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RECORD No. 1962/27

RUM JUNGLE DISTRICT, NORTHERN TERRITORY, INTRODUCTORY REPORT ON GEOPHYSICAL SURVEYS 1960-61

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SUMMARY

Test surveys over the Rum Jungle Creek and Rum Jungle Creek South prospects have shown that a strong electromagnetic anomaly, apparently due to a wide conducting body, is present close to the Rum Jungle Creek South orebody. The present Record refers to the results of further surveys using electromagnetic methods over several other uranium prospects in the Rum Jungle area.

The methods used are described in detail, and an attempt is made to obtain a basis for the interpretation of electromagnetic anomalies.

As the results will be described in detail in subsequent Records, they are discussed only in general. The salient features are:

(a) a line of strong anomalies, due to a wide conductor, extends south from the Rum Jungle Creek South prospect to the Batchelor Laterites area, then turns north and continues to the Power Line area. It is considered that this is an important target, which should be tested for uranium minerals.

(b) in Area 55, Area 55 West, and the Dolerite Ridge and West Finniss area, strong anomalies due to narrow conducting bodies were observed. It is recommended that the survey should be extended to delineate these anomalies completely. They are important targets for testing for uranium and base metals.

1. INTRODUCTION

The uranium orebodies already mined in the Rum Jungle area were located in the first instance by the discovery of outcrops containing uranium minerals. Subsequent geological mapping showed that the beds containing these deposits, which could thus be considered favourable for the occurrence of other minerals, occur over a considerable area, but are mainly covered by soil and laterite. Prospecting these beds for uranium deposits has been found difficult. The obvious method, mapping surface radioactivity and testing areas showing radioactivity higher than normal by drilling, has only limited value. Areas showing radioactivity more intense than normal are numerous; testing of several such areas has proved that the extra radioactivity has little or no connexion with orebodies. The application of geophysical methods other than the use of simple radiation detectors was therefore considered.

Owing to the nature of most uranium minerals, it was thought most unlikely that the presence of uranium would cause any concealed deposit to possess particular physical properties that would make it amenable to detection by geophysical methods. However, there was some evidence that an indirect method of approach might be useful. In the known deposits, the uranium was fairly closely associated with sulphide minerals.

Surveys in several areas have shown that sulphide minerals are readily detectable by electromagnetic methods. It was therefore suggested that strong electromagnetic anomalies might indicate an area especially favourable for the presence of uranium minerals.

As a preliminary test of this suggestion, a survey using mainly electromagnetic methods was made over the Rum Jungle Creek area, in which a uranium orebody of commercial grade had been proved by drilling. The results of the survey are described by Daly and Rowston (1962). The survey showed that there were strong electromagnetic anomalies close to the orebody. The test was therefore successful, in that drilling in the neighbourhood of the strongest electromagnetic anomalies would have located the orebody immediately. Following this, similar surveys were made in 1960-61 over other areas selected by the geologists of Territory Enterprises Ltd.

The results of these surveys will be presented in separate reports, on the following areas:

Rum Jungle Creek South to Castlemaine anomaly

Batchelor Laterites

Power Line area

Flynns area

Area 55 West

Area 55

Dolerite Ridge area

Mount Fitch North

West Finnis area

The positions of the various areas are shown on Plate 1; the south-eastern group of areas (around Castlemaine Hill) are also shown in greater detail on Plate 2.

The reports on individual areas will discuss the nature of the anomalies recorded, and nominate specific drilling targets. The purpose of the present Record is to provide a general introduction to the series of detailed reports, including details of the methods used and the basis of interpretation adopted, and to discuss the results in a general way.

2. NOTE ON MAGNETIC ANOMALIES

Aeromagnetic surveys have shown that the Rum Jungle granite is surrounded by a ring of magnetic anomalies, which have been proved by drilling to be due to amphibolite. The anomalies are not continuous, and they range in strength from weak to very strong. Testing has shown that the magnetic susceptibility of the amphibolite varies between very wide limits. Some of it may be completely non-magnetic, and therefore the absence of magnetic anomalies does not indicate the absence of amphibolite.

