COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1962-2

RAVENSTHORPE AIRBORNE MAGNETIC AND RADIOMETRIC SURVEY, W.A. 1960

by

R. Wells

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ABSTRACT

An airborne magnetic and radiometric survey in the Ravensthorpe district of Western Australia was flown by the Bureau of Mineral Resources in November 1960. The survey operation is described and a preliminary analysis is made of the results.

The magnetic results are shown to correlate with known structural features and to assist in the geological mapping of the area.

1. INTRODUCTION

An airborne survey of the Ravensthorpe district of Western Australia was conducted by the Bureau of Mineral Resources during November 1960, following a request made by Ravensthorpe Copper Mines N.L., through the Mines Department of Western Australia. The Company requested an aeromagnetic survey to assist future exploration for copper in the district.

The aims of the survey were to define magnetically anomalous areas where detailed ground magnetometer surveys should be concentrated, and to elucidate the regional structure by tracing the strongly magnetic banded iron formations which occur east of the field. In particular, it was desired to determine the trend of the banded iron formations in the area south-east of Kundip, where they are concealed by Nullagine-type sediments.

The survey area forms part of the Phillips River Goldfield and includes part of the Ravensthorpe and Cocanarup 1-mile map areas (Plate 1).

Flying operations were conducted with the Bureau's DC.3 aircraft VH-MIN. The field party was based at Norseman and comprised the following officers of the Geophysical Branch of the Bureau :- R. Wells (party leader), G.A. Young, M.J.W. Duggin, P. Turner, D. Upton, J. Janulaitis, K.A. Mort, and D. Park; and the following officers of Trans-Australia Airlines:- Captain G. Close, First Officer G. Green, and Engineer W. Briggs.

2. METHOD

The survey was made with airborne magnetometer and scintillographs.

Anomalies in the Earth's magnetic field, recorded by the magnetometer, are related to differences in magnetic properties of the underlying rocks and to the geological structure. The recorded magnetic profiles are used to produce a contour map of the magnetic field; this map can be expected to aid geological mapping and interpretation.

Scintillographs were used to record terrestrial gamma-radiation and to detect areas of above-average radioactivity. Such areas may warrant examination for occurrences of radioactive minerals.

The aircraft was flown along east-west lines spaced $\frac{1}{4}$ mile apart. The height of the aircraft was maintained at a nominal 500 ft above ground level, but the actual height varied by as much as $\pm$ 50 ft under normal flying conditions.

Tie-lines were flown to enable corrections to be made for differences in magnetic datum levels of individual flight-lines, for diurnal variations, and for instrument drift. The tie-lines were flown north-south approximately 13 miles apart; each tie-line was flown in one direction only and intersected all the east-west flight-lines.

The aircraft was navigated with aerial photographs upon which the predetermined flight path had been drawn. A continuous photographic record of the flight path was taken for subsequent plotting of the flight path on photo-mosaics.

Correlation of the various instrument and photographic records was achieved by fiducial marks made by an accurate electronic timer.

3. EQUIPMENT

A saturable-core fluxgate magnetometer, type AN/ASQ-8, was used. The detector head was installed at the end of a boom which projected from the tail of the aircraft. This arrangement reduced to a minimum the effect, on the recorded magnetic field, of the magnetism of the aircraft.

The output of the magnetometer, representing a continuous measurement of the intensity of the Earth's total magnetic field, was recorded on a Speedomax chart recorder. Concurrently a digital record of the field was punched on 5-hole paper tape at one-second intervals, so that the magnetometer data could later be processed by a digital computer. An additional recorder was used to produce a paper chart record of the magnetic profile at a reduced scale. Some of these profiles are reproduced on Plate 2.

