REPORT 182

Tottenham Detailed Aeromagnetic Survey New South Wales 1971

by

J. E. Rees and R. J. Taylor

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DEPARTMENT OF NATIONAL RESOURCES
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Tottenham Detailed Aeromagnetic Survey New South Wales 1971

J. E. REES AND R. J. TAYLOR

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SUMMARY

The data presented in this report were obtained from a detailed aeromagnetic survey in the Tottenham area of New South Wales.

Interpretation of the magnetic data has indicated structural lineations, lithological variations, and basic and/or ultrabasic intrusive associations within the generally homogeneous metasediments of the ?Ordovician Girilambone Beds. The structural relation of the Girilambone Beds to Silurian-Devonian sediments and volcanics has also been defined.

It is concluded from the geophysical and geological results that the occurrence of particular rock types in specific structural environments is the primary prerequisite for the genesis of economic copper mineralization in the Tottenham district.

INTRODUCTION

At the request of the New South Wales Department of Mines, a detailed aeromagnetic survey was flown over that part of the NARROMINE 1:250 000 Sheet area (SI/55-3) bounded by latitudes 32°02'S and 32°28'S and by longitudes 147°07'E and 147°43'E and covering an area of 2700 km^2 centred on Tottenham (Fig. 1). Sheet areas are in capital letters to distinguish them from place names.

The aim of the survey was to elucidate regional and detailed structural and stratigraphic features in the area to assist in mineral exploration being conducted by the NSW Geological Survey and private companies. Operational details are given in Appendix 1.

GEOLOGY

The survey area is part of the Lachlan Geosyncline (The Central and Southern Highlands Fold Belt of Packham, 1969), and the geology is not well known because of extensive Quaternary alluvial cover. The major rock types are mildly folded, unfossiliferous, quartz-rich metasediments of the Girilambone Beds of ?Ordovician age, and basic and ultrabasic intrusives. The dominant structural trends are north to northwest. Sediments of Silurian to Devonian age crop out to the east, southeast, and far west of the survey area.

?Ordovician system

Metasediments in the survey area (Plates 1 and 2) are considered to be no younger than Middle Ordovician (Packham, 1969; Rayner, 1961a; Brunker, Offenberg & Rose, 1967; Brunker, 1968). They are part of Brunker's (1969) Girilambone Beds and they are also referred to as Girilambone Group or Girilambone Block elsewhere in the Lachlan Geosyncline.

Packham (1969) has divided the Ordovician rocks in the Lachlan Geosyncline into two 'associations'. The Girilambone Beds are included in the 'Quartz-rich greywacke-slate associations'. West of the survey area they are described by Rayner (1961 a,b) as unfossiliferous, sheared and contorted siltstone, sandstone, phyllite, claystone, slate, quartzite, cross-bedded arenaceous sandstone and schist of low metamorphic grade (commonly quartz-albite-chlorite-muscovite facies).

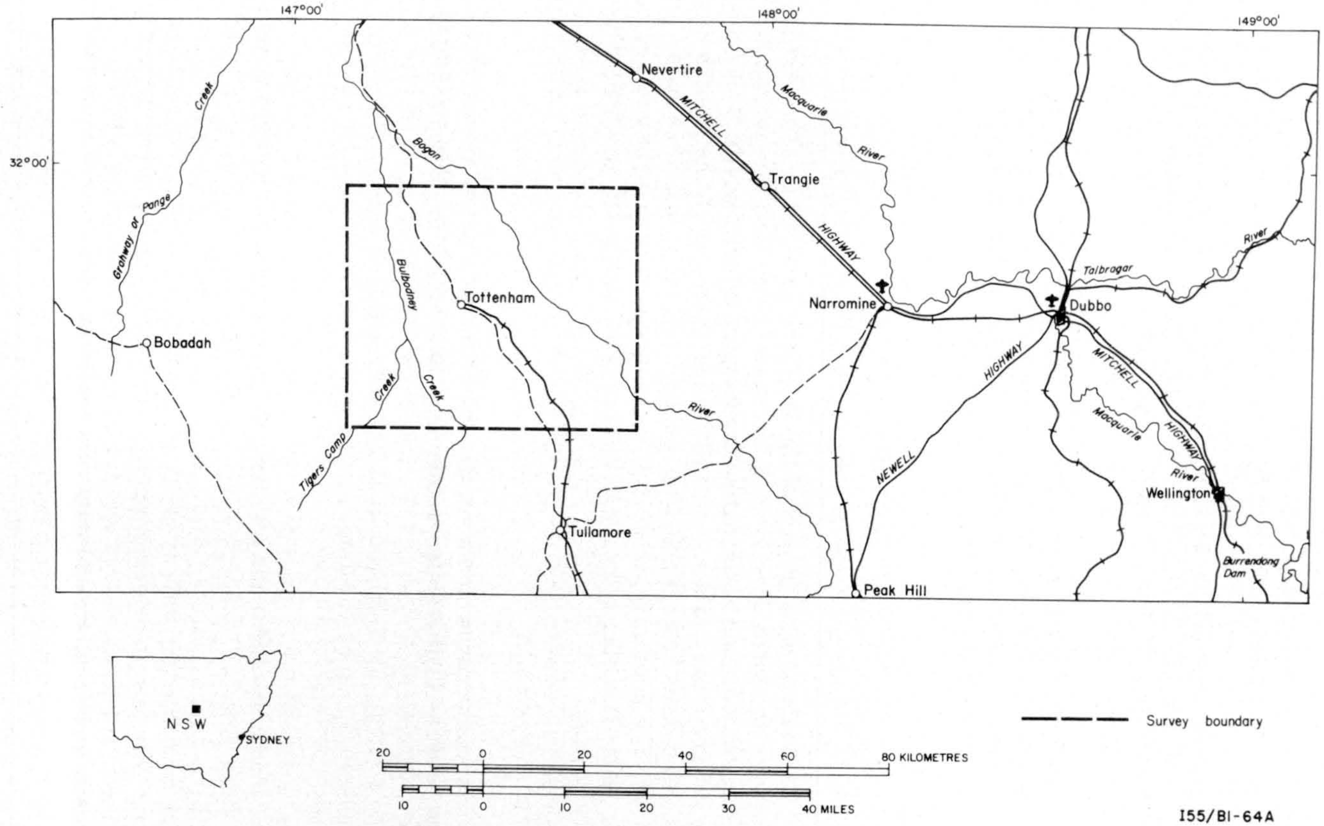

Fig. 1 Locality map

Units ascribed to Packham's (1969) 'Andesitic association' have not been reported in the survey area, but to the east in the Grenfell-Narromine region porphyritic andesite of the Goonumbla Volcanics and sedimentary derivatives crop out within the Girilambone Beds from Goonumbla to Peak Hill (Plate 1).

Suppel (1971) and Kemezys (1970) report lithological differentiation of the Girilambone Beds in some areas. Possible metabasalts have been identified at the Jimmy Woodser Mine, and metavolcanics at the Caroline Mine and along the Mount Royal/Effies Ace line of mines. Suppel (op. cit.) and Stevenson (1970) have identified two types of country rock in the Tottenham area: chlorite-epidote-tremolite/actinolite schists and epidote-chlorite rock probably of basic volcanic and andesitic origin, and quartz-albite-muscovite-chlorite/biotite schists of acid volcanic origin. Occurrences of banded magnetite quartzite have been recorded at the Bogan River, Caroline, and Underlay Mines (Suppel, 1971).

Post-Ordovician systems

Silurian-Devonian and Upper Devonian rocks occur to the west of the survey area in the Cobar-Bobadah region and to the southwest and south-east associated with the Lower-Middle Devonian Murda Syncline and the Upper Devonian Tullamore Syncline respectively (plate 1).

Within the Lachlan Geosyncline, the major Silurian rock types are acid to intermediate volcanics with associated tuff, tuffaceous sandstone, shale, slate, and conglomerate. East of Tullamore and Gobondry, units of the Silurian-Devonian Ootha and Trundle Beds ?conformably overlie Ordovician metasediments and are themselves overlain farther east by Upper Devonian sandstone and siltstone forming the Tullamore Syncline (Plate 1).

The association of younger sediments with Ordovician units in the east of the survey area is repeated farther east. A belt of phyllite and schist extending north from Goonumbla through Peak Hill and Tomingley to Narromine is overlain by younger sediments of the Hervey Syncline to the east and of the Tullamore Syncline to the west (Plate 1).

Rhyolite and porphyritic rhyolite are associated with Silurian-Devonian sediments east of the survey area (Plate 1) and far to the west in the Cobar-Nymagee-Bobadah area, where dominantly acid volcanics of the Babinda Volcanics are associated with sediments of Silurian age (Rayner, 1961b).

Kemezys (1970) has mapped scattered occurrences of ?Tertiary conglomerate, ferruginous shale, and possibly laterite along old river courses south of Tottenham (Plate 2).

Quaternary river alluvium and aeolian and talus deposits are very extensive in the Lachlan Geosyncline and about 60 percent of the survey area is covered by clay, sand, and silt of this age (Plates 1 and 2).

Orogenesis, igneous activity, and structure

All major structural and stratigraphic lineations in the northwest of the Lachlan Geosyncline have a consistent regional trend between north and northwest. Only the earliest two orogenies associated with the evolution of the Lachlan Geosyncline appear to have influenced the structural setting and igneous associations in the survey area.

<u>Benambran Orogeny</u>. Tectonism during and after Ordovician sedimentation and extending to early Silurian created the regional framework for later depositional patterns. Events concentrated along two main axes within the Lachlan Geosyncline, and emplacement of Cooma-type granites along the western axis (Wagga Metamorphic Belt) west of the survey area caused regional metamorphism of Ordovician sediments (Packham, 1969) and folding of pre-Silurian sediments (Joklik, 1950).

<u>Bowning Orogeny</u>. Diastrophism from late Middle Silurian until Lower-Middle Devonian caused further folding, development of a regional cleavage striking 320°, thrust faulting, and en echelon movements.

Within the Girilambone Beds of the survey area, Kemezys (1970) and Packham (1969) describe very large broad folds with flanks dipping between 40° and 60°, and schistosity and chevron folding generally concordant with bedding. Faults displace and/or disorientate the stratigraphic successions with more intense deformation in the Albert area. Numerous en echelon faults have been recorded in the Mount Royal group of mines (Mulholland, 1943; Suppel, 1971).

Brunker et al. (1967) suggest that during the entire span of the Bowning Orogeny, deep emplacement of massive concordant granite, granodiorite, porphyry, and diorite of the Murrumbidgee type progressed in a general northeasterly direction along north-northwest to north trends. The intrusives are foliated and associated with Ordovician and/or Silurian metasediments with the characteristics of low-grade greenschist facies.

The later Tabberabberan Orogeny, which ended synorogenic sedimentation in the Lachlan Geosyncline, and the Kanimblan Orogeny which followed, had little influence on structure within the survey area. Towards the end of the Bowning Orogeny the area was probably part of an emerging structural high separating areas of deposition of the Hervey Group from the Mulga Downs Group, which crops out in the neighbouring NYMAGEE 1:250 000 Sheet area.

Ultrabasic rocks. There is extensive evidence for the occurrence of basic and ultrabasic rocks in the survey area, and all may relate to the Gundagai Serpentinite Belt of Rayner (1961a), who considers that all intrusives in the region are structurally controlled.

In the Hylea homestead/Tigers Camp Creek area, Kemezys (1970) and Suppel (1971) describe an outcropping intrusive complex consisting dominantly of quartz-feldspar-hornblende diorite with some porphyritic hornblende diorite, schistose diorite, quartz-feldspar-epidote-magnetite pegmatite, and serpentinite (Plate 2). Diamond-drill hole TM 360 D139 was drilled to an inclined depth of 217 m by Lamadec Exploration Ltd and intersected mainly diorite and hornblendite with some serpentinite, monzonite, and abundant magnetite in places (Kemezys, 1970).

