DEPARTMENT OF MINES
SOUTH AUSTRALIA.

GEOLOGICAL SURVEY
GEOPHYSICAL SECTION

GROUND SCINTILLATION SURVEY OF PORTION OF SECTION 334, RADIUM HILL, FOR THE LOCATION OF URANIUM MINERALIZATION.

by

I.A. MUMME
Geophysicist

Rept. Bk. No. 5/32
S.R. 11/2/80
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Geophys. Report GS. 3/57

30th May 1957/

TO THE DEPUTY DIRECTOR

GROUND SCINTILLOMETER SURVEY - RADIUM HILL.

Herewith a report entitled "Ground Scintillation Survey of Portion of Section 334, Radium Hill, for the Location of Uranium Mineralization", by I.A. Mumme.

This report deals with part only of the area which it is intended to cover at Radium Hill, so should be considered as progress report.

Three anomalies have been located, and testing of these is in progress. The results will be considered in the final report.

J.E. WEBB
SENIOR GEOPHYSICIST.

18/6/57

DEPARTMENT OF MINES
SOUTH AUSTRALIA

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30th May, 1957

Department of Mines
South Australia

GROUND SCINTILLATION SURVEY OF PORTION OF SECTION 334, RADIUM HILL, FOR THE LOCATION OF URANIUM MINERALIZATION

SUMMARY

A ground scintillation survey was carried out by the writer over an area of approximately one square mile immediately north-east of the known Radium Hill lodes, in an attempt to locate extensions to the known lode systems.

Three areas of uranium mineralization, called the Railway, Intermediate, and Creek Bed Prospects, were located by the writer, who carried out preliminary investigations of these areas by pit sinking, costeaning and mapping.

INTRODUCTION:

A scintillation survey of approximately one square mile of country was carried out by the writer in an area adjacent to the known Radium Hill lodes, in an attempt to locate extensions to the known lode system.

Three anomalous radioactive areas were located by the writer.

Preliminary investgations carried out in these areas by pit sinking and costeaning located davidite mineralization at each prospect.

These areas have been called the "Railway Prospect", (8300N, 200 E), "Intermediate Prospect", (11300 N, 600 W), and "Creek Bed Prospect", (11,100 N, 800 W), as shown in plan L 57-8

The railway Prospect appears to be the most significant area of mineralization, and warrants exploration by pit sinking or diamond drilling.

Initially, a La Roe Scintillometer (type FV - 6S) was used, and subsequantly a Scintillometer (type FV - 5S).

Apart from minor breakdowns, these instruments behaved satisfactory in the field, and because of their short time constant (one second) the radioactove areas were easily delineated.

A Survey plan of the area was compiled from aerial photographs and from field observations to form a framework for the scintillation survey.

Traverses were run at intervals of 50 feet in a landrover at low speed with the instrument held outside the vehicle at about two feet from the ground.

Readings were taken every 50 feet along traverses, and noted, and a continuous check was kept on the instrument during the traversing so that no small significant anomaly would be missed.

Closer intervals were adopted when a significant anomaly was located and the area around it pegged and gridded on foot, and and isorad plan and a geological map prepared to determine the attitude of the surface expression of the lode.

When warranted, bulldozing was carried out and sampling or the exposed lodes completed.

Using this technique, the area was effectively explored for shallow-seated uraniferous lodes to determine whether or not the deposits deserve further prospecting at depth by diamond drilling.

PREVIOUS GEOPHYSICAL WORK

Aerial radiation surveys, ground scintillation, and prospecting work has been previously carried out in the area which was remapped radiometrically by the writer.

Scintillation gridding was carried out by D. Pegum with an aerial scintillometer installed on a boom in front of a jeep; however, due to faulty equipment, the results were considered unreliable.

Aerial scintillometer surveys were carried out by J. Harris, (with pilot J. O'Hagen), in the area at low altitude, and the results presented in report "Airborne Radiometric Survey of Portion of Olary Province" (Geophysical Report No. 2/56). A number of radioactive "highs" were located, some of which were already known from previous ground surveys.

Ground magnetometer surveys were conducted in the area by C. Kerr Grant and M. Bartlett with a Watt's vertical force magnetometer, and the results presented in Bulletin No. 30, "Uranium Deposits of South Australia."

Aerial scintillometer and aerial magnetometer work was carried out in the Radium Hill area by the Bureau of Mineral Resources in a DC 3, and the total magnetic force contours and scintillometer anomalies were presented on plan No. (G 143-7) Ballara area.

As this aerial survey was carried out on a regional basis (at a height of 500 feet, with traverse lines half a mile apart), the scintillometer results are not accurate enough, and the small radiometric anomalies due to the shallow-seated weathered lodes are not recorded by the aerial scintillometer.

GEOLOGICAL MAPPING

Regional mapping has been carried out in the area by R.C. Sprigg and the results incorporated in the regional plan entitled "Ballara Geological Map" (one mile per inch). R.C. Sprigg also conducted detailed mapping in the mine area.

Geological mapping was carried out by the writer in the immediate vicinity of the uranium prospects discovered as an aid to the interpretation of the scintillometer anomalies.

METHODS USED

Appriximately half the area was mapped with a FV-6S scintillometer, and the rest with a modified type of La Roe (FV-5S) set on identical sensitivity, and bagkground count.

Scintillation survey was carried out by the writer and a driver at low speed. The left-hand door of the landrover was removed during the survey, and the instrument held outside the vehicle at approximately two feet from the ground.

Using such a technique, a wide core of gamma rays was received at the scintillation counter. The instrument was kept on a short time constant (= one second), so that the instrument rapidly responded to changes in the intensity of gamma radiation.

A surface topgraphical plan was prepared from ground surveying and the aid of aerial photographs of the area.

INTERPRETATION OF RESULTS

The scintillometer results were corrected for drift and an isorad plan was constructed showing variations in the radioactivity throughout the area.

Three levels were adopted for radiation contouring. Counts in excess of 30 per second are shown by subsequent prospecting to be significant.

Generally the attitude of the isorad lines of lower intensity do not show much relation to the surface geology due to the masking effects of the soil mantle which generally covers this area. However, a generally higher gamma radiation level occurs over the rounded hills due to the thinner veneer of soil masking the radiations from the bedrock.

The significant anomalies are narrow, apparently conforming to the configuration of the uraniferous lode material concealed under the alluvium.

Davidite crystals, being resistant to weathering, tend to remain in the soil immediately overlying the lode. During erosion of uranium lodes, the radium disintegration products tend to accumulate in the soil, whereas the soluble uranium minerals are dispersed. Tropical conditions and acid environments are favourable for this, but it also occurs to a smaller extent in dry climates. Radium C salts are hard gamma emitters, and are readily detected in the soil. The absence of wide areas of radioactive zones containing radium salts around the significant anomalies suggest that in previous geological time no large ore bodies of uranium existed above the erosion level, and this suggests also that only small bodies may exist at depth in the area.

The uranium mineralization in the lode shear is erratic, so that "pattern drilling" may be necessary to test for extensions of the lode shears beyond their surface expressions.

The most significant radioactivity occures at the Railway Prospect (see plan 57-147 for relation of surface activity to lode structure.)

Two to four narrow and closely spaced lodes occur over a distance of 200 feet at the Creek Bed Prospect. Owing to the transported soil inthe creek, only a small area of anomalous radioactivity was located in the bank, but subsequent bulldozing showed that the mineralization continued beneath the creek.

Incipient mineralization occurs at the Intermediate Prospect but does not appear significant.

