copy 3

DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1977/15

GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS FOR URBAN DEVELOPMENT, GUNGAHLIN, A.C.T., 1975-76

by

C.L. Horsfall, P.D. Hohnen, and G.R. Pettifer

Record 1977/15

GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS FOR URBAN DEVELOPMENT, GUNGAHLIN, A.C.T., 1975-76

by

C.L. Horsfall, P.D. Hohnen, and G.R. Pettifer

CONTENTS

PLATES

SUMMARY

Seismic and geological investigations have been carried out on the proposed Gungahlin urban development area. The bedrock is mostly shale, which rarely crops out; assuming a 1200 m/s seismic velocity limit for rippable material, it will usually be rippable by backhoe to a depth of 1.5 to 4 m. Many hilltops are capped by volcanics, generally tuff. Excavation in these rocks generally requires the use of explosives.

Depths to fresh bedrock range from 5 to 30 m, but are generally 10 to 15 m. Very deep weathering is apparent in the Canberra Racecourse area, but the low velocities may represent a very thick succession of alluvium, rather than in situ weathered rock.

Many faults are delineated by quartz veins and have zones of deep weathering adjacent to them.

1. INTRODUCTION

The National Capital Development Commission (NCDC) requested the Bureau of Mineral Resources to carry out a geotechnical investigation, to determine the feasibility of urban development of the Gungahlin area, which includes parts of both the Hall and Gungahlin Districts, A.C.T. As part of this study, shallow seismic refraction surveys were conducted, to investigate the nature and properties of the subsurface - the depth and strength of bedrock, the type of overburden and its rippability, and the positions of faults.

The Geophysical Branch of BMR did previous geophysical survey work in 1962 in the form of a resistivity survey over brick clay deposits near Wells Station Road (Jesson & Kevi, 1962; drawing no. 155/B7-1), and in 1971 in the form of a seismic survey over a proposed gravel pit in the Hall District (Kellett & Vanden Broek, 1971).

A party from the Engineering Geophysics Group, BMR, consisting of C.L. Horsfall (Geophysicist) and field hands, did the fieldwork in August 1975. Fifty-five spreads totalling 5060 m were shot and about 1100 m of magnetic traverse was surveyed. A Wenner resistivity depth probe was carried out in one area to a maximum electrode spacing of 256 m.

The geophysical interpretation of the seismic data was made by C.L. Horsfall and checked by G.R. Pettifer. M. Elliston assisted in the interpretation of the seismic data and in the fieldwork. P.D. Hohnen did the geological mapping and assisted with the geological aspects of the seismic interpretation.

This Record also contains a reinterpretation of the seismic surveys over the Hall and Gungahlin reservoir sites, for which fieldwork and preliminary interpretation was done in 1973/74 by F.N. Michail, D.C. Ramsay, and F.J. Taylor.

2. GENERAL GEOLOGY

The engineering geology of the Gungahlin urban development area was described by Hohnen (1974). Plate 1 shows the geology of the area and the locations of the major surveys. The area is underlain predominantly by Silurian shale and slate. Volcanic rocks overlie the shale to the east and west, where they cap most hills. Volcanics are also present on a number of small ridges and hills on the flat, central areas. In the southwest of the area, upfaulted wedges of sandstone, shale, and chert of Lower Silurian and Ordovician age form steep to rolling hills.

These rocks have weathered to form soils up to 3 m thick that have been eroded locally and redeposited downslope in shallow depressions. The residual soils are predominantly lean to heavy clays (CL to CH of Unified Soils Classification); the thicker, transported soils are silt, sand, or gravel where the deposits are very young, or sand, silt, and heavy clay where older soils are present.

The shales and volcanics have been gently folded about north-northeast-axes. The style of folding appears to be concentric, with dips of 5^{o} to 30^{o} commonly occurring on the limbs of folds. Fold axes tend to be subhorizontal; plunges are shallow and variable. An axial-plane cleavage is well developed in the shale and is often recognisable in weathered volcanics.

Reverse faults parallel or subparallel to the axial planes of the folding have been mapped throughout the area. Some faults have been injected with hydrothermal fluids which have deposited quartz and magnetite and have altered wall rocks to kaolin. Weathering has oxidised magnetite to limonite-hematite, which crops out as resistant gossans - particularly in the south of the area where faulting and/or hydrothermal activity appear to have been most intensive.

3. METHOD AND EQUIPMENT

Seismic refraction technique

The velocity with which a vibration is transmitted through rock varies with rock type, and in general increases with the strength of the rock. Seismic velocity also generally increases with the degree of water saturation of the rock, and decreases with the presence of faults, joints, cracks, and other discontinuities (Domzalski, 1956). The velocity of transmission of vibrations through underground rock can be determined in a seismic refraction survey, and the depths and thicknesses of the various rock types and weathered zones calculated.

All sites were investigated using a 24-geophone spread with 4-m intergeophone spacing. Details of equipment and operational statistics are in Appendix I. The spreads were linked on traverse by a common geophone position, Five shots were fired into each spread. Long shots were at 94 m so that the end shot of one spread lay at the long shot-point of the adjacent spread.

The intercept method was used for interpretation at each shot-point (Heiland, 1946). The reciprocal time method (Hawkins, 1961) was used to determine the depth to bedrock under each geophone.

Most errors in depth and velocity are expected to be less than 15 percent for the deeper layers and of the order of 50 percent for the topmost soil profile layer.

The ground surface is generally represented on the seismic sections as a straight line because the differences in elevation are small and levelling was not available. At the reservoir sites, however, where surveying information was available and necessary, the topography of the ground surface has been indicated on the seismic sections.

4. RESULTS

4.1 Seismic velocities

Seismic profiles in all areas examined generally show four layers. The general interpretation of the seismic velocities is as follows:

(1) 250-500 m/s : Soil and unconsolidated alluvium, completely weathered unsaturated material, generally 1 to 2 m deep

(2) 600-1750 m/s : Completely to highly weathered rock or consolidated alluvium, generally to 5-m depth

(3) 1800-3200 m/s : Saturated, highly weathered to moderately weathered bedrock, generally to 15-m depth but highly variable

(4) 3200-5600 m/s : Slightly weathered to fresh rock of uncertain and possibly varied lithology.

Depths of rippability using a backhoe are given throughout this Record on the assumption that a seismic velocity of 1200 m/s is the upper velocity limit for rock material in this area which is rippable with a backhoe (see Caterpillar Tractor Company, 1966).

4.2 Crace industrial area

Plate 1 shows the geology of this area. Plate 2 shows the locations of the 25 seismic spreads shot in this area and the locations of the five follow-up diamond-drill holes along Dunsmore Street. The purpose of the surveys was to determine foundation conditions and rippability of the near-surface rock and to locate faults - particularly the City East Fault, which is believed to extend into this area.

4.21 Local geology

The geology of the area is poorly known because exposures of rock are sparse. Shale appears to be the predominant rock type, and contains small lenses of limestone. Most outcrops are of pyroclastic rock, predominantly tuff, which forms a row of hills running northeast; Crace is the most prominent. The volcanic rocks form a capping on the more easily eroded shale, and lie on what is thought to be the western limb of a syncline plunging to the south-southwest.

Van Dijk (1959, figs. 8,9) studied the soils and geomorphology of the Canberra region and included the Crace area as part of the Sullivan's Creek Valley pediplain Basin. Kellett (1971) carried out a soil survey in the Division of Watson.

The shale was ripped by backhoe to a depth of 2-3 m at the brickworks site in the industrial area. The shale has been extensively drilled to evaluate its potential as brick shale (Gardner, 1962). Further BMR drilling, as a follow-up to the seismic survey along Dunsmore Street, intersected extremely weathered rock material to depths greater than 50 m (Pl. 4). The reasons for the existence of such an extensive area of very deep apparent weathering are unknown.

Plate 2 indicates the positions of lineaments observed in aerial photographs of the area. The photo-lineament which strikes north near the 212000 grid line may mark the northward extension of the City East Fault from its northernmost known location in Downer.

4.22 Dunsmore Street seismic traverse

The locations of the five drill holes and the 12 seismic spreads along Dunsmore Street are shown in Plate 2. Interpreted seismic sections are in Plate 3. Drill logs of holes on Dunsmore Street are shown in Plate 4 and are included in Appendix II.

The low, deepest-refractor velocities (1900-2050 m/s) of spreads 1, 2, 3, and 4, on the eastern end of the traverse, contrast with deepest-refractor velocities of the remainder of the traverse. In this zone, diamond-drill hole 5 (Pl. 4 and Appendix II), at the junction of spreads 3 and 4, revealed the following:

1. The 300-m/s layer corresponds to sandy silt and silty clay.
2. The 800-m/s layer corresponds to clayey sand and clay with iron-manganese nodules.
3. The 1450-1500-m/s layer and the 2000-m/s layer collectively correspond to sandy and silty clays and highly weathered volcanics. The change in velocity from 1450-1500 m/s to 2000 m/s in an apparently uniform lithology may be related to a slight change in degree of weathering, or more likely to a change in moisture content of the rock at 8-m depth, which may represent the water-table.
4. The seismic results indicate a possible refractor of 3400-m/s velocity at a depth of 47 m. DDH 5 indicated a contact between: (a) highly weathered shale and mudstone fragments embedded in clay; and (b) highly weathered black and red mudstone at 47 m.

To further investigate this zone, a Wenner resistivity depth probe (inset in Pl. 3) was carried out to a maximum electrode spacing of 256 m near the eastern end of spread 5 (Pl. 2). The results compare with the seismic results and drilling results at DDH3 and DDH5 as follows:

1. The 10-ohm-m and 350-ohm-m upper layers correspond to sandy silt and silty clay with iron-manganese nodules respectively, and collectively to the 300-m/s refractor.

2. The 8-ohm-m layer, extending to 5.6 m, corresponds to the 800-m/s refractor, which extends roughly to the same depth at the depth probe centre and corresponds to clayey sand and clay with iron-manganese nodules.
3. The 150-250-ohm-m layer corresponds to the 1450-1500-m/s and the 1900-2050-m/s refractors, which collectively correspond to sandy and silty clays and completely weathered volcanics.
4. The 400-ohm-m layer at 45.6 m appears to correspond to the interpreted 3400-m/s refractor at 47 m and to the highly weathered black and red mudstone intersected at 47 m in DDH 5. However, the depths to this contact and the adjacent resistivities can be significantly varied, while producing a similar close fit to the field data.

Throughout this section of the traverse, the 2000-m/s refractor shows a gradual increase in velocity with depth from 1900 m/s to 2050 m/s.

A strong later-arrival reflection was observed on one record from spread 3, which indicated a spread-reflector distance of 190 m. Spread 3 is about 190 m from a faulted contact with high-velocity bedrock near the junction of spreads 5 and 6. It is unlikely however, that this is the reflector, since little moveout appeared on the record. The reflection may be from fresh volcanics or shale at 190-m depth, or from a contact subparallel to the spread at a distance of 190 m.

Two faults, indicated below spread 5, separate the area of low, deepest-refractor velocities from high, deepest-refractor velocities to the west. These faults correspond to a photolineament indicated in Plate 2. The high, deepest-refractor velocities of ≥ 4900 m/s encountered in spreads 6, 7, and 8 are probably related to limestone and calcareous shale, which were encountered in drill holes DDH 4 and DDH 1 at depths that are in excellent agreement with the deepest-refractor depths. Velocities greater than 6000 m/s are not genuine and are due to deviations from a simple, layered model. The fault below spread 8 corresponds to a photo-lineament (Pl. 2).

In the above section of traverse, drill holes DDH 2 and DDH 3 were drilled in, or adjacent to, low-velocity bedrock zones presumed to represent faults with associated deep weathering. These drill holes intersected clays and extremely weathered shale fragments.

At the western end of the traverse (spreads 9, 10, 11, and 12), bedrock velocities of 3900-4400 m/s probably represent shale which is exposed in part of the road-cutting at spread 9. The bedrock seismic velocity of 6000 m/s in spread 10 may represent limestone or volcanics. The increase in depth to fresh bedrock below spread 10, on the western flank of the topographic ridge, may be related to deeper weathering along the contact between the 6000-m/s and 3900-m/s bedrock velocities.

The second layer of seismic velocities, in the range 750-1400 m/s, is not indicated as being present throughout the section. In the area around spread 8 the section is complicated by excavation and fill associated with road construction on the hillside. Changes in rock condition close to the surface are very rapid, with the above layer generally not being evident. East of spread 4, the layer thins, so that it is generally not indicated in the data and its seismic velocity is undefinable within a wide range. Its presence in the section insignificantly affects the interpreted depth to the 2000-m/s refractor.

A magnetometer traverse was carried out at 8-m spacing along most of the seismic traverse. The magnetic profile has not been included in this report. The maximum anomaly size was about 100 nT, and much of the profile was affected by noise. Significant anomalies were encountered at two localities:

1. At the centre of spread 5, where a 40-nT anomaly appeared to be associated with the faults. Assuming a dipping-dyke model striking north, the fault appears to dip to the east.
2. At the junction of spreads 6 and 7, where an 80-nT anomaly appeared to be associated with an apparent bedrock velocity of 14 400 m/s and a shallowing of the bedrock. This section of the bedrock may be volcanics or limestone.

Depths of rippability with a backhoe range widely from 1 to 7 m along the traverse.

4.23 Northbourne Avenue and Randwick Road traverses

Four spreads were shot at intervals along Northbourne Avenue between Dunsmore Street and Wells Station Road. Two spreads were shot along the eastern end of Randwick Road. Their locations are shown in Plate 2 and the interpreted seismic sections are shown in Plate 5. The spreads were shot to determine the northerly extent of the 2100-m/s deepest refractor located by the eastern spreads of the Dunsmore Street traverse. It was also hoped that any faults not detected by geological mapping would be located, in particular the City East Fault, which was located in Downer and may extend northwards along the trace of the photo-lineament indicated near the 212000 grid line in Plate 2.

The 2100-m/s refractor extends to the northeast at least as far as midway between Flemington Road and Wells Station Road. (Pl. 2.). The depth to the 2100-m/s refractor increases to the northeast from 5 to 23 m along Northbourne Avenue (Pl. 5).

Spreads 22, 52, and 54 (Pl. 5) indicate lower velocity zones within the 2100-m/s refractor which may represent faults or shear zones. In particular, the lower-velocity zone in spread 54 may correspond to the observed nearby photo-lineament, which may reflect the City East Fault.

Depths of backhoe rippability range from 5 to 7 m in this area.

4.24 Crace industrial centre

Nine spreads were shot in two staggered parallel traverses in the Crace industrial centre. Their locations are shown in Plate 2, the interpreted seismic sections in Plate 6.

The seismic sections indicate highly varied bedrock velocities: velocities of 3700 m/s to 4800 m/s probably represent fresh shale, mudstone, and siltstone; and velocities greater than 5200 m/s probably represent fresh volcanics or limestone. Zones in the bedrock with seismic velocities less than 3300 m/s are assumed to represent faults. The low-velocity zones below spreads 13, 14, 16, and 51 may be related to the nearby photo-lineament and geologically mapped faults (Pl. 2).

The depth of weathering greatly increases in spreads 19 and 20. A photo-lineament passes close to spread 20 and may represent the trace of a possible fault, which may have given rise to the increased depth of weathering.

Depths of rippability with a backhoe range from 1.5 m over most of the traverse, to 5 m at the eastern end of the traverse. A backhoe removed overburden to a depth of 2-3 m at an excavation at the brickworks site, a short distance south of the traverse.

4.25 Conclusions - Crace industrial area

Fresh bedrock in this area has highly varied seismic velocities. A prominent feature is the great thickness of low-velocity completely weathered rock that apparently lies beneath the eastern third of Dunsmore Street. This low-velocity area extends north across the racecourse to the northern end of Randwick Road and at least as far eastwards as Northbourne Avenue. Apparently deep weathering was also encountered at the western edge of the industrial area.

The apparently deeper weathering may be related to intensive faulting and/or a lower erosion rate. An alternative explanation for the inferred great depth of weathering is that the low-velocity material is alluvial. Van Dijk (1959, figs. 8, 9) included the Crace area as part of the Sullivan's Creek Valley Pediplain Basin. He defined a pediplain basin to be a landform formed on wide valley pediplains with gentle gradients which have layered colluvial/alluvial soils. A pediplain basin generally has a bar or narrowing of the basin-like depression toward the outlet. Colluvial and alluvial deposition predominates with very little stream erosion, resulting in deep superficial deposits of layered relict soils. Some of these colluvial fills in the Crace Area were interpreted by Opik (1954) to be lake deposits, but no further evidence has been found to support this. Thus the weathered material of low seismic velocity encountered in the drill holes may represent a cyclic succession of fossil soil profiles, rather than very deeply weathered bedrock.

Narrow zones of low velocity in the lowermost refractor which are interpreted as faults are indicated in Plate 2 by shading on the seismic spread lines. The positions of these low-velocity zones can be compared with the positions of lineaments, which are assumed to represent faults and shear zones.

From its northernmost known occurrence in Downer, the City East Fault is expected to strike roughly northwards along the 212000 grid line. It may follow the photo-lineament (Pl. 2) which passes the eastern edge of the racecourse, and may be indicated by the low velocity zone encountered in spread 54 on Randwick Road (Pls 2 and 5).

Depths of rippability with a backhoe range from 1.5 m to 4 m over most of the area, but these depths increase to 5-7 m in the area around the racecourse. The depth to fresh bedrock outside the racecourse area ranges from 10 to 15 m.

4.3 First residential area, Gungahlin

The locations of three spreads shot in this area are shown in Plate 7; the seismic sections are shown in Plate 8. The spreads were shot to determine ground conditions near a fault.

4.31 Local geology

The area is predominantly underlain by shale, siltstone and mudstone with bands of northeast-striking cherts and devitrified ashstone. The area is transected by a major, quartzveined fault striking northeast (Pls 1 and 7).

4.32 Seismic interpretation

Spreads 24, 25 and 53 were shot to determine depths of weathering adjacent to the northeast-striking fault. Spread 24 indicates that the weathered zone of low velocity is 40 m wide. The bedrock velocities are different on either side of the fault zone, possibly indicating a change of lithology; the velocities on the northwest side are consistent with shale, but the 5000-m/s bedrock velocity on the southeast side may indicate the presence of chert or devitrified ashstone, which is mapped to the northeast on the southeast side of the expected continuation of this fault.

Spreads 25 and 53 show little evidence of the fault in the line covered by the spreads. The lower bedrock velocity at the western end of spread 53 may represent deeper weathering near the fault. The velocities of 4300-4400 m/s may indicate fresh shales, and the 6000-m/s velocity in spread 25 may represent a bed of fresh ashstone.

4.33 Conclusions - First residential area

Because of the large thickness of highly to completely weathered rock beneath the southwestern part of the fault (Pl 8), it is recommended that the designers of blocks of flats, or other buildings with high bearing pressures, be made aware of the probability of varied bearing strengths within the fault zone and along the margins.

Most rocks beneath the area are argillaceous and many can be excavated by mechanical means, where they have open joints and/or cleavage planes. Some hard siliceous volcanic rocks crop out in the northeastern corner of the area. The seismic sections indicate depths to moderately weathered or non-rippable rock of 1 to 4m. Limited information obtained by auger drilling indicates that the rippable depth is likely to range from 2 to 4 m on hillslopes and to more than 4 m near watercourses.

4.4 Gungahlin town centre

Spreads 26 to 36 were shot in this area. Spread locations are shown in Plates 7 and 9, and seismic sections in Plates 8, 10, and 11. Local geology is shown in Plate 1. The spreads were shot to determine foundation conditions near a fault zone and depths of rippability throughout this area.

4.41 Local geology

This area is covered by a mantle of soil which is generally between 1 and 3 m thick. Outcrop is sparse and is limited to occasional exposures of shale on rises and a few quartz veins. Until the auger and diamond-drilling contract is completed, subsurface information is available from only one borehole, (Gu3, Canberra 87; Pls. 7 and 9). The log of this hole is as follows:

0 to 1.8 m - mottled red and yellow clay
1.8 to 7.5 m - strong buff shale
7.5 to 15.0 m - completely weathered fine-grained tuff; red and grey clay and shale with white flecks
15.0 to 18.0 m- soft grey clayey shale
18.0 to 19.5 m- buff shale with some vein quartz
19.5 to 22.5 m- grey and buff shale
22.5 to 25.5m - grey shale and yellow clay
25.5 to 39.0 m- hard, pale to medium grey shale
39.0 to 45.0 m- hard, blue-grey shale with some vein quartz and finely disseminated pyrite.

There is no gradual downward progression to fresher rock and lithology controls the distribution of weathered rock below the surficial soil layer. Shale is generally quite strong below 2 m, but the tuffs that are interbedded with the shale can be completely weathered to depths of $\geqslant$ 18 m.

Several faults pass through the area between the proposed Northern group centre and Block 10, about 600 m southeast of the group centre (Pl. 7). The large Gungahlin Fault Zone, which is marked by large quartz vein outcrops over a distance of 7 km, passes through the eastern portion of the group centre. This fault zone has been determined from drilling to dip 60° west, and the geology adjacent to the fault zone indicates that it is of the reverse type. There are insufficient records to state positively that the fault zone is inactive, although the possibility of movement along the fault zone is extremely remote, since most movement along the fault zone is thought to have taken place in Late Silurian or Devonian time (350-400 x 10^6 years ago). Rock adjacent to the fault zone is expected to be more deeply weathered than rock more than 20 m from the fault zone. The fault planes are silicified in places across zones between 1 and 3 m wide, and are thus stronger than surrounding weathered rock. Because of the expected wide range of strengths of rock near the fault zone, sites for large structures should be subjected to detailed geotechnical investigations.

4.42 Seismic interpretation

The Gungahlin Fault Zone was intersected by spreads 26 (Pl. 8), 32 (Pl. 10), 33, and 35-36 (Pl. 11). Spread 26 indicates the fault zone and associated deeper weathering by a single 55-mwide zone of low velocity in the bedrock. Spreads 32, 35, and 36 indicate that the Gungahlin Fault Zone consists of at least three faults and that the fault zone widens to the south to at least 170 m at spreads 35-36. There are many strongly contrasting velocity zones in the fault zone owing to the different rock types and various degrees and depths of weathering. Sites for large building structures near the fault zone should be investigated to determine foundation conditions.

