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RECORDS 1959, No. 87

GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE DERWENT RIVER, TASMANIA

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by

E. J. POLAK and F. J. MOSS

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GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE, DERWENT RIVER, TASMANIA.

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C O N T E N T S

P L A T E S

ABSTRACT.

Details and results are given of seismic refraction, resistivity and magnetic surveys which were made in response to a request from the Hydro-Electric Commission of Tasmania, to investigate a proposed site for a dam on the River Derwent. The dam will be part of the Derwent-Dee Power Development Scheme.

The purpose of the survey was to determine the depth to bedrock, the rock types in the overburden and bedrock, and to delineate the boundary between dolerite and Triassic sediments. The overburden consists of scree, talus, weathered dolerite and weathered sandstone. The bedrock consists of jointed and unweathered dolerite or sandstone.

It is considered that the errors in estimated thicknesses of the strata is no more than $\pm$ 15% of the thicknesses.

1. INTRODUCTION.

The Cluny Power Station is a part of the Derwent-Dee Power Development Scheme of the Hydro-Electric Commission of Tasmania.

The Commission proposes to erect a dam on the River Derwent above its junction with the Dee River. The Commission requested the Bureau of Mineral Resources, Geology and Geophysics to investigate the site. The object of the survey was to determine the depth to the bedrock, the rock types in both overburden and bedrock and to delineate the boundary between dolerite and Triassic sandstone.

The survey was carried out in November 1957 by a geophysical party consisting of E.J. Polak (party leader) and F. J. Moss, geophysicists. The Commission provided additional assistants and carried out the topographical surveys.

It is desired to acknowledge the assistance given by the geologists and Mr. Hawkes and his staff of the Commission.

2. GEOLOGY.

The dam site is located on a 'U' bend of the river in a narrow valley (Plate 1). The power station will be erected below the spur dividing both arms of the 'U' bend and the tail-race open cut will take the water across the river flats to the lower arm of the river.

There is no written geological description of the area. The area was geologically mapped by R. Mather, H.E.C. geologist. The results of the mapping are shown on Plate 2.

On the left (west) bank of the river the main rock is dolerite of Jurassic age. The dolerite is covered on the upper slopes of the hill with products of its weathering; Triassic sediments are found upstream along the axis of the dam.

On the right (east) bank dolerite crops out near the river on the axis of the proposed dam, but further uphill it is covered by Triassic sediments. Upstream on the dam's axis the Knocklofty Sandstone (Triassic) forms a high ridge with vertical cliffs.

The tail-race area is covered with river gravels, which overlie lake deposits.

At the time of the survey several test-pits had been sunk (see Plate 2) in the area and one borehole had been drilled. Subsequent to the geophysical survey additional holes have been drilled.

3. METHODS AND EQUIPMENT.

Seismic, resistivity and magnetic methods were used. They are discussed separately below.

(a) Seismic Method:

The seismic method of exploration depends on the contrast in the velocity of propogation of elastic waves through different formations. When an explosive shock is applied to the ground seismic waves propagate in all directions.

Both longitudinal and transverse waves are propagated through the ground; of these the longitudinal (compressional) wave is the faster and also the more important for surveying.

Hard, unweathered rocks have higher longitudinal wave velocities than their weathered counterparts. The velocity in soil and scree is considerably lower than in the weathered and fractured rock.

The transverse (shear) wave advances by shearing displacement. With knowledge of the density of the rock and its shear and compressional wave velocities, it is possible to evaluate all the elastic properties of the rock. An attempt was made to measure the velocities of both types of waves.

The seismic refraction "Method of Differences" was used (Heiland, 1946, p.548) and some fourteen reflection shots were fired, but no reflections were recorded.

The following types of spreads were used for the refraction survey:-

(i) Weathering spreads. These were used to obtain the seismic wave velocities and the thickness of the soil and near surface layers. Geophone interval was 10ft. and shot-points were at distances of 5 and 50 ft. from both ends of the spread.

(ii) Normal spreads. The geophone interval was 50 ft. and shot points were at distances 25 and 50 ft. and 200 ft. or more (up to 600 ft.) from both ends of the spread, the distances depending on the depth to the refractor and the seismic velocity contrast between it and its overburden. The geophysical equipment in the survey consisted of a Mid-Western shallow reflection-refraction twelve-channel seismograph with Mid-Western vertical geophones with a natural frequency of 8 c.p.s. to record the longitudinal waves, and S.I.E. horizontal geophones, with a natural frequency of 6 c.p.s. to record the transverse waves.

(b) Resistivity method.

The variations in apparent resistivity show changes in the rock type. In general, non-porous rocks such as dolerite have a high resistivity. The resistivity of porous rocks such as sandstone depends on their porosity and on the salinity of the water contained in the pores.

A Megger Earth Tester with the Wenner arrangement of electrodes was used. Electrode spacings were 50 and 100ft. and the station interval was 50 ft.

(c) Magnetic Method.

Different rock types have different magnetic susceptibilities and these affect the strength of the magnetic field measured on the surface.

A Watts vertical force variometer was used and the station interval was 50 ft.

Table 1 gives the lengths of traverses surveyed with different geophysical methods.

Table 1.

Method	Length Ft.	Traverses.
Seismic refraction	19,500	All traverses (A to S)
Resistivity	6,000	D.E.I. & R.
Magnetic	8,000	M.L. & R.

4. RESULTS.

(a) Seismic Survey.

Longitudinal wave velocities used for identifying the various rock types at the Cluny Damsite are shown on Table 2.

Table 2.

Rock Type.	Seismic velocity in ft/sec.
Soil	800 - 1400
Lake Deposits (Traverse R)	2000
Dolerite-scree and talus	2500 - 4400
Dolerite - weathered	5500 - 6500
Dolerite - jointed	9000 - 19000
Sandstone - weathered	4000 - 6000
Sandstone - unweathered	6000 - 11000

Notes to Table 2.

1. Dolerite-scree and talus. Velocity was measured on the upper slopes of the left bank. A higher velocity was indicated on the steep slopes near the river than on the less sloping upper part.

2. Dolerite-weathered, jointed, and unweathered. As there are no outcrops of dolerite on the traverses surveyed at Cluny, the velocities were allotted to the various groups of dolerite according to the findings on the upstream damsites on the River Derwent. (i.e. Lower and Upper Repulse, Black Bobs, etc.)

3. Sandstone - weathered and unweathered. The upper layers of the sandstone showed lower velocity (4000-6000 ft/sec) than the rest of the sandstone below. The lower velocity sandstone is referred to as "weathered" in this report, but the lower velocity may indicate that there is a larger proportion of clays and mudstones than in the section showing higher velocity.

   The interpretation of the results from the seismic surveying is shown on Plates 3-6 and it will be discussed fully later.

In some earlier reports on the geophysical investigations of H.E.C. Damsites the Young's Modulus was calculated from longitudinal wave velocities after Poisson's Ratio and the density of the rocks had been assumed. At the Cluny Damsite the transverse wave velocities were recorded on some areas confined mostly to the right bank of the river.

Fig.1. shows a copy of a field record taken on a weathering spread on Traverse L (stations L200-L210). The vertical geophones were placed 10 ft. apart along the traverse and a shot was fired 5 ft. from No.1 geophone (No.1 geophone is connected to the second trace from the top). The timing lines are at two millisecond intervals. The record shows the shot instant (SM) and times of arrival of the longitudinal wave at successive geophones.

Fig.2. shows a copy of a field record taken at the same place using horizontal geophones. All the conditions were the same except for the shot, which was placed 10 ft. from No.1 geophone to avoid ground shattered by the first shot.

From the data from the above two records the time-distance curves have been plotted and are shown on Fig.3. The slopes of the curves give the values of longitudinal and transverse wave velocities.

If the density of the rocks is known, or can be estimated, it is possible to determine values of all the elastic constants from the following equations (Heiland 1946 p.p.443-449) or (Leet, 1950 p.p.45-46)., -

$$(V_p/V_s)^2 = (\sigma-1)/(\sigma-\tfrac{1}{2})$$

$$E = \frac{(12V_p)^2\,\delta}{1+(2\sigma^2)/(1-\sigma-2\sigma^2)}$$

$$G = E/2(1+\sigma)$$

$$B = E/3(1-2\sigma)$$

B = bulk modulus, or modulus of incompressibility (lbs/in^2).

E = Young's Modulus (lbs/in^2).

G = Modulus of Rigidity (lbs/in^2).

σ = Poisson's Ratio.

V_p= longitudinal wave velocity (ft/sec).

V_s= transverse wave velocity (ft/sec).

