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ALBURY - WODONGA GEOPHYSICAL SURVEY, 1975

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ABSTRACT

A geophysical survey in the Albury-Wodonga region from 20.1.75 to 28.2.75, was concentrated in three main areas; the Thurgoona and Middle Creek areas to determine foundation conditions, and the River Murray flood plains to locate gravel and sand deposits. Four geophysical methods were used; seismic refraction, gravity, magnetic, and resistivity. Where applicable and practicable several different methods were used over the same traverse.

In the Thurgoona area seismic refraction data indicated a three-layer velocity profile. The top layer consisted of dry unconsolidated sediment and had a velocity range of 600 to 900 m/s and should be easily ripped. The second layer consisted of saturated weathered bedrock (or alluvium) with a velocity range of 1400 to 1900 m/s. The third layer consisted of the unweathered bedrock with a velocity range of 3300 to 6000 m/s. In many cases in the Thurgoona area, velocity laminations were observed. The depth of weathering is considerable and in general the unweathered bedrock is estimated to occur at depths in excess of 50 m.

The Middle Creek area showed a similar three-layer profile with corresponding velocity ranges. Again the depth of weathering was considerable and in several places the unweathered bedrock was not reached with 200 m offsets. The depth of weathering varied along the main traverse along Boyes Road, and a shallowing of the bedrock to approximately 40 m was observed by seismic refraction. The magnetic and gravity traverses confirmed this shallowing. In many other cases the depth exceeded 70 m.

In the flood plain area, west of Wodonga, resistivity depth probing and profiling were used to locate the gravel and sand deposits. From these investigations a southern limit to sand and gravel has been suggested; to the north of this, resistivity profiling indicates that the sand and gravel are concentrated in some channels. Resistivity depth probing presents the vertical distribution of sand, gravel, clay, and silt. Comparison with existing boreholes is good. Gravity, seismic refraction, and magnetic data indicate areas of shallow bedrock in this region.

1. INTRODUCTION

Albury-Wodonga has been chosen as a growth centre with an ultimate population of about 300 000. The planning responsibility lies with the Albury-Wodonga Development Corporation (AWDC), and the Bureau of Mineral Resources, Geology and Geophysics (BMR) has agreed to co-ordinate and assist with the geological, geophysical, and soil mechanics investigations.

At the request of the AWDC, the Engineering Geophysics Group of BMR conducted a geophysical survey in the Albury-Wodonga area from 20 January 1975 to 28 February 1975. The organizational details are given in Appendix 1.

The purpose of the survey was to determine the foundation conditions in the Middle Creek area in Victoria and the Thurgoona area in New South Wales, and to investigate the extent of the sand/gravel deposits on the Murray River flood plains. Additionally the survey was used to give field experience to BMR technical trainees.

The AWDC provided four field hands, the office accommodation, and generous help in solving local problems in running the party. The topographical surveying was done by the Department of Services and Property. The help of these organizations is gratefully acknowledged. Permission to use data on the Murray flood plains obtained by the North Broken Hill Co. and Milos and Son Co., Wodonga, is gratefully acknowledged.

This report is the first prepared by the BMR for the AWDC, therefore descriptions of the methods used are given more fully than will be given in subsequent reports.

2. GEOLOGY

The Albury-Wodonga Development Area is enclosed by a circle with a radius of 55 km centred on the Union Bridge, and extends over 5000 km^2 of NSW and Victoria. The boundary between the two States follows the south bank of the Murray River.

Only the general geology of the area will be given; the details will be discussed with each separate project.

Quaternary deposits

The centre of the area consists of an old river plain with unconsolidated sediments varying in thickness up to more than 100 m. There are alluvial deposits of clay,

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silt, sand, and gravel. On the flood plain of the present rivers, meandering buried channels of former watercourses constitute the so called Coonambidgal Formation of Victoria. The high-level alluvium is the so-called Shepparton Formation containing red soil, but no meandering channel deposits. Higher up the slope Recent piedmont, hillwash, and colluvial deposits are common.

The character of the Quaternary deposits, their shape and the method of deposition were discussed by Butler, (1958); CSIRO (1966); Schum (1968); Brumley et al. (1974); and Chesnut (1974). Although the discussion in some of these papers applies mostly to areas west of Albury-Wodonga, the investigations there help with the understanding of the geology of the district we are concerned with. A summary of these findings is given by Butler et al. (1973).

Tertiary

Tertiary sediments do not crop out in the area, but were located in some bores (Woolley, 1971). They consist of fluvial deposits, gravel, sand, silt, and conglomerate, the so-called Calivil Sands.

Devonian - Ordovician

The solid rock geology is complicated. The boundaries between different rocks are not well known, being covered by thick deposits of alluvium and/or colluvium. The bedrock is believed to consist of:

(a) Metamorphic rocks comprising gneiss and schist formed by metamorphism of Ordovician mudstone, shale, and sandstone probably in early Silurian time. (Brumley et al., 1974). Gneiss is the hardest and most resistant to weathering, and generally crops out on ridges and high ground. Gneiss and schist are closely associated and areas with a complex mixture of both rocks are common. In general the gneiss is the more resistant to weathering, whereas adjacent areas of schist tend to weather more completely and to greater depth.

(b) Igneous rocks, comprising mostly granite, and as it weathers readily, outcrops are limited.

3. PREVIOUS GEOPHYSICAL WORK

A seismic refraction survey by BMR in 1953 (Chamberlain, 1953) sought to determine depth to bedrock for the proposed reconstruction of the Albury-Wodonga railway bridge (Plate 9).

During the survey five reversed traverses were shot. The vertical distribution of velocities was:

dry soil, sand, etc.	300 m/s
second layer	1600 to 2000 m/s
bedrock	4600 m/s

The second layer may consist of alluvium and decomposed weathered bedrock. As the velocities in these materials overlap, the differentiation between them on the basis of velocities alone is impossible. The depth to the high velocity bedrock was found to be about 100 m.

Two seismic refraction traverses were shot in 1968 (Woolley, 1971) during an investigation for the ground water supply for the City of Albury. The depth of alluvium was mapped near the Albury Airport and at Doctor's Point (Pl. 1). In the survey the uppermost layer showed velocities of 500 to 600 m/s. The other two layers had the same velocities as found near the railway line on the BMR survey. The boundary between alluvium and the weathered bedrock was not indicated by the seismic work. Two bores drilled there gave the thickness of alluvium as 44 to 76 m.

4. METHODS AND EQUIPMENT

In the survey four main geophysical methods were used: seismic refraction, resistivity, gravity, and magnetic. In each method, different physical properties of rocks are measured and interpreted in the form of a geological structure. It was attempted, where possible, to use more than one method in the same locality.

4.1 Seismic Method.

The seismic refraction method is based on the sound wave velocity contrast between geological formations. The unconsolidated rocks are characterized by low seismic velocities; velocities in these materials increase with the water content and may reach 1700 m/s in a fully saturated coarse gravel. The weathered rock may show the same velocity as the unconsolidated rocks, the velocity depending on the degree of weathering but may reach about 3000 m/s for slightly weathered jointed rock. The velocity of unweathered rock depends on the constitution of the rock, its jointing, porosity, and density. Generally it varies between 3000 and 5500 m/s. As the velocities in some groups of rocks overlap, a unique interpretation of rock type from velocities is possible only if the geological knowledge of the area is well advanced.

The sound waves produced by buried explosives or other impact type sources travel in all directions following different paths. They are refracted, reflected, or diffracted at the velocity discontinuities; they may travel as longitudinal (compressional) or transverse (shear) waves (Heiland, 1946).

The seismic refraction method used in the Albury-Wodonga survey relies on the refracted compressional waves. line on the ground at 4-m intervals forming a spread. Six shots were fired per spread, three from each end geophone at distances (called offsets) of 4, 104, and 204 m. Long offsets were required to reach the bottom refractor (the unweathered rock). In the 204 m offsets, 15 kg of explosive charges was sometimes required to obtain useful records.

The arrival of a seismic wave at a geophone produces an electric signal which is transmitted along a cable to the recording equipment, where it is photographically recorded on a fast-moving recording paper. The arrival times at each geophone are plotted against the distance from the shot to the geophone to form a time distance (T/D) curve (Pl. 2) (Heiland, 1946). The seismic velocities in the refractor then equal the reciprocals of the gradients of the best-fitting straight lines through the arrival times.

From the T/D curves, the depth to the seismic velocity interfaces may be calculated by several different methods. In the Albury-Wodonga survey the method using the critical distance between the shot and the geophone at which the wave from deeper refractor arrives ahead of the wave from overlying beds (Heiland, 1946, p. 507) was used. The depth computations were carried out using a Wang 600 electronic calculator.

An ideal condition for a seismic refraction survey is that the seismic wave velocity increases in each underlying bed. This condition was not met in the Thurgoona area of the Albury-Wodonga survey. To facilitate the discussions on these conditions, a set of T/D curves is reproduced in Plate 2.

Chesnut (1974) indicates a possibility of lamination of strata in the NSW part of the investigated area. The T/D curves of Plate 2 support this idea and there is a suggestion of similar conditions in the T/D curves in Figure 1. The waves propagating from a shot are refracted along the first higher-velocity bed to arrive at a few geophones. But some of the energy goes to the underlying lower-velocity bed and is refracted along another higher-velocity deeper bed to reach the next few geophones in delayed time giving a stepped character to the T/D curves as in Figure 2. These indications are noticeable if the spacing between geophones is close enough to give refraction signals on two or more geophones coming from the same bed. The apparent velocity shown on the T/D curve is always lower than the average velocity of these beds and therefore the depth to the lowest refractor is underestimated.

Figure 2 (Pl. 2) shows a higher-velocity bed close to the shot at the 24th geophone end of the spread. The waves travelling along this bed are clearly represented on 13 geophones indicating that this bed is thicker (relative to the depth from surface) than the beds in the area represented in Figure 1 and the bed is able to transmit enough energy to be recorded. The bed does not seem to extend throughout the whole length of the spread as it was not indicated by the shot located next to No. 1 geophone.

Figure 3 (Pl. 2) shows seismic results from an area where the bedrock is much shallower, and the lower-velocity bed does not show lamination.

The T/D curves from any refractor may show different apparent velocities when shooting from each end of the spread. It indicates that the interface is not parallel to the surface. The lower velocity is from the propagation of the wave in the downslope direction and vice versa. The true velocity equals the harmonic mean of the apparent velocities.

A refraction seismic survey can provide for any area some or all of the following subsurface information:

(a) The depth to different rock layers and their thicknesses can be established within ± 10 percent accuracy providing that each successive layer is characterized by higher velocities and is thick enough to be detected. This information may also provide the dip and the structure of the geological section.

(b) The engineering properties of rocks.

1. <u>The Rock or Soil Type</u>

The seismic velocity may identify the rock and soil type. The identification may not be perfect, but with sufficient knowledge of the local geology the probability of a correct identification is very high.

2. The consolidation of the rock

It is generally true that all rocks with velocities up to 1500 m/s can be excavated by use of bulldozer blade, blasting is not required, and thus the velocity acts as an index of rippability (Caterpillar, 1966).

3. The dynamic properties of rocks

Seismic velocities provide information on the dynamic properties of rocks: the modulus of elasticity (Young's), the modulus of rigidity, and the bulk modulus. The compressional wave velocity is related to the modulus of elasticity by the relationship.

$$Vp = [E (1-\sigma) / \delta (1 + \sigma)(1-2\sigma)]^{\frac{1}{2}}$$

Vp = compressional wave velocity
E = Modulus of elasticity
δ = density
σ = Poisson's ratio

The determination of the modulus of elasticity requires a knowledge of the density and of Poisson's ratio. The density of the rock is easily measured but to obtain the Poisson's ratio it is necessary either to measure the transverse wave velocities or approximate it. It is generally accepted that Poisson's ratio equals to 0.25 for solid rock (Brown & Robertshaw, 1952) and 0.4 for unconsolidated rocks. Therefore a good approximation of the value of the modulus of elasticity from velocity are given by the two following formulae:

for solid rock (Poisson's ratio = 0.25; δ = 2.6)

$$E = 2.16\ Vp^2$$

for unconsolidated sediments (Poisson's ratio = 0.4; δ = 2.0)

$$E = 0.933\ Vp^2$$

These two relations are shown in Plate 3, fig. 1. Figure 1 also gives the results of field determination actually carried out on geophysical surveys in Australia (Polak, 1967). Comparison of these data indicates that there is a very small difference between the values of modulus of elasticity estimated from the formula and measured in the field.

