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GEOPHYSICAL SURVEY OF THE UPPER REPULSE DAM SITE, DERWENT RIVER, TASMANIA

by

W. A. WIEBENGA and E. J. POLAK

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CONTENTS

ILLUSTRATIONS

ABSTRACT

Details and results are given of seismic refraction and resistivity surveys made in response to an application from the Hydro-Electric Commission of Tasmania to investigate a proposed site for a dam on the River Derwent. The dam is to be part of the Derwent-Dee power development scheme.

The purpose of the surveys was to determine the depth to bedrock and the nature of the overburden and the bedrock. The overburden consists of scree, alluvial deposits, sandstone and weathered dolerite and is up to 104 ft. thick. The bedrock consists of jointed and unweathered dolerite.

The following velocities (ft. per sec.) were recorded :-

Soil	1,000 - 1,200
Dolerite scree	2,500 - 3,200
Weathered dolerite	3,100 - 6,000
Jointed unweathered dolerite	11,000 - 15,000
Unweathered dolerite	15,000 - 22,000
Weathered sandstone	3,000 - 5,000
Partly weathered sandstone	7,000 - 9,000

Comparison with drilling data shows that the average thickness of overburden indicated by the seismic method is about 13 per cent too large.

1. INTRODUCTION

As part of the Derwent-Dee power development scheme, the Hydro-Electric Commission of Tasmania proposes to erect a dam on the Derwent River near its junction with the Repulse River (Plate 1).

Two possible sites for the dam were chosen by the Commission for investigation, one 900 ft. below the junction of the two rivers (known as the Lower Repulse dam site) and the other above the junction (known as the Upper Repulse dam site). A seismic refraction survey of the Lower Repulse dam site was carried out by the Bureau in 1955 (Wiebenga, Dyson and O'Connor, 1956).

The object of the survey of the Upper Repulse dam site was to determine the depth to bedrock and the character of both overburden and bedrock. Twelve diamond drill holes put down by the Commission were used as controls for the geophysical survey.

The survey was carried out in May, 1956, by a geophysical party consisting of E.J. Polak (party leader) and A. Stocklin, geophysicists, and K. Mort, field assistant. The Commission provided additional assistants and carried out the topographical survey.

It is desired to acknowledge the co-operation of the staff of the Resident Engineer's office at Wayatinah.

2. GEOLOGY

The geology of the area has been described by Jennings (1955) and Mather (1955). The main rock in the area is a medium-grained Jurassic dolerite (see Plate 1), which is extensively jointed. The dolerite crops out in several places, and is covered elsewhere by alluvial deposits and scree. Sandstone is present on the left bank of the Derwent River. In drill hole 8970, in the north-western portion of the area surveyed, the sandstone is almost 100 ft. thick and is covered by river terrace material. The sandstone is of Triassic age (Knocklofty Group) and ranges from fine-grained silty sandstone to coarse grit. At the contact between sandstone and dolerite, the sandstone is metamorphosed into a hornfelsic quartzite.

3. METHODS AND INSTRUMENTS

Resistivity and seismic refraction methods were used :-

(a) Resistivity method.

The variation in apparent resistivity for electrode spacings of 40, 80 and 160 ft. of a standard Wenner configuration shows how the electrical resistivity changes with depth. In general, non-porous rocks such as dolerite have a high resistivity. The resistivity of porous rocks such as sandstone depends on the degree of porosity and on the character of the water contained in the pores.

A Megger E..rth Tester was used in the resistivity traversing with station intervals of 40 ft. Nine thousand feet of traverse were surveyed by the resistivity method, which was confined to the left bank of the Derwent River.

(b) Seismic method.

The seismic method of exploration depends on the contrast in the velocity of elastic waves through different rock formations. Hard, unweathered rocks have higher velocities than their weathered and fractured counterparts. The velocity in soil and scree is considerably lower than in the weathered and fractured rock.

The method of differences was used (Heiland, 1946, p. 548; Boniwell, 1952) and the following types of spreads were shot :-

(i) Weathering Spreads. These were used to obtain seismic wave velocities and the thickness of the soil and near-surface layers. Geophone interval was 10 ft. and shot points were at distances of 5, 10, 20 and 40 ft. from both ends of the spreads.

(ii) Normal Spreads. The geophone interval was 40 ft. and shot points were at distances of 20, 40, 120 and 200 ft. from both ends of the spread.

(iii) Broadside Spreads. This type of spread was used on steep slopes. Geophones were spaced at 40-foot intervals and shot points were 50 and 150 ft. from the spread along a line approximately perpendicular to the spread from its mid-point.

The geophysical equipment used in the survey consisted of a Heiland six-channel refraction recorder and Technical Instrument Co. geophones with a natural frequency of about 19 cycles per second.

The total length of traverses surveyed by the seismic method was 10,320 ft.

4. RESULTS

(a) Resistivity Survey.

The results of the resistivity survey using an electrode spacing of 80 ft. are shown as a resistivity contour map (Plate 2). The results from this spacing show more detail than those from the 40-foot and 160-foot spacing.

