COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

RECORDS

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AIRBORNE SCINTILLOGRAPH TEST SURVEY IN THE CLONCURRY-MT. ISA DISTRICT, QUEENSLAND BY DC 3 AIRCRAFT

by

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C O N T E N T S

ILLUSTRATIONS

ABSTRACT

A brief test survey was made in the Cloncurry-Mt. Isa district to determine the relation between anomalies detected by the scintillographs flown in a D.C.3 aircraft and the strength of known sources of radiation. The type of anomaly recorded when the aircraft is deliberately flown over known uranium prospects and deposits is a valuable guide in interpreting records obtained in field surveys, and in planning future techniques. The survey was carried out for this purpose.

Tests were made at heights of 500 feet and 200 feet above known deposits. Not only were the anomalies from the lower height more pronounced (as was to be expected) but a comparison of the magnitudes of the anomalies at the two heights showed that a good indication of the grade of the radioactive outcrop (i.e. the percentage equivalent U_3O_8 content) can be obtained.

From theoretical considerations, it is shown that within the limits imposed by approximations used, a linear relationship is to be expected between a "figure of merit" (obtained by dividing the square of the magnitude of the anomaly recorded at 200 feet by the magnitude recorded at 500 feet) and the grade of the surface deposit.

The magnitudes of the anomalies obtained at the two heights, the respective "figures of merit" and the corresponding grades and areas of the surface deposits are shown in tabular form. A comparison of the "figures of merit" with the respective grades shows a reasonable correlation consistent with the approximate theory.

The results obtained in these tests indicate the desirability of towing a second scintillograph about 250 feet below the D.C.3 aircraft flying at 500 feet above ground.

1. INTRODUCTION.

The question of what kind of records are obtained by an airborne scintillograph being flown over concentrations of radioactive minerals is one that cannot be answered purely theoretically. It is important to have some kind of calibration by making test flights over known prospects and deposits. This is particularly valuable if the grade of each occurrence is known and there is a wide range in the grades of the occurrences. An opportunity to carry out such a test was presented when a D.C.3 aircraft (VH-MIN), belonging to the Bureau of Mineral Resources was in Queensland in October, 1955. Geologists of the Queensland Mines Department were consulted in order to find out which sections of the Cloncurry-Mt. Isa uranium field would be best suited to this type of test survey. The areas flown (see Plate 1) were chosen on the advice of Messrs. I. W. Morley, State Mining Engineer, and J. H. Brooks, geologist of that Department.

2. AREAS SURVEYED AND METHODS USED.

The aircraft, with Messrs. Parkinson, Irving and Baeke of the Bureau of Mineral Resources and Capt. Duffield and Messrs. Purnell and Lee of Trans Australia Airlines, flew to Mt. Isa from Cairns on the 3rd October, 1955, and returned on the 5th October, 1955. Three flights were made on the 3rd and 4th October.

An area of 45 square miles north-west of Mt. Isa, containing the "Mothers' Day" and "Flat Tyre" leases, was surveyed at 500 feet along ten north-south traverses half a mile apart. Four of the flight lines were reflown at 200 feet. A second area to the east of Mt. Isa, containing the "Counter" lease, was flown at both 500 and 200 feet, with half-mile spacing between flight lines. Navigation over both of these areas was effected by means of photographs on which the flight lines had been plotted.

In addition to gridding these two areas, the aircraft flew over six leases, the pilot being guided by Mr. Brooks; some of these leases are within the two areas and some outside them. Leases surveyed in this way were "Mothers' Day", "Flat Tyre", "Skal", "Hopeful", "The Pile" and "Mary Kathleen".

Two scintillographs were in operation on all these flights. The ratemeter of one scintillograph had an output circuit with a time constant of 0.9 seconds and the other had a time constant of 2.0 seconds. Portions of the records obtained with the instrument of shorter time constant are reproduced in Plate 2. This shows typical profiles recorded at heights of 200 and 500 feet over some known deposits, and at heights of 500, 700 and 1000 feet over the "Mary Kathleen".

Altitude above terrain was controlled with the aid of an STR-30A radio-altimeter, and corrections for height variations were made to the scintillograph record where necessary.

3. RESULTS OBTAINED.

(a) "Flat Tyre" and "Mothers' Day" leases.