Northwest from Fifield (Plate 1) melanosyenite, melanodiorite, diorite, hornblende pyroxenite, and monzonitic hornblende pyroxenite crop out. There is no evidence for direct granitic associations with ultrabasics in the survey area.

Economic geology and mineralization

The survey area is centred on the Tottenham-Albert mineral field, which is considered to be more related to the Girilambone field to the northwest than to the Cobar-Nymagee-Melrose field to the west.

McClatchie (1970) and Carne (1899) have discussed the distribution of mines within the general region. Rayner (1961a) and McClatchie (op. cit.) have compared ore-types and their modes of occurrence in the Cobar and Tottenham areas. Suppel (1971), Twist (1967) and Stevenson (1970) have discussed in detail mineralization in the Tottenham and Albert districts.

Production up to 1930 was 74 000 tonnes of low-grade copper ore, principally from the Mount Royal, Caroline, Bogan River, and Iron Duke mines (Plate 2). Primary ores are pyrite, chalcopyrite, and gold with minor pyrrhotite and cobaltite. Gangue is dominantly siliceous in the mines to the east and south of Tottenham, but non-siliceous in the Tottenham Group (Suppel, 1971).

Geological mapping by Suppel (1971), Kemezys (1970), Twist (1967), and Mulholland (1943) indicates that copper mineralization is dominantly structurally controlled and has two distinct modes of occurrence: narrow, stratiform pyritic lodes at the Caroline, Underlay, Nelson's, and Ace mines and at the Mount Royal Group, commonly associated with faulting offsets, contrast with cupriferous, transgressive, fissure-filling quartz lodes in the Albert area at the Iron Duke, Christmas Gift, Monarch, and Mount Pleasant mines (Plate 2). A disseminated ore may occur at Jimmy Woodser Mine. In the Tottenham area, host rocks are of the types already described under ?Ordovician system, and lodes dip from 30° to 60° to the south. Carne (1910) reported that the zone of secondary enrichment extended to depths of 60 to 85 m.

MAGNETIC PROPERTIES OF THE ROCKS

Within the survey area only the ultrabasic rock complex at Hylea was expected to cause strong magnetic anomalies. The metabasalts and metavolcanics reported by Suppel (1971) and Kemezys (1970) were expected to give rise to weak anomalies. Elsewhere in the survey area the outcropping rock types are those which have traditionally been regarded as non-magnetic.

The magnetic results in the NARROMINE 1:250 000 Sheet area (Young, 1963) suggest that units of the Ootha Beds may occur in the east of the survey area. The volcanic material in these beds may be expected to cause weak to moderate magnetic anomalies.

The only susceptibility measurements made on rocks from the area were those on core samples from Hylea. These gave values ranging from 0.0020 to 0.0057 c.g.s. Other susceptibility values were calculated from the anomalies. Published values of susceptibility (Birch, Schairer, & Spicer, 1942; Heiland, 1946) show that for most rock types susceptibility is rather variable. However, such values are a useful guide in that they at least give an order of magnitude.

PREVIOUS GEOPHYSICS

Geophysical techniques employed within the survey area have been confined to regional aeromagnetic and radiometric coverage and detailed ground magnetic, induced polarization, and geochemical surveys over various mines.

Regional surveys

Regional aeromagnetic and radiometric surveys by the Bureau of Mineral Resources covered NARROMINE (Young, 1963) and COBAR and NYMAGEE (Spence, 1961). Intense magnetic anomalies over Hylea homestead and northwest of Fifield and Kelvin Grove (Plates 1 and 2), ascribed to subsurface ultrabasic material (Young, 1963), are similar to features detailed by Spence (1961) in the Girilambone area to the northwest.

Interpretation of other regional magnetic features in the NARROMINE Sheet (Plate 1) is presented in a later section.

Detailed surveys

Results of various detailed induced polarization surveys in the Tottenham-Caroline area and a copper geochemical anomaly near Nelson's Prospect and the Underlay Mine are presented in Plate 3 together with the present aeromagnetic contours and interpretation. Agostini (pers. comm.) has detected offset magnetic anomalies in ground surveys over the Mount Royal group of mines, and IP traverses over the Iron Duke mine west of Albert detected only moderate to weak anomalies. The implications of these results are discussed in a later section.

RESULTS AND INTERPRETATION

The magnetic data are presented in preliminary contour form in Plates 4A, 4B, 4C, and 4D.

Interpretation has co-ordinated the results of the current survey and previously acquired geophysical and geological information, and is presented in Plate 2. Details of specific interpretation methods used are given in Appendix 3. All depths referred to in the text are in metres below ground level.

Six characteristic types of magnetic anomaly have been defined over the survey area, and each is discussed separately. They have been numbered from 1 to 6 in Plates 4A, 4B, 4C and 4D for ease in identification. Where necessary, the results of the survey of the NARROMINE 1:250 000 Sheet area have been used to correlate anomalies with known geology. In general, however, it is not possible to directly correlate magnetic anomalies with known geology in the survey area.

Eastern extremity of Girilambone Beds

Subparallel sets of linear anomalies (1 and 2) extend along the entire eastern edge of the survey area (Plates 4A, 4B) and have been interpreted as defining the eastern extremity of the Girilambone Beds in the Tottenham-Fifield area.

Alluvial deposits cover eastern part of the survey area, but the character of the eastern anomalies is very similar to strong magnetic lineations elsewhere in the NARROMINE Sheet. To obtain consistent interpretations it is thus necessary to consider the correlation between the geology and the anomalies outlined in the regional aeromagnetic survey (Plate 1).

Within the NARROMINE Sheet there are several occurrences of Upper Devonian synclinal sediments overlying rocks with ages from Lower-Middle Devonian to Ordovician. Where magnetic anomalies or similar form to the eastern lineations in the survey area exhibit direct geological correlation, the source rocks are either Silurian-Devonian volcanics and/or basic rocks of Middle Ordovician age.

The Silurian-Devonian rocks include the Dulladerry Rhyolite encasing the Hervey Syncline in the north and east, areas of Trundle Beds in the Trundle-Kadungle area and 4 km east of Yethero, and the rhyolite, dacite, and other volcanics within the Ootha Beds east of Gobondry, Kadungle, and Trundle. Middle Ordovician rocks with which magnetic anomalies can be correlated include outcrops of Goonumble Volcanics between Goonumbla and Peak Hill, basic intrusives of the Hawkes Creek Beds and Tantitha Ultrabasics 15 km southeast of Narromine and along a belt parallel to and west of the axis of the Hervey Syncline, and an outcrop of Hawkes Creek Beds 12 km southwest from Narromine.

Within the survey area (Plate 2), anomalies in the east have been subdivided into two distinct sets (1 and 2) based on attitude, orientation, continuity, and estimated susceptibility.

Eastern set. Anomalies with amplitudes from 100 to 300 nT form continuous north-striking lineations (1). They correspond to lineations along the eastern flank of the Tullamore Syncline and to anomalies delineating the synclinal zone which runs north from Narromine (Plate 1).

The interpreted distribution of the causes of the eastern set is presented in Plate 2. Estimates of depths to the top of the bodies range from 70 m in the south to 220 to 500 m in the north. The bodies dip 70° to 80° east in the south of the area, near vertical in the centre, and 60° to 70° east in the north. Susceptibility estimates range form 0.0009 to 0.002 c.g.s. The interpreted causes of these anomalies are post-Ordovician volcanic sequences which are possibly either equivalents of the Dulladerry Rhyolite or the Ootha Beds and Trundle Beds within a northerly extension of the Tullamore Syncline.

Western Set. These anomalies (2) contrast with the eastern set in being less continuous. They strike between 320° and 340°, are generally broader, and are less intense. The magnetic patterns suggest the presence of numerous transcurrent faults, striking northeast. These faults do not appear to disturb the eastern set of lineations.

Within the western set there are two constituent groups which are distinguished by differences in interpreted depth, dip, and susceptibility. One group has a general dip of 50° to 70° west, susceptibility contrasts from 0.001 to 0.002 c.g.s., and depths from 40 m in the south to 220 to 500 m in the north. Causes of the other group of less intense anomalies have an estimated susceptibility contrast of 0.0005 to 0.0008 c.g.s., generally lie to the west, and are not as deep.

To the northeast and east of Albert (Plate 4B) anomalies similar to those of the western set in the north generally strike northeast. The interpreted causes dip to the east (Plate 2), which may reflect local structural influence by the Minemoorong feature, which is discussed later.

The causes of the western anomaly set have been interpreted as Ordovician volcanic sequences of andesitic or magnetically equivalent composition and/or their sedimentary derivatives. The more intense group may be due to equivalents of the Goonumbla Volcanics or units of the Hawkes Creek Beds and are overlain in the west by either younger less magnetic volcanics or sedimentary derivatives of the Ordovician volcanics.

An interpreted structure of the eastern margin of the Girilambone Beds is shown in Figure 2.

Tullamore Syncline. Continuity and consistency of the magnetic contour pattern north from the Tullamore Syncline in the southern half of the NARROMINE Sheet area (Plate 1) suggest that a very thick post-Ordovician sedimentary sequence underlies the extensive alluvial cover in the east of the survey area.

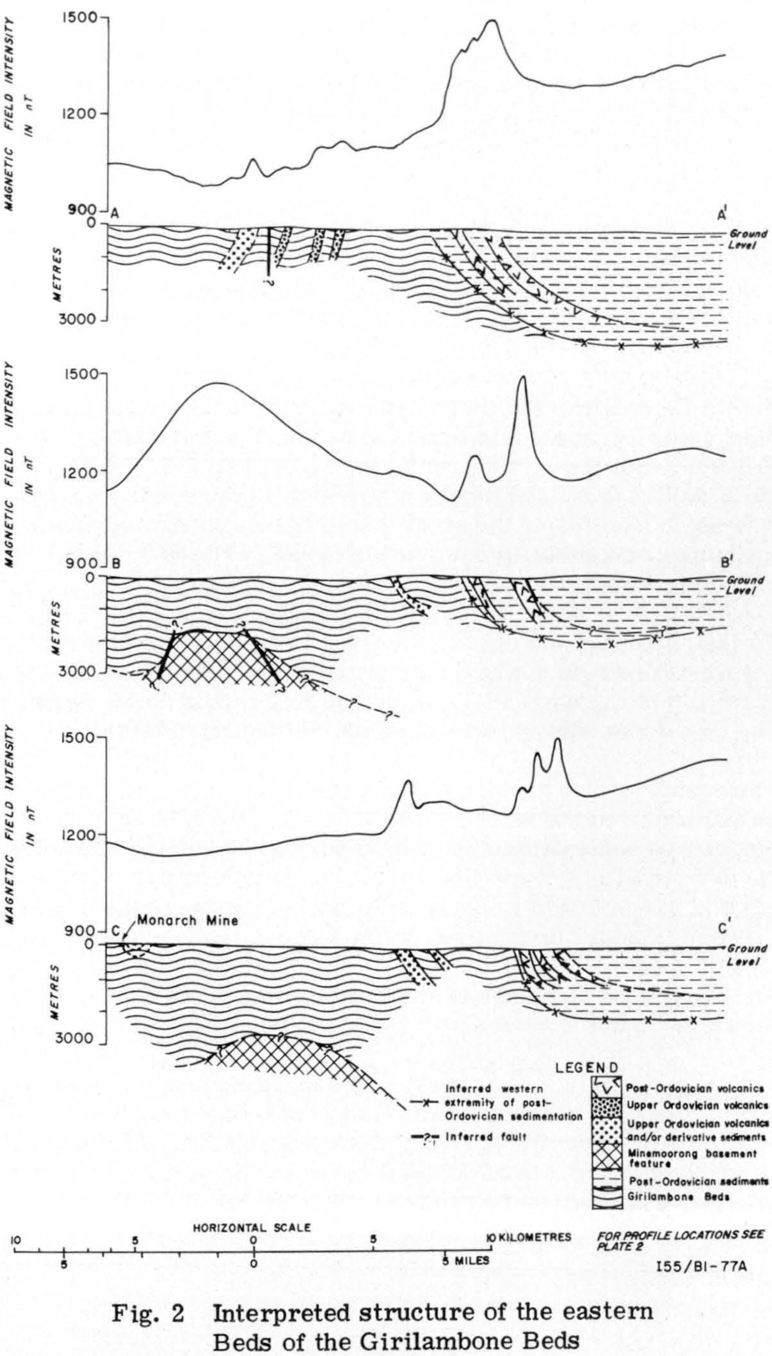

Fig. 2 Interpreted structure of the eastern Beds of the Girilambone Beds

Basement depth estimates (Plate 2) range from 1500 to 4000 m. A discontinuity in depth estimates and the magnetic contour pattern suggest that the Tullamore Syncline may be truncated east of Dandaloo (Plates 1 and 2) and perhaps a deeper basin extends farther north with post-Ordovician sedimentary thicknesses ranging from 3000 to 4000 m. Alternatively the Tullamore Syncline may continue to the north, deepening rapidly north of Dandaloo.

