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BULLETIN 101

Great Lake North Engineering Geophysical Surveys Tasmania 1951-1959

BY

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SUMMARY

Between 1951 and 1959 four engineering geophysical surveys were made in the Great Lake North District of Tasmania. Gravity, magnetic, seismic, resistivity, and radiometric methods were used to investigate geological conditions and rock properties along the line proposed for tunnels and other works for a hydro-electric scheme. The surveys provided much information that was of value in both planning and construction of the scheme.

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1. INTRODUCTION

The Hydro-Electric Commission of Tasmania spent many years investigating the possibilities of a hydro-electric power scheme taking water from Great Lake on the Central Plateau and using it in a power station near Blackwood at the foot of the Western Tiers, east of Great Lake (Fig. 1). This scheme is known now as the Poatina Power Development.

The scheme included an intake tunnel about 23,000 ft long from Great Lake to the Western Tiers, an outlet portal, penstock lines, a vertical pressure shaft, an underground power station, and a tailrace tunnel. The water was to be taken from the north-eastern part of Great Lake. The power station would be near the East Branch of Palmers Rivulet and situated about 36 miles south of Launceston. The intake would be about 5.6 miles west-south-westerly from the power station. The tailrace would discharge into the East Branch of Palmers Rivulet, a tributary of Brumby Creek which joins the Lake River.

It is essential in planning such a scheme to obtain as much information as possible about the geological structure and the rocks and conditions that exist where the tunnels, shafts, pipelines, and power station are to be constructed. The Hydro-Electric Commission had regional and detailed geological surveys made and some test drilling conducted to determine the rocks present at and beneath the surface, and the probable geological structure below the surface. In order to obtain further information, particularly about the structure underground, the Commission asked the Commonwealth Bureau of Mineral Resources, Geology & Geophysics (BMR) to make geophysical surveys of the tract of country to be traversed by the tunnels, pipelines, etc.

Between 1951 and 1959 four geophysical surveys were made by BMR and the results transmitted to the Commission in the form of typewritten and duplicated reports with accompanying plates. This *Bulletin* incorporates the description of the four surveys and the results obtained by them. During the period of the geophysical surveys more diamond-drill holes were drilled by the Commission.

In this *Bulletin,* the region surveyed will be referred to as the Great Lake North District and the separate parts as the Intake Tunnel Area, the Outlet Portal Area, the Penstock Line Area, and the Tailrace Tunnel Area.

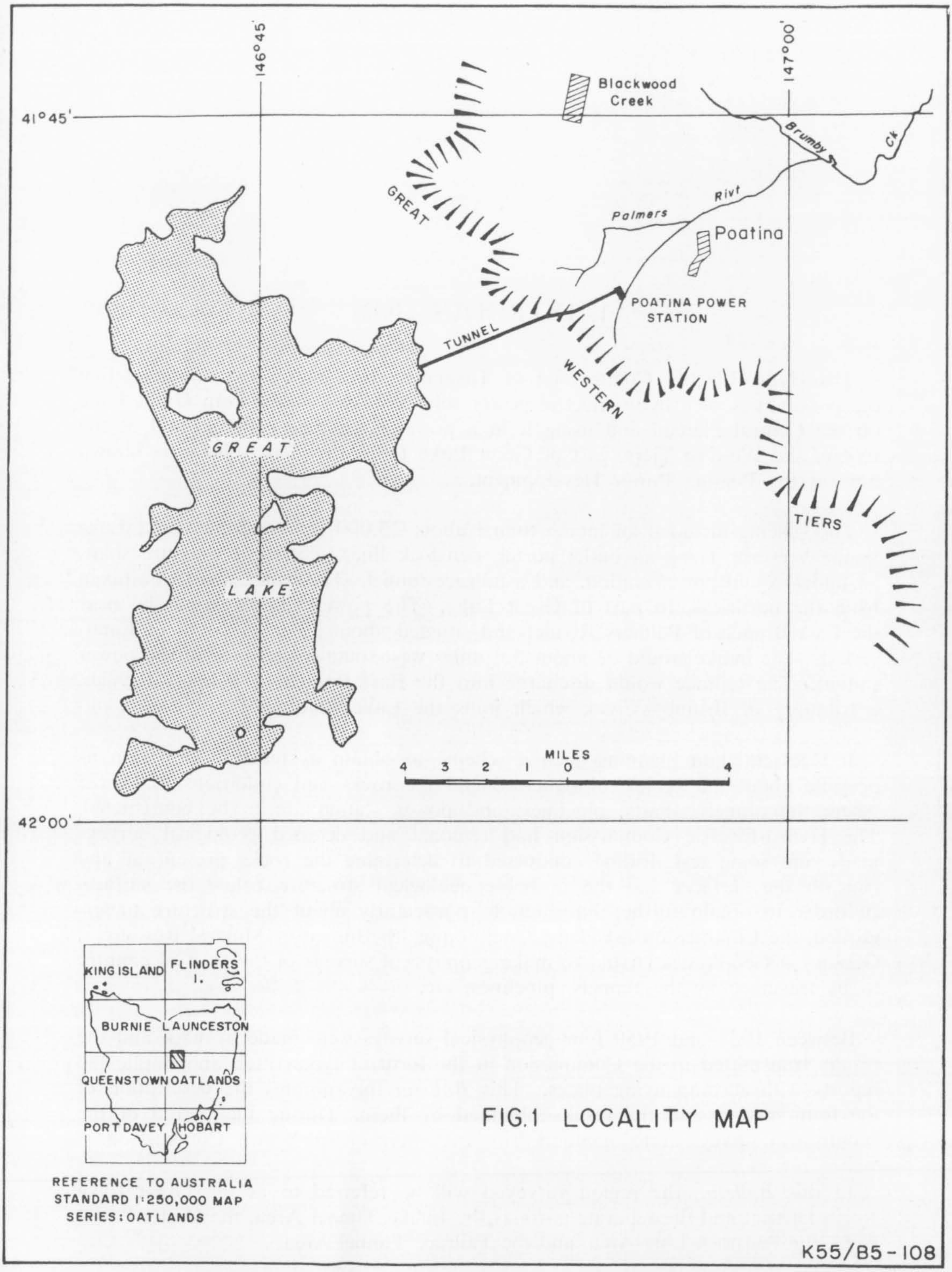

FIG.1 LOCALITY MAP

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It is desired to acknowledge the assistance and co-operation of the Commission's survey and administrative staff both at Poatina and at the Head Office in Hobart.

Since the geophysical surveys were completed, the hydro-electric scheme has been completed and the power station established at Poatina.

2. GEOPHYSICAL SURVEYS MADE

The four surveys were made between 1951 and 1959. Each successive survey was made either over a different part of the scheme or over a part previously surveyed but using methods different from those of earlier surveys. The four surveys when completed covered all parts of the scheme from intake tunnel to tailrace tunnel by one or more methods. The surveys were:

1951 survey. Gravity surveys were made by N. G. Chamberlain in the Intake Tunnel Area. Four traverses (A, B, C, & D) were surveyed, the two main ones (A & B) being along proposed tunnel lines No. 1 & 2 respectively. The 1956 and 1957-58 surveys were also made along tunnel line No. 1. At the time of the 1959 surveys, however, tunnel line No. 1 became known as the Old Tunnel line, and the 1959 surveys were made along a New Tunnel line.

1956 survey. Surveys were made in the westernmost 5500 ft of the Intake Tunnel Area, and in the Outlet Portal, Penstock Line, and Tailrace Tunnel Areas. Methods used were radioactive, magnetic, resistivity, and seismic refraction. The gravity data obtained by the 1951 survey were reviewed. The surveys were made during the period between February and May by E. J. Polak (party leader) and J. Cleary (replaced by A. Stocklin for April and May).

1957-58 survey. Surveys were made in the eastern part of the Intake Tunnel Area (between stations B5500 and B19300) — that is, the part of the intake tunnel not covered by the 1956 survey. Methods used were magnetic, micro-magnetic, resistivity, resistivity drill hole logging, and seismic refraction and reflection. The surveys were made by E. J. Polak (party leader) and F. J. Moss.

1959 survey. Surveys were made along the first 6000 ft of the New Tunnel line in the Intake Tunnel Area. Methods used were gravity, magnetic (vertical and horizontal intensity), resistivity, and seismic refraction. The surveys were made by E. J. Polak (party leader), M. J. Duggin, and D. J. Harwood.

The details of the lengths of traverses surveyed by each method and in each Area are given in Table 1.

TABLE 1: LENGTHS OF TRAVERSES SURVEYED

(All measurements in feet)

Method	*Year of Survey*	*Intake Tunnel Area*	*Outlet Portal Area*	*Penstock Line Area*	*Tailrace Tunnel Area*	*Total*
Gravity	1951	Traverse A 0 to 19 200	—	—	—	
		Traverse B 0 to 17 200				
		Traverse C 4 600				
		Traverse D 4 000				45 000
	1959	New Line 8 600	—	—	—	8 600
Radioactivity . .	1956	4 800	3850	4800	—	13 450
Magnetic	1956	4 800	3850	4900	—	13 550
	1957-58	14 000	—	—	—	14 000
	1959	9 000	—	—	—	9 000
Resistivity	1956	5 900	750	4850	9600	21 100
	1959	7 200	—	—	—	7 200
Seismic Refraction	1956	4 800	3850	4600	—	13 250
	1957-58	9 000	—	—	—	9 000
	1959	9 000	—	—	—	9 000
Seismic Reflection	1957-58	9 000	—	—	—	9 000
						172 150

Totals	1951 Survey	45 000
	1956 Survey	61 350
	1957-58 Survey	32 000
	1959 Survey	33 800
		172 150

Note: 1959 surveys are along the New Tunnel line. 1956 and 1957-58 surveys are along Old Tunnel line; that is, the Traverse A of 1951 survey.

3. GEOPHYSICAL REPORTS PREPARED

The following geophysical reports were prepared to describe the four surveys and the results obtained from them:

Preliminary statement on the geophysical survey of the Great Lake Area, Tasmania, by N. G. Chamberlain, 5/11/51. Bureau of Mineral Resources; typewritten statement with 1 plate.

Preliminary report on a geophysical survey of the Great Lake North Area, Tasmania, by W. A. Wiebenga and E. J. Polak. Bureau of Mineral Resources Record No. 1956/69, with 7 plates.

Geophysical survey of the Great Lake North Area, Tasmania, by W. A. Wiebenga and E. J. Polak. Bureau of Mineral Resources Record No. 1957/44, with 8 plates.

Great Lake Power Development geophysical surveys, Tasmania 1957-59, by W. A. Wiebenga and E. J. Polak. Bureau of Mineral Resources Record No. 1961/92, with 9 plates.

4. GEOPHYSICAL TRAVERSES, ZERO POINTS, DATUM POINTS

The traverses along which the geophysical surveys were made were laid out and also surveyed and levelled by the Survey Branch of the Hydro-Electric Commission. This arrangement greatly assisted the geophysical parties and ensured that traverses were accurately laid above the lines of the proposed tunnels, etc.

The distances along the traverses were measured by the Survey Branch along the surface of the ground, and stations for the geophysical parties were established. All distances measured were therefore slope distances and, as the geophysical parties used distances along the traverses to designate stations, it must be emphasised that such stations refer to slope distances and not to horizontal distances. On the traverses in the western part of the District, there was little difference between slope and reduced horizontal distances because slopes were gentle. However, on the traverses in the eastern part of the District, that is, on the face of the Western Tiers, the slopes were much steeper and there was a considerable difference between slope distance and reduced horizontal distance (further reference is made to this factor later in this Chapter).

The datum for the levels was that used by the Hydro-Electric Commission, based on levels referred to sea level.

The zero-points for the traverses were selected by the Survey Branch. The geophysical parties used either these zero points or selected suitable starting points on the traverses.

For the traverses along the western part of the No. 1 or Old Tunnel line, the Survey Branch used as starting point (or zero point) the intake portal in Great Lake; this zero point was situated about 700 ft south-westerly from the place where the No. 1 or Old Tunnel line crossed the shore of the lake. This zero point and traverse were used in the 1951, western part of the 1956, and the 1957-58 geophysical surveys. The plans, profiles, and reports on those surveys are based on that traverse and that zero point.

For the 1959 geophysical survey of the New Tunnel line, the traverse had a zero point (station No. T50) chosen on the shore of Great Lake. The relation between this traverse and that of the No. 1 Tunnel line is shown in Plate 1.

The traverse for the eastern part of the 1956 geophysical surveys was also laid out and surveyed by the Survey Branch. The geophysical party selected a reference point on the traverse 90 ft downhill (easterly) from diamond-drill hole 5034. This reference point was referred to as station A28400, and the distances between stations (50 ft) were measured along the sloping surface of the ground (and not horizontally). An attempt was made in the report *(Record 1957/44)* and plans of the 1956 geophysical survey to show "the relation between the two methods of plotting". This was shown diagrammatically in Plate 5 of the above *Record* where on one side of a line were shown the reduced slope distances for the eastern traverse or part of the survey and on the other side "horizontal distances (HEC plan A3254)". During the compilation of the present *Bulletin* it was found that the latter distances were at variance with those shown on the traverses in Plate 1 in each of the following *Records: 1956/69, 1957/44, 1961/92.*

Moreover, detailed examination of the distances between stations on the traverses in Plates 1 of *Records 1956/69* and *1957/44* showed that many had been plotted inaccurately and most were greater than the actual slope distance of 100 ft between stations, whereas they should have been less. It is clear that this inaccurate plotting was an attempt to compensate for a gap of 400 ft that will be revealed immediately below.

Subsequent investigation and correspondence with the Hydro-Electric Commission revealed that:

1 the survey of the eastern portion of the traverses had not been connected with the survey of the western portion (stations B0 to B19200);

2 there was a gap of 400 ft between the eastern end of the western portion and the western end of the eastern portion of the traverses;

3 the Plate 1 of each of the Records referred to immediately above was inaccurate because it did not allow for the 400 ft between the two ends of the surveys referred to in (2);

4 the zero point for HEC plan A3254 was 1000 ft westerly from the zero point of the western geophysical traverse (No. 1 Tunnel line).

The profiles and sections of the traverses in the western part of the District were inaccurate because the slope distances along the surface were plotted in full along the baselines. As the slopes were gentle, the differences between slope distance and reduced horizontal distance would be small.

In the present *Bulletin,* the plan in Plate 1 has been recompiled. The general and geological information in previous Plates 1 had been copied from geological maps based on aerial photographs. The new plan is based on an accurate map forwarded by the Hydro-Electric Commission of Tasmania. The geophysical traverses have been placed on the plan as accurately as possible. All the other plates, however, have been copied from the original plates, and those showing surveys on the Intake Tunnel Area are slightly inaccurate because slope distances are plotted in full along the baselines of profiles, etc.

The geophysical stations on all surveys except the 1959 survey of the New Tunnel line were designated by the slope distance from the zero point, e.g. station 5000. It would be possible to show the stations along traverses with the slope distances reduced to horizontal distances, but as the station numbers represent distances, there would be confusion. For this reason a letter (e.g. A) has been added to the station numbers. On the Outlet Portal, Penstock Line, and Tailrace Tunnel Areas, the stations had already been shown with a number representing the slope distance to that station, e.g. A28400. On the Intake Tunnel Area the stations are designated by adding the letter B to the number representing the slope distance to that station. On the New Tunnel line, the station numbers used are those used in the survey and shown in Plates 8 and 9, namely T50, etc. For the 1951 survey the letter B will be placed before the slope distances to designate the station, because the same traverse line (A or No. 1 or Old Tunnel line) and stations were used by the 1956 and 1957-58 surveys and the letter B has been used for the stations on those two surveys.

