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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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WEST MURRUMBIDGEE GEOPHYSICAL SURVEY, 1975

by

D.G. Bennett and E.J. Polak

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SUMMARY

Seismic refraction and magnetic methods were used to investigate three separate problems in the proposed subdivision of West Murrumbidgee, A.C.T.

Seismic refraction investigations over a concealed section of the Murrumbidgee Fault clearly detected it in some locations and in others the evidence suggested its existence. The locations agreed with those predicted by geological mapping. Magnetic traverses over the same area showed some correlation with the different rock types, but there is no clear indication that the contacts are faulted.

Twenty reticulating reservoir sites were investigated by the seismic refraction method, to determine the depth of rippable material and foundation conditions. The elevation of the base of rippable material shows considerable lateral changes along most seismic traverses. Excavation for several sites will require some blasting, but this can be minimized by slight changes in the location of the reservoirs. The results suggest the presence of faults at or near some of the investigated sites.

The seismic refraction method was used to provide information on depths and velocities of near-surface layers in poorly drained alluvium near Freshford homestead. The sections indicate areas of sediment thickening possibly due to old creek channels.

1. INTRODUCTION

The National Capital Development Commission (NCDC) proposes to construct a major suburb on the left bank of the Murrumbidgee River west of Pine Island and Point Hut Crossing (Plate 1). The Bureau of Mineral Resources, Geology and Geophysics (BMR) is carrying out geological and geophysical investigations for the project.

The Engineering Geophysics Group of BMR conducted a geophysical survey in the area to help solve three problems:

1. to trace and ascertain the width of a concealed part of the Murrumbidgee Fault.

2. to determine foundation conditions for a number of reservoir sites.

3. to determine the thickness of materials associated with a poorly drained area.

During the fieldwork - in May and September 1975 and January 1976 - seismic refraction and magnetic methods were used: 78 spreads totalling 6560 m were shot and 3200 m of magnetic traversing were recorded. D.G. Bennett interpreted the field data, which E.J. Polak checked.

2. GENERAL GEOLOGY

The West Murrumbidgee area is confined by the Murrumbidgee River to the east (Plate 1). To the north and west the high ground and steep slopes of the Tidbinbilla Ranges impose limits on land occupation, while to the south Castle Hill restricts the width of the valley.

Only the general geology of the area is given here; a more detailed account is included in a report being prepared by the Engineering Geology Group (Hohnen & Briscoe, in prep.).

The Murrumbidgee Fault, which crosses the West Murrumbidgee area, juxtaposes two distinctive geological formations. On the Canberra 1:250 000 geological map (Strusz, 1971), this fault is clearly defined north of the area shown in Plate 1. Throughout the area shown in Plate 1 though, and for about 40 km south, the fault is concealed; it is exposed again near Michelago.

In the area of investigation near Freshford (Plate 1) the rock to the west of the fault consists mostly of Tharwa Adamellite, part of the Silurian to Devonian Murrumbidgee batholith. Two areas of Ordovician greywacke, sandstone, slate, chert, limestone, and quartzite are also found on the western side of the fault.

The rocks between the Murrumbidgee Fault and the river are of Late Silurian age, and are mainly acid volcanics with some inliers of calcareous shale and sandstone.

There are many outcrops of bedrock on the river banks and in creeks; at other locations bedrock is covered with products of weathering either in situ or as hillwash. On flat-lying areas alluvium and colluvium have been deposited, and marshy conditions prevail at some locations.

3. METHODS AND EQUIPMENT

3.1 SEISMIC REFRACTION METHOD

The method is based on the sound-wave velocity contrast between geological formations.

During the survey, 24 geophones 2 or 4 m apart in each spread were laid out in a straight line on the ground. Five shots were fired per spread; two from each end geophone at distances generally 2 and 50 m, and one in the centre of the spread. The arrival times at each geophone were plotted against the distance from the shot to the geophone to form a time distance (T/D) curve. The seismic velocities of the refractor are equal to the reciprocals of the gradient of the best-fitting straight lines through the arrival times.

From the T/D curves the depths to the seismic-velocity interfaces may be calculated by several different methods. In the West Murrumbidgee survey the intercept-time and reciprocal-geophone methods were used (Heiland, 1946, p. 507 and p. 548 respectively). The depths were computed on the Wang 600 electronic calculator.

In plotting the results, a different procedure to that usually used by the Engineering Geophysics Group has been adopted. Using the geophone positions as a centre, an arc representing the calculated depth is drawn. A line is then plotted through an accumulation of arcs giving a minimum distance of wave travel from the bedrock. The procedure is shown on the northwest-southeast traverse in Plate 7.

A seismic refraction survey can add greatly to the subsurface geological information, and also provide quantitative data about the engineering properties of the rocks.

1. Geological information:

   (i) The depth to the different rock layers and their velocities can be established to within ± 10 percent if each layer has a higher velocity than the one above it, and each layer is thick enough to be detected.

   (ii) The different velocity layers can be interpreted in terms of soil, rock types, and degree of weathering if there is a reasonable geological control.

(iii) Sheared and fractured rocks in fault zones are indicated in seismic sections as a decrease in bedrock and overburden velocity or an increase in depth of weathering, or both. In shear zones, seismic velocities are often strongly anisotropic.

2. Engineering data:

(i) Rippability. Seismic velocities of the rocks provide an approximate index of rippability (Caterpillar Tractor Co., 1966): rocks with velocities up to 1200 m/s can generally be ripped without blasting; rocks with velocities 1200 to 1500 m/s may require some blasting to excavate; some rocks with velocities greater than 1600 m/s will definitely require blasting to excavate.

(ii) Elastic properties of rocks. Seismic velocities provide information on the elastic properties of rocks. The determination of the modulus of elasticity requires a knowledge of the density and of Poisson's ratio. A good approximation to the value of the modulus of elasticity from velocity is given by the following formulae:

for solid rock $E = 2.16\ V^2$

for unconsolidated sediments $E = 0.933\ V$

where E = modulus of elasticity in Pa

V = seismic velocity in m/s.

These two relations are shown in Plate 2 Figure 1. Fig. 1 also gives the results of field determinations actually carried out on geophysical surveys in Australia using longitudinal velocities (Polak, 1963).

All moduli are at present expressed in mega-Pascals; to convert them to p.s.i. multiply by 1.45×10^2.

(iii) Compressive and bearing strength. The empirical relation between the dynamic modulus of elasticity and the compressive strength of soils is shown in Plate 2, Fig. 2.

The relation between dynamically determined modulus of elasticity (E) and the California Bearing Ratio (CBR) was determined by Heukelom & Foster (1960).

$$E = 110 \text{ CBR}$$

3.2 MAGNETIC METHOD

The magnetic method depends on the differences in magnetic susceptibility and intensity of remanent magnetization of different rock types. Both characteristics are principally related to the magnetite content, and therefore the presence of basic rocks is generally indicated by magnetic 'highs'. However, magnetite weathers to form hematite or limonite, so the magnetic effect of the rock in shear zones and faults, for example, is lowered. Where magnetic horizons have been displaced relative to one another, the characteristic shape of the magnetic anomaly is diagnostic of a fault.

A G-816 proton magnetometer manufactured by Geometrics, Palo Alto, USA, was used during the survey. Measurements were taken on stations 5 m apart.

4. RESULTS

4.1 FAULT INVESTIGATION

To detect the Murrumbidgee fault, 11 seismic spreads were shot along two main traverse lines (F1 and F3) in the Freshford area (Plate 3). Geological mapping had suggested that one branch of the fault strikes north-northwest along the base of the Freshford Hills, and another branch strikes north-northwest below Freshford homestead. Seismic traverses were located across the fault zones inferred from the geological mapping. In addition to the seismic investigation, three magnetic traverses totalling over 3 km were recorded. Two of these traverses coincided with the two seismic traverses.

The seismic sections and interpreted faults are shown in Plate 4; the magnetic profiles are shown in Plate 5, in which magnetic anomalies due to power-lines, fences, telephone cables, etc., have been smoothed out.

4.1.1. Traverse F1

The seismic results for the western part of traverse F1 show a three-layer velocity profile: the surface layer has a velocity of 400-500 m/s; the second layer has a velocity ranging from 1300 m/s on the eastern end of the section to 1700 m/s on the western end; and the bedrock velocity is 4500-4800 m/s. The results show a decrease in bedrock velocity to 3200 m/s near the western creek and a relatively gradual increase in the depth of the weathered layer from west to east, indicating a zone of minor faults in this area. At the western end of the traverse the depth to the unweathered bedrock is 10-12 m below the surface and this deepens over 120 m laterally to a uniform depth of 28 m. The surface layer thickens considerably from 1 m to 5 m between the creeks near the interpreted faults.

The seismic results for the eastern part of traverse F1 indicate a four-layer profile, with the velocities of the layers from the surface to bedrock being 400-500 m/s, 1050-1300 m/s, 1950-2100 m/s and 3500-4700 m/s. They show that the depth of weathering gradually increases from east to west. The depth to bedrock increases more abruptly: the drop from 17 m to 28 m across the seismically interpreted fault occurs over a distance of less than 55 m. At the far eastern end of this traverse the bedrock deepens again but this may be due to a smaller fault note near reservoir site 1B (section 4.2.1).

The magnetic results from traverse F1 do not show any clear correlation with the seismic results. A magnetic high peaks near the western end of the traverse and drops off sharply over the area where the seismic results indicate an increase in weathering. However there is no correlation of any sort between the magnetic profile and seismic section on traverse F3 which crosses the same fault 700 m to the south. Over the eastern part of traverse F1, there is a 30 nT low over the fault detected by seismics, but 100 m farther east the total magnetic intensity drops by 70 nT.

4.1.2 Traverse F3

Traverse F3 extends eastward from reservoir site 2C. The seismic results clearly indicate a fault (a decrease in bedrock velocity from 3400 m/s to 1500 m/s and an increase in the depth of weathering) with its shear zone located between 60 and 80 m east of the centre of reservoir 2C. To the west of the faul a four-layer profile was interpreted, with seismic velocities of 700 m/s for the surface layer, 1300 m/s for the second layer, 2100 m/s for the third layer and 3600 m/s for the bedrock. The seismic velocity of the slightly weathered third layer decreases as it becomes more fractured near the fault, and has a velocity of 1500 m/s. To the east of the fault the second and third laye have been combined, and the seismic velocity of this layer range between 1500 and 1800 m/s. The bedrock velocity still remains between 3400 and 3800 m/s. The depth to the fresh rock forms a distinct step, as it changes from 13 to 23 m from west to east over the fault. A magnetic traverse over this part of the fault failed to detect it.

The eastern branch of the fault along this traverse was investigated by extending the centreline traverse of reservoir site 1A to the west (Plate 6). The seismic sections are shown in Plate 7. The results show a four-layer profile with velocities of 700, 1300, 2100-2400, and 3700-4000 m/s for the successive layers. A deepening of the weathered layer is indicated under the road, and suggests the possibility of faulting in this area. The magnetic traverse over this area is affected by interference from two fences bordering the road on the traverse.

4.1.3 Traverse F2

Because of the poor correlation between the magnetic profiles and the seismic sections along traverses F1 and F3, nothing definite about the fault could be deduced from the magnetic profile over F2.

4.1.4 Conclusions

Two branches of the Murrumbidgee Fault were detected along the two seismic traverses. On the western parts of traverses F1 and F3, the positions of the fault interpreted from the seismic results agree with the trace of the fault predicted from geological mapping. On the eastern parts of the traverses, the seismically interpreted position of the fault coincides with the geologically interpreted position on traverse F3, but is 110 m west of the geologically interpreted position on traverse F1.

The magnetic results showed some correlation with the several different rock types in the area, but there is no clear indication from the magnetics that these contacts are faulted. It is recommended that further closely spaced magnetic traverses be recorded and the magnetic susceptibility of the various rock types be measured, in order to clarify the correlation.

