

1980/46. Magnetic surveys, Fingal Tier region

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Abstract

Ground and airborne surveys across Fingal Tier in eastern Tasmania have established the magnetic method as a useful mapping aid, able to resolve dolerite and dolerite talus whether on dolerite or coal measures, and dolerite sheet structures. The dolerite sheet capping the sedimentary section, including coal measures, is very irregular and while magnetic techniques are not as useful as gravity surveys, they do add an important independent perspective on concealed intrusion edges and forms. The local dolerites have also been shown to have very low susceptibilities but quite intense natural remanent magnetisation.

INTRODUCTION

The first magnetic survey in the Fingal Tier region was undertaken in 1972 by one of the authors (D.E.L.); it was an evaluation of the use of the magnetic method as a mapping aid in talus-covered areas. The work was restricted to the vicinity of Valley Road, south-east of Fingal, on the lower portion of the escarpment [around EP885890]. A drill hole (DOM DDH 14) had been abandoned in dolerite talus nearby and questions had arisen concerning the exact location of the boundary between Jurassic dolerite and Triassic coal measures.

Many dolerite boundaries in eastern Tasmania are concealed by surface deposits, soil or talus, and are not easily located. Where intrusions are discordant, boundary location is critical since it is possible to unknowingly site a borehole on talus above the intrusive. The error can be costly. The problems are much less for near-concordant boundaries, although drilling difficulties may be great. The degree of difficulty depends on the nature and thickness of the cover, the geometry - especially slope - of the rock surface, the thickness of the rock wedge drilled and the nearness of the basal contact. These factors may impose considerable stress on plant and driller alike and it is better to site the hole either on outcropping rock, irrespective of side of boundary, or at least definitely on the coal measures side. However, this is not always an easy mapping assignment. The particular problems near Hole 14 are shown in Figure 1.

Dolerite is clearly exposed at the top of the escarpment. Coal measures sandstone, and some shale is exposed, if somewhat patchily, lower in the valley. Most slopes, however, are covered by talus fields containing boulders ranging in size from 0.2 to 15 m across. Interstices are normally occupied with lesser fragments and soil or clay. Many blocks are weathered. The marked change in slope onto the escarpment reflects the presence of dolerite but does not reliably indicate the position of the boundary due to the smoothing effects of the talus cover on the topography. Four magnetic situations exist; dolerite, talus on dolerite, talus on coal measures, coal measures.

The 1972 survey sought to obtain signatures for each combination. It was found that the magnetic method was workable in these conditions since sufficient differences in character existed. Although similar techniques and character signatures have been used in north-east Tasmania for the location of basalt boundaries, they were not used in the Fingal area until late 1978 when the Shell Oil Co., having become aware of the mapping

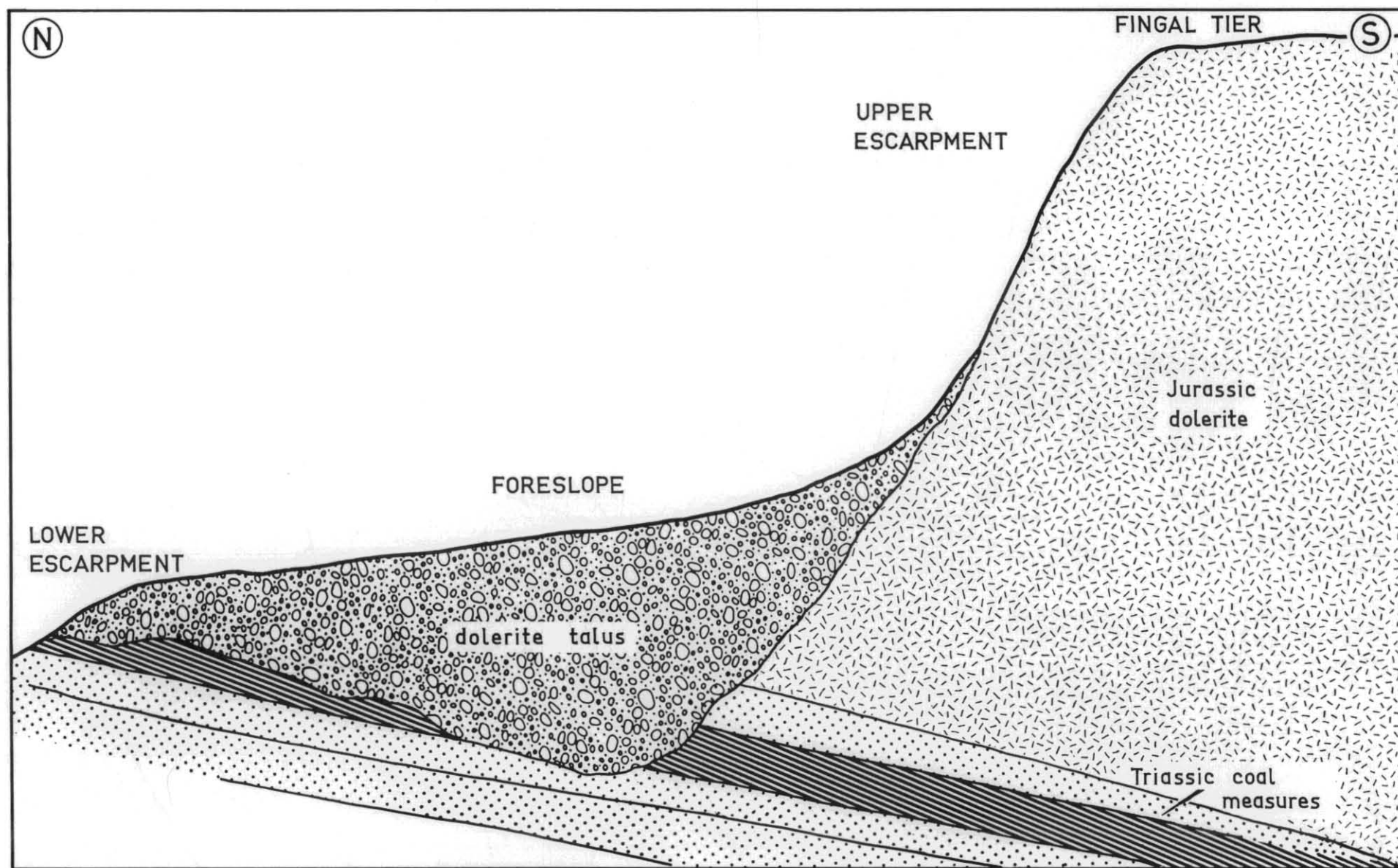


Figure 1. Materials on the Fingal Tier escarpment

problems, was advised of the potential value of the method. The geological map of their joint venture lease area (EL 5/61) depends heavily on magnetic survey traverse lines.

At about the same time, a regional gravity survey of the eastern coalfields was completed (Leaman and Richardson, 1980) and a detailed survey of Fingal Tier begun (*op.cit.*). Preliminary interpretations were encouraging and pending establishment of the feasibility of the reflection seismic method as a means of independent control, it was decided to extend surface magnetic observations and undertake an aeromagnetic survey. The object was to obtain data which related directly to dolerite forms, one of the two main sources of gravity anomalies, thereby improving the reliability of the gravity interpretations related to coal measures targets.

The surveys were restricted to the consolidated Fingal Tier State Reserve (exemptions under statutory rules 1978/110, 1979/107, 1979/168) and immediately adjacent areas. They overlap directly the area covered by the detailed gravity survey.

SURFACE MAGNETIC SURVEYS

Objectives

Surface surveys have been undertaken to yield information on:

- (a) the general applicability and restrictions on the use of the magnetic method as a mapping aid,
- (b) the characteristics of the magnetic response of massive dolerite bodies,
- (c) the possibility of establishing or defining control anomalies for assessment of airborne data,
- (d) the susceptibility and remanence properties of the dolerite.

Although the early work (1972) and subsequent use of the technique by the Shell Company in the Dalmaine region (5-10 km east of the Fingal Tier State Reserve) have demonstrated the general application and effectiveness of surface magnetic methods as a mapping aid, some doubts and problems have arisen.

Work by one of the authors (D.E.L.) on dolerites in southern Tasmania, though still incomplete, has indicated that great care must be exercised when attempting interpretations related to dolerite contacts. Some dolerites, it seems, have very low resultant magnetisations - or the remanent and induced components cancel - and are not easily separated from the intruded rocks. Further, the observation spacing and pattern of results appears to require local control surveys and experience. These factors were alluded to in Leaman (1978) and need to be the object of considerable research if the origin of the magnetic properties of Tasmanian Jurassic dolerite is to be understood. It is certain, as a result of comparison between work on dolerite in southern Tasmania and that in the north-east (Fingal - St Marys - Bicheno), that the north-eastern dolerite is not similarly differentiated nor has it similar ranges of magnetic properties. Consequently, properties need local definition and a number of traverses have been observed on and around Fingal Tier. The results establish proper field techniques and qualitative interpretation guidelines for this general region and form the basis for comparisons with other areas and ultimately deductions about the dolerite itself.