5. GEOLOGY

Regional geological surveys of the region around the District under review were made by J. B. A. McKellar in 1954, and detailed geological surveys over a smaller region were made over a period of 12 months in 1954 and 1955. A report by McKellar was prepared in 1956. The geology used in this *Bulletin* is based on the maps and sections of the detailed survey.

The stratigraphy of the District is shown in Table 2. The surface geology of a narrow area along the proposed tunnel, etc., and a longitudinal vertical section along the line of the tunnel, etc., are shown in Plate 1. These are based on the report of McKellar (1956) and subsequent drilling. It will be realised that not all of the information was available in 1951 and 1956 (when the earlier geophysical surveys were made) but additional information, particularly on the structure underground, became available as more and more diamond-drill holes were put down. The earlier drilling was done where only shallow holes were necessary, namely at the western end of the Intake Tunnel Area and in the Outlet Portal and Penstock Line Areas.

The oldest rocks are sedimentary rocks of the Permian System and these are overlain by sedimentary rocks of the Triassic System. The rocks of both systems are nearly horizontally bedded (dips of two to three degrees to the south-west) and the junction between the two systems is probably a disconformity. These rocks crop out in the Outlet Portal and Penstock Line Areas on the slopes of the Western Tiers and in the Tailrace Tunnel Area at the foot of the Tiers. Drill holes prove that they extend underground from the Outlet Portal Area westerly to within 5500 ft of Great Lake.

At the surface, Jurassic dolerite occurs along the greater part of the Intake Tunnel Area. As will be seen from the vertical section in Plate 1, drill holes prove that the dolerite overlies the Triassic rocks and is in the form of a sill, although sedimentary rocks do not now exist above the dolerite. Information

TABLE 2: STRATIGRAPHY AND PHYSICAL CONSTANTS

System	*Group*	*Unit*	*Rock Type*	*Seismic Velocity, ft per second*	*Young's Modulus c.g.s. units x 10^{11}*	*Density g/cm^3*	*Poisson's Ratio*
Quaternary			Alluvial deposits				
			Scree material	2 500 - 5 100			
			Soil	1 000 - 2 000			
			Glacial deposits	5 000 - 6 000			
Jurassic			Dolerite, weathered	5 000 - 6 000			
			,, jointed	10 000 - 15 000	2.1 - 5.0	2.9(1)	0.26(2)
			,, unweathered	17 000 - 22 000	6.3 - 13.0	2.9(1)	0.26(2)
Triassic		New Town Coal Measures	Sandstone, siltstone, shale				
	Knocklofty	Tiers	Siltstone, shale				
		Cluan	Sandstone, siltstone	6 300 - 7 000	0.68 - 0.9	2.6(3)	0.3(2)
		Ross	Sandstone	9 000 - 10 000	1.4 - 1.6	2.6(4)	0.3(2)
		Jackey	Shale				
Permian	Ferntree	Eden	Mudstone				
		Blackwood	Conglomerate				
		Drys	Mudstone	5 500(W) 9 500(U)	0.53 - 1.65	2.6(4)	0.3(2)
		Palmer	Sandstone	5 300(W) 10 500(U)	0.47 - 1.83	2.45(4)	0.3(2)
		Springmount	Mudstone	7 500(W) 10 000(U)	1.0 - 1.8	2.6(4)	0.3(2)
		Risdon	Sandstone	7 900(W) 14 000(U)	1.04 - 3.5	2.45(4)	0.3(2)
	Woodbridge	Weston	Mudstone	6 500(W) 9 000(U)	0.77 - 1.46	2.6(4)	0.3(2)
		Dabool	Sandstone				
		Meander	Mudstone				
	Liffey	Creekton	Sandstone				
		Woodside	Sandstone				
		Kopanica	Shale				
		Flat Top	Sandstone				
	Golden Valley	McRae	Mudstone				
		Billop	Sandstone				
		Brumby	Mudstone				
		Quamby	Mudstone				
		Stockers	Tillite				
Precambrian							

Note: (W) = Weathered; (U) = Unweathered
(1) = Measured by Jaeger and Joplin (1955)
(2) = Estimated from Birch, Schairer and Spicer (1950)
(3) = Measured by HEC
(4) = Estimated

about the base of the sill was obtained from drill holes, and the details are given in Table 3. The information was used in the compilation of the section in Plate 1. The base of the sill is not regular, and three explanations are possible:

(1) Faulting at a few places.

(2) The base of the sill transgresses the bedding of the sedimentary rocks.

(3) Faulting and transgression.

Some faulting has been proved by the drill holes, but it is not known whether transgression is present in the area tested by the drill holes in Table 3.

TABLE 3: ELEVATIONS OF THE BASE OF THE DOLERITE SILL IN DRILL HOLES

Drill hole	*Elevation of collar, ft*	*Thickness of dolerite, ft*	*Elevation of the base of dolerite, ft*	*Elevation change of dolerite base between adjacent drill holes, ft*
DDH 5042	3612	104	3508	
				—45
DDH 5041	3646	183	3463	
				+81
DDH 5040	3716	172	3544	
				+119
DDH 5002	3835	172	3663	
				—10
DDH 5087	3883	230	3653	
				—82
DDH 5083	4340	769	3571	
				—512
DDH 5084	4239	1180	3059	
				—171
DDH 5086	3908	1020*	2886	
				—6
DDH 5085	3693	817*	2882	
				+35
DDH 5033	3495	578	2917	

* Drill hole not vertical; thickness of dolerite corrected to vertical.

The eastern end of the sill has been eroded and the sill now terminates in the Outlet Portal Area. Towards the west, and at a place about 5500 ft east of Great Lake, the Jurassic sediments end against a body of dolerite. This contact was indicated by drill holes 5001 and 5002. The 1951 gravity survey indicated a much greater thickness of dolerite on the western side of the contact and also indicated generally the position of the contact. Subsequent drilling confirmed the results of the gravity survey.

The difference in structure on opposite sides of this contact could result from any of the following possibilities:

(1) The contact is a fault later than the dolerite and with a downthrow to the west.

(2) On the western side of the contact the dolerite sill thickens and its bottom is at a lower horizon in the Jurassic or Permian sedimentary sequence.

(3) West of the contact the dolerite is a transgressive body connecting with the sill and probably representing one of the feeders to the sill.

Scree and talus material and alluvial deposits overlie the above rocks in the form of thin superficial layers. The alluvial deposits occur near Great Lake and also in the Tailrace Tunnel Area. The scree and talus material occur over the greater part of the surface of the Intake Tunnel, Outlet Portal, and Penstock Line Areas.

A few faults were revealed by the geological mapping and the diamond drilling; others were indicated by the geophysical surveys. These traverse the Triassic (and probably also the Permian) strata and the Jurassic dolerite and are therefore post-Jurassic.

With specific reference to the proposed tunnels and other works, the geological conditions are described below. From the inlet portal, the intake tunnel would be in dolerite for about 5000 ft. From there to the outlet portal, the tunnel would pass through Triassic sedimentary rocks, mainly Triassic Coal Measures with Tiers Sandstone and Cluan Sandstone for short distances. Near the outlet portal appreciable thicknesses of scree material occur. The upper part of the penstock lines would be over Triassic sedimentary rocks and the lower part over Permian sedimentary rocks. The pressure shaft and tailrace tunnel would be in Permian sedimentary rocks.

In places where the tunnels, etc., are at or near the surface, the presence and depth of alluvial deposits, glacial deposits, scree material, and weathered and partly weathered rocks are important. Faults and shear zones are also important. The above features as indicated by the geophysical surveys are shown in the geological map and section and in the geophysical profiles.

6. PURPOSES OF THE SURVEYS

The general purpose of the geophysical surveys was to give as much information as possible about the rocks and the geological structure at and below the surface. The particular purposes of the four surveys conducted are described below.

1951 Survey To obtain information about the rocks within, and the geological structure of, the Intake Tunnel Area (station B0 to B19200).

1956 Survey (a) To determine the depth of weathering and to detect any shear zones in the rocks between stations B700 and B6300 along the western part of the intake tunnel (old site).

(b) To determine the thickness of the scree material and to detect any shear zones in the rocks within the Outlet Portal Area (stations A19700 to A23550), at the eastern end of the intake tunnel.

(c) To determine the thickness of the soil and of the zone of weathered rocks, and, if possible, the rock types below the weathered zone, within the Penstock Line Area (stations A23550 to A28400).

(d) To detect any faults and shear zones in the Tailrace Tunnel Area (stations A28400 to A38000).

1957-58 Survey To determine the thickness of the dolerite sill and the character of the base of the sill, and, if possible, the positions of any faults along the line of the intake tunnel between stations B5500 and B19300.

1959 Survey To obtain for the westernmost 6000 ft of the proposed New Line of the intake tunnel, information similar to that obtained in the 1951 and the 1956 part (a) surveys.

7. ROCK PROPERTIES

Physical constants for some of the rock formations in the district are shown in Table 2. Further information is given in Tables 4 and 5 and in this chapter of the *Bulletin*.

MAGNETIC PROPERTIES

Cores from DDH 5001 give high, but variable, values of magnetic susceptibility and remanent magnetism for dolerite (Jaeger & Joplin, 1955):

Magnetic susceptibility : 0.55×10^{-3} to 3.0×10^{-3} c.g.s.e.m. units

Remanent magnetism : 0.24×10^{-3} to 4.0×10^{-3} c.g.s.e.m. units

Faults, shears, and fractures in dolerite may be indicated on the magnetic profile by a decrease in vertical magnetic intensity because weathering is deeper along such features and this causes demagnetisation of the magnetite to greater depths in the dolerite than elsewhere. This evidence, and evidence from gravity, resistivity, and seismic data, were used to interpret the magnetic profiles.

Decrease in the magnetic intensity may also be caused by differences in magnetic susceptibility and by differences in the direction of the remanent magnetisation vector; but past experience of surveys on dolerite has shown that these factors play only a minor part in the interpretation of magnetic data.

RESISTIVITY

In general the unweathered rocks have high resistivities and the weathered counterparts have low resistivities. The lower resistivity of a weathered rock is caused largely by the greater amount of ground water it contains, because of its high porosity. Moreover, the salinity of the ground water in the pores of the weathered rock is higher than that usually found in ground water.

Zones of fracturing and shearing have lower resistivities than the normal rocks. This lowering is the result of greater amounts of ground water in the zones and of greater depths of weathering.

The depth of weathering in a shear zone is usually greater than it is outside the shear zone, because sheared rock provides better access to surface solutions than fresh solid rock; also, the porosity of weathered rock is higher than that of unweathered rock, and the salinity of the pore solutions in weathered rock is higher than the salinity usually found in ground water. Therefore, shear zones are indicated as low-resistivity zones. Low resistivity, however, does not necessarily indicate a shear zone; for instance, small pockets of clay near the potential electrodes may cause low resistivity.

The resistivity of the unweathered dolerite is very high.

The resistivity log of DDH 5502 (Fig. 2) shows that the resistivity of dolerite is not uniform and that some bands of very high resistivity occur (up to 250,000 ohm-cm). The average value is about 80,000 ohm-cm. Lower resistivity values probably indicate the positions of weathered joints; the high values indicate unweathered dolerite.

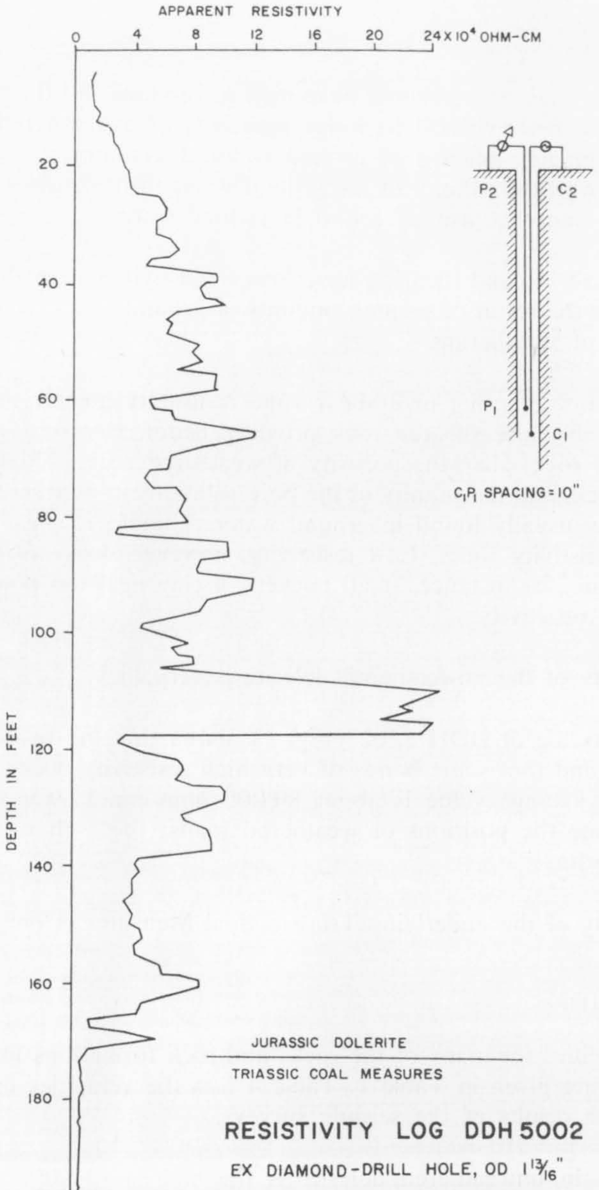
The resistivity of the underlying Triassic Coal Measures is only 8000 ohm-cm.

SEISMIC VELOCITIES

Seismic velocities for many of the rocks and rock formations in the Great Lake North District are given in Table 2. Table 4 lists the velocities used in the interpretation of the results of the seismic surveys.

The velocity in unweathered dolerite is the highest (15,000 to 20,000 ft/s) and that in weathered to jointed dolerite is lower (5000 to 11,000 ft/s). The velocity in unweathered sedimentary rocks in the District is 8000 to 10,000 ft/s. The velocities in glacial deposits, scree material, and soil are much lower (see Table 4).

FIG. 2



RESISTIVITY LOG DDH 5002

EX DIAMOND-DRILL HOLE, OD 1 13/16"

LIQUID IN HOLE FRESH WATER

K55/B5-96

TABLE 4: SEISMIC VELOCITIES USED IN THE INTERPRETATION OF THE SEISMIC RESULTS

Rock Type	*Seismic velocity, ft/s*
Soil	1000 to 2000
Scree material and completely weathered dolerite	2000 to 5000
Glacial deposits	5000 to 6000
Weathered to jointed dolerite	5000 to 11000
Jointed to unweathered dolerite	11000 to 18000

As indicated, the velocities in weathered rocks are lower than in unweathered rocks. Further, the velocities in rocks in zones of fracturing and shearing are also lower and depend largely on the amount of shearing, faulting, or jointing.

Shear zones are characterised by local thickening of the weathered rock, accompanied by lower seismic velocities in the unweathered sheared rock.

ROCK DENSITY

The densities of some of the rocks in the District are given in Table 2. In the interpretation of the gravity data, the density value used for unweathered dolerite was 2.95 g/cm^3 (Jaeger & Joplin, 1955) and for the underlying sediments was between 2.5 and 2.6. For the computation of Bouguer and terrain corrections, the value used for the density of dolerite was 2.95 g/cm^3.

8. METHODS AND EQUIPMENT USED

The following geophysical methods were used in the four surveys in the Great Lake North District:

Radioactivity
Magnetic
Micro-magnetic
Resistivity
Resistivity drill hole logging
Seismic refraction
Seismic reflection
Gravity

RADIOACTIVITY

This method depends upon the radioactivity of the materials at the surface of the Earth. In the present investigation it was used specifically to detect, if possible, zones of sheared and fractured rocks. Under favourable conditions the radioactive gas radon may be concentrated in such zones and thus increase the natural radioactivity and render possible the detection of such zones. Radioactivity of the underlying rocks can be obscured or dispersed by the superficial layers of soil, etc.

