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DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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RYAN SEWER TUNNEL GEOPHYSICAL INVESTIGATION, A.C.T., 1974

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D.C. RAMSAY

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SUMMARY

The Bureau of Mineral Resources, Geology & Geophysics (BMR) carried out seismic refraction and dipole-dipole resistivity surveys along the route of the proposed Ryan sewer tunnel. The object of the surveys was to determine tunnelling conditions from a knowledge of the seismic velocity and electrical conductivity of the rock.

Measured values for bedrock velocity ranged from 1.9 to 5.6 km/s, and apparent resistivity varied from 24 to 2000 ohm-m, indicating a wide range in rock conditions. The Record gives detailed predictions of tunnelling conditions along the length of the proposed tunnel, based on the above results. It is probable that some form of support will be required for 40 to 50 percent of the tunnel line.

1. INTRODUCTION

The Ryan tunnel forms part of the proposed Molonglo Valley Interceptor Sewer, connecting the existing Weston Creek treatment works with the proposed Lower Molonglo Water Quality Control Centre situated near the confluence of the Molonglo and Murrumbidgee rivers (Plate 1). The tunnel will be 1.5 km long and at its deepest point will be 48 m below the surface.

In co-operation with the BMR Engineering Geology Section, which is providing geological assistance to the tunnelling contractors, the Engineering Geophysics Group carried out seismic refraction and dipole-dipole resistivity surveys along the proposed tunnel line. The aim of the geophysical work was to predict tunnelling conditions from such information as seismic velocity, depth of weathering, and electrical conductivity, together with a knowledge of the local geology. The field work was carried out in May, July, and September 1974; personnel involved are listed in the appendix. Assistance in interpretation was provided by B.H. Dolan and F.J. Taylor (geophysicists).

Seismic refraction coverage of this same area was previously done by Central Testing and Research Laboratories, Commonwealth Department of Works (CTRL, 1971), as part of a more extensive survey.

The term 'bedrock' as used in this report refers to the deepest refractor detected, and the term 'overburden' to the soil and weathered rock above this refractor.

2. GEOLOGY

The proposed Ryan tunnel is located almost entirely in a sequence of volcanic rocks, the Deakin Volcanics, of Late Silurian age. The rocks include blue-grey welded dacite, rhyodacite, rhyolite, and ashstone. Within this sequence a few thin beds of tuffaceous sandstone and shale occur. Bedding within the volcanics and associated sediments generally dips to the southwest at about 50°.

Several faults are known to exist in the area and many more probably exist but have remained undetected. Faulting is more developed at the northern end of the tunnel in the rhyodacite and tuffaceous sediments, and has probably caused many zones of close jointing, fracturing, and shearing.

Weathering along the tunnel line appears to be fairly deep. Diamond-drill holes (Plate 2) show fresh rock at 14 m and 39 m in rhyodacite and at 15 m in dacite. The sediments could be even more deeply weathered.

More detailed information may be obtained from a BMR Record on the geology of the proposed tunnel route, by Purcell & Simpson (1973).

3. METHODS AND EQUIPMENT

Two geophysical methods were employed in this investigation, namely seismic refraction and dipole-dipole resistivity traversing.

Using the seismic refraction method (Dobrin, 1952), depths to refracting surfaces were calculated from intercept times and a modification of the reciprocal method (Hawkins, 1961). The spreads were laid end to end along the line of the tunnel with a geophone spacing of 4 m, each spread consisting of 23 geophones with a 24th as the reciprocal. Five shots per spread were fired: one in the centre, one 1 or 2 m beyond each end, and one generally 50 m beyond each end. Standard BMR 24-channel SIE PSU-19 refraction equipment with 14 Hz HSJ geophones was used.

In the dipole-dipole resistivity traversing method (Polak & Ramsay, 1974) a collinear array of four electrodes is used. One pair of adjacent electrodes with separation 'a' transmits current into the ground; the other pair, also with separation 'a', measures the potential drop produced by the ground current. The separation of these pairs, or dipoles, is increased with successive readings, increasing the depth of investigation. This separation is an integral multiple of 'a', and is referred to as the 'n' number. The assembly of electrodes is moved along a line, thus measuring both lateral and depth changes in resistivity. An electrode spacing of 'a' = 10 m was used for the survey, with readings taken at 'n' = 2, 4, 6,and 8. The equipment consisted of a Geotronics induced polarization transmitter and a Data Precision digital voltmeter. The transmitter produced a square wave with amplitude generally 0.5 A or less at a frequency of 0.1 Hz.