No significant anomalies were recorded from 500 feet over the area containing "Flat Tyre" and "Mothers' Day" leases. These two leases lie between two flight lines, and these lines were reflown at 200 feet, but no anomaly was recorded at this altitude. Two small anomalies (Nos. 1 and 2 of Table 1) were recorded from 200 feet on another flight line in this area. Neither of these anomalies is reported by Knight and Bennett (1954)

When flying directly over the "Flat Tyre" lease, a small anomaly (1200 counts per minute) was recorded at 500 feet. This anomaly would probably have been overlooked among the normal fluctuations of the record obtained at 500 feet. No anomaly was recorded at 500 feet over "Mothers' Day" lease. However, distinct anomalies were recorded over both leases at 200 feet. (See Plate 2, Profile 5).

(b) <u>"Counter" lease</u>.

Over the area to the east of Mt. Isa, one anomaly was recorded during the surveying at 500 feet (Plate 2, Profile 1). This is a second order anomaly and occurs over the "Counter" lease. In the same place a prominent sharp anomaly was recorded at 200 feet (Plate 2, Profile 2). Further, seven other anomalies could be picked out by comparing the traces from the two heights.

Knight and Bennett (1954) show 16 anomalies in the area surveyed by them east of Mt. Isa. Most of these are close to the positions of the eight anomalies recorded by VH-MIN. A conspicuous exception is an intense anomaly near the road between Mt. Isa and Kajabbi, which was not recorded at either height by aircraft VH-MIN.

(c) <u>"Pile", "Skal" and "Hopeful" leases</u>.

First order anomalies of between 2500 and 4000 counts per minute were recorded when the aircraft was flown at 500 feet over "Hopeful", "The Pile" and "Skal" leases (Plate 2, Profile 3). When the aircraft was flown at 200 feet, anomalies of about 10,000 counts per minute were recorded over each of these three leases.

(d) <u>"Mary Kathleen" lease</u>.

A full scale deflection (greater than 16,000 counts per minute) was recorded over "Mary Kathleen" lease at both 500 and 700 feet, and an anomaly of 9000 counts per minute was recorded at 1000 feet (Plate 2, Profile 4). Half a mile to the east of the lease no anomaly was recorded at 500 feet, but a small, rather broad anomaly was recorded at the same altitude half a mile to the west. This asymmetry is due to the topography of the area in the immediate neighbourhood of the lease which gives the outcrop a westerly aspect.

4. <u>THEORETICAL CONSIDERATIONS</u>.

If the radiation from a radioactive occurrence is recorded by a scintillograph at two different heights, the ratio of the anomalies affords a method of estimating the area, and indirectly the grade, of the deposit.

From a knowledge of the characteristics of the detector, and by assuming a reasonable value for the absorption coefficient of gamma rays in air, it is possible to calculate the magnitude of the anomaly which would be recorded at a height of 500 feet directly over a deposit of given area and grade (percentage of equivalent U_3O_8). It is assumed that the deposit is circular in shape and is surrounded by an unlimited non-radioactive area.

Let A be the area of the deposit, and G the percentage of equivalent U_3O_8. The solid line in Plate 3, Figure 1, shows how the magnitude of the anomaly varies with A for a constant value of G. The magnitude is conveniently expressed as F, the fraction of the magnitude of the anomaly that would be produced by a deposit of infinite area and of the same uniform grade.

Now if S and S' are the magnitudes of the anomalies recorded at 500 and 200 feet respectively above a deposit, the ratio S'/S is a function of A and is independent of G. The solid line in Plate 3, Figure 2, shows this relation. The ratio R has a maximum value of approximately 9, which corresponds to a point source (i.e. A $\doteqdot$ 0).

With the aid of Figure 2 the area can be determined from the observed ratio. Then from Figure 1, the value of F can be determined corresponding to this value of A. The percentage of equivalent U_3O_8 which would give rise to the recorded anomaly of magnitude S at 500 feet, if it were produced by an area of infinite extent, can be calculated. The actual percentage in the deposit of area A, which produces an anomaly of the same magnitude, is this percentage divided by F.

There are many approximations in this theory, such as the assumption that the area is circular, and high accuracy cannot be expected. Therefore, it seems worthwhile to simplify the treatment somewhat. This can be done by substituting simple approximate expressions for the relationships in Figs. 1 and 2, of Plate 3. The dotted curve of Fig. 2 is the expression

$$A.R^2 = 50 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (i)$$

where $R = S'/S$ and the unit of A is 10^5 square feet. This is a reasonable approximation to the solid line curve for a considerable range of values of R.