To obtain other moduli we have two theoretical relations:

Bulk modulus $B = E/3(1-2\sigma)$ and

modulus of rigidity $G = E/2(1+\sigma)$

All moduli are at present expressed in mega Pascals (MPa); to convert them to psi multiply by 1.45 x 10^2.

The empirical relations between the dynamic modulus of elasticity and the compressive strength of soils is shown in Plate 3, fig. 2. The figure is adopted from Wilson & Dietrich (1960).

The relation between the dynamically determined modulus of elasticity 'E' and the California Bearing Ratio (CBR) test was determined by Henkelon & Foster (1960):
E = 110 CBR.

4.2 Resistivity Method

The resistivity of the rock depends on the resistivity of the rock matrix and of the fluid that occupies the spaces within the rock matrix. If the resistivity of the interstitial fluid is constant, the resistivity which is measured depends mainly on the porosity of the material, and the porosity of unconsolidated alluvium may be as high as 40%. The addition of clay particles which contain generally saline water lowers the resistivity of the rock and therefore it is possible to predict the clay and sand/gravel content from the measurements of resistivity provided that the resistivity of the fluid is known and it is constant laterally.

The resistivity of the unweathered bedrock is high and the porosity is low. Weathering increases the porosity and permits water to enter the rock, therefore the resistivity of weathered rock is lower, and the degree of weathering may be correlated with the decrease in resistivity. However, this correlation is less accurate than is the case with seismic velocities.

Two types of resistivity surveying were used: resistivity traversing and resistivity depth probing. The purpose of resistivity traversing is to locate the lateral variations in resistivity, while the depth probing is used to determine vertical variations in electrical resistivity. There are several arrangements of ground electrodes which can be used in both types of resistivity surveying. (Heiland, 1946, p. 709). In all cases 4 electrodes are used, two to pass current into the ground and two to measure the resulting potential at the ground surface.

In the survey two types of electrode arrangements were used and in both the outer electrodes are the current electrodes, and the inner electrodes the potential electrodes.

(1) In the Wenner arrangement (Pl. 7 inset) all four electrodes are moved for each reading. The separation between the electrodes is 'a' for a total spread of 3a. This arrangement was used for traversing.

(2) In the Schlumberger (Pl. 8, inset) arrangement the separation of potential electrodes (P1, P2) is kept small compared with the separation of the current electrodes (C1, C2). The outer electrodes are moved and the potential electrodes remain fixed until the reading of the potential between the potential electrodes becomes too small to be reliable. Then the distance between the potential electrodes is extended and the outward movement of the current electrodes is continued. This arrangement was used in depth probing.

The interpretation of data obtained in traversing is only qualitative, and the values of apparent resistivity are plotted against the distance between points of measurements. The higher values of apparent resistivity indicate higher-resistivity rocks within the depth range approximately equal to the electrode spacing 'a' from the surface.

In the depth probing a graph of a depth probe is obtained by plotting on a log-log scale the apparent resistivity value against the spacing (Pl. 10).

There are several methods of interpretation of the results of a resistivity depth probing. In the interpretation of the results from Albury-Wodonga the following sequence of interpretation has been adopted.

The initial interpretation was done by use of the BMR precalculated two-layers curves, superimposed on the field curves (van Nostrand & Cook, 1966). The process of interpretation was repeated for underlying resistivity layers using the Hummel (1931) equivalence principle. The values for the thicknesses and resistivities obtained in the interpretation were used as input for a computer program on the Cyber 7600 computer. The program is based on the method of Vozoff (1958) and compares the data from the field curve with theoretically computed data and adjusts the thicknesses and resistivities to make the best possible correlation.

During the survey an induced polarization transmitter manufactured by Geotronics Pty Ltd was used. This instrument transmits a square wave at constant current amplitude up to 10A with a maximum of 850 v potential difference between the current electrodes.

As a receiving unit a Data Precision digital multimeter was coupled to a BMR backing-off device which compensates the natural or spontaneous potential observed between the two receiving electrodes.

4.3 Gravity Method

The gravity method depends on the density contrast between subsurface rocks. Dense nonporous rocks have high density (2.6 to 2.8 g cm^{-3} for the granitic rocks of the survey area) whilst porous near-surface alluvium has a density of 2.0 g cm^{-3} and weathered rock has density varying from 2.0 to 2.4 g cm^{-3} (approx). For the purposes of interpretation of the gravity data all gravity data are reduced to mean sea level assuming a uniform earth of density 2.6 g cm^{-3}. This standard earth or standard column is used as a reference for the actual vertical distribution of densities and all interpretation is carried out using density contrasts or differences from the standard column. Increases in thickness of low-density alluvium or weathered rock will produce very small decreases in the local gravity field, called gravity 'lows', and relative shallowing of high-density bedrock produces local 'highs' in the gravity field. These anomalous highs and lows are typically of the order of 1 part in 10^6 of the Earth's field but can be measured using a gravimeter which has an extremely sensitive spring system capable of detecting relative changes in the Earth's field as small as 1 part in 10^8.

A gravity survey was conducted across the Murray floodplains along 3 main traverses to determine the profile of the valley bedrock and along a traverse in the Middle Creek area to determine bedrock highs in deeply weathered granite. In the Doctor's Point area (section 5.4) the measured gravity field was compared with the calculated gravity field from a simple model to give an interpretation of the subsurface bedrock topography.

Appendix 1 summarizes the pertinent survey data. The gravity survey is tied to the Australian Isogal gravity station network through the base station at Albury Airport (6793.1136) and all stations have been levelled into the Australian Height Datum to comply with standard gravity survey procedure. The observed gravity field at each station has been corrected for elevation above sea level using the combined elevation factor of free air correction and the simple Bouguer correction factor (Nettleton, 1971). In addition terrain corrections have been made to correct for the gravity attraction of nearby hills which is superimposed on the gravity anomalies caused by subsurface features. The simple Bouguer and terrain corrections are proportional to the density of the near-surface rocks. In this survey 2.6 g cm^{-3} has been taken as the Bouguer reduction density (i.e. the density of the standard columns). Samples of rock were taken in the survey area and density measurements were carried out in the BMR rock-testing laboratories. The results are included in Table 1 below.

TABLE 1. DENSITY OF ROCKS, ALBURY-WODONGA AREA

Rock description	Location	Density g cm^{-3}
sw gneiss	Parkers Road (Sheathers Road South)	2.68
sw mica schist	Riverina Highway (Sheathers Road Traverse)	2.65
sw mica schist	Doctor's Point (Northern end of Traverse)	2.57

(sw = slightly weathered)

The observed gravities were also corrected for the normal decrease of gravity towards the equator using the so-called latitude correction calculated from the 1930 International Gravity ellipsoid formula (Nettleton, 1971). The final corrected gravity, called the Bouguer anomaly, is plotted in Plates 6, 11, 13, and 15, with a strip map of each traverse showing the gravity traverse locations. Additional gravity stations were also established on permanent benchmarks in Albury and Wodonga and on several boreholes to bedrock (Woolley, 1971) to establish density control for interpretation of the gravity data and to establish the regional gravity field which generally reflects the broad scale or deeply seated geological changes. It is often necessary to remove a regional gradient from the Bouguer anomaly to obtain a gravity anomaly which reflects local geological features only.

4.4 Magnetic Method

The magnetic effect of a subterranean rock structure measured at any point on the Earth's surface is the resultant of two vectors; an induced magnetic intensity vector in the approximate direction of the Earth's magnetic field, and a remanent magnetic intensity vector which may lie in any direction. Magnetic measurements may indicate in certain areas, such features as faults and boundaries between near surface formations and depths to magnetic bodies below the non-magnetic rocks. The magnetic susceptibility of a rock is principally related to its magnetite content and therefore the proximity of basic rocks is generally indicated by magnetic 'highs'. However, in weathering the magnetite is changed to hematite or limonite, thus lowering the magnetic susceptibility of the rock in shear zones, faults etc.

A G-816 Proton Magnetometer manufactured by Geometrics, Palo Alto, USA was used during the survey.

5. RESULTS

Two town centres, Thurgoona and Middle Creek, will be developed initially. Each of the developments will house more than 70 000 people grouped in small houses and flats around a high-rise town centre.

5.1 Thurgoona

The centre of Thurgoona will be located close to the intersection between St John's Road and Correys Road (Pl. 4).

Two rock types cover the area (Pl. 4); the transported sediments and the residual soil material (Chesnut, 1974). No outcrops of solid rock are visible. The information at depth is obtained from three water-bores, one located inside the area and two located outside the area of investigation. All three bores show similar thick layers of unconsolidated material; bore No. 25205 drilled to 68 m (water table at 7 m) did not reach bedrock; bore No. 25206 reached bedrock at 81 m (water table at 11 m); and bore No. 32011 at a depth of 24 m did not reach bedrock (water table at 18 m). Two auger bores Nos 38 and 39 went down 10 m in highly weathered dry rock.

Chesnut (1974) indicated several conditions of the near-surface rock which affected the seismic wave propagation. They are: the great thickness of the unconsolidated and highly weathered material; the interlayering of sediment types, e.g. sands within clays and vice versa, and the low permeability of the surface material resulting in high-rate surface floods, low surface recharge and a deep water table.

During the seismic refraction work, 22 spreads with a geophone spacing of 4 m were shot. The locations of the spreads are shown in Plate 4. The interpretation of results indicates that there is a three-layer system:

near-surface layers	600 to 900 m/s
second layer	1400 to 1900 m/s
bedrock	3300 to 6000 m/s

The near-surface layers represent a thin residual soil overlying extremely weathered rock; and the seismic velocities indicate that the layer is either dry or the moisture content is very low. Only one spread, south of St John's Road and Correys Road corner, showed a higher-velocity bed near the surface and it may indicate an area where the residual soil was stripped and a high-velocity layer came close to the surface. Most sections showed velocity lamination (indicated by the letter 'L') and only seven spreads showed a lack of lamination (NL). Five of these are located in the southeastern corner of Plate 4. The apparent lack of lamination may represent a change in the character of the rock.

A layer with velocity of 600 to 900 m/s can be easily ripped in normal conditions, but some of the thin beds with higher velocities may prove to be resistant to a bulldozer blade. Also the compressive strength of the laminated material may be higher than deduced from Plate 3.

The second refractor may consist of either saturated unconsolidated material or weathered rock. On some spreads the second layer is not indicated. This layer would exist there but it is too thin to be shown in refraction work. The anisotropy of velocity shown on two spreads on Thurgoona/St John's Roads intersection suggests that it is a weathered rock (alluvium generally does not show velocity anisotropy as the physical properties are the same in all directions). The higher velocity shown on the east-west spread may indicate that jointing is parallel to this direction. The velocity in the second layer indicates that excavation would require blasting.

The bedrock velocity is variable between 3300 and 6000 m/s which indicates that in places where the bedrock velocity is lower we may be dealing with a sedimentary bedrock.

5.2 Middle Creek

The centre of the proposed town will be located southwest of the Kiewa Valley Highway and south of the Middle Creek course (Pl. 5). Geologically the area is complicated and not well known owing to the cover of the unconsolidated deposits.

In the Kiewa River and Middle Creek valleys recent sediments of unknown thickness were deposited (Brumley, 1974). Two other Quaternary formations are predominant in the area: the Shepparton Formation, consisting of clay, silt, sand, and gravel; and the hillwash deposits consisting of clay, silt, sand, subangular bedrock fragments, etc.

At four locations, bedrock crops out as gneiss and gneissic granite metamorphosed in the late Ordovician, and at two localities as Yackandandah Basin Granite (Silurian).

Two soil investigation bores were augered there. Bore No. 17 (Pl. 5) was drilled to a depth of 6 m in silt, sand, and clay and the water table was struck at 3 m. Bore No. 18 was drilled to 15 m in fine sandy silt and stiff clay with about 20 percent sand. The water table was not reached.

During the seismic refraction work 29 spreads with a geophone spacing of 4 m were shot. The locations of the spreads are shown in Plate 5. The interpretation of the results indicates that there is a three-layer system similar to that found in Thurgoona.

near-surface layer	450 to 1150 m/s
second layer	1550 to 1900 m/s
bedrock	2400 to 5000 m/s

The near-surface layer represents the unconsolidated rocks, mostly dry, except for the spread on the Kiewa Valley Highway on the left bank of Middle Creek where the velocity of 1150 m/s represents saturated silt, clay and gravel. The thickness of this layer is less than in Thurgoona, indicating a much shallower water table especially along Boyes Road.

The second layer represents saturated weathered material which will be resistant to excavation without blasting.