The magnetic method was also used on a previous test survey (Hill, 1971), and the results relevant to this investigation are included in Plate 2. The total intensity of the Earth's magnetic field was measured at intervals of 25 feet along the line of the traverse using an Elsec model 592N proton-precession magnetometer. This man-portable instrument has a claimed sensitivity of ± 0.5 nT in a total field of approximately 60,000 nT, and will detect changes in either the remanent magnetization or magnetic susceptibility of the rock beneath the detecting head.

4. RESULTS

The seismic cross-section is shown in Plate 2. With a few exceptions unweathered bedrock boundary was interpreted as being well above tunnel level and so the main criterion in estimating rock condition was the bedrock seismic velocity. Generally speaking, the higher the velocity, the sounder the rock will be.

The measured velocity ranged from 3.1 to 5.6 km/s, but several localized zones showed a significantly lower velocity than that in the adjacent rock. Some of these zones occurred at approximately chainages (ch.) 650 and 2900 feet, and probably represent major fractured zones caused by faulting. The remainder was interpreted as slightly weathered to fresh volcanic rock, the jointing being more open towards the low-velocity end of the range.

At the time of writing, tunnelling has started from the northern end and reached approximately ch. 1400. Steel supports were used from the portal to ch. 450 because of the loosely jointed, blocky nature of the rock. Previous experience in geophysical investigations of this type (Ramsay, 1974) would suggest better quality rock as an interpretation of the seismic velocity (4.5 km/s), but perhaps the proximity of the bedrock boundary could account for this. From ch. 450 the quality of the rock improved and no support was needed; this zone was characterized by a seismic velocity of 5.6 km/s. Starting from ch. 650, a 15-m-wide shear zone was encountered where the rock was completely fractured and contained a lot of clay. This zone was predicted from the seismic interpretation, which showed bedrock velocity reduced to 2.8 km/s, the overburden also showing a velocity lower than that on either side. Following this, the tunnel entered tuffaceous sandstone and shale at ch. 700, followed by rhyodacite at ch. 900: no further support was required through this section to the present position of the tunnel face.

The section from approximately ch. 1600 to 2550 has a bedrock velocity of 3.2 to 3.6 km/s which would imply poor tunnelling conditions. However, discrepancies in the reciprocal times suggested that there might be a higher-velocity layer at a depth such that the layer would not be apparent on the time-distance graphs for the shot distances used. Assuming a velocity of about 4.5 km/s for this layer, theoretical modelling showed that at a depth greater than 35 m this layer would not appear on the records. This possibility also correlates with results from drill hole MV4, which struck fresh rock at a depth of 39 m at ch. 1950. This is above tunnel level, so the existence of this higher-velocity layer would alter tunnelling conditions from poor to good. From ch. 2550 to 2900, bedrock velocity is about 4.5 km/s, and may represent the same rock sequence as postulated lying deeper in the section immediately before: tunnelling conditions here should be good.

The next section, from ch. 2900 to 3500, contains one definite shear zone and possibly one other. From ch. 2900 to 2950 bedrock velocity is reduced to 1.9 km/s and the overburden shows a similar reduction in seismic velocity. From here to ch. 3220 the tunnel should be through fairly sound rock, at which point the bedrock velocity again changes, to 3.1 km/s. It is possible there may be another shear zone up to 12m wide associated with this change in bedrock velocity. This zone is also characterized by a low total magnetic intensity reading as compared with the rock on either side. (Plate 2; Hill, pers. comm. (1971).

From ch. 3500 to the end of the traverse, the rock should be fairly sound except in two short sections. Centred on ch. 3950 is a zone with bedrock velocity 3.2 km/s; this could represent either a shear zone or a band of different rock type. The northern end of this zone correlates with both an airphoto lineation (Purcell & Simpson, 1973) and a sharp change in character in the magnetic profile, which suggests a change in rock type. Either possibility would probably require support during tunnelling. Also, at ch. 4600 there is another short zone where the bedrock velocity may be reduced to about 3.0 km/s. This zone also correlates with airphoto lineations at both ends, and might represent another band of softer rock; this again will probably require support during tunnelling.

The results of the resistivity traversing are presented as a pseudo cross-section, shown in Plate 3. It should be noted that this is not a true cross-section of rock resistivity, either laterally or vertically, and considerable caution is needed in interpretation. The profile has been qualitatively divided into regions of low, intermediate, and high resistivity for convenience in comparison with the seismic section. A certain amount of correlation is apparent between the two sections. However a number of resistivity features cannot be simply interpreted, and an explanation must be sought during the geological mapping of the tunnel.

