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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1964/65

RUM JUNGLE AREA
RADIOMETRIC INVESTIGATIONS,

NORTHERN TERRITORY 1949-53

by

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SUMMARY

This Record gives a brief account of the geophysical operations of the Bureau of Mineral Resources, Geology and Geophysics at Rum Jungle, NT, in the period 1949-53 from the purely physical aspect. The operations involved the establishment of procedures for making a large number of accurate physical measurements under unfavourable climatic and general conditions. Details of the design and performance of equipment for surface radioactive measurements, testing of workings, radiometric assaying, and bore logging are given.

1. INTRODUCTION

Rum Jungle railway siding is about 70 miles south of Darwin. Uranium minerals were discovered close to the siding in 1949. Brief preliminary inspections were made during that year, and in succeeding years the Bureau of Mineral Resources, Geology and Geophysics carried out a programme of systematic testing by geological investigation, drilling, and shaft sinking. At the end of 1952, exploitation of the deposits was taken over by Territory Enterprises Pty Ltd.

The Bureau's operations in the Rum Jungle area were under the general charge of officers of the Geological Branch. The Geophysical Branch was responsible for the provision and maintenance of the necessary instrumentation, the development of techniques for field and laboratory work, and the supervision of field surveys and assaying. The operation has been discussed in a considerable number of geological reports, which include the results of the relevant geophysical surveys. The purpose of this Record is to present a brief review of the purely physical aspects of the geophysical operations, without reference to geological considerations. It was prepared by J. Daly and is based mainly on unpublished memoranda and reports by D.F. Dyson, who was in charge of geophysical operations on the field during the whole of the period in question and to whom a great deal of the credit for the successful outcome of the Bureau's operation is due.

As a result of a considerable amount of experience in the investigation of uranium deposits all over Australia, it is now possible to say that operations at Rum Jungle were conducted under conditions of maximum difficulty. The following may be quoted as specific difficulties:

(a) the country is deeply weathered and extensively lateritised, and the proportion of outcrop is not large. This makes geological mapping difficult,

(b) the carbonaceous slates in which the deposits occur are very bad mining and drilling ground,

(c) the rainfall is high and falls mainly in heavy storms during a short wet season. For this reason, there is considerable movement of ground water, and the interpretation of surface radioactive anomalies is very difficult,

(d) when the operation commenced, Geiger counters were still laboratory instruments and the construction of portable counters had received very little attention. Most of the equipment used had to be designed and made locally,

(e) field and laboratory techniques had to be developed. Little help was available from overseas experience, as information on such developments was under strict security classification and was difficult to obtain,

(f) for a considerable part of the year, the area has high temperatures and high humidity. These interfere seriously with the performance of electronic equipment.

Several of these factors are discussed in more detail later. A good indication of the effectiveness of the Bureau's operation may be seen in the fact that when information on overseas developments became available, no alterations in the instrumentation and techniques developed by the Bureau appeared advisable. No inadequacies were apparent in methods, nor had any important aspect of the operation been overlooked.

The following officers of the Geophysical Branch took part in the investigations at Rum Jungle:

J. Daly - in general charge of geophysical operations concerned with the search for radioactive minerals.

D.F. Dyson - in charge on the field during the whole of the Bureau's operations.

J. Pearce, K.H. Tate, R.J.P. de Groot, W. Compston, I.A. Mumme, and R. Green, who assisted in the work for limited periods.

Valuable assistance in the nature of technical suggestions was given by several visitors to the field, in particular by D.H. Peirson, F. Hale, and W. Munnock, of AERE, Harwell.

In addition to the radiometric work, geophysical investigations using the standard methods were made. These are not discussed in this Record. A brief historical account has been given by Daly, Horvath, and Tate (1962).

The various types of operation are discussed in more detail below.

As a preliminary to this discussion, some general remarks are offered on (a) the effect of climatic conditions on electronic equipment and (b) the relative merits of equipment of Australian and overseas manufacture. The report on the first geophysical investigation of the Rum Jungle deposits is attached as an appendix, as it may have bee some historical interest.

The effect of climatic conditions on electronic equipment

Basically, two separate problems are involved, viz. the effect of high temperatures and the effect of high humidity.

The effect of high temperatures on communication equipment has long been a matter of concern to the armed services; it was known that a considerable amount of information had been collected and could have been obtained if necessary. However, no serious attempt was made to obtain this information, as it was realised that electronic equipment used in connexion with radioactive measurements presented a completely different problem to communication equipment.

It is only rarely that high temperatures cause complete failure of electronic components. The effect of high temperatures is generally to cause actual values of components to change from the nominal values, so that the operating points of valves shift to a position on the characteristic different from the design position. In communication equipment, valves are generally used on the linear portions of the characteristics. A shift from the design position may result in impaired efficiency but there is generally a tolerance region over which the equipment is still usable.

In pulse equipment, such as is used in radioactive measurements, this tolerance region does not exist. Valves are used on the non-linear portions of the characteristics, and a relatively minor shift is frequently sufficient to cause complete failure of the equipment. Account must be taken of the fact, owing to the heat caused by the power dissipated in the equipment, the temperature in the equipment is higher than ambient temperature.

The effect of humidity is most serious on equipment in which the functioning requires a high impedance at particular points of the circuit. It is impossible to maintain a high impedance if humid air has access to the equipment, as high-resistance components are effectively short-circuited by a moisture film deposited on them.

It is difficult to envisage any simple means of preventing both of these effects, as the requirements are contradictory. The obvious method of preventing the ingress of moisture is by sealing the equipment; on the other hand, the effects of temperature are most easily minimised by improving ventilation. However, it is found in practice that different types of equipment are affected in different ways and that in, general, only one of the effects needs to be considered.

The following general conclusions are derived from experience at Rum Jungle (some types of equipment are discussed in more detail later):

(a) mains-operated equipment dissipates so much power that its temperature is generally considerably above ambient temperature. This prevents the formation of moisture films, so that only the effect of temperature needs to be considered,

(b) equipment of a moderate degree of complexity is unaffected by temperature. Thus a mains-operated laboratory ratemeter containing high-voltage supply, two stages of voltage amplification, a univibrator for pulse shaping, diode pump, and vacuum-tube voltmeter circuit has worked efficiently at very high temperatures,

(c) scaling equipment, such as is used for radiometric assaying, is very seriously affected by even moderately high temperatures,

(d) portable equipment dissipates so little power that its temperature is not raised above ambient temperature. The circuits used on most portable Geiger counters are so simple that the instruments are not seriously affected by temperature; hence the effect of humidity is the only one to be considered.

Storage of equipment

Storage of equipment not in use, and of stocks of dry batteries, was a constant problem. A reference is made later to the practice of storing portable counters in a hot box between periods of use, but this could only be a short-term expedient. Dry batteries were stored in a refrigerator, but only a small portion of the stocks required could be treated in this way. There is no doubt that the best method of storing equipment and batteries under tropical conditions is in a fully air-conditioned room. As air-conditioned space is also required for assaying, it appears that in any long operation in a tropical climate the expense of providing an air-conditioned room is well warranted.

Comparison between equipment of Australian and overseas manufacture

The principles of the design of radiometric equipment are relatively simple and well known. One type of instrument made by a reputable overseas manufacturer was encountered, in which persistent difficulties in servicing were finally traced to a gross error in design. Apart from this, no reason was found to criticise the basic design of any of the equipment used. The main advantage to be gained from comparisons of equipment of different manufacture is to exemplify the extent of which the usefulness of the equipment can be compromised by insufficient attention to practical considerations, some of which the designer could not reasonably be expected to appreciate.

Several instances of this will appear in later sections. However, a general remark may be made which was found to apply particularly to equipment of American manufacture. At the date of the Bureau's operations at Rum Jungle the range of electronic components available in Australia was limited, particularly as regards small resistors and condensers of low rating. If a resistor of $\frac{1}{4}$-watt rating failed, it could be replaced with a readily available 1-watt resistor without affecting the functioning of the equipment. If, however, the equipment was designed for maximum compactness (as was frequently the case with American equipment), sufficient space to insert the larger component was often unavailable. This caused constant difficulty with American equipment. The range of electronic components available in Australia is much greater now and perhaps is not likely to be restricted again in the future. However, it is essential in selecting equipment to take account of the availability of replacement components. In this regard the use of equipment of Australian manufacture was found to be much more convenient.

2. FIELD MEASUREMENTS

Field measurements under this heading include all survey operations involving the use of portable radiation detectors without any attempt to obtain values of uranium content. Operations of this type were carried on continuously. They can be divided into the following classes:

(a) surface investigations,

(b) investigation of workings (underground or surface workings such as costeans).

In a sense, radioactive bore-logging could also be included under this heading but owing to the special instrumental problems involved, it is best discussed separately.

Instruments

The instruments used in this work were portable Geiger counters. Two types were used mainly, the ratemeter type PRM200, manufactured by Austronic Engineering Pty Ltd, and the portable ratemeter designed and constructed in the first instance by AERE, Harwell.

The ratemeter type PRM200 was made to a specification prepared by the Bureau, as no other suitable instruments were available at the time. For the basic principles of design, reference may be made to Daly, Urquhart, and Gibson (1956).

It was decided that the instrument would be powered by portable radio batteries. The high-tension supply for the Geiger tube was obtained from a multivibrator, with a small choke as the plate load of one tube. The Geiger tube was about six inches long and one inch in diameter and had a background of 50 to 60 pulses per minute. The ratemeter circuit was of conventional design. Provision was also made for inserting head phones.

This instrument was very convenient to use and its performance was comparable with similar counters of overseas manufacture which became available later. It was widely used in prospecting for uranium all over Australia. The main criticism which could be made against it was that it was readily affected by humidity and could not be used in the Rum Jungle district for several months of the year. The effect of humidity was only temporary; it was constantly found that instruments which would not function at Rum Jungle could be used almost immediately when taken south of Adelaide River, where temperatures were considerably higher, but humidity was lower. It would have been impossible to eliminate the effects of humidity on the performance of this instrument, as it had an open phone-jack on the front panel. However, later experience showed that very elaborate precautions are necessary to seal equipment against humidity, and some equipment of overseas manufacture, which was nominally enclosed, was equally defective.

