COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
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RECORDS 1953 No. 106

RADIOACTIVE SURVEYING FROM A HELICOPTER

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1. INTRODUCTION

In connection with the use of airborne equipment for the detection of deposits of radio-active minerals, the Bureau has successfully used a DC.3 aircraft for the rapid coverage of large areas. It has been frequently suggested that a helicopter would have the following advantages over a conventional aircraft :-

(i) It can fly safely at lower heights and slower speeds than an ordinary aircraft, thus obtaining greater sensitivity from the detecting apparatus.

(ii) It can be used effectively and safely in mountainous areas, in which low flying by a conventional aircraft would be impossible.

(iii) It would enable the observer to locate exactly and identify from the air any small area on the ground showing radio-activity.

In order to assess the performance of helicopters, a programme of tests of helicopter-mounted equipment over selected areas in New South Wales was carried out during March, 1953. The areas selected were :-

(i) Carcoar. This is a hilly area, but not timbered.

(ii) Wunglebung, near Tenterfield. This is a mountainous, heavily timbered area.

(iii) Broken Hill. This is a relatively flat featureless area.

(iv) A test run was also made over Plen's deposit at Toongi, near Dubbo, in order to obtain a check on the sensitivity of the detecting instrument.

The survey techniques used and the results obtained in the several areas are discussed in detail below. Technically, the method showed to best advantage at Carcoar, where a picture of the distribution of radio-activity over a considerable area was obtained, a picture which probably could not have been obtained by any other method.

Results at Tenterfield were highly encouraging from a prospecting point of view, but drew attention to certain deficiencies in the detecting apparatus used.

At Broken Hill, although indications were observed over known deposits, results generally were not particularly striking, owing in part to the almost featureless topography which made accurate positioning of the aircraft very difficult, and in part to peculiarities in the distribution of radio-activity in this area, which would probably affect the performance of any airborne instrument.

The aircraft used was a Sikorsky S51 helicopter made available by R.A.A.F., who also supplied the pilot and maintenance crew. A report by the pilot on the navigational aspects of the operation is attached as Appendix 1. R. J. P. de Groot and L. E. Howard, geophysicists, were responsible for navigation and operation of the scintillometer during the tests.

The tests commenced at Carcoar on 27th February and were concluded at Broken Hill on 30th March, 1953.

2. DESCRIPTION OF SCINTILLOMETER

The circuit diagram of an airborne scintillometer is shown schematically on Plate 1. Gamma rays falling on the crystal cause scintillations, which are amplified by the photo-multiplier tube, and appear as voltage pulses at the photo-multiplier output. These pulses are amplified by the voltage amplifier, and are fed into the pulse shaping stage, which is a "one shot" multivibrator. Upon receiving an input pulse of amplitude greater than a certain level the multivibrator gives an output pulse of standard shape. The shaped pulses are fed into a resistance-capacity tank circuit, and a voltage appears across the tank circuit, which is proportional to the rate of arrival of the pulses. This voltage is measured by a vacuum tube voltmeter, and recorded on a pen recorder.

Available instruments differ considerably in details of construction. It is considered that the ideal instrument for use in a helicopter would provide certain facilities, which have not been provided on any of the scintillometers so far used. The principal of these are :-

(i) Provision for checking the response of the equipment. It is obvious from the schematic diagram that the scintillometer consists of two sections, the dividing line between which is shown at A on Plate 1. The response of the two sections should be checked separately. It is considered that the proper means of checking the second section would be by means of a fixed frequency pulse generator, feeding pulses in at A. When this portion of the circuit is functioning correctly, the response of the first section may be checked by the use of a standard sample.

(ii) Provision for reducing the overall sensitivity of the equipment. This should be done by reducing the sensitivity of the pen recorder, by means of suitable shunts.

(iii) Provision for operating the equipment at maximum sensitivity, whatever the general level of activity present. This would involve switching known backing-off currents through the recorder.

3. CARCOAR SURVEY

(a) Previous work.

The occurrence of uranium in the cobalt deposits mined at Carcoar has been known for many years. The area surrounding the workings has been investigated by field parties from the Bureau, and their reports contain details of the geology (Matheson, 1952a) and the level of radio-activity observed (Daly, Dyson and Pearce, 1951).

The known deposits occur in a relatively small area, which is a contact zone between diorite and slates. Close traversing on the ground with portable Geiger counters revealed small areas of high activity on the dumps, and a wide area over which some slightly high readings were obtained. It was hoped that when observed with a very sensitive instrument from a height of 100 feet the integrated effect from this area would be detectable, and would serve to characterize the area, and that other areas showing similar effects might be discovered. Such areas could be considered favourable for prospecting for deposits similar to those already worked.

(b) Method of operation.

The area is hilly and lightly timbered in places. An attempt was made to fly parallel traverses 200 feet apart, using a truck as a marker at one end. Traverses 1 to 14 were flown in this manner and are shown on the map (Plate 2) in their theoretical position. However, it was found quite impossible to position these traverses with any approach to accuracy. The position of the actual flight paths probably differs considerably from that shown, but as the recordings on these traverses showed nothing of interest it was considered that re-flying was not justified.

For the remainder of the traverses a different method of surveying was used. The area was divided into sections. For each section a map feature, such as a road, a creek, or ridge, on each side was chosen, and traverses were flown between these features, the beginning and end of each traverse being identified on a map. The map used was a section of the Blayney 1-mile sheet, enlarged to a scale of 8 inches to the mile. The distance of 200 feet between traverses was estimated (it will be noted from the map that distances were generally under-estimated.) This method of location proved satisfactory, in that the actual points at which the map features were crossed could be located accurately in this type of country. It has the disadvantage that the direction of the traverses is controlled by the map features, and cannot always be chosen to suit the strike of geological formations. Due to the topography to the west of Carcoar, the traverses flown have a general east-west direction. North-south traverses would be very difficult to fly in this area. However, the radio-active high area has a northerly strike, so that east-west traverses are best suited to outline it.

(c) Accuracy of positioning.

The position of traverses flown and a portion of the results are shown on Plate 2.

Inaccuracies in positioning are due to the following causes :-

(i) The impossibility of maintaining constant ground speed in country of this type.

(ii) The effect of wind, which cannot be allowed for readily with a helicopter, especially when flying in very hilly country.

(iii) Inaccuracy of recording the beginning and end of each traverse.

(iv) Difference between the actual flight length of traverse and the map length due to the aircraft following the slope of the country.

A measure of the effect of these may be seen in Appendix 2 which shows the overall chart length per mile of map covered along traverses 15 to 115 flown at Carcoar. It will be observed that the divergences are serious, although they tend to average out in a contour plot of a broad anomaly such as that shown, because each end of each traverse has been fixed with fair accuracy.

(d) Results.

In general, results over the area surrounding the cobalt workings were disappointing. Small definite anomalies were observed when the aircraft flew directly over the dumps, but no general effects were observed over this area. Very definite anomalies were observed on numerous traverses along the western boundary of the area surveyed. It was found possible to contour some of the traverses, and this method of presentation of the results has been adopted in Plate 2.

So that the contours may present a picture of results as obtained, including inaccuracies, smoothing and adjustment of the data have been kept to a minimum. It is considered that the displacement of the contours on traverses 64 to 68 shows the effect of inaccuracies of positioning. Traverses 1 to 47 were flown in one block, and contours derived are shown in full lines. Traverses 48 to 83 were flown on the next day and contours are shown in dotted lines. It will be noted that there is a slight break in level between the two sets of contours. This is due to a different adjustment of the background setting of the instrument.

(e) Checks on ground.

Tests were made on the ground, using portable Geiger counters in order to correlate the observed anomalies with the geology. It was found, however, that the sensitivity of the airborne scintillometer is so high compared with the portable instruments that it was difficult, without a very thorough examination, to observe sufficient range in the readings obtained on the ground and obtain definite results. The areas of high radio-activity in the neighbourhood of the cemetery appear to be associated with outcropping granite, on which readings up to twice background were observed by Geiger counters. The long area of high readings on the western edge of the area could not be associated with any geological formation. This area lies on a very steep slope, and outcrops are few. A generally high reading of up to twice background was observed over the soil cover. Recent geological mapping (Matheson, 1952a) indicates that this portion of the area consists of basic rocks, possibly sheared. It is considered that the readiest method of interpreting the results would be to extend the survey by helicopter considerably to the north and west and re-examine the geology in the light of the findings of the extended survey.

Typical records over the Carcoar area are shown on Plate 3.

The total amount of flying time on the Carcoar survey was about 7 hours.

(f) Assessment.

The results obtained at Carcoar show that the inaccuracies of positioning the aircraft are such that this method could not be used economically to search for small anomalies, such as those associated with the cobalt deposits. The results obtained over the western portion of the area, however, show the method in a very favourable light. It appears that if it is desired to obtain a picture of the regional distribution of radioactivity over an area too hilly for the use of the DC.3, and for which detailed photomosaic or map coverage is available, the use of helicopter-mounted scintillometer equipment is superior in speed and sensitivity to any method of ground surveying.

Results of geological interest would certainly be obtained by extending the work at Carcoar to the north and west. It cannot, of course, be presumed at the present stage that such results would necessarily have any direct usefulness in the search for deposits of radio-active minerals of commercial value.

4. TENTERFIELD SURVEY

(a) Previous work.

The Wunglebung area lies about 25 miles south-east of Tenterfield. Here, molybdenite has been mined from small pipe-like deposits, adjacent to a contact of granite with porphyry. The deposits worked are described briefly by Andrews (1916), but owing to the extreme roughness of the country the area has not been thoroughly prospected.

It was discovered, during the programme of radio-active testing of specimens in mineral collections carried out by the Bureau during 1948, that molybdenite specimens from Wunglebung showed radio-activity. A brief visit was paid to the workings by a geophysical party during 1948, and it was observed that the main spur upon which the workings lie shows general high activity, readings on a portable Geiger counter ranging up to five times background. The area was selected as giving the opportunity of testing the performance of the helicopter in mountainous, heavily timbered country.

(b) Method of operation.

Operations were seriously interfered with by bad weather. It appears that work in this area should be confined to late spring and early summer. Persistent low cloud prevented any flying for two days, and only two flights to the Wunglebung area were possible. The aircraft was based on Tenterfield, and test flights were made over various features in the neighbourhood of the town.

A feature of the Tenterfield area generally was the number and magnitude of the radio-active anomalies encountered. A preliminary test flight was made over the Wunglebung area, and it was found that over much of the area the recorder was continuously off scale. For the remainder of this flight the bias setting was adjusted to keep the recorder reading on scale. For more thorough coverage of the area near the workings a set of flight lines following the tops of the ridges was laid out, using a portion of the Tenterfield 1-mile map sheet, enlarged to a scale of two inches to the mile. These were flown, starting in each case from the highest point of the traverse. Flights were also made following the course of the main creeks. For these traverses, a shunt was fitted to the milliammeter, for the purpose of reducing its response by one half. As resistors of the correct values were not available, the performance of the shunt was only approximately as designed and the sensitivity of the shunted recorder being rather lower than that aimed at.

(c) Results.

The lines flown are shown on Plates 4 and 5. The test flights around Tenterfield showed numerous very definite and isolated anomalies, and their positions are shown on Plate 4. Time did not permit of the location of these anomalies on the ground. Their significance is therefore not known, but it seems possible that some at least are associated with radio-active molybdenite veins. An attempt was made to locate the anomaly south of Bluff Rock during the return trip, as the traverse was flown along the road. Some hours were spent testing the area with portable Geiger counters, and readings of twice background were obtained beside the road for a distance of over a mile. It is considered, however, that these readings are insufficient to account for the observed anomaly. It is possible that the anomaly was due not to radio-active material below the aircraft, but to strong activity in the high ground south of Bluff Rock itself, which would be on a level with the aircraft in flight. Such anomalies would be located most readily by spotting the area of highest activity by manoeuvring the aircraft rather than by flying a definite course from a map.

High activity was observed in the Wunglebung area. The anomalies appeared as high readings along considerable lengths on the flight lines, and their locations are shown on Plate 5. The nature of the anomalies suggests the presence of large areas of low grade mineralisation, rather than the known small, pipe-like molybdenite deposits. If it were possible to operate the scintillometer at maximum sensitivity, it might be possible to detect isolated anomalies superimposed on the main activity and due to molybdenite pipes. Without further geological examination and laboratory tests on samples, it is not possible to offer an estimate of the significance of the Wunglebung anomalies with any confidence.

(d) Assessment.

It is considered that the results obtained in the Tenterfield area give a very favourable impression of the capabilities of helicopter-mounted equipment in country of this type, much of which would be inaccessible to conventional aircraft. All flights made followed the tops of ridges; however, around Tenterfield itself, semi-routine coverage, similar to that flown at Carcoar, would be possible. The most efficient use of a helicopter in this country would be as an adjunct to a full-scale geological survey party. The aircraft could then be used, either for routine coverage of a small area as required, or for prospecting flights on which actual anomalies could be spotted on to a photomosaic and investigated immediately.

Typical records from the Tenterfield area are shown on Plate 6.

Total flying time was about 8 hours.

5. BROKEN HILL SURVEY

(a) Previous work.

Tests were made over portions of the Broken Hill field as this area is very similar in physical characteristics to a large part of the Pre-Cambrian area of Australia. The general distribution of radio-activity in this area has been investigated on the ground by the Geophysical Section (Daly and White, 1952).

(b) Method of operation.

Test flights were made over the following areas :-

(i) The known radio-active deposits (Balaclava Copper Blow, Hen and Chickens, Great Western).

(ii) Patterson and Polkinghorne's prospect (a recently discovered radio-active occurrence).

(iii) Outcrops south of the racecourse, and in the Rockwell Paddock area, which have been found to show radio-activity rather greater than normal (Daly and White, 1952).

The positions of these areas are shown on the map (Plate 7). An attempt was made to cover the area around the Balaclava Copper Blow systematically, by flying north-south traverses 200 feet apart, marking the northern ends by means of a truck. It was found, however, that it was quite impossible to locate the position of the aircraft with any accuracy in flat featureless country of this type.

(c) Results.

Anomalies were observed over all known deposits. As was expected, the largest anomaly was a narrow one over the Warren shaft at the Balaclava Copper Blow, where the main radio-active anomaly had been found on the ground. A feature of the Broken Hill district, previously noted by Daly and White (1952) is the general high level of radio-activity in the country rocks. This has affected the results in two ways :-

(i) On the scintillometer used, the means provided for setting the response of the instrument to the background activity affects the overall sensitivity, with the result that the instrument, when adjusted according to the makers' recommendations, is less sensitive in areas where the general level of activity is high. The effect of the high back-ground may be seen in the strong negative anomaly obtained over Umberumberka reservoir (see Plate 9, Sheet 5).

(ii) On all profiles, numerous small anomalies are present, due to the passage from rock outcrop to soil cover. These may be seen in the profiles over the racecourse, and the Rockwell area. (Plate 9, Sheets 6 and 7). These complicate the records and could possibly obscure readings of greater significance. It is possible that results obtained using the DC.3 aircraft will be affected similarly.

A prospecting flight to the south, along the border fence was made. The approximate course of this flight is shown on Plate 8. No strong anomalies were encountered on this flight. The general level of activity along the border fence was rather less than that on the return flight, probably due to the fact that outcrops are fewer along the fence.

