COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Report No. 16

SEISMIC REFLECTION SURVEY AT ROMA, QUEENSLAND

By

J. C. DOOLEY

☆

Issued Under The Authority Of Senator the Hon. W. H. Spooner, M.M.,
Minister For National Development
1954

LIST OF REPORTS

1. Preliminary Report on the Geophysical Survey of the Collie Coal Basin-N.G. Chamberlain, 1948.

2. Observations on the Stratigraphy and Palaeontology of Devonian, Western Portion of Kimberley Division, Western Australia-Curt Teichert, 1949.

3. Preliminary Report on Geology and Coal Resources of Oaklands-Coorabin Coalfield, New South Wales-E. K. Sturmfels, 1950

4. Geology of the Nerrima Dome, Kimberley Division, Western Australia-D. J. Guppy, J. O. Cuthbert and A. W. Lindner, 1950

Observations of Terrestrial Magnetism at Heard, Kerguelen and Macquarie Island, 1947-1948. (Carried out in co-operation with the Australian National Research Expedition, 1947-1948). N. G. Chamberlain, 1952.

Geology of New Occidental, New Cobar and Chesney Mines, Cobar, New South Wales -C. J. Sullivan, 1951.

Mount Chalmers Copper and Gold Mine, Queensland-N. H. Fisher and H. B. Owen, 1952.

8. Geological and Geophysical Surveys, Ashford Coal Field, New South Wales-H. B. Owen and L. W. Williams.

9. The Mineral Deposits and Mining Industry of Papua and New Guinea-P. B. Nye and N. H. Fisher

10. Geological Reconnaissance, South-Western portion of Northern Territory-G. F. Joklik.

11. The Nelson Bore, South-Western Victoria; micro-palaeontology and stratigraphical succession-I. Crespin,

12. Stratigraphy and micro-palaeontology of the Marine Tertiary rocks between Adelaide and Aldinga, South Australia-I. Crespin,

13. Geology of Dampier Land-R. O. Brunnschweiller,

14. A Provisional Isogonic Map of Australia and New Guinea Showing Predicted Values for the Epoch 1955·5-F. W. Wood and I. B. Everingham, 1953

15. Progress Report on the Stratigraphy and Structure of the Carnarvon Basin, Western Australia; M. A. Condon.

16. Seismic Reflection Survey at Roma, Queensland; J. C. Dooley.

17. Mount Philp Iron Deposit; E. K. Carter and J. H. Brooks.

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Secretary - H. G. Raggatt

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ABSTRACT

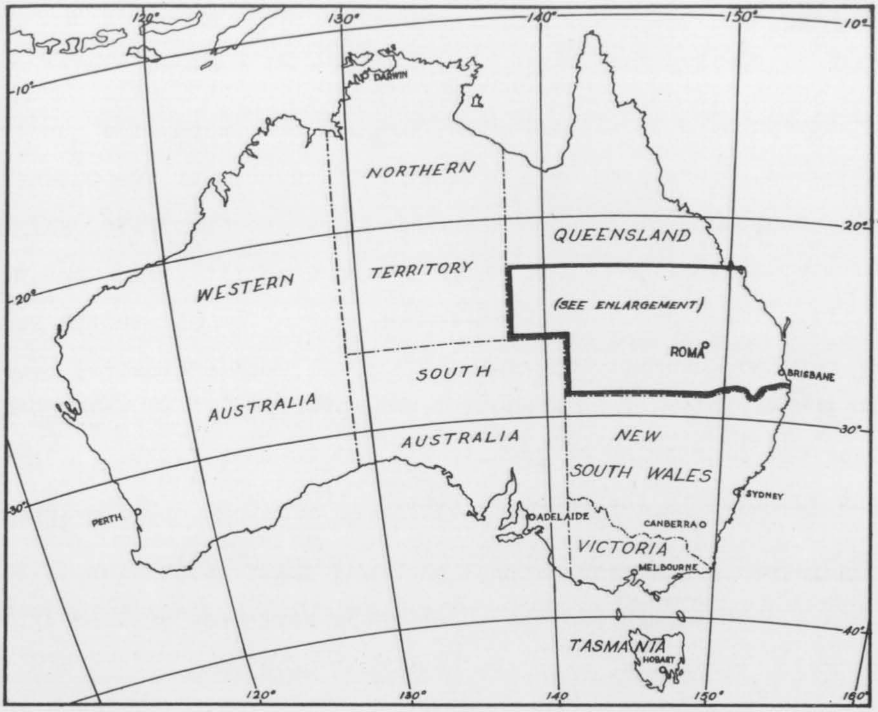
In the vicinity of Roma about 3,000-4,000 ft. of Mesozoic sediments overlie a basement consisting of granite and metamorphic rocks. Permian rocks outcrop about 70 miles to the north of Roma.

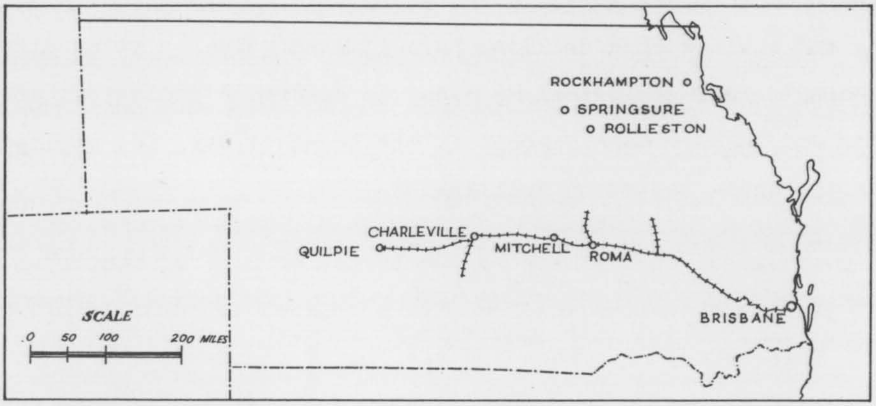
Considerable flows of natural gas, and small quantities of oil, have been found since 1900 in many of the bores which have been drilled in the Roma area, but no major commercial supplies have been developed.

The sediments are mostly obscured by soil. Experience also suggests that pitting and shallow core drilling have limited value. It is difficult therefore, using normal geological methods, to determine geological structures in the region and to ascertain, except in the broadest way, the geological structure in the areas tested by drilling.

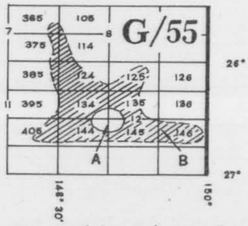
A geophysical survey made by the Bureau of Mineral Resources revealed two residual gravity anomalies which might be related to possible oil-bearing structures. This report describes the testing of these structures by the seismic reflection method. Good reflections were obtained in some parts of the area, but the quality was not consistent. The seismic results appear to confirm a small closure near one of the gravity anomalies. No definite closure is shown near the other anomaly. It is recommended that one or more test bores be drilled in the area where the seismic work confirms the gravity anomaly.

FIG.1





REFERENCE TO ROYAL AUST. SVY. CPS. MAPS



GEOPHYSICAL SURVEY AT ROMA, QLD.

LOCALITY MAP

J. C. Dooley
GEOPHYSICIST

A *Area covered by Seismic Survey*

B *Area covered by Gravity & Magnetic Survey*

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Geophysical Section, Bureau of Mineral Resources Geology and Geophysics

INTRODUCTION

The Bureau of Mineral Resources, Geology and Geophysics undertook to do geophysical work in the Roma area at the joint request of the Queensland Government, and four companies, Roma Blocks Oil Co., No Liability, Kalimna Oil Co., No Liability, Australian Oil Development, No Liability, and Roma North Oil Co., No Liability, which are associated in the search for oil in the Roma area. The companies hold an Authority to Prospect for oil (non-exclusive) over an area bounded by longitudes 148°00'E and 149°30'E, and latitudes 25°27'S and 26°45'S, and exclusive Petroleum Prospecting Permit covering about 200 square miles around Roma. The first stage of the geophysical work comprised gravity and magnetic surveys, which have been described by Dooley (1950).

The seismic reflection survey described in this report was carried out in an attempt to confirm the results of the gravity survey, and to provide more detail in the critical areas. Fig. 1 shows the location of the area surveyed.

The seismic field work began in November-December, 1949, with Mr. K.R. Vale as party leader. After a short break in the summer months, during which the equipment was overhauled and the initial results were analysed, the field work was resumed in March, 1950 and completed in October, 1950, with the writer as party leader. Mr. Vale assisted at all stages of the survey with advice on technical matters, and the interpretation of the results was discussed fully with him. The writer gratefully acknowledges this assistance. Messrs. E. R. Smith and J. B. Boniwell assisted with the field work and the computation of results.

SUMMARY OF PREVIOUS EXPLORATION

This section and the following one "Geology of the Area" are adopted from the report by Dooley (1950). In compiling this summary, reports by Raggatt and Crespin (1944) and Reeves (1947) were consulted.

Natural gas was first discovered in Roma in 1900, in a Government water bore on Hospital Hill. By 1922 the Government had drilled two more bores and made several unsuccessful attempts to obtain gas for commercial use. By 1932 another twenty-five deep wells had been drilled in the Roma district in the search for gas or oil. It is doubtful whether reliable evidence of structure was found to support the selection of sites for any of these wells. Roma Oil Corporation Bore No. 1 on Hospital Hill struck light oil and wet gas. Thirty thousand (30,000) gallons of petrol were produced from this bore between 1928 and 1932. In 1930, Roma Blocks Oil Co. No. 1 bore struck a yield of 10 gallons of light oil per day at Block 16, about 8 miles north-east of Roma. Several of the bores near Blythdale also yielded small quantities of oil. None of the other bores drilled during this period showed any substantial quantities of oil or gas, though traces were common.

The area in the immediate vicinity of Roma is mainly soil-covered, and geological mapping does not generally give enough information to enable structures to be mapped. In order to obtain the necessary information for selecting a drill-site, some geophysical method or scout-drilling must be used. Some work of this nature has been done in the past. In 1927-29, Builders Ltd. put down 158 shallow scout bores in the vicinity of Roma. In 1928-29 Queensland Geophysical Surveys Ltd. arranged with a German firm (Piepmeyer Co.) to carry out some geophysical work as the result of suggestions made by Dr. Jensen, Chief Geologist of Roma Oil Corporation. Complete details of this work are not available, but it is believed that magnetic, gravity, electrical, seismic and radioactive methods of exploration were used. However, the work was confined to local testing at various places, and no useful results were obtained.

In 1933-34, Drillers Ltd., a subsidiary of Oil Search Ltd., drilled 78 shallow scout bores, as the result of which a deep well was drilled at Warooby. This gave a gas flow of 600,000 cubic feet per day, but no oil. In 1934 a well was drilled at Wallumbilla to a depth of 4,968 feet without reaching basement. No oil or gas was found.

Oil Search Ltd. undertook a programme of regional mapping, and engaged Dr. F. Reeves as consulting geologist. He located two structures to the north of Roma where Permian and Triassic rocks outcrop, and the Hutton Creek and Arcadia bores were drilled on these structures in 1935-39. The Arcadia bore struck a flow of petroliferous gas at 1,187 feet, giving 250,000 cubic feet per day. Further gas flows were met between 2,487 and 2,900 feet. These gave a total flow of 3,000,000 cubic feet per day of gas containing about 70 per cent carbon dioxide. No gas or oil of any significance was found in the Hutton Creek bore.

The Roma Blocks Oil Co. drilled three more bores near Block 16 in 1938-41. Bore No.3 gave a flow of gas of 60,000 cubic feet per day, and it is reported that Bore No.4 intersected about 10 feet of oil sands, but no commercial production was obtained.

Since 1939, Shell Development (Queensland) Pty. Ltd. has conducted a wide-scale survey over a large area, comprising aerial, geological and geophysical reconnaissance. It is believed that their geophysical survey covered 192,000 square miles, with gravity stations at wide intervals. More recently, this Company has been scout-drilling in an area near Rolleston, about 100 miles north of Roma, using electrical well-logging methods. As a result of the scout-drilling campaign, a test bore has been sunk at Morella without revealing oil or gas, having met igneous rocks at a depth of about 4,000 feet.

In connection with the present survey, Mr. D. A. Pitman, consulting geologist for the four associated companies, has spent much time in gathering and correlating information about past work. The Commonwealth has carried out gravity and magnetic surveys during 1947 and 1948. Miss Irene Crespin, Commonwealth Palaeontologist, has visited Roma and collected samples for micro-palaeontological examination. The Royal Australian Air Force has photographed part of the area, to assist mapping. A geologist from the Bureau of Mineral Resources, Geology and Geophysics has worked on correlation, based on samples from bores and from the surface, by determination of heavy mineral content (Glover, 1949).

The companies have given full co-operation in conducting the survey. The help given by Mr. Pitman and his staff at all stages of the work is gratefully acknowledged.

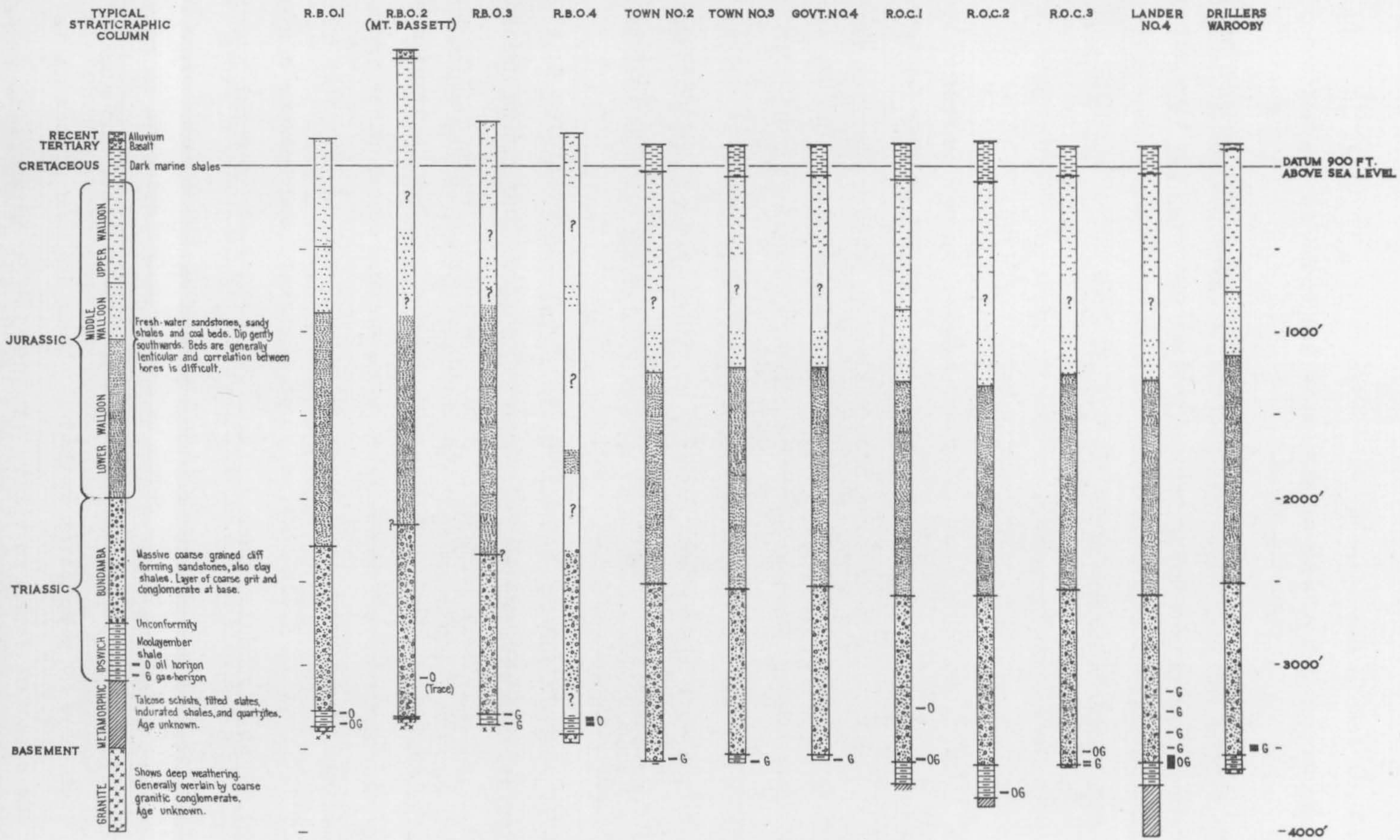

FIG. 2 — SECTIONS OF BORES NEAR ROMA SHOWING STRATIGRAPHY, WITH OIL AND GAS HORIZONS.

NOTE: FOR LOCATIONS OF BORES SEE PLATE I

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GEOPHYSICIST

GEOLOGY OF THE AREA

The following geological notes are based chiefly on the work of Dr. Frank Reeves, formerly consulting geologist for Oil Search Ltd., on discussions with Mr. Pitman, and on examination of the original logs of bores, where available. For a more detailed account of the geology, the report by Dr. Frank Reeves (1947) should be consulted. Fig. 2 shows briefly the stratigraphic section.

The locations of the bores near Roma are shown on Plate 1, and diagrammatic logs are shown in Fig. 2. Those bores which struck granite basement lie in a definite N.W. - S.E. band between Roma Dome bore and Blythdale. Metamorphic rocks have been found on either side of the granite band. In the area covered by the seismic survey, Warooby bore and the R.B.O. bores at Block 16 struck granite basement, and those at Hospital Hill struck metamorphic rocks. Lander No.4 well on Hospital Hill penetrated more than 300 feet of metamorphic rocks without striking granite. These may be Permian or earlier sediments, perhaps altered by the intrusion of the granite.

The basement shows mainly a regional rise of the order of 100 feet per mile to the north or north-west in the vicinity of Roma, but Hutton Creek and Arcadia bores show that there must be a considerable dip in basement to the north of Kayenta and Stewart's Mooga bores. Local relief of the basement surface also occurs; in two places, evidence from bores close to each other indicates fairly steep features. From R.O.C. No.1 to R.O.C. No.2 on Hospital Hill there is a drop of 100 feet in a distance of about 900 feet, and between A.R.O. No.4 and A.R.O. No.11 at Blythdale, there is a drop of 250 feet in about 3/4 mile.

The evidence from many of the bores is rather indefinite, as in many instances drillers' logs only are available, cores have been lost, and much of the drilling has been done by percussion methods. Thus in some places it is doubtful whether the basement found in a bore was granite or metamorphic rock, or even whether basement was reached at all. The interpretation of the logs shown in Fig. 2 differs from that of Dr. Reeves in some details.

Near Roma, the Ipswich Series lies directly on the basement. The Permian sediments crop out to the north of Roma, and show folding with dips up to 40°. Reeves mapped four anticlines in the Permian, namely the Serocold, Consuelo, Woolsack and Arcadia. These persist for 12 or 15 miles southwards into the Triassic sediments, in which the folding is less intense. He also mapped the Hutton-Eurombah Creek anticline in the Triassic. The folding probably occurred chiefly in the late Permian and early Triassic epochs and persisted later in the western part of the area. In the most westerly structure mapped, the Serocold anticline, the Bundamba Sandstone (the lowest stage of the Upper Triassic) is folded with dips up to about 13°. The Jurassic sediments have no keybeds suitable for mapping detailed structures; their general southerly tilt is apparent, but there is no evidence of major folding having occurred in them.

In the vicinity of Roma, oil and gas occur mainly in the conglomerate immediately overlying granite basement (as at Blythdale and Block 16), or in a coarse-grained sandstone and grit at the base of the Bundamba sandstone (as in the Hospital Hill bores). The Jurassic and Triassic rocks penetrated by the bores near Roma consist of fresh water sediments and do not appear to contain suitable source beds for oil. The Permian sediments to the north are generally considered to be the probable source beds; even there, the known thickness of marine sediments is not very great. Nothing is known of the sub-surface geology to the south of Roma, and it is possible that source beds may exist there. In any case, it is probable that the oil which has been found in the bores near Roma has migrated a considerable distance.

The most promising conditions for an oil-trap would seem to be either a suitable high feature in granite bedrock, overlain by conglomerate, with an impervious layer of shale acting as a caprock, or a closed structure at the base of the Bundamba Sandstone, forming a dome in the grit bed. The Middle Triassic, being mostly dense shales, might form a suitable caprock for the first type of structure. It is unlikely, however, that this formation would contain suitable porous reservoir rocks. The second type of structure might be due to compaction folding of the Bundamba Series, which would occur over a high feature in the Middle Triassic surface. As there is an unconformity between the Upper and Middle Triassic, it is possible that the Middle Triassic surface was eroded before the Upper Triassic sediments were deposited. A high feature in this surface might be composed of Middle Triassic rocks. On the other hand, an outcrop of basement rocks might have protruded through the Middle Triassic sediments because an insufficient thickness of sediment was deposited; or a hill of basement rocks might have been exposed by the erosion of the Middle Triassic sediments. Thus it is possible that a compaction fold in the Bundamba Series might be directly associated with a high basement feature.