When searching for a hypothesis to guide the application of geophysical methods, it was noticed that the known mineral deposits, and certain other areas showing strong electromagnetic anomalies, occur close to magnetic portions of the amphibolite, as shown by the presence of magnetic anomalies. In general, the anomalies were strong, though in one case (Rum Jungle Creek) the magnetic anomaly was weak and indefinite. It was considered that this association might provide a criterion for selecting areas for examination, at least on a reconnaissance scale. The hypothesis as originally proposed, contained two parts :

(1) Areas of Rum Jungle slates that are close to magnetic anomalies are most likely to contain bodies capable of causing strong electromagnetic anomalies.

(2) Areas in which strong electromagnetic anomalies occur are most likely to contain uranium deposits of economic value.

The first part has not been made use of in selecting the areas covered by surveys in question in the present Record, so its value has not been tested. However, there are considerable areas around the Rum Jungle granite in which tests would be possible. It is hoped that such tests may be made at a later date.

3. GEOPHYSICAL METHODS USED

Electromagnetic methods were used on all surveys. Some use was also made of the self-potential and magnetic methods. Notes on the principles of the various methods are given below. Routine radiometric measurements were made on all surveys, but they contained no features that call for detailed discussion.

Electromagnetic methods

These methods involve the application of an electromagnetic field to the ground. The field at any point is determined by the position of the point with reference to the source of the field, and the electrical properties of the ground. If the ground is electrically homogeneous, the distribution of the field can be calculated. In general, its intensity decreases steadily with increasing distance from the source. However, if the ground contains a particular geological body whose conductivity is significantly different from that of the surrounding rocks, the primary field will induce currents in that body. These currents will cause a secondary electromagnetic field, which will appear at the surface as an anomaly in the general field.

Two types of electromagnetic method were used, known as the Slingram and Turam methods. The Slingram method uses a primary field produced by a small horizontal coil, driven by an oscillator. The field is detected by a similar horizontal coil kept at a fixed distance from the transmitter coil. The quantities measured are the amplitude and phase of the field in the detecting coil, with reference to that in the transmitting coil. Frequencies of 500 and 1500 c/s are used. Transmitting and receiving coils are moved along the traverse at constant separation.

In the Turam method, the primary field is provided by a long cable laid horizontally on the ground, carrying a constant current supplied by a motor-driven alternator. The primary circuit may be completed either by earthing the cable at each end, or by making the cable one side of a large loop laid on the ground. In general, both of the arrays should give the same results. However, under special geological conditions, the results obtained using the earthed cable might be complicated by the effects of the return current in the ground. In order to be able to compare results obtained in different areas, it is considered preferable to use the primary loop layout wherever possible. In mountainous or heavily timbered country, however, the laying out of a loop would be a difficult and slow operation. In such circumstances, the earthed cable is more economical.

The measuring element in the Turam method consists of two horizontal coils kept a fixed distance apart. The quantities measured are amplitude ratio and phase difference of the fields in the two coils. Frequencies of 440 and 880 c/s are used.

The Slingram method is generally more suited for reconnaissance work than the Turam method, as no primary field layout is required. However, it is at a disadvantage in the following respects:

(a) to obtain accurate measurements using the Slingram method, it is necessary that transmitting and receiving coils be at the same level and their spacing accurate to 0.5 per cent. If this is not done, corrections must be made to the readings. Before the elevation corrections can be made, a levelling survey must be done; this slows up the survey, particularly in hilly country. Results of the Turam method are less sensitive to differences in level and spacing between the two coils.

(b) to keep the Slingram equipment reasonably portable, the power applied to the transmitting coil must be small. The Turam method, on the other hand, can use much greater power, and the field can penetrate the ground to a greater depth.

Self-potential method

The self-potential method uses measurements of naturally occurring electric potentials at the surface of the ground. These potentials may arise from various electrochemical processes, which are very imperfectly understood. However, it is found empirically that a body containing sulphides or graphite, and lying partly above and partly below ground water-level, is commonly associated with a characteristic potential distribution, with a negative centre approximately above the body.

An attempt has been made by Sato and Mooney (1960) to provide a theory for the generation of potentials by bodies of this type. This theory fits the facts in some cases. However, in the Bureau's experience many cases of the presence (or absence) of self-potential anomalies have been encountered which are difficult to reconcile with any simple theory.