The path of the Gungahlin Fault Zone as determined from the seismic spreads is given in Plate 9. A resistivity survey conducted as part of the Gungahlin District clay investigation (Jesson & Kevi, 1962) indicated the southward continuation of this fault by a band of apparent resistivity less than 60 ohm- m. This resistivity survey also located other nearby faults. The white clay deposits lie in hydrothermally altered zones adjacent to the faults.

In each of spreads 26, 32, 35, and 36 the seismic velocities of 5100-5600 m/s in the bedrock adjacent to the fault zone may represent fresh middle to Upper Silurian volcanics which crop out adjacent to this fault to the north (Pl. 1). Seismic velocities in the range 3800-4500 m/s are expected to represent relatively fresh shales or slightly weathered volcanics.

Rotary drill hole Gungahlin No. 3 (Canberra 87) was drilled in the Gungahlin Fault Zone about 55 m south of the centre of spread 32. The drill log is in section 4.41. The depth of 1.8 m to strong shale corresponds to the depth of 2 m to the 1000-m/s layer. Standing water-level in the drill hole was 13.5 m which corresponds to the depth of 12 m to the 2300-m/s layer. The depth of 25.5 m to hard shale shown in the drilling log corresponds to the depth to fresh bedrock (5100 m/s) of 24.5 to 28 m (Pl. 10).

Spreads 27 to 32 (Pl. 10) were shot as a traverse. The bedrock velocities of 4000-4200 m/s over most of the traverse are expected to represent fresh shales. High bedrock velocities of 5100 m/s occur at both ends of the traverse and probably represent middle to Upper Silurian volcanics which are mapped to the north (Pl. 1) but do not crop out along the seismic traverse.

Disregarding the effects of the Gungahlin Fault Zone on the bedrock velocities in spread 32, a mirror symmetry of bedrock seismic velocities can be seen in spreads 27 and 32. This might indicate that the traverse has crossed a fold in the underlying rock if the 5100-m/s bands in spreads 27 and 32 were the same rock unit. The 5100-m/s band is wider in spread 32, which may indicate that the eastern limb of the folded bed has a shallow dip or that the lithology thickens to the east. A change in bedrock velocity from 4000 m/s to 4200 m/s occurs at the centre of spread 29. The 4000-m/s band to the east is wider than the 4200-m/s band to the west, as was observed for the 5100-m/s bands. If the dip of bedding is shallower to the east, then considering that the dip of the axial plane cleavage is to the east, the proposed fold would be an asymmetric anticline, with the fold axis passing through the centre of spread 29.

Spread 34 (Pl. 11) shows velocity anisotropy in the fresh bedrock and weathered layers when compared with spreads 30 and 31 (Pl. 10). The higher velocities are recorded in spread 34 which is subparallel to the strike of the slatey cleavage (016^{0}).

4.43 Conclusions - Gungahlin town centre

Seismic profiles from the proposed Gungahlin town centre generally exhibit four layers. Fault zones appear to be located near contacts between rock types of different elastic properties (e.g., shale and volcanic rocks). Differential weathering near such faults gives rise to highly varied bearing strengths of foundation material, and sites for large structures near known faults should be subjected to detailed geotechnical investigations. Sites near outcrops of quartz reef, limonitic gossan, and mapped contacts of different rock types should similarly be investigated.

The average thickness of the uppermost soil layer is 2 m but ranges from 0.5 to 4 m. The average depth of rippability is 8 m, but the range is 4 to 16 m. The depth to the 2300-2500-m/s layer appears to be related to the depth to the water-table. The depth to fresh bedrock ranges from 12 to 35 m, but averages about 18 m.

Velocity anisotropy is present with the higher velocities recorded in the north-south direction, subparallel to the strike of the cleavage.

4.5 Northern group centre (near 'East View')

Spreads 37 to 40 were shot in this area to determine foundation conditions and depths of rippability. Spread locations are shown in Plate 7, and seismic sections in Plate 12. Local geology is indicated in Plate 1.

4.51 Local geology

Most of the area is covered by alluvium and humic gley soils underlain by shales at depths of about 1-2 m. The soils are expected to contain aquifers which may be fed along depressions by groundwater rising towards the high potentiometric surface.

The Gungahlin Fault passes through the ridge in the eastern portion of the area. The ridge is formed of acid volcanic rocks, and a massive quartz reef strikes along the crest.

4.52 Seismic interpretation

Spreads 37-38 and 39 show similar results. The uppermost soil layer has a thickness of 1 m, locally increasing to 2 m. The 1400-m/s layer at 1-2 m probably corresponds to shale which is exposed in a nearby creek channel at 1.5 below the level of spread 39. The depth to the 2200-2550-m/s layer, which may indicate the depth to the water-table, ranges from 3.5 to 6 m. The average depth to fresh bedrock is 15 m but ranges from 11 to 19 m. Spreads 37, 38, and 39 show depths of rippability of 1 to 2 m.

Spread 40, on the side of a ridge, is dissimilar to the above spreads and shows a depth of rippability of at least 4-5 m, possibly as much as 12 m. The profile has five layers, with a depth to fresh bedrock of 34 m. The bedrock topography is more pronounced and a small fault is present, possibly part of the Gungahlin Fault Zone.

4.53 Conclusions

A greater depth of weathering is encountered in spread 40, beneath a ridge, than in spreads 37-38, beneath the plain. This is the converse of that expected, but may be accounted for by the proximity of spread 40 to the Gungahlin Fault Zone. The presence of the water-table near the surface on the plain may also have given rise to the higher velocities at shallower depths.

The poorly drained soils of this area may undergo consolidation when built upon. Efficient drainage, possibly by pumping from one or more bores, will be essential if the group centre is developed. Two or three storey buildings in this area may require foundations on rafts, and buildings with higher bearing pressures will require foundations on moderately weathered rock.

4.6 Northwestern Gungahlin

Plate 13 shows the detailed geology of this area and the locations of the 10 seismic spreads. Plate 14 shows geological sections, and Plates 15, 16, and 17 show the seismic sections. The spreads were shot to examine the correlation betweed depths of rippability obtained from seismic data and those obtained from power augering.

4.61 Local geology

This area, in the northwestern part of the planned urban development area, has been mapped in detail because of anticipated excavation difficulties in rock overlain by very thin soils (Pls. 13 and 14).

Outcrop is sparse over about 80 percent of the area. In the extreme northwest, outcrops of moderately to slightly weathered tuff and porphyritic volcanic rocks are common. The rest of the area is covered by a thin mantle of soil; though shale occurs fairly commonly at, or just below the ground surface, it does not form raised outcrops.

Shale is the predominant lithology of the area, and it almost certainly has a volcanic provenance. At the base of the local stratigraphic succession, volcanic rocks are interbedded with shale, as well as volcanically derived sandstone. The volcanic interbeds are mostly ashstone (welded volcanic ash). The shale beds commonly contain brachiopod moulds, though the genera of these fossils have not been identified.

Overlying this essentially sedimentary unit, is a rather massive, resistant volcanic unit, comprising plagioclase, quartz, and lesser hornblende crystals of 2 to 3 mm diameter, in a fine-grained grey groundmass. The rock is probably a welded crystal tuff of rhyodacitic composition.

The next youngest unit in this east-southeasterly dipping sequence is another shale unit which shows fewer volcanic affinities than the lower sedimentary unit. Above the shale is another tuff, which is the youngest unit west of the Gundaroo Fault. East of this major east-northeast striking fault there is mainly shale, with pods of volcanic rocks (mainly welded tuff) that have been exposed by ploughing and which otherwise are not exposed at the surface.

It appears that the block to the east of the fault has been uplifted relative to that on the west of the fault, and that the uppermost volcanic unit and part of the lower volcanic unit have been eroded off, leaving the lowermost sedimentary unit and outliers of lower volcanic unit exposed.

Sparsely distributed dips (Pl. 13) are predominantly of the order of 28° to 32° to the east-southeast. However, the shale/ volcanic contacts indicate that the rocks have been folded about north-trending axes after the region was tilted to the southeast, probably the result of large-scale folding or faulting, or both.

The large-scale folding in the Gungahlin area comprises a series of asymmetric anticlinal and synclinal folds with northeast-trending axes. The eastern limbs of these folds are long, with dips of the order of 20° to 40°, and the western limbs are shorter and have dips of about 10° to 15° (Pl. 13).

Between the Gundaroo Fault and the ACT/NSW border to the west, there is tenuous evidence of two northeast-trending folds. From just west of the border, the eastern limb of an anticline continues across almost as far as the Gundaroo Fault; just west of the fault however, the strata dip westward forming a syncline with the axial plane striking about 20° east.

East of the fault, the structure is not as clear, because of the absence of continuous volcanic marker beds; however, there is some evidence of an anticline parallel to the syncline west of the fault. Farther east, the outcrop is too sparse to interpret the structure. In the southwest of the map area, but east of the Gundaroo Fault, there is good evidence of three smaller folds, whose axes all strike within 15° either side of true north (Pl. 13).

The volcanic units of the strata that form the large syncline just west of the Gundaroo Fault, appear to be tightly folded about axes parallel to the main synclinal axis. This probably reflects the different competence of the volcanic and sedimentary rocks forming the syncline. It appears that the shale has thickened or thinned in response to folding stresses, whereas the volcanics have been buckled near the fold axes, resulting in minor folds, parallel to the major fold.

The predominant orientation of the axial-plane cleavage produced by the folding strikes between 015° and 025° east, and dips vary from vertical to about 80°E. Cleavage is ubiquitous in shale, but is poorly developed in volcanic rocks, in contrast to volcanics in the upper catchment of Sullivans Creek, to the east, where a well-developed fracture cleavage is characteristic of these rocks.

Rock weathering. The preliminary geotechnical study of Gungahlin (Hohnen, 1974), suggested that much of the shale within 1 m of the surface may not be rippable. Detailed mapping has confirmed a large area of shale at, or very close to the surface, but ripping at several sites for tree planting has confirmed that the shale should be rippable with heavy equipment in most areas. Volcanic rocks will require blasting for excavations in all areas of outcrop where the rocks are only slightly weathered (Plate 13). In areas of soil underlain by volcanic rocks, depths to moderately weathered, or non-rippable rock will generally range between 1 and 3 m.

4.62 Seismic interpretation

Seismic spreads were shot to determine the rippability of shale and volcanics that were known to be within 2 m of the surface. Because of the strongly developed axial-plane cleavage in the shale, spreads were shot in two directions to measure the degree of seismic-velocity anisotropy. Each of the seismic spread pairs was shot near a previously drilled power-auger hole in order to compare results.

Spreads 41 and 42 (Pl. 15) were shot near auger hole 16, which intersected volcanics and indicated a depth to moderately weathered rock of 6.4 m (Pl. 14). The geological map indicates the volcanics to be faulted against shale at this point. Spread 42 (direction 112^{o}) indicates the edge of the volcanics to the west against the highly sheared and weathered shales at the fault. Spreads 41 and 42 indicate a depth to moderately weathered volcanics of 3-5 m, and a depth of rippability by backhoe of 0 to 1.3 m in the volcanics. Seismic-velocity anistropy is the opposite of that expected with the higher velocity measured across cleavage. This result may be due to the complicating effects of the fault and should be viewed with caution.

Spreads 43 and 44 (Pl. 15) were shot near auger hole 17, which intersected shale and indicated a depth to moderately weathered rock of 3.7 m (Pl. 14). These spreads indicate a depth to moderately weathered rock of 3 m and a depth of rippability by backhoe of 0.8-2.5 m (average 1 m). Velocity anisotropy is present, with higher seismic velocities recorded subparallel to the cleavage.

Spreads 45 and 46 (Pl. 16) were shot on a hilltop near auger hole 18, which intersected weathered volcanics resembling shale and indicated a depth to moderately weathered rock of 2.1 m (Pl. 14). Spreads 45 and 46 indicate that the depth to moderately weathered rock ranges from 1.5 m to 10 m, and that the depth of rippability by backhoe is 1 m. Velocity anisotropy is present but is not marked. The sections indicate a high-velocity refractor at about 60-m depth with an apparent dip to the west. This probably represents fresh volcanic rock with tightly closed fracture cleavage.

Spreads 47 and 48 (Pl. 17) were shot near auger hole 19, which intersected clayey gravel soil overlying shale (Pl. 14). This hole indicated a depth to moderately weathered rock of 7.3 m which compares with a depth of 5 m from the seismic sections. Velocity anisotropy is present in most of the layers. The depth of rippability by backhoe is 1 m.

Spreads 49 and 50 (Pl. 17) were shot near auger hole 20, which intersected shale and indicated a depth to moderately weathered bedrock greater than 5.5 m (Pl. 14). The hole also intersected an aquifer at 1.4-m depth. The seismic sections indicate a depth of 2.5 m to a 2100-m/s layer, which appears to be related to the depth of water saturation, rather than the strength of the rock. Velocity anisotropy is the reverse of that expected in the fresh bedrock, but the velocities are higher subparallel to the cleavage in the upper weathered layers. There is a discrepancy in the depths to fresh bedrock in each of the spreads. The depth of rippability by backhoe is 1 m.

4.63 Conclusions

In general the seismic sections from this area exhibit four layers. Comparison of the depths to moderately weathered rock indicated by auger refusal and depths obtained from seismic sections (using the depth to the third layer) indicates that the auger refused in material of seismic velocity greater than about 2000 m/s. However a seismic velocity of 2000 m/s can apply to weak rock material which is saturated with water, as became evident in spreads 49 and 50.

In the limited cases examined, the indicated depths of rippability by backhoe and the depths to moderately weathered rock are similar for shale and volcanics. However, the shot-holes in areas of volcanic rock outcrop (spreads 41 and 42) had to be located in alluvium, and outcropping volcanic rock may indeed be non-rippable with a backhoe. Depths of rippability by backhoe are generally 1 m. Large, slightly weathered volcanic rock outcrops are widespread and may impose a constraint on urban development.

Seismic-velocity anisotropy was observed on most seismic sections, and in general, for layers other than the topmost soil layer, the velocity measured subparallel to the cleavage was 1.2 times the velocity measured subperpendicular to the cleavage.

4.7 Reservoir sites

4.71 Hall No. 1 reservoir

Plate 1 shows the location of the reservoir site, and Plate 18 shows the two seismic traverses across it. The interpreted sections are shown in Plate 29. The spreads were shot to determine the depth of rippability and foundation conditions at the reservoir site.

(i) Site geology. Moderately to slightly weathered rhyodacitic tuff crops out at the site. The rock is massive and jointed and will be difficult to rip with a bulldozer. Seismic and lithologic investigations were carried out by BMR on an extension of this rock mass to the southeast for a proposed gravel pit (Kellett & Vanden Broek, 1971) and lithological investigations were made to the west for the proposed urban development of the Hall's Creek area (Hohnen, 1973).

(ii) Seismic interpretation. The two seismic sections over the reservoir site show the floor level and the seismic velocities of the westhered rock (Pl. 19). Velocity anisotropy does not appear to be present, reflecting the absence of cleavage in the rock.

A seismic velocity of 1200 m/s is considered to define the upper velocity limit at this site of rock material that is rippable with a D8 bulldozer. The seismic sections indicate that all of the material to be excavated will require blasting to the floor level of the reservoir.

4.72 Hall No. 2 reservoir

Plate 1 shows the location of the reservoir site, and Plate 20 shows the five seismic spreads across it. The interpreted sections are shown in Plate 21. The spreads were shot to determine the depth of rippability and foundation conditions at the reservoir site.

(i) Site geology. The bedrock consists of volcanic rocks which are hard and strong when fresh. These rocks are expected to be massive and jointed. They are expected to crop out on the ridge top and are unlikely to be rippable with a bulldozer.

(ii) Seismic interpretation. The five seismic sections over the two reservoir positions show the floor levels and the seismic velocities of the material to be excavated (Pl. 21).

Examination of the seismic sections reveals the following:

(1) Some velocity anisotropy is present in the lowermost refractor, with higher velocities recorded in the northeast-northwest direction (Spreads 13, 14, 15). This anisotropy may indicate that jointing with an approximate northeast-southwest orientation is more closely spaced than that in any subperpendicular direction. Alternatively, the volcanics may show some cleavage due to a high content of oriented phyllosilicate minerals.

(2) At this site a seismic velocity of 1200 m/s is considered to define the upper velocity limit of material that is rippable with a D8 bulldozer. The seismic sections indicate that all the material to be excavated will require blasting or will only be marginally rippable.

(3) There is good agreement between spreads as to the depth of the lowermost refractor at the spread intersection points. Spreads 13, 14, and 15 all indicate an increased depth of weathering to the northeast down to an elevation of 721 to 723 m.

(4) At all three spread intersection points there is disagreement in the number of layers present. Spreads 12, 14, and 15 indicate the presence of a layer of velocity 1150-1450 m/s that does not appear in spreads 12A and 13. This layer may still be present, however, but may be too thin to be detected by the geophone spacing used.

4.73 Gungahlin No. 1 reservoir

The location of the site is shown in Plate 1. The locations of the 12 spreads are shown in Plate 22. The interpreted sections are given in Plates 23 (spreads 1, 2, 3 and 10, 11, 12 of 2-m geophone spacing), 24 (spreads 4 and 5 of 4-m geophone spacing) and 25 (spreads 6, 7, 8, and 9 of 1-m geophone spacing). The spreads were shot to determine the depth of rippability and foundation conditions at the reservoir site.

(i) Site geology. The reservoir site lies on slightly to moderately weathered quartz sandstone of the Pittman Formation. The sandstone is jointed at 10-cm to 25-cm spacings. At the top of the ridge a band of finely cleaved and jointed, silicified Acton Shale transects the Pittman Formation and trends in a northeasterly direction. The approximate position of the lithological boundaries of the Acton Shale and Pittman Formation as determined from drilling and float indications are shown in Plate 22. The cleavage in these rock types is expected to trend 030° and to dip steeply to the west.

(ii) Seismic interpretation, measurements on samples. Measurements of longitudinal velocity in three directions were made on two surface samples of fine-grained sandstone - probably of the Pittman Formation. Sample 1 gave velocities of 2480 m/s and 2440 m/s; the sound attenuation was too high for even an estimate of velocity in the third direction, which was normal to a set of fractures. Sample 2 gave velocities of 3150 m/s, 2900 m/s, and 2690 m/s. The anisotropy in velocities is probably due to the several sets of fracture planes in this sample.

(iii) Seismic interpretation, reservoir sites. The nine seismic sections over the floor area of the two reservoir positions indicate the level of excavation and the seismic velocities of the material to be excavated (Pls. 23, 24, 25).

Examination of the seismic sections, particularly the velocities of material at the base level of excavation, reveals the following:

(1) Velocity anisotropy is present in the subsoil layers. Higher seismic velocities were recorded in spreads 4, 5, 6, 7, 8, and 9, which were subparallel to the cleavage, then in spreads 1, 2, and 3, which were oriented across the cleavage.

(2) Zones of low velocity in the moderately weathered rock layer were encountered in spreads 1, 3, 5, 8, 10, and 11. The positions of these zones appear to correspond with the approximately mapped lithological boundaries. The low velocity zones are probably due to weathering along the contacts, which may also be faulted. From the seismic data the southeastern boundary between the Pittman Formation and the Acton Shale appears to be placed too far to the northwest. It may be more appropriately placed to intersect spread 11 at the low-velocity zone in the centre of the spread (see dotted line Plate 22).

(3) At this site a seismic velocity of 1300 m/s is considered to define the upper velocity limit of rock material which is rippable with a bulldozer. This velocity must be read parallel to the cleavage. At this site a cross-cleavage velocity of 1000 m/s is equivalent to a velocity of 1300 m/s subparallel to the cleavage. Plate 22 shows the extent of material at the base level of excavation (643 m elevation) which will require blasting. At least half the floor area of the reservoirs will require blasting. The depth of rippability is shallowest (0.4 m) at the top of the ridge where slightly to moderately weathered rock occurs just below the surface.

(4) Four power-auger holes were drilled within the area of the two reservoirs. The depths to power-auger refusal, shown in Plate 22, show excellent agreement with the depths to non-rippable rock indicated by the seismic spreads, except at the auger hole near the intersection of spreads 3 and 7.

(iv) Seismic interpretation, outlet pipe. The three seismic spreads which were shot adjacent to the outlet pipe (10, 11, and 12 in Pl 22 and 23) indicate that blasting will be required to the pipe level for nearly the whole distance between the reservoir and the vertical bend.

5. REFERENCES

CATERPILLAR TRACTOR COMPANY, 1966 - HANDBOOK OF RIPPING: A GUIDE TO GREATER PROFITS. Peoria, Illinois, Caterpillar Tractor Company.

DOMZALSKI, W., 1956 - Some problems of shallow refraction investigations. Geophys. Prospecting, 4(2), 140-166.

GARDNER, D.E., 1962 - North Crace brick shale deposit. Bur. Miner. Resour. Aust. Rec. 1962/1 (unpubl.).

HAWKINS, L.V., 1961 - The reciprocal method of routine shallow seismic refraction investigations. Geophysics, 26(6), 806-819.

HEILAND, C.A., 1946 - Geophysical exploration. New York,Prentice-Hall.

HOHNEN, P.D., 1973 - Engineering geology for urban development of Halls Creek area, Hall District, A.C.T. Bur.Miner.Resour.Aust.Rec. 1973/162 (unpubl.).

HOHNEN, P.D., 1974 - Engineering geology of Gungahlin urban development area, A.C.T. Bur. Miner. Resour. Aust. Rec. 1974/186 (unpubl.).

JESSON, E.E., & KEVI, L., 1962 - Gungahlin geophysical survey for white clay, A.C.T. Bur. Miner. Resour. Aust. Rec. 1963/137 (unpubl.).

KELLETT, J.R., 1971 - Soil survey, division of Watson, Canberra, A.C.T. 1970. Bur. Miner. Resour. Aust. Rec. 1971/3 (unpubl.).

KELLETT, J.R., & VANDEN BROEK, P.H., 1971 - Proposed gravel pit, Block 12, Hall District, A.C.T. Bur. Miner. Resour. Aust. Rec. 1971/133 (unpubl.).

OPIK, A.A., 1954 - The geology of the Canberra City district; in WHITE, H.L., (ed.) - CANBERRA, A NATION'S CAPITAL. Aust. Ass. Adv. Sci., Handbook for Canberra, 131-48.

