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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1966/39

NILLAHCOOTIE DAM SITE GEOPHYSICAL SURVEY, VICTORIA 1965

by

L. KEVI

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SUMMARY

The object of the survey was to determine the depth and nature of the bedrock at the site of a proposed dam on the Broken River, 22 miles south of Benalla, Victoria.

The results indicate that a shear zone crosses the area in a north-east direction. The bedrock is at a considerable depth (maximum depth 225 feet) under the eastern half of the site and dips steeply to the north. A change in the position of the dam is suggested to avoid this region.

1. INTRODUCTION

The State Rivers and Water Supply Commission of Victoria (SRWSC) proposes to build a dam on the Broken River, 22 miles south of Benalla (Plate 1). The approximate co-ordinates of the site are latitude 36° 51' 30", longitude 146° 01'.

In response to a request from SRWSC, the Geophysical Branch of the Bureau of Mineral Resources (BMR) made a geophysical investigation of the site. The field work was done between 24th February and 22nd March, 1965. The geophysical party consisted of L. Kevi (party leader), J.P. Pigott (geophysical assistant), and four field assistants supplied by SRWSC.

2. GEOLOGY

The following short description of the geology of the area is based on the preliminary geological report provided by SRWSC (Jacobson, 1965).

A relatively small area of the dam site consists of Silurian quartzites and hornfels. The greater part of the area is underlain by Devonian granites. The granite is decomposed in places to a considerable depth. Drill hole DDH4 encountered 135 feet of decomposed granite without reaching the fresh granite.

Tertiary river deposits consisting of rounded pebbles in a sandy clay matrix cover the granite and the quartzite. According to drill hole evidence, the Tertiary deposits are up to 50 feet thick.

In discussing the seismic results, the term 'bedrock' as used in this record is defined as the deepest refractor detected by the seismic survey. In this area the bedrock has a longitudinal wave velocity of from 10,000 to 20,000 ft/s, which represents slightly weathered to fresh granite and quartzite.

3. METHODS AND EQUIPMENT

Seismic refraction method

The method used is described in reports of previous surveys (e.g. Sedmik, 1961).

A 24-channel seismograph manufactured by South-western Industrial Electronics Co. was used with Technical Instruments Co. geophones having a natural frequency of 20 c/s to record the arrival of the longitudinal waves. Three-component Hall-Sears Inc. geophones with a natural frequency of 4.5 c/s were used to record longitudinal and transverse waves.

The layout of the traverses is shown in Plate 2. The geophone spacing used was 50 feet. Two shots were fired from each end of each geophone spread, one at 25 feet and one at 200 feet from the end. One shot was also fired at the centre of the spread. In addition to the 'normal' spreads with 50-ft geophone-spacing, 'weathering' spreads with 10-ft geophone-spacing were used to obtain the velocities of the upper layers. The total length of seismic traverses was 19,500 feet.

Magnetic method

The method is described by Sedmik (1961). A vertical component fluxgate magnetometer manufactured by Sharpe (Type MF1, serial number 30749) was used. The sensitivity of the instrument is 20 gammas per scale division.

Readings were taken along some of the seismic traverses at 50-ft intervals. The total length of the magnetic traverses was 7000 feet.

Laboratory tests

Laboratory measurements were made on cores obtained from drill holes to determine the elastic properties of the rocks. The method is based on measurements of the velocity of longitudinal waves in a bar - bar velocity (V_b) - and in the extended medium - bulk velocity (V_p).

The bar velocity was obtained using the Cawkell electrodynamic materials tester type SCT4. The specimen was clamped at its centre in a horizontal position and was subjected to longitudinal sonic vibrations. The frequency (f_o) at which the specimen resonates in its fundamental mode was measured. The width of the response curve (Δf) at $1/\sqrt{2}$ of the amplitude at the resonant frequency was also measured. The bar velocity is given by :

$$V_b = 2Lf_o$$

where L is the length of the specimen. The logarithmic decrement (δ) and the quality factor (Q) are given by :

$$\delta = \pi \Delta f / f_o \qquad \text{and} \qquad Q = \pi / \delta$$

The bulk velocity was obtained using a Cawkell ultrasonic materials tester type UCT2. This equipment measures the travel time of a pulse of ultrasonic longitudinal waves at 120 kc/s through a specimen of known length (L), so that the bulk velocity is obtained.