It was found possible to make somewhat greater use of the instruments in early summer by storing them overnight in a hot box, consisting of a large masonite box containing a 60-watt globe. When stored in this way the counters could often be used for some hours in the morning before the effects of humidity became apparent.

The following minor criticisms of the ratemeter type PRM200 could be made:

(a) owing to the small size and low background count of the Geiger tube, a long time-constant had to be used to obtain accuracy on the most-sensitive range. Reading times of some minutes were sometimes necessary. A faster response would have been convenient,

(b) the rapid indication using headphones is very useful in prospecting. However, continued wearing of headphones in a tropical climate is unpleasant, and some other type of indicator such as a flashing neon light would be more convenient. However, in equipment using dry batteries the voltage swings available are not large enough to make this easily possible,

(c) although the equipment used ordinary radio components, one of the valves required a severer specification than the normal commercial one. About 70 percent of commercial valves of the type were satisfactory for this service.

The other instrument largely used was the portable ratemeter type 1011B and succeeding types, designed and manufactured by AERE, Harwell. This instrument was designed on a different basis to the one previously mentioned. The design was based on the following principles:

(a) the Geiger tubes should have as high a background as possible to allow the use of a short reading time,

(b) the high-tension supply for the Geiger tubes should be obtained from dry batteries,

(c) the instrument should be effectively sealed.

The instrument consisted of two parts, <u>viz</u>. the probe and the box containing the ratemeter and batteries, which were connected by a cable about seven feet long. The probe was cylindrical, roughly three inches in diameter by 12 inches long, and contained three Geiger tubes about 10 inches long by $\frac{3}{4}$ inch in diameter. The normal background was about 200 counts per minute. A handle about three feet long was provided by which the probe could be held either in a horizontal or a vertical position. To keep the weight of the ratemeter box to a reasonable figure, hearing-aid batteries were used exclusively. This meant that ordinary radio valves could not be used in the ratemeter and the design was based on cold-cathode valves, which drew a very small current. Headphone indication was also provided.

This instrument gave very reliable service. It was slightly less portable than the ratemeter type PRM200 because of the long cable, but for the same reason it was somewhat more flexible in use. Owing to the high background count, the headphone indication was not of much use in prospecting. The main disadvantage of the instrument was one which the designer could not have anticipated. Considerable difficulty was experienced in maintaining supplies of batteries. At the date in question, hearing-aid batteries were not widely used in Australia, and most supplies were manufactured overseas. As each instrument contained over 50 batteries it was impossible to obtain sufficient stocks from the ordinary suppliers. However, the demand was not sufficient to induce local manufacturers to provide continuous supplies. Manufacturers would supply only large orders at rather infrequent intervals. The shelf life of batteries of this type is short, particularly under the climatic conditions of Rum Jungle, so that obtaining batteries in this way involved a large wastage.

Some use was also made of the Philips Pocket Monitor type P4010. This, as the name implies, was a very small instrument, with correspondingly low sensitivity. It was, in fact, originally designed with possible civil defence applications in mind. Its sensitivity was so low that it was practically useless for surface prospecting work, but, for the same reason, allied to its small size, it found some application in testing working faces underground.

Several portable counters of American manufacture were tried at different times. Their performance was not superior to that of the instruments previously described and in view of the difficulty of servicing, referred to earlier, it was considered that there would be no advantage in using them. During the period of the Bureau's operations at Rum Jungle, the first models of portable scintillation detector became available. However, it was found that none of these could withstand the climatic conditions. Models of satisfactory performance only became available at a later date.

Techniques for surface investigations

Ideally, surface investigations should proceed in three stages. The first is a general inspection of the rocks in an area to search for indications of high radioactivity. If such indications are found, the second stage consists of measurements along roughly spaced traverses, to determine the strike and general distribution of the high radioactivity. The third stage involves measurements over a surveyed grid in areas of particular interest.

The first-stage work generally involved testing areas selected on geological grounds, such as fault or shear zones, particular geological formations, contact zones, etc. The results were communicated directly to the geologists, and generally no plans were drawn. The second stage was generally confined to areas in which it was known that detailed work would be warranted, and was merely a preliminary investigation, to determine the area to be covered, and the best disposition of the survey grid. Generally plans were not prepared.

The third stage consisted of detailed surveys. A baseline was laid out by chaining, and traverses laid out at right angles to it. Distances along traverses were chained where time permitted; in other cases, they were measured by pacing. Station spacing along traverses was not greater than 25 feet. Spacings as small as five feet were used in areas of complex geology. Readings at stations were reduced to multiples of background count. These were plotted as profiles and smoothed where it appeared desirable. A plan was then prepared showing contours of radioactivity expressed in multiples of background count. Attempts were made to close the twice-background contour, but this was not always possible. However, care was taken to close all contours of three-or-more-times background. Examples of such contour plans are shown in Plates 2 to 4.

Where radioactive anomalies occurred over soil cover, tests were made to determine whether costeaning was warranted. Holes were drilled using a manually-operated post-hole digger. If the hole was less than seven feet deep the probe of the ratemeter type 1011 was lowered into it and the radioactivity was tested at various depths. If the hole was greater than seven feet deep, cuttings from various depths were tested for radioactivity. If the radioactivity increased with depth, it was considered that it might arise from radioactive rocks at depth, and that investigation by costeaning was warranted. If the radioactivity remained constant, or, as happened in the great majority of cases, decreased with increasing depth, no further investigation was undertaken.

Techniques for testing of workings

Testing of workings was carried on almost continuously. This involved detailed measurement of the radioactivity over working faces to assist in geological mapping and to guide sampling. The amount of detail varied according to the nature of the workings. In shafts and winzes, the strike faces were examined in detail, and the bedding faces checked for any abnormal radioactivity. Examinations were made of the walls and backs in crosscuts and of the working faces in drives. In costeans a single profile was measured along the centre of the floor.

In underground workings, the ratemeter type 1011B was generally used, as it was better suited to conditions underground than the ratemeter type PRM200 because it was effectively sealed. The method of measurement was to take profiles across the face at uniform heights above the floor, with the probe held horizontally against the face. Readings were taken at probe-length intervals. The vertical spacing of profiles ranged from $1\frac{1}{2}$ to 5 feet, depending on the degree of radioactivity observed. Readings were plotted in multiples of background count and a contour plan of the radioactivity of the face was drawn.

The significance of such contour plans is not easy to assess. They are a valuable aid to geological mapping in zones of weak radioactivity, but in or near the ore zone their value is much more debatable. In this region, which is not actually exposed at the face, but near enough to affect the instrument reading considerably, there may be a large amount of material emitting strong gamma radiation. Also, contamination by blast dust was sometimes a source of error though, as it was usual to inspect working faces, it was considered that this could generally be disregarded. In general, the contour plan had to be checked by assaying samples from different parts of the face, before it could be relied on. Examples of such contour plans are shown on Plates 5 and 6.

In costeans readings were taken along a traverse along the centre of the floor. Location pegs were put in at each end of these traverses, and these pegs were tied in to the general survey of the area. Positions of readings were located on a linen tape stretched between the pegs. To minimise contamination, the floor was cleaned before readings were taken. The results were plotted as profiles in multiples of background count.

The significance of these profiles depended on the nature of the costean. In narrow hand-cut costeans, where the material removed was stacked along the edges, the readings were so much influenced by radioactive material in the walls and stacked on the surface, that the profile gave only a general indication of the distribution of radio-activity on the floor. Wider costeans were cut with a bulldozer, and the material shifted was removed beyond the ends of the costean. In such cases, the information obtained was much more reliable.

Some attempts were made to obtain more detailed information by taking measurements along each edge of the floors of the wider costeans, but the surfaces were so irregular that the information was of little value.

Examples of profiles along costeans are shown on Plates 7 and 8.

3. BORE LOGGING

Radiometric logging of drill holes was an important part of the investigation of the Rum Jungle deposits. The main purpose of such logging was to obtain a full picture of the distribution of radioactivity along the hole without the necessity of complete assaying of the core. Assaying could be confined to those portions of the core that contained uranium in concentrations approaching ore grade. It was particularly valuable at Rum Jungle, as, owing to the nature of the ground, high core-recovery was difficult to obtain without taking special precautions which considerably increased the cost of the drilling.

Instruments

The design of equipment for radiometric logging of boreholes of small diameter is a very difficult matter. The various problems involved have been discussed in some detail by Daly (in press).

At the date in question, radiometric bore-logging equipment was not available commercially, so that equipment had to be designed and made locally. The equipment was manufactured by Austronic Engineering Laboratories to a specification prepared by the Bureau. The essential points of the specification were:

(a) the equipment had to be used in EX holes and so the outside diameter of the probe could not exceed $1\frac{3}{8}$ inches,

(b) the equipment had to be capable of use in horizontal holes and so some form of rigid connexion with the face had to be available.

As the diameter of the probe was so small, it was impossible for the probe to contain the high-voltage supply for the Geiger tube or any device for coupling the impedance of the Geiger tube to the cable.

It was decided that the probe would contain only the Geiger tube. This meant that the high voltage had to be generated in the ratemeter section and transmitted to the Geiger tube along the cable. As the cable also had to transmit the pulses from the Geiger tube to the ratemeter, its capacity had to be as low as possible. The construction of a special cable could not be considered and it was impossible to obtain a standard cable with adequate mechanical strength and insulation resistance and sufficiently low capacity. To overcome this difficulty the manufacturer suggested that, as push-rods had to be used in some holes, they should be made an integral part of the design, so that they must be used in all holes. By making the push-rods of metal, they could be used as a conducting connexion to the probe, as well as providing adequate mechanical strength; by careful design of the input circuit to the ratemeter it was possible to use in addition a readily available coaxial cable type PT11M, which had very low capacity and sufficient insulation resistance, but practically no mechanical strength. The push-rods were made of U-section phosphor-bronze channel, in six-feet lengths, and assembled with interlocking joints pinned with wire clips. The cable lay along the groove in the channel, and was thus protected to some extent. As the surface installation involved a high-voltage supply for the Geiger tube, an input amplifier, and the usual ratemeter circuits, it required more power than could be economically supplied by dry batteries, so that it was powered by a vibrator-operated power supply from a six-volt accumulator.