Magnetic method

The magnetic method cannot be expected to be of any use in the direct detection of orebodies of the type expected, so it has not been generally applied. Magnetic anomalies in the Rum Jungle district are of two types:

(a) sharp irregular anomalies due to near-surface material, usually lateritic.

(b) large-scale regular anomalies, with a considerable range of amplitudes. These are due to magnetic portions of amphibolite bodies.

4. INTERPRETATION OF ELECTROMAGNETIC SURVEYS

The problem of interpreting the results of a gravity, magnetic, or electromagnetic survey may be described as an inverse potential problem. The measured quantities specify a field derived from a potential over a certain surface (which can generally be taken to be a horizontal plane). It is required to determine the distribution in space of the particular physical property in question that would cause this field.

The mathematical basis of the problem is discussed briefly by Bullard and Cooper (1948). The problem is essentially indeterminate. The method used is basically to determine a family of solutions and to restrict the admissible solutions to those that satisfy certain geological or physical requirements. Where geological knowledge justifies a strong restrictive assumption, the range of admissible solutions may be so far reduced that the indeterminacy is for practical purposes removed. In the simplest case of the potential problem, the gravitational one, solutions can be obtained by direct calculation from the observed results, using the method described by Bullard and Cooper (op. cit.). However, the method usually employed in all cases is to obtain solutions by trial and error, by comparing the fields to be expected from particular solutions with the observed field.

Either method of calculation involves, fundamentally, a boundary value problem in Laplace's equation, and the ease of solution depends critically on the complexity of the boundary conditions that the solution must satisfy. In general, the gravitational problem is soluble by approximation methods. The magnetic problem is very much more complicated by the polar nature of magnetism, but solutions having a certain degree of plausibility are frequently possible.

The electromagnetic problem is practically insoluble. The problem is basically one of calculating eddy currents, which can be solved explicitly only in a few special cases. A good discussion of the mathematics involved, including solutions of special problems, is given by Smythe (1950). However, none of the available solutions has much application to the prospecting problem, for the following reasons:

(a) the cases most easily solved are those in which the inducing field is uniform in magnitude and direction. Such a field would be produced by a source at infinite distance from the conducting body. However, in all the problems of interest in electrical prospecting, the primary field is produced from a source close to the conducting body. The potential specifying such a field is essentially a vector potential and the associated boundary conditions are very intractable.

(b) the theoretical solutions apply to part of the prospecting problem only. This problem consists of two parts: the eddy currents induced in the conducting body by the primary field must be evaluated, and the field induced by these eddy currents in the detecting coil must be calculated. Solutions given in the literature refer to the first part only.

(c) the magnitude of the currents induced in the conducting body by the primary field depends on the impedance of the material of the body. This impedance will in general be complex. Much information on the resistivity of rocks and minerals is available from laboratory measurements on samples. There is some doubt as to how far such measurements apply to geological formations _in situ_, but they are probably sufficient to specify the real part of the impedance of a geological formation to within an order of magnitude. At present there is almost no information available as to the reactive components of geological formations generally.

Some general conclusions can be drawn concerning the distribution of the field induced in the conducting body. This will depend on the distribution of the primary field in space and will also be affected by the attenuation of the primary field in the conducting body. This attenuation increases with the frequency of the field and the conductivity of the body, and has the effect that in a large body induction effects are practically confined to layers of finite thickness in those parts of the body that 'see' the source directly. The primary field for the Turam method is produced by a long horizontal cable. Neglecting the effect of finite ground conductivity, such a field is uniform along directions parallel to the cable, and has circular symmetry in vertical planes normal to the cable. The primary Slingram field is produced by a horizontal coil of small dimensions. To a first approximation, such a field is similar to that produced by a vertical dipole. It has circular symmetry in horizontal planes and is strongly directional with a maximum along the axis of the coil.

Both the Slingram and Turam methods involve relative measurements of field in two coils a fixed distance apart. The two methods are not entirely comparable, but provide the same type of information, which may be considered as an approximation to the horizontal gradient of the vertical component of the field. Major differences in response of the two methods over the same conducting body can be attributed mainly to the different disposition of the primary fields.