Survey specification and recording

Observations have been made at nominal five metre intervals along each traverse. Experience from the 1972 test survey and surveys elsewhere suggests that such a spacing is a reasonable compromise between speed of survey and information sufficient to identify adequate spectral detail. A McPhar M700 fluxgate magnetometer has been used throughout. This is slightly limiting since only the vertical component of the field is recorded, but precession magnetometers are often unable to cope with the severe gradients induced by some dolerite masses.

Base stations have been established on Fingal Tier and in the valley near the junction of Valley Road and the Esk Highway (fig. 2). These stations have not been continuously recorded but have been observed regularly. Where severe abnormalities ($>50\text{nT}$) are implied, line sections have been repeated. The technique has been made as practical and rigorous as possible in order to yield a realistic evaluation of its usefulness in the hands of non-geophysicists. This presumes that staff geologists could, with guidance, apply the technique with the same confidence as other more familiar techniques without undue concern for more esoteric considerations.

Results may be plotted as shown in the examples of Figures 3, 4 and 5 and qualitatively interpreted graphically. In addition, it is possible to make direct interpretations from the field notebook. An example of this is shown in Table 1. In either case qualitative interpretations depend on differences between consecutive observations. Graphical plots are not necessarily clearer versions of these differences. Field book 'between-line' calculation is a workable means of focussing extra coverage at the time of the survey and does allow a boundary to be followed in a mapping sense. The traverse coverage is, for greatest efficiency, a high angle zig-zag. The data shown in Table 1 are plotted in the upper profile of Figure 5. In this case the plot is very clear and stresses the varied character of the observations which, though apparent in the table, are not as obvious by differences. Cases can occur in which the profile character changes substantially but where the differences remain relatively small. Such instances are identified by consistent sign of the differences. In a true low relief profile, the differences oscillate about zero. Prior to *1 (table 1) differences range from ± 20 to ± 3000 whereas after *2 the range is $+100$ to -180 . The zone *1 to *2 is indeterminate, but examination of the actual profile would suggest placement of the boundary at *2.

Nature of responses

Before any interpretations are possible, however, it is essential to obtain typical ranges or differences for the common structural situations in the particular area. For the Fingal Tier region these are:

- (1) Triassic coal measures
- (2) Dolerite talus/Triassic
- (3) Dolerite talus/Dolerite
- (4) Dolerite

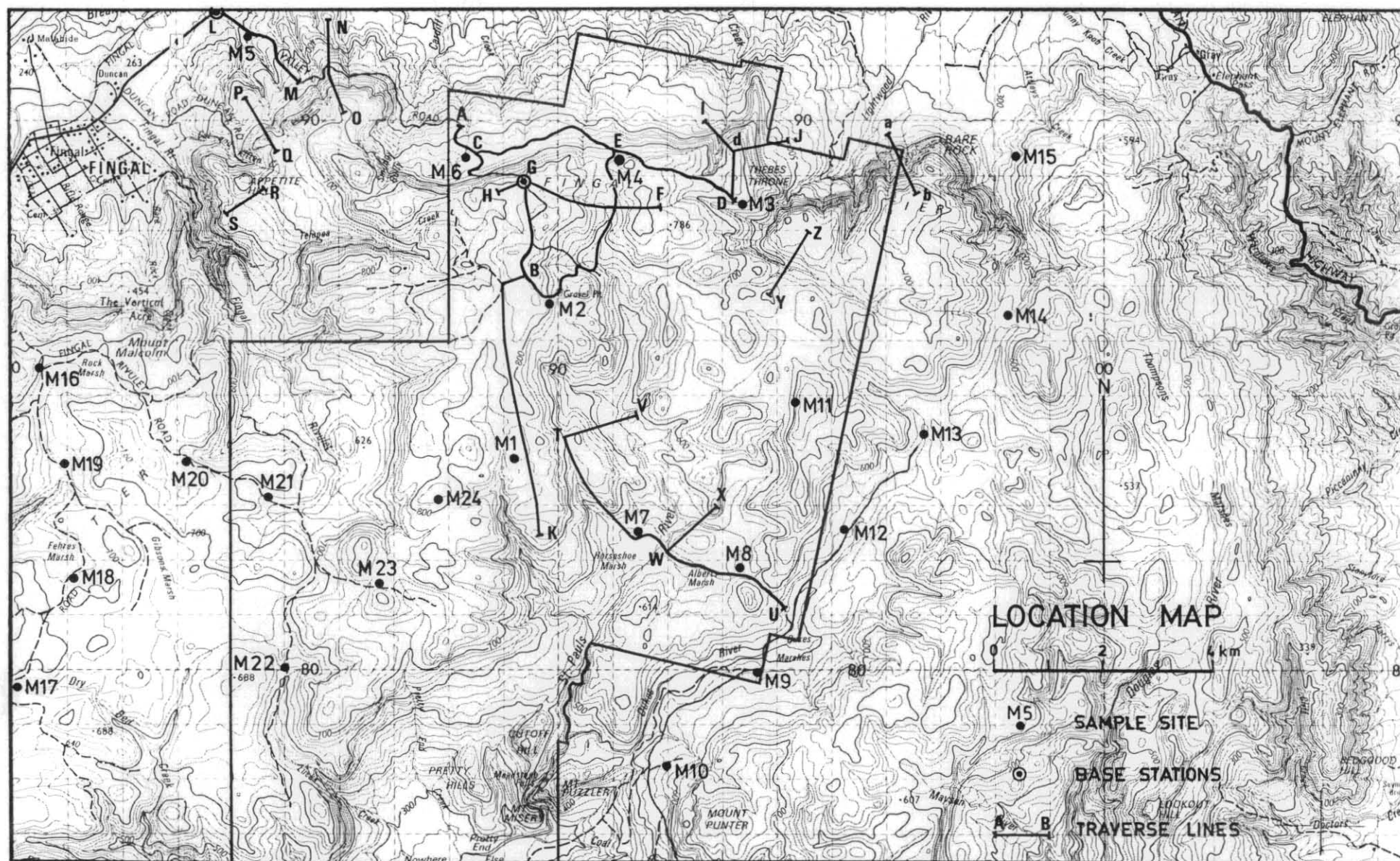


Figure 2.

Table 1. FIELD DIFFERENCE CALCULATION

Observation	Difference	Observation	Difference	Observation	Difference
+ 520	- 160	+ 460	+ 100	+ 300	+ 30
+ 360	+ 30	+ 560	+ 130	+ 330	- 20
+ 390	- 50	+ 790	- 140	+ 310	+ 60
+ 340	+ 10	+ 650	+ 30	+ 370	- 40
+ 350	- 360	+ 680	- 80	+ 330	+ 50
- 10	+ 310	+ 600	- 80	+ 380	- 20
+ 300	+ 10	+ 520	- 120	+ 360	- 60
+ 320	- 20	+ 400	- 80	+ 300	+ 60
+ 300	- 180	+ 320	- 50	+ 360	- 40
+ 120	- 340	+ 270	- 20	+ 320	+ 50
- 220	- 30	+ 250	0	+ 370	- 10
- 250	- 390	+ 250	+ 50	+ 360	- 40
- 640	- 10	+ 300	- 730	+ 320	+ 40
- 650	- 70	- 430	+ 590	+ 360	+ 40
- 720	- 280	+ 160	+ 80	+ 400	- 100
-1000	+3300	+ 240	+ 20	+ 300	- 180
+2300	-4000	+ 260	+ 160 ^{*1}	+ 220	+ 10
-1700	+ 650	+ 420	0	+ 230	- 90
-1050	+ 740	+ 420	+ 100	+ 140	0
- 310	+ 30	+ 520	- 150	+ 140	+ 30
- 280	+ 580	+ 370	- 20 ^{*2}	+ 170	- 20
+ 300	+ 160	+ 350	- 50	+ 150	

The most extreme variations are shown by class 4. This is due to topographic effects, localised and extreme anomalous sources often related to lightning strikes in exposed areas, and substantial compositional variations. However, in all but the most quiescent state the differences recorded over exposed dolerite are greater than those for the other materials. Dolerite is magnetically 'quiet' when fine-grained and glassy, which means that the apparent position of the boundary is always displaced slightly toward the dolerite side.

Class 3 anomalies are the most difficult to appraise rapidly since two key factors are involved. First is the smoothing effect of increased cover and consequently greater depth to magnetic basement. Second is the original magnetic signature of the dolerite at the site. It is possible that highly magnetised concealed dolerite can still yield surface differences suggestive of other outcropping dolerites. This ambiguity may only be resolved by considering a graphical treatment and noting any gross trends of anomaly upon which any local 'spikiness' may be superimposed (see example fig. 4).

The differences between class 1 and 2 anomalies may often be slight but since the essential requirement of any interpretation is the identification of the dolerite boundary, concealed or exposed, there is rarely any difficulty. The distinction between classes 2 and 3, 2 and 4 or 1, 2 and 4 is far greater than that between 1 and 2.

