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Record No. 1971/78

Applications of Regional Airborne Geophysical Data to Metals Search in Western Australia.

by

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APPLICATIONS OF REGIONAL AIRBORNE GEOPHYSICAL DATA TO METALS SEARCH IN WESTERN AUSTRALIA

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SUMMARY

A programme of airborne magnetic and radiometric surveying of the goldfields region of Western Australia was commenced by the Bureau of Mineral Resources (BMR) in 1956. By 1968, 125,000 line miles had been flown.

The initial survey objectives were to delineate banded iron formations to assist geological mapping in areas of alluvium cover, and to map radioactivity for uranium search.

A geological map, derived from magnetic data, clearly indicates the disposition of greenstone belts, thereby high-lighting the more significant areas for metals search. Major gold production centres are seen to occur near contacts of basic metaigneous or ironrich metasediments with granites, acidic metaigneous or nonmagnetic metasediments.

Comparisons of magnetic contours with stacked profiles indicate the latter to be more useful for determining 'fine structure' within greenstone belts. Further development of magnetic data display combined with photo geological studies is required to upgrade the value of regional aeromagnetic data for geological interpretation.

Exploration companies could probably make greater use of the data already collected by the BMR, about and to the south of Kalgoorlie, by extending interest beyond aeromagnetic contour maps. It is possible that a significant quantity of the information sought in detailed follow-up aeromagnetic surveys is already available in the original BMR magnetometer records. These would require display and interpretation appropriate to the exploration problem in question.

At this time, the radiometric data collected appear to be of limited value for both geological mapping and metals search. As was the case with the magnetic data, an ore discovery could rapidly alter this situation.

1. INTRODUCTION

In 1956, the Bureau of Mineral Resources, Geology and Geophysics (BMR) commenced an extensive program of airborne magnetic and radiometric surveying in the goldfields region of Western Australia at the request of the Department of Mines, Western Australia. The main objectives at that time were to delineate, by the magnetic method, banded iron formations, which might serve in establishing the control on geological structure and ore genesis in areas of extensive alluvium cover. It was not considered probable that economic mineralization would be detected directly.

The radiometric tool was applied primarily for the direct detection of uranium mineralization. It was recognized, however, that the regional nature of this work would only result in a 10 percent radiometric coverage of the areas surveyed.

Plate 1 illustrates the area surveyed by the Bureau of Mineral Resources between 1956 and 1968, using DC3 aircraft operating at an altitude of 500 feet above ground level on flight lines oriented east-west, spaced at 1 mile intervals. A total of 125,000 line miles have been flown to effect this coverage, which has taken 77 weeks of survey operations.

This paper deals in particular with the results obtained from data collected since 1964. At that time, new survey approaches to airborne geophysical data display and interpretation were introduced by the BMR (Young & Tipper, 1966). These were directed towards the delineation of boundaries of major rock units and geologic structure to aid the Western Australia Geological Survey's program of systematic mapping of this Precambrian shield area as related to metals search.

The BMR records of Menzies-Leonora (Young & Tipper, 1966), Laverton-Edjudina (Tipper, 1967), Sir Samuel-Duketon (Shelley & Waller, 1967), and Sandstone-Youanmi (Gerdes, Young, Beattie & Cameron, 1970) illustrate in detail the results obtained from the continued development of data display and interpretation in the region bounded by latitudes 27°00'S to 30°00'S and longitudes 118°30'E to 123°00'E. It is now possible to obtain from these data the more regional geological picture to assist both metals exploration and geological mapping.

2. GEOLOGY

The region bounded by latitudes 27°00'S to 30°00'S and longitudes 118°30'E to 123°00'E forms part of the Archaean Yilgarn Block, which is itself a subdivision of the West Australian shield. Plate 2 illustrates the most recently published regional geological mapping of this area. From this, it may be seen that this region is primarily composed of granitic and gneissic rocks, which enclose relatively narrow bands of metasedimentary and metaigneous rocks.

The metasedimentary and metaigneous rocks are the oldest recognizable rocks of the region. They form a layered sequence of rocks previously described as 'greenstones' (mainly altered basaltic lavas) and 'whitestones' (mainly clastic sediments and acid volcanics). Both units include minor developments of banded ironstones, or jaspilites, which can form key horizons for structural geological interpretation (Miles, 1953). The lavas, acid volcanics, and sediments have been intruded concordantly by gabbros, dolerites, and ultrabasic rocks, and subsequently folded about north north-west trending axes contemporaneously with widespread granitic intrusion, granitization, and metamorphism.

The granitic rocks are of three main varieties, namely, porphyritic granite, a more basic even-grained granite, and a foliated granite. The latter rock type represents the gneiss of earlier workers, and apparently is produced by granitization at the margins of intrusive granites (Horwitz, 1966).

For convenience, areas which contain metasedimentary rocks and/or metaigneous rocks will be referred to as 'greenstone belts'. The strikes of individual rock units within these belts commonly parallel the intrusive granite boundaries and are predominantly oriented north northwest to northwest.

Sofoulis & Mabbutt (1963) suggest that the granites occupy anticlinal positions, whereas the greenstone belts occur in synclinal structures. In general, strata in the greenstone belts dip steeply.

A superimposed system of subordinate folding, whose axial trend is east northeast to northeast is thought to have a significant role in localizing mineralization (Ellis, 1939; McMath, 1953).

Although few major faults have been recorded in this region, numerous cross-trending dolerite dykes, which marked the end of Precambrian time, have been mapped. Many of these dykes extend over great distances, and are often only delineated by their magnetic properties.

Economic mineralization has been mainly confined to gold in this region, in the past. In general, such mineralization is confined to the greenstone belts near the contact with granite bodies. The recent discoveries of economic nickel mineralization in areas around Kalgoorlie are also confined to the greenstone belts, and in particular to intrusive ultrabasic rocks.

3. MAGNETIC DATA DISPLAY AND INTERPRETATION

Dating from the survey of Menzies-Leonora, two forms of data display have been produced by the BMR. Immediately after the completion of a survey, stacked magnetic profiles are produced at a linear scale of 1:250,000. These profiles remain unpublished but are contained within the BMR Record series. At a later date, contour maps of total magnetic intensity are published at a scale of 1:126,720.