No magnetic anomalies are associated with sediments of the Murda Syncline to the southwest of the survey area (Plate 1). This indicates that either there was no Silurian-Devonian volcanic activity in this area or any such extrusives were eroded before deposition of the Condobolin Formation.

Minemoorong anomaly (Plates 2, 4B)

This magnetic feature (3) of broad elliptical form is immediately east of Minemoorong. Two similar anomalies occur immediately south of the survey area (Plate 1) near Minnalong and Babathnie Lagoon.

Interpretations using various methods (Plate 2) suggest an average depth of 1950 m to the top of the causative body, an average width of 3000 m, and susceptibility contrast of 0.0023 c.g.s. Dipping dyke model interpretations are illustrated in Figure 3. The consistently narrower and deeper estimates obtained using the symmetric component in the separation method suggest that the body has a dome-shaped upper surface.

The Minemoorong anomaly types are also characterized by a general absence of associated contrasting magnetic features. The local intense anomaly 3 km east of Albert (Plate 4B), and two similar features on the broad anomaly near Babathnil Lagoon south of the survey area (Plate 1) are the only exceptions to this rule. Variations in the strike directions of magnetic lineations east and southeast of the Minemoorong anomaly suggest that the body that causes it has influenced the attitude of stratigraphic and/or structural patterns in the immediate vicinity.

The Minemoorong anomaly is due to a deep-seated body of prismatic form, plunging to the northwest with an average susceptability of 0.0023 c.g.s. It may be a granitic intrusion, remnant basement topography underlying the Girilambone Beds, and/or horst and graben basement faulting.

It is possible that bodies similar to the Minemoorong type but shallower and less extensive may underlie the interpreted intrusive complexes west of the

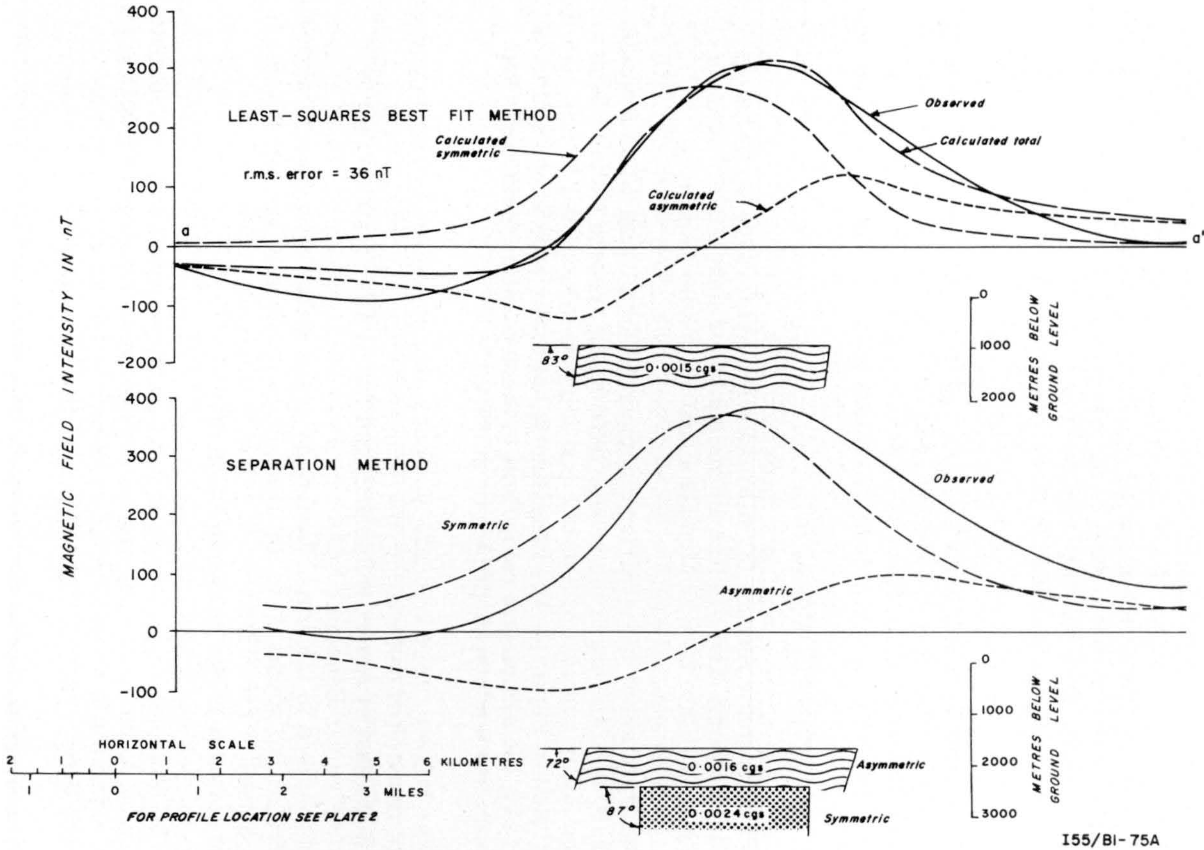

Fig. 3 Interpretation of Minemoorong anomaly

in the south of the area, near vertical in the centre, and 60° to 70° east in the north. Susceptibility estimates range form 0.0009 to 0.002 c.g.s. The interpreted causes of these anomalies are post-Ordovician volcanic sequences which are possibly either equivalents of the Dulladerry Rhyolite or the Ootha Beds and Trundle Beds within a northerly extension of the Tullamore Syncline.

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A third possible complex, termined the Ace Intrusive Complex, lies south and southeast of Tottenham. The individual anomalies are more localized than those associated with the other complexes. Units of the Ace Complex may be more extensive than indicated, as it is difficult to differentiate them from the nearby metavolcanics. They appear to conform to stratigraphic and structural lineations within the Girilambone Beds to the north and northwest.

There are insufficient data available to adequately define the anomalous magnetic zone in the far north of the survey area north of Wyoming homestead. The complex of anomalies north of the intense magnetic low defines the Cowal Complex (Plate 2). The magnetic character of this area is similar to the anomalous zone near Fifield and the zone near Kelvin Grove south of the survey area (Plate 1). Alternatively, the Cowal Complex may reflect a major discontinuity along the eastern extremity of the Girilambone Block in the far north of the survey area.

Isolated intrusions (Plates 4A, 4B, 4C, 4D). Local intense anomalies (5) attributable to basic intrusions into the Girilambone Beds occur southeast of the Minemoorong anomaly, 9 km northwest of Tottenham, and 10 km southeast of Hylea homestead. As discussed in the following section, some of these and other anomalies, e.g. near Lunn's Dam and Rocky Tank, may be due to more basic metavolcanics within the Girilambone Beds. Lack of any geological control prevents more positive identification of the causes of the intense isolated anomalies.

Girilambone Beds - stratigraphy, structure, and mineralization

Anomalies which have amplitudes from 5 to 100 nT and which exhibit persistent form over considerable strike lengths indicate stratigraphic and structural trends within the metasediments of the Girilambone Beds. These anomalies are shown on the contour maps as type 6.

The origin of the semi-continuous arc of 20 to 30 nT anomalies striking north to northwest from the Caroline Mine area (Plates 4A, 4C) has been interpreted as metavolcanic units with susceptibilities ranging from 0.0002 to 0.0003 c.g.s. As indicated in Plate 2, the sequence is fairly shallow and dips steeply east in the north, flattening to dip southeast and south in the south. Continuity is obscured immediately northwest and west of the Caroline Mine by possible fault offsets and to the east and southeast by other anomalies. There is evidence that residual segments of these units persist to the southwest on an arc passing through the Tottenham group of mines to emerge as a set of lower-order lineations striking northwest from Tottenham (Plates 2, 3). The source rocks for these anomalies are probably units of the quartz-albite-muscovite-chlorite schists which Suppel (1971) suggests were originally acid volcanics and which are intimately associated with the Caroline lode and the Mount Royal group of lodes.

Similar but less extensive features occur 10 km northwest of Tottenham, near Lunn's Dam and Rocky Tank, and in the far southwest of the survey area (Plate 2).

The extent and distribution of magnetic anomalies attributable to units of the chlorite-epidote-tremolite/actinolite schist host-rock type, which Suppel (1971) suggests are altered basic volcanics and andesite, are not clearly defined because of the proximity of units associated with the Ace Intrusive Complex. Suppel (op. cit.) reports this schist in deeper core sections from drilling at Nelson's Mine and as an association with the Ace Mine Lode.

In the Mount Royal Group, induced polarization anomalies (Plate 3) are offset to the north, and parallel associated magnetic anomalies; both techniques indicate an en echelon fault pattern. A similar association of magnetic and induced polarization anomalies exists at the Caroline, Nelson's, and Underlay mine areas. McClatchie's (1970) suggested serpentinite near the Caroline mine is not consistent with the interpretation of anomalies east of the Caroline lode and south of the Mount Royal Group (Plate 3; Figures 4 and 5), which appear to have a similar origin. From geophysical and geological evidence the source rocks for these magnetic anomalies are interpreted as metavolcanics, originally of basic and/or andesitic composition. The isolated anomalies 12 km northwest from Tottenham and in the vicinity of Lunn's Dam may thus be due to remnant volcanic centres or necks (Plate 2).

Details of possible structural association and distribution of the interpreted rock types in the Tottenham area are shown in Plate 3 and Figure 5. Low-grade copper mineralization of the Tottenham Caroline type is found at places where several features occur in close proximity. All known deposits are associated with metavolcanics of basic and/or acidic origin within the Girilambone Beds. Most are near en echelon faulting either observed or inferred from magnetic and IP anomaly patterns, and some are close to magnetic anomalies ascribable to basic/ultrabasic elements of the Ace Intrusive Complex. The close proximity of the Minemoorong feature to the southeast may also be relevant.