The profiles shown in Figures 3, 4 and 5 are representative samples of many kilometres of traversing in the region. They are included only to illustrate the value of the method as a mapping aid and have no established quantitative value.

Profile A-B (fig. 3)

This profile indicates four distinct magnetic regimes (a-b, b-c, c-d, d-e). The portion of A-B shown in Figure 3 covers the escarpment and the upper section of its foreslope (see fig. 1). The marked change of slope occurs a little to the left of (b).

Regime (a-b). Values generally have a range of $\pm 100\text{nT}$ and the profile smooths towards a. This regime reflects a variable cover of talus on coal measures.

Regime (b-c). Values have an elevated base level when contrasted with regimes (a-b), (c-d). The base change is some 300-400nT. This regime reflects a thick talus cover on dolerite such that the field effects of the dolerite are smoothed and integrated.

Regime (c-d). Values are much more erratic than in the previous two regimes, having a range of $\pm 600\text{nT}$. The talus cover on dolerite is now variable but thin and the true magnetic character of the dolerite is becoming evident.

Regime (d-e). On dolerite outcrop. Typical field over dolerite, range $> \pm 2000\text{nT}$.

Interpretation of such a profile is rarely ambiguous for segments a-b, c-e which reflect Triassic or dolerite basement respectively. However, only the elevated base levels associated with b-c suggest a fundamental change in the intermediate zone. The presence of occasional large 'spikes' may aid in interpretation. Clearly, the boundary occurs between a and c and might be placed at c except for the observations and contrast seen near b.

Profile C-D (fig. 3)

Two magnetic regimes are shown; f-g, g-j. This profile portion covers the lower section of the upper escarpment.

Regime (f-g). The portion shown is typical of observations around the face of the escarpment and is comparable with those of a-b, (profile A-B). Apart from the effects of one or two large ($> 10\text{ m}$) boulders, the regime is typical of talus on Triassic coal measures.

Regime (g-j). Observations are representative of dolerite terrain with a variable and sometimes negligible cover of talus. Anomaly ranges are of the order of $\pm 600\text{nT}$. Some zones of lesser contrast have been indicated (g, h) and these are typical of thick pockets of talus on dolerite. Note that in each case the overall value of the field is elevated by some 400nT when compared with non-dolerite zones. (Compare b-c, section A-B).

In sections such as C-D there is little doubt that the dolerite boundary occurs within about 10 m of g.

Profile L-M (fig. 3)

This profile presents, in very condensed form, a typical section. From k-l the values are typical ($\pm 50\text{nT}$) of a thin talus cover on coal measures. From l-m two large boulders are included. The overall level of the field has declined but the variations between observations are relatively small. From m-n the differences increase from $\pm 600\text{nT}$ to more than

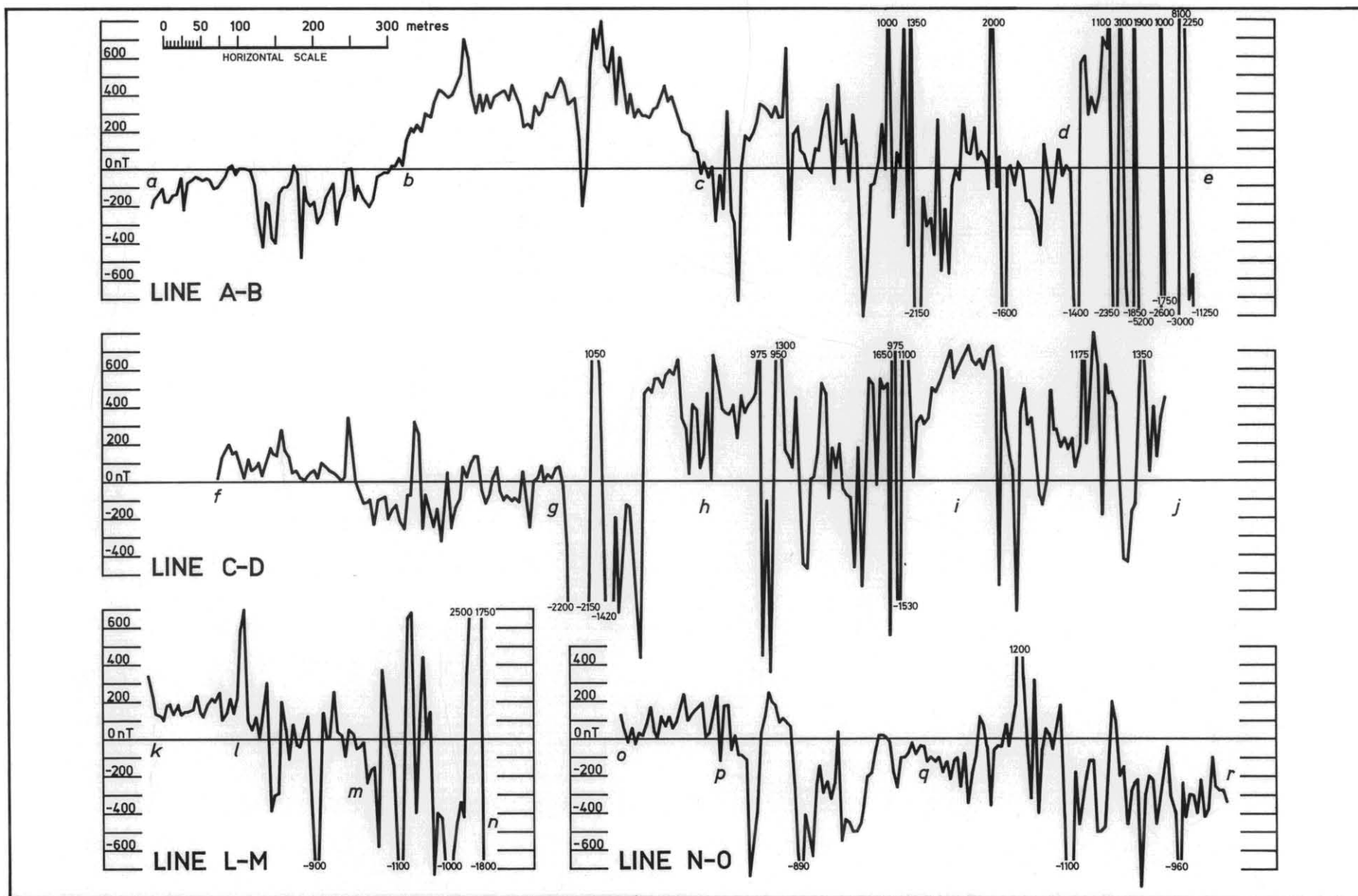


Figure 3. Surface surveys, Profiles A-B, C-D, L-M, and N-O

5 cm

$\pm 2000\text{nT}$ near *n*. The profile covers the upper portion of the abrupt razor-back ridge near the Duncan mine. Dolerite crops out only at the top and forms a thin dyke within the hill. In such cases the dolerite boundary cannot be accurately located, but it must occur near *m*.

Profile N-O (fig. 3)

This profile is typical of those from the lower part of the escarpment and the portion shown covers the mid-section of the lower escarpment. No dolerite outcrop can be positively identified.

Regime (o-p). Anomaly ranges are less than $\pm 100\text{nT}$ and are typical of talus on Triassic coal measures.

Regime (p-r). The change of character near *p* is fundamental even though the range of values does not generally exceed 400nT . Many of the features are too large to be related to massive coherent blocks within the talus and clearly represent a dolerite basement. However, the talus cover is clearly variable (especially thick near *q*). South of *r* the range increases to more than 1000nT (up slope) and dolerite is unambiguously identified. Valley Road is crossed midway between *p* and *q*.

Profile L-M (fig. 4)

The portion of profile L-M shown may be divided into two magnetic regimes (*s-t*, *t-u*). The consistent values of *s-t* are typical of observations on Lower Triassic or Permian rocks where there is a negligible cover of dolerite talus. The typical reading variation is $\pm 40\text{nT}$. From *t-u* however the character changes to yield variations of the order of $\pm 150\text{nT}$, and this is typical of a moderate thickness of dolerite talus on the sedimentary units.

Profile W-X (fig. 4)

The entirety of profile W-X is presented. It covers the central portion of the major dolerite feeder near Dukes River. While there is little doubt that the profile crosses a dolerite terrain (variation $\pm 600\text{nT}$), there are no large excursions or high gradients. The smoothed portion in the centre of the profile represents a marshy area with increased thickness of surface deposits.

Profile B-E (fig. 4)

The portion of B-E shown in Figure 4 demonstrates the effect of surface cover on dolerite. The profile crosses dolerite with a variable talus cover. Typical variations along the profile exceed $\pm 2000\text{nT}$. However in the region of the old sawmill [EP900870] the field is muted by a wedge of talus. The accumulation is associated with topographic changes.