The seismically interpreted shear zones at ch. 650 and 3250 are both characterized by a low value of the apparent resistivity. The latter zone in particular displays a very wide band of low-resistivity readings, indicating the presence of multiple fractures with electrically conductive clay on the joints.

Centred on ch. 2600 is a wide band of high-resistivity readings which appears to correlate with bedrock with a seismic velocity of 4.5 km/s. This band extends to the north, where the measured bedrock velocity decreases to about 3.3 km/s and where the upper bedrock layer is underlain by a postulated layer with velocity 4.5 km/s. The continuity of the high-resistivity zone could be regarded as further evidence of this higher-velocity layer, which if present would minimize support requirements in this region.

Between ch. 3700 and 3900 the apparent resistivity is lower than on either side. This zone corresponds to a bedrock velocity of 5.0 to 5.2 km/s and a very pronounced peak in magnetic intensity. The correlation of high seismic velocity with low resistivity is unexpected, and a change in rock type seems highly probable.

5. CONCLUSIONS

Tunnelling conditions along the length of the proposed Ryan tunnel will be very varied. The southern end, from the portal to about ch. 3500, should be through sound, fresh rock except in two short sections centred on ch. 3950 and 4600 respectively, and a section close to the portal where the tunnel will probably intersect overburden. From ch. 3500 to 2900 several fault zones are predicted, and support will probably be required in much of this section. No support should be required from ch. 2900 to 2600. From ch. 2600 to the present position of the tunnel face, support may or may not be required: the geophysical methods used suggest that sound rock may exist in this portion, but the depth to this rock is indeterminate.

The resistivity method did not produce as much information as the seismic method, for similar times spent collecting data. The seismic method was able in general to distinguish between fresh and weathered rock and to accurately locate the limits of highly sheared zones which could be related to rock conditions at tunnel level.

The combination of seismic, resistivity, and magnetic data probably indicates changes in rock type which would not be apparent from seismic data alone.

6. REFERENCES

COMMONWEALTH DEPARTMENT OF WORKS, 1971 - Molonglo outfall sewer seismic report. Central Testing and Research Laboratories, Technical Report No. 80.

DOBRIN, M.B., 1952 - INTRODUCTION TO GEOPHYSICAL PROSPECTING. New York, McGraw-Hill Inc.

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

POLAK, E.J., & RAMSAY, D.C., 1974 - Goulburn valley (Victoria) dipole-dipole resistivity survey, 1974. Bur. Miner. Resour. Aust. Rec. 1974/134 (unpubl.).

PURCELL, D.C. & SIMPSON, G.B., 1973 - Molonglo Valley Interceptor Sewer, Canberra, A.C.T.: geological investigations, 1970-72. Bur. Miner. Resour. Aust. Rec. 1973/173 (unpubl.).

RAMSAY, D.C., 1974 - Pine Ridge sewer tunnel seismic refraction investigation, A.C.T. 1974. Bur. Miner. Resour. Aust. Rec. 1974/180 (unpubl.).

APPENDIX

Field personnel involved in resistivity work were:

D.C. Ramsay	geophysicist
S.A. Green	trainee technical officer

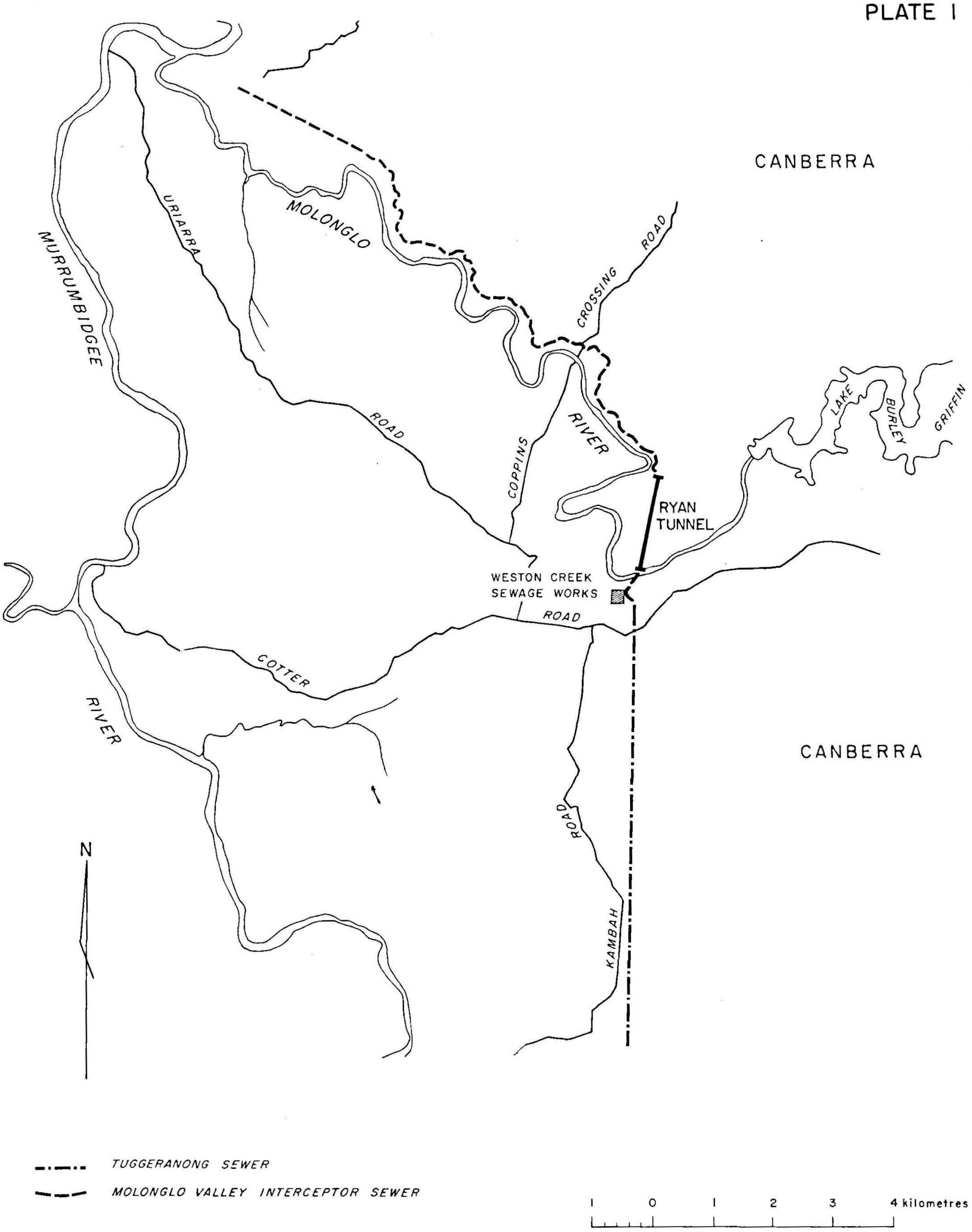
and field hands from various sections of the BMR.

Those involved in seismic work were:

M.I. McDowell F.N. Michail D.C. Ramsay	geophysicists
C. Rochford G. Green S.A. Green	trainee technical officers

and several field hands.