Examples of records obtained in the Broken Hill area are shown on Plate 9.

Total flight time was about 9 hours.

(d) Assessment.

The results obtained at Broken Hill drew attention to the difficulties of the operation in country of this type. Some of these difficulties are due to geological causes, which would probably affect any airborne equipment to some extent. Routine coverage is practically impossible with the helicopter. There is one possible way of covering the field in some detail. Most of the area has been carefully mapped by the geologists of Zinc Corporation

Ltd., and maps are available on which all creeks of any importance are marked. If all these creeks were systematically flown with the helicopter, a fairly good general coverage of the known field would be obtained. This work could be completed in about three weeks, and it is possible that the results could be more readily correlated with the geology than results obtained from routine coverage with the DC.3 aircraft. On the other hand, it should be noted that the country around Broken Hill is ideally suited to the operation of the DC.3 with Shoran positioning, and any major anomalies would be located much more rapidly by this means than by the use of the helicopter.

6. TESTS AT TOONGI.

In order to obtain definite information on the sensitivity of the scintillometer, a test flight was made over a deposit of trachyte, showing high radio-activity at Toongi, near Dubbo. The location of this area is shown on Plate 10. This outcrop, known as Plen's deposit, had been examined previously (Matheson, 1952b). The outcrop consists of a low hill approximately half a mile wide, which records about eight times normal background reading on a portable Geiger counter.

A very strong anomaly was observed over this deposit. Several profiles were run across the outcrop in different directions at heights up to 500 feet, using different bias settings of the scintillometer. The results are shown on Plate 11.

On the return flight from Toongi to Blayney, a strong anomaly was observed about 4 miles south of Plen's deposit. (See Plate 10). Profiles over this anomaly are shown on Plate 5. The region was visited and the radio-active area was located. It lies about ½ mile east of Eulandool homestead, and consists of three hills of considerable size. Tests with a portable Geiger counter gave readings of about five times background generally over the surface of the hills. The rock in the area is identical in appearance with that at Plen's deposit.

This test was undertaken purely as a check on the performance of the scintillometer. It indicates that the helicopter could be used to search for other deposits similar to Plen's and the Eulandool deposit. However, such a search could be carried out much more rapidly in this type of country by using the DC.3 aircraft.

7. SUMMARY AND CONCLUSIONS.

The present report covers a series of tests made over selected areas in New South Wales, in order to assess the suitability of scintillometer equipment mounted in a helicopter in the search for deposits of radio-active minerals. Attention was directed primarily to regions of high topographic relief, over which the use of an aircraft of conventional type would be difficult or impossible. The aircraft used was a Sikorsky helicopter, Type S51, made available by the Royal Australian Air Force. The aircraft was flown at a speed of about 70 miles per hour, and a height of 100-150 feet. No attempt was made to use the hovering capabilities of the helicopter.

The following conclusions are drawn from the results of the tests :-

(i) The sensitivity of a scintillometer of suitable design used in this way is adequate to detect any significant radio-activity.

(ii) Due to the comparatively low speed and altitude at which the aircraft is flown, the record of surface radio-activity is more detailed than could be obtained using an aircraft such as a DC.3. Such a record is advantageous since it can be correlated with the areas of radio-activity with a minimum of radio-active survey on the ground.

(iii) None of the usual methods of determining the position of the aircraft, such as photography or the use of radio navigation aids, is applicable with the helicopter. Navigation must be by eye, using photomosaics, or maps showing equivalent detail. The accuracy of positioning depends on the rapidity with which a definite point on such a mosaic or map can be located accurately, and is therefore greatest in areas of considerable topographic relief, or in areas on which features such as roads or fences are numerous.

(iv) For a routine air survey over a large area, the most economical method of coverage is to fly the aircraft along straight parallel traverses, the spacing of which is accurately maintained. The helicopter is quite unsuited to this type of work.

(v) In order to make economical use of an expensive aircraft such as a helicopter, it is essential that all flying be as systematic as possible. Two main modes of operation may be envisaged:-

(a) Systematic coverage of an area. This would be done by flying sets of traverses so chosen that their course may be established with reference to easily identifiable map features. For this type of flying, a crew of four would be desirable and would consist of a pilot, a co-pilot to act also as navigator and direct the pilot along the flight line, an instrument operator, and an observer keeping a detailed flight log.

(b) Spotting of anomalies for later investigation on the ground. This would be done by following flight lines generally along ridges, and either marking the positions at which high readings were obtained directly on a map or photomosaic, or dropping a ground marker of some type from the aircraft. It is understood that a marker suitable for this purpose has been used by the R.A.A.F., consisting of a grenade, filled with fuze, exploder, and a charge of aluminium powder.

(vi) It is possible that, in a particular case, the helicopter could be used for following up anomalies recorded by a fast aircraft such as the DC.3, although the use of such an expensive aircraft for this purpose would be fundamentally uneconomical. If a radio-active anomaly were discovered by the DC.3 aircraft in a completely featureless area such as the Mulga scrub country to the south of Broken Hill, a ground party might have great difficulty in locating the radio-active area. It is possible, however, that the anomaly could be re-located with a helicopter by a restricted amount of flying, and the spot marked with a marker grenade as suggested in (v) above, or some other means adopted of guiding the ground party. Such an operation as this would be resorted to only in very special circumstances.

(vii) Due to the inevitable uncertainty in positioning, the helicopter should be used only as an adjunct to a geological party large enough to permit of immediate following up of indications. The programme of flying for the aircraft would be decided on a day-to-day basis.

(viii) The hovering capabilities of the helicopter are not as great as is popularly supposed, and it is considered that they will not be found particularly useful for this type of work under Australian conditions.

(ix) The helicopter best suited to the type of operations described above appears to be the Sikorsky, Type S55. Considerable use could be made of a smaller machine, such as the Sikorsky S51 or the Bristol, Type 171. The use of a helicopter smaller than these would be so restricted as to be uneconomical.

8. ACKNOWLEDGMENTS.

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Mr. B. P. Thompson of Zinc Corporation Ltd.

The officers of Australian National Airways Ltd., Broken Hill.

The owner of Billyrimba Station, and Mr. M. West, Tenterfield.

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Melbourne,
October, 1953.

APPENDIX 1.

REPORT ON APPLICATION OF HELICOPTER IN URANIUM SURVEY BY FLYING OFFICER R. A. SCOTT.

1. **INTRODUCTION:**

For the purpose of evaluating the Helicopter for use in locating radio-active material, the Royal Australian Air Force, in conjunction with the Commonwealth Bureau of Mineral Resources, has been operating a Sikorsky S51 in the Carcoar, Tenterfield and Broken Hill districts of New South Wales. This is the first time in Australia that a Helicopter has been used for this purpose, and naturally several difficulties in the performance and handling of the aircraft were encountered.

2. The purpose of this report is to present these difficulties for guidance in any future operation of this type and, also, for the procurement of a more suitable type of Helicopter.

3. To appreciate the limitations of Helicopter aircraft, several characteristics of Helicopter flying must be understood. To many, such aircraft must seem puzzling and complex machines, whereas they are no more difficult to understand than conventional types. Both rely for their support on the "lift" produced by airflow around the wings, and it is in the method by which this airflow is created that they differ.

4. **Lift:**

Basically, the rotor of a Helicopter is a large diameter propellor mounted with its axis vertical. The airflow created by the rotation of the rotor produces "lift" which acts directly against the weight of the aircraft. The aircraft will climb, hover or descend, depending on whether the lift is greater, equal to, or less than the weight of the aircraft. The lift produced by the rotors varies according to their speed of rotation, angle of attack to the airflow and the density of the air.

5. All control, apart from the directional control, is gained by varying the angle of attack of the rotors at different stages of their orbit. Due to aero-dynamics considerations the angle of attack cannot be changed very much, and this limits the control of the Helicopter, particularly about the horizontal axis. The S51 Helicopter is unstable in all planes, and constant manipulation of the controls is necessary to control the aircraft.

6. **Engine Failure:**

In common with conventional aircraft, the Helicopter is capable of gliding with power off. Provided the Pilot takes the appropriate action, the rotors will revolve under the air loads acting on them, and produce sufficient lift to enable the aircraft to make a slow descent. This property of the rotor is known as "autorotation."

7. In the event of engine failure, it is essential that the angle of attack of the rotors be reduced, in order to put them in the autorotation pitch range, which decreases drag and permits high rotor R.P.M. to be built up. With this stored inertia in the rotor system, the aircraft can be glided until just above the ground where it is flared out and eased on to the ground.

8. The higher the airspeed the greater the inertia of the rotor blades, and some speed is a very desirable feature when dealing with engine failure. Engine failure at reasonable forward speeds (50-60 knots) presents no problems, but if the failure occurs whilst hovering or climbing vertically, a heavy landing, probably entailing complete destruction of the machine would result unless sufficient height was available to gain forward speed. To attain the desired speed a minimum height of 400 feet is required, so for this reason hovering or vertical flight below an altitude of 400 feet, except when close to the ground, is not normally carried out.

9. Ground Cushion:

The "ground cushion" or "ground effect" is a very important feature of Helicopter flying. When the aircraft hovers with its wheels within 10 feet of the ground, the air driven downwards by the rotors becomes packed between the rotors and the ground. This packing increases the density of the air, and the dense air so formed beneath the aircraft is known as the "ground cushion" or "ground effect." It is very important when hovering at high altitudes or when heavily laden.

PROBLEMS ENCOUNTERED DURING THE SURVEY

10. Tracking:

Accurate tracking presented the greatest difficulty throughout the survey. To cover the areas thoroughly, parallel tracks, 200 feet apart had to be flown. This called for a standard of course steering which is impossible with the instrument aids fitted to the S51 Helicopter. The only direction indicator fitted is a magnetic compass, and during turbulent conditions the compass rose oscillated up to 10 degrees either side of the correct heading. Wind drift, together with the characteristic of the Helicopter in being able to fly sideways even though the aircraft is pointed in the correct direction added to the difficulty of accurate tracking. At times tracks overlapped or were too far apart and had to be reflown.

11. The most successful method of tracking used was to fly one track as accurately as possible, and whilst doing so, note features on the ground 200 feet to one side. The next track was then flown over these selected features and further features noted for the following track. This proved successful where prominent features existed and the traverses were short. As the traverses lengthened, it became increasingly difficult for the pilot to fly accurately and select and remember the pinpoints chosen. It would be advantageous to have a crew member sitting beside the pilot, concentrating entirely on map reading and selection of pinpoints. This is unfortunately impossible in the S51 due to its seating arrangement. The fitting of an electrically driven gyro direction indicator is necessary, due to the oscillating of the magnetic compass.

12. It should also be possible to carry some form of indicator (e.g., smoke generator) to be dropped from theaircraft at the end of each traverse, or to have indicators on the ground in charge of ground personnel. These indicators, however, would be successful in flat or gently undulating country only, as any large hills would obscure them from the pilot's view.

13. Speed:

Accurate airspeed was not a great problem, although it was necessary to keep it reasonably constant so as to help correlation of the recorder reading with the positions on a map. A speed of 50-60 knots was normally maintained as this gave a good rate of climb and also is the best speed in the event of engine failure. Turbulence affected the airspeed needle rather badly, but the normal procedure to maintain a constant ground-speed of keeping the aircraft's attitude constant was carried out and proved successful.

14. Height:

As no instrument to indicate height above the ground is fitted to the S51 (a normal altimeter is fitted, but this indicates height above a pre-set altitude only) the required height (100 to 150 feet) was maintained solely by visual means. This was quite successful, and it is considered that no special instruments for height indication are required.

15. At times, the rate of climb of the Helicopter was insufficient to fly to the bottom of some valleys and then climb over the surrounding mountains, maintaining the required height, and sufficient airspeed to give control in the event of engine failure. Throughout the survey no attempt was made to fly the aircraft to its limit. This was due to the over present realisation that it is the only Helicopter in the Royal Australian Air Force, and any manoeuvre which entailed more than the normal amount of risk, should not be carried out.

16. Weather:

The weather generally was good. The main difficulties experienced were :-

(a) High temperatures, which increased the density altitude at which the aircraft was operating and hence lowered its hovering ceiling (see Appendix "A").

(b) Turbulence which made accurate flying difficult. It also produced strong and unpredictable air currents in the valleys and near the mountain crests.

17. In the Carcoar area, flying was begun at 0630 hours and ceased at 1130 hours to escape or minimise the effect of these weather conditions. In the Tenterfield area, early morning flying was prohibited by low mist and rain. Two days' flying was lost during the survey due to adverse weather.

18. Load:

The centre of gravity of the S51 is very sensitive to load changes, and great care must be taken in loading the aircraft. Ballast must be positioned in the aircraft to compensate for different loadings, and this ballast is dead weight which lowers the useful load carrying capacity of the aircraft.

19. Hoisting:

The S51 is equipped with an electric-hydraulic hoist, and crew members could have been lowered to the ground to investigate high recorder readings. However, no hoisting was carried out during the survey because :-

(a) The aircraft was operating at or near its hovering ceiling.

(b) The country was generally too heavily timbered for safe hoisting operations (a clearing of 30 feet diameter is required).

(c) The two Geophysicists carried were not experienced in hoisting.

(d) Immediately the person on the hoist touches or leaves the ground, the aircraft's centre of gravity moves. Ballast must be arranged prior to the flight to compensate for this movement.

20. Maintenance:

The Royal Australian Air Force maintenance cycle consists of :-

(a) A daily inspection, which takes approximately 40 minutes.

(b) An inspection after every 25 hours' flying. This inspection usually takes 1 to 2 days.

Two men trained in Helicopter maintenance are required for these inspections. During the survey one day's flying was lost due to the aircraft being unserviceable.

21. Conclusions:

The pilot had carried out Helicopter flying in mountainous terrain previously, but never under such critical conditions. As a pilot training exercise it was excellent. It demanded great concentration to fly the aircraft, judge height, look for obstructions and select pinpoints, and it is considered that 4 to 5 hours' flying per day is the maximum a pilot could carry out without becoming fatigued.

22. Mountain flying is perhaps the most difficult type of Helicopter flying, and pilots should have at least 100 hours flying on Helicopters before attempting this type of operation in rugged terrain.

23. The country generally is unsuitable for a forced landing in the event of engine failure, and there would be a great danger of fire if a crash landing became necessary. Some form of automatic fire extinguisher fitted to the aircraft is required.

24. Bases from which the aircraft operates should be as close to the area to be surveyed as possible, so that travelling time, and hence the fuel load required can be cut to the minimum.

25. For extensive surveying, a Helicopter having a better performance is necessary. Improvements considered desirable are :-

(a) Higher hovering ceiling.

(b) Greater rate of climb.

(c) Greater useful load.

(d) Passenger compartment capable of seating 5 passengers and also of carrying additional equipment such as cameras.

(e) Passenger compartment situated so that addition or removal of passengers or cargo does not affect the centre of gravity.

(f) Hoist situated so that hoisting operations do not move the centre of gravity beyond its limits.

(g) Provision for a crew member to sit beside the pilot to help in map readings.

(h) Greater range.