Profile T-U (fig. 5)

The upper segment of T-U has been discussed above in relation to character identification by differences. Dolerite is clearly indicated left of *1/*2 (Table 1). However, in the region of *B* the dolerite, if present, is deeply buried. The small difference range suggests that talus on glassy dolerite or coal measures is more likely. At *C* there is a localised character change which may reflect part of a basal contact or some very large boulders. Surface examination of local materials reveals dolerite outcrop from *A* to *1, hornfelsed coal measures fragments and

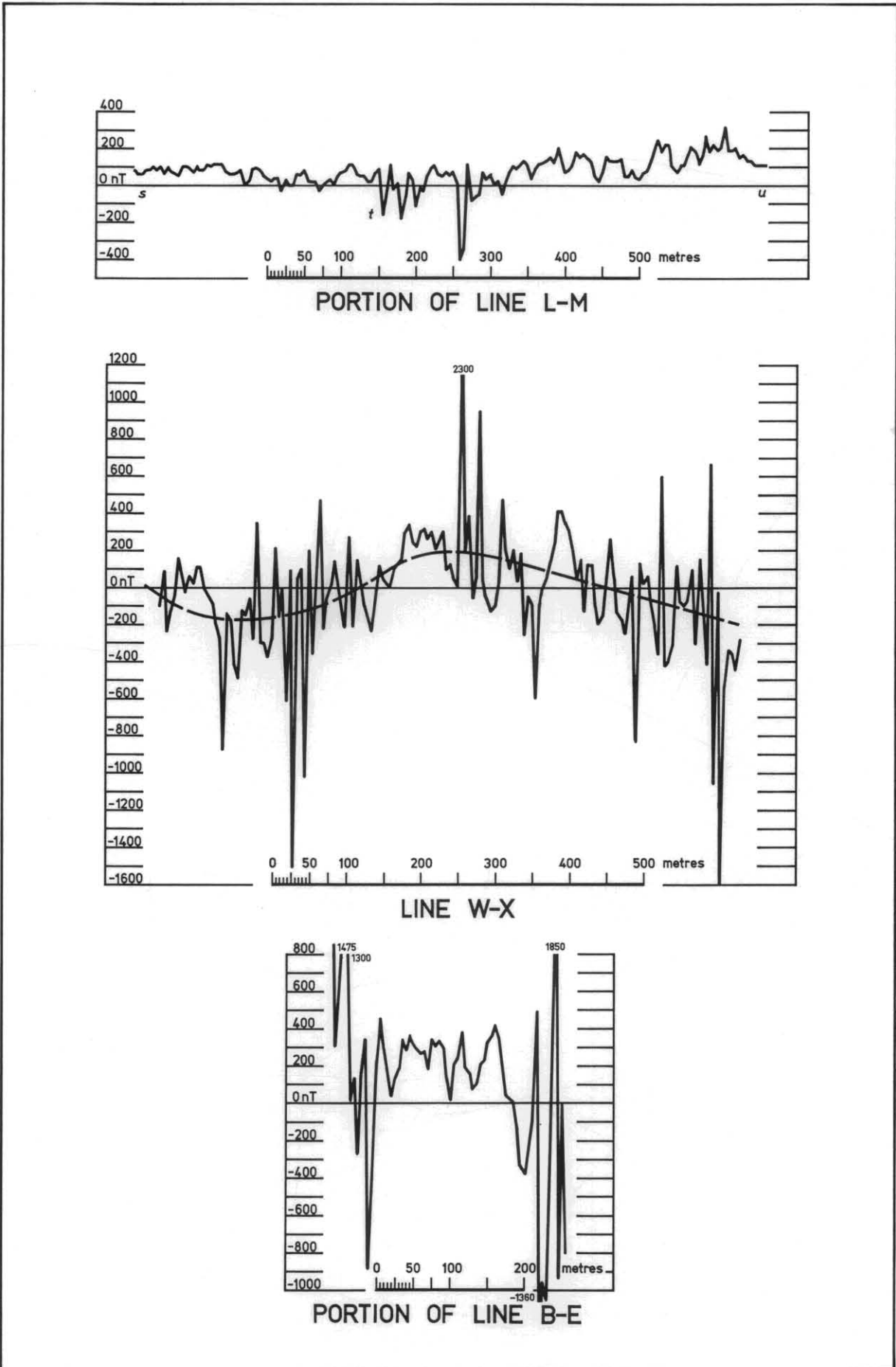


Figure 4. Surface surveys, Profiles L-M, W-X, and B-E



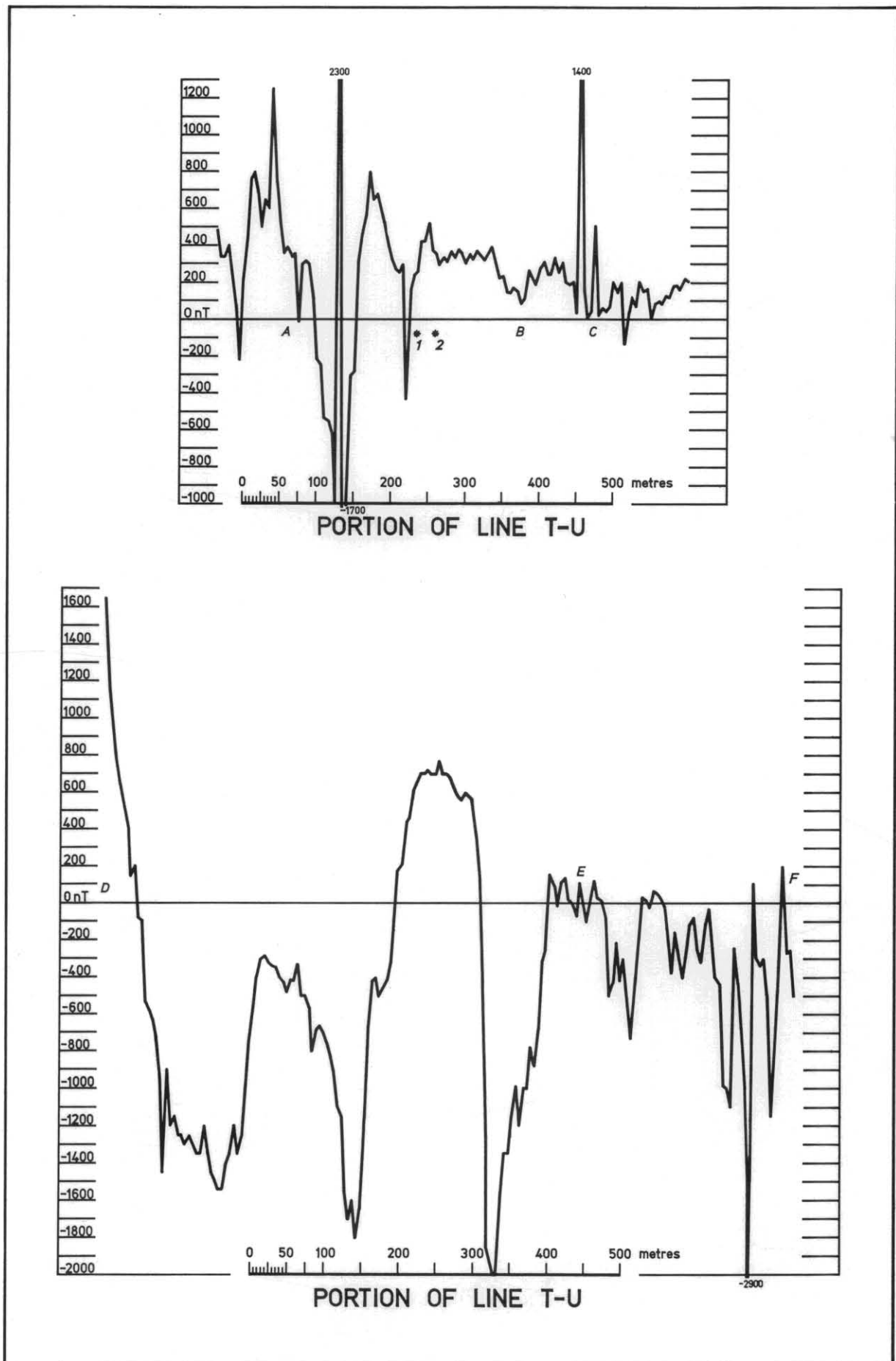


Figure 5. Surface survey, Profile T-U

talus near B, and with a slope change further dolerite outcrop to the right of C.

The lower segment of T-U is virtually unique. No similar character was recorded on other lines. The observation differences are large, often consistent in sign and superimposed on a long wavelength high amplitude waveform. The section DE can be contrasted with EF which displays more normal dolerite character. Dolerite is exposed throughout and the profile would be so interpreted, but the character difference is not easily explained from magnetic or visual textural observations. The gravity survey of the region, however, shows that this traverse segment crosses the side of a large feeder pipe and a changed depth-source function is extant.

