COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

RECORDS
1956, No.124

SEISMIC SURVEY OF THE EASTERN ABUTMENT OF DAM SITE "B", UPPER COTTER RIVER, A.C.T.

by

L. V. HAWKINS and A. STOCKLIN.

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ABSTRACT

The eastern abutment of the proposed Dam Site "B" on the Upper Cotter River, A.C.T., is a topographic spur in an area of granite. A seismic survey of the abutment was carried out to determine the depth to suitable foundation rock.

The seismic results show the rocks on the spur to be deeply weathered; the average depth to suitable foundation rock is of the order of seventy five feet, and in places is greater than one hundred feet. The error in the depth estimates is considered to be a maximum of ± 25 per cent, but it is considered that the general configuration of the bedrock profile is real.

A refinement in the technique of the "method of differences", which admits of a more accurate and detailed determination of the velocity of elastic waves in the bedrock, is discussed.

1. INTRODUCTION

In response to an application from the Department of Works, Canberra, a seismic refraction survey of the eastern abutment of the Upper Cotter River Dam Site "B" was carried out in July, 1956, by the Geophysical Section of the Bureau of Mineral Resources. The dam site is near Cow Flats on the Upper Cotter River, and the foundation rock at the proposed site is the Cow Flat Granite.

The purposes of the survey were :-

(i) to determine the depth to bedrock, that is, suitable foundation rock or unweathered granite, and

(ii) to obtain from the observed velocity of the elastic compressional waves an indication of the condition of the bedrock and of the overburden (weathered granite, scree, etc.).

The location of the dam site and the layout of the five seismic traverses are shown on Plate 1.

The Cotter River in this area follows the northerly trend of the Cotter Fault, which is a near-vertical major fault (Noakes, 1946). The Cow Flat Granite crops out to the east of this fault. The proposed dam site lies in the granite area, and is about one-third of a mile east of the fault.

The geophysical party consisted of L.V. Hawkins (party leader) and A. Stocklin, geophysicists, J.P. Pigott, field assistant, and two field hands supplied by the Department of Works, Canberra.

Access to the site was rendered difficult by adverse weather conditions and the washing away of a bridge, which necessitated the use of a "flying fox" to cross the river about one mile north of the dam site.

It is desired to acknowledge the assistance given to the seismic party by officers of the Engineering Group of the Geological Section of the Bureau, and by staff from the Construction Engineer's office, Department of Works, Canberra.

2. METHOD AND EQUIPMENT

The seismic refraction method depends on the contrast between the elastic properties of different zones of rock. Elastic waves propagated through the ground are reflected and/or refracted at elastic discontinuities. The waves which are refracted at the critical angle and travel along the discontinuity and are refracted at the critical angle back to the surface are used in the seismic refraction method.

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An explosive charge is used as the source of the elastic waves. In the normal refraction method the charge is in line with a number of detectors (geophones) arranged in a line and known as a spread, and the first arrival times of the elastic waves are recorded at each geophone. A graph of the first arrival times against the distance from the shot point is called a time-distance curve.

As only the first arrivals of the elastic waves are recorded, the method requires the lower layer at a discontinuity to have a higher velocity than the overlying material. As suitable foundation rock for a dam site has high elastic constants and therefore in practice a high elastic wave velocity, the seismic refraction method is particularly applicable to such investigations.

A technique known as the "method of differences" (Edge and Laby, 1931 p.339) was used in this survey, as it is the most suitable method for detailed investigations of near-surface structures. This technique has the advantage that it determines the depth to bedrock at each geophone station.

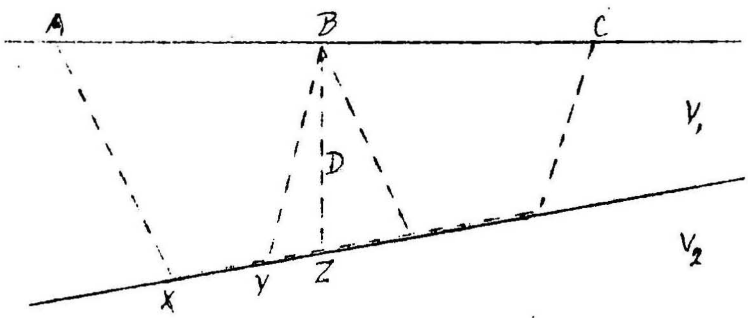

Fig. 1. Method of Differences.