It is of considerable importance that the use of these two data displays is fully appreciated. Plate 3A shows magnetic contours applicable to part of the southwest quadrant of the Leonora 1:250,000 Sheet. As previously mentioned, the initial objective of the aeromagnetic work was to delineate banded iron formations, which produce intense magnetic anomalies. A contour interval of 50 gammas was therefore chosen to best display such features.

For a more critical inspection of rock units and structure within greenstone belts, the stacked magnetic profiles, as displayed in Plate 3B, are far more useful; anomalies elongated north-south with amplitudes as low as 10 gammas are recognizable from line to line. Fine structure is readily apparent from this profile display, which is of considerable value for extrapolating geology from areas of outcrop into areas of alluvium cover.

An example of this is demonstrated by the comparison of the aerial photograph in Plate 4 with a part of the interpretation as displayed in Plate 3B. This indicates that conventional methods of photogeological interpretation can readily be co-ordinated with magnetic interpretation for mutual improvement of mapping.

A more interesting example of the relative value of these two forms of magnetic data display is that shown in Plates 5A and 5B, for the region about Kambalda. It is quite apparent that considerably more detail is available for geological interpretation than that which is displayed by the contour map. Marker horizons within the metabasalts are clearly shown by the stacked profiles, yet are in general unresolvable from the contours. It is important to note that where flight-lines parallel geological strike, such as at the northern extremity of the domal structure, interpretation of regional magnetic data becomes more difficult as magnetic anomaly forms become more complex.

The interpretation procedures developed to obtain maximum usage of the stacked profile display is based on a qualitative assessment of the local characteristic of the magnetic field. In effect, the magnetic pattern produced by short wavelength anomalies is interpreted as being produced by near-surface variations in magnetic susceptibility. These variations are in turn attributed to near-surface lithological variations from steeply dipping strata. Correlation of anomaly forms is sought between adjacent flight-lines to reveal marker horizons.

Eight physical divisions are made of the magnetic pattern as listed below:

Zone Type	Magnetic Anomaly Range	Anomaly Linearity between Flight Lines
1	Mainly less than 50 gammas	Poor
2	Mainly 50 to 100 gammas	Poor
3	Mainly 100 to 250 gammas	Poor
4	Mainly greater than 250 gammas	Poor
5	Mainly less than 100 gammas	Good
6	Mainly 100 to 250 gammas	Good
7	Mainly 250 to 500 gammas	Good
8	Mainly greater than 500 gammas	Good

As indicated by Plates 3, 4, and 5, with some local geological knowledge the significance of these zone types may be determined. However, as the delineation of greenstone belts is of primary consideration for metals search it is appropriate to rationalize the above listed zone types into more general subdivisions to obtain the regional geological picture.

Plate 6 illustrates such a rationalization, large zones of types 1 and 2 generally being interpreted as granitic masses. Zones of type 3 and erratically occurring zones of types 5 and 6 are interpreted as intermediate igneous masses, or alternatively areas of foliated granite or gneiss which show some remnants of partly assimilated greenstone bands. Zones of type 4 are attributed to gabbroic rocks when these zones occur in areas of predominantly granitic composition.

Zones of types 5, 6, 7, and 8 are commonly interpreted as rock units of increasing basicity within the greenstone bands. It is somewhat difficult, however, to determine the degree to which these greenstones have become assimilated into the granitic rocks. Anomalies exceeding 3000 gammas in zones of type 8 are invariably caused by banded iron formations. In general, the presence of a type 8 zone is taken as a positive indication that the greenstone band remains unaltered. Although serpentinite outcrops occur in zones of type 5 to 8, they do not appear to produce anomalies in excess of 3000 gammas.

Elongated zones of types 1 and 2 contained within the greenstone belts are interpreted as indicating sedimentary and/or acid volcanic sequences. It is thus attractive to relate these zones to the 'whitestone' series; however, such a generalized interpretation would require extensive ground investigations to confirm it.

Referring again to Plate 6, the more promising areas for metal search are those in the greenstone belts shown as 'basic volcanics and banded ironstones'. The interpreted areas of 'basic igneous rocks' also warrant ground investigation. This is best demonstrated by the distribution of the mining centres which have produced over 5000 fine ozs of gold. More than 80 percent of these centres are located near the contacts of basic metaigneous rocks or ironrich metasediments with granitic rocks, acidic metaigneous rocks, or irondeficient metasediments.

The major dyke system, as shown in Plate 6, and revealed by the magnetic data rarely has any expression in outcrop. No significant economic mineralization appears to be associated with these features, although at latitude 28°33'S, longitude 121°50'E the convergence of two dykes at a granite/greenstone contact in coincidence with the intersection of two interpreted fold axes obviously warrants more detailed examination.

Both local and regional geological structures are interpreted from analyses of zonal configurations, variations in the trends of individual magnetic anomalies, and magnetic anomaly forms. To some extent, the delineation of dykes also assists this interpretation.

4. RADIOMETRIC DATA DISPLAY AND INTERPRETATION

Dating from the Menzies-Lenonora airborne survey in 1964, two forms of radiometric data display have been produced by the BMR, namely contours of gamma radiation and spot anomalies. Prior to this survey only spot anomalies were displayed.

Plate 7 illustrates these data displays for the area under consideration. It is immediately apparent that these data are not as useful as the magnetic for regional geological mapping. Some differences in the regional characteristics of the granites are evident, however, particularly in the Leonora and Duketon areas. In addition, salt lakes are commonly seen to have high radioactivity. There is some evidence that this radioactivity is mainly due to the potassium isotope K^{40}. A detailed study of all such features by an airborne gamma-ray spectrometer would be required to confirm this broad interpretation.

It is important to note that some salt lakes are characterized by radiometric lows. Examination of survey photography reveals that these lows are occasionally produced by a water table that is near surface or exposed.

Spot anomalies, indicating localized sources of anomalous radioactivity, are recommended for further investigation, and are selected by anomaly shape. No account is taken at this stage of the geological environment, it necessarily being the responsibility of subsequent workers to evaluate the economic significance of any of these anomalies by photogeological ground surveys, or more detailed airborne surveys.