The aircraft was fitted with two separate scintillograph systems. One system was mounted in the aircraft and consisted of two M.E.L. scintillograph detector heads; the combined output of these heads was integrated by a B.M.R.-pattern ratemeter and recorded on a single-channel Kelvin & Hughes chart recorder. The time-constant of the ratemeter was approximately two seconds. The second scintillograph system was housed in an aerodynamically stable fibreglass shell and trailed 300 ft below the aircraft at the end of a cable controlled by a hydraulic winch. The fibreglass shell contained a plastic phosphor detector, a transistorised power unit, and a preamplifier; the output of the preamplifier was fed via the towing cable to a second ratemeter and Kelvin & Hughes chart recorder mounted in the aircraft. The time-constant of the second ratemeter was approximately one second.

The flight path of the aircraft was recorded by an Aeropath continuous-strip 35-mm camera. This equipment was supplemented by an air position indicator which provided an air plot of the aircraft's path along each flight-line. The air position was resolved into two components at right angles and was recorded graphically on a "Rectiriter" chart recorder. The components of position were also displayed on two milage counters which were photographed at regular intervals.

An STR-30B radio-altimeter recorded the height of the aircraft above ground level; this height was continuously displayed on a Kelvin & Hughes recorder.

4. GEOLOGY

Lithology

The regional geological map of the surveyed area, shown on Plate 2, is based on a report of a geological survey of the Phillips River Goldfield (Sofoulis, 1958).

Apart from recent, superficial, sandy, lateritic, and boulder deposits and alluvium, the rocks that crop out in the area are of Precambrian age, some Proterozoic and others Archaeozoic.

The Upper Proterozoic is represented by a sequence of slightly folded metamorphosed sediments made up of conglomerate, dolomite, quartzite, and phyllite. This sequence, known as the Mt Barren Beds, extends from the central part of the southern boundary of the area to a line half a mile north of Kundip. These unfossiliferous sediments are structurally and lithologically analogous to the Nullagine "System" in the northern part of Western Australia (Hall, 1960) and consequently they are generally regarded as Proterozoic. Sofoulis (1958, p. 54) however, regards them as post-Nullagine and possibly early Palaeozoic.

The Archaeozoic is represented (op.cit., 54) by a highly and completely folded and metamorphosed geosynclinal remnant structure preserved within a granitised environment; it extends in a north-westerly direction across the centre of the area. Two lithological phases are delineated in this structure and are known as the Whitestone phase and the Greenstone phase; the Greenstone phase is stratigraphically the lower phase. Together these are known as the Ravensthorpe System.

The Whitestone phase consists of metasedimentary schist, phyllite, quartzite (David, 1950, p. 14), and silicified banded iron formations (jaspilite) which are highly magnetic. These beds overlie the Greenstone phase either conformably or disconformably. The Greenstone phase consists of metamorphosed basic and ultrabasic lavas and pyroclastic rocks which overlie meta-arenaceous and argillaceous horizons. The lower margin of the Greenstones grades into gneiss which is thought to be the granitised counterpart of their basal horizons (Sofoulis, 1958, p. 54-55).

The magmatic granite that crops out in the south-western part of the survey area lies within the remnant geosynclinal structure. The granite has caused thermal metamorphism of the enclosing Greenstones. Parallel and en echelon shear zones occur at, or within a mile of, the periphery of the granite body (op.cit., 82). These shear zones play an important part in the mineralisation of the area.

The rocks of the Ravensthorpe System are completely enclosed in gneisses, generally of granitic variety. The foliation pattern and banding of these gneisses faithfully reflect the geosynclinal configuration of the Ravensthorpe System. Sofoulis (op.cit., 84-5) therefore considers them as the granitised counterparts of lower horizons of the System.

Structure and Tectonics

The disposition of the Archaeozoic rocks of the area indicates that the Ravensthorpe System is synclinally folded along a major axis which has been traced from Mt Short in the north to Kundip in the south. At this point the axis is deflected west-south-west and follows the general direction of the coast. The axial zone of the folding is marked by the Whitestone phase which is there enfolded within the Greenstone phase.