Referring to Fig. 1, if A is a shot point at one end of the spread, let the time for the energy (elastic waves) to reach a point B, within the spread, be T_{AB}, and the time to a point C, beyond the spread, be T_{AC}. Similarly, if a shot is fired at C, let the time for the energy to travel from C to B be T_{CB}, and from C to A be T_{CA}, which is equal to T_{AC}.

The depth below B is computed from the vertical travel time T_D which is defined as :-

$$T_D = \tfrac{1}{2}\,(T_{AB} + T_{CB} - T_{AC}) \qquad (1)$$

The depth, D, then becomes :-

$$D = \frac{V_2}{(V_2^2 - V_1^2)^{\frac{1}{2}}} \cdot T_D \cdot V_1 \qquad \ldots\ldots\ldots \quad (2)$$

where V_1 is the velocity in the material above the discontinuity and V_2 the velocity in the material below.

The term: $\dfrac{V_2}{(V_2^2 - V_1^2)^{\frac{1}{2}}}$ is a correction for the inclined travel path through the layer of velocity V_1.

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It should be pointed out that the computed depth, D, is the depth normal to the surface of the bedrock. The vertical depth may be obtained graphically from the plotted bedrock profile.

Two types of geophone spread were used :-

(a) Normal spreads, in which geophones were placed at 40-foot intervals and shot distances were 40 feet and 240 feet.

(b) Weathering spreads, with a geophone interval of 10 feet and shot distances of 10 feet and 40 feet.

The vertical travel times (see below) and the velocities in the different layers were computed from the data obtained from the spreads.

The rock type and condition of the rock can usually be inferred from the elastic wave velocities, provided some geological control is available. It is, therefore, desirable to measure the velocity of the bedrock with as much accuracy and detail as the method permits. To do this, a refinement in the technique may be introduced.

The vertical travel time (T_D) is the time taken to travel through the overburden below each geophone station. If the vertical travel time is substracted from the total travel time (T_{AB} or T_{CB}), then the travel time T'_{AB} can be written as :-

$$T'_{AB} = T_{AB} - T_D \qquad (3)$$

From Figure 1, $T_{AB} = AX/V_1 + XY/V_2 + YB/V_1$

and equation (1) reduces to $T_D = YB/V_1 - YZ/V_2$

Equation (3) therefore becomes :-

$$T'_{AB} = AX/V_1 + XY/V_2 + YZ/V_2$$
$$= T_{AZ}$$

which is the travel time from A to the point Z, vertically below the geophone B.

The travel times T_{AZ} (or T_{CZ}) are plotted as new time-distance curves, in which the effect of the thickness and velocity of the overburden are removed, thereby giving true bedrock velocities.

This refinement is particularly valuable when detailed knowledge of the bedrock is desired or where very irregular overburden or weathered layers makes the estimation of the bedrock velocity difficult.

A "Century" 12-channel refraction seismograph was used, with "T.I.C." geophones of natural frequency 20 cycles per second.

3. RESULTS

The results are shown on Plate 2 in the form of profiles showing the depth to bedrock (unweathered granite) as estimated from the seismic data. The profiles also show the seismic (elastic wave) velocities in the bedrock and the average seismic velocities in the overburden.

The depth to bedrock ranges from 36 feet on traverse E to 119 feet on traverse D. In general, and along traverses A, B and D in particular, the depth to bedrock is great and the overburden very weathered. The thickness of the overburden appears to be least near the river and greatest near the intersection of traverses D and B.

It is to be noted that the spur is so deeply weathered that the advantage to be gained from its topographic relief is considerably reduced. The average velocities in the overburden on the spur (3,000 and 3,500 feet/sec.) are lower than elsewhere, indicating that the overburden there is more weathered. Also, the bedrock velocity of 10,000 to 13,000 feet/sec. on the flattened part of the spur near the intersections of traverse D with traverses A and B indicates that the bedrock there is partly weathered.

