COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1967/40

UPPER RAMU HYDRO-ELECTRIC PROJECT MAGNETIC MEASUREMENTNS,

NEW GUINEA 1964

by

M. WAINWRIGHT and J.C. DOOLEY

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SUMMARY

Following the seismic and magnetic work in 1963 in the area of the Upper Ramu hydro-electric project, further short magnetic traverses and tests of drill-cores were made in 1964. These tests show that many of the magnetic anomalies previously interpreted as dykes are more probably due to granodiorite boulders.

1. INTRODUCTION

A geophysical survey was made by the Bureau of Mineral Resources in 1963 along proposed tunnel and penstock lines, which were to be part of a projected hydro-electric power station in the Upper Ramu Valley, New Guinea (Polak, 1964). In several places, dykes were inferred from magnetic or seismic results, or from a combination of the two.

During 1964, some short magnetic traverses were surveyed and magnetic tests of hand specimens and bore cores were made during brief visits to the site. These indicated that much of the dyke material was not significantly magnetic, thereby necessitating revision of the previous conclusions.

2. FIELD WORK AND RESULTS

Tests were made on the following occasions:

30th July 1964 (W. A. Wiebenga and J. T. G. Andrews)

A magnetic traverse was conducted along the penstock line between BM6 and BM7 (Plate 1). The portion of the traverse from chainage 00 to 300 is plotted in Plate 2. From 300 to 1192 no significant anomalies were discovered, and the magnetic profile (Plate 2) remains approximately constant at about 510-515 gammas relative to the arbitrary datum adopted.

28th August 1964 (J. T. G. Andrew and M. Wainwright)

Magnetic traverses were conducted along a creek bed (Traverse 1) and across part of the Ramu River (Traverse 2) near the intake end of the proposed tunnel line (Plate 1). Traversing was done for a total distance of 400 ft with readings at 20-ft intervals. No major anomalies were recorded; the magnetic readings were generally in the vicinity of 520 + 20 gammas on the same datum as used in Plate 2 on both traverses.

Rough measurements of magnetic properties of rocks specimens were made by holding them close to the magnetometer. Some water-worn rock boulders caused substantial deflections, in one case as much as 1000 gammas.

26th October 1964 (J. A. Brooks, J. P. MacGregor and J. C. Dooley)

Tests were made on some hand specimens of outcropping rocks from the intake area and penstock sites, and from drill cores. The results are listed in Appendix 1. These indicate that much of the dyke material is not significantly magnetic, though some of the hand specimens showed some effect. There was no obvious distribution between magnetic and non-magnetic dyke material.

Three specimens that showed magnetic effects were later examined petrographically and mineragraphically by W. Oldershaw, whose report is given in Appendix 2. The magnetism of two of the rocks is apparently due to magnetite and that of the third to pyrrhotite.

Hill (1962) also reported a petrographic examination of one specimen of altered dyke material which contained iron oxide minerals. These were also found in a specimen from a granodiorite boulder at the base of the lake sediments, and in a metamorphosed greywacke.

3. INTERPRETATION

From measurements made on Traverses 1 and 2 it was found that some outcropping dolerite dykes did not give any significant anomaly. Hence it seemed possible that the magnetic anomalies recorded by Polak (1964) were not all associated with dolerite dykes. Also, an inference from the 1963 survey was that the absence of localised magnetic anomalies implied that no major dykes were present, e.g. on the penstock line, where the only anomalies recorded were broad variations attributed to a change in lithology down the ridge from metamorphosed siltstone to marble.

Thus is became important to investigate the reason for the absence of magnetic anomalies over dykes in the intake area, whether basic dykes (and hence possible weak zones due to differential weathering) could be present in the penstock ridge without giving rise to magnetic anomalies, and whether the magnetic anomalies along the tunnel line recorded by Polak could have an origin other than the dykes. The measurements made on 26th October were undertaken in order to throw further light on these points.

Estimates of magnetic susceptibility

Some approximate estimates were made of susceptibility of the hand specimens and drilling cores tested on 26th October. These should be taken merely as giving an order of magnitude, as the measurements were not made under suitable conditions for accurate estimates.