A review of all profiles suggests that the four geological categories exhibit the following properties.

- | | |
|-------------------------------------|--|
| (1) Coal measures. Difference range | $< \pm 50\text{nT}$ (order of magnitude) |
| (2) Talus/coal measures | $\pm 150\text{nT}$ |
| (3) Talus/dolerite | $\pm 500\text{nT}$ |
| (4) Dolerite | $> \pm 1000\text{nT}$ |

Anomaly wavelength data may be important if the impact of observation spacing can be identified and removed. For example, consider profile W-X (fig. 4). Much of the character of this profile is related to station spacing with an indicated anomaly frequency of at least one per five metres (wavelength five metres or less). Some features are larger than this by an order of magnitude. It is also possible to draw a smoothed profile through the data which has a wavelength of around 600 m. All purely dolerite or dolerite influenced profiles show similar low amplitude long wavelength features. Close examination of most profiles show similar effects, including those where talus overlies coal measures (see f-g, C-D, fig. 3). In such cases the amplitude is very small and the wavelength rarely more than 100 m.

Table 2 presents the parameters specifying long wave features from all profiles (2A is the peak-peak contrast on anomalies).

While no pattern relating material and wavelength emerges from the data of Table 2, there is a clear correlation between amplitude and material. Where talus and country rocks are involved, 2A is generally less than 150nT or if talus or weathered dolerite are present $2A < 500\text{nT}$. Where dolerite is exposed, or nearly exposed, and in good condition $2A > 1000\text{nT}$. When this broad scale effect is superimposed on the common 500-1000nT short period variations a very ragged profile results with total variations up to twice those of the regional effect. Some true regional gradients can be seen along several traverses but the ground coverage is generally inadequate to define the sources.

The quasi-regional long wave anomalies are especially significant in that they are features that appear distinctly in the aerial survey. The relationship between surface and aerial profiles is suggested in Figure 6.

Table 3 presents the gradient data derived for long wave anomalies observed on each profile. The gradient is defined as positive for values increasing in the direction of the profile point indicated. It should be noted that the value quoted represents only one component of the gradient and thus does not fully specify it. The table stresses the differences between materials.

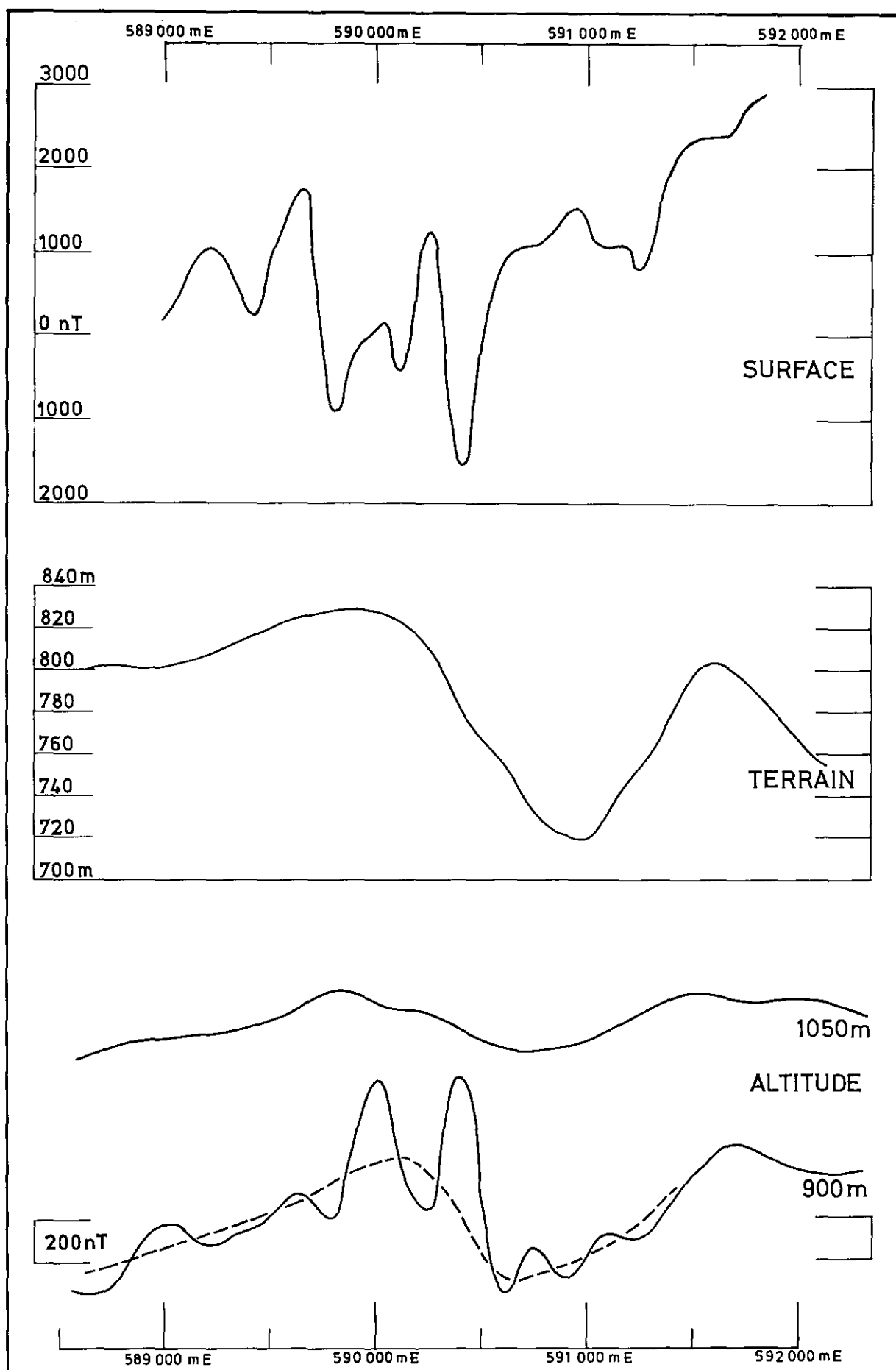


Figure 6. Surface/air profile comparison along 5388500 mN

Table 2. LONG WAVE ANOMALIES (GROUND)

Profile - Fingal	2A (nT)	λ (m)	Material	Comment
AB	< 200	350	Jdt/cm	
	~ 350	150	Jdt/Jd	
	1500	400	Jd	
CD	150	300/350	Jdt/cm	
	1000	500	Jd	
LM	-	-	Permian	
	100	250	Jdt/P	
NO	50	250	Jdt/cm	
PQ	~ 100	350	Jdt/cm	
FG	3000	1200	Jd	
BE	800	350	Jd	A variable 300 - 2000 m
WX	400	600	Jd?	
TV	300	450	Jd?	
TU	500	400	Jd	
	2200	250	Jd	adjacent feeder
	350	500	Jd	
GH	1000	~ 500	Jd	
Dd-I	1000	900	Jd	
B-K	500	650	Jd	
	1000	700	Jd	
a-b	1000	600	Jd	
RS	100	450	Jdt/cm	
TZ	1500	900	Jd	
dJ	-	-	Jd	
Mt Henry				
AB	< 150	350	Jdt/cm	[EP813689 - EP834696]
BC	500	300	Jdt/Jd	[EP834696 - EP844679]
CD	2000	450	Jd	[EP834696 - EP823672]
EB	1000	350	Jd	[EP825680 - EP844679]
FG	500	300	Jdt/Jd	[EP843652 - EP810639]

Table 3. GRADIENT DATA (GROUND)

Profile - Fingal	nT/km	Material	Comment
AB	+ 30 to B		'regional'
CD	-		
LM	+ 200 to M	Jdt/P//cm	
	-1000 to M	Jdt/Jd	anomaly induced
NO	0	Jdt/cm	'regional'
	-1000 to O	Jdt/Jd	anomaly induced
PQ	+ 400 to Q	Jdt	
GF	+2000 to F	Jdt/Jd	
BE	+ 500 to E	Jd	persistent trend disrupted to two major discontinui- ties
WX	0		
TV	+1400 to V	Jd	
TU	+ 600 to U	Jdt/Jd?	
TU	+ 400 to U	Jd	
GH	-		
DdI	-		
BK	+ 500 to K	Jd	
ab	+ 750 to b	Jd	
RS	0		
TZ	-		

Table 3. (continued).

Profile - Mt Henry	nT/km	Material	Comment
AA'	0		
CD	-		
GF	+1500 to F?	Jd	

Structural implications

As shown in Figure 2, the coverage of surface traverses is highly selective and directed at particular zones in order to provide reference data and evaluation of the mapping uses of the technique. Even so, a number of features have been identified and the dolerite-coal measures boundary has been recognised in several places around the escarpment. All features are shown in Figure 7.

The traverses have clearly demonstrated the general presence of dolerite talus around a broad arc on the northern slopes of Fingal Tier and indicated that *in situ* dolerite is restricted to the main tier mass and a few relatively small dykes. One, near M on Profile LM, may be 30 m wide.