4.2 RESERVOIR SITES

The supply of water to homes of more than 70 000 inhabitants of the proposed West Murrumbidgee complex will require several reticulating reservoirs. Plate 1 gives the general locations of the investigated areas and Plates 6, 8, 10, 12, 14, 16, 18, and 19 show the possible location of reservoirs. The foundation conditions, cost of excavation, and possible structural disturbances are to be taken into account before the final sites are chosen. Geophysics is being used to supplement geological information in the selection of the most economic sites and methods of excavation.

The results for all sites are summarized in Table 1, and discussed in detail in the following paragraphs.

4.2.1 Reservoir No. 1

Six alternative locations for reservoir No. 1 were investigated. The locations are shown in Plates 6 and 8, and the seismic sections in Plates 7 and 9.

Site 1A (Plate 6) shows three possible locations: one rectangular and two round. Seismic results are shown in Plate 7. The SW-NE section indicates a possible fault along the road; this was referred to in section 4.1.2. Seismic results show that the weathering is thickest in the fault zone and decreases considerably towards the north-east. The thickness of 1300 m/s material decreases in the same direction, and under the rectangular reservoir it is too thin to be recorded on a seismic spread. Whereas a bulldozer could excavate the round reservoirs, the eastern half of the rectangular reservoir would require blasting.

TABLE 1. SUMMARY OF SEISMIC RESULTS OF TRAVERSES ACROSS POSSIBLE RESERVOIR SITES

RESERVOIR SITE	LENGTH OF TRAVERSE (m)	ELEVATION (m)			REMARKS
		CENTRE POINT		HIGHEST POINT WITH VEL 1500* m/s	
		SURFACE	LAYER 1500 m/s		
1A south-west	270	648	643	644	Possible fault
1A centre	180	647	644.5	645	
1A north-east	360	652.5	648.5	656	
1B south	270	657	655	655.5	Possible fault
1B north	270	648	646	650.5	Possible fault
1C	270	651	649	653	
2A	180	679.5	675	678	Shear zone
2B	180	679	676	679	
2C	450	680	673	675	
2D	180	679	664	669	
3A	180	719.5	714	717.5	Seismic anisotropy
3B	180	720.5	719.5	720	Possible fault
3C	180	721	715	717	Possible fault, shear zone
3D	180	725	721	725	Possible fault, shear zone
3E	180	723.5	722	724	
3F	360	723.5	722.5	724	Possible fault
4A	180	648	645	649	Seismic anisotropy Possible fault
4B	180	649	647	650.5	
5A	180	680	678	681	Possible fault
5B	180	683	679	683	Seismic anisotropy Shear zone

Site 1B Two alternative sites (Plate 8) for rectangular reservoirs were investigated. At both sites (Plate 9) the weathering is much thinner than at site 1A. The weathered sequence consists of two layers: the upper layer has a seismic velocity of 1000 m/s; the lower layer has a velocity of about 2000 m/s, and would require blasting. A possible fault is indicated beneath the western half of site 1B (north) and the southwestern corner of 1B (south).

Site 1C. One location was investigated (Plate 8). A thin layer with a velocity of 1000 m/s overlies a thick layer with a velocity of 2200 to 2600 m/s (Plate 9). Blasting for excavation would be required.

4.2.2 Reservoir No. 2

Four alternative positions (Plate 10) for the reservoir were investigated. All these sites are close to the Murrumbidgee Fault (Plate 3). Seismic sections are shown in Plate 11.

Site 2A. The top layer with velocity of 700 m/s has a thickness of up to 5 m. This is the depth to which the weathered rock can be excavated without blasting, as the underlying bed with a velocity of 1700 m/s will require blasting.

Site 2B. The character of rocks at site 2B is similar to that at site 2A. The second layer shows an anisotropy in seismic velocities; but the velocity of 1700 m/s indicates that blasting will be required.

Site 2C. The character of the weathered material changes here; an additional layer with a velocity of over 2000 m/s appears on the time-distance graphs. The northeast-southwest traverse has been extended to cross the Murrumbidgee Fault (section 4.1.2), and the extension is shown in Plate 4. The weathered material should be marginally rippable to a depth of 7 m.

Site 2D. The velocities in the weathered material are much lower than on other sites of reservoir 2. The thickness of rippable material is up to 15 m.

4.2.3 Reservoir No. 3

Six alternative positions (Plates 12 and 14) for the reservoir were investigated. Seismic sections shown in Plate 13 indicate a possible fault zone cutting through sites 3B and 3C.

Site 3A. The site is characterized by a layer up to 5 m thick of completely weathered material overlying a thick layer of material with a seismic velocity of 1600-2100 m/s, which would require blasting for excavation.

Site 3B. This site is similar to 3A except that the rippable material is thinner. The 700 m/s layer is only 1 m thick at the centre of the spreads and thickens to 2-3 m at the flanks. The underlying layer has a seismic velocity of 1900-2200 m/s and will require blasting to excavate. A fault is suggested by the increase in weathering and is supported by more positive indications on site 3C.

Site 3C. The distribution of seismic velocities along the northwest-southeast traverse indicates different weathering profiles on either side of a fault, which is indicated by a zone of decreased bedrock velocity (2200 m/s compared with 4800 m/s) and an increase in the depth of weathering. Whereas on the downthrown side the excavation may not require blasting to a depth of 6 to 8 m, on the upthrown side, the rippable material decreases to a depth of only 2.5 m at the SE end. The northeast-southwest traverse is located mostly on the downthrown side of the fault and should be rippable to a depth of 5 to 8 m. Velocity anisotropy in the bedrock suggests the major joints strike northeast-southwest.

Because of the proximity of reservoir sites 3A, 3B, and 3C to the proposed power-line easement, a further three sites - 3D, 3E, and 3F were investigated. The locations of these sites are shown in Plate 14 and the seismic sections are shown in Plate 15. The possible faults are also shown on the locality plan.

Site 3D. This site has three possible faults passing nearby. There appears to be a pocket of highly weathered material (850-900 m/s) below the centre of the reservoir site; this extends to a depth of 3.5 m, but is lateral extent does not cover the whole area. The northeast-southwest traverse shows a possible fault at the northern end; to the north of this fault, slightly weathered rock with a velocity of 2000 m/s will inhibit excavation. The other weathered layer of 1300-1500 m/s may be marginally rippable.

Site 3E. This site shows a thin layer, less than 1 m, of highly weathered material (300 m/s) overlying slightly weathered rock with a seismic velocity of 2000-2300 m/s. Blasting will be required to excavate.

Site 3F. Several alternative sites were investigated for the final location of this reservoir. The main north-south traverse line shows a thin layer generally less than 1 m of highly weathered material (300 m/s) overlying weathered rock which will need blasting to excavate. Two possible faults cut this traverse, and the bedrock is deepest at the northern end. The lowest seismic velocity of the weathered layer was recorded below the centre of reservoir site 3F-1 (1700 m/s).

4.2.4 Reservoir No. 4

Two alternative positions (Plate 16) for the reservoir were investigated. Seismic sections are shown in Plate 17.

<u>Site 4A</u>. The site is characterized by a thin layer of completely weathered material overlying a thick layer of material with a seismic velocity of 2100-3300 m/s. This high-velocity anisotropy supports the evidence from the thickening of the weathered material that a fault cuts the east-west traverse roughly in a north-south direction. Blasting will be required to excavate the material.

<u>Site 4B</u>. The sections through site 4B are similar to those through site 4A, except that the marked velocity anisotropy is confined to the intermediate layer and may be due to jointing and weathering rather than to faulting. Blasting will be required in excavation.

4.2.5 <u>Reservoir No. 5</u>

Two alternative positions (Plate 16) for the reservoir were investigated. Seismic sections are shown in Plate 17.

<u>Site 5A</u>. The rippable material at the site is thin; the maximum thickness of 5 m is under the eastern end of the east-west traverse. The underlying jointed layer with a seismic velocity of 2500 m/s does not show velocity anisotropy. A possible fault cutting the north-south traverse is indicated, and supported by more positive indications at site 5B.

<u>Site 5B</u>. The rippable material at this site is slightly thinner than at site 5A. A probable shear zone in an east-west direction is indicated by a bedrock velocity contrast of 2700 m/s to 5600 m/s in the north-south traverse, and by a bedrock velocity of 3600 m/s on the east-west traverse. If this shear zone represents a fault, it may be an extension of the fault at site 5A (Pl. 16).

4.2.6 <u>Reservoir No. 6</u>

Two alternative position (Plates 18 and 19) were investigated. Seismic sections are shown in Plate 20.

Site 6A. Two alternative, closely spaced positions for this reservoir are shown in Plate 18. The arrangement of traverses allows the planning engineer the opportunity to move the reservoir within the surveyed area. Blasting may be necessary in excavations. The uneven surface of the fresh rock may indicate the existence of either a fault or a change in character of the bedrock.

Site 6B. The location of the reservoir is shown in Plate 19 and the seismic sections in Plate 20. The rippable material is up to 7 m thick at the western end of the east-west traverse, and blasting will not be required.

4.2.7 Reservoir No. 7

Only one location for reservoir No. 7 was chosen. It is shown in Plate 18, and the interpreted sections in Plate 20. At the intersection point of the two seismic traverses the thickness of rippable material is less than 4 m, with the underlying jointed and slightly weathered bedrock showing a seismic velocity of more than 2100 m/s. The thickness of rippable material is uniform over the site and blasting may be required if the reservoir is located farther uphill.

4.2.8 Conclusions

1. The seismic survey indicates the depth of the rippable material on twenty possible sites for the location of reticulating reservoirs. The elevation of the base of the rippable material shows considerable lateral changes along most of the seismic traverses. Excavation for several reservoirs will require some blasting; however, by changes in the exact locations blasting may be minimized.

2. The seismic survey suggests the existence of faults on at least eleven sites out of the twenty investigated.

3. The seismic survey indicated high-velocity anistropy on several sites. This anisotropy may control the direction of excavation.

4.3 DRAINAGE IN THE AREA

A total of 11 seismic refraction spreads were shot along five separate traverses crossing the marshy areas near Freshford homestead. The locations of these traverses are shown on Plate 3. Geophones were spaced at 4 m on traverses D1 and D2, and at 2 m on the remaining traverses. These marshy areas were easily defined in the field by the growth of button grass. The aim of this part of the survey was to identify the depths and seismic velocities of the near-surface layers, to assist with the planning of drainage in the area. The seismic sections are shown in Plate 21.

Traverse D1: The main feature of this traverse is a possible step-fault detected near the centre of the traverse. It shows a vertical displacement of nearly 5 m in the bedrock/weathered-rock interface, and the time-distance plots indicate that this discontinuity also extends through the overlying layers. The seismic sections along this traverse indicate a four-layer profile: the surface layer has a velocity of 450 m/s and a thickness of 2-3 m; the second weathered layer has a velocity of 1000 m/s and extends to a depth of 3.5-6.5 m; the third layer has a seismic velocity of 2850 m/s, indicating slightly weathered rock overlying the bedrock, which has a velocity of 4800 m/s.

Traverse D2: The seismic sections indicate a four-layer profile over most of the traverse. The surface layer (300-400 m/s) is generally very thin (less than 1 m) over most of the profile except near the creek; here there has been a sediment build up by deposition from the creek, and the seismic results indicate a channel 3 m deep centred to the west of the creek. The second weathered layer has a velocity between 700 and 1100 m/s, and shows considerable variation in its depth; three possible old river channels are indicated by thickenings of this layer. Overall this second layer is thicker towards the western end, and it appears to lens out over a bedrock high to the west of the creek. The velocity of the third layer increases from 1600-1800 m/s in the swampy areas to 2300-2600 m/s in the far eastern end of the swampy areas and in the drier areas up the hill. The bedrock weathered-rock interface shows a general shallowing to a depth of 6 m west of the creek, and appears to shallow slightly at the western end of the traverse. The velocity of the bedrock layer varies from 4500 m/s in the east to 5000 m/s in the west.

