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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORDS 1952, No. 16

SEISMIC SURVEY OF THE MOSSY MARSH TUNNEL AREA, TASMANIA

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ABSTRACT

Details and results are given of a seismic refraction survey made at the request of the Hydro-Electric Commission of Tasmania, to investigate the site of the western portal of the proposed Mossy Marsh Tunnel. The tunnel is part of the No. 2 Tarraleah Canal project to transport water from Lake King William to the Tarraleah Power Station. The primary object of the survey was to determine the thickness of till overlying the dolerite bedrock, and hence the contours of the bedrock surface.

Seven traverses were surveyed between July and December, 1951, and an additional traverse further north was surveyed in April, 1953. Seismic velocities in the till ranged from 5,000 to 8,000 f.p.s., and in the dolerite from 12,000 to 19,000 f.p.s. The contour plan of the bedrock shows two important troughs where the bedrock is below tunnel invert level (approx. 2,220 ft.). A broad trough, striking approximately E-W, extends across the south-western part of the surveyed area, and a smaller, but deeper, N-S. striking trough exists in the eastern part of the area.

Depths calculated from the seismic survey were in close agreement with those indicated by drill hole logs, particularly where the latter were in close proximity to seismic geophone stations.

1. INTRODUCTION

The survey described in this report was made at the request of the Hydro-Electric Commission of Tasmania. The purpose of the survey was to investigate the site of the western portal of the proposed Mossy Marsh Tunnel. The tunnel forms an integral part of the No. 2 Tarraleah Canal project which will transport water from Lake King William to the Tarraleah power station.

The Commission's preliminary investigations of the tunnel site by drilling tests and geological examination indicated that a tunnel portal in solid rock was not readily available and that a considerable length of overburden (glacial till) would have to be traversed either by reinforced lined portal or by open cut. Owing to the difficulties involved in both types of construction, it became necessary to obtain more detailed information on the subsurface rocks in order to be able to select the tunnel route that would traverse a minimum length of overburden before entering solid rock. The problem to be solved was the determination of the thickness of till overlying the bedrock and hence the contours of the bedrock surface. The Geophysical Section of the Bureau was requested to conduct a seismic refraction survey to obtain this information.

The greater part of the field work was done between July and December 1951, with the geophysical party based on Butler's Gorge construction camp. The survey was extended during April 1953 by making an additional traverse to the north of the previously investigated area. The 1953 work was undertaken from Tarraleah.

The survey party and field hands were provided by the Commission. It is desired to acknowledge the ready co-operation received by the geophysical party from officers of the Investigation Branch, Hobart, and from personnel of the Resident Engineer's Offices at Butler's Gorge and Tarraleah.

2. GEOLOGY

Geological surface mapping of the area covered by the geophysical survey has not been carried out in detail and no attempt has been made to show the geology in the surface plan (Plate 2). However, data compiled from drill holes and test pits show that Pleistocene glacial till forms the overburden above Jurassic dolerite. The till contains boulders mainly of dolerite, either fresh or partly decomposed, in a matrix of small dolerite grains now largely weathered to clay.

Drill holes put down along the No. 2 proposed tunnel line (which coincides with geophysical traverse A) before the start of the survey showed that the dolerite surface was irregular and that considerable differences in the thickness of till existed. The maximum thickness of till encountered in these drill holes was 140 feet.

South of traverse A, drilling along the originally proposed tunnel route (which follows an E-W line through H.E.C. survey station 40 and drill hole No. 4026) revealed a deeply weathered basalt flow and indicated that there must be a buried scarp of dolerite striking approximately east between this line and traverse A, with the basalt extending up to, and tending to conceal, the scarp [illegible]. North of the scarp other tunnel routes corresponding to the geophysical traverses A, B and H were considered as offering possibilities of siting the tunnel entirely or mainly in solid dolerite. However, positioning of the tunnel depended largely on finding a suitable site for the western portal and this required fuller knowledge of the configuration of the dolerite bedrock in the area shown in the surface plan (Plate 1).