Lines BE, TU proved especially interesting. Both cross ostensibly dolerite terrains, but in each case substantial pockets of talus have been recognised. On line BE two major discontinuities ($\sim 1500, 2000$ nT) were noted and faulting is implied (e.g. fig. 8). A similar discontinuity was recorded on line FG. Observations near the southern end of line TU indicate that the base of the sheet is nearby or absent. A subsequent detailed inspection of burrow and tree stump holes located many fragments of glassy dolerite and hornfelsed mudstone. A major variation in the dolerite occurs near EP905835 and comparison with the gravity survey (Leaman and Richardson, 1980) suggests that the cause is a feeder pipe.

Table 4. SUSCEPTIBILITY VALUES (SI) $\times 10^{-3}$

Profile - Fingal	Average values	Range	Comment
AB	15	2-42*	talus fragments
	10	2-24	talus/Jd
	15	5-22	Jd
	12	5-22	Jd
CD	12	4-42*	talus fragments (*near C only)
	12	3-27	talus
	10	1-21	talus + talus/Jd
	10	2-36	Jd
	10	2-26	Jd
LM	6	0-19	talus/Permian or Permian
	6	1-16	talus
	8, 11	1-19	talus, Jd
NO	5, 10	1-18	talus, Jd
	12	2-21	talus/Jd
PQ	8	1-21	talus/Jd
GF	12	2-21	Jd
	12	3-27	Jd
	10	2-18	Jd
BE	12	5-27	Jd
	10	2-19	Jd

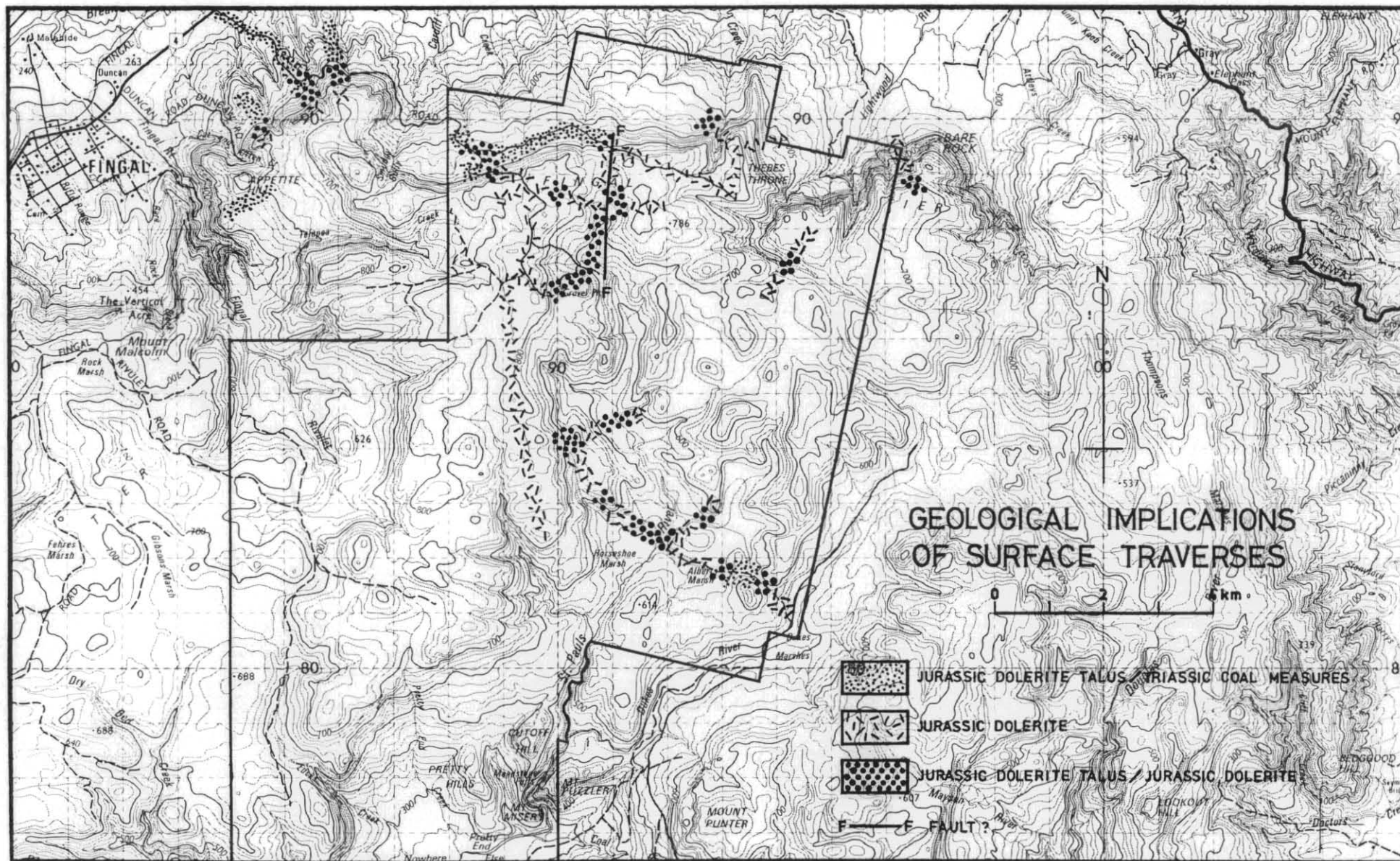


Figure 7.

5 cm

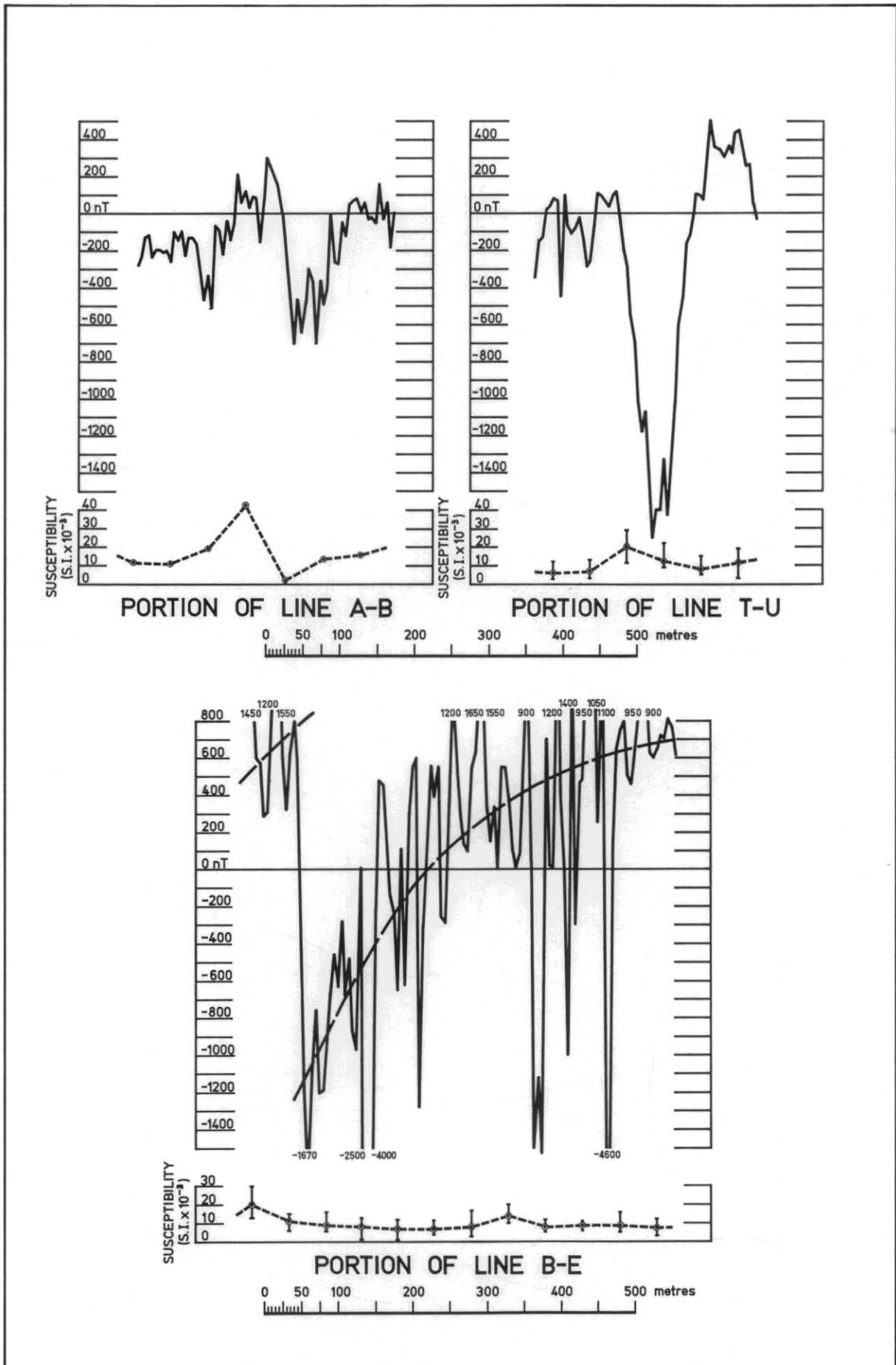


Figure 8. Relationship between susceptibility and field

Table 4. (continued)

