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Moura Coalfield Geophysical Survey, Queensland, 1970.
Part I — Seismic Reflection

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MOURA COALFIELD GEOPHYSICAL SURVEY QUEENSLAND 1970. PART 1 - SEISMIC REFLECTION

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SUMMARY

Some experimental geophysical work was undertaken by the Bureau of Mineral Resources at the Moura Coalfield in Queensland in order to investigate the structure of coal seams which lie within 1000 feet of the surface. The aim of the survey was to evaluate the use of geophysical techniques for locating faults of small displacement. Most of the effort was concentrated on shallow seismic reflection techniques but additional techniques (magnetic, gravity, resistivity, electromagnetic and induced polarization) were used.

The whole area of the survey was covered with a close-spaced grid of gravity and magnetic stations. A lesser effort was devoted to resistivity, electromagnetic, and induced polarization methods, the object being to take advantage of the opportunity to try out these relatively inexpensive methods in the hope that they might give some indications of fault locations. These methods will be evaluated in a separate Record; this one deals with the results of the seismic work.

Encouraging results were obtained from seismic reflection work. The uppermost economic coal seam was mapped to within 300 feet of the surface and areas of faulting could be deduced from time differences and lack of continuity in reflections.

1. INTRODUCTION

The Moura coal district is situated 100 miles west of Gladstone in Queensland. It is a part of the Bowen Coal Basin and has extensive reserves of coal available for both open-cut and underground mining. The Queensland Mines Department has made a close study of the coal-fields and has concluded that the form of subsurface structures will be a major factor in determining the amount of coal that can be mined underground. As a greater part of the reserves believed to be present in the Bowen Basin will have to be mined underground the problem of obtaining reliable information on the geological structure is of great importance. If a reliable interpretation of this structure can be obtained using geophysical methods of exploration then the amount of drilling required to determine the extent of extractable reserves will be greatly reduced. The Queensland Mines Department issued a contract in 1968 for a seismic reflection survey around Moura with one aim being the location of faults in coal seams. The results of the survey were disappointing in this regard. It was thought that part of the failure rested with the techniques applied in so far as conventional reflection methods, used for deep petroleum exploration, were applied to regions where the reflecting horizon of interest is less than 1000 feet below ground level. Essentially the contract survey suffered from a lack of concentration on the problems associated with shallow seismic reflection work.

As a result the Bureau of Mineral Resources agreed to undertake some experimental work in seismic reflection and also to investigate the possibility of using other geophysical techniques in order to locate faults. The program was carried out in March, April, and May 1970 by officers from the Geophysical Branch of BMR.

This report deals with the results of intensive seismic reflection experiments in an area where the uppermost coal seam dips from outcrop to 700 feet below the surface over a distance of 3000 feet.

The results of other geophysical methods will be discussed in a separate record.

The area of the survey is shown in Plates 1, 2, and 3. It is bounded by the Dawson Highway, the Dawson Valley Railway, the Gibihi Road, and the outcrop of coal on the eastern side. These plates also show the location of stratigraphic drill holes, seismic traverses, and the geophysical survey grid.

The area is mostly flat with an elevation of approximately 400 feet above sea level and a maximum elevation change of about 80 feet over a distance of two miles. Much of the land has been cleared of original vegetation and is used for farming and grazing.

2. GEOLOGY

Introduction

The Moura Coalfield lies on the southeastern part of the Bowen Basin, an area of subsidence and sedimentation during Permian and Triassic times. The regional geology and sedimentation of this vast coal bearing area have been discussed by Malone (1964) and Jensen (1968). The description of the geology which follows was supplied by E. Chiu Chong of the Department of Mines, Queensland.

The area chosen for the geophysical survey is situated some four miles southeast of Moura township in a mining reserve of the Queensland Government. It lies down dip of the southern part of the present workings of the Moura open-cut coal mine operated by Thiess Peabody Mitsui Coal Pty Ltd. The area is relatively flat and is traversed irregularly by Kianga Creek. Access is by good gravel roads (Plate 1).

Stratigraphy

The area is flat and covered by several feet of soil and alluvium, and outcrops are rare. The stratigraphic succession in this part of the coalfield is:

Triassic	Rewan Formation (0-400 feet in the survey area)	
Upper Permian	Baralaba Coal Measures	
		Productive member
		Kaloola member

The bottom 1,000 feet of the freshwater Rewan Formation consists of non-coaly, unfossiliferous, green mudstone and light green lithic labile arenite. Higher in the formation, red mudstone and chocolate-brown mudstone occur interbedded with similar green sediments.

Disconformably underlying the Rewan Formation is the productive member of the Baralaba Coal Measures which comprises 700 feet of white labile arenite with minor pebble conglomerate, grey mudstone, and economic coal seams. The stratigraphic succession of this member in the survey area is shown on the accompanying section of boreholes N.S. 32-33 and N.S. 70 (Plate 7). However, lateral variation of the sediments, particularly of the coal seams, occurs throughout the coalfield and makes stratigraphic correlation difficult (Chiu Chong, 1969).

Four coal seams of workable thickness and quality exist in the area. Three of these seams at present being worked by open-cut methods are tentatively correlated with the Moura B, C, and D-E seams. The working sections are 8 feet of coal for the A seam, up to 14 feet of mudstone and 14 feet of coal for the B seam, and approximately 10 feet of coal for C seam and D-E seam. Splitting of the B seam occurs at depth, and the top section is unworkable in the above mentioned boreholes. In fact, it is not recognized in N.S. 70.

The Kaloola member of the Baralaba Coal Measures, approximately 400 feet thick, lies at the base of the D-E seam. It comprises labile arenite, tuffaceous in parts, with subordinate grey mudstone and uneoconomic thin coal seams. The top of the member is characterized by a sequence of about 30 feet of white siliceous and tuffaceous mudstone containing abundant plant fossils, interbedded with thin coal bands. A lower sequence of these 'cherty leaf beds' occurs about 100 feet below the top of the member.

Structure

The Baralaba Coal Measures in the survey area dip to the west at under 10°. There is a general increase in dip northwards along strike while in the east-west direction dip decreases with depth as shown in Plate 5.

The area is traversed by a series of northwest-trending, low-angle, reverse fault zones about 3/4 mile apart. The strata are downthrown on the southwestern side. Vertical displacement varies. Maximum displacement on the fault lying between open-cut workings and boreholes N.S. 28-29 is about 300 feet. Displacement on the fault which stopped work in the Moura No. 1 underground mine is about 80 feet. However, displacements on faults penetrated in open-cut workings are about 20 feet.

Assessment of data from boreholes drilled in the area by the Department of Mines and the operating company indicates that minor faults occur between the major zones of disturbance. Some of these faults are of the normal type.

3. PREVIOUS EXPLORATION

The detailed study of the coal seams around Moura by Chiu Chong (1969) was the result of a systematic drilling program in which the economic coal formation was cored in a series of drill holes spaced half a mile apart. No less than twelve holes reaching depths of 800 to 1500 feet have been drilled in the survey area alone. In addition the operators of the open-cut mine have drilled holes on a 300-foot grid in the region between the open-cut and the point where coal reaches depths of 250 feet.

Several contract seismic surveys have been carried out for mining companies interested in coal. The Moura No. 1 oil well (Target Petroleum, 1969) some four miles north of Moura was drilled to a depth of 10,000 feet on a small anticline delineated by one of these seismic surveys. This well was dry except for small gas shows evident in the Baralaba Coal Measures at depths between 1,600 ft and 2,600 ft. Other gas wells have been drilled some 100 miles west of Moura around Rolleston but as yet no commercial discoveries have been made.

On a regional basis Moura is situated on the eastern flank of the Mimosa Syncline. This syncline is the major structural feature of the central and southern parts of the Bowen Basin. Its trend is meridional and its axis is some 26 miles west of Moura. At the axis the top of the Permian is estimated to be about 20,000 feet deep. The top of the Permian lies at 1,600 feet at Moura and crops out 5 miles east of Moura at the open-cut coal mines. Basement in the area is considered to be the lower Permian Camboon Andesite, which crops out some 18 miles east of Moura. From these facts it is deduced that basement lies around 6,000 feet at Moura.

4. OBJECTIVES

The objectives of the seismic survey are listed below.

(1) Seismic Reflection: (a) To develop a technique of recording siesmic reflections from coal seams which lie within 1000 feet of the surface and to establish the shallowest depth to which such seams can be mapped.

(b) To establish the best resolution that can be obtained using this seismic technique and hence evaluate its potential for mapping small faults.

(2) Seismic Refraction: To map the weathering profile using shallow refraction and hence determine whether any relation exists between this profile and faults in the coal seams.

5. SEISMIC REFLECTION

General

An SIE PT700 seismic system was used and its most important characteristics are summarized in Appendix A and Plate 13. The parameters used for any particular traverse are listed alongside the seismic cross-sections shown in Plates 4, 6, 8, 9, 10, 11, and 12. Hence the author feels it will be sufficient to simply state the reasons for selecting these parameters and to omit any detailed description of equipment or the seismic reflection technique.

Since the majority of the seismic work was done over those regions where the uppermost coal seam is within 700 feet of the surface the discussion of parameters will be confined to this situation. With an average vertical velocity of about 9 ft/msec the arrival time for signal from 700 feet is 160 msec and for depths of 300 feet this time is 80 msec. Thus the section of record which is of prime interest is the time interval 0-160 msec.

The principal factor that controls the clarity of received signal in this time interval is the intensity of the shot-hole noise. This noise is a result of the interaction between the explosion and the weathered zone. This weathered zone has an average velocity of 3 ft/msec and refracted waves travelling through this zone would take 100 msec to travel the length of a 300-ft spread. In addition the surface layer of lower-velocity material (1 ft/msec) generates long-period surface waves which take as much as 300 msec to travel this same spread; the longer the spread the greater is the length of this noise 'cone'. The refracted signals from either the 1 ft/msec layer or the 3 ft/msec layer are always much greater in amplitude than reflected signals (1,000 to 1,000,000 times as great). Fortunately, these refracted waves tend to have longer wavelengths than the reflected waves and it is possible to discriminate against shot-hole noise by using the low-cut filters of the amplifiers. Spatial filtering (employed successfully in oil surveys) using multiple geophone patterns cannot be used here as any overlap of geophones will introduce ground mixing which in turn will affect resolution, and in particular will obscure horizontal discontinuities in the reflecting horizons.

Parameters

Because of the shallow horizons being investigated, a spread length of 300 ft, i.e. about half the depth to the uppermost economic coal seam, was selected. Thus, using a conventional split spread length 300 ft, experiments were conducted along traverse A at shot-points 18, 19, 38 and 46 (Plate 3). As a result of extensive experimentation and bearing in mind that only the first 500 msec of record is of interest, the following conclusions were reached.