In view of the low degree of accuracy, we may approximate the bore cores by line elements magnetised along their lengths. The magnetic field F at a point along axis is then (Nettleton, 1942):

$$F = \frac{\pi R^2 I}{z_1^2} - \frac{\pi R^2 I}{z_2^2}$$

where R = radius of core

I = polarisation contrast; if magnetisation is supposed to be due to the Earth's field H, $I = kH$, where k is the susceptibility of rock

z_1 = distance from measuring element to nearer end of core

z_2 = distance to further end of core.

For our purposes the second term may be neglected in comparison with the first for most of the specimens tested. The above formula is based on the assumption that z_1 is small compared with R, which is not true for some of the measurements. For $R = z_1$, the field calculated from the above formula should be decreased by 1.7.

The hand specimens were irregular in shape but for these calculations they were treated as spheres. For a uniformly magnetised sphere the maximum field occurs along the axis of magnetisation and is given by Nettleton (1942):

$$F = \frac{8}{3}\pi \frac{R^2 I}{z^3} = \frac{8\pi I}{3(1 + h/R)^3}$$

where R = radius of sphere

z = distance from centre of sphere

h = z - R = distance from surface of sphere.

Estimates made from hand specimens will, of course, be even less accurate than those from bore cores.

The following dimensions were used in the calculations:

z_1 or h	:	magnetometer in case	- 5 cm
z_1	:	magnetometer out of case	- 2 cm
R	:	NXL or NX core	- 5.5 cm
		NMLC "	- 5.2 cm
		BMLC "	- 3.5 cm
		hand specimen (unless otherwise specified)	- 10 cm

The estimated susceptibilities are listed in Appendix 1.

Where no deflection was observed, an upper limit to the susceptibility was estimated on the assumption that the field was less than 10 gammas. In general this limit was about 100 to 150 x 10^{-6} c.g.s.; for the cores in DD5, for which the outer case of the magnetometer was removed, the limit was about 60 x 10^{-6} c.g.s.

If we assume a susceptibility of 50 x 10^{-6} c.g.s., then the maximum anomaly that could be caused by a dyke of width 5 ft and depth to the top surface 50 ft would be about 6 gammas. In fact, the anomaly would probably be less, depending on the dip, strike, and direction of magnetisation of the body. Thus it is clear that no anomaly would be observed with a magnetometer with sensitivity of 10 gammas/division from dykes consisting of material that gave no deflection in the specimen tests. (Note that '1 division' is 0.1 of the distance between adjacent graduations on the scale.)

Thus it is possible for dykes to exist in the basement without causing magnetic anomalies. In particular, specimens from dykes intersected by DD5 showed no magnetism; Polak's interpretation of magnetic anomalies in terms of dykes was partly based on the coincidence of a magnetic anomaly with these dykes.

On the other hand some dyke material showed magnetic properties. On the information available, it is not possible to say whether the magnetic rocks have any special properties, different from the non-magnetic dyke rocks, which would enable them to be identified with particular structural units, such as a series of dykes intruding at a particular epoch.

Using empirical formulae and graphs given by Grant and West (1965), estimates of the susceptibility based on magnetite content can be made for specimens 438 and 439 tested by Oldershaw (Appendix 2). With 2% magnetite, the susceptibility of specimen 438 should be about 0.005 c.g.s., and for 10%, that of specimen 439 should be about 0.03 c.g.s. Pyrrhotite has a saturation magnetisation of about 2/3 that of magnetite, so one might expect a susceptibility of the order of 0.005 c.g.s. for specimen 440. These figures are substantially higher than those determined from the field tests. Differences may be expected, as the data on which the empirical formulae are based show variations of a factor of 10 or so, and the measurements made here are approximate only; however, the differences are larger than might be expected. No further explanation of the discrepancy can be offered at present.

Some of the magnetic anomalies on Polak's traverse have a half-width or a peak-trough distance of only about 50 ft. The depth of the anomalous body for these should be no more than about 50 ft. Examples are near stations 16, 21, 37, 70, and 113. At these places, seismic basement depth is about 200 ft. ~~The material above this is about 200 ft~~. The material above this is either Pleistocene lake deposits, which were not intruded by the dykes, or weathered bedrock, which may include weathered dyke material.