Considering the fact that the design was based on no previous experience, the equipment functioned remarkably well. The original mechanical design required modification in only two respects. The design of the push-rod joints was altered to eliminate a weak section, and it was found that the difficulty of sealing the probe had been seriously under-estimated. Several arrangements of increasing complexity were tried before a satisfactory seal was obtained.

The electronic portion of the equipment functioned satisfactorily. It was often used in difficult and damp conditions underground without any serious failure. The following general criticisms could be made:

(a) the fact that the push-rods had to be used in all holes made the equipment very cumbersome to use in steeply-dipping holes. However, this procedure was not without advantages. Most of the drill holes were rough, and the rigid connexion of the probe to the surface greatly facilitated entering the probe in the hole, and often enabled it to be recovered when it stuck. In vertical holes, particularly those of AX diameter or larger, the push-rods were sometimes replaced by a steel cable, and the probe allowed to enter under its own weight. However, the weight was often insufficient to allow complete logging of the hole. In fact, it was found essential in this method of logging to make a preliminary run using a dummy probe, and even with this precaution, probes were lost owing to jamming,

(b) the original cable was far from ideal. The cable consisted of a central conductor, an insulating layer, an outer conducting sheath of metal braid, and an outer PVC coating. It was necessary to the design that the potential of the outer conducting sheath should be floating with respect to earth, so that the PVC coating had to be an effective insulator. However, this coating was far too light to withstand the abrasion in the hole, and frequently failed. At a later date, cables more satisfactory in this respect were obtained, but a better cable for this purpose could easily be designed. However, it is a feature of the design of bore-logging equipment that cables of standard type must be used. Cables are manufactured on a large scale, and manufacturers will not supply small orders of cables of special design,

(c) the instrument could not be used for continuous recording.

However, these criticisms do not bear against the design of the instrument, but are mainly a consequence of the broadness of the specification, and the difficulty of reconciling the various requirements. For example, it is difficult to see how continuous recording could be compatible with the use of push-rods. It cannot be said that loggers of improved design became available later. Loggers suitable for continuous recording, but which could not be used in horizontal holes, or loggers simple in use, and employing a strong cable, but which could only be used in shallow steeply-dipping holes, have been produced, but it is not known that any later attempt has been made to produce a logger meeting such a comprehensive specification.

A logger designed to have comparable performance was produced by AERE, Harwell and one instrument was tested at Rum Jungle. The design was based on the use of a thin, but very strong, armoured cable of high quality. The probe contained the Geiger tube and high-voltage supply, and a pulse transformer for coupling the output of the Geiger tube to the cable. The instrument incorporated a well-designed winch. Push-rods were also provided. These consisted of steel tubing of the same diameter as the probe, slit longitudinally, and parted off in six-feet lengths. The lengths were assembled with 50 percent overlap and held by welded clips. The assembly of probe and push-rods thus consisted of an extremely rigid column of uniform diameter.

The mechanical design of this instrument was excellent in detail, but appeared to have taken insufficient account of practical considerations, which made it useless at Rum Jungle. The main objections were:

(a) owing to the size of the pulse transformer, the diameter of the probe could not be made less than about two inches, so that the instrument could not be used in EX or AX holes,

(b) the push-rod assembly appeared to be over-designed for rigidity. No opportunity arose of testing its performance, as holes of large enough diameter were not used. However, experience in logging showed that some flexibility was desirable in the push-rod column. It is considered that the rigidity of the Harwell design would have put great strain on the clips, and it is very doubtful that they could have supported it.

<u>Techniques</u>

Owing to the design of the logger, continuous recording was not possible. Holes were logged by taking readings with the probe held stationary in the hole for a long enough period to obtain a steady reading on the ratemeter. Readings were taken at six-inch intervals in zones of high activity and at one-foot intervals in less-interesting portions. Readings were recorded in counts per minute.

Lengths were measured along the push-rods, which were marked off in six-inch intervals for this purpose. The readings were plotted on three-decade semi-log paper, which was made up in 50-yard rolls. This method of presentation was adopted in order to allow plotting of high readings and at the same time showing adequate detail in areas of low activity. It was realised later that, owing to the geological conditions at Rum Jungle, anomalies of low amplitude were generally of very little significance. After this, readings were plotted on a linear scale as this method of plotting is somewhat more convenient and allows a more-convenient estimation of readings as multiples of background count. No attempt was made to estimate uranium content from bore logs, as the uncertainties of this process were fully realised.

Examples of bore logs are shown in Plate 9

4. ASSAYING

The fundamental methods of assaying for uranium, as for any other element, are chemical ones. However, in the case of uranium particularly, these methods are slow and laborious, and require a high degree of skill. Also any chemical process requires a properly equipped laboratory, which cannot be provided for an exploratory operation in a remote area. As against this, radiometric assay methods are rapid, well-suited to routine operations, and do not require skilled operators. They appear therefore to have considerable advantages in operations of the type undertaken at Rum Jungle.

Radiometric assay methods as developed in the Bureau's laboratories are described in detail by Daly, Urquhart, and Gibson (1956). At the time of the Bureau's operations at Rum Jungle the methods were not fully developed, but the main requirements had become clear. The following discussion is concerned mainly with the difficulties experienced, owing to the local conditions at Rum Jungle, in establishing an accurate procedure.

Instruments

Before specially designed assay equipment was obtained, various makeshift arrangements were used, involving Geiger tubes mounted in improvised holders, feeding into portable counters of various types. The samples were held in sample holders, such as tobacco-tin lids, in a standard position relative to the Geiger tube. Such arrangements are capable of only rough estimates of relative activity. It was fully realised that no arrangement involving gamma-ray measurements only is of any value in obtaining reliable estimates of uranium content.

The essential requirements for accurate radiometric determinations of uranium content are:

(a) detectors of beta and gamma radiation,

(b) standard samples of material in radioactive equilibrium, the uranium content of which has been determined by chemical methods, and

(c) methods of controllable accuracy for counting pulses.

Suitable detectors in the form of Geiger tubes with thin walls or windows, were available. The methods of using such tubes are described by Daly *et al.* (1956). Suitable standard samples were not available at the start of the radiometric investigations at Rum Jungle. Such samples must be made from primary ore to ensure radioactive equilibrium. No such material was available in Australia. Nothing could be done about this problem. During the course of operations at Rum Jungle, suitable standard samples from overseas became available, and it was only after this that reliable assays were possible. The counting equipment used was governed entirely by the available power supply; special equipment had to be designed in the early stages.

The design was conditioned by the fact that the power demands of counting equipment are too high to be economically supplied by dry batteries, and no mains power supply was available. The only alternative was a vibrator-operated supply, powered by an accumulator. This set an upper limit to the power that could be used and hence to the degree of electronic complexity that the equipment could involve. It was decided that the set could contain a high-voltage supply for the Geiger tube, a pulse-shaping stage, and a register-drive stage, but no scale-of-two circuits. It was therefore necessary to use a mechanical register of the shortest possible resolving time. The fastest available register was the LKB register of Swedish manufacture, which could count upwards of 100 random pulses per second quite reliably. The equipment was manufactured by Austronic Engineering Laboratories.

The equipment functioned extremely well. It had two disadvantages which occasionally caused some delays:

(a) although current drain had been kept to the minimum, the current required was the maximum that could be supplied by a six-volt accumulator. The batteries had to be kept fully charged and it was found that, as the batteries became older, the time for which they could supply full current became less,

(b) the mechanical registers behaved well when new. However, the short resolving time was obtained by the use of a very light movement which proved extremely difficult to adjust when it became worn. A skilled instrument maker was required and even with the utmost care the adjustment frequently proved unsatisfactory. It was found best to change the registers after a relatively short life.

When a 230-V AC power supply became available, ordinary mains-operated power supplies and scaling counters could be used. Apart from difficulties due to the inefficient nature of the power supply, these functioned as expected, except for constant trouble due to climatic conditions. It had been anticipated that difficulties due to this cause might be experienced, but the extreme sensitivity of scaling circuits to high temperatures had not been appreciated. As mentioned previously, the effect of humidity is unimportant, as it is inhibited by the power dissipated in the equipment. However, the rise in temperature due to this dissipation of power makes the effect of ambient temperature more serious. It was found that in the ambient temperatures experienced at Rum Jungle, scaling equipment was very often unserviceable. Attempts were made to remedy the situation by the installation of a package-type room air-conditioner in the assay room, but very little improvement was obtained, possibly owing to the fact that the room had not been designed or constructed for efficient air-conditioning. The only means of obtaining continuous assaying under tropical conditions is to provide a properly designed and fully air-conditioned assay laboratory.

Techniques

The methods of determining uranium content, checking the degree of radioactive equilibrium, and distinguishing between uranium and thorium have been described in detail by Daly et al. (1956). These methods were used at Rum Jungle. A check on overall accuracy was provided by radiometric assays of duplicate samples at the Bureau's laboratories at Footscray, Melbourne and by occasional checks by chemical assay both within and outside the Bureau. The degree of accuracy maintained was quite satisfactory.

The methods of recording assays and organising the collection of samples and the flow through the assay room contained no features calling for special comment.

5. MISCELLANEOUS INVESTIGATIONS

Numerous minor radiometric investigations were undertaken from time to time. Two of these call for some discussion. Both of them involved the problem of obtaining approximate values of uranium content from measurements of gamma-ray activity only.

Ore sorting

The problem of distinguishing ore from waste by radioactive measurements has received attention overseas. However, most of the available published information concerned the separation of high-grade ore from waste. Instruments have been described which automatically sort coarsely broken ore from waste using radioactive measurements. This is really equivalent to a hand-picking process. In large-scale mining of a deposit containing disseminated mineralisation, such processes cannot be used. Such a deposit is generally bounded by assay walls. The ore must be broken more finely, and sorting of individual lumps is impossible. Some form of bulk sorting is necessary.

As the Bureau was not actively mining the deposit, no attempt was made to design complete sorting facilities. The purpose of the tests made was to obtain basic information on count rates against grade of ore, which could be used in the design of equipment for continuous operation when mining was undertaken. It was decided that the ore would be sorted most conveniently in trucks at the shaft head. Large Geiger tubes were mounted in various positions at the shaft head and readings were taken on filled trucks of ore of various grades. The ore trucks were grab-sampled and the uranium content of the ore determined by radiometric assay. As mains power was available at the shaft head, the readings were taken on a conventional laboratory ratemeter.