Subsidiary fold axes parallel to the major axis occur in the area which the two distinct trends of the geosyncline link (Plate 2). The evidence for these subsidiary axes is the repetition of the Whitestone phase east of Kundip. A minor conjugate folding, which trends approximately at right angles and parallel to the main geosynclinal axis, is also recognised. The major structure is thus seen to be complex and is best categorised as a major synclinorium which has been superimposed by conjugate or cross folding in the form of anticlinoria and synclinoria. The steepness of bedding and schistosity suggests that the folds are generally isoclinal and often overturned (op.cit., 111).

The geosynclinal structure described above has undergone a major anticlinal folding along a south-easterly axis which passes about a mile south of Kundip and plunges to the south-east at an angle of 25 to 35 degrees. The structure is approximately symmetrically disposed about this axis; the northern portion trends north-north-west and dips steeply east, and the southern portion trends west-south-west and dips south (op.cit., 111).

Mineralisation

Gold and copper have been mined in the Ravensthorpe area since 1899. All the ore-bodies are metasomatic replacement deposits within shear zones which lie within one mile of the granite mass. The richest deposits have been those that occur in sheared Greenstones located along the eastern edge or hanging wall of the granite body. In the Greenstones, the lava amygdaloids have been the most favoured host rocks (op.cit., 100). Generally the ore-bodies have been small and the ore shoots short and erratic. In most ore-bodies both gold and copper minerals were present in varying proportions; those ore-bodies that were worked superficially for gold tended to pass into low-grade copper deposits at depth. Mining has generally been confined to the oxidised zone and seldom reached a depth of 200 ft; the deepest working did not exceed 500 ft (op.cit., 124).

It is considered that the eastern and southern edges of the granite body, which was the source of the mineralising solutions, have been structurally controlled by the Whitestone phase. To the north and west a similar control has been exercised by the Greenstone phase (op.cit., 87). As mineralisation has been concentrated mainly in the thin Greenstone wedge sandwiched between the eastern edge of the granite and the enclosing Whitestones (op.cit., 117), the mapping of the Whitestone phase along this line of structural control is of importance in the search for possible ore-bodies. Fortunately the highly magnetic jaspilite beds within this phase provide useful markers for detection by magnetic surveying techniques.

5. RESULTS

Accuracy of mapping

Comparison of the geophysical results with the geological map of the Ravensthorpe district (op.cit.) is subject to some uncertainty because the geological map had been based on uncontrolled planimetric maps. In the process of transferring the geological information to the more recent photo-compilation maps by reference to topographic detail, discrepancies were noted. These were most serious in the eastern part of the area, where the position of Burlabup Creek on the geological map was about two miles west of its position on the photo-compilation map. After discussion with the Geological Survey of Western Australia, it was agreed that the boundary between the Greenstones and gneiss near the headwaters of Burlabup Creek should be moved east accordingly. This meant that the area of greenstone outcrop in this locality had to be arbitrarily widened. The assumed boundaries (Plate 2) show interrogation marks. The easternmost minor synclinal axis was also moved about two miles farther east to a position which appears to be confirmed by the magnetic results.

Magnetic results

A detailed study of the magnetic results will not be possible until the final magnetic contour map has been completed. For the purpose of the present preliminary assessment, only the principal features of the magnetic results are considered. These are illustrated on Plate 2 in relation to the geology.

Several well-defined lines of magnetic anomalies have been noted and their positions are shown on Plate 2. In addition, the magnetic profiles along selected flight-lines have been reproduced from the reduced-scale recorder charts. In presenting the profiles, it has been necessary to adjust their lengths to agree with the base map and also to rectify the original curvilinear record. Consequently some distortion has been introduced and the profiles should be regarded as diagrammatic representations only. The position of the peak of each anomaly has been plotted with an accuracy of $\pm \frac{1}{4}$ mile.

The dominant feature of the magnetic pattern is a zone of steep anomalies, of up to 4000 gammas amplitude, which extends along Ravensthorpe Range from the northern boundary of the survey area, and south-eastwards to the southern boundary at a point south-east of Kundip. Within this disturbed zone two or more separate lines of anomalies can be distinguished. These anomalies are associated with the steeply-dipping jaspilite beds of the Whitestone phase which marks the axis of the major geosynclinal structure. The magnetic results clearly indicate the position of the jaspilite beds where they are concealed by the Proterozoic sediments (Mt Barren Beds) in the area south-east of Kundip. In this area the anomalies become weaker and broader, indicating a deepening of the jaspilite beds to perhaps 2000 ft below the surface.