Knowing V_p, V_b, and the density (ρ), Young's modulus (E) and Poisson's Ratio (σ) can be computed using the formulae :

$$E = cV_b^2 \rho$$

and

$$(V_p / V_b)^2 = (1-\sigma)/(1-2\sigma)(1+\sigma)$$

where c is a constant that depends on the system of units used.

The laboratory tests were done by C. L. Cookson in the BMR laboratories at Footscray.

4. RESULTS

Seismic velocities

The seismic velocities observed can be arranged in groups as shown in Table 1.

The bedrock velocities obtained along the seismic traverses are shown in Plate 2. A zone of low bedrock velocities is present at about 500 feet east of the river. This low-velocity zone suggests a shear zone with a strike approximately north-east.

At some intersections of traverses, different velocities were observed in different directions (see Table 2).

Small differences may be due to observational errors. Larger differences (intersections 01 & 13, 02 & 04, 04 & 08) are probably due to velocity anisotropy, this may be due to jointing, the velocity along the direction of joints being greater than across the joints.

TABLE 1

Relation between seismic velocity and rock type

Longitudinal wave velocity (ft/s)	Rock type
1000	Soil
2000-5000	Hillwash, sandy clay, soft decomposed granite
6000-7000	Weathered granite
10,000-20,000	Slightly weathered to fresh granite and quartzite.

TABLE 2

Seismic velocities at traverse intersections

Traverse intersections	Bedrock velocity (ft/s)	;	Direction	Bedrock velocity (ft/s)	;	Direction
01 & 13	20,000	;	116°	16,000	;	175°
01 & 09	16,000	;	116°	14,000	;	68°
02 & 04	16,000	;	149°	12,000	;	116°
03 & 13	15,000	;	116°	16,000	;	175°
04 & 10	18,000	;	116°	16,000	;	35°
04 & 13	15,000	;	116°	16,000	;	175°
04 & 09	15,000	;	116°	14,000	;	68°
04 & 08	12,000	;	116°	15,000	;	47°
05 & 08	14,000	;	116°	15,000	;	47°
06 & 08	16,000	;	116°	15,000	;	47°

TABLE 3

Comparison of drilling and seismic results

Drillhole	Depth to bedrock according to seismic results (feet)	Depth to fresh or hard weathered granite in drillhole (feet)	Error (%)
DDH1A	59	50	+ 18
DDH1	68	65	+ 3
DDH2	115	97	+ 18
DDH12	40	36	+ 9
DDH13	52	45	+ 16

Depths to bedrock

The depths to bedrock are shown in Plates 3 and 4. The bedrock is deepest (225 feet) at the northern end of Traverse 08.

The contours of the bedrock as obtained by the seismic survey are shown in Plate 2. Traverse 14 is located about three-quarters of a mile downstream from the area shown in Plate 2. No plan is available for this area, thus Traverse 14 is shown only as a profile in Plate 4.

The bedrock contour map shows the lowest bedrock elevation at the northern end of Traverse 08. Steep gradients of bedrock are observed along the eastern half of the proposed axis of the dam (Traverse 01).

Accuracy of seismic depth determination. The depth to bedrock (d) was computed using the formula :

$$d = t . C$$

where t is the travel time and C is a conversion factor.

For the meaning of these terms the reader is referred to Sedmik (1961).

The error in the conversion factor depends on the error due to the extrapolation involved in determining the intercept time and on the error involved in fitting straight lines to points of the time/distance curves to determine the velocity of the various layers. By computing several conversion factors for the same points, using different possible extrapolations and different possible velocities, the standard percentage error in C was found to be ± 13%.

The error in the travel time depends on the readability of the seismic record. The standard percentage error in t was estimated as ± 3%.

The standard error of a product equals the square root of the sum of the squares of the standard errors of the factors forming the product. Thus the standard percentage error in d is 13.4%.

Table 3 compares drilling and seismic results.

At the point of intersection of two seismic spreads, two values of depth were obtained. The difference between these values gave further information about the accuracy of the depth determination. Twenty-three pairs of values were obtained. The greatest deviation from the mean was found to be 18%. The standard deviation was 9.6%.

Magnetic results

The results of the magnetic measurements are shown in Plate 5. No correlation was found between depth to bedrock and variation in the vertical component of the magnetic field. The disturbance on the magnetic profile along Traverse 07 between 0707 and 0702 and along Traverse 05 between 0507 and 0501 may be an indication of the edge of the granite intrusion.