3. SEISMIC REFRACTION METHOD

(a) General description of method.

Seismic methods of subsurface exploration depend on the contrast in velocities of wave propagation through different kinds of rocks in the earth's crust. The properties of a rock which determine the velocity of wave propagation within it are its elastic moduli and density. The seismic waves undergo reflection and refraction at any interface between two different types of rocks characterised by different velocities of propagation.

The seismic refraction method is used where shallow depth determinations are required. The essential condition for use of the method is that each successively deeper layer should have a velocity higher than the layer above it. An explosive charge is set off in the ground and the times taken by the seismic energy to reach each of a series of geophones are measured. Only the first arrivals of the seismic disturbance are used. For the geophones nearest the shot point, the first arrivals will be due to waves which have travelled directly through the first layer of low velocity. For more distant geophones (at distances greater than the "critical distance") the first arrivals will be waves which have travelled down through the first layer, been refracted along the interface of the first and second layer with the velocity of the second layer and returned to the surface. Geophones still further away will receive their first arrivals from waves refracted from deeper interfaces with higher velocities. The time-distance graph obtained by plotting the travel times against the geophone - shot point distance gives the velocities of the different layers and allows calculation of the depths to the refracting horizons.

(b) Application of method in Mossy Marsh area.

The problem of determining the thickness of glacial till overlying dolerite bedrock was considered to be capable of solution by the refraction method because it could be safely assumed that the unconsolidated till would have a much lower velocity than the dolerite. This assumption was borne out by the results of the survey. The velocity of seismic waves in till fell within the range 5,000 - 8,000 f.p.s. and in dolerite within the range 12,000 - 19,000 f.p.s.

It was expected that, in general, the dolerite surface would be irregular and at a relatively shallow depth (probably less than 200 feet), and it was therefore considered that the refraction technique known as the "method of differences" would be suitable for the investigation. This technique, which is described by Heiland (1946, p. 548) and Edge and Laby (1931, p. 339) has the advantage of giving a depth determination below each geophone station and, with suitably chosen geophone separations along a traverse, enables a detailed bedrock profile to be obtained.

(c) Equipment and field operations.

The equipment used in this survey was manufactured by ADEM, a Swedish Company, and consisted of a six channel recorder, geophones and amplifiers and shot control box.

The instant of detonation of the charge and the time of arrival of the wave disturbances reaching each geophone are photographically recorded. Time marks derived from an electrically driven tuning fork are superimposed on the photographic record and enable travel times to be measured to an accuracy of one milli-second.

The geophones were spaced at 50 ft. intervals so that each spread of five geophones covered 200 ft. of traverse. The "method of differences" required shots to be fired in the line of the traverse first beyond one end of the spread and then at corresponding positions at the other end. In general, the shots were at distances of 50 ft., 400 ft. and 600 ft. from the nearest geophone. The shortest shot distance was required to give information on the low velocity surface layer. This layer is nearly always observed in seismic exploration and has been referred to as the "weathered" or "aerated" layer, but it does not necessarily conform to geological weathering. Because of its characteristic low velocity, it is important to take account of the "weathered layer" in calculating the depths to bedrock from the vertical travel times given by the "method of differences". The longest shot distance was used to give sufficient depth penetratiom to ensure that refraction from bedrock would be recorded as first arrivals.

The seismic survey consisted of eight traverses totalling 19,450 ft. The traverses encompass an area of nearly ¼ square mile. Traverses A and B follow lines of two early alternative tunnel routes. Traverse H was surveyed in 1953 to investigate a tunnel route further to the north. The short cross-traverse C was surveyed to obtain a depth determination at bore hole No. 4051. Traverses D, E, F and G, commenced at surface contour 2260 and provided coverage of the ground west of traverse A.

4. RESULTS OF SURVEY

(a) Bedrock Depths.

The depths of the bedrock below the surface have been calculated from the observed seismic data, and the resulting bedrock profiles along traverses A, B, C, D, E, F and G are shown in Plate 2, and along H in Plate 3. A bedrock contour plan (Plate 4) with a contour interval of 20 feet has been drawn on the basis of these profiles. It will be clear that, owing to the necessary interpolation between the traverses, the contours for the most part will not give the depths as accurately as do the profiles.