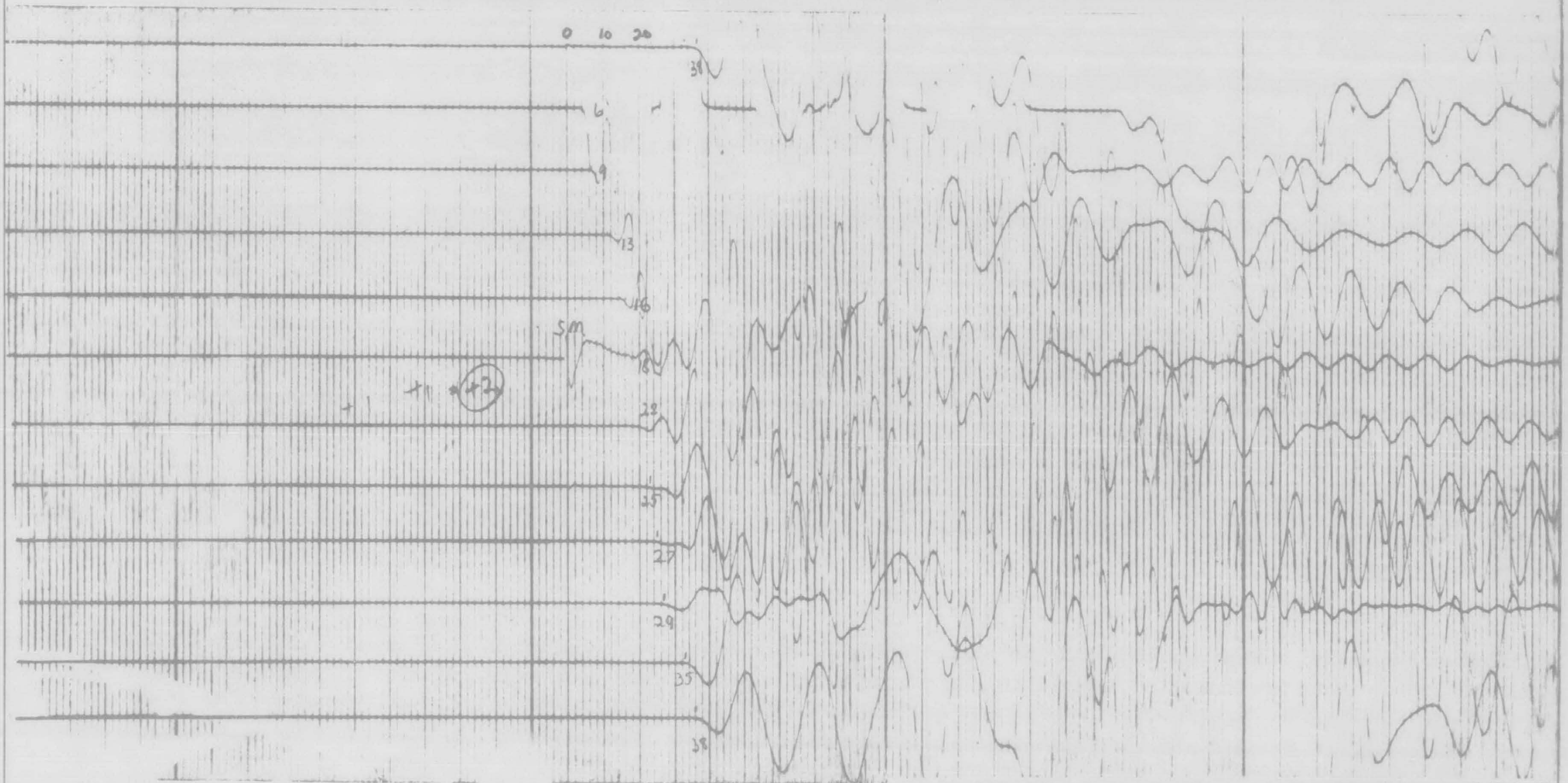
δ = density (lbs/in^3).

(Note: lbs in B, E & G is a force, not a mass).

Table 3 shows the values of longitudinal and transverse velocities where they were recorded together on Cluny Damsite. The densities shown were determined by the H.E.C. on cores of sandstone collected from drillholes put down near the place where velocities were determined. There is no drillhole near Traverses D and I; therefore the density was assumed. An error in assumed density of 0.1 would lead to an error of 4% in the calculated value of Young's Modulus. Values of elastic constants shown have been calculated from the corresponding velocity and density data.

GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE, DERWENT RIVER, TASMANIA

FIG.1. SAMPLE OF SEISMIC RECORD OBTAINED DURING THE SURVEY (VERTICAL GEOPHONES)



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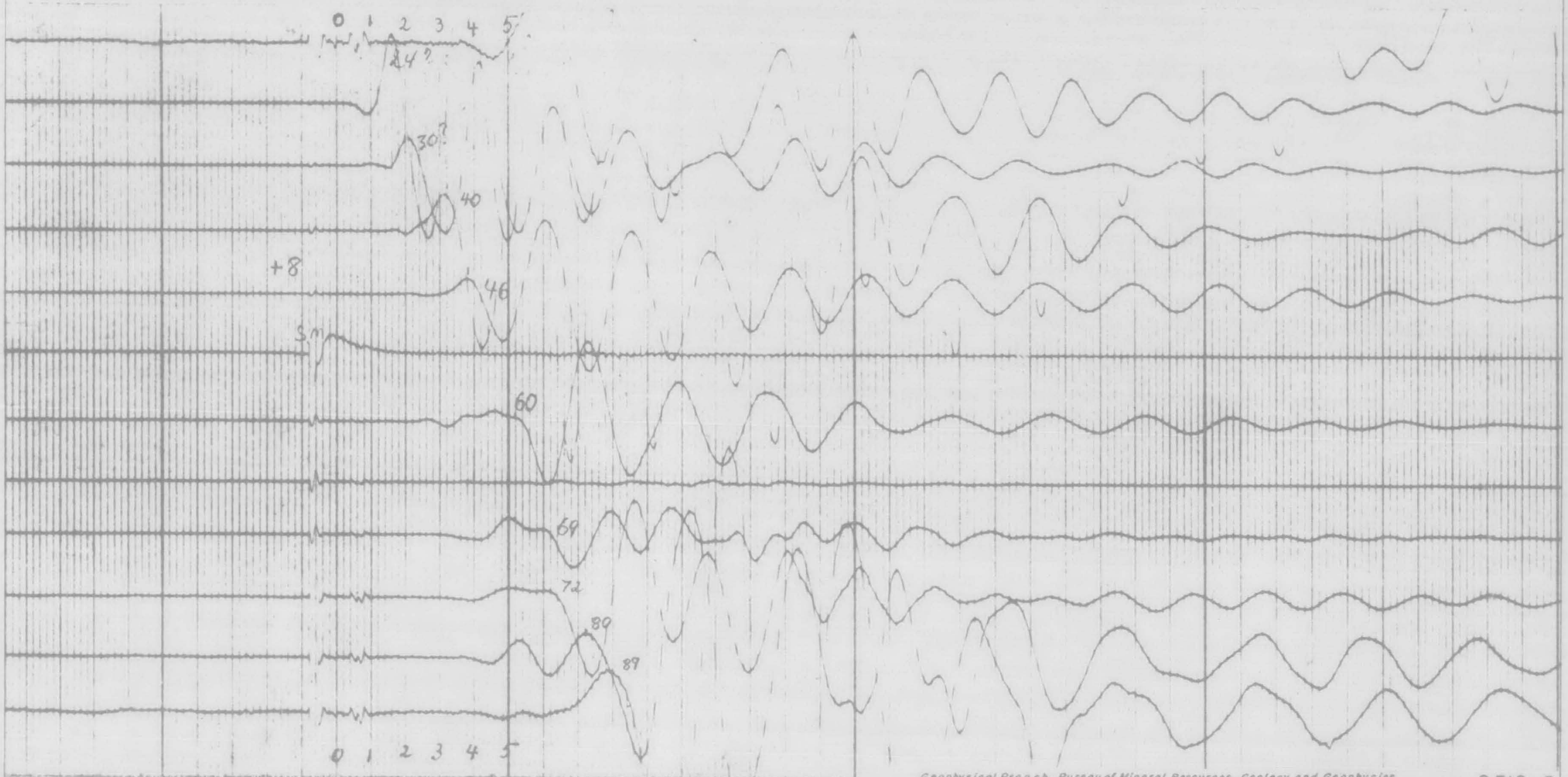
G 310-8

GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE, DERWENT RIVER, TASMANIA

FIG.2. SAMPLE OF SEISMIC RECORD OBTAINED DURING THE SURVEY (HORIZONTAL GEOPHONES)