Dynamic properties of rocks - field determination

The dynamic constants of the bedrock were determined by measuring the longitudinal and transverse wave velocities at two localities. The measurements were made along two 100-ft sections of Traverse 01; thus, the calculated values represent average moduli along the measured length in the direction of measurement. The values obtained are given in Table 4.

Young's modulus was computed for a density of 2.55 g/cm^3. This density was obtained by measurements on the core sample from drill hole DDH 13.

Accuracy of field determination of Poisson's ratio. The error in Poisson's ratio as determined by the seismic method depends on the error in the ratio V_p / V_s, where V_s is the transverse wave velocity. For a given error in V_p/V_s, the error in Poisson's ratio increases as its value decreases. The standard percentage error in V_p/V_s was estimated as ± 8%. The resulting standard percentage error in σ is ± 34% when σ = 0.25.

Accuracy of field determination of Young's modulus. Young's modulus was computed using the formula :

$$E = \rho \frac{V_s^2 (3V_p^2 - 4V_s^2)}{(V_p^2 - V_s^2)}$$

The standard percentage error in E is given by :

$$\alpha = \sqrt{\alpha_1^2 + f(V)\alpha_2^2 + F(V)\alpha_3^2}$$

where α = standard percentage error in E

α_1 = standard percentage error in ρ

α_2 = standard percentage error in V_p

α_3 = standard percentage error in V_s

$$f(V) = \left[\frac{2V_s^2 \cdot V_p^2}{(V_p^2 - V_s^2)(3V_p^2 - 4V_s^2)}\right]^2 = \left[\frac{V_p}{E}\frac{\partial E}{\partial V_p}\right]^2$$

$$F(V) = \left[\frac{2(3V_p^4 - 8V_p^2V_s^2 + 4V_s^4)}{(V_p^2 - V_s^2)(3V_p^2 - 4V_s^2)}\right]^2 = \left[\frac{V_s}{E}\frac{\partial E}{\partial V_s}\right]^2$$

α_1 was estimated as ± 4%, α_2 as ± 3%, and α_3 as ± 5%. The value of f(V) = 0.52 and F(V) = 1.64 when V_p = 15,000 ft/s and V_s = 9,000 ft/s. Thus, the standard percentage error in E was found to be ± 8%.

Dynamic properties of rocks - laboratory tests.

The results of laboratory tests are given in Table 5.

The accuracy of the laboratory determination of Young's modulus is estimated as ± 10%. The values refer to the individual samples tested in the laboratory and may not be correct for the rock in bulk.

5. CONCLUSIONS

(1) The axis of the proposed dam crosses a probable shear zone situated 400 to 600 feet east of the river.

(2) East of this shear zone the axis of the proposed dam (Traverse 01) crosses an area where bedrock is deep (maximum depth 225 feet) and sloping steeply to the north. It may be advisable to realign the proposed dam axis to avoid this region.

(3) Values of Young's modulus of bedrock as measured in the field are 6.6 and 7.7 x 10^6 lb/in^2. Laboratory measurements give values of 3.3 and 8.2 x 10^6 lb/in^2.

TABLE 4

Dynamic properties of rocks - field determination

Traverse	Station	V_p (ft/s)	$\frac{V_p}{V_s}$	σ	E (lb/in^2)
01	4-6	15,000	1.70	0.24	6.6×10^6
01	20-22	16,000	1.67	0.22	7.7×10^6