Drill holes 8690 and 8691 show dolerite scree at the surface, overlying weathered and jointed dolerite; dolerite crops out near stations T452 and I.P.E. The high resistivity area shown on Plate 2, delineated approximately by the 30,000 ohm-cm contour, coincides generally with the area where dolerite occurs close to the surface or in out crop. The indications are, therefore, that the overburden along traverse Q probably consists mainly of weathered dolerite.

In the graph of Plate 2 the depth to the interface between sandstone and dolerite (from drill hole data) is plotted on a logarithmic scale against the value of apparent resistivity. The approximate empirical formula derived from the graph is :-

$$x = 1.7 \times 10^{14} \times y^{-3.16}$$

where x is the depth in feet to the dolerite/sandstone interface and y is the apparent resistivity in ohm-cm.

The area enclosed by the 10,000 ohm-cm resistivity contour corresponds, according to the above formula, to a sandstone thickness of between 40 and 100 ft.

(b) Seismic Survey.

Longitudinal-wave velocities for the various rock types at the Upper Repulse dam site are shown in Table 1.

TABLE 1.

Rock type	Seismic velocity (ft/sec)
Soil	1,000 - 1,200
Dolerite scree and talus	2,500 - 3,200
Weathered dolerite	3,100 - 6,000 (1)
Jointed unweathered dolerite	11,000 - 15,000 (2)
Unweathered dolerite	15,000 - 22,000
Weathered sandstone	3,000 - 5,000
Partly weathered sandstone	7,000 - 9,000 (3)

Notes:

1. Determined on traverse T (stations 455-454) and near traverse O (stations 575-577) where weathered dolerite crops out.

2. Determined on traverses O, Q and T where the logs of drill holes 8689, 8696 and 8691 respectively show jointed dolerite.

3. Determined on traverses T, L and V where the logs of drillholes 8679, 8970, 8699, 8692 show sandstone (as the results were calculated using average velocities some of the velocities recorded do not appear on Plate 3).

Because the velocities in weathered dolerite and weathered sandstone overlap, as indicated in Table 1, these two rocks cannot be distinguished from seismic data alone. However, the resistivity contour plan provides additional data from which it is possible to delineate the boundary between them fairly accurately. In this report the terms "overburden" and "bedrock" are used to distinguish between rocks with low seismic velocities and those with high seismic velocities. The overburden is here defined as rock with seismic velocity not exceeding 9,000 ft. per sec. and bedrock as rock with seismic velocity exceeding 11,000 ft. per sec.

The seismic results are shown on Plate 3 as profiles along the traverses.

The depth to bedrock was determined by using average overburden velocities. These were computed either from weathering spread data or by application of the curved-ray technique (Handley, 1954). In this technique the assumption is made that the increase of velocity with depth can be expressed as an exponential function. This technique enables the interpreter to determine the approximate seismic velocity at any selected depth or to determine the approximate depth to which a given velocity corresponds.

Near drill hole 8692, the 7,500 ft. per sec. velocity horizon is at a depth of 44 ft. The log of drill hole 8692 states that "Rock appears sound below 44 ft." A 7,500 ft. per sec. horizon was therefore computed and plotted on those portions of the seismic profiles where drilling data and the resistivity contour plan indicated sandstone at, or

close to, the surface, i.e. on profile T between stations 461 and 1006, on profile R between 165 and 1060, on U-Q between 246 and 1082, and over nearly the whole length of profile V. Assuming a density of 2.4 for the sandstone and a Poisson's ratio of 0.3 (Birch, Schairer and Spicer, 1950), Young's modulus for sandstone of 7,500 ft. per sec. velocity is 1×10^{-11} c.g.s. units.

Plate 4 shows the bedrock contours plotted from the seismic data. The southern boundary of the sandstone (Knocklofty Group), represented by the 30,000 ohm-cm contour of Plate 2, is indicated on this plan.

Plate 5 shows the comparison between seismic and drilling data. The drill logs and seismic velocities and depths to discontinuities are shown side by side. The plate also shows a statistical analysis with regression lines of the following :-

(i) Correlation between depth to bedrock from seismic data and depth to jointed dolerite from drilling data.

(ii) Correlation between depth to bedrock from seismic data and depth to rock which shows 100 per cent core recovery.

The regression lines show that the seismic data indicate the depth to bedrock fairly accurately (standard error is 6 ft.), irrespective of whether the bedrock is defined geologically as jointed dolerite (the joints being filled with calcite or zeolites) or as rock with 100 per cent core recovery.

5. CONCLUSIONS

The geophysical survey provided information on the depth to bedrock on both sides of the Derwent River. On the right (south) bank, the overburden consists of weathered dolerite and the bedrock of jointed unweathered dolerite. On the left (north) bank, the overburden consists of weathered dolerite near the river and sandstone further from the river. The interpretation of the seismic refraction data enabled the thickness of the overburden to be estimated, but it was not possible to differentiate between sandstone and weathered dolerite on the basis of seismic velocities alone. The data from the resistivity survey indicated clearly the boundary between low-resistivity sandstone and high-resistivity dolerite. Thus the two methods were complementary and enabled a complete interpretation to be made.