The instruments used were of Type G.M. 260. The radioactivity was measured as the number of counts per minute on the instruments. This method was used in the 1956 and 1957-58 surveys.

MAGNETIC

The measured magnetic intensity at any point on the Earth's surface is the resultant of two vectors, namely the induced magnetic intensity vector in the approximate direction of the Earth's magnetic field and a remanent magnetic intensity vector inherent in the rock and which may be in any direction.

Different rock types have different magnetic susceptibilities, and these affect the intensity of the magnetic field measured at the surface. In some regions, therefore, magnetic methods can indicate boundaries between different near-surface rock types, faults, and possibly rough estimates of depths to such boundaries. Along the line of the intake tunnel, the magnetic intensity is proportional to the thicknesses of the scree material and the weathered layer of dolerite.

Shear zones permit weathering to take place to greater depths than is possible in unsheared rocks. If igneous rocks contain magnetite the weathering in the shear zones causes demagnetisation of the rocks and thus gives rise to lower vertical magnetic intensities. Lower intensities on a magnetic profile may therefore indicate shear zones (Manley, 1956).

In field surveys, the vertical and horizontal components of the Earth's magnetic field are measured. The vertical component was measured in the 1956 and 1957-58 survey, and both components were measured in the 1959 survey.

Magnetic stations were spaced 50 ft apart along the traverses. The measurements were corrected for diurnal variation by observations at half-hourly intervals at base stations. The instruments used were Hilger & Watts, Schmidt-type magnetic variometers.

MICRO-MAGNETIC

A micro-magnetic method as described by Lauterbach (1953-1954) and Wiebenga (1958) was used. In this method, small sample areas or panels are selected in places where the rocks have only thin weathered layers, and on these panels, magnetic measurements are made in a dense observation grid. A Hilger & Watts vertical variometer was used.

Geological features with which the micro-magnetic features may be correlated include:

(1) The strike of jointing or shearing planes.

(2) The direction of flow in plutonic rock.

(3) Some features of sedimentary rocks related to the direction of sedimentation.

(4) Subsurface vertical boundaries between formations.

RESISTIVITY

Different rock types have different electrical resistivities. Hard, non-porous, and unweathered rocks generally have high resistivity. Soft, porous, and weathered rocks have lower resistivity. In general it may be said that the resistivity of a rock is inversely proportional to its porosity and to the salt content of the solutions in the pores and other spaces.

Shearing and fracturing result in localised weathered zones which, because of the consequent increase in the amount of saline solutions present, cause a decrease in resistivity in the zones and thus enable the detection of the zones.

In the Wenner method of resistivity measurements, there are four electrodes equally spaced in a straight line. In the technique known as resistivity traversing, which was used in the surveys, the four electrodes are moved as a whole along a traverse and readings are taken at consecutive stations. In the interpretation, absolute values of resistivity are not as important as sudden changes in resistivity; such changes usually indicate a change in rock type, e.g. from unweathered rock to sheared or fractured and weathered rock, or from sandstone to shale.

The apparent resistivity of the near-surface layers measured with electrode separations of 50, 100, and 200 ft gives evidence of the way in which the electrical resistivity changes with depth.

The results of resistivity traverses on thick scree material were not reliable and the use of the method was confined to portions of the District free from scree material.

In depth probing, the electrodes are also placed in the Wenner arrangement. The distance between electrodes is then gradually increased, taking resistivity readings with each step. The measured apparent resistivity values are plotted against the electrode spacing.

RESTIVITY DRILL HOLE LOGGING

Parts of three drill holes (DDH 5001, DDH 5002 and DDH 5084) were logged with a two-electrode assembly (Fig. 2). Heiland (1946, pp. 826-831) describes the method used. The assembly consists of a current and a potential electrode 10 in apart; this is lowered in a drill hole which contains liquid. The other current and potential electrodes are earthed at the surface and are connected to the terminals of a Megger Earth Tester (resistivity meter); an apparent resistivity is measured in the drill hole at depth intervals of one foot. The variations in apparent resistivity indicate variations in the resistivity of the wall rock of the drill hole. If the salinity of the solutions in the rock pores remains about the same over the logged section, then variations in apparent resistivity indicate variations in rock porosity, and hence in rock type. High-porosity rock has a low resistivity and low-porosity rock has a high resistivity.

SEISMIC

The seismic method of exploration measures the velocity of elastic waves in the near-surface layers of rocks. Its application depends on the difference in the velocities of propagation of elastic waves through different rock formations. When an explosive charge is detonated in the ground, seismic waves are propagated in all directions. The waves are of three types: longitudinal, transverse, and surface waves. Longitudinal and transverse waves are refracted or reflected at the boundary between rocks of different characteristics. Thus the method can measure the depths to interfaces between geological formations that have different seismic velocities.

The seismographs used were a Midwestern reflection/refraction seismograph and a TIC reflection seismograph. The geophones were TIC geophones with a natural frequency of 20 c/s.

Refraction. The seismic refraction method uses the waves refracted at the boundary between rock types. These waves travel along the interface but in the lower rock layer with a higher seismic velocity, and continuously send energy to the surface (Fig. 3). This method requires the lower layer to have a higher seismic velocity than the upper layer. In the Great Lake North District it was possible to determine the depth of weathering, but it was impossible to obtain refraction from the top of sediments under dolerite because the velocity in dolerite is 16,000 to 18,000 ft/s whereas in sediments it is only 8000 to 10,000 ft/s (Wiebenga & Polak, 1957, p.3). The geophones were placed along the traverse at 50-ft intervals. The shots were fired 50 ft and 350 ft beyond both ends of the spread and in line with the spread. The 'method of differences' was used for depth calculations (Heiland, 1946, pp.548-549) and the following types of spread were shot:

1 WEATHERING SPREADS. These were used to obtain the seismic wave velocity and thickness of the soil and near-surface layers. Geophone interval was 10 ft and shot-points were at distances of 5, 10, 20, and 50 ft from both ends of the spread.

FIGS 3-4

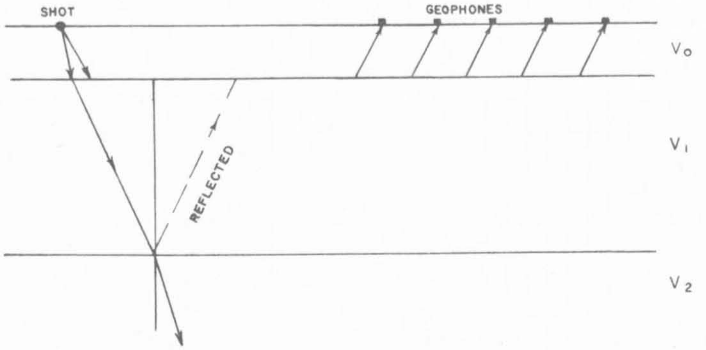


FIG. 3 Refracted waves in area where velocity in second layer V_1 is higher than those in first and third layers.

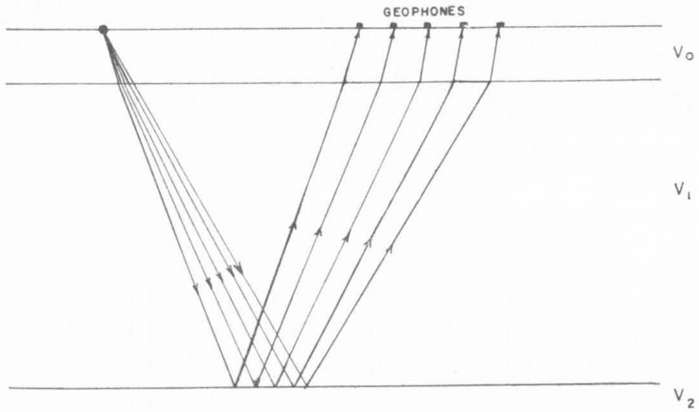


FIG. 4 Reflected waves

ILLUSTRATING SEISMIC METHODS

K55/B5-97

2 NORMAL SPREADS. The geophone interval was 50 ft and the shot-points were at distances of 20, 50, 200, and 400 ft or more from both ends of the spread.

3 BROADSIDE SPREADS. This type of spread was used on steep slopes and the geophones were spaced at 50-ft intervals. The shot-points were up to 1200 ft distant along a line at right angles to the spread from its mid-point.

In the portal area, where the excessive thickness of scree material necessitated the placing of the shot as far as 2000 ft from the first geophone, the method of step-out times (Wiebenga, Dyson & Hawkins, 1956) was substituted for the 'method of differences'.

Reflection. In the seismic reflection method (Heiland, 1946, pp.549-579), the recorded waves from an explosion are reflected from a subsurface layer. The geophones are usually placed in line with and not far from the shot-point; the geophone interval is kept relatively small compared with the depth of the reflecting horizon (Fig. 4). Direct waves and shallow refraction waves arrive at the geophones early and with relatively large phase difference. Reflected waves arrive at the geophones later and with only small phase differences because the differences in the paths travelled are relatively small. This makes it possible to recognise reflections on the records even if the traces are disturbed by other events.

To decrease the background noise of the traces and to make the reflections stand out as clear events, several techniques were used:

(1) Pattern shooting, with four, nine, and sixteen shots in a pattern (Parr & Mayne, 1955).

(2) Air shooting, with shots placed six feet above the ground; the air acts as an additional layer with filtering properties (Poulter, 1950).

(3) Mixing of the geophone traces with geophones spaced at 16, 25, and 50 ft (Parr & Mayne, loc.cit.).

(4) A geophone pattern with six geophones per trace; the geophones were up to 32 ft apart (ibid.).

GRAVITY

The gravity method depends on the density contrast between different types of rock. Heiland (1946, pp.67-70) describes the gravity method. In the present surveys a Worden gravity meter was used. Stations were spaced along the traverses at 50-ft intervals; the elevations were determined with an accuracy at ±0.1 ft.

9. RESULTS: INTAKE TUNNEL AREA (No. 1 TUNNEL OR OLD LINE)

This area extends from station B700 to station B19300. Most of the surface of the western portion of the Area is occupied by scree material and, to a lesser extent, by alluvial deposits. Small outcrops of dolerite are present in the central portion of the Area, and the eastern portion is occupied almost wholly by dolerite. Eleven drill holes were put down in the Area. Of these the two westernmost were entirely in dolerite, but the other nine passed through dolerite and into sedimentary rocks and proved the dolerite to be a sill in that portion of the Area.

These drill holes were put down at different periods, and not all the above information was available in the early stages of the planning of the scheme. The geophysical surveys were made in order to give as much information as possible about the structure underground. The particular problems were:

1 To determine the thicknesses of alluvial deposits, scree material, and the layer of weathered dolerite.

2 To detect any faults, shear zones, etc., in the dolerite.

3 To determine the thickness of the dolerite.

Geophysical surveys were made as follows:

1 Gravity from station B0 to B19200 in 1951.

2 Radioactive, magnetic, resistivity, and seismic refraction between February and May 1956 from station B0 to B5500.

3 As for (2) between December 1957 and February 1958 from station B5500 to B19300.

Gravity

The results of the 1951 survey are shown in the upper part of Plate 2. The lower part of Plate 2 shows a corrected and re-interpreted profile based on information available during and after the 1956 surveys.

In the 1951 survey four traverses were surveyed. Traverse A was along the proposed Tunnel Line No. 1 (later called the Old Tunnel line) and Traverse B along the proposed Tunnel Line No. 2. Traverse C was a short one parallel to Traverse A, and Traverse D a short one crossing Traverse B. Of these four traverses, only Traverse A is shown in Plate 1. Stations were read at intervals of 200 ft.

The observations on Traverse A show that the gravity values decrease from station B0 to about station B11200, and then tend to level out. Although the anomaly appears as a rather gradual feature on the gravity profile, its total magnitude is large, being about 15 milligals, and it must therefore be related to a major geological structure. This gravity anomaly can be accounted for by a major geological feature near station B5400, which would result in a much greater thickness of dolerite on the western side than on its eastern side. In other words, a thick block of dolerite is present on the western side and a thin layer of dolerite overlying sedimentary rocks on the eastern side.

This explanation is consistent with the evidence from the two drill holes, Nos. 5001 and 5002; the first of these continued in fresh dolerite down to a depth of 1049 ft, and the second showed dolerite to a depth of 190 ft, and then sediments continuing to a depth of 1000 ft, the limit reached in the hole.

The gravity profile along the short Traverse C, parallel to Traverse A, showed a trend in the values similar to that observed along A, and indicated that the strike of the feature is approximately at right angles to the traverse direction, i.e., approximately 20 degrees west of north.

The gravity results on Traverse B and the short Traverse D also showed the presence of a large gravity anomaly, which had a magnitude of about 17 milligals; like the anomaly observed on A, this anomaly can be most satisfactorily explained by a major feature, but in this case striking approximately 30 degrees east of north.

The similarity of the gravity anomalies observed on the two main traverses (A and B), both in the gravity gradient and in the total drop in values from west to east, together with the fact that the anomaly on each line is obviously related to a major geological structure, has led to the belief that it is the same feature; it seems reasonable then to assume that north of Traverse A the line of the feature curves somewhat to the north-east, as is tentatively shown in the plan (Plate 1). It will be noted that this line runs roughly parallel to the scarp to the east.

The picture inferred from the gravity results is then that the feature shown on the plan represents the western boundary of the sediments encountered in drill hole No. 5002 and that west of the feature dolerite occurs to a depth which, although proved only to a depth of 1049 ft in drill hole No. 5001, is probably considerably greater than this. If it is assumed that the feature is vertical and the density contrast between dolerite and the sediments is 0.5 g/cm^3, calculations show that the dolerite must be at least 2000 ft thicker on the western than on the eastern side. In other words, there must be approximately this total thickness of dolerite on the western side of the feature, abutting a similar thickness of sediments on the east.

On Traverse A to the east of the major feature near station B5400, the gravity results show no evidence of any major dislocation between the main feature and the Tiers. It is therefore considered that the feldspathic sandstone and the mudstone and shale of the Triassic Coal Measures, proved in drill hole

No. 5002 to be at least 810 ft thick, continue eastwards to the Tiers. The drill hole shows that the bottom of the Triassic Coal Measures is below the 2840 ft level, which is approximately the same elevation as the top of the Knocklofty Sandstones where observed on the Tier face. If it is assumed that the sediments are horizontally bedded, the Triassic Coal Measures must conformably overlie the Knocklofty Sandstones, and there is no evidence to support the theory that an intrusive sill of dolerite has elevated the Triassic Coal Measures and separated them from the Lower Triassic sediments.

The major geological feature referred to above was regarded by N. G. Chamberlain as a major fault with a vertical dip and a downthrow to the west of at least 2000 ft. In departmental correspondence commenting on the report on the 1951 survey, Prof. S. W. Carey, Geological Consultant to the Hydro-Electric Commission, stated that the interpretation of the gravity anomaly as a fault was untenable, and that he regarded the feature as a transgressive contact of the dolerite with the sedimentary rocks, and that the contact was a shelving one.

In the final report on the 1956 geophysical survey, the gravity values obtained in the 1951 survey were corrected, and because of this, and because additional geological information was obtained between the two surveys, the gravity data were re-interpreted.

For the calculation of Bouguer and terrain corrections the density of the dolerite was taken as 2.95 g/cm^3 (Jaeger & Joplin, 1955). To ensure that the contact between the dolerite and sedimentary rocks was below the reference level along the profile, a level of 3900 ft above datum was taken as reference.

The recalculated gravity profile between stations B0 and B19200 is shown in Plate 2, together with a detailed profile between stations B6000 and B19400. By applying the above corrections to the gravity data, the variations in thickness of the dolerite may be deduced directly from variations in the gravity profile.