(1) Shot-hole depth. Optimum shot-hole depth was 15 ft below the lower limit of the weathered zone. This corresponded to 15 ft below the top of the 'blue shale', which consist of green mudstone and sandstone of the Triassic Rewan Formation. The average velocity above this shale is 3.5 ft/msec while the average velocity of the blue shale is 9.0 ft/msec. For most shots the depth of weathering was 60 feet and the shot-hole depth 75 ft.

(2) Charge size. Charge size was adjusted to give the best possible signal-to-noise ratio. The minimum charge desirable was 1.25 lbs while charges over 5 lbs did not improve the signal-to-noise ratio. Most charges used were either 1.25 lbs or 2.5 lbs.

(3) Geophones. Single 20-Hz geophones (T.I.C.) were tried but it was found that they were responsible for 'ringing' effects on the record. That is to say received signals tended to be characterless as if due to lack of damping of the geophones. Conventional HSJ 14-Hz geophones in sets of 8 were tried and proved quite satisfactory. It was found by experiment that geophones spaced 3 ft apart gave improved results over bunched geophones. Further, there was no difference between geophones spaced along the traverse line and geophones spaced on a line at right angles to the traverse line. Hence to avoid ground mix, geophones were spaced at right angles to the line. There appeared to be no advantage in increasing the geophone spacing beyond 3 ft. The effect of spacing the geophones 3 ft apart was to provide more reliable ground coupling and to give some random noise cancellation. This arrangement does not of course cancel ground roll.

(4) Recording speeds. A camera speed of 24 inches per second was used and a monitor record of 1.5 seconds was obtained. A total of 6 seconds was recorded on magnetic tape at a speed of 7.5 inches per second. Paper speeds below 24 inches per second are not suitable for the frequencies concerned while speeds above this can create mechanical problems inside the camera.

(5) Filters. In conventional seismic work it is general practice to record using the lowest practical low-cut filter (e.g. L16) and the highest high-cut filter (e.g. OUT). This practice has the advantage that a maximum amount of information is recorded on magnetic tape and any desired filtering can be accomplished during playbacks. However, there is a strong possibility that the inclusion of low frequencies in the recording may saturate the tape recording and distort the reflected signal. Also in playing back the tapes the signal is again passed through the equipment filters and subjected to further distortion. For these reasons on this type of survey the author prefers to record on that frequency setting which will give the best presentation on the original record. The natural frequency of signals received was 100 Hz and a low-cut filter of L65 has a good signal-to-noise ratio without noticeable loss of character. Higher low-cut filters are to be avoided because of loss of character produced by instrumental distortion. For more detailed information on instrument distortion see Anstey (1956). The high-cut filter of the equipment was omitted and as a result the upper limit of the frequency band-pass was about 300 Hz.

(6) AGC. The selection of Automatic Gain Control (AGC) speed is very critical for record character. Where signals arrive at intervals less than 20 msec apart it is imperative that recording parameters be capable of resolving between them. A slow AGC speed tends to destroy character and to mould two separate events into a continuing sinusoidal wave. A fast AGC speed preserves the character of such signals but also reduces the signal-to-noise ratio. As a result a medium AGC speed was selected for routine work. The AGC characteristics of these amplifiers are similar to that of the TGA-1 amplifier shown in Plate 13. Programmed gain although available was not used as the program gain unit available allows for a change in gain only in steps of 100 msecs which is far too large.

Routine profiling

Part of traverse A (S.P.4 - S.P. 37, Plate 10) and all of traverse F, (Plate 11) were shot using parameters of:

Spread length	300 ft
AGC	M
Filter	L65-OUT
Charge	1-5 lbs
Depth	15 feet below the top of the 'blue shale'

The results were not satisfactory for two reasons.

(1) Shot-hole noise extended down the record to as far as 170 msec (d, Fig. 1).

(2) The combination of noise and AGC action created a 'dead' zone on most of the inner traces (d, Fig. 1). The effect is evident on the seismic cross-sections, Plates 10 and 11, as poor signal strength and lack of continuity immediately under each shot-point. In general very few of the original records from these two traverses show continuity across 24 traces.

In an effort to reduce the shot-hole noise and hence improve record clarity for events shallower than 170 msec the remainder of traverse A(S.P. 38 - S.P. 52) was shot using a slow AGC speed and a filter setting of L82-OUT. Some reduction in noise was achieved (e.g. d and e, Fig. 1) but the results were still far from those desired. Following the completion of traverses A and F it became obvious that further experimenting was required to eliminate the defects in record quality explained above. The area between S.P. 44 and S.P. 48 along traverse A was then shot with a spread length of 150 feet in an attempt to improve correlation between traces and reduce the duration of shot-hole noise. Two shots were fired in each hole, one recorded with a filter of L82-OUT and the other with a filter of L130-OUT (the highest low-cut frequency). Plate 12 shows the resulting cross-sections. There appears to be little or no improvement in results. Reducing the spread length below 300 feet does not alter the extent of shot-hole noise to any large degree. The effect of the initial shock wave from the shot can be felt by an observer anywhere within 100 feet of the shot-point. Reducing the spread length will tend to bring more geophones into this region. If all geophones could be placed outside this area then the recorded shot-hole noise might be greatly reduced. The higher low-cut filters do not selectively reduce noise but attenuate both signal and noise.

Offset shooting

Experiments were then conducted at S.P. 40 to S.P. 41 on traverse A. The spread layout which is at right angles to traverse A is shown in (g) in Figure 1. Essentially the shot was placed 300 feet out from the centre of the spread. The technique is called offset shooting and the distance between the shot and the centre of the spread is called the offset distance. (a), (b) and (c) in Figure 1 shows three shots on different filters for the same spread and shot positions. For comparison, (f) shows the record from S.P. 41 obtained while shooting traverse A. The comparison leaves no doubt that offset shooting greatly reduces the amount of noise recorded in the useful part of the record.

Having achieved a substantial improvement in signal-to-noise ratio it was decided that at least 10,000 feet of traversing should be completed to evaluate the offset shooting technique. Once again a filter of L65-OUT was adopted as it was considered the best for clarity. Two traverses, G and H, were then shot using the following parameters:

Spread length	300 feet	
AGC	M	
Filter	L65-OUT	Traverse H
	L65-OUT)	
	)	Traverse G
	L31-OUT)	
Shot offset distance	300 feet	
Charge	1-1/4 - 2½ lbs	
Depth	15 ft below the top of the blue shale.	

It was observed on records from traverse A that shooting up dip gave better reflections than shooting down dip. Hence for traverse H and G the position of the shot was down dip from the spread. Traverse G was actually shot twice using the two different filters shown above.

The continuity of the principal event is satisfactory on both traverses in those regions where Moura 'A' seam is at least 300 feet below the surface. On traverse G, Plate 4, between S.P. 610 and S.P. 616 no clear events can be seen. In the 1800 feet between these two shot-points, 'A' seam rises from a depth of 300 feet to outcrop. The principal event, which originates from Moura 'A' seam arrives at roughly the same time as the first breaks and the signal-to-noise ratio around this arrival time (80 msec) is too small to allow continuity of the event to be observed. This time (80 msec) is the limit to which events may be followed, and the depth to the reflector at this point is 300 feet. The absence of reflections from lower seams tends to indicate that most of the energy is absorbed or reflected by the uppermost seam. This is confirmed by the following:

(1) Calculations of reflection coefficients from the Moura No. 1 sonic log (Target Petroleum, 1969) show reflection coefficients at coal seams as large as 0.3, which is about 4 to 6 times as great as those shown for other stratigraphic changes.

    This does not mean that deep structures cannot be mapped in areas where shallow coal seams occur. In sedimentary basins around Australia deep structures have been mapped in such areas. That is to say seismic energy does penetrate the barrier presented by coal seams. However, in such cases the signals from the deep structures have arrival times of one or two seconds and are beyond the time zone on the record where they are subject to interference by intense shot-hole noise. Further, these signals arrive much later than those from coal seams and therefore are not influenced by the high signal level associated with reflections from the coal seams.

(2) Van Riel (1965) concluded that of a group of coal seams only the uppermost coal section could be mapped because of this strong reflection coefficient associated with coal seams.

This conclusion is strengthened by the results from Traverse B where the offset distance was reduced to 200 feet in an attempt to obtain reflections from seams at depths less than 300 feet. Along this traverse the average depths to the coal horizons are:

Coal seam	Depth
A	Crops out west of traverse line
B	60 ft
C	260 ft
D	400 ft
E	500 ft

The dip is practically zero along the traverse line.

The cross-section from this traverse is shown in Plate 9, which shows that there are no clear events across the section. Along this traverse and on the eastern end of traverse G (Plate 4) the noise level has increased to a considerable degree. It is the author's view that this strong noise is refraction from the shallow coal seam. The comparatively low velocity of seismic waves in coal (7 ft/msec compared with 10 ft/msec for the surrounding sandstone (see Seismic Refraction)) ensures that this noise persists for a comparatively long interval. The fact that the low-cut filter does not reduce the effect to any large degree indicates that the noise contains a fair proportion of high frequencies. Hence it is concluded that the presence of a very shallow coal seam of economic thickness effectively prevents the mapping of deeper seams.

One more reflection traverse (J) was completed in an area containing known faults. The offset distance in this case had to be reduced to 230 feet because of the presence of power lines and railway lines. The author expects that far better results would have been obtained with a greater offset distance, e.g. 500 ft. Plate 8 shows the seismic cross-section. The section is dominated by noise extending down the record as far as 230 msec while the reflection occurs at about 200 msec. Such a reflection time would allow the offset distance to be increased to at least 500 feet which would result in greater attenuation of the shot-hole noise without change in the reflected signal strength.

Results

Traverses A, F, G, and H all show one primary reflector which is correlated with the uppermost economic coal seam (Moura 'A' seam, 10-20 feet of coal). Intermittent reflections originate from lower seams and from discontinuities above this seam. The first multiple from 'A' seam can be observed occasionally. Traverse A (Plate 10) indicates that the coal seams have dips that are as great as 1 in 6 near outcrop and gradually reduce to 1 in 30 towards the west. Traverse F (Plate 11) shows a gradual dip of 1 in 30 from the southeast to the northwest end of the traverse.

A detailed analysis of traverses H and G was undertaken because of the high quality of the reflections. When attempting to determine the resolution power of the seismic technique one finds that the static corrections are the controlling factor. Static corrections in this particular case were calculated on the following formula.

$$\frac{Es - ds}{Ve} + \frac{EG}{Ve} + \left(1 - \frac{Vo}{Ve}\right) tw$$

which is of the form

Total correction = Elevation correction + Weathering correction.