CONCLUSIONS

Several small lodes were discovered by the writer, namely, the Railway, Intermediate, and Creek Bed Prospects.

A programme of bulldozing carried out to determine the significance of the surface radioactive anomalies due to the disseminations of davidite in the soil, showed that the most significant radio-activity was associated with the "Railway Prospect."

Bulldozing has shown that the concentration of uranium minerals in the Railway Prospect lode is erratic as in the main lode systems, but they may improve at depth. This can be rapidly proved by diamond drilling.

Co-ordination of previous geophysical work carried out at Radium Hill may aid in the location of concealed uranium lodes.

I.A. MUMME
GEOPHYSICIST

30/5/57

RB 532

DEPARTMENT OF MINES.
SOUTH AUSTRALIA.

GROUND SCINTILLATION SURVEY OF PORTION OF SECTION 334, RADIUM HILL, FOR THE LOCATION OF URANIUM MINERALIZATION.

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DEPARTMENT OF MINES.
SOUTH AUSTRALIA.

GROUND SCINTILLATION SURVEY OF PORTION OF SECTION 334, RADIUM HILL, FOR THE LOCATION OF URANIUM MINERALIZATION.

SUMMARY.

A scintillation survey was carried out by the writer adjacent to the known Radium Hill lodes in an attempt to locate extensions to the known lode system.

Three areas of uranium mineralization, called the Railway, Intermediate, and Creek Bed Prospects, were located by the writer, who carried out preliminary investigations of those areas by pit sinking, costeaning, and mapping.

INTRODUCTION.

A scintillation survey of 25,400,000 square feet of country was carried out by the writer adjacent to the known Radium Hill lodes in an attempt to locate extensions to the known lode system. Field work was carried out during the periods 10th. September to 7th. October, 15th. October to 21st. November, 1956, and 14th. January to 8th. February, 1957. (see appendix Part 2).

Three anomalous radioactive areas were located by the writer who carried out preliminary investigations in these areas by pit sinking and costeaning, and located davidite mineralization at each prospect.

These areas have been called Railway, Intermediate, and Creek Bed Prospects.

The Railway prospect appears to be the most significant area of mineralization and warrants exploration by pit sinking or diamond drilling to see whether the uranium mineralization improves at depth.

Initially a La Roe scintillometer (type FV-68), the property of the USAEC was used; however, of the return of geologist Woodmansee to the USA, the writer used a scintillometer (type FV-53).

Apart from minor breakdowns, these instruments behaved satisfactorily in the field, and because of their short time constant (one second) the radioactive areas were easily delineated.

A survey plan of the area was compiled from aerial photographs and from field observations to form a framework for the scintillation survey.

Traverses were run at intervals of 50 feet in a landrover at low speed with the instrument held outside the vehicle at about two feet from the ground.

Readings were taken every 50 feet along traverses and noted, but a continuous check was kept on the instrument during the traversing so that no small significant anomaly would be missed.

Closer intervals were adopted when a significant anomaly was located and the area around the anomaly pegged and gridded on foot.

When a significant anomaly was located a detailed radiation and geological plan was prepared and pit sinking was carried out by the writer and driver, and the attitude of the surface expression of the lode determined.

When warranted, bulldozing was carried out and sampling of the exposed holes completed.

Using this technique, the area was effectively explored for shallow seated uraniferous lodes to determine whether or not the deposits deserve further prospecting at depth by diamond drilling.

PREVIOUS GEOPHYSICAL WORK.

Aerial radiation surveys, ground scintillation, and prospecting work has been previously carried out in the area which was remapped radiometrically by the writer.

Ground parties equipped with Geiger counters carried out prospecting work in this area in an attempt to locate extensions to the main lode system.

Scintillation gridding was carried out by D. Pegum with an aerial scintillometer installed on a boom in front of a jeep; however, due to faulty equipment, the results were considered unreliable.

Aerial scintillation surveys were carried out by J. Harris (with Pilot J. O'Hagen) in the area at low altitude and the results presented in report "Airborne Radiometric Survey of Portion of Olary Province". (Geophysical Report No. 2/56.)

A number of radioactive "highs" were located. These were numbered 79, 80, 81, 82, 83, 84, and 85, and their locations are shown on plan(No. 56 - 175 FT). Some of these were already known from previous ground surveys.

These were located on the ground by prospector Harry Campana, and an area around a significant surface anomaly located (referred to as the northern prospect) was gridded by Bruce Webb (Geologist-in-Charge at Radium Hill) and geological mapping and a diamond drilling programme undertaken, but the results were disappointing.

Ground magnetometer surveys were conducted in the area by C. Kerr-Grant and M. Bartlett with a Watt's vertical force magnetometer and the results presented in Bulletin No. 30, "Uranium Deposits of South Australia" (by S.B. Dickinson, F.L. Stillwell, D. King, M.L. Wade, B.F. Webb, A.W.G. Whittle, R.C. Sprigg, and A.E. Edwards) on page 25.

The writer wishes to draw attention to the fact that the magnetic anomalies as presented here are ten times actual size.

Little or no interpretation of the magnetic data has been carried out irrespective of the large amount of field work undertaken.

It is a pity that ground magnetometer surveys were carried out extensively in the area as a method for prospecting for uranium mineralization instead of detailed radiometric gridding being undertaken, as the Radium Hill area is unsuited for magnetic surveys. Analysis of the magnetic results with the aid of detailed geological maps and magnetic susceptibility experiments on the different rock types in the area may aid in the interpretation of geological structures in concealed areas.

Aerial scintillometer and aerial magnetometer work was carried out in the Radium Hill area by the Bureau of Mineral Resources in a DC3 (VH-BUR) and the total magnetic force contours and scintillometer anomalies were presented on plan No. (G143-7), Ballara area.

As this aerial survey was carried out on a regional basis (at a height of 500 feet, with traverse lines half a mile apart) the scintillometer results are not accurate enough, and the small radiometric anomalies due to the shallow seated weathered lodes are not recorded by the aerial scintillometer.

GEOLOGICAL MAPPING.

Regional mapping has been carried out in the area by R.C. Sprigg and B. Campana, and the results incorporated in the regional plan entitled "Ballara Geological Map" (1 mile per inch).

R.C. Sprigg also conducted detailed mapping in the region. Geological mapping was carried out in the immediate vicinity of the uranium deposits discovered, by the writer, as an aid to the interpretation of the scintillometer anomalies.

Regional mapping has been commenced by R. Coats in the Radium Hill area as well as detailed mapping at the Railway Prospect.

Underground mapping has been carried out by R.C. Sprigg, Ken Glasson, Bruce Webb, and Noel Hiern, and other officers of the Survey.

METHODS USED.

Approximately half the area was mapped with a PV-63 scintillometer and the rest with a modified type of La Roe (PV-53) set on an identical sensitivity and background count. (For theory, see appendix Part (1)).

Repairs to breakdowns and battery replacements were carried out by the writer and A. Burrows (Technician - Radium Hill.)

The scintillation survey was carried out by the writer and a driver in a landrover at slow speed.

The left-hand door of the landrover was removed during the survey and the instrument held outside the vehicle at approximately two feet from the ground.

Using such a technique, a wide cone of gamma rays were received at the scintillation counter. The instrument was kept on a short time constant (= one second), so that the instrument rapidly responded to changes in the intensity of gamma radiation.

A surface topographical plan was prepared from ground surveying and the aid of aerial photographs of the area.

INTERPRETATION OF RESULTS.