Profile - Fingal	Average values	Range	Comment
	10	1-27	Jd
	15, 10	3-31	Jd discontinuity
	10	1-30	Jd
WX	6	2-12	Jd
TV	5	1-17	Jd
TU	10, 20	5-35	talus, Jd
	10	4-21	Jd
	10	0-35	Jd
	5	1-29	Jd
	10, 5	3-37	Jd, talus
	10	4-53	Jd
GH	15	4-26	Jd
DdI	10	2-35	Jd
BK	12	3-26	Jd
	12	4-23	Jd
	11	2-22	Jd
	12	4-26	Jd
	12	4-40	Jd
ab	10	2-21	Jd
	10	4-39	Jd
RS	10	2-21	talus/cm, talus fragments
TZ	10	2-38	Jd
dJ	15	2-32	Jd

Mt Henry

AA'	2	0-12	talus fragments
	3	0-30	talus fragments
	9	2-22	Jd
CD	7, 10	1-19	Jd, Jd
	10	1-26	Jd
EB	16	5-25	Jd
GF	10	2-21	Jd
	10	3-29	Jd
	10	5-28	Jd * = isolated value

Average values are based on averages of each group of ten readings taken 50 m apart. The range quoted represents the range of all observations in the line section and does not represent the spread of group averages.

PROPERTIES OF THE DOLERITE

Table 4 presents a summation of susceptibility determinations from the 10 000 observations made, while Table 5 details determinations of the remanent field intensity and orientation. Results in each table stress the differences between the dolerite of this area and those of central or southern Tasmania.

The range of susceptibility values is $0-42 \times 10^{-3}$ SI, but only two determinations recorded values in excess of 40 SI units and very few others in excess of 30 units. Most values are in the range 5-15 and this is reflected by initial averages and hence the average summations per kilometre of traverse as shown in the table. Values for glassy contact dolerite rarely exceed 6-8 units and appropriate values are noted for line A-A' (Mt Henry). Similar values, however, have been observed on lines N-O, T-V, T-U,

and W-X. Lines N-O and T-U encompass a contact, but no sedimentary material is known on lines T-V and W-X and the observations of the field on these lines do not suggest any. This is compatible with the gravity survey (Leaman and Richardson, 1980) which indicates that these lines (T-V, W-X) cross thickened dolerite which includes two feeders. In such circumstances it could be expected that K values would exceed 50 units, since coarser magnetite-rich phases would be present.

Other values (10-15 units) reflect a dolerite which is fine-medium in grain, even in texture and colour and generally uniform. Considering the considerable thickness variations (100->500 m) established by drilling and gravity surveys, it is surprising that visual and magnetic evaluations of the dolerite are very uniform; whereas similar sheets of dolerite elsewhere are strongly differentiated and variable texturally and magnetically.

There is no consistent relationship between field response and susceptibility, and this is demonstrated by the traverse fragments shown in Figure 8. In the case of A-B there is a positive correlation between response and susceptibility, but this may reflect changes in materials since the overall pattern implies a local *in situ* body surrounded by talus which may not be representative of the local material. In the case of T-U there is a negative correlation, as might be expected, but the magnitude of the response (1700nT) is out of proportion to the ten unit variation in susceptibility. Line B-E shows the normal condition; strong field fluctuation, no correlated susceptibility changes. It is clear that the NRM characteristics of the dolerite dominate and that any interpretations of the field must consider the orientation and magnitude of the remanent field.

Twenty-four samples of dolerite were collected by Geoex Pty Ltd in the Fingal Tier region (see fig. 2) and determinations of NRM were made by F. Chamelon at Flinders University. The results are listed in Table 5 and plotted in Figure 9. They show a wide variation in both declination and inclination and there are three possible explanations:

- (a) sampling of large talus blocks, not established outcrops,
- (b) faulty sample orientation,
- (c) major field fluctuations at the time of intrusion.

The first and last possibilities could yield quite random results, while the second could yield declination variations at fixed inclination if the orientations were made by magnetic rather than sun compass as occurred here. There is little evidence in the literature of major field changes (e.g. Irving, 1956; Schmidt and McDougall, 1977; Stott, 1963), although there are suggestions of a reversal. In the authors' view the literature represents less than 50 sites, usually near contact zones, and may not be representative of the entire province.

However, each site on Fingal Tier has been reviewed, and consideration of surface survey profiles, where available, has established that several are unquestionably on dolerite talus (2, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 22) some are doubtful (4, 20) and only 1, 3, 11, 16, 17, 18, 19, 21, 23, 24 are probably from outcrop. Data from sample 20 would suggest that it too is of talus. Of the ten samples considered acceptable only four determinations have been made and these group at about 360°, 55°.

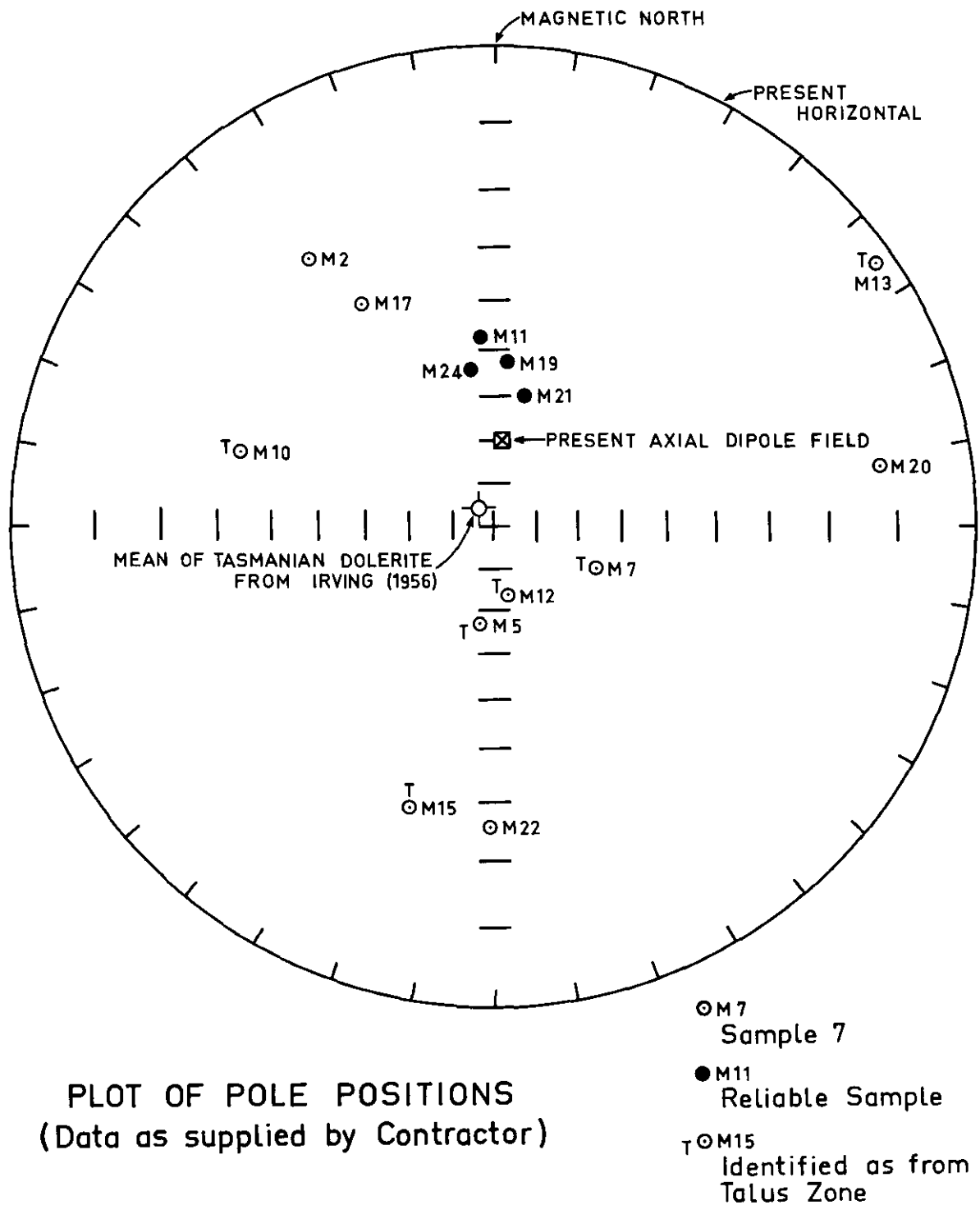


Figure 9.