The percentage error in the depth computations $\frac{\delta Z}{Z}$ may be expressed as :-

$$\frac{\delta Z}{Z} = \frac{\delta T}{T} + \frac{\delta V}{V}$$

where $\frac{\delta T}{T}$ is the percentage error in the travel time, and $\frac{\delta V}{V}$ the average percentage error in overburden velocity, irrespective of sign.

$\frac{\delta V}{V}$ is estimated, on five determinations of possible error, at $\pm$ 15 per cent.

$\frac{\delta T}{T}$ is estimated at $\pm$ 10 per cent.

The results may therefore be considered to have a possible error ranging up to $\pm$ 25 per cent. The possible error is larger than would normally be expected, because of the poor energy transmission in the ground and the adverse weather conditions experienced.

It should be pointed out that while the possible error pertains to the order of the variations in the depth to bedrock, the general configuration of the bedrock as indicated by the seismic results is thought to be real. It is stressed that drill hole control would greatly improve the accuracy of predictions made from the results.

4. CONCLUSIONS

The seismic results show that the topographic spur, which is the eastern abutment of the proposed dam site, is deeply and extensively weathered.

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Suitable foundation rock appears to be at an average depth of about 75 feet; near the intersections of traverse D with traverses A and B, it is greater than 100 feet. This area of deeper weathering coincides with the most prominent part of the spur where the overburden is more weathered than elsewhere, and where the bedrock appears to be slightly weathered.