Similarly, a considerable part of Fig. 1 can be approximated by the straight line

$$F = 0.1\ A \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (ii)$$

where the unit of A is 10^5 square feet.

Now the radiation level over an infinite area, with a percentage G of equivalent U_3O_8, is proportional to G and is 1/F times the radiation level at the same height over a deposit of area A and the same value of G (assuming no radiation from outside the deposit). Hence the magnitude of the anomaly as recorded at 500 feet can be expressed as

$$S = C.G.F$$

where C is an instrumental constant depending on its sensitivity,

$$\text{or } G = S/C.F \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (iii)$$

Substituting from equations (ii) and (i) for F and A, which are not directly observable, gives

$$G = S.R^2/5C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (iv)$$

By definition, $R = S'/S$ and substitution for R^2 gives

$$G = (S')^2/S \times \text{constant.}$$

Hence the simple expression $(S')^2/S$ is approximately proportional to the percentage G of equivalent U_3O_8 in the deposit. It may be useful as a "figure of merit" which can be used as a measure of the relative quality of an anomaly.

The approximations shown in Figs. 1 and 2 of Plate 3 do not appear to be very good except over a limited range. However, the departures of the dotted-line curves from the solid-line curves cause errors which partially cancel out.

..4/

If the area of the anomaly becomes too large or too small the approximation is no longer valid, but the errors are less than 20 per cent if the ratio S'/S lies between 7.0 and 2.5 which correspond to circular areas of 57,000 and 1,250,000 sq. ft. respectively (i.e. diameters 270 ft. and 1,260 ft.). At either extremity of this range the figure of merit gives too low an estimate of the percentage of U_3O_8 in the deposit.

5. DISCUSSION OF RESULTS.

Table 1 summarises the results of the flights. The "figure of merit" is obtained by dividing the square of the magnitude of the anomaly recorded at 200 feet by the magnitude of the anomaly recorded at 500 feet, the magnitudes at each height being expressed in thousands of counts per minute. According to the theoretical calculations given above, the "figure of merit" should be proportional to the percentage of equivalent uranium in the deposit. The information regarding sizes and grades of deposits was supplied by Mr. Brooks.. It will be seen that there is a reasonably good correlation between the "figure of merit" and the grade of the deposit (Plate 3, Fig.3), over the range of grades encountered, viz.: 0.03 percent to 0.4 percent equivalent U_3O_8. Unfortunately the magnitudes for anomalies Nos. 4 and 8 are doubtful.

TABLE 1.

Anomaly No.	Magnitude 500 ft	200 ft	Figure of merit	Remarks
1	1.4	4.8	16	No anomaly shown in K&B.
2	0.6	2.4	10	No anomaly shown in K&B.
3	1.2	8.6	62	"Flat Tyre" lease; 700 sq.ft. of 0.3% eU_3O_8.
4	(0.1)	3.0	90	"Mothers' Day" lease; 200 sq.ft. of maximum 0.4% eU_3O_8.
5	0.6	3.0	15	Intense 1st order anomaly in K&B ½-mile to north.
6	1.4	4.0	11	Not surveyed by K&B.
7	1.4	4.0	11	Intense 1st order anomaly in K&B.
8	2.2	(12.0)	65	"Counter" lease; 5000 sq.ft. of 0.2% eU_3O_8.
9	1.4	6.0	26	Small, moderately intense anomalies to N. and W. in K&B.
10	0.4	2.6	17	Intense anomaly ½ mile to E. shown by K&B.
11	0.8	2.0	5	Moderate anomaly ½ mile to W. observed by K&B.

Anomaly No.	Magnitude 500 ft	200 ft	Figure of merit	Remarks
12	0.4	1.6	6	Large second order anomaly in K&B.
13	4.0	10.0	25	"Hopeful" lease; 1000 sq.ft. of 0.05% eU_3O_8.
14	3.4	10.0	29	"Skal" lease; two areas 8000 sq.ft. of 0.03% eU_3O_8, and 15,000 sq.ft of 0.06% eU_3O_8.
15	2.6	9.0	31	"The Pile" lease; 7000 sq.ft. of 0.06% eU_3O_8.
16	(40.0)	-	-	"Mary Kathleen" lease; 69,000 sq.ft. of 0.2% eU_3O_8.

Note: (a) Figures in brackets are doubtful or extrapolated.

(b) "K&B" refers to Knight and Bennett (1954).

(c) Magnitudes are expressed in thousands of counts per minute.