The scintillometer results were corrected for drift and an isorad plan was constructed showing variations in the radioactivity throughout the area.

Six levels were accepted in the area mapped by the writer, (plan L57-8). The level of gamma radiation (30 to 32) counts per second and the adjacent higher ones are shown to be significant levels of gamma radiation on "opening" them up by bulldozing and pit sinking.

Generally the attitude of the isorad lines of lower intensity do not show much relation to the surface geology due to the masking effects of the transported and residual soil mantle which generally covers the area.

However, a generally higher gamma radiation level occurs over the rounded hills due to the thinner veneer of soil masking the radiations from the bedrock.

The significant anomalies are not very wide and are related to the configuration of the uraniferous lode material concealed under the alluvium. This is due to the linear arrangements of the lode structures and to the gentle topography of the area which hasn't caused much resorting of the products of erosion in recent times except along the creek beds.

Davidite crystals, being resistant to weathering, tend to remain in the soil formed by erosion of the bedrock containing lode material, and this enables one to locate concealed weathered lodes at shallow depth.

During erosion of uranium lodes, the radium disintegration products tend to accumulate in the soil, whereas the soluble uranium minerals are carried away by meteoric waters and carried down to the water table and precipitated.

Tropical conditions and acid environments are favourable for this, but it also occurs to a smaller extent in dry climates. The Radium C salts are hard gamma emitters and are readily detected in the soil. The absence of wide areas of radioactive zones containing radium salts around the significant anomalies suggest that in previous geological time no large orebodies of uranium existed above the erosion level, and this suggests also that only small bodies may exist at depth in the area.

The uranium mineralization in the lode shears is erratic so that "wild catting" may be necessary to determine whether or not uranium mineralization occurs at depth in the area in extensions of the lode shears beyond their abnormal radioactive surface expressions where the uranium mineralization in the lode is weathered and in close proximity to the surface.

The most significant radioactivity occurs at the Railway Prospect (see plan 57-147 for relation of surface radioactivity to lode structure.)

Two to four narrow and closely spaced lodes occur over a distance of 200 feet at the Creek Bed prospect. Owing to the transported soil in the bed of the creek only a small area of anomolous radioactivity was located on the bank, but subsequent bulldozing showed that the mineralization continued beneath the creek.

Incipient mineralization occurs at the Intermediate prospect and does not appear significant.

RECOMMENDATIONS AND CONCLUSIONS.

An area adjacent to the Radium Hill mines was radiometrically surveyed by the writer in an attempt to locate eastern extensions of the Radium Hill main lode system.

Several small lodes were discovered by the writer, namely, the Railway, Intermediate, and Creek Bed prospects. A programme of bulldozing was carried out to determine the significance of the surface radioactive anomalies due to the disseminations of davidite in the soil. The most significant radioactivity was associated with the Railway prospect.

Bulldozing has shown that the concentration of uranium minerals in the Railway prospect lode are erratic as in the main lode systems, but they may improve at depth. This can be rapidly proved by diamond drilling.

Owing to the patchy nature of the ore, "wild catting" may be necessary to attempt to locate concealed lodes at depth beyond the limits of the linear surface radioactive anomalies (due to the shallow seated weathered lode material).

Unfortunately, no detailed surface radioactive plans of the mine area are in existence, although active exploration started 13 years ago.

It is usual to conduct surface radiometric gridding over known lodes early in exploration work for the following reasons:-

(1) To obtain a surface radioactive picture of the area as an aid to the interpretation of the radioactive anomalies located further afield during exploration.

(2) Surface contamination during mining operations destroy the natural ground radioactivity producing large numbers of artificial anomalies due to slime dumps, road metal, tailing dumps, etc., and if further exploration is carried out in the neighbourhood of the mine, no reliance can be placed on the isorad plan constructed long after mining operations have started.

(3) The size, shape, and intensity of the radiometric anomalies determine the conditions under which aerial scintillometer surveys are carried out and the method of interpretation employed.

Although reference is made to a detailed Geiger survey, carried out over the main lodes and extended as far as South Hill, in Bulletin 30 on page 24, no such plans are in existence to the knowledge of the writer.

A large amount of magnetometer work has been carried out, but no interpretation of the results has been prepared or magnetic susceptibility experiments of the different rock types carried out on a basis to the interpretation of the Isogam plans with the aid of the detailed geological maps.

Magnetic susceptibility experiments could be carried out rapidly with little or no expense by using one of the Department's vertical force magnetometers and a small amount of laboratory equipment.

Diamond drill holes at Radium Hill should be logged for the following reasons:-

(1) To obtain a continuous log of variation of radioactivity with depth. Variations occur in the trace amounts of radioactive potassium and/or uranium and thorium minerals with varying rock types intersected in the drill hole apart from the lode formations, and this information is valuable in interpretation of the geological structures.

(2) To locate radioactive intersections due to uranium and/or thorium mineralization, and to check the information gained from core obtained by diamond drilling, as core losses may have occurred in the lode material due to the brittle nature of the ore.

(3) Check core samples have been placed in the core boxes in the right position.

The writer recommends that detailed mapping, regional mapping, ground and aeromagnetic, ground scintillation works, interpretation of borehole logs be co-ordinated in the attempt to locate concealed orebodies in the main area due to the known small grade reserves at the mine.

Initial investigation should be carried out at the Railway prospect by diamond drilling at depth beneath the lodes.

12.4.57

GEOPHYSICIST.

APPENDIX (PART 1)

OPERATING PRINCIPLE OF THE RADIATION DETECTOR.

The primary function of the portable scintillation detector is the detection of radiation in the form of gamma rays released by the uranium - thorium minerals and their disintegration products dispersed in the soil.

The instrument detects the gamma rays through observation of light flashes which are created when the ray or particles enter the scintillation crystal by the photosensitive tube.

The scintillation crystal is composed of sodium iodide which has been activated by the addition of about 1.0 per cent by weight of thallium iodide, NaI(Th). The crystal, which is very hygroscopic, is hermetically sealed in a container of aluminium and glass.

The detection efficiency of the scintillation crystal and hence that of the instrument is dependent upon the ability of the crystal to stop and transform the energy of the gamma rays into light photons. The stopping efficiency of the crystal increases with its volume, as an increase in the mass of the crystal defines a higher probability of collision between the incident rays or particles and the elementary particles making up the structure of the crystal.

A voltage pulse is the product of each electron which has been multiplied in the photomultiplier tube, and the amplitude of which is indicative of the energy of the ray or particle which entered the scintillation crystal and produced a burst of light therein.

Each voltage pulse of sufficient amplitude triggers a a univibrator which converts the multiamplitude pulses from the photomultiplier tube into pulses of constant amplitude.

The pulses of constant amplitude enter an integrating voltmeter wherein their integrated number as seen by the grid of the voltmeter tube is proportional to the number of pulses seen by the univibrator. The proportionality fails when the pulses from the photomultiplier tube are too close in time for the univibrator to separate and convert them into pulses of constant amplitude, and some pulses are then lost.

The voltmeter tube conduction is maximum for zero bias which also defines the minimum voltage drop across the tube. When the negative pulses from the univibrator are integrated, the grid of the voltmeter goes negative and the drop across the tube increases.

The indicating meter is in parallel with the voltmeter tube, and this sees an increase in the voltage drop as an increase in the indicating current as an increase in the radiation measured.

APPENDIX PART (2)

THE MATHEMATICAL THEORY OF RADIATION FROM DIFFERENT SHAPED RADIOACTIVE SOURCES.