On the three north-south profiles the depth to the 7,500 ft. per sec. velocity horizon (Young's Modulus 1×10^{-11} c.g.s. units) is shown. This represents a horizon defined by the geologist as "sound rock" in drill hole 8692.

The geophysical results indicate that the most suitable area for further investigations is near cross-traverse Q - U, because:

(i) The overburden along this traverse consists mostly of weathered dolerite.

(ii) The depth to bedrock is less than along the other cross-traverses T and R.

(iii) The bedrock is less jointed than along other traverses, as is shown clearly by the seismic velocities on Plate 3.

6. REFERENCES

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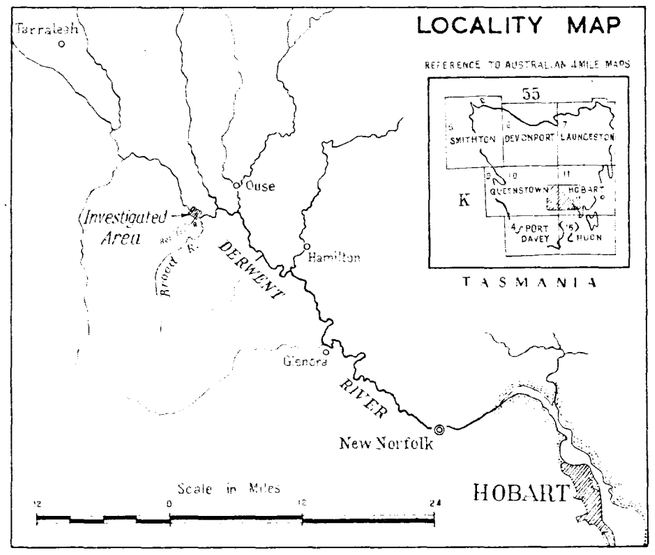
PLATE 1



LEGEND

- Dolerite outcrop
- Dolerite, talus and scree
- Sandstone outcrop
- Sandstone, talus and scree
- Alluvial deposit (River terrace)
- Alluvial deposit (Recent)
- D.D.H. 8692 — Drill hole
- Geophysical traverse

GEOLOGY BASED ON H.E.C. MAPS

SCALE IN FEET

100 0 100 200 300 400

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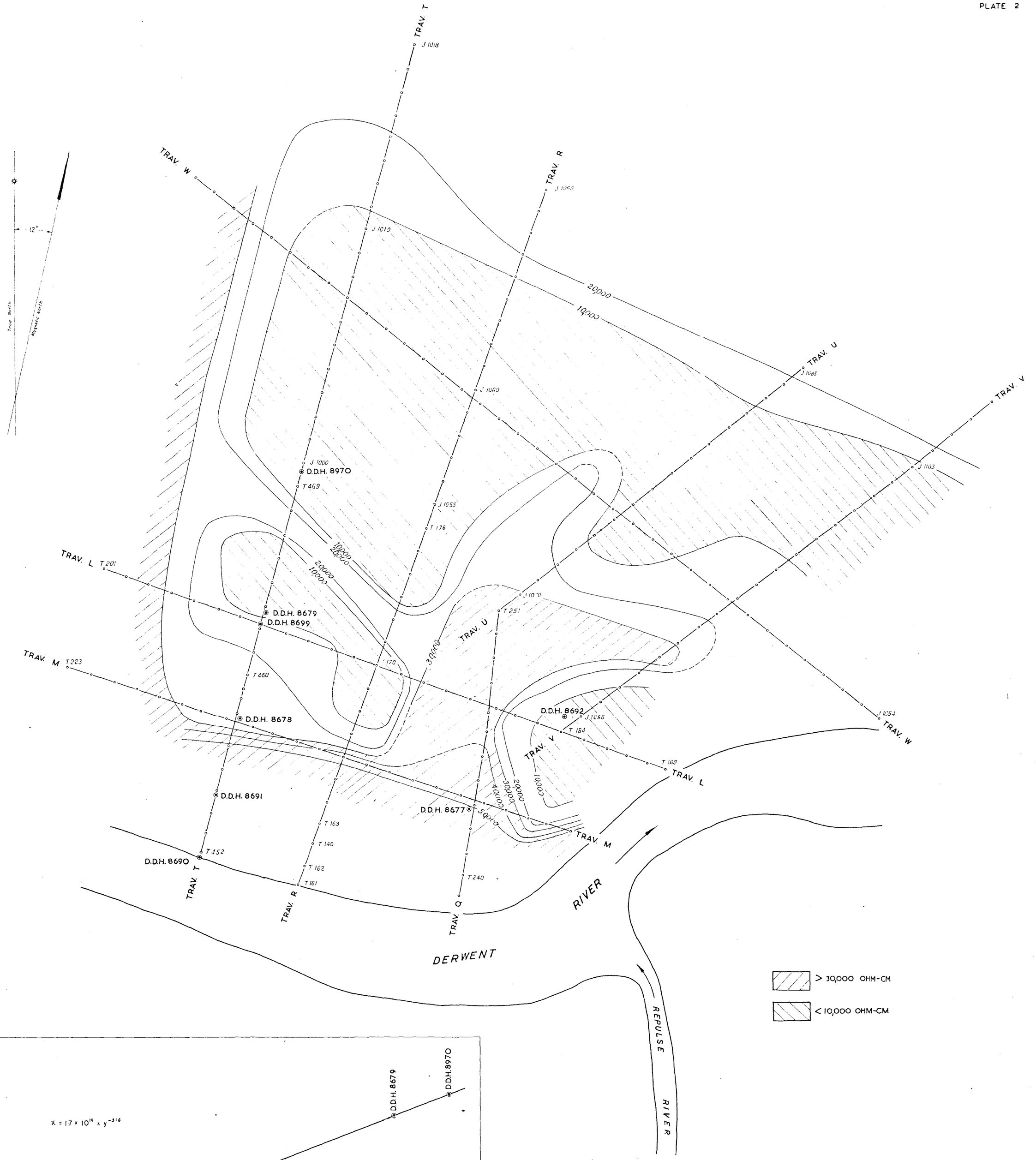
GEOPHYSICIST