An apparent discrepancy is revealed if the difference between the corrected Bouguer gravity values near DDH 5002 and DDH 5033 is compared with the difference in elevation of the contact of the dolerite and sedimentary rocks at these drill holes. This discrepancy is probably due to a regional gravity trend, which, unfortunately, is not clearly indicated in Plate 2 because of the lack of sufficient data.

Major variations in the gravity profile near stations B9000, B14000 and B16000 suggest sudden changes in the thickness of the dolerite. In Plate 2 these changes in thickness have been interpreted as faults F1, F2, and F3, but this interpretation is by no means certain. An alternative interpretation is that the dolerite sill was not intruded along a single bedding plane, and it therefore varies in thickness.

On the eastern part of Traverse A there are also three small anomalies. These anomalies may indicate minor faults located at stations B8600, B10200 and B13000. The size of the anomalies indicates that the respective throws of the faults must be comparatively small. The block between stations B8600 and B10200 is downthrown relative to the rocks on either side, the throw being probably no more than 200 or 300 ft. At station B13000 the rocks on the east side of the fault appear to be downthrown by a smaller amount.

The reinterpretation of the data confirmed the existence and approximate position of the major geological structure (transgressive contact), near station B5000. The position was confirmed by the profiles of the vertical magnetic intensity and the resistivity surveys. The gravity method is not sufficiently sensitive to determine the dip of the transgressive contact.

Radioactivity

Surveys were made over the western portion (stations B800 to B5600) in 1956. The profile is shown in Plate 3, but it does not show any anomalies.

The surface is occupied by either scree material or alluvial deposits. The layers of these rocks would obscure any radioactive effects arising from concentrations of radon in shear and fracture zones in the underlying dolerite. As a result, no anomaly appears in the profile and it is clear that the method cannot give any useful results in this Area.

Magnetic

The western portion (stations B700 to B5500) was surveyed in 1956 and the eastern portion (stations B5500 to B19300) in 1957-58. The profiles are shown in Plates 3 and 5. Values for the magnetic susceptibility and remanent magnetism of the dolerite in DDH 5001 have been given in Chapter 7.

Between stations B700 and B5000 the profile has several peaks and troughs. The low values may be the result of:

(a) Local change in magnitude of magnetic susceptibility of the dolerite.

(b) Change in direction of the remanent magnetism.

(c) Demagnetisation of dolerite in shear zones.

At station B5100 the values decrease sharply, and low and uniform values continue for the remainder of the tunnel line. The sharp decrease indicates a considerably smaller thickness of dolerite east of station B5100. This difference confirms the result of the gravity survey.

Between stations B5100 and B19500, minor anomalies occur at stations B10200, B14100, B15400, B16000, and B17000.

The negative gravity and magnetic anomaly at station B10200 is interpreted as a local thickening of scree material at the side of dolerite cliffs, and is possibly associated with a fault. Dolerite cliffs are present at station B10700 where a steep rise to the east in vertical magnetic intensity is evident. F2 is the position of a fault as indicated by Wiebenga and Polak (1957). The evidence of the 1957-58 survey indicates that F2 is between stations B14000 and B14200.

The magnetic and seismic evidence suggests the possibility of faults at station B15400 and at B16000 (F3). The thickening of the weathered layer and the negative magnetic anomaly at station B17000 may represent a fault.

All the features mentioned above are indicated by the letter P in Plates 5 and 1.

Resistivity

Surveys were made in 1956 between stations B700 and B6600. The profiles for electrode spacings of 50, 100, and 200 ft respectively are shown in Plate 3. Depth probes were made at the places shown in Plate 3.

The profiles show many peaks and troughs. The troughs correspond to low resistivity, and zones of low resistivity may indicate shear zones. Zones of low resistivity may arise from other features, however. For example, such zones, especially if they are limited to the near-surface, may be caused by local thick accumulations of soil. In Plate 3, possible shear zones at tunnel level are shown on a vertical section; these are based on the interpretation of constant spacing profiles and depth probes.

Seismic refraction

The results of the seismic refraction survey in 1956 from station B700 to B5500 are shown in general form in Plate 3 and in detail in Plate 4. Four layers are shown, with velocity ranges as follows:

1	0 - 6 000	ft/s
2	8 600 - 11 000	,,
3	13 000 - 15 000	,,
4	13 000 - 20 000	,,

Layer (1) is interpreted as marsh deposits, completely weathered dolerite, and scree material. Layer (2) is slightly weathered jointed dolerite. Layers (3) and (4) are unweathered dolerite.

The determinations of thickness of the scree material and weathered dolerite are considered to have an accuracy of about ± 15 percent. Drill hole 5073 was used as a control. It was difficult, however, to determine accurately the lower limit of the partly weathered (or jointed) dolerite because of the gradual transition from partly weathered to unweathered dolerite.

The 1957-58 seismic refraction survey was made over parts of the remainder of the intake tunnel line, namely from station B5500 to B8000 and from station B12500 to B17500. The results are shown in Plate 5. Layers with velocities of 1000, 2300, 3000, 5000, and 11000 ft/s are shown at a few points, and are included in a layer of irregular thickness marked as weathered rock. Below this layer, velocities of 17000, 18000, and 19000 ft/s are shown; these velocities are regarded as being characteristic of unweathered rock. The thickness of the layer of weathered rock ranges from about 15 to 115 ft. In some places there are appreciable increases in depth over short distances; these may represent fault or shear zones that have permitted weathering to extend to greater depths than elsewhere. Examples are at stations B15400, B16000, and B17000, and the magnetic profile also indicates the possibilities of fault or shear zones at these places.

Between stations B6000 and B19300, sedimentary rocks underlie the dolerite, but it was not possible to get a refraction from this surface and therefore not possible to determine the thickness of the dolerite. The reason for the absence of refraction is that the velocity in the dolerite (16000 to 18000 ft/s) is higher than that in the sedimentary rocks (8000 to 10000 ft/s).

Seismic reflection

In the 1957-58 survey the seismic reflection method was used to try to determine the thickness of the dolerite between stations B5500 and B9500, and between stations B12500 and B17500. Despite the use of the techniques described in Chapter 8, no readable reflections were recorded that might indicate the thickness of the dolerite layer; hence the seismic reflection method yielded no results.

Several explanations for the failure to obtain reflections can be suggested.

(a) The Midwestern seismograph had a frequency range of 75 to 400 c/s, and the TIC seismograph had a frequency range of 5 to 45 c/s. Reflections possibly occurred in the frequency range 45 to 75 c/s, but as this range is outside the filter setting ranges of both seismographs these reflections would not be recorded. A ground roll with a velocity of about 9000 ft/s and a frequency of 60 to 65 c/s was recorded on refraction settings, and probably would have overshadowed the reflection events in the 45- to 75-c/s range even if this filter range had been available.

(b) The dolerite is probably fractured along fault and shear zones, and may possibly be zoned. Under such conditions the seismic energy may possibly have been completely dispersed within the dolerite.

Micro-Magnetic

Two micro-magnetic panels each containing 88 stations with a station interval of 10 ft were surveyed around stations B3850 and B15900. The layout and results are shown in Plate 6. A Hilger & Watts vertical variometer was used.

Following Lauterbach's procedure (Wiebenga, 1958) a frequency analysis of the direction of the contours at each station was made; the results are plotted in histograms (Plate 6) and are summarised in Table 5.

TABLE 5: STRIKES OF FEATURES INDICATED BY MICRO-MAGNETIC HISTOGRAMS

Station	*Range of predominant strikes*	*Frequency as percentage of total*
	25° to 55°	28
B3850	270° to 275°	8
	355° to 10°	26
	45° to 70°	44
B15900	270° to 275°	6
	315° to 330°	27
	335° to 10°	17

Both histograms suggest the presence of faults or fractures with northerly, north-easterly, and westerly strikes. Trends with a north-westerly strike, strongly represented at station B15900, are missing at station B3850. On the other hand, the three trends mentioned for station B3850 are somewhat overshadowed by other trends which possibly represent cooling joints. The presence of cooling joints would indicate that the dolerite in this locality is close to a contact; this is confirmed by Jaeger and Green (1958, pp. 34-36) and by the discovery of Permian rocks close to station B2000 (E. A. W. Clothier, pers. comm.).

10. RESULTS: INTAKE TUNNEL AREA (NEW LINE)

In 1959 the Hydro-Electric Commission selected a new line for the proposed intake tunnel. The New Tunnel line is north of the Old Tunnel line; at the western end the two lines coincide, but at 10,000 ft on the new line the lines are 500 ft apart (see Plate 1). The difference between the zero points of the surveys of the two lines has been explained in Chapter 4.

The geological structure is the same as for the Old Tunnel line, and the objects of the geophysical surveys over the new line were identical with those over the old line.

The methods used were gravity, magnetic, resistivity, and seismic refraction. Surveys were made of the westernmost 6000 ft of the new intake tunnel line during December 1959.

Gravity

The gravity profile of the New Tunnel line is shown in Plate 7 and closely resembles that of the Old Tunnel line. A comparison suggests that the dolerite thins abruptly near station T140 (4500 ft). Also, a Bouguer gravity interval of 11 mgal between stations T60 and T160 indicates that the dolerite at the western end of the tunnel line must have a thickness between 2300 and 4600 ft; this is the same thickness as estimated for the Old Tunnel line.

An estimate of the density contrast between the dolerite and underlying sediments can be made from the gravity stations near DDH 5083 and DDH 5084 at the centre of the ridge (see Plate 1). Correcting for the weathered layer, the gravity difference between the two stations is $1.21 + 0.14 = 1.35$ mgal. The elevation difference of the lower dolerite contact is 512 ft. The density contrast is obtained from the following formula derived from Dobrin (1960, p. 175):

$$\triangle g = 12.77 \text{ L } \triangle d$$

in which $\triangle g$ is gravity difference, L the thickness of a layer in kilofeet, and $\triangle d$ the density contrast in g/cm^3. The density contrast is 0.21, i.e. about half the density contrast originally used in interpreting the gravity survey; hence variations in dolerite thickness may be up to twice the amount originally computed from the gravity results.

The dolerite is more than 400 ft thick at DDH 5073, about 104 ft thick at DDH 5042, and it thins abruptly close to station T160. The Bouguer gravity interval between stations T60 and 6400 ft is about 12 mgal. If the original value of 0.4 g/cm^3 is assumed for the density contrast then the dolerite thickness on the western end of the tunnel line is about 2300 ft; but if a density contrast of 0.2 is assumed, then the dolerite thickness is about 4600 ft. These two estimates can be used as limits.

A tracing of the gravity profile of the Old Tunnel line was superimposed on the gravity profile of the New Tunnel line, and corresponding features were identified. These corresponding features were plotted on the plan of the Old and New Tunnel lines, and the strike of these features appeared to be about 096° and to cut the tunnel line at an acute angle of about 25° (Plate 1).

It follows that the edge of the zone where the dolerite thins abruptly has a strike of 096°, and that the faults or shears located on the New Tunnel line near station T135 and at stations T154, T175 and T204 are parallel to the edge of this zone, and also have a strike of 096°. The strike of these features coincides with a major trend shown by the histograms of the micro-magnetic panels (Plate 6).

Magnetic

Profiles for vertical and horizontal intensities are shown in Plate 7. The profile of vertical intensity is generally similar to that over the Old Tunnel line and reveals similar anomalies, but the anomalies are not at the same positions along the traverse line.

Resistivity

Surveys were made between stations T50 and T190 (0 to 7000 ft) with electrode spacings of 50 and 100 ft. The profiles are shown in Plate 7. The profiles are generally similar to those for the Old Tunnel line, and have similar anomalies, but the anomalies are not at the same positions along the traverse. Fault and shear zones are indicated at stations 64, 71, 102, 118, 129, 137, 153, 174, 184 and 203 and possible zones at stations 86 and 92.

Seismic refraction

Surveys were made from stations T50 to T174 (0 to 6000 ft). The results are shown in generalised form in Plate 7 and in detail in Plates 8 and 9. The detailed results show at several places two to four layers with some of the following seismic velocities, in feet per second: 1000, 2300, 2800, 3000, 5000, 5500, 6000 and 11,000; below these layers there is bedrock with velocities of 16,000, 17,000 or 18,000 ft/s. The generalised results show a layer of weathered bedrock (dolerite) ranging in thickness from 10 ft at station T60 to 98 ft at station T137; this includes all layers with velocities less than 16,000 ft/s. This layer includes alluvial deposits and scree material as well as weathered dolerite.

In some places there are considerable increases in depth over short distances, and these deeper portions may represent weathering that extends to greater depths. Examples are at stations T72, T118, T137 and T154. These places correspond generally with fault or shear zones deduced from the resistivity profiles.

11. RESULTS: OUTLET PORTAL AREA

The Outlet Portal Area extends from station A19700 to station A23550 (see Plates 1 and 10).

The geological plan (Plate 1) shows that scree material occupies almost all the surface of this Area. The geological section (Plate 10) shows that the dolerite sill may extend from the west into the western part of the Area and that Cluan Sandstone occurs under the scree material on the remainder of the Area and overlies the Ross Sandstone. These Triassic sedimentary rocks are bedded almost horizontally. The above information as to the rocks and formations is based on drill holes 5030, 5032, and 5033.

The problems to be investigated were the thickness of the scree material and the detection and location of any shear zones in the rocks beneath the scree material. Geophysical surveys were made between February and May 1956.

Radioactivity

The profile is shown in Plate 10. It shows that the values are uniform and that no anomaly is present that could indicate a shear or fault or other geological feature.

Magnetic

Only the vertical component of the Earth's field was measured. The profile is shown in Plate 10. The profile between stations A19700 and A22400 is relatively uniform with only a few minor peaks and troughs on it. This uniformity in values may be due partly to demagnetisation of the dolerite boulders in the scree material as a result of weathering, and partly to a random orientation of the magnetic intensity vectors of the dolerite boulders in the scree material; this implies the presence of remanent magnetisation (Irving, 1956).

One of the minor but important features on the profile is the anomaly between stations A20900 and A21200. The anomaly resembles that of the theoretical curve obtained over the edge of a slab of magnetised material, and suggests that this feature indicates the eastern edge of the dolerite sill. This is confirmed by the results of the seismic survey and is proved by drill holes 5033 and 5032 which show that the eastern boundary of the dolerite is between them.

The profile near station A22400 indicates the thinning-out of the scree material towards the east, with increased influence of small and shallow depressions in the weathered rocks beneath the scree material and which probably contain local concentrations of magnetite.

The irregularity of the profile between stations A22400 and A23550 suggests that magnetite minerals occur at or near the surface. Such occurrences may be accumulations of magnetite from weathered dolerite on ledges on the eastern slope of the Tiers. These conditions continue as far as station A25300 on the Penstock Line Area to the east.

Resistivity

The Wenner arrangement of four equally spaced electrodes in a straight line was used. The electrodes were moved along the traverse as a group, readings being taken at consecutive stations.

The profiles for spacings of 50, 100, and 200 ft are shown in Plate 10. Only the eastern part of the Outlet Portal Area was surveyed, namely from station A22600 to A23550.

For 50-ft spacing, the profile shows a sharp decrease in value near station A23200 and then continues at a uniformly low value for the remainder of the Portal Area. This sharp decrease marks the eastern boundary of the scree material. The uniformly low resistivity east of station A23200 and extending onto the Penstock Line Area corresponds to the outcropping Cluan Sandstone.

Seismic refraction

The 'method of differences' was employed; weathering, normal, and broadside spreads of geophones were used.