A result of the flight line spacing being 1 mile is that of the areas surveyed only a 10 percent coverage of spot anomalies is obtained. It is prudent, therefore, to look upon a display of this kind as data useful in a statistical sense for the selection of the more promising areas for future investigation.

5. CONCLUSIONS

Analyses of airborne magnetic data clearly indicate the disposition of the greenstone belts, thereby accentuating the areas of greatest interest for metals search. Areas of significant gold production are seen to be located near the contact of basic metaigneous or ironrich metasediments with granitic rocks, acidic metaigneous rocks, or irondeficient metasediments.

Comparisons of the data displays of the total magnetic intensity contours and stacked profiles indicate the latter to be of considerably more value for the determination of 'fine structure' within the greenstone belts, Further development of both of these forms of data display are required to improve their value for geological interpretation.

It is appropriate that further development of aeromagnetic interpretation in this region should be closely co-ordinated with photogeological and ground studies.

It is probable that greater use could be made by exploration companies of the data already collected by the BMR, about and to the south of Kalgoorlie. It is understood that in this region reference has mainly been confined to the published aeromagnetic maps. It is possible that a significant quantity of the information sought in detailed follow-up aeromagnetic surveys is already available in the original BMR data. These data would require display and interpretation appropriate for the exploration problem in question.

At this time, the radiometric data collected appear to be of limited value for both regional geological mapping and metals search. As was the case with the magnetic data, an ore discovery could alter this situation very quickly.

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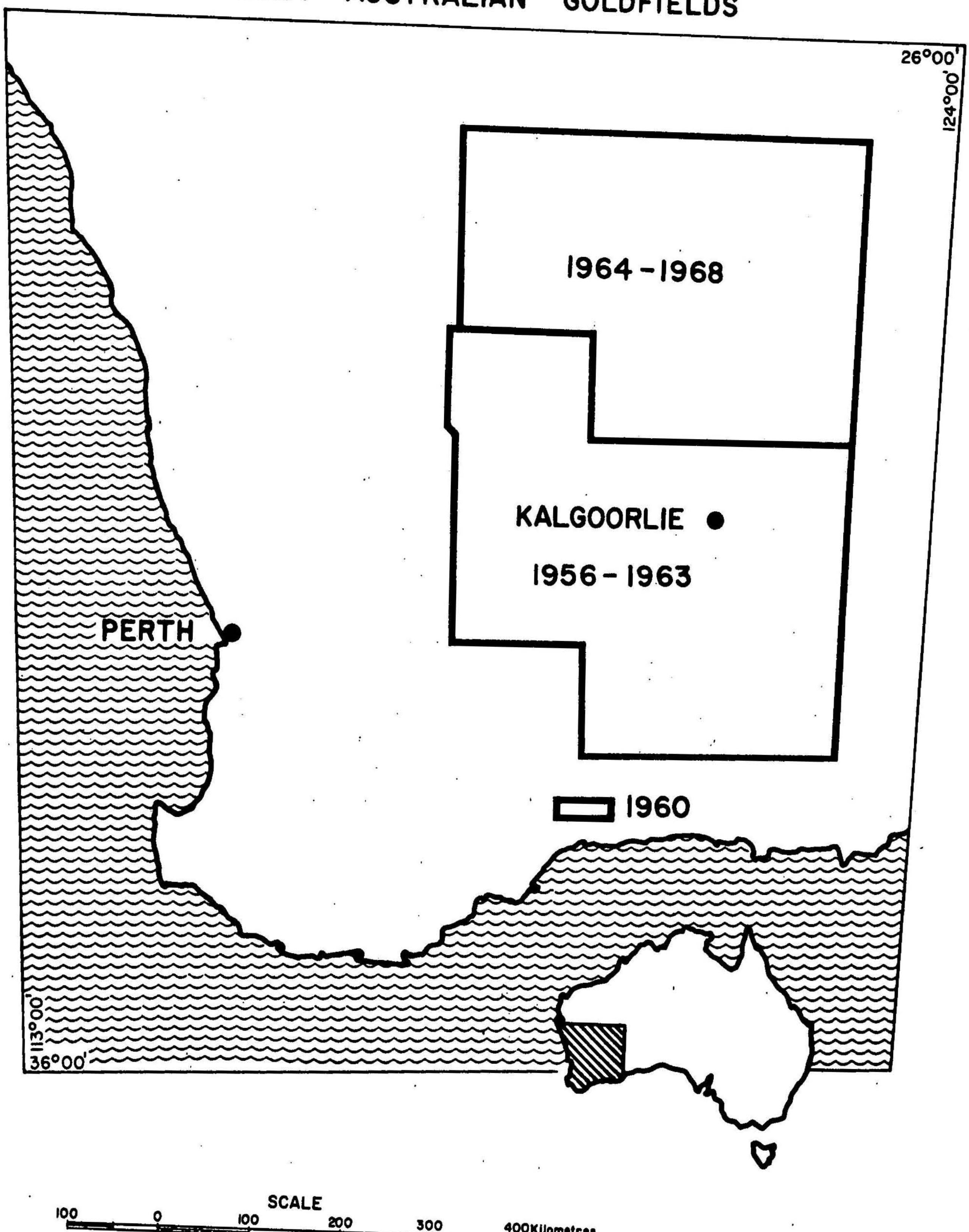
PLATE I