In the Turam method, the primary field cable is fixed relative to the conducting body, and is 'seen' by the side of the body nearest the cable, and by the top of the body. In the Slingram method, the transmitting coil is moved across the conducting body, and will be 'seen' by different parts of the body according to its position. If it is on either side of the body, it will be 'seen' by that side of the body nearest to it. It will also be 'seen' by the top of the body, but owing to the directional nature of the field, it will not act efficiently in inducing currents in this region. When the transmitting coil is centrally above the body, the top will be the only part of the body to 'see' the primary field.

The theoretical basis for estimating which particular type of anomaly would be caused by vertical or horizontal conductors, respectively, is yet incomplete. However, it is well established by experience that narrow steeply-dipping conductors can cause very strong anomalies.

From the foregoing discussion it appears that anomalies associated with wide conducting bodies may be caused by induced currents confined to restricted sections of the bodies. It is therefore possible that such anomalies will be similar to those caused by narrow conductors located near the edges of the bodies. Pending further mathematical investigation, some uncertainty must remain as to the actual anomaly to be expected from a wide conductor.

It should be noted that the terms 'narrow' and 'wide' cannot be defined very closely in this connexion. The actual width of a conductor that is effectively 'narrow' will depend on the frequency used, and on the conductivity of the material of the conductor.

The theory is complicated by the necessity of making allowance for the dip of the conducting body. It is generally agreed that electromagnetic survey methods are most effective when the primary field is applied from the footwall side. However, pending further mathematical investigation, the effect of the dip of the conducting body on the field produced at the measuring point remains uncertain.

5. METHOD OF INTERPRETATION EMPLOYED

In surveys using the Slingram and Turam techniques, the following characteristics of anomalies may be of diagnostic value :

(a) the individual strengths of anomalies in amplitude or phase

(b) the relative strengths of amplitude and phase anomalies that may reasonably be attributed to the same conductor

(c) the coincidence or otherwise in position of amplitude and phase anomalies

(d) the relation in position and strength of Slingram and Turam anomalies along the same traverse.

With regard to (a), not much use can be made of the absolute intensities of the anomalies. Owing to the incompleteness of the theory and the fact that the anomalies are subject to the influence of many parameters, it is not possible to relate the intensity of the anomaly due to a particular formation to the degree of mineralization of the formation.

Characteristic (b) is generally considered to be related to the conductivity of the formation that causes the anomaly, the intensity of the anomaly in amplitude with reference to that in phase decreasing with decreasing conductivity. Results of testing are not sufficient to provide a complete check on this assumption. In some cases, a study of the geology gives a certain plausibility to the supposition, and it can be supported by calculations made on a simplified model, so it may be accepted with caution. Results of surveys at Rum Jungle Creek South prospect indicate that (c) and (d) may be important although the evidence available is not sufficient to support detailed conclusions.

The results of the Turam survey over the Rum Jungle Creek South area are described by Daly and Rowston (1962). The salient features of the results are:

(a) the Turam survey showed a single strong anomaly in both amplitude and phase

(b) the maximum of the phase anomaly is displaced by about 100 ft from the maximum of the amplitude anomaly, in the direction away from the cable.

A single Slingram profile was made along the only traverse accessible at the time of the 1961 surveys, and showed two strong anomalies in both amplitude and phase, one corresponding in position with the Turam anomaly and the other some hundreds of feet closer to the position of the Turam cable. The Slingram amplitude and phase anomalies correspond closely in position.

The uranium orebody has been thoroughly explored by drilling. It consists of a zone some hundreds of feet wide containing uranium minerals, a small percentage of pyrite, and a rather smaller percentage of graphite. The Slingram anomalies coincide roughly in position with the edges of the uranium orebody. The Turam cable was laid out south of the orebody, and the Turam amplitude anomaly corresponds roughly in position with the northern edge of the orebody. The main Turam phase anomalies occur north of the orebody.

The evidence available is far from conclusive for the following reasons:

(a) The results of the Turam and Slingram surveys are not strictly comparable. The Turam survey was made before the ground had been disturbed. Before any Slingram tests could be made, preparations for open-cut mining were well advanced. Only one of the previous traverses was accessible, and this crossed a bench in the open-cut, and was about 20 ft below the previous level.

(b) the Turam primary cable was not well placed to investigate the ground under the southern Slingram anomaly under the best conditions. It is possible that a Turam anomaly might have been obtained in this position, if the cable had been laid farther south.