VAN DIJK, D.C., 1959 - Soil features in relation to erosional history in the vicinity of Canberra. CSIRO Aust. Soil Publ. 13.

APPENDIX I

OPERATIONAL DETAILS

(excluding the Gungahlin & Hall Reservoir sites)

PERSONNEL

Party leaders	G.R. Pettifer C.L. Horsfall
Technical staff	D. Francis
Field assistants	M. Preston-Stanley M. Elliston

SEISMIC

Operational Statistics

No. of spreads	55
Distance covered	5060 m
No. of geophones/spread	24
Geophone spacing	4 m
Length of spread	92 m
Long shot distance	94 m
Short shot distance	2 m
No. of shots/spread	5
No. of shots fired	278
No. of reshoots	1
Explosives used	661 sticks = 110 Kg
No. of detonators used	282
No. of days of fieldwork	17
Period over which field work was done	28.7.75 to 10.2.76

Equipment

Amplifiers	SIE PSU-19
No. of Channels	24
Camera	SIE VRO-6D
Geophones	8Hz GSC-20D
Blaster	BC 8A
Vehicles	1 shooting truck 1 Recording Van

MAGNETICS

Operational Statistics

Length of traversing	1100 m
Spacing of readings	10 m
Duration of survey	1.5 hours

Equipment

Geometrics G816 Proton Precession Magnetometer

RESISTIVITY

Operational Statistics

Maximum current electrode spacing	256 m

Equipment

Transmitter	Geotronics FT-10
Receiver	Data Precision Digital Multimeter with BMR Self Potential backoff device

---

DRILLING

Operational Statistics

No. of holes	5
Logged by	P. Rosengren
Period of Drilling	August, Sept. 1975
Location	Dunsmore Street
Depth range of holes	13.8 m to 54.0 m

Equipment

Drill	Gemco Rotary Rig with coring equipment and straight auger flights
Core barrel type	Triefus and 2'6" split tube
Core diameter	BQ (1½")

OPERATIONAL DETAILS

(Gungahlin & Hall Reservoir sites only)

PERSONNEL

Party leaders	D.C. Ramsay (1973) F.N. Michail (1973) C.L. Horsfall (1976)
Technical staff	M.J. Dickson (1973) L. Hemphill (1973) D. Francis (1974 + 76)

SEISMIC

Operational Statistics

No. of spreads	19
No. of geophones/spread	24
Geophone spacings:	4 spreads of 1 m
	11 " " 2 m
	2 " " 2.5 m
	2 " " 4 m
No. of rock samples measured	3
Equipment as described earlier	

DRILLING

Operational Statistics

No. of holes	5
Logged by	P.D. Hohnen
Period of drilling	November 1973
Location	Gungahlin Reservoir No. 1
Power auger rig	Proline HDBA

APPENDIX II

DUNSMORE STREET DRILL LOGS

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Gungahlin, Dunsmore St Investigation
LOCATION Dunsmore St
ANGLE FROM HORIZONTAL (θ) 90°
DIRECTION
COORDINATES 936 985 Canberra 1:100 000
R L OF COLLAR
HOLE NO. 1
SHEET 1 OF 1

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc	Casing	Graphic Log	Lift and % core recovery	Depth and size of Core	Fracture Log 0 6 12 18+	RQD	Defect Frequency Intercept Angle 0 30 60 80 90	Structures Joints, veins, seams, faults, etc	Water Level	Water Pressure Test Losses (Lugeons) *
sandy silt ML	brown → light brown			100							
silty clay	red yellow → red										
				100	1						
				100	2						
				100	3						
				100							
sst ⌐	sst pebbles angular ⌐			40	4						
				100	5						
clay & silty clay				100							
volcanics ⌡	in situ xw → cw ⌡			100	6						
clay				75	7						
silty clay				60	8				Hole drilled by Gemco auger drill to 18·0m with auger flights & 2'6" split tube barrel. 18·0 – 18·6 m with BQ barrel & diamond bit.		
	saturated clay & sc			40							
	saturated silty clay			100	9						
	saturated silty clay			90	10						
	saturated silty clay brown → yellow brown			80	11						
				80	12						
				75							
				100	13						
	saturated brown clay & silty clay			100	14						
	brown → yellow brown with red/white/yellow streaks			100	15						
				100							
cw shale & clay weathered in situ	brown-pink & yellow clay shale small fragments → 1cm			100	16						
				100	17						
				100							
calcareous mudstone fr → mw	fr → mw fine grained grey/crenulations strong core → 10cm				18				crenulations some qtz veins at 85° recemented 3-4cm		
	End Hole 18·60m										

Drill type Gemco Rotary
Feed
Core barrel type 2'6" split tube & triefus barrel
Driller BMR
Commenced
Completed
Logged by P. Rosengren
Vertical scale 1:100
Checked by

Notes

Fracture Log — *Number of fractures per 25 cm of core. Zones of core loss blocked in*

Bedding and Joint Planes — *Angles are measured relative to a plane normal to the core axis*

Defect Frequency — *Number of natural defects (shears, joints, fractures) per 25 cm of core occurring at specified intercept angle range.*

Water Level Measurements — ▼ *Level when hole in progress at specified depth.*
▽ *Level in completed hole on specified date.*

Water Pressure Tests

** Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blacked in strips.*

Core Photograph Negative No.

Depth (m)	Black & White	Colour

155/A16/1810

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Gungahlin, Dunsmore St Investigation
LOCATION Dunsmore St
ANGLE FROM HORIZONTAL (θ) 90°
DIRECTION
COORDINATES 936 985 Canberra 1:100 000
R.L. OF COLLAR

HOLE NO. 2
SHEET 1 OF 2

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc	Casing	Graphic Log	Lift and % core recovery	Depth and size of Core	Fracture Log 0 6 12 18+	RQD	Defect Frequency Intercept Angle 0 30 60 80 90	Structures Joints, veins, seams, faults, etc	Water Level	Water Pressure Test Losses (Lugeons) *
sandy silt	*light brown*			100							
silty clay	*red → yellow* *cont fe mg nodules*			100	1						
silty clay *& nodules*	*carbonate pan (nodules)* *& fe mg nodules*			100	2						
sandy clay *silty clay*	*yellow cont. fe mg nodules*			100 100 100 100	3 4 5						
shale & clay cw	*in situ weathering of shale & clay cw fragments of pink shale & black, pink & yellow clays* *shale fragments → 0·5 cm* *yellow/brown → yellow → pink → black clays*				6 7 8 9 10 11 12 13 14 15 16 17 18 19 20						

Drill type Gemco Rotary
Feed
Core barrel type 2'6" split tube
Driller BMR
Commenced
Completed
Logged by P. Rosengren
Vertical scale 1:100
Checked by

Notes

Fracture Log — Number of fractures per 25 cm of core. Zones of core loss blocked in.

Bedding and Joint Planes — Angles are measured relative to a plane normal to the core axis

Defect Frequency — Number of natural defects (shears, joints, fractures) per 25 cm of core occurring at specified intercept angle range.

Water Level Measurements — ▼ Level when hole in progress at specified depth.
▽ Level in completed hole on specified date.

Water Pressure Tests

** Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blocked in strips.*

Core Photograph Negative No.

Depth (m)	Black & White	Colour

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Gungahlin, Dunsmore St Investigation
LOCATION Dunsmore St
ANGLE FROM HORIZONTAL (θ) 90°
DIRECTION
COORDINATES 936 985
Canberra 1:100 000
R.L. OF COLLAR
HOLE NO. 2
SHEET 2 OF 2

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc	Casing	Graphic Log	Lift and % core recovery	Depth and size of Core	Fracture Log 0 6 12 18+	RQD	Defect Frequency Intercept Angle 0 30 60 80 90	Structures Joints, veins, seams, faults, etc	Water Level	Water Pressure Test Losses (Lugeons) *
				100							
				100							
					21						
				100							
					22						
				50							
				25	23						
				75							
					24						
				25							
					25						
				40							
				40	26						
				40							
					27						
				50							
				100	28						
				No recovery	29						
					30						
					31						
	End Hole 31·09m										

Drill type
Feed
Core barrel type
Driller
Commenced
Completed
Logged by
Vertical scale
Checked by

Notes

Fracture Log — Number of fractures per 25 cm of core. Zones of core loss blocked in.

Bedding and Joint Planes — Angles are measured relative to a plane normal to the core axis

Defect Frequency — Number of natural defects (shears, joints, fractures) per 25cm of core occurring at specified intercept angle range.

Water Level Measurements — ▼ Level when hole in progress at specified depth.
▽ Level in completed hole on specified date.

Water Pressure Tests

** Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blocked in strips.*

Core Photograph Negative No.

Depth (m)	Black & White	Colour

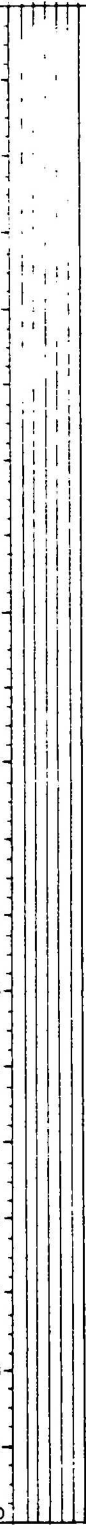
155/A16/1811

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Gungahlin, Dunsmore St Investigation
LOCATION Dunsmore St
ANGLE FROM HORIZONTAL (θ) 90°
DIRECTION
COORDINATES 936 985 Canberra 1 100 000
R.L. OF COLLAR

HOLE NO. 3
SHEET 1 OF 2



Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc	Casing	Graphic Log	Lift and % core recovery	Depth and size of Core	Fracture Log (0 6 12 18+)	RQD	Defect Frequency Intercept Angle (0 30 60 80 90)	Structures Joints, veins, seams, faults, etc	Water Level	Water Pressure Test Losses (Lugeons) *
sandy silt *clay*	*brown* *red/yellow mottled*			100							
clay	*brown/yellow, light yellow, grey/yellow, mottled brown & black*			100	1						
sandy clay/ silty clay	*red sandy clay occuring throughout profile*			100	2						
				90	3						
				100							
				100	4						
				90	5						
	red sandy clay/coarse fraction size 0·5cm angular qzt pebbles → 3cm			90	6						
				90							
	fe mg nodules in clay			80	7						
				90	8						
clay & xw shale	*small grains → 1-2cm*			70							
clay & silty clay & some xw shale	*clay — yellow/brown, black containing fe mg nodules*			50	9						
				50	10						
				50	11						
				50	12						
				50							
				40	13						
				100	14						
				60	15						
				70							
				50	16						
				60	17						
				60	18						
				60							
				60	19						
				60	20						

Drill type Gemco Rotary
Feed
Core barrel type 2'6" split tube & triefus barrel
Driller BMR
Commenced
Completed
Logged by P. Rosengren
Vertical scale 1:100
Checked by

Notes

Fracture Log — Number of fractures per 25 cm of core. Zones of core loss blocked in

Bedding and Joint Planes — Angles are measured relative to a plane normal to the core axis

Defect Frequency — Number of natural defects (shears, joints, fractures) per 25 cm of core occurring at specified intercept angle range.

Water Level Measurements — ▼ Level when hole in progress at specified depth.
▽ Level in completed hole on specified date

Water Pressure Tests

** Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blocked in strips.*

Core Photograph Negative No.

Depth (m)	Black & White	Colour

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Gungahlin, Dunsmore St Investigation
LOCATION Dunsmore St
ANGLE FROM HORIZONTAL (θ) 90°
DIRECTION
COORDINATES 936 985
Canberra 1:100 000
R.L. OF COLLAR
HOLE NO. 3
SHEET 2 OF 2

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc	Casing	Graphic Log	Lift and % core recovery	Depth and size of Core	Fracture Log 0 6 12 18+	RQD	Defect Frequency Intercept Angle 0 30 60 80 90	Structures Joints, veins, seams, faults, etc	Water Level	Water Pressure Test Losses (Lugeons) *
				60							
				50	21						
				75	22						
				80	23						
				50							
				50	24						
				60	25						
				50	26						
				60	27						
				50							
				45	28						
				20	29						
	End Hole 29·75m				30						

Drill type
Feed
Core barrel type
Driller
Commenced
Completed
Logged by
Vertical scale
Checked by

Notes

Fracture Log — Number of fractures per 25 cm of core. Zones of core loss blocked in

Bedding and Joint Planes — Angles are measured relative to a plane normal to the core axis

Defect Frequency — Number of natural defects (shears, joints, fractures) per 25 cm of core occurring at specified intercept angle range.

Water Level Measurements — ▼ Level when hole in progress at specified depth.
▽ Level in completed hole on specified date

Water Pressure Tests

** Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blocked in strips.*

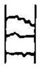
Core Photograph Negative No.

Depth (m)	Black & White	Colour

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Gungahlin, Dunsmore St Investigation
LOCATION Dunsmore St
ANGLE FROM HORIZONTAL (θ) 90°
DIRECTION
COORDINATES 936 985 Canberra 1:100 000
R.L. OF COLLAR
HOLE NO. 4
SHEET 1 OF 1

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc	Casing	Graphic Log	Lift and % core recovery	Depth and size of Core	Fracture Log 0 6 12 18+	RQD	Defect Frequency Intercept Angle 0 30 60 80 90	Structures Joints, veins, seams, faults, etc	Water Level	Water Pressure Test Losses (Lugeons) *
	No recovery *Probably clays washed out of core barrel*			*Nil* *Nil* *Nil*							
limestone (fresh)	*grey, fine grained, (calcareous mudstone) no fossils*			90	6-30 cm				*Joints at 45° to core. Core easily broken along these joints. Some high angle fractures recemented with calcite at angle 85° to core. "Bedding" type structure. Crenulated foliations through core spaced at 2-3cm*  *No bedding planes evident in limestone*		
volcanics cw to clay in situ	*aggregate of clays & dark fe mg grains with some quartz apparently weathered in situ*			100							
limestone (fresh)	*grey, fine grained (calcareous mudstone)*										
	End Hole 13·80m										

Drill type Gemco Rotary
Feed Hydraulic
Core barrel type Triefus
Driller BMR
Commenced 1-9-75
Completed
Logged by P. Rosengren
Vertical scale 1:100
Checked by

Notes

Fracture Log — Number of fractures per 25 cm of core. Zones of core loss blocked in.

Bedding and Joint Planes — Angles are measured relative to a plane normal to the core axis

Defect Frequency — Number of natural defects (shears, joints, fractures) per 25 cm of core occurring at specified intercept angle range.

Water Level Measurements — ▼ Level when hole in progress at specified depth.
▽ Level in completed hole on specified date.

Water Pressure Tests

** Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blocked in strips.*

Core Photograph Negative No.

Depth (m)	Black & White	Colour

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Gungahlin, Dunsmore St Investigation
LOCATION Dunsmore St
ANGLE FROM HORIZONTAL (θ) 90°
DIRECTION
COORDINATES 936 985
Canberra 1:100 000
R.L. OF COLLAR
HOLE NO. 5
SHEET 1 OF 3

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc	Casing	Graphic Log	Lift and % core recovery	Depth and size of Core	Fracture Log 0 6 12 18+	RQD	Defect Frequency Intercept Angle 0 30 60 80 90	Structures Joints, veins, seams, faults, etc	Water Level	Water Pressure Test Losses (Lugeons) *
sandy silt	brown				0						
silty clay	cont. fe mg nodules, red										
silty clay	yellow				1						
clayey sand	dark brown qtz → 2mm			90							
clay	grey/yellow, fe mg nodules				2						
no core taken				50	3 4 5						
clay, sandy clay, silty clay, c.w. volcanics	brown/yellow clay, fe mg (weath), qtz in situ. c.w.		V V V V V V V V V V		6 7						
no core taken				60	8						
clay, sandy clay silty clay c.w. volcanics	brown/yellow clay, fe mg, qtz in situ.		V V V V V V		9						
no core taken				0 10	10 11 12 13 14 15 16						
sandy, silt and clay c.w. volcanics	yellow/red, brown clay/fe mg, qtz in place		V V V V V		17						
no core taken				10	18 19 20						

Drill type Gemco Rotary
Feed Hydraulic
Core barrel type Triefus
Driller B M R
Commenced 8·9·75
Completed 25·9·75
Logged by P. Rosengren
Vertical scale 1:100
Checked by

Notes

Fracture Log — Number of fractures per 25 cm of core. Zones of core loss blocked in

Bedding and Joint Planes — Angles are measured relative to a plane normal to the core axis

Defect Frequency — Number of natural defects (shears, joints, fractures) per 25 cm of core occurring at specified intercept angle range.

Water Level Measurements — ▼ Level when hole in progress at specified depth.
▽ Level in completed hole on specified date.

Water Pressure Tests

** Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blocked in strips.*

Core Photograph Negative No.

Depth (m)	Black & White	Colour

155/A16/1814

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Gungahlin, Dunsmore St Investigation
LOCATION Dunsmore St

ANGLE FROM HORIZONTAL (θ) 90°
DIRECTION
COORDINATES 936 985 Canberra 1:100 000
R.L. OF COLLAR

HOLE NO. 5

SHEET 2 OF 3

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc	Casing	Graphic Log	Lift and % core recovery	Depth and size of Core	Fracture Log 0 6 12 18+	RQD	Defect Frequency Intercept Angle 0 30 60 80 90	Structures Joints, veins, seams, faults, etc	Water Level	Water Pressure Test Losses (Lugeons) *
no recovery					21 22						
sandy clay c.w. volcanics	yellow qtz, clay, fe mg weath in place				23						
no recovery					24 25						
sandy clay c.w volcanic	yellow qtz, clay, fe mg weath in place				26						
no core taken					27 28 29 30 31 32 33 34 35 36 37 38 39 40						

Drill type
Feed
Core barrel type
Driller
Commenced
Completed
Logged by
Vertical scale
Checked by

Notes

Fracture Log — Number of fractures per 25 cm of core. Zones of core loss blocked in

Bedding and Joint Planes — Angles are measured relative to a plane normal to the core axis

Defect Frequency — Number of natural defects (shears, joints, fractures) per 25 cm of core occurring at specified intercept angle range.

Water Level Measurements — ▼ Level when hole in progress at specified depth.
▽ Level in completed hole on specified date.

Water Pressure Tests

** Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blacked in strips.*

Core Photograph Negative No.

Depth (m)	Black & White	Colour

155/A16/1814

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Gungahlin, Dunsmore St Investigation
LOCATION Dunsmore St
ANGLE FROM HORIZONTAL (θ) 90°
DIRECTION
COORDINATES 936 985
Canberra 1:100 000
R.L. OF COLLAR
HOLE NO. 5
SHEET 3 OF 3

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc	Casing	Graphic Log	Lift and % core recovery	Depth and size of Core	Fracture Log 0 6 12 18+	RQD	Defect Frequency Intercept Angle 0 30 60 80 90	Structures Joints, veins, seams, faults, etc	Water Level	Water Pressure Test Losses (Lugeons) *
shale - c.w. clay mudstone - c.w.	shale and mudstone in completely weathered fragments embededded in clay (sticky clays). weathering colours yellow, red, brown, grey			10	41 42 43						
				30	44 45 46						
mudstone	black xw→hw grey clay on fractures core pieces up to 4cm joints at 45° to core common core pieces generally <3 cms			60	47 48				core fissile along planes at 45° to core→30° clay on these planes		
mudstone	red xw→hw and red brown clay on fractures. same structure as black mudstone			40	49 50 51						
				10	52 53						
End Hole 53·64 m					54						

Drill type
Feed
Core barrel type
Driller
Commenced
Completed
Logged by
Vertical scale
Checked by

Notes

Fracture Log — *Number of fractures per 25 cm of core. Zones of core loss blocked in.*

Bedding and Joint Planes — *Angles are measured relative to a plane normal to the core axis*

Defect Frequency — *Number of natural defects (shears, joints, fractures) per 25 cm of core occurring at specified intercept angle range.*

Water Level Measurements — ▼ *Level when hole in progress at specified depth.*
▽ *Level in completed hole on specified date.*

Water Pressure Tests

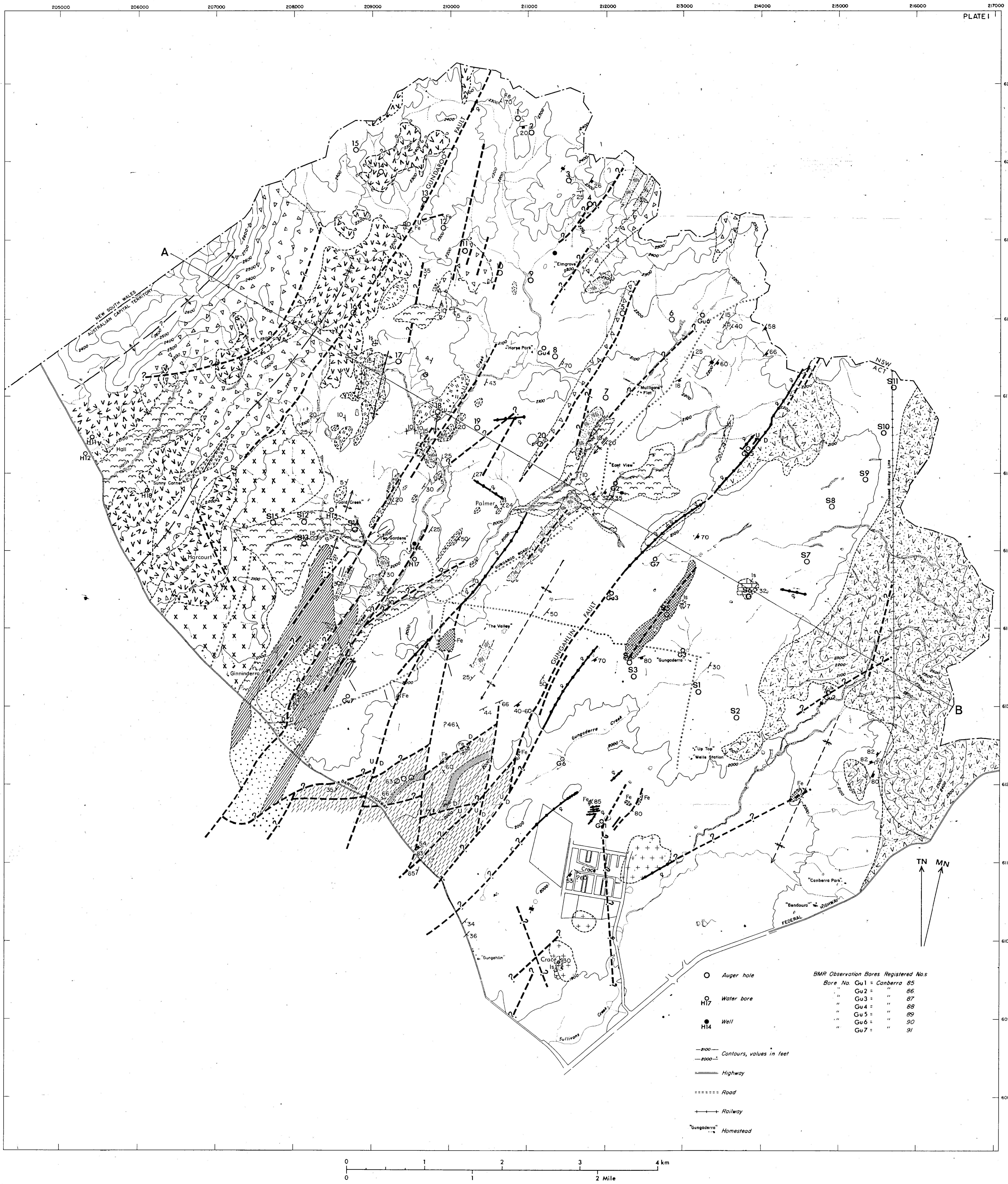
* *Values in lugeons should be read in conjunction with computation sheets. Test sections are indicated by blocked in strips.*

Core Photograph Negative No.