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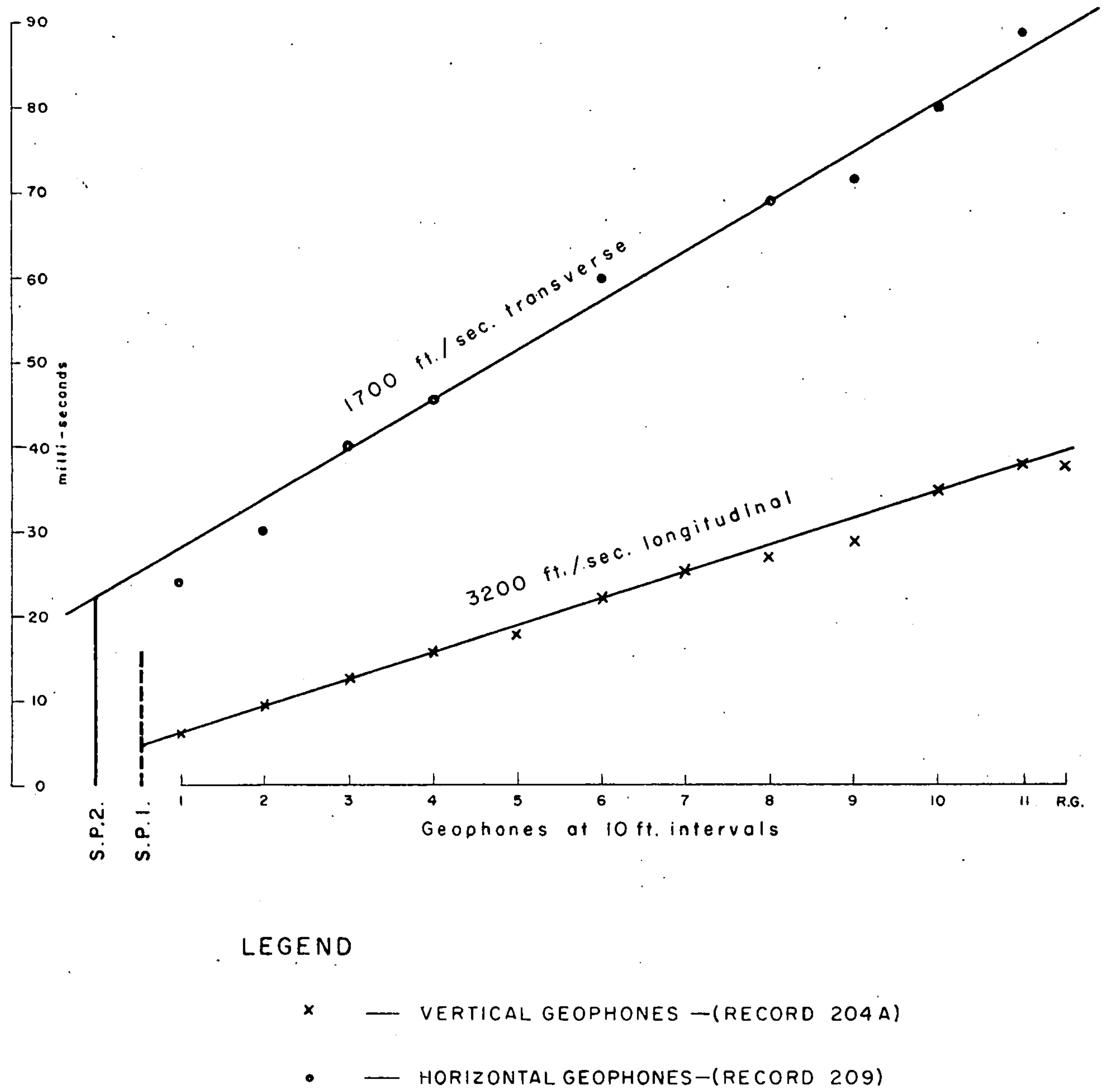

GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE,

DERWENT RIVER, TASMANIA

FIG. 3. TIME-DISTANCE CURVE PLOTTED

FROM FIG. 1 AND 2

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TABLE 3.

Traverse	Station No.	Longitudinal Velocity V_p ft/sec	Transverse Velocity V_s ft/sec	Density lbs/cu ft	Poisson's Ratio	Young's Modulus E $\times 10^6$ lbs/in^2	Bulk Modulus B $\times 10^6$ lbs/in^2	Rigidity Modulus G $\times 10^6$ lbs/in^2	
D	60-70	4400	2200	160.0	0.33	0.44	0.43	0.165	Weathered Dolerite (TALUS)
I	0-10	4200	2600	148.0	0.192	0.52	0.28	0.214	Sandstone
L	130-145	2500	1400	152.1	0.28	0.16	0.12	0.062	Mudstone
L	200-210	3200	1700	160.1	0.305	0.25	0.215	0.096	Claystone
M	35-50	1400	630	140.0	0.362	0.025	0.030	0.009	Gravels
R	100-110	5400	3200	148.2	0.24	0.77	0.49	0.35	Sandstone
	drill-hole	5800	3000	148.2	0.315	0.76	0.69	0.29	Sandstone

b) Resistivity Survey.

The results of the resistivity survey are shown on Plates 6 and 7. High apparent resistivity values indicate the area where dolerite is concealed under scree and talus. Low apparent resistivity values indicate the area of sandstone.

The resistivity constant spacing results along Traverse R (Plate 6) show comparatively low and uniform values, indicating that there is no abrupt change in composition of the near surface rocks along the traverse.

c) Magnetic Results.

The results of the magnetic survey are plotted on Plate 3 (Traverse M) and Plate 6 (Traverse R). The high magnetic values (greater than 900 gammas) indicate where the dolerite may be expected to be near to the surface or relatively thick.

5. INTERPRETATION OF RESULTS.

(a) Left (West) bank of the river (Plates 3, 4 and 7).

The geophysical results indicate that the following traverses appear to be located over dolerite.

A,B,F and G - along their full length
D between 0 and 80
E between 0 and 85

The overburden along these sections consists of scree, talus and weathered dolerite; the bedrock consists of jointed or fresh dolerite.

Resistivity constant spacing traverses (Plate 7) indicate that sandstone exists under the overburden in the southern part of the left bank area. The following traverses appear to be located over sandstone.

D, between 80 and 150
E, between 85 and 140
C, I. and K, along their full length.

(b) Right (East) bank of the river (Plates 3,5,6)

On the axis of the proposed dam, near the river, dolerite was proved in test pit No.5 (Plate 2). Seismic results along Traverse M indicate that dolerite extends to somewhere between Traverse O and Traverse L (from the geological mapping it would appear to underlie the sandstone along a portion of the traverse). It then either terminates or is displaced downwards more or less abruptly. The velocity of 10,000 ft/sec. further east which underlies 7,100 ft/sec. material suggests that the dolerite may continue at the lower level.

The magnetic curve supports the suggestion of the vertical displacement of the dolerite, but indicates that the displacement is not so abrupt. Another steep buried bank is suggested by the magnetic results east of M140. It is outside the area investigated seismically. Because of the relatively low magnetic reading the bed with velocity 8,500 ft/sec. east of peg M110 is considered to be sandstone.

A drillhole 8986 just completed at M50 proved 231 ft. of sediments above dolerite (as against 215 ft. obtained from seismic) but it indicated a 20 ft. bed of dolerite (between 152 and 172 ft.). This bed of dolerite is apparently too thin for it to have been recorded by the seismic method, but its existance may explain certain differences between conclusions drawn from seismic and magnetic results (steepness of the buried bank mentioned already).

The displacement in the dolerite indicated on traverse M (near peg M50) appears to continue under traverse O, where it is recorded between 030 and 040. (see plate 5). The assumed dolerite at the lower level shows 10,000 ft/sec. velocity as against 16,000 ft/sec. at the higher level. Further south along traverse O a velocity of 10,500 ft/sec. is recorded. This bed continues south to traverse R and it is interpreted there as sandstone (see below).

On Traverse L the high velocity rock (16,000 - 18,000 ft/sec.) on the north-west end of the traverse was proved to be dolerite. Further south-east the velocity of 10,000 ft/sec. is recorded. This is assumed to be from the same formation which, on traverse O and R, was interpreted as sandstone.

On Traverse P the bedrock is dolerite with very high velocity of 18,000 ft/sec.

On Traverse N the change in velocity at the south-eastern end of the traverse may indicate a change from dolerite to sandstone. If so, this change probably takes place near station N65.

The results of interpretation of the seismic, magnetic and resistivity data on Traverse R, the proposed tail-race open cut, are shown on Plate 6. A drill hole near the western end of the traverse showed that dolerite does not exist within a depth of 300 ft; therefore, the 11,000 ft/sec. bed must be sandstone. On the magnetic traverse there is a large drop in the magnetic anomaly indicated near R85; it is suggested that it correlates with the similar drop on Traverse M east of M140 (Plate 3). The structure along Traverse R from R85 to R235 is uniform; east of R235 the dolerite rises slowly as indicated on the magnetic curve. It appears to be too deep here to be recorded on seismic traverses, but it is indicated by a velocity of 19,000 ft/sec. east of peg R285.