East of Ravensthorpe township the magnetic pattern shows a discontinuity which coincides with the valley of Cordingup Creek, giving evidence of a transverse displacement of about one mile, the northern sector having moved to the east. This feature of the magnetic pattern supports the inference of a fault which strikes south of east along Cordingup Creek and corresponds to the superimposed south-easterly axial trend (Sofoulis, 1958, p.113). About three miles to the north-west another break occurs in the magnetic trend. This break correlates with an inferred fault which may be associated with a west-south-west anticlinal cross flexure (op.cit.).

The line of magnetic anomalies striking north-east and passing north of Ravensthorpe township appears to be associated with the quartz dolerite dykes system. There is evidence of a continuation of the same line on the north-eastern side of Ravensthorpe Range.

East of the main geosynclinal axis, another prominent zone of magnetic anomalies is associated with the repetition of the Greenstone phase that crops out near Burlabup Creek. The anomalies are generally less than 1000 gammas, but a few approach 2000 gammas. The anomalies suggest that Whitestone outliers may exist along the minor synclinal axis with which this band of Greenstones is associated.

It should be noted that the rocks of the Whitestone phase associated with the minor synclinal axis immediately east of Kundip show fairly weak magnetic anomalies. Evidently the jaspilite beds, which characterise the Whitestones in the major geosynclinal zone, are relatively rare in this locality.

Between Ravensthorpe and the Phillips River there is an isolated line of anomalies of about 500 gammas. The anomalies occur in an area of Greenstones and appear to follow the trend of the contact between metasediments on the west and basic lavas on the east.

The preliminary examination of the magnetic results has not revealed any direct association of magnetic anomalies with the known mineralised areas. However, it will be desirable to investigate this aspect more closely when the final contour map has been completed.

Radiometric results

No radiometric anomaly of sufficient interest to warrant further investigation by ground follow-up was detected during the survey. Changes in the level of radioactive intensity are shown in Plate 3, where they have been plotted with an accuracy of $\pm \frac{1}{4}$ mile. Some of the level changes show trends similar to those of the geological boundaries, but in general there does not appear to be any strong correlation between the radioactive data and the geology.

6. CONCLUSIONS

The preliminary examination of the survey results show that the main structural features of the Ravensthorpe district are clearly revealed by the magnetic pattern.

The axis of the major geosynclinal fold in the Ravensthorpe System is indicated by a well-defined zone of strong magnetic anomalies arising from the jaspilite beds of the Whitestone phase. In the Kundip area, the jaspilite beds are shown to continue to the south beneath the Proterozoic sediments of the Mt Barren Beds at depths of the order of 2000 ft below the surface.

The magnetic results give confirmation of cross-faulting in the northern part of the geosynclinal zone and of minor synclinal axes in the eastern part of the surveyed area.