Figure 3 of Plate 3 shows the figures of merit of some of the anomalies listed in Table 1, plotted against the known percentages of U_3O_8 in the deposits with which they are associated. The values for Nos. 4 and 8 are doubtful but lie within the ranges shown. Although the relationship is not a direct proportion, there is quite a high correlation, as indicated by the dotted-line curve, between the "figure of merit" and the known percentages of eU_3O_8.

6. CONCLUSIONS.

In conclusion it may be said that, if the above results had been obtained in a normal 500-foot survey, the anomalies over "Mary Kathleen", "The Pile", "Hopeful" and "Skal" would have been investigated further. It would, of course, have been necessary for a flight line to pass directly over each of them in the course of the survey. "Mary Kathleen" would have been detected had a flight line passed within a quarter of a mile to the west of it. "Counter" may or may not have been investigated further, although the anomaly would probably have been reported. "Flat Tyre" and "Mothers' Day" would not have been detected. Any of these that were re-surveyed from 200 feet would have attracted attention because of the high ratios of anomalies at the two heights. The figure of merit, as defined above, seems to be a valuable guide in indicating approximately the grade of the source of a radioactive anomaly.

7. RECOMMENDATIONS.

Without some guidance from low-level flying (i.e. below 250 feet), it would be possible to overlook potentially important uranium deposits when analysing records obtained at 500 feet in a reconnaissance survey. This fact has always been recognised. However, the results of this test survey show that, if a measurable anomaly is obtained at 500 feet, a re-fly at 200 feet is likely to give a fairly reliable indication of the grade of the source. This applies, however, only if the navigation is sufficiently accurate for the aircraft to follow the same flight line when flown at the lower height as it did

..6/

at 500 feet. Such accuracy is not easy to achieve in rough or featureless country. Therefore, attention should be given to developing a satisfactory technique for towing a scintillometer about 250 feet below the aircraft. This would mean that

(1) the area would be surveyed from both 250 feet and 500 feet; the records from 250 feet would be used to plot the anomalies;

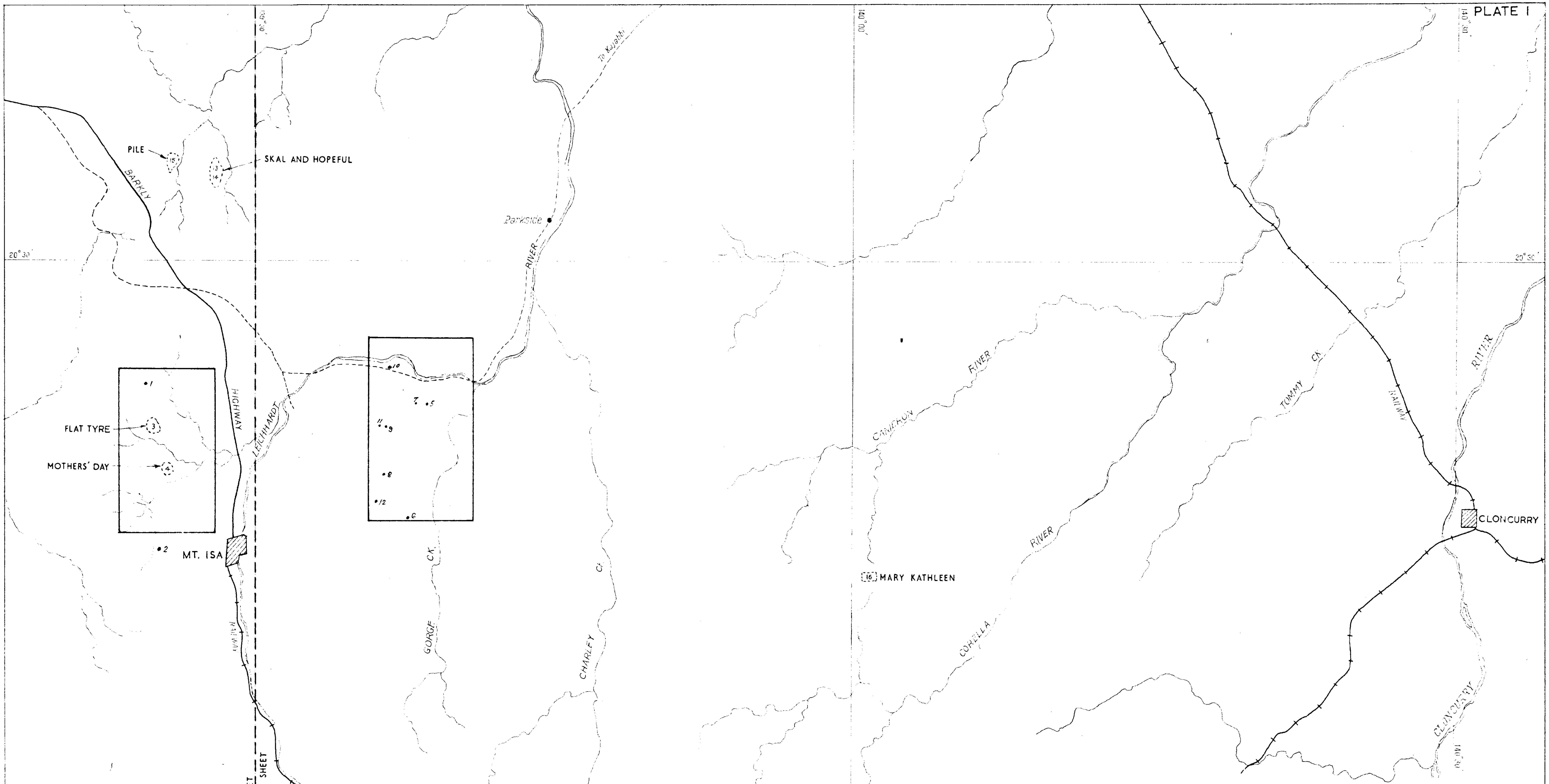
(2) the records from the 250 foot and 500 foot surveys could be used to indicate approximately the grade of the sources of the anomalies.