(1) Point Source on the Ground.

Traverse Passing Over Radioactive Point Source.

Consider a vehicle moving along a traverse AB which runs directly through a point S of gamma emitting material. The scintillometer in the vehicle is held at a height L (2 feet) from the ground; X is the horizontal distance of the scintillometer from the source and R is the slant of distance. If v is the velocity and t is the time

$$X = vt = \sqrt{(R^2 - L^2)} = L \cot \theta \quad \ldots\ldots\ldots\ldots(1)$$

The instantaneous effects of gamma radiation on the scintillometer in the vehicle is γi

$$\text{and} \quad \gamma i = \frac{K e^{-MR}}{R^2} = \frac{K \sin^2 \theta \; e^{-ML \operatorname{cosec} \theta}}{L^2} \quad \ldots\ldots\ldots(2)$$

where M is the apparent absorption coefficient of the gamma radiation in air and K is a constant equation, (2) has a maximum value at θ = 90 degrees given by

$$\gamma i \text{ max.} = \frac{K \exp(-ML)}{L^2} = \frac{K e^{(-ML)}}{L^2}$$

Since γ_i varies with time in the manner determined by equations (1) and (2) and since the instrument has a finite response time, the signal indicated by the instrument S will be less than γ_1 max., and will occur somewhat later.

We may put -

$$S = f \gamma_1 \text{ max.} = \frac{f K e^{-\mu L}}{\bar{L}^2} = \frac{f K}{\bar{L}^2}$$

where f, a function of $\bar{L}$ and v, is less than unity.

As the vehicle is travelling at slow speed (four miles per hour) f was determined as 0.76

$$\therefore S = \frac{(0.76) K}{4}$$

Practical Measurements.

Figures (1) and (2) show the variation in gamma ray intensity with distance from a one cubic inch of Radium Hill Davidite and three cubic inches of Radium Hill Davidite as measured with the La Roe Scintillometer (type FV-58). These readings were static measurements, i.e., the instrument set on ten second time constant, and readings were averaged over 30 seconds.

The signal was (0.76) of this value when the instrument was moved past these radioactive sources at a velocity of four miles per hour, i.e., $\frac{(88)}{(60)} \times 4$ feet per second = 5.8 feet per second.

(2) Point Source on the Ground.

Traverse Offset from Point Source.

Let AB represent a traverse running through the point source S, and CD represent a traverse parallel to AB but offset by 1 foot = 6. Let height of scintillometer above ground level equal $\bar{L}$ = 2 feet.

To calculate the variations in the gamma ray intensity along CD

P represents the scintillometer and Q the projection of P on a vertical plane through traverse AB.

Now $r^2 = d^2 + R^2$ and $R = X^2 + L^2$

The instantaneous effect of gamma radiation on the scintillometer at Q (by proof on previous page) equals

$$\gamma_i = \frac{Ke^{-\mu r}}{r^2} = \frac{K}{r^2} \text{ (as } e^{-\mu r} \text{ is nearly unity)} = \frac{K}{d^2 + R^2} \quad \ldots\ldots(3)$$

Equation has a maximum value at $r^2 = d^2 + R^2$ given by

$$\gamma_i \text{ max.} = \frac{K}{h^2 + d^2} = \frac{K}{S}$$

Hence the signal indicated by the instrument S

$$\text{equals } f\,\gamma_i \text{ max.} = f\,\frac{K}{S}$$

The value of f was determined as 0.76

$$\therefore S = f\,\gamma_i \text{ max.} = (0.76)\,\frac{(K)}{(S)}$$

Practical Measurements.

Figure (3) shows the variation in the gamma ray intensity with distance along a traverse one foot offset from one cubic inch mass of Davidite. These readings were static measurements, i.e., the instrument set on ten second time constant and readings were averaged over 30 seconds. The signal was (0.76) of this value when the instrument was moved past the radioactive source at a velocity of four miles per hour.

P is the position of the scintillometer in a vehicle. This is moved in a direction normal to the line of point sources (S_1 S S_2) bisecting them at S so that (S_1 S) equals (S S_2) at a constant height $\bar{L}$ above the ground. The distances between the point sources are unity.

(the gamma ray intensity)

$$= \frac{Io e^{-\mu r}}{r^2} + \frac{Io e^{-\mu r}}{r^2 + 1} + \frac{Io e^{-\mu r}}{r^2 + 4} + \frac{Io e^{-\mu r}}{r^2 + 9} \quad \text{etc.}$$

$$\therefore \gamma = Io \left\{ \frac{\pi^2}{6} - \Sigma_1^n \frac{1}{(n-1)^2 \left(1 + \frac{(n+1)^2}{r^2}\right)} \right\}$$

$$= \left\{ \frac{\pi^2}{6} - \Sigma_1^n \frac{1}{(n-1)^2 \left(1 + \frac{(n+1)^2}{(L^2 + X^2)}\right)} \right\} Io$$

$$= \left\{ \frac{\pi^2}{6} - \Sigma_1^n \frac{1}{(n-1)^2 \left\{1 + \frac{(n+1)^2}{(4 + X^2)}\right\}} \right\} Io$$

$$\gamma_{max.} = \left\{ \frac{\pi^2}{6} - \Sigma_1^n \frac{1}{(n-1)^2 \left\{1 + \frac{(n+1)^2}{4}\right\}} \right\} Io$$

Hence the signal indicated by the instrument

= S equals f γ max.

$$= (0.76)\left\{\frac{\pi^2}{6} - \sum_1^n \frac{1}{(n-1)^2\left(1 + \frac{(n+1)^2}{4}\right)}\right\} I_o$$

Where Io is the gamma ray intensity due to unit source strength, So for 1 cc at 1 cm.

Practical Measurements.

Figure (4) shows the variation in gamma ray intensity with distance from a rod of davidite 1" x 1" x 29".

The measurements are across the rod at right angles along a line bisecting it.

The readings were taken with the instrument set on the ten second time constant; settings and readings were averaged over a period of three times the time constant.

The signal was (0.76) of this value when the instrument was moved past this radioactive source at four miles per hour along the same path (on a one second time constant).

METHOD OF CALCULATION OF BACKGROUND COUNT.

The ground surface contains traces of radioactive elements in mineral form as uranium, thorium, and potassium minerals. The uranium and thorium are associated with the daughter products. Due to surface weathering these may or may not be in equilibrium with the parent element. These emit gamma rays (apart from alpha and beta rays) which are registered by the scintillation counter and with cosmic ray contributions form the background count.

Over sandstones, limestones, marbles, etc., the background count is small due to the paucity of the trace radioactive elements, whereas over shales, granites, etc., the background count is appreciably higher.

Let S represent the scintillometer and AB the ground surface. To determine the radioactivity at S due to the surrounding and underlying rock assumed to contain gamma emitting elements in constant proportion throughout.