The third layer represents the unweathered bedrock. The attenuation of seismic energy was very high and bedrock was not reached on all spreads. Spreads where the bedrock was not reached are indicated in the plate by a "more than" symbol. The bedrock velocities indicated are those accepted for computation. The spreads north of Boyes Road show lower velocities than spreads south of it. It is possible that the northern part of the area is underlain by Ordovician metasediments. Metasediments generally show lower velocities than granites.

Plate 6 shows the seismic, magnetic, and gravity profiles along Boyes Road. The seismic section indicates the variable weathering. The centre of the profile shows much shallower weathering and the depth to fresh bedrock was obtained with shot offsets of 200 m. At both ends of the traverse the weathering is much deeper and the bottom refractor was not reached with 200 m offsets. The minimum possible depth was calculated assuming the bottom layer velocity of 4000 m/s. Larger offsets were generally not fired as this would have required more explosives and the larger blasts would have caused too much surface damage.

The Bouguer gravity profile shows a local high superimposed on the regional gradient and this correlates with the bedrock high shown in the seismic section. On the total magnetic intensity profile, a magnetic feature between 300 and 1000 m could possibly be caused by this bedrock high, assuming the unweathered rock has somewhat higher susceptibility than the weathered rock on either side. However, further field work would be necessary to confirm this. The broad magnetic low along the profile is also an absolute low in relation to readings taken in the Stock Route area and could be indicative of a lower susceptibility bedrock, possibly granite as this is mapped in the area.

Plate 6 indicates that the use of the magnetic and gravity methods before other geophysical methods in areas like the Middle Creek area could produce geologically interpretable results much faster and cheaper than the seismic method alone.

5.3 River Flats Investigation

Two areas (Pl. 1 and 7) were investigated for sand and gravel deposits, required to provide a supply of building materials lasting up to the year 2000. The maximum depth of excavation will be 30 m.

The Sheathers Road area (Pl. 7 and 8) is enclosed by Sheathers Road to the west, the Murray River to the north, Melrose Drive to the east, and to the south by a lane north and parallel to the Hume Highway. It is proposed to fill in this area with waste, after completion of extraction.

The Stock Route area (Pl. 7 and 9) forms a large triangle with the apex near the Wodonga Golf Club and enclosed by the Hume Highway, Murray River and Wodonga Creek. This area may form a future water recreation area.

Both areas are fully in Victoria.

The solid rock geology is obscured by overlying sediments. Small outcrops of Ordovician metasediments are located south of these two areas and may form bedrock in the area of investigation (Brumley, 1974).

The surface sediments belong to the Coonambidgal Formation and consist of river deposits of clay, silt, sand, and gravel forming numerous meanders. Part of the Sheathers Road area is covered with deposits of the Shepparton Formation. This formation is similar in composition to Coonambidgal but the meanders are absent.

The subsurface information on the river flats comes from:

1. gravel pit workings. Two gravel pits are located in the Sheathers Road section and three pits near the Union Bridge in the Stock Route area.

2. boreholes. The Murray River flats were drilled by the North Broken Hill Co. (Plumridge, 1969). Six of the bores were located in the Sheathers Road area and two in the Stock Route area (Pl. 8, 10, and 11).

In the Stock Route area four bores were drilled to a depth of 12 m (40 ft) for the Milos and Son Co. The results are given in a report by Evans & Associates (1974).

In the geophysical survey for sand and gravel, four methods were used: seismic refraction, resistivity depth probing and traversing, gravity, and magnetics.

a) Seismic refraction method

The vertical distribution of velocities is as follows:

Top layer - soil	300 - 1000 m/s
Second layer - alluvium to weathered bedrock	1700 - 2200 m/s
Bedrock	4500 - 5000 m/s

In the Stock Route area bedrock has not been reached on all spreads. An offset of only 200 m was used as longer offsets were not practicable owing to the large explosive charges required.

The location of seismic spreads is shown in Plates 8 and 9. The depths on the sections indicate that the thickness of the low velocity second layer is more than the expected depth of excavation of 30 m. The shallowest point is indicated along Sheathers Road (Pl. 8) and it is also the location of bore MG 44.

An unusually high seismic velocity of 2200 m/s for the second layer has been indicated by the spread across the bridge on the Stock Route. A bore should be put down to find the character of the rocks present there. The velocity is higher than usually met in alluvium.

b) Resistivity surveying

(i) Resistivity depth probing.

Plate 8 shows the positions of the 39 resistivity depth probes taken in the Sheathers Road area and Plate 9 shows the 6 in the Stock Route area. On Plate 10 the depth probes taken along Sheathers Road are shown with the block diagrams indicating the interpretation. Plate 12 gives the depth probes for the Stock Route area. A complete list of interpretatins is given in Table 3.

Plate 10 shows the field curves, their interpretation and sections of four bores drilled by the North Broken Hill Co. From this comparison of resistivity block diagrams and the data from the bore hole logs, Table 2 has been prepared.

TABLE 2. RESISTIVITY IN OHM-M OF DIFFERENT ROCKS.

Bore Depth probe	MG2 A00	MG1 A700	MG44 A1040	MG15 A1500	MG11 B00
Sand-gravel	630	650		400	
Sand, gravel, clay	80	120	180	280	
Clay - near surface			120		80
- at depth	20		30		30
Silt				100	

Table 3 lists the interpretation of all of the depth probes in the sand and gravel area giving resistivities and depths of each layer. From Table 2 a boundary called "Southern limit of sand and gravel deposits" has been obtained and plotted in Plate 8. All investigations for gravel should be concentrated north of this line. However, not all places in this area will contain sand and gravel and

R = Resistivity
h = depth

Albury Wodonga

TABLE 3
INTERPRETATION OF THE RESISTIVITY DEPTH PROBES

Depth Probe Number	Top layer		Second layer		Third layer		Fourth layer		Fifth layer		Sixth layer		Seventh layer		Eighth layer		Remarks
	R_1	h_1	R_2	h_2	R_3	h_3	R_4	h_4	R_5	h_5	R_6	h_6	R_7	h_7	R_8	h_8	
A00	625	1.68	21.4	4.36	94.8	65.6	313										
A200	34	1.1	14	3.59	40.6	29.9	65.9	100	1000								
A400	139	0.804	26.4	0.879	1.65	2.18	55.6	18.3	12.9	96.3	100,000						
A500	147	0.706	16.7	1.05	398	2.9	24.2	5.87	182	17.8	13.8	48	100,000				Gravel
A600	72	0.131	2430	0.871	280	15.3	58	100	10.9	108	100,000						Gravel
A700	65.1	0.542	583	2.77	114	43.2	1020										Gravel
A1040	120	1.03	176	2.91	107	11.2	43.7	36.3	542								Gravel and shallow bed-rock
A1190	154	0.571	27.8	1.88	479	12.5	151	53.6	1510								Gravel
A1500	138	0.397	5.73	0.95	329	71.8	468	104	1990	161	246	266	5750				Gravel
A1700	243	0.289	79.2	1.79	297	19.5	357	109	6200								Gravel
A2100	308	0.438	2.8	1.16	372	26.6	56.7	104	904								Gravel
B00	256	0.385	77.1	1.66	65	3.8	31.1	19.8	588	32.5	309	65.3	100 000				
B700	238	1.45	40.6	4.4	310	28.2	839	150	784								Gravel
C00	54.1	0.663	17.9	3.24	25.1	40.8	100 000										
D00	217	1.52	45	6.48	3.57	12.9	84.4	104	100 000								
D1140	119	1.119	139	3.3	242	24.4	47.3	87.7	890								Gravel
E200	539	1.06	2.02	1.16	42.6	8.07	11.5	10.3	40	143	653						
E850	25.5	0.658	2.41	1.57	65.2	93.1	19	151	100 000								
E1150	101	1.14	5.89	2.04	571	14.7	111	65	128	143	100 000						Gravel
E1400	230	.4	920	7.1	420	38	80	160	100 000								Gravel
F300	73.7	0.719	8.2	1.23	76.3	5.54	98.8	115	100 000								
F500	493	0.248	10.9	0.784	44.7	3.69	34.2	8.22	153	29.2	34.7	63.6	950				
F700	27.5	0.239	2.57	2.77	13.9	17	5.62	104	100 000								
F900	121	1.3	119	19.2	483	42.7	226	137	100 000								Gravel
F1140	138	0.653	24.9	4.54	331	29	304	36.5	684	123	318	283	100 000				Gravel
F1230	209	0.976	166	1.91	398	14.9	199	87.6	3970								Gravel
F1330	147	1.49	47.4	6.37	452	55.9	318	69.3	549								Gravel
F1530	179	1.7	54.8	3.97	274	21.8	566	96.7	892	283	100 000						Gravel
G300	332	0.191	29.2	30.5	946	32.4	11.4	39.9	272	58.9	7.68	84.8	99999				
G500	188	0.688	36.4	2.48	125	33.4	35.5	82.6	100 000								
G700	165	0.651	18.5	4.7	190	30	320	97	44	118	100 000						
G1100	32.2	1.27	33	5.65	397	17.5	111	47.6	3869	69	315	103	880				Gravel
G1200	185	0.288	50.4	2.37	253	27.3	100 000										Gravel and shallow bed-rock
G1400	129	0.683	28.6	3.62	490	56.5	71.4	78.7	100 000								Gravel
H300	26.3	4.61	71.6	29.3	67.1	136	100 000										
H500	174	2.3	57.6	2.68	22	5.83	82.3	19.2	53.3	118	100 000						
H750	112	0.54	19.6	2.62	200	19.3	17.6	56.1	10 000								Gravel
H900	122	1.28	79.5	4.1	132	15.7	38.4	57	10 000								Gravel
SR1	161	0.26	3530	2.04	528	24.8	448	62	86	142	1480						
SR2	749	1.44	19900	2.4	350	34.8	35.6	40.6	132	182	1780						
SR3	150	8.4	1300	7.4	225	17.8	500	33	173	183	1690						
SR4	331	0.32	515	2.43	208	5.71	387	8.25	294	11.6	1190	24	482	453		3150	
SR5	540	2.0	280	5.2	320	29.2	220	116	100	185	18000						
SR6	320	1.8	500	14	280	52	440	282	800								

in some places the gravel will be overlain by a thick layer of clay and silt. Depth probe B700 may indicate a subsidiary channel, but its continuity was not investigated.

An area of shallow bedrock is shown by depth probes A1040 and G1200. This bedrock uplift indicates the northern bank of a gravel channel on which two existing gravel pits are located (Pl. 7). The gradual decrease in resistivity along the channel indicates an increase in the percentage content of fine sand and clay in the deposit in the downstream direction.

Farther north from this channel, high resistivity values on constant spacing resistivity profiles (Pl. 7) show the possible location of the gravel deposits; but the low resistivity values may indicate either clay and silt or a thick cover above deeper gravel deposits.

Examining Plate 10 and Table 2, it is clear that the southern part of the area does not show higher resistivity beds above the resistive unweathered bedrock. The probe A500 shows the presence of a layer with resistivity higher than 200 ohm-m. The same indications are shown on probes A600 and A700. This is a body of sand and gravel which was developed in the Wodonga Shire sand pit. Farther north, an auger bore MG44, the depth probe A1040 and the seismic spread indicate gravel and clay above a shallow bedrock. Still farther north the depth probes and the auger bore MG15 indicate gravel deposits on depth probes A1190, A1500, A1700, and A2100. Probe A1700 shows gravel at a greater depth under a cover of clay. In the northern part of the area gravel directly overlying the bedrock is shown on resistivity depth probes; erosion by the river has apparently removed the weathered rock in the main channel. Probe A700 indicates also a low-resistivity zone in the bedrock. Similar indications exist on depth probes G700 and F700, possibly representing a shear or a fault zone.

The interpretation of the depth probes along Sheathers Road is also shown in Plate 11 for comparison with the gravity Bouguer anomaly. The gravity profile reflects well the weathered bedrock configuration as is shown by comparison with the depth to the high velocity (unweathered bedrock) obtained on two seismic spreads.

Plate 12 shows the six resistivity depth probes obtained in the Stock Route area and their interpretation. In Plate 13 the results of gravity, total magnetic intensity, seismic refraction, resistivity profiling, and depth probing are shown.

The Bouguer anomaly profile indicates an increase in thickness of the alluvium and weathered bedrock from the bridge on the Wodonga Creek northwards. A slight thinning begins near the farm buildings but the northern end of the valley has not been reached.

The total magnetic intensity profile indicates generally higher and more uniform values south of the Causeway Anabranch (Pl. 9 and 13). This may represent an accumulation of clayey alluvium thinning to the south. North of the Causeway Anabranch the total magnetic intensity is much more uneven, indicating a more complex composition of the alluvium.

(ii) Resistivity profiling.