B.M.R. AIRBORNE SURVEYS FOR METALS
WEST AUSTRALIAN GOLDFIELDS



To Accompany Record No. 1971/78 G455-82-1

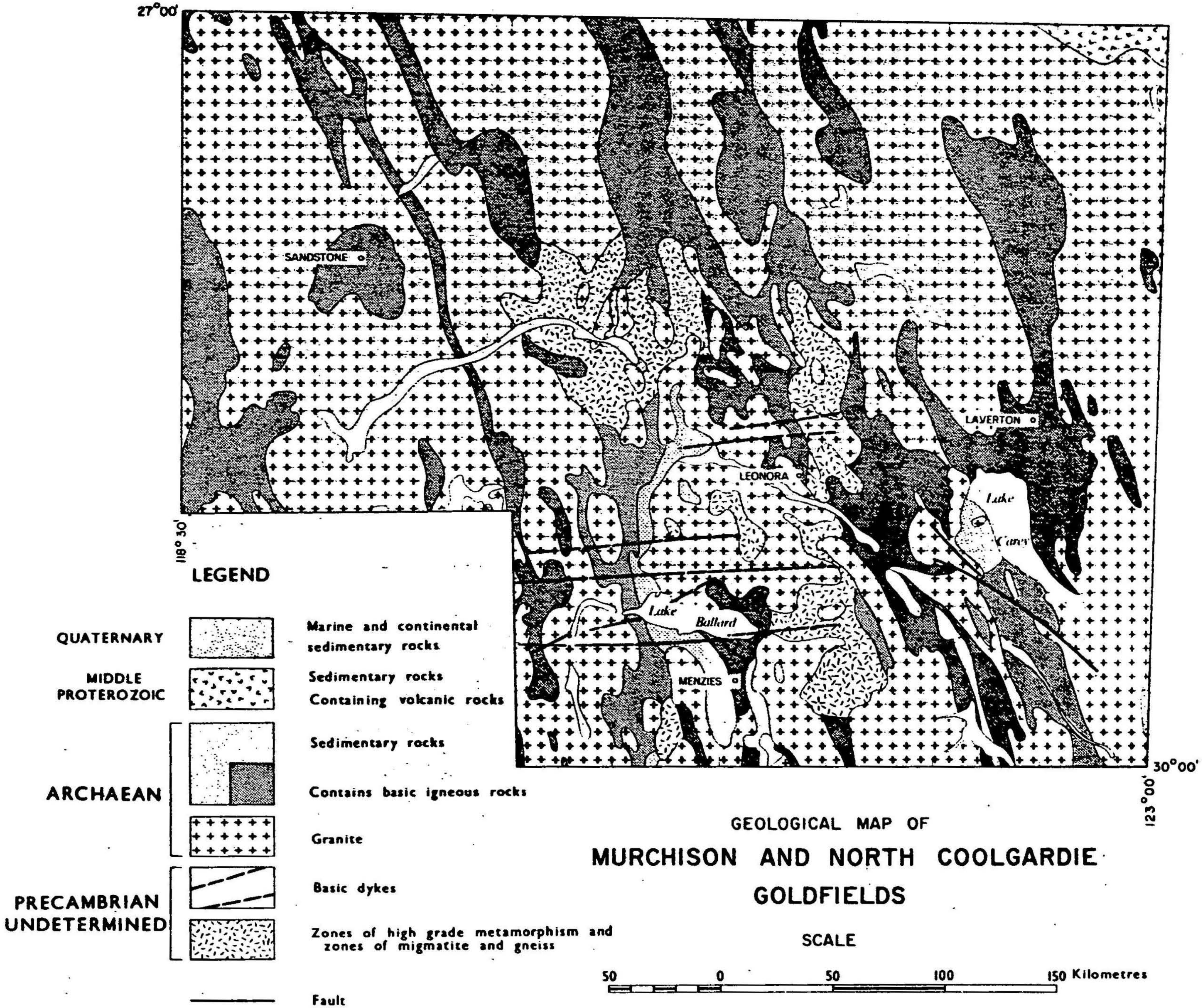
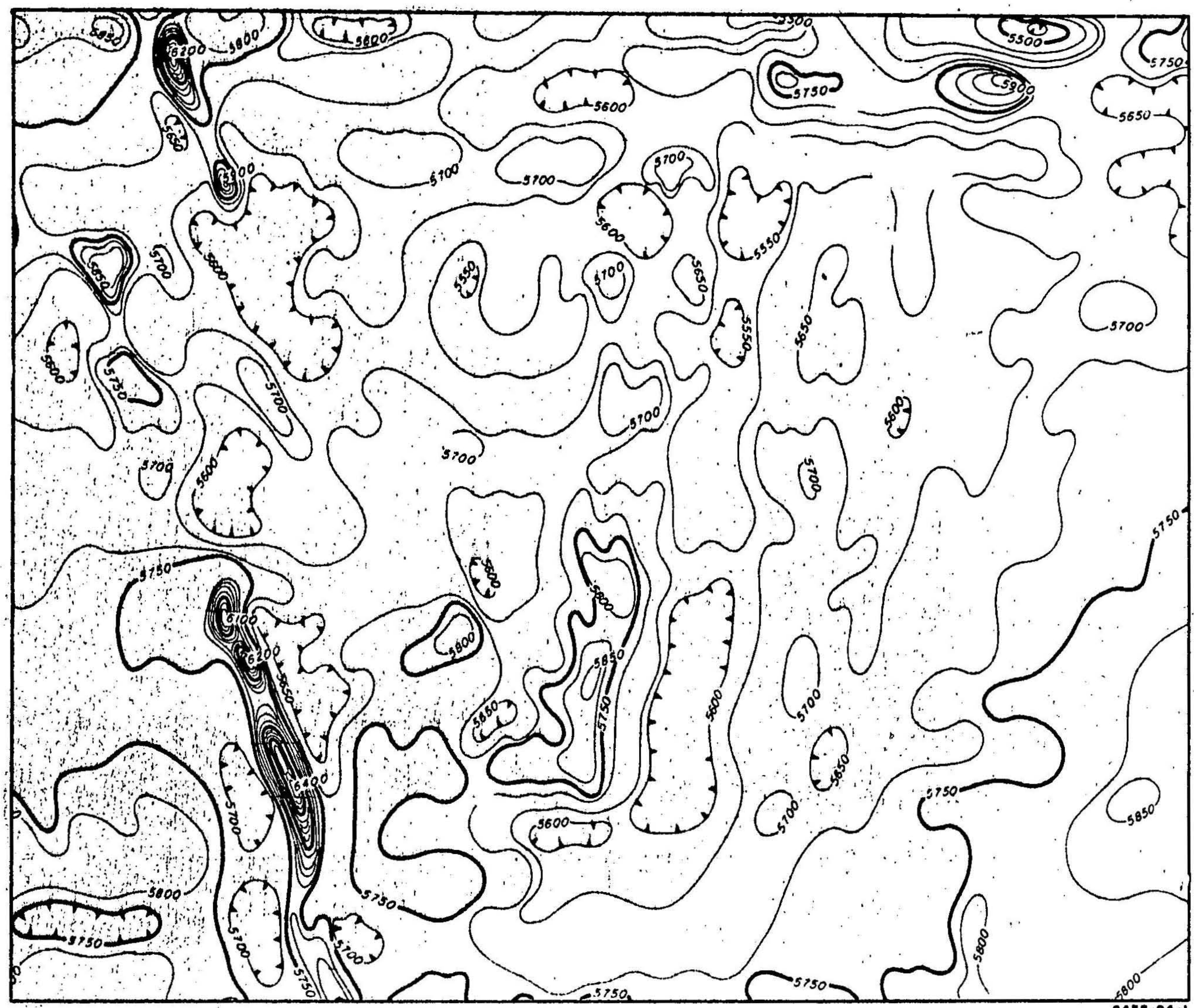