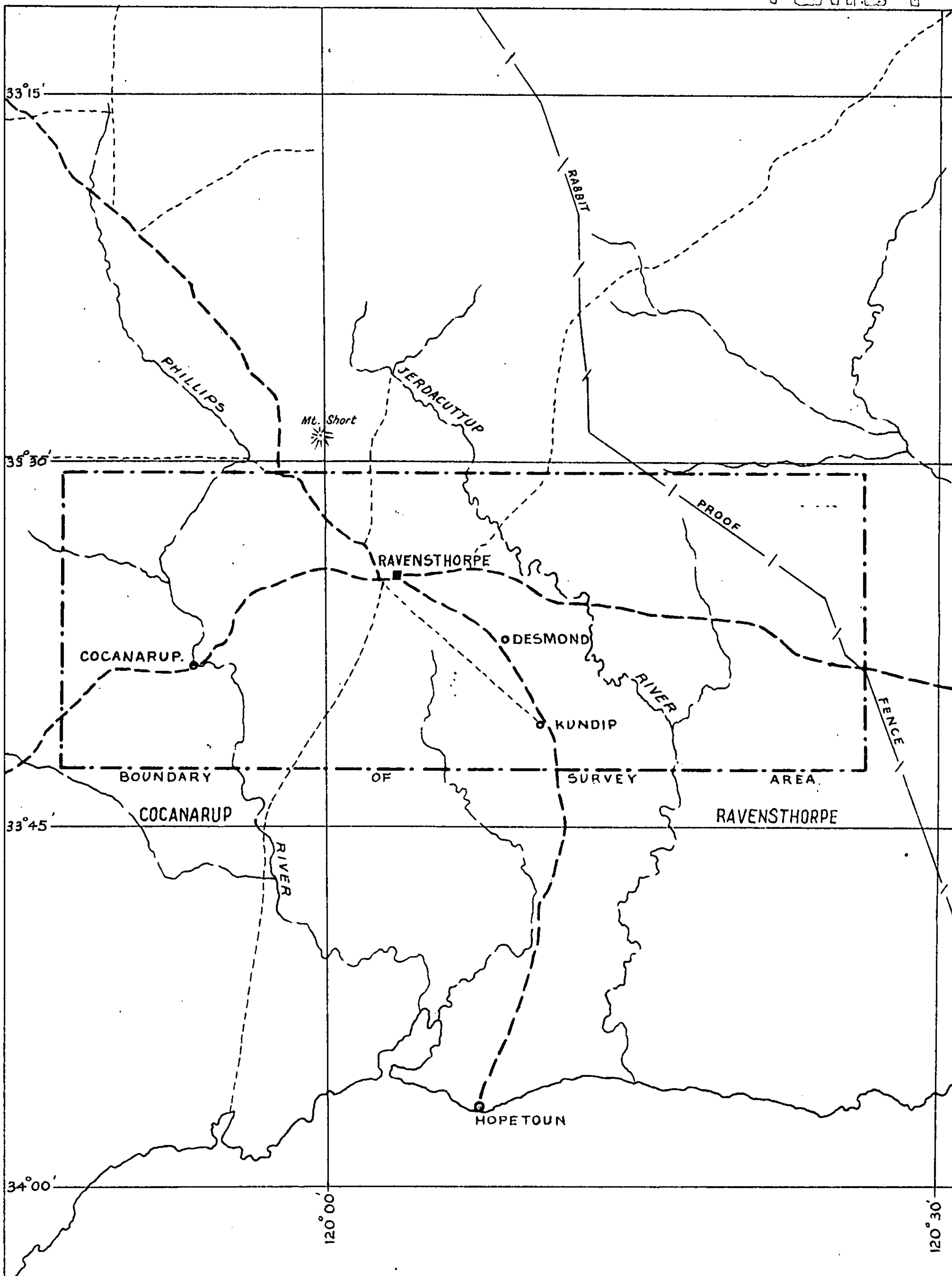
In the Cordingup Creek area east of Ravensthorpe where the Archaean rocks are covered by alluvium, the trends of the Whitestones are revealed by the magnetometer and should be a guide to the behaviour of the potentially metalliferous Greenstone lavas which occur between the eastern edge of the granite and the Whitestones. When the results are presented in the form of a final contour map, a detailed study will have to be made, to determine whether there is any direct association of magnetic anomalies with the known mineralisation.

The radiometric survey showed no anomalies worth further investigation. The changes in level of radioactivity recorded during the survey show no strong correlation with the geology.

7. REFERENCES

DAVID, T.W.E.	1950	THE GEOLOGY OF THE COMMONWEALTH OF AUSTRALIA, Vol. 1. Edward Arnold, London.
HALL, H.E.	1960	Personal communication.
SOFOULIS, J.	1958	The geology of the Phillips River Goldfield, W.A. <u>Bull. geol. Surv. W.Aust</u>. 110.