The total radioactivity registered at the counter (due to the ground)

$$\text{is} \int_{a_1}^{a_2} \frac{2\pi R^2 \; dR I e^{-M(PQ)}}{R^2}$$

where I is the gamma ray intensity 1 cm. from unit sonne strength, Go of the matter per c.c., and M is the linear coefficient of absorption.

$$\int_{a_1}^{a_2} \frac{2\pi R^2 \; I e^{-M(PQ)} dR}{R^2}$$

$$= \int_{a_1}^{a_2} 2\pi I e^{-MR} e^{a_1 M} \, dR = \frac{2\pi I e^{a_1 M} \{I e^{-MR}\}_{a_1}^{a_2}}{-M}$$

$$= 2\pi I \frac{\left(e^{-Ma_2} - e^{-Ma_1}\right)}{-M} e^{+Ma_1}$$

Let $a_2 \longrightarrow \infty$

$$\therefore \; 2\pi I \frac{\left(e^{-Ma_2} - e^{-Ma_1}\right)}{-M} e^{-Ma_1} = \frac{2\pi I}{M}$$

Hence the total radioactivity at a point S equals

$$\frac{\text{constant } X \text{ (equivalent uranium content)}}{\text{linear coefficient of absorption.}}$$

therefore the total radioactivity registered by the counter equals

$$\frac{2\pi I}{M} + \text{cosmic count.}$$

This can be shown to be independent of the height of the band scintillometer from the ground on ground surveys.

<u>To calculate the thickness of granite equivalent to an infinitely thick gamma ray emitter assuming that the activity is due to radio-active potassium K40: and the surface of the granite is a plane.</u>

The gamma ray energy of K40 is 1.459 Mev. Therefore the mass coefficient of absorption is 0.053. The linear coefficient of absorption equals density of rock x 0.053.

Suppose the density of the rock is 2.67 gms. per c.c. (which is an average value for granite), and in equation

$$I = Io e^{-\mu D}$$

Let D equal 10 inches

$$\therefore \frac{I}{Io} \text{ equals } e^{(-10 \times 2.54)(2.67)(0.053)}$$

$$\text{equals } e^{-3.59} = 0.027$$

Therefore 97.3 per cent of the gamma ray photons are absorbed internally by a thickness of granite rock.

Let D equal 15 inches.

$$\therefore \frac{I}{Io} \text{ equals } e^{-(15 \times 2.54)(2.67)(0.053)}$$

$$\text{equals } e^{-(5.39)}$$

$$\text{equals } 0.0045$$

Therefore 99.55 per cent of the gamma rays are absorbed by a thickness of 15 inches of granite.

<u>To calculate the thickness of granite equivalent to an infinitely thick gamma ray emitter assuming that the activity is due to trace amounts of uranium (in equilibrium with its daughter products) and the surface of the granite is a plane.</u>

Most of the gamma radiation from the uranium series (88 per cent of the total) comes from radium C. The energy of these gamma rays is 1.8 Mev.

As these gamma ray photons are somewhat more energetic than the potassium gamma rays, a slightly greater thickness of granite is required to produce the same amount of absorption.

Calculations show that most of the rays are absorbed by 17 inches of granite.

Practical Example.

Diagram No.   shows the variation in gamma ray intensity with rock type.

To determine the thickness of alluvium (non-radioactive) to "conceal uraniferous lodes from the scintillometer."

AB represents the cross-section of the surface, and MN OP represents a concealed lode under D inches of alluvium.

Now $I = I_o e^{-\mu D}$

where I_o is the gamma ray intensity measured at C with the alluvium stripped off the uranium lode system.

Taking the density of the alluvium as 1.65 gms. per c.c. (this is the average value for clay).

$$I = I_o e^{-(1.65 \times .047)(15)(2.54)}$$

$$\therefore \frac{I}{I_o} = e^{-2.96} = 0.049$$

Therefore for a thickness of 15 inches, 95.1 per cent of the gamma radiations are internally absorbed, hence owing to the statical variation of the counts and the integrating circuit of the scintillometer cosmic ray background, a deposit concealed under 15 inches of soil (non-radioactive) would go undetected.

However, due to the weathering process, the radium compounds being insoluble tend to remain in the soil, and as Radium C is a hard gamma emitter, the concealed uraniferous lode would be detected. If, however, the soil was transported, then 15 inches of soil would conceal it.

EFFECT OF WEATHERING OF A SHALLOW SEATED URANIFEROUS LODE.

Weathering processes oxidise primary uranium minerals, when by surface erosion processes they enter the zone of aeration. It has been shown that the secondary uranium salts are readily soluble in ground water, and these secondary salts are carried down to the ground water table and deposited there, and if the surface run-off is appreciable a large amount of the secondary uranium minerals are gradually dissolved and transported away and deposited in flat lying areas where they are gradually carried down to the ground water table by meteoric waters.

The insoluble radium salts tend to remain in the soil above the ore body and radon gas diffusing from the primary zone (having a half life period of 3.83 days) migrates up towards the surface disintegrating into the real radioactive member of the uranium family, and so on. This enhances the concentration of the radium disintegration products at the surface above the lode.

As Radium C is a hard gamma emitter abnormal gamma ray radioactivity occurs at the surface above the weathered lode.

Practical Examples.

Plan No. (57-D7) shows a surface radiation plan of the significant area of the Rum Jungle uranium field which was carried out by the writer during 1952.

Dyson's lode is subparallel to the baseline as shown by the configuration of the highest levels of radioactivity.

Two tongues of abnormal surface radioactivity like wings spread out in opposite directions from the concealed lode which occurs on a ridge. This is due to the transportation of the insoluble radium disintegration products with the residual soils down the slopes.

Open cutting showed that the secondary uranium minerals (autunite, saleeite) were concentrated below the area of highest activity at the water table level along the axis of the uraniferous pyritic lode shear in carbonaceous rocks.

At Whites prospect, Whites extended, and a continuation discovered by the writer, the surface radioactive anomaly pattern due to the concealed lode (although relatively narrow) is broad, betraying the presence of uranium at depth beneath the alluvium.

ANGULAR SENSITIVITY OF THE SCINTILLOMETER.

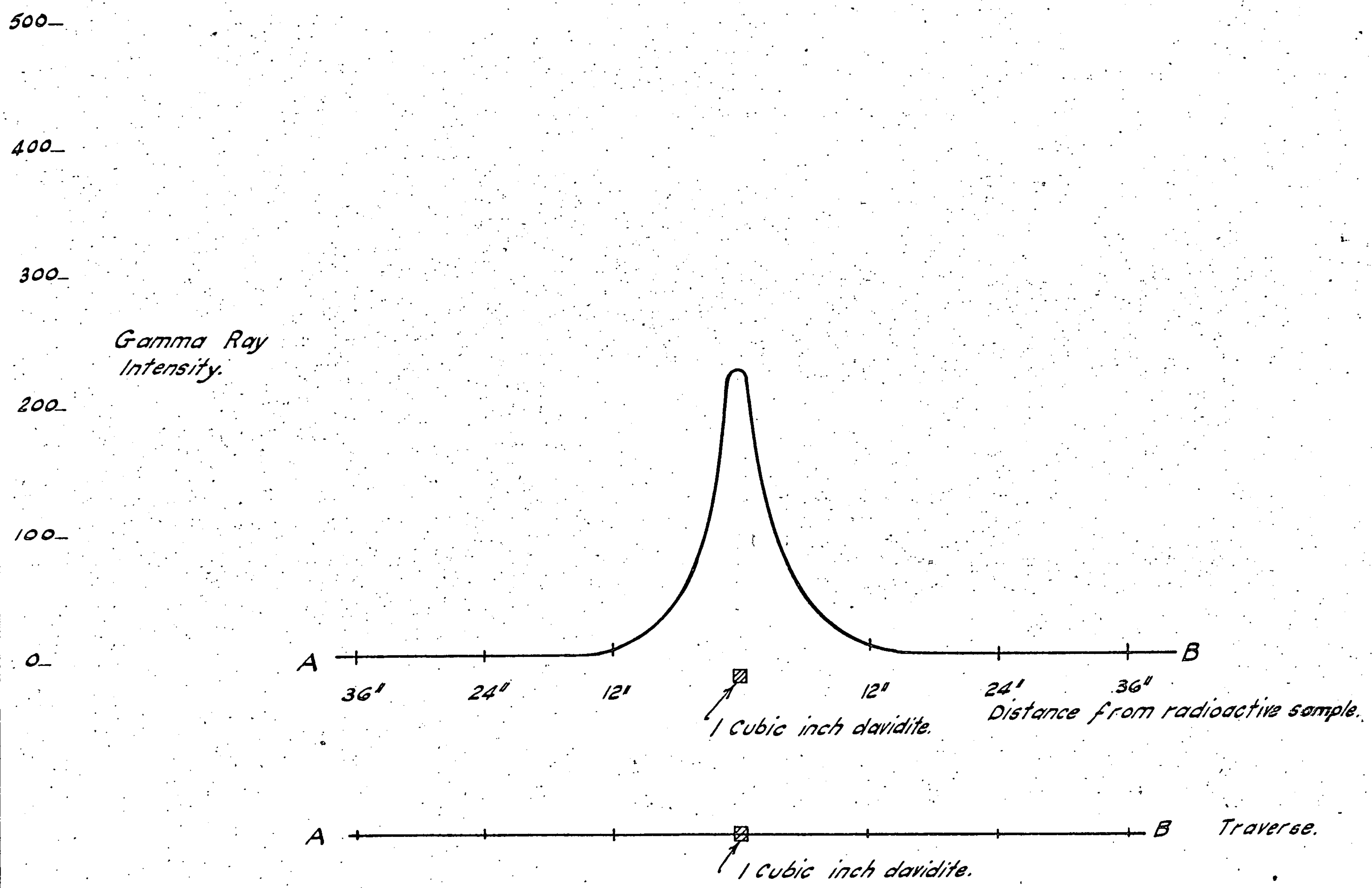
(LA ROE TYPE FV - 55)