The results are shown in general form in Plate 10 and in detail in Plate 11. Plate 11 shows the layers of differing seismic velocities and the formations corresponding to such layers, namely scree material, dolerite, weathered sediments, partly weathered sediments, and unweathered sediments. The thicknesses of these layers as determined by the seismic survey are indicated in Plate 11 and may be summarised as:

Scree material	0 to 400 ft
Weathered sediments	0 to 90 ft
Partly weathered sediments	50 to 120 ft

Dolerite and unweathered sediments are also shown but not their thicknesses. The seismic survey did not indicate any layer of weathered sediments beneath the scree material around and between drill holes 5032 and 5030, although these drill holes revealed 29 and 21 feet of weathered sediments respectively. It appears that both the velocity contrast between weathered and unweathered sediments and the thickness of weathered sediments are too small to enable the seismic refraction method to detect the layer of weathered sediments in this part of the Area.

In the Outlet Portal Area, the vertical velocities were determined in three test pits between 27 and 34 ft deep. The computed thicknesses of scree material were checked by drill holes DDH 5031 and 5032 and the maximum error is less than 10 percent. It is therefore considered that the section between DDH 5031 and DDH 5032 has been determined with a possible error within $\pm$ 10 percent.

The profile of the part of the Outlet Portal Area between DDH 5032 and the cliff edge, where unweathered dolerite crops out, was computed by a method of step-out times using DDH 5032 as a tie-point. The accuracy is considered to be high. This was confirmed at DDH 5033, where the seismic results indicated unweathered dolerite beneath the scree material at 360 ft and subsequently the diamond-drill hole showed unweathered dolerite between 362 ft and 432 ft.

The results indicate that the eastern boundary of the dolerite sill is near station A21000. This is in agreement with the results of the magnetic survey and is confirmed by the information from drill holes 5033 and 5032.

12. RESULTS: PENSTOCK LINE AREA

This section of the scheme extends from station A23550 to station A28400 (see Plates 1 and 10). It is located on a spur on the face of the Western Tiers.

The geological plan and sections show that scree material occurs immediately to the west of the Area but that Triassic and Permian rocks crop out over the Area except where a layer of soil is present. The Triassic rocks include the Cluan Sandstone, Ross Sandstone, and Jackey Shale; the Permian rocks include formations from the Blackwood Conglomerate to the Woodbridge Tillitic Mudstone. [illegible] rmian rocks are almost horizontally bedded. Three faults in [illegible] of the Area were mapped geologically; they have northerly strikes.

The problems to be investigated by the geophysical surveys were the determination of the thicknesses of the layers of soil and scree material and of the zone of weathered rocks; also, if possible, the type of rock below the weathered layer. Geophysical surveys were made between February and May 1956.

Radioactivity

The profile is shown in Plate 10. The values were uniform and there is no anomaly present that could indicate a shear or fault zone or other geological feature.

Magnetic

Only the vertical component of the Earth's field was measured. The profile is shown in Plate 10. From station A23550 to A24800 the profile shows a slight increase in intensity; the small irregularities on it are probably caused (as in the Outlet Portal Area to the west) by magnetite at or near the surface. The magnetite would be derived from weathered dolerite to the west, and probably accumulated on ledges. East of station A24800 the intensity increases sharply and attains a maximum value between stations A24950 and A25200. It then falls sharply and maintains a generally uniform value to station A28400. A comparison of the profile with the geological section (see Plate 10) shows that the higher values correspond to outcrop of the Ross Sandstone and that the maximum values correspond to the lower part of the Ross Sandstone (and possibly the Jackey Shale). The uniform profile between stations A25500 and A28400 shows no anomaly that could be correlated with geological features, but apparently corresponds to mudstones of the Ferntree Group.

Resistivity

The Wenner arrangement of four equally spaced electrodes in a straight line was used. The electrodes were moved along the traverse as a group, readings being taken at consecutive stations. The profiles for spacings of 50, 100, and 200 ft are shown in Plate 10.

The profile for 50-ft spacing has low and uniform values between stations A23200 and A23650 and these correspond to the Cluan Sandstone. Between stations A23650 and A25350 the resistivity values increase but the profile has subsidiary peaks and troughs on it; this part of the profile corresponds to outcropping Ross Sandstone. Between stations A25500 and A28400 the values are low and generally uniform with only minor features on the profile.

The profiles for 100- and 200-ft spacings are generally irregular. The profile for 200-ft spacing shows several peaks between stations A25500 and A28400; these peaks may indicate beds of sandstone (high resistivity) alternating with beds of shale (low resistivity).

Seismic refraction

The 'method of differences' was employed; weathering, normal, and broadside spreads of geophones were used.

The results of the seismic survey between stations A23600 and A28200 are shown in Plate 10 and in greater detail in Plate 12. Between stations A28200 and A28400, the land was disturbed by road building and could not be surveyed. Plate 12 shows the layers of differing seismic velocities and also the formations corresponding to such layers, namely soil, weathered sediments, and unweathered sediments. The thickness of soil as determined by the seismic survey ranges up to 45 ft. The thickness of the layer of weathered rocks ranges from 10 to 110 ft.

A notable feature of the upper boundary of the unweathered rocks is the indication of ledges (probably of sandstone) near stations A24200, A25100, A25850, A26400, and A26800.

No data are available to check the seismic results in the Penstock Line Area but it is considered that the thickness of soil (low-velocity layer) has been determined with an error within $\pm$ 10 percent of depth. The accuracy in determining the thickness of the weathered sediments below the soil layer is probably not as high, and the error may be as much as $\pm$ 25 percent of depth.

13. RESULTS: TAILRACE TUNNEL AREA

This section of the scheme extends from station A28400 to station A38000 (see Plates 1 and 13).

The geological longitudinal section in Plate 1 shows that the tailrace tunnel will be in Permian sedimentary rocks (Liffey Sandstone at the western end, but Golden Valley Group for the greater part of its length). These formations, together with the overlying Woodbridge Tillitic Mudstone, occur at the surface above the remainder of the tunnel line. The Permian sedimentary rocks are almost horizontally bedded.

The particular problem to be investigated by geophysical survey was the detection of any faults and shear zones along the tunnel line.

The geophysical survey was made between February and May 1956. The method used was a resistivity one employing the Wenner arrangement of four equally spaced electrodes in a straight line. The electrodes were moved along the traverse as a group, readings being taken at consecutive stations.

The resistivity profiles for constant electrode spacings of 50, 100, and 200 ft are given in Plate 13.

The profile for 50-ft electrode spacing shows that the resistivity values are low and fairly uniform. The reason for such values is that the measurements are mainly of the alluvial deposits, and the deeper rocks had little effect on the values.

The profiles for 100-ft and 200-ft electrode spacings were not so uniform, and the values were higher because the effect of the Permian rocks was greater. The profiles contained many narrow peaks and troughs. It was thought at first (and so stated in *Record No. 1959/69*) that the troughs, or zones of low resistivity, might indicate shears, but close examination of the geological data (McKellar, 1956) suggested that the peaks and troughs in the resistivity profiles are more likely to be indications of alternating bands of sandstone and shale in the unweathered Permian rocks combined with local changes in the thickness of the overlying alluvial deposits.

The sudden decrease in resistivity near station A34000 (particularly on the profile for 200-ft electrode spacing) may indicate a fault or a buried sandstone cliff with mudstone to the east and shaly sandstone to the west.

14. CONCLUSIONS

The radioactivity and seismic reflection methods yielded no useful results because the geological conditions were not suitable for the application of these methods.

The magnetic, resistivity, seismic refraction, and gravity methods yielded numerous important results and indicated many geological features. At many places the results of two or more methods gave independent and confirmatory evidence of the presence and position of the same geological feature. The most important geological features indicated were:

(1) Thickness of dolerite.

(2) Faults and shear zones.

(3) Strikes of faults, fractures, and joints.

(4) Presence and thicknesses of layers of soil, scree material, weathered and partly weathered dolerite and sedimentary rocks, and the thinning out or termination of such layers.

(5) Eastern edge of dolerite sill.

(6) Ledges of bedrock or sedimentary rocks on the face of the Western Tiers.

In some places, such features occurred where engineering works were to be planned and constructed, and the advance information regarding their presence and factors associated with them was of the utmost importance for the planning, costing, and construction.

The most important feature indicated by the geophysical surveys was the large difference in thickness of the dolerite east and west of station B5400. The 1951 gravity survey indicated such a feature, and re-interpretation in 1957 in the light of additional geological information confirmed this feature. The results of the 1959 gravity survey along the New Tunnel line also confirmed this feature and indicated that it occurred near station T140 (4500 ft). The interpretation of this feature was that to the east of station T140 the outcropping dolerite occurs as a sill (up to about 1180 ft thick) overlying sedimentary rocks, but that west from station T140 the dolerite has a thickness of 2300 to 4600 ft. This showed that the dolerite contact is transgressive to the sedimentary rocks. The magnetic (vertical intensity) and resistivity surveys confirmed the position of this transgressive contact.

The presence of this thick body of dolerite made it clear that the westernmost 5000 ft of the intake tunnel would have to be driven through dolerite, whereas if the dolerite had continued to the west as a sill the intake tunnel would have been in the softer and less tough sedimentary rocks. Advance information on this matter greatly assisted the planning, costing, and construction of the tunnel.

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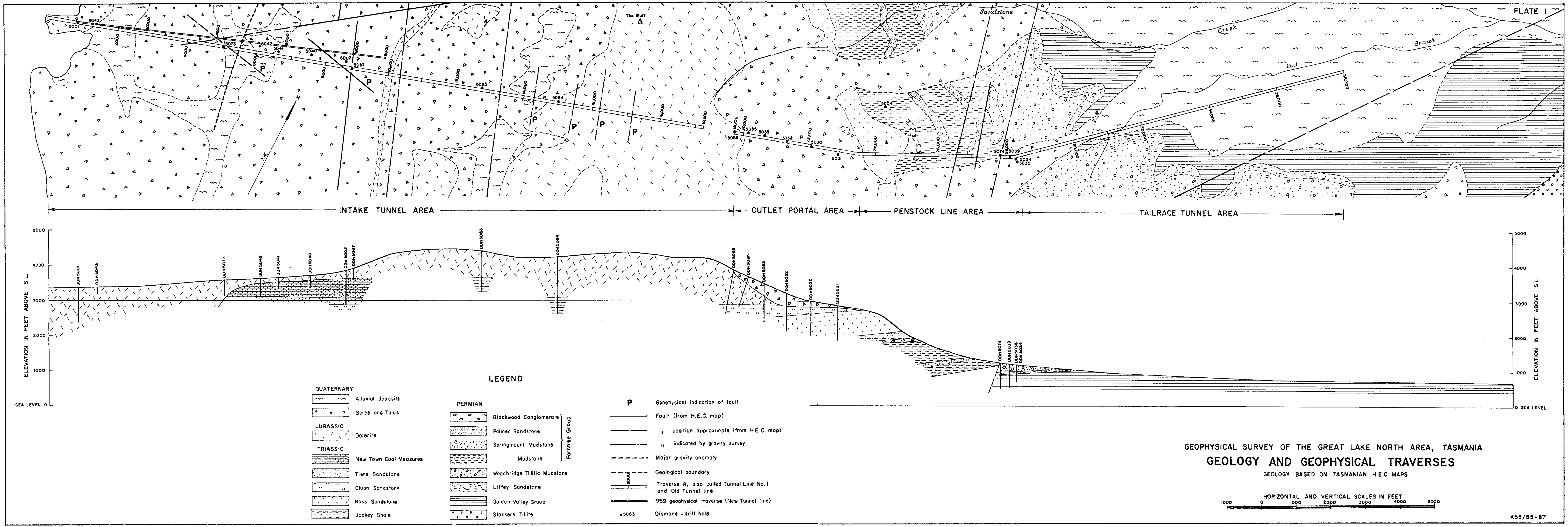
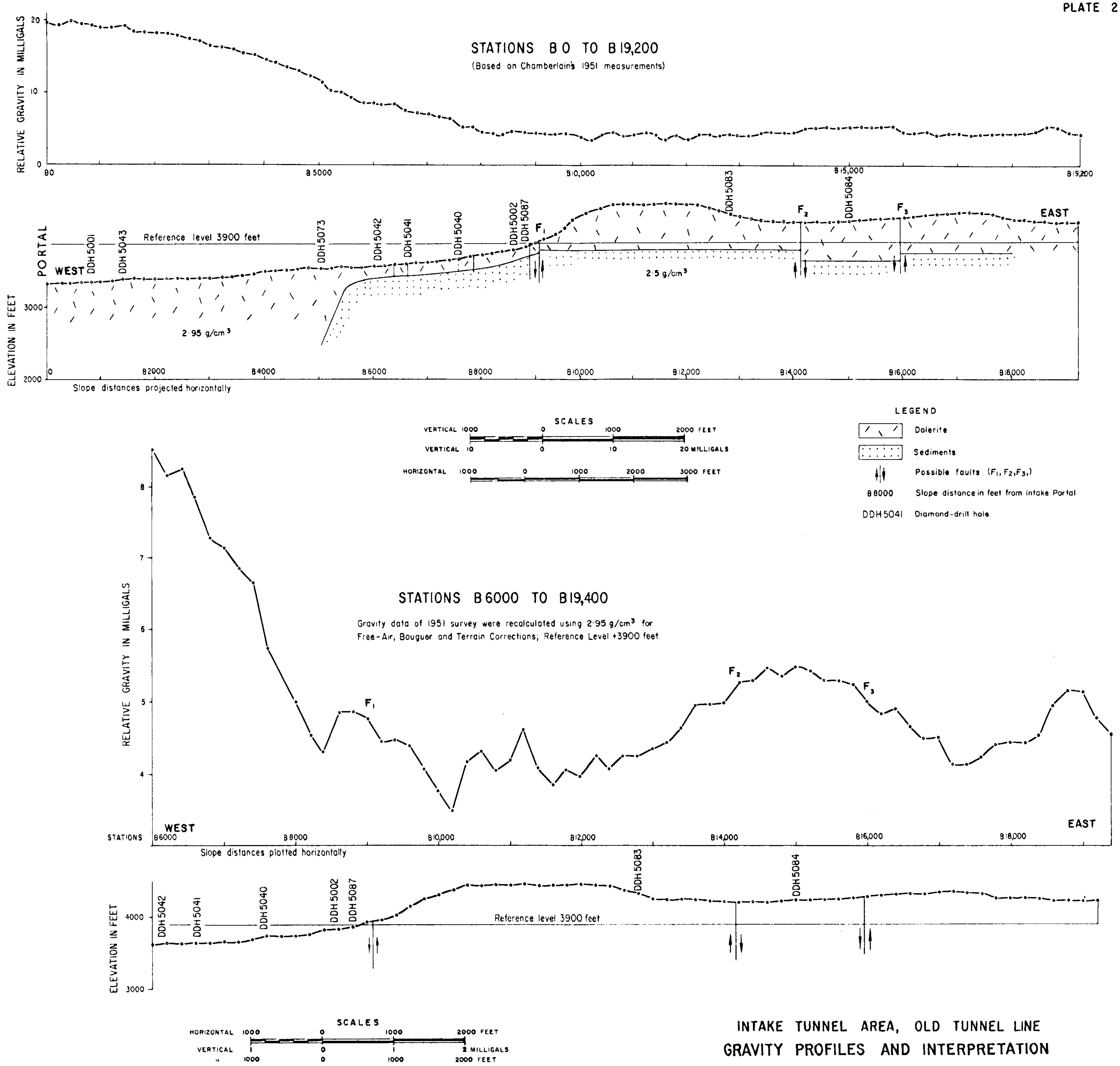