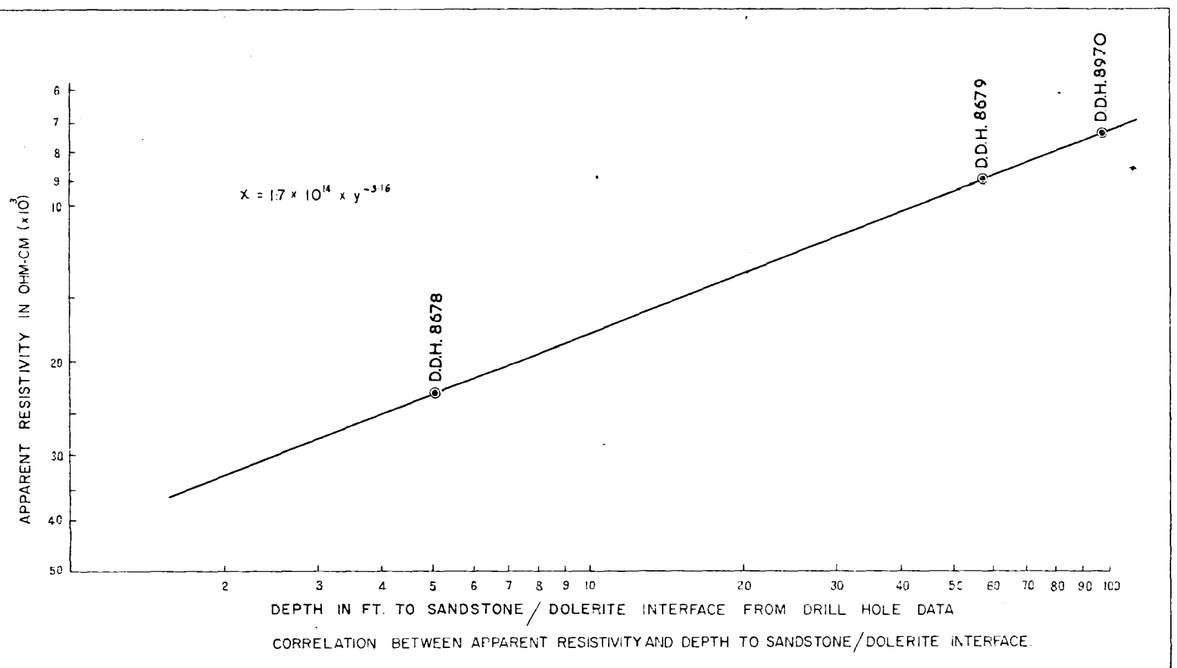
GEOPHYSICAL SURVEY OF THE UPPER REPULSE DAM SITE
DERWENT RIVER, TASMANIA

GEOLOGY AND GEOPHYSICAL TRAVERSES

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics. G 253-1

PLATE 2





CORRELATION BETWEEN APPARENT RESISTIVITY AND DEPTH TO SANDSTONE/DOLERITE INTERFACE.