The only bore cores tested that showed any magnetism were from granodiorite boulders. Thus it seems that at least some of these anomalies may be due to large granodiorite boulders or local concentrations of boulders, rather than to dykes.

Traverse along penstock line

The anomalies between chainage 00 and 150 appear to be associated with a change in seismic velocity and a dip in the bedrock surface. It is believed that the junction between marble and metamorphic bedrock occurs in this area. Marble is expected to be non-magnetic, which accounts for the low magnetic activity at the lower end of the penstock line.

Marble was revealed at a depth of a few feet in costeans in the lower 400 ft of the penstock line. However, Polak (loc. cit.) recorded a seismic velocity of 6000 ft/s to depths ranging from about 60 to 160 ft in this area. This is typical of a substantially weathered or jointed rock or a stiff clay, whereas solid marble generally has a velocity of 16,000 ft/s or more.

This suggests that the marble is dissected by open joints or solution cavities, and will not be particularly suitable as an anchor for a penstock line.

4. CONCLUSIONS

Many (if not most) of the dyke rocks in the Upper Ramu intake area tunnel and penstock lines are not sufficiently magnetic to cause a detectable magnetic anomaly at the surface. However, some magnetic anomalies may be associated with dykes.

Some (if not most) of the anomalies measured by Polak (1964) are probably caused by large granodiorite boulders, or local concentrations of granodiorite boulders, at depths less than 50 ft.

There is no obvious basis for distinguishing between magnetic and non-magnetic basement rocks in terms of any structural or stratigraphic relation.

Marble bedrock occurs at the lower end of the penstock line, but is probably not of sufficient strength to support a penstock.

5. REFERENCES

GRANT, F. S., and WEST, G. F.	1965	"Interpretation theory in applied geophysics." New York, McGraw Hill Book Co.
HILL, J. K.	1962	Detailed geological investigation, Upper Ramu hydro-electric project, New Guinea, 1961. _Bur. Min. Resour. Aust. Rec_. 1962/95.
NETTLETON, L. L.	1942	Gravity and magnetic calculations. _Geophysics_ 7, p. 293.
POLAK, E. J.	1964	Upper Ramu hydro-electric project geophysical survey, New Guinea, 1963. _Bur. Min. Resour. Aust. Rec_. 1964/20.

APPENDIX 1

Magnetic testing of rocks, 26th October, 1964

Observers: J.A. Brooks, J.P. MacGregor, and J.C. Dooley.

The geological descriptions are by J.P. MacGregor.
F.G. = fine-grained; C.G. = coarse-grained; W = weathered, S slightly and V very.

Geological description	Jelander magnetometer reading change (Range 1, approx.10 gammas per division)	Estimated susceptibility (x10-6 c.g.s.)
Intake site		
1. Coarse gabbro slightly weathered about 6" irregular shape (from rubble)	7-19 as rotated	890
2. Moderately weathered coarse gabbro in situ in dyke.	No effect	<150
3. Siltstone	No effect	<150
4. Fresh gabbro from dyke (horizontal) (turned over)	1 to 2, 3	450
5. F.G. gabbro in situ (another dyke)	No effect	
6. Gabbro C.G. S.W.	No effect	<150
7. Dolerite V.W., F.G., fresh	No effect	<150
8 & 9. C.G. & F.G. gabbro from rubble in creek	No effect	<150
10. C.G. & F.G. gabbro from rubble in creek	No effect	<150
11. F.G., S.W. gabbro	No effect	<150
12. C.G., fresh, 3-4 inches	2-3	450
13. F.G. dolerite	Nil	<150
14. V.W. gabbro (crumbles in hand)	Nil	<150
Traverse across several gabbro dyke outcrops	No effect	
Penstock site		
Dolerite fresh near DD13 (100 yds south)	Nil	<150
Boulder F.G. near DD13 about 2 ft irregular shape gave about 50 div. change when magnetometer set on top.		2100
Specimen broken off gives about 1 div.		300