26. A Helicopter possessing the above characteristics could possibly transport all necessary equipment and personnel and carry out a survey without the aid of any ground vehicle.

27. The writer has studied the performances of all Helicopters manufactured to date, and the only aircraft which appear to fulfil the above requirements are the Bristol 173 and the Sikorsky S55. The Bristol 173, however, would probably prove too large and clumsy, particularly in steep mountains and valleys, and as it is still very much in the experimental stage, it probably would not be a worthwhile proposition.

28. The Sikorsky S55 is a proven aircraft which has been thoroughly tested in Korea. From all reports this aircraft is far easier to maintain than the S51, and it possesses all those characteristics mentioned in paragraph 25, which are considered essential. A comparison of the performance of the S51 and S55 Helicopters is included as Appendix "B".

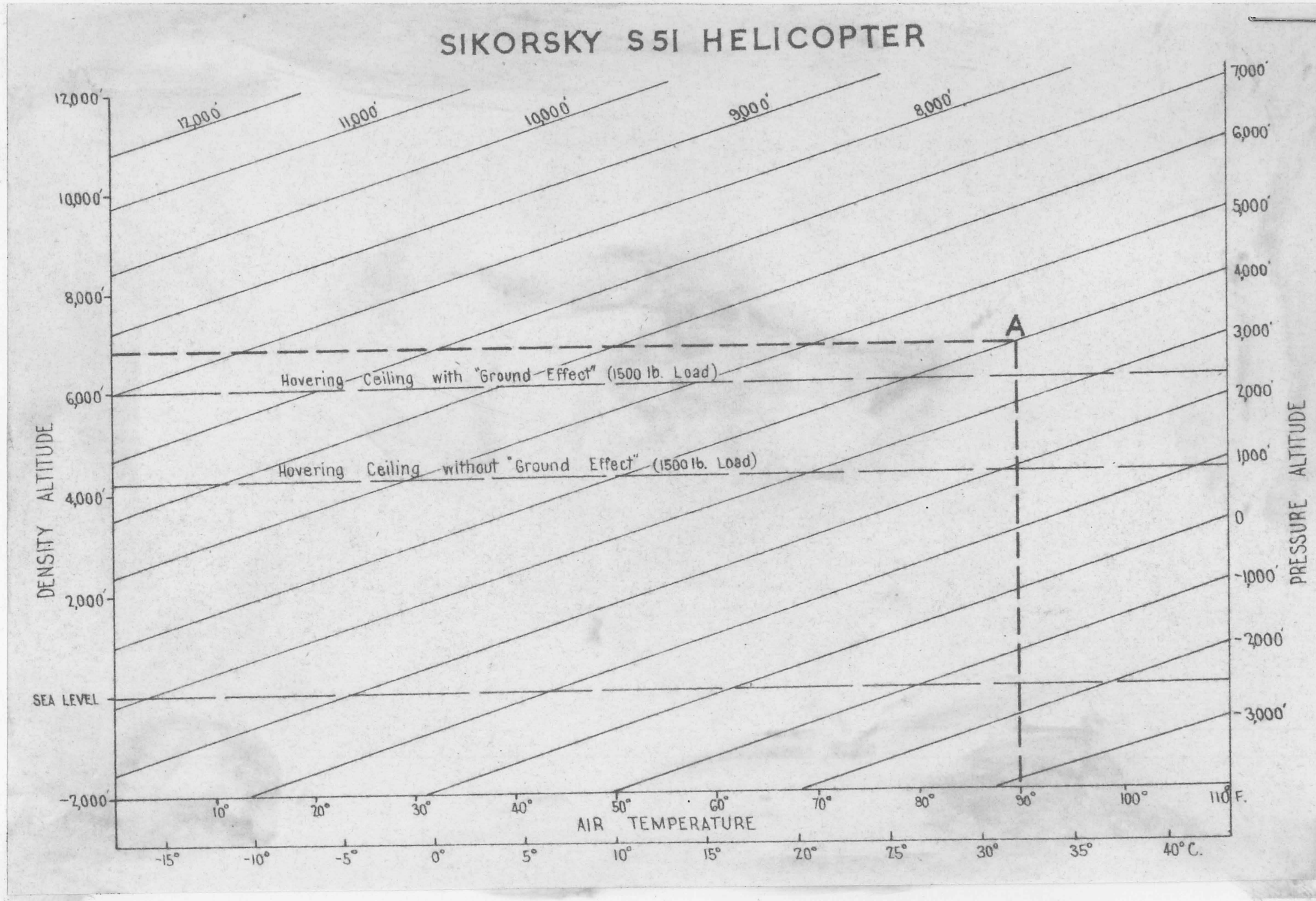
29. The Sikorsky S51 Helicopter, although not the ideal Helicopter, performed quite well and appeared to do the job reasonably successfully. In the writer's opinion, no other vehicle could cover the Tenterfield area or any other rugged area as quickly or as thoroughly as a Helicopter.

(Signed) R. SCOTT.

(R. A. Scott)
Flying Officer.

APPENDIX "A"

CORRELATION BETWEEN ALTITUDE AND N.A.C.A. STANDARD AIR AND PRESSURE ALTITUDE AND TEMPERATURE.



Example. Suppose it is desired to find the altitude (often referred to as "Density Altitude") equivalent to a pressure altitude of 4,000 feet at a temperature of 90°F. On slanting line marked 4,000 feet pressure altitude, locate point "A" directly above 90°F. in the temperature scale at the bottom. The equivalent density altitude of 6,800 feet is read on the scale at left on the same horizontal line as point "A". The S51 hovering ceiling with 1500 lb. load and without ground effect is normally 4,200 feet. However, due to the high temperature it would be above its hovering ceiling under the above conditions.

APPENDIX "B"

PERFORMANCE FIGURES SIKORSKY S51 & S55 HELICOPTERS

Detail	Sikorsky S51	Sikorsky S55
Seating Capacity	4	10 - 12
Engine Horse Power	450	600
Useful load (includes Fuel)	1695	2400 lbs.
Maximum speed	103	110 m.p.h.
Maximum rate of climb	1000	1130 f.p.m.
Gross weight	5500	6800 lbs.
Hovering ceiling with ground effect (at maximum gross weight)	5000	5500 feet
Hovering ceiling without ground effect (at maximum gross weight)	3200	4200 feet
Hovering ceiling with ground effect (with 1500 lb. load)	6000	10600 feet
Hovering ceiling without ground effect (with 1500 lb. load)	4200	8000 feet
Fuel consumption (cruising)	24	36 g.p.h.
Maximum range	308	477 miles *

* Extra tankage can be fitted to increase range to 1,000 miles.

N.B. Performances quoted are for the American built models. British versions differ slightly from the above figures.

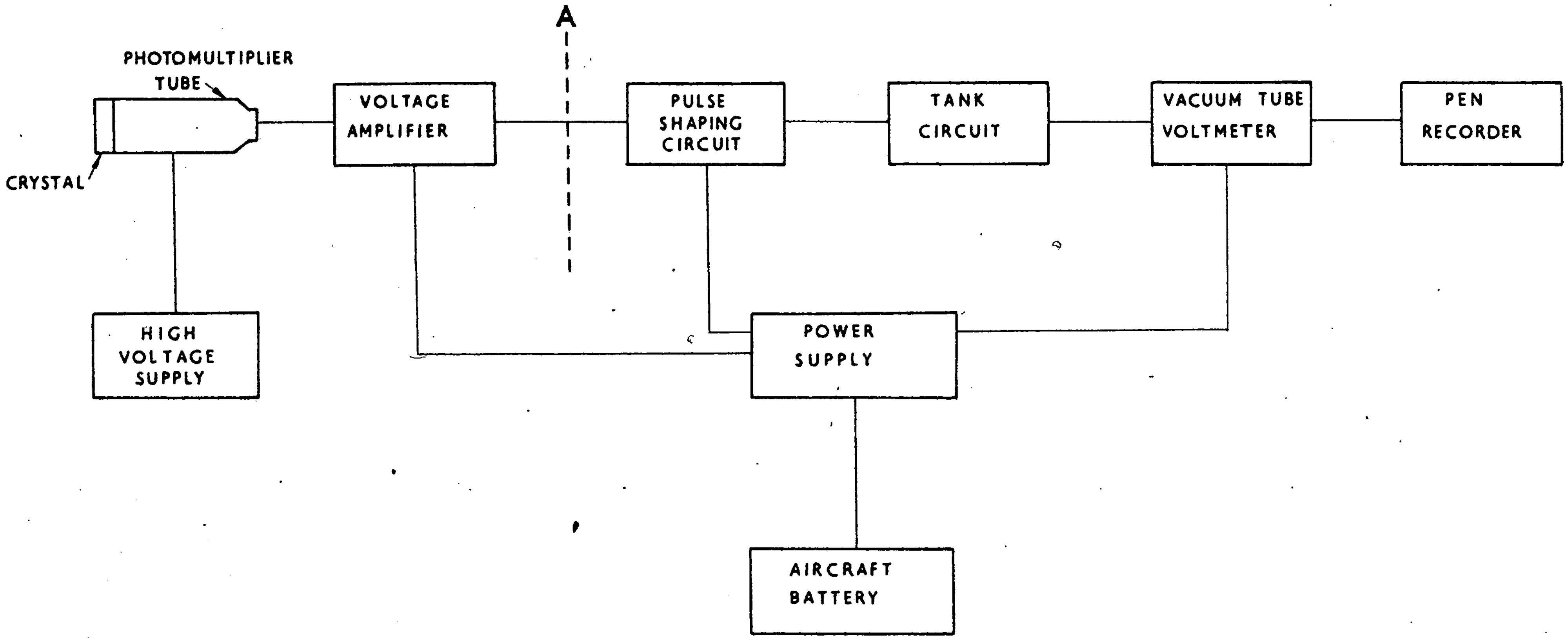
APPENDIX 2.

THE CONSISTENCY OF THE DISTANCE SCALE OF THE SCINTILLOMETER RECORDS.

As a measure of the accuracy of surveying attained on the tests, the quantity length of record per mile of traverse is tabulated below for traverses 15-115 flown at Carcoar :-

Traverse No.	Length of Record per mile (inch)	Traverse No.	Length of Record per mile (inch)
15	5.5	63	2.7
16	3.1	64	2.4
17	3.1	65	2.7
18	2.8	66	2.3
19	2.8	67	2.7
20	2.7	68	2.3
21	3.3	69	2.7
22	2.5	70	2.6
23	2.6	71	2.7
24	2.4	72	2.6
25	2.7	73	2.5
26	2.8	74	2.3
27	2.7	75	2.5
28	2.9	76	2.0
29	3.2	77	2.2
30	2.5	78	2.3
31	3.1	79	2.4
32	2.9	80	2.4
33	3.3	81	2.3
34	3.4	82	2.8
35	3.6	83	2.8
36	3.6	89	2.7
37	3.8	90	2.9
38	3.5	91	2.8
39	3.3	92	2.6
40	3.0	93	2.5
41	2.9	94	2.6
42	2.9	95	2.4
43	3.1	96	2.5
44	3.1	97	2.5
45	3.1	98	2.5
46	2.7	99	2.4
47	2.9	100	2.5
48	2.4	101	3.3
49	2.6	102	3.4
50	2.5	103	3.4
51	2.6	104	2.5
52	2.6	105	3.4
53	2.5	106	2.4
54	2.5	107	3.2
55	2.3	108	2.4
56	2.5	109	3.3
57	2.6	110	2.5
58	2.7	111	3.2
59	2.5	112	2.1
60	2.5	113	3.3
61	2.7	114	2.4
62	3.0	115	3.1

Traverses 84-88 inclusive were discarded due to uncertainty in positioning.



SCHEMATIC CIRCUIT DIAGRAM OF AIRBORNE SCINTILLOMETER

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

G 45-41

PLATE I

PLATE 2

TRAVERSES 1-47 FLOWN ON 1·3·53 CONTOURS SHOWN —+100—
" 48-83 " " 2·3·53 " " --+100--
AREA GEOLOGICALLY MAPPED

SCALE
20 0 20 40 60 80 CHAINS

SCINTILLOMETER SURVEY AT CARCOAR N.S.W.

LOCALITY MAP

SHOWING

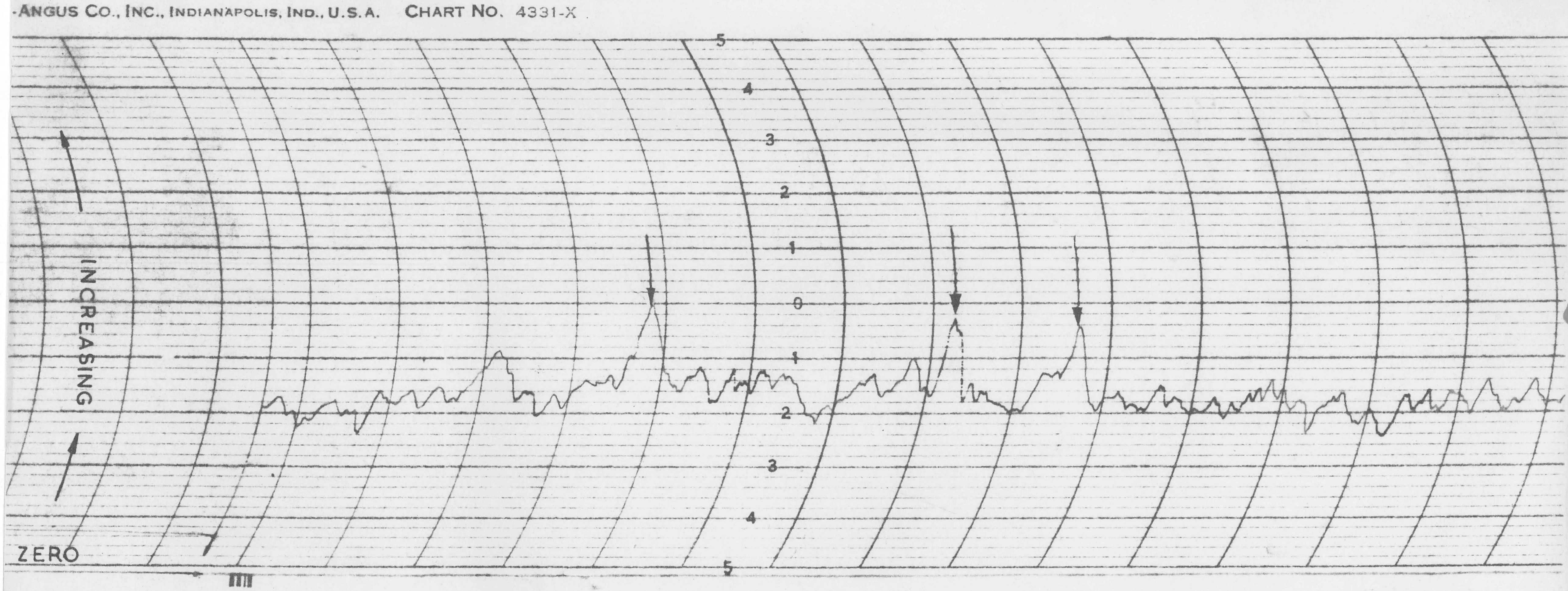
TRAVERSES FLOWN BY HELICOPTER AND CONTOURS OF GAMMA RAY INTENSITY

BASED ON RECORDER LEVELS IN MICRO AMPS ABOVE AN ARBITRARY ZERO

J. Da E. ..... GEOPHYSICIST

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

G138-1



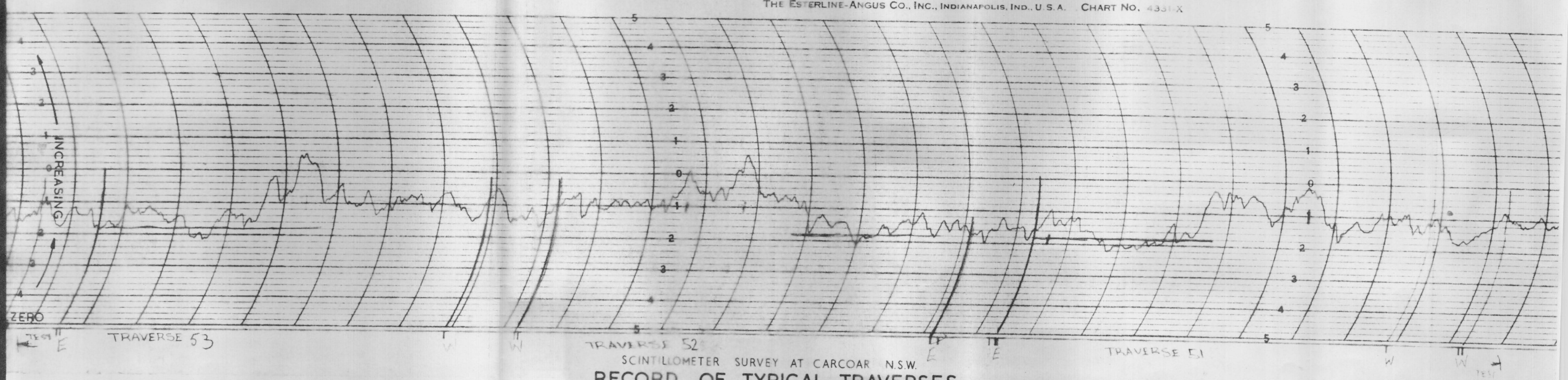
SCINTILLOMETER SURVEY AT CARCOAR N.S.W.

