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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS

RECORDS:

1964/194

CAPITAL HILL, CANBERRA, A.C.T.: SEISMIC INVESTIGATIONS OF SOIL AND WEATHERED BEDROCK, AUGUST, 1964

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SUMMARY

A seismic refraction investigation, using a seismic timer, was carried out on Capital Hill in August, 1964, to obtain information on excavating conditions and bearing strength for foundations in soil and weathered bedrock.

Capital Hill consists of Lower Ordovician Black Mountain Sandstone overlain unconformably by a Lower Silurian sequence - Camp Hill Sandstone and State Circle Shale. A major fault, the Deakin Fault, passes through the south-western slope of the hill and a large branch-fault through the north-western slope. South-west of the Deakin Fault, the bedrock consists of Upper Silurian Deakin Volcanics and intrusive Mount Painter Porphyry.

The hardest rock, and the most resistant to weathering is the Black Mountain Sandstone; the softest rock and possibly one of the least resistant to weathering is the State Circle Shale. The Camp Hill Sandstone is strongly jointed and contains numerous interbeds of shale; it is likely to weather deeply. Adjacent to the faults the rocks are probably weakened by fracturing and alteration, though locally they may be hardened by silicification.

Random seismic impulses caused by heavy traffic on a main road that encircles Capital Hill hampered operations with the equipment that was used; refracted waves from depths greater than about 20 feet were masked by the random waves and not recorded.

Excavating conditions were assessed on the basis of seismic velocities. Where the bedrock consists of Mount Painter Porphyry, Deakin Volcanics and Black Mountain Sandstone excavating can be done by blade and shovel type of equipment probably to depths ranging from 5 to 15 feet (average 8 to 9 feet); below this blasting will probably be needed, with medium explosive charges in the Black Mountain Sandstone, and light blasting and ripping in the porphyry and volcanics. Where the bedrock consists of State Circle Shale and Camp Hill Sandstone, excavating by blade and shovel type equipment will be practicable to depths ranging from 10 to 20 feet (average 14 to 15 feet); below these depths ripping and light to heavy blasting will be needed.

An augering programme is outlined to check the seismic results.

INTRODUCTION

The general area of Capital Hill and the route of a proposed Inner Road were investigated seismically in August, 1964, using a Dynametric Model 117 seismic timer. Localities of the traverses are shown on the geological map of the area (Plate 1), and seismic cross-sections in Plate 2. The aim was to obtain general information about ease of excavation and bearing strength of the soil and weathered bedrock, by measuring seismic velocities.

GEOLOGY

GENERAL (Öpik, 1958)

Capital Hill consists largely of Lower Ordovician(?) Black Mountain Sandstone. In the north and north-east the Black Mountain Sandstone is overlain unconformably by Lower Silurian Camp Hill Sandstone, from which a lobe extends westwards from Brisbane and King's Avenues to the crest of the hill. In the north, Lower Silurian State Circle Shale lies conformably over the Camp Hill Sandstone. In the south-west, near Hobart Avenue, the Black Mountain Sandstone is unconformably overlain by sandstone and shale of the Middle Ordovician Pittman Formation.

The general area is cut by several known faults, and others are probably present. A major fault in the south-west, the Deakin Fault runs north-west from about the intersection of State Circle and Hobart Avenue. A large fault, here termed the Rift Fault, runs northerly a short distance west of the two hostels. On the western side of the Deakin Fault, the bedrock consists of Upper Silurian Mount Painter Porphyry, and dacitic crystal tuffs of the Upper Silurian Deakin Volcanics. The fault block on the western side of the Rift Fault consists of State Circle Shale.

A second major fault, the Acton Fault, branches from the Deakin Fault half a mile south-east of Hobart Avenue; it strikes northwards and curves around towards the west, roughly parallel to, and a quarter of a mile east and north-east of State Circle. The Rift Fault probably continues northwards beneath soil and alluvium to join the Acton Fault, and it is quite likely that similar faults occur east and south-east of the Rift Fault.