GEOPHYSICAL SURVEY OF THE UPPER REPULSE DAM SITE
DERWENT RIVER, TASMANIA

RESISTIVITY CONTOUR PLAN

SCALE IN FEET

100 0 100 200 300 400

CONTOUR INTERVAL 10,000 OHM-CM

W A Wilunga
GEOPHYSICIST

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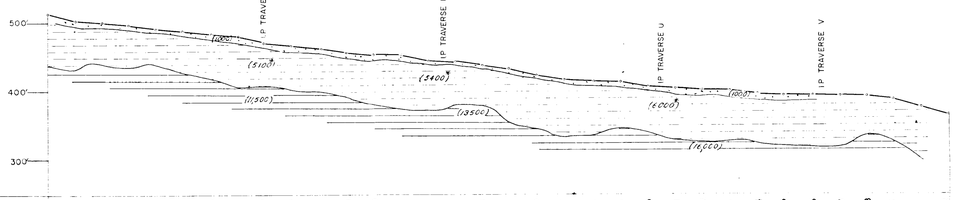
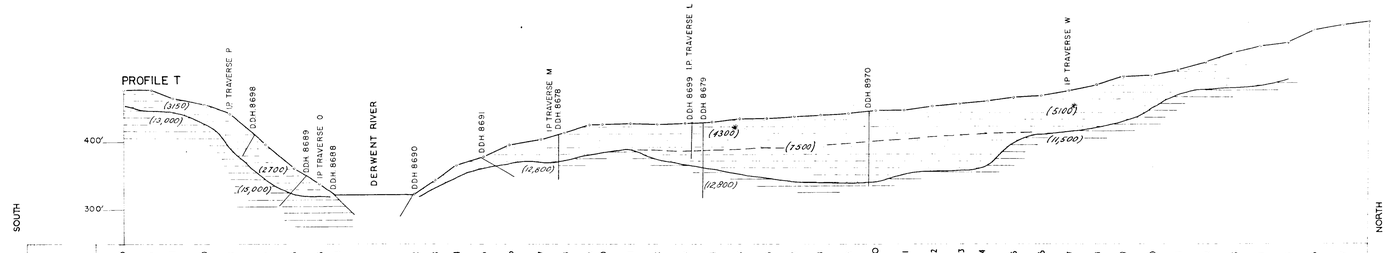
PROFILE W



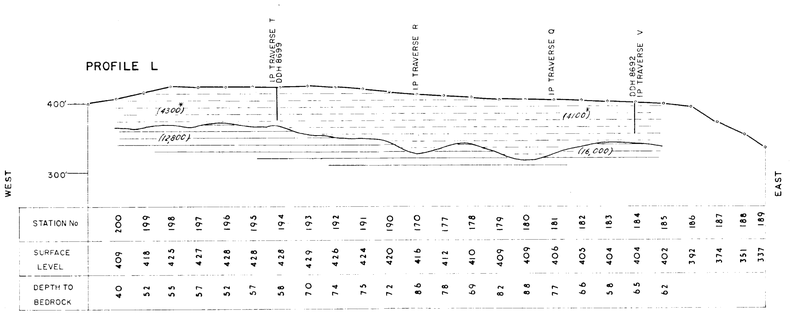
STATION No	1025	1024	1023	1022	1021	1020	1019	1007	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1051	1052
SURFACE LEVEL	509	504	449	494	488	483	480	479	469	462	458	455	452	448	444	439	432	424	419	415	413	409	408	404	404	400	397	397	397	396	390	365	361
DEPTH TO BEDROCK	70	61	60	48	60	65	74	60	62	60	65	72	80	70	62 60	56	74	80	85	72	66	65	73	73	72	71	74	74	73 79	55	65	73	

PROFILE T



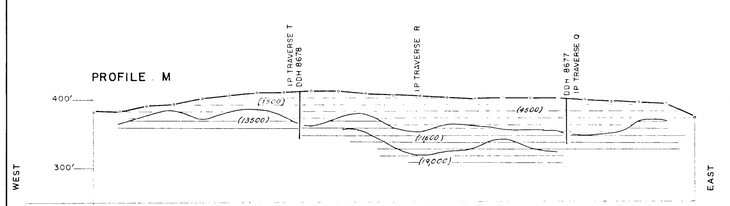
STATION No	1106	1105	451	450	449	448	447	446	445	444	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017
SURFACE LEVEL	479	473	463	454	440	449	420	448	397	368	341	328	328	347	362	378	391	404	414	420	422	424	426	429	429	431	433	436	440	440	444	448	452	456	459	463	467	474	481	491	496	504	517	528	540	549	561	570
DEPTH TO BEDROCK	25	27	20	28	50	45	47	38	30 16				9	16	15	26	32	47	42	40	40	50	58	65	81	89	93	97	98	100	92	92	96	92	63	55	58	62	67	48	30	36	48	58	52		

PROFILE L



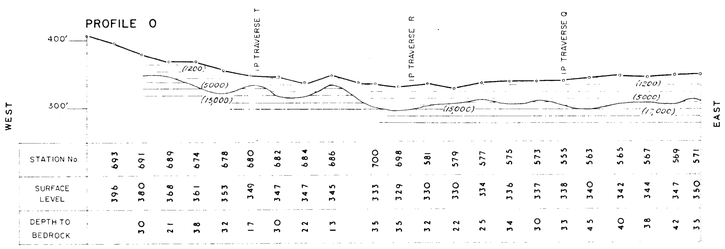
STATION No	200	199	198	197	196	195	194	193	192	191	190	170	177	178	179	180	181	182	183	184	185	186	187	188	189
SURFACE LEVEL	409	418	425	427	428	428	428	429	426	424	420	416	412	410	409	409	406	405	404	404	402	392	374	351	337
DEPTH TO BEDROCK	40	52	55	57	52	57	58	70	74	75	72	86	78	69	82	88	77	66	58	65	62				