The determination of the thickness of scree and weathered dolerite from the seismic work on the left bank of the river is considered to have an error of about $\pm 10\%$. The error in calculation of the thickness of overburden on the Triassic deposits may be higher but is not expected to exceed $\pm 15\%$. As already mentioned the calculated thickness of sandstone at M50 was 7% smaller than that proved by drillhole 8986. Thin beds of high velocity embedded in low velocity layers are often not detected in seismic work.

6. CONCLUSIONS

The geophysical survey provided information on the depth to bedrock, on the degree of weathering and fracturing of the strata and on their elastic constants.

The main features of the area, as indicated by the geophysical survey are:-

a) On the left (West) bank of the river the bedrock consists of dolerite downstream, but of sandstone upstream from D80 and E85. The boundary has been determined by the resistivity method.

b) On the right (East) bank the dolerite extends underneath sandstone and the seismic and magnetic surveys indicate that it drops down steeply in the form of two steps at 400 ft. and 1,500 ft. from the river along Traverse M.

c) On the tail-race open-cut the rocks appear to be relatively uniform along the whole length.

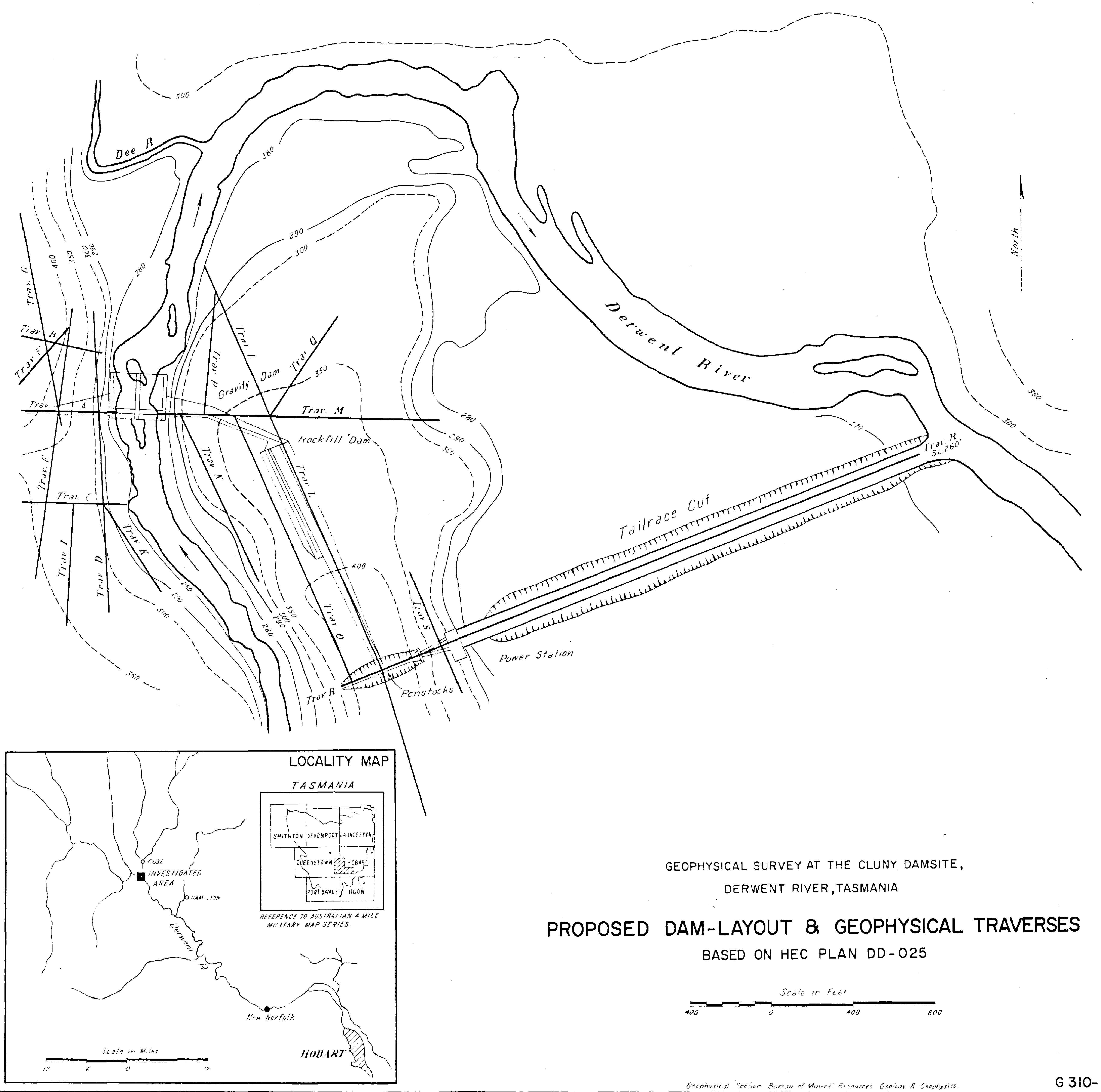
The error in determination of thickness is expected to be not more than $\pm 15\%$.

7. REFERENCES.

Heiland: C.A., 1946. Geophysical Prospecting., Prentice Hall Inc. New York.

Leet: L.D., 1950. Earth Waves., Harvard University Press.

PLATE I



GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE,

DERWENT RIVER, TASMANIA

PROPOSED DAM-LAYOUT & GEOPHYSICAL TRAVERSES

BASED ON HEC PLAN DD-025

Scale in Feet

400 0 400 800

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G 310-1

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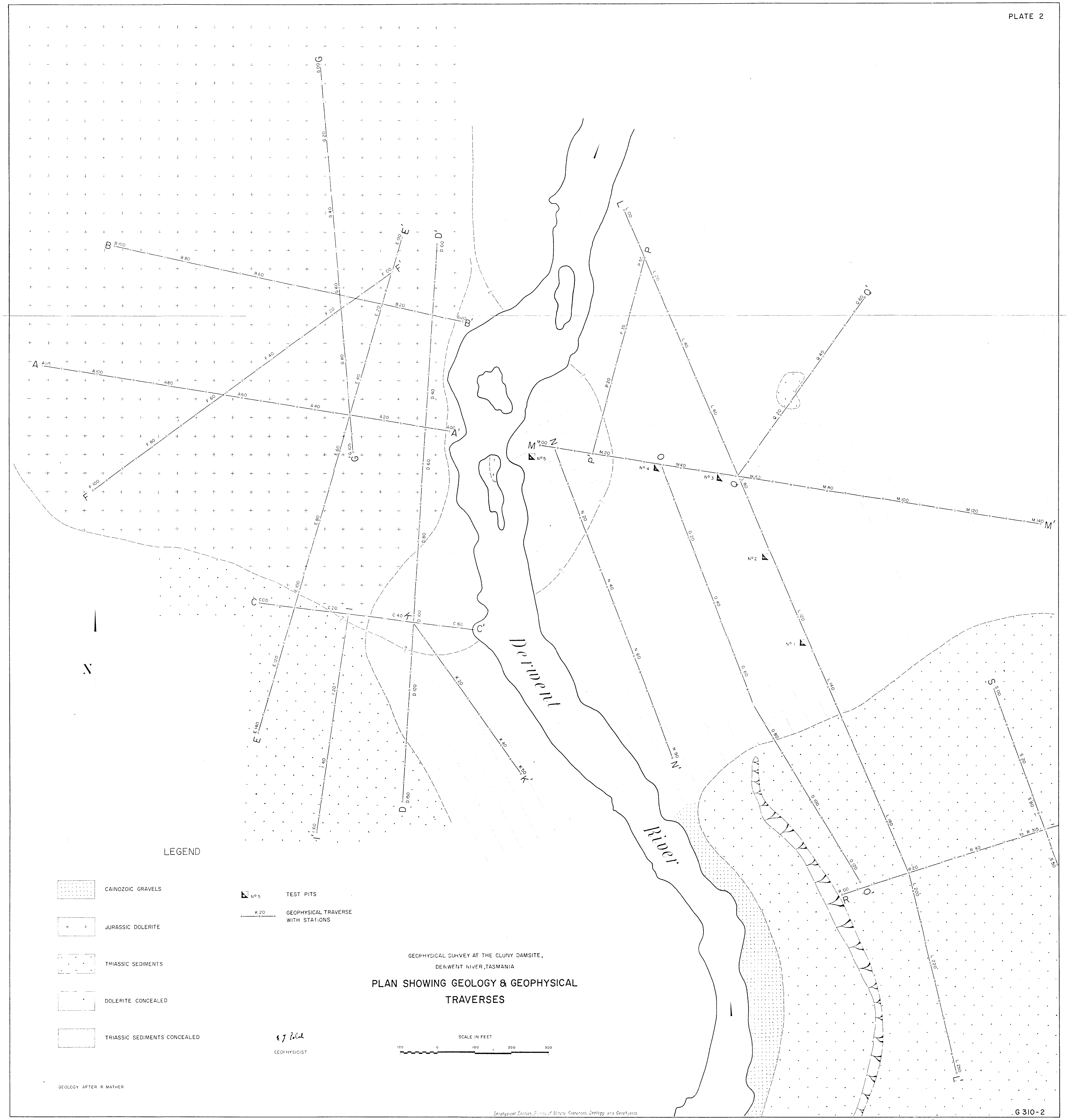