ANOMALY OVER COBALT WORKING G.

(REFER MATHESON 1952a)

PLATE 3
SHEET I

G138-2



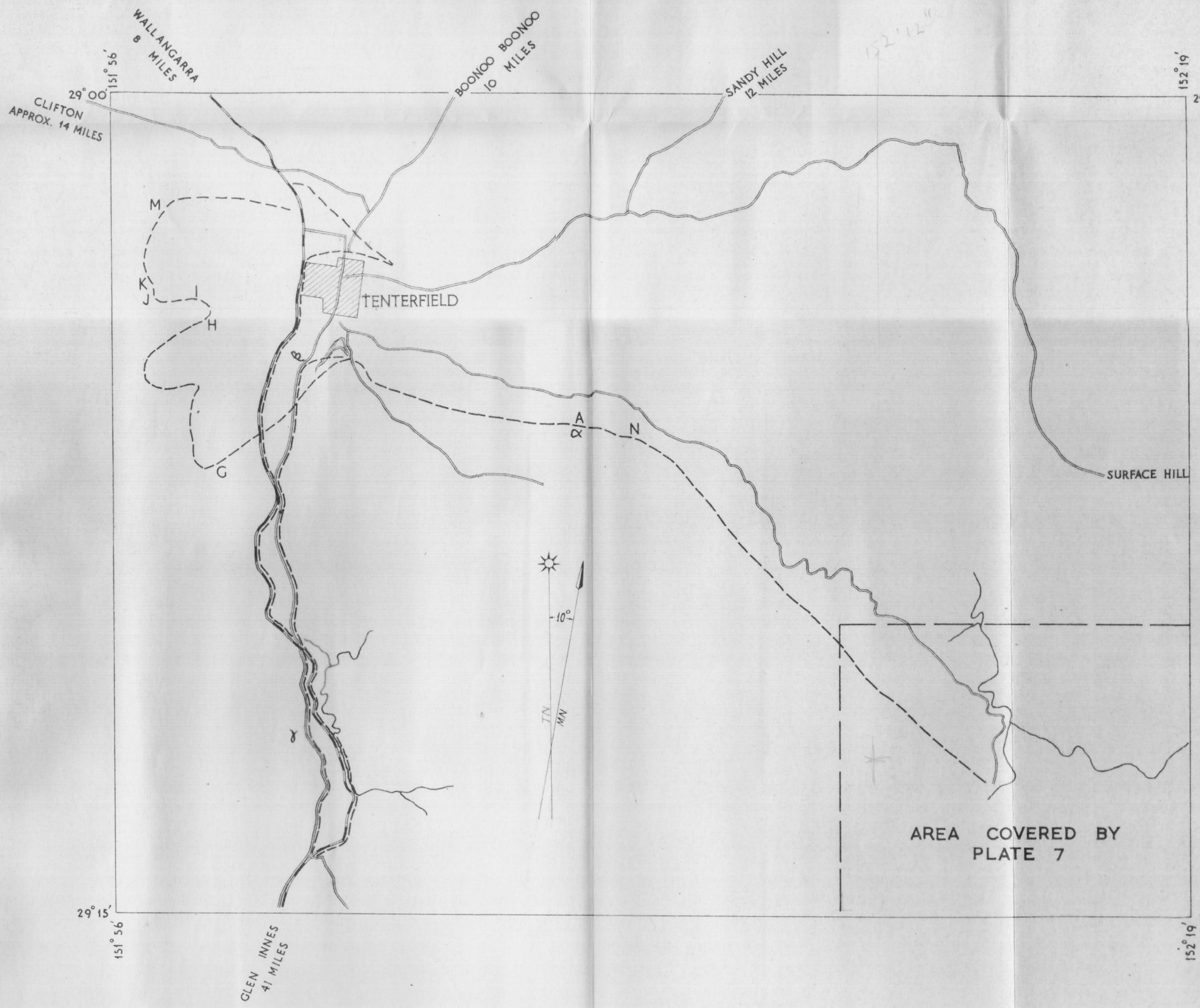
SCINTILLOMETER SURVEY AT CARCOAR N.S.W.

RECORD OF TYPICAL TRAVERSES

(NUMBERS 51, 52 AND 53)

G138-3

PLATE 4



SCINTILLOMETER SURVEY AT TENTERFIELD N.S.W.

LOCALITY MAP

SHOWING HELICOPTER FLIGHT LINES AND POSITIONS OF PRINCIPAL ANOMALIES

SCALE IN MILES

2 0 2 4 6

LEGEND

ROAD

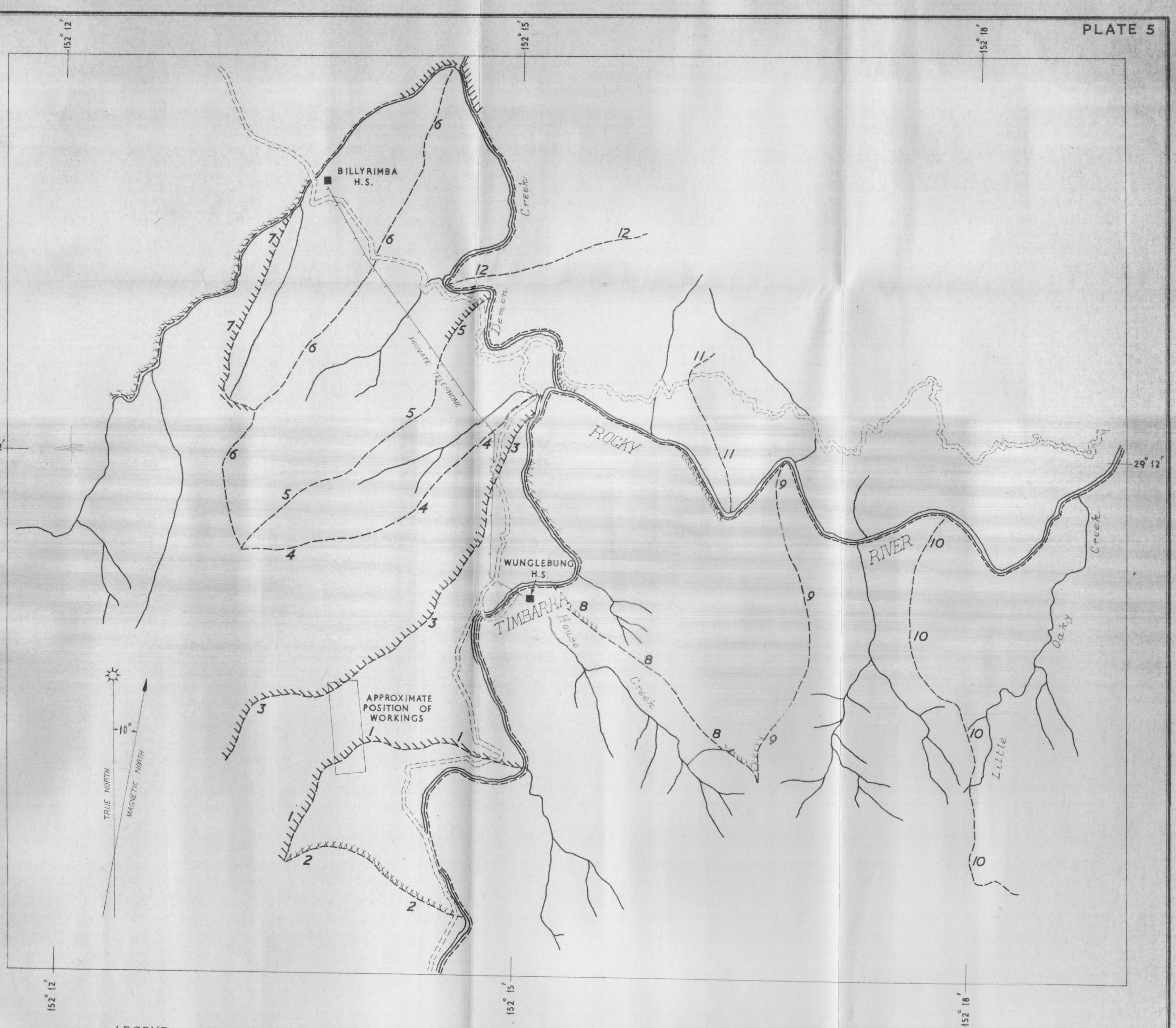
RAILWAY

HELICOPTER FLIGHT LINE

J. Daly
Geophysicist

Geophysical Section: Bureau of Mineral Resources, Geology and Geophysics

G 136-2



LEGEND

ROAD
TELEPHONE
HELICOPTER FLIGHT LINE
RECORDS SHOWING HIGH ACTIVITY
RECORDS SHOWING MODERATE ACTIVITY

SCINTILLOMETER SURVEY AT TENTERFIELD N.S.W.