PROFILE M



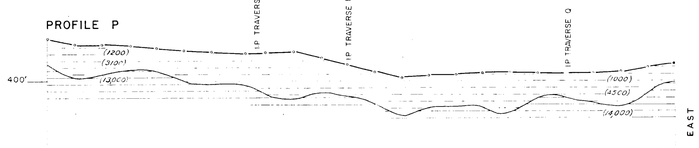
STATION No	222	221	220	219	218	217	216	215	214	213	212	166	202	203	204	205	206	207	208	209	210	211
SURFACE LEVEL	385	390	397	404	409	413	414	414	413	410	407	405	402	401	401	403	402	400	398	396	390	370
DEPTH TO BEDROCK	18	15	11	29	22	25	38	47	38	32	48	54	40	39	48	47	50		48	24	26	

PROFILE O



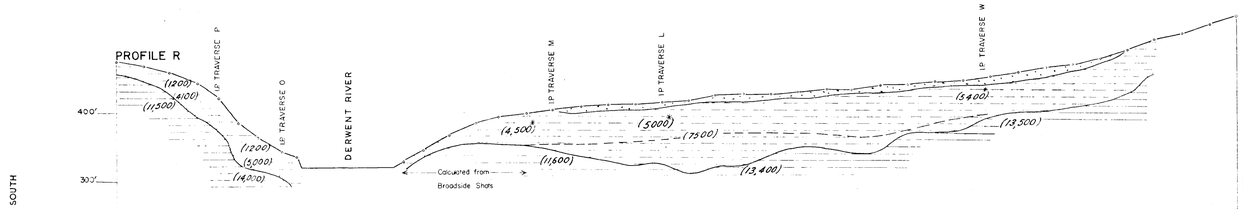
STATION No	693	691	689	674	678	680	682	684	686	700	698	581	579	577	575	573	555	563	565	567	569	571
SURFACE LEVEL	396	380	368	361	353	349	347	347	345	335	329	330	330	334	336	337	338	340	342	344	347	350
DEPTH TO BEDROCK		30	21	38	32	17	30	22	13	35	35	32	22	25	34	30	33	45	40	38	42	35

PROFILE P



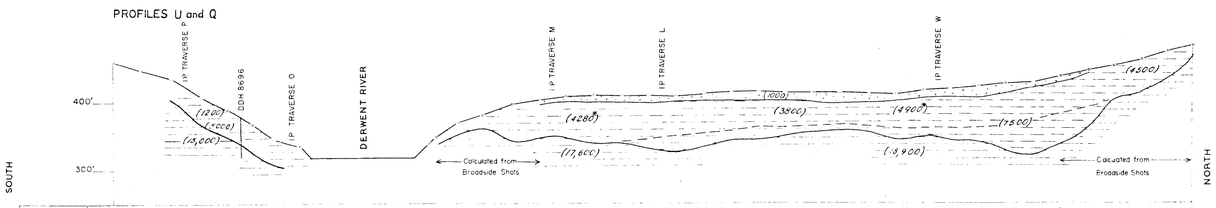
STATION No	656	654	652	650	648	647	643	641	639	618	616	614	612	610	608	605	604	602	585	594	596	598	600
SURFACE LEVEL	436	434	432	430	428	427	426	425	424	425	416	415	409	410	410	413	413	413	415	418	419	424	429
DEPTH TO BEDROCK	46	44	37	32	45	48	45	60	68	49	45	43	52	46	45	50	59	35	30	45	48	32	26

PROFILE R



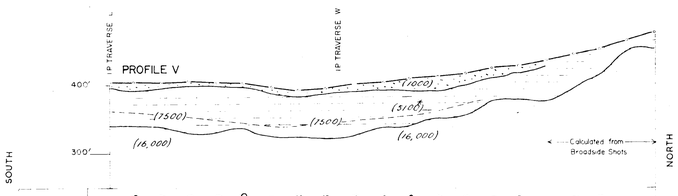
STATION No	633	631	629	628	627	616	623	621	619	582	161	162	140	163	164	165	166	167	168	169	170	171	172	173	174	175	430	433	435	438	440	443	446	450	455	463	469	478	489	500	513	525
SURFACE LEVEL	477	470	461	456	447	425	389	366	344	335	326	347	366	381	391	398	405	409	411	413	416	419	422	426	427	430																	
DEPTH TO BEDROCK	19	22	30	43	40	55	48	35	35		14	14	16	26	38	45	54	72	85	87	86	104	102	102	87	78	83	93	92	70	72	70 62	59	56	62	59	63	63	52			