PLATE 1



RAVENSTHORPE W.A.

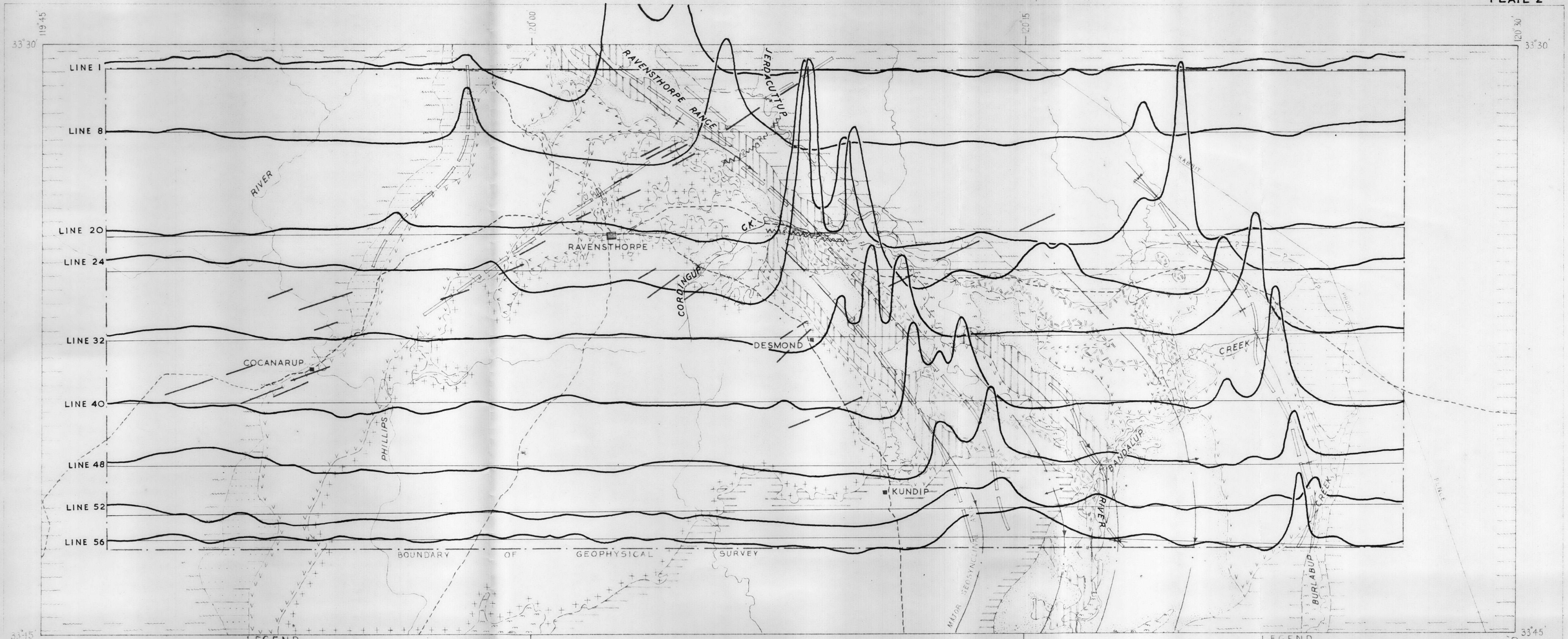
LOCALITY MAP FOR

AIRBORNE SURVEY 1960

SCALE 10 0 10 20 MILES

Geophysical Branch, Bureau of Mineral Resources, Geology & Geophysics G 363–3

To accompany Record No.1962-2



LEGEND

RECENT		ALLUVIUM, SAND DUNES, SANDY SOIL.
LATE TERTIARY		LATERITIC AND SUPERFICIAL
PROTEROZOIC MT BARREN SERIES		UNDIFFERENTIATED META SEDIMENTS
		QUARTZ DOLERITE INTRUSIVES
ARCHAEOZOIC		GRANITE
		GNEISS