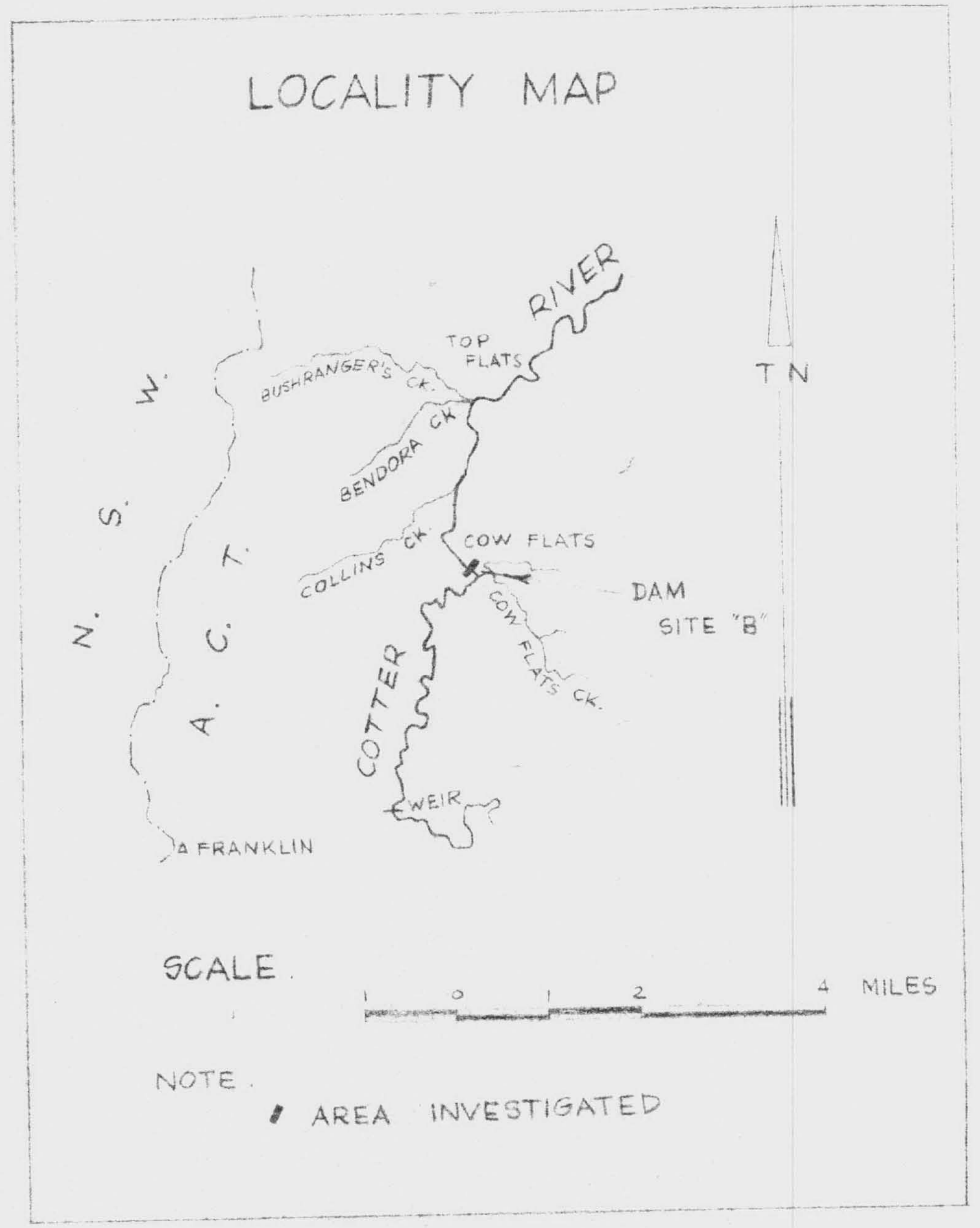
5. REFERENCES

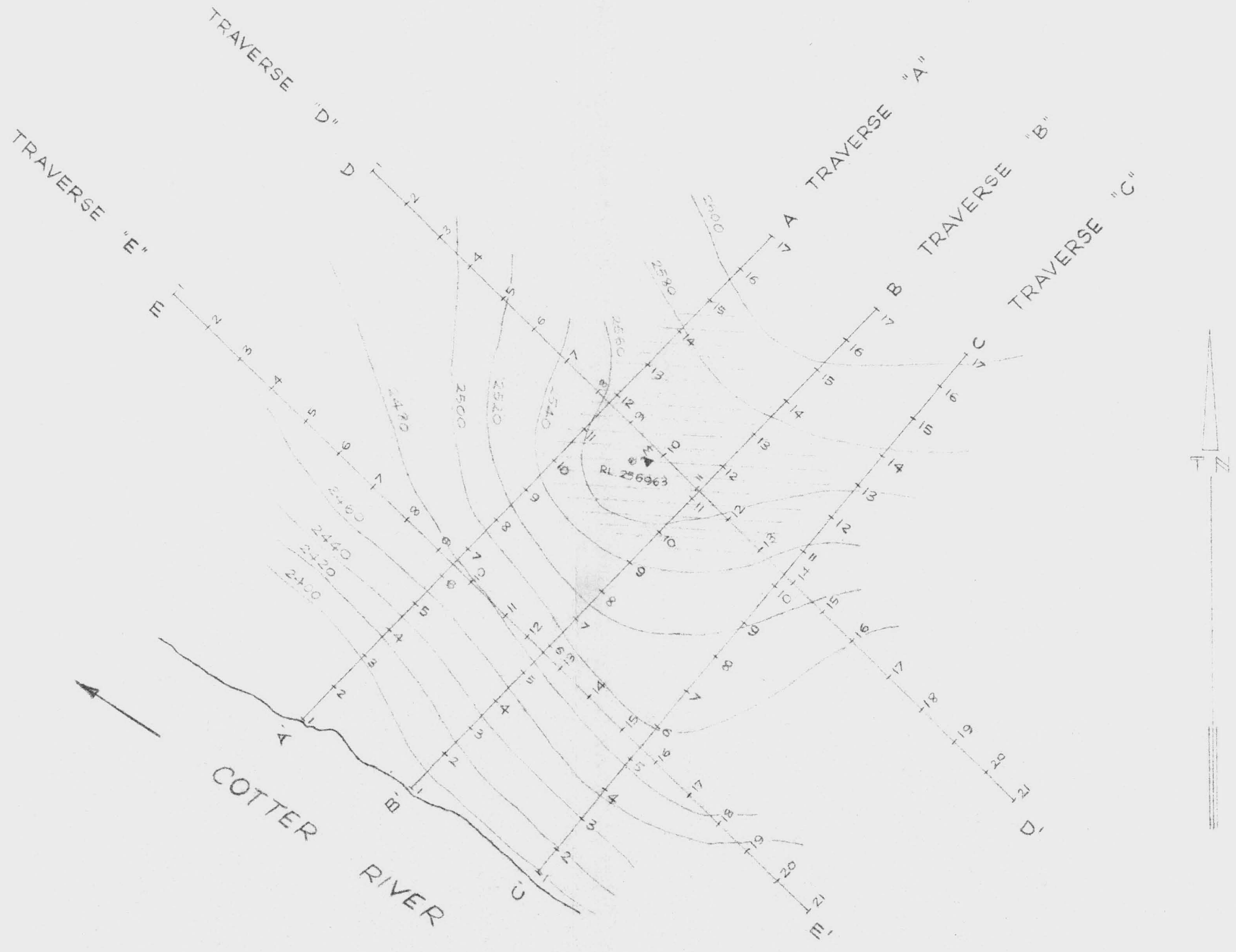
Edge, A.B., and Laby, T.H., 1931 - The Principals and Practice of Geophysical Prospecting. Cambridge University Press, London.