The results do not call for detailed discussion here, as the design of the final equipment was not the responsibility of the Bureau. However, the results made very clear the extreme difficulty of maintaining accuracy in an operation of this kind. A major difficulty arises in secondary ore, as only gamma-ray measurements are possible, and these are seriously affected by disturbance of radioactive equilibrium. In addition, equally serious errors can arise owing to the disposition of ore of various grades in the truck. It appears that accuracy can only be maintained by stringent control of the disposition of the ore at every stage of its progress from the face to the mill. The difficulties are greatly increased if the ore is handled more than once. Practically all ore at Rum Jungle was stockpiled, so that it had to be handled at least twice. It was necessary to control the selection of ore at the face, the disposition on the dump, and the final selection from the dump. With this degree of control, the radioactive sorter merely becomes a final check, and it is doubtful if the expense of it is warranted.

Testing of drummed ore

During the course of the Bureau's operations, it was decided to send parcels of development ore overseas for treatment tests. It was desired to sort the ore into the following grades:

(a) mullock, containing less than 0.1 percent U_3O_8,

(b) retainable grade, containing between 0.1 and 0.5 percent U_3O_8, and

(c) exportable grade, containing more than 0.5 percent U_3O_8.

As the ore had been dumped without control, it was impossible to sort the ore on the dump, so that it had to be tested after packing into drums. This was done by taking a number of readings around the curved surface of each drum, using a portable ratemeter type 1011, with the probe held parallel to the axis of the drum. One particular instrument was retained for this work exclusively. In order to standardise the measurements, a large number of readings was taken on each of several drums, which were then carefully grab sampled, and the uranium content determined by radiometric assay. Constant checks on background count were necessary, as the background was affected by spillage of ore. It was considered that readings indicating a uranium content greater than one percent were likely to be unreliable, so that drums showing such readings were classified at one percent.

Precise checks on accuracy were unobtainable, but the following figures suggest that a reasonable degree was achieved.

The number of drums of exportable grade tested to the end of 1952 was as follows:

an unknown number of small drums, at four drums to the ton, estimated to contain more than 0.5 percent U_3O_8 (these were tested before it was decided to keep a record of grade)

397 small drums at four drums to the ton, estimated to contain 0.9 percent U_3O_8,

243 large drums at $2\frac{1}{2}$ drums to the ton, estimated to contain at least 1.0 percent U_3O_8, and

156 large drums at $2\frac{1}{2}$ drums to the ton, estimated to contain 0.6 percent U_3O_8.

The first shipment overseas consisted of most, and possibly all, of these drums. The recipient's record of the shipment was 275 dry tons, containing 1.03 percent U_3O_8.

6. REFERENCES

DALY, J.	-	Radiometric methods. *In* Volume on exploration and mining geology. *Aust. Inst. Min. Metall.* (in press)
DALY, J., HORVATH, J., and TATE, K.H.	1962	Browns deposit geophysical survey, NT 1957. *Bur. Min. Resour. Aust. Rec.* 1962/146 (unpubl.)
DALY, J., URQUHART, D.F., and GIBSON, M.R.	1956	Assaying of radioactive rocks and ores. *Bur. Min. Resour. Aust. Bull.* 31

APPENDIX 1

GEOPHYSICAL INVESTIGATIONS AT RUM JUNGLE, NT, DURING 1949

by J. Daly.

1. INTRODUCTION

This report describes radioactive investigations performed during 1949 by officers of the Geophysical Branch of the Bureau in the Rum Jungle area. The circumstances of the discovery of this deposit are described in the geological report by Ward (1950).

2. TECHNICAL DETAILS

After preliminary tests, work of the following types was undertaken:

(a) detailed traversing over an area around the uranium occurrence (now known as Whites), involving readings at 25-feet intervals along traverses 25 feet apart,

(b) testing of geological formations generally in the Rum Jungle area, particularly in the neighbourhood of old workings.

These tests were performed using portable Geiger-Muller counters of the ratemeter type, manufactured by Austronic Engineering Laboratories to specifications prepared by the Bureau. The performance of these instruments has been found very satisfactory.

3. RESULTS

Detailed work over the uranium find

The results of this work are shown in Plates 10 and 11 attached. Plate 10 shows the gamma-ray profiles obtained over an area surrounding the uranium occurrence. Ratemeter readings have been reduced to counts per minute, using the scale factor supplied by the manufacturer. Plate 11 is a plan of the area, showing geological boundaries (Ward, 1950) and contours of radioactivity. These contours have been drawn from the dotted curves of Plate 10 local irregularities having been smoothed out. Contours have been drawn at 100, 150, and 200 counts per minute. These figures possess only relative significance, but, as the background of the instrument used is 60 counts per minute, all the above readings indicate significant radioactivity.

General prospecting in the Rum Jungle area

An examination was made of the main Rum Jungle copper workings, (now known as Browns), which lie about one mile west of the uranium find. They consist of several shallow shafts and costeans, lying roughly east-west along a line about ½ mile long. The deepest shaft showed water at about 20 feet, but from the dimensions of the spoil heap the depth of the shaft could not have been much more than 30 feet. Readings were taken on all dumps and accessible workings, and over the surrounding area, but no readings above background were encountered, except on the dump surrounding the deep shaft. Here, readings of up to 600 counts per minute were obtained. Because no evidence of activity was obtained away from the dump, it was thought that the effect may be due to radioactive minerals which had been encountered at depth in the shaft. To test this, the Geiger counter was lowered to water level on a rope, but no evidence of increased activity was observed. Satisfactory tests would be possible only if the shaft were dry.

J. White, the discoverer of the uranium deposit, pointed out small copper workings some miles west of the above mentioned areas (now known as Mount Fitch). These workings were reported to have contained some cobalt. Two sets of workings were examined. One consisted of a shallow shaft on the edge of an outcrop of manganese-stained 'gossan' (the term 'gossan' is used purely descriptively. Accurate description of the rock must await the results of laboratory tests). Slight activity was observed on the dump, readings of 150 counts per minute being recorded. No activity was observed on the 'gossan'.

The other workings are about ½ mile farther west, and consist of two shallow shafts on the top of a low rise. Moderate activity was observed on and around the dump, readings of 200 counts per minute being recorded. Time did not permit detailed traversing work on this occurrence, but it is obviously much smaller than the main uranium discovery.

Between the two sets of workings, there is an outcrop of 'gossan' of considerable extent. Readings of 200 counts per minute were recorded over the 'gossan', and also over a fairly large area of the surrounding soil.

Other outcrops of 'gossan' showing similar activity were located farther east.

4. CONCLUSIONS AND RECOMMENDATIONS

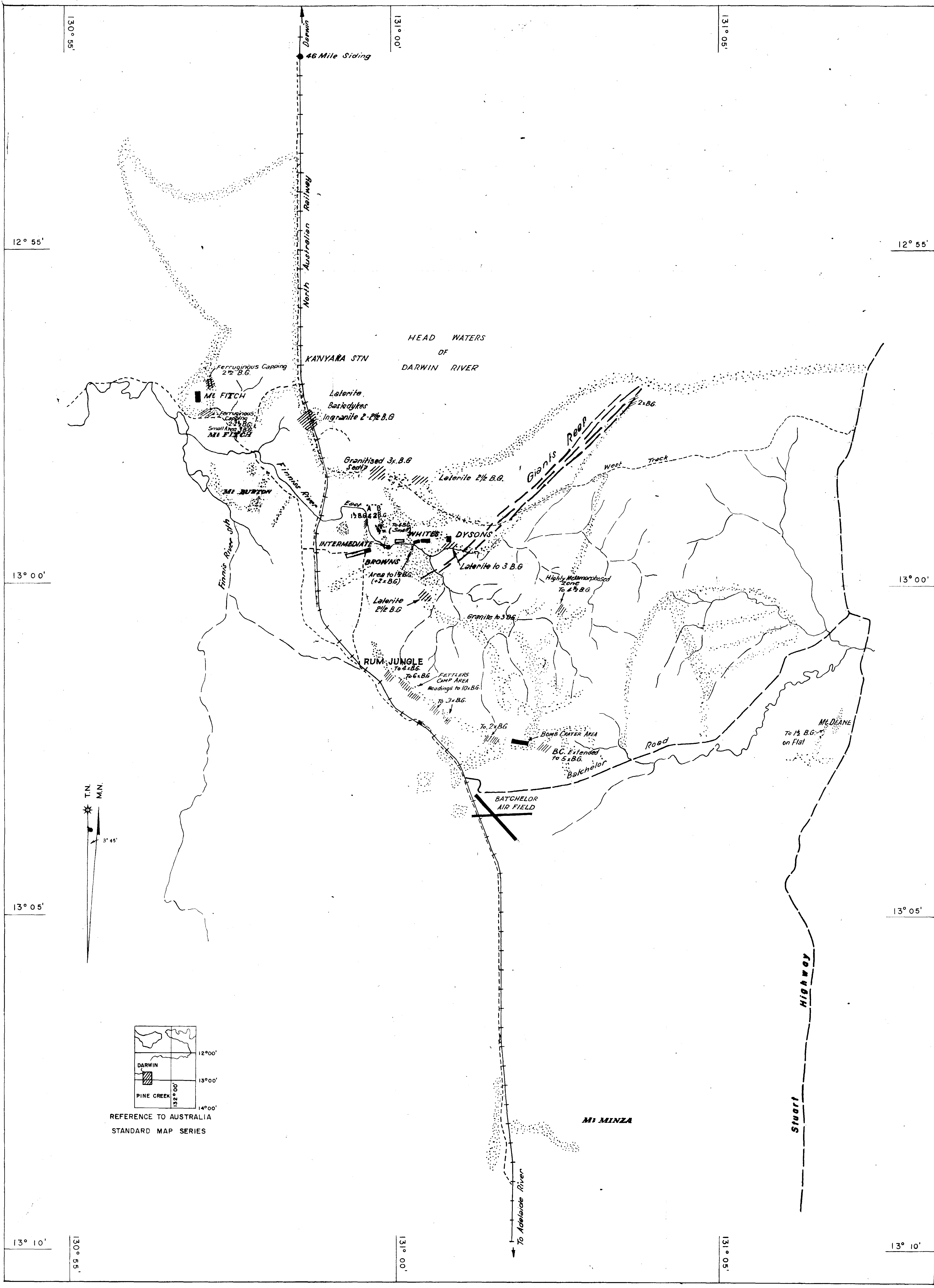
The importance to be attached to contours of radioactivity such as those shown on Plate 11 is very difficult to assess on theoretical grounds.