As stated above, the Bundamba Sandstone is folded in parts of the area. This folding might have slightly affected the Bundamba Series near Roma, although Reeves shows no unconformity between it and the Jurassic Sediments, which do not show any marked folding. If the Cretaceous, Jurassic, and Upper Triassic Series are conformable, then a structure in the Bundamba Series would be reflected at the surface, and could be located by surface geology or shallow scout drilling. As there is an unconformity between the Upper and Middle Triassic, the first type of structure mentioned may not be reflected at the surface.

SEISMIC FIELD WORK

The equipment used for the seismic survey comprised a Heiland 12-channel Compander seismograph mounted on a Ford truck, and a Failing F750 portable drilling rig, also mounted on a Ford truck. Two water tenders were used in conjunction with the drill, and a shooting truck with water tank was used in conjunction with the recording truck. Other vehicles with the equipment included a mobile workshop fitted with welding gear, a compressor and storage space for spare parts and tools, and a Land Rover fitted with a cable-laying reel. Apache geophones were used with the equipment.

The number of personnel in the party varied from time to time according to requirements. The normal strength was three geophysicists (party leader, recorder and computer), two foremen drillers, two assistant drillers, two water tender drivers, shooter and assistant, three recorder truck assistants, and cook. The surveying was done by Mr. F. J. Arnold, who was on loan from the National Mapping Section of the Department of the Interior. The number of surveyor's assistants varied from one to five according to the nature of the country and the amount of clearing to be done.

Initially, the drill was worked for only one shift each day, but it was found that drilling was holding up the progress of the survey and the drill was later worked for two shifts each day. Even with the two shifts it was found that the recording and shooting crews could comfortably shoot all the holes that were drilled, although the drill was sometimes temporarily well ahead.

Shot points were laid out along traverses at 1/4 mile intervals. Twelve geophones were laid out between each pair of shot points and the spread was shot from each end. The geophones were spaced at 100 ft. intervals, with 110 feet between each end geophone and the nearest shot point. Shot holes were drilled generally to a depth of 70 to 80 feet. In some places deeper holes were drilled, up to 140 feet, in an attempt to improve the quality of the records. This was not always successful. Comparison of records from shots fired at different depths is illustrated on Plate 2.

Some shots were fired by an air shooting technique, several charges being supported on wooden or iron stakes and detonated simultaneously. These shots were largely experimental in nature. Improved records were obtained by this method in some places, but the conventional shot-hole technique was more reliable in others. Plates 2, 3, 5 and 6 show comparisons of hole-shot and air-shot seismograms. All traverses were shot by the conventional methods. Air-shots were fired in places where records obtained by the conventional method were bad, or to obtain confirmation of dip in critical areas.

Altogether, 202 holes were drilled and shot, in a total of 140 field days. Twenty-seven days were lost owing to rain or breakdown of equipment. The drill worked two shifts on 50 days, during which 106 new holes were drilled and 18 re-drilled. During the remaining 90 field days 96 new holes were drilled and 23 re-drilled.

Charges used were generally 5 or 10 pounds. It was usually necessary to shoot a hole 4 or 5 times in each direction to obtain a satisfactory record. The multiple geophone technique was not used, as extra geophones were not available. It is recommended that this technique be used in any future shooting in this area, as record quality may thus be considerably improved.

REDUCTION OF RESULTS

In general, the quality of the reflections recorded was poor, although good reflections occurred in some parts of the area. Reliable correlations could not be followed over any considerable distance along the traverses. The results were therefore treated mainly by the dip method, the dips of all reflections were calculated, and at points along the traverse, the average dip of the reflections within a certain depth range was calculated. A phantom horizon was built up by integrating these average dips from point to point along the traverse.

All reflections recorded were picked. They were graded according to the system suggested by Gaby (1947) for certainty of existence and accuracy of dip. The apparent dip was measured as a step-out in milliseconds per thousand feet by calculating the gradient of the best least-square linear fit to the times recorded by the twelve geophones as a function of their distance from shot point. A special least-square circular slide rule was used for this operation.

Two corrections were applied to the step-out. The first correction was for changes in surface conditions across the spread, and the second was for normal step-out, or the step-out which would be recorded if the reflector had zero dip.

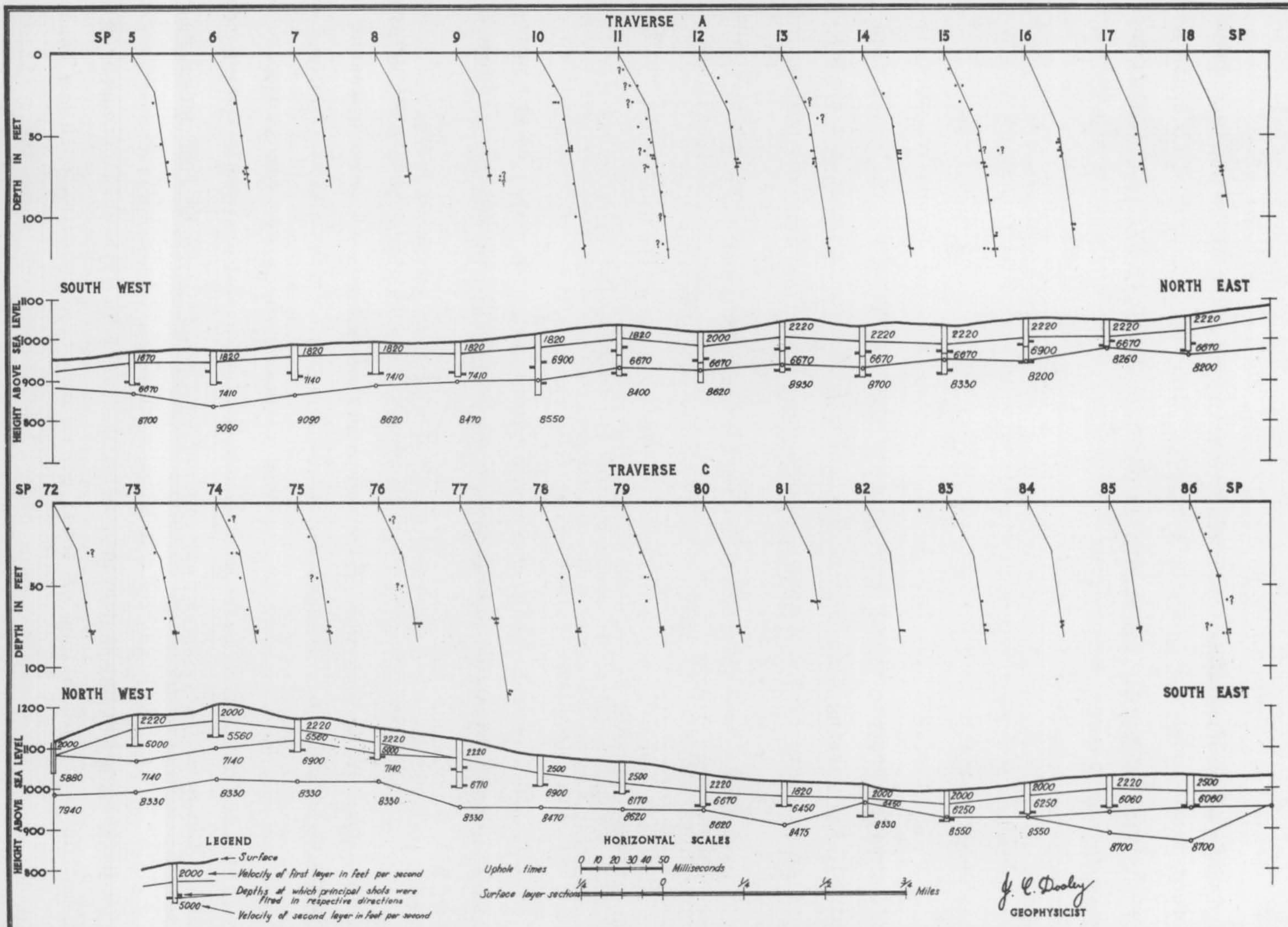

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FIG.3 — SURFACE LAYERS AND UPHOLE TIMES FOR PORTIONS OF TRAVERSES A AND C

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<u>Surface Corrections</u>. The reflection times were corrected to a datum of 900 feet above sea-level, and the corrected times were converted to depth as described later. The velocities and thicknesses of the layers near the surface, which were required for the correction and for the surface step-out correction, were estimated from three considerations.

Firstly, at every third or fourth shot hole, shots were fired at varying depths and the up-hole times were recorded. These times were plotted against depth (see Figs. 3 and 4), and thus showed the weathering velocities and depths. Curves were plotted at intermediate shot points using the velocities so obtained, and passing through the up-hole time recorded at the shot depth; this gave an estimate of the depth of weathering at the intermediate points.

Secondly, special weathering shots were fired at the surface with the geophones spaced much closer to the shot point than for the regular shots. Weathering shots were fired at selected points throughout the area covered, and the velocities were used as a guide in interpreting the up-hole data.

Thirdly, the first breaks on the reflection records were treated as refraction problems, with weathering corrections made on the basis of the previous calculations. Thus the velocities and depths of the next layer or layers could be calculated.

The surface corrections were not a simple problem, as the near-surface velocities varied considerably over the area, and the number of layers present varied from one to three. As pointed out in the preliminary report (Dooley, 1951), the closure on the structure found was not much more than the probable errors. The surface corrections were therefore investigated closely during the revision of the results, as a variation of a few milliseconds in them could substantially alter the final contour plan.

Normally, the datum correction is not required with great accuracy for the dip method, as calculations of total depth are very approximate in any case. In the simple single-layer weathering case it is easy to calculate the weathering correction at each geophone, or the average variation across the spread.

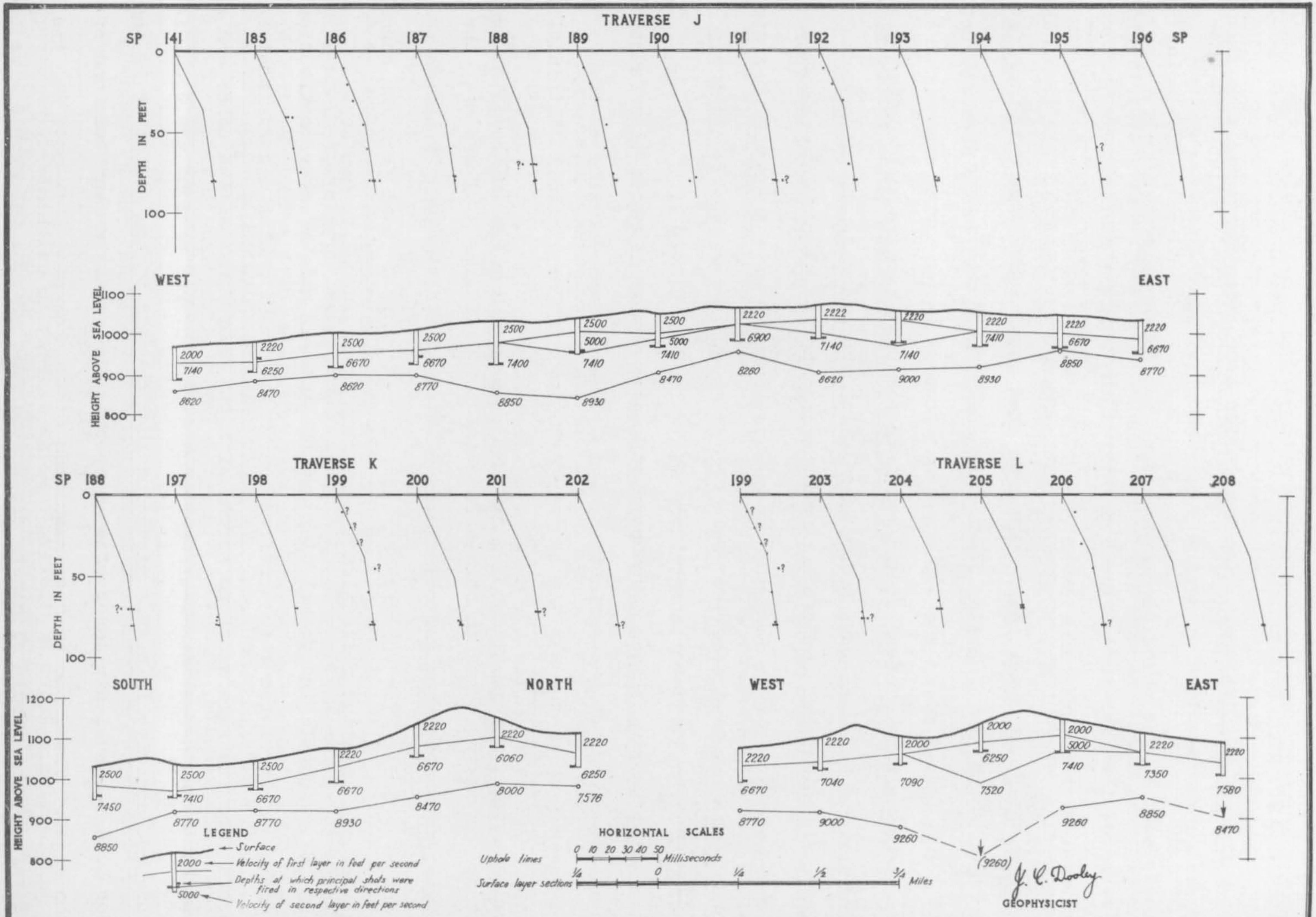

FIG. 4 – SURFACE LAYERS AND UPHOLE TIMES FOR TRAVERSES J, K AND L

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The method finally adopted was to consider all the available information from the three sources mentioned above, and to consider each shot point individually and in relation to its neighbours so as to arrive at a distribution of velocities and depths of layers beneath the shot point. Typical distributions as finally adopted are plotted on Figs. 3 and 4 (for part of the area only). A correction to datum was then calculated at each shot point. The correction to the dip was calculated assuming that conditions varied linearly between shot points. This assumption is likely to produce small errors in the dip correction between individual pairs of shot points. However, these errors will not accumulate along traverses as the dip corrections are fundamentally in agreement with the datum corrections at the shot points. The probable errors introduced in the relative depths shown on the final contour plans will therefore be more or less constant over the whole area, and will be equivalent to the probable errors in the datum corrections at the shot points.

Normal Corrections. The correction for normal step-out is a function of the observed time of the reflection, and of the average velocity of the seismic waves between the surface and the reflector. The vertical distribution of velocity was, of course, not known, and could not be measured directly, as facilities for making tests in bore-holes were not available. Therefore, the normal step-out correction was calculated by a statistical method, from the reflections recorded. The velocity distribution was then deduced from the normal correction, and thus the reflection times could be converted to depths.

To calculate the normal step-out, a list was made of every reflection which could be correlated with a reflection on the interlocking record (that is, the record from the same geophone spread with the shot fired at the other end of the spread). The normal step-outs for such a pair of reflections are equal in magnitude but opposite in sign. Assuming that the dip of the reflector is the same for both records, dip and surface step-outs are equal in magnitude and of the same sign. Thus, the average magnitude of the recorded step-outs for the pair of reflections should eliminate dip and surface effects and should give the normal step-out.

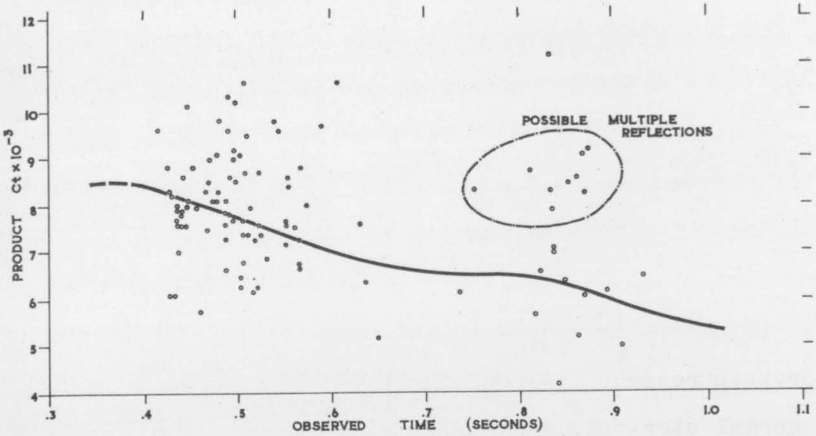

FIG.5 - GRAPH OF PRODUCT Ct
SHOWING STANDARD CURVE ADOPTED

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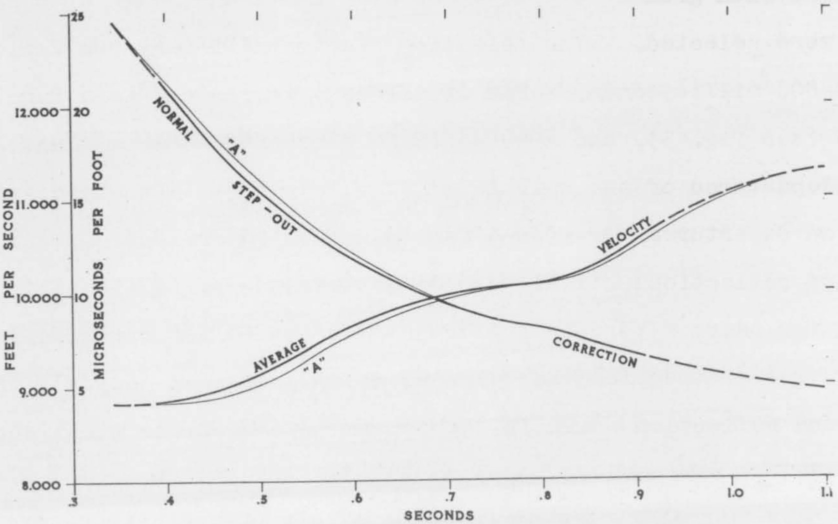

"A" INDICATES CURVE FOR AIR-SHOTS OFFSET 1500 FEET

FIG.6—NORMAL STEP - OUT CORRECTION AND AVERAGE VELOCITY DISTRIBUTION CURVES

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GEOPHYSICIST

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Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics.

Let C = normal step-out correction

t = observed time

V = average velocity to the depth of the reflector

Then V is calculated from the formula:-

$$V^2 = \frac{K}{Ct}$$

where K is a constant depending on the distance of the geophones from the shot point.

Thus, if the velocity does not vary with depth, the product Ct is a constant. For this reason, the product Ct was found more convenient to work with than the normal step-out, especially with regard to multiple reflections, as will be shown later.

The calculated Ct values showed substantial variations for reflections with the same observed time. In order to determine the best curve to adopt for them as a function of observed time, the following procedure was adopted. First, reflection pairs with grades fair to good, with small dips, and with good correlation times, were selected. The selection process left very few reflections in the range 600-800 milliseconds. The Ct values were plotted as a function of observed time (see Fig. 5), and a curve drawn through them as a first approximation. The departures of the calculated Ct values from this curve were determined, and mean departures were found for the selected reflections and also for other groups of reflections. The mean departures for reflection pairs with high dips, or for pairs with correlation jumps up to 30 milliseconds, were not significantly greater than for the selected group. It was decided, therefore, to include these reflection pairs in the determination of the final curve, as shown in Fig. 5.

Multiple Reflections. At this stage it is necessary to consider the possible effect of multiple reflections. Reference should be made to an issue of Geophysics (Vol.13 No.1,1948), which contains a symposium of papers on this subject.

The most common type of multiple reflection is caused by repeated reflections between one good reflector and the surface or the base of the weathered layer. This would appear on the record as a reflection at twice the observed time, with twice the dip of the single reflection, and with the phase inverted. If the velocity did not vary with the depth, the normal step-out for the multiple reflection would be the same as for a true reflection at the same observed time. However, the velocity almost invariably increases with depth. Therefore, the average velocity for a multiple reflection is the same as for a true reflection with half the observed time, and is lower than for a true reflection with the same observed time. Similarly, the normal step-out and the Ct value for a multiple reflection are larger than for a true reflection with the same observed time, and the Ct value is the same as for a reflection with half the observed time.

Examination of the graph (Fig. 5) shows that values are rather widely scattered. Hence the curve chosen is inevitably an approximation, as are the normal step-out correction curve and the velocity distribution curve which are derived from it. This does not affect the phantom horizon seriously, as the normal step-out corrections are applied with opposite signs to alternate shots along the traverse, and therefore any error in them does not tend to accumulate. However, the calculated depths of reflectors depend on the velocity distribution, and absolute depths are therefore not very accurate.

The scattering of the Ct values makes it difficult to identify multiple reflections positively. However, the scattering is noticeably larger for reflection pairs with observed time greater than 800 milliseconds. Moreover, the reflection pairs plotted in this range appear to fall into two groups - those with Ct value greater than 7.9, and those with Ct value less than 7.1. The higher-valued group (enclosed by a circle in Fig. 5) have approximately the same Ct value as the reflection pairs at about half the observed time, and it is possible that these may be multiple reflections. Because of the wide scattering in Ct values, it is impossible to say definitely that any particular reflection is a multiple one. The records with the suspected multiple reflections were examined to see whether the corresponding single reflection could be identified.