Where Es = elevation of shot-point relative to datum

ds = depth of shot

Eg = elevation of geophone relative to datum

tw = weathering time

Vo = weathering velocity

Ve = sub-weathering velocity

The weathering time tw was obtained from special refraction shots. This is the most satisfactory method of obtaining corrections, and corrected times will generally lie within one or two milliseconds of a smooth line. The depth plots in Plates 5 and 7 were obtained by graphically smoothing the corrected time plot and using an average vertical velocity of 9.3 ft/msec. The calculation of absolute depths requires very reliable information on such parameters as weathering time, elevation, and average vertical velocity. Naturally the identification of an event is of prime importance and will be reliable only if good field records are obtained. The error in depth which can be introduced by small errors in time and velocity is as follows.

Parameter error	Depth error
t: $\pm$ 4 msec	$\pm$ 20 feet
V: $\pm$ 4 ft/msec	$\pm$ 30 feet at depths of 600 feet.

The accuracy which can be achieved in recording time is at best $\pm$ 2 msec. This uncertainty in time is an inherent limitation in this method of geophysical exploration and is not a result of faulty equipment or faulty recording. The greatest errors introduced in selecting the time of an event are possibly those associated with distortion of the visual recording. This distortion is produced by noise events and by the rapid increase in gain at the commencement of the record. Experience with these amplifiers indicates, that the change in gain should not exceed 20 dB per 100 msec. Hence it must be expected that signals arriving before 100 msec will be subject to instrumental distortion, which is in turn expressed as timing errors.

In the interpretation of traverses G and H the author made a depth plot on an expanded scale of 100 ft/inch in order to discern greater detail. This was considered necessary since the standard seismic cross-sections produced at a speed of 7.5 inches per second have too small a scale for accurate calculations. The dynamic corrections used for all traverses were calculated from a velocity log run in borehole NS 70 (obtained from an unpublished report with the Department of Mines, Qld) The adopted moveout is considered very accurate since changes in average velocity have very little effect on it.

The principal event on traverses G and H is identified with Moura 'A' seam. Only on odd occasions is there evidence of reflections from lower seams. Some intermittent, low-level events were recorded before the event from Moura 'A' seam, and these have been correlated with Moura 'X' seam and the bottom of the Rewan Formation. However, only the event due to Moura 'A' seam is clear enough for detailed analysis, and a depth profile of the seam is shown in Plates 5 and 7.

The faults illustrated in Plates 5 and 7 are listed below with relevant comments. The seismic sections are shown in Plates 4 and 6.

S.P. 715 A fault of 15 ft throw, downthrown on the southern side. A change in the near-surface velocity also occurs at this same point.

S.P. 707 A fault of 30 ft throw, downthrown on the northern side. This fault is considered quite definite, on the basis of good record quality either side of the fault.

S.P. 705 A fault of 20 ft throw, downthrown on the southern side. This fault is considered doubtful because of changes in character produced by a 'pinchout' effect that occurs at this point.

S.P. 606 - 607 A large change in dip occurs between these two shot-points. The seismic records show a change in depth of 70 feet occurring over a surface distance of about 400 feet. Downthrow in on the western side.

S.P. 600 A fault of 30 ft throw, downthrown on the eastern side. This fault is considered doubtful because of the absence of further records on the western side. However, there is a strong possibility that this fault is an extension of the one that occurs at S.P. 707. Consistent anomalies also occur in the weathered layer in this region. As the intersection of traverses H and G occurs close to the faulted area, it is not possible to state the direction of the fault with any reliability. However, the little information available suggests that the fault runs slightly west of true north.

Because of the absence of good reflections from lower seams, it is not possible to determine the plane of these faults. Additional parallel traverses would be required to obtain the direction of the faults. Such traverses would naturally improve the reliability of the interpretation. All of these faults, except that at S.P. 606-607, are associated with poor signal strength and lack of continuity on the seismic records. This fact is clear on the seismic cross-sections and is even more evident in the case of traverse J, (Dawson Highway). In such cases is appears as though the shot has been fired in the weathered zone.

One additional anomaly exists at the junction of records 603 and 604 on traverse G (Plate 4). The author suggests that the interruption of smooth continuity at this point is a result of a relatively sharp change in dip which commences immediately under S.P. 603. The possibility of minor faulting in this area should not be excluded. There is no obvious explanation for the break in signal continuity between S.P. 604 and 605.

The depth profile (Traverse G) in Plate 5 shows the calculated depth of 'A' seam to be about 20 feet deeper than that shown by the stratigraphic hole (NS131). Along traverse H, on the other hand, the profile is actually about 20 feet shallower than true depth. Note that NS33 is 600 ft north of S.P. 600. No explanation is considered necessary for these discrepancies as such errors in absolute depth are well within the normal limits of probable error for seismic reflection work.

The quality of the records from traverse S (Plates 10 and 12), B (Plate 9), F (Plate 11), and J (Plate 8) is not adequate to allow an analysis to be undertaken. However, some probable faults are outlined below. All these faults muchst be considered doubtful, as the continuity of signal is poor. The evidence for faulting is based on time discrepancies in the variable-area seismic sections.

Traverse A (Plates 10 and 12). Probable faults are:

S.P. 45 A sharp change in dip occurs in the vicinity of this point. Downthrow in on the western side.

S.P. 36 A fault downthrown on the eastern side.

S.P. 30 A fault of about 60 feet throw, downthrown on the western side.

S.P. 28 A minor fault, downthrown on the western side.

S.P. 15-18 The depth to 'A' seam changes by approximately 100 feet over a surface distance of about 700 feet. This gives a dip of 1 in 7 in a region where the general dip is as small as 1 in 30. For this reason it is considered that this region may be faulted.

Traverse F (Plate 11). Faults are considered possible at S.P. 538, S.P. 532 and S.P. 518 with downthrow on the northern side. In addition the region between S.P. 509 and S.P. 513 may be faulted. A change in dip occurs at S.P. 513, and the seam displays a smaller dip to the south.

Traverse J (Plate 8). As previously stated this traverse was undertaken because of known faults in the general area. The poor record quality over the entire traverse indicates that the area may be extensively faulted. It is suspected that a fairly large fault exists at S.P. 802, downthrown on the western side.

6. SEISMIC REFRACTION

Shallow refraction shooting to determine weathering times was carried out along traverses A, G, and H. These weathering times were used in correcting the reflection results. From the results it was observed that the sub-weathering velocity increased from 9 ft/msec to 11.5 ft/msec on the eastern side of the survey area where the coal seams crop-out. Further shallow refraction work was done along traverses B, C, D, and E in order to determine the sub-weathering velocities associated with coal seams B, C, D, and E. The sub-weathering velocities determined for these traverses are:

Traverse	Velocity, ft/msec
B	9.6
C	10.7
D	11.3
E	11.5

On these traverses the name of the uppermost seam corresponds with the name of the traverse.

In order to obtain some idea of the velocity of seismic waves in coal a short refraction spread was placed on an exposed coal seam in the open-cut mine. The velocity measured was as low as 3.4 ft/msec. However, it is suspected that this low measurement was due to shattering of the coal by the explosive charges used for shattering the overburden. A more accurate measurement of coal velocities was obtained from the sonic log of Moura No. 1 oil well. The velocities of several coal seams in this well ranged between 6.5 and 7.5 ft/msec. This agrees with widely accepted values. Thus the coal seams have a substantially lower velocity than the material above and below them; this condition effectively screens them from the seismic upfraction record, and makes the direct mapping of coal seams by refraction shooting impossible.

7. CONCLUSIONS

The results of the seismic reflection traverses G and H show that small faults can definitely be detected by seismic reflection using offset shooting. Besides being outlines by direct measurements of time it is shown that faults are associated with poor signal strength and lack of continuity. This in itself can be a fair indication of the location of faults. For areas such as traverse J, longer traverses would be required in order to obtain clear reflections on either side of the fault. In such areas improvements in record clarity could possibly be achieved by orientating the spread in another direction and by increasing the offset distance of the shot.

The shallowest depth from which clear reflections can be obtained is shown to be 300 feet. It is not possible to improve on this limit in this area with the technique outlined in this Record. Perhaps some improvement could be achieved if the energy source were capable of giving a better signal-to-noise ratio.

The use of shallow refraction to map the weathered layer is considered necessary in order to determine accurate weathering times for correcting the reflection results. However, in the area investigated there is no distinct correlation between weathering times and faults. The weathering times tend to change smoothly. Mapping of a coal seam by direct refraction is not possible because of the low velocity of coal compared with the surrounding sandstones.

8. ACKNOWLEDGEMENTS

The geological summary was supplied by E. Chiu Chong of the Department of Mines, Queensland. All previous geophysical and geological information on the area was made available by the Department of Mines, Queensland. The author is indebted to F.J. Moss of the Bureau of Mineral Resources for his advice during the survey and for his assistance with this report.

9. RECOMMENDATIONS

The following experiments are recommended should any more seismic reflection work in coal areas be undertaken:

(1) The shot offset distance should be varied in order to determine the optimum distance.

(2) The maximum spread length possible should be determined in relation to the depth to the reflecting horizon.

(3) At least 10 miles of routine traversing using offset shooting should be undertaken in order to determine the reliability of the technique.

(4) It would be an advantage to have an amplifier capable of accepting a change in gain greater than 20 dB per 100 msec as this is a limitation with the amplifiers used in the experiments.

10. REFERENCES

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APPENDIX A : EQUIPMENT

Equipment used during this survey is listed below:

Amplifiers:	SIE PT700, 24-channel system with TGA-7 amplifiers Low-cut filter DLC-7, OUT-130 (18 or 36 dB/octave) High-cut filter DHC-7, 24-OUT " " " " Measured frequency limit of the amplifiers with filters out is 500 Hz AGC: F, M, S, SS and OUT. (See Plate 13) PROGRAM GAIN CONTROL: GCU-3E (not used).
Camera:	S.I.E. TRO-6 Galvanometers 125 Hz (natural frequency) Measured frequency limit of the galvanometers - undistorted up to 500 Hz Recording paper, Dupont 6" Papu speed, variable 4" to 36" /sec.
Magnetic Recorder:	S.I.E. PMR 20 frequency modulation Tape speed 7½"/sec Frequency response, 1-300 Hz within 1dB, 3dB down at 500 Hz.
Geophones:	(1) TIG 20 Hz, single geophones, approx. 320 ohms critically damped output 0.3V/in/sec with 27-ohm coils (2) HSJ-L2 14 Hz, sets of 8 with 27-ohm coils in series, and critically damped combined output 0.2V/in/sec.
Cables:	Nector 960', 14 take-outs.

