyry	Tpe	Dacite and andesite porphyry
CAINOZOIC / TERTIARY	UPPER MIOCENE	Elandora Porphyry	Tme	Hornblende andesite porphyry, microdiorite. Minor serpentinite
CAINOZOIC / TERTIARY	MIDDLE MIOCENE TO UPPER MIOCENE * Tf to Tg	Kabwum Limestone Member	Tmgk	Bedded fossiliferous biomicrite
CAINOZOIC / TERTIARY	LOWER MIOCENE TO UPPER MIOCENE * upper Te to Tg	Gowop Limestone	Tmgo	Bedded and massive fossiliferous biomicrite; minor calcarenite, calcilutite
CAINOZOIC / TERTIARY	MIDDLE MIOCENE * lower Tf	Bismarck Intrusive Complex	Tmb	Granodiorite, quartz diorite; minor tonalite, serpentinite
CAINOZOIC / TERTIARY	MIDDLE MIOCENE * lower Tf	Morobe Granodiorite	Tmm	Granodiorite, adamellite; minor monzonite, diorite, pegmatite
CAINOZOIC / TERTIARY	MIDDLE MIOCENE * lower Tf	Langimar Beds	Tmg	Volcanolithic conglomerate, silty sandstone, basaltic and andesitic agglomerate. Limestone lenses
CAINOZOIC / TERTIARY	MIDDLE MIOCENE * lower Tf	Yaveufa Formation	Tma	Volcanolithic conglomerate, greywacke, tuff. Minor limestone lenses
CAINOZOIC / TERTIARY	MIDDLE MIOCENE * lower Tf	Aifunka Volcanics	Tmf	Andesitic lava, tuff, agglomerate
CAINOZOIC / TERTIARY	LOWER MIOCENE	Akuna Intrusive Complex	Tmak	Gabbro, porphyritic dolerite, diorite; minor granodiorite. Minor serpentinite
CAINOZOIC / TERTIARY	LOWER MIOCENE ?		Ts	Gabbro, andesitic porphyry, diorite
CAINOZOIC / TERTIARY	LOWER MIOCENE TO MIDDLE MIOCENE * upper Te to lower Tf	Movi Beds	Tmo	Volcanolithic and tuffaceous sandstone, shale, siltstone, conglomerate
CAINOZOIC / TERTIARY	LOWER MIOCENE TO MIDDLE MIOCENE * upper Te to lower Tf	Mena Beds	Tml	Micaceous sandstone, greywacke, lithic siltstone, conglomerate. Minor limestone lenses
CAINOZOIC / TERTIARY	LOWER MIOCENE * upper Te	Tipsit Limestone	Tmt	Fossiliferous micritic limestone, thin lignitic and calcareous shale, siltstone; fine sandstone
CAINOZOIC / TERTIARY	UPPER OLIGOCENE TO LOWER MIOCENE * Te	Mebu Beds	Tom	Greywacke, argillite, volcanolithic conglomerate; minor basaltic lava, pyroclastics, limestone lenses
CAINOZOIC / TERTIARY	UPPER OLIGOCENE * lower Te	Kwama Volcanic Member	Tofk	Basaltic lava
CAINOZOIC / TERTIARY	UPPER OLIGOCENE * lower Te	Finisterre Volcanics	Tof	Basaltic lava, peperite, pyroclastics. Minor limestone lenses
CAINOZOIC / TERTIARY	MIDDLE OLIGOCENE TO MIDDLE MIOCENE * Td to lower Tf	Aure Beds	Tm	Greywacke, siltstone, pebbly sandstone, shale. Minor limestone lenses
CAINOZOIC / TERTIARY	MIDDLE OLIGOCENE TO UPPER OLIGOCENE * Td to lower Te	Omaura Greywacke	Tou	Tuffaceous shale and siltstone, greywacke, pebbly conglomerate, lithic sandstone; minor lava, pyroclastics. Limestone
CAINOZOIC / TERTIARY	OLIGOCENE	Nasananka Conglomerate	Ton	Conglomerate, arkose, greywacke, siltstone
CAINOZOIC / TERTIARY	MIDDLE EOCENE TO LOWER OLIGOCENE * Ta3 to Tc	Chimbu Limestone	Teoc	Foraminiferal dark grey buff and white limestone, siltstone
CAINOZOIC / TERTIARY	EOCENE * Ta2 to Tb		Te	Limestone, calcareous mudstone, calcarenite, sandstone, siltstone
MESOZOIC	UPPER CRETACEOUS	Mount Victor Granodiorite	Kuv	Biotite hornblende granodiorite
MESOZOIC	LOWER CRETACEOUS		Kl	Massive to thick-bedded greywacke, thin-bedded mudstone, siltstone; minor limestone, greywacke. Section only
MESOZOIC	JURASSIC ? TO CRETACEOUS	Owen Stanley Metamorphics	Ko	Schist, slate, phyllite, metagreywacke, conglomerate, argillite. Recrystallized limestone
MESOZOIC		Goroka Formation	Mg	Schist, phyllite, schistose and carbonaceous siltstone, greywacke, quartzite; minor limestone, siltstone, andesite hornfels
MESOZOIC	LOWER JURASSIC ?	Karmantina Gneissic Granite	Mjk	Gneissic granite
MESOZOIC	PRE-JURASSIC	Bena Bena Formation	Mb	Schist, gneiss, phyllite, metagreywacke, meta-arkose