In one case only was a good quality reflection recorded at half the observed time. Most of these records showed a weak reflection at approximately half the observed time, and three showed no reflection. It is unlikely that a reflector would give rise to a weak single reflection followed by a fair to good double reflection, although the earlier reflections are near the beginning of the records, and the influence of the compander and the presence of extraneous noise may have reduced their quality. There is also the possibility that multiple reflections may occur between two subsurface reflectors.

It seems possible therefore that multiple reflections with observed times of 800 milliseconds or more have been recorded, but it is not possible to identify an individual reflection as a multiple with any certainty.

Velocity Distributions. In drawing the final curve of Ct value as a function of observed time it was decided to ignore the points enclosed in the circle in Fig. 5, and to draw the curve through the lower group. Several other points were ignored as being obviously erroneous. The normal step-out correction curve and the velocity distribution curve were derived from the Ct curve, and are shown in Fig. 6.

The departure from the final curve of the Ct values for the reflection pairs of all grades was determined. Fig. 8 shows the distribution of these departures for various ranges of observed time. The peak of the curves shows that if all the reflections had been used in determining the Ct graph, the earlier part would have been somewhat higher than the curve adopted, which was based on fair to good reflections only. For observed times greater than about 600-700 milliseconds, the curves show a double peak, which supports the evidence that multiple reflections may be present.

Weight of graded reflections. The Ct departures from the final curve were classified according to the grade of the reflections in order to determine what weight should be given to the various grades in calculating the phantom horizon. The results are summarized in Table 1. They indicate that the departures vary with the accuracy grade rather than with the certainty grade; that there is a substantial difference between good and fair accuracy grades, but not much between fair and poor; and that RP reflections are somewhat worse than other poor accuracy grades. In accordance with statistical practice, the weights should be inversely proportional to the squares of the errors; this would lead to a weighting system similar to the following:-

GG, FG	10
GF, FF, PF	3
FP, PP	2
RP	1.7

TABLE 1.

Mean departures of Ct from standard curve

(Figures in brackets indicate number of reflection pairs used)

Grade	Range of observed time (seconds)							
	0.4 to 0.6		0.6 to 0.8		0.8 +		Total	
GG	0.7	(8)	-		0.7	(4)	0.7	(12)
FG	0.5	(16)	-		1.5	(1)	0.6	(17)
GF	1.7	(7)	-		1.2	(3)	1.5	(10)
FF	1.2	(44)	1.2	(6)	2.2	(12)	1.2	(62)
PF	0.9	(51)	1.5	(10)	1.6	(7)	1.0	(68)
FP	1.1	(18)	1.5	(6)	1.5	(8)	1.3	(32)
PP	1.3	(74)	1.3	(33)	1.5	(19)	1.3	(126)
RP	1.2	(63)	1.9	(47)	1.4	(9)	1.4	(119)

However, other considerations led to modification of the weighting syste follows:-

GG, FG	5
PG, GF	4
FF, PF	3
FP, PP	2
RP	1

This weighting system was checked later by taking the mean departures of the dips of the reflections from the phantom horizons.

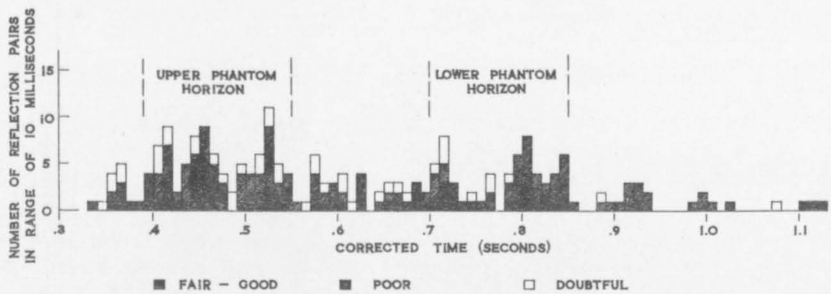

FIG.7– DISTRIBUTION OF REFLECTION PAIRS

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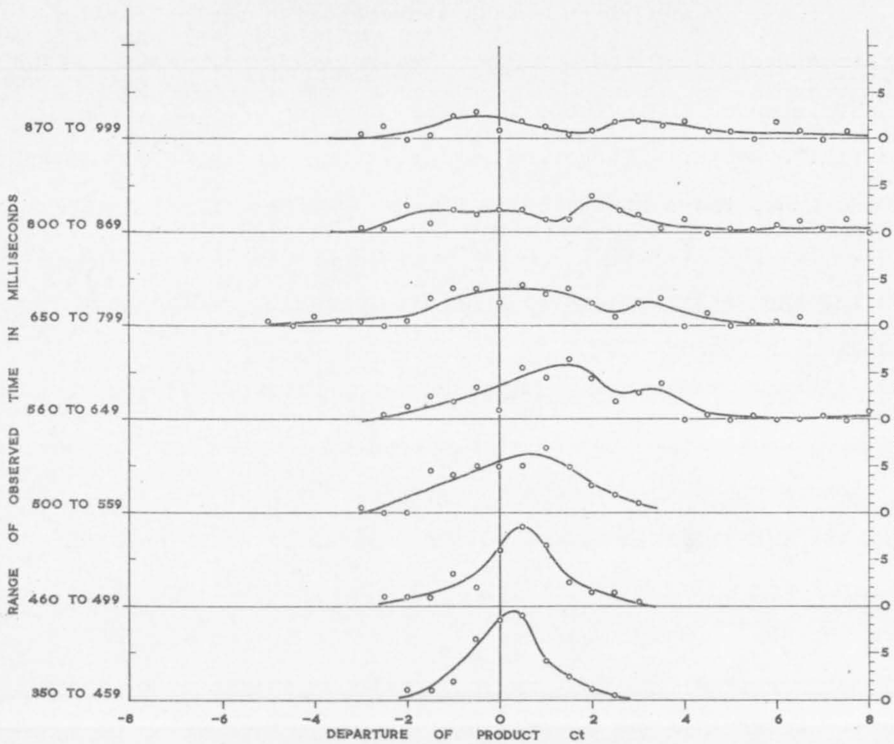

FIG.8– DEPARTURE OF PRODUCT Ct FROM STANDARD CURVE

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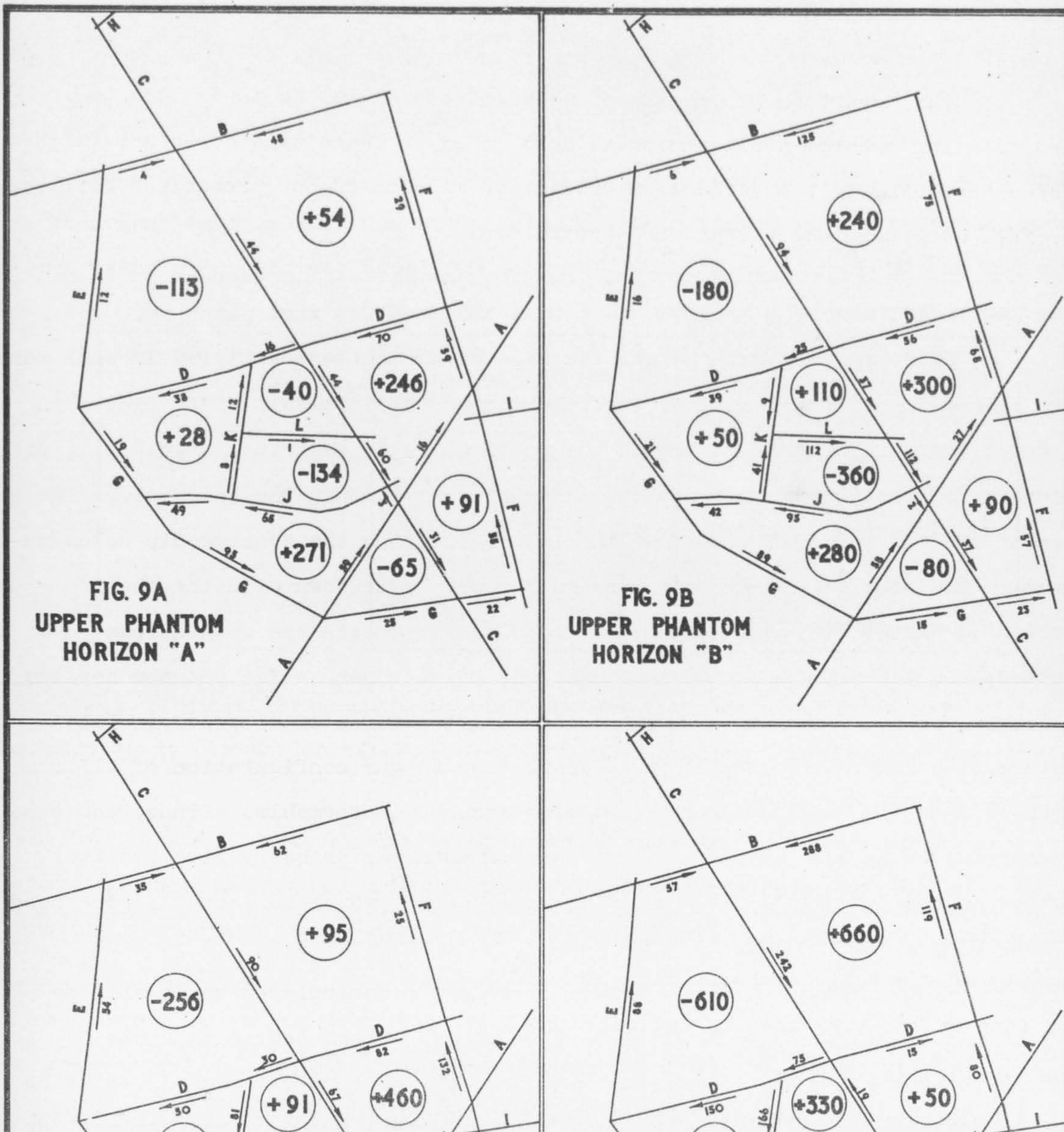
Phantom horizons. Fig. 7 shows the frequency distribution of reflections with respect to corrected time. This was used in choosing the upper and lower zones for determination of the phantom horizons. These were chosen as from 390 to 550 msec. (i.e. 1,700 feet to 2,600 feet) for the upper zone, and from 700 to 850 msec. (i.e. 3,500 feet to 4,300 feet) at shot point 12.

Starting from this point, the dips of the reflectors lying in each zone were averaged over a distance of half the shot point interval. The dips were weighted according to the grades of the reflections as explained previously, and according to the proportion of each reflector lying within the interval. The phantom horizon was then drawn for the interval, using the average dip so calculated. The zone as a whole was assumed to move up or down with the phantom horizon. Plates 8, 9, 10 and 11 show each traverse with the reflections plotted, and the boundaries of the upper and lower zones. The phantom horizon, of course, is not intended to indicate the configuration of some particular feature at a definite depth. It refers rather to the configuration of all the strata within the zone, these strata being assumed conformable. Thus, the zone boundaries, which are parallel to the phantom horizon, probably give a better picture of the interpretation, and also show clearly which reflections were used in determining the horizon.

As a first step, the phantom horizons were calculated using all the reflections in each zone. This led to misclosures around the loops, some of them large (see Figs. 9B, 9D). Then the horizons were re-calculated, omitting certain reflections which were contrary to the general trend of reflections, or which were doubtful for some other reason. Such reflections are marked on Plates 8, 9, 10 and 11. In some intervals, reflections just outside the zones were used, if they appeared more reasonable than those in the zone, or in the absence of any information in the zone itself. The unadjusted original and revised phantom horizons are plotted on Plates 12, 13, 14 and 15. The original phantom horizon is referred to as "B", and the revised phantom horizon as "A". The misclosures for most of the loops were reduced by the revision (see Figs. 9A, 9C).



DIAGRAMS SHOWING MISCLOSURES AND DISTRIBUTION OF ERRORS FOR PHANTOM HORIZONS

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The departure of the dip of each reflection in the zones from the corresponding phantom horizon dip was determined. These departures were listed according to the reflection grades, as a check on the probable errors. The following mean departures were determined:-

Grade	No. of Reflections	Weight	Mean Departure	Calculated Weight (RP = 1)
GG, FG	178	5	.014	5.6
PG, GF	38	4	.019	3.5
FF, PF	393	3	.017	
FP, PP	343	2	.028	1.6
RP	220	1	.033	1.0

The weights in the last column bear out those used fairly well, except that the weight 4 reflections (mostly GF) should not have been distinguished from those with weight 3.

These values of the mean departures for the various grades of reflections were used to calculate a probable error for the phantom horizon dip between each pair of shot points. This probable error was based on the number and the quality of the reflections in the zone. The degree of reliability of various sections of the traverses is indicated by this, and is shown on the contour maps (Plates 16, 17, 18 and 19) by the markings along the traverses. The heavier lines indicate good quality reflections, and the lighter and more broken lines indicate poor quality.

Fig. 9 shows the misclosures found in each case and the distribution of adjustments around the loops. The distribution was made by a least-square method, in which the weighted sum of the squares of the adjustments over the whole area was made a minimum, the weight depending on the probable errors along the links. Two distributions were made for each of the upper and lower phantom horizons. The "B" distribution (Figs. 9B, 9D) was based on the original phantom horizons, which included all reflections in the zone. The "A" distribution (Figs. 9A, 9C) was based on the revised phantom horizons with some reflections omitted as explained above.

The profiles on Plates 12, 13, 14 and 15 show the various stages of the adjustment of the phantom horizons. The profiles shown for each horizon are:-

(1) the original phantom horizon "B",

(2) adjusted phantom horizon based on original phantom horizon "B",

(3) revised phantom horizon "A",

(4) adjusted phantom horizon based on revised phantom horizon "A".

The adjusted phantom horizons are drawn as contour plans on Plates 16, 17, 18 and 19. The depths shown on the contour plans are depths from datum (900 feet above mean sea level) to the centre of the respective zones. However, it is emphasized that the contours are not supposed to represent a particular formation at the depth shown, but are intended to represent the relative depths of any stratum within the zone.

Correlations. An attempt was made to correlate reflections in the area south of Traverse D, around the gravity anomaly of most interest. Correlations were attemoted in the upper zone only, as reflections in the lower zone were generally not persistent enough for correlation. Even in the upper zone, it was possible to correlate a reflection for only a few shot points. These correlations are plotted on Plates 12, 13, 14 and 15 for comparison with the phantom horizons. As it was not possible to close any correlations around loops, they were not used in making adjustments to the phantom horizons.

Air Shots. As stated earlier, shots were fired above the ground at some shot points. In using this technique, it is necessary to set the shot point at some distance from the geophone spread, because the sound waves due to the explosion disturb the geophones to such an extent that reflections cannot be detected upon their arrival. If the shot point is removed along the line of the geophone spread, then the normal step-out becomes large and reflections are difficult to identify. Therefore, shot points were generally offset at right-angles to the spread, although some in-line shots were tried. Examples of seismograms from offset air shots are illustrated in Plates 2, 3, and 6; seismograms from in-line air shots are illustrated in Plate 7.

With the shot point offset, the reflections recorded are from the layers below a line half way between the shot point and the geophone spread. In all cases the geophone spread was set up on the normal traverse lines. Therefore, the reflections recorded with the offset air shots do not represent the same part of the reflecting bed as that recorded by the conventional method.

PROBABLE ERRORS

It is apparent that the accuracy of the phantom horizons is not of the highest order. Moreover, the possible structure shows a closure of only about 100 feet. Detailed estimation of the probable errors in the method has therefore been attempted, so that the probability of the existence of the structure may be appraised.

Most of the errors involved have been referred to in the previous section. The errors to be considered are:-

(1) Errors in surface corrections.

(2) Errors in normal step-out corrections.

(3) Observational errors, errors due to incomplete information, irregular reflectors and other unknown causes.

The surface corrections, as stated previously, were calculated individually for each shot point. The probable error has been estimated from the different values possible for the corrections using various interpretations for the velocities and thicknesses of the surface layers. The average probable error in the correction at a shot point is estimated as 2.5 milliseconds, which corresponds to an error in depth of reflectors of $\pm$ 12 feet. The probable error in the relative depth between any two shot points is $\sqrt{2}$ times this, i.e. $\pm$ 17 feet

It is possible for a systematic error to occur in the surface corrections. Such an error may be caused, for example, by assuming an overall too high or too low velocity for a particular layer, and would lead to over-correction or under-correction for surface effects. If this were so, anomalies corresponding to the surface features would occur in the final contour pattern. A contour plan of the surface corrections (Plate 20) has been drawn for comparison with the phantom horizon contours. There is no obvious overall correlation between the correction and the phantom horizons. To check this further, the correlation of the surface correction with upper phantom horizon "A" was investigated mathematically. A direct correlation between the surface corrections and the phantom horizon depths would not necessarily mean that the surface corrections are in error. The surface corrections and the phantom horizon will each have an areal trend; that is, each of them will correlate to some extent with the co-ordinates of the shot points. These areal trends may be in the same direction or some other relative direction. Unless the trends are at right angles to each other, the surface corrections will show a correlation with the phantom horizon depths. This correlation will reflect the degree of similarity of the natural trends which may well be positively or negatively correlated without implying any systematic error in the corrections.

We define a residual value of surface correction or of horizon depth as the difference between the value at a shot point and the average value at two shot points equidistant along the traverse on either side of the shot point. In order to eliminate the possible correlation of the general areal trends, a correlation was sought between the residual values of surface correction and the residual values of the depth to upper phantom horizon "A". The correlation factor found was + 0.05, which means that virtually no correlation exists between the two residuals. We may assume therefore, that the systematic error due to wrong surface corrections is negligible.

The normal step-out corrections are applied with opposite signs to reflections in the two interlocking spreads between a pair of adjacent shot points. Thus, errors in them cancel out in calculating the phantom horizons and may be ignored for this purpose. However, the vertical velocity distribution, and hence the conversion of time to depth, depend on these corrections. The probable error in the Ct values is ± 16%. As the velocity and depth are inversely proportional to the square root of Ct, the probable error in absolute depth is half this, i.e. ± 8%. Another error in absolute depth occurs owing to the fact that the reflections are usually picked at a later phase than the initial onset of energy. They may be picked on the average about one cycle later than this, the average cycle being about 0.025 seconds. This implies that, on the average, reflectors are probably about 120 feet shallower than plotted, with a mean error in absolute depth of perhaps ± 100 feet.

Other types of errors have been investigated on the assumption that they occur at random. Part of this investigation has been discussed in the section on Reduction of Results. The probable error in dip for various grades of reflections was determined, and on this basis the probable errors between shot points were calculated. These probable errors are indicated on the contour plans (Plates 16, 17, 18 and 19) by lines of various types between the shot points. The classification according to the probable errors is as follows:-

Classification	Probable error (dip)
Very good	Less than .010
Good	.010 - .014
Fair	.015 - .020
Mediocre	.021 - .028
Poor	.029 - .040
Doubtful	.041 - .070
No reflections (value interpolated from adjacent spreads)	Greater than .070

The probable errors in phantom horizon relative depths can be calculated theoretically from the adjustments necessary to close the loops. This calculation gives the probable error for a spread with estimated dip error ± 0.010, as follows:-

Upper	phantom	horizon	"A",	unadjusted	± 15ft.,	adjusted	± 12ft.
Upper	"	"	"B",	"	± 19ft.,	"	± 15ft.
Lower	"	"	"A",	"	± 20ft.,	"	± 15ft.
Lower	"	"	"B",	"	± 29ft.,	"	± 22ft.

The probable error in depth for any spread is proportional to the estimated dip error.

These figures confirm that the "A" horizons are more reliable than the "B" horizons, and that the upper phantom horizon is more consistent than the lower. The values for the probable errors in depth are comparable with the estimated dip errors, but are somewhat larger, especially for the lower phantom horizon.

The probable error in depth between any two shot points can be calculated as the square root of the sum of the squares of the individual probable errors for the spreads between them. In this way, the probable error has been estimated for the relative depth between the highest point and the critical point of the main closure on each phantom horizon. These probable errors are:-

Upper	phantom	horizon	"A",	± 41ft.;	combined	error	± 45ft.
Upper	"	"	"B",	± 51ft.;	"	"	± 55ft.
Lower	"	"	"A",	± 96ft.;	"	"	±100ft.
Lower	"	"	"B",	± 138ft.;	"	"	±140ft.

The combined errors in the above include the probable errors due to surface corrections, and have been rounded off to the nearest 5 feet.

The term "probable error" has been used here in the sense that an error is equally likely to be less than or greater than the figure stated. The figures quoted are, of course, necessarily approximate, as the theory assumes that the errors follow a normal distribution, and this has not been proved. However, the figures should give some idea of the reliability of the results.

DISCUSSION OF RESULTS

The contour plans (Plates 16, 17, 18 and 19) each show a high closure coinciding approximately with the residual gravity anomaly in the southern part of the area.

There is also a suggestion of a high closure near the northern residual gravity anomaly. However, the reflections eastwards and southwards from S.P.44 were weak, and the contours show no definite closure in that area. As the survey progressed, it was realized that the best chance of a high closure was in the southern part of the area. Additional traverses were therefore run, and existing traverses were checked at critical places by re-shooting in order to delineate the supposed structure as accurately as possible. The work was concentrated on the southern structure in preference to the northern one, and the southern high closure is the main feature to be considered here.