The resistivity traversing indicates clearly the two channels which were mentioned in the discussion on Plate 7. The very high resistivity shown by the second layer may indicate dry conditions above the water table. This section is elevated above the river level and is covered with very dry mud characterized by low permeability. Therefore some surface water may be perched above the water table.

All the depth probes terminate in a high-resistivity bed, which is the unweathered bedrock. The lower-resistivity bed, above the unweathered bedrock may be either weathered bedrock or alluvium, so that the depth of alluvium can not be determined by resistivity depth probing alone.

South of the area where gravel was indicated by four boreholes drilled for the Milos Company in the Stock Route area, the resistivity profile is characterized by much lower resistivity, indicating more clay (Pl. 13). This correlates with the smoother part of the magnetic profile and may indicate "the southern limit of sand and gravel deposits".

The continuation of the high-resistivity channels downstream is not indicated by the last traverse near Wodonga Creek (Pl. 7). It is possible that the channels either pass the traverse on both sides of the profile or some fine sediments were introduced into the sand and gravel from the Wodonga Creek. Aerial photographs indicate several old river channels in this area.

5.4 ADDITIONAL GRAVITY DATA

In addition to the three gravity traverses, a fourth gravity traverse and a total of 21 regional gravity stations were established in the Albury-Wodonga area to determine the regional gravity gradient across the survey region. The regional stations were located at benchmarks and at boreholes in the Albury airport area (Woolley, 1971) which were levelled by the surveyor during the time of the survey. The complete data for these regional stations are contained in BMR's Regional Gravity group file system (File No. 7503) along with the complete data for the detailed gravity traverses. The fourth gravity traverse was carried out in the Doctor's Point area where seismic and borehole control existed (Pl. 15, Woolley, 1971).

Regional Gravity

Plate 14 shows the regional gravity results contoured at 1 mGal interval. The contours are shown in a solid line where good gravity station control exists near benchmarks and the detailed traverses. Elsewhere the gravity contours (shown by a broken line) are diagrammatic only and have been inferred from the known geology and the interpretation of the detailed traverse results. Such contours would provide useful geological information and further gravity stations should be established in the survey area to determine the detailed pattern.

The principal features of the regional Bouguer anomalies are firstly, a gradient of 1 to 1.8 mGal/km, values decreasing from west to east. Zadoroznyj (in prep.) postulates that the gravity gradient is due to the presence of a lower-density granitic belt in the Snowy Mountains region centred to the east of the survey area and localized higher-density metamorphics west of Albury.

Secondly, the detailed gravity traverse work has revealed a gravity low associated with the deeper alluvial areas of the old Murray Valley. Superimposed on the east west regional gradient, this low produces a "nosing" to the west of the contours in the region of the course of the present Murray River. This nosing effect is well defined in the areas of control and is inferred diagrammatically in between the traverses.

It is fortuitous that the direction of the strong gradient is parallel to the direction of the valley with only a negligible component of the regional gradient being present in the north-south direction of the three gravity traverses across the Murray Valley. The traverse (Pl. 5) in the Middle Creek area is in a northeast-southwest direction and shows an appreciable regional gradient of 1.4 mGal/km. If the gradient had been across the direction of the valley then it would have proved difficult to separate the Bouguer anomaly low associated with the river valley from the regional field and the value of the gravity results would be greatly reduced.

Doctor's Point Gravity Profile

Two-dimensional gravity modelling of the residual gravity for Traverse 4 across the valley at Doctor's Point was carried out (Pl. 15). The modelling was achieved using a series of vertical prisms to approximate the bedrock (density 2.6 gcm^{-3}) and weathered bedrock interfaces. The gravity modelling program was programmed for the Wang 600-14 desk calculator and 612 plotter by F.J. Taylor. A three-layered model of alluvium, weathered schist, and schist was used to account for the residual gravity profile.

In the Doctor's Point area the results of a previous seismic traverse and two boreholes from the WCIC survey (Woolley, 1971) some 300 m west of the gravity traverse (Pl. 15) are available. The boreholes show depths to weathered schist of 55 to 58 m and the seismic results indicate calculated depths to fresh bedrock of 87 to 128 m. The seismic method failed to detect a distinct velocity associated with the weathered schist. This agrees with the present seismic survey results also.

Woolley (op. cit.) indicates that the weathered schist layer forms a seismic blind zone (i.e. refracted waves from the weathered schist appears only as second arrivals). Using borehole depths to the top of the weathered schist and calculated seismic depths to fresh bedrock, it is possible to calculate the maximum thickness and velocity of the weathered schist using standard blind zone nomograms (Hawkins & Maggs, 1961). The results of these calculations are presented in Table 4 below.

TABLE 4 - DOCTOR'S POINT SEISMIC RESULTS - BLIND ZONE CALCULATIONS

Two-layer solution (Woolley, 1971)		Equivalent three-layer solution incorporating maximum thickness of blind zone	
Velocities (m/s)	Depths to top of layer (m)	Velocities (m/s)	Depth to top of layer (m)
Southern borehole (WCIC No. 25303)			
1800	0	1800	0
5000	128	2100-2200	55
		5000	145

Northern borehole (WCIC No. 25357)

1800	0	1800	0
5000	87	2600	58
		5000	108

Using the calculated depths for the three layer solution on the southern borehole and a simple Bouguer plate correction factor of 4.19 mGal/100 m thickness of an infinite plate of unit density contrast, the maximum density of the weathered bedrock is calculated as being 2.33 g cm^{-3}. If this calculated density, the residual gravity, and the depths to weathered schist are used to calculate the depth to fresh bedrock at the northern borehole, then it is necessary to invoke a depth to fresh bedrock of 170 m to account for the residual Bouguer anomaly observed at the northern borehole. This value is far in excess of the maximum depth of 108 m calculated in Table 4 above, from the seismic results. If lower-density weathered schist is postulated beneath the northern borehole the anomaly can be accounted for. The model presented in Plate 15 appears to reconcile the gravity, borehole and seismic results. The calculated gravity effect is 90% of the maximum value of the residual anomaly; however, given the uncertainties in choosing a regional gradient and the number of variables in the model, the fit between observed and calculated residual gravity is considered adequate. It is stressed that although the model is consistent with the observed gravity, borehole and seismic data, conceivably other models could fit the observed data. This ambiguity of the gravity interpretation is well documented (Skeels, 1947). However, the seismic and borehole data have set certain limits on any gravity model which will fit the observed residual gravity. The model presented in Plate 15 has the essential features of such a model. These features are firstly the absence or near absence of any high-velocity (greater than 2600 m/s, Table 4) or high-density weathered schist beneath the northern borehole area. This means that the alluvium and weathered schist are virtually indistinguishable in seismic velocity or density in the northern borehole area. Secondly, in the southern borehole area, the gravity, borehole, and seismic data suggest that the weathered schist has a higher seismic velocity and density than the alluvium.

Because of the uncertainties in estimating the density of the weathered schist owing to the apparent variability of weathering, plus the difficulties in constructing a unique gravity model, even in such an area as the Doctor's Point area where excellent seismic and borehole control exist, no further modelling has been carried out on similar detailed traverses on Sheathers Road (Pl. 11) and the Stock route area (Pl. 13).

6. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. Seismic refraction surveys provided information on the depth of weathering in the Thurgoona and Middle Creek area. The depth of weathering is considerable. In the Thurgoona area, velocity layering is clearly shown on the seismic data.

2. Seismic velocities indicate that excavation in many areas can be done without blasting.

3. Seismic velocities in weathered rock and in the alluvium in the Murray River flood areas are either equal, or the weathered bedrock layer has a thickness and seismic velocity such that it forms a seismic blind-zone. The depths quoted from seismic results thus represent the maximum thickness of alluvium and minimum depths to fresh bedrock.

4. The resistivity method clearly indicates areas of sand and gravel both near-surface and at depth and distinguishes them from low-resistivity clays and silts. The areas of exploitable sand and gravel are restricted to zones defined by the resistivity and are less extensive than expected.

5. Magnetic and gravity surveys may indicate shallow weathering in the Middle Creek area but do not provide useful information in the Thurgoona area. In the Murray River flood area the gravity method may indicate the total thickness of alluvium and weathered bedrock. The gravity method with seismic or borehole control may give a better interpretation of the relative thickness of alluvium and weathered bedrock.

B. Recommendations

1. During core boring and excavation in the Thurgoona area, samples from different layers should be collected and laboratory determinations of their velocities should be carried out for correlation with survey results.

2. Resistivity measurements should be extended to cover the area between the southern limit of sand and gravel and the river, extending from Sheathers Road to the Stock Route, to map continuous channels.

3. In the Middle Creek area, gravity and magnetics should be carried out before seismic work to locate further areas of shallow bedrock. This will prove more economical and quicker than the use of seismic alone.

4. When further surveys are carried out the opportunity should be taken to complete the detailed gravity coverage of the Albury-Wodonga area.

7. REFERENCES

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APPENDIX 1

Personnel, Equipment and Survey Data

1. Personnel

Geophysicists:

G.R. Pettifer from 10/2/1975 to 28/2/1975
E.J. Polak from 20/1/1975 to 14/2/1975
F.J. Taylor from 20/1/1975 to 26/1/1975

Geologist

P.H. Vanden Broek

Surveyor

L. Walters

Draftsman

R.C. Watson

Technical Trainee Officers

S.A. Green
M.N. Johnson
N. Maciejewski
J. Pittar
D. Tarlinton

Shooter

R.D. Cherry

Fieldhands

D.G. Bennett (B.Sc.(Hon.) Flinders University)
E. Chudyk (Student, Aust. Nat. Univ.)
A. Martindale (Student, Canberra College of Advanced Education)

GRAVITY

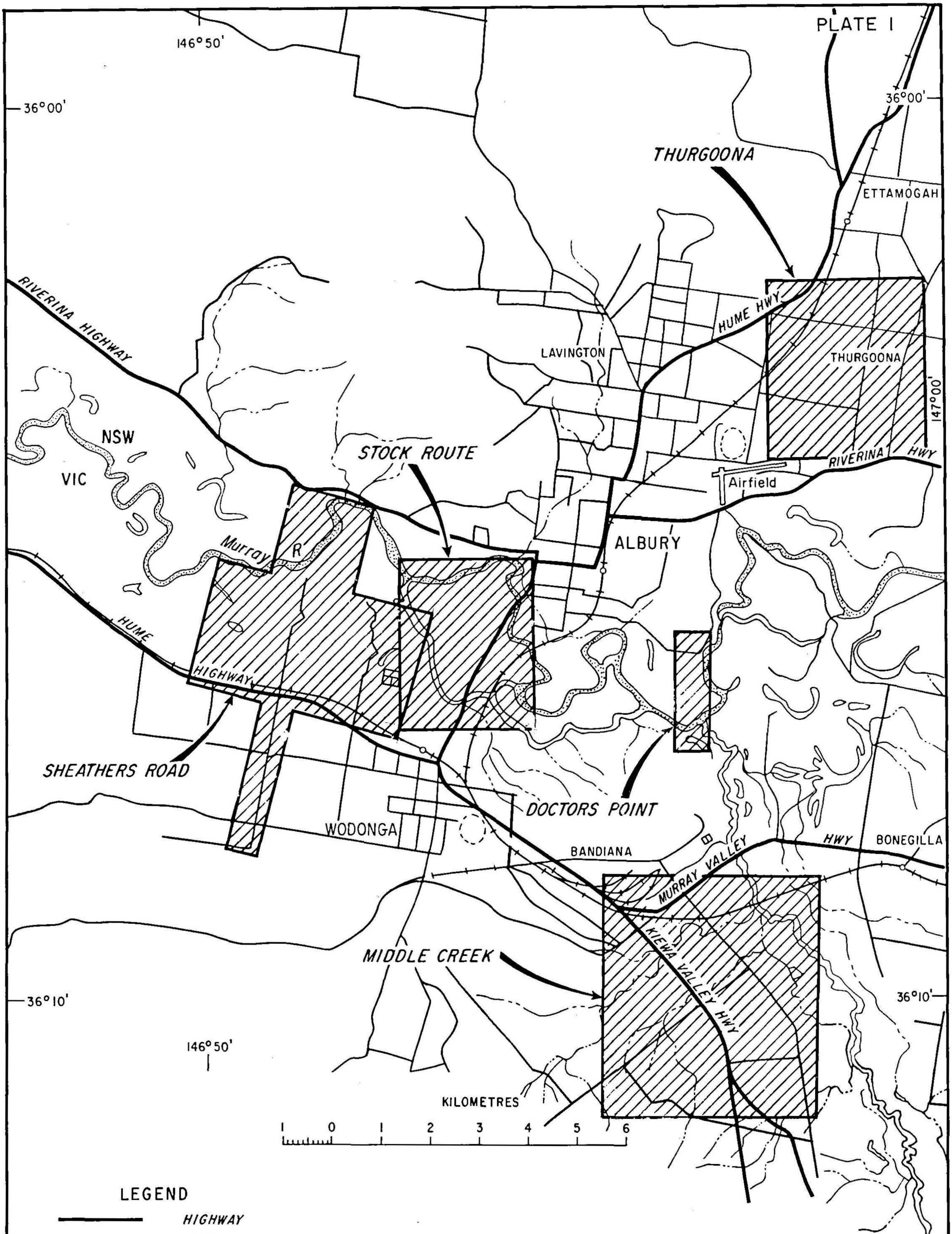
Time of Survey: February 1975

Meter Operators: G.R. Pettifer, D.G. Bennett, J. Van Son (part-time)