This test survey also indicates that areas should be chosen for re-survey if the records of a 500-foot survey contained sharp anomalies, even if the magnitude of such anomalies is quite small. With a spacing of one mile between flight lines, as normally used in reconnaissance surveys, there is a distinct possibility of missing concentrations of radioactive material because a flight line may not pass sufficiently close tothem. The area including any isolated sharp anomaly is therefore worthy of investigation, because the anomaly may arise from the only one of a group of radio-active sources that happens to lie exactly under a flight line. For this reason it is desirable to space reconnaissance flights as closely as practicable and preferably less than one mile apart, or in other words to approach the "detailed" type of survey that has always been recommended by the Bureau.

8. REFERENCE.

Knight, C.L. and Bennett, E.M., 1954 - Uranium Search by Mt. Isa Mines Ltd., Cloncurry-Mt. Isa Area, 1954 (Unpublished).

PLATE I



AIRBORNE SCINTILLOGRAPH TEST SURVEY IN THE CLONCURRY - MT. ISA DISTRICT. BY D.C.3 AIRCRAFT

LOCALITY MAP

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics G 181-2

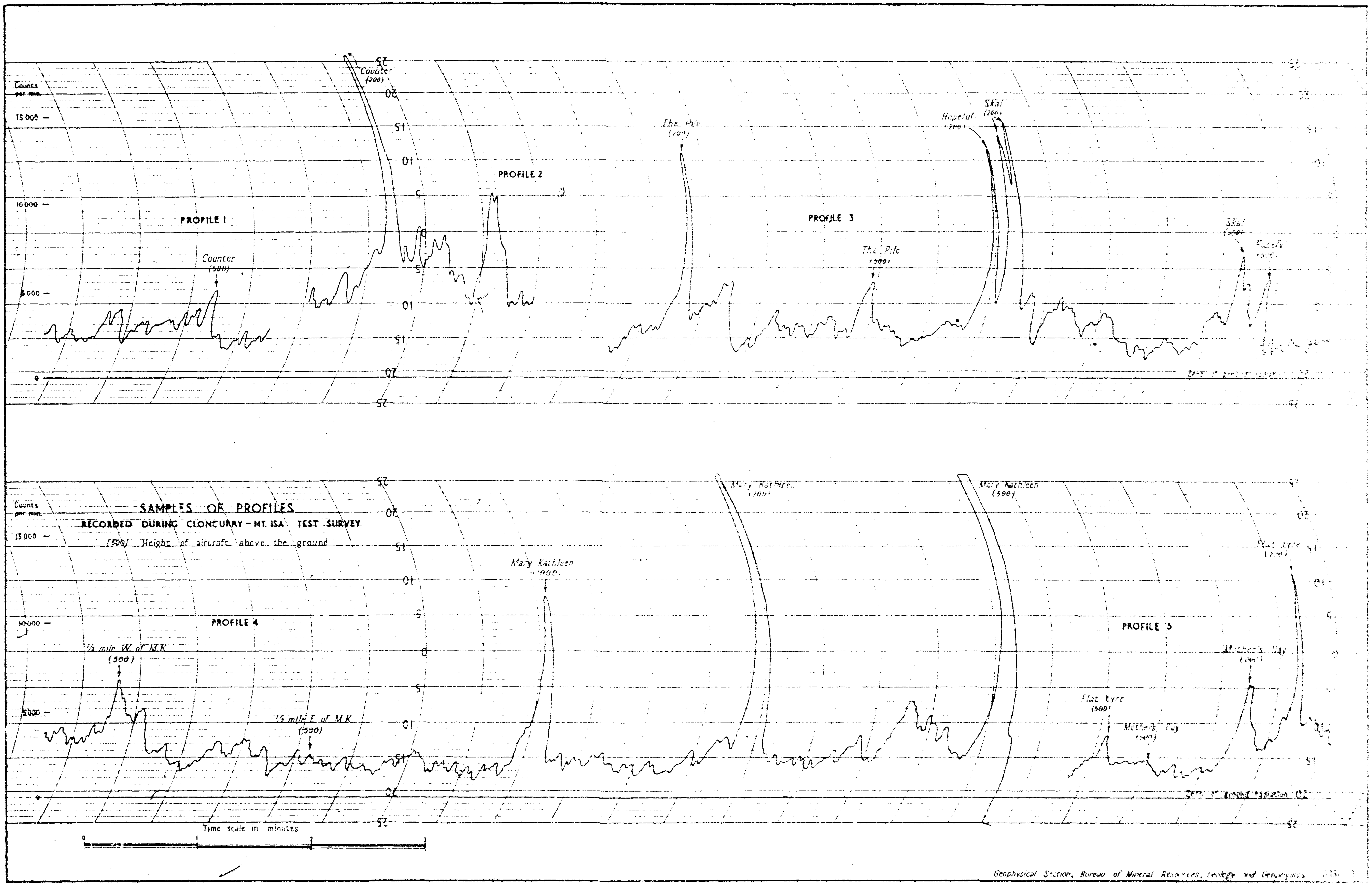

SAMPLES OF PROFILES
RECORDED DURING CLONCURRY - MT. ISA TEST SURVEY
[500] Height of aircraft above the ground
Counts per min.
15 000
10 000
5000
0
PROFILE 1
Counter (500)
PROFILE 2
Counter (200)
PROFILE 3
The Pile (200)
The Pile (500)
Hopeful (200)
Skal (200)
Skal
PROFILE 4
½ mile W. of M.K. (500)
½ mile E. of M.K. (500)
Mary Kathleen (1000)
Mary Kathleen (700)
Mary Kathleen (500)
PROFILE 5
Flat tyre (500)
Flat tyre (200)
Mothers' Day (500)
Mothers' Day
Time scale in minutes
0
1
2
3
Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics

PLATE 3

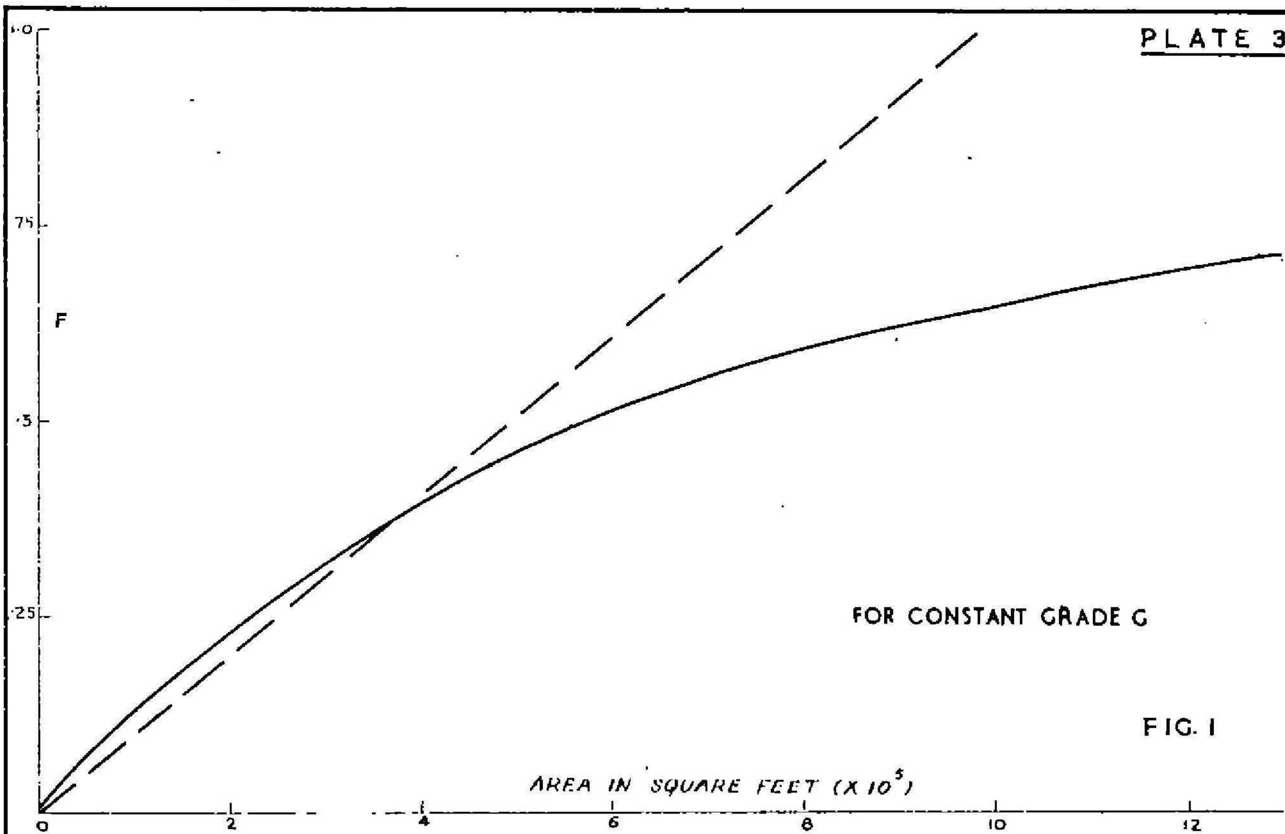


FIG. 1

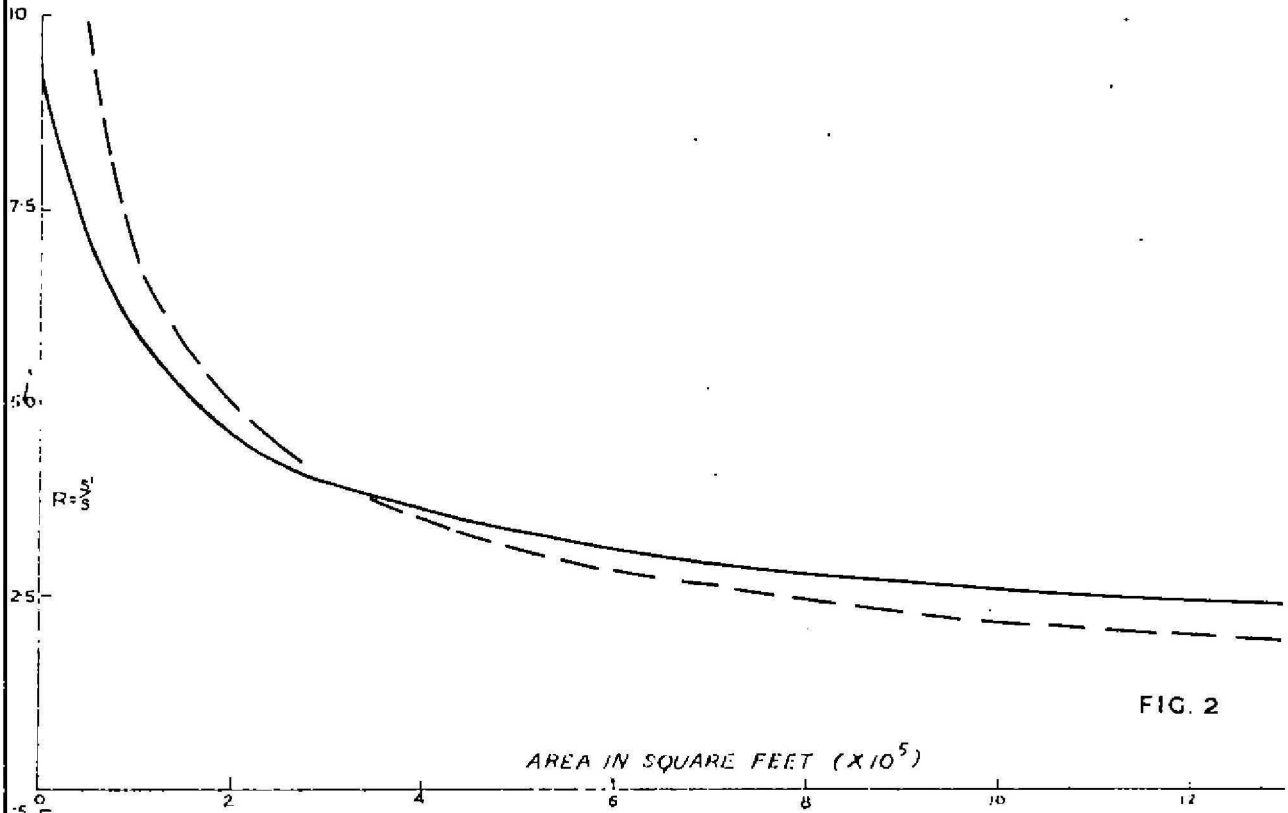


FIG. 2