PLATE 2
Derwent
River
N
LEGEND
CAINOZOIC GRAVELS
JURASSIC DOLERITE
TRIASSIC SEDIMENTS
DOLERITE CONCEALED
TRIASSIC SEDIMENTS CONCEALED
Nº 5
TEST PITS
K 20
GEOPHYSICAL TRAVERSE
WITH STATIONS
GEOPHYSICIST
GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE,
DERWENT RIVER, TASMANIA
PLAN SHOWING GEOLOGY & GEOPHYSICAL
TRAVERSES
SCALE IN FEET
100
0
100
200
300
GEOLOGY AFTER R. MATHER
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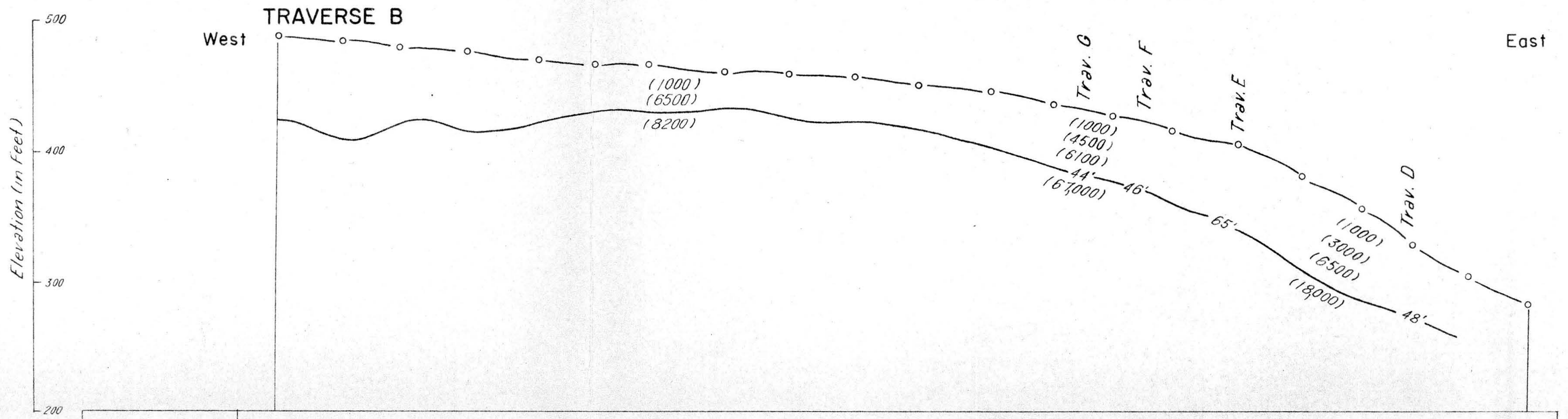
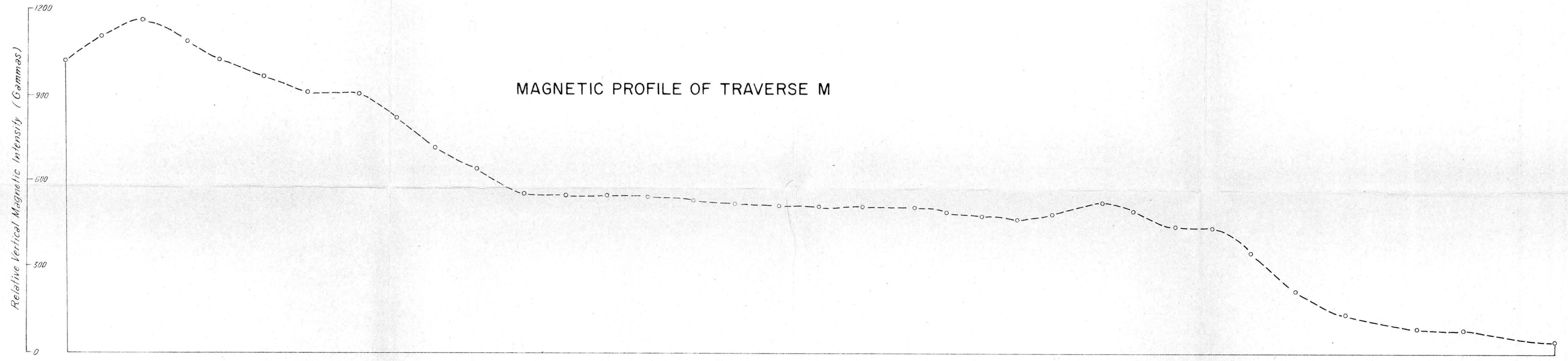
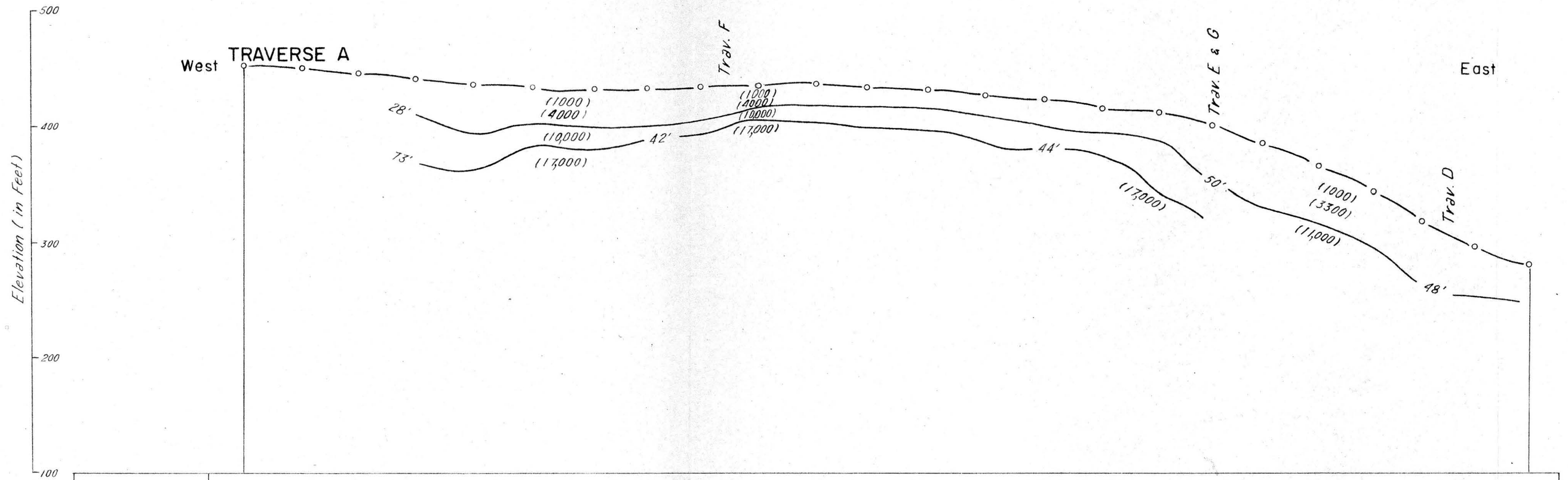
WEST BANK