The angular sensitivity was measured by a small source and is shown in diagram (S - 1462). Measurements of the azimuth sensitivity in the horizontal plane showed no variation.

S.A. DEPARTMENT OF MINES

VARIATION OF GAMMA RAY INTENSITY WITH DISTANCE FROM 1 CUBIC INCH OF DAVIDITE AS MEASURED WITH THE LE ROE SCINTILLOMETER

Approved	Director
Passed	
Drn.	
Tcd. A.W.	
Chd.	
Exd.	
D.M.	
Req.	
Scale	5/443 M.
Date 21-3-57	



PLAN VIEW.

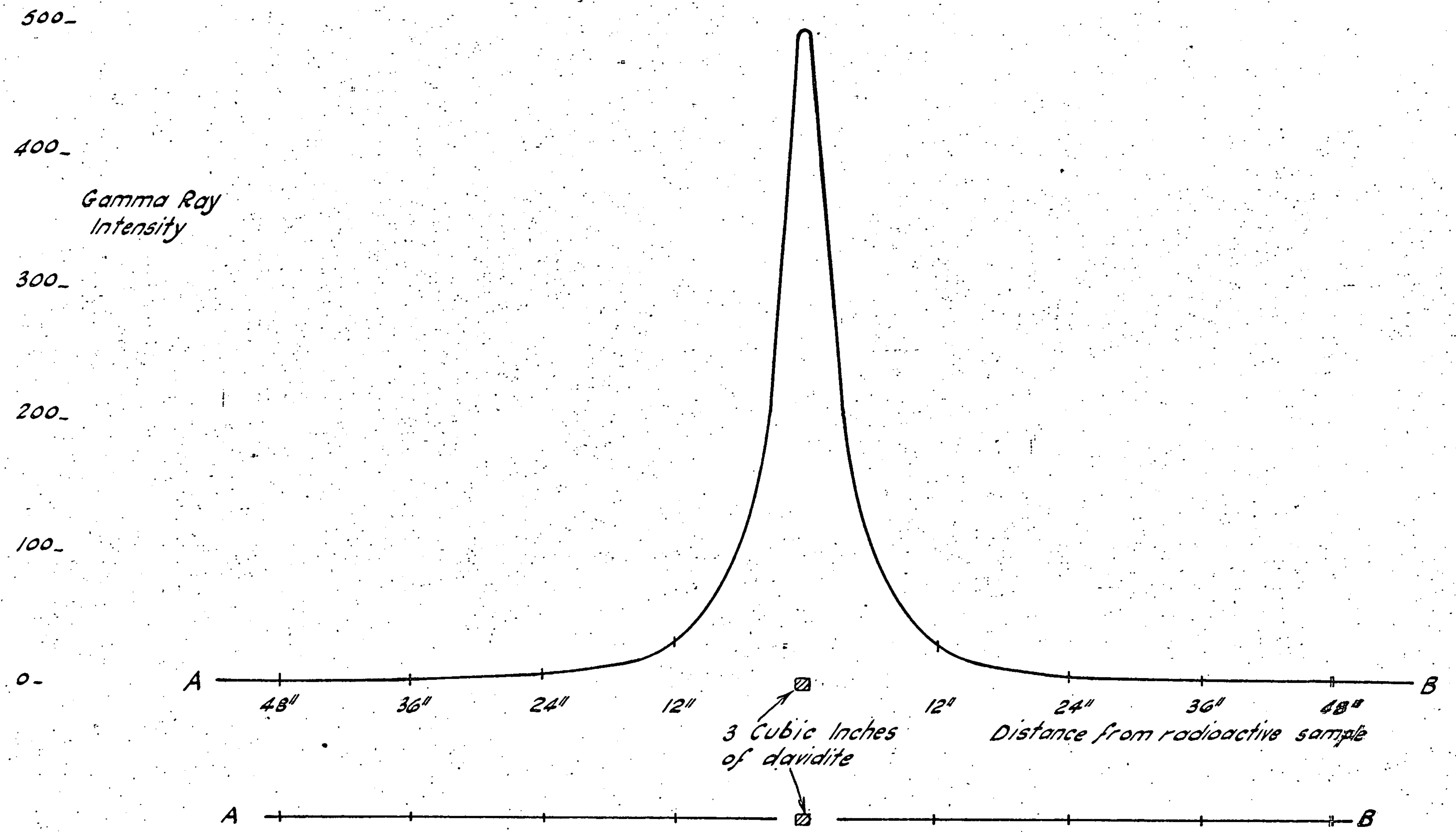
FIG. 1.

To accompany report by I.A. Mumme.

S.A. DEPARTMENT OF MINES

VARIATION OF GAMMA RAY INTENSITY WITH DISTANCE FROM 3 CUBIC INCHES OF DAVIDITE AS MEASURED WITH THE LE ROE SCINTILLOMETER.

Drn.	D.M.	Scale	
Tcd. A.W.	Req.	S/444	
Ckd.		M.	
Exd.		Date 21.3.57	
Approved	Passed		
Director			



PLAN VIEW.

FIG.2

To accompany report by I.A. Mumme.