The closures shown on the various phantom horizons are as follows:-

Upper phantom horizon			"A",	90 ± 45ft.,	highest point		S.P.208.
Upper	"	"	"B",	100 ± 55ft.,	"	"	S.P.208.
Lower	"	"	"A",	160 ± 100ft.,	"	"	S.P. 78.
Lower	"	"	"B",	50 ± 140ft.,	"	"	S.P. 11.

It has been shown that the "A" phantom horizons are more reliable than the "B" ones, and it is mainly the former therefore which will be considered in this discussion.

Assuming a normal distribution of errors, the above figures indicate with about 90% certainty that the structure on the upper horizon exists, about 85% certainty that the closure is more than 20 feet, and 75% certainty that it is more than 50 feet. For the lower horizon, there is about 85% certainty for existence, and 80% certainty for a minimum closure of 50 feet. These figures are based on a statistical analysis of the results themselves. The probability that the reflections correspond to a series of conformable beds which can be represented by a phantom horizon must be considered separately.

It was difficult to correlate reflections for more than a few shot points (see Plates 12, 13, 14 and 15). The quality of the reflections changes along the traverse. In many places, one cycle persists prominently across several records and then fades out, while another cycle of the same reflection becomes predominant. The number of reflections and their continual changes in character make it impossible to identify any outstanding event which could be correlated across a gap of poor records, or which could be definitely tied to any geological horizon. Correlations have been followed in places for a few shot points, and these are plotted on Plates 12, 13, 14 and 15, for comparison with the upper phantom horizon. Where differences occur, the upper phantom horizon has not been altered to agree with the correlation plots, as no correlations were followed around a complete loop, so that the possibility of jumping a cycle was not checked.

In the upper zone, two or three reflections were recorded in nearly all parts of the area, although the quality of the reflections varies somewhat. The dips are generally consistent. The "A" and "B" upper horizon contours show substantial agreement. This is because nearly all the upper zone reflections were thought to be consistent with the supposition of a conformable series, and only a few were omitted during the revision of the original "B" horizon. It seems reasonable to suppose therefore that the upper phantom horizon does represent the configuration of a conformable geological series.

In the lower zone, good reflections are comparatively few, and several gaps occur for two or three spreads where no reliable reflections were recorded from that zone. For the lower horizon, the "A" and "B" contour patterns differ more noticeably than for the upper horizon, as many reflections show dips in contrast to adjacent reflections, and so are not compatible with the theory of a conformable series (see Plates 8, 9, 10 and 11). Such reflections were omitted from lower horizon "A". This feature of the lower zone suggests, on seismic evidence alone, that a substantial proportion of the lower zone reflections do not belong to a conformable series. The same conclusion is suggested by the geological evidence.

According to Reeves (1947), the main stratigraphic divisions in the vicinity of the supposed structure occur approximately at the following depths below datum (see Fig. 2):-

Walloon - Bundamba,	2,400 feet.
Bundamba - Ipswich,	3,400 "
Basement,	3,600 "

(These figures are by interpolation between bores.)

The depths of the upper and lower zones are approximately:-

Upper zone, 1600-2400 (probable error ± 200 feet).

Lower zone, 3400-4200 (" " ± 350 ").

(see section on "Probable Errors").

Thus, the upper zone probably corresponds to the lower portion of the Walloon Series. The lenticular nature of the beds and the lack of definite and persistent characteristics which make useful markers, renders geological surface mapping and correlations between bores in the Walloon very difficult.

These features could well cause reflections with the characteristics described above to the upper zone; then the upper phantom horizon would represent the general configuration of the series without giving detail on any definite horizon.

From the data given above, it appears that the Bundamba Series is comparatively deficient in reflecting beds. The lower zone probably includes the Ipswich Series, the basement surface, and the top few hundred feet of basement rocks. It may also include the lower portion of the Bundamba Series. Thus, the geological significance of the lower phantom horizon is somewhat uncertain. There is no persistent outstanding reflection which could represent the basement surface continuously, as might be expected. However, it is very probable that reflections from the basement surface occur and are included in the lower zone in various places. Similarly, the Bundamba/Ipswich contact may produce some reflections.

As there is an unconformity between the Bundamba and the Ipswich Series the only reasonable interpretation by which the lower phantom horizon could be taken to represent a conformable series would be to assume that it corresponds mainly to the Ipswich Series.

It may be that, after elimination of erratic reflections, the "A" horizon represents substantially the Ipswich Series. However, as Reeves considers that this series is only about 200 feet thick near Roma, it is probable that reflections from other sources are included.

The existence of reflections from sources apparently deeper than the basement surface is surprising. At shot point 69SE (see Plate 3) reflections up to 1 second were recorded. In a previous section it was concluded that some multiple reflections may be present, but that it is difficult to identify them. The occurrence of late reflections without a strong shallow reflector, and without the typical repetition pattern, suggests that many of them must correspond with real deep reflectors. Reflections could hardly be expected from within the granite mass, and it is noteworthy that, near the Block 16 bores and Warooby bore, where granite basement is known to occur, the very deep reflections are absent.

Little is known of the metamorphic basement rocks. It may be that these are Permian sediments or older, and the gravity work suggested that they may attain considerable thickness in parts of the area. These rocks may contain beds with suitable characteristics that give rise to reflections in places where the beds are nearly horizontal and not faulted.

Thus, the source of deep reflections is doubtful. It is unlikely that they have any bearing on oil accumulation, unless the so-called metamorphic rocks could be regarded as source rocks, and the deep reflections as indicative of a considerable thickness of these rocks. This, however, on the basis of present knowledge, is pure speculation.

The possibility of faulting being present cannot be discounted. Sudden changes in the quality of the records, as between shot points 17 and 18 or between shot points 93 and 94 could be due to faulting. However, there is no outstanding reflection which can be identified across the gap, and attempts to line up gaps on different traverses have not been successful - perhaps because there are too many such gaps. Faulting could, of course, account for some of the large misclosure errors in the phantom horizons.

A discussion of the main features of interest in the individual traverses is now given.

Traverse A. (Plates 8 and 12). This traverse was intended to cut the southern gravity residual anomaly approximately at right angles to its main axis. The upper horizon shows an overall rise to the north-east, with a low-dip reversal between shot points 10 and 16, which corresponds fairly well with the gravity anomaly. This section of the traverse was re-shot with 120-ft. holes, and air shooting was used over part of it. Plate 2 shows records from hole shots and air shots at shot points 15SW and 20NE, and a deep shot at 120 feet at 15SW. The deep shooting gave improved records, but these were probably due to improved technique rather than to the extra depth. The air shooting confirms the reversal. Some air shots gave improved records, as at shot point 15SW (Plate 2), but others gave worse records than the corresponding hole shots (e.g. shot point 20NE, Plate 2).

The high at shot points 10-12 is more marked on the lower horizon, but the quality of the records is worse. Another local high occurs at shot points 4-5. A good steep-dipping reflection occurs near shot point 17 in the lower zone (see seismogram 17NE, Plate 3). This was included in the "B" horizon, but was omitted from the "A" horizon, causing the large difference between the horizons as shown on Plate 12. There is a marked lack of conventional reflections between shot points 17 and 19. Air shooting has covered part of the gap, but no air shots were fired between shot points 18 and 19. The sudden break in the reflections suggests faulting as a possibility.

Traverse B. (Plates 8 and 12). This traverse was intended to cut the northern gravity residual anomaly approximately at right angles to its main axis. The upper horizon shows a rise to the north-east as far as shot point 44, then a slight reversal. The reflections are fair to good as far as shot point 43, but to the north-east of this they deteriorate considerably on both horizons. The "B" lower horizon shows north-east dip north-east of shot point 46, although this depends largely on interpolation from one doubtful steep-dipping reflection which was omitted from the "A" horizon. The north-east dip from shot points 50-52 is also by interpolation. Thus, the eastern portion of Traverse B is unreliable, particularly on the lower horizon.

Traverse C. (Plates 9 and 13). This traverse was laid out so as to cut Traverses A and B near the high points which correspond approximately with the gravity anomalies.

It was expected that this traverse would show the regional dip of the beds, which is supposed to be to the south-east. However, no such effect was apparent until after the misclosures were adjusted, and even then there is only about 200 feet south-east drop in 8 1/2 miles on the upper horizon, and practically none on the lower horizon.

There appears to be a small high feature associated with each of the two structures. However, in the case of the northern structure, the quality of the reflections is poor, and on the upper horizon the feature is very small. The highest point of the southern feature is at shot point 78 on both horizons. The feature is small however. Air shooting was carried out at shot points 72-73, 78-80 and 86 in an attempt to confirm dip at critical places. However, the quality of the air shot records was no better than that of the conventional ones (see Plate 2 for a comparison of the records at S.P.73 N.W.), and at shot points 79-80 and 86 no reflections were recorded in the lower zone, where the check was required.

Between shot points 69 and 77 there is a sequence of fair to good reflections near the centre of the lower zone, which may well represent some definite horizon such as the basement surface. Some gaps occur in the sequence, but there is a definite suggestion of continuity which is unusual for the lower zone.

Many apparently deep reflectors occur along Traverse C, the deepest recorded being between shot points 69 and 70, at more than 8,000 feet. The seismogram at shot point 69SE is shown on Plate 3. The pattern here and at some other places suggests that some of these very late reflections are multiple ones.

Both horizons show a tendency to rise at the south-east end of Traverse C. As this is contrary to the supposed regional dip, it may be worth further investigation, especially as good reflections were recorded here.

<u>Traverse D</u>. (Plates 9 and 13). Good quality reflections were recorded at both ends of Traverse D, but some poor reflections occurred in between. Seismograms from shot points 90 to 93 (Plate 4) show a marked deterioration. An attempt to improve the quality of the records by using deeper shots was made at shot points 92-94 and 98-99. Air shots were fired at shot points 99 and 101.

Two of the sir shot records are shown on Plate 3 beside the conventional records. None of the air shots gave additional information of any value. Two steep reflections were recorded from the air shot at shot point 101, contrary to the general trend. However, their quality is poor and they cannot be regarded as very significant.

A sequence of reflections occurs in the lower zone between shot points 95 and 100. These are not as regular as the sequence mentioned on Traverse C, which crosses here, but they probably represent the same feature.

Traverse E. (Plates 9 and 13). The quality of the reflections is fair to good throughout, particularly on the upper horizon. Each horizon shows a small but steady dip to the south.

Traverse F. (Plates 10 and 14). The south-east regional dip is much more prominent here than on Traverse C. A reversal of dip causes a prominent high feature on the upper horizon near shot point 130. However, the reversal is based on two low-grade reflections between shot points 132 and 131, and is therefore not very reliable. The high feature at shot point 121 appears to be associated with the southern structure indicated by Traverses A and C. Reflections south-east of shot point 126 are abundant, except near shot points 166 and 165, and are of relatively high quality. Continuous correlation was possible between shot points 121 and 161.

Traverse G. (Plates 10 and 14). This traverse comprises three sections, with major bends at shot points 143 and 151, and forms the southern boundary of the main outside loop. Reflections are mostly fair to good, but a bad patch occurs between shot points 154 and 157. Air shooting was done here, and some fair and good reflections were recorded. Not many were in the lower zone however. Plate 5 shows the hole-shot records from shot point 154 to 157, and Plate 6 shows the corresponding air-shot records.

Two high features are prominent on the lower horizon, one between shot points 145 and 150 and the other at shot point 157. Corresponding, but smaller features occur on the upper horizon. These are part of the main southern structure. The comparatively steep dip in the lower horizon to the west of shot point 157 is not very reliable.

Correlations were followed on a shallow reflector from shot point 148 to 160, with a break from shot point 156 to 157.

Traverse H (Plates 11 and 15) runs north-eastwards from the north-west end of Traverse C, and passes through two Roma Blocks Oil Company bores. R.B.O. No.1 bore is at shot point 178, and No.4 bore is between shot points 176 and 177. The depth of basement (granite) is 3,379 feet below datum at R.B.O. No.1, and 3,518 feet below datum at R.B.O. No.4. This is just above the upper zone, as plotted, and suggests that the fair to good reflections at the top of the upper zone near shot point 178 may be associated with the basement surface. However, this does not account for the good reflections which would appear to be several hundred feet below basement at shot points 176 and 177.

The fact that the entire lower zone appears to be below basement at these bores does not necessarily imply that this is the case for the rest of the area. It should be noted that the adjustments of the closed loops in other parts have had the effect of raising the lower horizon of Traverse H by 300 to 400 feet. Moreover, the tie between the bore and the rest of the work is by several miles of unclosed traverse containing many poor reflections, and the relative levels of the horizon may be substantially in error. Also, the error in converting reflection times to absolute depth may be several hundred feet.

The main reflectors in the upper zone appear to be well within the Walloon Series near the bores, the depth to the bottom of this formation at R.B.O. No.1 bore being 2,284 feet, according to Reeves (1947).

Both horizons show a rise to the north-east. The high feature at shot point 173 on the lower horizon is not very well substantiated.

Traverse I. (Plates 11 and 15). This short traverse connects Traverse F to Warooby bore, which is at shot point 184. The lower horizon shows an east dip from shot point 179, followed by a rise from shot point 181 to 184. The upper horizon shows a smaller rise towards shot point 184.

The basement depth at Warooby (granite) is 3,621 feet below datum. There is a poor reflection near this depth, just above the lower zone. The fair to good reflections between shot points 182 and 183, which are somewhat deeper, would seem more likely to represent basement surface, and in view of the possible errors in converting time to depth, this may well be so.

The adjusted lower horizon here is about 200 feet above the original, and again the tie to the rest of the work is not very good, as reflections were weak near shot point 180.

Reeves (1947) gives the depth to the Walloon-Bundamba contact as 2,507 feet below datum; this is near the bottom of the upper zone. The good reflectors beneath shot points 183 and 184 appear to come from within the Walloon Series.

Traverse J (Plates 11 and 15) follows the railway line, from shot point 141 on Traverse G to near shot point 80 on Traverse C. The upper zone contains reflections of fair to good quality over most of this traverse, but the lower zone has some weak patches. The high at shot point 191 on the upper horizon is associated with the main southern structure. The lower horizon shows a general tendency to rise to the east, although there is a culmination at shot point 191. The steep dipping reflections near shot point 189 were omitted from the revised horizo as being of doubtful origin. Their omission also decreased the loop closure errors.

Traverse K (Plates 11 and 15) runs north from shot point 188 on Travers J to Traverse D near shot point 95. The southern part is characterised by good reflections in the lower zone, but both zones are poor at the northern end. Air shooting was done here, and on Traverse L, in an attempt to improve the informati on the upper horizon. The air-shot seismograms for Traverse K (shot points 199-2 are shown on Plate 7. As these traverses pass through thick scrub, the air shot were fired in the line of traverse to avoid additional clearing work. The air shot points were located half-way between the conventional shot points, the geophones being in the same spreads as used for hole shooting. Thus, the air shot was 770 feet away from the first geophone, and the noise of the shot affected the first trace on the record after about 700 milliseconds, so that no reflections could be recorded from the lower zone. Slight improvement in quality for the zone was found in places. It should be noted that with the in-line air shots th reflector is immediately beneath the traverse, so that the reflections can be regarded as part of the zone, and not offset from it as with the air shots on other traverses.

Traverse L (Plates 11 and 15) runs east from shot point 199 on Traverse K, to intersect Traverse C near shot point 77. It shows a rise to the east on both horizons, and the highest point of the main southern structure on the upper horizon is at shot point 208.

This traverse has comparatively good lower zone reflections and weak upper zone reflections. In-line air shooting was carried out as described for Traverse K, in an attempt to improve the quality of the information in the upper zone. On the whole, the quality of the air-shot records was not substantially better than that of the conventional records.

CONCLUSIONS AND RECOMMENDATIONS

The seismic survey has indicated a probable closed structural high feature centred approximately at a point whose co-ordinates on the military grid system are 167,000E and 1,698,000N (Zone 8) on the Roma 4-mile sheet. The closure of the structure appears to be about 100 feet on the upper phantom horizon and about 150 feet on the lower phantom horizon. The quality of the reflections is not good, but the closures quoted are sufficiently above the estimated probable errors to make the existence of the structure reasonably certain, at least on the upper phantom horizon, which probably represents the Lower Jurassic. There is some doubt as to the source of the reflections in the lower zone, and as to whether they should be represented by a phantom horizon. However, both seismic phantom horizons show the feature in approximately the same position, and this agrees well with a high feature shown by the residual gravity pattern. This coincidence increases the probability that the structure is real. The area of closure is about 2 square miles. It is impossible to determine the apex of the feature accurately from the seismic results, because of the low dips and the mediocre quality of the reflections.

If a structure such as that indicated above exists, it could serve as an oil-trap under favourable conditions. It is recommended that a close study be made of this report by the companies concerned, at the same time taking into account geological and other factors associated with the possible structure and the testing of it.

Further seismic work might be carried out to advantage. Greatly improved records would probably be obtained with the 24-channel A.V.C. equipment now at the Bureau's disposal, and with several geophones per trace. The work done so far does not warrant the adoption of air shooting as the chief technique in further exploration, but it may be a useful auxiliary tool. Features suggested as targets for further reflection work are the area near the bores at Roma township, Block 16, Warooby, and possibly Blythdale, the high features suggested by the present survey near the intersection of Traverses B and C, and reversal of regional dip at the south-east end of Traverse C. Deep refraction traverses might give useful information which would help the interpretation of the geophysical results.

If any drilling is done, it is recommended that, in addition to any other methods of logging adopted, velocity tests should be made by lowering a geophone down the hole. This would give more accurate depth control, and might lead to the identification of some reflectors.

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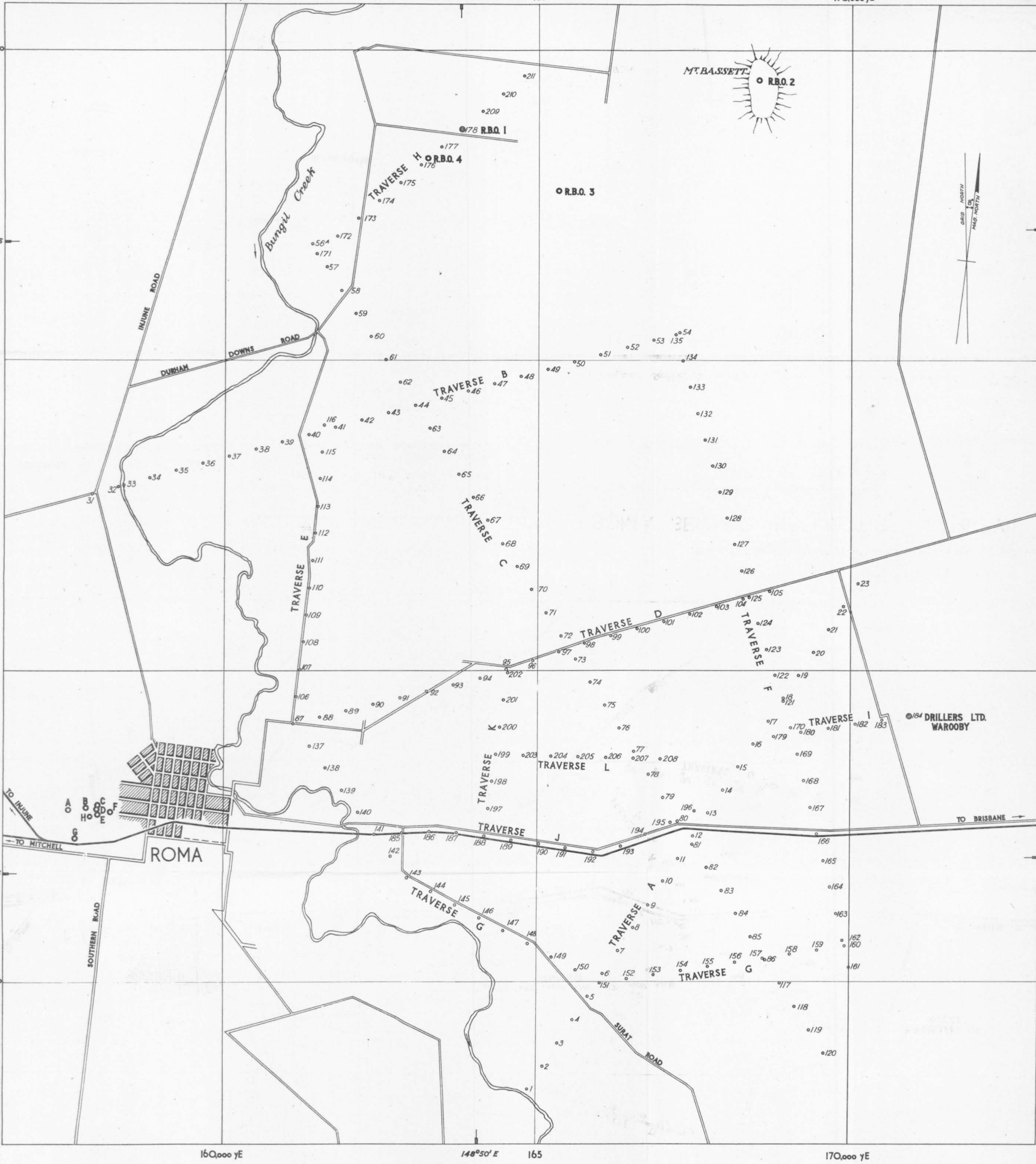
APPENDIX

Before publication of this report, a well had been drilled by Australian Associated Oil Company on the structure recommended. This hole was dry. Beds which were believed to be the equivalent of the oil and gas sands in neighbouring bores were penetrated, but the rocks were very compact and unsuitable for a reservoir rock.