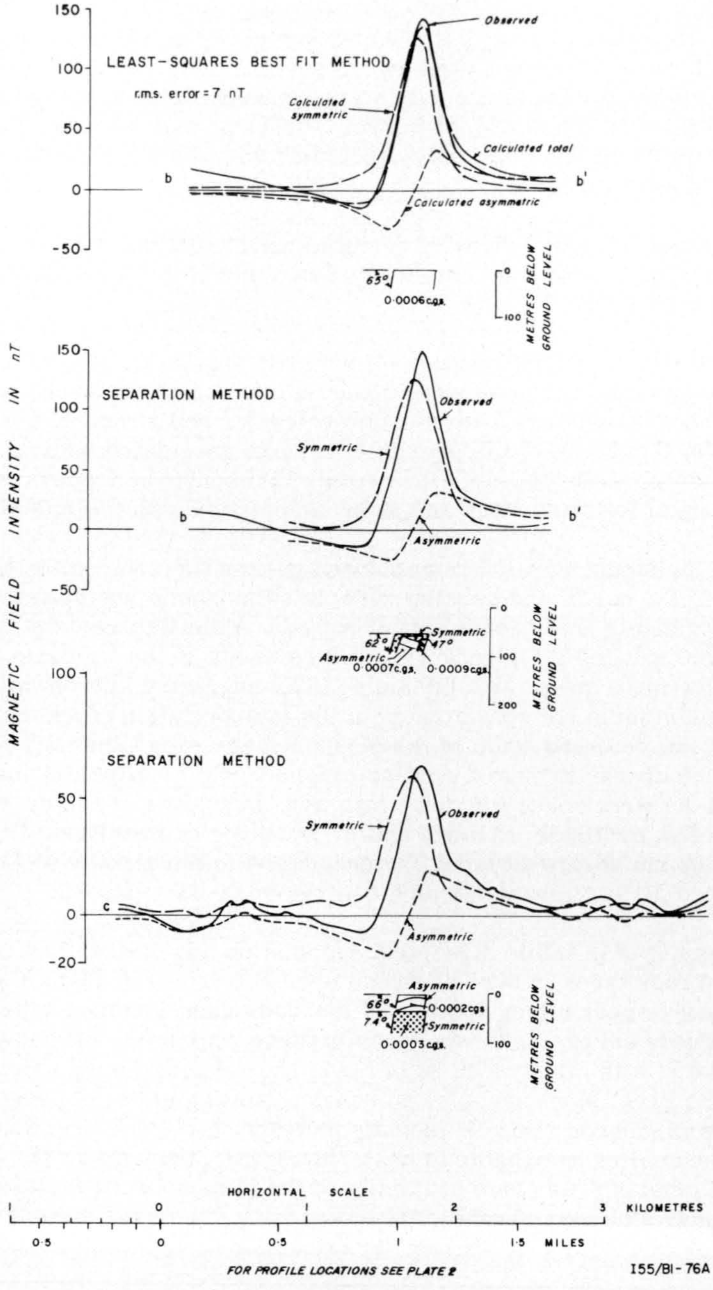

Fig. 4 Specific anomaly interpretations - Caroline area

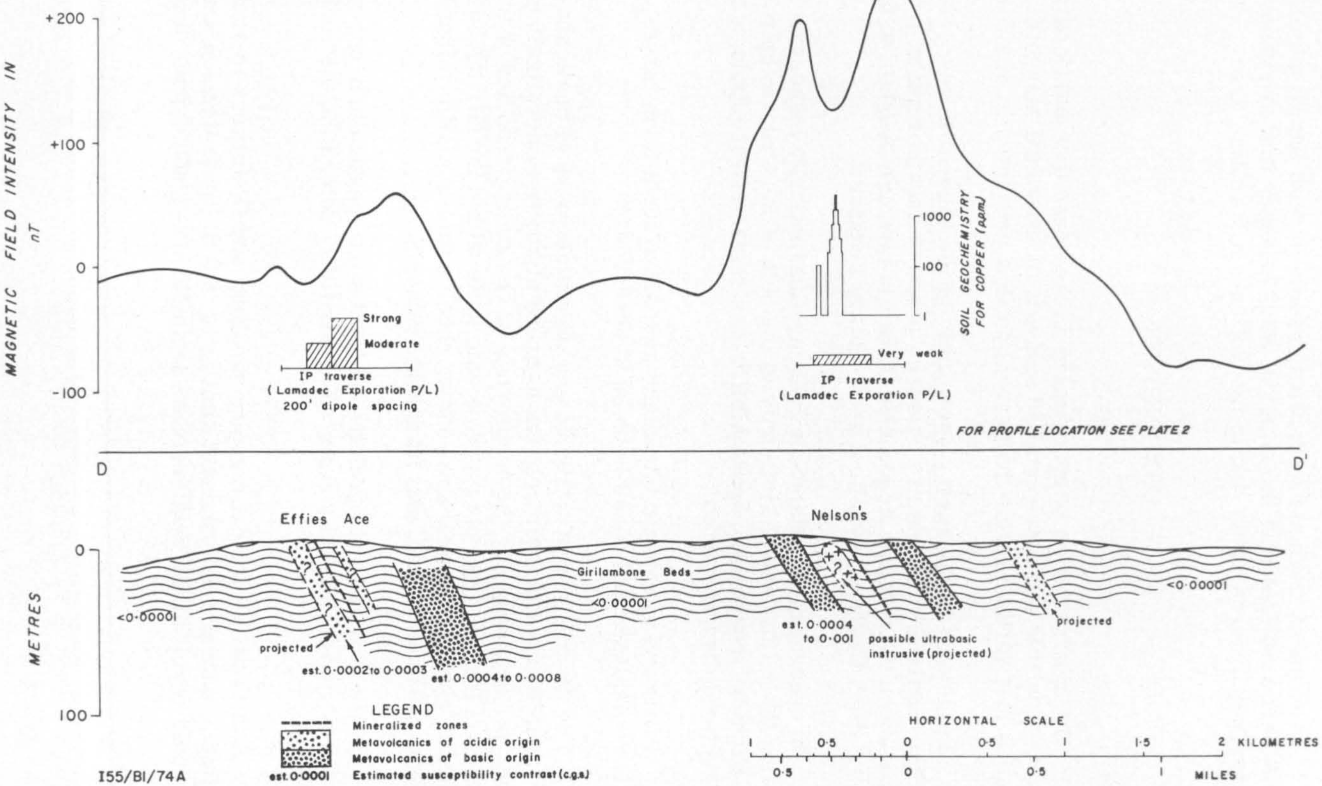

Fig. 5 Interpretation: Mount Royal/Nelson's Mine area

The lack of magnetic anomalies associated with known mineralization in the Albert area confirms the mineralogical evidence that ore genesis in that area was different from that in the Tottenham/Caroline area.

CONCLUSIONS

The interpretation is preliminary in the sense that additional geological controls and more detailed analysis of individual magnetic anomalies may further refine the generalizations presented in this Report.

In the east of the survey area, units of the 'Andesitic association' within the Girilambone Beds are overlain, possibly unconformably, by Silurian-Devonian volcanic sequences. These in turn are overlain to the east by a thick Devonian synclinal sedimentary sequence.

In general the Girilambone Beds are magnetically homogeneous, reflecting their lithological similarity to the bulk of the Ordovician rocks in the Lachlan Geosyncline. Susceptibility contrasts reflect lithological and structural discontinuities.

Basic and ultrabasic intrusions at shallow depth form three intrusive complexes and possible isolated occurrences.

The distribution of intrusive and extrusive rocks of basic and/or acidic composition and their relation to areas of known mineralization suggest that the pre-requisites for the occurrence of economic orebodies of the Tottenham/Caroline type are metavolcanic units within the Girilambone Beds, later basic/ultrabasic intrusions, and en echelon faulting. Mineralization of the Albert type has no apparent magnetic response.

Further drilling at carefully selected sites, particularly north and south of Tottenham, would be required to positively determine the rock types in this area.

Additional geological mapping, drilling, and IP surveys in areas exhibiting a magnetic environment similar to that in the Tottenham/Caroline area should result in the location of more small low-grade copper deposits.

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APPENDIX 1 : OPERATIONAL DETAILS

Personnel			
BMR	J.E. Rees	Geophysicist	
	K.R. Horsfall	"	
	R.J. Taylor	"	(part time)
	B.W. Wyatt	"	(part time)
	L.M. O'Toole	Draftsman	
	T.J. Kimber	"	
	A.S. Scherl	Technical Officer	(part time)
	H. Alexander	" "	(part time)
	D. Park	Technical Assistant	
	M.N. Johnson	" "	
TAA	B.N. Joel	Pilot	

Survey base — Dubbo, NSW

Survey duration — 23 March to 30 June 1971

Aircraft — Aero Commander, VH-BMR

Survey configuration — Altitude : 300 m above M.S.L.

Line spacing : 250 m

Line flight direction : east-west

Aircraft speed : 90-120 knots

Navigation : photographic

Airborne instruments

Magnetometer: proton procession BMR MNS-1 and MNS-2, 1-second cycle with detector 10 m below the aircraft

Recorder : analog chart from 2-channel Moseley 100B Recorder with 100 and 1000-nT f.s.d. sensitivity and a chart speed of 6 inches per minute

Timing : BMR unit with 6-second fiducial interval

Camera : BMR modified Vinten 35-mm frame camera with fish-eye lens

Ground instruments

Location	:	Dubbo airport
Magnetometer	:	proton procession BMR MNS-1 with 30-second cycle
Recorder	:	single-channel Esterline Angus ink chart recorder with 100-nT f.s.d. sensitivity and chart speed of 6 inches per hour

APPENDIX 2 : DATA PROCESSING

Magnetic data reduction

The analog magnetic data were digitized at a sampling interval of 0.6 second. Diurnal variations recorded at Dubbo Airport (using a reference field intensity of 57 535 nT) and the regional magnetic component computed using the IGRF Model at time 1971.4 for an altitude of 0.30303 km (1000 ft) above M.S.L. were removed from the data.

An aribitrary constant of 10 000 nT was added to the data, which were subject to low-pass filtering with a sharp cutoff at 8 cycles per km.

Flight path recovery

Photo-control points recovered every 1-2 km were transferred to planimetric base maps at a compilation scale of 1:31 680 and digitized for use in data processing and presentation.