TABLE 5

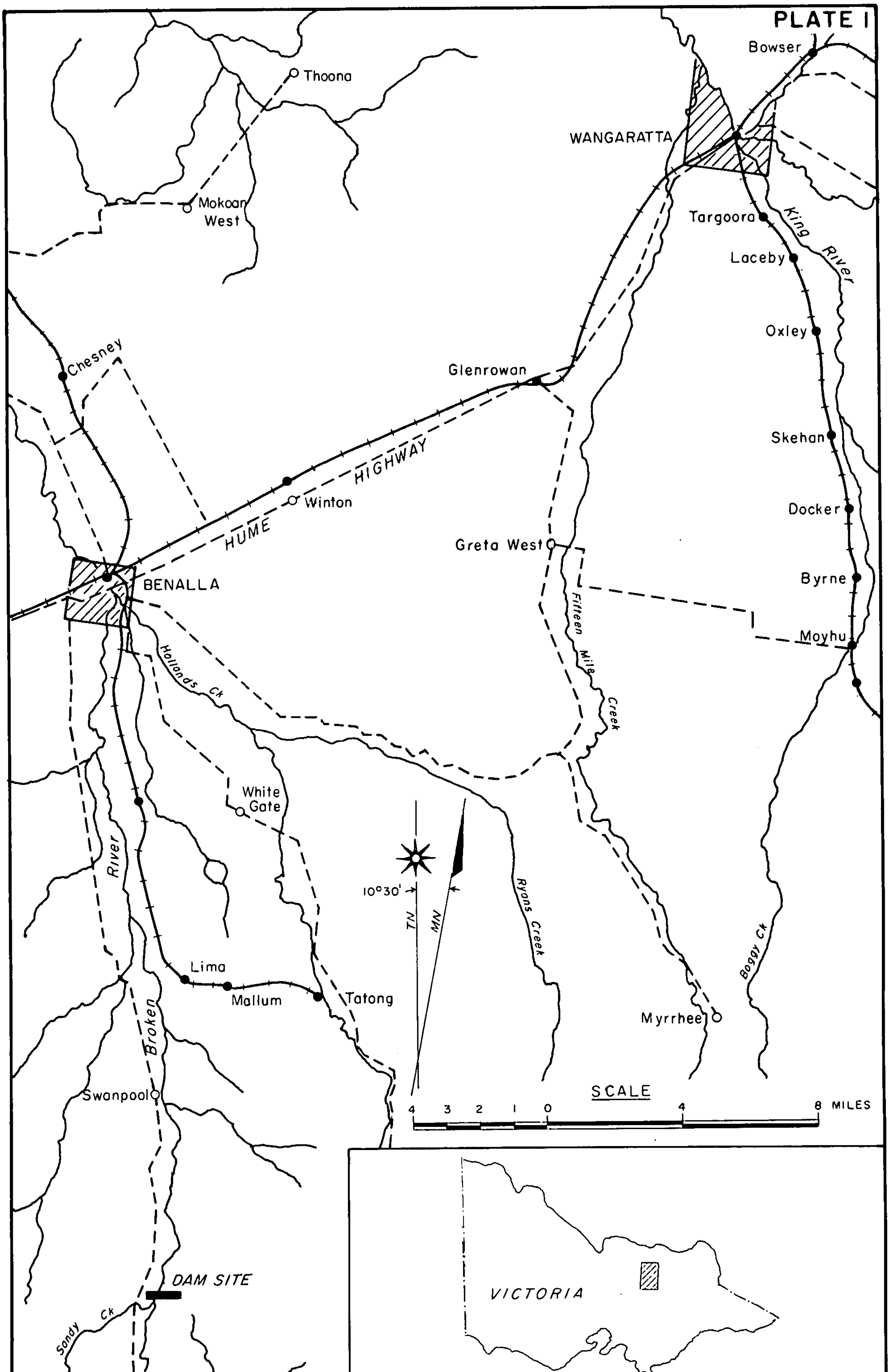
Dynamic properties of rocks - laboratory tests

Drill hole	Depth (feet)	Description	ρ (g/cm^3)	V_p (ft/s)	V_s (ft/s)	σ	E (10^6lb/in^2)	δ
DDH13	26.6	Granite, soft decomposed	1.77	3500	1522	0.46	0.06	0.78
DDH13	30	Granite, soft decomposed	1.89	3600	3190	0.27	0.26	0.16
DDH13	55	Granite, hard weathered, ironstained joints	2.40	7380	4280	0.43	0.40	0.21
DDH13	59	Granite, hard weathered	2.49	13,620	9870	0.38	3.3	0.14
DDH13	77.6	Granite, hard weathered	2.55	17,100	15,500	0.26	8.2	0.09

6. REFERENCES

G. JACOBSON 1965 Nillahcootie dam site - geology. Progress Report No. 1 State Rivers and Water Supply Commission (unpublished).

E.C.E. SEDMIK 1961 Buffalo River No. 1 dam site geophysical survey, Victoria 1961. Bur. Min. Resour. Aust. Rec. 1961/136.