PLATE 2

To Accompany Record No. 1971/78

G455-93-1

Geology after Geological Map of Western Australia, 1966 (Geological Survey of WA)

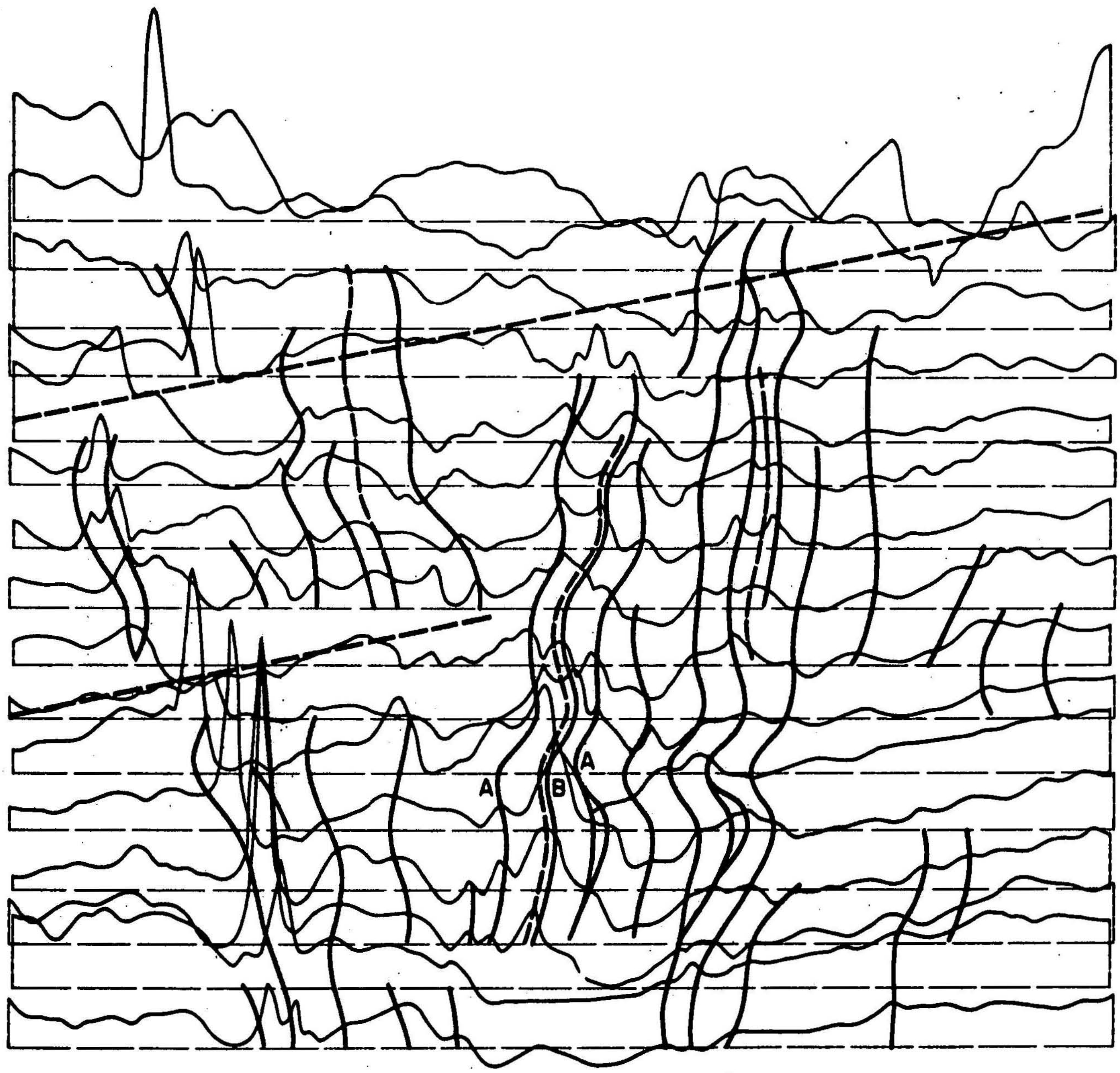


G455-94-1

SOUTH CENTRAL LEONORA
MAGNETIC CONTOURS

To Accompany Record No. 1971/78

PLATE 3B



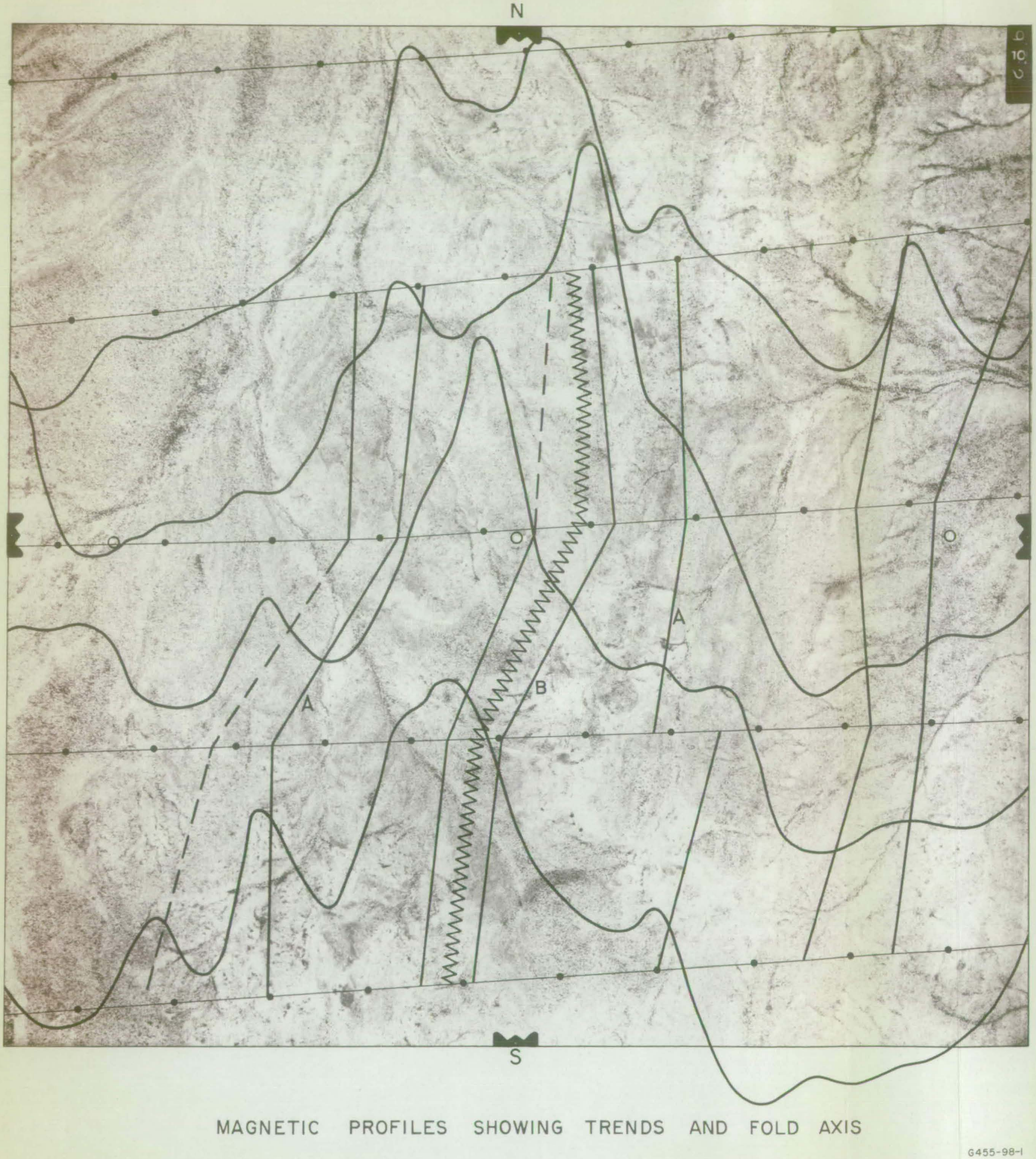