Contouring

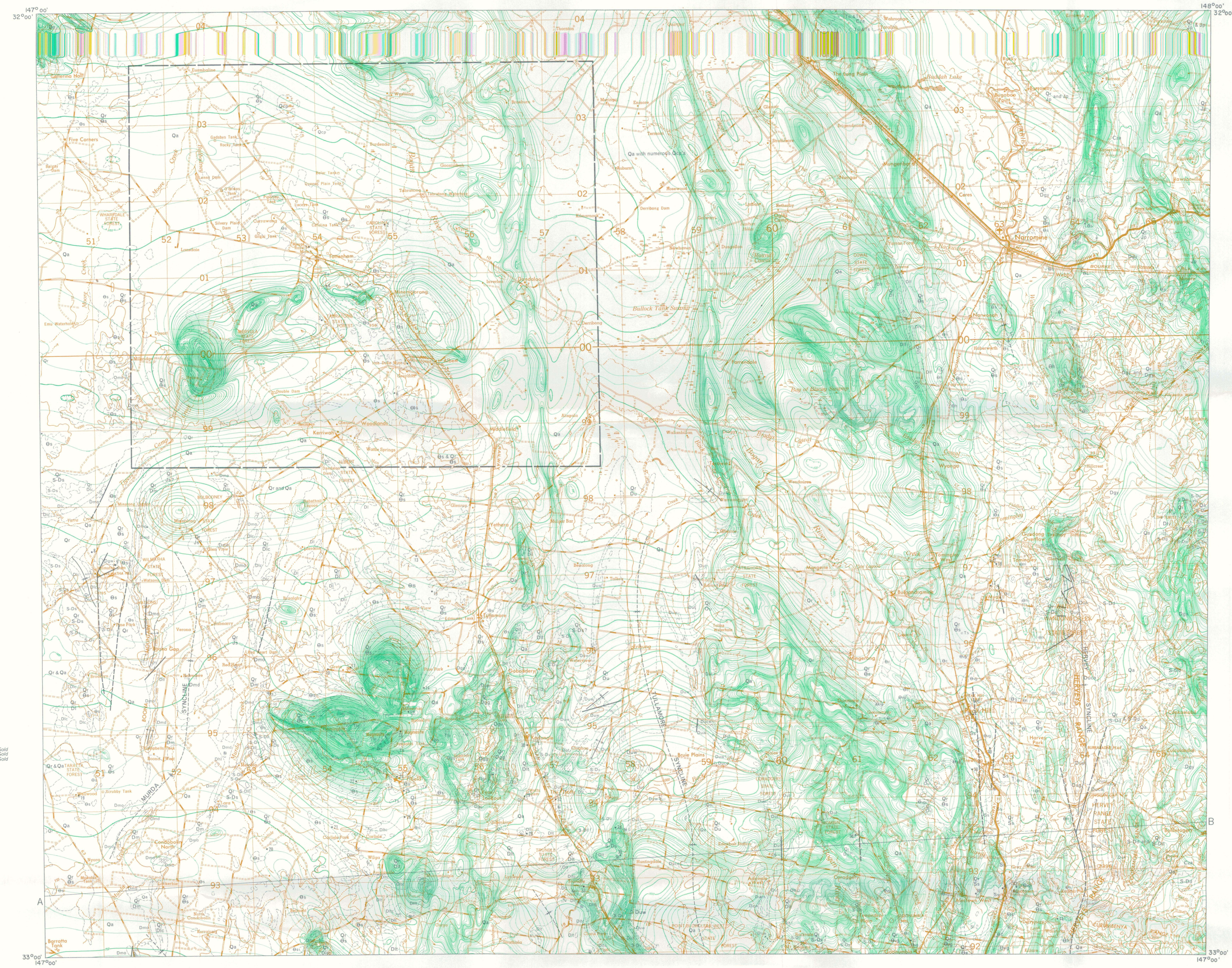
The preliminary contours were produced with a BMR contouring program utilizing a data sample of every third observation and a grid size of 0.1 inches (at 1:31 680).

APPENDIX 3 : INTERPRETATION METHODS

Selected anomalies were interpreted using computer programs of the graphical separation method of Koulomzine, Lamontagne & Nadeau (1970) and a best-fit method employing least-squares or linear fit criteria as outlined by McGrath & Hood (1970). These methods assume a dipping dyke model of infinite length along strike and down dip. Hence details of interpretations presented in Plates 2 and 3 and the examples illustrated in Figures 3 and 4 are subject to the limitations imposed by these assumptions. Estimates of depth, width, and dip are thus in error up to 20% for anomalies drastically departing from the assumed model. Peters' (1949) half maximum slope, Moo's (1965) graphical method, and Gay's (1963) curve matching techniques were also used on some anomalies.

In some areas interpretation of individual anomalies is inadequate and has been used only as a general guideline.

NARROMINE



Reference

- Road sealed surface first class, route marker
- Road sealed surface second class
- Road loose surface all weather
- Road loose surface dry weather
- Road unimproved earth
- Railway single track with station and siding
- Horizontal control point major, minor
- Building, school, post office, church
- River or stream perennial
- River or stream intermittent
- 1000 Contours

Geological Boundaries

- Established boundary — position accurate
- Established boundary — position approximate
- Probable or inferred boundary
- Igneous intrusions delineated by magnetic anomolies

Strike and Dip of Strata

- 60 Inclined, measured
- Vertical

Folds

- Established anticline — position accurate
- Established anticline — position approximate
- Established syncline — position accurate
- Established syncline — position approximate
- Plunge of fold axis

Faults

- Established fault — position accurate
- Established fault — position approximate
- Inferred or probable fault
- Trend
- Macro fossil locality
- Plant fossil locality

•12 Mineral Deposits

1	Mt. Royal, Bogan River, Chris Watson Copper Mines	Copper
2	Caroline Copper Mine	Copper
3	Lady Elywin Copper Mine	Copper
4	Ace Copper Mine	Copper
5	Underlay Copper Mine	Copper
6	Albert Water Hole Group of Copper Mines (Mt. Pleasant, Mt. Keenan, Monarch, Christmas Gift, Lind's)	Copper
7	Iron Duke Copper Mine	Copper
8		Limestone
9	Maligalore Copper Mine	Copper
10	Burra Alluvial Tin Mines	Tin
11	Tullamore Gold Developments N.L.	Gold
12		Limestone
13	Carlisle Gold Reefs	Gold
14	Cincinatti Magnesite Deposit	Magnesite
15	Lightning Reefs Gold Mines	Gold
16	Peak Hill Gold Mine	Gold
17	Myall (McPhail's) Gold Mine	Gold
18	Tomingley Gold Mine	Gold
19	Wellwood Gold Mine	Gold
20	Coronation Copper Mine	Copper
21		Limestone
22	Carlisle Magnesite deposit (some gold nearby)	Magnesite
23	Fifield Magnesite deposits	Magnesite
24	Fifield Lead	Platinum & Gold
25	Gillenbine Tank Lead	Platinum & Gold
26	Platina Lead	Platinum & Gold
27	Gobondery Iron deposit	Iron
28		Limestone
29		Limestone
30	Kadungle?	Limestone
31	Gobondery Magnesite deposit	Magnesite
32	The Toffs?	Limestone
33	Trundle?	Limestone
34	Mordialloc Copper Mine	Copper
35		Limestone
36	Coradgery Gold Mine	Gold
37	Goonumbla	Limestone
38		Limestone
39	Alectown?	Limestone
40		Limestone
41	Alick's Paddock Alluvial Gold	Gold
42	Stockman's Gold Reef	Gold
43	Emu and Great Britain Mines	Gold
44	Gold Deposit (no name available from records)	Gold

Geology and topography after 1:250 000 Geological Series sheet SI 55–3 First Edition, by Geological Survey of New South Wales Division of Regional Geology.
Total Magnetic Intensity Contours after 1:126 720 series sheets I55/BI-7-1, I55/BI-8-1, I55/BI-9-1, and I55/BI-10-1, by Bureau of Mineral Resources, Geology and Geophysics.

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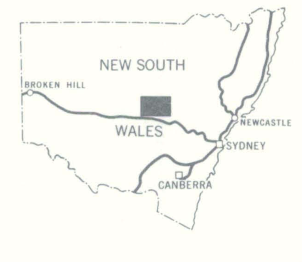


INDEX TO ADJOINING SHEETS
Showing Magnetic Declination 1965

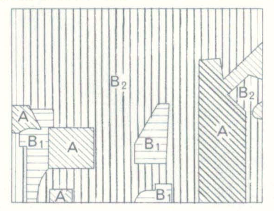
COBAR	NYNGAN	GILGANDRA
NYMAGEE	NARROMINE	DUBBO
CARGELLIGO	FORBES	BATHURST

DETAILED AIRBORNE SURVEY, TOTTENHAM, NSW 1971

GEOLOGY AND TOTAL MAGNETIC INTENSITY CONTOURS (REGIONAL)

Scale 1:250,000

GEOLOGICAL RELIABILITY DIAGRAM

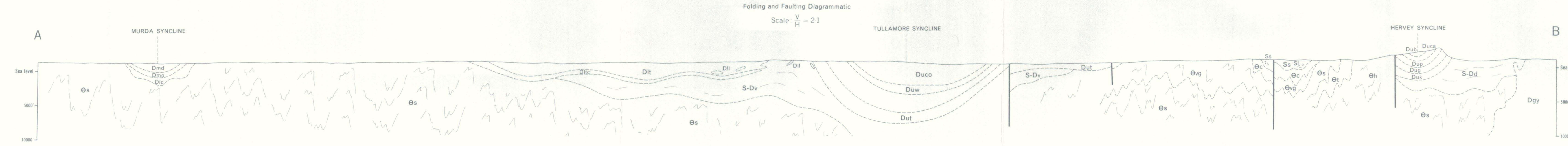


- A Detailed Mapping
- B_1 Airphoto interpretation with many ground traverses
- B_2 Airphoto interpretation with several ground traverses