LOCALITY MAP OF WUNGLEBUNG AREA

SHOWING POSITIONS OF HELICOPTER FLIGHT LINES

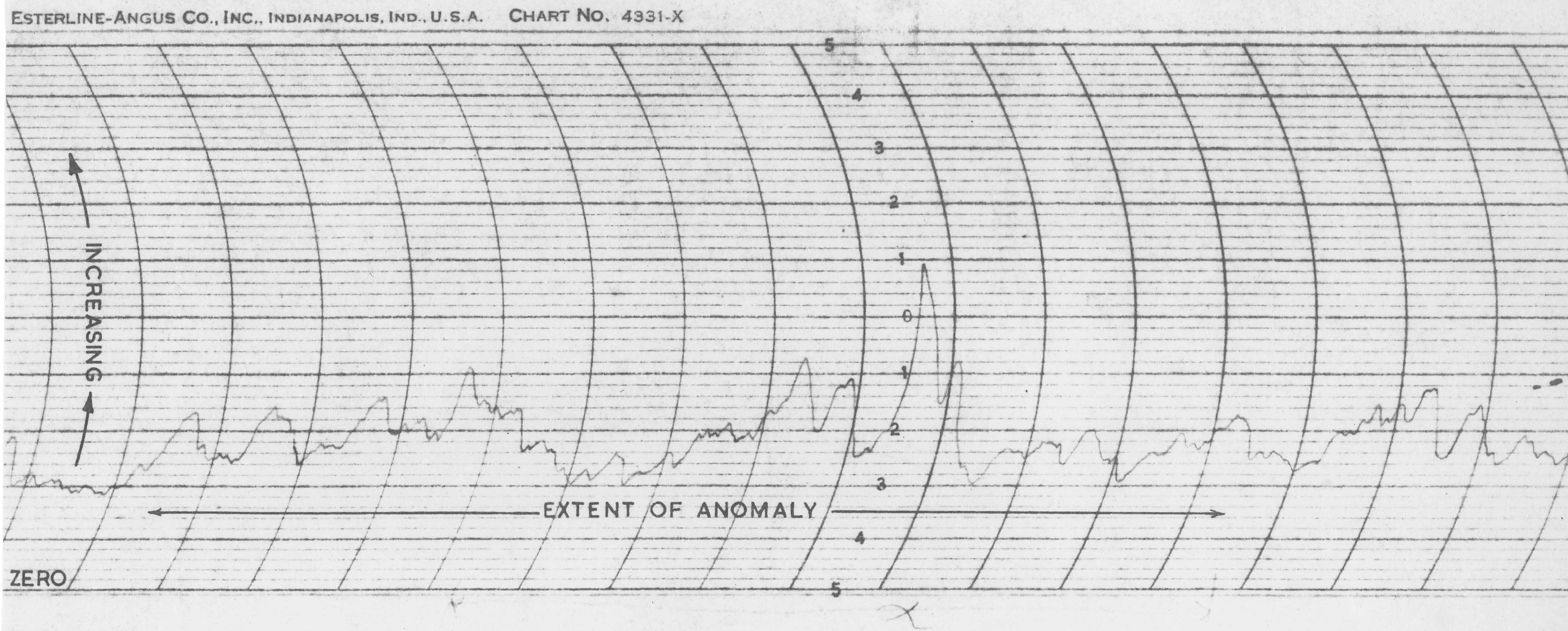
SCALE

1 0 1 MILES

GEOPHYSICIST J. Da E

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

G 136-1



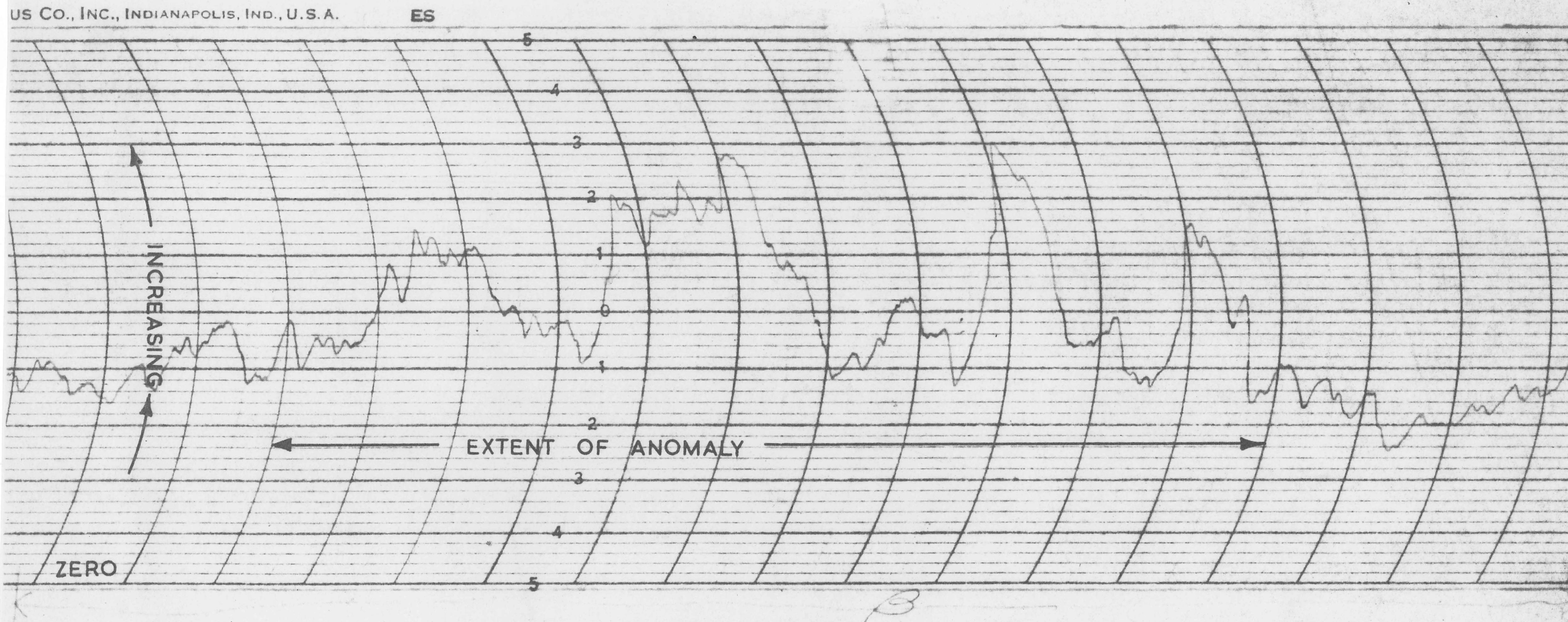
SCINTILLOMETER SURVEY AT TENTERFIELD N.S.W.

ANOMALY α

(RECORER AT LOW SENSITIVITY)

PLATE 6
SHEET 1.

G136-3

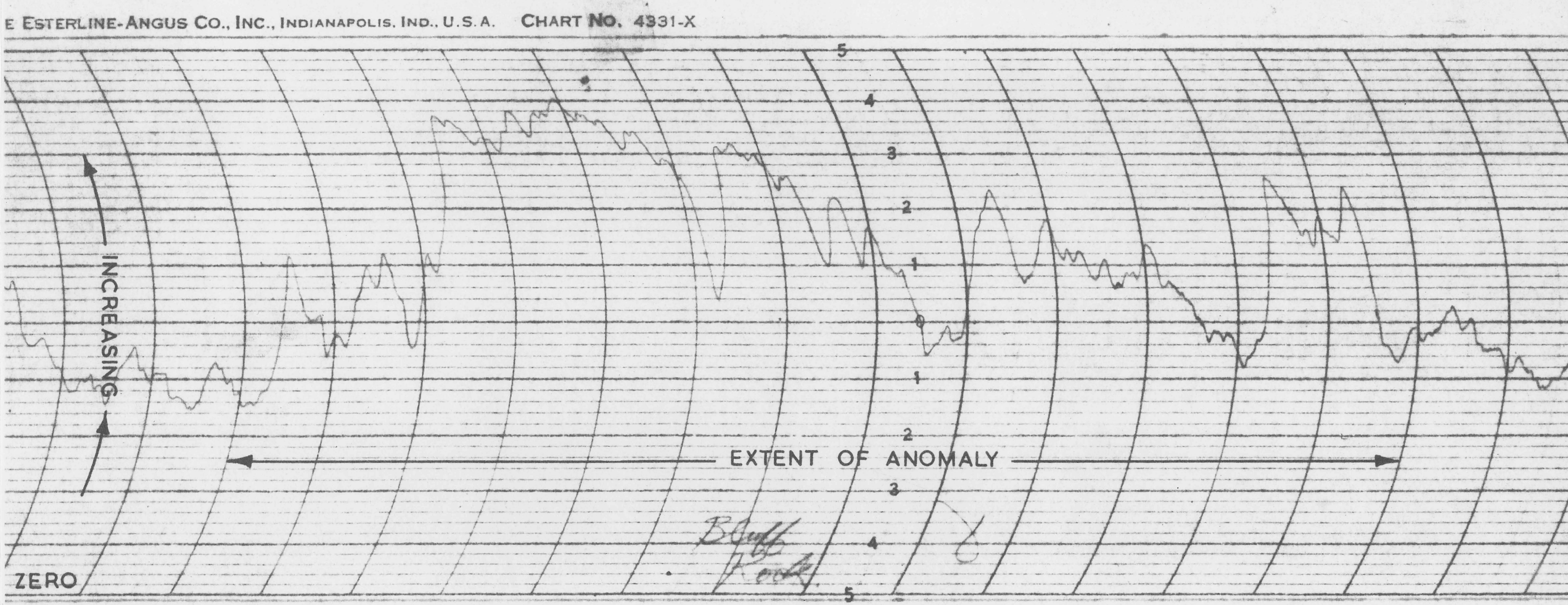


SCINTILLOMETER SURVEY AT TENTERFIELD N.S.W.

ANOMALY β

PLATE 6
SHEET 2.

G136-4



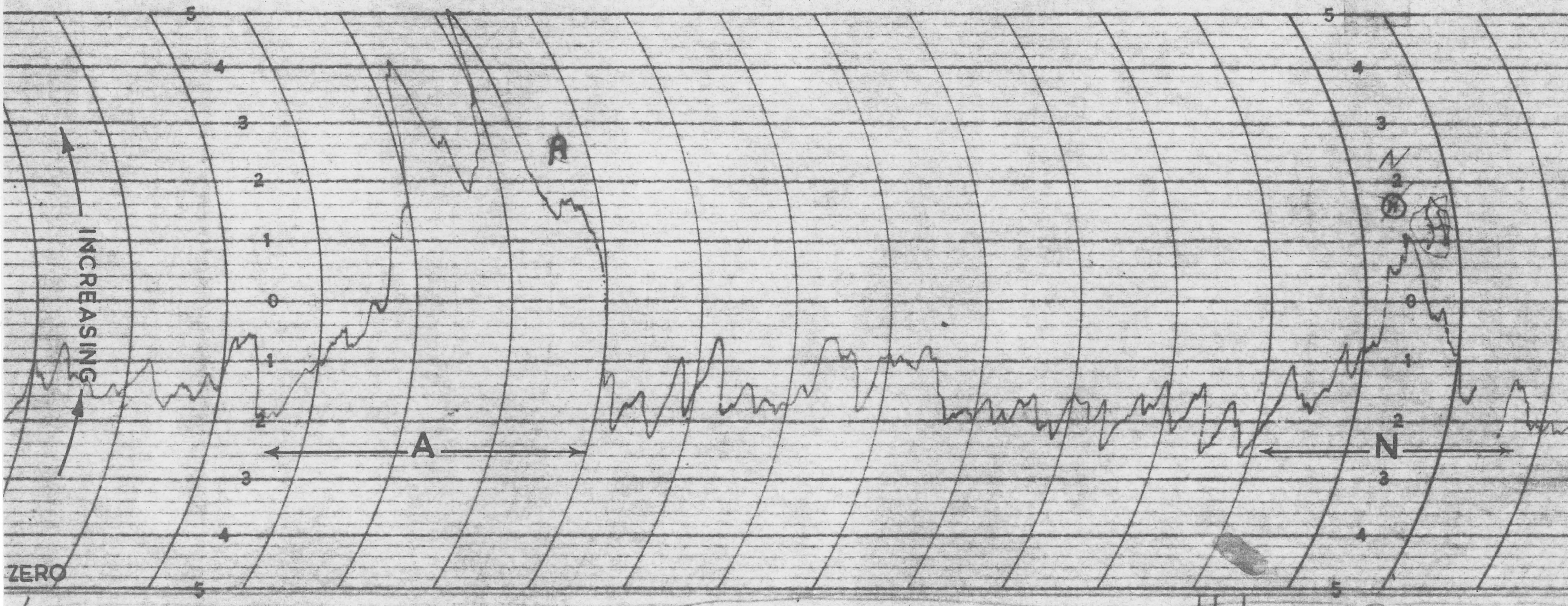
SCINTILLOMETER SURVEY AT TENTERFIELD N.S.W.

ANOMALY γ

PLATE 6
SHEET 3.

G136-5

THE ESTERLINE-ANGUS CO., INC., INDIANAPOLIS, IND., U.S.A. CHART NO. 4331-X



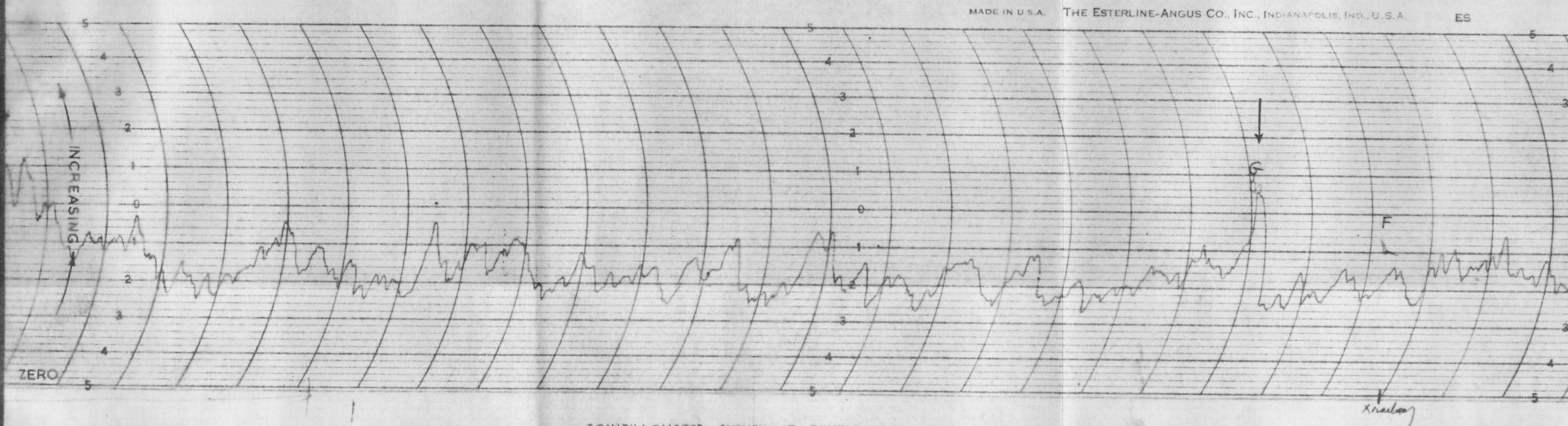
SCINTILLOMETER SURVEY AT TENTERFIELD N.S.W.

ANOMALIES A & N

PLATE 6
SHEET 4

G136-6

PLATE
SHEET 5



SCINTILLOMETER SURVEY AT TENTERFIELD N.S.W.

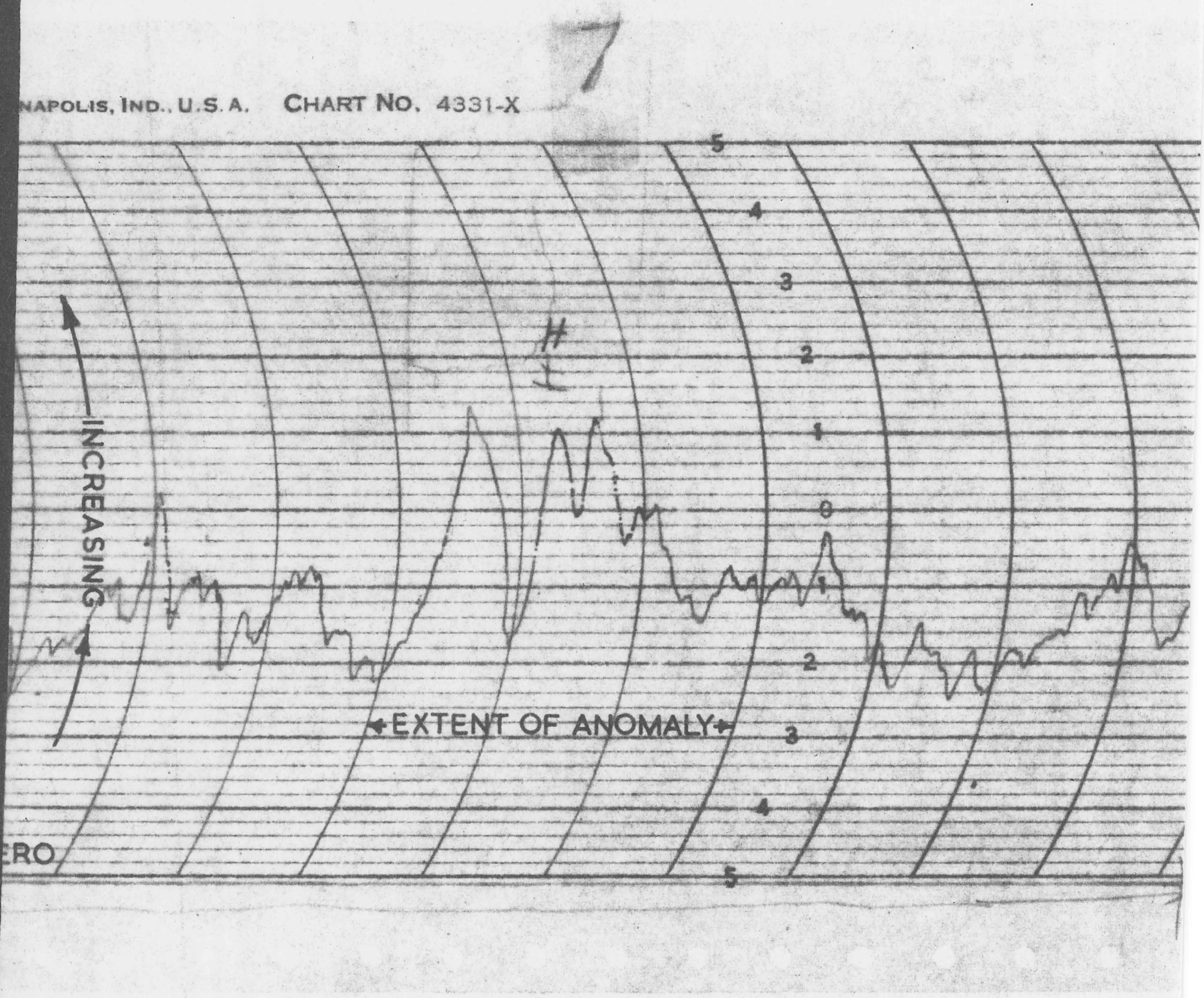
ANOMALY G

G136-7

PLATE 6
SHEET 6.