SOUTH CENTRAL LEONORA

MAGNETIC PROFILES

AND INTERPRETED TRENDS AND STRUCTURE

0455-95-1

To Accompany Record No. 1971/78

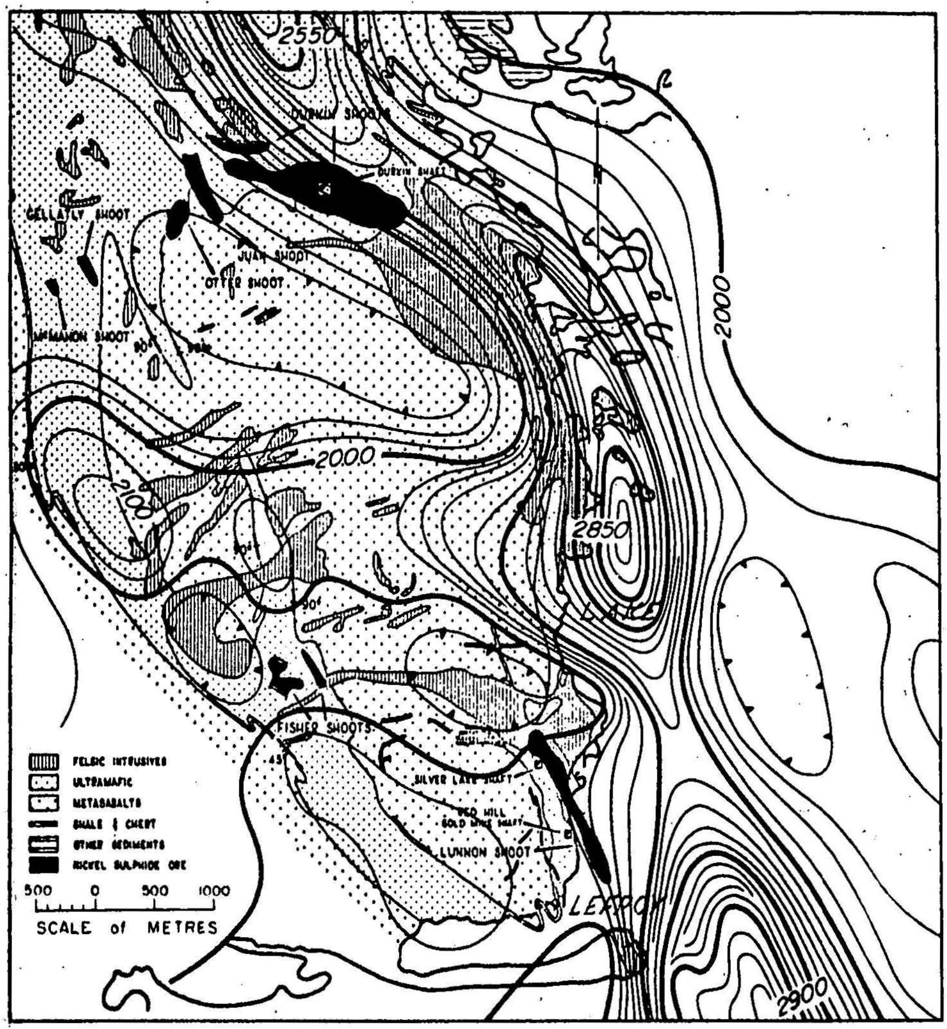


MAGNETIC PROFILES SHOWING TRENDS AND FOLD AXIS

G455-98-1

To Accompany Record No. 1971/78

PLATE 5A