Traverse D3: This traverse shows a fairly simple four-layer profile with seismic velocities of 400-450 m/s, 700-800 m/s, 1700 m/s, and 3400-3600 m/s. The main features are the bedrock and surface layer shallowing at the western end, and a thickening of the second layer in a broad channel near the eastern end.

Traverse D4: This traverse has been interpreted as having three layers. The surface layer (300-400 m/s) changes in depth from 3 m in the west to 1 m in the east. The second layer shows a large range of seismic velocities from 700 m/s in the west to 1600 m/s in the east, however the time distance plots suggest that these velocities belong to the one layer. The bedrock has a velocity of 3200 m/s.

Traverse D5: This traverse indicates a possible fault near the centre of the traverse. This is shown by an increase in the depth of weathering and the introduction of another layer to the north. The surface consists of a very thin layer (0.5-1 m) with a seismic velocity of 300 m/s. A wedge of material with velocities between 650 and 850 m/s has been interpreted north of this possible fault. Underlying this is a layer of weathered rock with velocities ranging between 1500-1900 m/s. The bedrock velocity increases from 3000 m/s in the north to 4000 m/s in the south, and the depth to the bedrock decreases from 15 to 7 m.

<u>Conclusion</u>: The seismic sections indicate three and four layers, with depths to the bottom refractor ranging from 7 to 21 m. The intermediate layers show variable thicknesses, and suggest channels of thicker sedimentary deposition in some places. Two possible faults have been identified.

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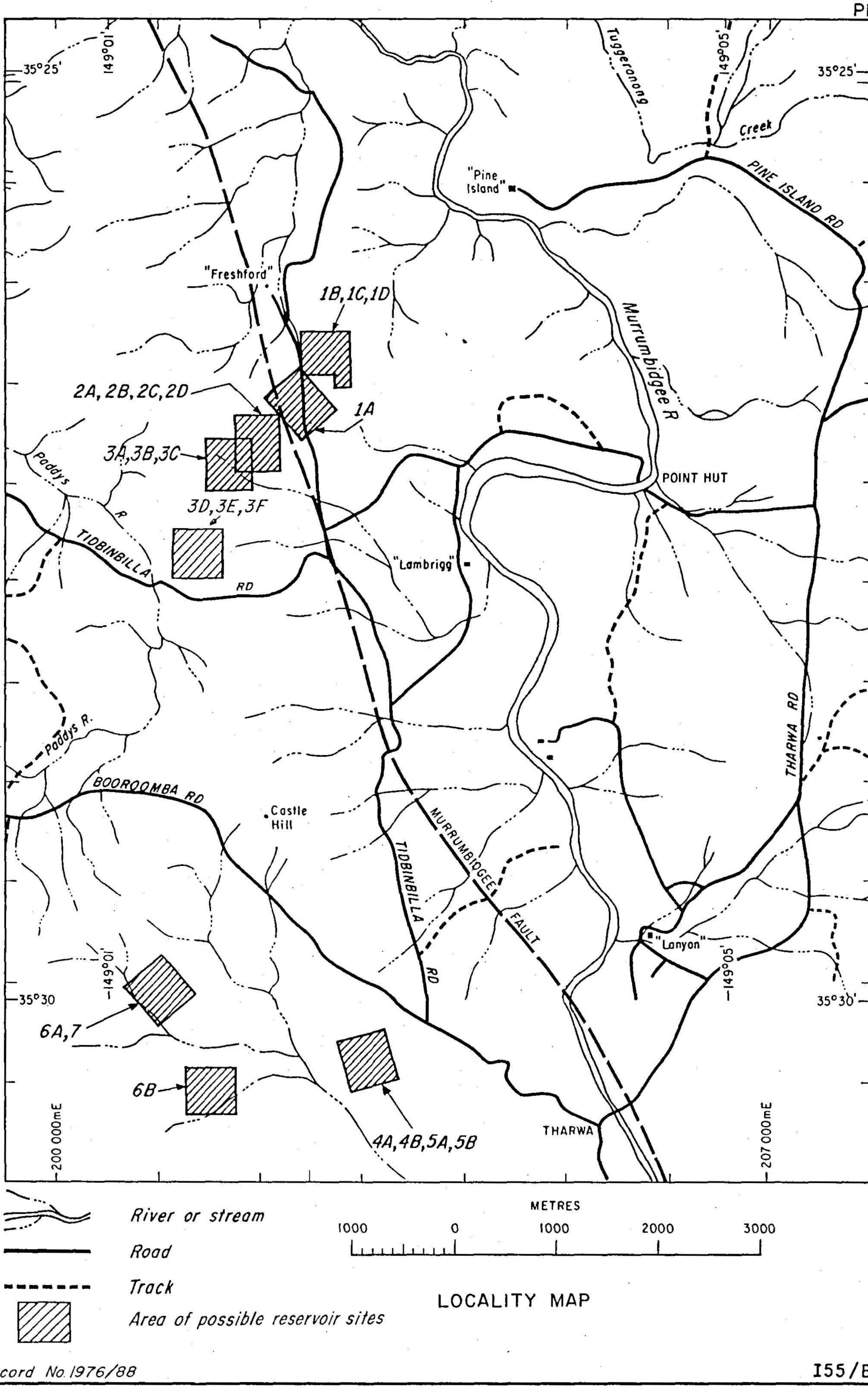
PLATE 1

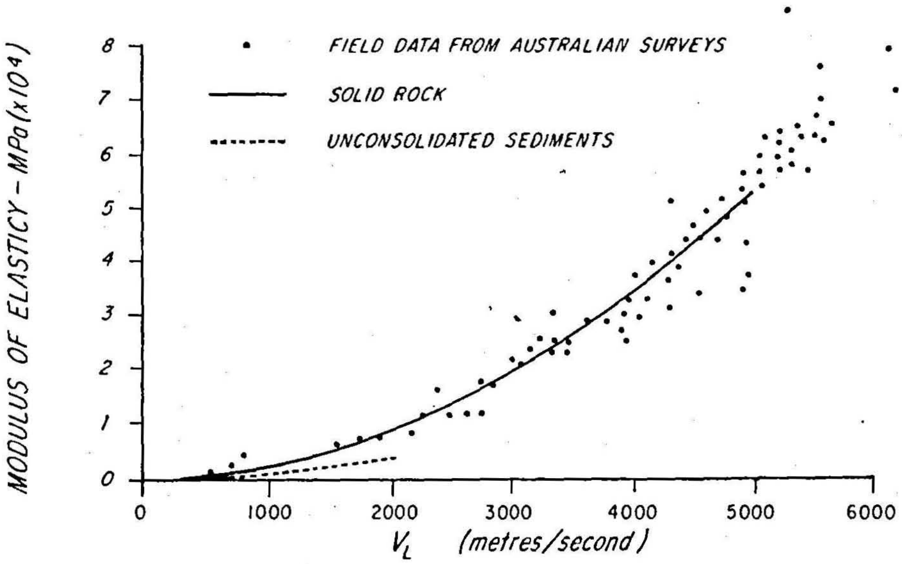


LOCALITY MAP

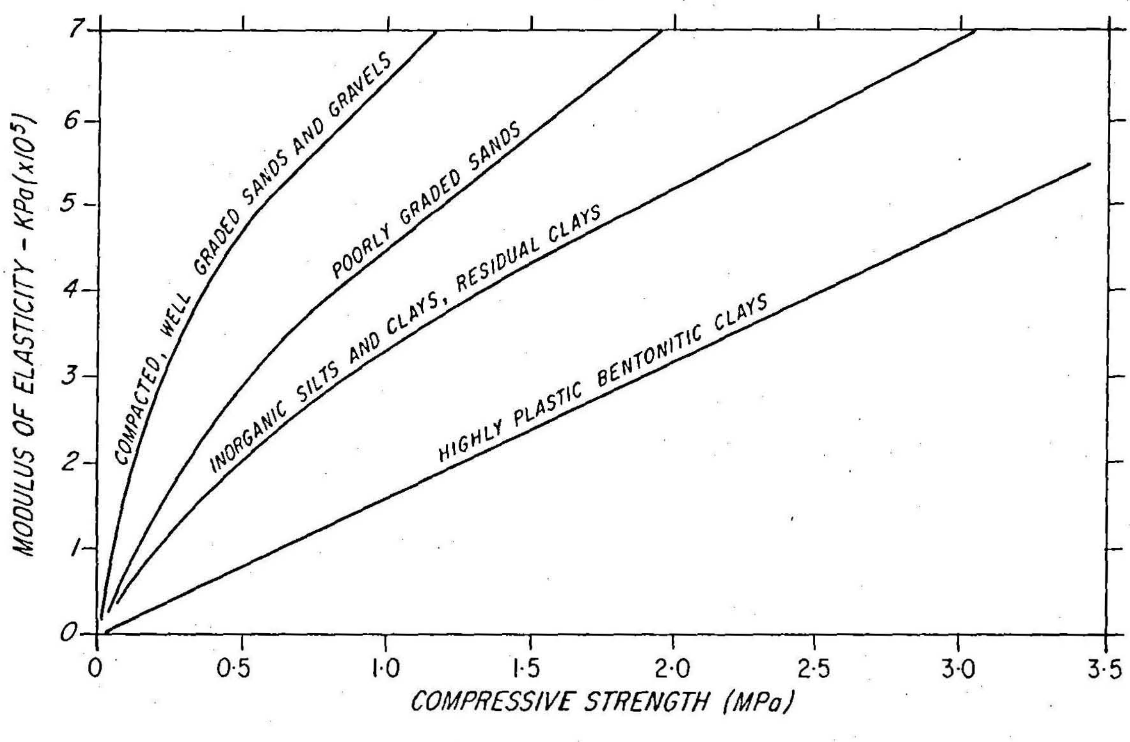
Record No. 1976/88

I55/B5-281A

(Based on I55/B0-78A)