SCINTILLOMETER SURVEY AT TENTERFIED N.S.W.

ANOMALY H

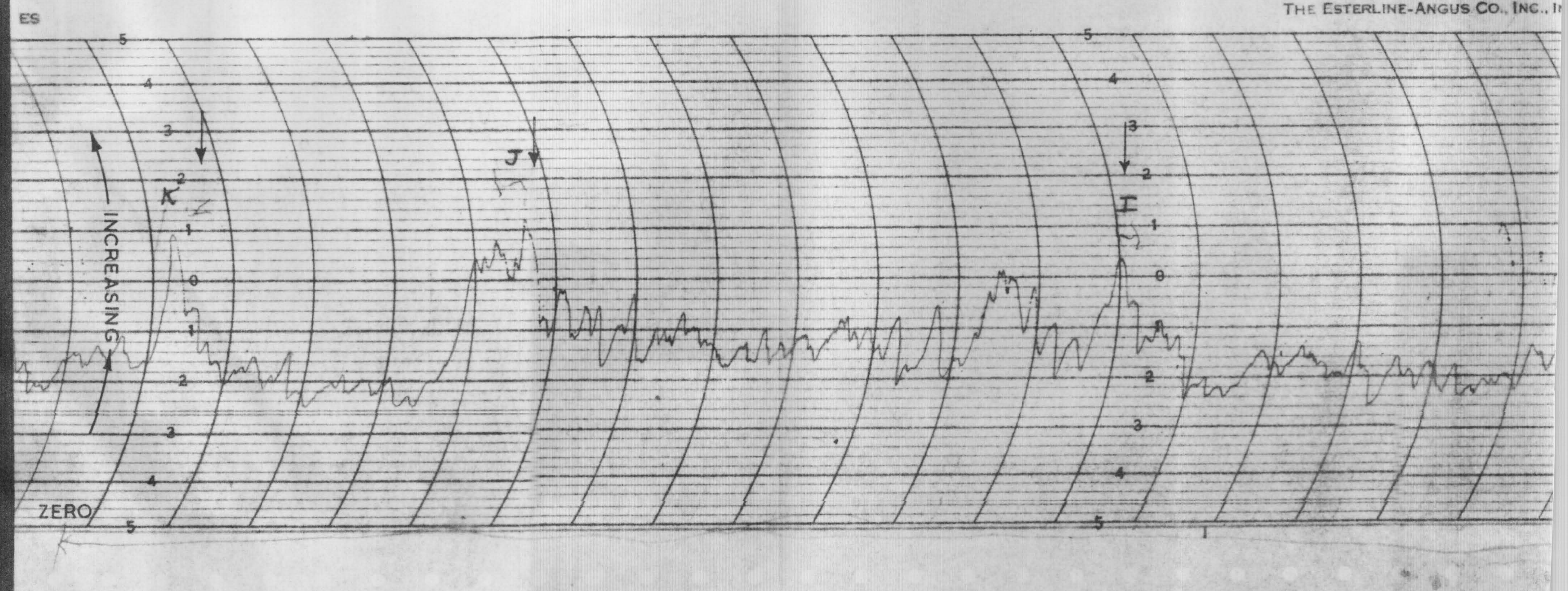


G136-8

PLATE 6
SHEET 7.

SCINTILLOMETER SURVEY AT TENTERFIELD N.S.W.

ANOMALIES I, J & K

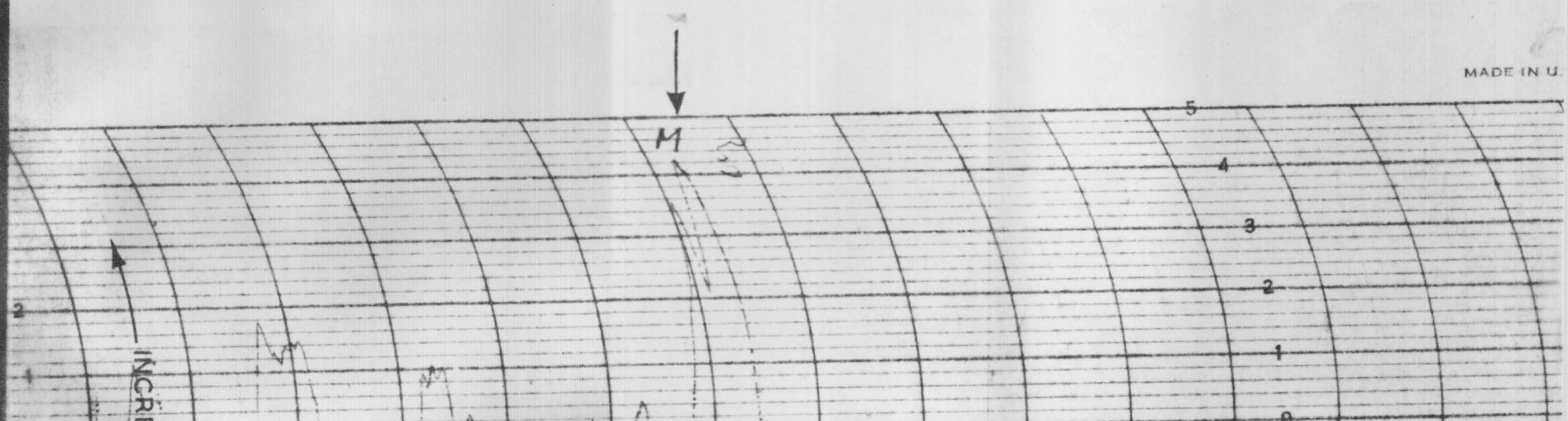


G136-9

PLATE 6
SHEET 8.

SCINTILLOMETER SURVEY AT TENTERFIELD N.S.W.

ANOMALY M



G 136-10

PLATE 7

SCINTILLOMETER SURVEY AT BROKEN HILL N.S.W.

LOCALITY MAP

SHOWING POSITIONS OF HELICOPTER TEST FLIGHTS

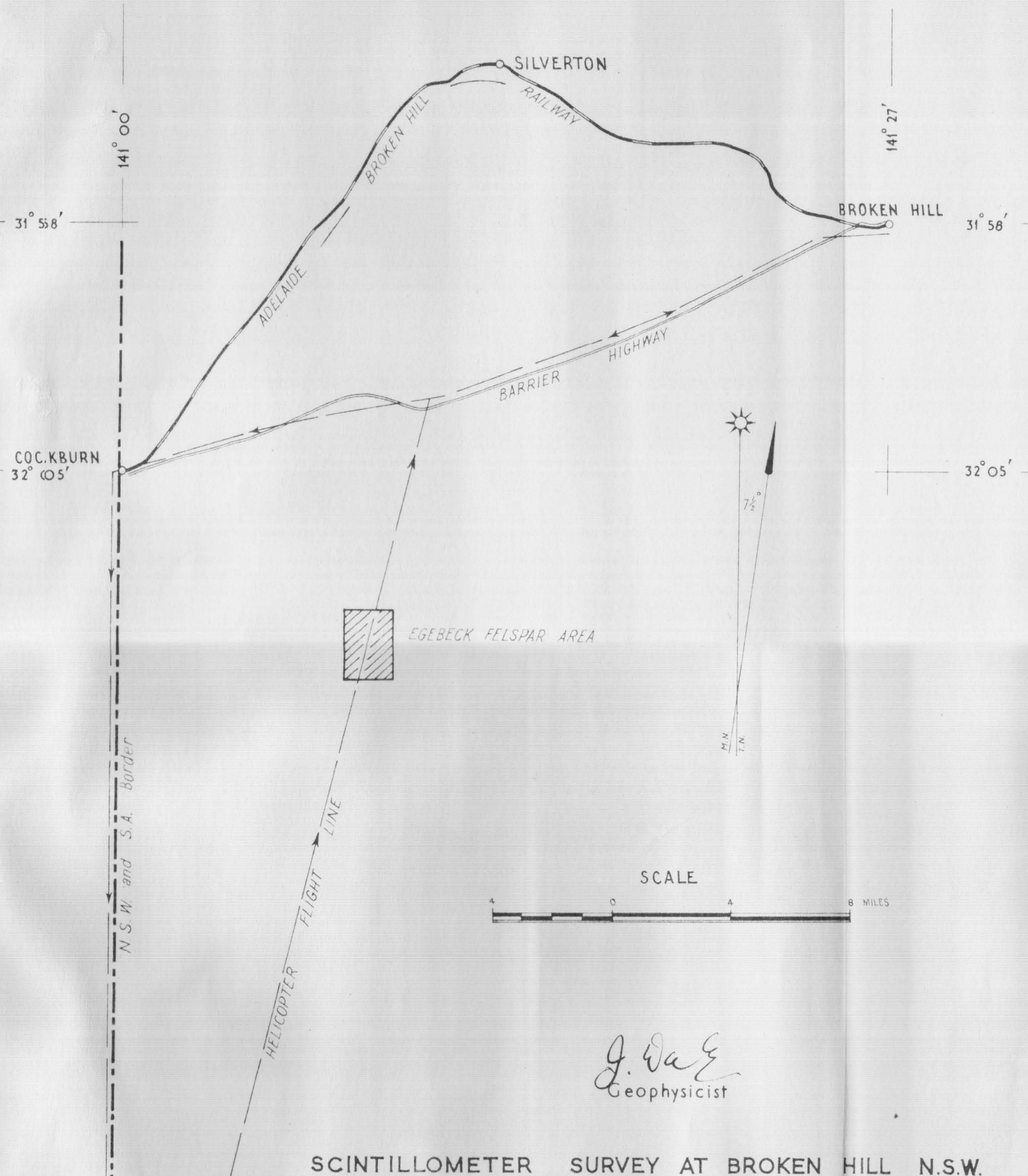
SCALE IN MILES

2 0 2 4 6

J. Da E
Geophysicist

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

G 135-1

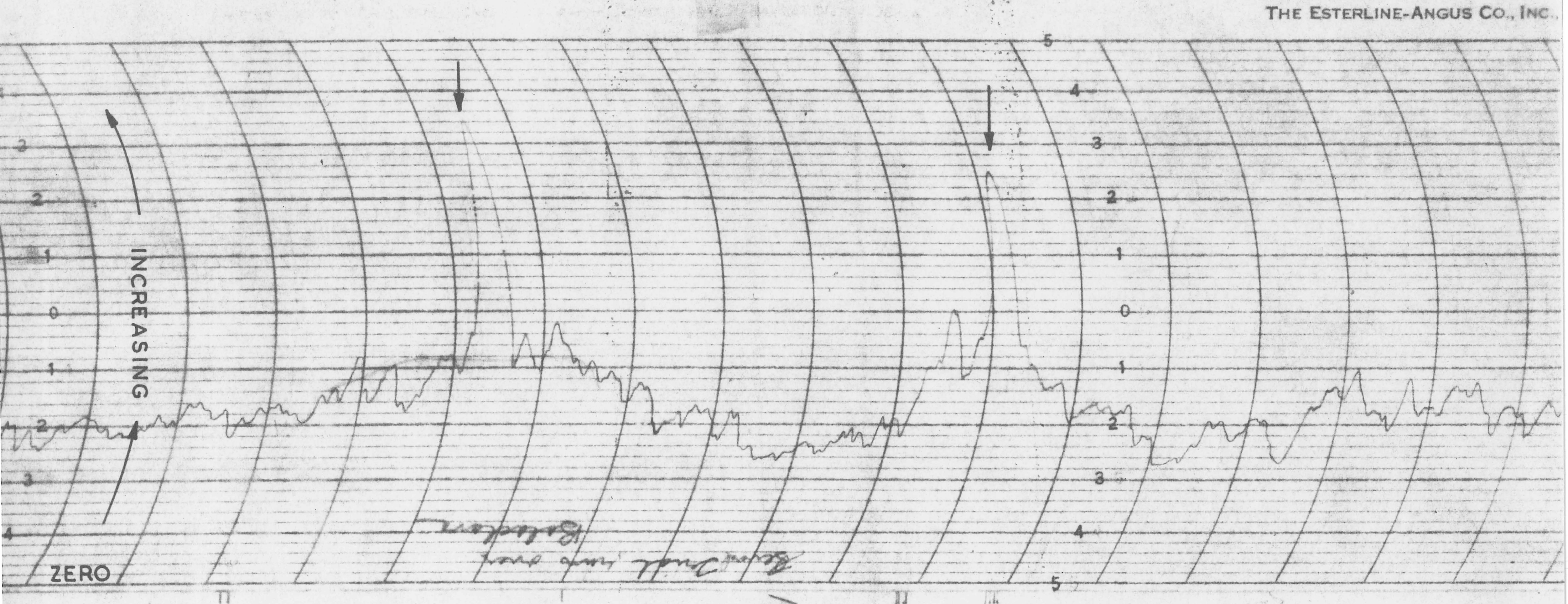


J. Da E
Geophysicist

SCINTILLOMETER SURVEY AT BROKEN HILL N.S.W.

LOCALITY MAP

SHOWING APPROXIMATE COURSE OF HELICOPTER PROSPECTING FLIGHT



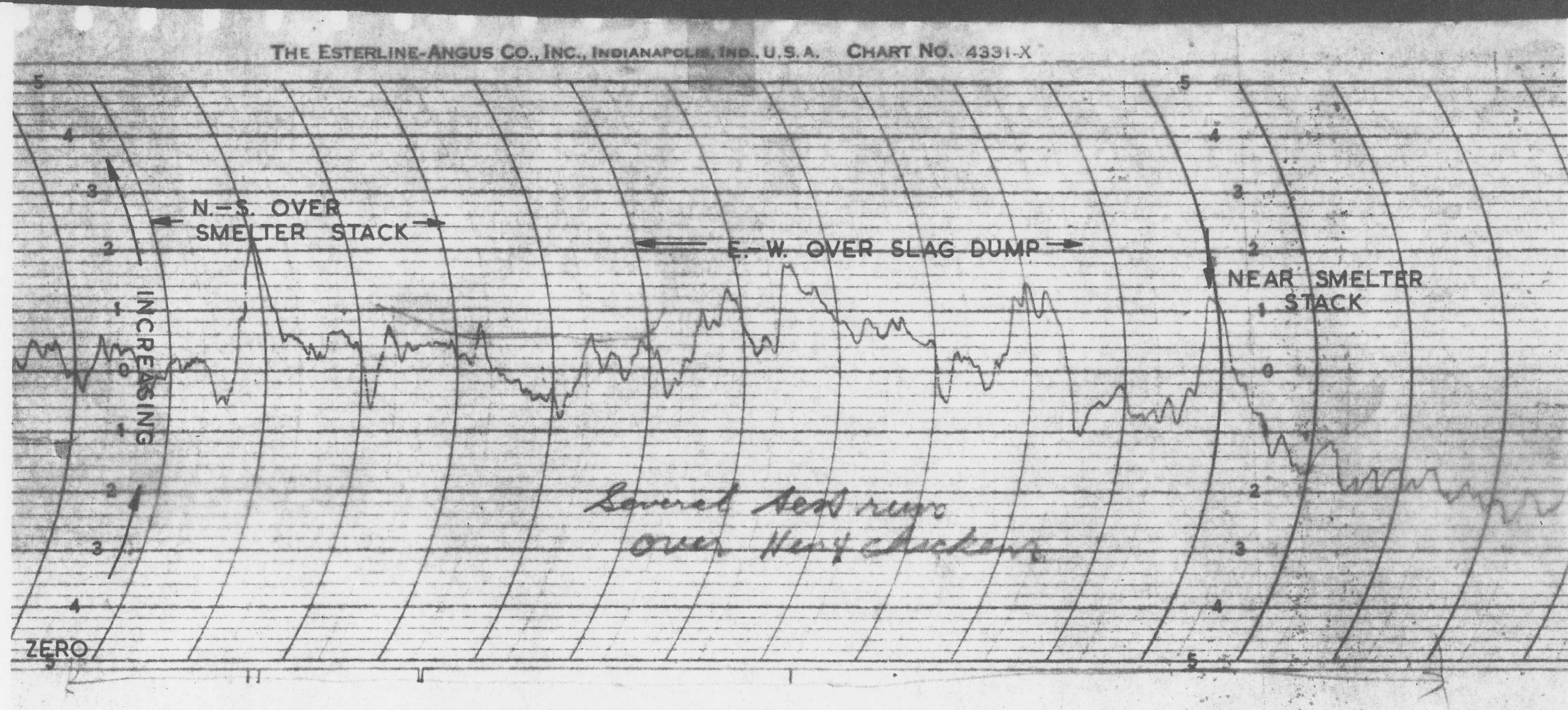
SCINTILLOMETER SURVEY AT BROKEN HILL N.S.W.