Tests on Drill cores

Hole No.	Depth (ft)	Rock type	Length of core (inches)	Diameter	Magnetometer Deflection	Estimated susceptibility ($x10^{-6}$c.g.s.)
S1	188	Siltstone	6	N X L	Nil	<140
	198	Shale	6	N X L	-	<140
	204	W. gabbro	9	N X L	-	<130
	155	W. gabbro C.G.	12	N X L	Nil	<125
	165	F.G. gabbro	9	N X L	-	<130
	168	Fresh siltstone	4	N X L	-	<150
S4	169-171	Siltstone & shale	24	NMLC	-	<130
DD13	34	Siltstone	12	BMLC	-	< 220
	59	Shale	6	BMLC	-	< 220
DD13	74	Gabbro fresh	15	BMLC	-	< 220
	73	Gabbro fresh	6	BMLC	-	< 220
DD14	78-80	Gabbro fresh	24	BMLC	-	<220
S3	118	Fresh granodiorite C.G.	12	N.L.	2 div.	245
	630	Fresh granodiorite F.G.	12	N.L.	1-2	245
	127	V.W. granodiorite	8	N.L.	-	<130
		Charcoal	2	N.L.	-	<190
	109	Clay	4	N.L.	-	<150
	142	Fresh granodiorite	24	N.L.	3-4	490
	Magnetometer out of case - specimens closer					
DD5	30	Clay yellow	3		-	< 77
	55	W. green sand handful			-	<150
	95	W. gabbro	1		-	<140
	144	Black shale	12		-	< 60
	281	Dolerite	8		-	< 62
	290	Fresh dolerite	18		-	< 60
	315	Green sludge	handful		-	<150
	31	Granodiorite W. boulder	4		slight(1 div.)	67
	65	Siltstone boulder			-	<64

APPENDIX 2

Petrographic and mineragraphic examination of three rocks from the Upper Ramu Hydro-electric Project, New Guinea.

by

W. Oldershaw

Specimen 438, T.S.R.14591 (From dyke near intake site)

The specimen is a green porphyritic rock with some lustrous phenocrysts.

Under the microscope the rock is seen to consist of large subhedral phenocrysts of augite, 2 to 3 mm across, and patches of sericite flakes set in a matrix of euhedral plagioclase, fibrous actinolite, flaky chlorite, and grains of magnetite and pyrite.

Augite makes up about 50 percent of the rock and occurs as subhedral zoned phenocrysts. Some are slightly corroded and are rimmed by, and veined with, fibrous actinolite. Others are extensively altered to actinolite and chlorite.

Some of the masses of sericite flakes may be completely altered phenocrysts of plagioclase, since a few contain relics of plagioclase. The euhedral crystals of plagioclase in the matrix of the rock consist of clear, well-twinned andesine. Some of the larger crystals are zoned and the cores of some have been replaced by fine-grained sericite.

The interstices between the plagioclase crystals are filled with chlorite, actinolite, and opaque minerals.

The rock is a highly altered porphyritic augite andesite, or probably a porphyritic microgabbro. It contains about 5 percent of opaque minerals which, when examined in a polished section, were found to be cubes of magnetite, blebs of chalcopyrite, and veinlets of pyrite. Magnetite constitutes less than 2 percent of the rock and this would account for the reported low magnetism of the rock.

Specimen 439, T.S.R.14592 ('Floater' from Ramu River near intake site)

The specimen is a dark grey granular rock containing veinlets and patches of green epidote and chlorite.

Under the microscope the rock is seen to consist of subhedral phenocrysts of augite, about 1 mm across, and altered plagioclase set in a matrix of granular plagioclase, epidote, chlorite, and magnetite.

Some of the phenocrysts of augite have aggregated around irregularly shaped crystals of untwinned plagioclase. These crystals of augite are quite fresh; but isolated crystals of augite tend to be extensively chloritised.

The rectangular-shaped masses (up to 1 mm long) of minute granules of albite, with a little epidote and chlorite, probably represent altered phenocrysts of plagioclase. There are a few irregularly-shaped phenocrysts of poorly twinned plagioclase.