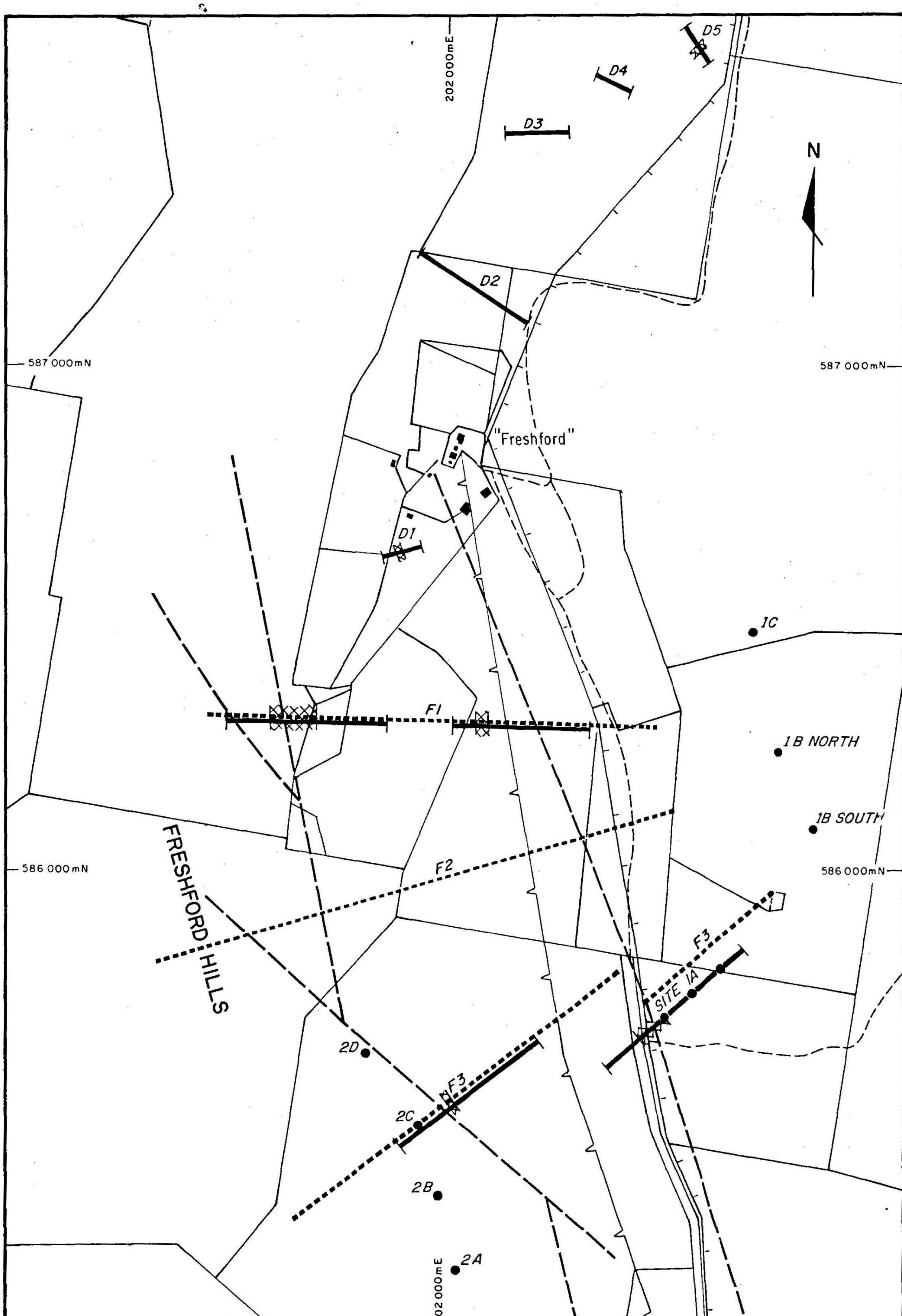
RELATION OF MODULUS OF ELASTICITY TO LONGITUDINAL SEISMIC VELOCITY



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

DYNAMIC PROPERTIES OF ROCKS

PLATE 3



LEGEND

Fence
Telephone line
Power line
Magnetic traverse
Seismic traverse
Reservoir site
Track
Fault zone (seismic)
Predicted fault (geology)

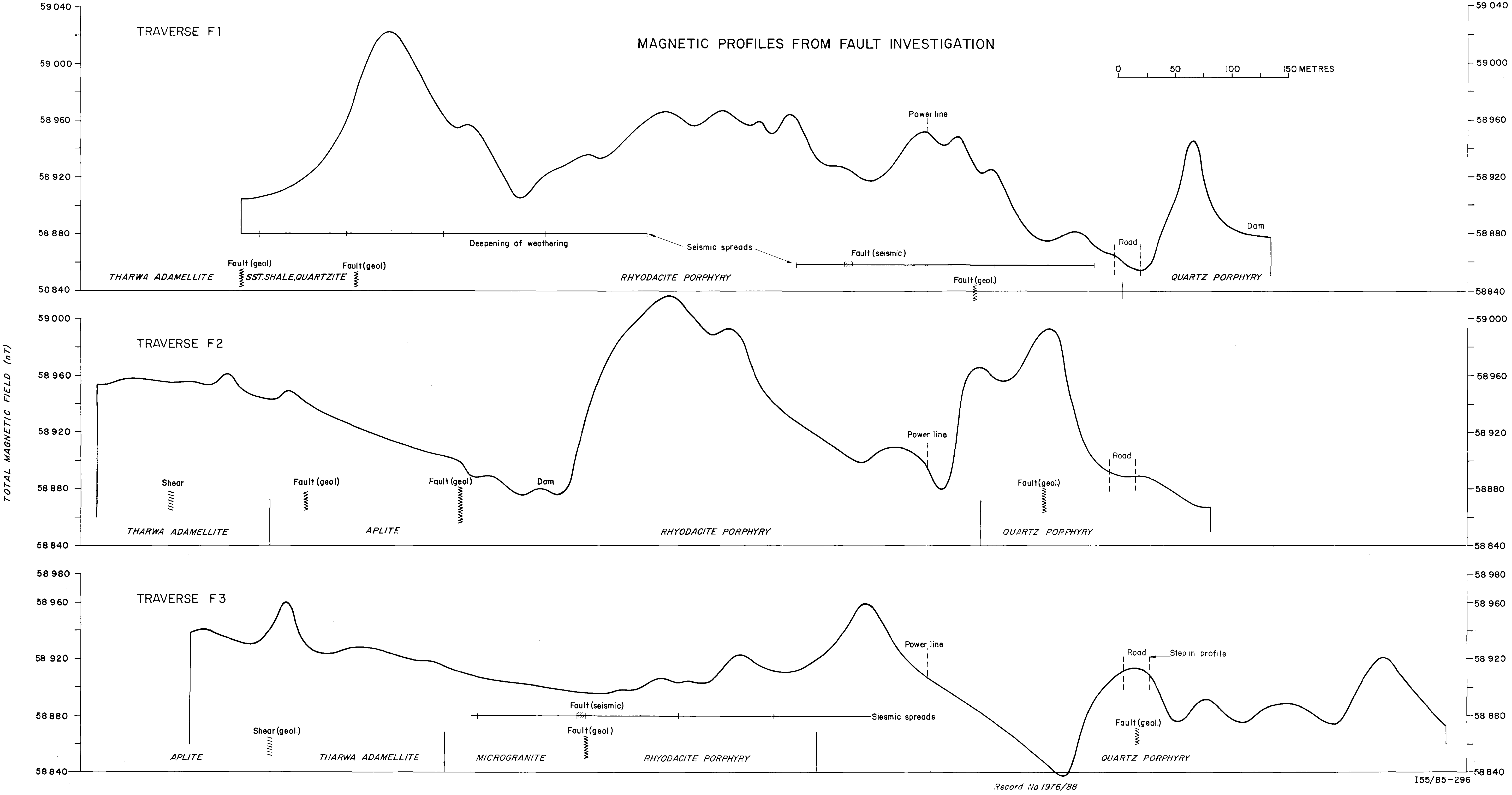
METRES
0 100 200 300 400 500

FAULT AND DRAINAGE INVESTIGATIONS, SEISMIC TRAVERSE PLAN

Record No. 1976/88

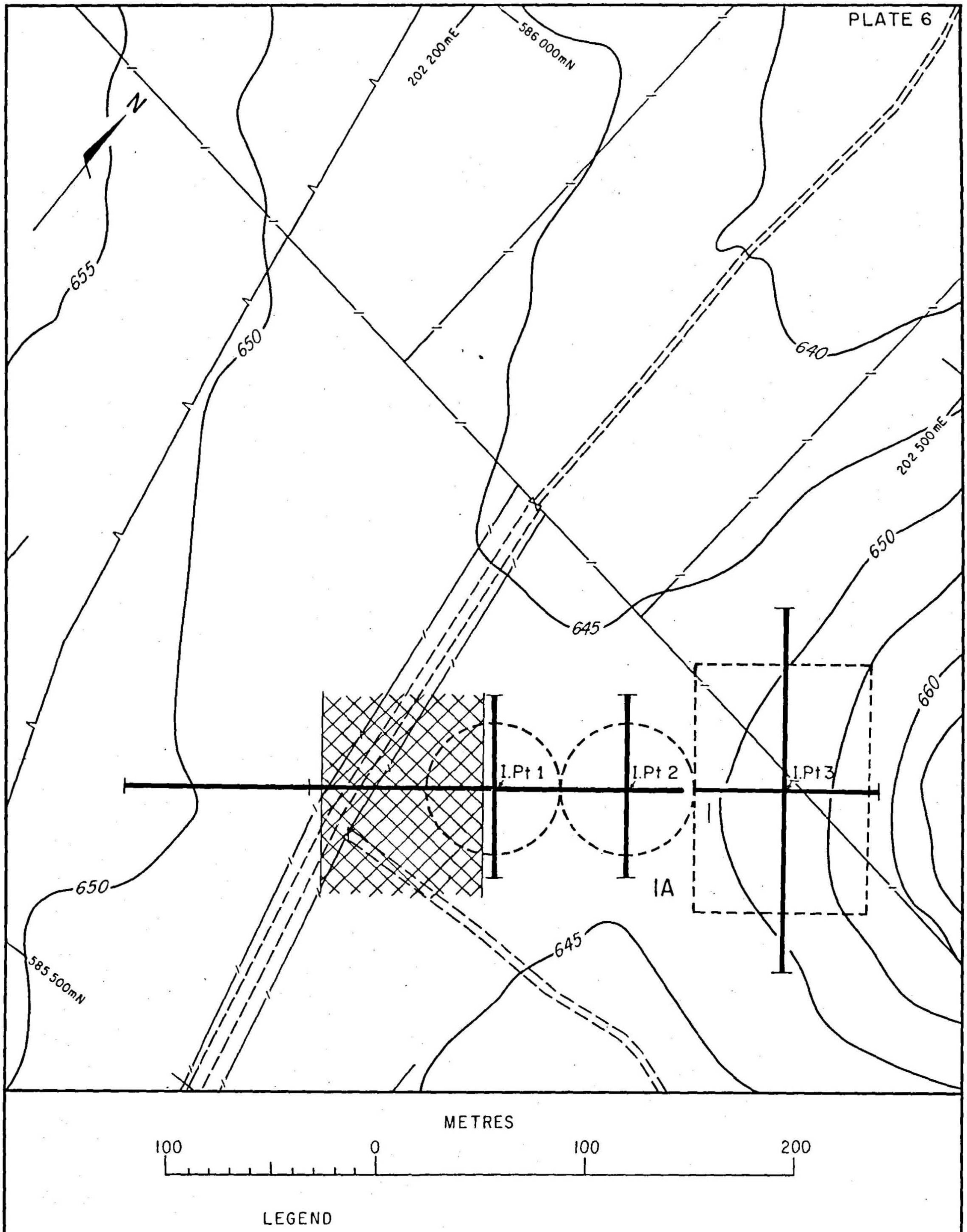
I55/B5-297

SEISMIC SECTIONS FROM FAULT INVESTIGATION


MAGNETIC PROFILES FROM FAULT INVESTIGATION
TRAVERSE F1
TRAVERSE F2
TRAVERSE F3
0 50 100 150 METRES
TOTAL MAGNETIC FIELD (nT)
Power line
Deepening of weathering
Seismic spreads
Fault (seismic)
Fault (geol)
Fault (geol.)
Road
Dam
Shear
Shear (geol.)
Step in profile
Siesmic spreads
THARWA ADAMELLITE
SST.SHALE,QUARTZITE
RHYODACITE PORPHYRY
QUARTZ PORPHYRY
APLITE
MICROGRANITE
59 040
59 000
58 980
58 960
58 920
58 880
58 840