BMR survey number: 7503

Survey based on Albury isogal: Station No. 6793-1136
Value 979,765.62 mGal

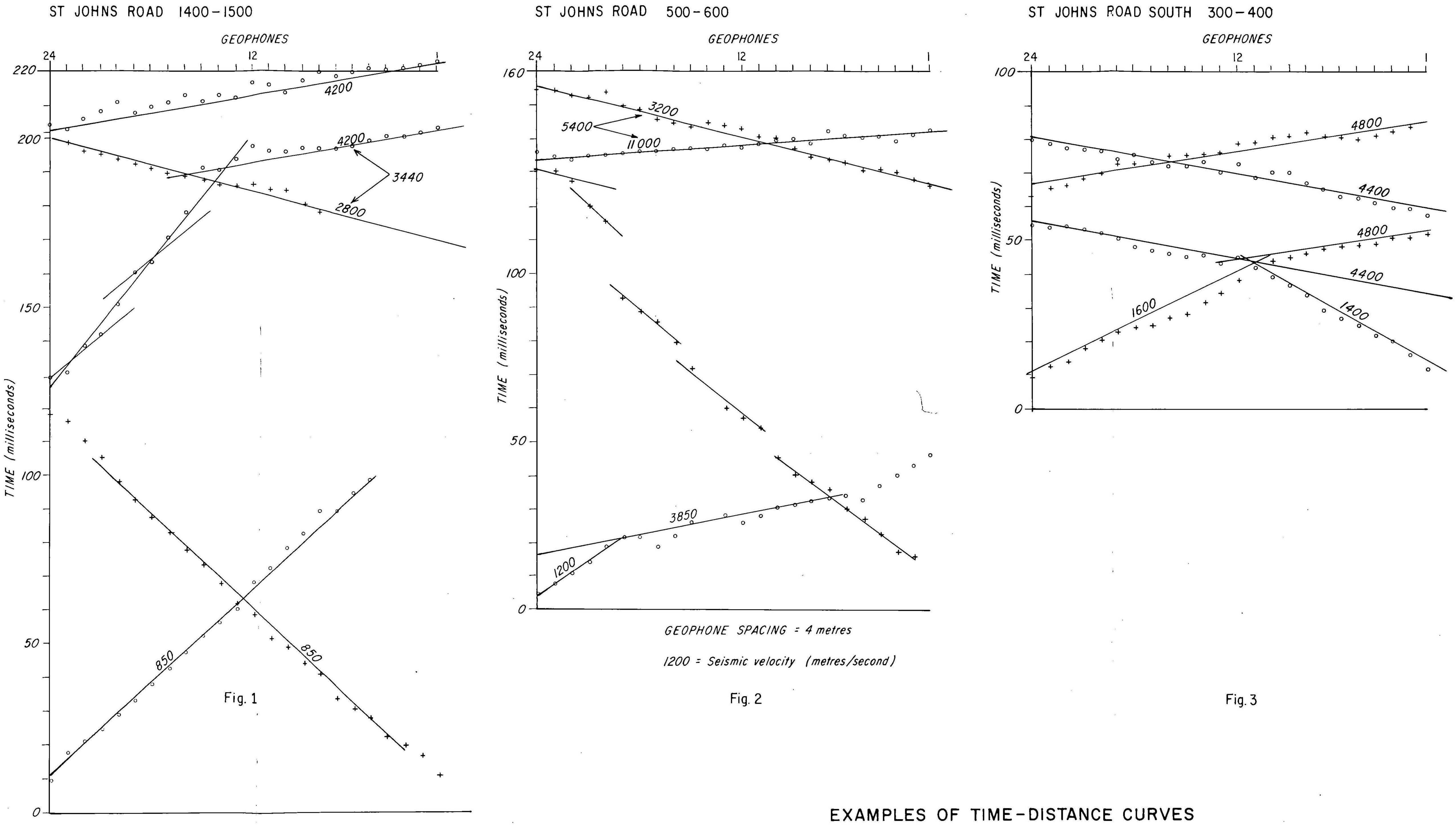
PLATE I



ALBURY - WODONGA GEOPHYSICAL SURVEY, 1975
LOCALITY MAP

BASED ON J55/B0-29A *Record No. 1975/108*

J55/B5-132A



EXAMPLES OF TIME-DISTANCE CURVES

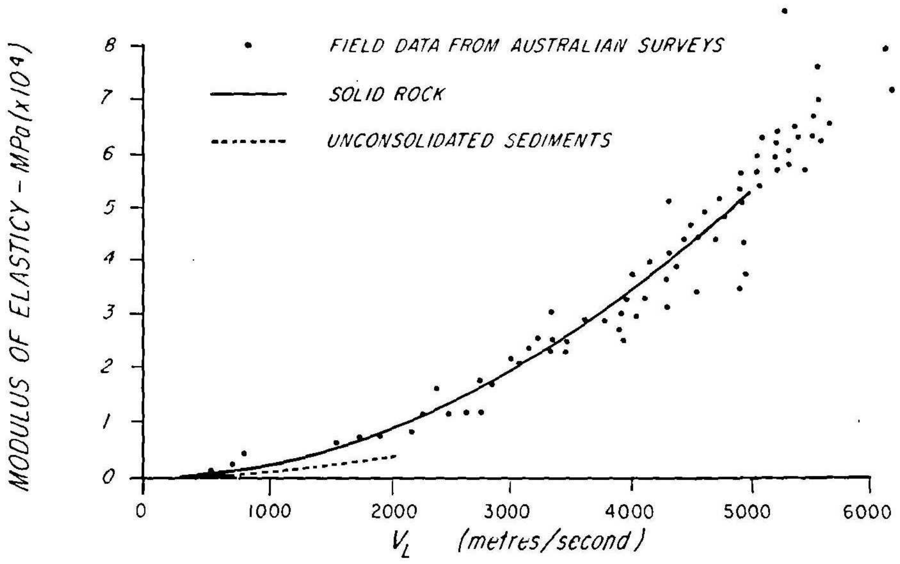


Fig. 1. RELATION OF MODULUS OF ELASTICITY TO LONGITUDINAL SEISMIC VELOCITY

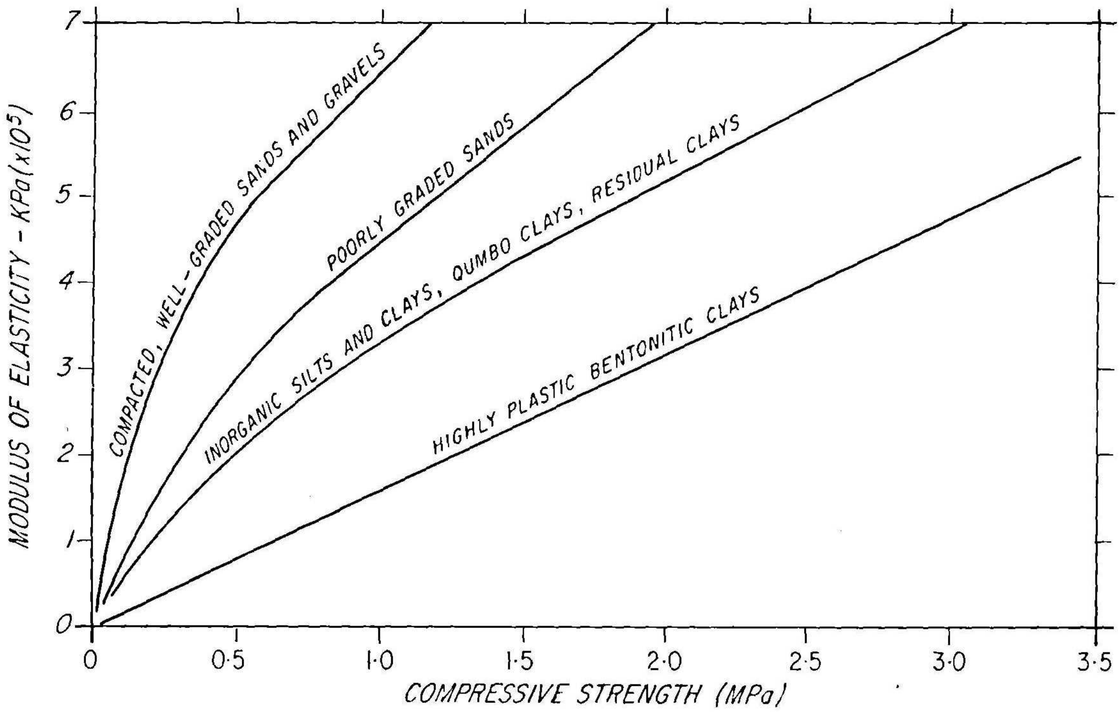
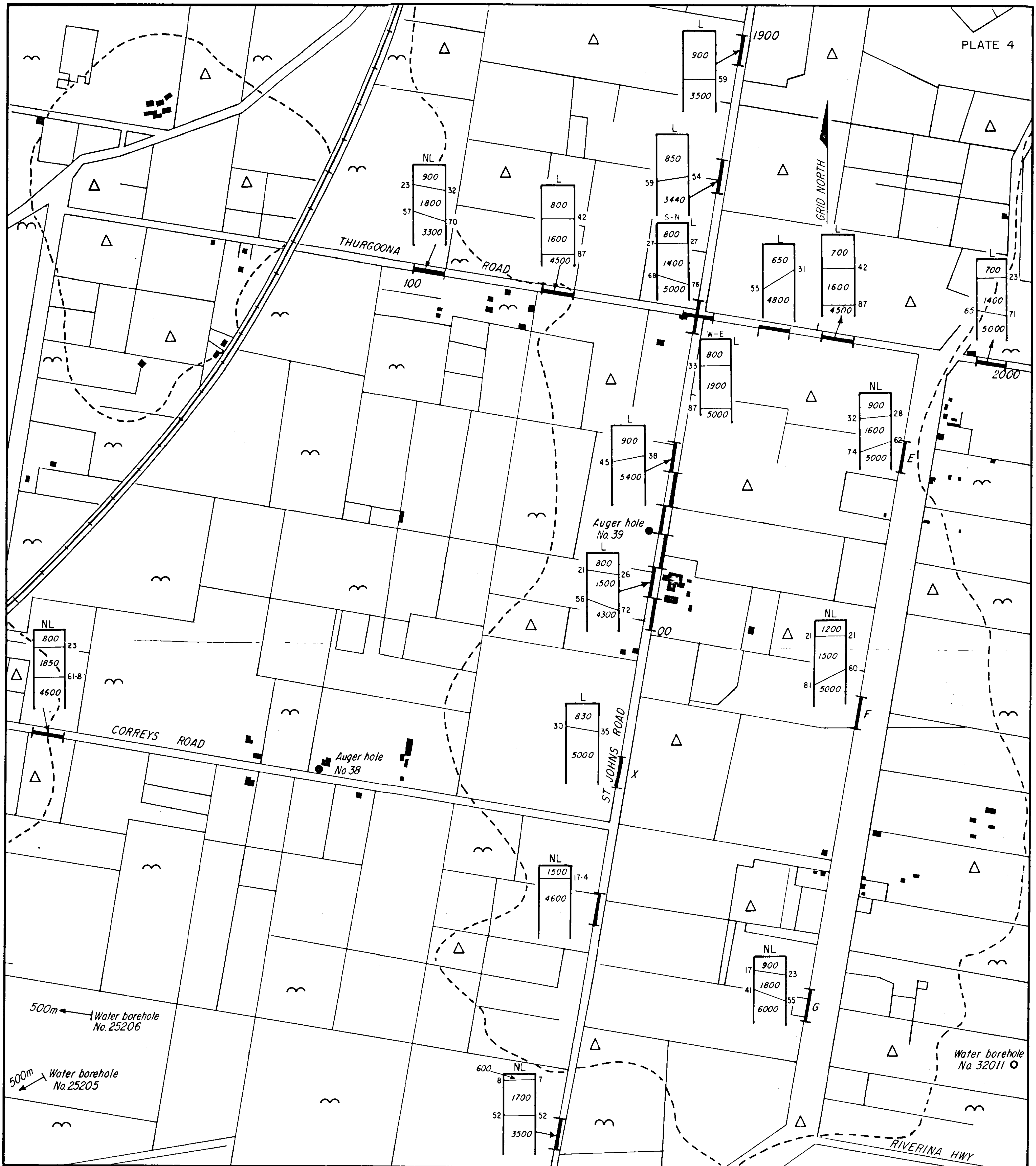