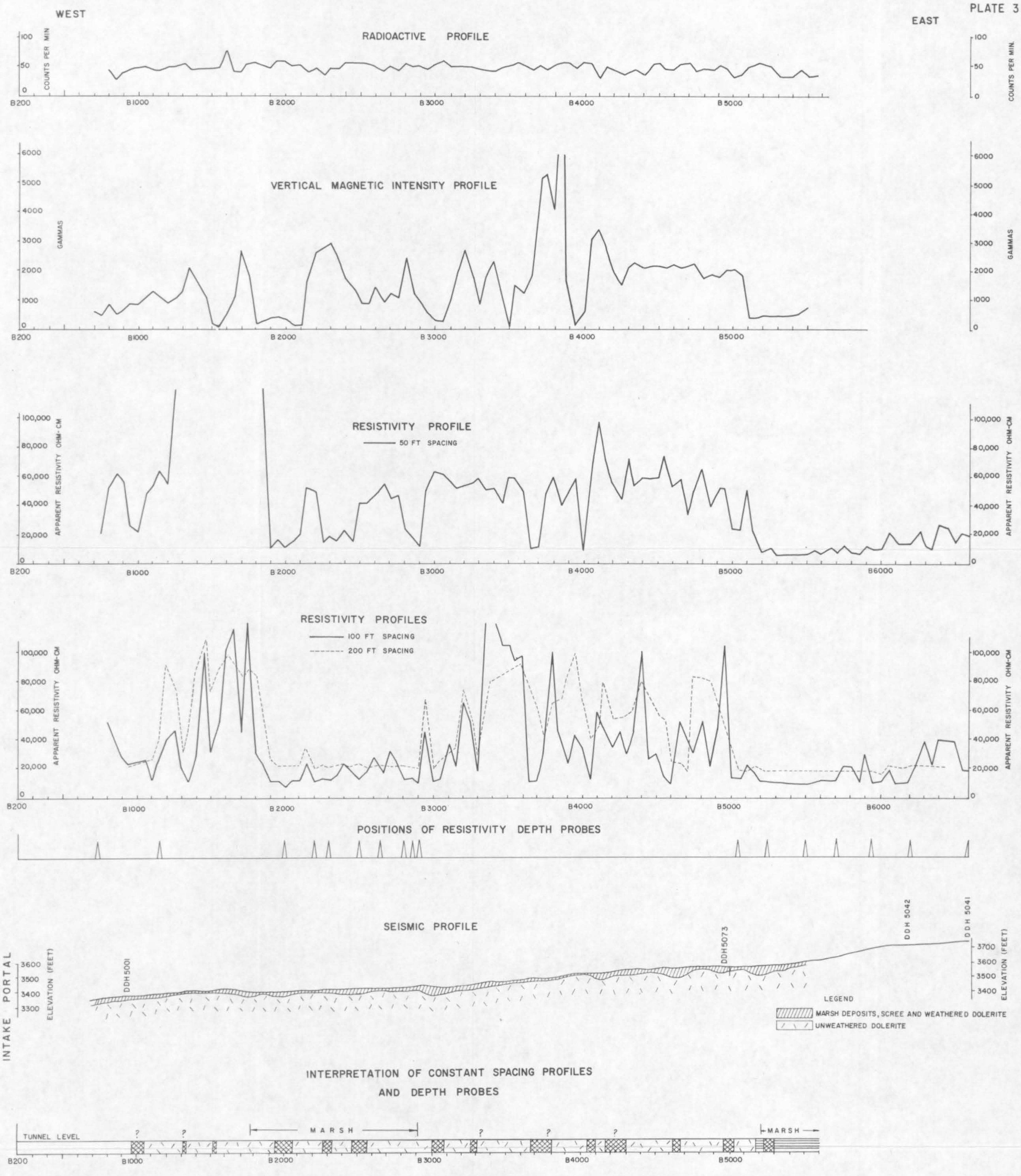
PLATE I
The Bluff
Sandstone
Creek
East
Branch
INTAKE TUNNEL AREA
OUTLET PORTAL AREA
PENSTOCK LINE AREA
TAILRACE TUNNEL AREA
ELEVATION IN FEET ABOVE S.L.
SEA LEVEL
LEGEND
QUATERNARY
Alluvial deposits
Scree and Talus
JURASSIC
Dolerite
TRIASSIC
New Town Coal Measures
Tiers Sandstone
Cluan Sandstone
Ross Sandstone
Jockey Shale
PERMIAN
Blackwood Conglomerate
Palmer Sandstone
Springmount Mudstone
Mudstone
Ferntree Group
Woodbridge Tillitic Mudstone
Liffey Sandstone
Golden Valley Group
Stockers Tillite
Geophysical indication of fault
Fault (from H.E.C. map)
" position approximate (from H.E.C. map)
" indicated by gravity survey
Major gravity anomaly
Geological boundary
Traverse A, also called Tunnel Line No. 1 and Old Tunnel line
1959 geophysical traverse (New Tunnel line)
Diamond - drill hole
GEOPHYSICAL SURVEY OF THE GREAT LAKE NORTH AREA, TASMANIA
GEOLOGY AND GEOPHYSICAL TRAVERSES
GEOLOGY BASED ON TASMANIAN H.E.C. MAPS
HORIZONTAL AND VERTICAL SCALES IN FEET
K55/B5-87



INTAKE TUNNEL AREA, OLD TUNNEL LINE
GRAVITY PROFILES AND INTERPRETATION

K55/B5-90

PLATE 3



LEGEND

UNWEATHERED DOLERITE

SHEAR ZONE

SEDIMENTS

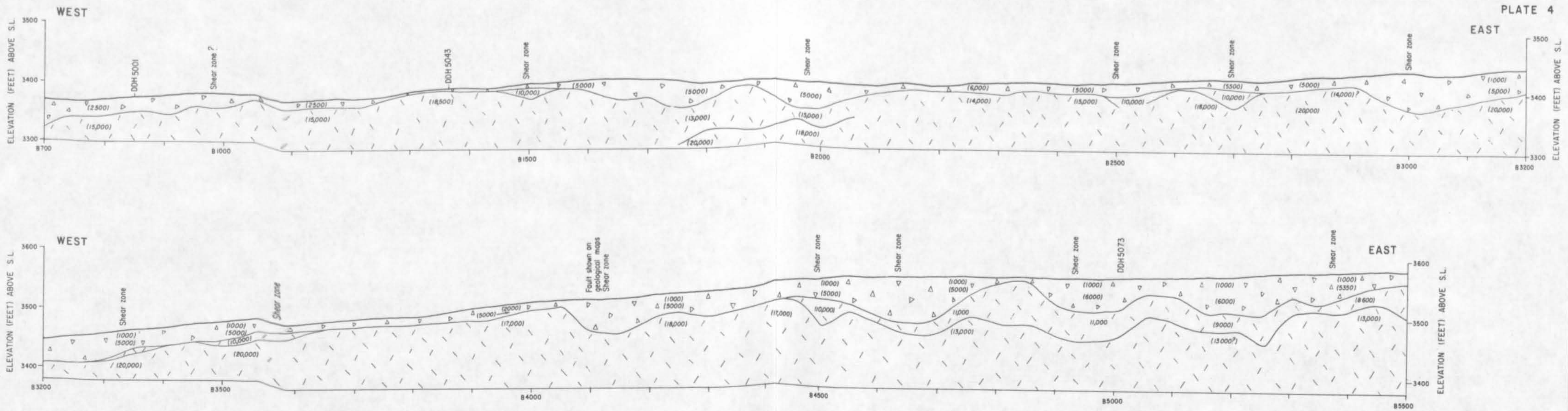
B 2000 HORIZONTAL DISTANCE IN FEET

SCALE IN FEET

0 500 1000

INTAKE TUNNEL AREA, OLD TUNNEL LINE,
STATIONS B700 TO B5500
RADIOACTIVE, MAGNETIC, RESISTIVITY, SEISMIC PROFILES,
AND INTERPRETATION OF RESISTIVITY DATA

K55/B5-88



LEGEND

DDH 5001	Diamond-drill hole
(6000)	Seismic velocity (ft/s) in formation
B3500	Slope distance in feet from intake portal
△ ▽	Scree material and weathered dolerite
/ \ /	Unweathered dolerite

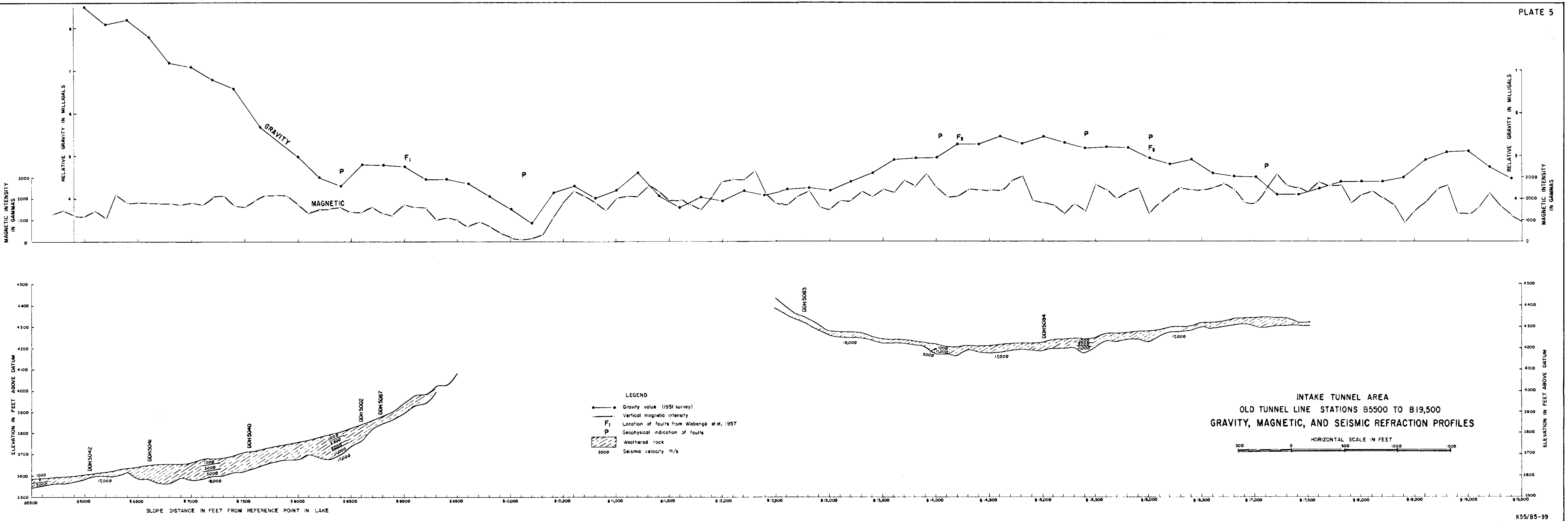
HORIZONTAL AND VERTICAL SCALES IN FEET

100 0 100 200 300 400

NOTE: Thickness of strata calculated from seismic results.
Shear zones shown are taken from interpretations of resistivity results Plate 3