The matrix of the rock consists of minute grains of albite, epidote, chlorite, and black iron oxide.

The rock is a highly altered porphyritic augite andesite. Examination of a polished section shows that disseminated cubes of magnetite form about 10 percent of the rock. This accounts for the reported magnetism of the rock. In view of the extensive alteration of the rock, it is unusual that none of the magnetite is altered to hematite.

Specimen 440, T.S.R.14593 (metamorphic? from cliff down penstock line)

The hand-specimen is a fine-grained banded grey rock with a sub-conchoidal fracture.

Under the microscope the rock is seen to consist of lenticles and layers of fragments, 0.3 to 0.1 mm across, of quartz, vein quartz, altered plagioclase, microcline, and acid volcanics, alternating with lenticles and layers of smaller grains, 0.1 to 0.05 mm across, of the same minerals. The interstices are filled with epidote, chlorite, and limonite, the latter being prominent in the fine-grained layers.

The rock is probably a silicified tuff. Examination of a polished section shows it to contain irregularly-shaped masses (up to 0.4 mm across), veinlets and isolated cubes of pyrrhotite, which make up about 5 percent of the rock. As pyrrhotite is strongly magnetic, this mineral probably accounts for the slight magnetism reported in the rock.

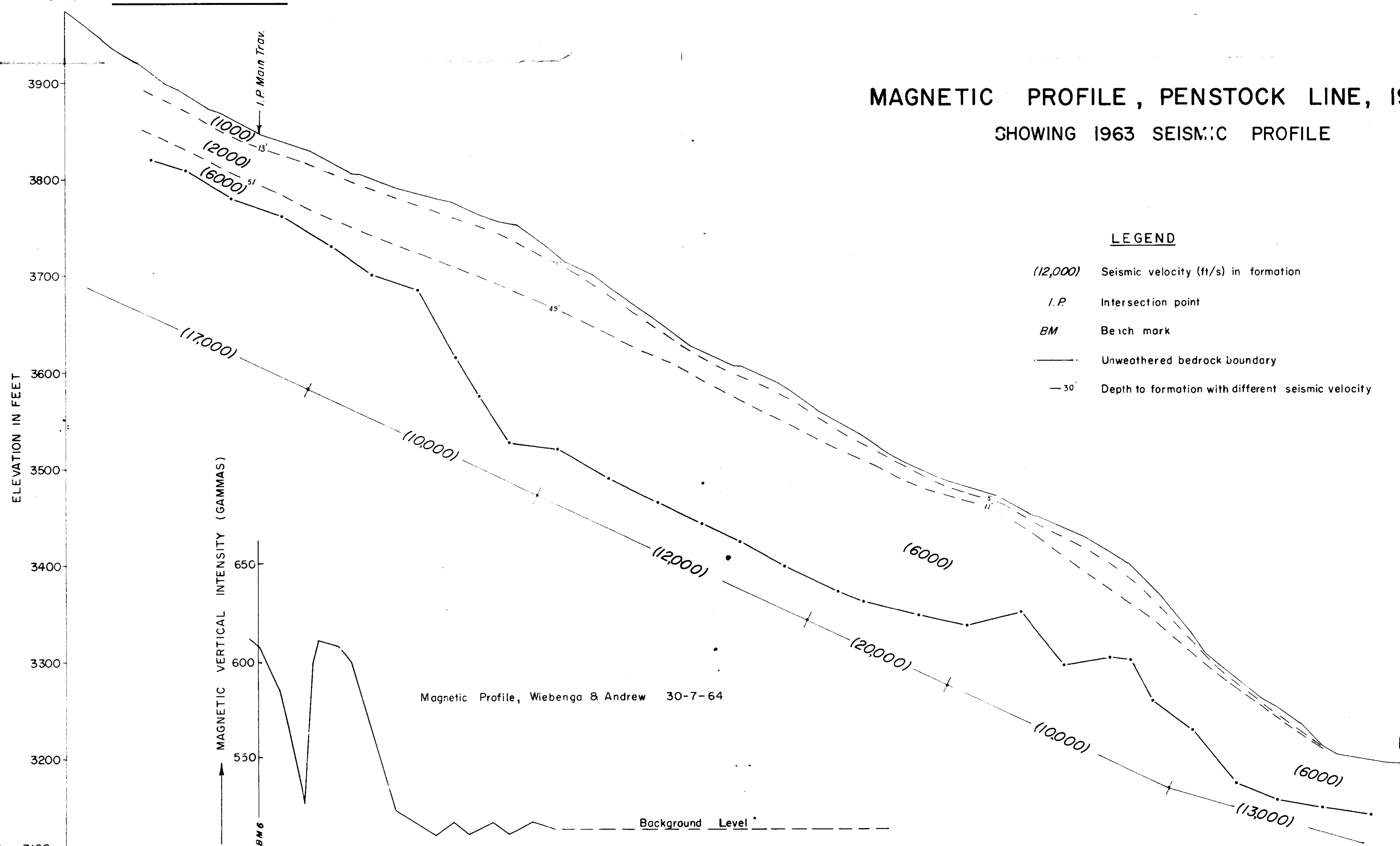

PLATE I
UPPER RAMU VALLEY, N.G. 1963
LOCALITY MAP
SHOWING GEOLOGY, GEOPHYSICAL TRAVERSES, AND LOCATION OF DRILL HOLES
LEGEND
Lacustrine sediments
Basal?granodiorite boulder bed
Basic intrusives
Metamorphic rocks
Bedded marble and crystalline limestone
Dip of dyke
Strike and dip of bedding