GEOPHYSICAL LEGEND

- Magnetic contours
- Magnetic "low"
- Survey boundary

Section A–B
Folding and Faulting Diagrammatic
Scale $\frac{V}{H} = 2{:}1$



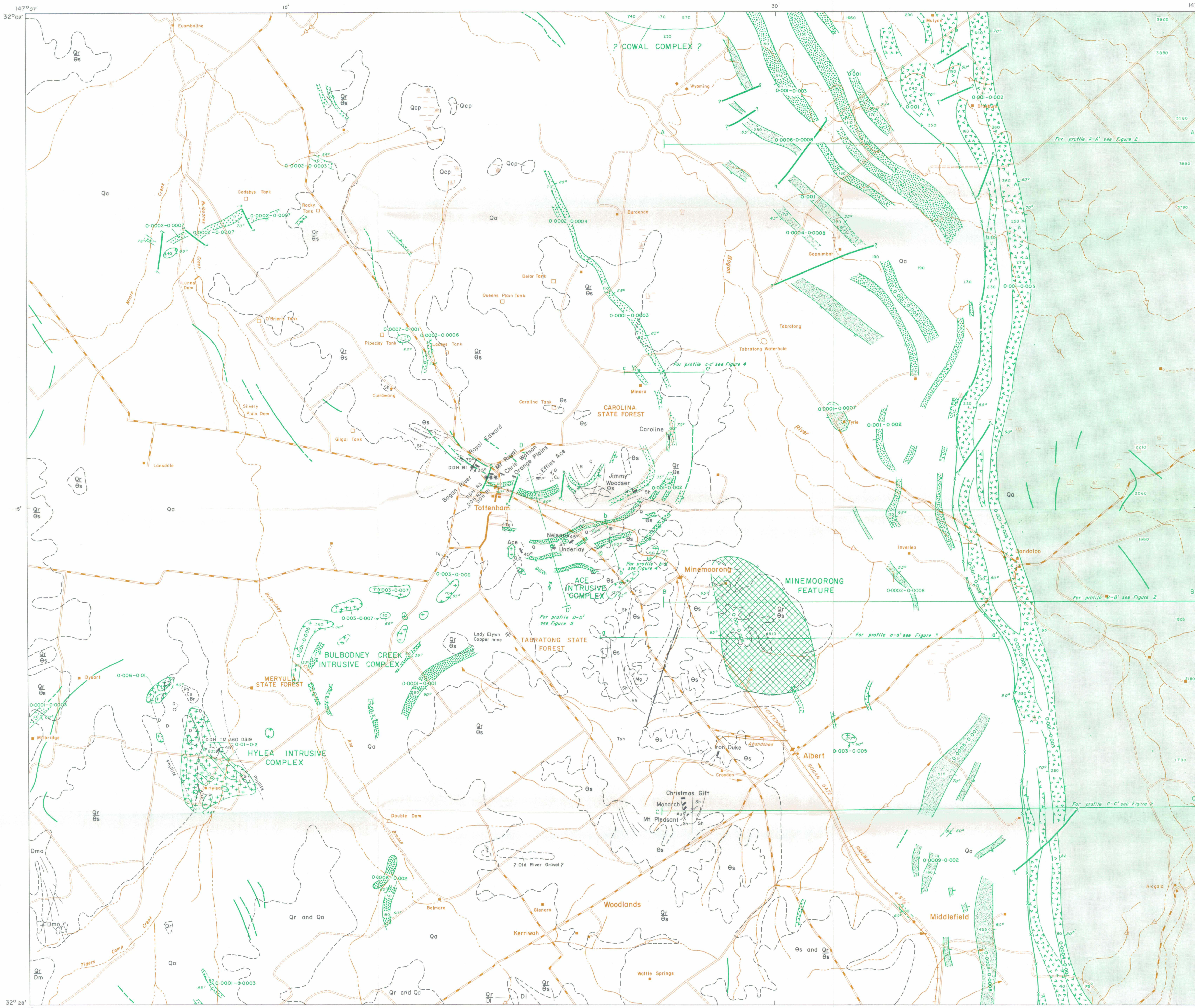
Reference

CAINOZOIC	QUATERNARY		Qa	Clay, sand and silt
			Qcp	Clay and silt (internal drainage areas)
			Qr	Eluvial soil cover
	UNDIFFERENTIATED		Cza	Clay, sand and silt, moderate relief probably incorporating areas of Qr
	TERTIARY		Tsi	Silicified conglomerate, quartzite, diagenetic siliceous cement
			Tfe	Lateritic ironstone
			Tb	Basalt
			Tt	Trachyte
			Ts	Quartzose and polymictic conglomerate, sandstone and clayey siltstone
MESOZOIC	JURASSIC	Pilliga Sandstone	Jp	Quartz sandstone, conglomerate, ferruginous in part
			Qr/Jp	Pilliga sandstone obscured by eluvial waste
			Qr/Js	Conglomerate and fine sandstone
PALAEOZOIC	UPPER DEVONIAN	Turtle Rock Volcanics	Dtv	Porphyry and rhyolite
			Qr/Du	Sandstone, shale, siltstone and conglomerate covered by eluvial deposits
		HERVEY SYNCLINE — Hervey Group, Cookamidgera Sub-Group: Burrill Formation	Dub	Red siltstone and sandstone
		Nangar Sub-Group: Caloma Sandstone	Duca	White sandstone with minor conglomerate beds
		Pipe Formation	Dup	Red and white sandstone and siltstone and green shale
		Mandagery Sandstone	Dug	White sandstone with minor shale and red sandstone
		Beargamil Sub-Group: Kadina Formation	Duk	Red siltstone and fine grained red sandstone
		Clagger Sandstone	Duc	Red, white sandstone, red siltstone and red conglomerate
		TULLAMORE SYNCLINE — Undifferentiated	Duco	Red siltstone
		Weddin Sandstone	Duw	White and red sandstone, green and white siltstone and conglomerate
		Cloghnan Shale	Ducs	Shale and siltstone
		Troffs Formation	Dut	White sandstone and red siltstone
	LOWER – MIDDLE DEVONIAN	Belvedere Formation	Dmd	Red sandstone, shale and siltstone
		Boona Sandstone	Dmo	White sandstone
			Dhl	Limestone (actual stratigraphic position uncertain)
		Condobolin Formation	Dlc	Green and red shale, red siltstone, minor sandstone, conglomerate and basal breccia
			Qr/Dlc	Condoblin Formation covered by eluvial deposits
			Qr/Dm	Undifferentiated Middle Devonian sediment covered by eluvial deposits
		Wilmatha Granite	Dgw	Granite and granophyre
		Gobondery Granite	Dgg / Dgv	Granite with basic phases (Dgv)
			Qr/Dgg	Gobondry Granite covered by eluvial deposits
			id	Hornblende melasyenite and hornblende meladiorite
			im	Quartz hornblende monzonite, pyroxene monzonite, quartz diorite
			ip	Magnetite pyroxenite
			ix	Hornblende pyroxenite, monzonitic hornblende pyroxenite
		Yeoval Granite	Dgy / Dpy	Granite, adamellite, granodiorite, diorite and porphyritic phases (Dpy)
			Qr/Dgy	Yeoval Granite covered by eluvial deposits
		Undifferentiated	Dl	Undifferentiated sediments
			Qr/Dl	Lower Devonian sediments covered by eluvial deposits
		Trundle Beds	Dltc	Quartz conglomerate and basal breccia
			Dll	Limestone
			Dlt	Quartzite, sandstone, siltstone and shale
			Qr/Dlt	Dlt covered by eluvial deposits
		Upson Downs Sandstone	Dlf	Quartzite, sandstone, fine lithic conglomerate
			Dlv	Rhyolite, tuff and chert
	SILURO – DEVONIAN	Ootha Beds	S-Dv	Tuff, chert, porphyritic rhyolite, tuffaceous sandstone and 'dacite'
			S-Dll	Limestone
			S-Ds	Sandstone, siltstone, claystone, conglomerate grit breccia and volcanics as in S-Dv
			Qr/S-Ds	S-Ds covered by eluvial deposits
		Dulladerry Rhyolite	S-Dd	Red, black, white banded rhyolite, porphyritic in part, tuff and ignimbrite
			Qr/S-Dd	Dulladerry Rhyolite covered by eluvial deposits
		Toongi Group: Glenwood Formation	S-Dg	Shale
		Whylandra Formation	S-Dy	Greywacke, shale and sandstone
			S-Dm	Shale and tuff
		Wambangalong Formation	S-Dw	Sandstone and shale
		Berridong Siltstone	S-Dq	Siltstone and greywacke
		Gilgal Formation	S-Di	Shale, siltstone and tuff
		Gullengumbel Formation	S-Dx	Sandstone, siltstone and shale
	UPPER SILURIAN		Ss / Sl	Micaceous siltstone and sandstone, phyllite and olive shale, minor quartz, siltstone pebble conglomerate, greywacke and tuff. Limestone lenses Sl.
			Qr/Ss	Ss covered by eluvial deposits
	UPPER ORDOVICIAN		Θc	Boulder conglomerate with boulders of andesite, quartz quartzite, tuff, greywacke, tuffaceous sandstone.
	MIDDLE ORDOVICIAN	Goonumbla Volcanics	Θvg / Θl	Porphyritic andesite with interbedded shale and limestone Θl
			Qr/Θvg	Goonumbla Volcanics covered by eluvial deposits
		Tantitha Ultrabasics	Θb	Clinopyroxenite, gabbro and diorite
		Tomingley Beds	Θt	Slate, silicified siltstone, fine sandstone, shale
		Hawkes Creek Beds	Θh	Chert with minor phyllite, sandstone and basic intrusions
		St Andrews Beds	Θa	Quartzite, mudstone, garnet hornfels, mica schist
		Girilambone Beds	Θs / Θl	Phyllite, schist, siltstone, silty sandstone, dolomite, andesite, conglomerate and shale with limestone lenses Θl
			Qr/Θs	Θs covered by eluvial deposits

PLATE 2

DETAILED AIRBORNE SURVEY, TOTTENHAM, NSW 1971

GEOPHYSICAL INTERPRETATION AND GEOLOGY



2 1 0 2 4 6 8 10 12 14 16 KILOMETRES

GEOLOGICAL LEGEND

CAINOZOIC	QUATERNARY		Qa	Clay, sand, and silt
			Qcp	Clay and silt (internal drainage areas)
			Qr	Eluvial soil cover
	TERTIARY		Tsh	Shale
			Tg	Gravel
			Tl	Laterite
PALAEOZOIC	LOWER-MIDDLE DEVONIAN	Boona Sandstone	Dmo	White sandstone
			Qr / Dm	Undifferentiated Middle Devonian sediments covered by eluvial deposits
	SILURIAN-DEVONIAN	Undifferentiated	Dl	Undifferentiated sediments
			Qr / Dl	Lower Devonian sediments covered by eluvial deposits
			D	Diorite
			S	Serpentinite
			P	Pegmatite
	MIDDLE ORDOVICIAN	Girilambone Beds	Ѳs	Phyllite(Ph), schist(Sh), siltstone, silty sandstone, dolomite, andesite, conglomerate and shale with metabasalt(B), quartizite(Q), breccia(Br), magnesite deposits(Mg)
			Qr / Ѳs	Ѳs covered by eluvial deposits

Established boundary-position approximate

Photo lineaments, geological boundaries

Copper mine with strike and dip of lode

Diamond-drill hole with direction and angle

Diamond-drill hole, vertical

Fault

Syncline

Geology after 1:250 000 series sheet SI 55-3 Provisional Edition 1968 compiled by Geological Survey of New South Wales, Division of Regional Geology, New South Wales Department of Mines (D. Suppel); and Lamadec Exploration Limited 1970, K.J. Kemezys.

Printed by: Mercury—Walch Pty Ltd., Hobart, Australia

GEOPHYSICAL LEGEND

INTERPRETED GEOLOGICAL BOUNDARIES

EASTERN LINEATIONS

- Eastern set: ? Post-Ordovician volcanics
- Western set: ? Upper Ordovician volcanics; ? Upper Ordovician volcanics and/or derivative sediments

Metavolcanics of acidic origin

Metavolcanics of basic origin

Minemoorong basement feature

Post-Ordovician sediments

Intermediate basic, and/or ultrabasic intrusive complexes

Low-order magnetic lineation

Inferred eastern extremity of post-Ordovician sedimentation

Inferred fault

ANOMALY INTERPRETATION

270 Depth calculated from anomalies

65° Dip calculated from anomalies

Dip (shallow, intermediate, steep) inferred from inspection of anomalies

0·001 - 0·003 Estimated susceptibility contrast (c.g.s.)

Depths in metres below ground level

TOPOGRAPHICAL LEGEND

Road, sealed surface

Road, loose surface all weather

Road, loose surface dry weather

Road, unimproved earth

Railway single track with station

River or stream intermittent

Building

Dam

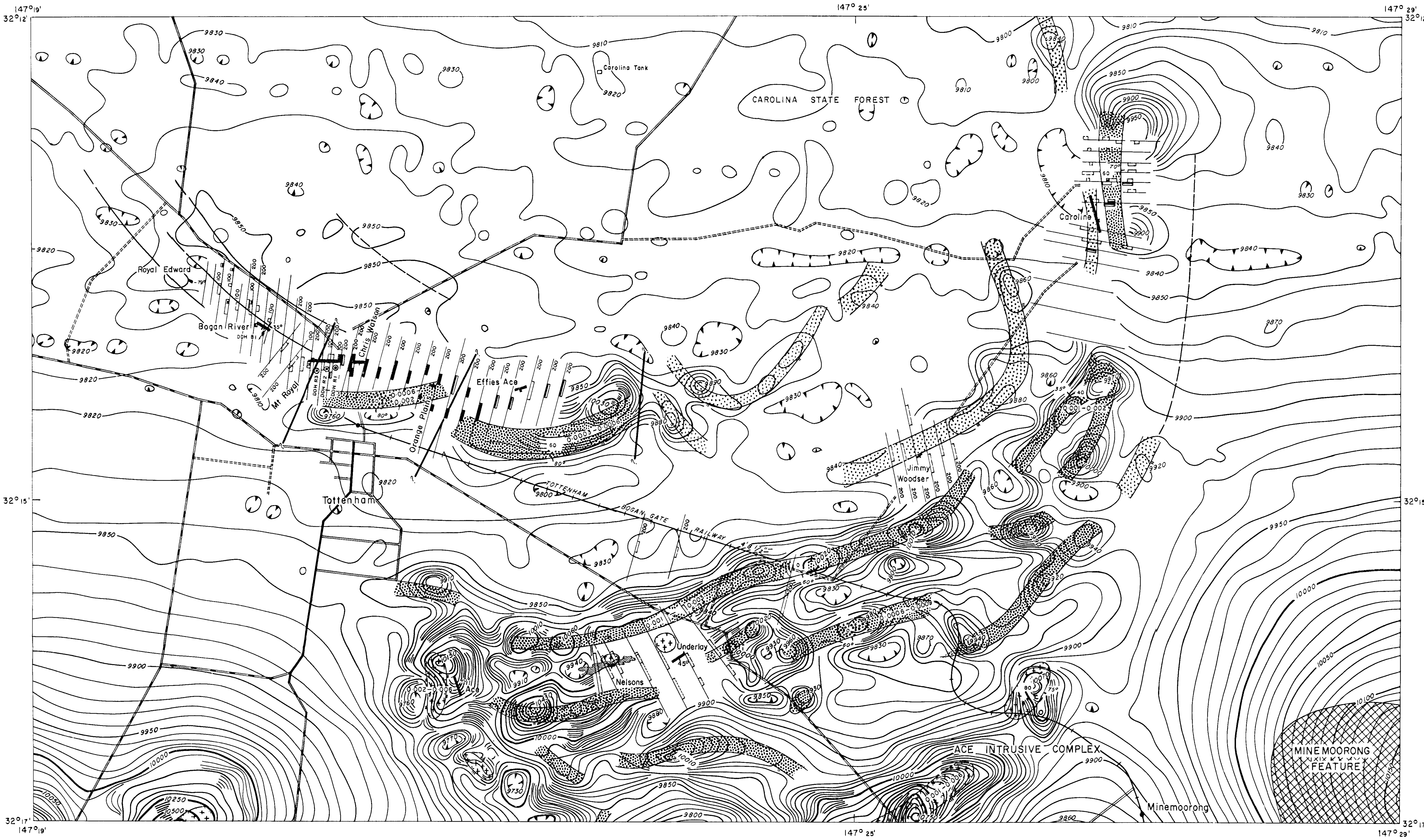
Swamp

REFERENCE TO 1:250 000 MAP SERIES

145° 30' — 150° 00'; 31° 00' — 34° 00'