PROFILE OVER BALACLAVA COPPER BLOW

REPEAT TRAVERSES OVER LODE NEAR WARREN SHAFT

PLATE 9
SHEET 1

G135-3

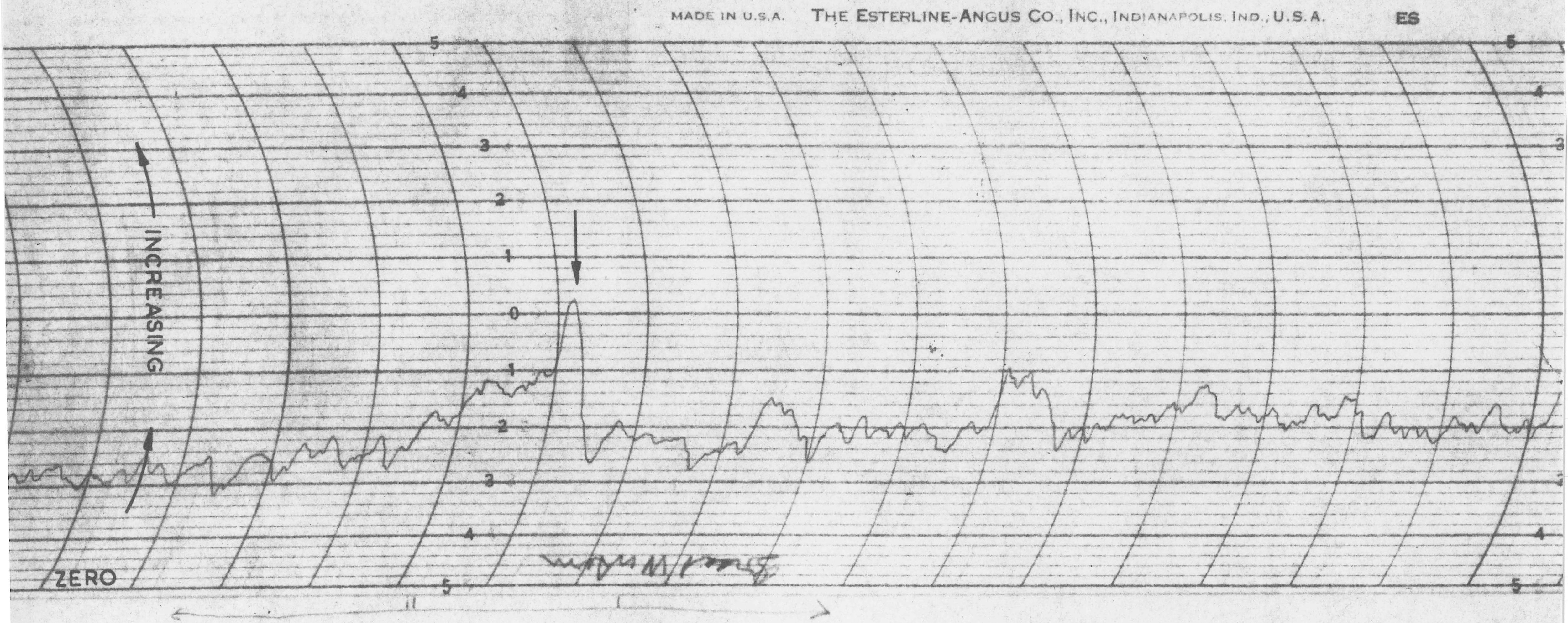


SCINTILLOMETER SURVEY AT BROKEN HILL N.S.W.

PROFILE OVER HEN AND CHICKENS

PLATE 9
SHEET 2

G 135-4



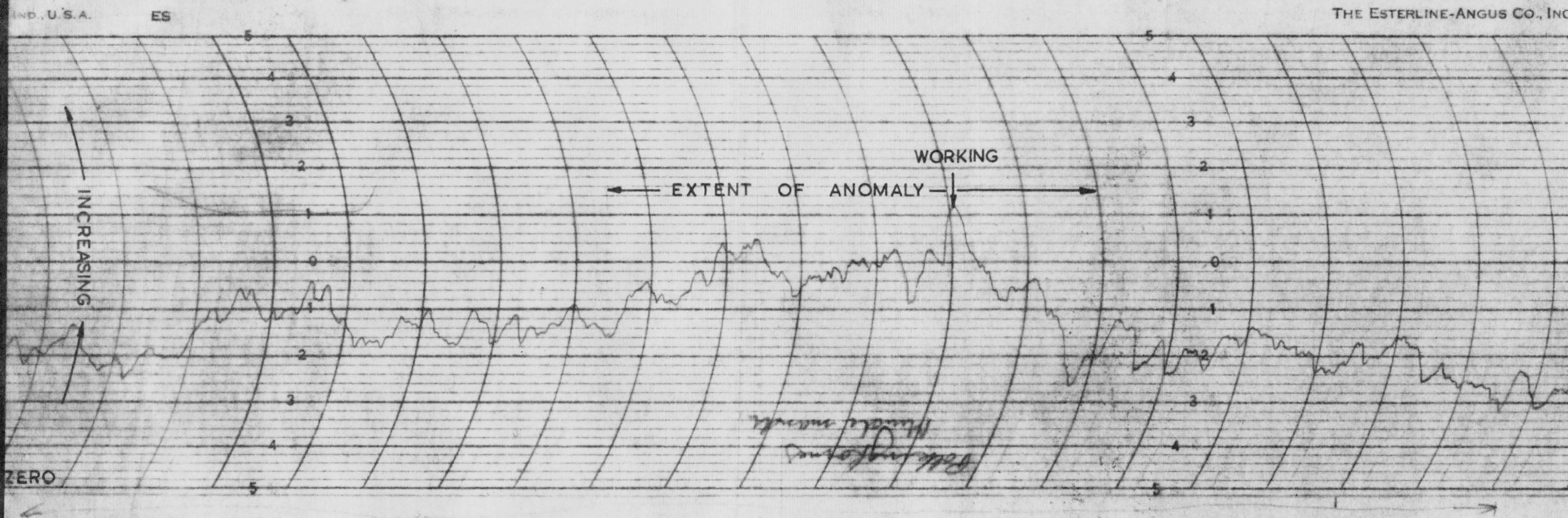
SCINTILLOMETER SURVEY AT BROKEN HILL N.S.W.

PROFILE OVER GREAT WESTERN

PLATE 9
SHEET 3

G135-5

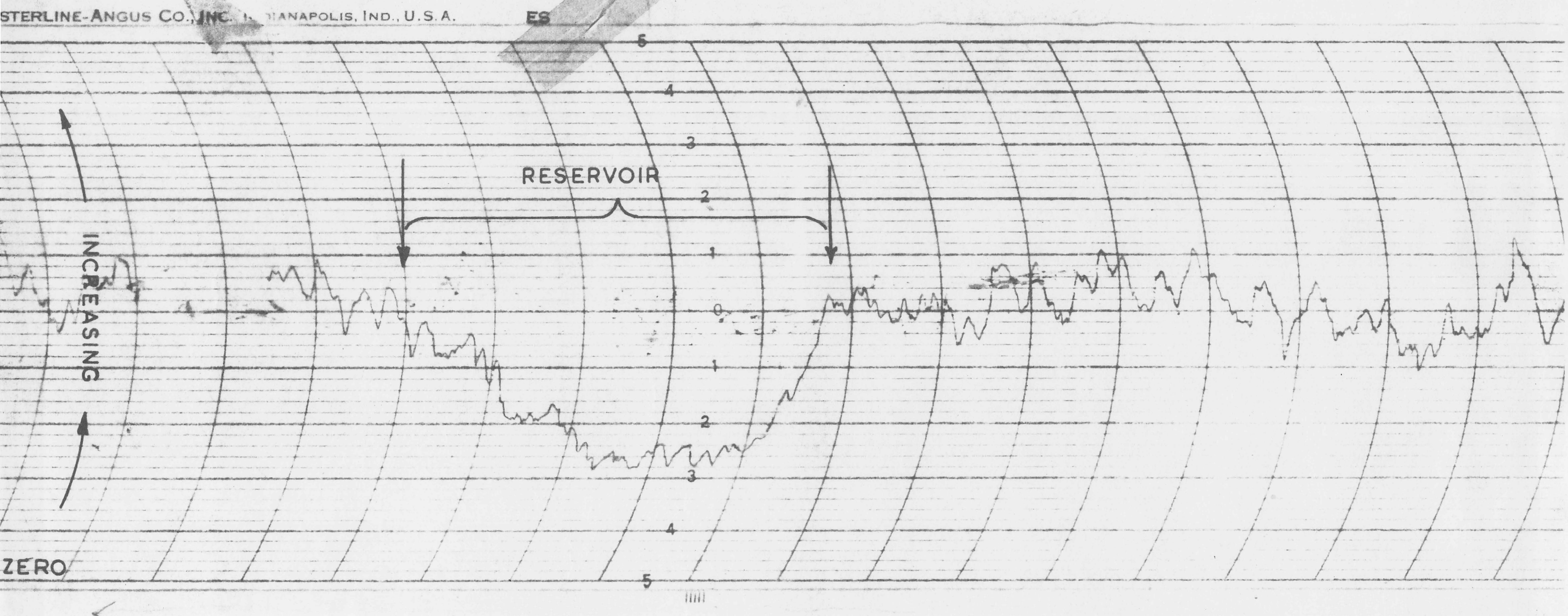
PLATE 9
SHEET 4



SCINTILLOMETER SURVEY AT BROKEN HILL N.S.W.

PROFILE OVER PATTERSON POLKINGHORNE DEPOSIT

G135-6

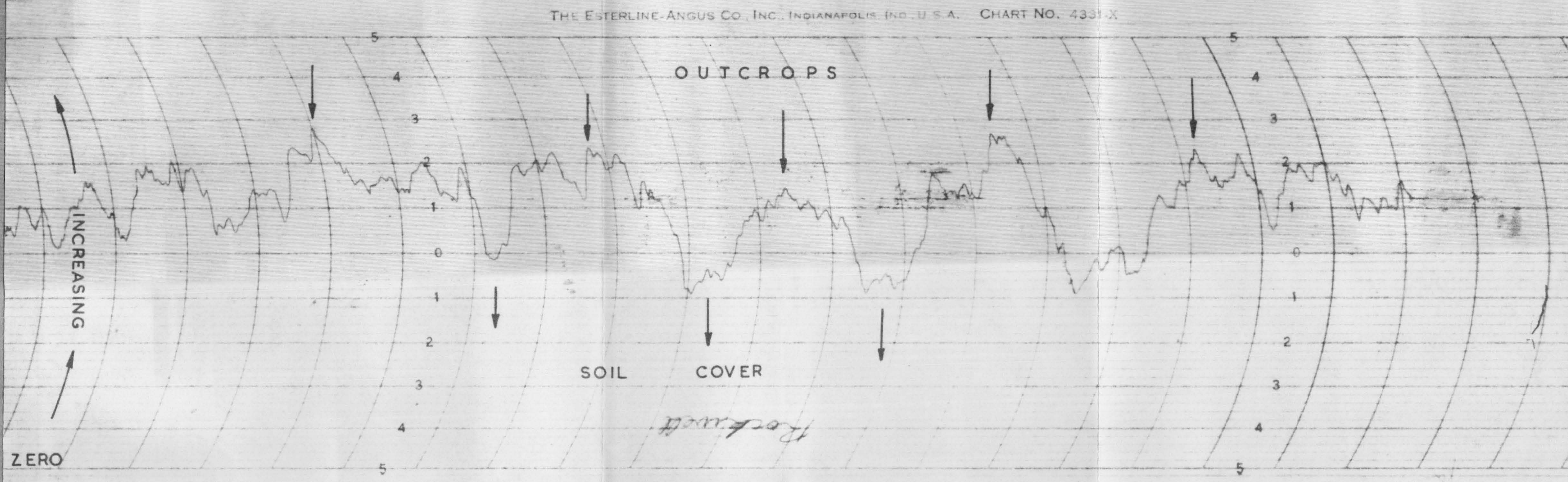


SCINTILLOMETER SURVEY AT BROKEN HILL N.S.W.