Bedrock is exposed in excavations at the crest and in scattered outcropsto the north and north-west, otherwise, Capital Hill is entirely covered by soil.

LITHOLOGY AND WEATHERING

Black Mountain Sandstone

The Black Mountain Sandstone is commonly very hard and thick-bedded. It is resistant to weathering and is probably hard and strong at a shallow depth below the soil. In the excavation at the crest of the hill, it is not closely jointed.

Pittman Formation

The Pittman Formation consists of interbedded sandstone and shale. The sandstone weathers more deeply than the Black Mountain Sandstone, and the shale commonly weathers deeply, probably to depths of 10 feet and more below the soil-cover.

Camp-Hill Sandstone

The Camp Hill Sandstone consists of sandstone, and thin beds of shale. In the road cutting in State Circle, between Commonwealth and King's Avenues, it is deeply weathered and closely jointed. If the Camp Hill Sandstone is similarly weathered and jointed throughout the area is should be readily excavated by heavy earth-moving equipment to depths of about 10 feet below the soil.

State Circle Shale

The State Circle Shale consists mainly of shale and mudstone which commonly weather to depths of 10 feet and more. Near its base it contains fairly thick beds of sandstone which weather less readily.

Deakin Volcanics and Mount Painter Porphyry

The Deakin Volcanics at Capital Hill consists of dacitic crystal tuff. The Mount Painter Porphyry is a quartz porphyry which consists mainly of quartz and feldspar, and is similar in composition to the crystal tuffs. The fresh, unweathered crystal tuff and quartz porphyry are hard and tough. The weathered layer of both may contain residuals of hard, unweathered rock which would require blasting while excavating.

Bedrock Adjacent to Faults

Weathering and Decomposition. Near a major fault the bedrock is commonly crushed, fractured and strongly jointed; in places it is decomposed to great depths, as a result of leaching and hydrothermal alteration and through the action of groundwater seeping through the fractured zone.

Silicification and Hardening. Along some faults the bedrock is silicified and hardened; it resists decomposition and is hard at a shallow depth.

Hard, silicified zones and adjacent parallel zones of decomposed rock may occur along a single fault.

General Remarks on Capital Hill Area. The Black Mountain Sandstone would probably be resistant to softening by alteration near a fault; though remaining hard, it could be closely fractured and jointed.

The other rocks in the area are liable to be decomposed to considerable depths near faults.

SUPERFICIAL DEPOSITS

The soil and subsoil that covers the weathered bedrock are thin near the top of the hill but probably are fairly thick on the slopes. For a few hundred feet north-east and south-west from the hill top, scattered large blocks of Black Mountain Sandstone project from the soil. Similar blocks may occur in the soil below the surface; any such blocks would probably need to be blasted during trenching.

The soil formed from decomposed State Circle Shale is a sticky clay; that formed from weathered Black Mountain Sandstone is essentially a sand; the other rocks give rise to sandy soils with admixed clay, the proportions of clay being highest in the soils derived from the Deakin Volcanics and Mount Painter Porphyry.

SEISMIC INVESTIGATION

SEISMIC VELOCITIES AND METHODS OF EXCAVATING

Table 1 shows typical seismic velocities of soil and bedrock and gives estimates of velocities of material that can be excavated by various types of equipment, including a Caterpillar D8 with attached hydraulic ripper (Bartlett, 1962).

Table 1: Seismic Velocities and Excavating Properties

Velocities (feet per second)	Excavating Properties
800 - 2000	Soil and subsoil; readily excavated.
2000 - 3500	Fairly soft; can be excavated with blade and shovel type equipment.
Up to 4500 - 5000	Can be ripped.
5000 - 6000	Usually requires some blasting before ripping.
More than 6000	Hard to very hard; requires an increasing amount of blasting with increasing seismic velocity.
10,000 - 20,000	The velocity range of the hardest rocks.