I55/B5-296

PLATE 6



LEGEND

Seismic traverse

Road or track

Fence

645 Elevation contour (metres)

Power line

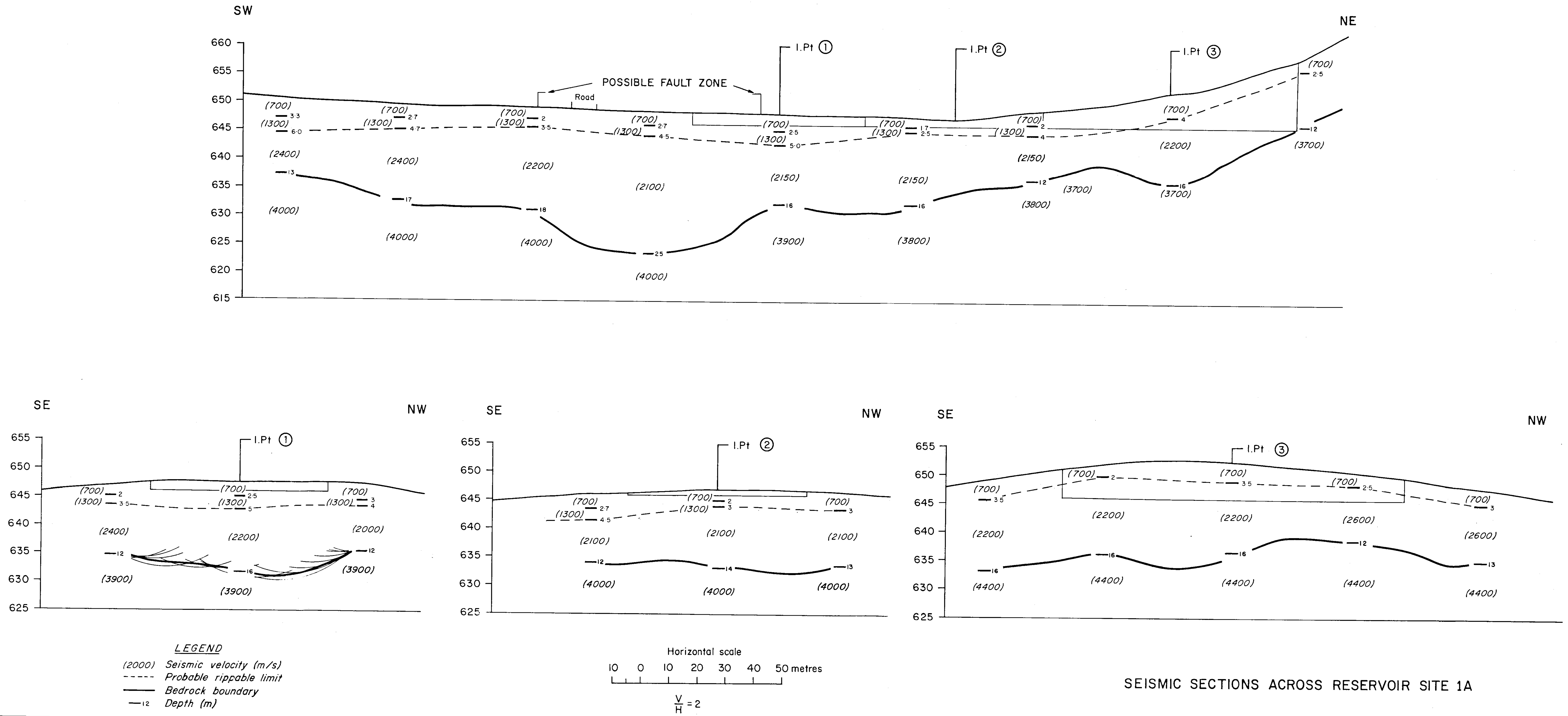
Possible fault zone

RESERVOIR SITE IA
SEISMIC TRAVERSE PLAN

Record No.1976/88

I55/B5-274A

PLATE 7



SEISMIC SECTIONS ACROSS RESERVOIR SITE 1A

Record No 1976/88

I55/B5-289

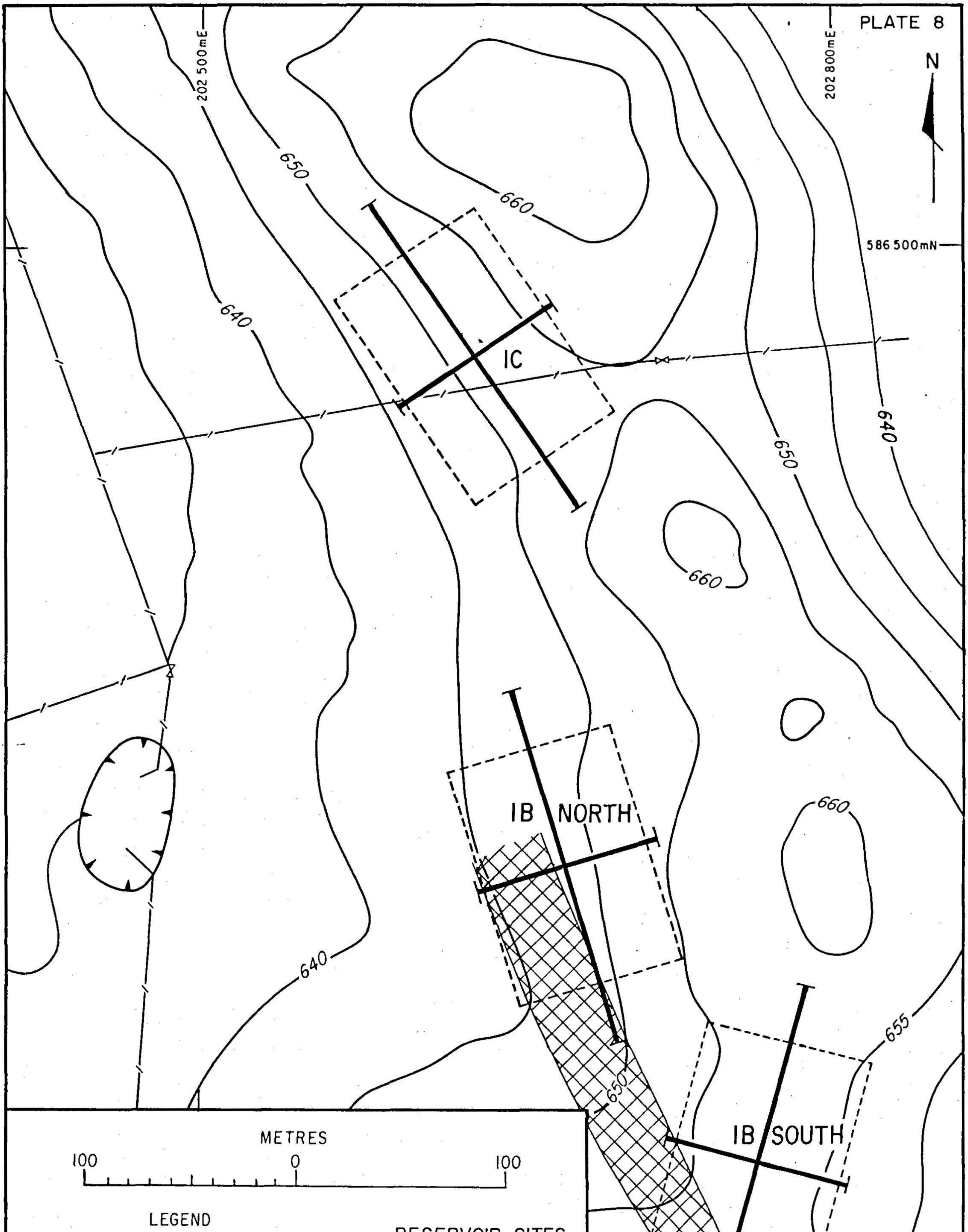


PLATE 8
N
202 500mE
202 800mE
586 500mN
586 000mN
650
660
640
650
640
660
660
640
650
655
650
660
IC
IB NORTH
IB SOUTH
METRES
100
0
100
LEGEND
Seismic traverse
640
Elevation contour (metres)
Fence
Possible fault zone
RESERVOIR SITES
1B AND 1C
SEISMIC TRAVERSE
PLAN
Record No.1976/88
I55/B5-273A

LEGEND

(1000) *Seismic velocity (m/s)*
— 4 *Depth (m)*
—— *Bedrock boundary*
- - - - *Probable rippable limit*