INTAKE TUNNEL AREA, OLD TUNNEL LINE
STATIONS B700 TO B5500
DETAILED SEISMIC PROFILE

K55/B5-89

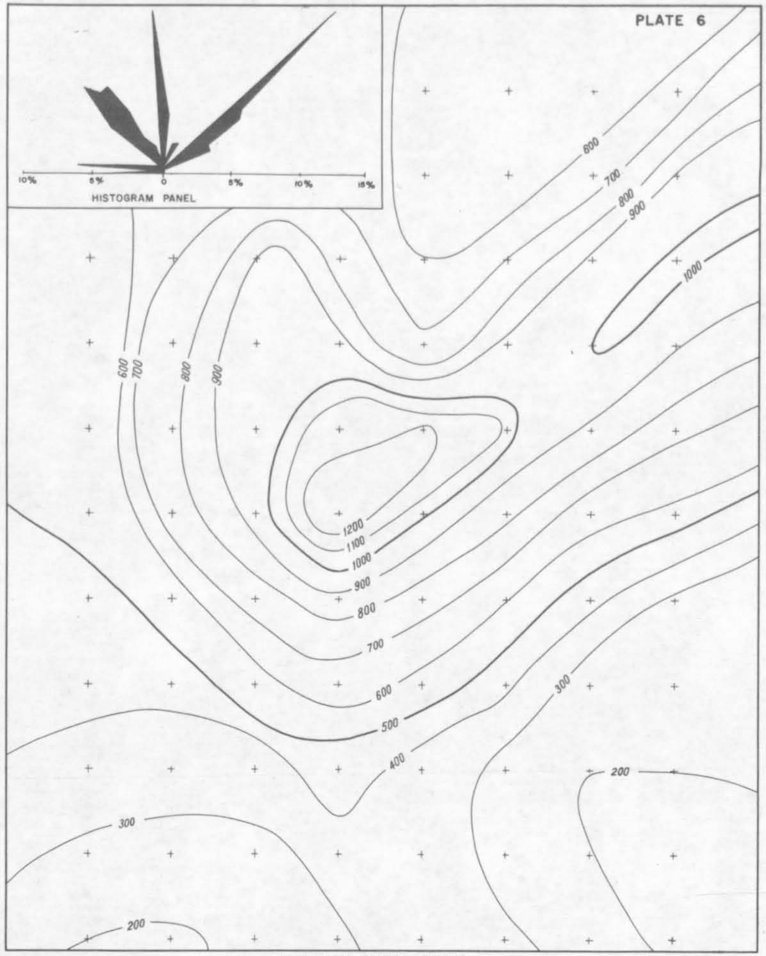


INTAKE TUNNEL AREA
OLD TUNNEL LINE STATIONS B5500 TO B19,500
GRAVITY, MAGNETIC, AND SEISMIC REFRACTION PROFILES

K55/B5-99

PLATE 6

PANEL NEAR STATION B 3850



PANEL NEAR STATION B 15,900

LEGEND

+ Magnetic station

1000 / 900 Magnetic contours in gammas

FEET

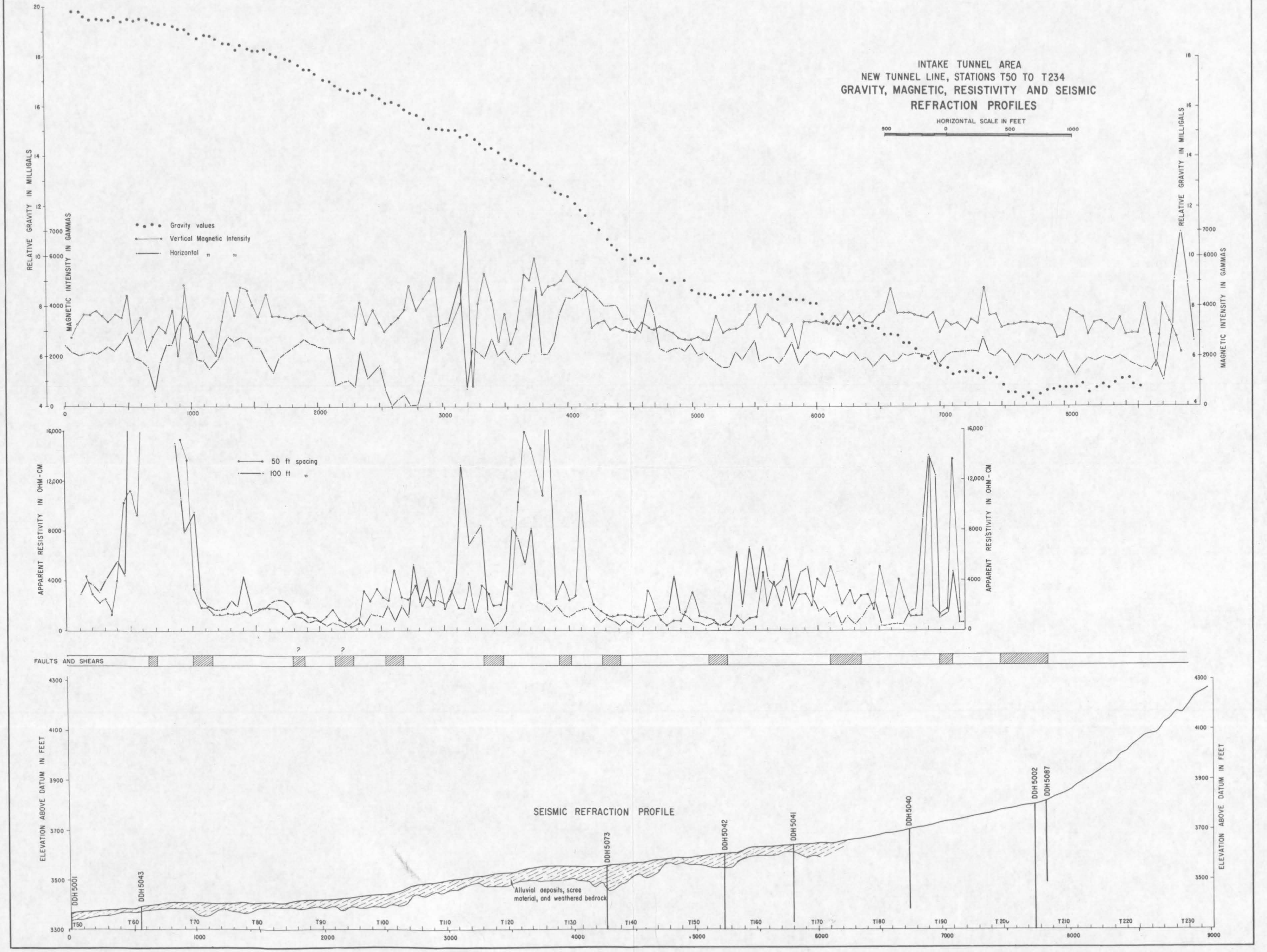
10 0 10 20 30

INTAKE TUNNEL AREA, OLD TUNNEL LINE

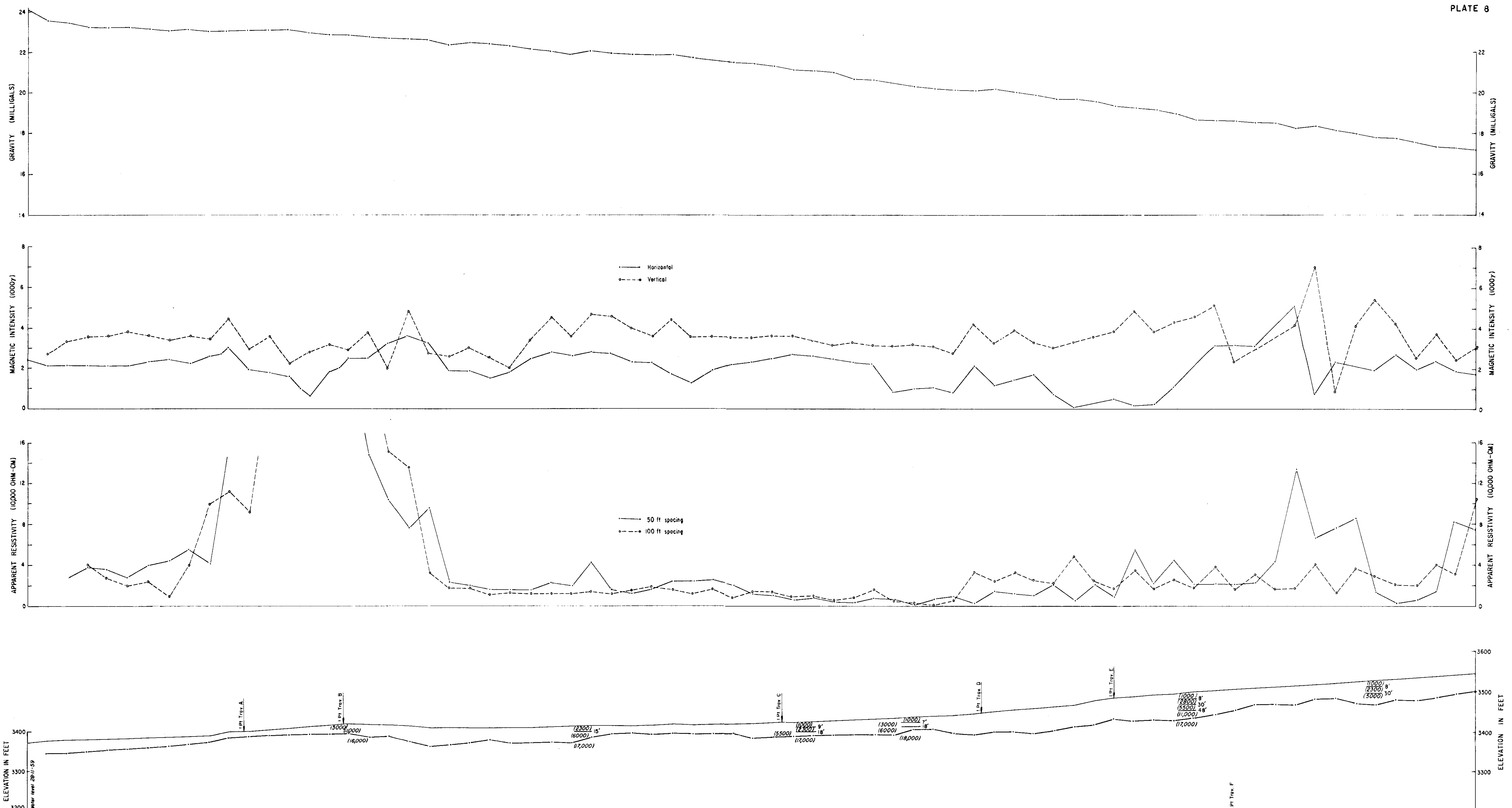
MICROMAGNETIC PANELS

K55/B5-98

PLATE 7



INTAKE TUNNEL AREA
NEW TUNNEL LINE, STATIONS T50 TO T234
GRAVITY, MAGNETIC, RESISTIVITY AND SEISMIC
REFRACTION PROFILES
HORIZONTAL SCALE IN FEET
RELATIVE GRAVITY IN MILLIGALS
MAGNETIC INTENSITY IN GAMMAS
Gravity values
Vertical Magnetic Intensity
Horizontal " "
APPARENT RESISTIVITY IN OHM-CM
50 ft spacing
100 ft "
FAULTS AND SHEARS
ELEVATION ABOVE DATUM IN FEET
SEISMIC REFRACTION PROFILE
Alluvial deposits, scree material, and weathered bedrock
DDH 5001
DDH 5043
DDH 5073
DDH 5042
DDH 5041
DDH 5040
DDH 5002
DDH 5087



STATION NUMBER	STATION ELEVATION	HORIZONTAL DISTANCE (FEET)	DEPTH TO BEDROCK
T50	3372	00	
T51	3377	48	30
BM 2762	3378.43	83	
T52	3379	99	31
T53	3381	150	28
T54	3382	197	27
T55	3383	249	25
T56	3385	300	23
T57	3386	350	21
T58	3388	399	19
T59	3389	447	16
T60	3400	498	13
	3401	533	
T61	3401	549	10
T62	3404	599	13
T63	3408	648	16
T64	3413	697	19
T65	3417	748	22
	3418	779	
T66	3418	795	22
T67	3417	846	27
T68	3416	896	27
T69	3413	946	38
T70	3408	996	45
T71	3408	1046	43
T72	3408	1096	36
T73	3408	1146	26
T74	3408	1196	35
T75	3408	1247	35
T76	3410	1297	36
T77	3412	1348	
T78	3414	1397	24
T79	3413	1447	20
T80	3414	1497	16
T81	3415	1547	20
T82	3418	1597	20
T83	3416	1647	18
T84	3417	1697	18
T85	3418	1747	20
T86	3419	1797	36
T87	3421	1847	36
	3422	1868	
T88	3422	1896	33
T89	3424	1946	32
T90	3426	1997	36
T91	3428	2046	37
T92	3429	2096	39
T93	3432	2146	44
T94	3434	2196	29
T95	3437	2245	31
T96	3439	2295	45
T97	3443	2345	50
	3345	2362	
T98	3447	2394	48
T99	3453	2444	53
T100	3456	2493	61
T101	3461	2543	56
T102	3465	2592	54
T103	3476	2640	56
T104	3483	2689	50
T105	3486	2738	63
T106	3490	2789	61
T107	3493	2838	63
T108	3497	2888	63
T109	3501	2938	59
T110	3504	2990	49
T111	3507	3039	36
T112	3510	3089	81
T113	3513	3139	45
T114	3517	3187	35
T115	3519	3238	35
T116	3524	3288	53
T117	3527	3338	57
T118	3529	3387	49
T119	3533	3437	49
T120	3536	3487	53
T121	3540	3536	47
T122	3544	3586	42

LEGEND

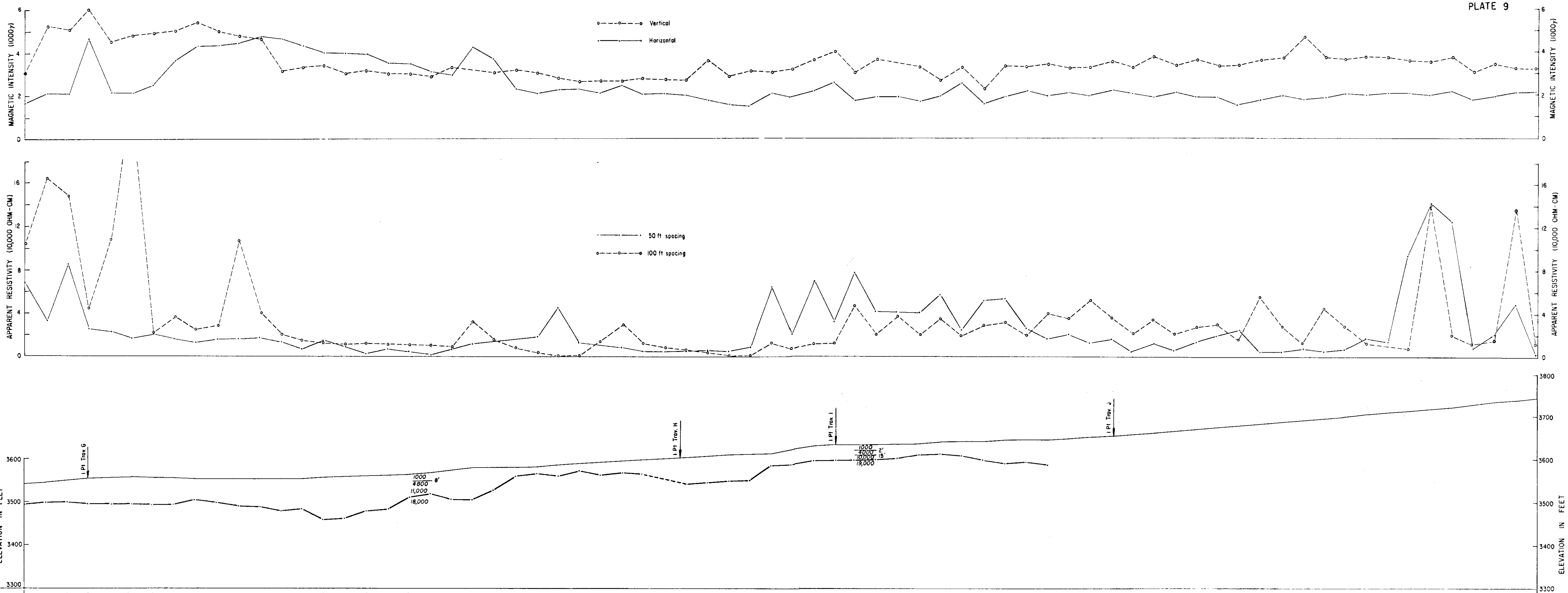
(5000) Seismic velocity (ft/s) in formation
9' Depth to formation with different seismic velocity
Unweathered bedrock boundary
I.Pt Intersection point

INTAKE TUNNEL AREA
NEW TUNNEL LINE, STATIONS T50 TO T122
GRAVITY, MAGNETIC, RESISTIVITY, AND SEISMIC REFRACTION PROFILES

HORIZONTAL SCALE IN FEET
100 0 100 200 300

K 55/B5-101

PLATE 9



STATION NUMBER	T122	T123	T124	T125	T126	T127	T128	T129	T130	T131	T132	T133	T134	T135	T136	T137	T138	T139	T140	T141	T142	T143	T144	T145
STATION ELEVATION	3544	3548	3552	3557	3559	3559	3559	3558	3557	3557	3557	3557	3558	3557	3561	3563	3565	3567	3569	3572	3579	3584	3583	3583
HORIZONTAL DISTANCE (FEET)	3586	3636	3686	3736	3787	3836	3886	3936	3986	4036	4086	4137	4187	4236	4286	4336	4386	4436	4487	4536	4585	4635	4685	4735
DEPTH TO BEDROCK	42	46	46	55	58	58	58	58	46	51	57	57	71	61	94	98	77	79	45	44	63	71	50	13

STATION NUMBER	T146	T147	T148	T149	T150	T151	T152	T153	T154	T155	T156	T157	T158	T159	T160	T161	T162	T163	T164	T165	T166	T167	T168	T169	T170
STATION ELEVATION	3586	3589	3593	3595	3598	3601	3603	3606 3606	3608	3612	3614	3616	3626	3633	3636 3636	3636	3637	3638	3639	3643	3644	3645	3647	3647	3648
HORIZONTAL DISTANCE (FEET)	4785	4835	4685	4935	4985	5034	5084	5122 5134	5185	5235	5285	5335	5382	5434	5482 5488	5533	5583	5633	5683	5733	5783	5833	5884	5933	5984
DEPTH TO BEDROCK	8	23	13	23	25	30		57	57	57	59	23	32	32	34		30	34	23	27	31	42	52	48	57

STATION NUMBER	T171	T172	T173	T174	T175	T176	T177	T178	T179	T180	T181	T182	T183	T184	T185	T186	T187	T183	T189	T190	T191	T192	T193
STATION ELEVATION	3650	3653	3655 3656	3659	3662	3666	3671	3674	3679	3683	3687	3691	3696	3700	3706	3711	3715	3719	3723	3730	3735	3740	3745
HORIZONTAL DISTANCE (FEET)	6033	6084	6134 6140	6183	6231	6282	6332	6381	6431	6481	6531	6581	6632	6680	6731	6779	6829	6879	6928	6978	7028	7078	7127
DEPTH TO BEDROCK																							