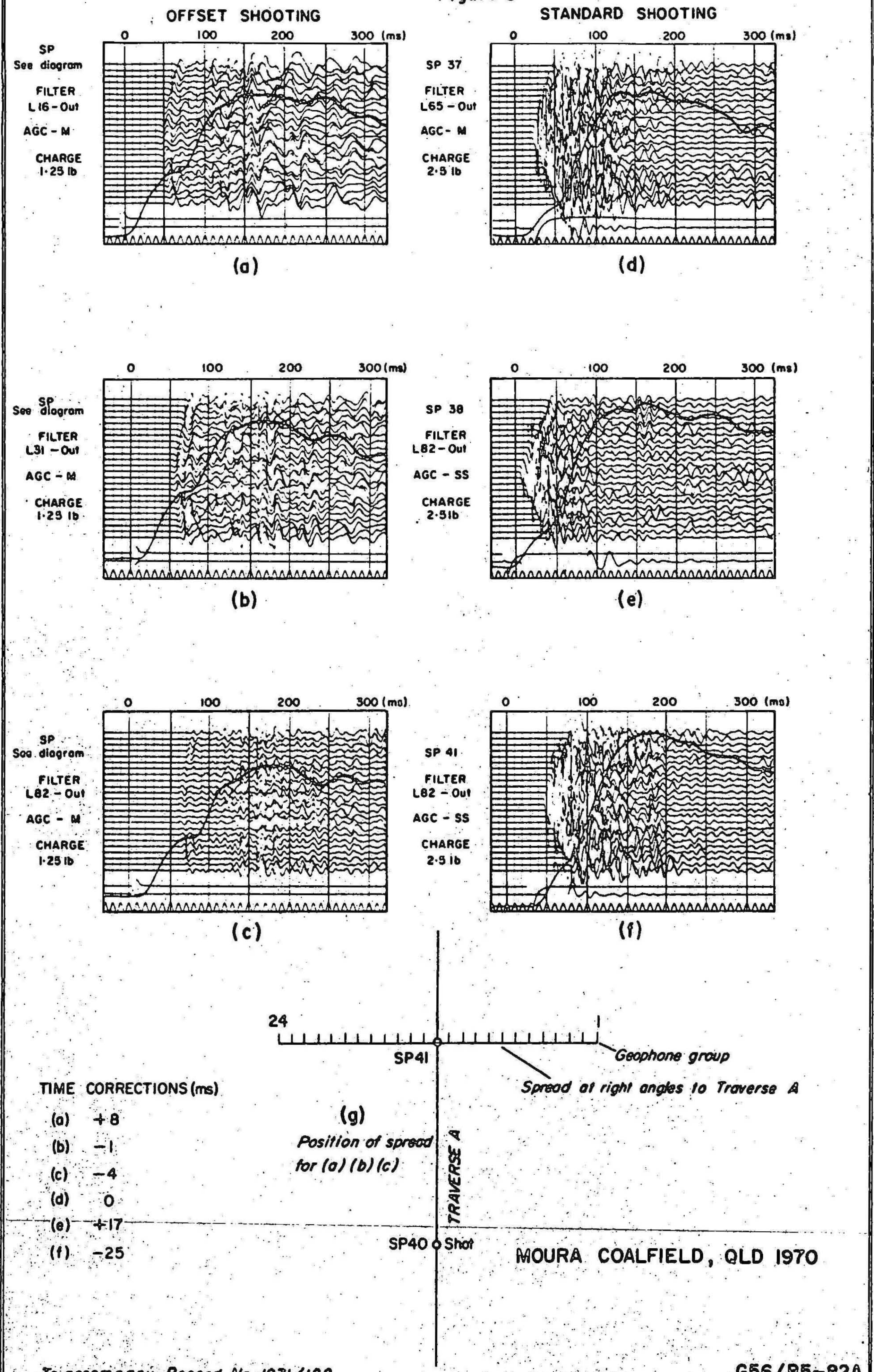
APPENDIX B : FIELD PERSONNEL

Field personnel involved in this survey are shown below:

F.J. Taylor	Party Leader
P. Hill	Geophysicist
R.C. Watson	Draftsman
L. Hemphill	Technical Officer (Observer)
R. Cherry	Technical Assistant (Shooter)
H. Pelz	Technical Assistant (Shooter)
D.K. McIntyre	Mechanic
G. Abbs	Technical Officer (part time)

and 5 field hands.