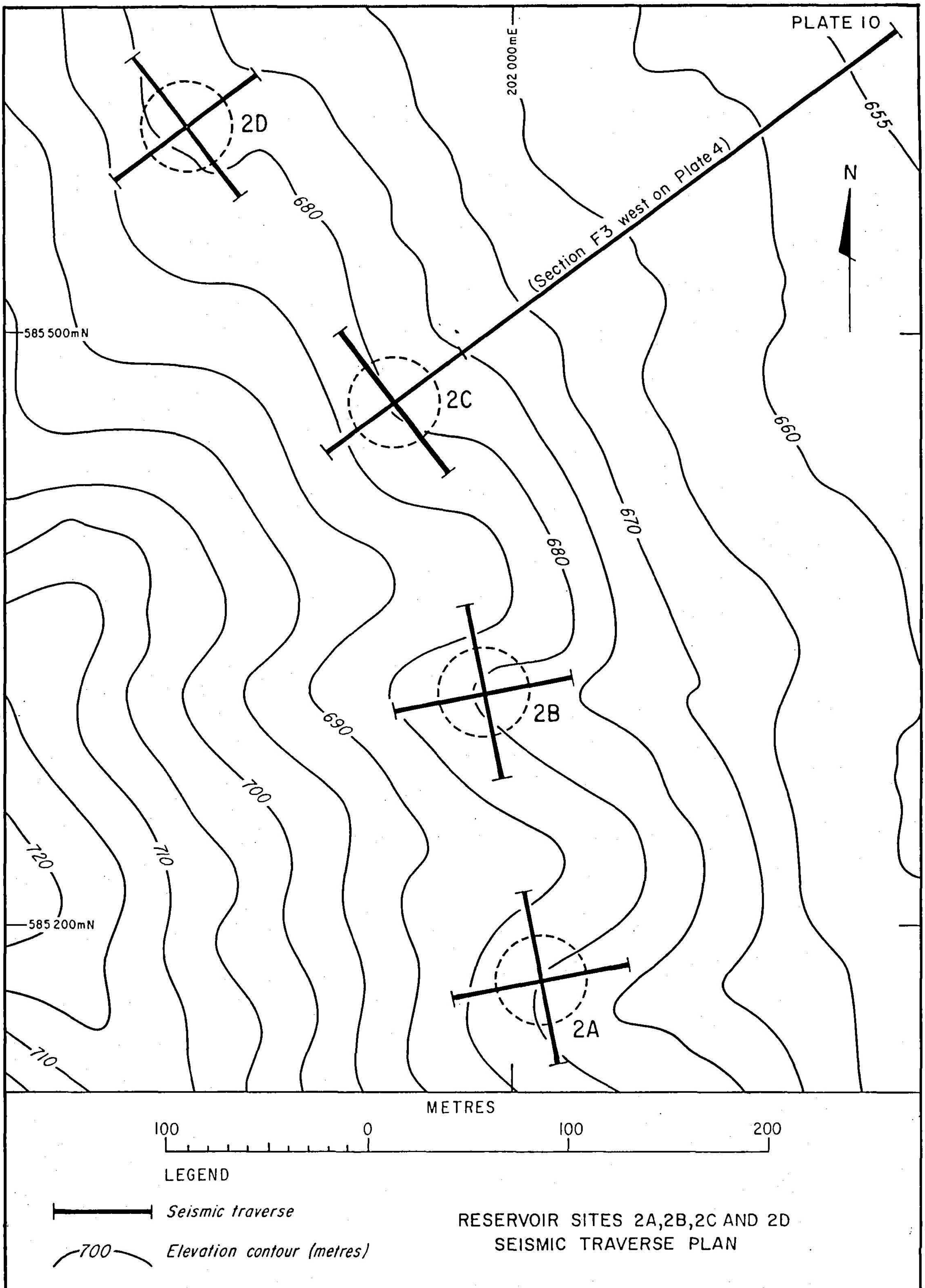
Horizontal scale

10 0 10 20 30 40 50 metres

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

SEISMIC SECTIONS ACROSS RESERVOIR SITES
1B AND 1C

PLATE 10



RESERVOIR SITES 2A, 2B, 2C AND 2D
SEISMIC TRAVERSE PLAN

Record No. 1976/88

I55/B5-275A

Horizontal scale
10 0 10 20 30 40 50 metres

LEGEND

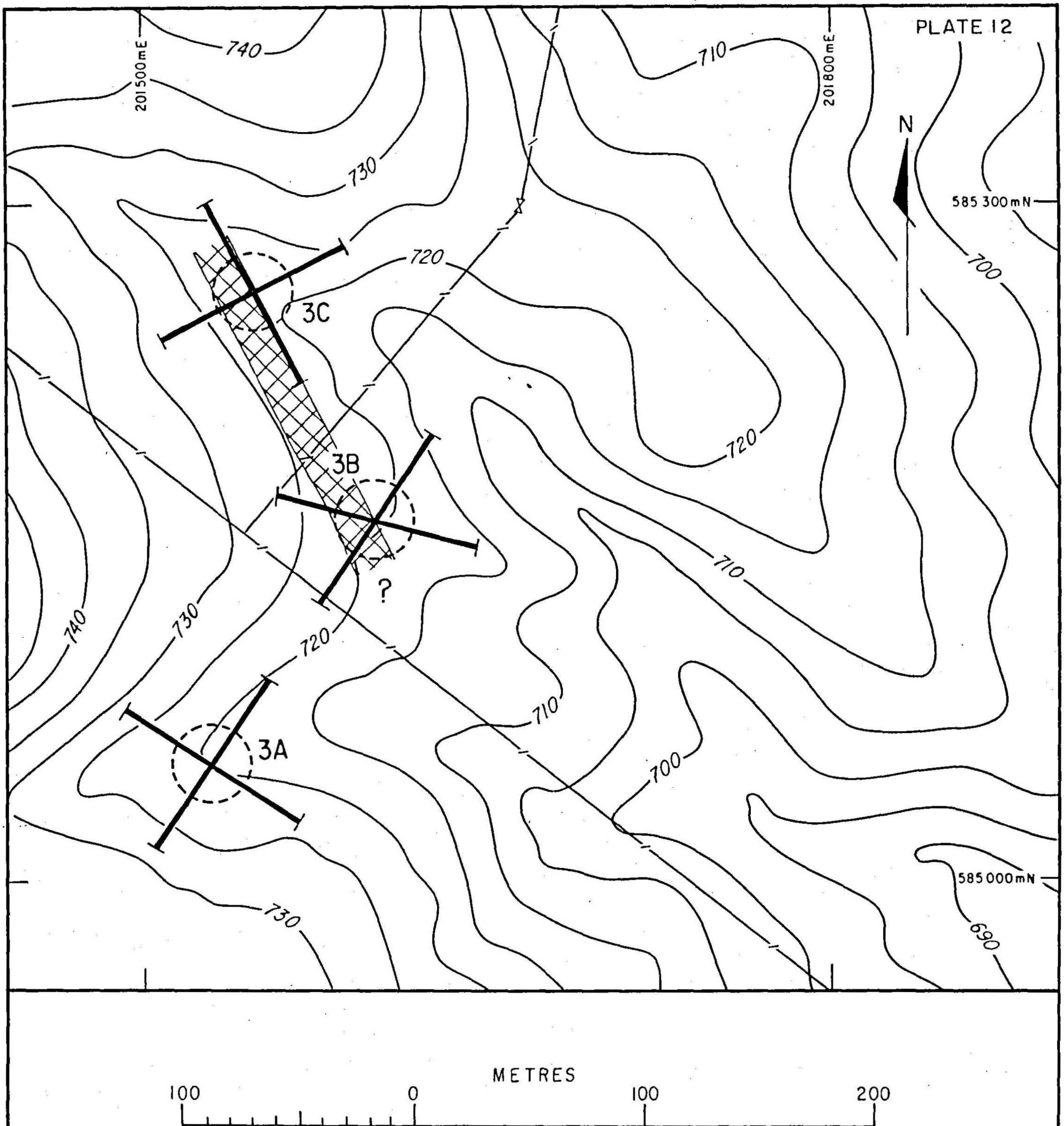
(1000) Seismic velocity (m/s)
— 4 Depth (m)
—— Bedrock boundary
- - - Probable rippable limit
$\frac{V}{H} = 2$
Seismic discontinuity