Depth (m)	Black & White	Colour

155/A16/1814

GEOLOGICAL MAP OF GUNGAHLIN

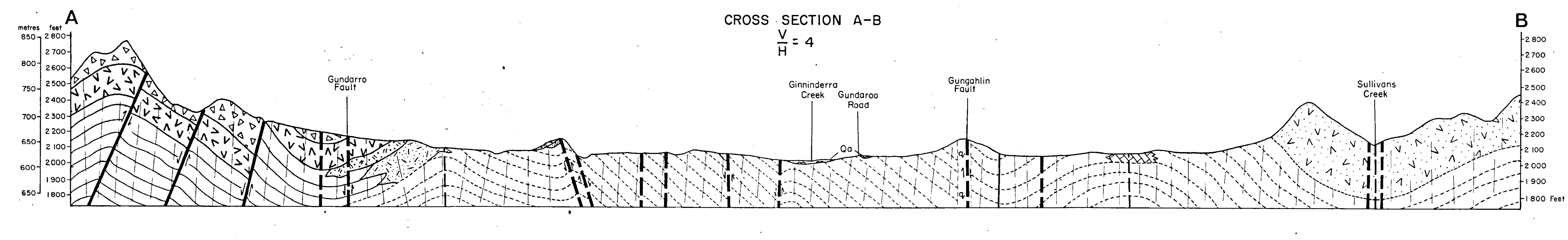


BMR Observation Bores Registered No.s

Bore No.	Gu1 =	Canberra	85
"	Gu2 =	"	86
"	Gu3 =	"	87
"	Gu4 =	"	88
"	Gu5 =	"	89
"	Gu6 =	"	90
"	Gu7 =	"	91

CROSS SECTION A-B

$\frac{V}{H} = 4$



QUATERNARY
- Alluvium

POST-SILURIAN
- Fe Limonite gossan
- q Vein quartz

MIDDLE TO UPPER SILURIAN
- Quartz porphyry
- Pyroclastics
- Purple and green dacitic welded breccia
- Greenish grey rhyodacitic flow
- Grey-green ash-flow tuff
- Welded rhyolitic tuff
- Chert or devitrified ashstone
- Predominantly shale with slate, siltstone, mudstone, and limestone lenses

Dacitic tuff; lithic tuff; biotite, plagioclase, quartz porphyry; greenish grey tuff; grey-green quartz porphyry

LOWER SILURIAN
- Sandstone
- State Circle Shale: Shale, mudstone

MIDDLE TO UPPER ORDOVICIAN
- Acton Shale Member: Siliceous shale
- Pittman Formation: Sandstone, siltstone, shale, mudstone, chert

△Palmer Trigonometrical station

- Geological boundary, position approximate
- Geological boundary, position inferred or concealed
- Fault, (U, D indicate relative vertical displacements)
- Fault, position approximate
- Fault, position inferred or concealed

- 30 Strike and dip of bedding
- 80 Strike and dip of joint
- Anticline, showing direction of plunge
- Syncline, showing direction of plunge

Record No. 1977/15

PLATE 1

AMENDMENTS

No.	DESCRIPTION	AUTHOR	DATE	CHECKED	DATE
A1					
A2					
A3					
A4					
A5					
A6					

SCALE
0 250 500 750 1000 1250m

BASE MAP/SURVEY
T.P./197/72

GEOLOGY BY
P. D. HOHNEN AND J. CEPLECHA

COMPILED AND CHECKED
PROJECT GEOLOGIST

CHECKED AND APPROVED
SENIOR GEOLOGIST

SUPERVISING GEOLOGIST

COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.

TITLE
GEOLOGICAL MAP OF GUNGAHLIN

PROJECT
GUNGAHLIN ADVANCED FEASIBILITY STUDY

TO ACCOMPANY RECORD 1974/186

DRAWN BY G. A. YOUNG

DRAWING NUMBER 155/A16/1247

2 11070 E
608800 N

LEGEND

▦ Limestone

Porphyritic rhyodacite and crystal-lithic tuff

▭ Shale, siltstone & mudstone of Canberra Group

Scattered outcrop

Dense outcrop

Quartz-veined fault

Airphoto lineament (possible fault)

Diamond-drill hole

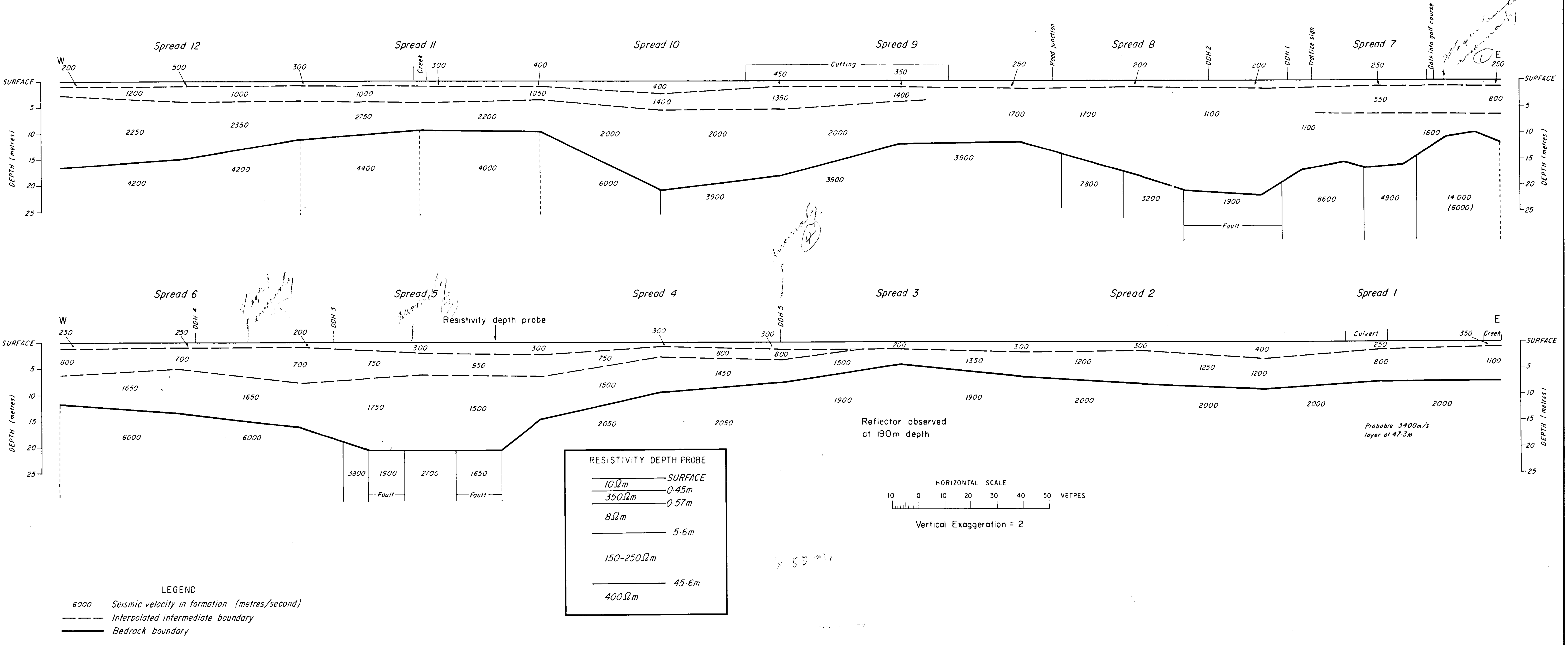
Seismic spread showing spread number, and low-velocity zone indicating possible fault

CRACE INDUSTRIAL AREA
TRAVERSE PLAN AND GEOLOGY

155/B5-315

PLATE 2

PLATE 3



CRACE INDUSTRIAL AREA
DUNSMORE STREET SEISMIC SECTION

Record No. 1977/15

I55/B5-318

PLATE 4

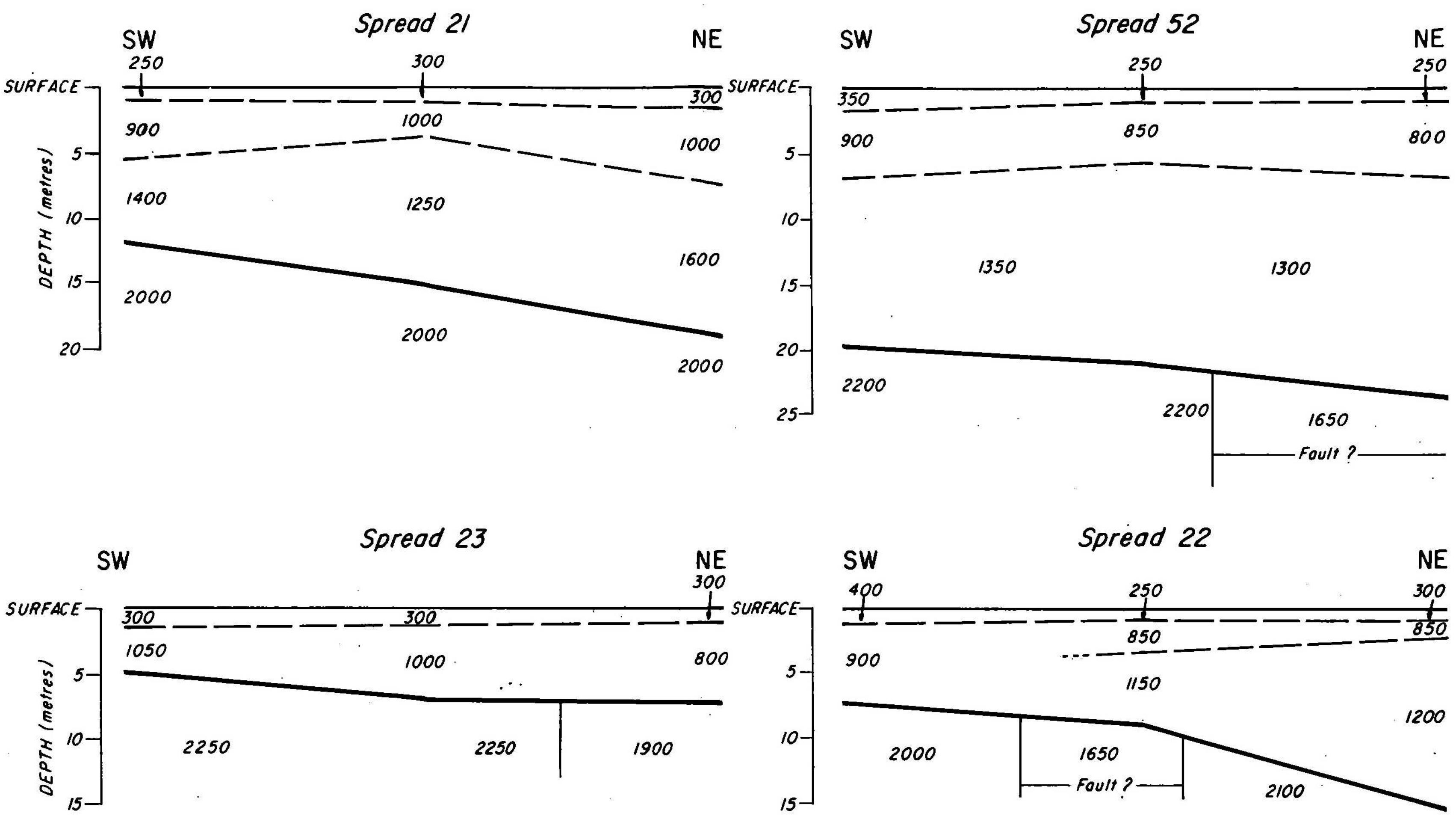
CRACE INDUSTRIAL AREA
CROSS-SECTION ALONG DUNSMORE STREET, SHOWING POSTIONS OF
AND LITHOLOGIES IN DRILL HOLES

Record No. 1977/15

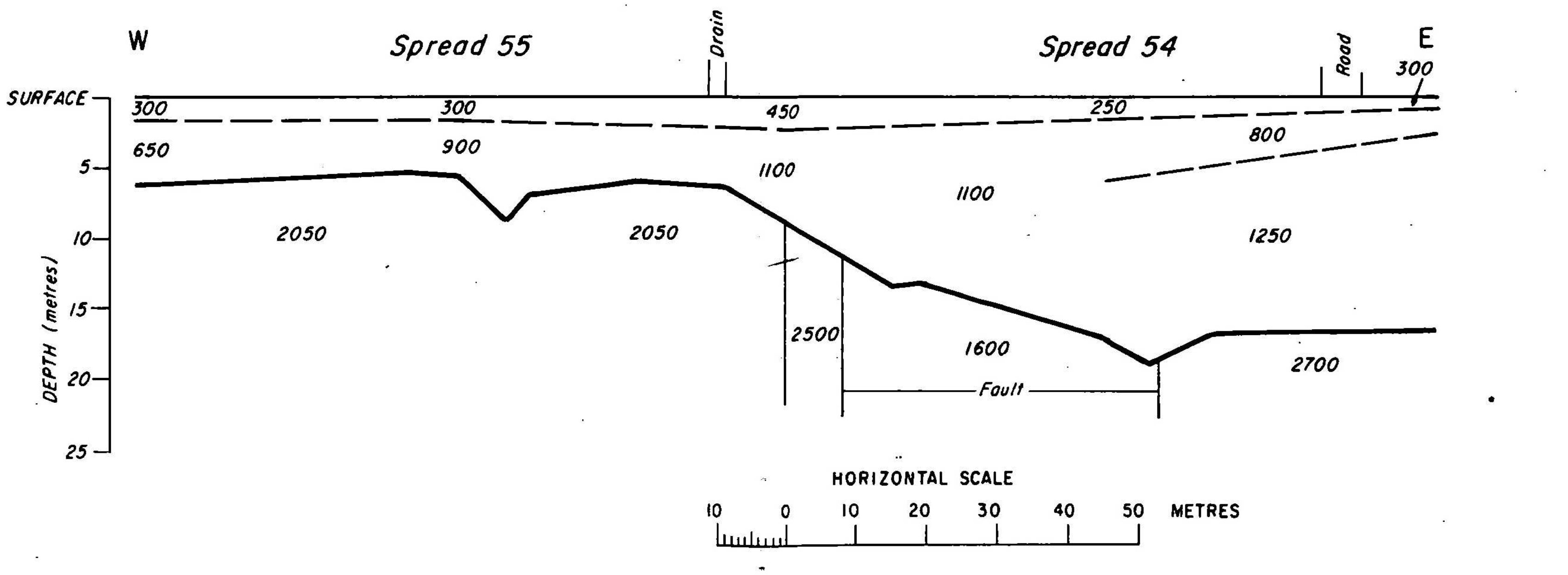
155/A16/1815

PLATE 5

NORTHBOURNE AVENUE



RANDWICK ROAD



LEGEND

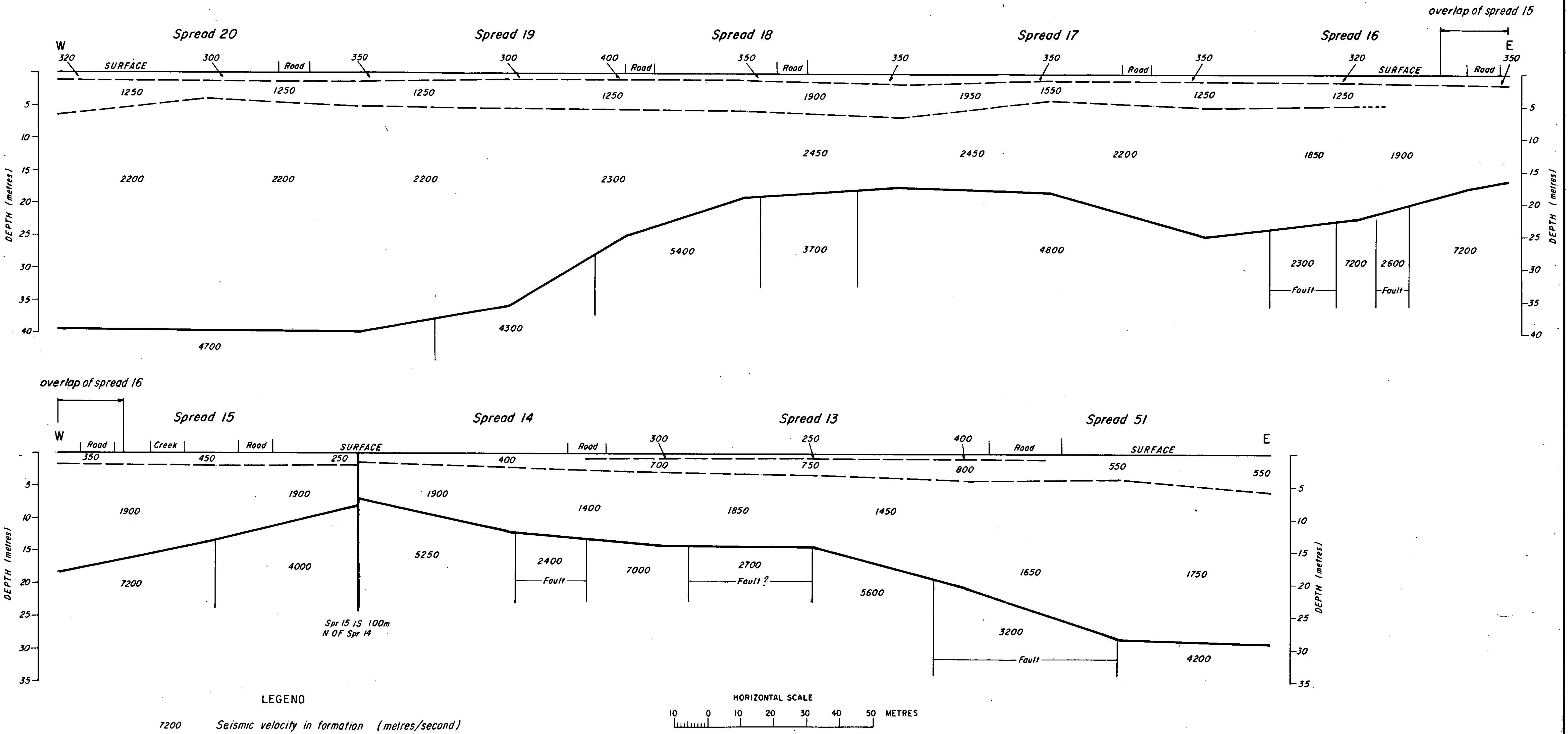
2050	*Seismic velocity in formation (metres/second)*
– – – –	*Interpolated intermediate boundary*
———	*Bedrock boundary*

CRACE INDUSTRIAL AREA
NORTHBOURNE AVENUE AND RANDWICK ROAD
SEISMIC SECTIONS

Record No. 1977/15

I55/B5-319

PLATE 6



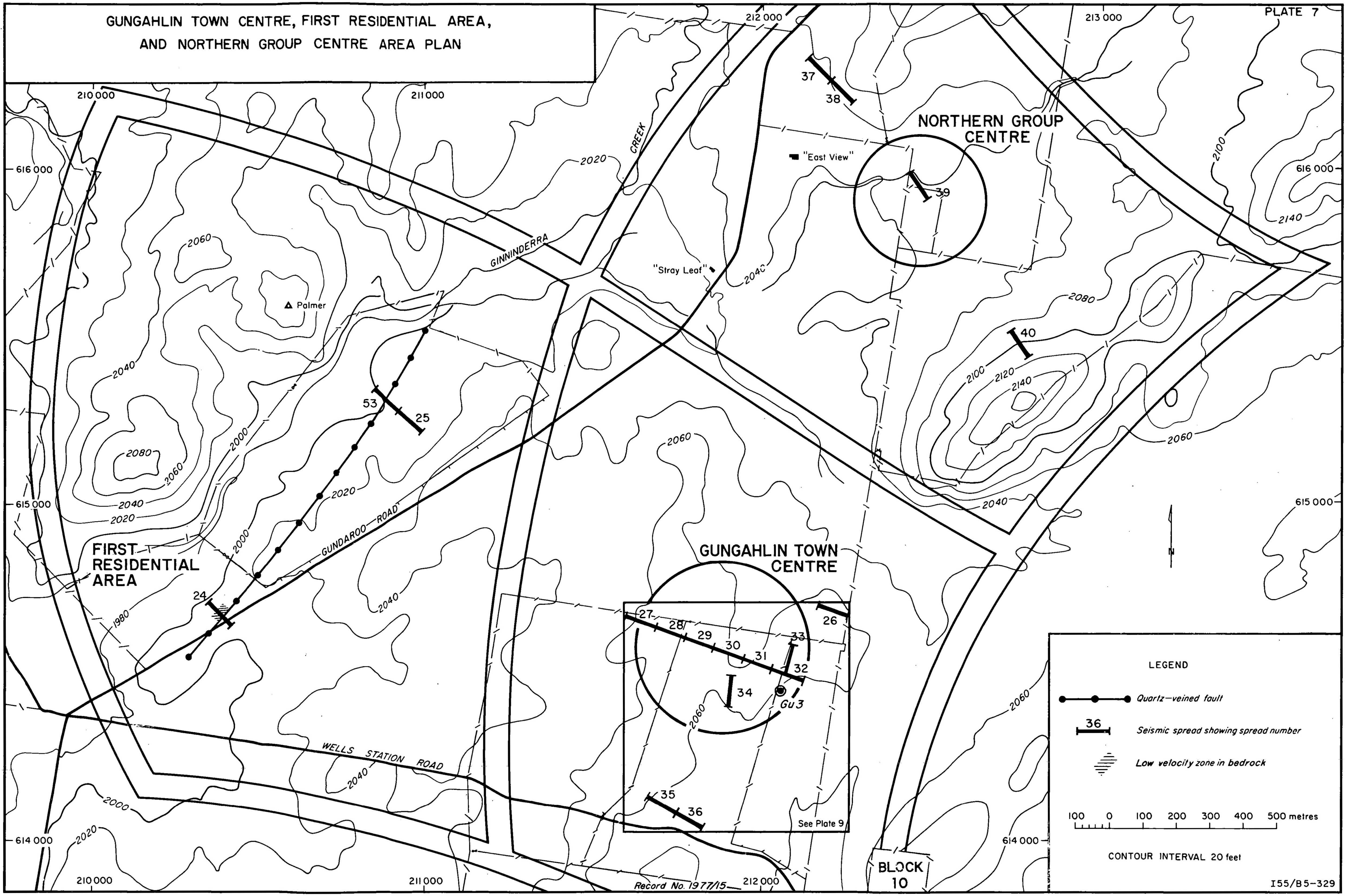
LEGEND

7200	*Seismic velocity in formation (metres/second)*
— — —	*Interpolated intermediate boundary*
———	*Bedrock boundary*