METHOD OF INVESTIGATION

Traverses were 200 feet long. On Traverse 1 (see Plate 1) a geophone was placed at one end of the traverse, and hammer stations were sited along the traverse at distances of 2.5 feet, 5 feet, 10 feet and multiples of 10 feet up to 200 feet from the geophone. This procedure was repeated with the geophone at the opposite end of the traverse.

Along the other traverses, the geophone was placed at the mid-point and hammer stations were established, in turn, on either side of it, as for traverse 1, up to each and of the traverse (100 feet from the geophone). The geophone was later placed, in turn at each end of the traverse, and hammer stations sited along the traverse to the mid-point.

Time-distance curves were plotted; seismic velocities were determined and depths to refraction calculated by the methods outlined in the manual provided with the seismic timer.

RESULTS

General

The seismic waves originated by the hammer were recorded by the timer from shallow refractors, but most of those arriving from deeper refractors were masked by higher-energy disturbances caused by heavy traffic in State Circle.

Table 2 is a brief summary of the depths from which refracted waves were received:

Table 2 – Response from Seismic Refractors

Velocity Range (ft. per sec.)	Percentage of Stations Recording Refractor, or a Refractor of Higher Velocity	Depth to Refractor	Remarks
Up to 3500	100	Up to 15 feet	
3500-5000	80	Up to 20 feet	Presumably refractors which were not recorded are deeper than 20 feet.
5000-7500	61 { 45	Up to 20 feet	
	16	20 to 30 feet	
Greater than 7500	10	At 3 stations shallower than 20 ft. At 7 stations deeper than 20 ft.	Of the 37 refractors not recorded, 5 are known to be deeper than 20 feet; presumably the others are deeper than 20 feet.

Excavations for roadmaking are not expected to be deep, and probably sufficient information has been obtained from the shallow refractors.

Seismic Cross Sections

Seismic cross-sections are plotted in Plate 2.

Soil. The upper low-velocity layer, which represents soil, is present at nearly all stations. It is not possible to draw an unique time - distance line for the short critical distance to the underlying refractor; hence estimated velocities and depths differ on either side of the mid-points of the traverses. Assuming that the average depths are the true depths the estimated errors range at five mid-points from 1.4 to 2.9 (average 2.2) feet and at eight mid-points from 0.1 to 0.9 (average 0.6) feet.

The time - distance plots could be amended to obtain better agreement where the errors are large.

Depth to Interface between Decomposed Bedrock and Weathered Bedrock. The depth to the interface between decomposed and weathered bedrock was obtained on both sides of the mid-point of three traverses. Assuming the average of the depths is correct, two of the traverses give errors of 2.2 and 1.8 feet. In the third traverse, the difference in the depth estimates is 25 feet; clearly, the recorded arrival times from the deepest refractor are incorrect.

Depth to Fresh Bedrock. Recorded arrival times from the farthest hammer stations are unsatisfactory, and hence velocities and depths of the deepest refractors are of doubtful value.

Local Abrupt Changes in Seismic Velocity. In most traverses the linear time - distance plot is interrupted by one or more local breaks caused by arrival times that are shorter or larger than is normal for the traverse. Presumably these are due to a local increase in seismic velocity through a mass of less-weathered rock, or a local decrease corresponding to more-weathered rock. These local breaks are listed in Table 3.

Table 3. Local Breaks in Seismic Velocities along Traverses

Traverse	Chainage along Traverse (in feet)	
	Higher Velocity	Lower Velocity
1	70-80	
3		1678-1688
4	About 180	250- 260
7		70- 80
8		20S-30S (or second arrival)
		30N
9	40N	50S
10		70N
12	80E	40W
13		70S-80S
14	50S	50N-60N

EXCAVATING CONDITIONS

GENERAL

Excavating conditions are assumed to be related to seismic velocities as shown in Table 4.