The seismic results provide bedrock contour information required in determining the best tunnel route. It is not proposed here to make any recommendation with regard to the tunnel position, as clearly this would raise engineering considerations outside the scope of this report. However, it is useful to refer to some of the more important bedrock features revealed by the survey.

Assuming that the invert level of the tunnel portal will be approximately 2,220 feet, it will be seen that the bedrock contour plan shows two important troughs where the bedrock is below invert level. A broad, and for the greater part shallow, trough extends from traverse G eastwards to traverse A and will have to be considered in selecting the portal site. The other trough is immediately east of traverse C and strikes north. This trough would be encountered on both tunnel routes A and B but it is clear from the bedrock contours that the trough becomes shallower towards the north and would be avoided by a tunnel along traverse H.

(b) Seismic Velocities.

The low-velocity, surface or "weathered" layer was found to have a velocity of approximately 1,300 f.p.s. The layer ranged in thickness from 0 to 15 feet.

The velocities in till and dolerite each had a considerable range throughout the area, 5,000 - 8,000 f.p.s. for till and 12,000 - 19,000 f.p.s. for dolerite. The range of the velocity in the till is considered to be in part due to differences in the water content, as there is a broad correlation between marshy conditions and the higher velocities, and in part to differences in the degree of consolidation of the till.

Over most of the area, the velocity in dolerite was within the range, 15,000 to 19,000 f.p.s., which is probably characteristic of solid dolerite, the variations within the range being attributable to normal small changes in both chemical and physical composition of the rock and perhaps to slight weathering. However, in some places, much lower velocities, ranging from 12,000 to 15,000 f.p.s. were observed. The low velocities occurred in fairly definite zones, which have been outlined in Plate 4. Where the traverses cross the boundaries of these zones, large changes in the velocity were observed between adjacent geophone spreads, suggesting a fairly abrupt transition from normal to low velocity dolerite.

On the evidence of holes 4033 and 4070, drilled in the low velocity zones, the low velocities appear to occur in closely jointed and partially weathered dolerite. The weathering occurs chiefly along the joints but in places is extensive enough to result in zones of completely weathered dolerite. In the light of these findings, it becomes apparent that in the zones of low velocity, the bedrock is likely to be in a condition that would make tunnelling difficult. Hence, the position and extent of the zones of low velocity bedrock will greatly affect the selection of the most favourable tunnel route.

5. COMPARISON OF SEISMIC RESULTS WITH DRILLING DATA

Before the start of the geophysical survey, the Commission had made drilling tests in parts of the Mossy Marsh area; additional drill holes were put down during the survey. It is desirable, as far as possible, to check the reliability of the method by reference to the drilling data. In the table below, the depths to the dolerite bedrock from the seismic survey and from the drill hole logs are set out for eleven drill holes.

Two sources of uncertainty affect the usefulness of the data shown. Firstly, as there is considerable relief in the dolerite surface, the figures are strictly comparable only where the drill hole coincides in position with a geophone station and this is so for less than half the holes listed; secondly, in most bore holes the upper limit of the solid dolerite is not well defined owing to weathering and jointing in the dolerite, so that it is not always possible to pick a definite depth for solid dolerite to use in comparison with the seismic depth.

COMPARISON OF SEISMIC RESULTS WITH DRILL HOLE DATA

(i) Drill Holes close to Geophone Stations

Drill Hole No.	Location	Depth to Dolerite Bedrock (feet)		Remarks
		Seismic Determination	Drill Hole Log	
4041	On trav. A, Stn. 656	46	40	
4039	On trav. A, Stn. 664	135	> 117	Hole stopped at 117' before reaching dolerite
4048	On trav. B, Stn. 264	73	77	Hole stopped at 77'; last few feet hard to drill and probably dolerite.
4051	On trav. C, Stn. G	129	127	
4070	On trav. H, Stn. 48	81	85	
(ii) Drill Holes distant from Geophone Stations				
4040	On trav. A, between Stns. 659-660	122	> 95	Hole stopped at 95' before reaching dolerite.
4033	On trav. A, between Stns. 688-669	99	110	101'-110' logged as partially weathered dolerite.
4045	On trav. A, between Stns. 248-249	150	115	
4025	Offset 50' N of Stn. 224, Trav. A	30	24	
4042	Offset 50' N of Stn. 259, Trav. A	153	130	
4037	Offset 30' N of Stn. 263, Trav. A	124	138	