ARCHAEOZOIC RAVENSTHORPE SYSTEM:

- WHITESTONES — UNDIFFERENTIATED JASPILITES AND META SEDIMENTS
- GREENSTONES:
  - SERPENTINES
  - BASIC LAVAS
  - AGGLOMERATIC LAVAS
  - META SEDIMENTS

BASE OF META SEDIMENTS NOW REPRESENTED BY GNEISSES

RAVENSTHORPE

MAGNETIC RESULTS

AIRBORNE SURVEY 1960

THE RAVENSTHORPE AND PORTION OF THE COCANARUP 1 MILE AREAS W.A.

Scale 2 1 0 2 4 6 Miles

VERTICAL SCALE IN GAMMA (APPROX.) 0 200 400 600 800 1000

MAGNETIC NORTH
TRUE NORTH

LEGEND

- GEOLOGICAL BOUNDARY
- ROAD OR TRACK
- INFERRED FAULT
- ANTICLINE
- SYNCLINE
- MAGNETIC PROFILE (DIAGRAMMATIC)
- TRENDS OF PRINCIPAL MAGNETIC FEATURES

GEOLOGY BY J SOFOULIS (OCT 1951 – OCT 1953) J McGRATH (OCT 1951 – SEPT 1952)
N GRAY (OCT 1951 – MAY 1952) AND J NOLDART (AUG 1952 – OCT 1953).
STRUCTURAL INTERPRETATION BY J SOFOULIS

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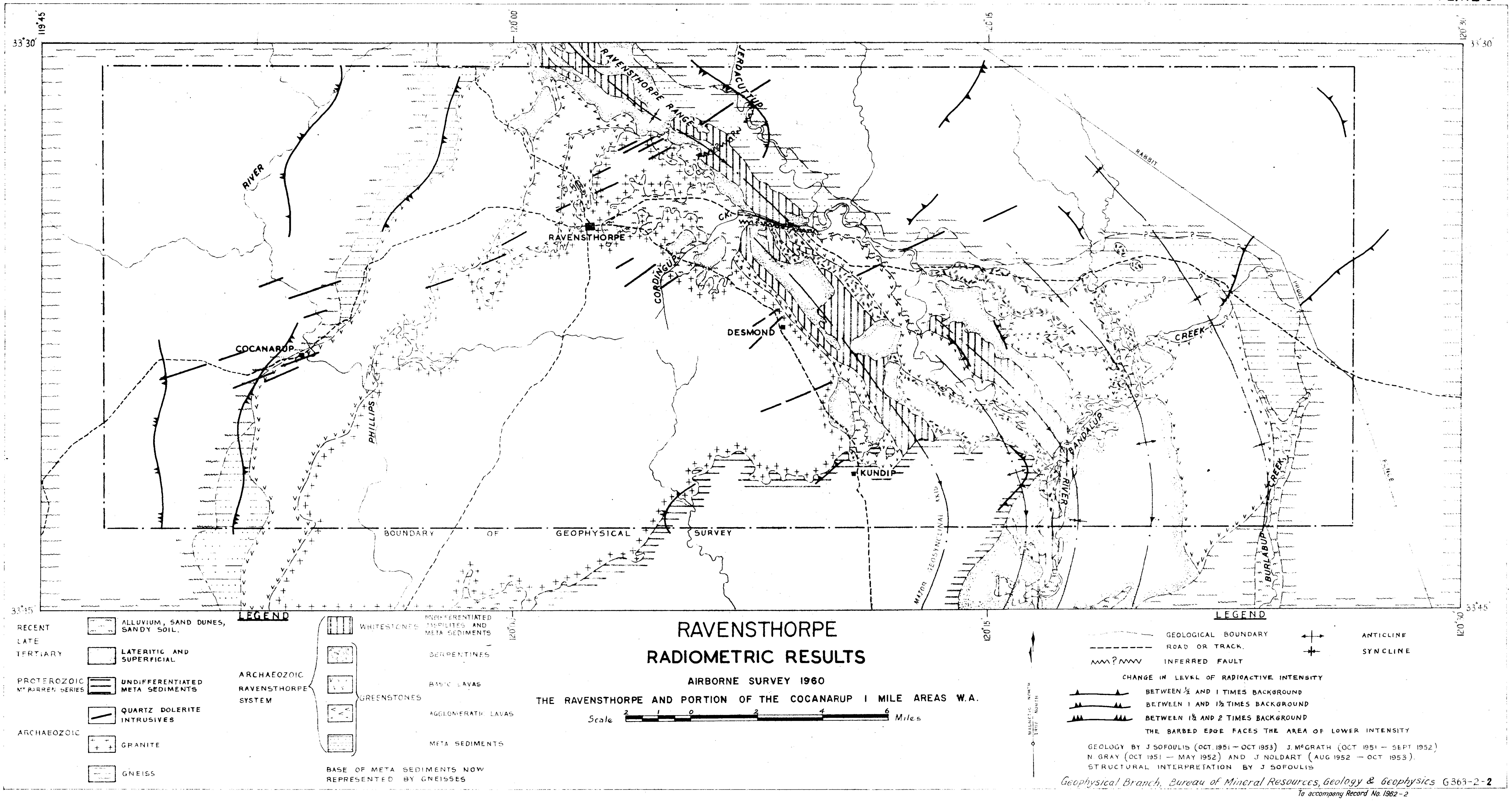
To accompany Record No. 1962-2