Fig. 2. RELATION OF MODULUS OF ELASTICITY TO COMPRESSIVE STRENGTH OF SOIL TYPES (Wilson & Dietrich, 1960)

DYNAMIC PROPERTIES OF ROCKS



THURGOONA AREA

L ← Laminated

600 ← Seismic velocity (metres/second)

30 ← Depth (metres)

Seismic spread

KILOMETRE 0 0·5 1

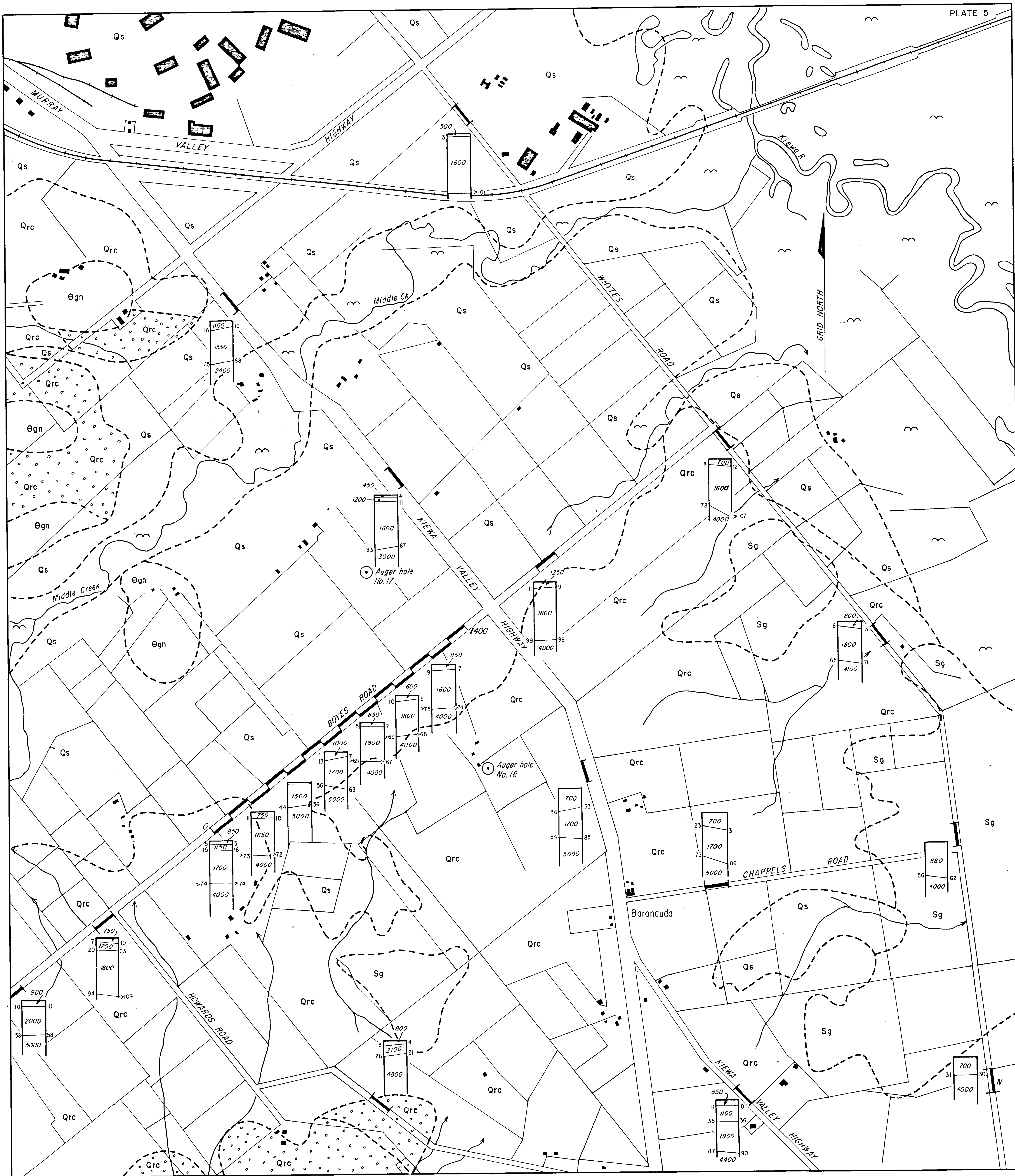
Geological boundary

Transported sediments

Residual soil material

Record No. 1975/108

J55/B5-123



LEGEND

Depth (metres)
Seismic velocity (metres/second)
Seismic spread
>74 Depth greater than 74 metres
Auger hole

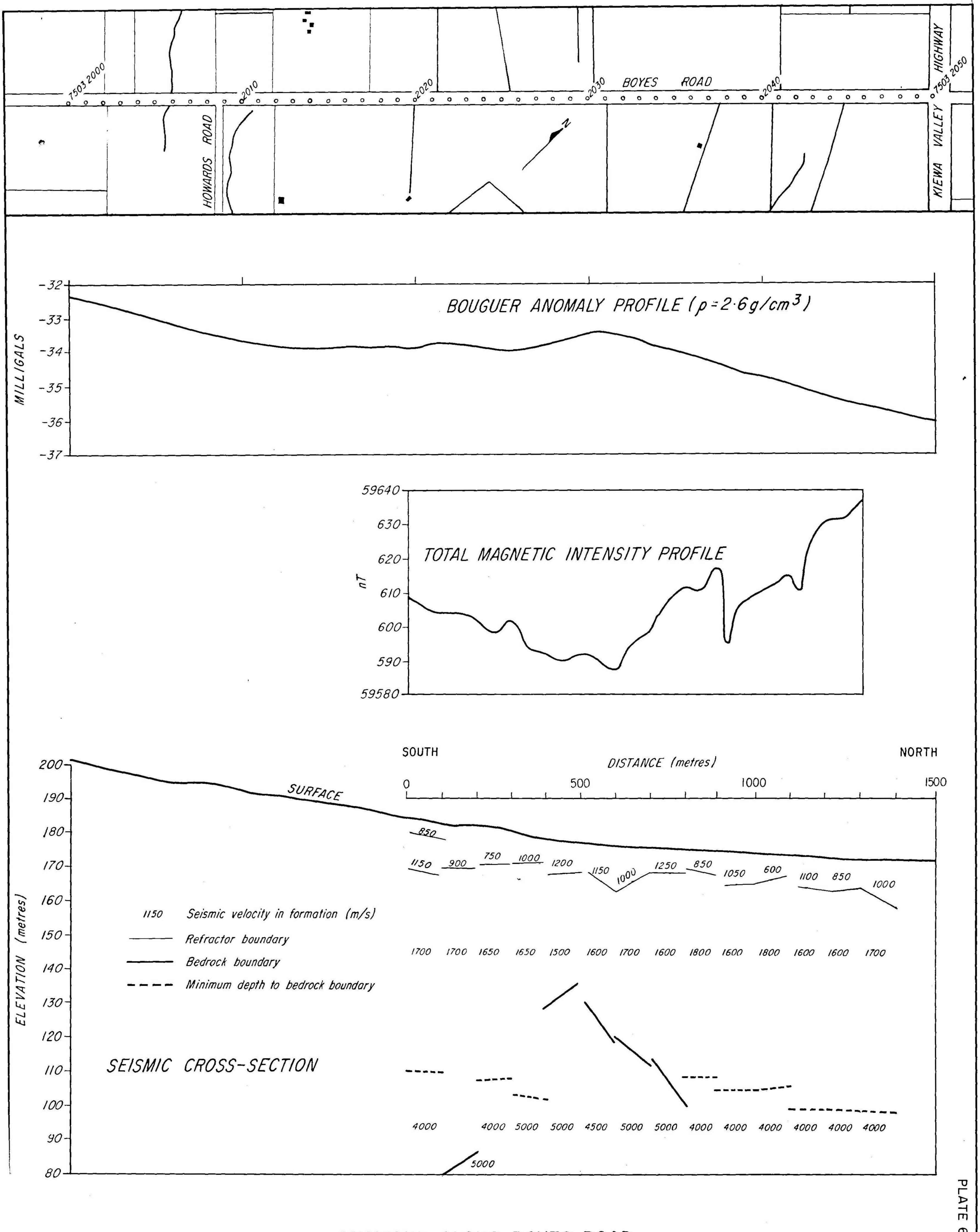
0 0·5 1 KILOMETRE

GEOLOGY

Geological boundary
Coonambidgal Formation
Qs Shepparton Formation
Qrc Piedmont and colluvial deposits
Qrc Alluvium
Θgn Gneiss, gneissic granite — ORDOVICIAN
Sg Yackandandah Basin granite — SILURIAN
(Coonambidgal Formation to Alluvium) QUATERNARY

MIDDLE CREEK AREA SEISMIC RESULTS

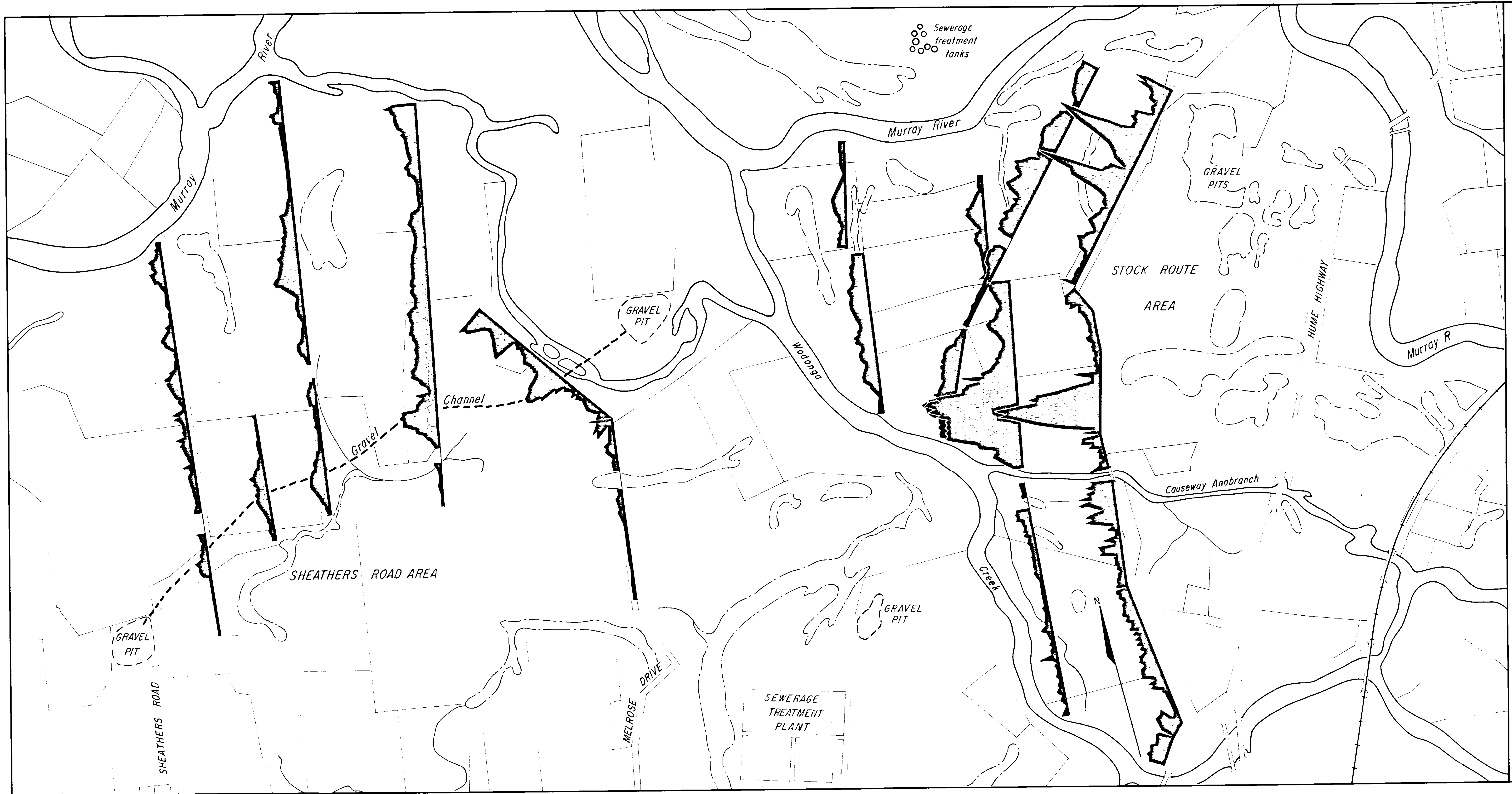
After Geological Survey of Victoria, 1974, Plate W-1033/G/3