Strike of joint pattern
Anticline, inferred
Anticline, position accurate
Fault, position accurate
Fault, vertical, position accurate
Geological boundaries, approximate, inferred
Costean
Fence
DD2 Proposed diamond-drill hole
P5 Proposed pricking
BM Bench mark
Pegged horizontal distances from Inlet Portal
Magnetic Traverse
DD 2 S3 Actual drill sites
FEET
200 100 0 200 400 600
Based on Geological Branch dwg No. PNC7E-10
LOCALITY MAP
NEW GUINEA
PAPUA
KAINANTU
LAE
PORT MORESBY
Numerous dykes in this section, striking E-W, dipping 60°-70°N
RAMU RIVER
Recorder Creek
Loop Creek
Chasm Creek
Dyke Creek
Intake Creek
Ramu River
BM7 3194·58'
Trig. Stn. 2 4421·90
BM5 4343·42'
BM4 4365·53'
BM3 4304·14'
BM2 4284·92'
BM1 3911·67'
BM6 3846·56'
R.L.
CHAINAGE
To Accompany Record No 1967/40
B55/B5-5-1

PLATE 2

S-W *PENSTOCK LINE*

MAGNETIC PROFILE, PENSTOCK LINE, 1964

SHOWING 1963 SEISMIC PROFILE



STATION NUMBER	156, 160, 165, 170, 175, 180, 185, 187
STATION ELEVATION	3975, 3950, 3935, 3920, 3899, 3893, 3869, 3847, 3830, 3804, 3792, 3778, 3774, 3762, 3755, 3751, 3728, 3715, 3701, 3687, 3656, 3626, 3607, 3589, 3581, 3559, 3547, 3533, 3515, 3506, 3492, 3487, 3476, 3472, 3451, 3431, 3408, 3372, 3334, 3312, 3295, 3262, 3255, 3236, 3215, 3205, 3195, 3195
CHAINAGE	-200, -151, -99, -52, 00, 50, 104, 200, 249, 300, 348, 400, 450, 498, 551, 600, 651, 701, 749, 800, 849, 900, 933, 979, 1052, 1108, 1192
DEPTH TO LOWEST REFRACTOR	77, 62, 72, 74, 79, 90, 94, 150, 180, 198, 176, 172, 163, 168, 168, 162, 162, 150, 138, 136, 97, 137, 95, 70, 84, 70, 95, 83, 57, 56

FEET

100 50 0 100 200 300

(Horizontal and Vertical)

UPPER RAMU VALLEY, NG, 1963

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