Figure 1

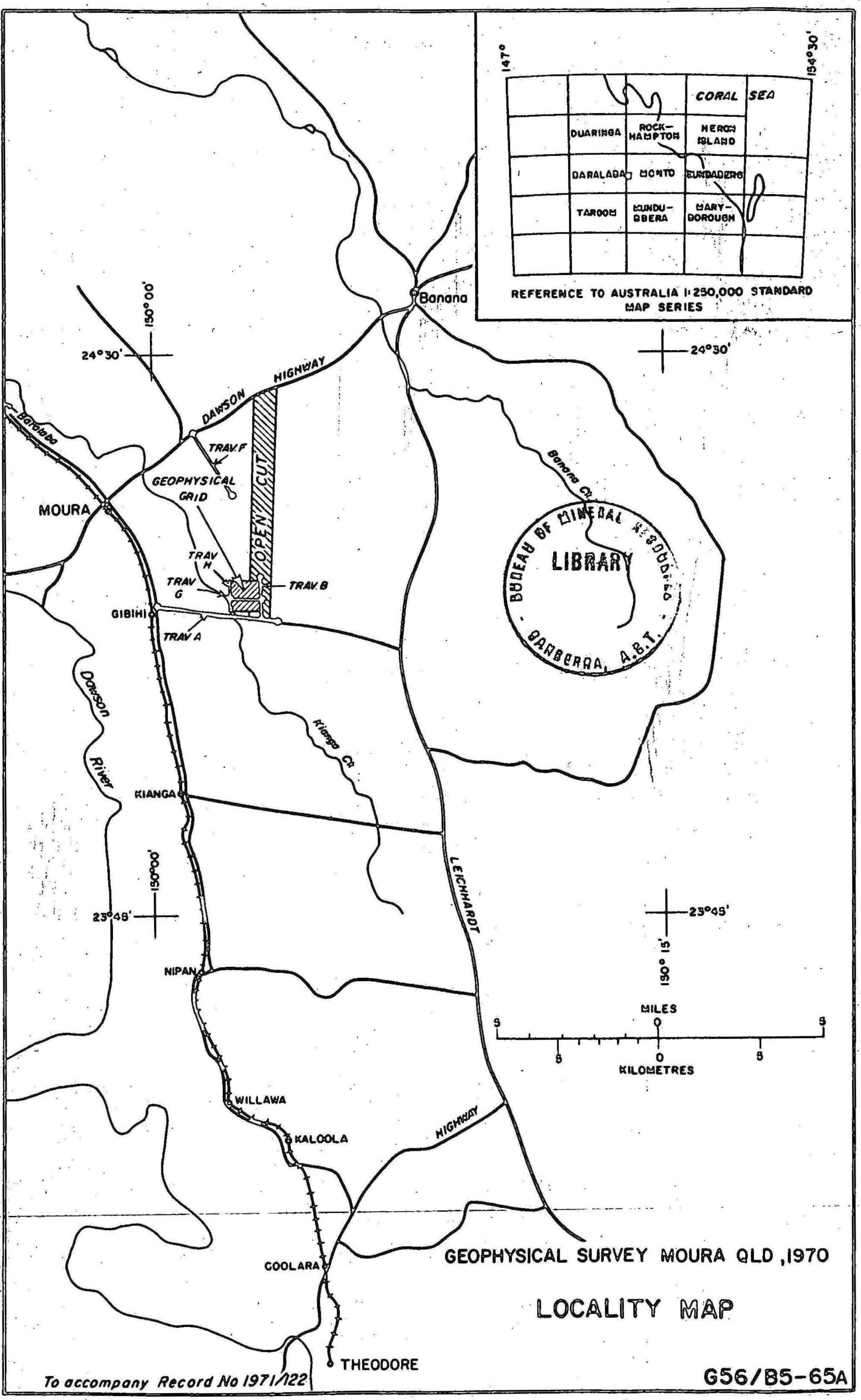


MOURA COALFIELD, QLD 1970

To accompany Record No 1971/122

G56/B5-82A

PLATE 1

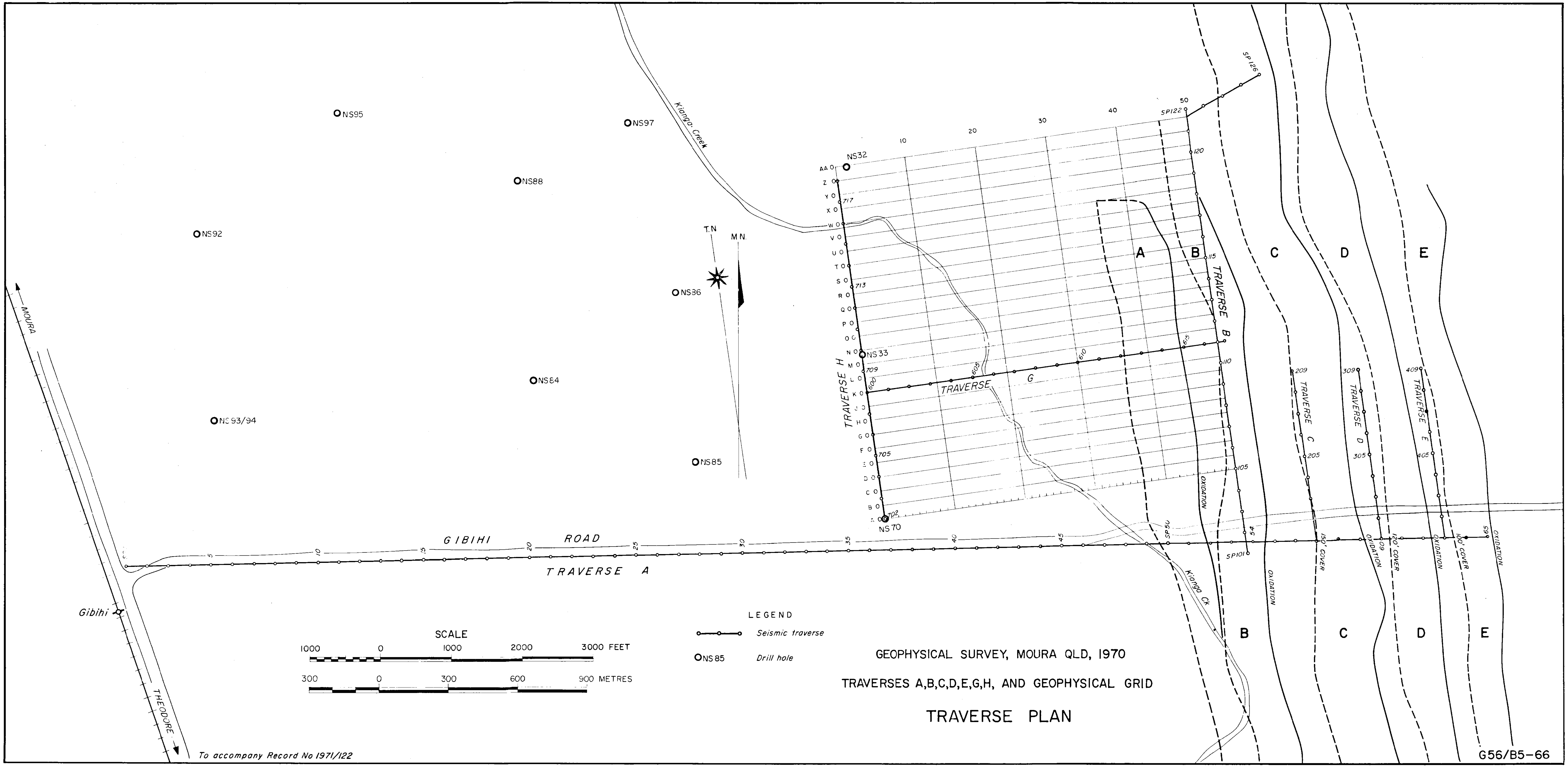


GEOPHYSICAL SURVEY MOURA QLD, 1970

LOCALITY MAP

To accompany Record No 1971/122

G56/B5-65A



GEOPHYSICAL SURVEY, MOURA QLD, 1970

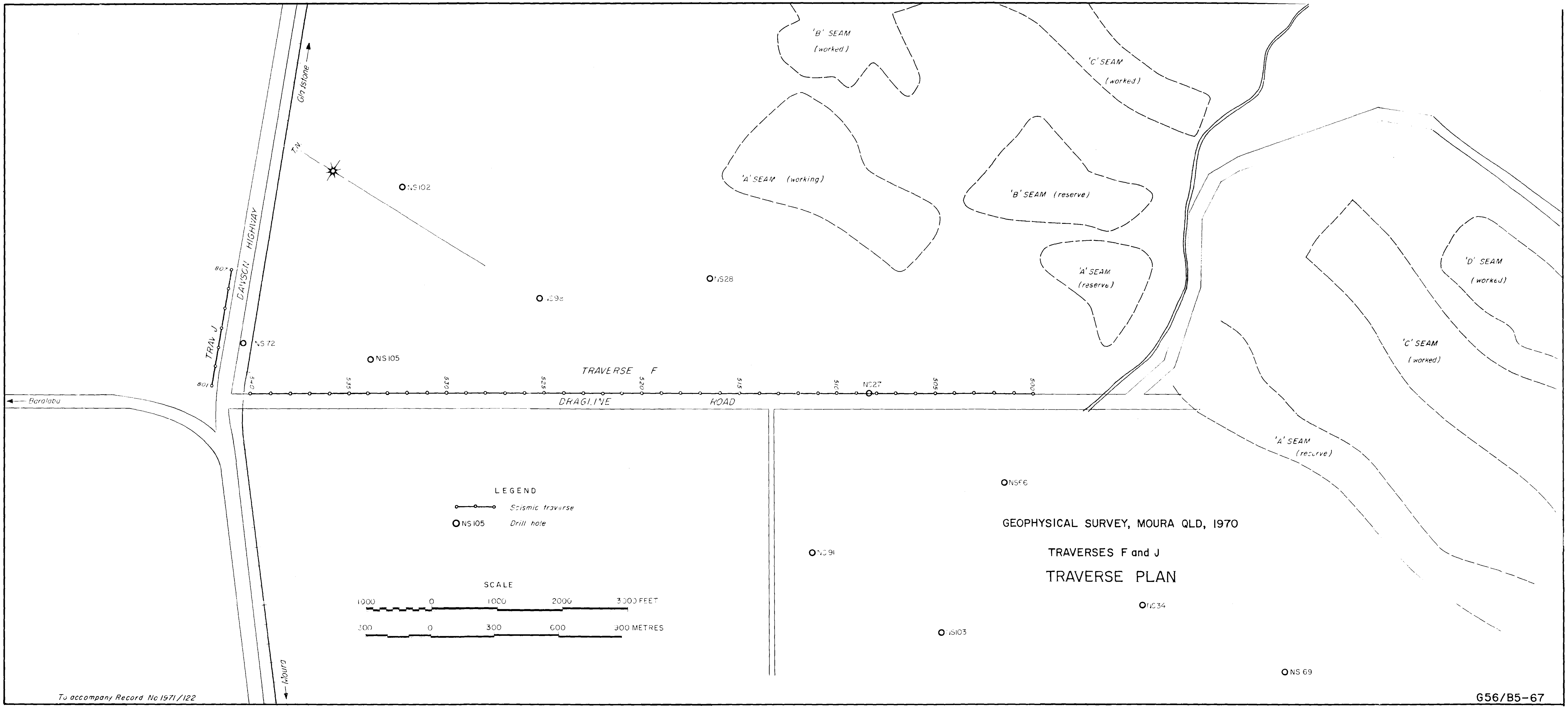
TRAVERSES A,B,C,D,E,G,H, AND GEOPHYSICAL GRID

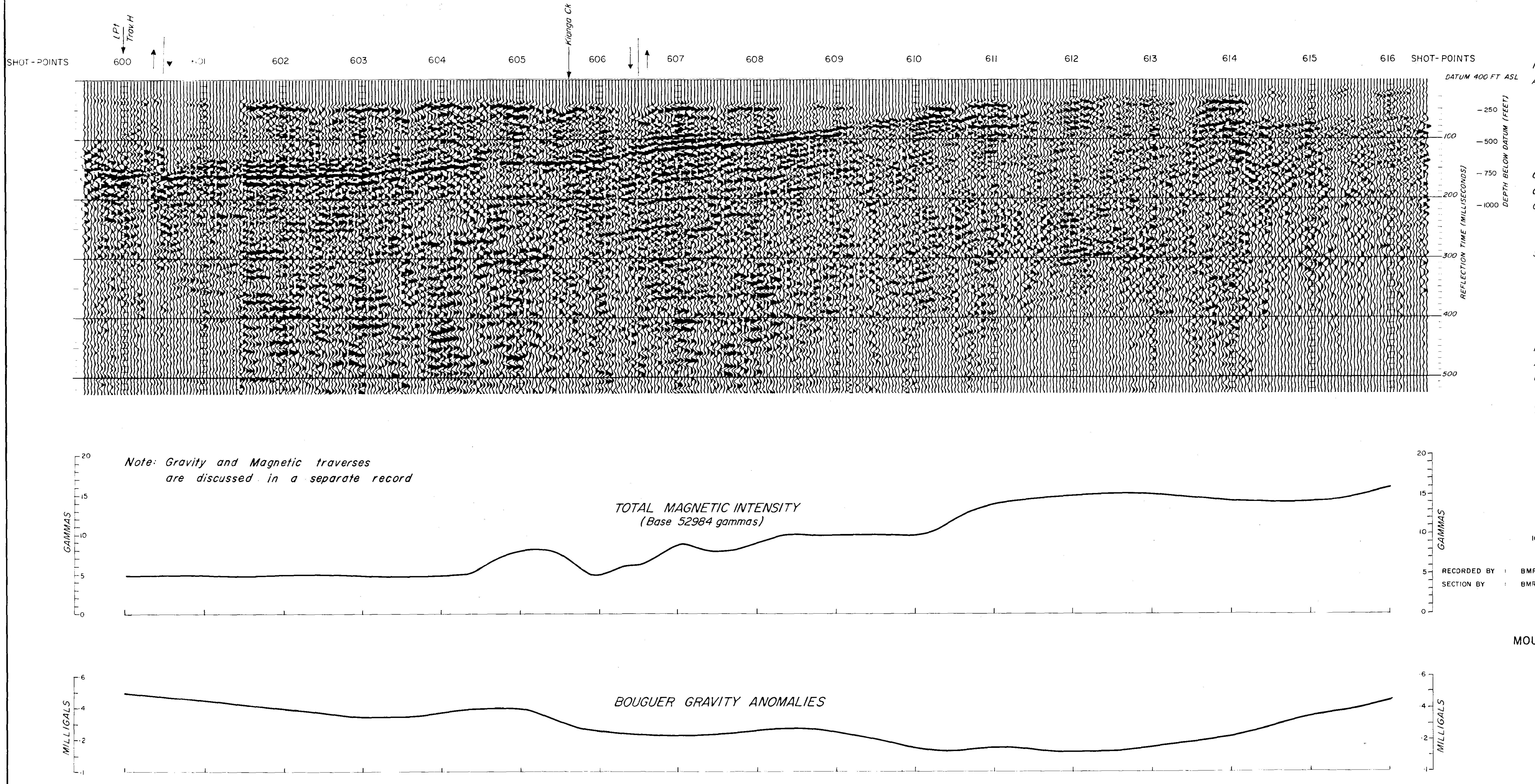
TRAVERSE PLAN

To accompany Record No 1971/122

G56/B5-66

MOURA, QLD 1970


'B' SEAM
(worked)
'C' SEAM
(worked)
'A' SEAM (working)
'B' SEAM (reserve)
'A' SEAM
(reserve)
'D' SEAM
(worked)
'C' SEAM
(worked)
'A' SEAM
(reserve)
Gladstone
DAWSON HIGHWAY
TRAV J
807
801
NS102
NS28
NS72
NS105
TRAVERSE F
540
535
530
525
520
515
510
NS27
505
500
Baralaba
DRAGLINE ROAD
Moura
LEGEND
Seismic traverse
NS105 Drill hole
NS91
NS34
NS103
NS69
SCALE
1000 0 1000 2000 3000 FEET
300 0 300 600 900 METRES
GEOPHYSICAL SURVEY, MOURA QLD, 1970
TRAVERSES F and J
TRAVERSE PLAN
To accompany Record No 1971/122
G56/B5-67



RECORDING INFORMATION

Magnetic Recorder	: PMR - 20
Amplifiers	: PT - 700
Prefilters	: ——
Filters	: L65 - Out
AGC	: Medium
Gain Initial	: -80
Final	-20
Geophones	: HSJ - 14Hz
Geophone Station Interval	: 25 ft
Geophone Pattern	:

8 per trace, 3 ft apart in line perpendicular to traverse

Shot-hole Pattern : 1 hole

Offset : 300 ft south

Depth : 60 to 90 ft

Charge : 1¼ lb to 2½ lb

PLAYBACK INFORMATION

Filters	: L65 - KK175
AGC	: Off
Gain Initial	: -30
Final	: -20
Trip Delay	: ·1 sec
Compositing	: Nil