Noakes, L.C., 1946 - Dam Sites in the Upper Cotter Valley between Bushrangers and Collins Creeks. Mineral Resources Survey Report No. 1946/12.

GEOPHYSICIST

L. V. Hawkins





LEGEND.

GEOPHYSICAL STATIONS

▲ TRIG. STATION

2500 SURFACE CONTOUR (APPROX.)

SLIGHTLY WEATHERED BEDROCK

SEISMIC SURVEY OF THE EASTERN ABUTMENT OF DAMSITE "B", UPPER COTTER RIVER, ACT

LOCALITY MAP AND GEOPHYSICAL TRAVERSES

SCALE 50 0 50 100 200 FEET

GEOPHYSICAL SECTION BUREAU OF MINERAL RESOURCES

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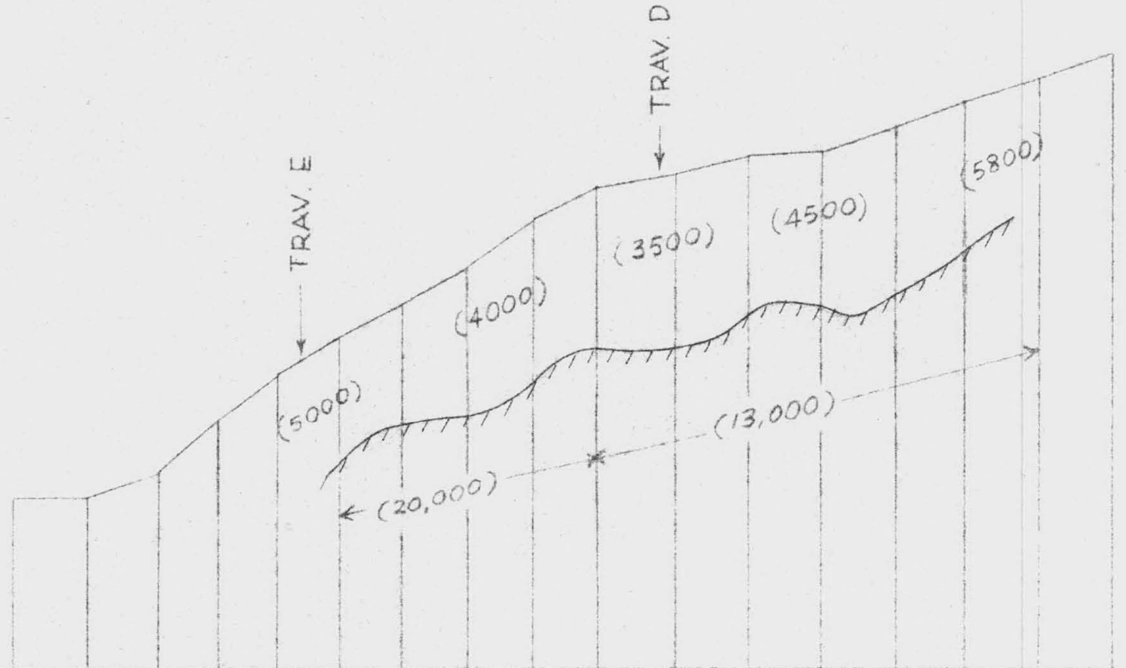
PLATE 2