The most reliable checks are given by the holes listed in part (i) of the table as these holes practically coincide with geophone stations. It is noted that there is close agreement between the seismic depths and the drill hole data.

The comparisons shown in part (ii) must be given less weight as the drill holes do not coincide with geophone points. Where the drill holes are situated on traverse lines, (Nos. 4040, 4033 and 4045) the seismic depth is obtained by interpolation between the results at the two adjacent geophone points 50 feet apart. Where the holes are offset from traverse lines (Nos. 4025, 4042 and 4037) the seismic depth is estimated by using the calculated depth at the nearest geophone point and the assumed trend of the bedrock contours. Large discrepancies occur at drill holes Nos. 4045 and 4042 but these are not considered to be very significant because at both places the bedrock dips steeply and the estimation of the seismic depths by interpolation is subject to considerable uncertainty.

The table does not contain sufficient data to enable the probable error of the seismic depth determinations to be obtained, but it is considered that it shows a very satisfactory agreement between the seismic and drill hole depths.

6. SUMMARY AND CONCLUSIONS

The refraction seismic method has been used successfully in the Mossy Marsh area to determine the contours of the dolerite bedrock beneath an overburden of glacial till of maximum thickness about 280 feet. The seismic velocities in till and dolerite were found to be within the ranges 5,000 - 8,000 f.p.s. and 12,000 - 19,000 f.p.s. respectively.

The survey has provided bedrock information which should be valuable to the Hydro-Electric Commission in designing the Mossy Marsh Tunnel and in particular in deciding on the most suitable portal site at the western end of the tunnel. The use of the seismic method has obviated the necessity for detailed drilling of the entire area of interest. The survey has shown numerous small irregular features in the bedrock topography as well as two large trough features where the bedrock is below the tunnel invert level.

The survey has also shown that the seismic method may provide information not only on the depth of the bedrock but also on the condition of the bedrock. The seismic results have outlined zones of low velocity bedrock and, from the evidence of two drill holes in such zones, it appears that the low velocity can be attributed to closely jointed and partially weathered dolerite.

Where the test drilling provides a check on the seismic results, the depths to bedrock determined by the seismic method are found to be in close agreement with the depths indicated by the drill hole logs. The Mossy Marsh survey is a typical example of the use of the refraction seismic method in connection with engineering problems requiring information on the depth of bedrock below the surface.

7. REFERENCES

Edge, A.B., and Laby, T.H., 1931 - THE PRINCIPLES AND PRACTICE OF GEOPHYSICAL PROSPECTING, Cambridge University Press.

Heiland, C.A., 1946 - GEOPHYSICAL EXPLORATION, Prentice-Hall, New York.


PLATE I
REFRACTION SEISMIC SURVEY
MOSSY MARSH TUNNEL, TASMANIA
SURFACE CONTOURS
AND
SEISMIC TRAVERSES
CONTOUR INTERVAL — 10 FEET
SCALE IN FEET
200 0 200 400 600
GEOPHYSICIST
LEGEND
○4040 BORE HOLE
·45 H.E.C. SURVEY STATION
TRAVERSE "H"
TRAVERSE B
TRAVERSE C
TRAVERSE D
TRAVERSE E
TRAVERSE F
TRAVERSE G
TRAVERSE A
N 795 KYDS
431 KYDS
432 KYDS
HIGH
LOCALITY PLAN
SCALE IN MILES
TASMANIA
LOCATION OF SEISMIC SURVEY
TARRALEAH
OUSE
NEW NORFOLK
HOBART
TASMAN SEA
G112-2