SEISMIC SECTIONS ACROSS RESERVOIR SITES 2A, 2B, 2C AND 2D

Record No 1976/88

I55/B5-280

PLATE 12



LEGEND

Seismic traverse

730 Elevation contour (metres)

Fence

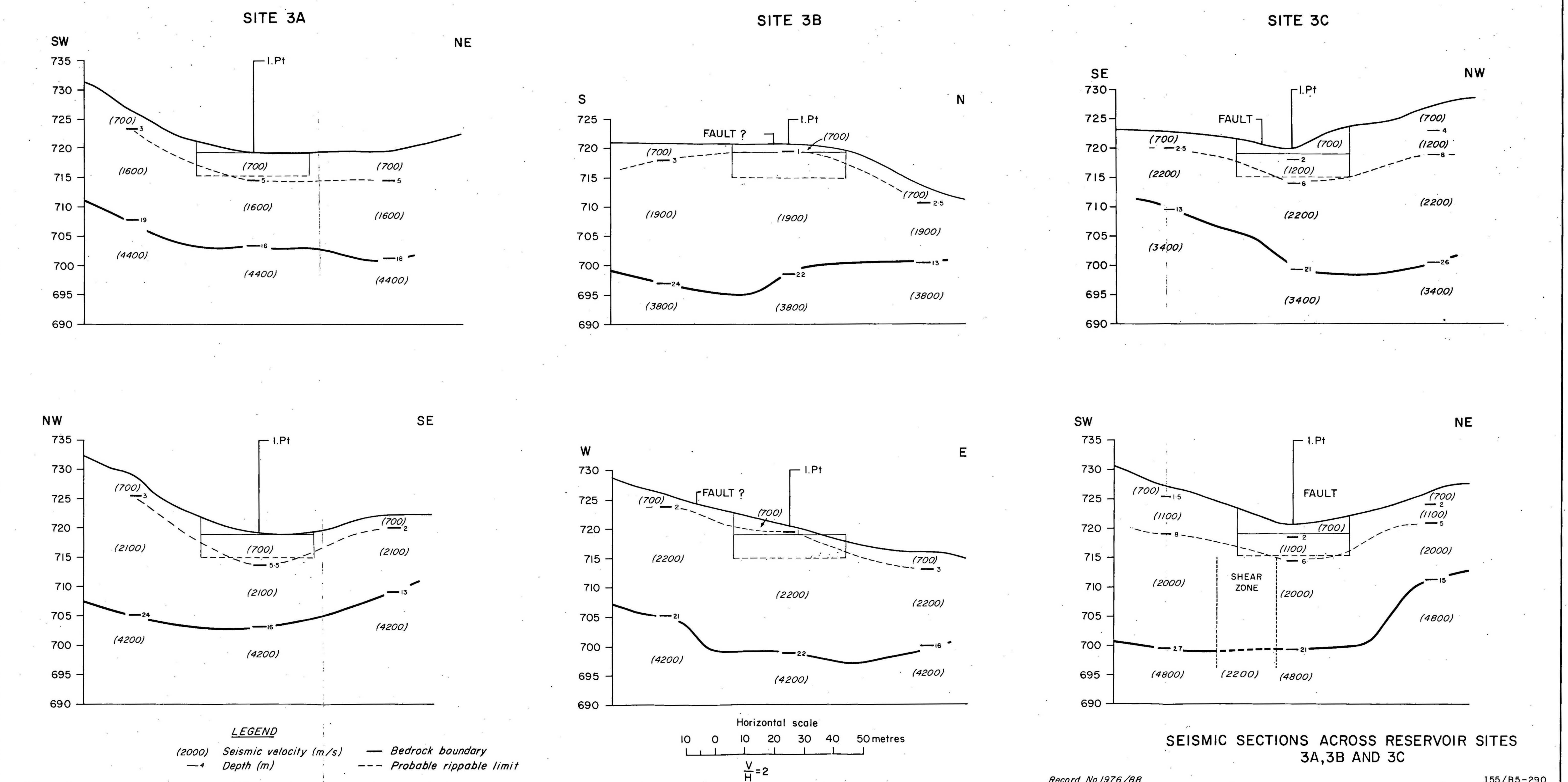
Possible fault zone

RESERVOIR SITES 3A, 3B AND 3C:
SEISMIC TRAVERSE PLAN

Record No. 1976/88

I55/B5-276A

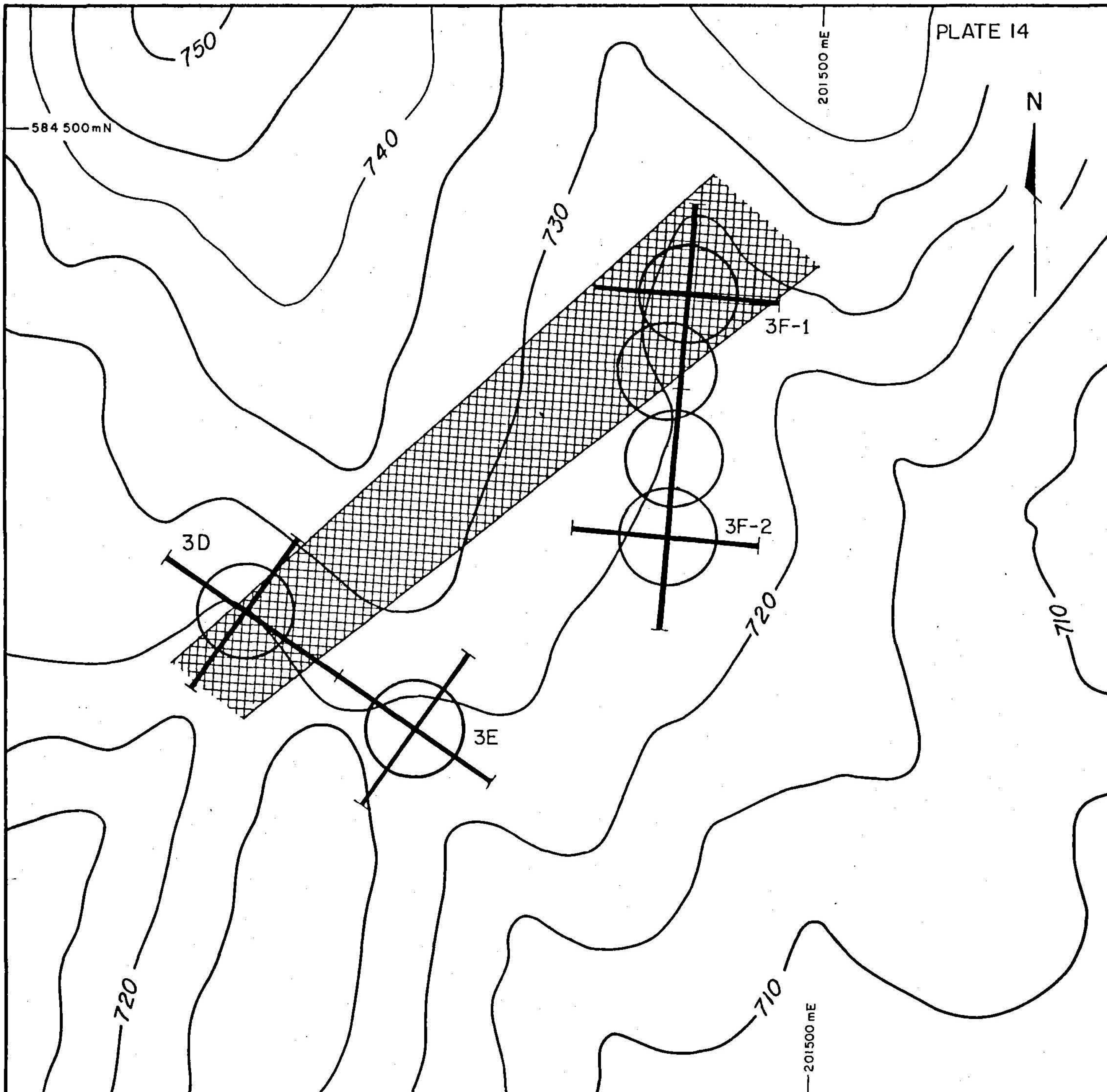
PLATE 13



SEISMIC SECTIONS ACROSS RESERVOIR SITES 3A,3B AND 3C

Record No.1976/88

155/B5-290



METRES

100 0 100

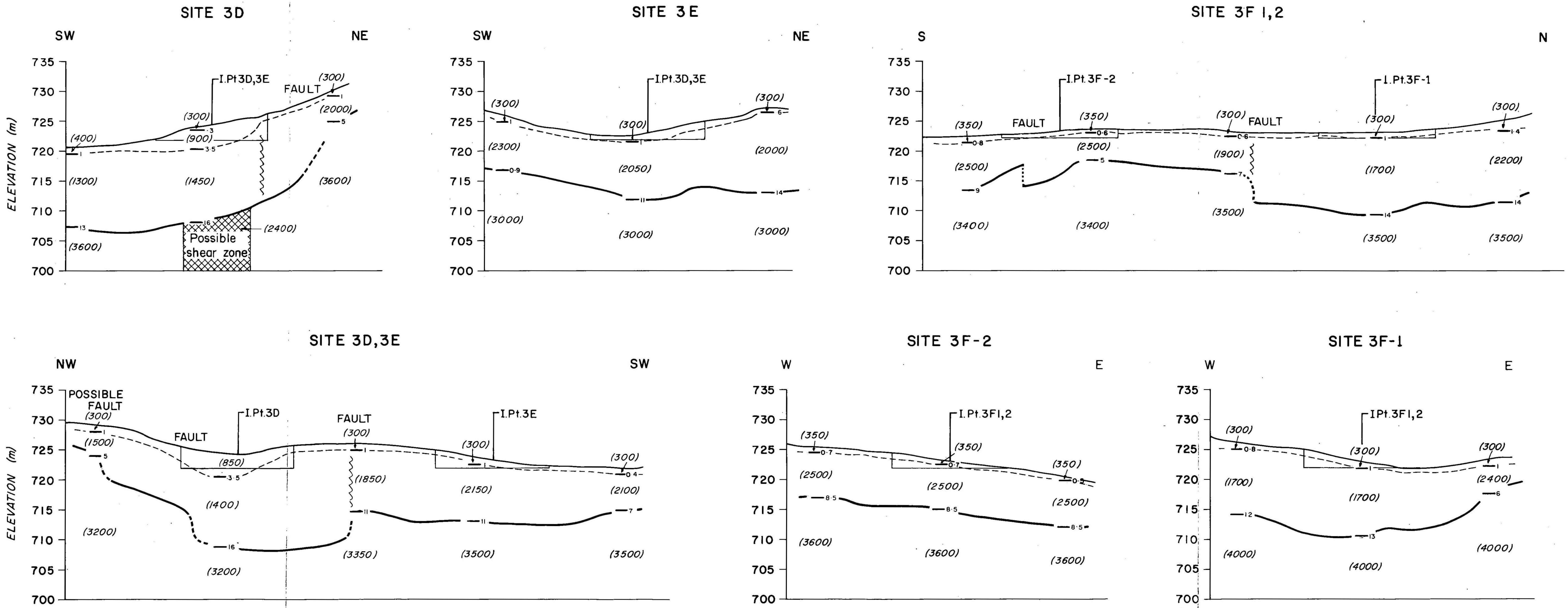
LEGEND

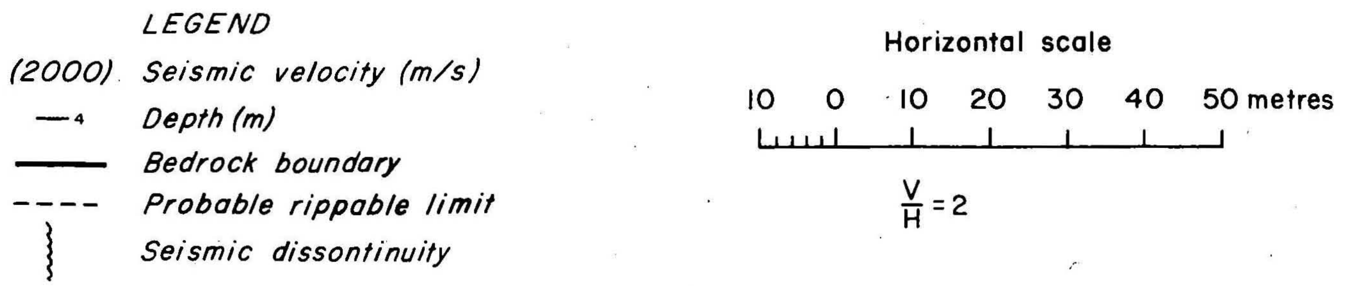
Seismic traverse

720 Elevation contour (metres)

Possible fault zone

RESERVOIR SITES 3D, 3E, AND 3F
SEISMIC TRAVERSE PLAN

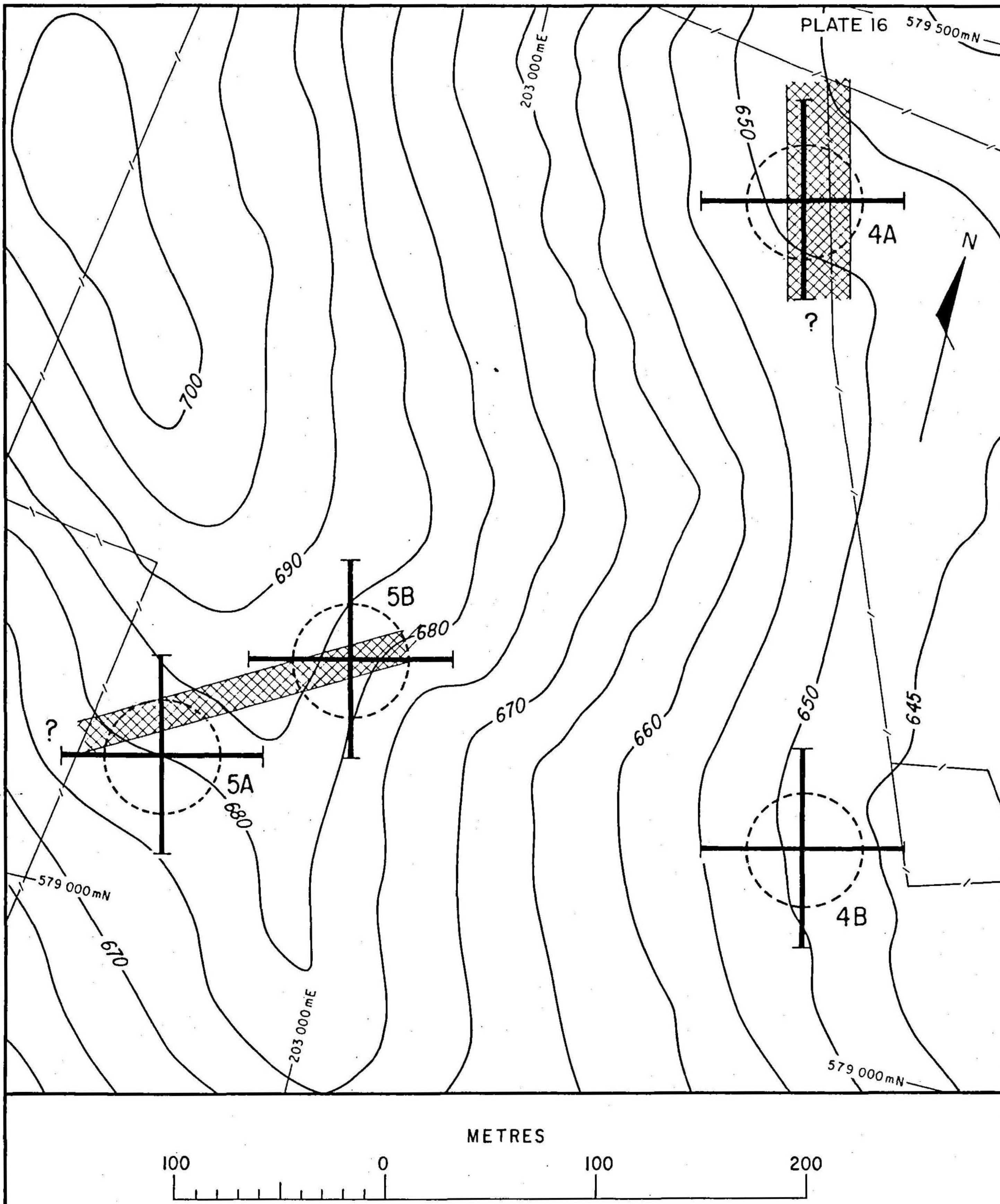




SEISMIC SECTIONS ACROSS RESERVOIR SITES 3D,3E, AND 3F

Record No.1976/88

I55/B5-313



LEGEND

Seismic traverse

Fence

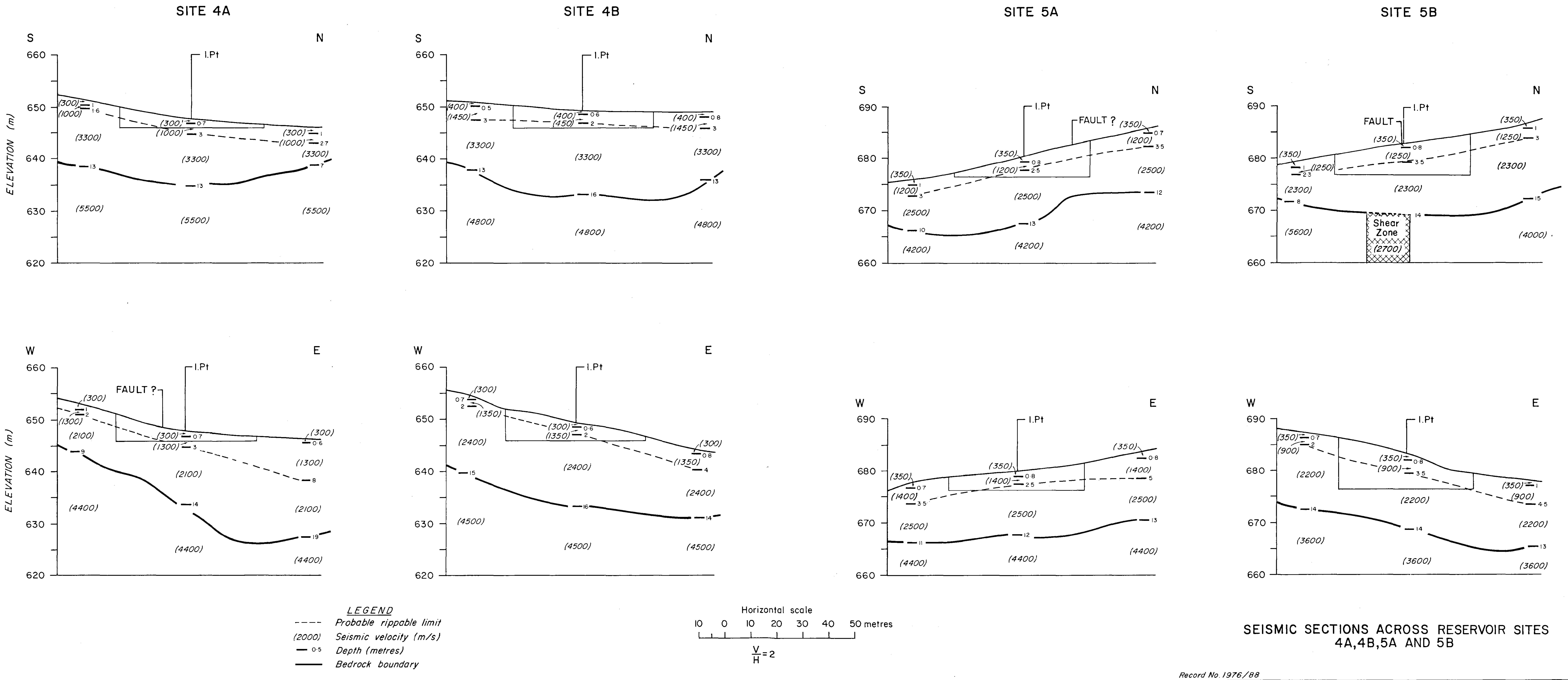
670 Elevation contour (metres)