In view of this unfavourable facies the company does not intend to drill any more holes in this vicinity. They plan rather to work in the neighbourhood of existing bores where the facies is known to be more favourable. To this end, another hole has been drilled near Block 16 and has shown some oil and gas, and further seismic work has been carried out by the Bureau between Block 16 and the Roma town bores.

A single hole, of course, neither proves nor disproves the existence of a structure, although it is believed that the strata in A.A.O. No.1 are structurally higher than in the Warooby or Hospital Hill bores. However, it is possible that the lack of porosity in the sands is associated with maximum compaction at the highest part of the structure, and that more favourable conditions for oil accumulation exist on the flanks of the structure.

PLATE 1



LEGEND

- ◦25 SHOT POINT
- o BORE
- RAILWAY
- ROAD
- CREEK

SCALE

0.5 0 0.5 1.0 1.5 2.0 MILES

REFERENCE TO HOSPITAL HILL BORES

A .... R.O.C. No 2
B .... R.O.C. No 1
C .... TOWN No 1
D .... TOWN No 2
E .... TOWN No 3
F .... R.O.C. No 3
G .... LANDER No 4
H .... GOVT. No 4

ORIGIN – DATUM 900' ABOVE SEA LEVEL

CO-ORDINATE REFERENCE TO ROYAL AUSTRALIAN SURVEY CORPS 10,000 YARD MILITARY GRID

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ROMA SEISMIC REFLECTION SURVEY

LOCALITY PLAN SHOWING LAYOUT OF TRAVERSES

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G 38-26

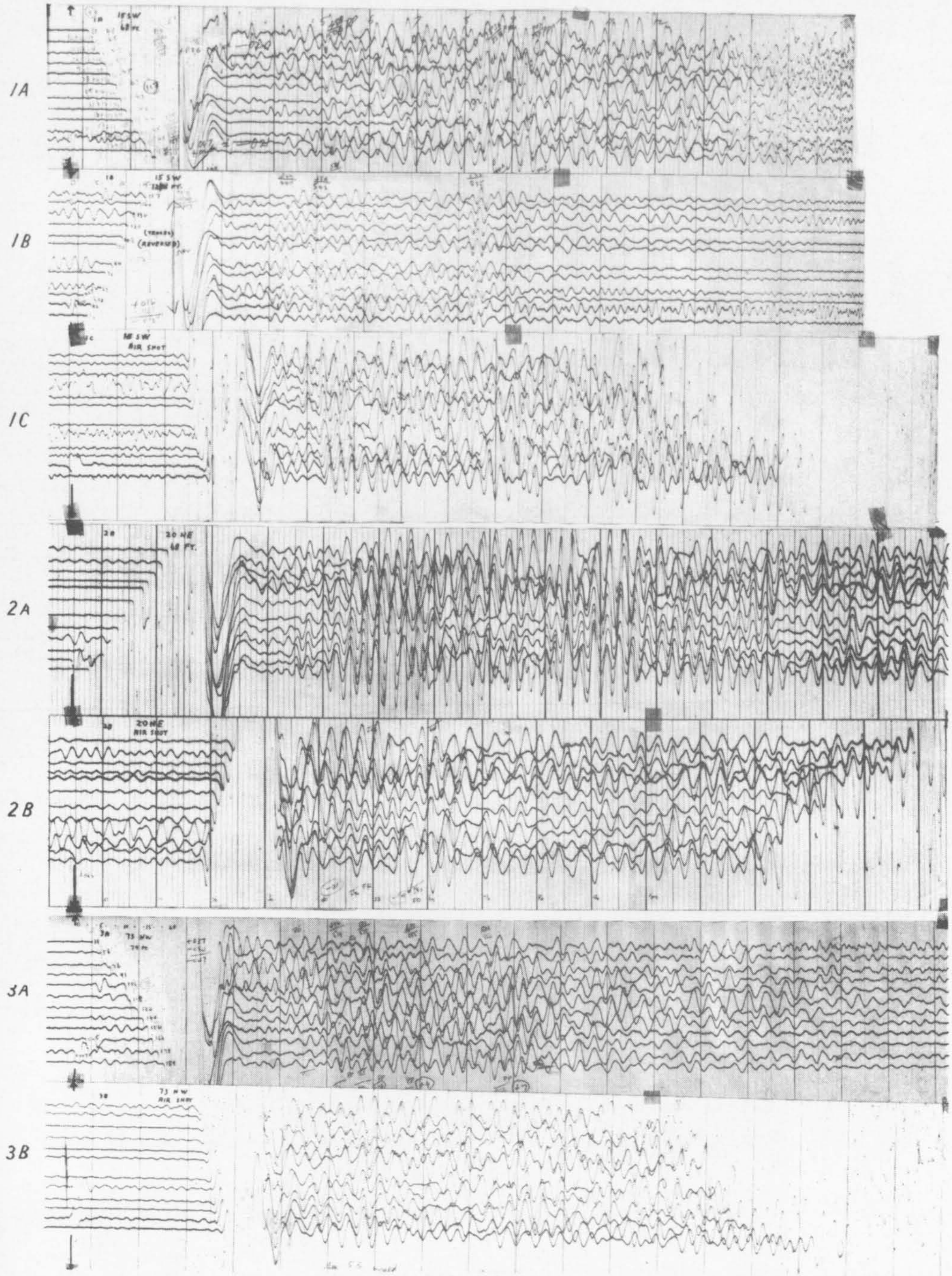


PLATE 2

1A, 1B, 1C Comparison of records from shots fired at different depths and air shot at S.P. 15 SW

2A, 2B Comparison of records from hole shot and air shot at S.P. 20 NE

3A, 3B Comparison of records from hole shot and air shot at S.P. 73 NW

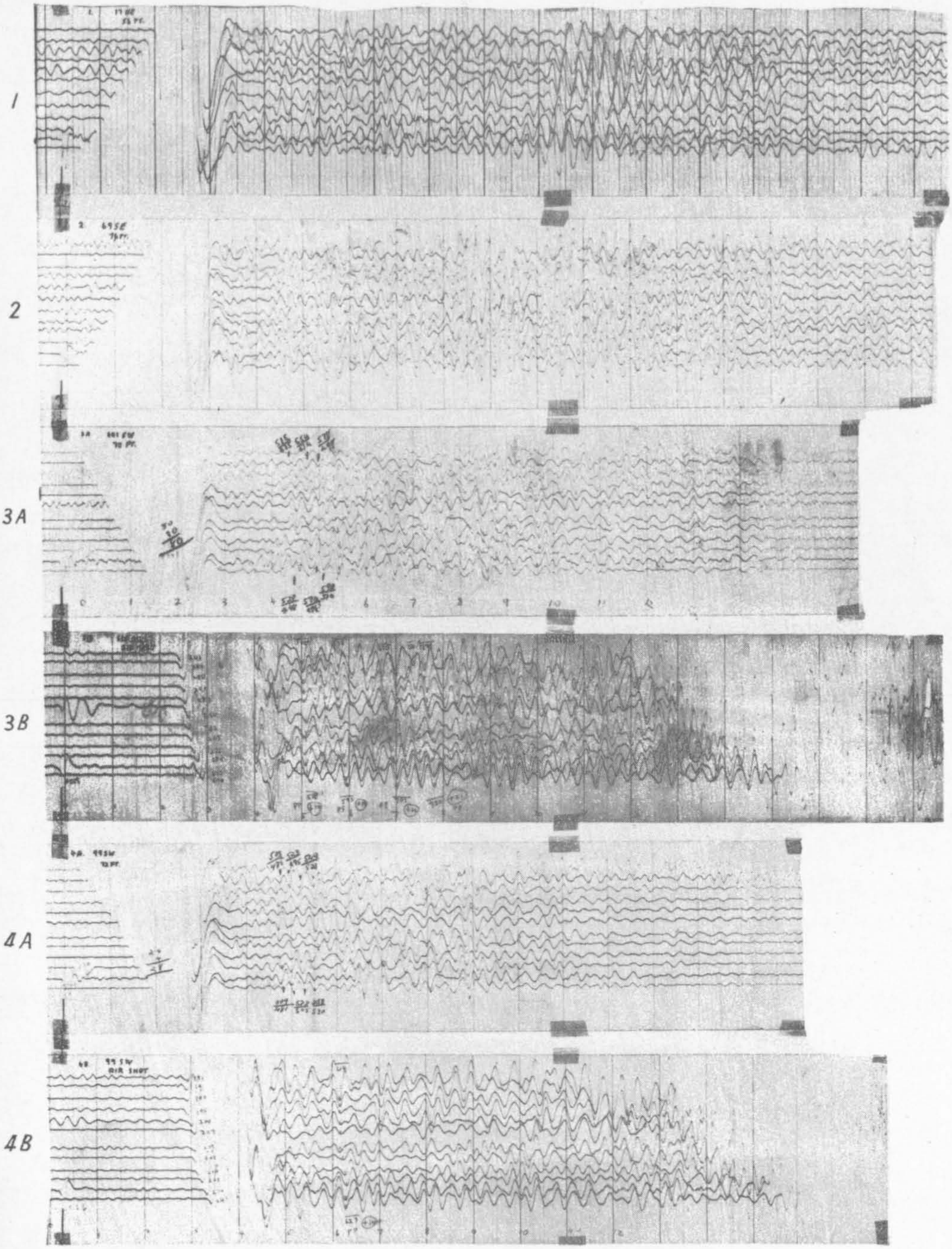


PLATE 3

1. Seismogram at S.P. 17 NE showing steep-dipping lower zone reflection
2. Seismogram at S.P. 69 SE showing late reflection apparently below basement
3A,3B Comparison of records from hole shot and air shot at S.P. 101 SW
4A,4B Comparison of records from hole shot and air shot at S.P. 99 SW

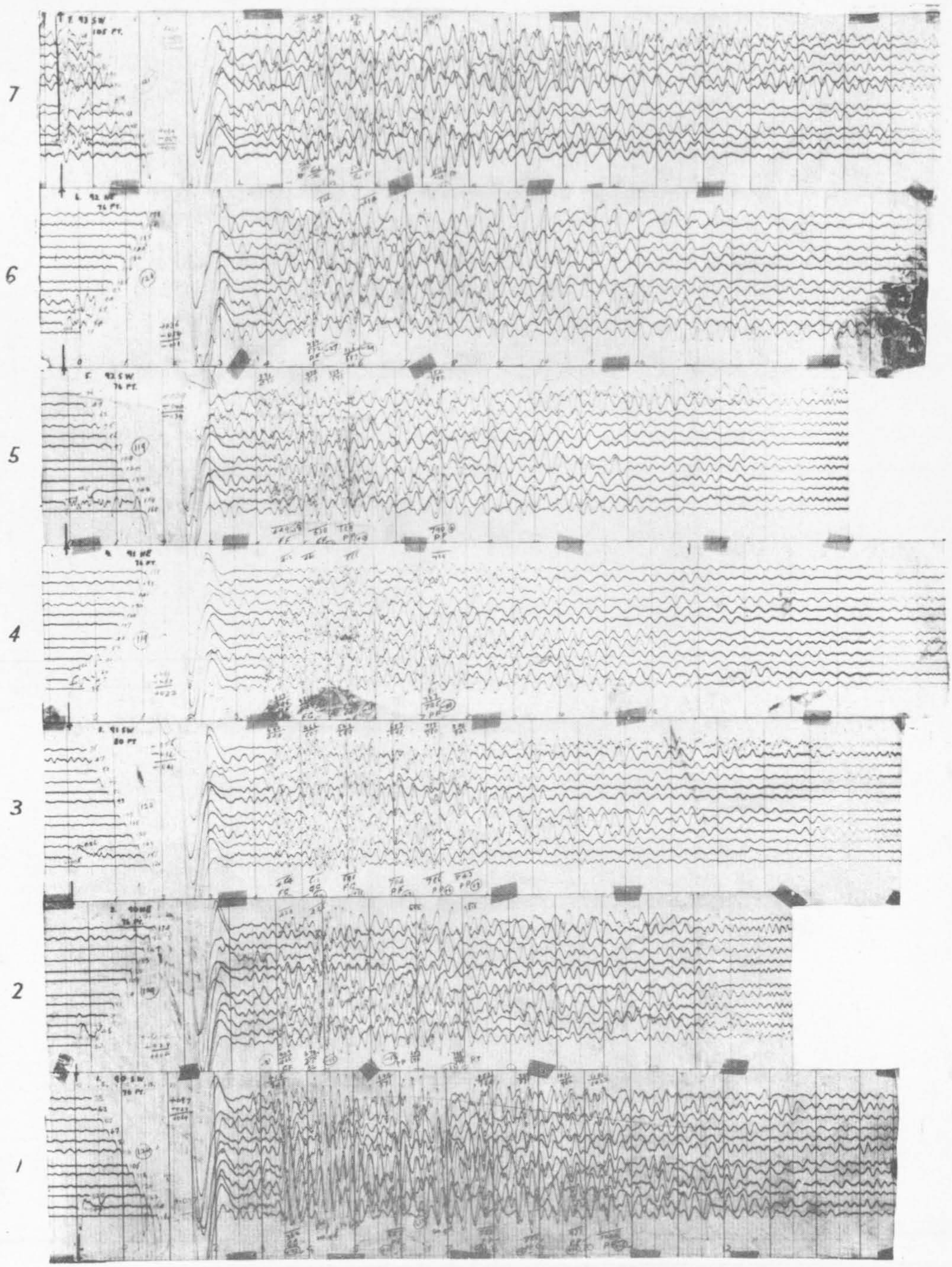


PLATE 4

Seismograms at S.P. 90 SW to S.P. 93 SW, Traverse D, illustrating deterioration in quality of reflections.