Table 4

Assumed relationship between seismic velocity and excavating conditions

Seismic Velocity (ft. per sec.)	Material	Method of Excavation
Up to 3500	Soil and soft weathered	Blade and shovel
3500 - 5000	Harder weathered bedrock	Bulldozer and ripper
5000 - 6000	Weathered bedrock, too hard for ripping	Light blasting followed by ripping
6000 - 7500	Partly weathered bedrock	Medium blasting
Greater than 7500	Slightly weathered and fresh bedrock.	Heavy blasting

SUMMARY OF RESULTS

Results of the work in the general area and around the Inner Road interpreted in terms of excavating conditions are summarized in Table 5.

SUGGESTED AUGERING

To check the interpretation of the seismic work and to obtain some disturbed samples for qualitative examination, a suggested programme of 17 auger holes is summarized in Table 6. Plate 1 shows the sites of an additional 24 auger holes, intended to obtain additional information, both in the general area and along the inner road.

Estimated maximum footage for the seventeen holes sited in the seismic traverse is 315 feet. Estimated maximum footage for the additional 24 holes is 450 feet, total estimated maximum footage is 765 feet.

REFERENCES

BARTLETT, A.H., 1962 - Refractor seismic surveys in road works. Proc. First Conf. Australia Road Research Board (1), 1164-1172 (reprint)

ÖPIK, A.A., 1958 - The geology of the Canberra City District. Bur.Min.Resour.Aust., Bull.32.

Table 5

Excavating Conditions, Estimated from Seismic Velocities

Method of Excavation	Area Classified by Assumed Bedrock			
	Mount Painter Porphyry and Deakin Volcanics	State Circle Shale	Camp Hill Sandstone	Black Mountain Sandstone
<u>General Area</u>				
<u>Blade and Shovel</u>				
Depth of excavating: Surface to (feet)	5-15 (average 8)	Typical 10-20 (average 15) Hard sandstone[I] near traverses 8 and 12 1.5-8 (average 5)	11-18 (average 14)	Typical (?) 5-11 (av.9) Near crest, traverses 1 and 7, 15-20 (average 19) ø
Excavating to greater depths.	Ripping and some light blasting.	Ripping and light to medium blasting.	Ripping and light to heavy blasting.	Medium blasting
<u>Inner Road</u>				
Blade and shovel: depth, from surface to (feet).		Typical(?) 14-27, and local ripping near those depths. Near traverses 8 and 12,[I] 1.5 to 8.	Generally 11 to 13, locally deeper than 17.	Two stations only, 15 and 21 feet.
Excavating to greater depths.		Typical: Ripping, and light to medium blasting. Near traverses 8 and 12, light to medium blasting.	Medium to heavy blasting.	Medium blasting.

I Silicified basal sandstone of State Circle Shale, or Black Mountain Sandstone.

ø The greater thickness of weathered rock suggests possible structural features and change of bedrock.

Table 6

Capital Hill: Suggested Augering to Check Seismic Work

Traverse	General Area			Inner Road		
	Chainage	ED*	Comments	Chainage	ED*	Comments
1	00	20	Depth to bedrock			
2				700 800	20 15	Depth to hard bedrock Depth to weathered bedrock
3				1728	20	Depth to weathered bedrock and lower limit of ripping
4				140	30	Check seismic section
5				3250	15	Check seismic profile
6				00	15	Lower limit of ripping
7	100W	20	Lower limit of ripping			
8				00	10	Lower limit of ripping
9	100S	15	Depth to bedrock	00	20	Lower limit of ripping
10				00	20	Lower limit of ripping
11	00	20	Check seismic profile	100E	20	Lower limit of ripping
12	00	20	Lower limit of ripping			
13	00	20	Seismic profile			
14	00	15	Lower limit of ripping			