VELOCITY INFORMATION

Velocity log of stratigraphic hole NS-70

HORIZONTAL SCALE

100 0 100 200 400 FEET

100 0 100 METRES

RECORDED BY : BMR Engineering

SECTION BY : BMR Playback Centre SIE MS 42

MOURA COALFIELD, QLD 1970

TRAVERSE G

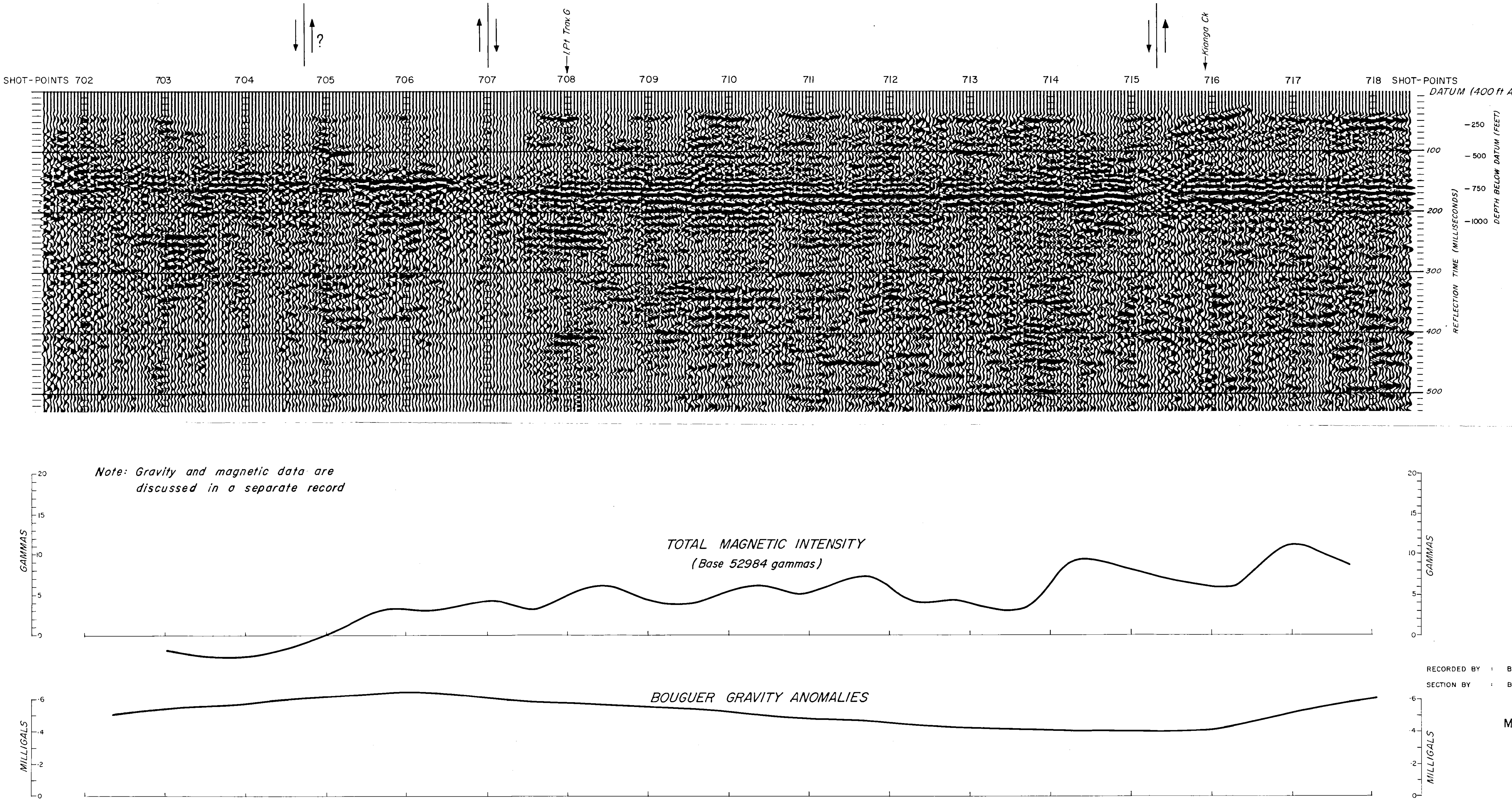
To accompany Record No 1971/122

G56/B5-81

STRATIGRAPHIC LOGS OF BOREHOLES NS 33, NS 31 AND DEPTH PLOT ALONG TRAVERSE G

To accompany Record No 1971/122

G56/B5—70



RECORDING INFORMATION

Magnetic Recorder	:	PMR-20
Amplifiers	:	PT-700
Prefilters	:	——
Filters	:	L65-Out
AGC	:	Medium
Gain Initial	:	-80
Final	:	-20
Geophones	:	HSJ - 14 Hz
Geophone Station Interval	:	25 ft
Geophone Pattern	:	8 ft per trace, 3 ft apart, in line perpendicular to traverse
Shot-hole Pattern	:	1 hole
Offset	:	300 ft west
Depth	:	60 to 75 ft
Charge	:	1¼ to 2½ lb

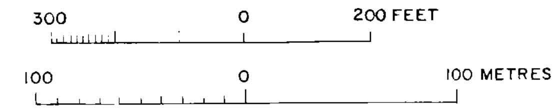
PLAYBACK INFORMATION

Filters	:	L65 - KK175
AGC	:	Off
Gain Initial	:	-30
Final	:	-20
Trip Delay	:	·1 sec
Compositing	:	Nil

VELOCITY INFORMATION

Velocity log of stratigraphic hole NS-70

HORIZONTAL SCALE



RECORDED BY : BMR Engineering

SECTION BY : BMR Playback Centre SIE MS42

MOURA COALFIELD, QLD 1970

TRAVERSE H

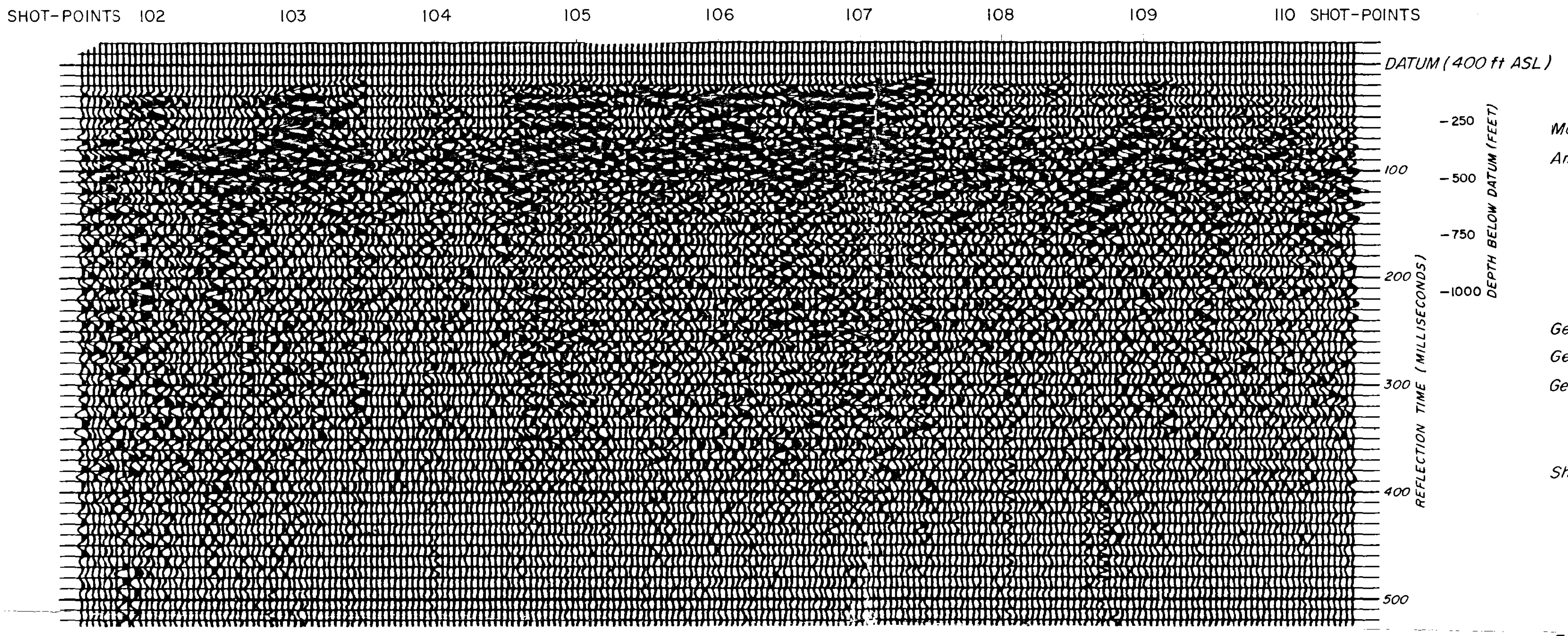
To accompany Record No 1971/122

G56/B5-80

STRATIGRAPHIC LOGS OF BORE HOLES NS70, NS 33, NS32
AND DEPTH PLOT ALONG TRAVERSE H

G56/B5—71

To accompany Record No 1971/122



RECORDING INFORMATION

Magnetic Recorder	:	PMR-20
Amplifiers	:	PT-700
Prefilters	:	——
Filters	:	L65-Out
AGC	:	Medium
Gain Initial	:	-80
Final	:	-20
Geophones	:	HSJ-14Hz
Geophone Station Interval	:	25 ft
Geophone Pattern	:	

8 per trace, 3 ft apart, in line perpendicular to traverse

Shot-hole Pattern	:	1 hole
Offset	:	200 ft West
Depth	:	45 to 75 ft
Charge	:	1/4 lb

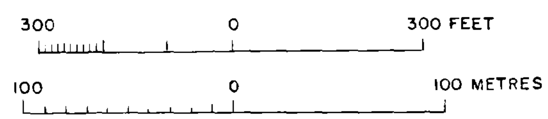
PLAYBACK INFORMATION

Filters	:	L65-KK175
AGC	:	Off
Gain Initial	:	-30
Final	:	-20
Trip Delay	:	·1 sec
Compositing	:	Nil