NILLAHCOOTIE DAM SITE, 1965

LOCALITY MAP

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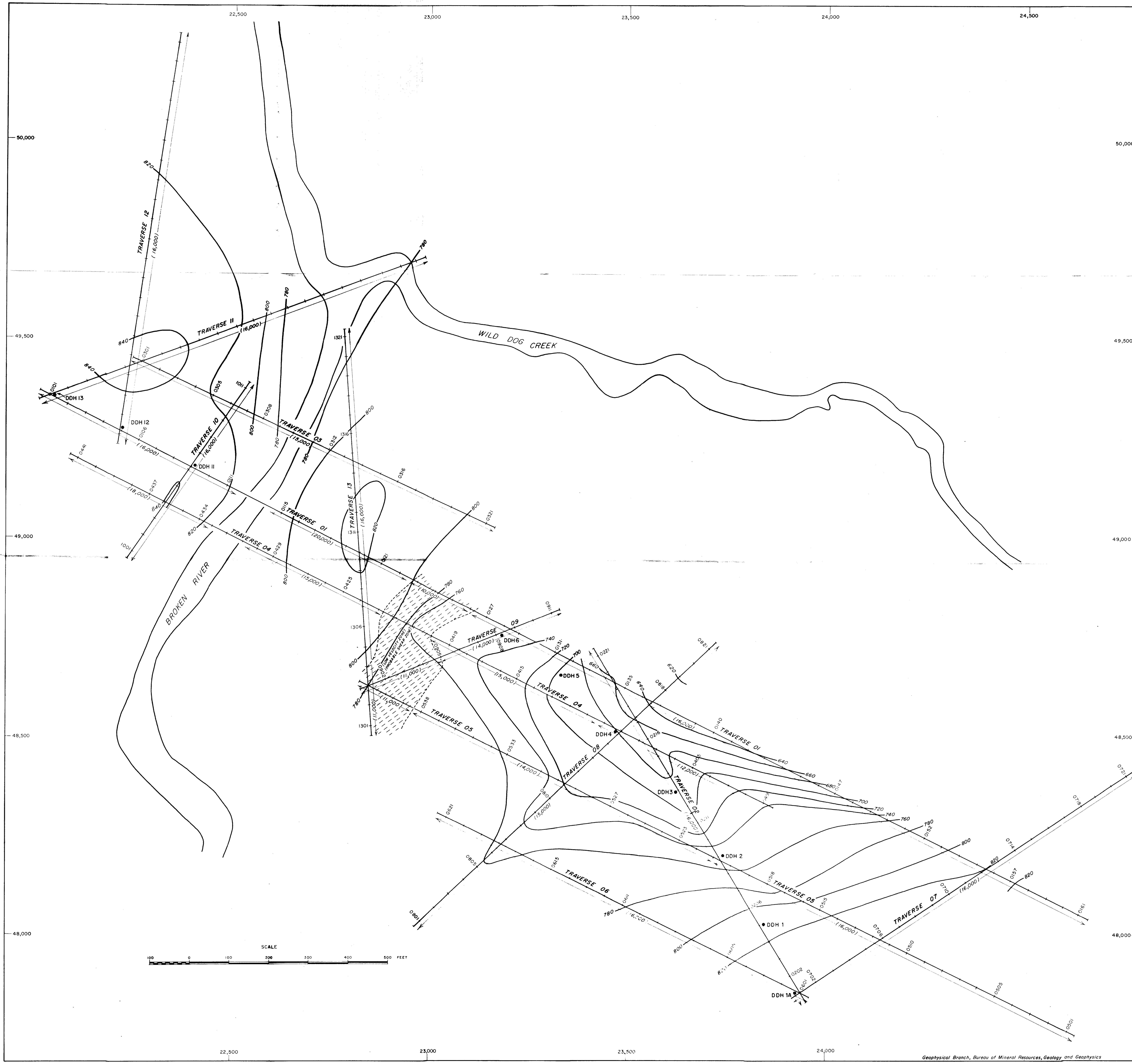
J55/B5-19

PLATE 2



LEGEND

720	Bedrock contours in feet above sea level (contour interval 20 feet)
0810 TRAVERSE 08	Seismic traverse with station number
(16,000)	Seismic velocity of bedrock in ft/s
● DDH 4	Diamond - drill hole

Co-ordinates refer to local grid established by State Rivers and Water Supply Commission