PLATE 3



119°45'
120°00'
120°15'
120°30'
33°30'
33°45'
RIVER
RAVENSTHORPE RANGE
JERDACUTTUP
RAVENSTHORPE
CK.
CORDINGUP
COCANARUP
PHILLIPS
DESMOND
KUNDIP
RABBIT
CREEK
BANDALUP
RIVER
CREEK
BURLABUP
MAJOR GEOSYNCLINAL AXIS
BOUNDARY OF GEOPHYSICAL SURVEY
LEGEND
RECENT
ALLUVIUM, SAND DUNES, SANDY SOIL.
LATE TERTIARY
LATERITIC AND SUPERFICIAL
PROTEROZOIC MT BARREN SERIES
UNDIFFERENTIATED META SEDIMENTS
QUARTZ DOLERITE INTRUSIVES
ARCHAEOZOIC
GRANITE
GNEISS
WHITESTONES
UNDIFFERENTIATED PHYLLITES AND META SEDIMENTS
ARCHAEOZOIC RAVENSTHORPE SYSTEM
GREENSTONES
SERPENTINES
BASIC LAVAS
AGGLOMERATIC LAVAS
META SEDIMENTS
BASE OF META SEDIMENTS NOW REPRESENTED BY GNEISSES
RAVENSTHORPE
RADIOMETRIC RESULTS
AIRBORNE SURVEY 1960
THE RAVENSTHORPE AND PORTION OF THE COCANARUP 1 MILE AREAS W.A.
Scale 2 1 0 2 4 6 Miles
MAGNETIC NORTH
TRUE NORTH
LEGEND
GEOLOGICAL BOUNDARY
ROAD OR TRACK.
INFERRED FAULT
ANTICLINE
SYNCLINE
CHANGE IN LEVEL OF RADIOACTIVE INTENSITY
BETWEEN ½ AND 1 TIMES BACKGROUND
BETWEEN 1 AND 1½ TIMES BACKGROUND
BETWEEN 1½ AND 2 TIMES BACKGROUND
THE BARBED EDGE FACES THE AREA OF LOWER INTENSITY
GEOLOGY BY J SOFOULIS (OCT. 1951 – OCT 1953) J. McGRATH (OCT 1951 – SEPT 1952)
N GRAY (OCT 1951 – MAY 1952) AND J NOLDART (AUG 1952 – OCT 1953).
STRUCTURAL INTERPRETATION BY J SOFOULIS
Geophysical Branch, Bureau of Mineral Resources, Geology & Geophysics G363-2-2
To accompany Record No. 1962-2