VELOCITY INFORMATION

Velocity log of stratigraphic hole NS70

HORIZONTAL SCALE



RECORDED BY : BMR ENGINEERING

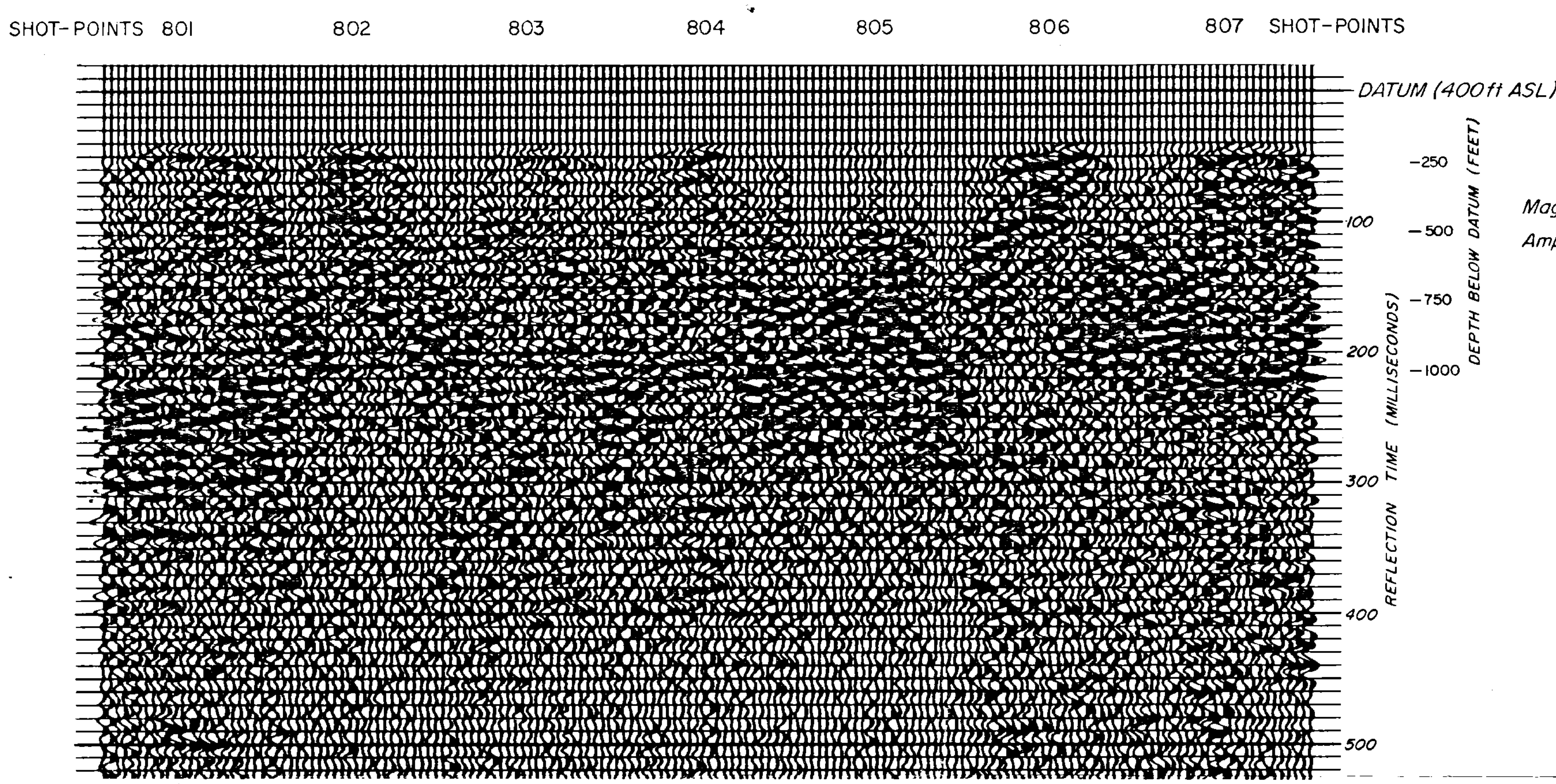
SECTION BY : BMR PLAYBACK CENTRE SIE MS 42

MOURA COALFIELD, QLD 1970

TRAVERSE B

To accompany Record No 1971/122

G56/B5-77



RECORDING INFORMATION

Magnetic Recorder	:	PMR-20
Amplifiers	:	PT-700
Prefilters	:	——
Filters	:	L65 - Out
AGC	:	Medium
Gain Initial	:	-80
Final	:	-20
Geophones	:	HSJ-14 Hz
Geophone Station Interval	:	25 ft

Geophone Pattern :
8 per trace, 3 ft apart, in line perpendicular to traverse

Shot-Hole Pattern : 1 hole

Offset	:	230 ft north
Depth	:	75 to 90 ft
Charge	:	1¼ lb to 2½ lb

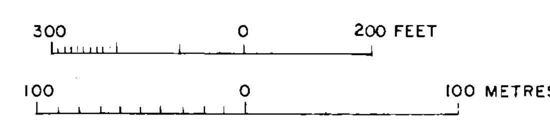
PLAYBACK INFORMATION

Filters	:	L65-KK175
AGC	:	Off
Gain Initial	:	-30
Final	:	-20
Trip Delay	:	·1 sec
Compositing		Nil

VELOCITY INFORMATION

Velocity log of stratigraphic hole NS 70

HORIZONTAL SCALE



RECORDED BY : BMR Engineering

SECTION BY : BMR Playback Centre SIE MS 42

MOURA COALFIELD, QLD 1970

TRAVERSE J

To accompany Record No 1971/122

G56/B5-78

PLATE 10

To accompany Record No 1971/122

G56/B5-75

PLATE 11

RECORDING INFORMATION

Magnetic Recorder : PMR-20
Amplifiers : PT-700
Prefilters : ——
Filters : L65-Out
AGC : Medium
Gain Initial : -80
Final : -20
Geophones : HSJ-14 Hz
Geophone Station Interval : 25 ft
Geophone Pattern :
8 per trace, 3 ft apart, in line perpendicular to traverse
Shot-hole Pattern : 1 hole,
Offset : Nil Depth : 75 to 105 ft Charge : 2½ to 15 lb

PLAYBACK INFORMATION

Filters : L82 - KK135
AGC : Off
Gain Initial : -30
Final : -20
Trip Delay : ·1 sec
Compositing : Nil