PLATE 2
TRAVERSE A
ELBOW
TRAVERSE C
TRAVERSE G
TRAVERSE B
TRAVERSE C
DATUM 2000'
BEDROCK LEVEL
SURFACE LEVEL
DISTANCE
STATION
TRAVERSE B
TRAVERSE E
TRAVERSE D
TRAVERSE C
SCALE IN FEET
200 0 200 400 600 800 1000 1200 1400 1600
TRAVERSE D
TRAVERSE E
TRAVERSE F
REFRACTION SEISMIC SURVEY
MOSSY MARSH TUNNEL . TASMANIA
BEDROCK PROFILES
GEOPHYSICIST
Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics
G112-4

PLATE 3

DATUM 2000'

STATION	BEDROCK LEVEL	SURFACE LEVEL
R.0	2273	2347
R.1	2310	2349
R.2	2331	2351
R.3	2336	2352
R.4	2325	2351
R.5	2319	2348
R.6	2313	2349
R.7	2312	2350
R.8	2329	2351
R.9	2308	2352
R.10	2300	2354
R.11	2304	2357
R.12	2304	2358
R.13	2307	2360
R.14	2315	2362
R.15	2321	2363
R.16	2332	2363
R.17	2331	2363
R.18	2332	2363
R.19	2325	2361
R.20	2324	2360
R.21	2286	2360
R.22	2294	2358
R.23	2304	2356
R.24	2307	2358
R.25	2296	2360
R.26	2279	2361
R.27	2318	2362
R.28	2302	2361
R.29	2322	2357
R.30	2320	2362
R.31	2309	2365
R.32	2342	2371
R.33	2334	2373
R.34	2331	2376
R.35	2335	2377
R.36	2346	2379
R.37	2339	2381
R.38	2327	2383
R.39	2336	2384
R.40	2346	2385
R.41	2326	2386
R.42	2320	2387
R.43	2322	2389
R.44	2314	2391
R.45	2300	2391
R.46	2289	2392
R.47	2302	2391
R.48	2310	2392
R.49	2316	2394
R.50	2321	2397
R.51	2321	2399
R.52	2315	2402
R.53	2325	2405
R.54	2330	2410
R.55	2356	2411
R.56	2349	2414
R.57	2357	2417
R.58	2349	2419
R.59	2372	2421
R.60	2372	2422
R.61	2378	2423
R.62	2401	2424
R.63	2402	2425
R.64	2402	2425
R.65	2404	2423
R.66	2395	2420
R.67	2389	2418
R.68	2381	2417
R.69	2349	2416
R.70	2359	2411
R.71	2350	2406
R.72	2331	2406
R.73	2296	2408
R.74	2299	2407
R.75	2273	2408
R.76	2264	2408
R.77	2245	2408
R.78	2248	2408
R.79	2240	2410
R.80	2273	2410
R.81	2276	2411
R.82	2299	2411
R.83	2292	2411
R.84	2302	2414
R.85	2310	2417
R.86	2327	2418
R.87	2321	2421
R.88	2333	2423
R.89	2341	2425
R.90	2320	2425
R.91	2318	2425
R.92	2325	2427
R.93	2334	2429
R.94	2319	2430
R.95	2323	2430
R.96	2335	2433
R.97	2332	2434
R.98	2316	2434
R.99	2312	2435
R.100	2297	2436
R.101	2309	2435
R.102	2299	2436
R.103	2314	2436
R.104	2343	2435

TRAVERSE "H"

SCALE IN FEET

200 0 200 400 600 800

REFRACTION SEISMIC SURVEY

MOSSY MARSH TUNNEL, TASMANIA.

BEDROCK PROFILE

GEOPHYSICIST

PLATE 4

REFRACTION SEISMIC SURVEY
MOSSY MARSH TUNNEL, TASMANIA
BEDROCK CONTOURS

CONTOUR INTERVAL 20 FEET