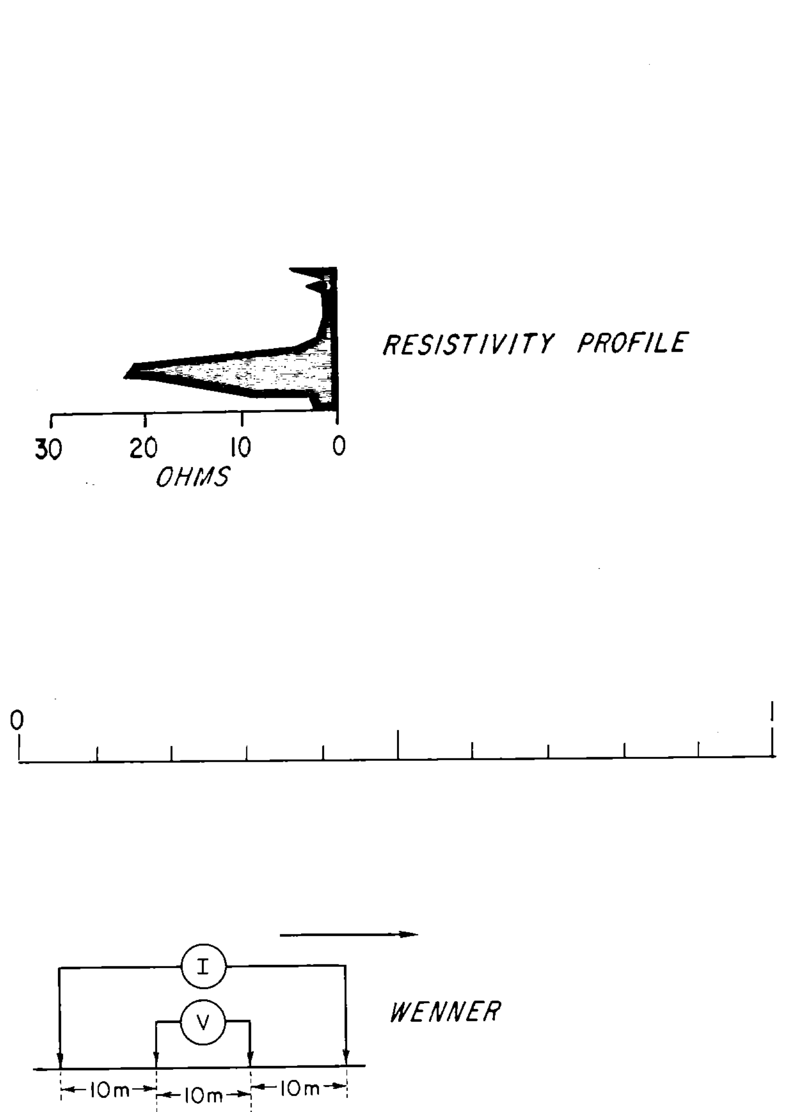


SECTIONS ALONG BOYES ROAD

Record No. 1975/108

J55/B5-127

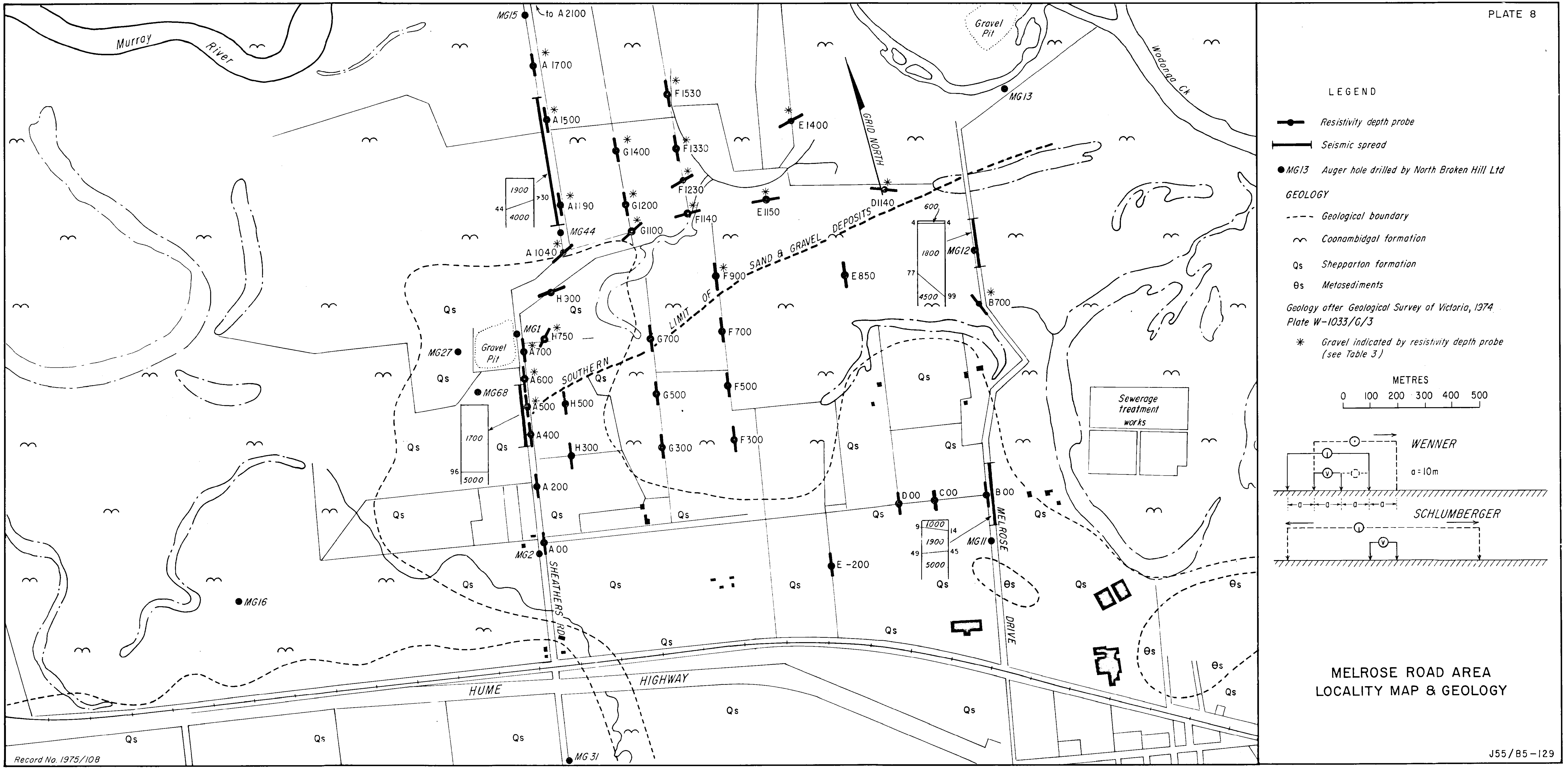




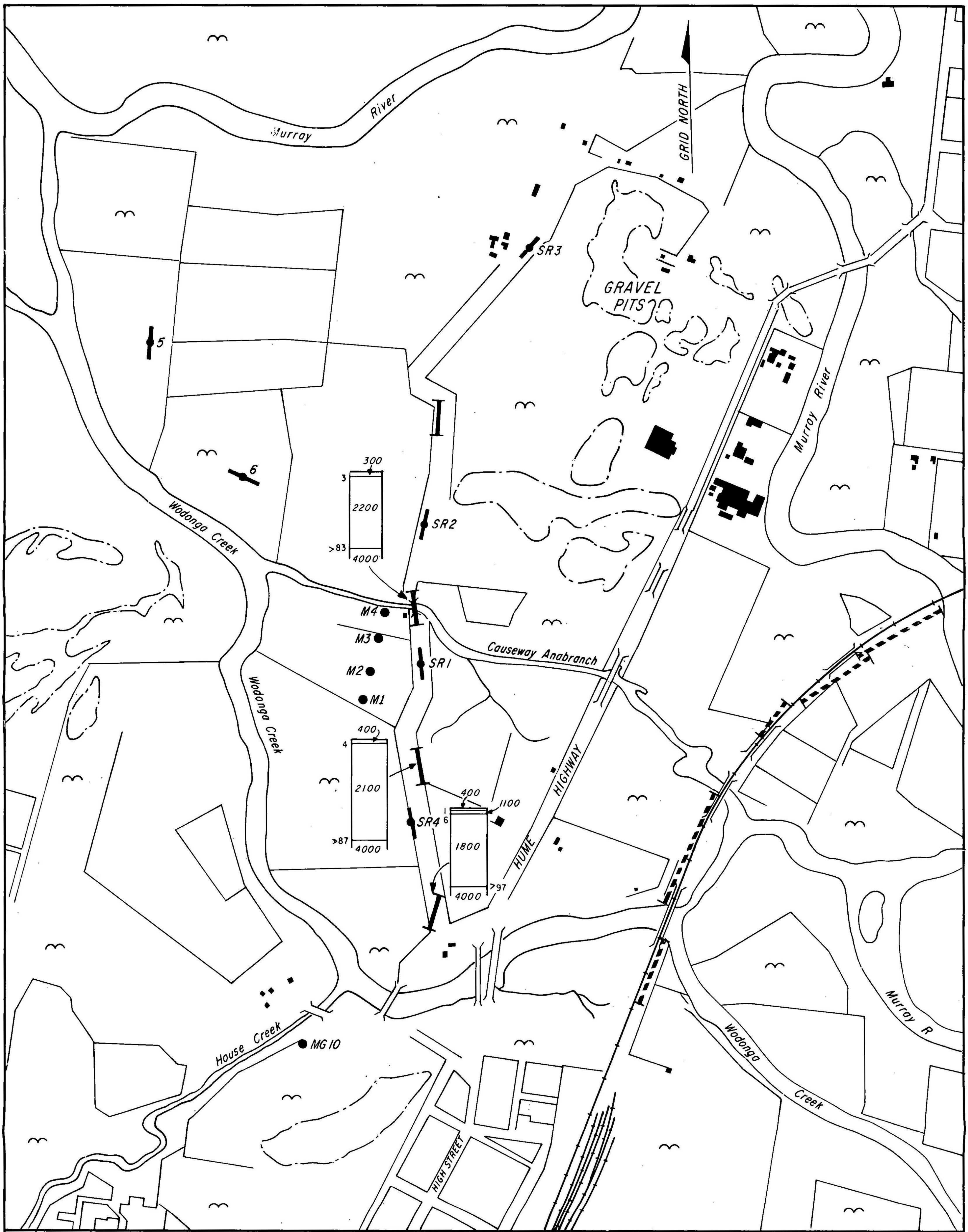
RESISTIVITY TRAVERSE PROFILES

Record No. 1975/180

J55/B5-125



MELROSE ROAD AREA LOCALITY MAP & GEOLOGY



0 0·5 1 KILOMETRE

LEGEND

SR2	Resistivity depth probe
	Seismic spreads 1975
	Seismic spreads 1953
M2 ●	Boreholes drilled for Milos and Sons
MG 10 ●	Auger hole drilled by North Broken Hill Ltd
⌒⌒	Coonambidgal formation

400, 10, 20 ← Depth (metres)

1800 ← Seismic velocity (metres/second)