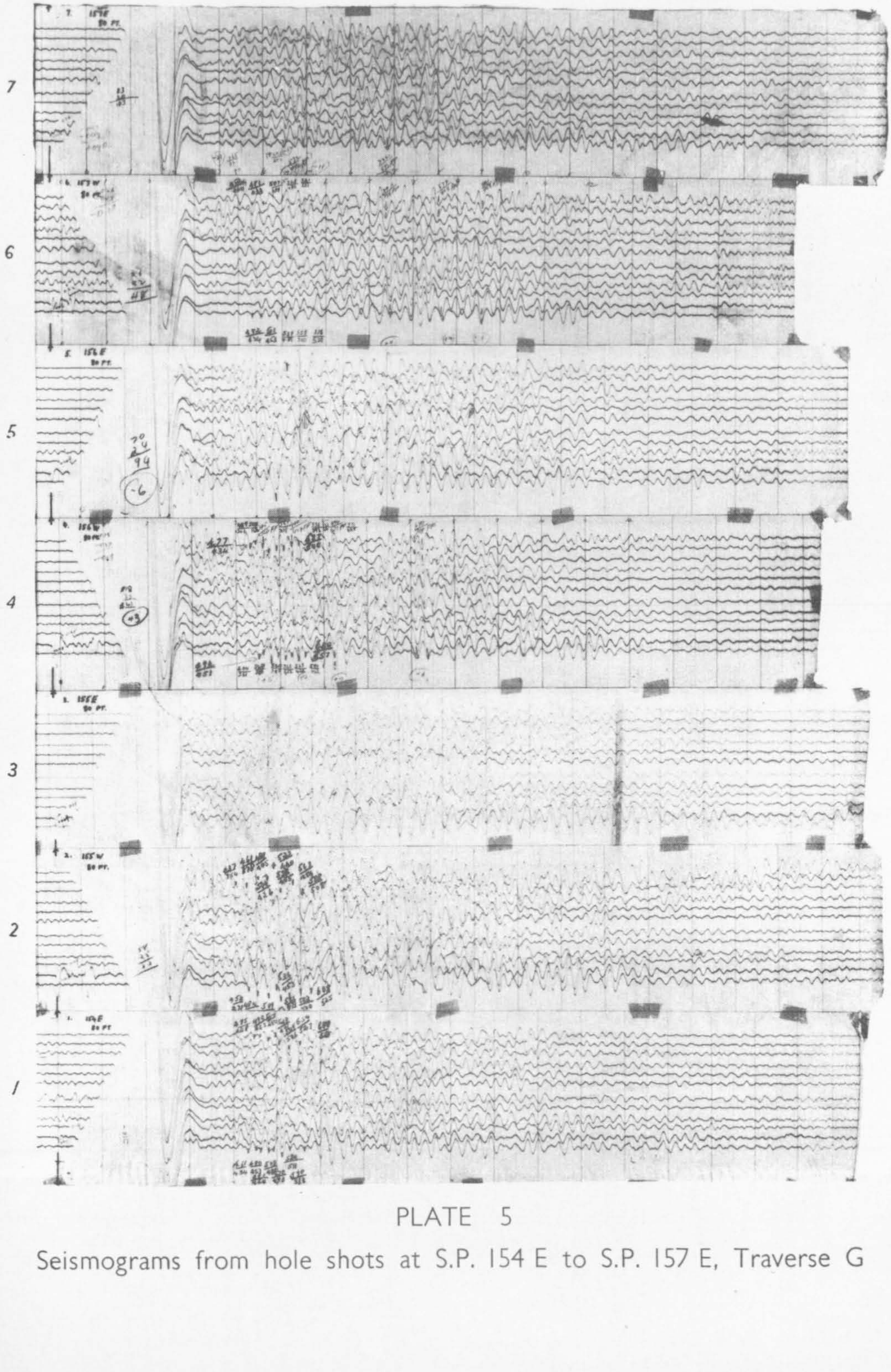


PLATE 5

Seismograms from hole shots at S.P. 154 E to S.P. 157 E, Traverse G

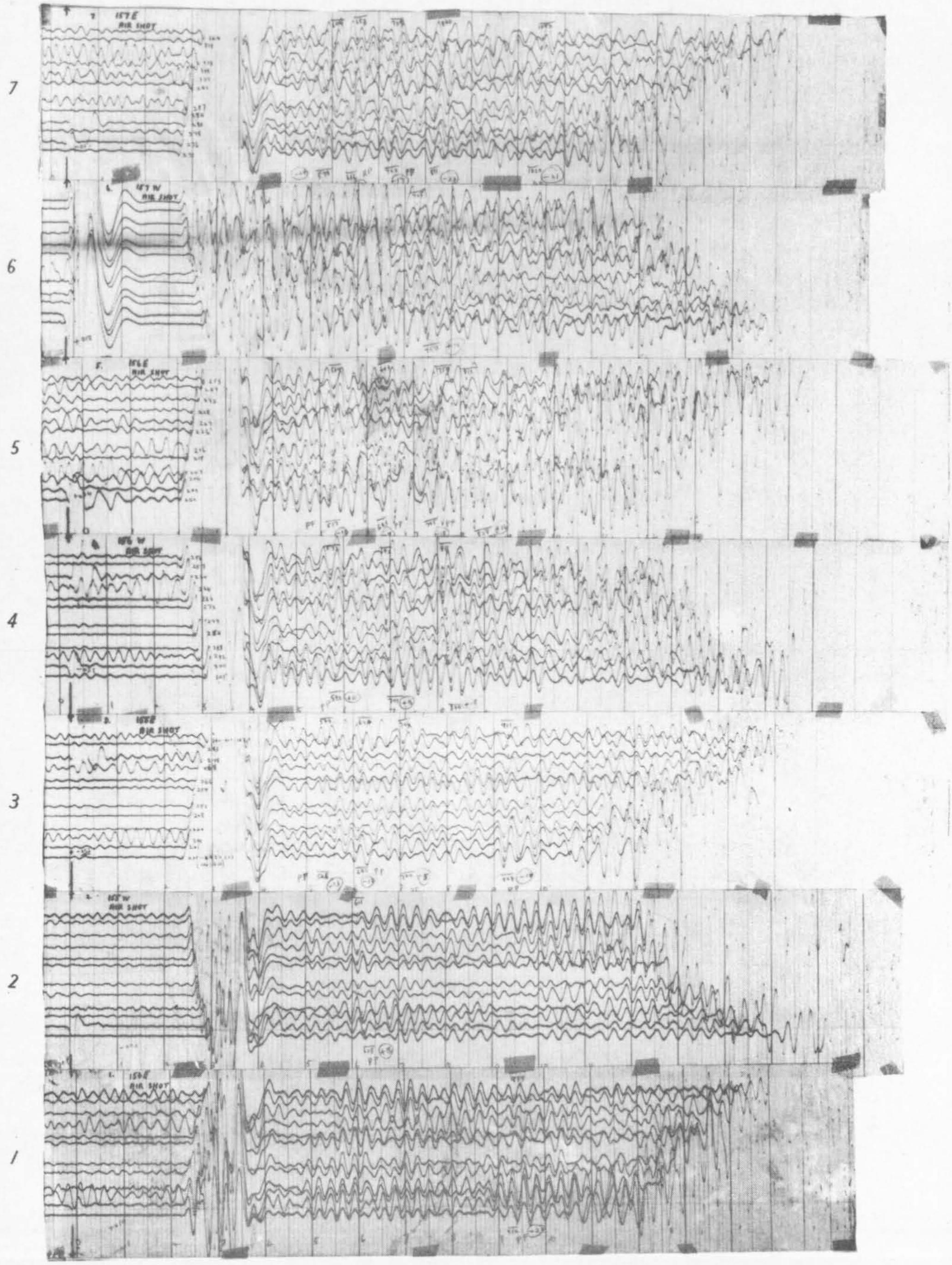


PLATE 6

Seismograms from offset air shots at S.P. 154 E to S.P. 157 E, Traverse G

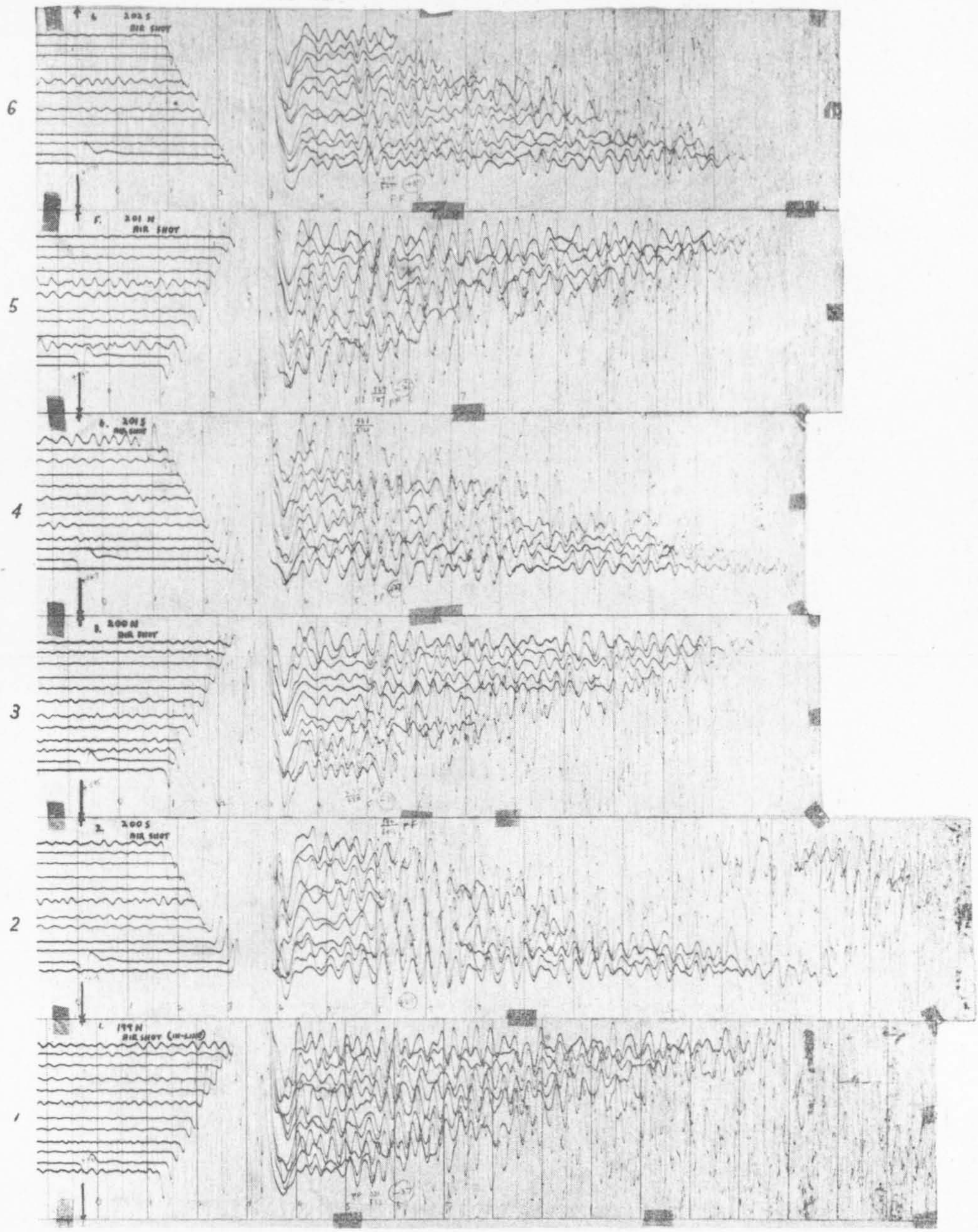
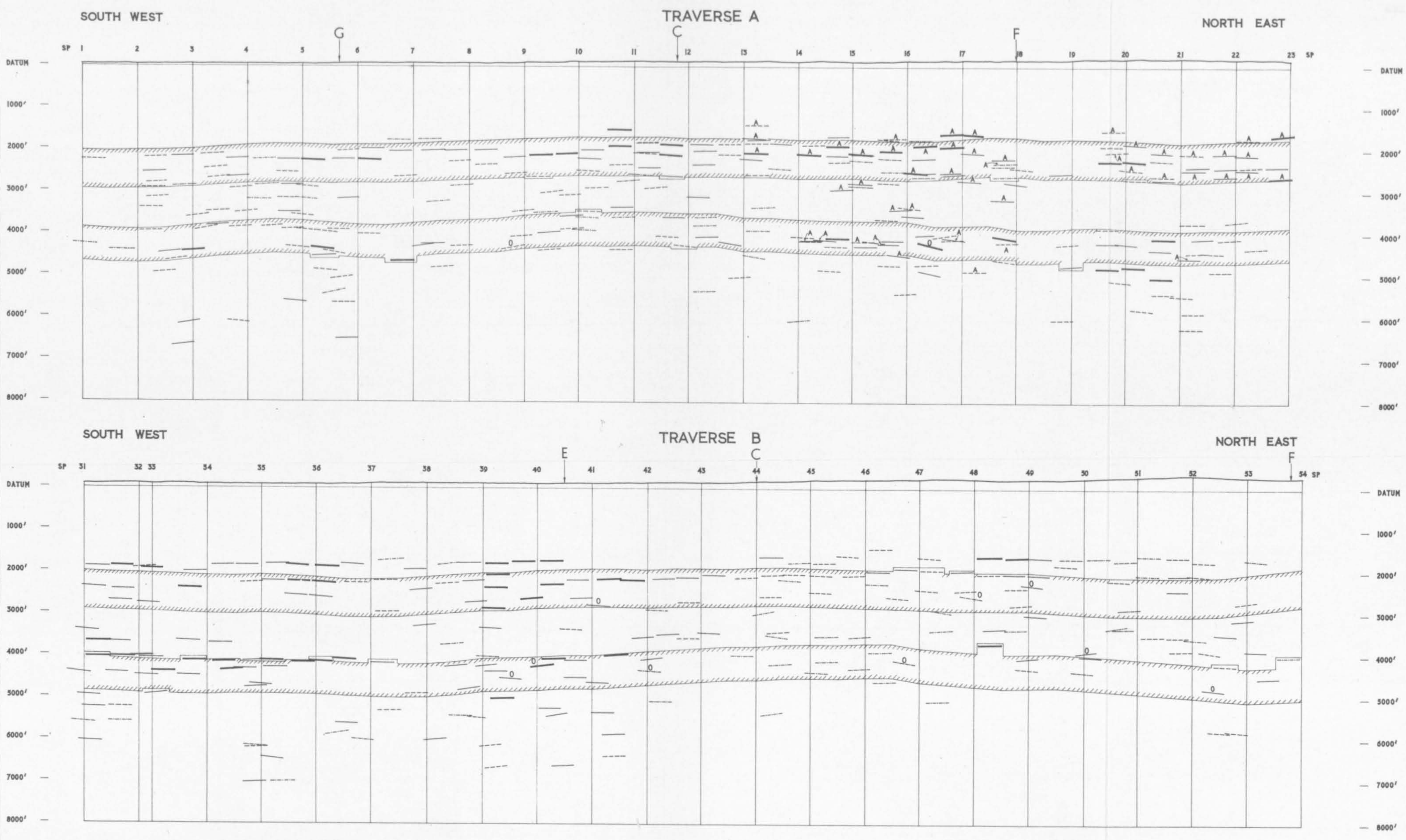


PLATE 7

Seismograms from in-line air shots at S.P. 199 N to S.P. 202 S, Traverse

PLATE 8



SCALE

HORIZONTAL 1000 0 1000 2000 3000 4000 FEET

ORIGIN – DATUM 900' ABOVE SEA LEVEL

LEGEND

A INDICATES AIR SHOT OFFSET 1500 FEET FROM TRAVERSE

0 INDICATES REFLECTION OMITTED FROM REVISED PHANTOM HORIZON

ZONES USED FOR PHANTOM HORIZON

INDICATES REFLECTION INCLUDED IN REVISED PHANTOM HORIZON

INDICATES REFLECTION NOT USED FOR PHANTOM HORIZON

GEOPHYSICAL SURVEY AT ROMA, QLD.

ROMA SEISMIC REFLECTION SURVEY

SECTIONS SHOWING REFLECTIONS WITH UPPER AND LOWER PHANTOM HORIZON ZONES TRAVERSES A AND B

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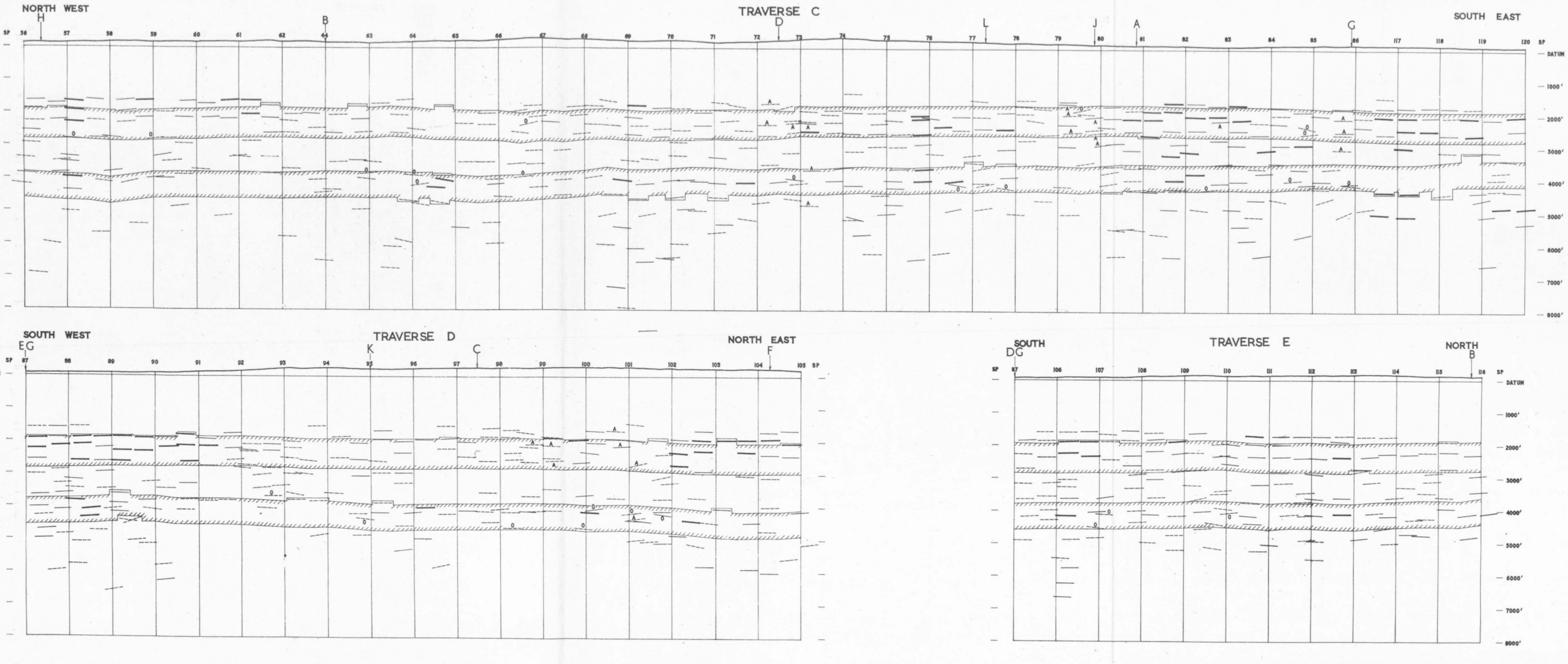
G 38–39

PLATE 9



SCALE

HORIZONTAL 1000 0 1000 2000 3000 4000 FEET

ORIGIN – DATUM 900' ABOVE SEA LEVEL

LEGEND

A INDICATES AIR SHOT OFFSET 1500 FEET FROM TRAVERSE

0 INDICATES REFLECTION OMITTED FROM REVISED PHANTOM HORIZON

ZONES USED FOR PHANTOM HORIZON

INDICATES REFLECTION INCLUDED IN REVISED PHANTOM HORIZON

INDICATES REFLECTION NOT USED FOR PHANTOM HORIZON

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SECTIONS SHOWING REFLECTIONS WITH UPPER AND LOWER PHANTOM HORIZON ZONES TRAVERSES C,D AND E

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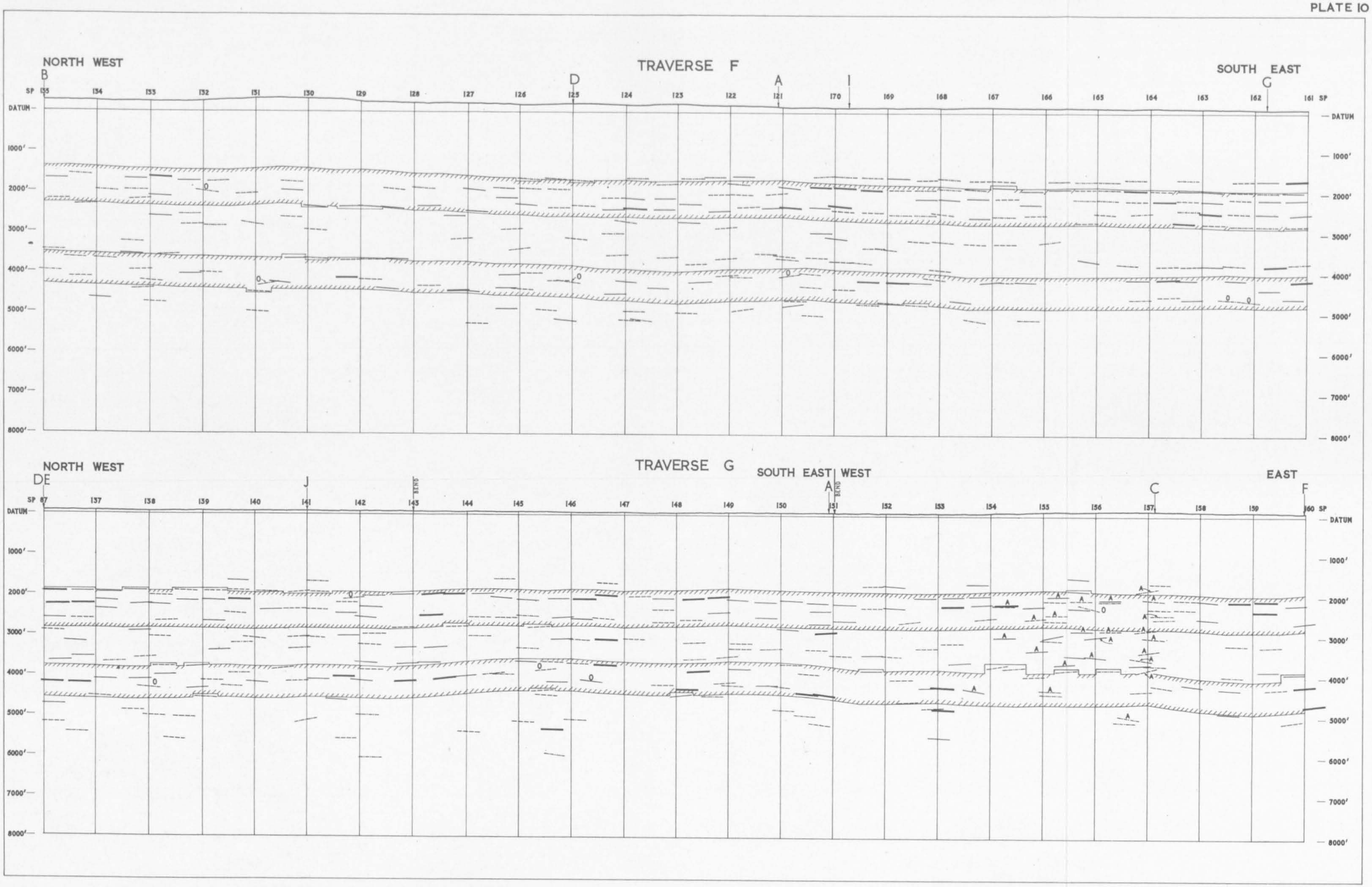
G 38-40

PLATE 10



SCALE

HORIZONTAL 1000 0 1000 2000 3000 4000 FEET

ORIGIN – DATUM 900' ABOVE SEA LEVEL

LEGEND

A INDICATES AIR SHOT OFFSET 1500 FEET FROM TRAVERSE
0 INDICATES REFLECTION OMITTED FROM REVISED PHANTOM HORIZON
ZONES USED FOR PHANTOM HORIZON
INDICATES REFLECTION INCLUDED IN REVISED PHANTOM HORIZON
INDICATES REFLECTION NOT USED FOR PHANTOM HORIZON

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SECTIONS SHOWING REFLECTIONS WITH UPPER AND LOWER PHANTOM HORIZON ZONES TRAVERSES F AND G

G38-41

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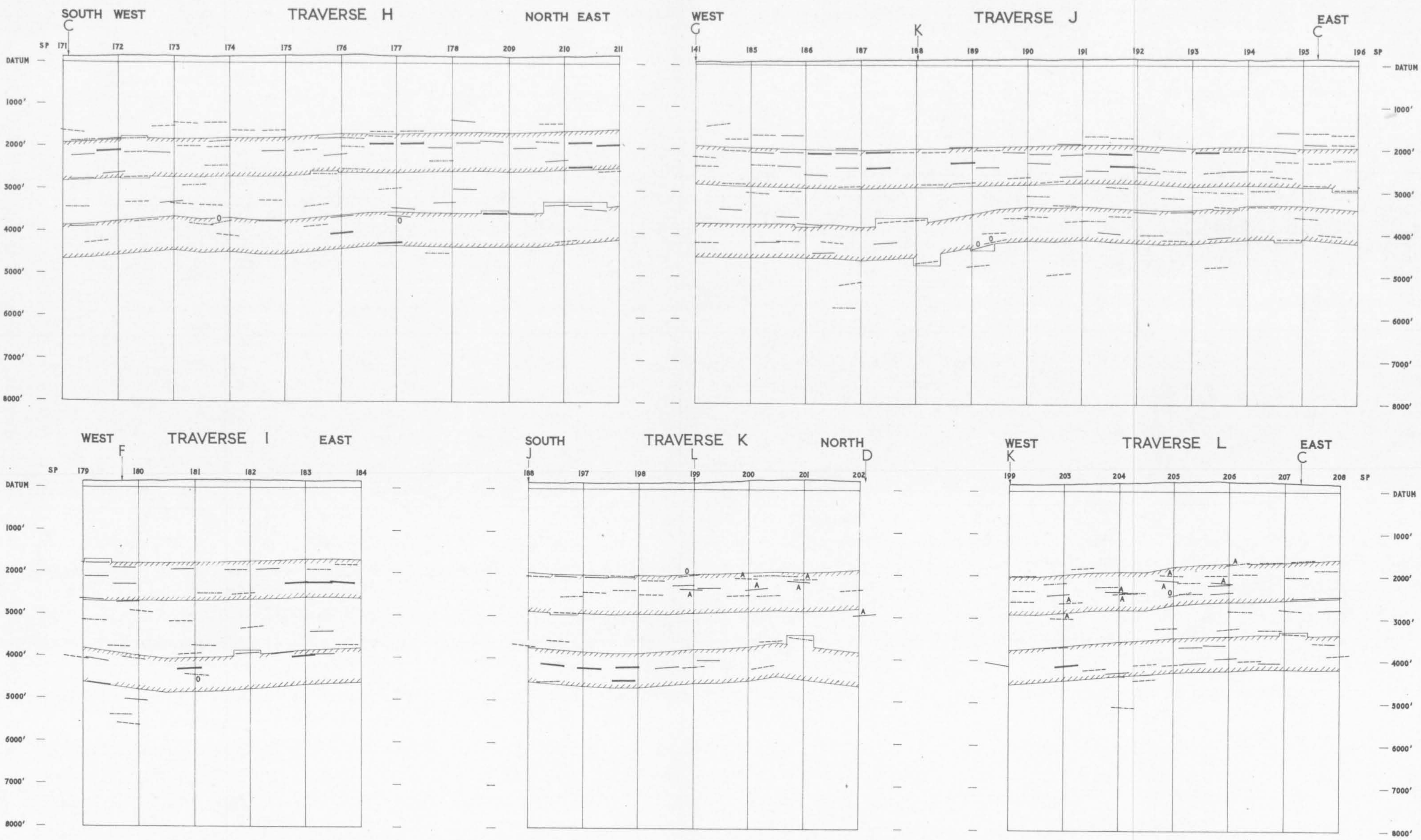
PLATE 11