(c) the results may be influenced by the ground north of the orebody. This ground has not been extensively drilled, and no information on its electrical properties is available.

However, if it is assumed that the anomalies are associated with the orebody it appears that the response of a wide conducting body may not be simple. If another orebody of similar character is discovered, it should be thoroughly examined by electromagnetic methods before any preparations for mining are begun.

Until more complete theoretical and practical information is available, the following tentative criteria are suggested to guide the interpretation of electromagnetic anomalies in the Rum Jungle district:

(a) a strong anomaly in either Slingram or Turam results indicates a good conductor

(b) if a single sharp anomaly is observed, with phase and amplitude anomalies coinciding in position, the anomaly can be attributed to a narrow conductor

(c) the presence of several strong anomalies on the same traverse, or unusual features of the anomalies, such as considerable width or displacement in position between phase and amplitude anomalies, may indicate the presence of a wide conducting zone.

6. RESULTS OF SURVEYS

Results of the geophysical surveys made in 1960 and 1961 will be discussed in detail in the reports on the various areas. The following brief account refers only to the main features.

The surveys may be considered in two groups :

(a) the following series of contiguous areas around Castlemaine Hill. (Plate 2):

Rum Jungle Creek and Rum Jungle Creek South

Rum Jungle Creek South to Castlemaine anomaly

Batchelor Laterites

Power Line area

Flynns area

(b) the following isolated areas (Plate 1):

Mount Fitch North

West Finniss

Dolerite Ridge

Dolerite Ridge East

Area 55

Area 55 West

As the character of the results is different for the two groups, they will be discussed separately.

Surveys around Castlemaine Hill

The main feature of the results of these surveys is a series of strong anomalies which appear to be due to a wide conducting zone. The approximate boundaries of this zone are shown on Plate 2. It appears first as a weak anomaly in the Rum Jungle Creek area. Proceeding south-east, the anomalies become very strong, and the zone of strong anomalies continues with minor breaks as far as the Castlemaine radiometric anomaly. It then appears to turn north and continue through the Batchelor Laterites area into the Power Line area, where it terminates.

It should be noted that the boundaries of the conducting zone as shown on Plate 2 have been defined by Turam anomalies in the Rum Jungle Creek and Rum Jungle Creek South areas, and by Slingram anomalies in the other areas mentioned. As discussed previously, there is some doubt as to the precise portions of the zone that give rise to Turam and Slingram anomalies respectively. However, the apparent displacement of the zone at about 44E on the Rum Jungle Creek South layout is too great to be attributed to any discrepancy of this type, and it is considered that it represents a geological feature, such as a fault or a fold. It is understood that available geological information is not sufficient to resolve this question. The position of the conducting zone to the south of the Batchelor Laterites area is not defined, as this area has not been surveyed. It appears also that there may be a branch of the conducting zone extending west from the Batchelor Laterites area into an area that has not been surveyed.

The presence of the Rum Jungle Creek South orebody in close proximity to this zone indicates that it is worthy of extensive testing for other uranium orebodies. Such testing should take the form of lines of drill holes across the anomalous zone and extending for some distance on each side. It is also possible that some of the anomalies may be due to sulphide mineralization in sufficient concentration to form base metal orebodies of economic grade. The known base metal deposit at Brown's is associated with anomalies caused by narrow conductors, and it may be that the wide conducting zone defined by the present surveys is less likely to contain mineralization of value. However, some testing of these anomalies is warranted. This should take the form of diamond-drill holes aimed to intersect the conducting zone below the level of oxidation.

Surveys in isolated areas

At Mount Fitch North and Dolerite Ridge East, no significant anomalies were observed. At West Finniss, Dolerite Ridge, Area 55, and Area 55 West, very strong anomalies were observed, which appear to be due to narrow bodies of high conductivity. The strikes of the anomalies are different in adjacent areas; this indicates that the bodies causing them may reflect structure.

Apart from their possible value as indicators of uranium minerals, these anomalies have considerable interest as possible indicators of base metals. Surveys over the known orebody at Brown's (Daly, Horvath, and Tate; in preparation) have defined a narrow conductor extending almost as far as the Dolerite Ridge area, and it appears reasonable to suppose that at least some of the anomalies discovered in the present series of surveys are directly connected with this zone. There is therefore a strong incentive to test these anomalies for base metal deposits. It is considered that the first requirement is an extension of the surveys to delineate completely the main conductors; this should be followed by geochemical testing and diamond-drilling.