* Tertiary letter stage

GEOLOGY AND LOCATION OF TRAVERSES

GEOLOGY AFTER GRAINGER, IN PREP

PLATE 2



—60—	Isogals
-145·3	Bouguer anomalies at density 2·0g/cm³
A = 7210 B = 7090	Gravity station
	For geological symbols see Plate 1

5 0 5 10 15 20 25 KILOMETRES

REGIONAL BOUGUER ANOMALIES

GEOLOGY AFTER GRAINGER, IN PREP

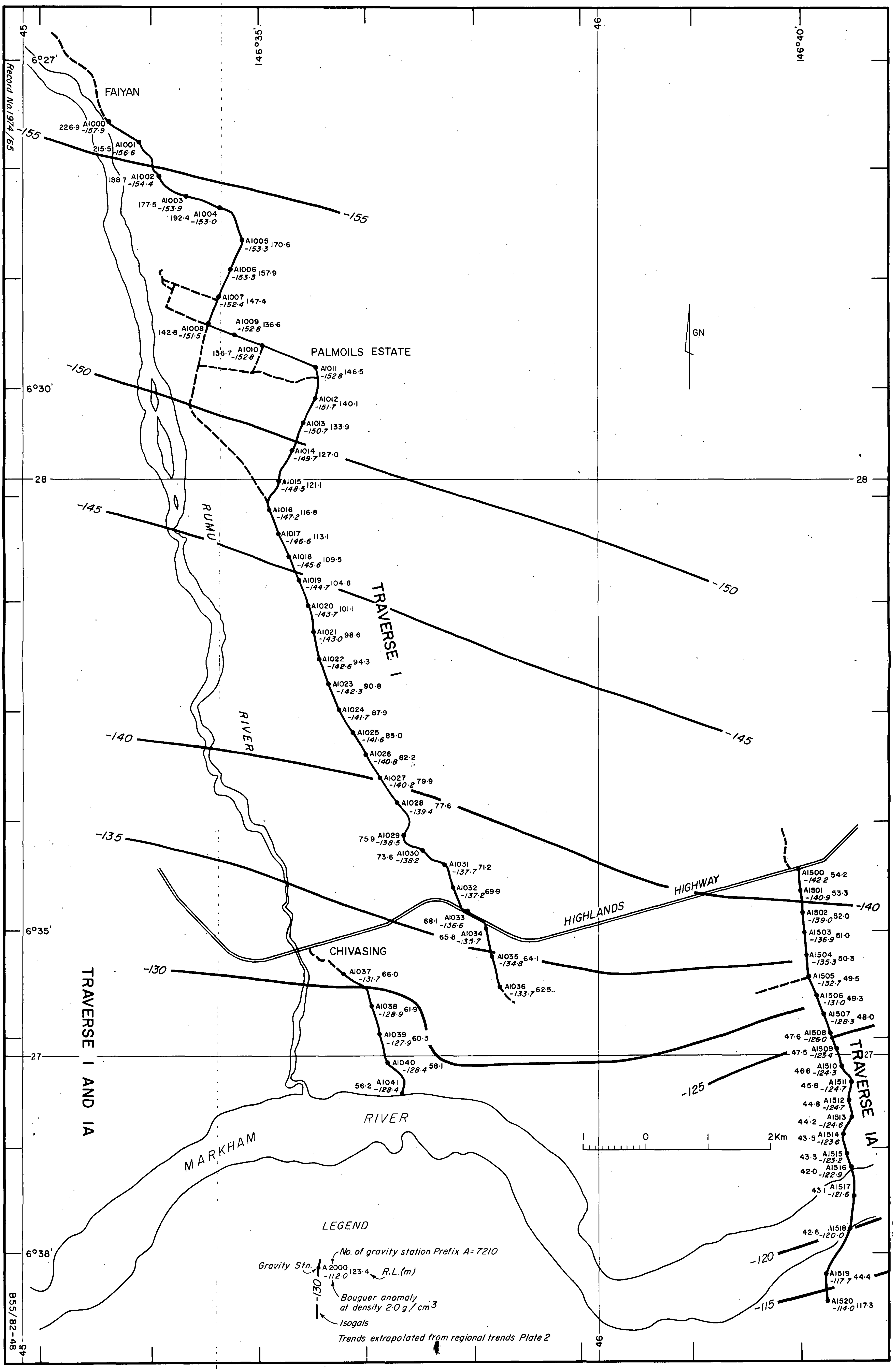


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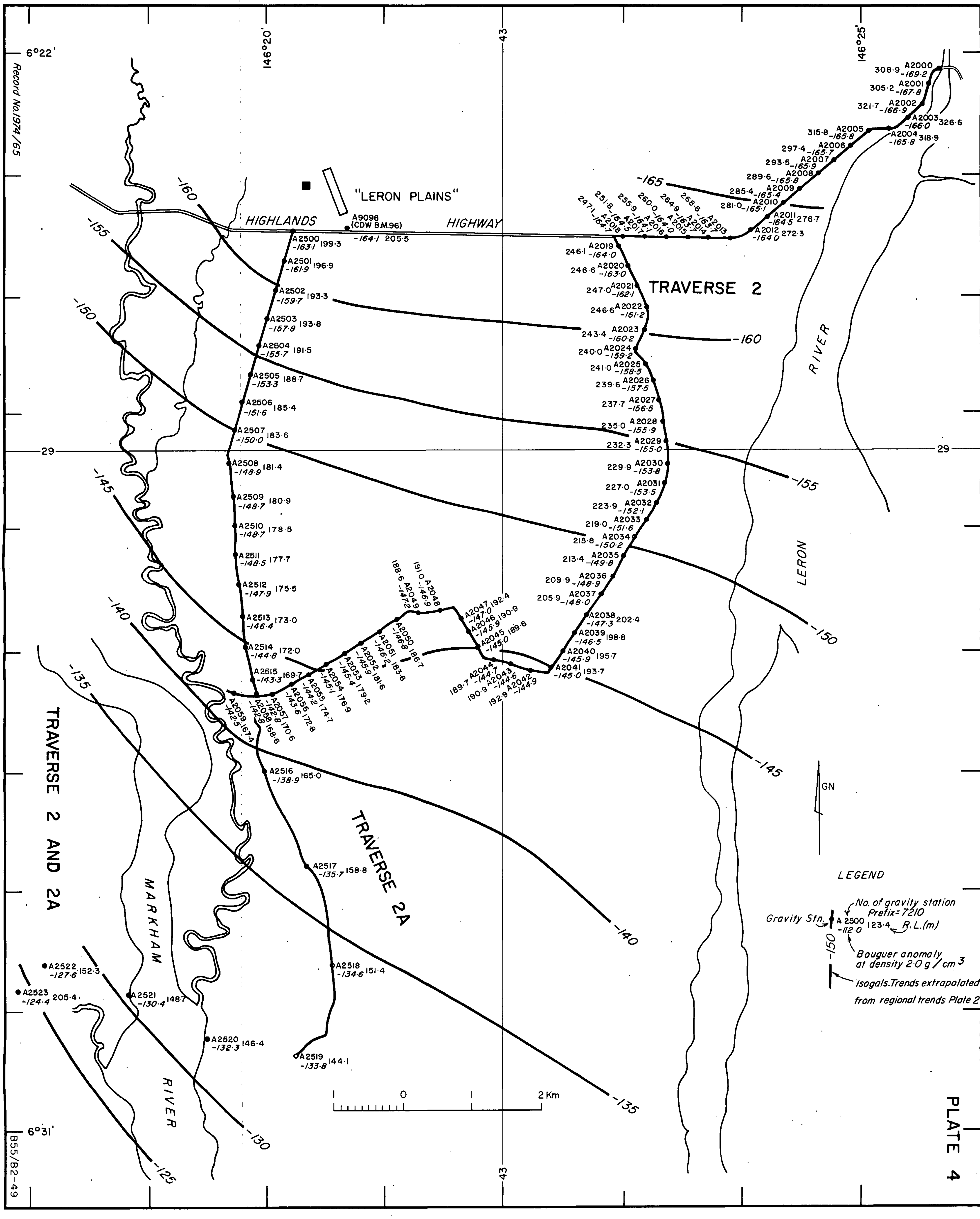
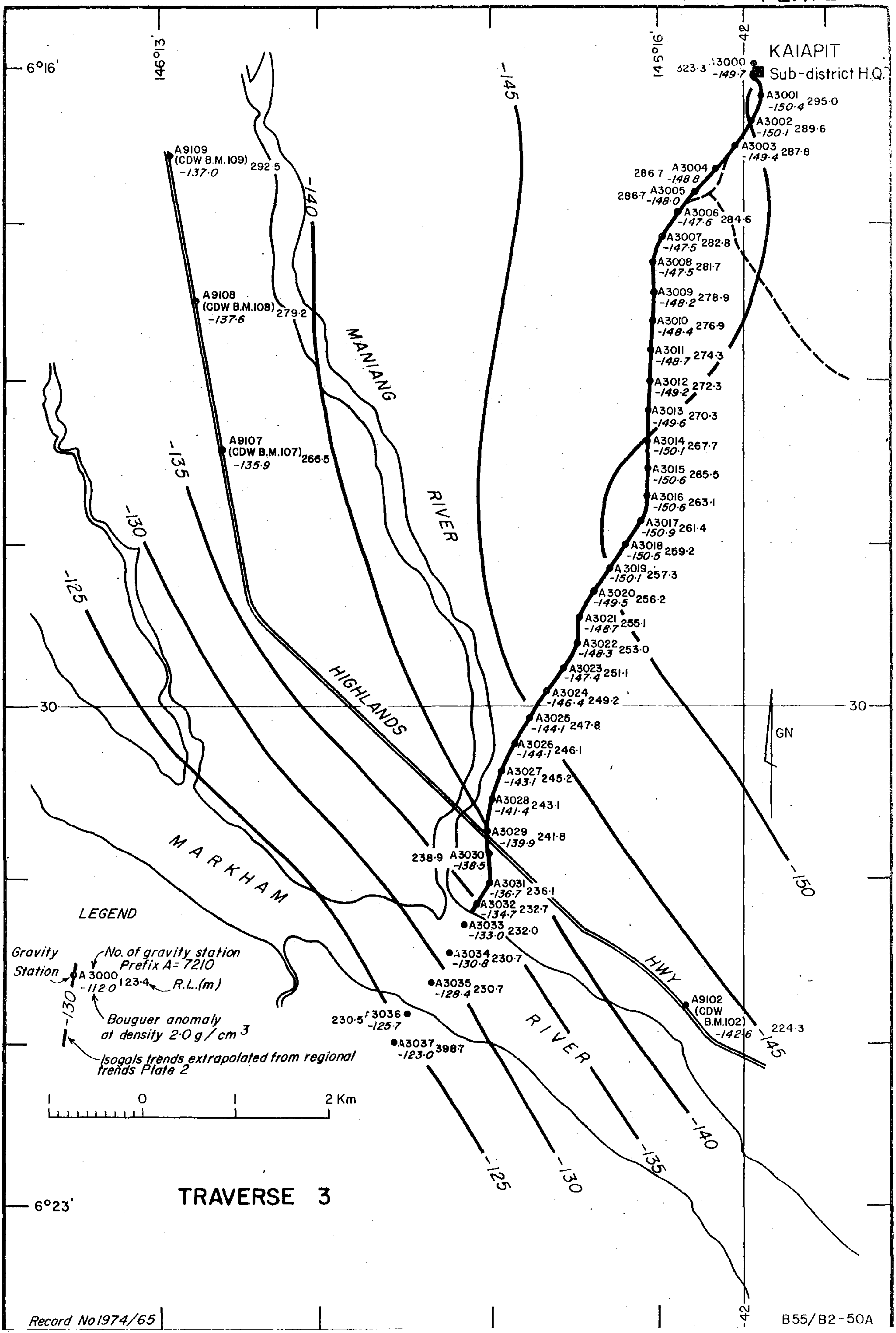
PLATE 3