EAST BANK



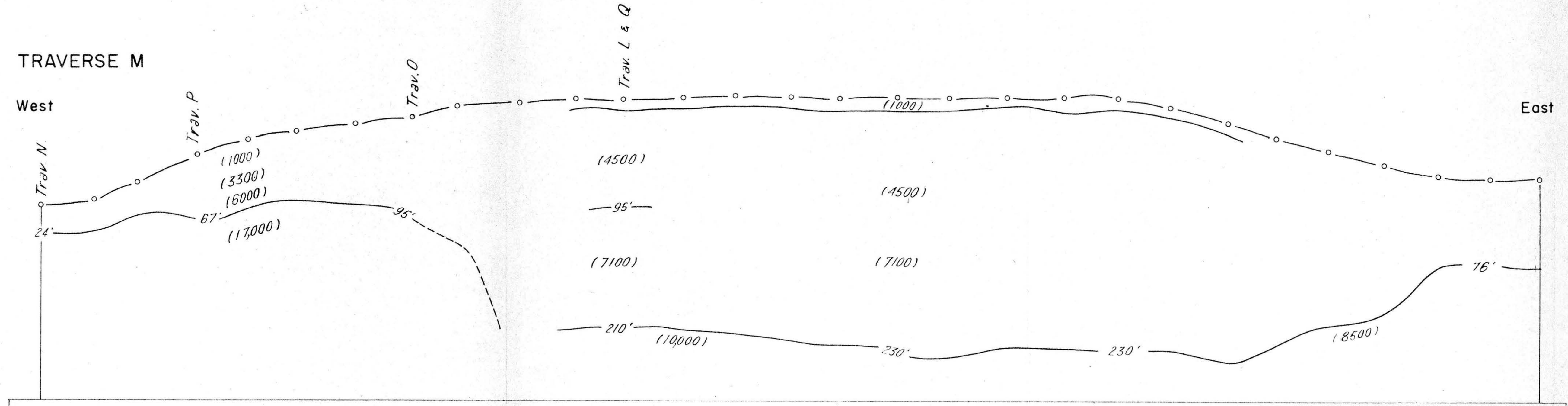
Station No.	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	00
Surface Level	485	482	479	474	469	465	462	459	457	453	448	442	434	425	415	401	380	356	329	301	281



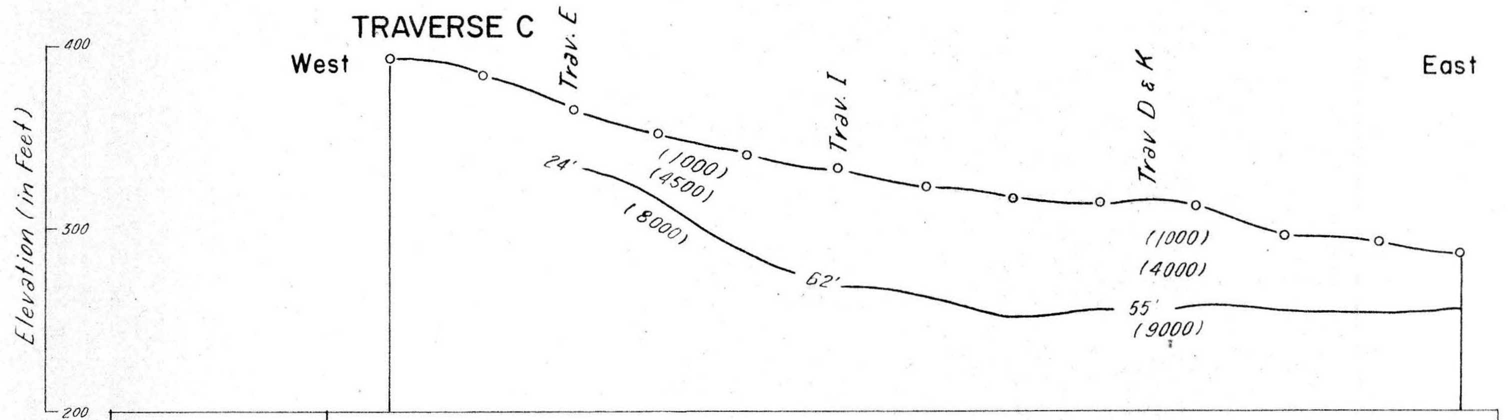


Station No.	115	110	105	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	00
Surface Level	454	452	449	441	438	435	434	435	437	438	438	437	434	429	425	419	411	401	386	368	344	319	297	281

DERWENT RIVER



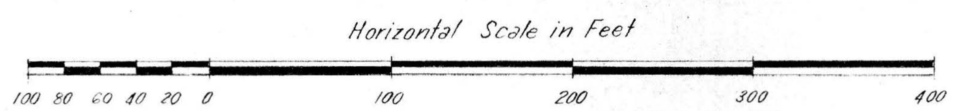
00	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140
275	281	299	321	337	344	350	358	366	371	374	375	376	376	376	376	377	378	379	379	378	365	357	340	330	316	303	306	306



Station No.	00	5	10	15	20	25	30	35	40	45	50	55	60
Surface Level	391	383	369	351	341	333	323	317	315	311	398	391	387

(6000) Seismic Velocity in ft/sec.

—67'— Depth from surface in feet.



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GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE,

DERWENT RIVER, TASMANIA

SEISMIC PROFILES ON TRAVERSES A, B, C, M AND MAGNETIC PROFILE ON TRAVERSE M

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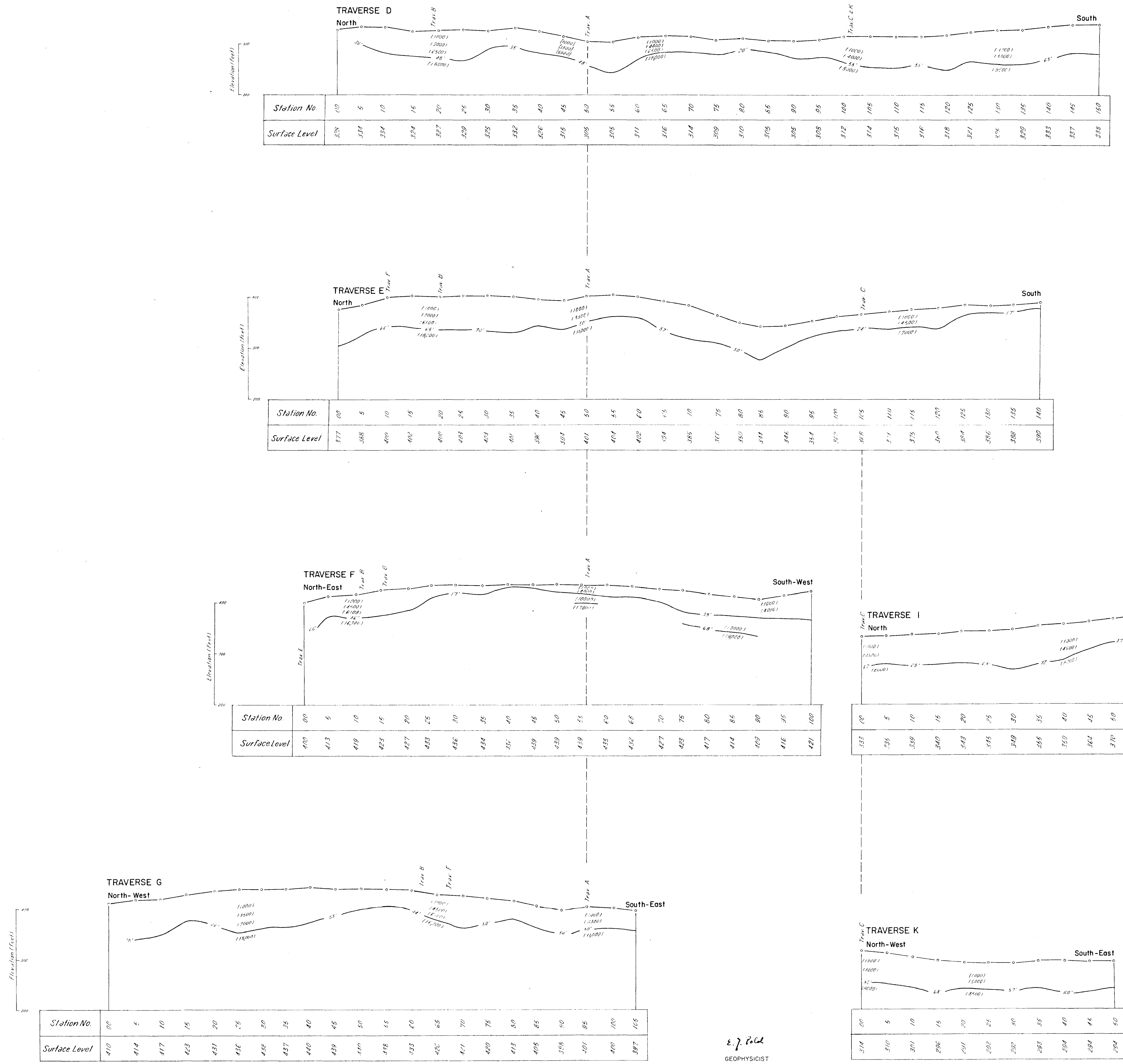