CRACE INDUSTRIAL CENTRE
SEISMIC SECTIONS

PLATE 7

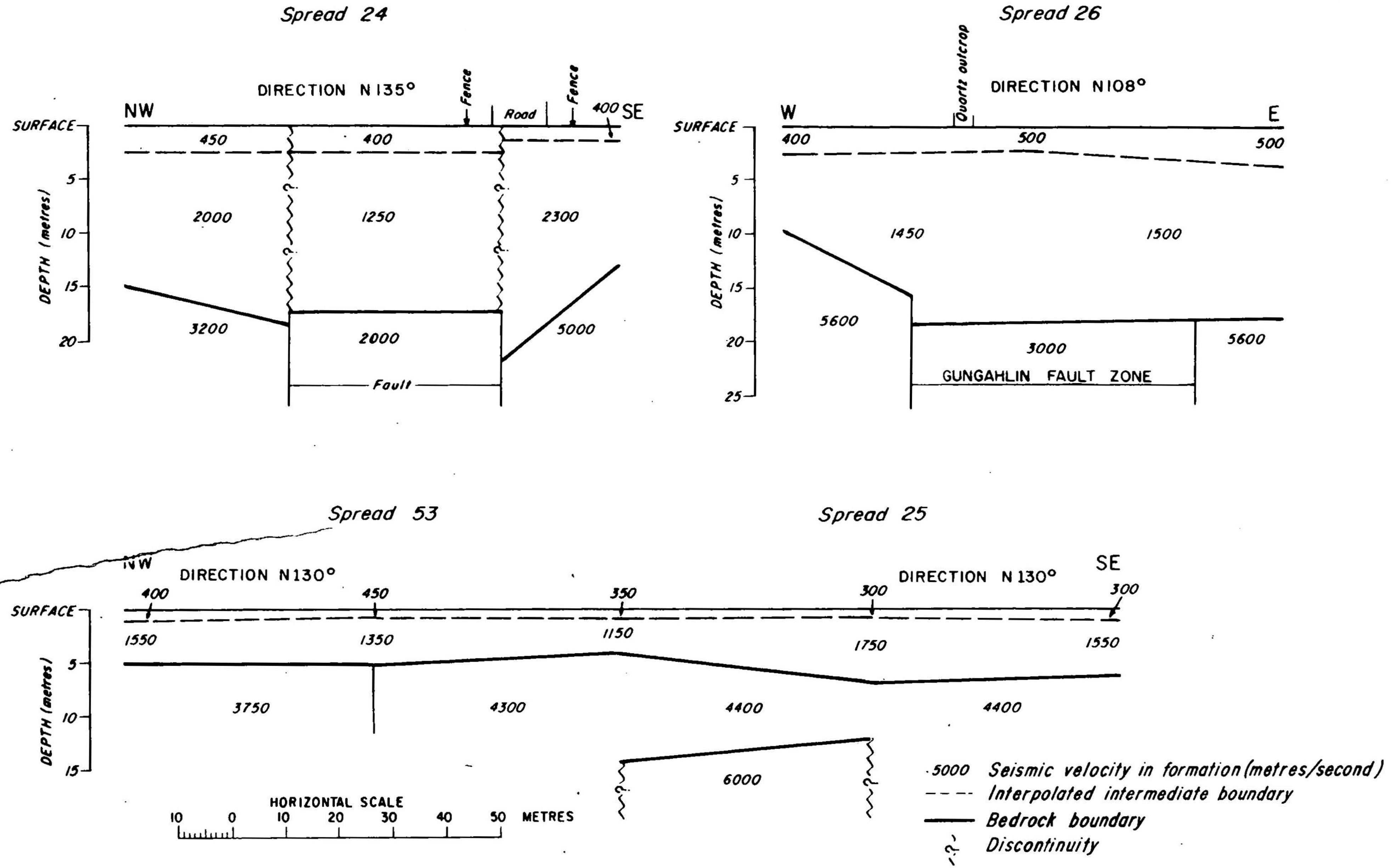
GUNGAHLIN TOWN CENTRE, FIRST RESIDENTIAL AREA, AND NORTHERN GROUP CENTRE AREA PLAN