80

STOCK ROUTE AREA
LOCALITY MAP & GEOLOGY

PLATE 9

Record No. 1975/108

J55/B5-131

RESISTIVITY DEPTH PROBE
SHEATHERS ROAD


GRID NORTH
FELL TIMBER CREEK RD
Fell Timber Creek
COYLES ROAD
PARKERS ROAD
HUME HIGHWAY
SHEATHERS ROAD
Murray River
7503 0000
0010
0020
0030
0040
0050
0060
0070
0080
0090
0100
0110
0120
0130
0140
0150
7503 0155
BOUGUER ANOMALY PROFILE (ρ=2·6g/cm³)
MILLIGALS
-23
-24
-25
-26
-27
ELEVATION (METRES)
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
SURFACE
MG2
A00
A200
A400
A500
A600
A700
MG1
H900
A1040
MG44
A1190
A1500
A1700
MG15
A2100
LEGEND
SAND AND GRAVEL
SAND, CLAY OR WEATHERED BEDROCK
CLAY OR WEATHERED BEDROCK
UNWEATHERED BEDROCK
PROBABLE WEATHERED BEDROCK SURFACE
DEPTH TO BEDROCK (HIGH VELOCITY LAYER) FROM SEISMIC REFRACTION
0
KILOMETRES
1
SECTIONS ALONG SHEATHERS ROAD

STOCK ROUTE AREA RESISTIVITY DEPTH PROBES

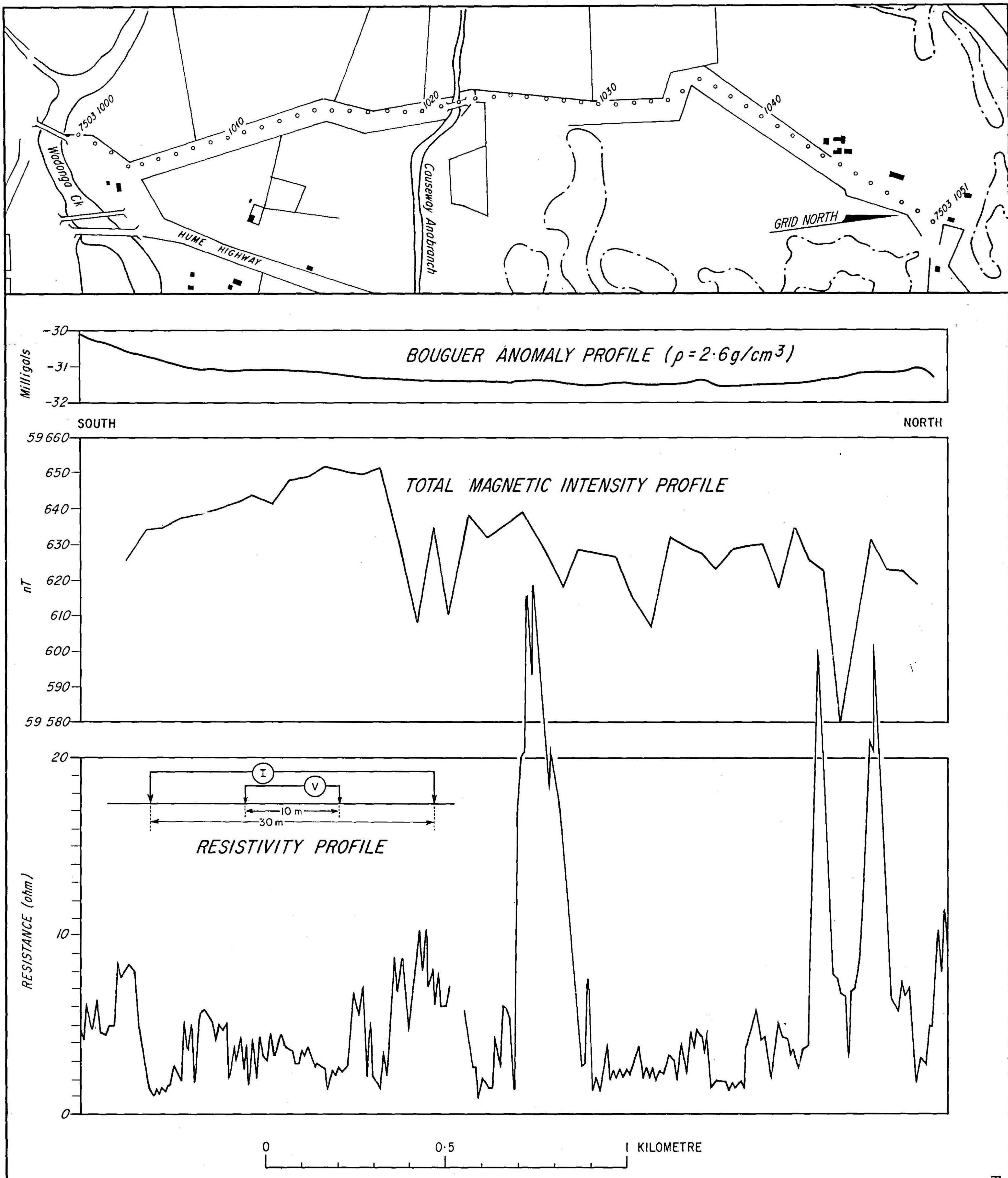


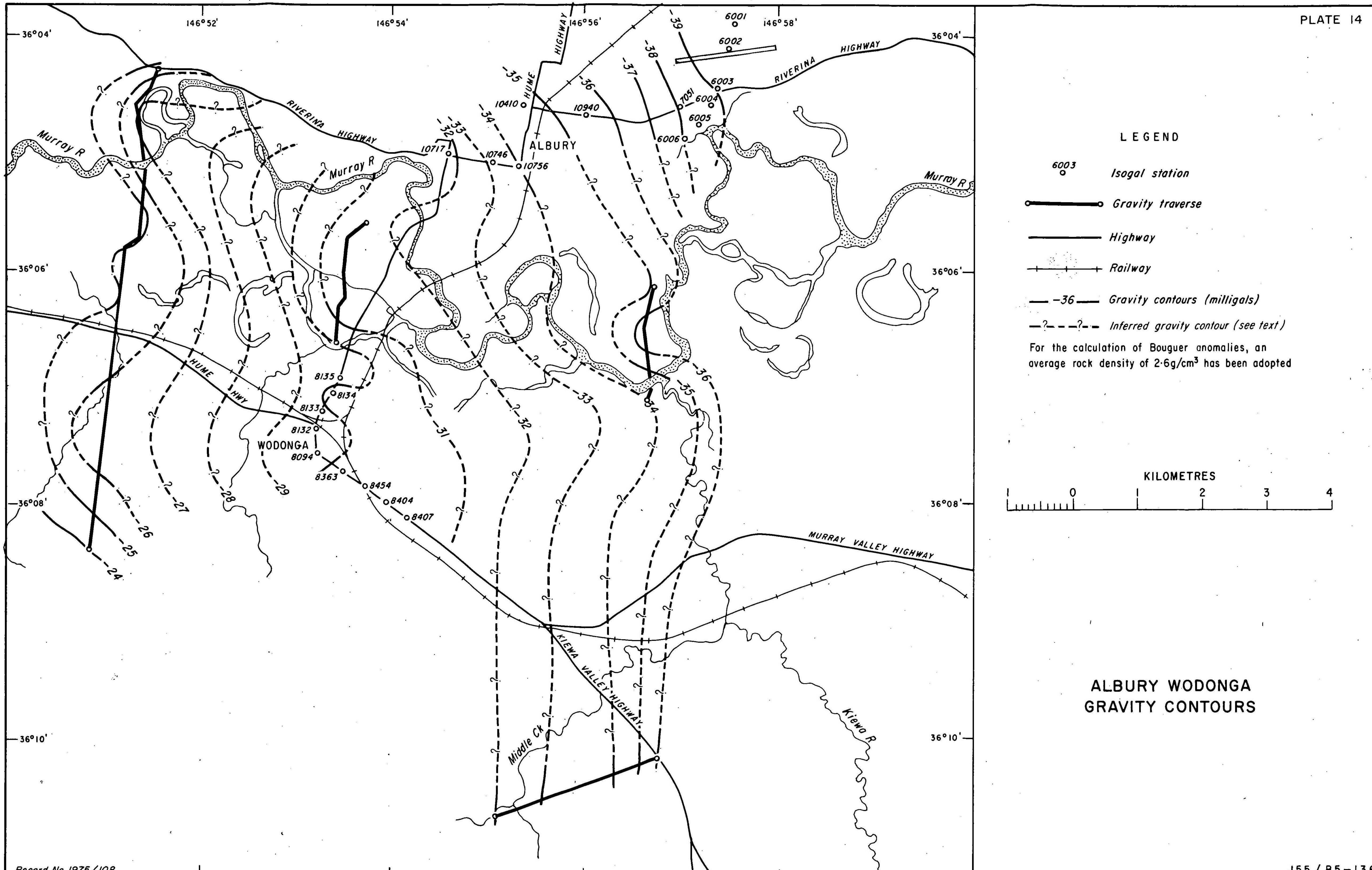
PLATE 13

STOCK ROUTE PROFILES

Record No. 1975/108

J55/B5-128

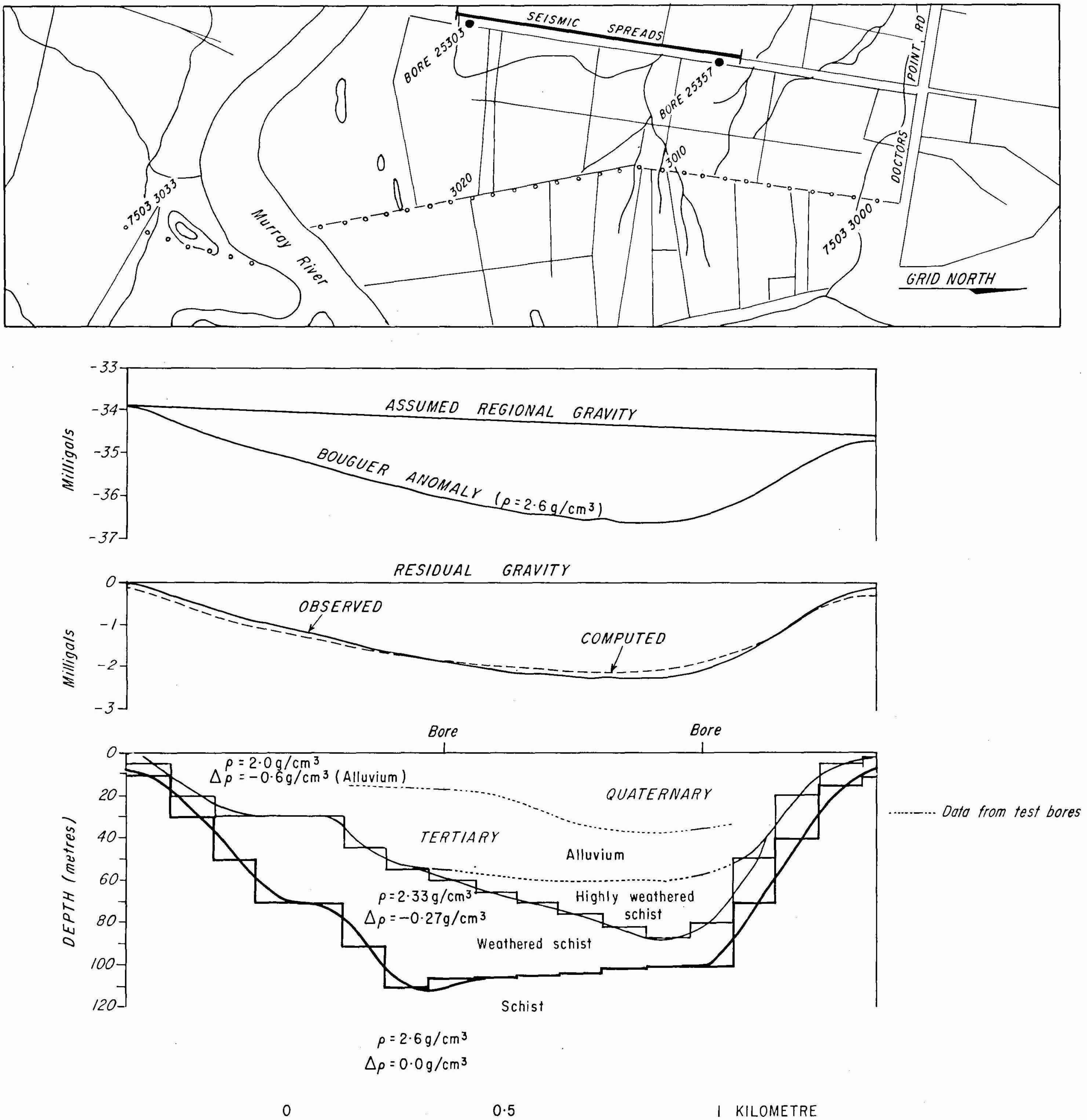
PLATE 14



ALBURY WODONGA
GRAVITY CONTOURS

Record No. 1975/108

J55/B5-136



DOCTORS POINT GRAVITY PROFILES

PLATE 15

Record No. 1975/108

J55/B5-135