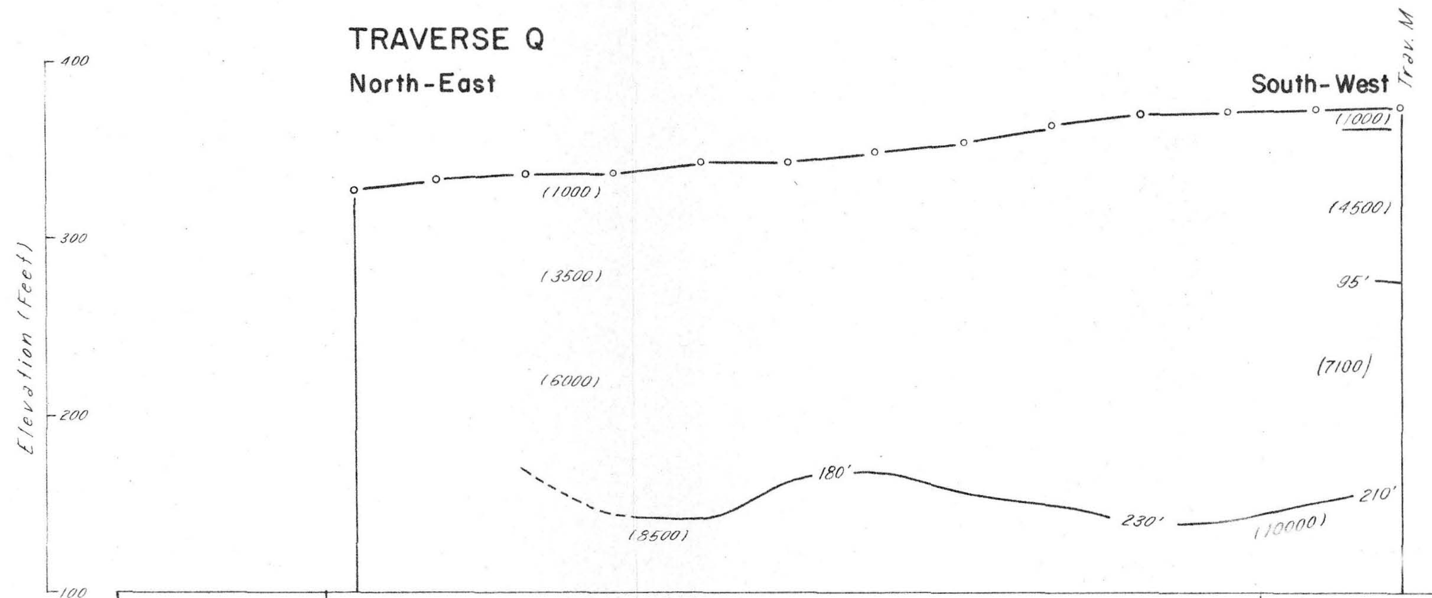
E. J. Polak
GEOPHYSICIST

GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE,
DERWENT RIVER, TASMANIA

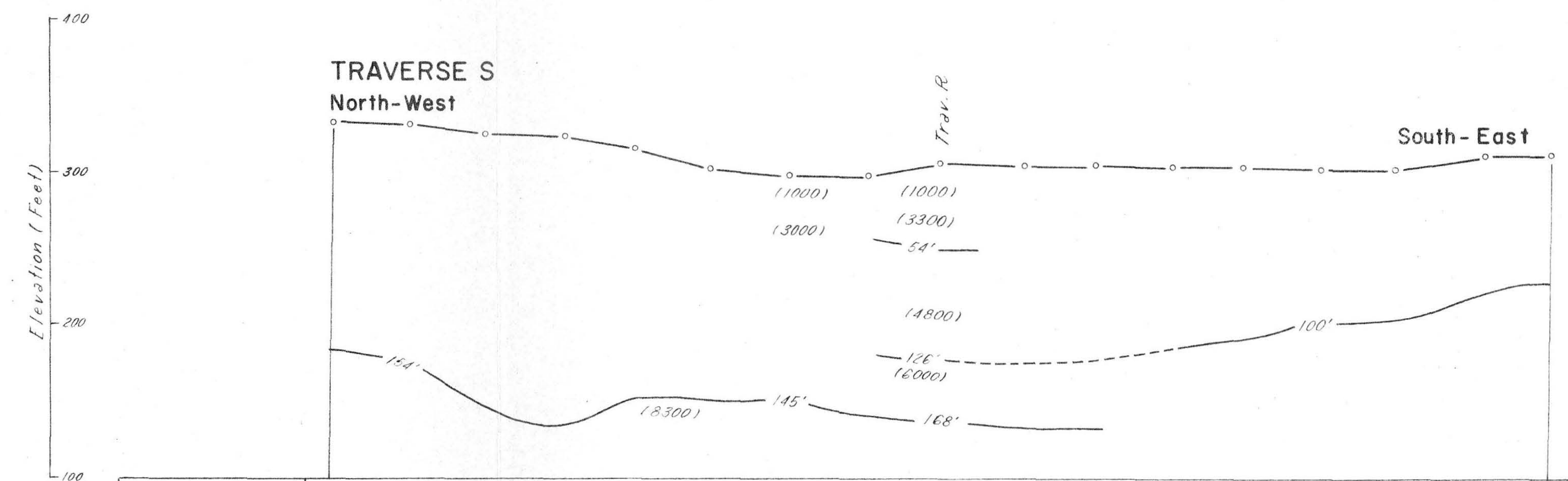
SEISMIC PROFILES ON TRAVERSES D,E,F,G,I,K

(4000) Seismic Velocity in ft/sec
— 48' — Depth from surface in ft.

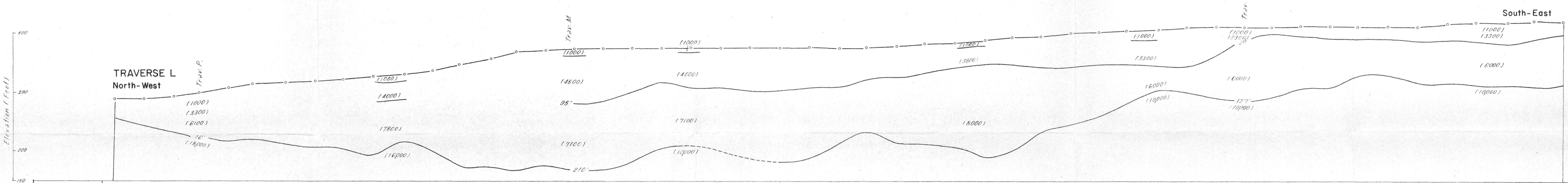
Horizontal Scale in Feet
100 80 60 40 20 0 100 200



Station No.	60	55	50	45	40	35	30	25	20	15	10	5	00
Surface Level	328	331	334	338	341	345	348	355	364	370	372	374	376

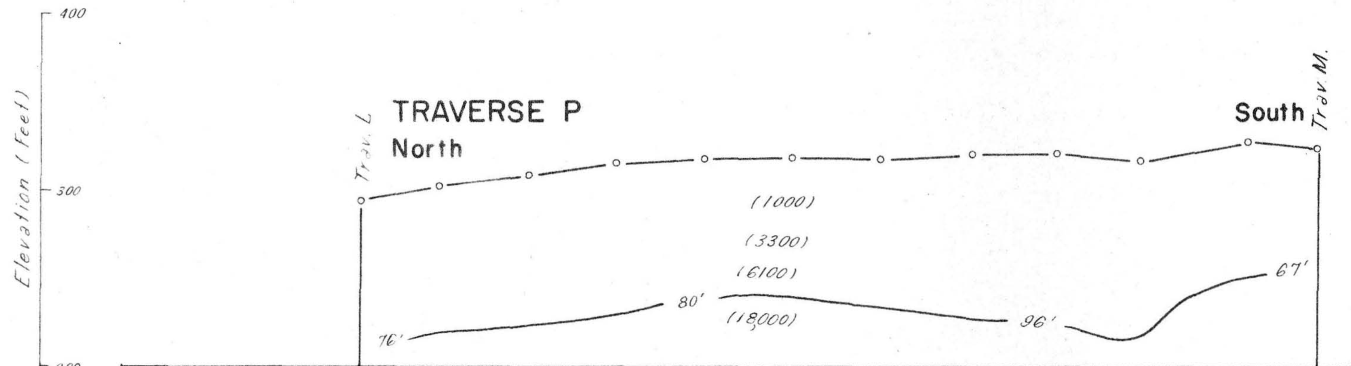


Station No.	00	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
Surface Level	335	331	328	326	317	304	300	297	303	304	309	308	307	305	305	314	317