COBAR	NYNGAN	GILGANDRA
NYMAGEE	NARROMINE	DUBBO
CARGELLIGO	FORBES	BATHURST

I55/BI-70



TOPOGRAPHICAL LEGEND

- Road, sealed surface
- Road, loose surface all weather
- Road, loose surface dry weather
- Road, unimproved earth
- Railway, single track with station

Printed by: Mercury-Walch Pty Ltd., Hobart, Australia

DETAILED AIRBORNE SURVEY, TOTTENHAM, N S W 1971

TOTAL MAGNETIC INTENSITY CONTOURS, INTERPRETATION, AND DETAILED GEOPHYSICAL EXPLORATION, TOTTENHAM/CAROLINE AREA

1 0 1 2 3 4 KILOMETRES

CONTOUR INTERVAL 10 nT

REFERENCE TO 1:250 000 MAP SERIES

145° 30' 150° 00' 31° 00' 34° 00'

COBAR	NYNGAN	GILGANDRA
NYMAGEE	NARROMINE	DUBBO
CARGELLIGO	FORBES	BATHURST

GEOPHYSICAL LEGEND

INTERPRETED GEOLOGY BOUNDARIES

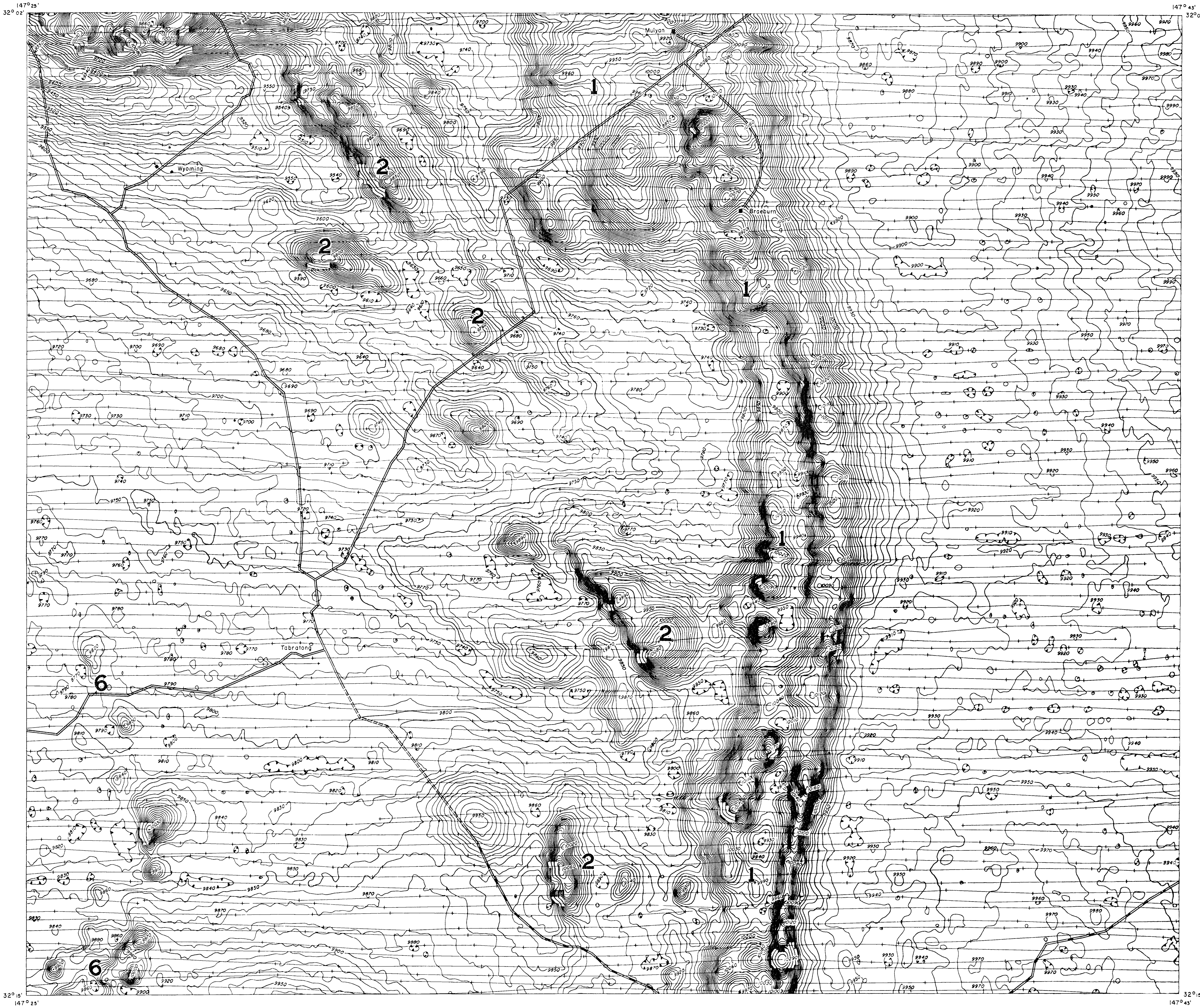
- Metavolcanics of acidic origin
- Metavolcanics of basic origin
- Minemoorong basement feature
- Intermediate, basic and/or ultrabasic intrusive complex
- Low-order magnetic lineation
- Inferred fault

ANOMALY INTERPRETATION

- 270 Depth calculated from anomalies
- 65° Dip calculated from anomalies
- Dip (shallow, intermediate, steep) inferred from inspection of anomalies
- 0·001–0·003 Estimated susceptibility contrast (c g s)
- Depth in metres below ground level

DETAILED GEOPHYSICAL EXPLORATION

- (Strong, moderate, weak, very weak, very very weak)
- 200/100 I P anomaly with dipole spacing in feet
- I P anomalies after Geological Survey of New South Wales, Lamadec Exploration Limited, and I M C Development Corp.
- Copper Geochemical anomaly 100–3200 p p m
- 45° Copper mine with strike and dip of lode
- -45° Diamond-drill hole with direction and angle
- Diamond-drill hole (vertical)
- 10000 / 9950 Total magnetic intensity contours



DETAILED AIRBORNE SURVEY, TOTTENHAM, NSW 1971

TOTAL MAGNETIC INTENSITY

CONTOUR INTERVAL 10 nT

TOPOGRAPHICAL LEGEND

Road, loose surface all weather

Road, loose surface dry weather

Road, unimproved earth

Printed by: Mercury–Walch Pty Ltd., Hobart, Australia

REFERENCE TO 1:250 000 MAP SERIES

145° 30' — 150° 00' — 31° 00' — 34° 00'

COBAR	NYNGAN	GILGANDRA
NYMAGEE	NARROMINE	DUBBO
CARGELLIGO	FORBES	BATHURST

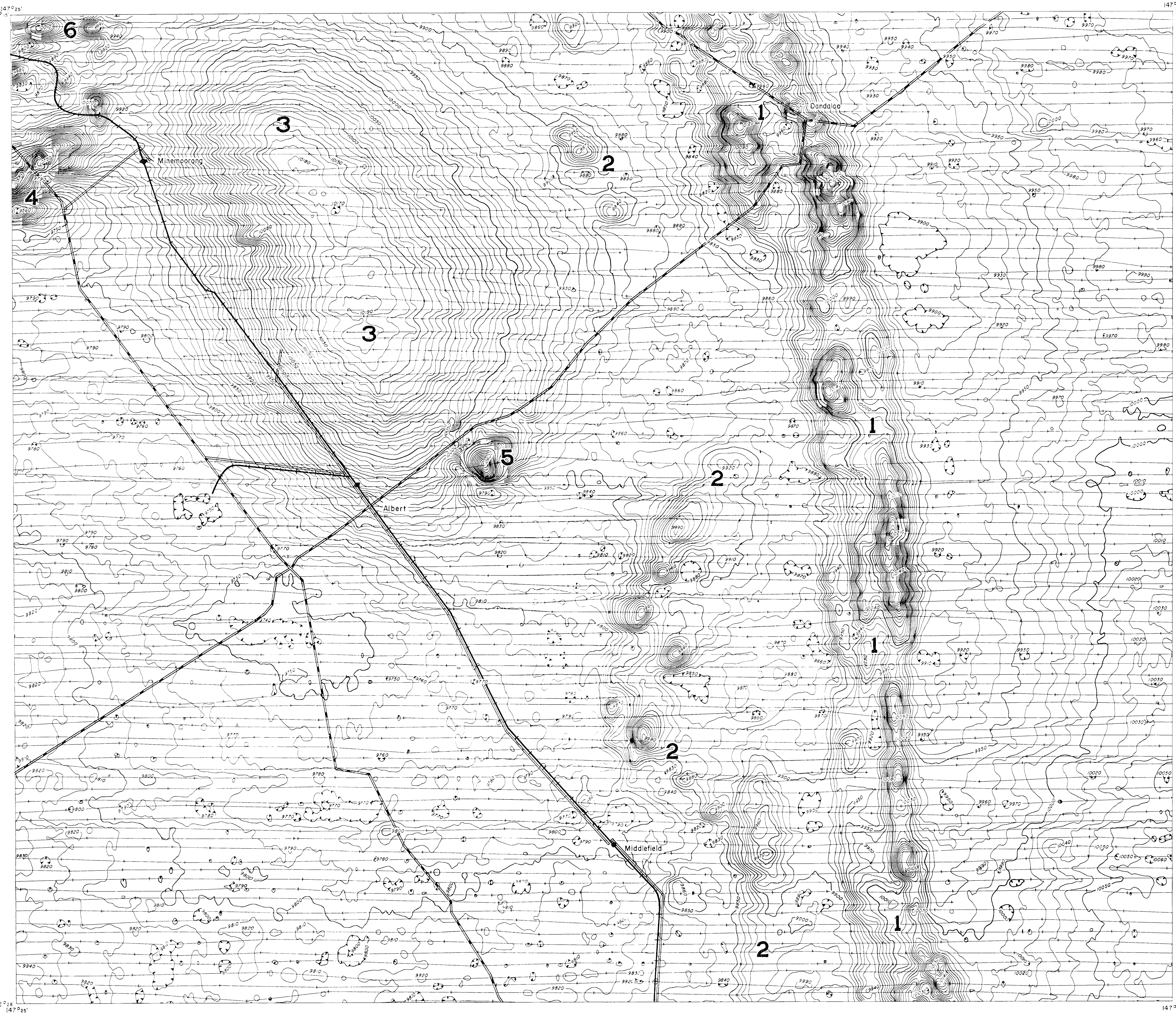
EXPLANATORY NOTES

This map was compiled from an airborne magnetic survey by the Bureau of Mineral Resources, flown at an average altitude of 300 metres above sea level along east–west lines spaced 250 metres apart. Aerial photographs were used for navigation and the track of the aircraft was recorded by a 35mm fish–eye camera.