GEOPHYSICIST

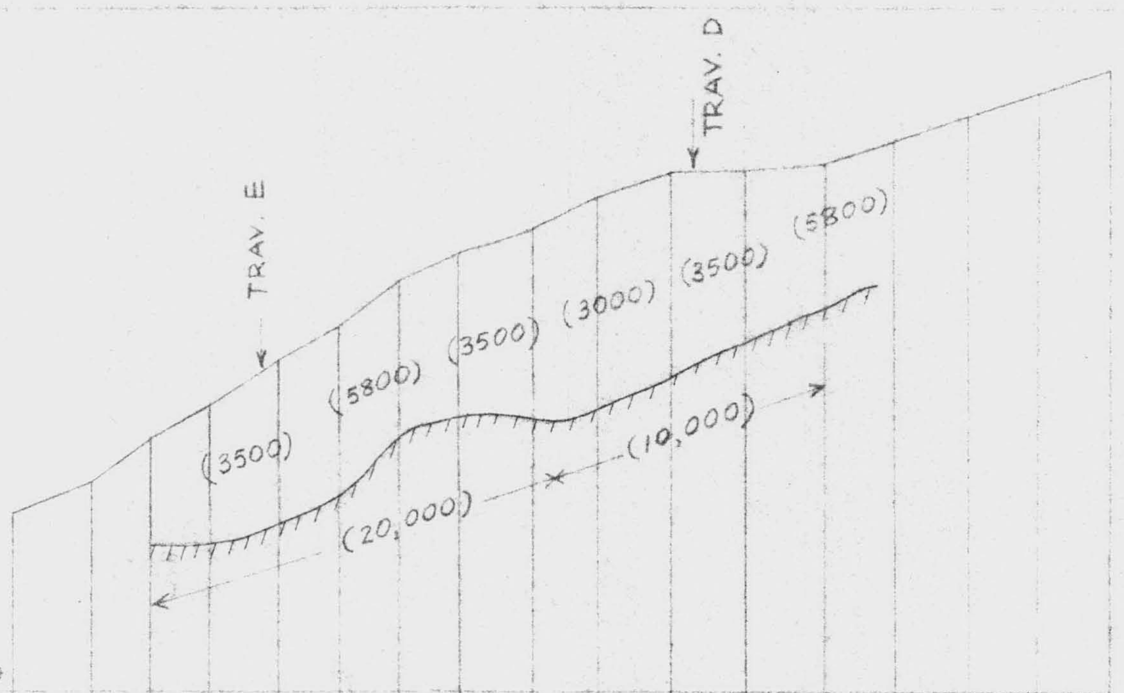
L. V. Hawkins



RL. 2300

R.L.	2387	2388	2401	2428	2451	2472	2488	2506	2532	2548	2558	2564	2568	2579	2592	2605	2618
CH. Nº	00	38	76	106	138	170	204	238	271	306	344	384	422	461	498	537	574
ST. Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
B'ROCK DEPTH						66	65	79	87	86	90	85	84	87	78		