SCALE

HORIZONTAL 1000 0 1000 2000 3000 4000 FEET

ORIGIN - DATUM 900' ABOVE SEA LEVEL

LEGEND

A INDICATES AIR SHOT IN LINE OF TRAVERSE 660 FEET FROM SHOT POINT

0 INDICATES REFLECTION OMITTED FROM REVISED PHANTOM HORIZON

ZONES USED FOR PHANTOM HORIZON

INDICATES REFLECTION INCLUDED IN REVISED PHANTOM HORIZON

INDICATES REFLECTION NOT USED FOR PHANTOM HORIZON

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SECTIONS SHOWING REFLECTIONS WITH UPPER AND LOWER PHANTOM HORIZON ZONES TRAVERSES H, I, J, K AND L

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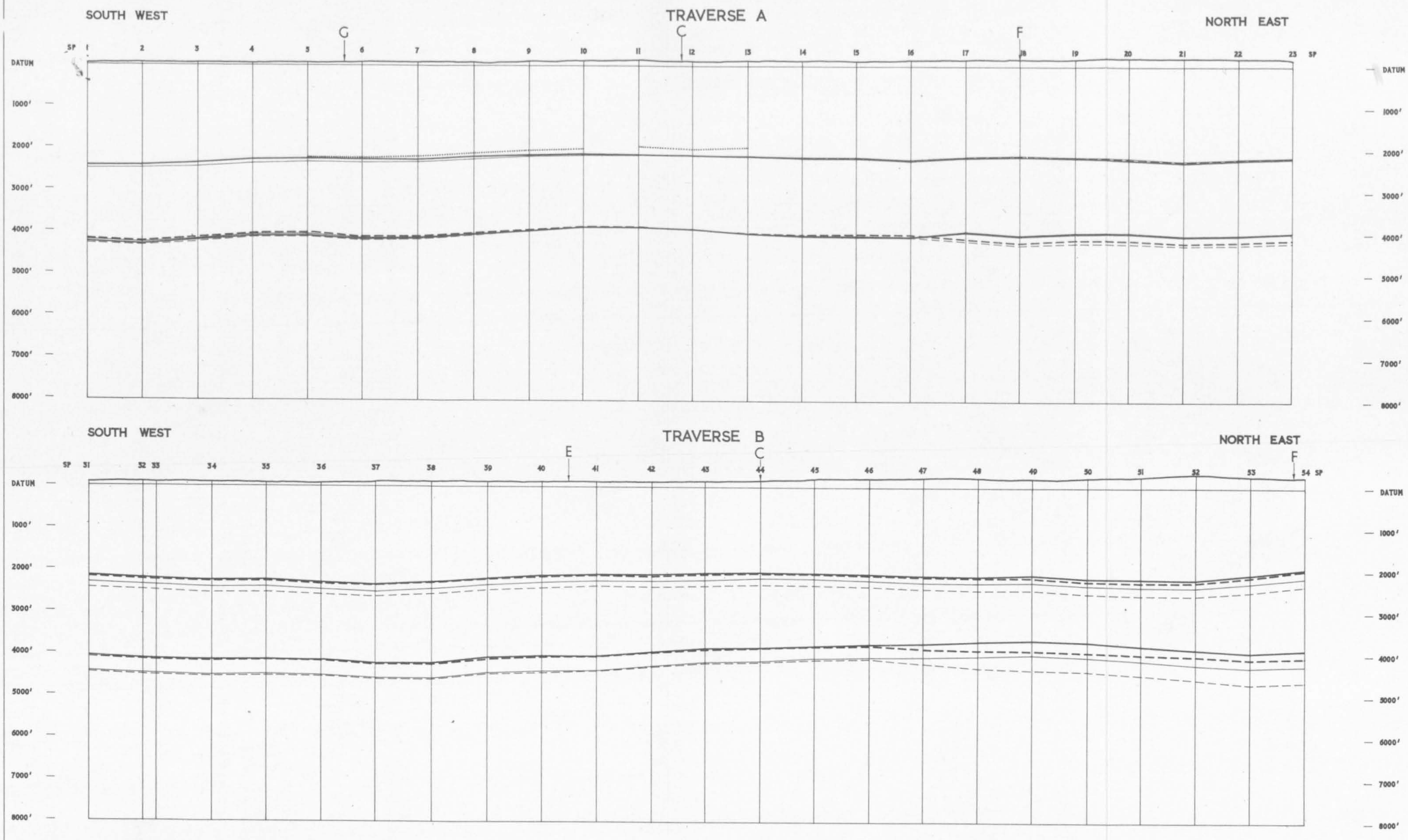
PLATE 12



SCALE

HORIZONTAL 1000 0 1000 2000 3000 4000 FEET

ORIGIN – DATUM 900' ABOVE SEA LEVEL

LEGEND

- UNADJUSTED PHANTOM HORIZON A
- ADJUSTED PHANTOM HORIZON A
- UNADJUSTED PHANTOM HORIZON B
- ADJUSTED PHANTOM HORIZON B
- CORRELATIONS

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ROMA SEISMIC REFLECTION SURVEY

SECTIONS SHOWING UPPER AND LOWER PHANTOM HORIZONS WITH ADJUSTMENTS AND REFLECTION CORRELATIONS TRAVERSES A AND B

G 38-43

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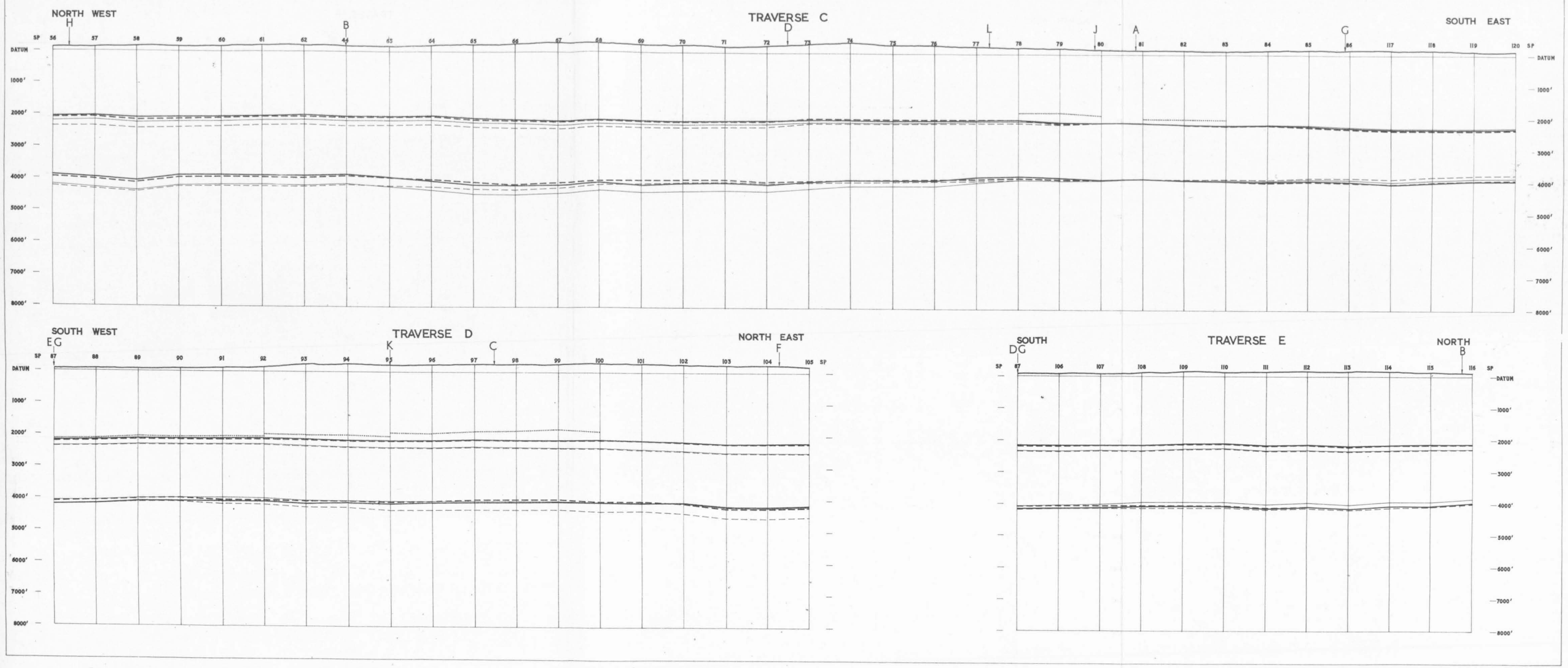
PLATE 13



SCALE

HORIZONTAL 1000 0 1000 2000 3000 4000 FEET

ORIGIN – DATUM 900' ABOVE SEA LEVEL

LEGEND

UNADJUSTED PHANTOM HORIZON A
ADJUSTED PHANTOM HORIZON A
UNADJUSTED PHANTOM HORIZON B
ADJUSTED PHANTOM HORIZON B
CORRELATIONS

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ROMA SEISMIC REFLECTION SURVEY

SECTIONS SHOWING UPPER AND LOWER PHANTOM HORIZONS WITH ADJUSTMENTS AND REFLECTION CORRELATIONS TRAVERSES C,D AND E

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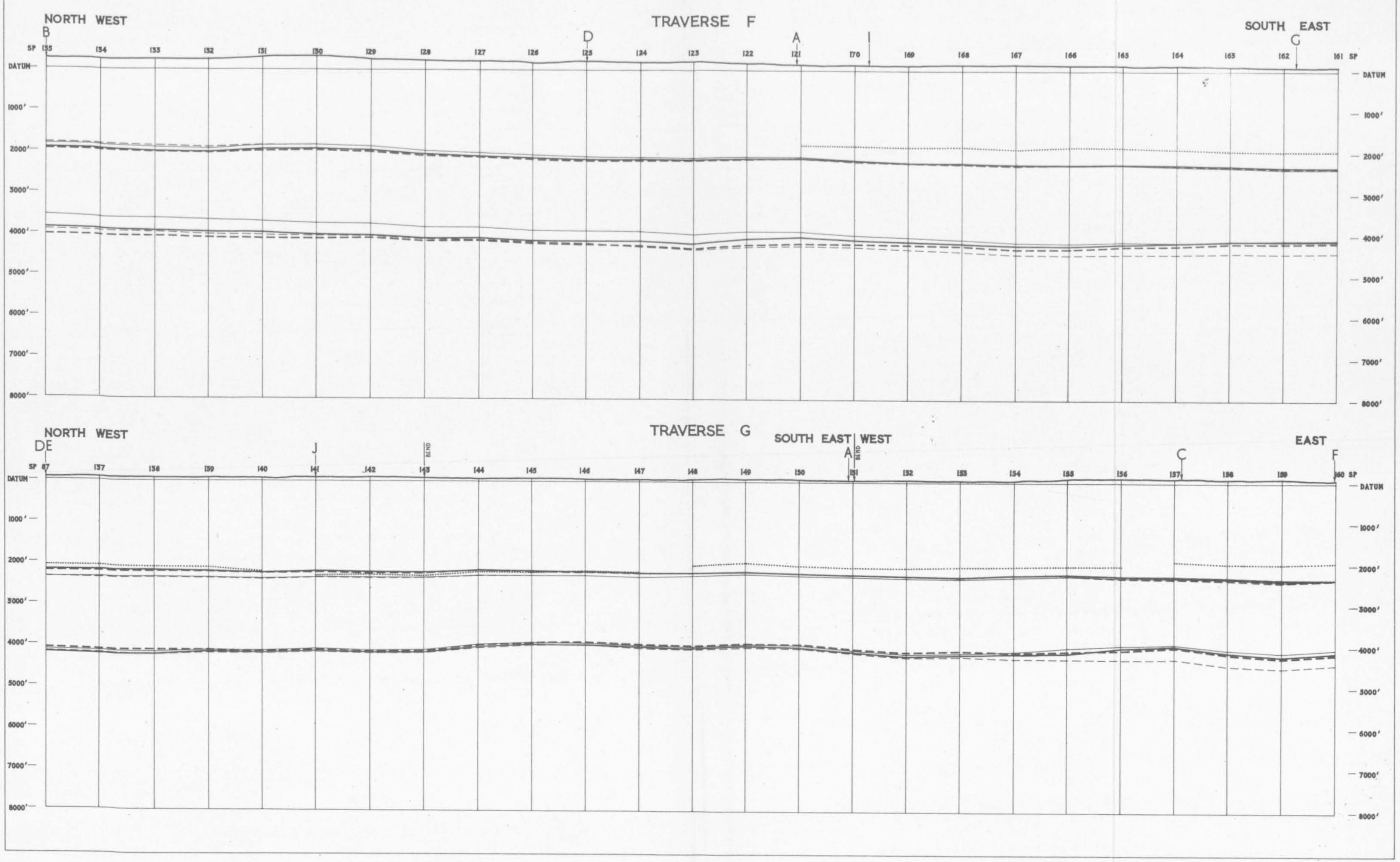
G 38-44

PLATE 14



SCALE

HORIZONTAL 1000 0 1000 2000 3000 4000 FEET

ORIGIN – DATUM 900' ABOVE SEA LEVEL

LEGEND

- UNADJUSTED PHANTOM HORIZON A
- ADJUSTED PHANTOM HORIZON A
- UNADJUSTED PHANTOM HORIZON B
- ADJUSTED PHANTOM HORIZON B
- CORRELATIONS

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ROMA SEISMIC REFLECTION SURVEY

SECTIONS SHOWING UPPER AND LOWER PHANTOM HORIZONS WITH ADJUSTMENTS AND REFLECTION CORRELATIONS TRAVERSES F AND G

G 38-45

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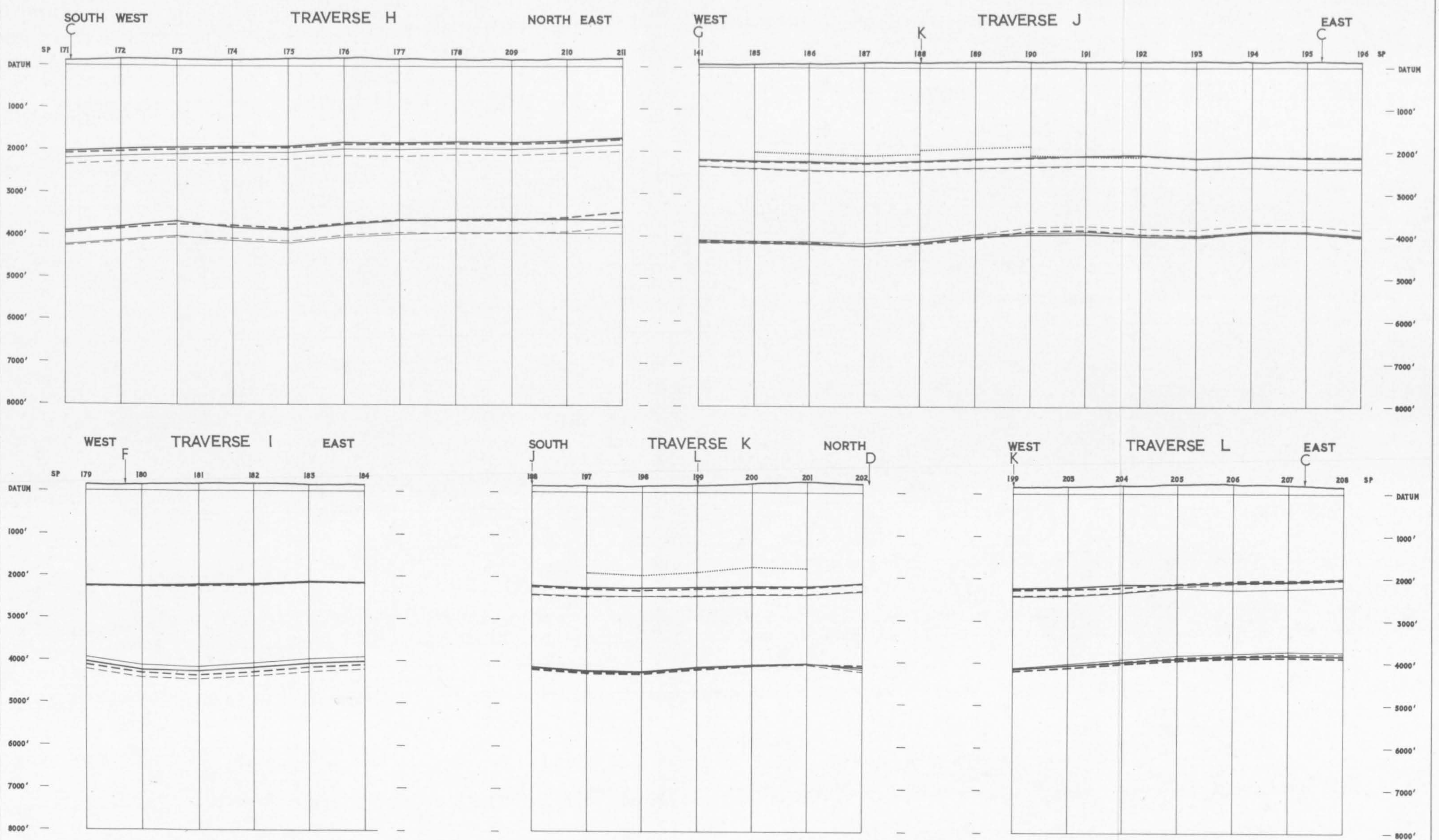
PLATE 15



SCALE

HORIZONTAL 1000 0 1000 2000 3000 4000 FEET

ORIGIN – DATUM 900' ABOVE SEA LEVEL

LEGEND

UNADJUSTED PHANTOM HORIZON A
ADJUSTED PHANTOM HORIZON A
UNADJUSTED PHANTOM HORIZON B
ADJUSTED PHANTOM HORIZON B
CORRELATIONS

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ROMA SEISMIC REFLECTION SURVEY

SECTIONS SHOWING UPPER AND LOWER PHANTOM HORIZONS WITH ADJUSTMENTS AND REFLECTION CORRELATIONS TRAVERSES H,I,J,K AND L

G 38-46

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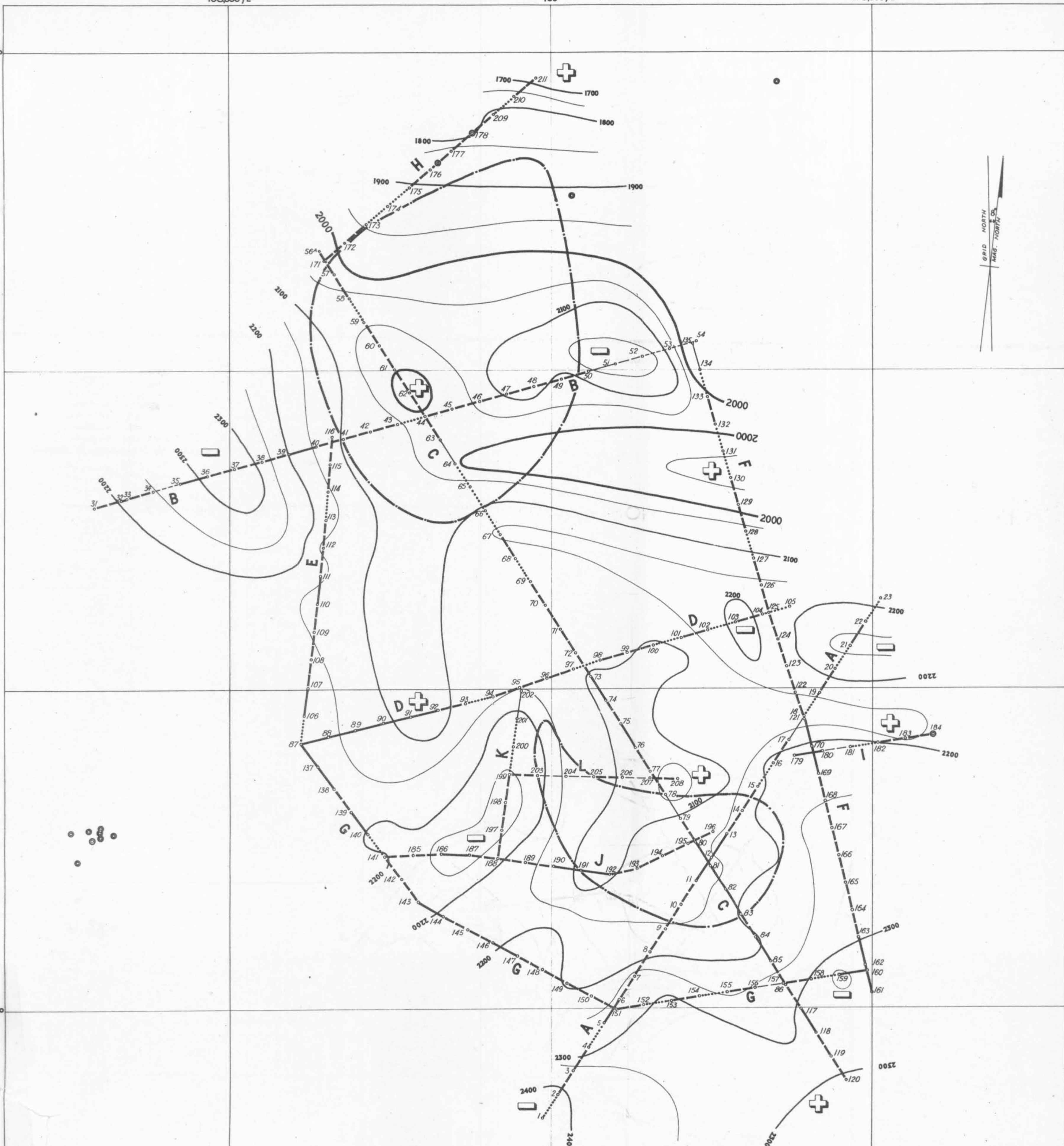
PLATE 16