The only possible method of interpretation is to test preliminary results as thoroughly as possible, in the hope of obtaining some correlation that can be applied to further work in the same area. The results of Plate 11 show an area of high activity, with a definite strike, together with another possible area lying parallel to the main one and a little to the north. Testing should include costeans across each of these. There is also an area of slight radioactivity to the south, coinciding roughly with the travertine outcrop. Some testing of this anomaly would be desirable; if the results of this test are positive, the survey could well be extended to the south and east.

The significance of the radioactive 'gossan' is discussed by Ward (1950). It appears that such 'gossan' may be rather widely distributed. A Geiger survey to map their distribution over a fairly large area would probably be of great service in the geological survey of the area. Attention is also drawn to the anomaly observed on the dump of the main copper shaft, in view of the possibility of this being due to material obtained from the bottom of the shaft. Testing should include cleaning out this shaft and, if an increase in activity is observed at the bottom, sinking and driving further.

5. REFERENCE

WARD, H.J., 1950 The occurrence of radioactive minerals in the vicinity of Rum Jungle railway siding, NT, Bur. Min. Resour. Aust. Rec. 1950/14 (unpubl.)



LEGEND

Regional work

Roughly traversed

Traversed in detail

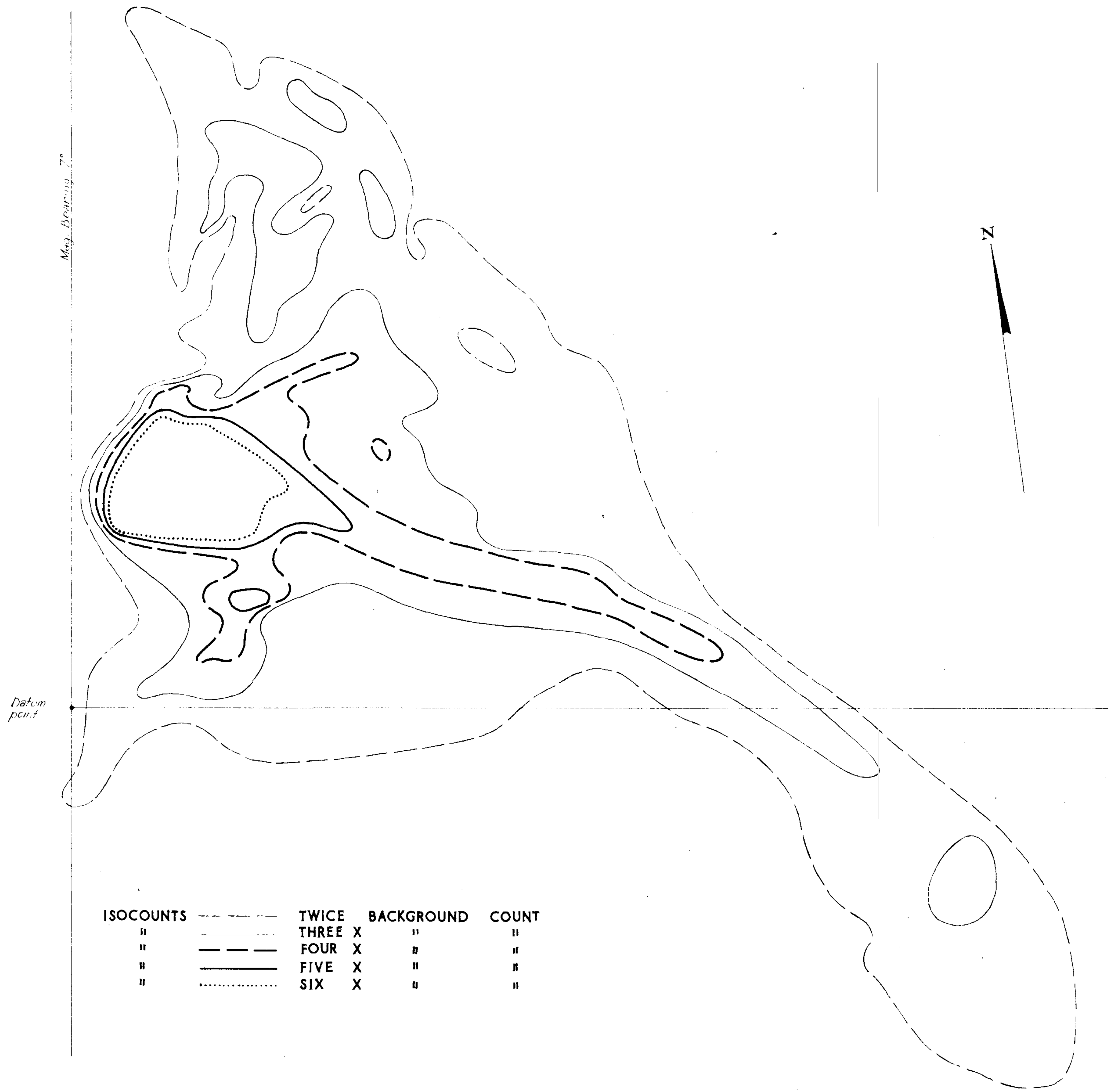
SCALE

1 0 1 2 3 Miles

GEOPHYSICAL SURVEY AT RUM JUNGLE, N T

LOCALITY MAP

PLATE 2



SCALE

100 0 100 200 FEET

GEOPHYSICAL SURVEY AT RUM JUNGLE, N T

DYSON S PROSPECT

PLAN SHOWING

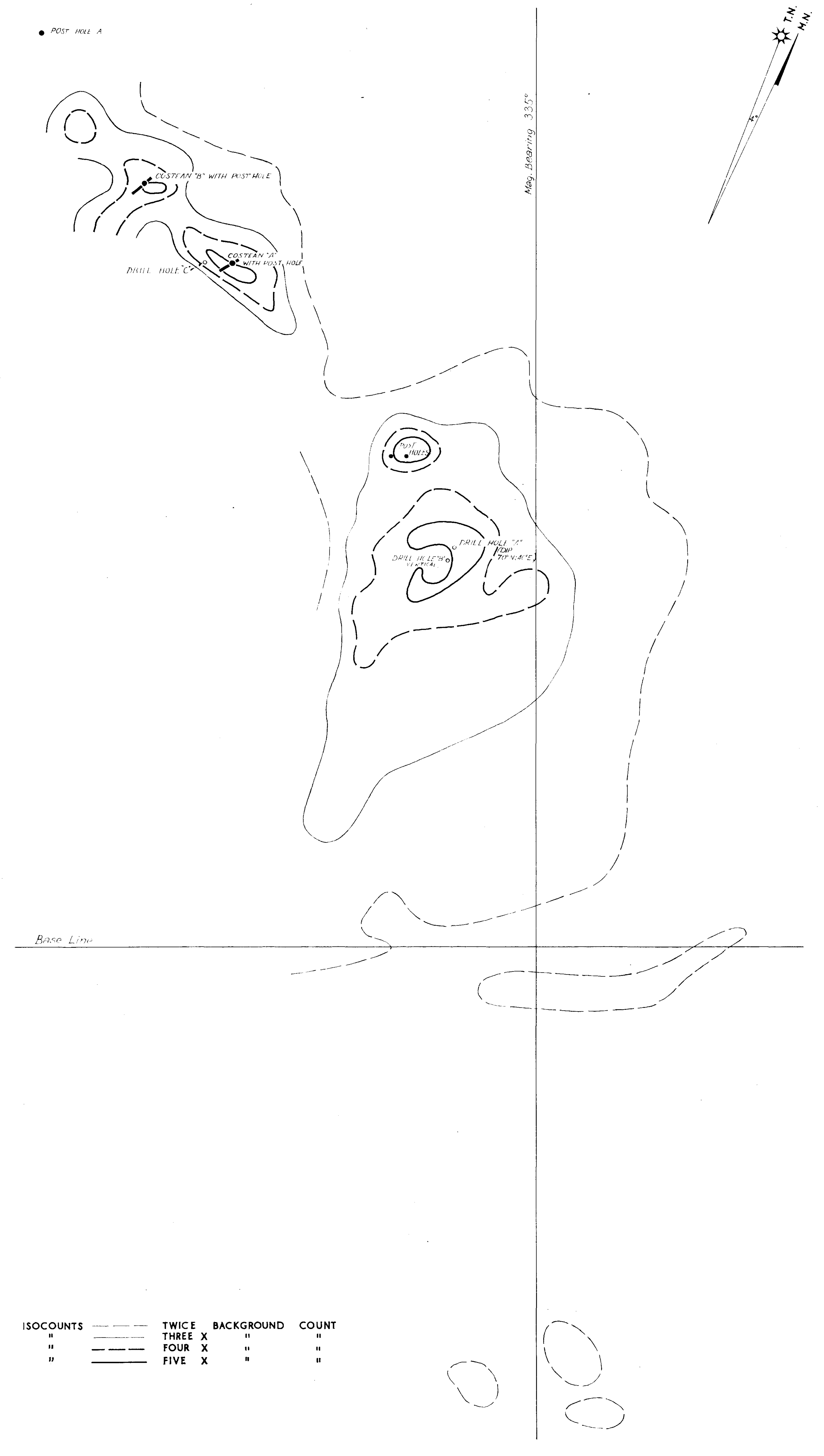
ISOCOUNTS OF GAMMA-RAY INTENSITY

D52/B4-13

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

To Accompany Record No. 1964/65

PLATE 3



SCALE

100 0 100 200 FEET

GEOPHYSICAL SURVEY AT RUM JUNGLE, N T

MT FITCH AREA

ISOCOUNTS OF GAMMA-RAY INTENSITY

D 52/B4-14

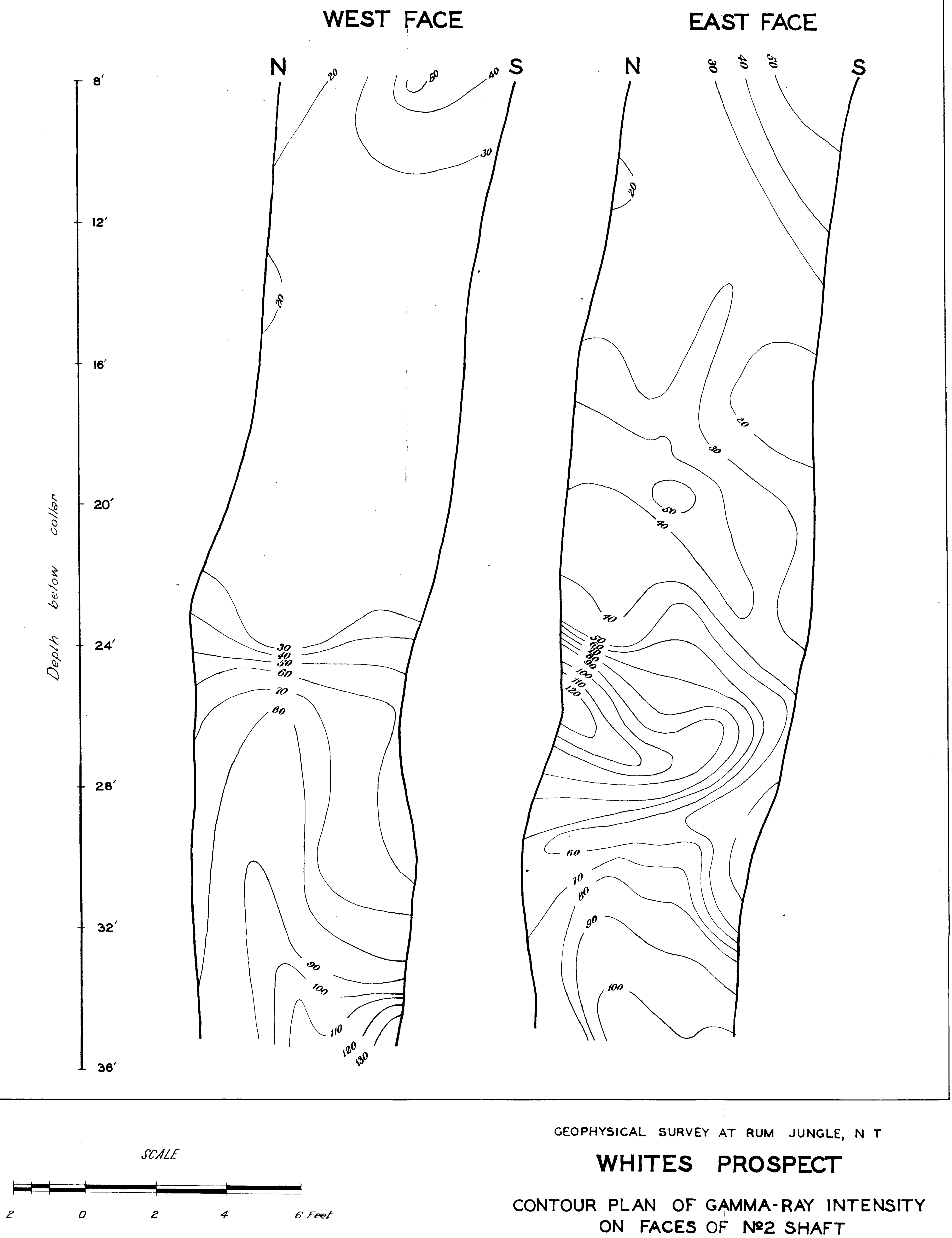
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

PLATE 3

To Accompany Record No. 1964/65

To Accompany Record No.1964/65

PLATE 5



GEOPHYSICAL SURVEY AT RUM JUNGLE, N T

WHITES PROSPECT

CONTOUR PLAN OF GAMMA-RAY INTENSITY ON FACES OF Nº2 SHAFT

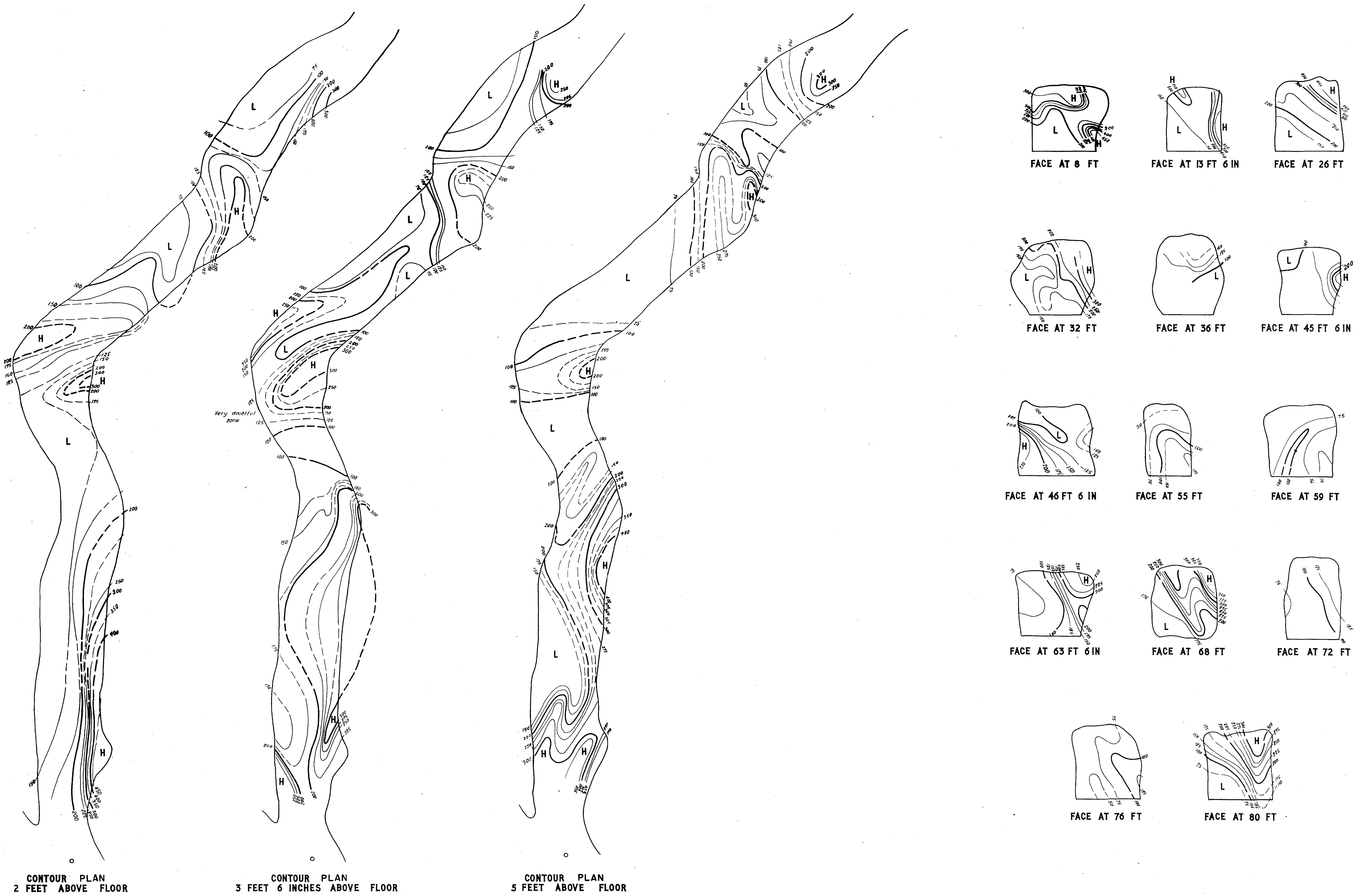
CONTOURS EXPRESSED AS "TIMES BACKGROUND COUNT" APPROX

D52/B4-16

Geophysical Branch, Bureau of Mineral Resources Geology & Geophysics

To Accompany Record No.1964/65

PLATE 6



SCALE

5 0 5 10 15 20 25 FEET

FACE – DIAGRAMS AND DRIVE – OUTLINE OBTAINED FROM GEOLOGICAL BRANCH

GEOPHYSICAL SURVEY AT RUM JUNGLE, N T

WHITES AREA
RADIOMETRIC CONTOURS

OF No. 4 FOOTWALL DRIVE

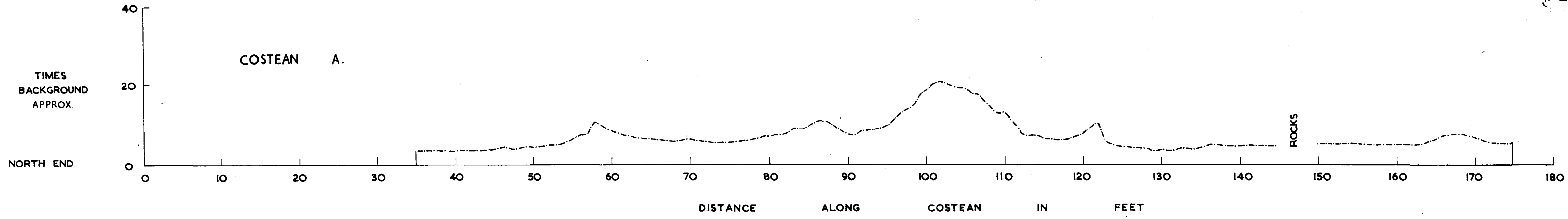
CONTOURS BEING "TIMES NORMAL BACKGROUND"
USING RATEMETER TYPE 1011 FITTED WITH GM5C TUBES