PROFILES U and Q

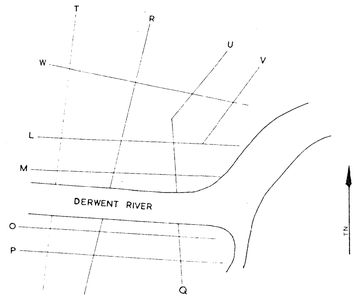


STATION No	591	590	587	584	560	558	556	581	IPE	240	241	242	243	244	245	246	247	248	249	250	251	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084
SURFACE LEVEL	458	447	432	408	389	368	345	333	345	364	380	392	399	403	405	405	407	406	407	408	409	411	411	411	410	410	409	409	412	416	421	428	434	441	451	459	470
DEPTH TO BEDROCK			28	42	40	40	33		12	16	22	40	45	50	59	59	67	77	80	73	68	65	60	55	52	55	67	66	72	77	94	104	94	80	47	45	40

PROFILE V



STATION No	184	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103
SURFACE LEVEL	404	403	403	402	402	402	398	391	393	401	404	407	410	415	423	428	435	444	451
DEPTH TO BEDROCK	65	62	65	75	72		70		73	77	62	72	60	55	41	47	58	48	37



LAYOUT OF TRAVERSES (NOT TO SCALE)

LEGEND

- SOIL
- OVERBURDEN
- BEDROCK
- (5000) AVERAGE VELOCITY IN FT/SEC IN OVERBURDEN
- I P INTERSECTION POINT
- (15,000) SEISMIC VELOCITY IN FT/SEC MEASURED FROM T.D. CURVES
- —(7500)— THEORETICAL HORIZON INDICATING THE DEPTH WHERE OVERBURDEN HAS A VELOCITY OF 7500 FT/SEC (SEE TEXT)

HORIZONTAL AND VERTICAL SCALES IN FEET

100 0 100 200 300 400

W A Wilson
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GEOPHYSICAL SURVEY OF THE UPPER REPULSE DAM SITE, DERWENT RIVER, TASMANIA

SEISMIC PROFILES

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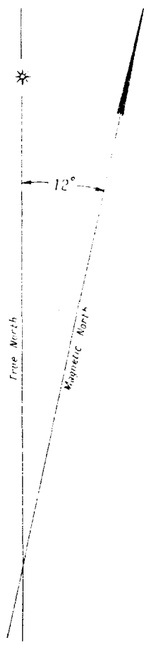

TRAV. T J 1018
TRAV. W J 1026
TRAV. R J 1069
TRAV. U J 1085
TRAV. V J 1103
TRAV. W J 1054
TRAV. L T 201
TRAV. M T 223
TRAV. O J 695
TRAV. P J 658
TRAV. T J 1105
TRAV. R J 633
TRAV. Q J 591
TRAV. O J 571
TRAV. P J 600
TRAV. L T 189
TRAV. M
TRAV. U
TRAV. V

+475 +450 +425 +400 +375 +350 +325 +300

D.D.H. 8970
T 459
J 1055
T 176
D.D.H. 8679
D.D.H. 8699
T 170
D.D.H. 8678
D.D.H. 8691
D.D.H. 8690
T 452
T 162
T 240
J 1070
T 251
D.D.H. 8692
J 1086
T 184
D.D.H. 8677
D.D.H. 8688
D.D.H. 8689
D.D.H. 8698
J 616
T 451
J 555
D.D.H. 8696

DERWENT RIVER
REPULSE RIVER

LEGEND

D.D.H. 8962 Drill hole
J 571 Traverse with seismic stations
+400 Contour
Southern boundary of Knockiofty Group (the 30,000 ohm-cm contour from Resistivity Contour Plan, Plate 2)

SCALE IN FEET
100 0 100 200 300 400

WA Winkler
GEOPHYSICIST

GEOPHYSICAL SURVEY OF THE UPPER REPULSE DAM SITE
DERWENT RIVER, TASMANIA

CONTOURS OF SURFACE OF BEDROCK

(FROM SEISMIC DATA)
(CONTOUR INTERVAL 25 FEET)