Record No.1974/65
6°22'
6°31'
146°20'
146°25'
43
29
"LERON PLAINS"
HIGHLANDS
HIGHWAY
A9096 (CDW B.M.96) -164·1 205·5
TRAVERSE 2
TRAVERSE 2A
TRAVERSE 2 AND 2A
MARKHAM
RIVER
LERON
RIVER
A2000 308·9 -169·2
A2001 305·2 -167·8
A2002 321·7 -166·9
A2003 326·6 -166·0
A2004 318·9 -165·8
A2005 315·8 -165·8
A2006 297·4 -165·7
A2007 293·5 -165·9
A2008 289·6 -165·8
A2009 285·4 -165·4
A2010 281·0 -165·1
A2011 276·7 -164·5
A2012 272·3 -164·0
A2019 246·1 -164·0
A2020 246·6 -163·0
A2021 247·0 -162·1
A2022 246·6 -161·2
A2023 243·4 -160·2
A2024 240·0 -159·2
A2025 241·0 -158·5
A2026 239·6 -157·5
A2027 237·7 -156·5
A2028 235·0 -155·9
A2029 232·3 -155·0
A2030 229·9 -153·8
A2031 227·0 -153·5
A2032 223·9 -152·1
A2033 219·0 -151·6
A2034 215·8 -150·2
A2035 213·4 -149·8
A2036 209·9 -148·9
A2037 205·9 -148·0
A2038 202·4 -147·3
A2039 198·8 -146·5
A2040 195·7 -145·9
A2041 193·7 -145·0
A2500 199·3 -163·1
A2501 196·9 -161·9
A2502 193·3 -159·7
A2503 193·8 -157·8
A2504 191·5 -155·7
A2505 188·7 -153·3
A2506 185·4 -151·6
A2507 183·6 -150·0
A2508 181·4 -148·9
A2509 180·9 -148·7
A2510 178·5 -148·7
A2511 177·7 -148·5
A2512 175·5 -147·9
A2513 173·0 -146·4
A2514 172·0 -144·8
A2515 169·7 -143·3
A2516 165·0 -138·9
A2517 158·8 -135·7
A2518 151·4 -134·6
A2519 144·1 -133·8
A2520 146·4 -132·3
A2521 148·7 -130·4
A2522 152·3 -127·6
A2523 205·4 -124·4
-165
-160
-155
-150
-145
-140
-135
-130
-125
GN
0
2 Km
LEGEND
No. of gravity station Prefix=7210
Gravity Stn.
A 2500 -112·0 123·4 R.L.(m)
Bouguer anomaly at density 2·0 g / cm 3
Isogals. Trends extrapolated from regional trends Plate 2
PLATE 4
B55/B2-49
504330