PROFILE OVER UMBERUMBERKA DAM

PLATE 9
SHEET 5

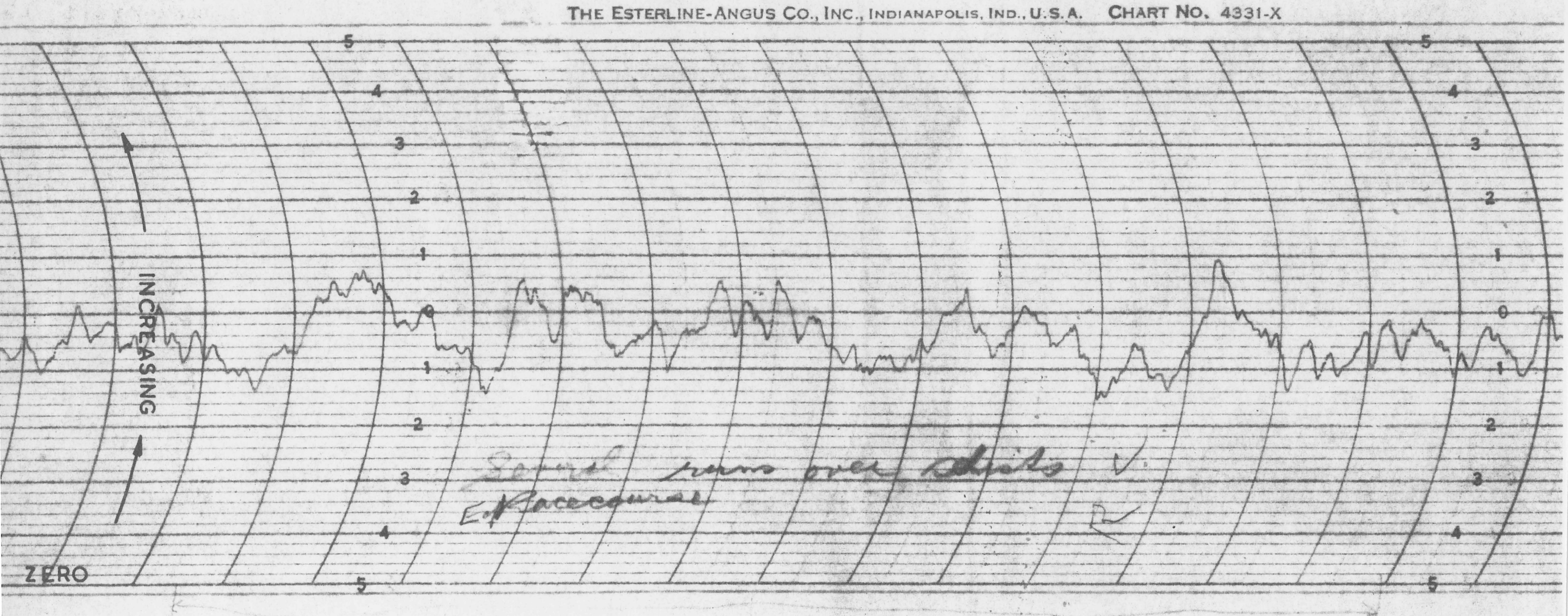
G135-7



SCINTILLOMETER SURVEY AT BROKEN HILL N.S.W.

PROFILE OVER ROCKWELL AREA

G135-8



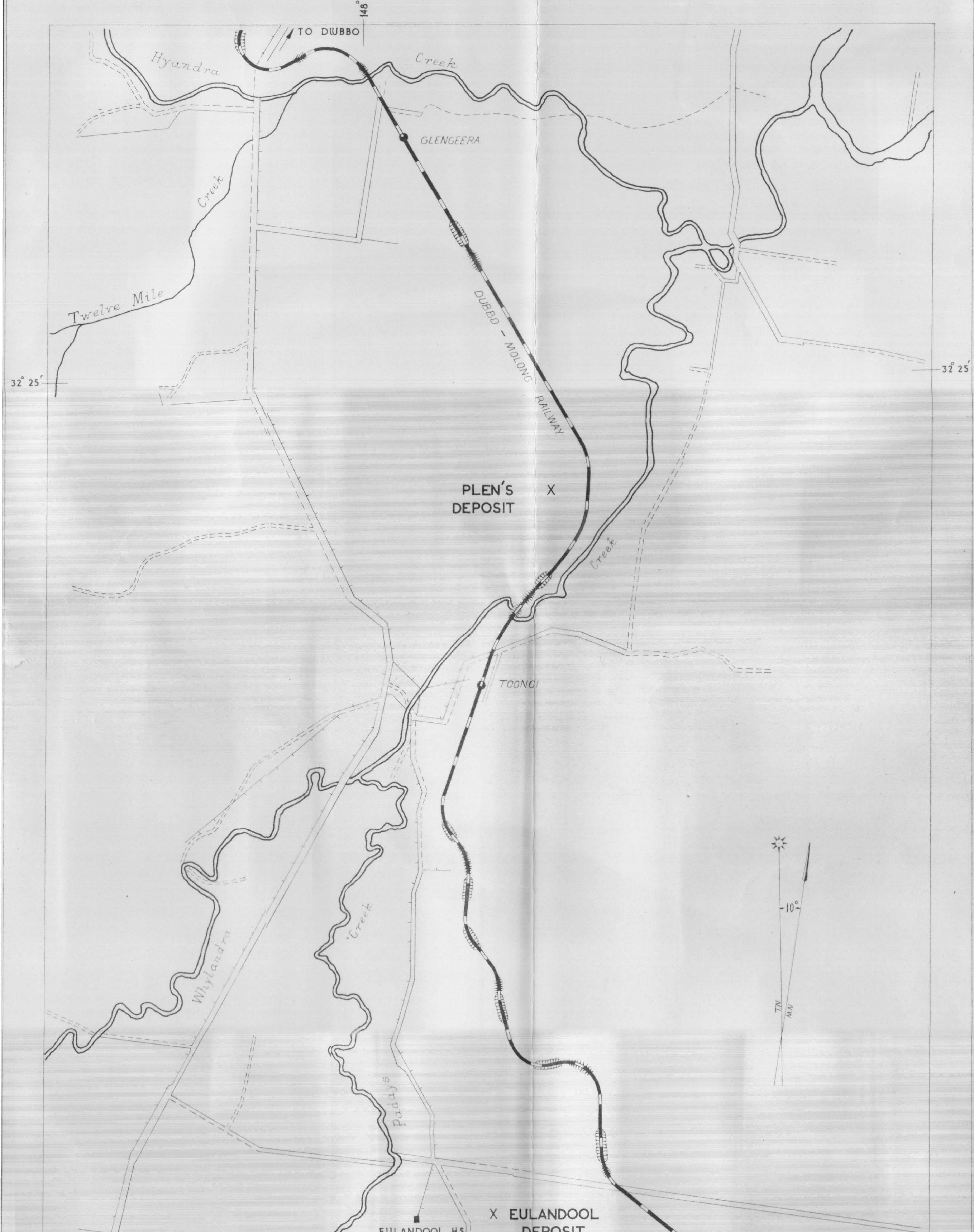
SCINTILLOMETER SURVEY AT BROKEN HILL N.S.W.

PROFILE OVER OUTCROPS EAST OF RACECOURSE

PLATE 9
SHEET 7

G135-9

PLATE 10



LEGEND

ROAD (FENCED)

ROAD (FENCED ONE SIDE)

ROAD (UNFENCED)

RAILWAY

TELEPHONE LINE

EMBANKMENT

CUTTING

SCINTILLOMETER SURVEY AT DUBBO, N.S.W.

LOCALITY MAP

SHOWING POSITION OF RADIOACTIVE TRACHYTE DEPOSITS

SCALE IN MILES

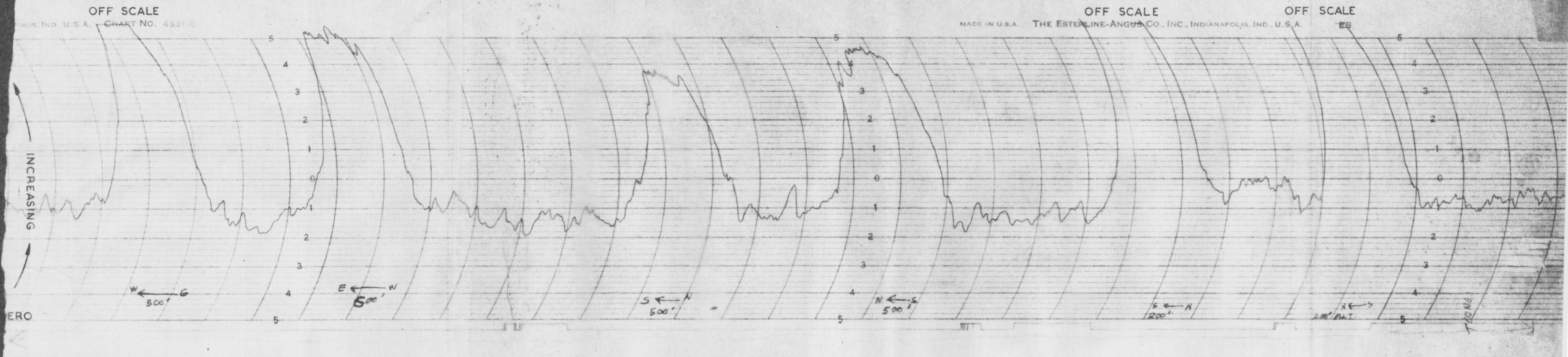
1 0·5 0 1

GEOPHYSICIST

Geophysical Section: Bureau of Mineral Resources, Geology and Geophysics

G 137-1

PLATE II
SHEET 1

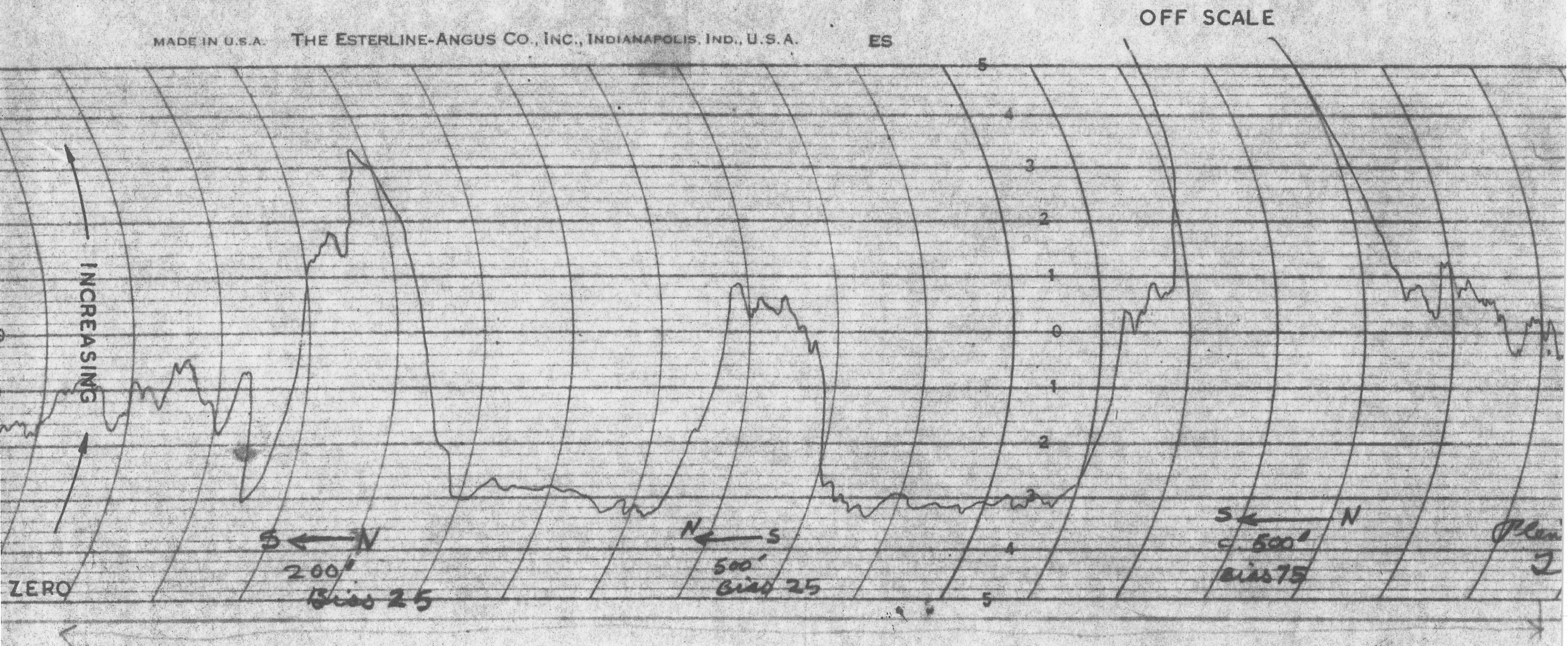


SCINTILLOMETER SURVEY AT DUBBO N.S.W.

ANOMALY OVER TOONGI DEPOSIT

REPEAT TRAVERSES OVER SAME AREA
AT 200' AND 500'

G137-2



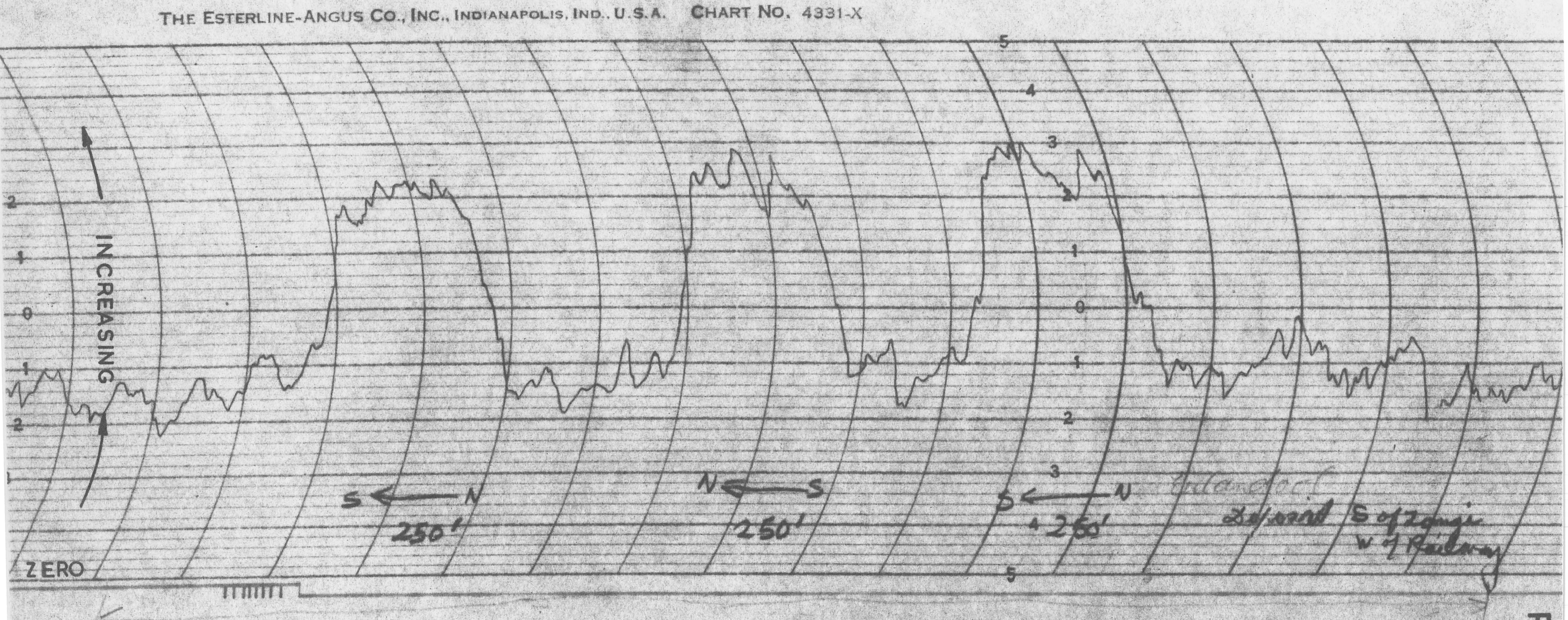
SCINTILLOMETER SURVEY AT DUBBO N.S.W.

ANOMALY OVER TOONGI DEPOSIT

SHOWING EFFECT OF VARYING BIAS
REPEAT TRAVERSES OVER SAME AREA

PLATE II
SHEET 2

G137-3



SCINTILLOMETER SURVEY AT DUBBO N.S.W.

ANOMALY OVER EULANDOOL DEPOSIT

REPEAT TRAVERSES OVER SAME AREA

G137-4

PLATE II
SHEET 3