Record No. 1977/15

I55/B5-329

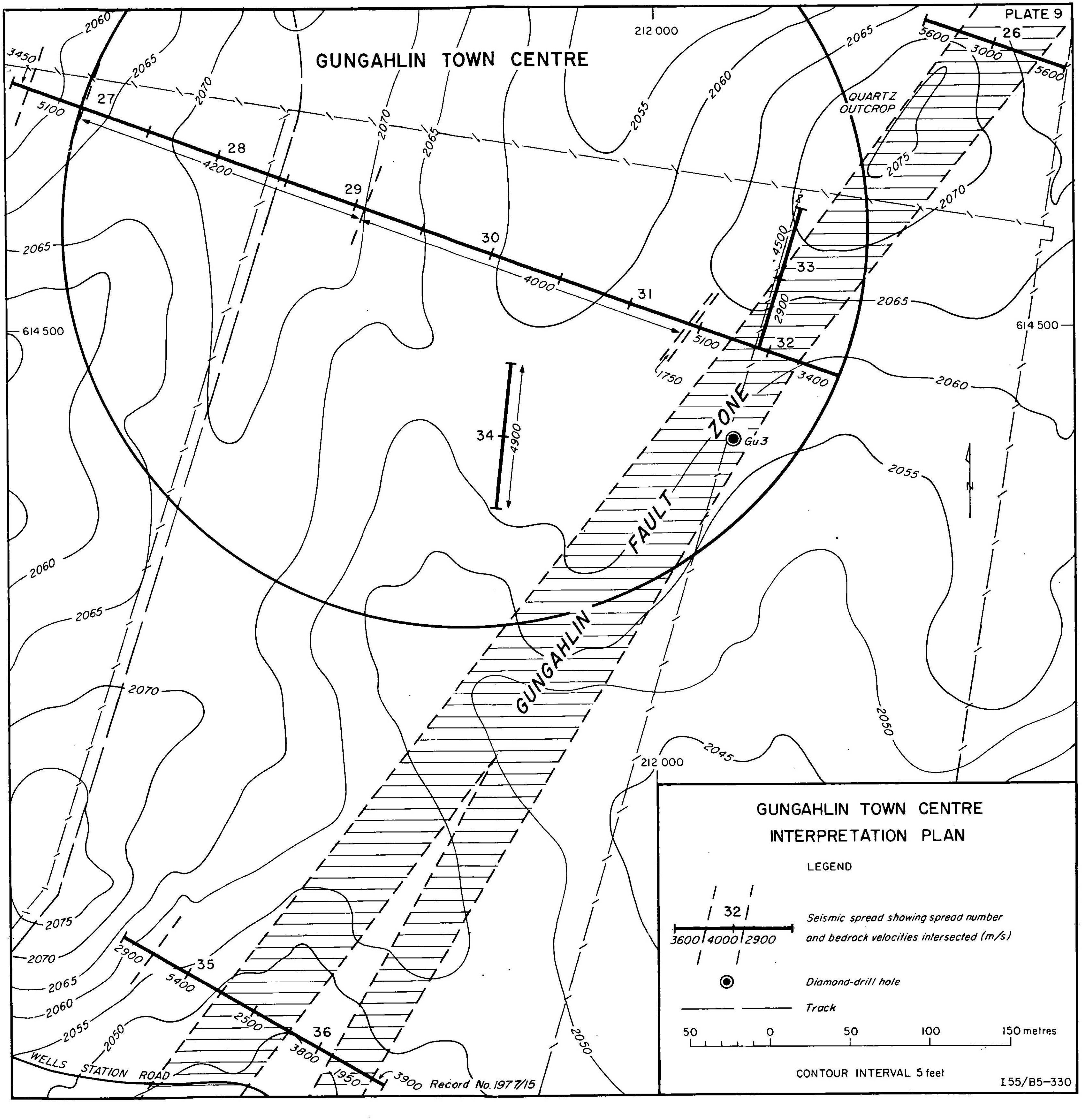
PLATE 8



FIRST RESIDENTIAL AREA AND GUNGAHLIN TOWN CENTRE
SEISMIC SECTIONS-SPREADS 24,26,53,25

155/B5-316A

PLATE 9

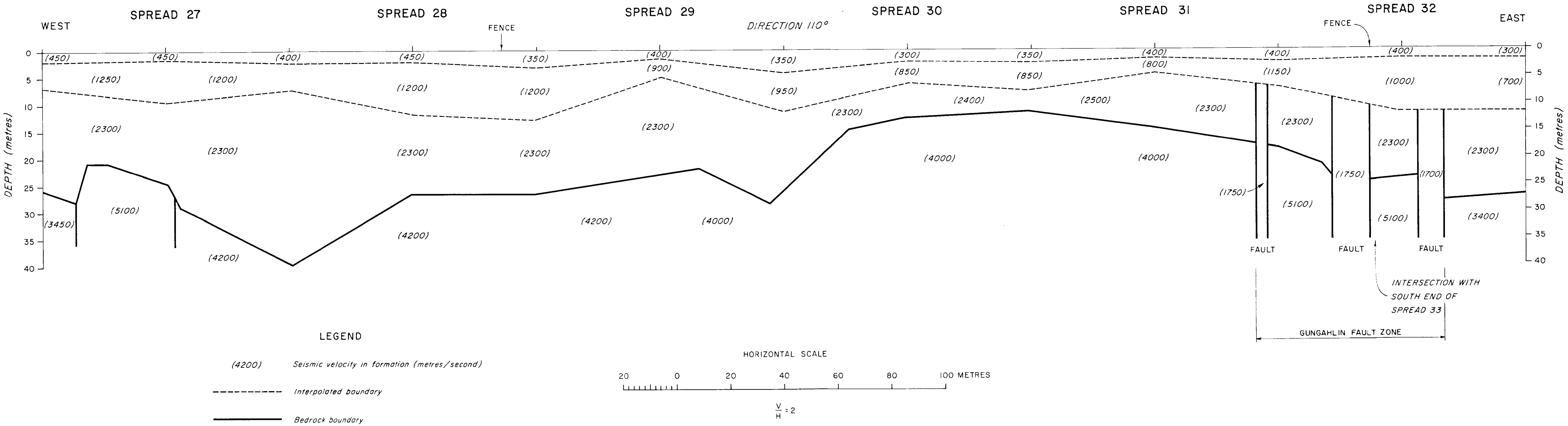


GUNGAHLIN TOWN CENTRE INTERPRETATION PLAN

Record No. 1977/15

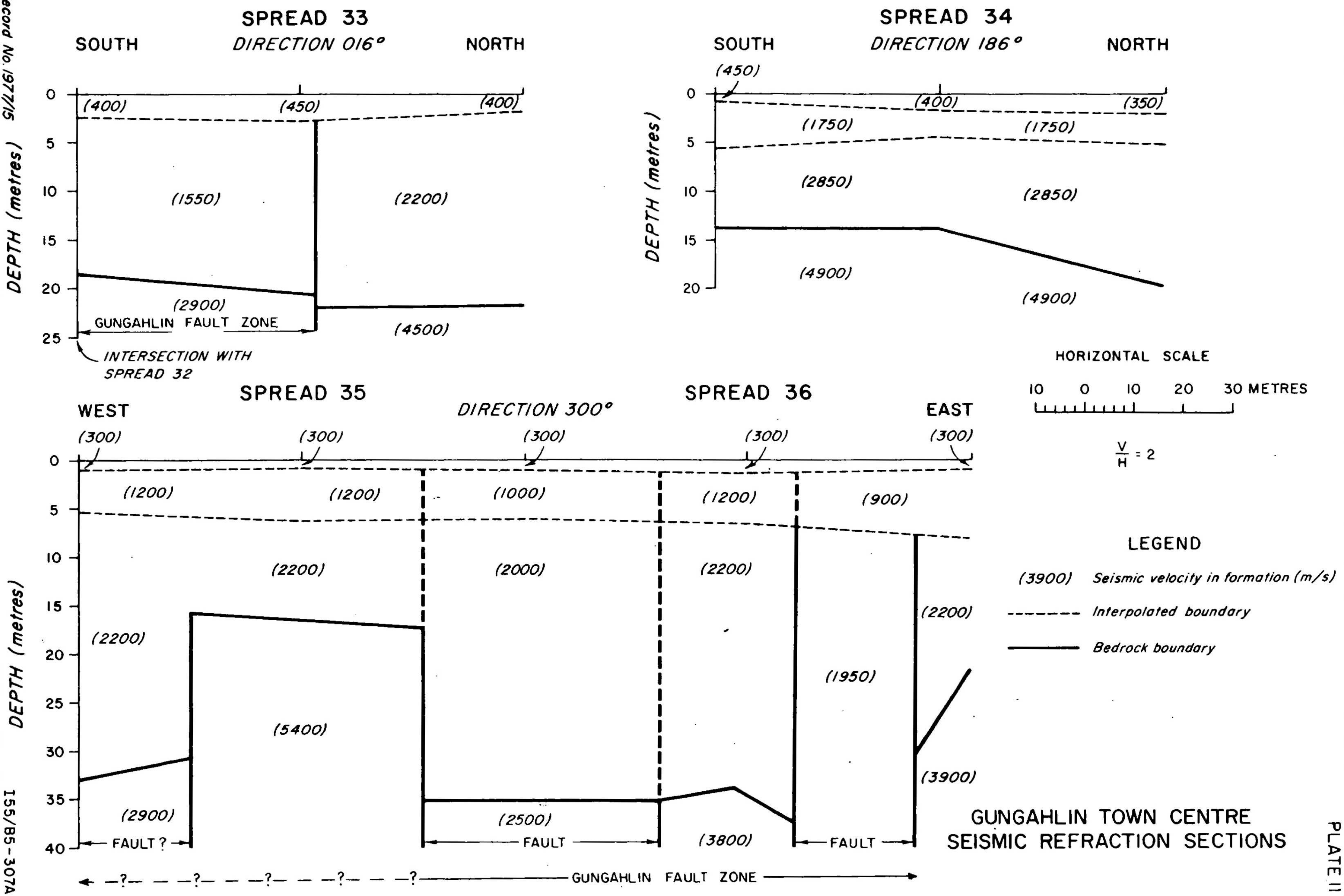
I55/B5-330

PLATE 10



GUNGAHLIN TOWN CENTRE
SEISMIC REFRACTION TRAVERSE

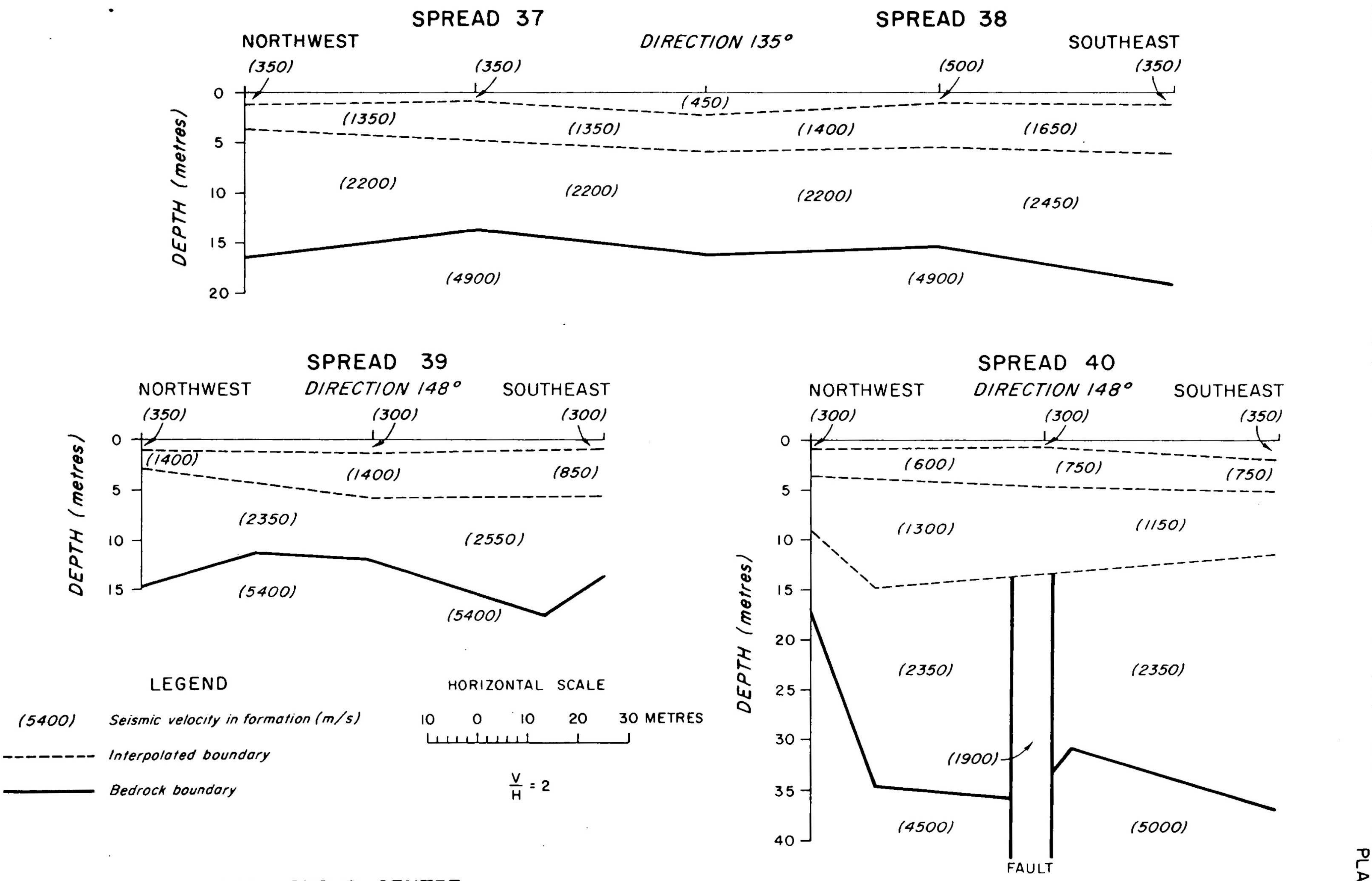
Record No. 1977/15



GUNGAHLIN TOWN CENTRE
SEISMIC REFRACTION SECTIONS

PLATE 11

155/B5-307A



NORTHERN GROUP CENTRE
SEISMIC REFRACTION SECTIONS

I55/B5-308A

PLATE 12

PLATE 13

GEOLOGY of NORTHWESTERN GUNGAHLIN

CONTOUR INTERVAL 20 FEET

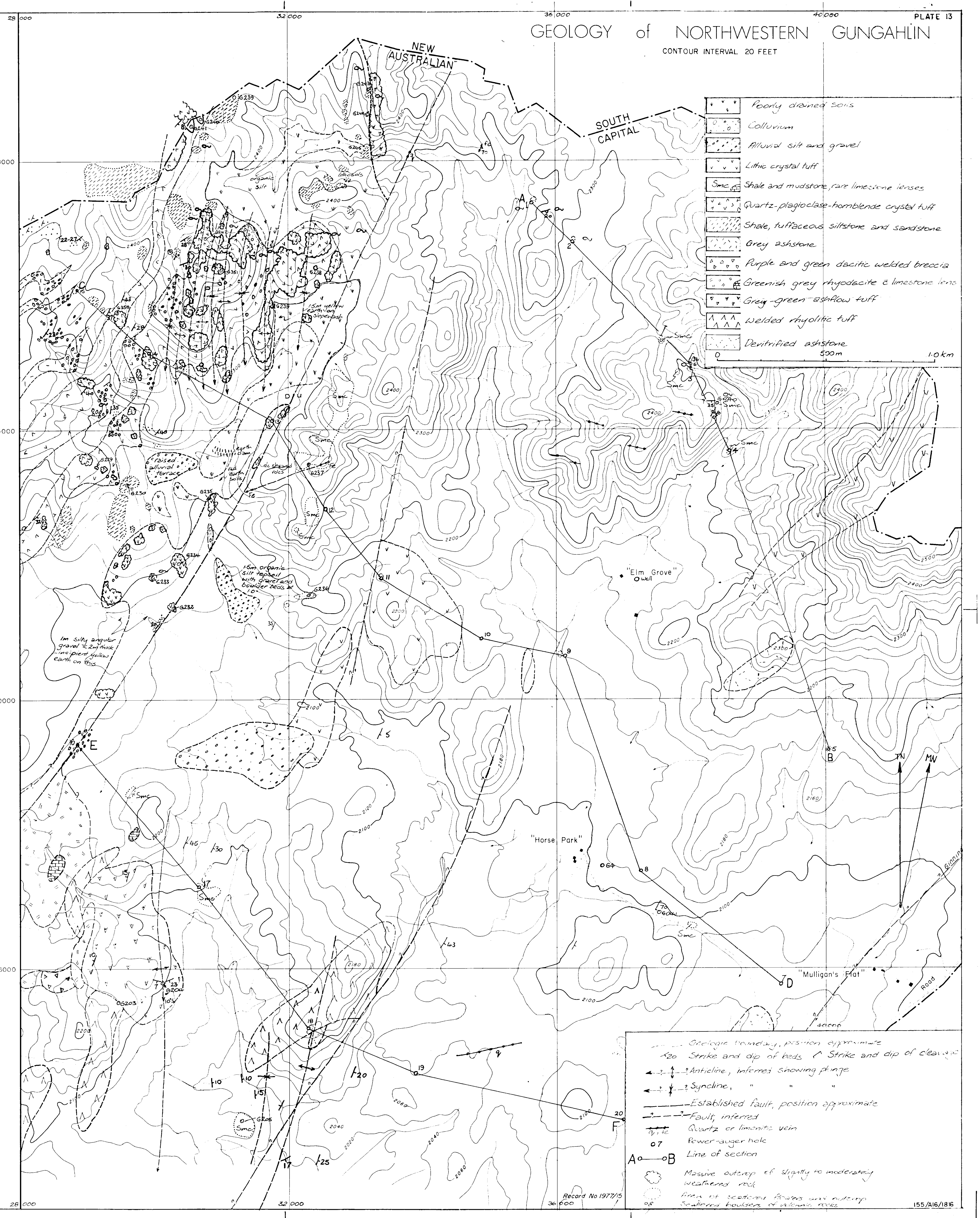
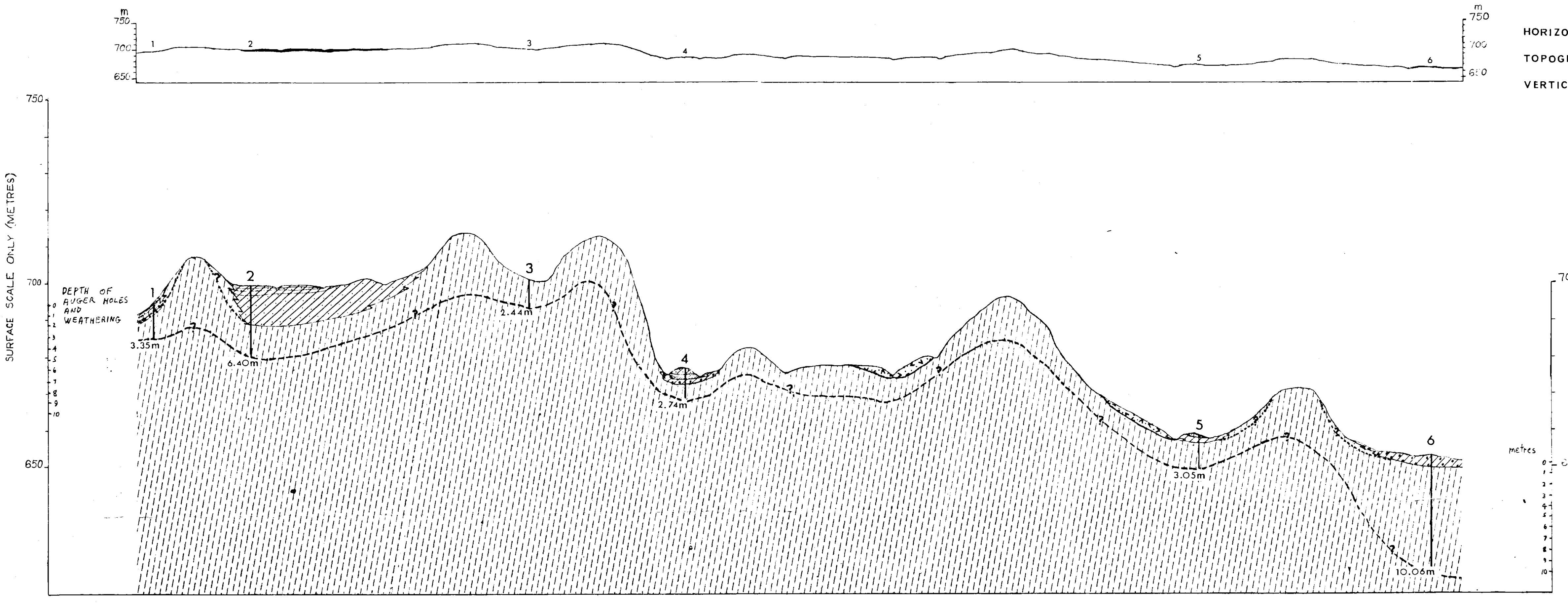


PLATE 14

VERTICAL SECTIONS THROUGH NORTHWESTERN GUNGAHLIN SHOWING ROCK WEATHERING AND SOILS

(see PLATE 13 for location of sections)

SECTION A - B

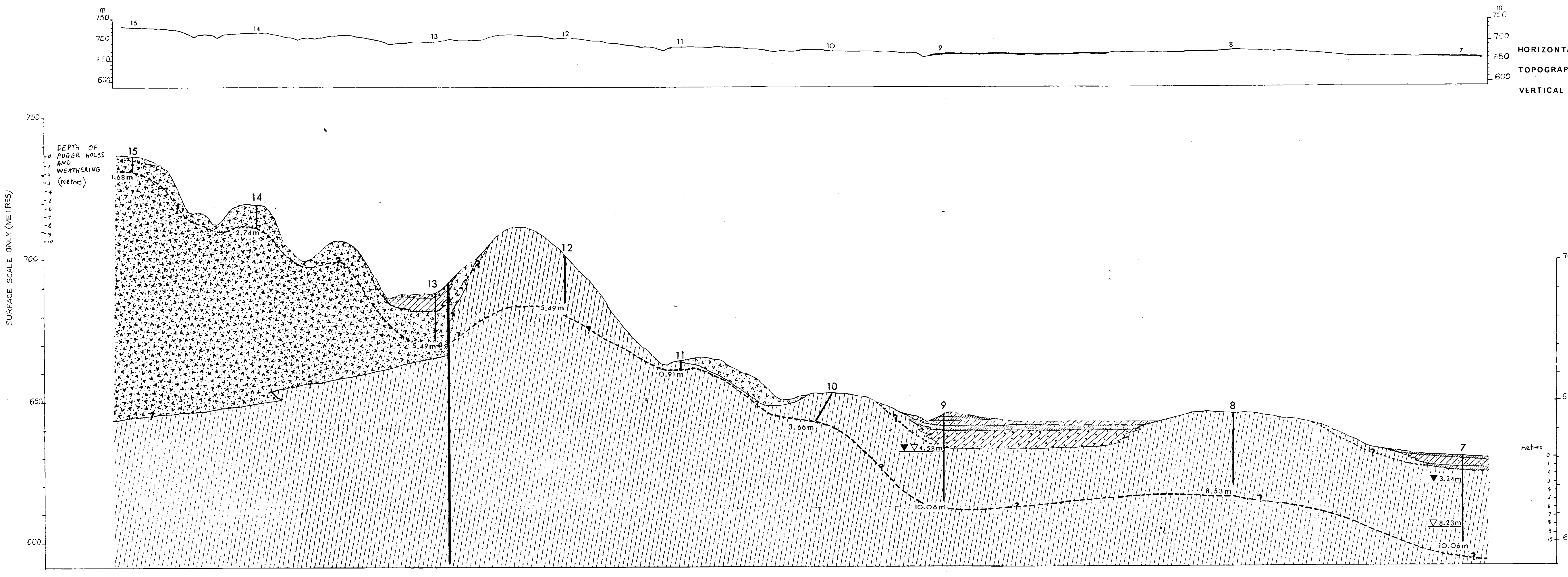


HORIZONTAL SCALE 1 : 9600
TOPOGRAPHIC SCALE 1 : 9600
VERTICAL EXAGGERATION x 1 (V/H = 1)

TOPOGRAPHIC SCALE 1 : 960
V/H = 10

VERTICAL AUGER LOG SCALE 1 : 320
V/H = 30

SECTION C - D

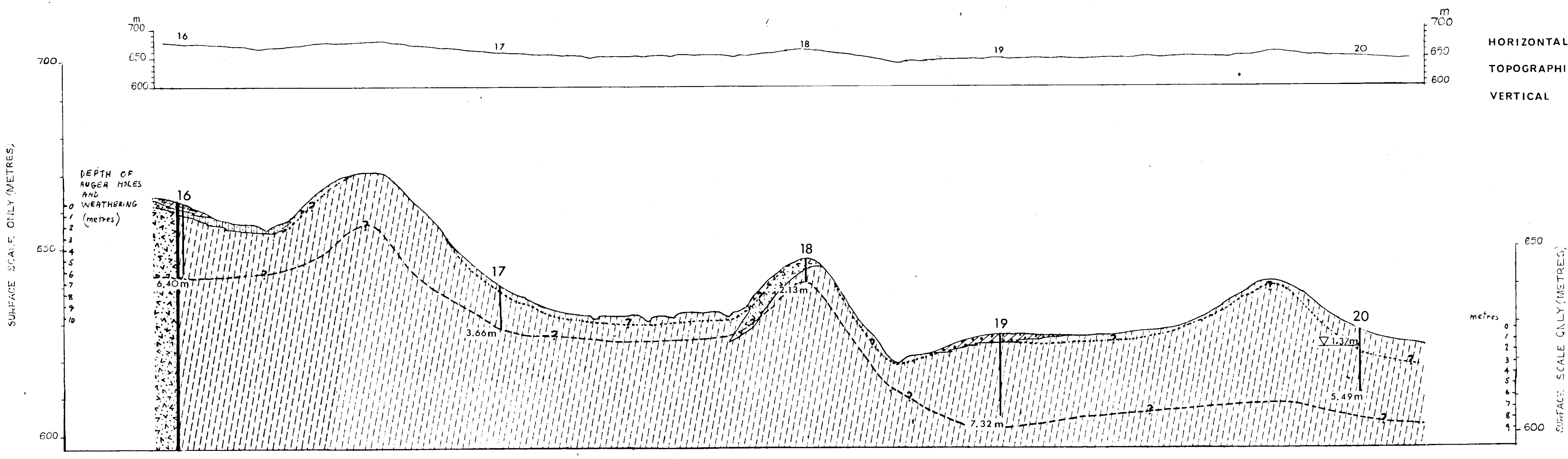


HORIZONTAL SCALE 1 : 9600
TOPOGRAPHIC SCALE 1 : 9600
VERTICAL EXAGGERATION x 1 (V/H = 1)

TOPOGRAPHIC SCALE 1 : 960
V/H = 10

VERTICAL AUGER LOG SCALE 1 : 320
V/H = 30

SECTION E - F

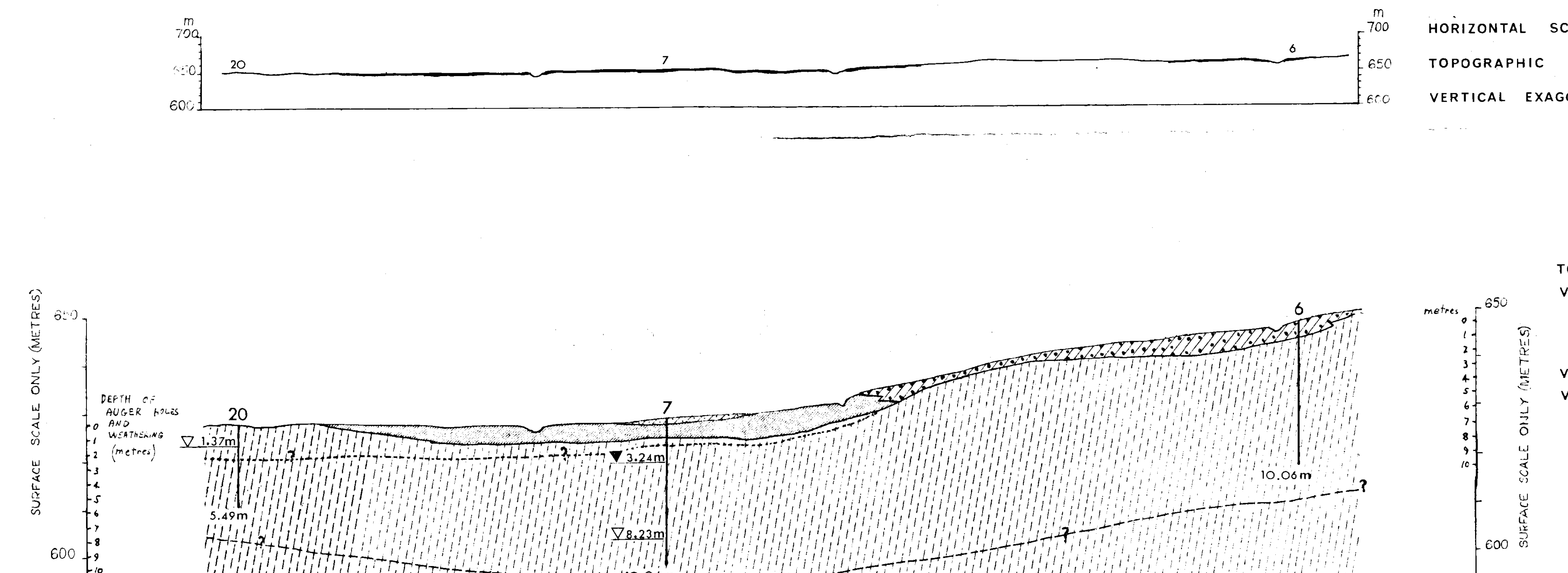


HORIZONTAL SCALE 1 : 9600
TOPOGRAPHIC SCALE 1 : 9600
VERTICAL EXAGGERATION x 1 (V/H = 1)

TOPOGRAPHIC SCALE 1 : 960
V/H = 10

VERTICAL AUGER LOG SCALE 1 : 320
V/H = 30

SECTION B - F



HORIZONTAL SCALE 1 : 9600
TOPOGRAPHIC SCALE 1 : 9600
VERTICAL EXAGGERATION x 1 (V/H = 1)

TOPOGRAPHIC SCALE 1 : 960
V/H = 10

VERTICAL AUGER LOG SCALE 1 : 320
V/H = 30

UNIFIED SOIL CLASSIFICATION SYSTEM

CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS		TYPICAL NAMES
COARSE GRAINED SOILS More than 1/2 of soil > No 200 sieve size	GRAVELS (More than ½ of coarse fraction > no.4 U.S. sieve size)		GW	▨	Well graded gravels or gravel-sand mixtures little or no fines*
			GP	▨	Poorly graded gravels or gravel-sand mixtures, little or no fines
			GM	▨	Silty gravels, gravel-sand-silt mixture
			GC	▨	Clayey gravels, gravel-sand-clay mixture
	SANDS (More than ½ of coarse fraction > no.4 U.S. sieve size)		SW	▨	Well graded sands or gravelly sands, little or no fines
			SP	▨	Poorly graded sands or gravelly sands, little or no fines
			SM	▨	Silty sands, sand silt-mixtures
			SC	▨	Clayey sands, sand-clay mixtures
FINE GRAINED SOILS More than 1/2 of soil < No. 200 sieve size	SILTS AND CLAYS Liquid limit > 50		ML	▨	Inorganic silt and very fine sands, rock flour, silty or clayey fine sands or clayey silts with low plasticity
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	▨	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS Liquid limit > 50		MH	▨	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
			CH	▨	Inorganic clays of high plasticity, fat clays
			OH	▨	Organic clays of medium to high plasticity, organic silty clays, organic silts
HIGHLY ORGANIC SOILS			Pt	▨	Peat and other highly organic soils

*fines - portion of a soil finer than a no.200 sieve

▨	Shale and ashstone
▨	Volcanics
9	Auger hole location
▼ 4.58m	Standing water level
▽ 1.37m	Depth to top of aquifer
10.06m	Total depth of auger hole
....	Depth to highly weathered rock
- - - - -	Depth to moderately weathered rock

PLATE 14

AMENDMENTS

No.	DESCRIPTION	AUTHOR	DATE	CHECKED	DATE
A1					
A2					
A3					
A4					
A5					
A6					

SCALE
0 92 184 276 368 460 m
0 304 608 912 1216 1520 ft

BASE MAP/SURVEY
A.C.T. 1 : 9600 PLANNING SERIES

GEOLOGY BY
P.D. HOHNEN

COMPILED AND CHECKED
P.D. HOHNEN
PROJECT GEOLOGIST

CHECKED AND APPROVED

SENIOR GEOLOGIST

SUPERVISING GEOLOGIST

COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.

TITLE
VERTICAL SECTIONS THROUGH NORTHWESTERN GUNGAHLIN SHOWING ROCK WEATHERING AND SOILS

PROJECT
GEOLOGICAL & GEOPHYSICAL INVESTIGATIONS FOR URBAN DEVELOPMENT, GUNGAHLIN, A.C.T.

TO ACCOMPANY RECORD

DRAWN BY
J.P.C.

DRAWING NUMBER

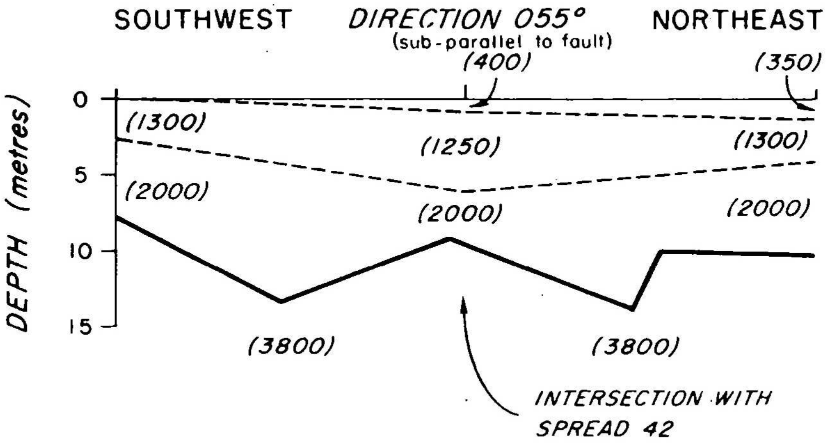
Record No. 1977/15

155/A16/1817

Record No. 1977/15

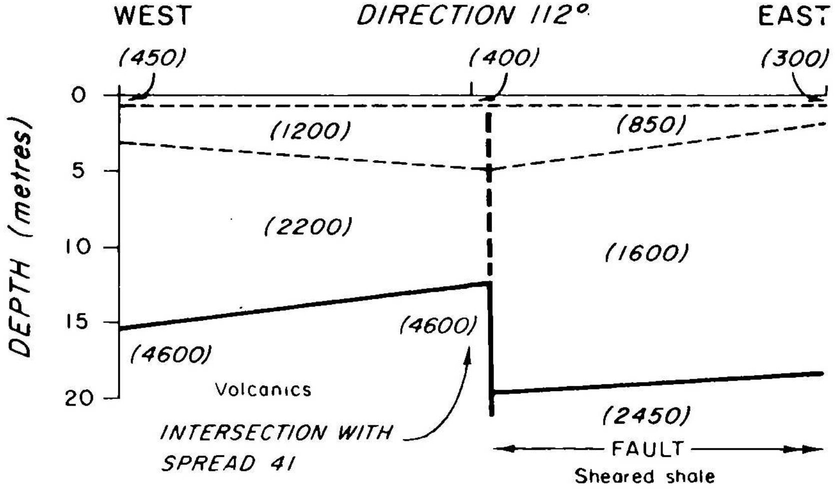
SPREAD 41

AUGER HOLE No. 16



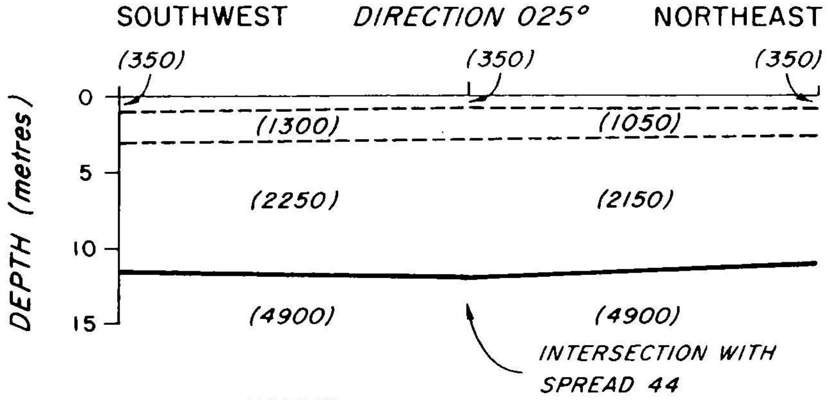
SPREAD 42

AUGER HOLE No. 16



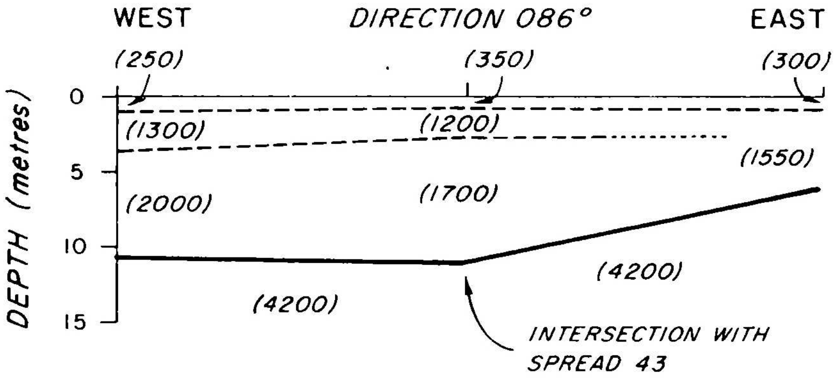
SPREAD 43

AUGER HOLE No. 17



SPREAD 44

AUGER HOLE No. 17



LEGEND

(4900)	*Seismic velocity in formation (metres/second)*
- - - - - -	*Interpolated boundary*
———	*Bedrock boundary*