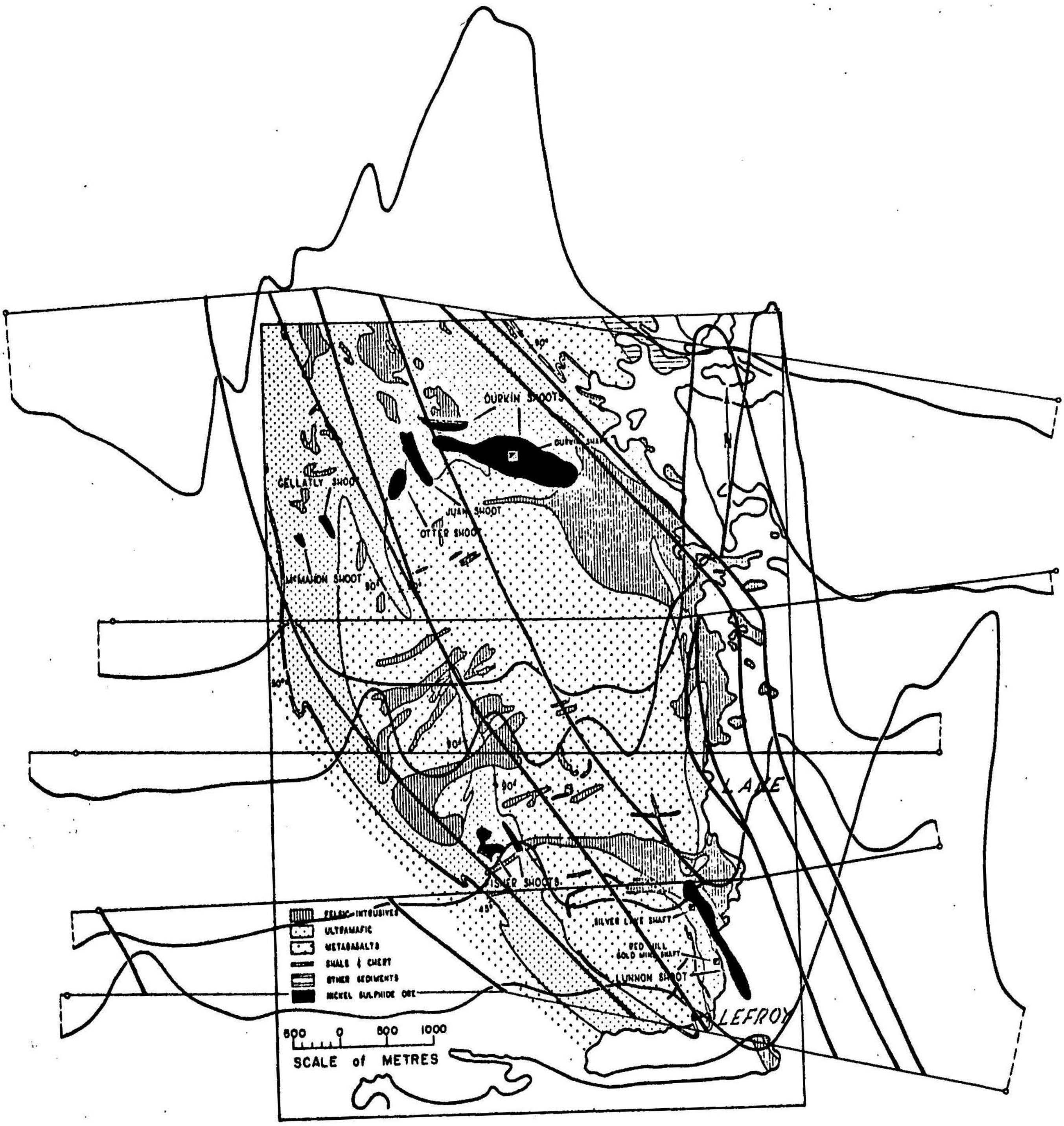


GEOLOGICAL MAP OF KAMBALDA
WITH MAGNETIC CONTOURS

G455-92-1

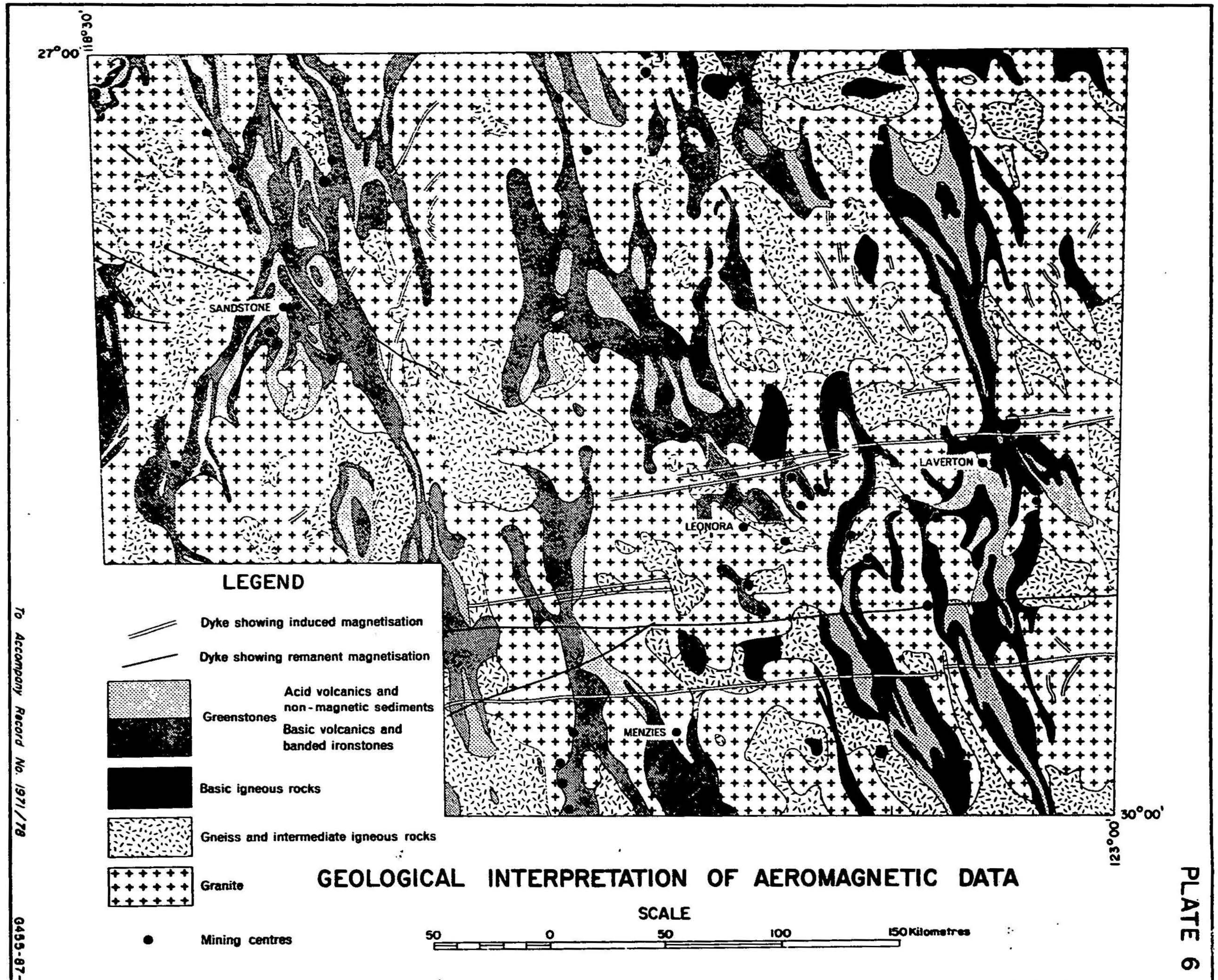
To Accompany Record No. 1971/78

PLATE 5B



GEOLOGICAL MAP OF KAMBALDA
WITH MAGNETIC PROFILES
SHOWING TRENDS

To Accompany Record No. 1971/78 G455-91