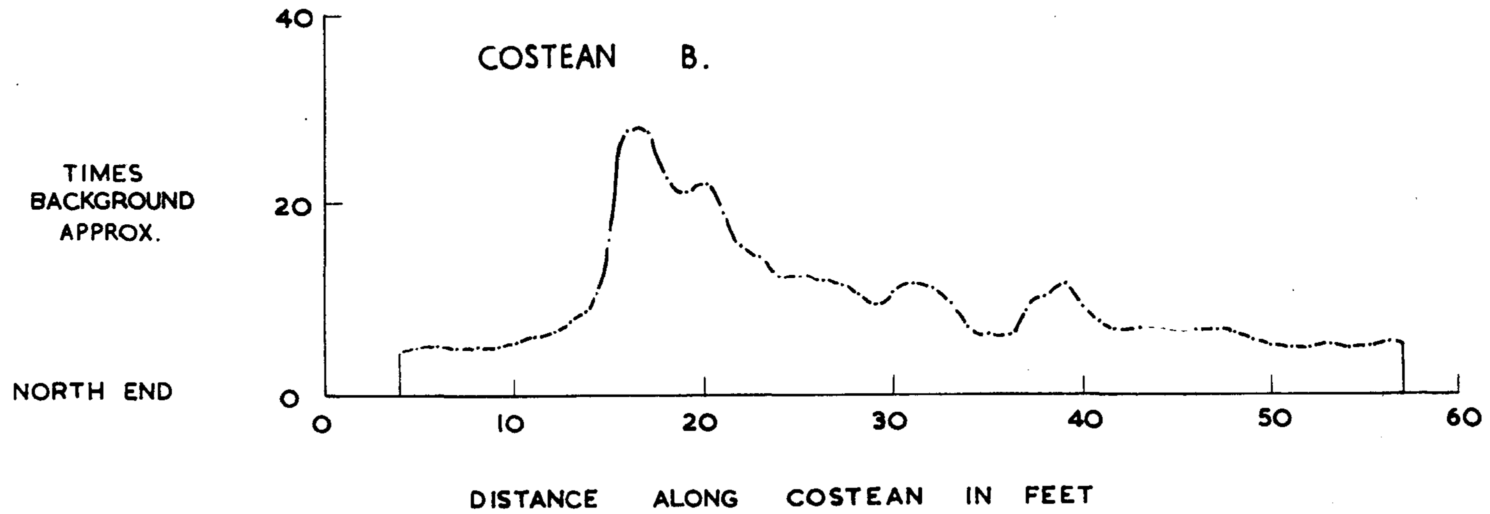
TO ACCOMPANY RECORD No. 1964 / 65

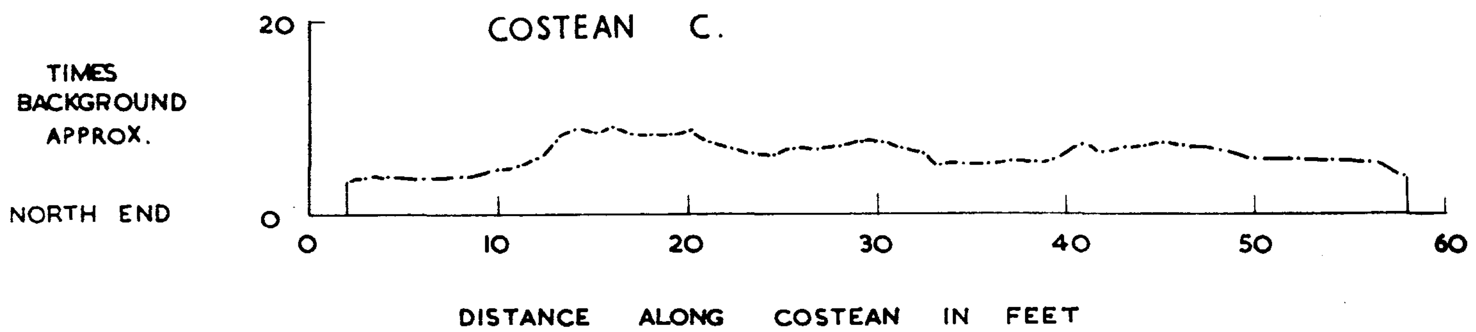
Geophysical Branch, Bureau of Mineral Resources, Geology and Geophysics

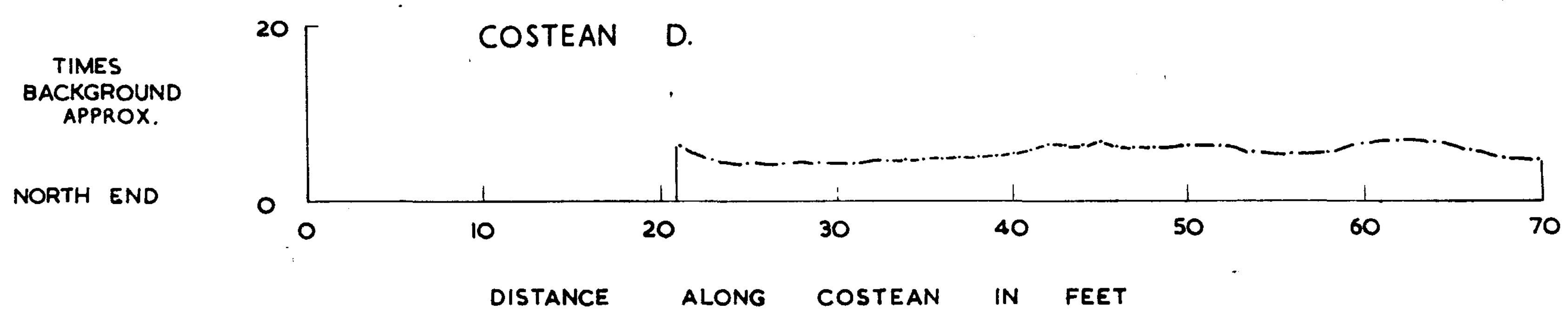
D 52 / B 4-17

PLATE 7









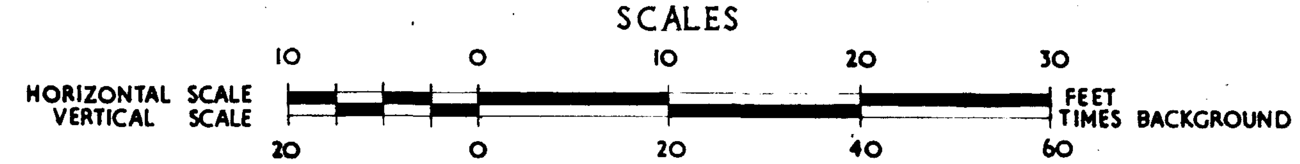
GEOPHYSICAL SURVEY AT RUM JUNGLE NT

WHITES EXTENDED PROSPECT

RADIOMETRIC SURVEY OF COSTEANS

PROFILES OF GAMMA-RAY INTENSITY

SCALES

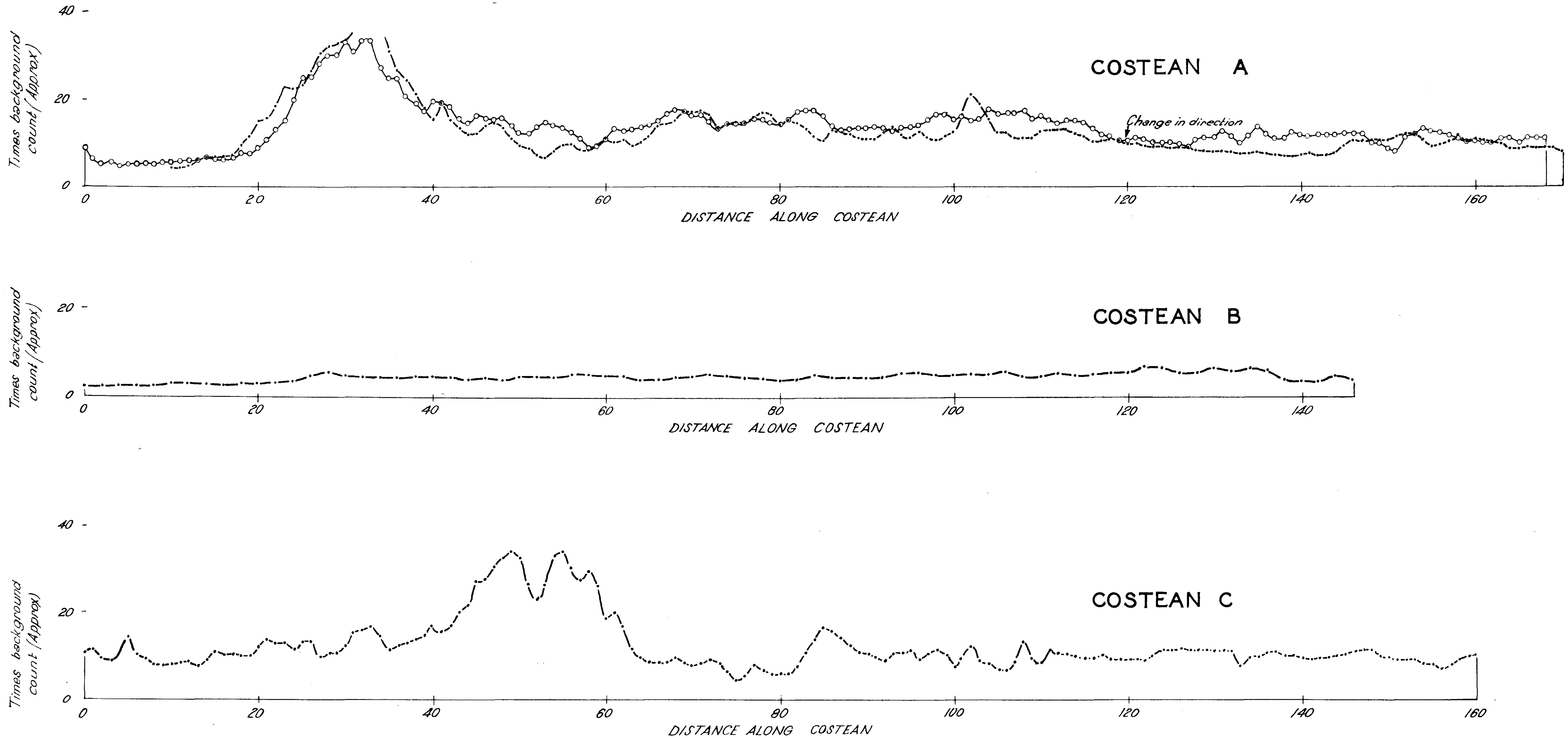


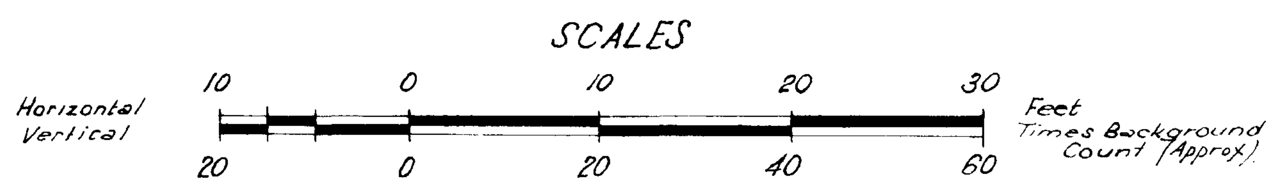
NOTE:

DISTANCES ARE MEASURED FROM MARKER PEGS AT NORTH ENDS OF COSTEANS

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS D52/B4-18
TO ACCOMPANY RECORD No 1964/65

PLATE 8





LEGEND FOR COSTEAN "A"

-.-.- Northside of Costean

o-o-o Southside of Costean

GEOPHYSICAL SURVEY AT RUM JUNGLE, N T

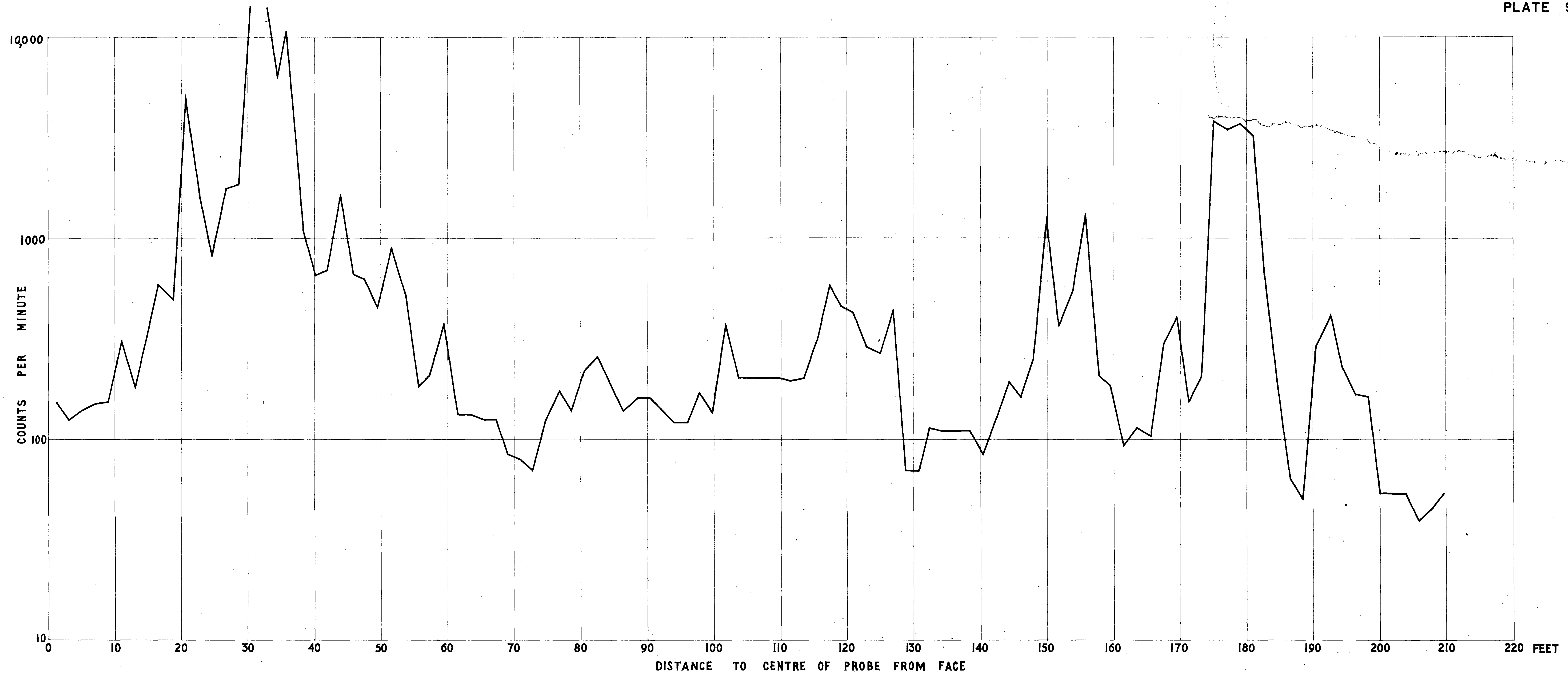
DYSONS PROSPECT

RADIOMETRIC SURVEY OF BULLDOZED COSTEANS

PROFILES SHOWING RELATIVE GAMMA-RAY INTENSITY

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS D54/B 4-19

TO ACCOMPANY RECORD No 1964/65



SCALE

10 0 10 20 FEET

GEOPHYSICAL SURVEY AT RUM JUNGLE, N T

WHITES AREA

RADIOMETRIC LOG.

UNDERGROUND DIAMOND DRILL HOLE No 4

PLATE 10

GEOPHYSICAL SURVEY AT RUM JUNGLE, NT
WHITES URANIUM DEPOSIT
GAMMA – RAY PROFILES

TO ACCOMPANY RECORD No 1964 / 66 GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

D52/B4-22

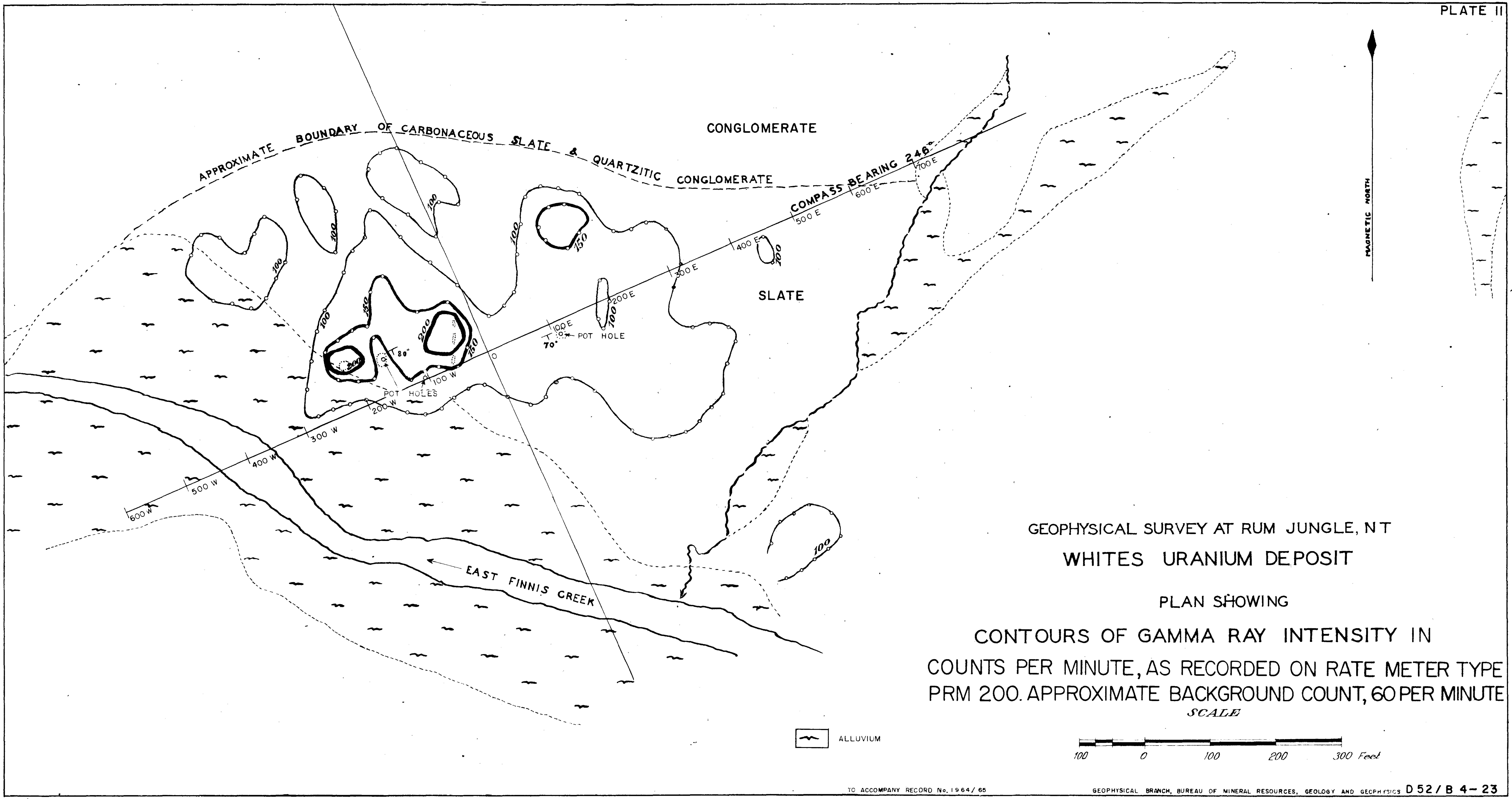


PLATE II
MAGNETIC NORTH
CONGLOMERATE
APPROXIMATE BOUNDARY OF CARBONACEOUS SLATE & QUARTZITIC CONGLOMERATE
COMPASS BEARING 246°
SLATE
POT HOLE
POT HOLES
EAST FINNIS CREEK
600 W
500 W
400 W
300 W
200 W
100 W
0
100 E
200 E
300 E
400 E
500 E
600 E
700 E
100
150
200
70°
80°
ALLUVIUM
GEOPHYSICAL SURVEY AT RUM JUNGLE, N T
WHITES URANIUM DEPOSIT
PLAN SHOWING
CONTOURS OF GAMMA RAY INTENSITY IN
COUNTS PER MINUTE, AS RECORDED ON RATE METER TYPE
PRM 200. APPROXIMATE BACKGROUND COUNT, 60 PER MINUTE
SCALE
100 0 100 200 300 Feet
TO ACCOMPANY RECORD No. 1964/65
GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS D52/B4-23