LEGEND

- ∘ 25 SHOT POINT
- ⊙ BORE
- OUTLINE OF GRAVITY RESIDUAL HIGH CLOSURE
- 50′ CONTOUR
- 100′ "
- 1000′ "

GRADING OF GEOPHYSICAL INFORMATION

- VERY GOOD
- GOOD
- FAIR
- MEDIOCRE
- POOR
- DOUBTFUL
- NO REFLECTION

SCALE

0.5 0 0.5 1.0 1.5 2.0 MILES

ORIGIN – DATUM 900′ ABOVE SEA LEVEL

CO-ORDINATE REFERENCE TO ROYAL AUSTRALIAN SURVEY CORPS 10,000 YARD MILITARY GRID

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ROMA SEISMIC REFLECTION SURVEY

UPPER PHANTOM HORIZON "A" CONTOURS
CONTOUR INTERVAL 50 FEET

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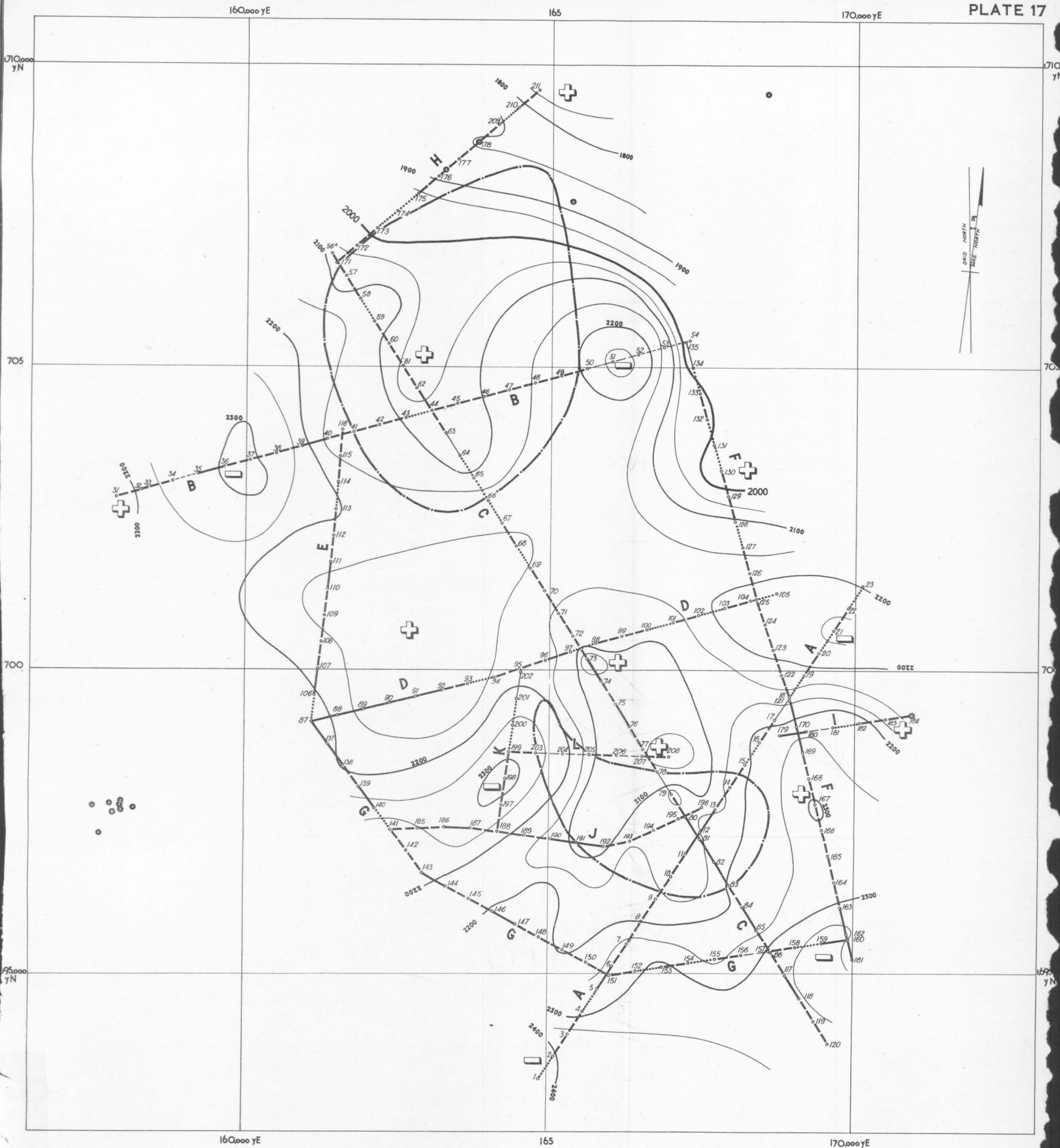
PLATE 17



LEGEND

- 25 SHOT POINT
- BORE
- OUTLINE OF GRAVITY RESIDUAL HIGH CLOSURE
- 50' CONTOUR
- 100' "
- 1000' "

GRADING OF GEOPHYSICAL INFORMATION

- VERY GOOD
- GOOD
- FAIR
- MEDIOCRE
- POOR
- DOUBTFUL
- NO REFLECTION

SCALE

0.5 0 0.5 1.0 1.5 2.0 MILES

ORIGIN – DATUM 900' ABOVE SEA LEVEL.

CO-ORDINATE REFERENCE TO ROYAL AUSTRALIAN SURVEY CORPS 10,000 YARD MILITARY GRID

J. C. Dooley
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ROMA SEISMIC REFLECTION SURVEY

UPPER PHANTOM HORIZON "B" CONTOURS
CONTOUR INTERVAL 50 FEET

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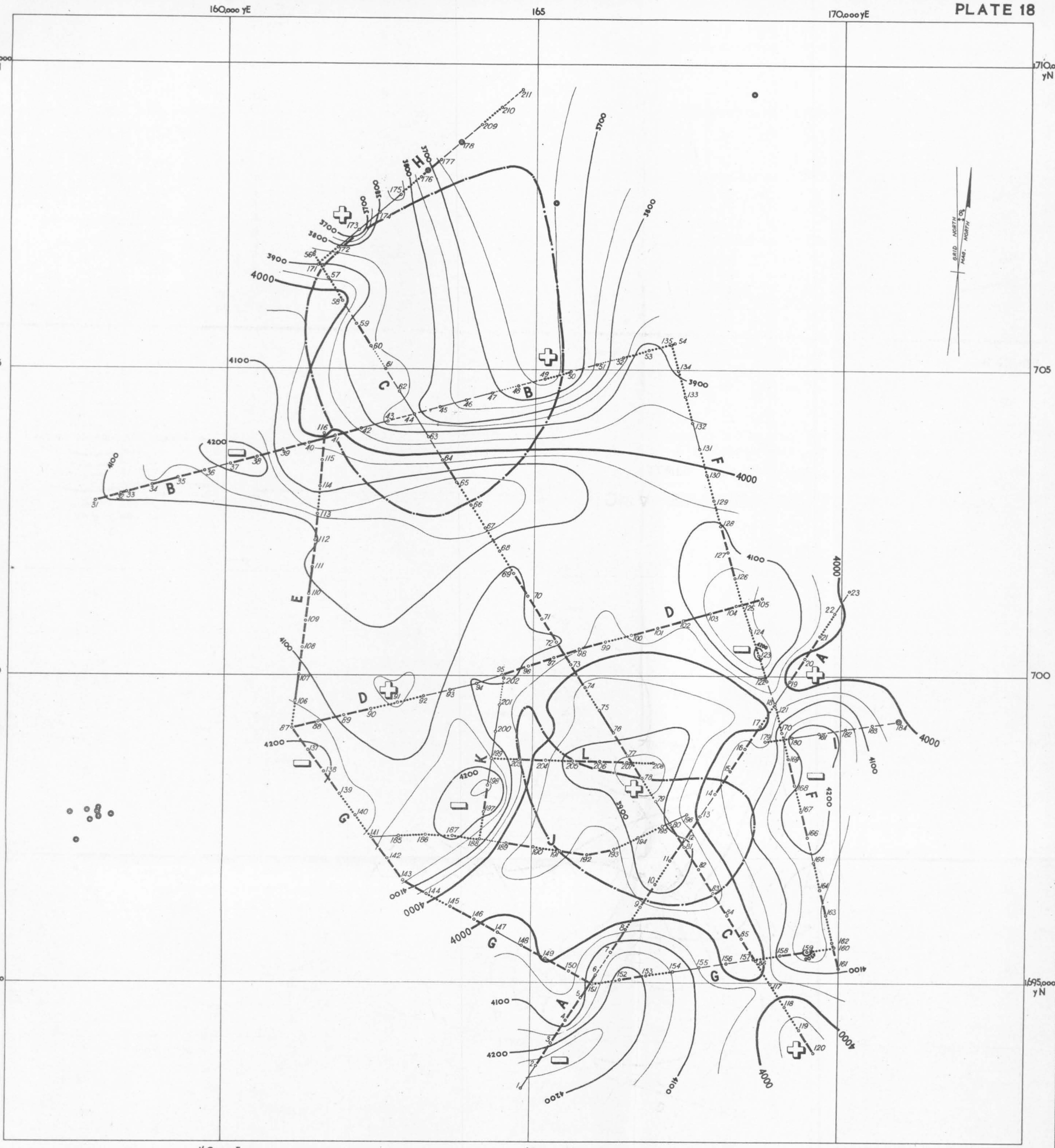
PLATE 18



LEGEND

- 25 SHOT POINT
- BORE
- OUTLINE OF GRAVITY RESIDUAL HIGH CLOSURE
- 50′ CONTOUR
- 100′ "
- 1000′ "

GRADING OF GEOPHYSICAL INFORMATION

- VERY GOOD
- GOOD
- FAIR
- MEDIOCRE
- POOR
- DOUBTFUL
- NO REFLECTION

SCALE

0.5 0 0.5 1.0 1.5 2.0 MILES

ORIGIN – DATUM 900′ ABOVE SEA LEVEL

CO-ORDINATE REFERENCE TO ROYAL AUSTRALIAN SURVEY CORPS 10,000 YARD MILITARY GRID

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GEOPHYSICAL SURVEY AT ROMA, QLD.

ROMA SEISMIC REFLECTION SURVEY

LOWER PHANTOM HORIZON "A" CONTOURS
CONTOUR INTERVAL 50 FEET

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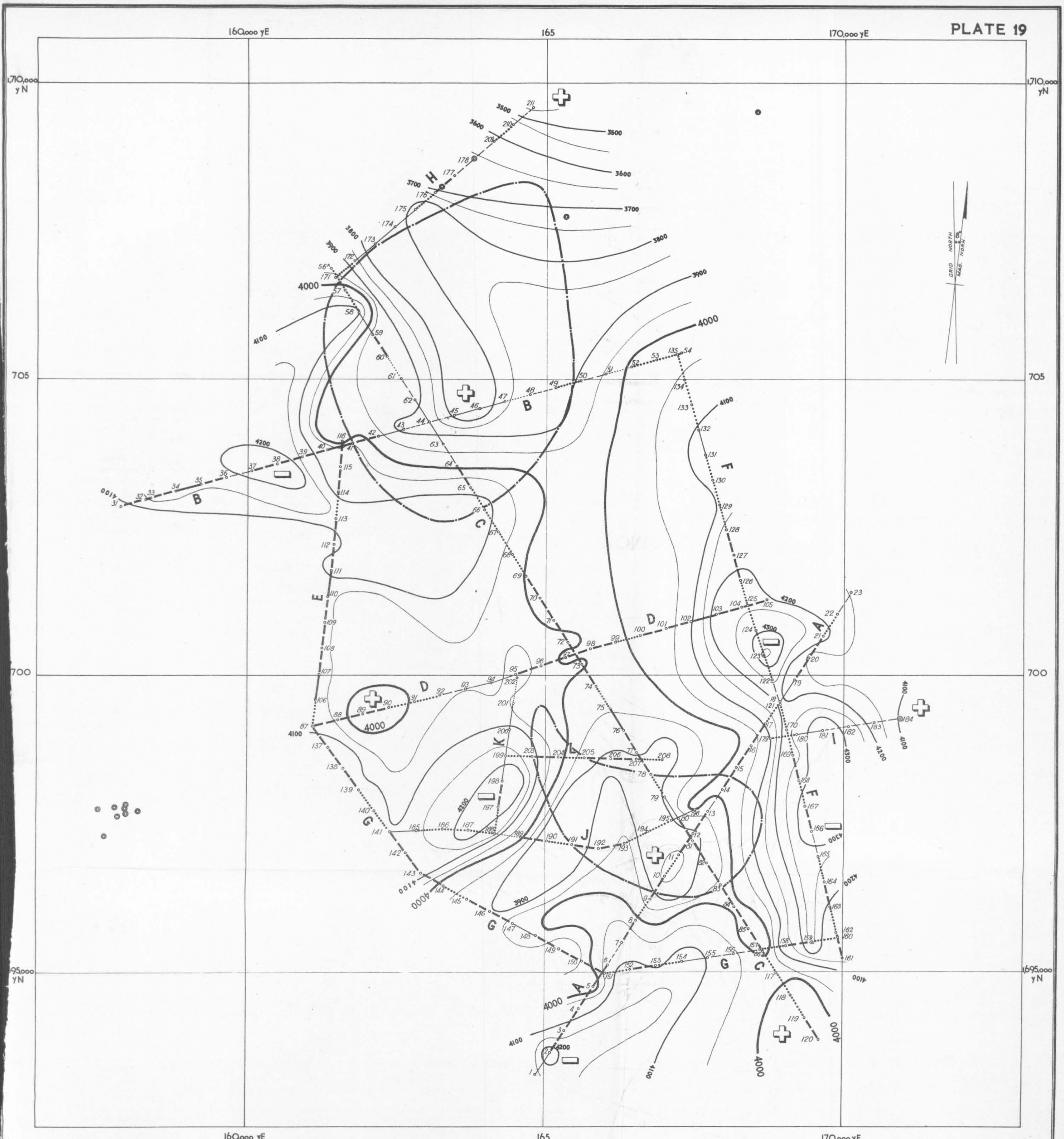
G 38-29



LEGEND

- ∘ 25 SHOT POINT
- ◎ BORE
- OUTLINE OF GRAVITY RESIDUAL HIGH CLOSURE
- 50′ CONTOUR
- 100′ "
- 1000′ "

GRADING OF GEOPHYSICAL INFORMATION

- VERY GOOD
- GOOD
- FAIR
- MEDIOCRE
- POOR
- DOUBTFUL
- NO REFLECTION

SCALE

0.5 0 0.5 1.0 1.5 2.0 MILES

ORIGIN – DATUM 900′ ABOVE SEA LEVEL

CO-ORDINATE REFERENCE TO ROYAL AUSTRALIAN SURVEY CORPS 10,000 YARD MILITARY GRID

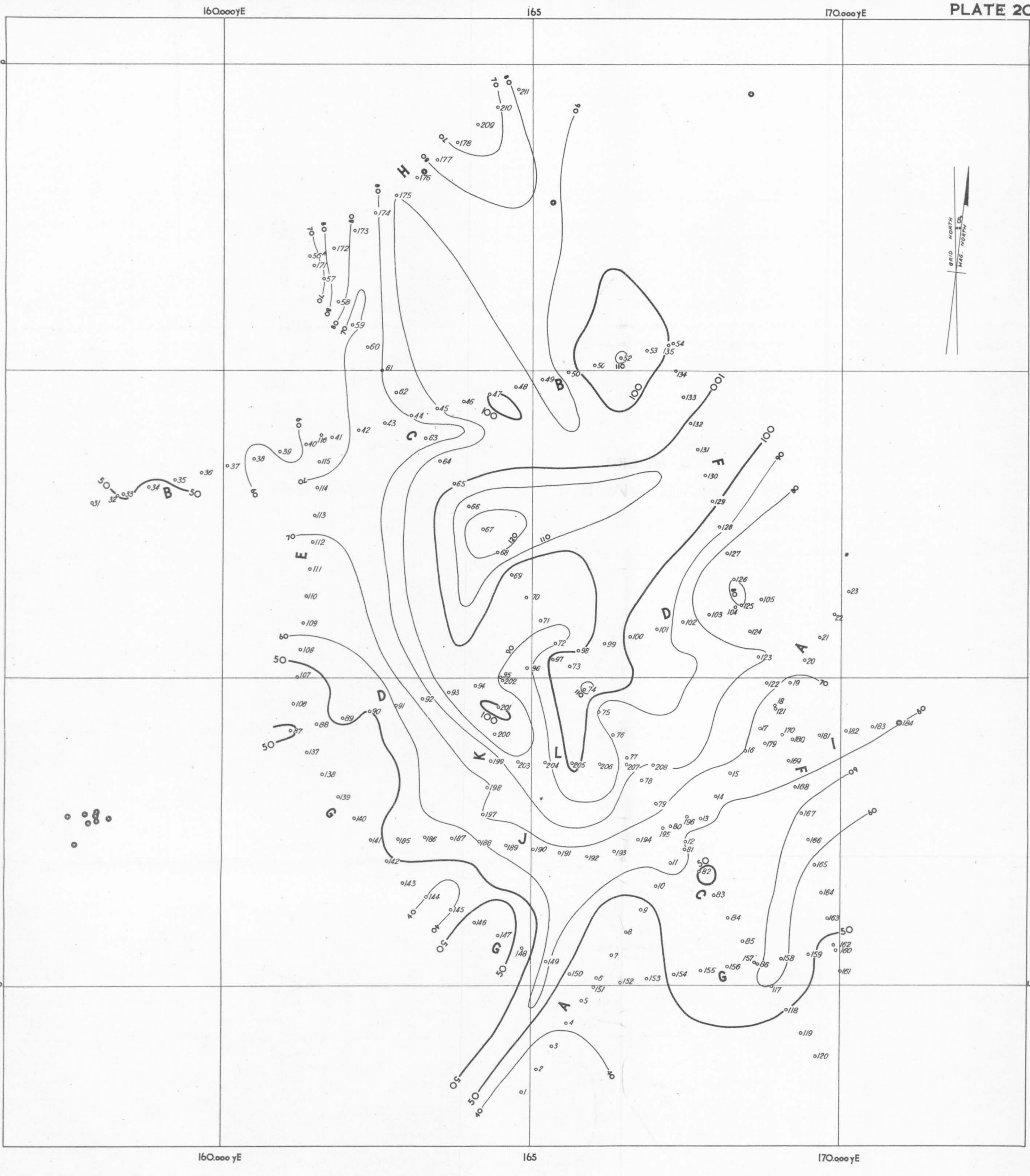
J. C. Dooley
GEOPHYSICIST

GEOPHYSICAL SURVEY AT ROMA, QLD.

ROMA SEISMIC REFLECTION SURVEY

LOWER PHANTOM HORIZON "B" CONTOURS
CONTOUR INTERVAL 50 FEET

PLATE 20



LEGEND

∘ 25 SHOT POINT

⊙ BORE

50 — 100 CONTOUR INTERVAL 10 MILLISECONDS

SCALE

0.5 0 0.5 1.0 1.5 2.0 MILES

ORIGIN – DATUM 900′ ABOVE SEA LEVEL

CO-ORDINATE REFERENCE TO ROYAL AUSTRALIAN SURVEY CORPS 10,000 YARD MILITARY GRID

J. C. Dooley
GEOPHYSICIST

GEOPHYSICAL SURVEY AT ROMA, QLD.

ROMA SEISMIC REFLECTION SURVEY

CONTOUR PLAN SHOWING SURFACE CORRECTIONS
CONTOUR INTERVAL 10 MILLISECONDS

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

G 38-36