GEOLOGICAL INTERPRETATION OF AEROMAGNETIC DATA

PLATE 6

To Accompany Record No. 1971/78

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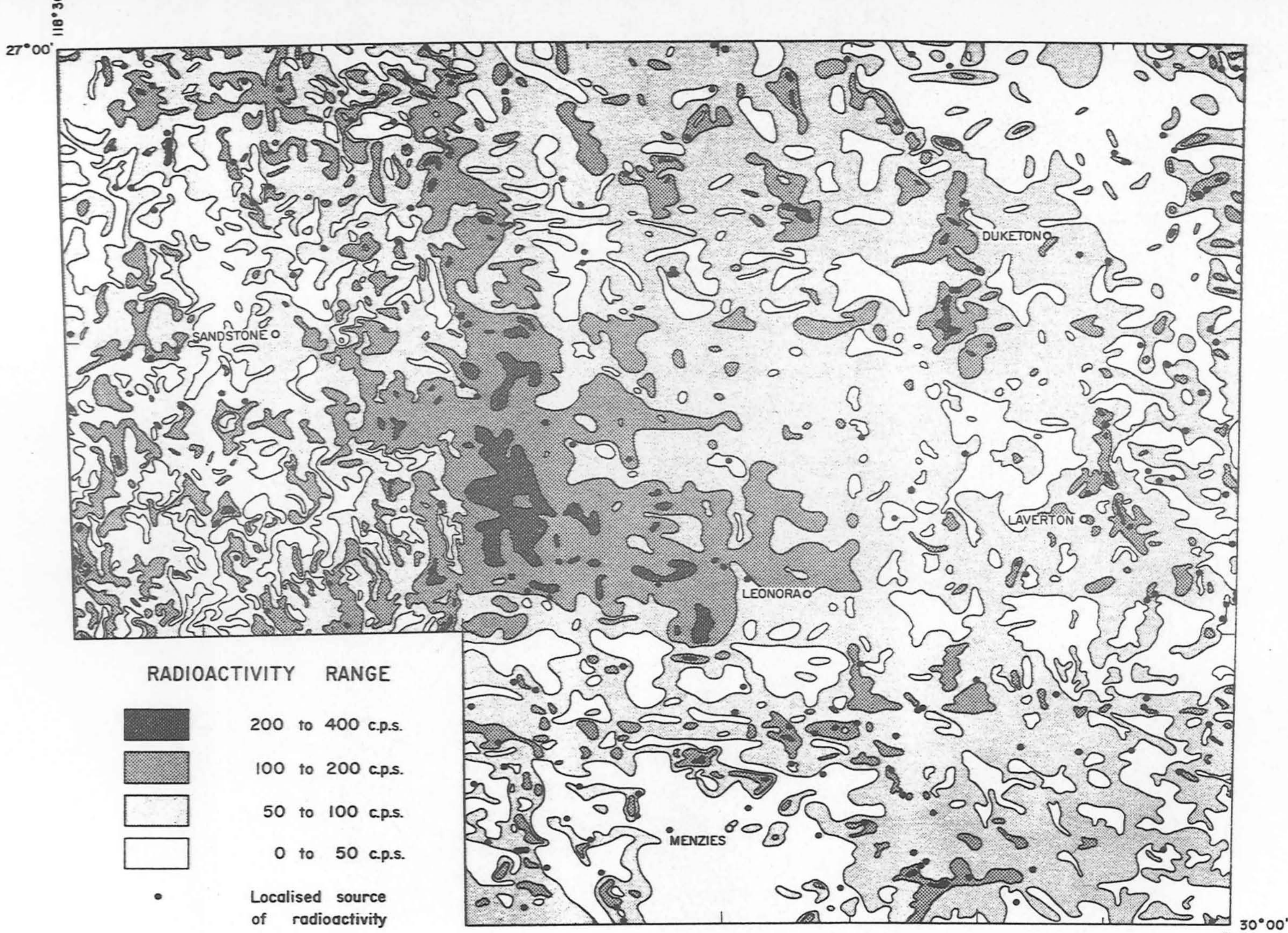

ANOMALIES AND CONTOURS OF RADIOACTIVITY

SCALE

50 0 50 100 150 Kilometres

PLATE 7

To Accompany Record No. 1971/78

G455-88-1