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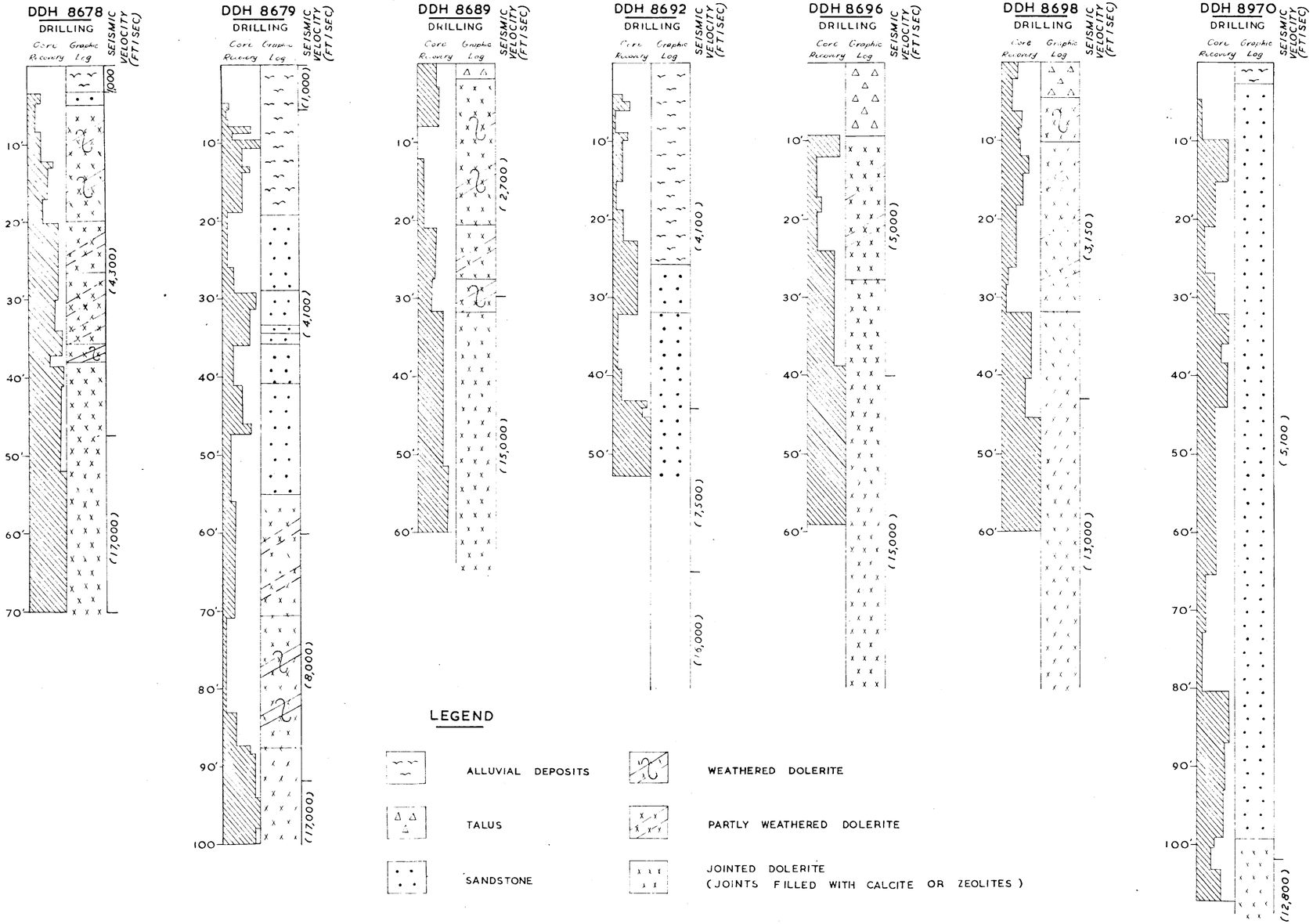
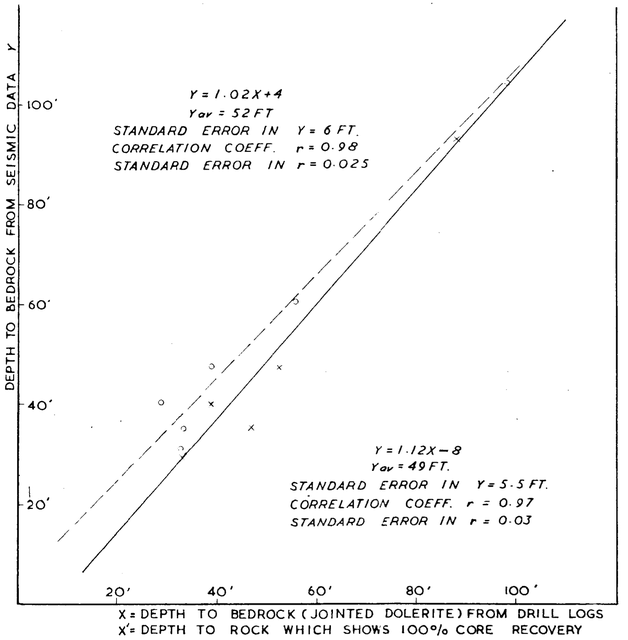


9 CORRELATION BETWEEN DEPTH TO BEDROCK FROM SEISMIC DATA AND DEPTH TO JOINTED DOLERITE

x CORRELATION BETWEEN DEPTH TO BEDROCK FROM SEISMIC DATA AND DEPTH TO ROCK WHICH SHOWS 100% CORE RECOVERY IN DRILLING



GEOPHYSICAL SURVEY OF THE UPPER REPULSE DAM SITE, DERWENT RIVER, TASMANIA

COMPARISON BETWEEN SEISMIC AND DRILLING DATA

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