504031 PLATE 5



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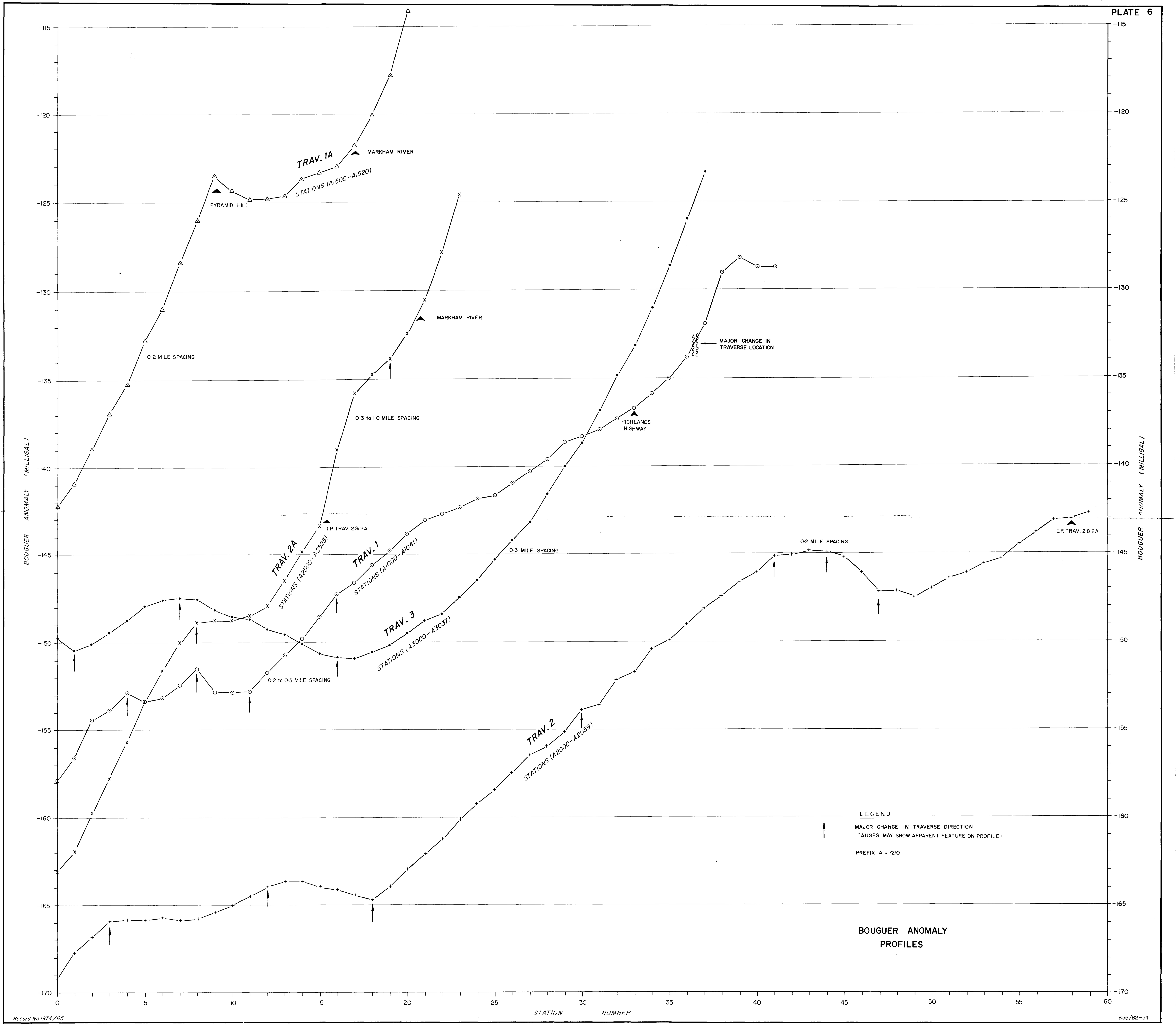