Possible fault zone

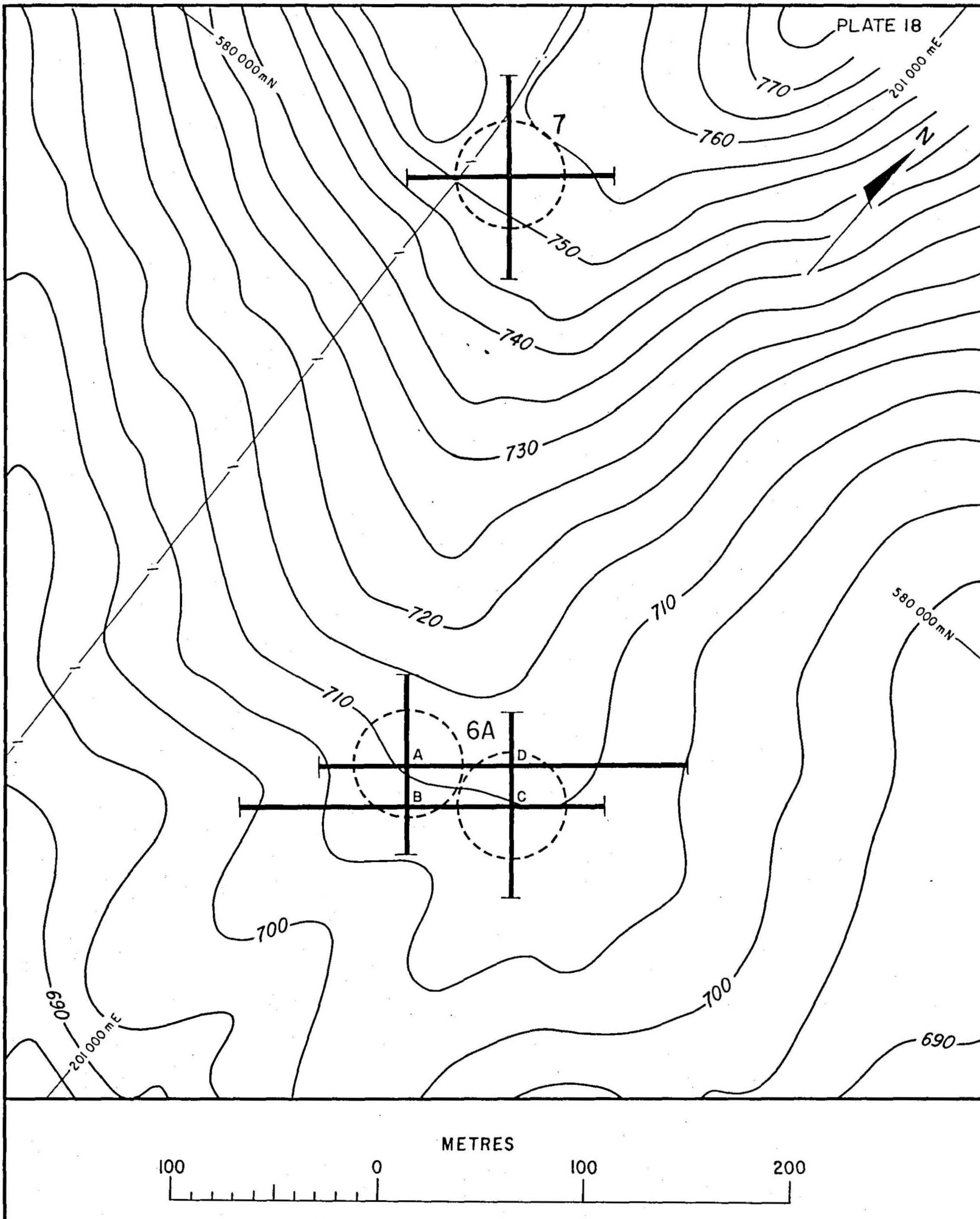
RESERVOIR SITES 4A, 4B, 5A AND 5B
SEISMIC TRAVERSE PLAN

Record No. 1976/88

I55/B5-282A



SEISMIC SECTIONS ACROSS RESERVOIR SITES 4A,4B,5A AND 5B



LEGEND

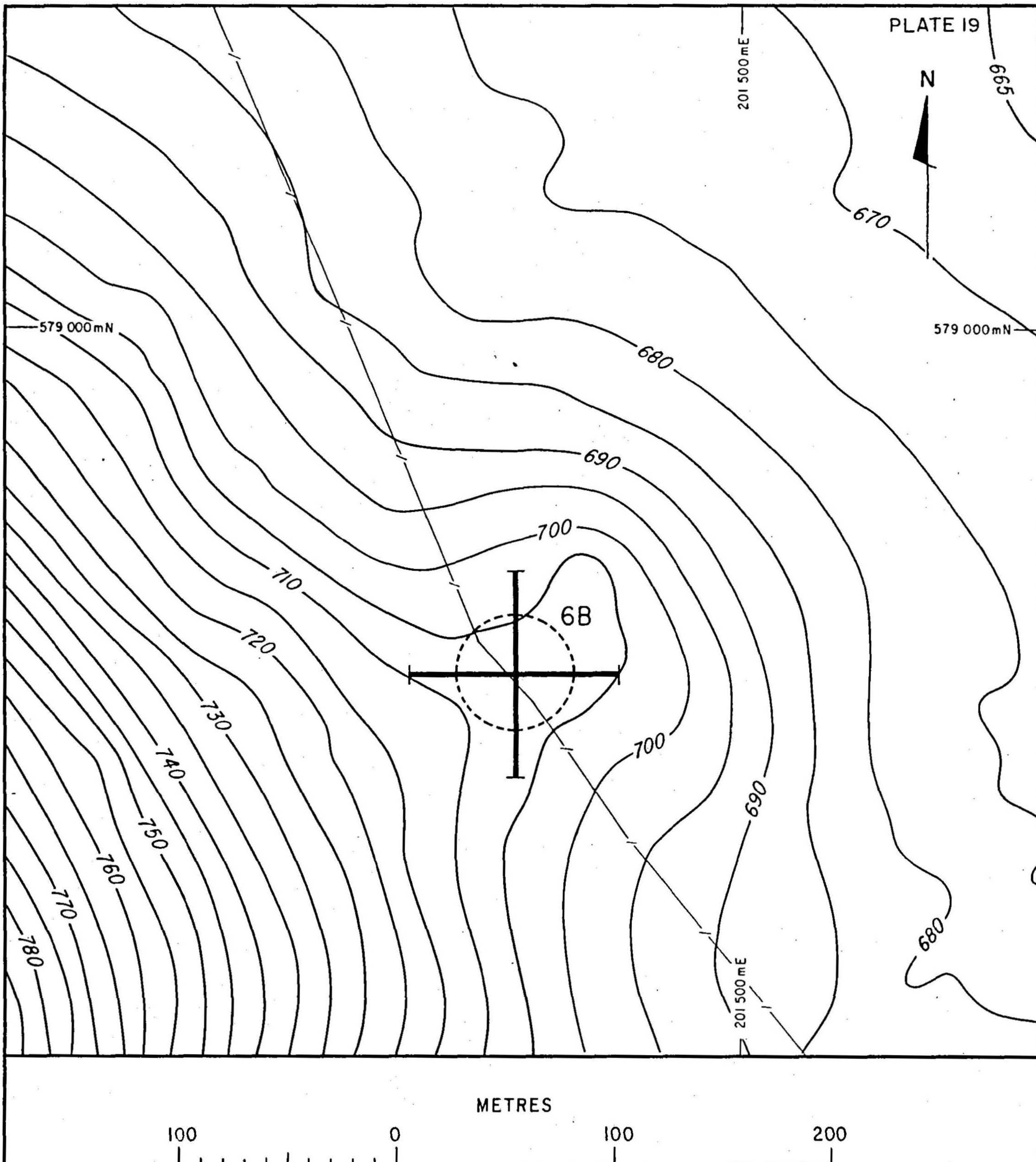
Seismic traverse

Fence

700 Elevation contour (metres)

RESERVOIR SITES 6A AND 7 SEISMIC TRAVERSE PLAN

PLATE 19



LEGEND

Seismic traverse

Fence

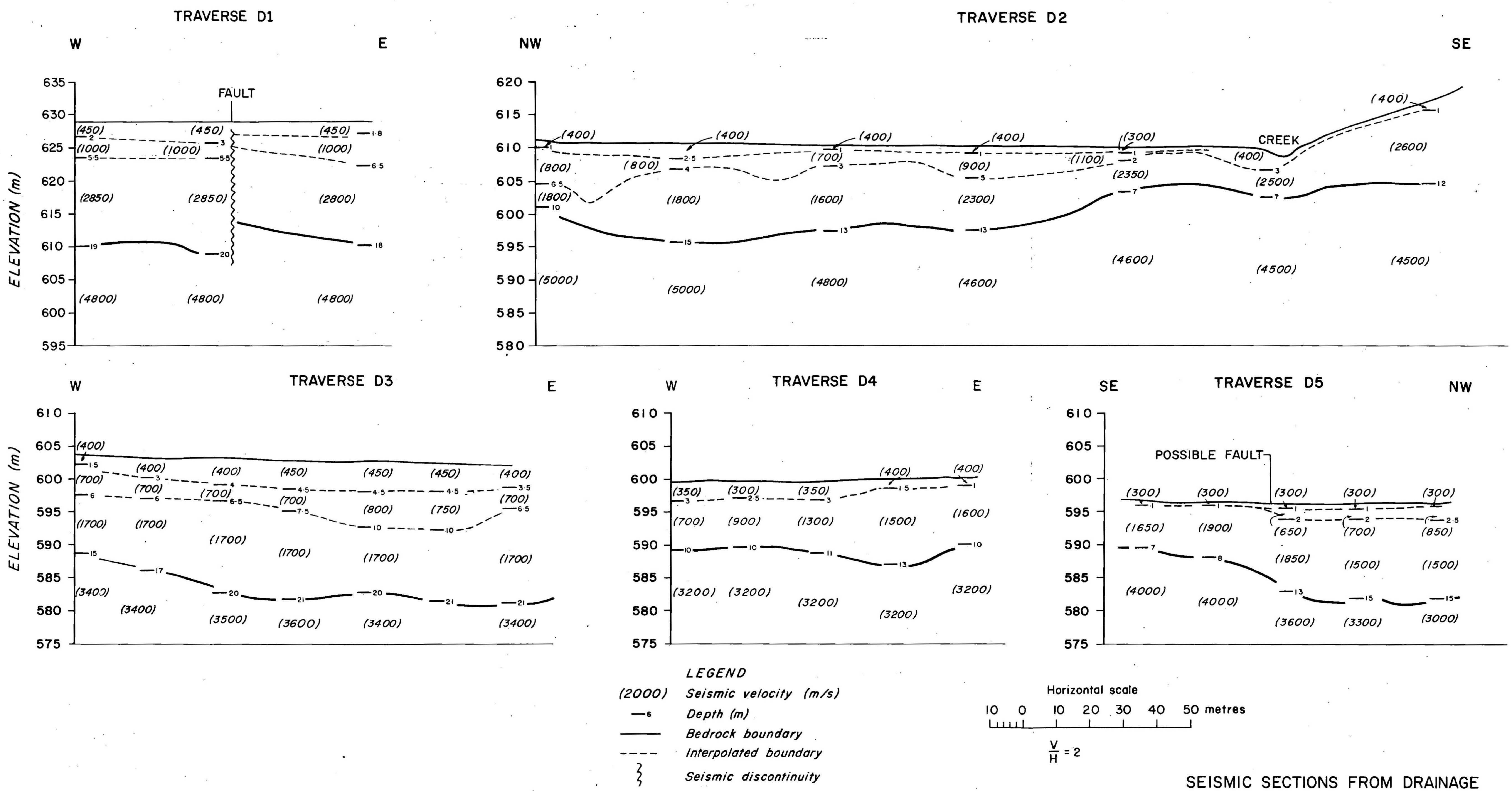
750 Elevation contour (metres)

RESERVOIR SITE 6B
SEISMIC TRAVERSE PLAN

SEISMIC SECTIONS ACROSS RESERVOIR SITES 6A, 6B AND 7

Record No. 1976/88

155/B5-294



SEISMIC SECTIONS FROM DRAINAGE INVESTIGATION