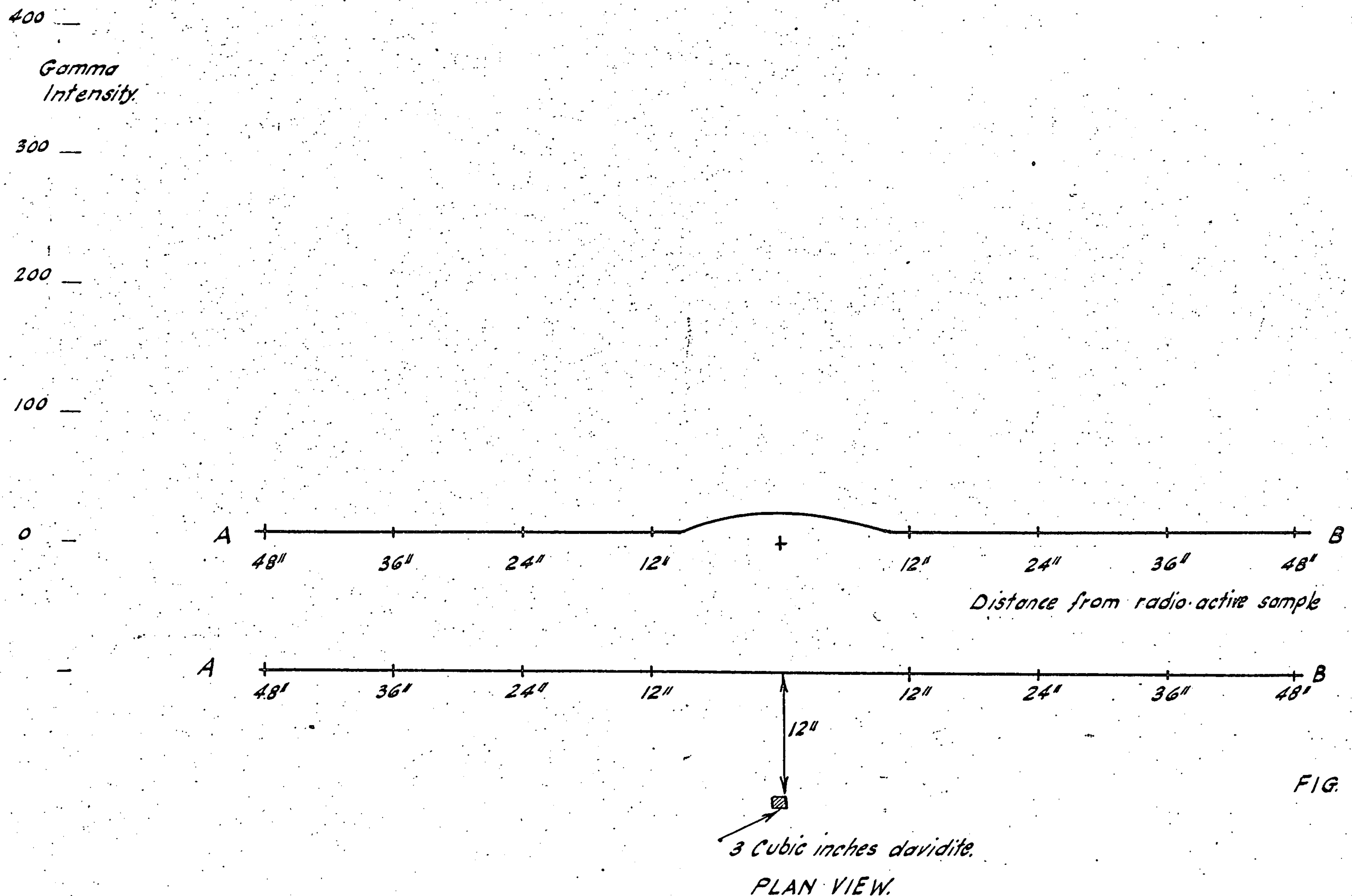


FIG. 3.

S.A. DEPARTMENT OF MINES

VARIATION OF GAMMA-RAY INTENSITY WITH DISTANCE ALONG TRAVERSE OFFSET 1 FOOT FROM 3 COUNTS PER SECOND OF DAVIDITE

Approved	Director
Passed	
Drn.	Tcd. A.W.
Ckd.	Exd.
D.M.	Req.
Scale	5/445 M
Date 21-3-57	

To accompany report by I.A. Mumme.