BOUGUER ANOMALY PROFILES

Record No. 1974/65

B55/B2-54

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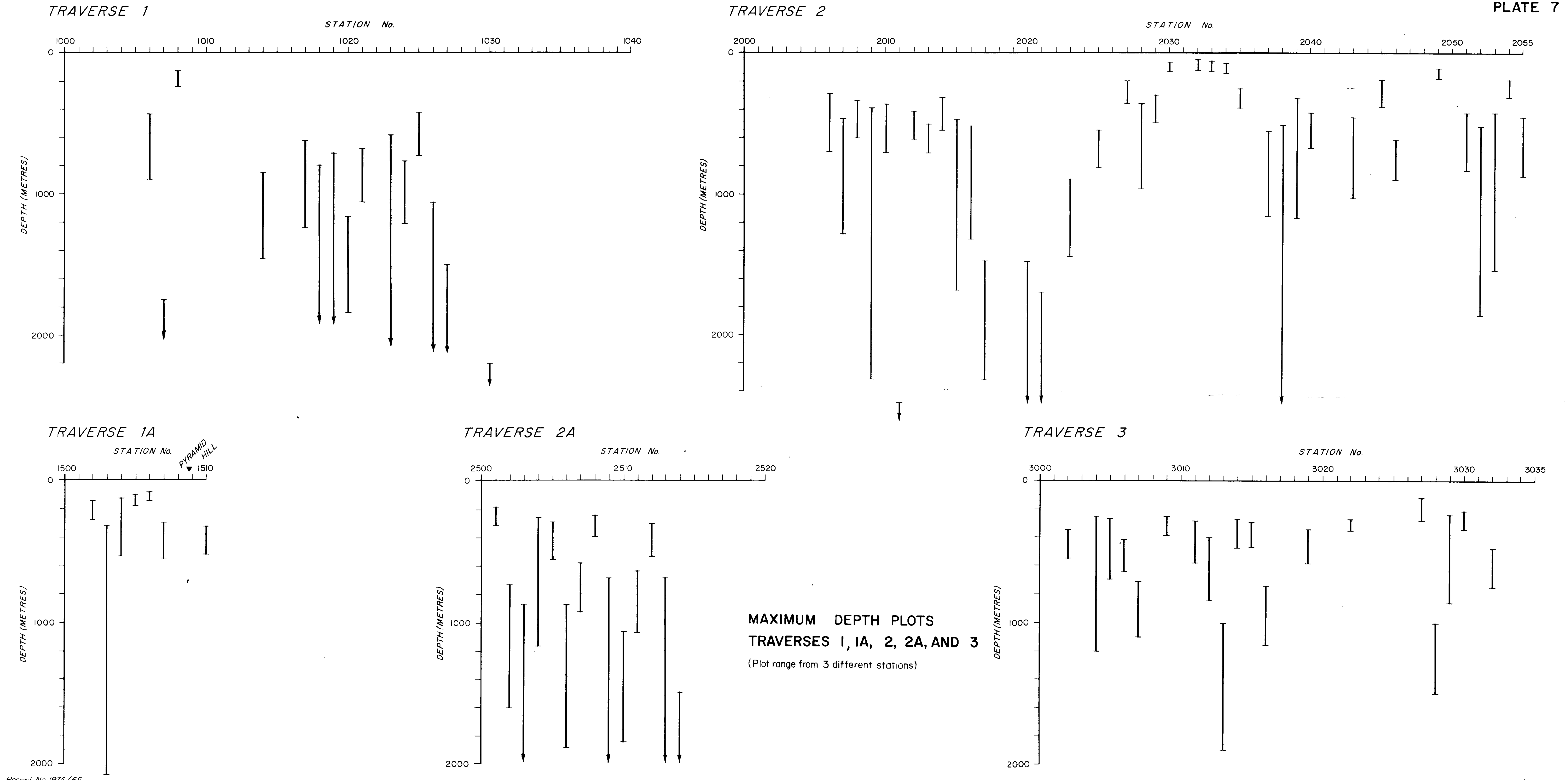
PLATE 7



MAXIMUM DEPTH PLOTS
TRAVERSES 1, 1A, 2, 2A, AND 3
(Plot range from 3 different stations)

Record No.1974/65

B55/B2-51