LOCATION OF TRAVERSES SHOWING BEDROCK CONTOURS BASED ON SEISMIC RESULTS

NILLAHCOOTIE DAMSITE VICTORIA, 1965

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PLATE 3

SEISMIC CROSS-SECTIONS
TRAVERSES 01,02,03,04,05,AND 06

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PLATE 4

SEISMIC CROSS-SECTIONS

TRAVERSES 07,08,09,10,11,12,13,& 14

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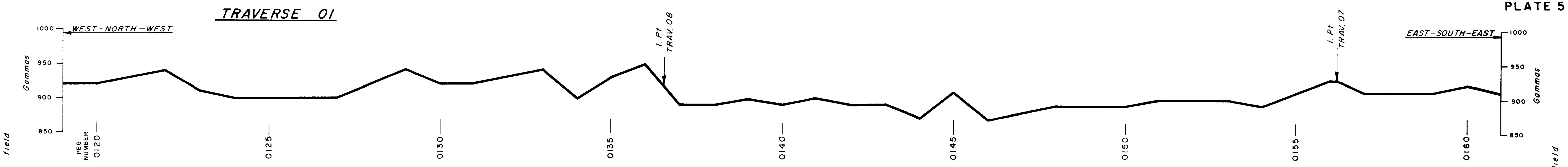
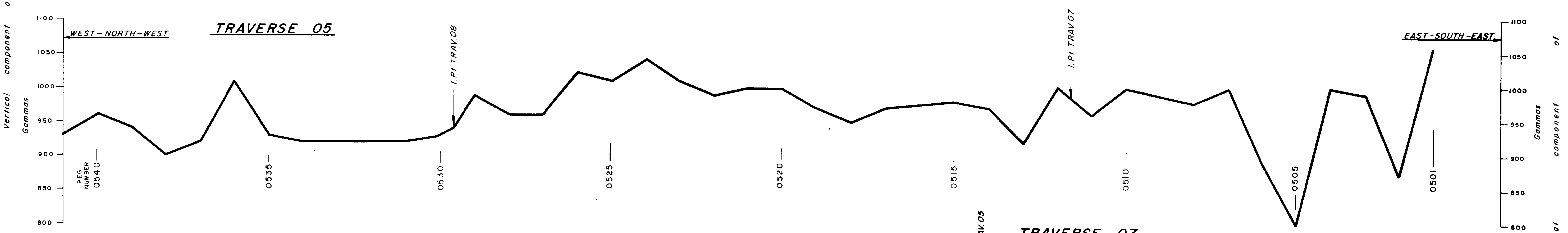
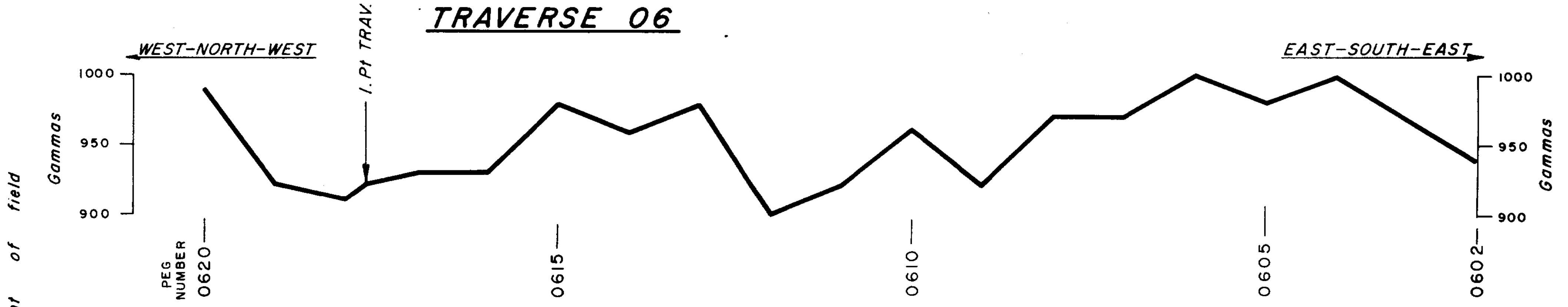
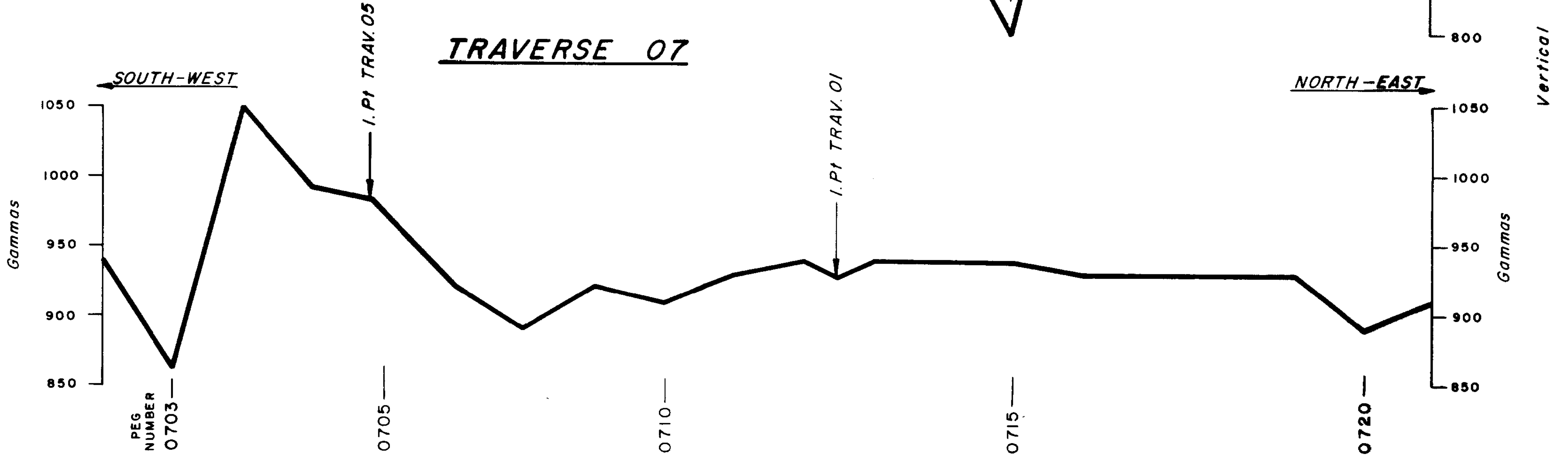
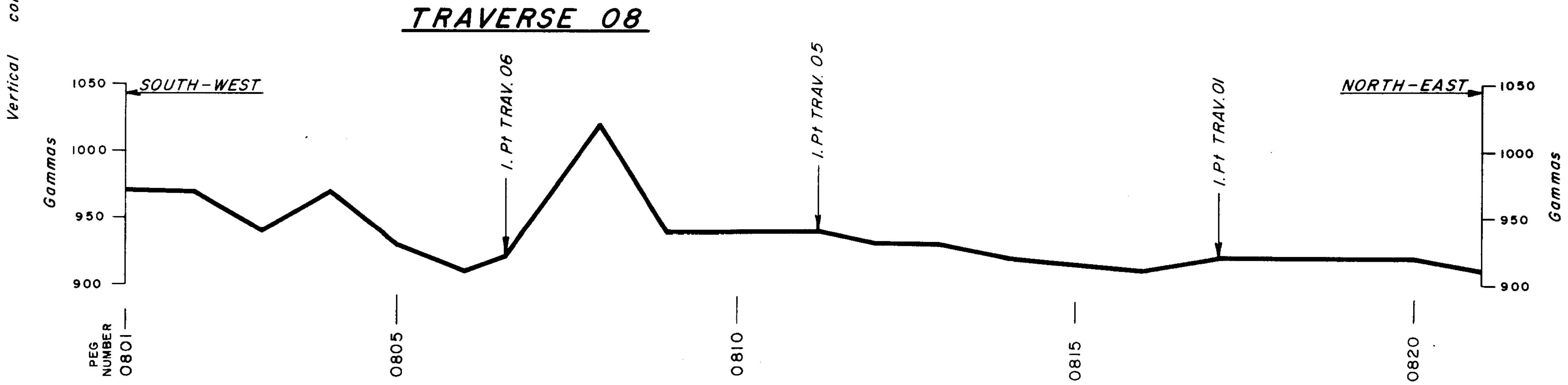
PLATE 5











Vertical component of field

I. Pt Traverse intersection point

MAGNETIC INTENSITY PROFILES

FEET

100 0 100 200 300 400

Vertical scales as shown