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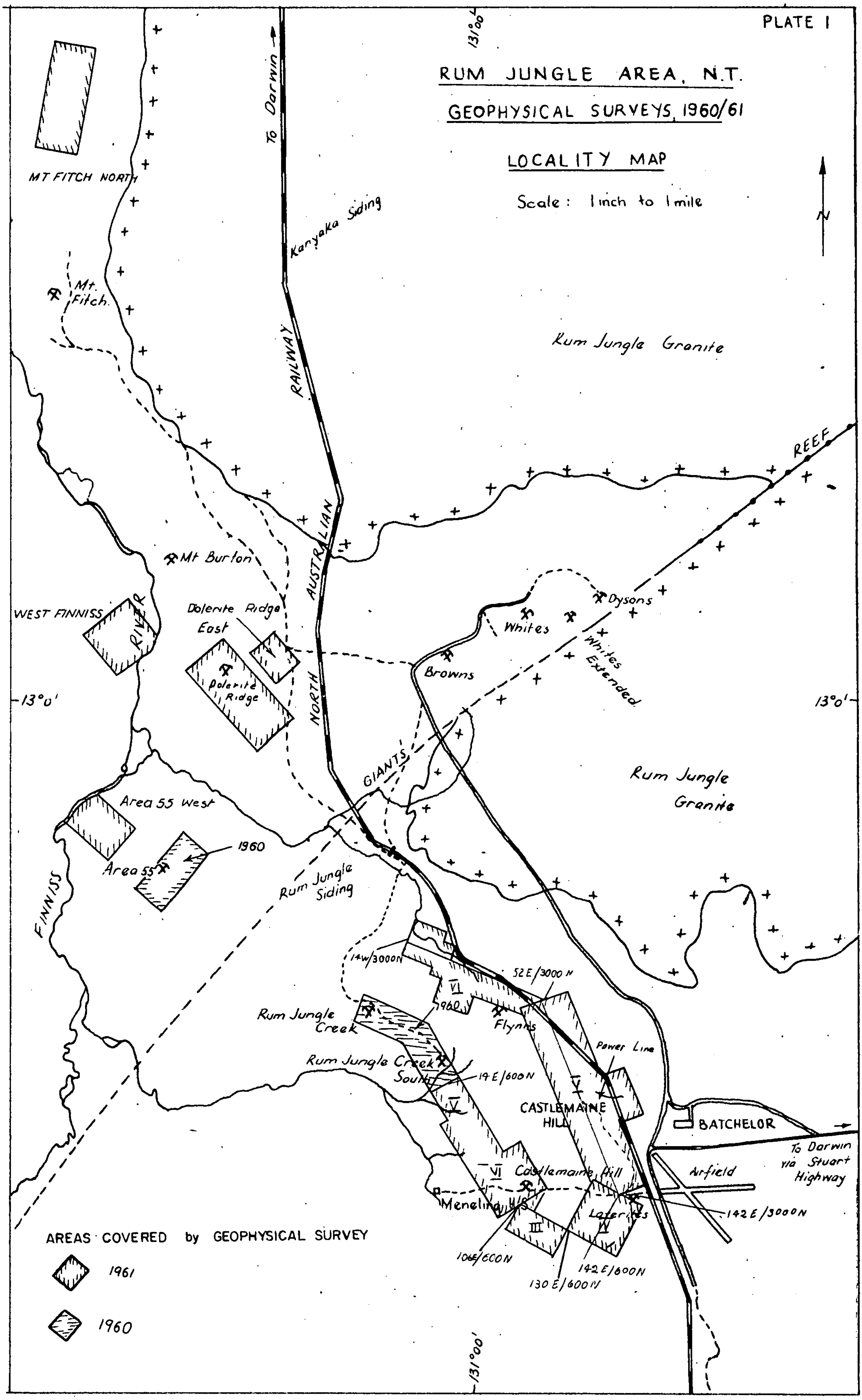