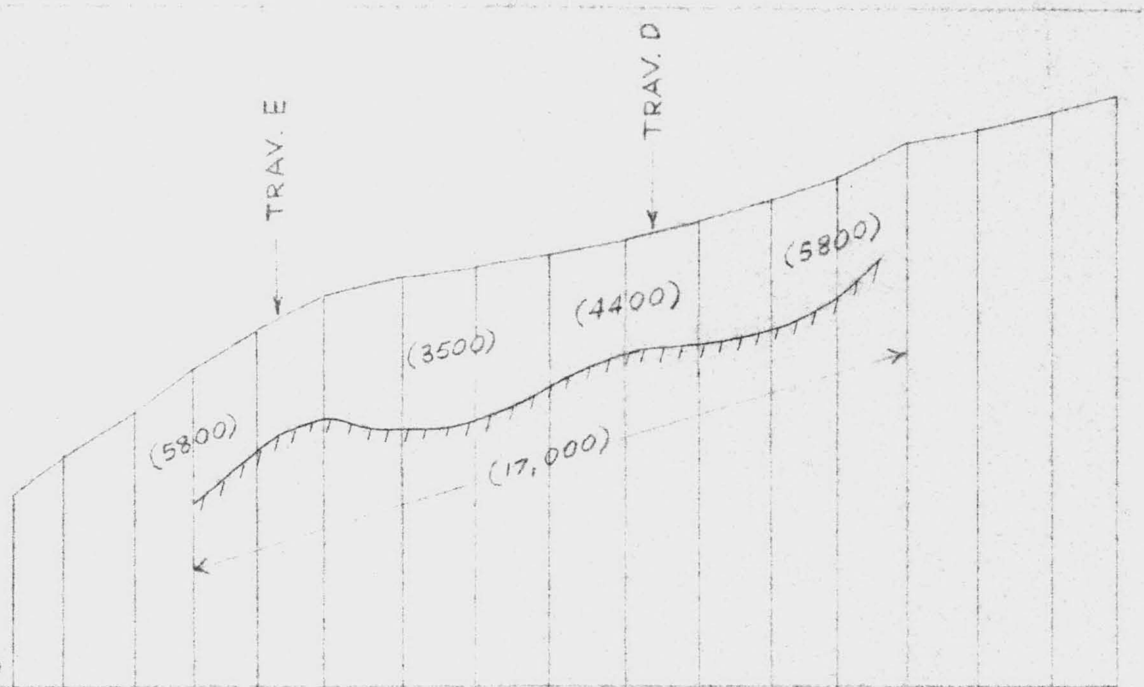
TRAVERSE "A"



RL. 2300

R.L.	2393	2409	2431	2450	2472	2490	2514	2528	2540	2556	2568	2570	2574	2585	2597	2610	2622
CH. Nº	00	41	72	104	139	172	202	234	271	307	345	384	424	461	500	537	574
ST. Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
B'ROCK DEPTH			55	72	87	90	83	87	101	110	107	89	76				

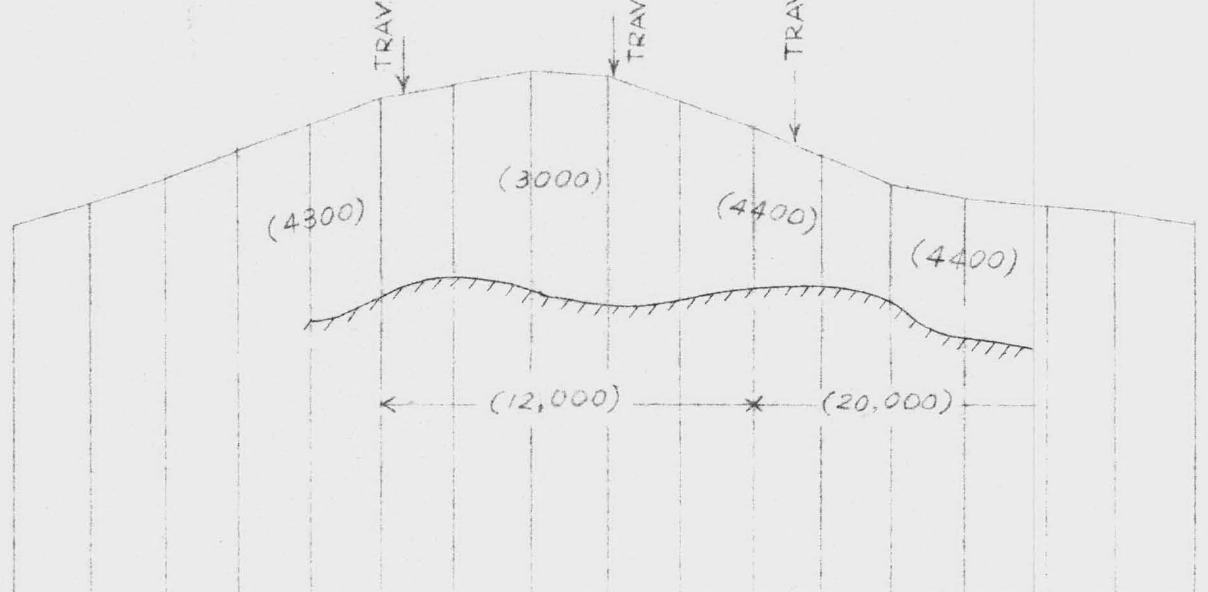
TRAVERSE "B"