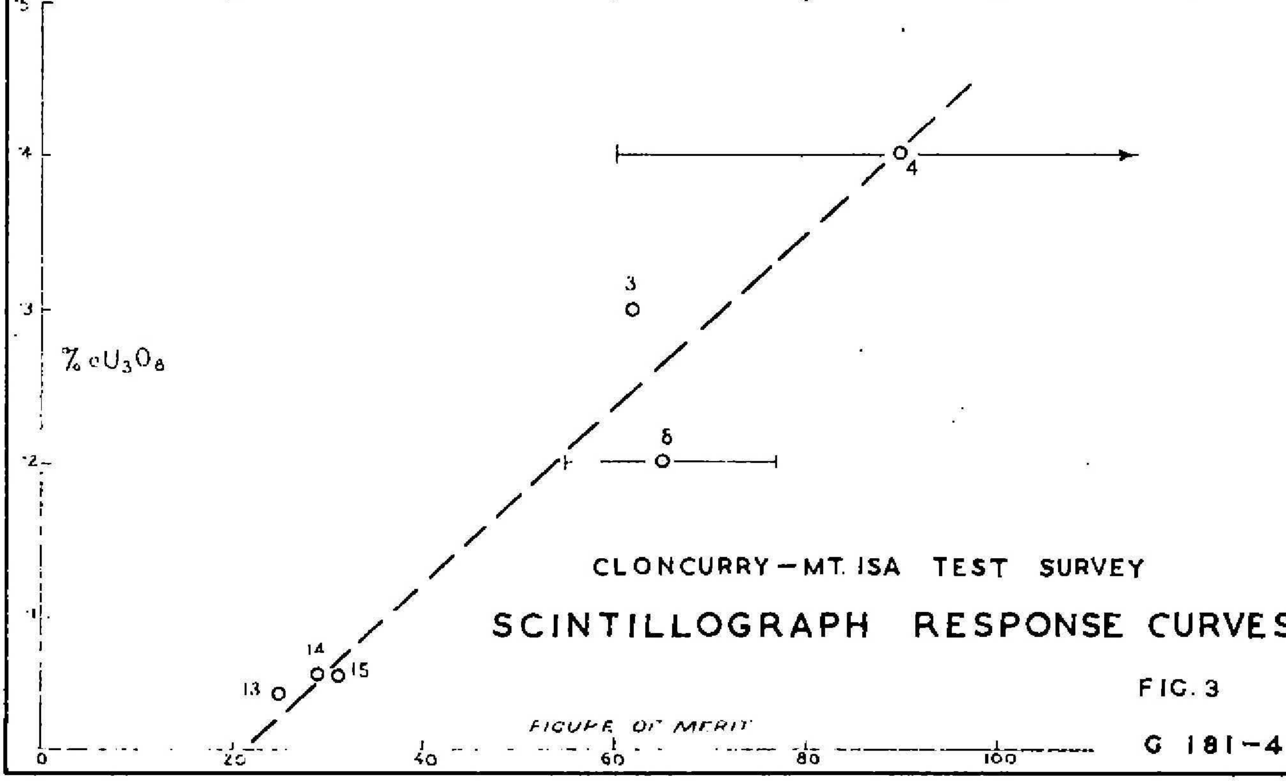


FIG. 3

CLONCURRY — MT. ISA TEST SURVEY

SCINTILLOGRAPH RESPONSE CURVES

G 181-4