LEGEND

4800 Seismic velocity (ft/s) in formation

8' Depth to formation with different seismic velocity

Unweathered bedrock boundary

I.Pt Intersection point

INTAKE TUNNEL AREA
NEW TUNNEL LINE, STATIONS T122 TO T193
MAGNETIC, RESISTIVITY, AND SEISMIC REFRACTION PROFILES

HORIZONTAL SCALE IN FEET

100 0 100 200 300 400

K55/85-102

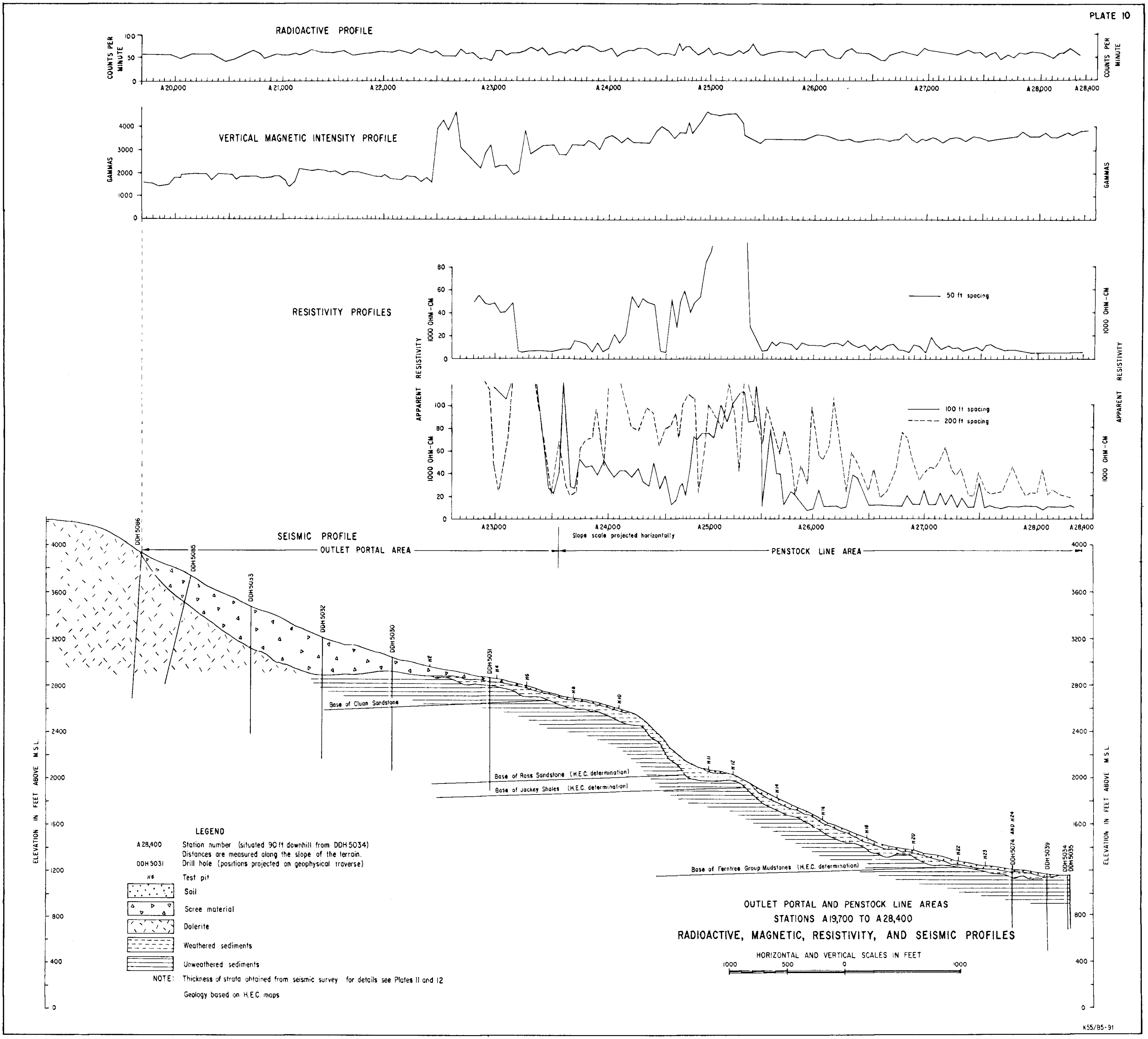


PLATE 10
RADIOACTIVE PROFILE
COUNTS PER MINUTE
A 20,000
A 21,000
A 22,000
A 23,000
A 24,000
A 25,000
A 26,000
A 27,000
A 28,000
A 28,400
VERTICAL MAGNETIC INTENSITY PROFILE
GAMMAS
RESISTIVITY PROFILES
APPARENT RESISTIVITY
1000 OHM-CM
50 ft spacing
100 ft spacing
200 ft spacing
Slope scale projected horizontally
SEISMIC PROFILE
OUTLET PORTAL AREA
PENSTOCK LINE AREA
ELEVATION IN FEET ABOVE M.S.L.
DDH 5086
DDH 5085
DDH 5033
DDH 5032
DDH 5030
DDH 5031
DDH 5074 AND H24
DDH 5039
DDH 5034
DDH 5035
Base of Cluan Sandstone
Base of Ross Sandstone (H.E.C. determination)
Base of Jackey Shales (H.E.C. determination)
Base of Ferntree Group Mudstones (H.E.C. determination)
LEGEND
A 28,400 Station number (situated 90 ft downhill from DDH 5034) Distances are measured along the slope of the terrain.
DDH 5031 Drill hole (positions projected on geophysical traverse)
H6 Test pit
Soil
Scree material
Dolerite
Weathered sediments
Unweathered sediments
NOTE: Thickness of strata obtained from seismic survey for details see Plates 11 and 12
Geology based on H.E.C. maps
OUTLET PORTAL AND PENSTOCK LINE AREAS
STATIONS A19,700 TO A28,400
RADIOACTIVE, MAGNETIC, RESISTIVITY, AND SEISMIC PROFILES
HORIZONTAL AND VERTICAL SCALES IN FEET
1000 500 0 1000
K55/B5-91

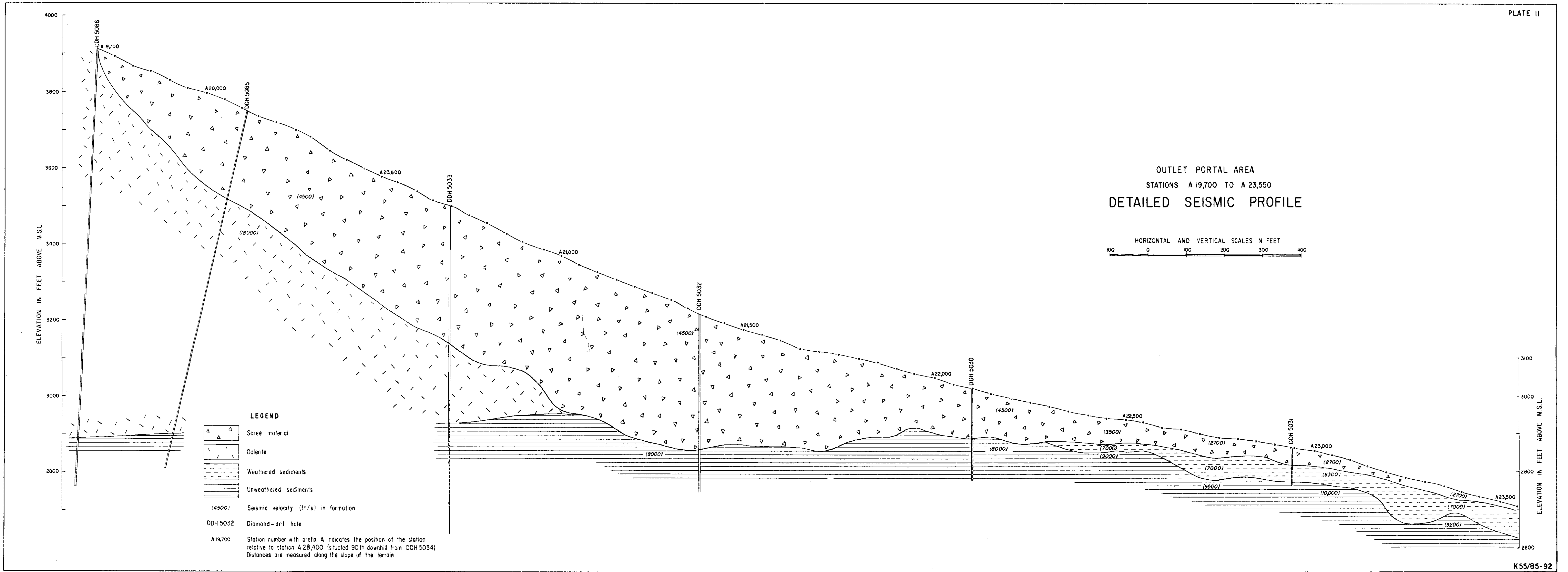
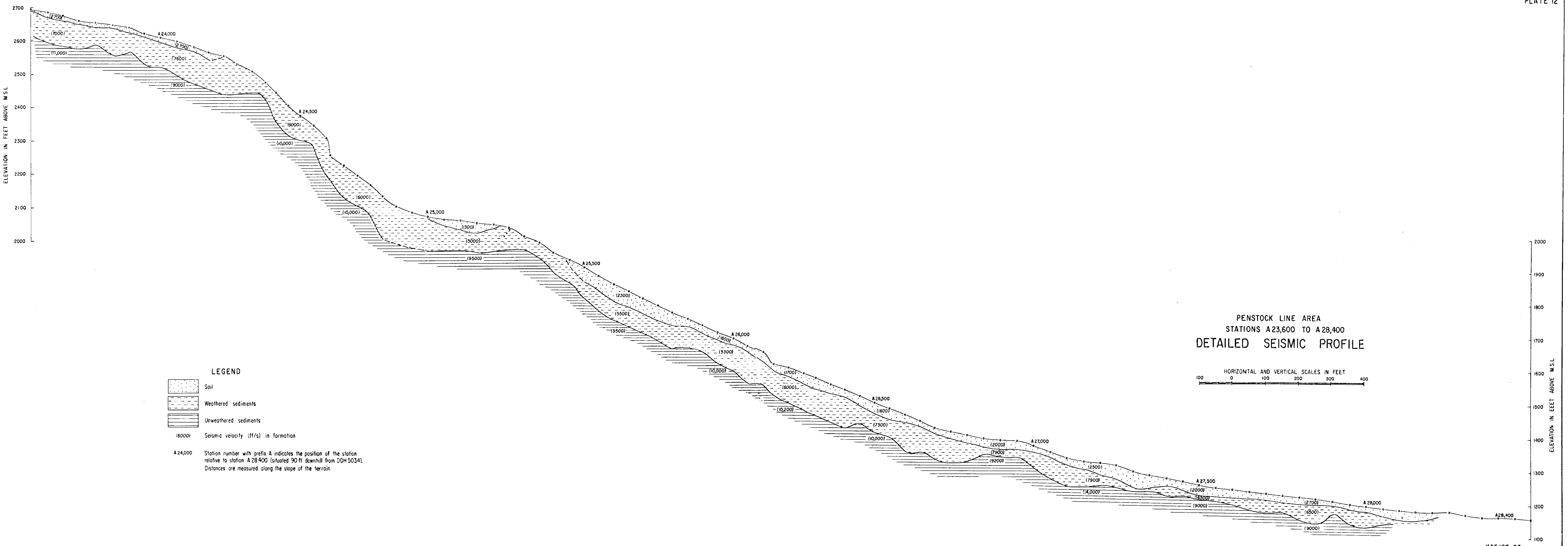
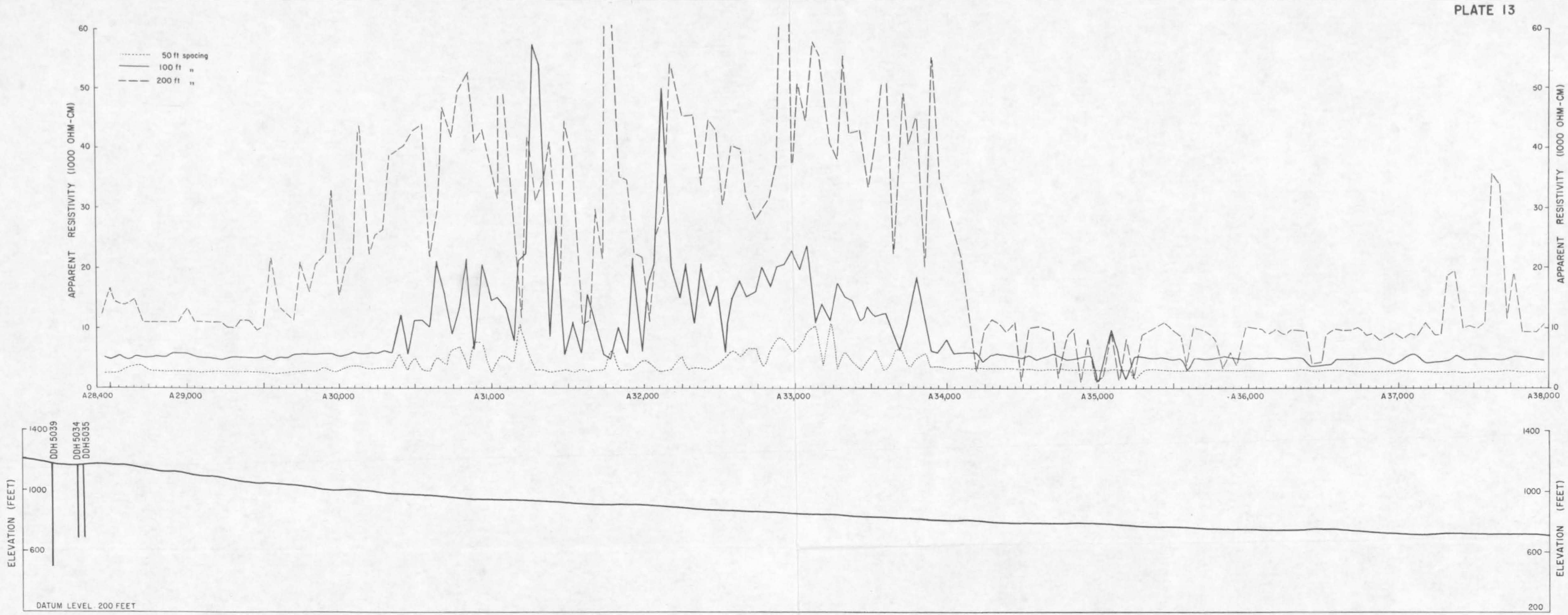


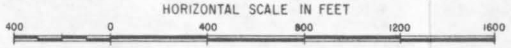
PLATE II
OUTLET PORTAL AREA
STATIONS A 19,700 TO A 23,550
DETAILED SEISMIC PROFILE
HORIZONTAL AND VERTICAL SCALES IN FEET
100 0 100 200 300 400
ELEVATION IN FEET ABOVE M.S.L.
DDH 5086
DDH 5085
DDH 5033
DDH 5032
DDH 5030
DDH 5031
A 19,700
A 20,000
A 20,500
A 21,000
A 21,500
A 22,000
A 22,500
A 23,000
A 23,500
(4500)
(18000)
(8000)
(3500)
(7000)
(9000)
(2700)
(9500)
(6300)
(10,000)
(9200)
LEGEND
Scree material
Dolerite
Weathered sediments
Unweathered sediments
(4500) Seismic velocity (ft/s) in formation
DDH 5032 Diamond-drill hole
A 19,700 Station number with prefix A indicates the position of the station relative to station A 28,400 (situated 90 ft downhill from DDH 5034). Distances are measured along the slope of the terrain
K55/B5-92


PENSTOCK LINE AREA
STATIONS A 23,600 TO A 28,400
DETAILED SEISMIC PROFILE
HORIZONTAL AND VERTICAL SCALES IN FEET
100 0 100 200 300 400
ELEVATION IN FEET ABOVE M.S.L.
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
A 24,000
A 24,500
A 25,000
A 25,500
A 26,000
A 26,500
A 27,000
A 27,500
A 28,000
A 28,400
LEGEND
Soil
Weathered sediments
Unweathered sediments
(6000) Seismic velocity (ft/s) in formation
A 24,000 Station number with prefix A indicates the position of the station relative to station A 28 400 (situated 90 ft downhill from DDH 5034). Distances are measured along the slope of the terrain.

K55/B5-93



Note: Station number with prefix A indicates the position of the station relative to station A28,400 (situated 90 ft downhill from DDH5034) Distances are measured along the slope of the terrain



TAILRACE TUNNEL AREA, STATIONS A28,400 TO A38,000

RESISTIVITY CONSTANT-SPACING PROFILES

AND

LONGITUDINAL SECTION ALONG TUNNEL LINE

K55/B5-94