RL. 2300

R.L.	2398	2417	2440	2464	2484	2501	2510	2515	2522	2529	2538	2550	2562	2578	2587	2595	2603
CH. Nº	00	27	64	94	128	163	202	241	280	319	357	396	431	466	504	542	577
ST. Nº	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
B'ROCK DEPTH				70	63	66	79	81	67	59	62	67	61				

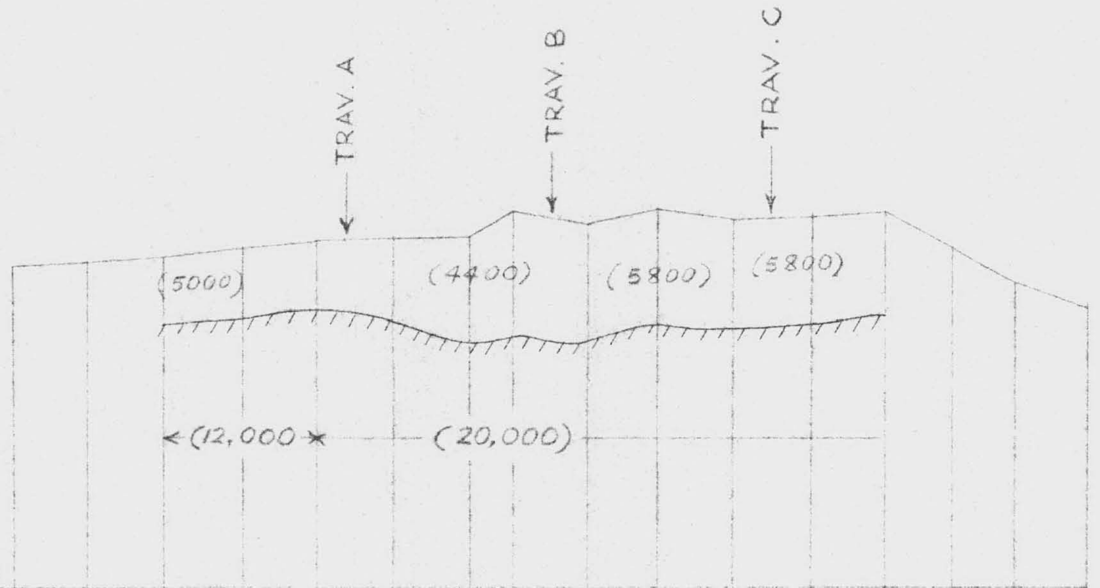
TRAVERSE "C"



RL. 2300

R.L.	2492	2505	2518	2531	2543	2559	2566	2573	2570	2559	2544	2528	2515	2500	2504	2501	2495
CH. Nº	79	117	156	194	232	269	308	348	388	425	463	500	537	574	618	655	697
ST. Nº	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
B'ROCK DEPTH					104	104	101	114	119	106	86	70	60	74			

TRAVERSE "D"



RL. 2300

R.L.	2467	2470	2472	2474	2478	2479	2481	2494	2488	2494	2490	2492	2493	2476	2456	2444
CH. Nº	158	197	237	277	315	355	395	418	457	493	532	573	613	647	680	717
ST. Nº	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
B'ROCK DEPTH			37	36	37	44	56	77	61	62	57	56	52			

TRAVERSE "E"

LEGEND.

WEATHERED GRANITE

GRANITE BEDROCK

(3500) SEISMIC VELOCITIES (AVERAGE) IN FEET PER SECOND.

SEISMIC SURVEY OF THE EASTERN ABUTMENT OF DAMSITE "B", UPPER COTTER RIVER, A.C.T.

VERTICAL SECTIONS SHOWING DEPTH TO BEDROCK (UNWEATHERED GRANITE) ALONG GEOPHYSICAL TRAVERSES

SCALE 50 0 50 100 200 FEET

GEOPHYSICAL SECTION BUREAU OF MINERAL RESOURCES

G 260 - 2