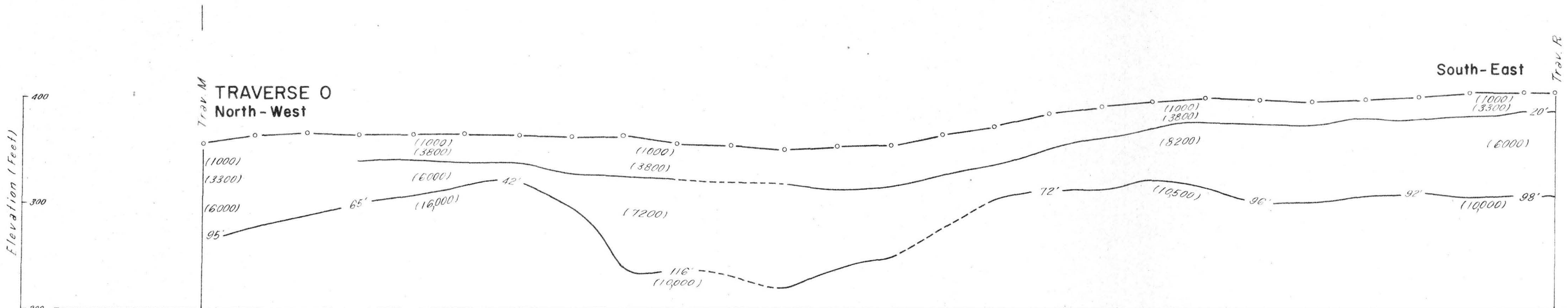


Station No.	00	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
Surface Level	288	288	291	297	307	313	317	320	323	326	330	337	346	359	370	374	376	377	378	379	379	379	379	379	380

Station No.	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245	250
Surface Level	379	379	381	384	387	391	395	399	403	406	408	410	411	413	415	416	417	416	415	416	417	421	423	425	426	429



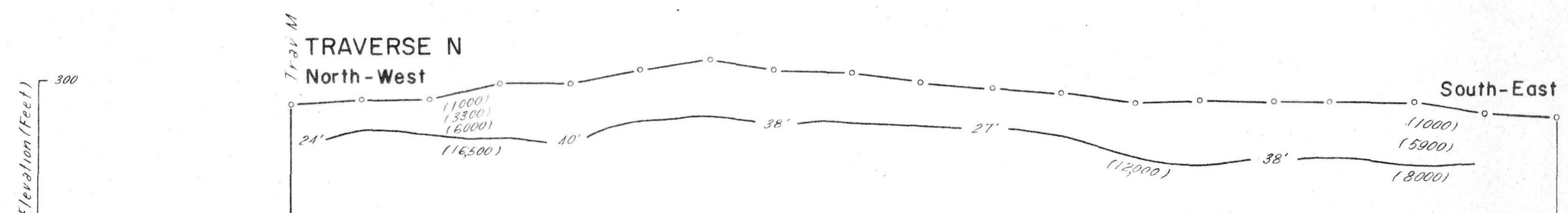
Station No.	55	50	45	40	35	30	25	20	15	10	5	00
Surface Level	295	301	308	313	316	317	318	320	320	319	326	323



Station No.	00	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	1263
Surface Level	358	362	364	364	364	364	364	365	364	359	354	351	352	356	367	374	385	391	397	400	399	399	400	402	405	407	409

(16,500) Seismic Velocity in ft/sec

— 67' — Depth from surface in feet.



Station No.	00	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
Surface Level	281	283	288	295	298	305	311	308	307	300	294	292	286	287	286	284	282	279	278

E. J. Polak

GEOPHYSICIST

GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE,

DERWENT RIVER, TASMANIA

SEISMIC PROFILES ON TRAVERSES L,N,O,P,Q,S

Horizontal Scale in Feet

100 80 60 40 20 0 100 200 300 400

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G 310-5

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STATION N°	00	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
SURFACE LEVEL	398	407	412	413	415	415	415	411	392	368	341	319	304	287	279	276

STATION N°	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155
SURFACE LEVEL	276	276	276	277	277	277	278	277	276	276	277	277	277	278	278	278

STATION N°	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235
SURFACE LEVEL	279	278	278	278	278	279	280	279	278	278	277	277	277	277	276	277

STATION N°	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315
SURFACE LEVEL	277	277	277	278	278	278	278	279	276	276	276	276	276	274	272	270

(6000) SEISMIC VELOCITY IN FT./SEC.

— 110' — DEPTH IN FT. FROM SURFACE

GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE,
DERWENT RIVER, TASMANIA

SEISMIC, MAGNETIC & RESISTIVITY PROFILES
TAILRACE TRAVERSE R

E. J. Polak
GEOPHYSICIST

HORIZONTAL SCALE IN FEET
100 0 100 200 300

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G310-6

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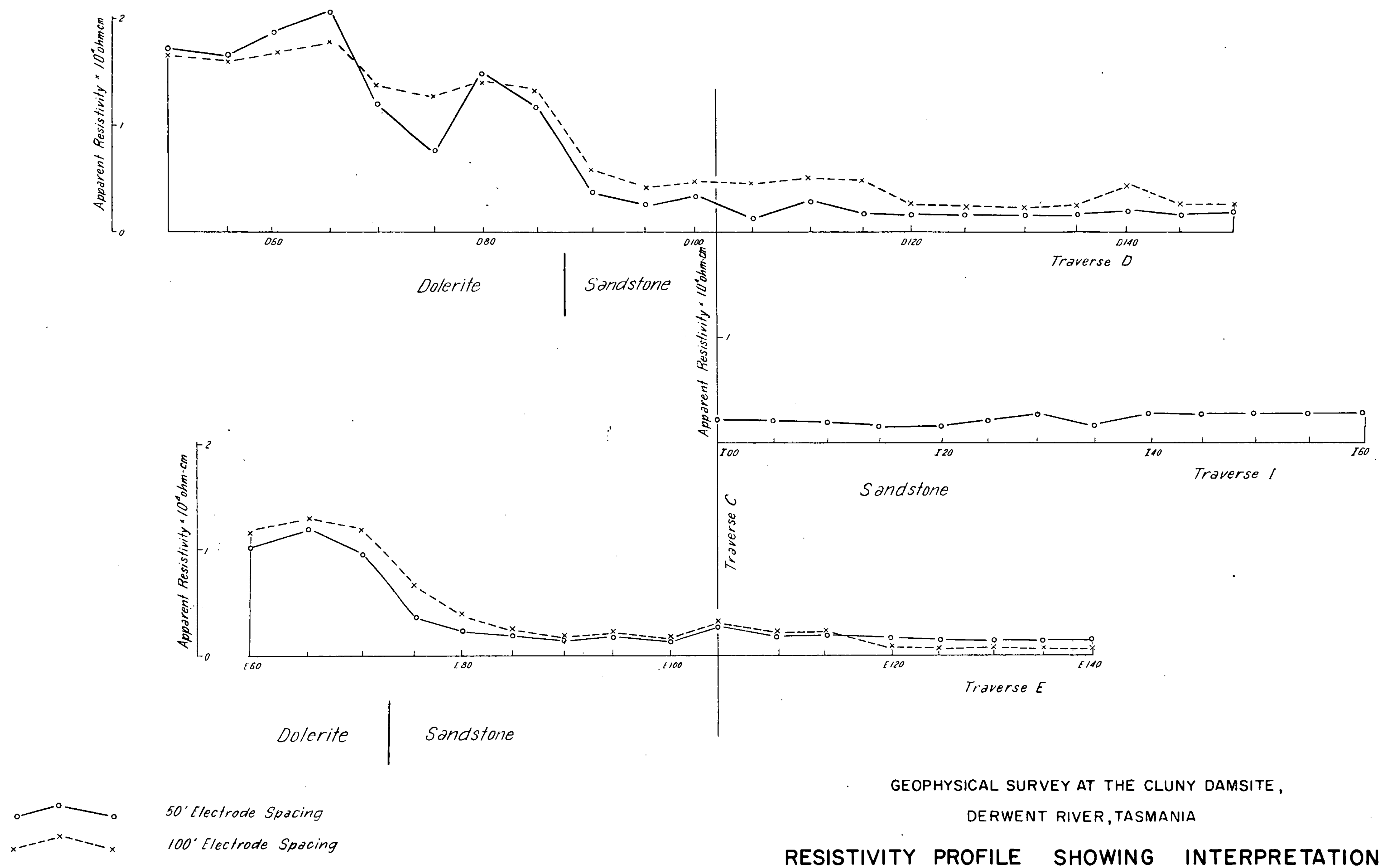

E.J. Polak
GEOPHYSICIST

GEOPHYSICAL SURVEY AT THE CLUNY DAMSITE,

DERWENT RIVER, TASMANIA

RESISTIVITY PROFILE SHOWING INTERPRETATION

Horizontal Scale in Feet

100 50 0 100 200

Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics.

G 310-7

To Accompany Records 1959, No 87