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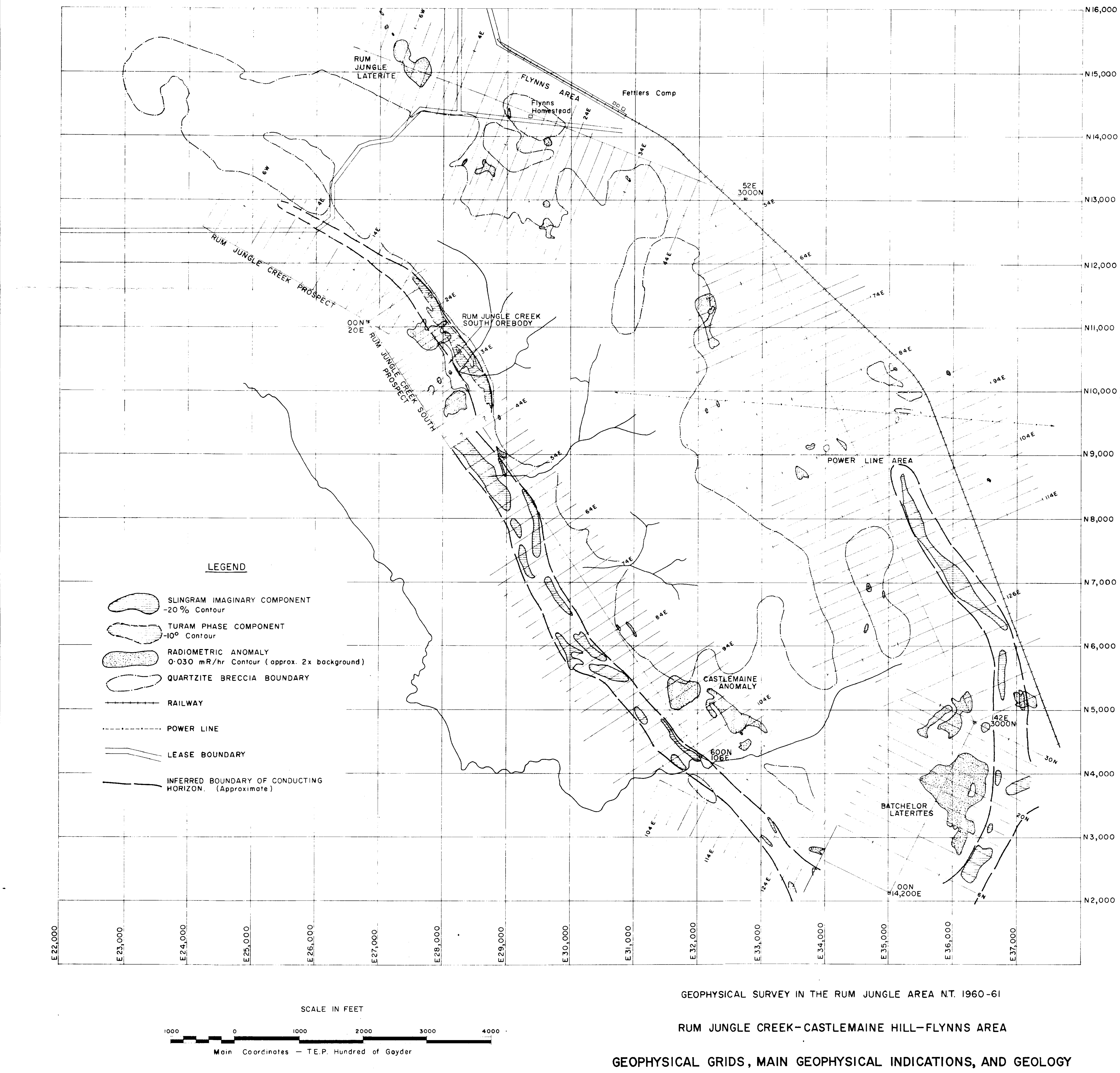
PLATE 2



GEOPHYSICAL SURVEY IN THE RUM JUNGLE AREA N.T. 1960-61

RUM JUNGLE CREEK–CASTLEMAINE HILL–FLYNNS AREA

GEOPHYSICAL GRIDS, MAIN GEOPHYSICAL INDICATIONS, AND GEOLOGY

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G71-219

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