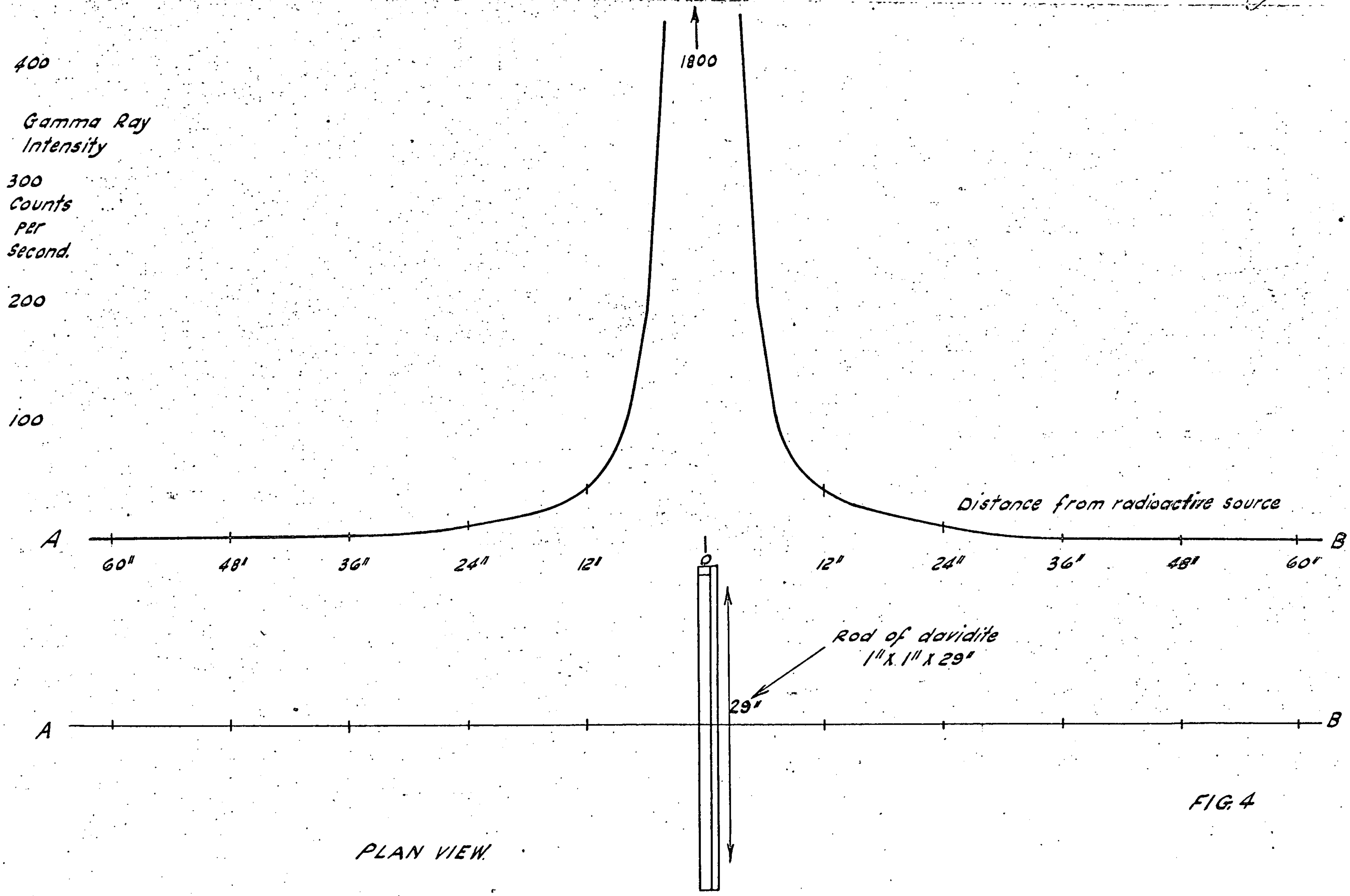


FIG. 4

S.A. DEPARTMENT OF MINES

VARIATION OF GAMMA-RAY INTENSITY ACROSS TRAVERSE AT RIGHT ANGLES BISECTING VEIN OF DAVIDITE

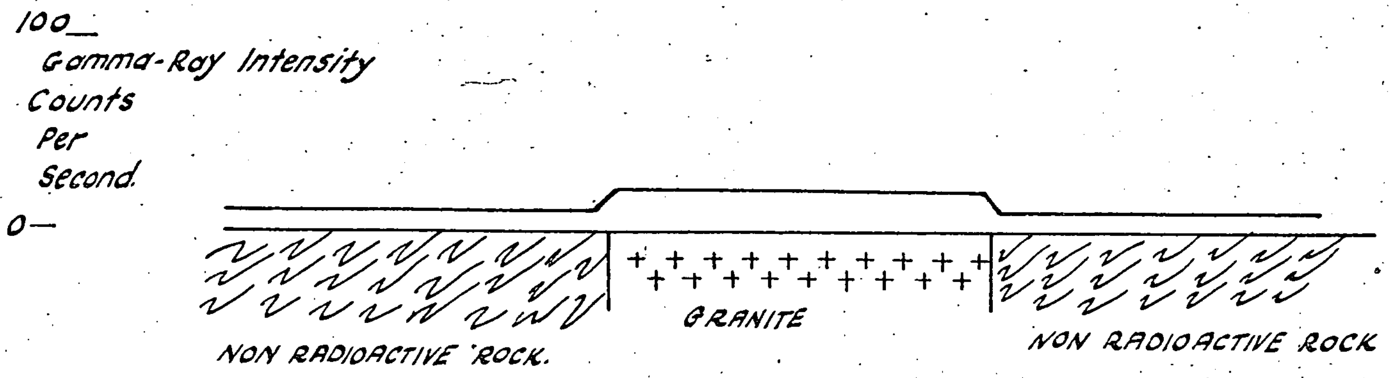
Approved	Director
Passed	
Drn.	
Tcd. R.W.	
Ckd.	
Exd.	
D.M.	
Req.	
Scale	
S/446 M	
Date 21.3.57	

To accompany report by I.R. Mumme.

S.A. DEPARTMENT OF MINES

VARIATION IN GAMMA-RAY INTENSITY FROM NON RADIOACTIVE ROCK TO GRANITE (EXPOSED)

Approved	Passed	Drn.
Director		Tcd. A.W.
		Ckd.
		Exd.
D.M.	Req.	
Scale	S1447 M	Date 21.3.57



VARIATION IN GAMMA-RAY INTENSITY FROM NON RADIOACTIVE ROCK TO GRANITE COVERED BY 4" OF NON RADIOACTIVE SOIL.

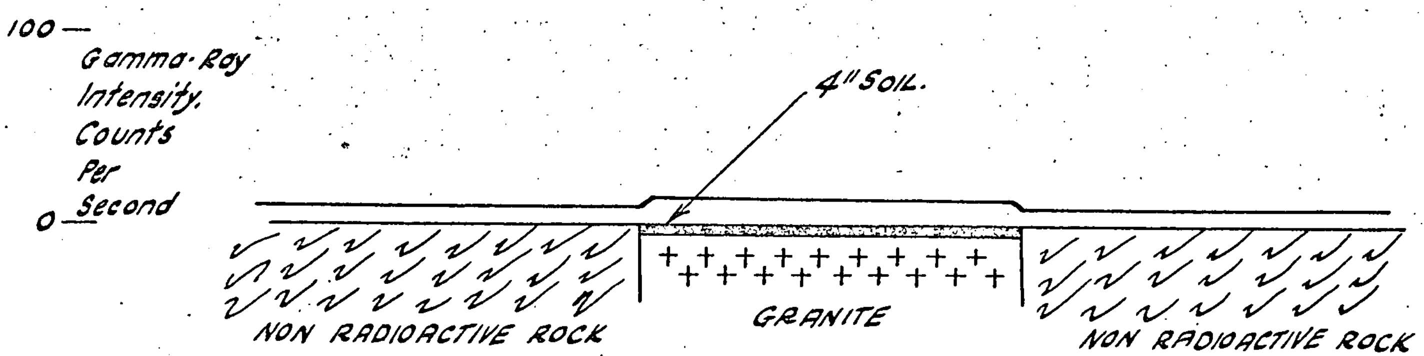
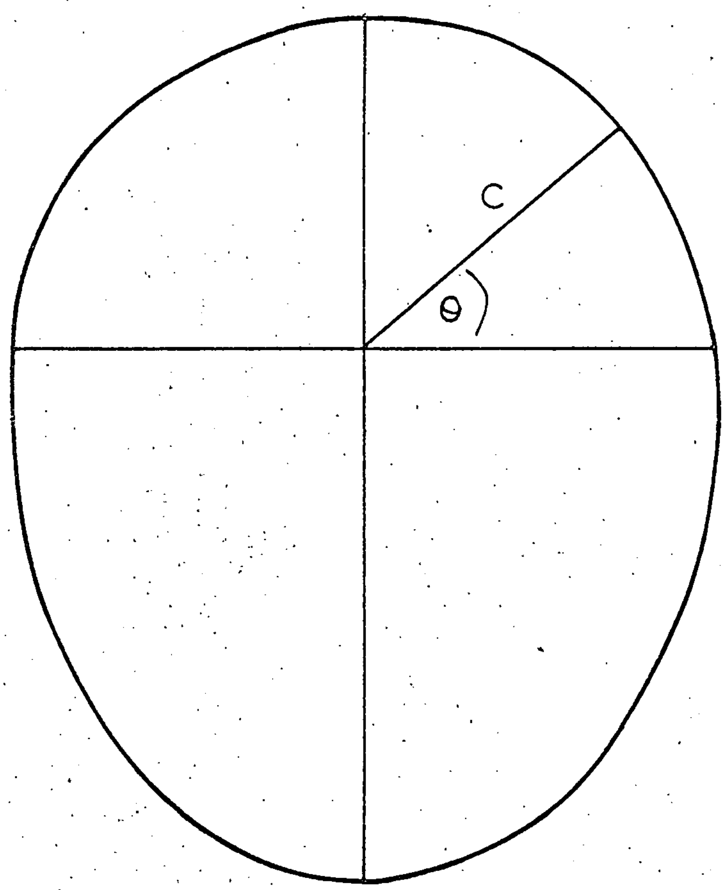


FIG. 5

To accompany report by I. A. Mumme.



C = Reading on Scintillometer

θ = Angle (in plane through the vertical axis of the scintillometer) subtended at the centre of the crystal by the radioactive point source and the horizontal plane bisecting the crystal.

To Accompany Report by I.A. Mumme.

S.A. DEPARTMENT OF MINES					
Approved	Passed	Drn.	VARIATION IN ANGULAR SENSITIVITY (FOR LE ROE SCINTILLOMETER F.V-55) RADIUM HILL SURVEY.	D.M.	Scale
		Tcd. A.W		Req.	S. 1462 F1
		Ckd.			
Director		Exd.			Date 1-4-57