The magnetic field intensity was recorded by a proton magnetometer and processed by a computer. Regional gradient as specified by I.G.R.F. at year 1971.4 and altitude 300 metres above sea level has been removed from data.

Magnetic anomalies are numbered for text reference only.

I55/BI-78



TOPOGRAPHICAL LEGEND

Road, loose surface all weather
Road, loose surface dry weather
Road, unimproved earth
Railway, single track with station

Printed by: Mercury-Walch Pty Ltd., Hobart, Australia

REFERENCE TO 1:250 000 MAP SERIES

145° 30' — 150° 00' — 31° 00' — 34° 00'

COBAR	NYNGAN	GILGANDRA
NYMAGEE	NARROMINE	DUBBO
CARGELLIGO	FORBES	BATHURST

DETAILED AIRBORNE SURVEY, TOTTENHAM, NSW 1971

TOTAL MAGNETIC INTENSITY

CONTOUR INTERVAL 10 nT

EXPLANATORY NOTES

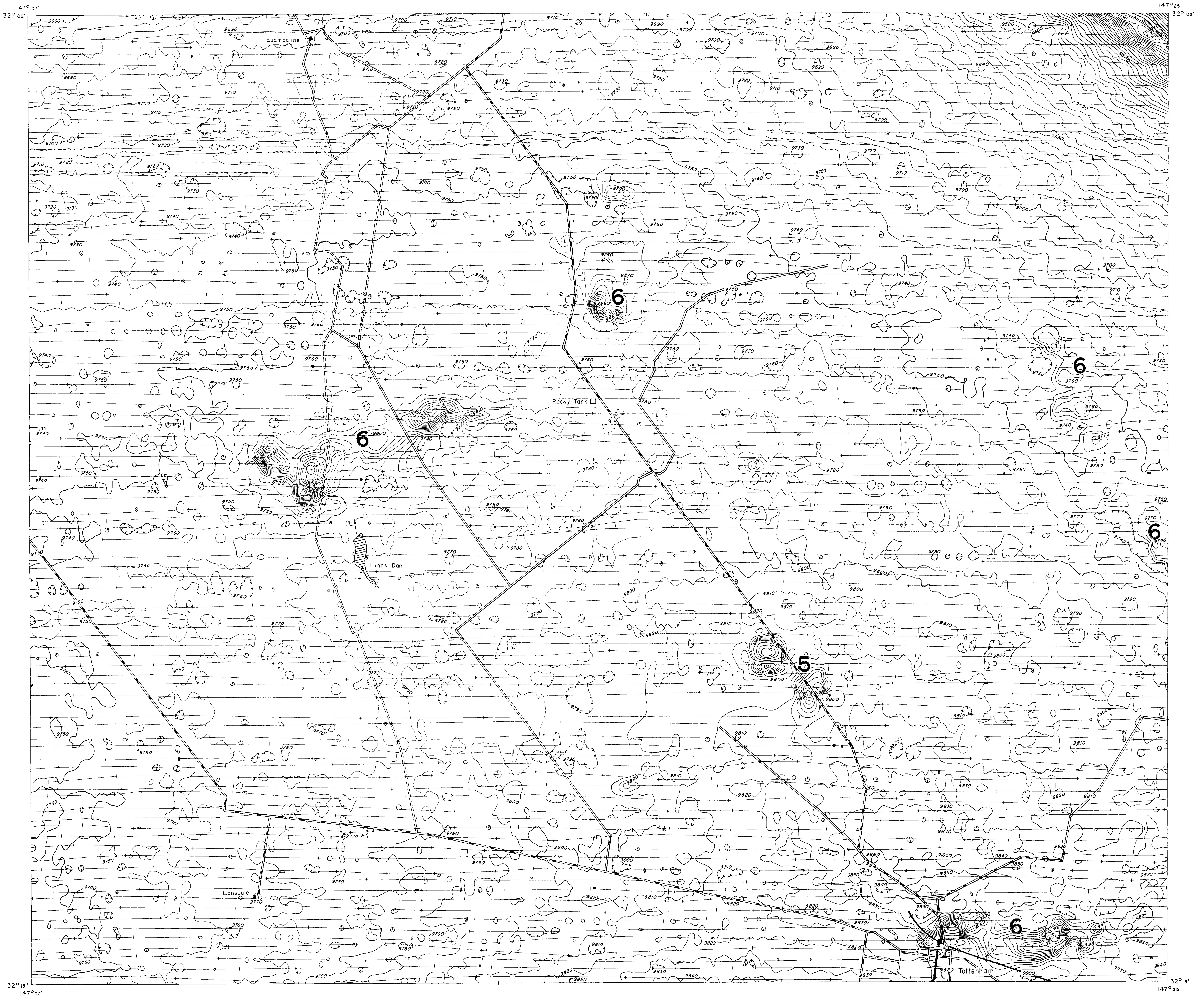
This map was compiled from an airborne magnetic survey by the Bureau of Mineral Resources, flown at an average altitude of 300 metres above sea level along east–west lines spaced 250 metres apart. Aerial photographs were used for navigation and the track of the aircraft was recorded by a 35mm fish–eye camera.

The magnetic field intensity was recorded by a proton magnetometer and processed by a computer. Regional gradient as specified by I.G.R.F. at year 1971.4 and altitude 300 metres above sea level has been removed from data.

Magnetic anomalies are numbered for text reference only.

I55/BI-80

PLATE 4C



TOPOGRAPHICAL LEGEND

Road, sealed surface
Road, loose surface all weather
Road, loose surface dry weather
Road, unimproved earth
Railway, single track with station

Printed by: Mercury–Walch Pty Ltd., Hobart, Australia

REFERENCE TO 1:250 000 MAP SERIES

145° 30' — 150° 00'; 31° 00' — 34° 00'

COBAR	NYNGAN	GILGANDRA
NYMAGEE	NARROMINE	DUBBO
CARGELLIGO	FORBES	BATHURST

DETAILED AIRBORNE SURVEY, TOTTENHAM, NSW 1971

TOTAL MAGNETIC INTENSITY

1 0 1 2 3 4 5 6 7 8 KILOMETRES

CONTOUR INTERVAL 10 nT

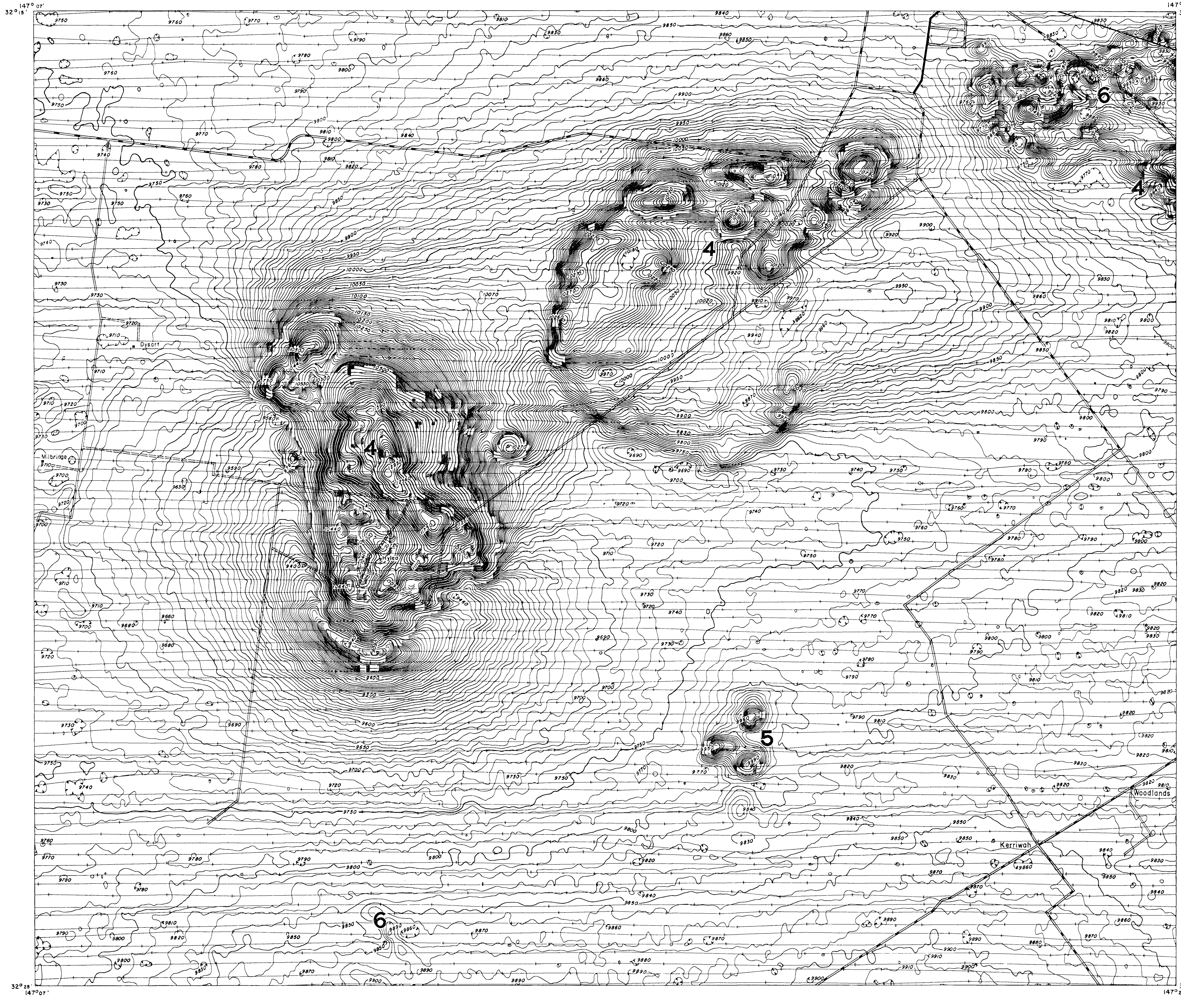
EXPLANATORY NOTES

This map was compiled from an airborne magnetic survey by the Bureau of Mineral Resources, flown at an average altitude of 300 metres above sea level along east–west lines spaced 250 metres apart. Aerial photographs were used for navigation and the track of the aircraft was recorded by a 35mm fish–eye camera.

The magnetic field intensity was recorded by a proton magnetometer and processed by a computer. Regional gradient as specified by I.G.R.F. at year 1971.4 and altitude 300 metres above sea level has been removed from data.

Magnetic anomalies are numbered for text reference only.

155/B1-79



DETAILED AIRBORNE SURVEY, TOTTENHAM, NSW 1971

TOTAL MAGNETIC INTENSITY

CONTOUR INTERVAL 10 nT

TOPOGRAPHICAL LEGEND

- Road, sealed surface
- Road, loose surface all weather
- Road, loose surface dry weather
- Road, unimproved earth
- Railway, single track

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REFERENCE TO 1:250 000 MAP SERIES

145° 30' — 150° 00'; 31° 00' — 34° 00'

COBAR	NYNGAN	GILGANDRA
NYMAGEE	NARROMINE	DUBBO
CARGELLIGO	FORBES	BATHURST

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I55/B1-81