PLATE I



RYAN SEWER TUNNEL

LOCALITY MAP

Record No. 1975/136

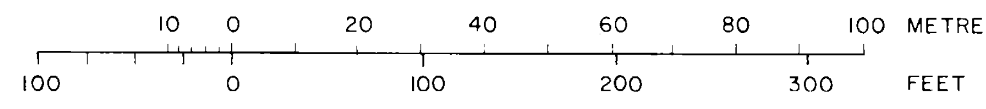
155/B5–259A

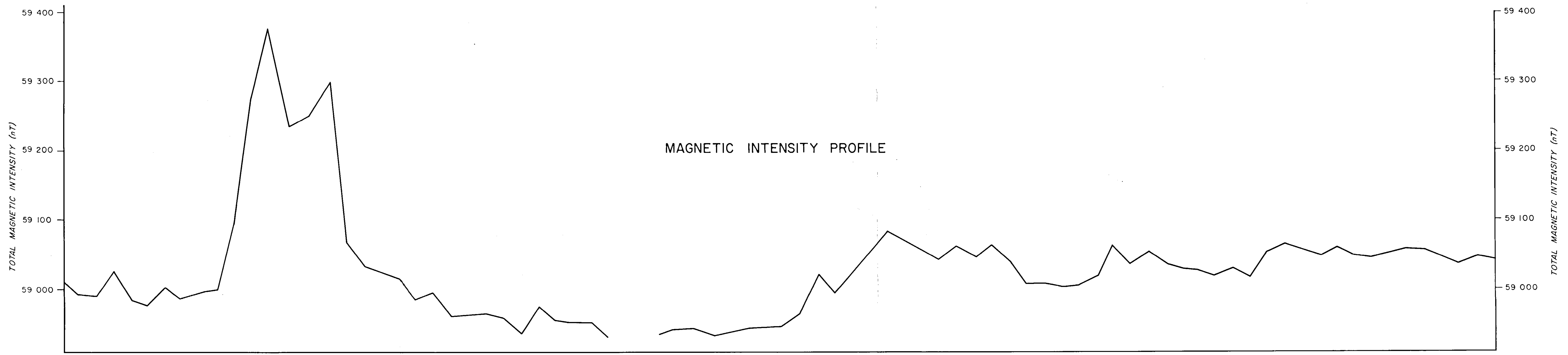
PLATE 2

MAGNETIC PROFILE AND SEISMIC CROSS-SECTION

LEGEND

CW	*Completely weathered dacite*	– – –	*Approx. position of boundary between layers of different seismic velocities*
HW	*Highly weathered dacite*	(5·20)	*Seismic velocity km/s*
MW	*Moderately weathered dacite*	═	*Position of sewer tunnel*
SW	*Slightly weathered dacite*	L	*Photo-interpreted lineament*
FS	*Fresh stained dacite*	∫	*Seismic discontinuity*
Fr	*Fresh dacite*		
MV 2	*Drillhole*		




MAGNETIC INTENSITY PROFILE

Record No. 1975/136

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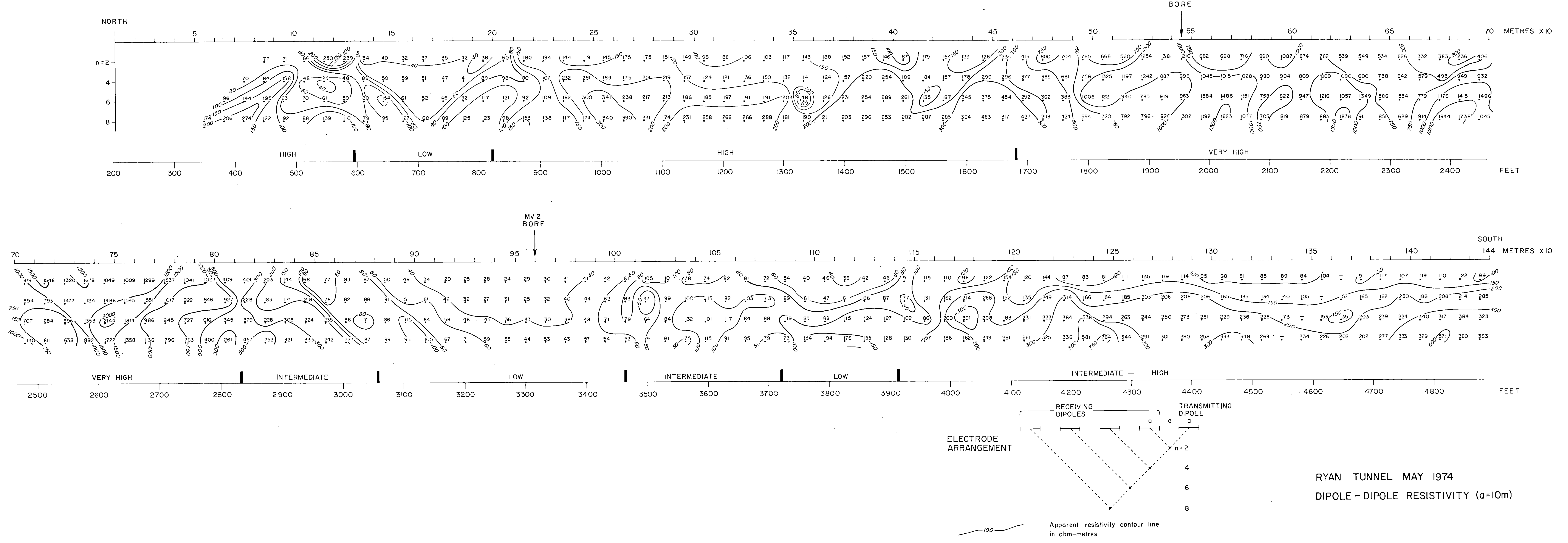

RYAN TUNNEL MAY 1974

DIPOLE - DIPOLE RESISTIVITY (a=10m)