HORIZONTAL SCALE

10 0 10 20 30 METRES

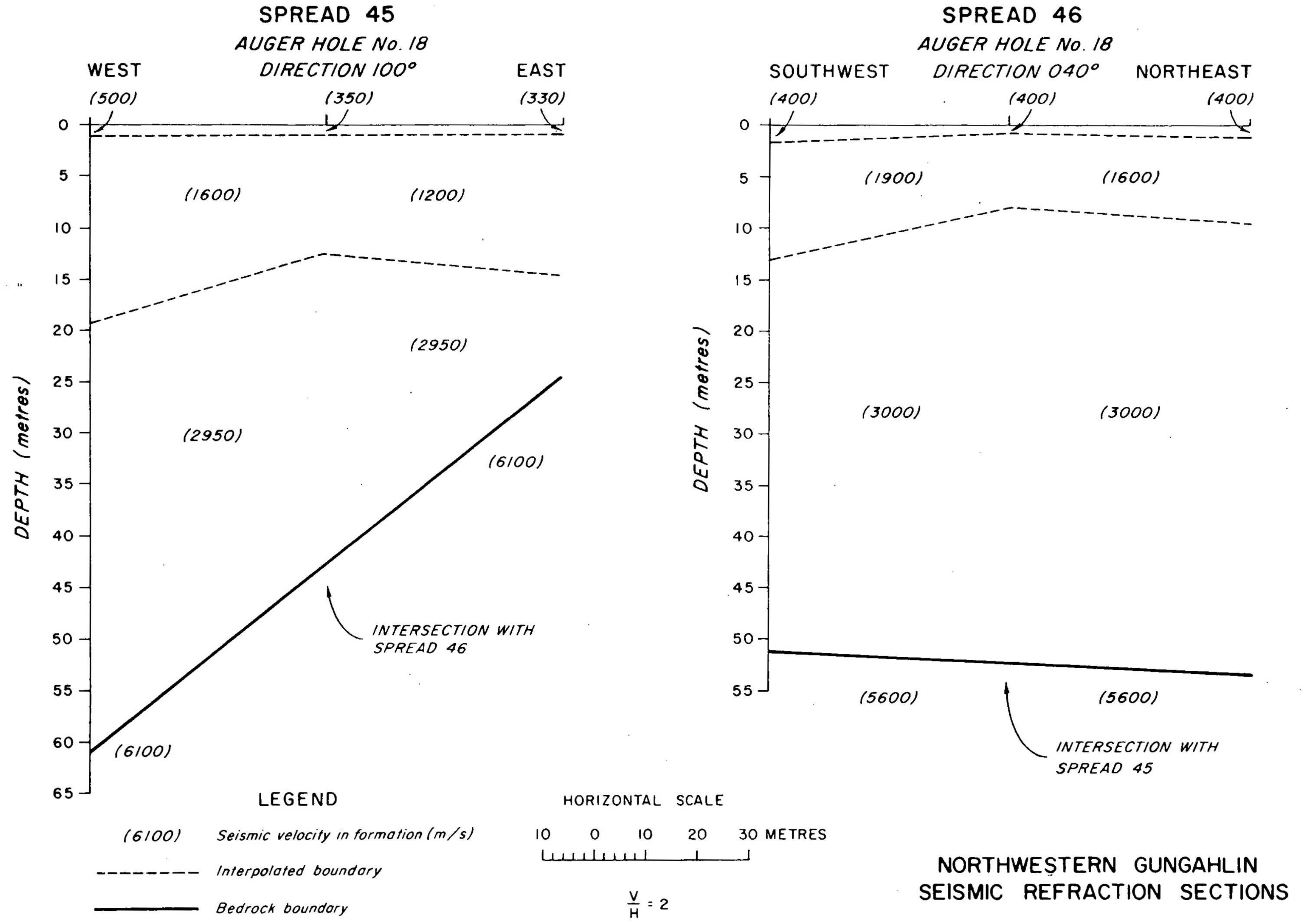
$\frac{V}{H} = 2$

NORTHWESTERN GUNGAHLIN
SEISMIC REFRACTION SECTIONS

I55/B5-309A

PLATE 15

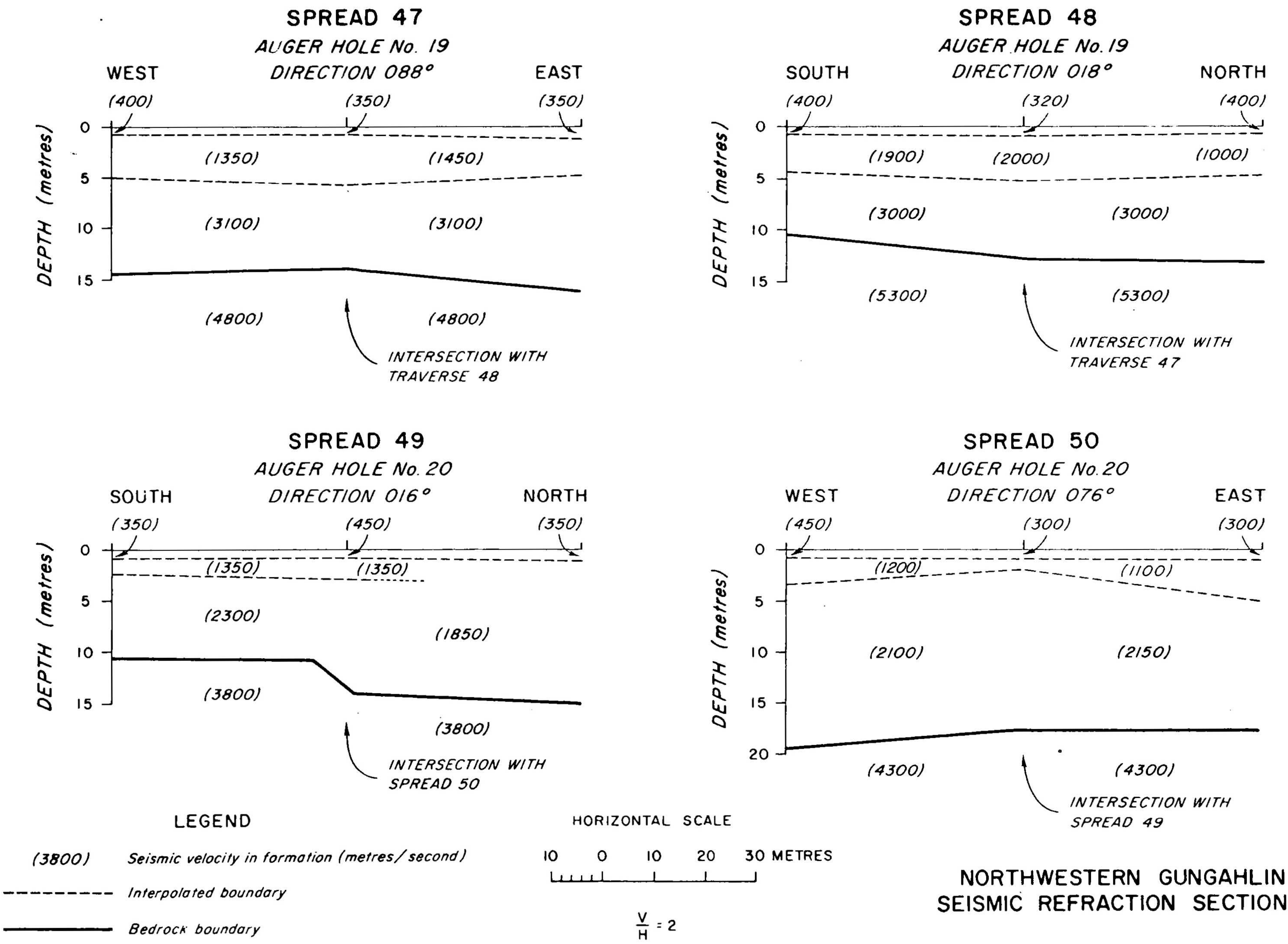
Record No. 1977/15



NORTHWESTERN GUNGAHLIN
SEISMIC REFRACTION SECTIONS

PLATE 16

I55/B5-310A

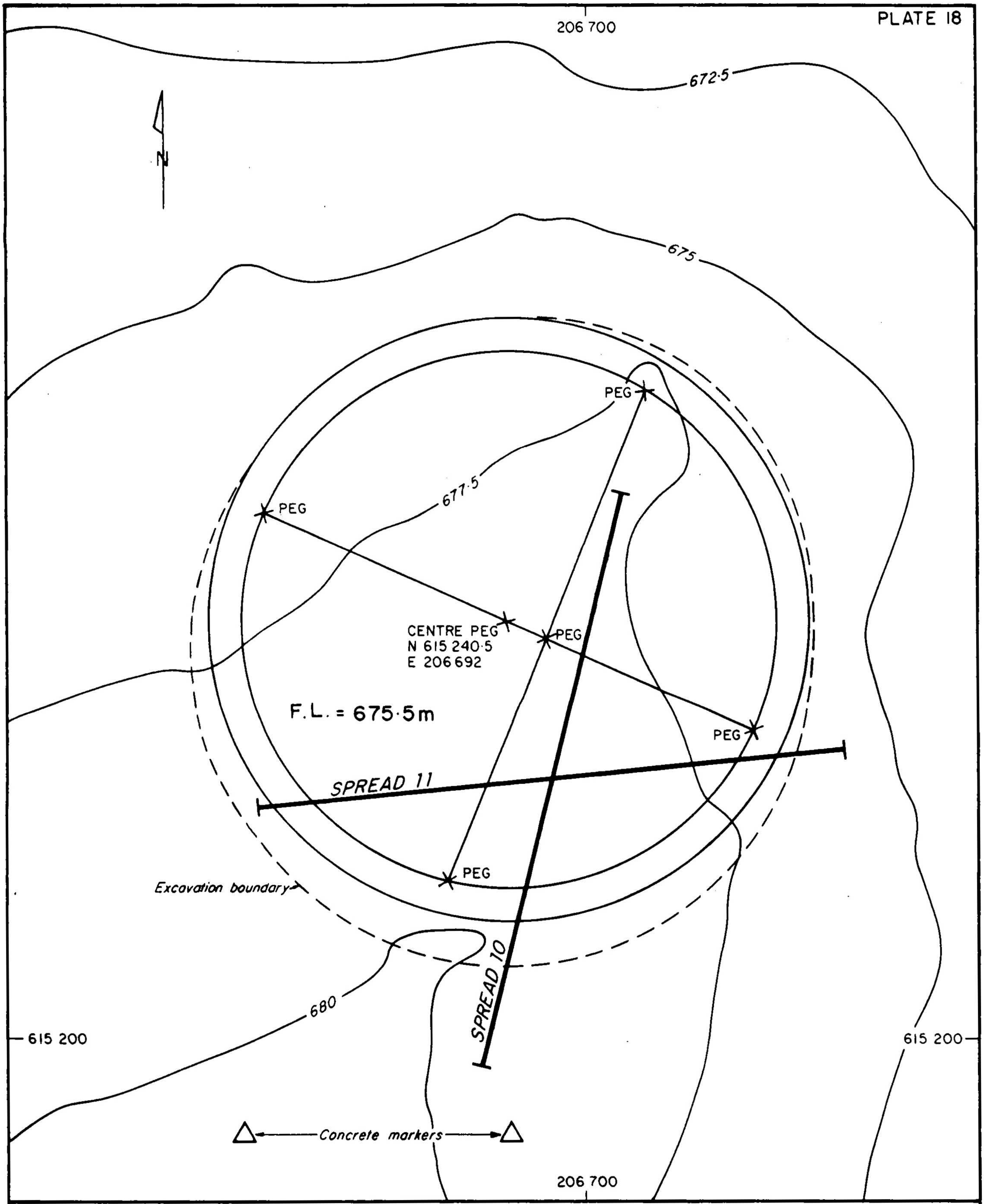


NORTHWESTERN GUNGAHLIN SEISMIC REFRACTION SECTIONS

PLATE 17

I55/85-311A

PLATE 18

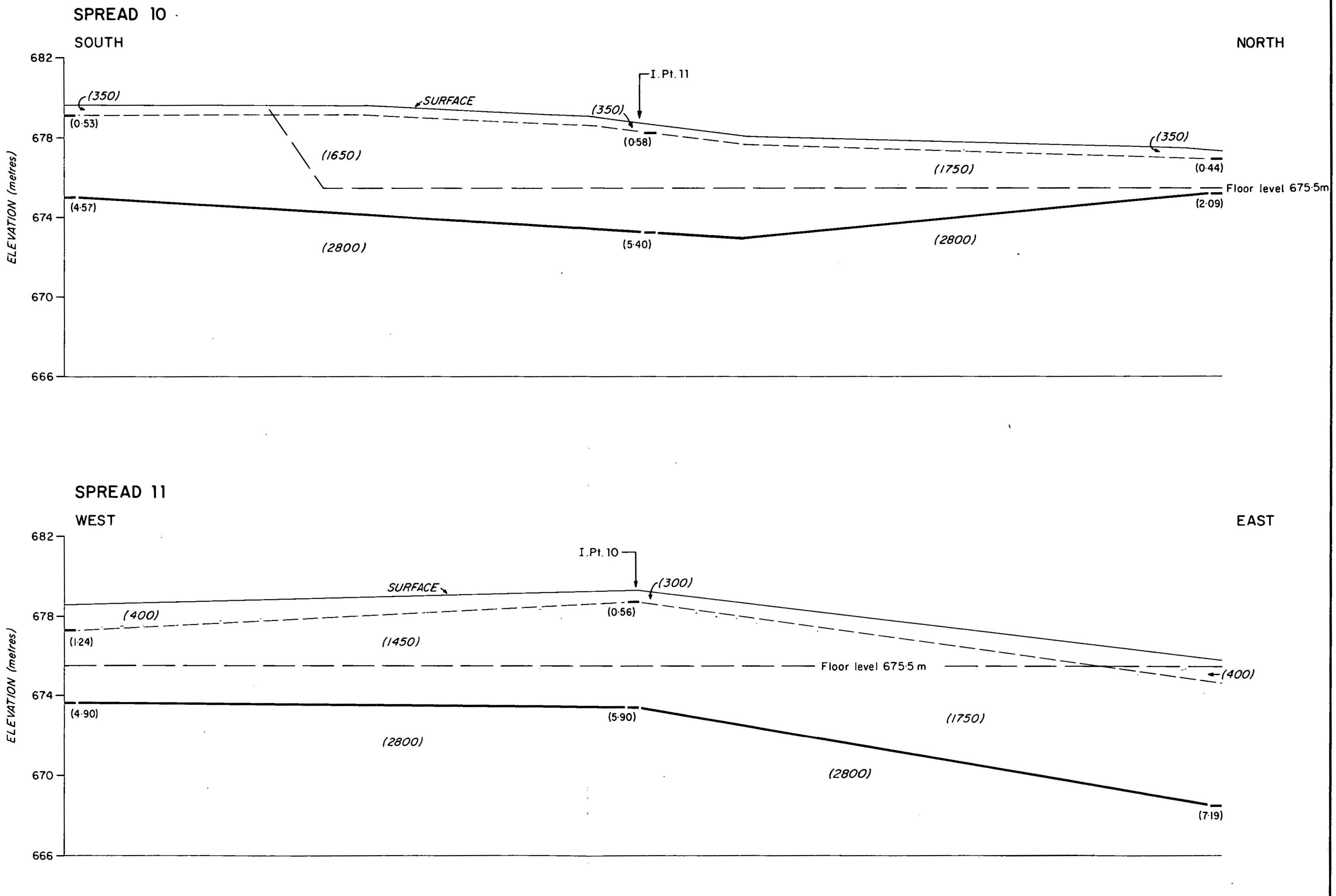


CONTOUR INTERVAL 2·5 metres

HALL RESERVOIR No. 1
SITE PLAN SHOWING SEISMIC TRAVERSES

Record No. 1977/15

I55/B5-331A



LEGEND

(2800)	Seismic velocity (m/s)
— (1·24)	Depth (m)
━━	Bedrock boundary
— —	Interpolated boundary