VELOCITY INFORMATION

Velocity log of stratigraphic hole NS70

HORIZONTAL SCALE

300 0 300 FEET

100 0 100 METRES

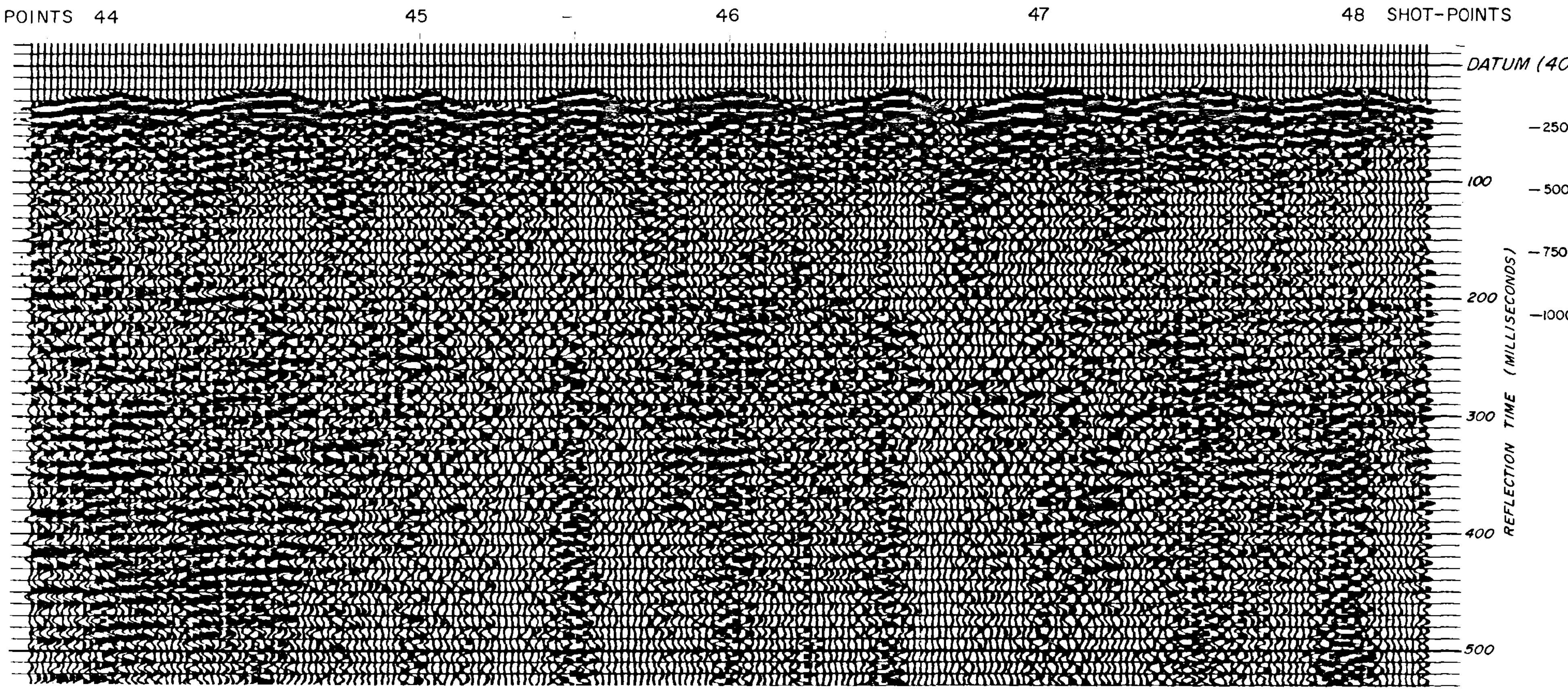
RECORDED BY : BMR ENGINEERING
SECTION BY : BMR PLAYBACK CENTRE SIE MS42

MOURA COALFIELD, QLD 1970

TRAVERSE F

To accompany Record No 1971/122

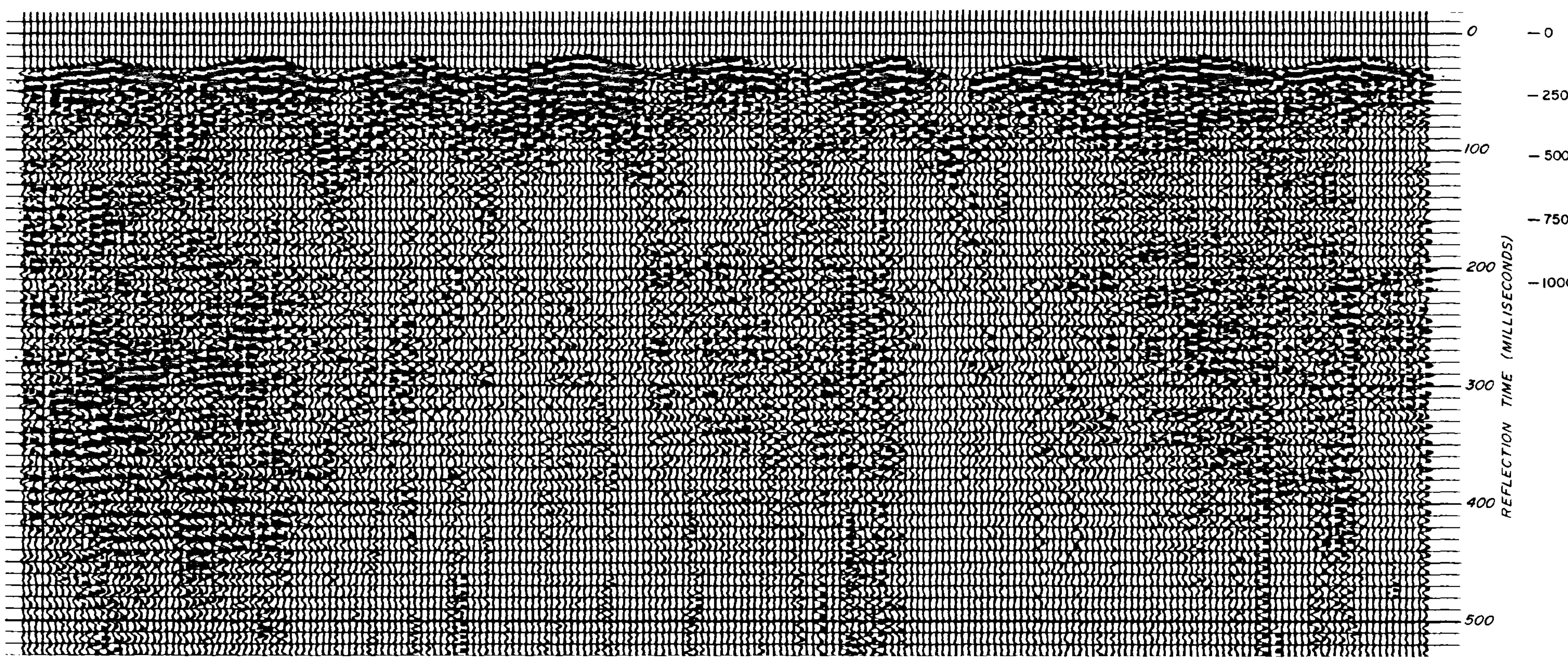
G56/B5-76



FILTERS

Record : L82-Out

Playback : L82-KK175



FILTERS

Record : L130-Out

Playback : L130-KK175

RECORDING INFORMATION

Magnetic Recorder : PMR-20
Amplifiers : PT-700
Prefilters : ——
Filters : *As indicated*
AGC : Medium
Gain Initial : -80
Final : -10
Geophones : HSJ-14 Hz
Geophone Station Interval : 12½ ft
Geophone Pattern :
8 per trace, 1 ft apart, in line perpendicular to traverse
Shot-Hole Pattern : 1 hole
Offset : Nil
Depth : 75 ft
Charge : 1 lb

PLAYBACK INFORMATION

Filters : As indicated
AGC : Off
Gain Initial : -30
Final : -20
Trip Delay : ·1 sec
Compositing Nil

VELOCITY INFORMATION

Velocity log of stratigraphic hole NS70

HORIZONTAL SCALE

RECORDED BY : BMR Engineering

SECTION BY : BMR Playback Centre SIE MS42

MOURA COALFIELD, QLD 1970

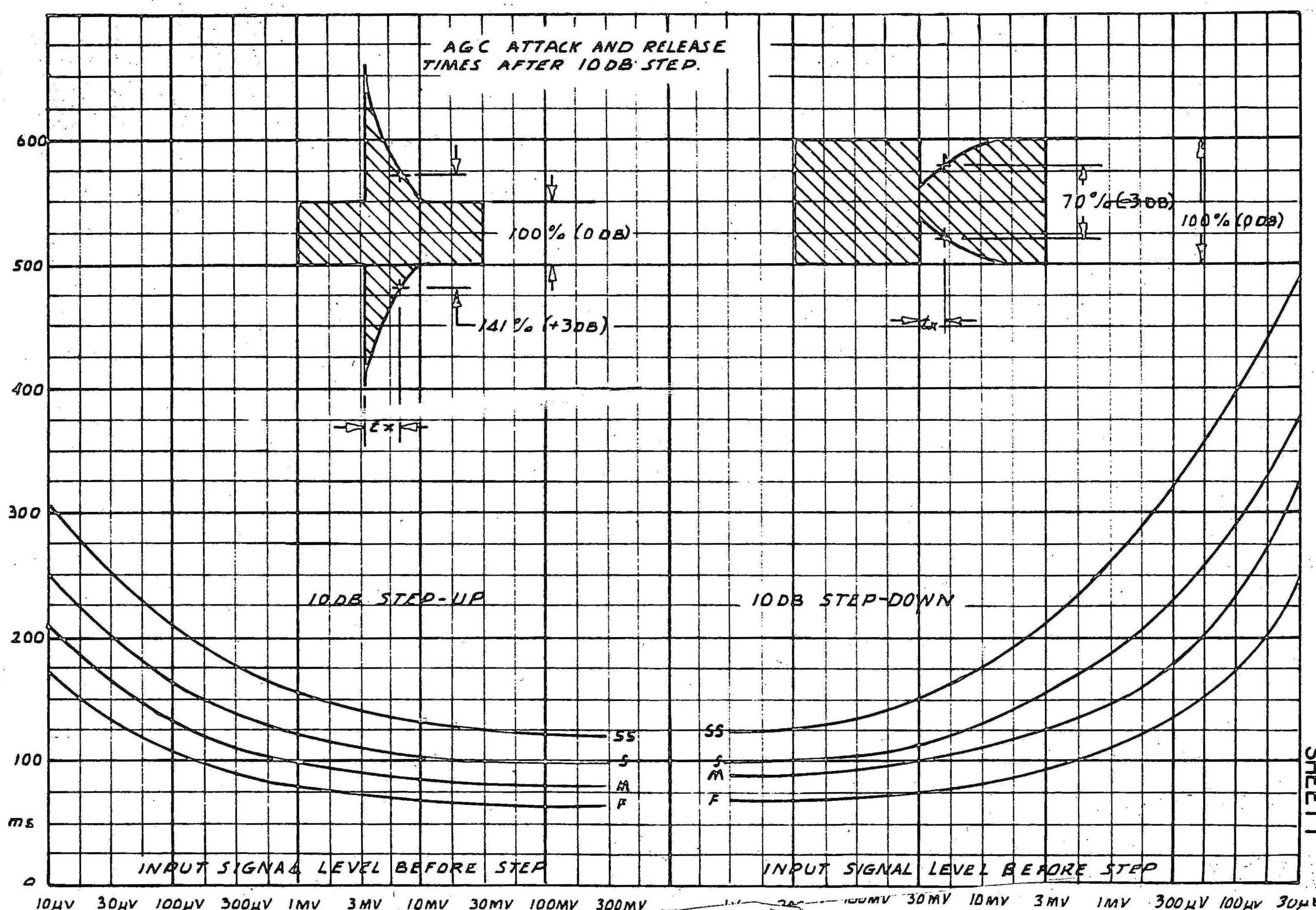
TRAVERSE A

SPs 44 to 48

To accompany Record No 1971/122

G56/B5-79

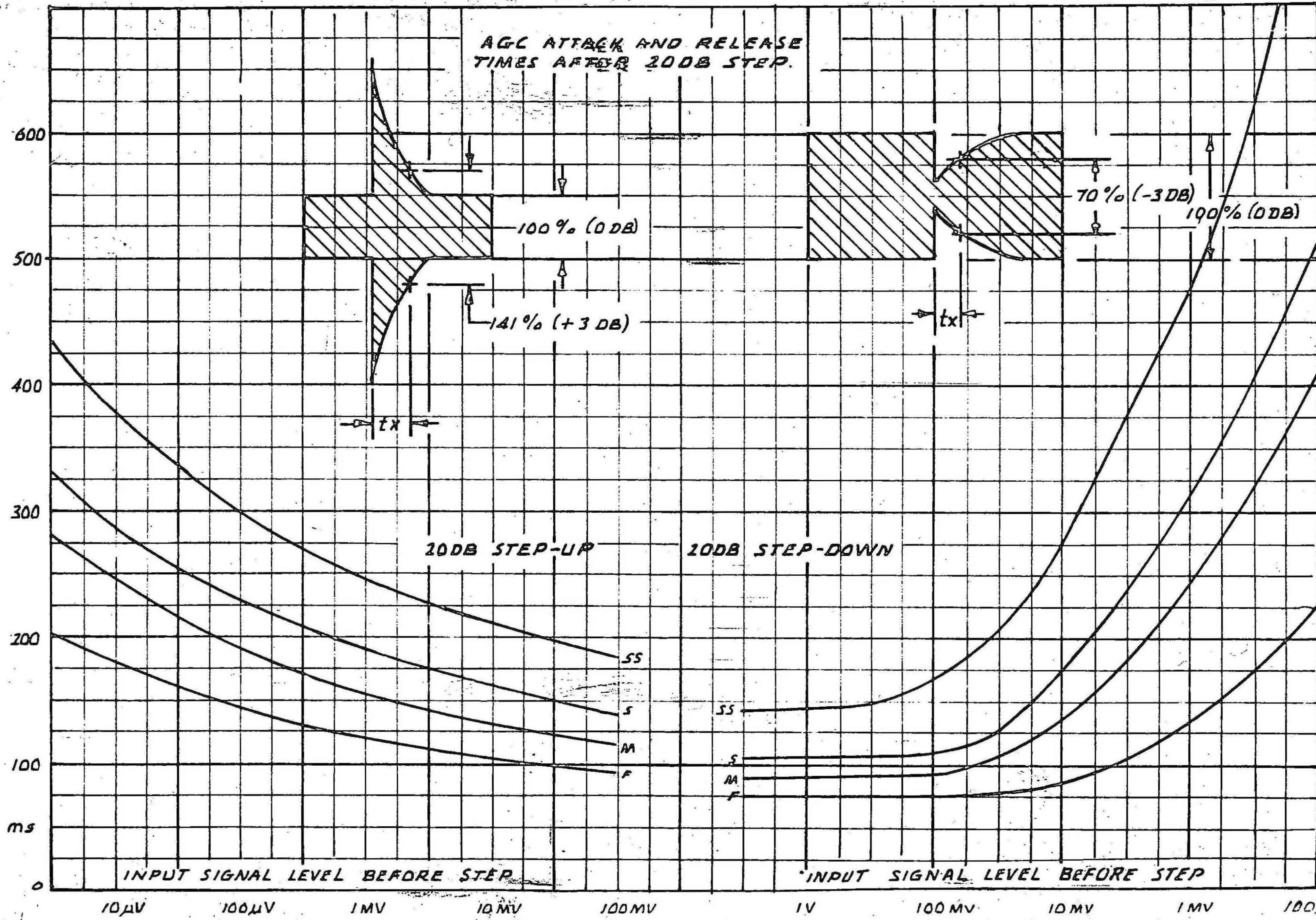
To accompany Record 1971/122



G 85/2-7A

PLATE 13
SHEET 1

To accompany Record 1971/122



G 85/2-6A

PLATE 13
SHEET 2