* Estimated maximum depth, in feet

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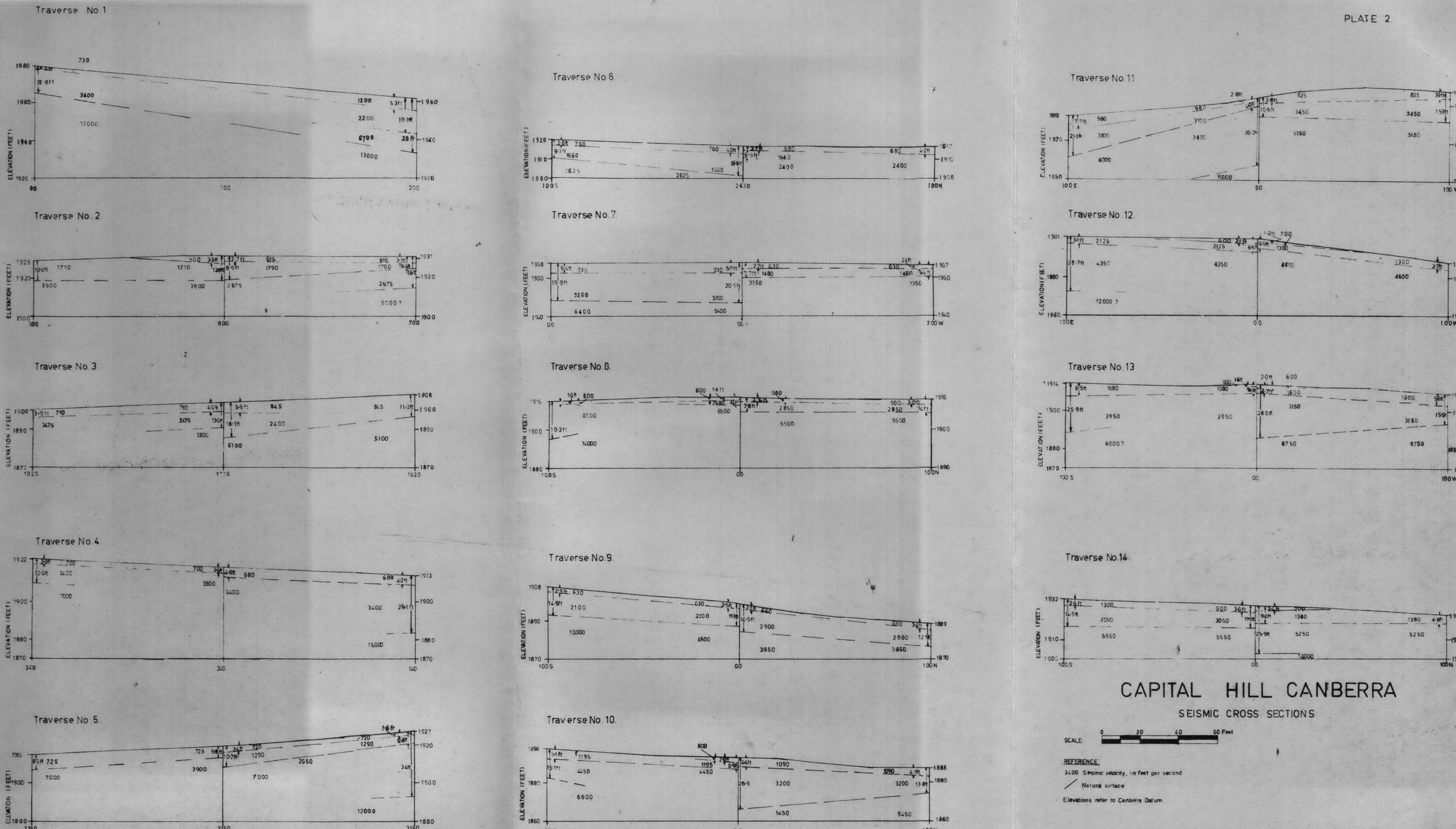
PLATE 2



CAPITAL HILL CANBERRA

SEISMIC CROSS SECTIONS

SCALE: 0 20 40 60 Feet

REFERENCE:

3400 Seismic velocity, in feet per second

Natural surface

Elevations refer to Canberra Datum

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