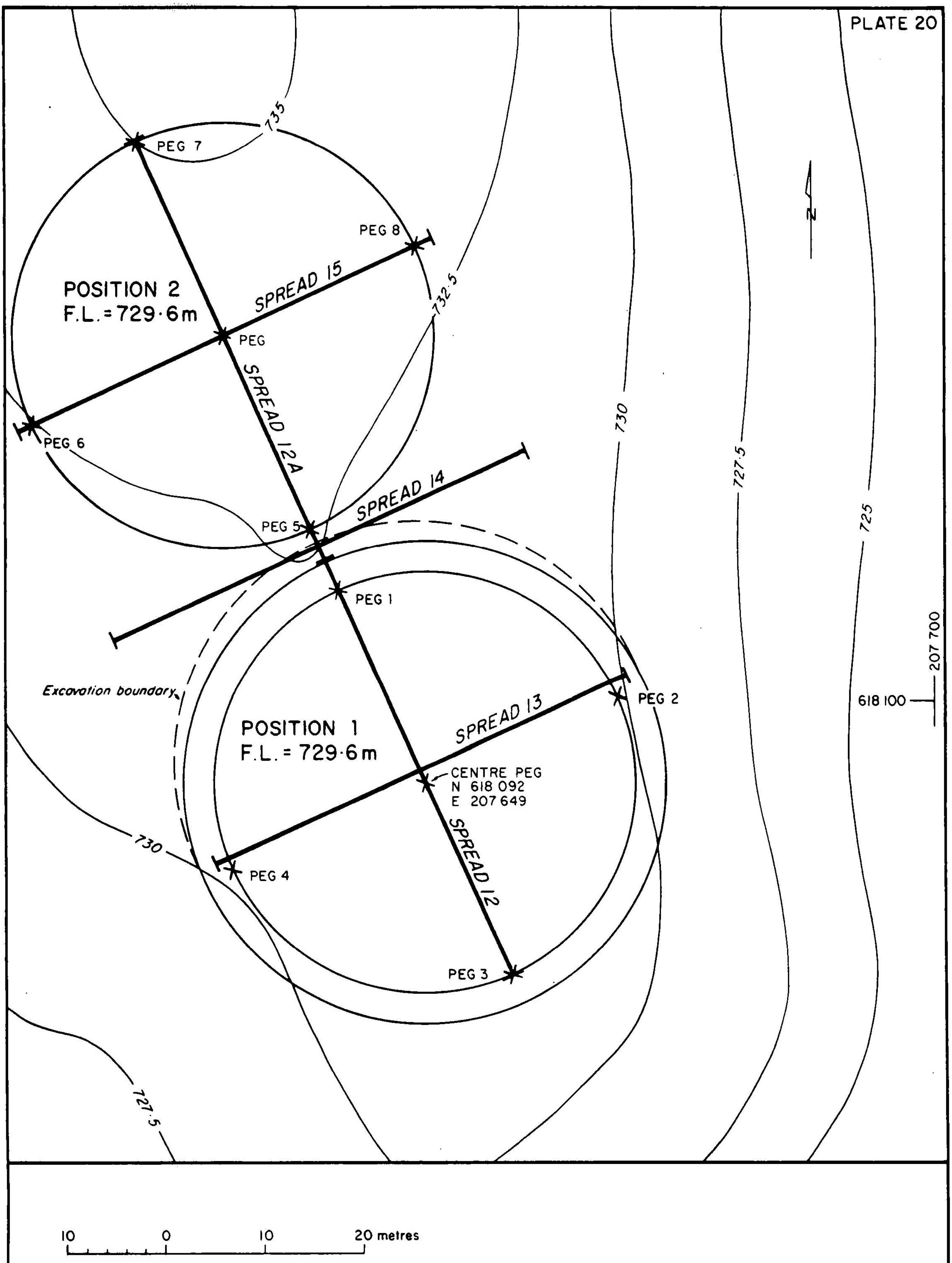
5 0 5 10 metres

$\frac{V}{H} = 1$

HALL RESERVOIR No. I
SEISMIC REFRACTION SECTIONS
GEOPHONE SPACING 2·5m

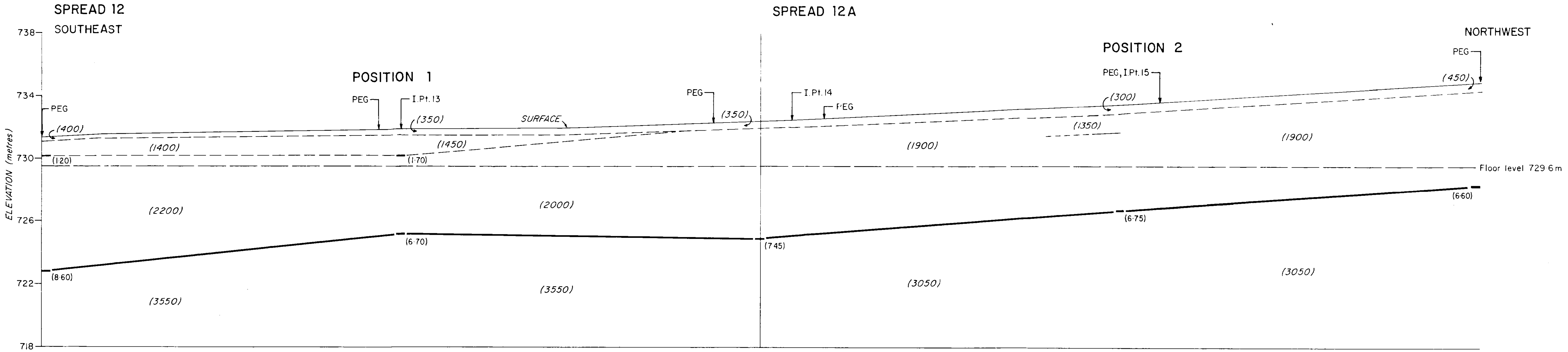
Record No. 1977/15

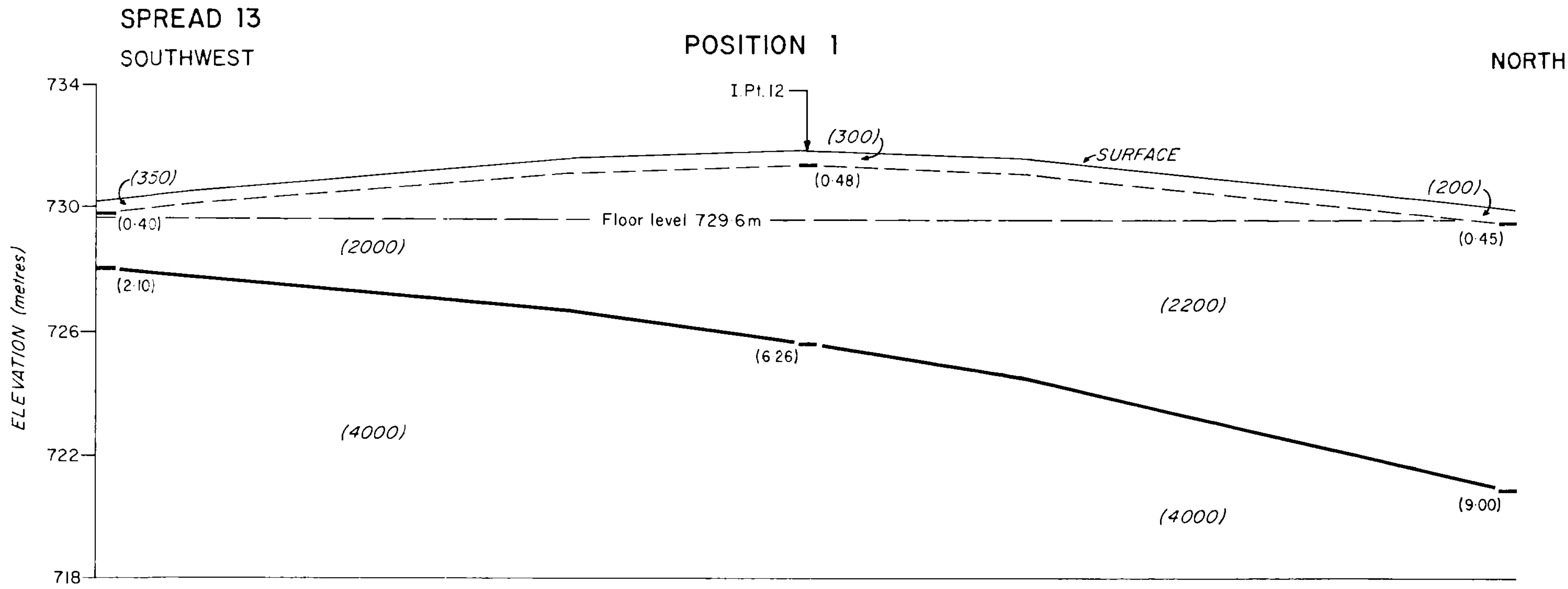
PLATE 20

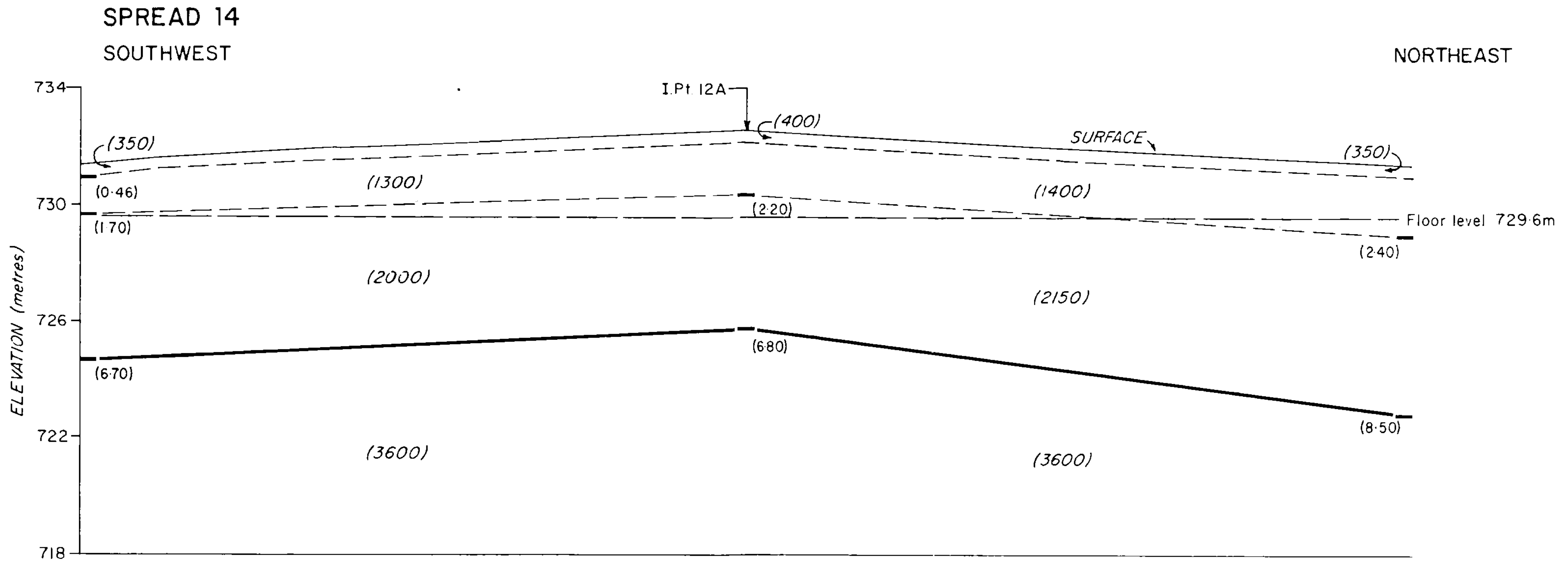


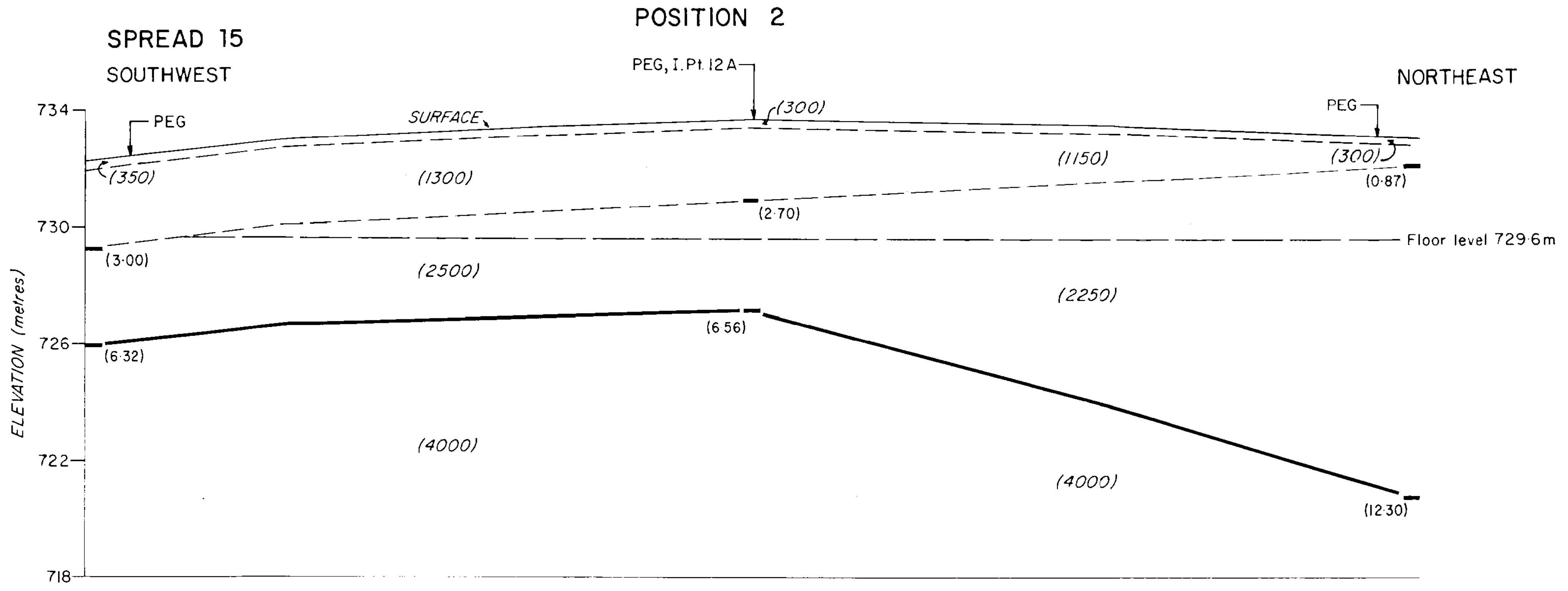
HALL RESERVOIR No. 2
SITE PLAN SHOWING SEISMIC TRAVERSES

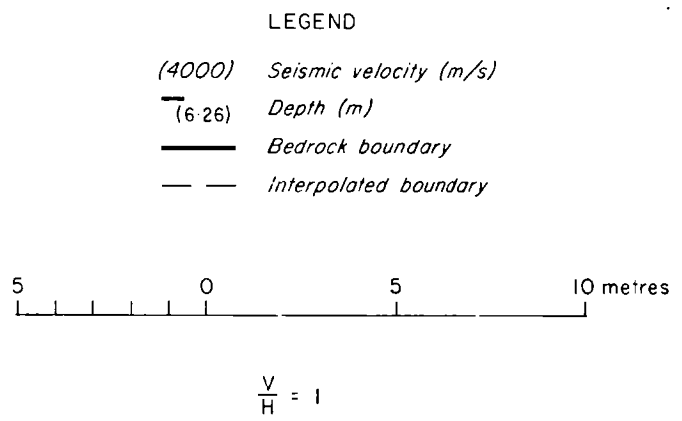
PLATE 21



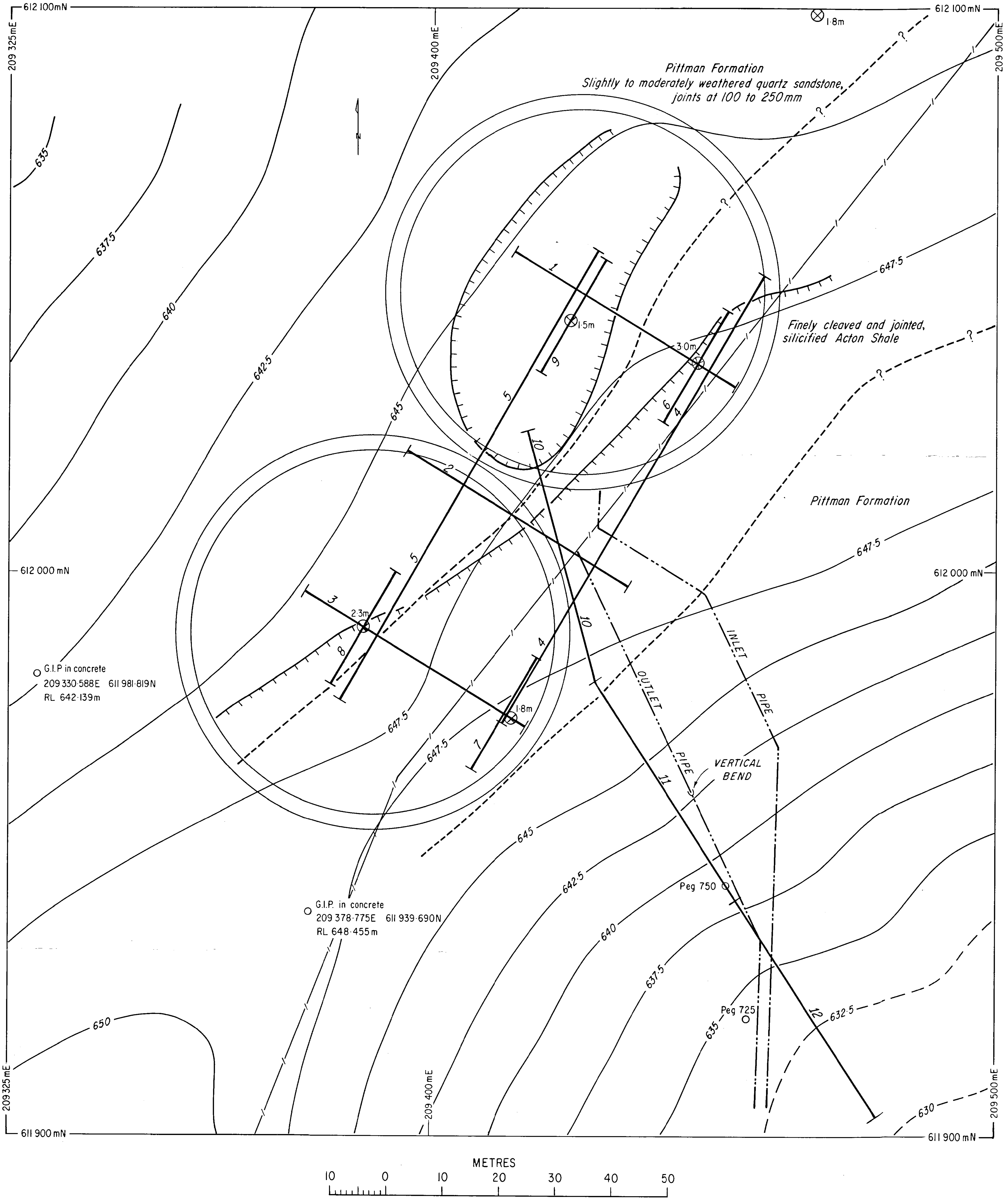








HALL RESERVOIR No.2
SEISMIC REFRACTION SECTIONS
GEOPHONE SPACING 2m



LEGEND

2 SEISMIC SPREAD

640 ELEVATION CONTOUR (metres)
CONTOUR INTERVAL 2·5m

PIPELINE

⊗1·8m POWER-AUGER HOLE SHOWING DEPTH TO AUGER REFUSAL (EQUIVALENT TO ROCK OF SEISMIC VELOCITY 1500m/s)

FENCE

GEOLOGICAL BOUNDARY

INFERRED GEOLOGICAL BOUNDARY

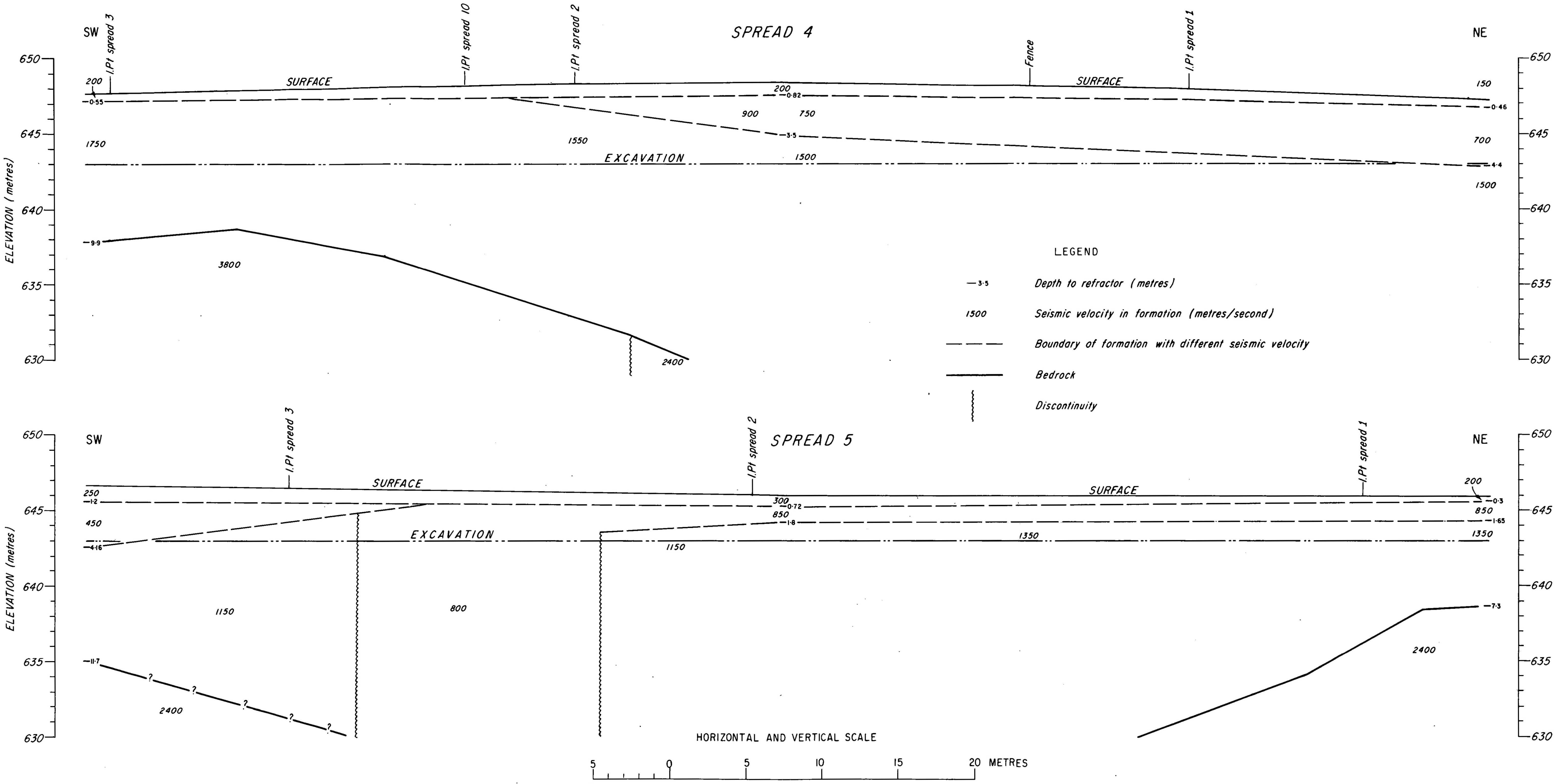
EDGE OF NON-RIPPABLE ROCK MATERIAL AT EXCAVATION BASE LEVEL
(Ticks indicate non-rippable rock material)

GUNGAHLIN No.1 RESERVOIR
SITE PLAN SHOWING SEISMIC TRAVERSES

GUNGAHLIN RESERVOIR No.1, SEISMIC SECTIONS

Record No. 1977/15

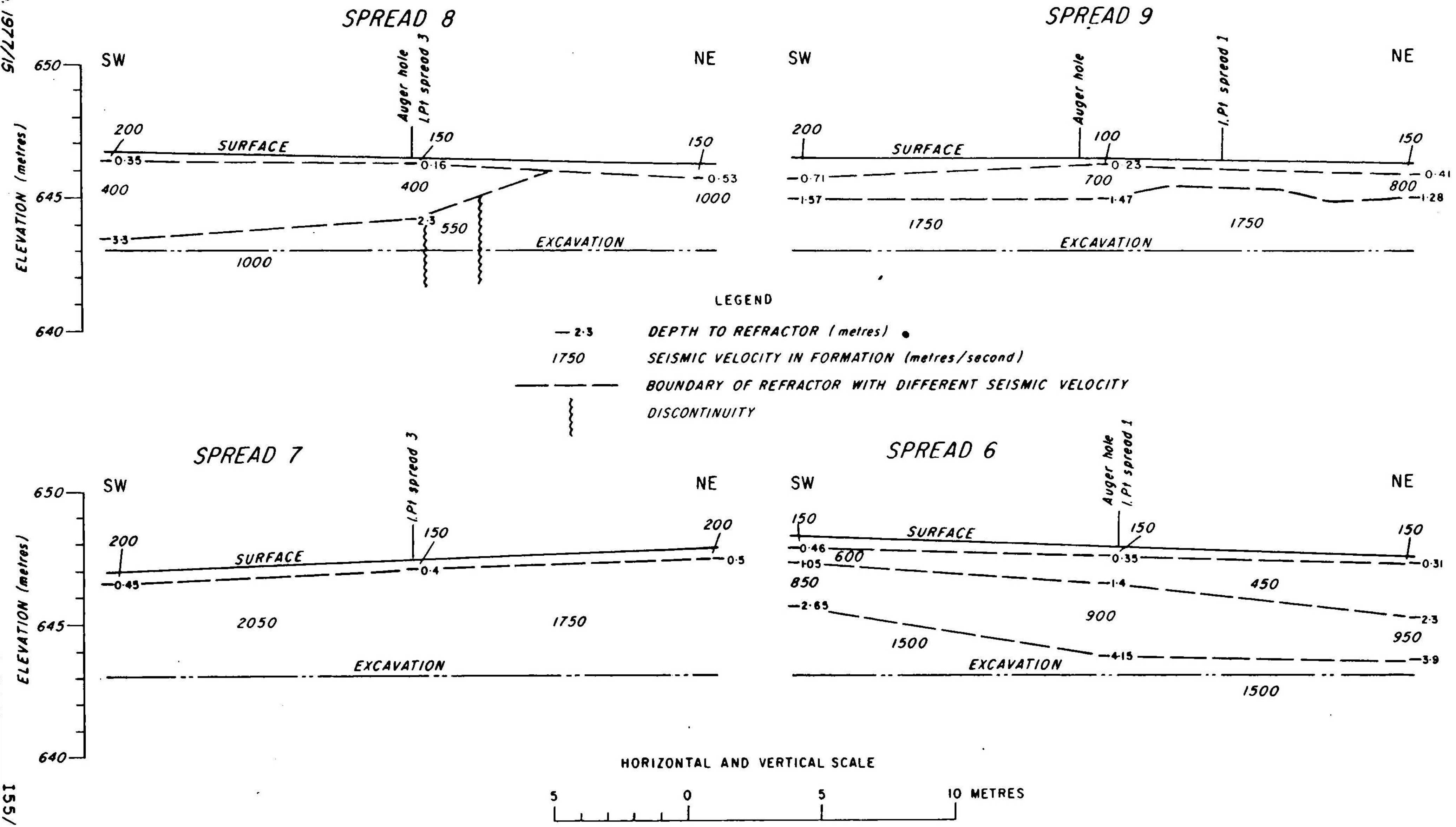
I55/B5-322



GUNGAHLIN No.1 RESERVOIR, SEISMIC SECTIONS

Record No. 1977/15

Record No. 1977/15



GUNGAHLIN No. I RESERVOIR, SEISMIC SECTIONS

155/B5-324A

PLATE 25