Table 5. N.R.M. DETERMINATIONS

Sample	Declination	Inclination	Magnetisation
M2	325	-22	3045
M5	189	-66	2646
M7	115	-64	6100
M10	286	-31	1423
M11	356	-47	1068
M12	169	-73	3278
M13	55	-0.2	4462
M17	329	-34	2244
M19	6	-52	1661
M20	81	-13	7136
M21	14	-59	1128
M22	181	-26	1015
M24	351	-53	1425

SUMMARY OF SURFACE SURVEYS

Surface magnetic surveys are able to distinguish the important geological conditions of talus/coal measures or talus/dolerite. These couplings may be identified by anomaly amplitudes and, often, anomaly wavelengths. It is important to obtain sufficient observations and a 5-10 m spacing is recommended. Twenty-five or fifty metre spacings not only reduce resolving power for boundary location but may also lead to a smoothed profile lacking the high frequency amplitude variations.

The local dolerite is very uniform and possesses a high NRM but low susceptibility. Anomalies are rarely less than 1000nT and may exceed 10 000nT (vertical component). Many gradients would preclude the use of proton magnetometers and their added sensitivity is not necessary for any aspect of boundary identification.

AIRBORNE MAGNETIC SURVEY

Objectives and specification

Prior to the completion of the gravity surveys of the East Coast Coalfields (Leaman and Richardson, 1980) an evaluation was made of methods which might assist the coal project and escalate the rate of progress. Gravity surveys, for example, proceed slowly in the local terrain even when barometric elevation methods are used. It was desirable that any additional method(s) employed be compatible with the gravity surveys and allow review of any ambiguities which might arise upon interpretation. The magnetic method is suited to both objectives in this environment, being able to provide a relatively cheap and rapid areal coverage and yield data on dolerite, one of the two key materials in the region. Preliminary gravity reductions suggested considerable variation in dolerite structural behaviour which, allied to unknown sedimentary sections with opposing density contrast, might result in ambiguous interpretations. Consequently any independent data on the form of the dolerite might resolve ambiguity in gravity interpretations leading to a more reliable assessment of the sedimentary section.

Options of drape or fixed height surveys were considered and it was decided to avoid any problems which might arise with drape flying over the varied terrain of Fingal Tier by surveying at two fixed heights. Fixed surface flying would permit processing to a drape form and at the same time

provide a reliable basis for continuations. Flying at two heights was considered desirable if any continuation tests were required but, more importantly, to ensure that anomaly shape and source depth assessment would be well controlled by quasi-gradient analysis or differences. The heights chosen were 900 and 1050 m, the first being 50 m clear of the highest point on Fingal Tier. Specifications for the survey are given in Appendix 1.

Unfortunately, due to funding and contractual delays, the survey was not flown until nearly one year after preliminary gravity results were available from the regional survey and the detailed gravity survey was virtually complete. Interpretation of results of the magnetic surveys was not available until nearly six months after comprehensive interpretation of both gravity surveys. The range of specialised processing methods used for the gravity interpretation was found to yield a relatively unambiguous result and the magnetic survey was not to be as useful as first hoped. The following discussion indicates the nature of the observations and their interpretation.

Observations

Figures 10, 11, 12 and 13 present, with variation in contour interval, the magnetic field at 900 and 1050 m over the Fingal Tier region. There is a strong correlation between topographic level and total intensity and topographic and magnetic gradients.

Terrain effects are especially apparent around the escarpment overlooking the Break O'Day valley and are strongest in the region east of grid line 588000mE. The western portion of the escarpment (e.g. west of the Vertical Acre [EP820866]) is less pronounced. Similar subdued gradients occur in the south of the area at EP880800, EP910810, EP920800 and EP950795.

The most intense anomalies occur in the northern half of the surveyed area, and this is only partly due to the more elevated terrain as shown by the difference in anomalies in a 2 km radius about EP960875 and EP970800, where the average terrain is comparable. If the northern arc of anomalies around EP960875 is ignored (due to scarp) and the southern area is compared with the second area, it will be noted that the magnetic field is very different. Similar observations apply to the single anomalies and high points across the southern half of Fingal Tier, as contrasted with the northern half. A comparison of the contour maps for 900 and 1050 m stresses the differences in response across the region.

Field intensities recorded at the low level (900 m) range from -125nT to 855nT, whereas those at the high level (1050 m) range from -5nT to 705nT. (Note that the maps presented exclude the International Geomagnetic Reference Field and are therefore residuals). The difference and sign of ranges for the two heights reflects the greater smoothing with increased elevation. Similar comparative modifications of anomaly form and magnitude occur for individual features.

Interpretation

Initial qualitative interpretation of the observed residual field has been based predominantly on the 50nT contour maps (figs. 12, 13) and is summarised in Figure 14.

Figure 14 also includes a synthesis of geological control information. Several escarpments are indicated in the north and south of the area. In each case the base of the capping dolerite sheet is present, if concealed by talus (see fig. 1). Permian rocks are exposed near Fingal, but in all

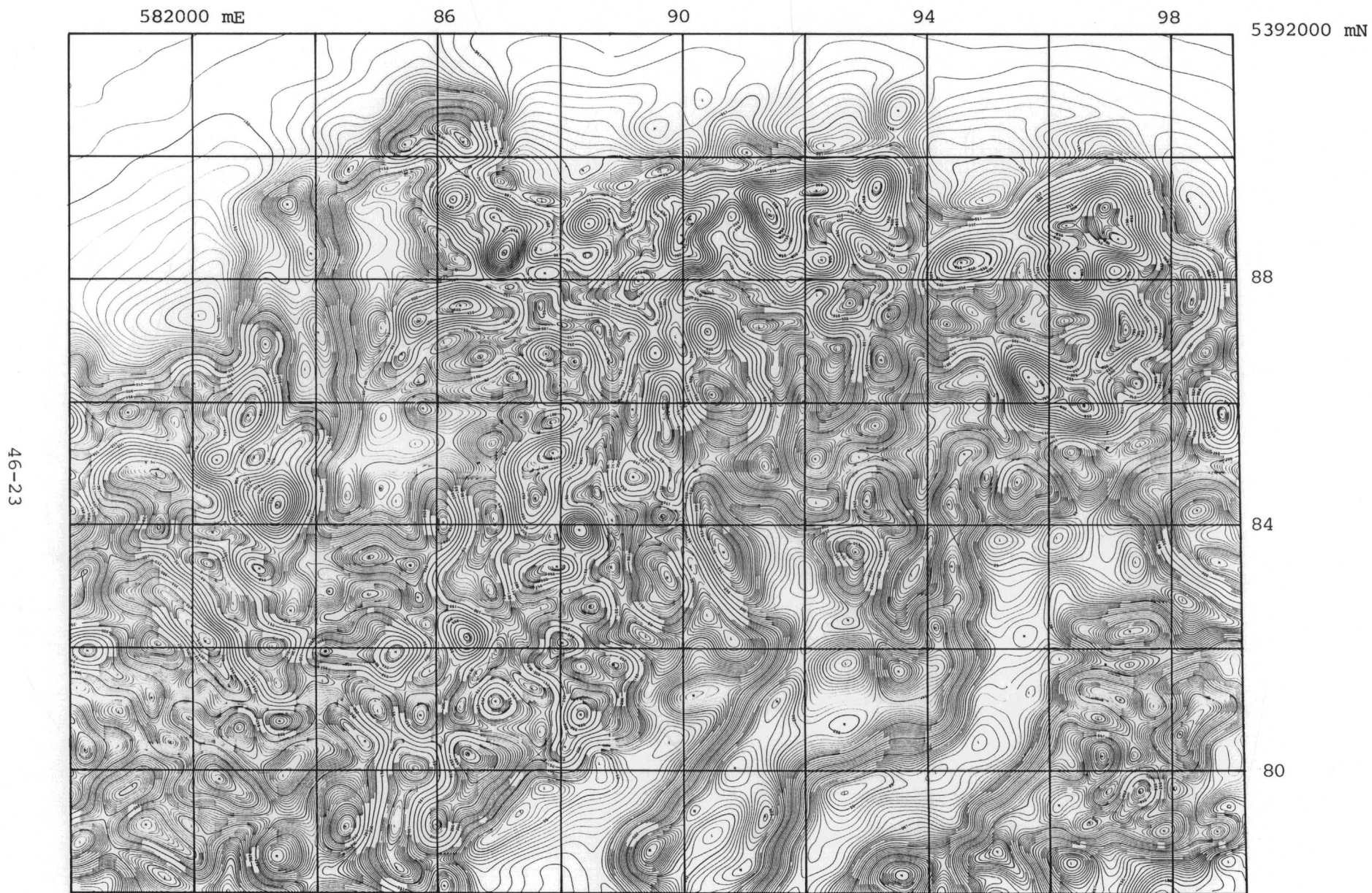


Figure 10. Aeromagnetic survey; $h = 900$ m, 5 nT contour

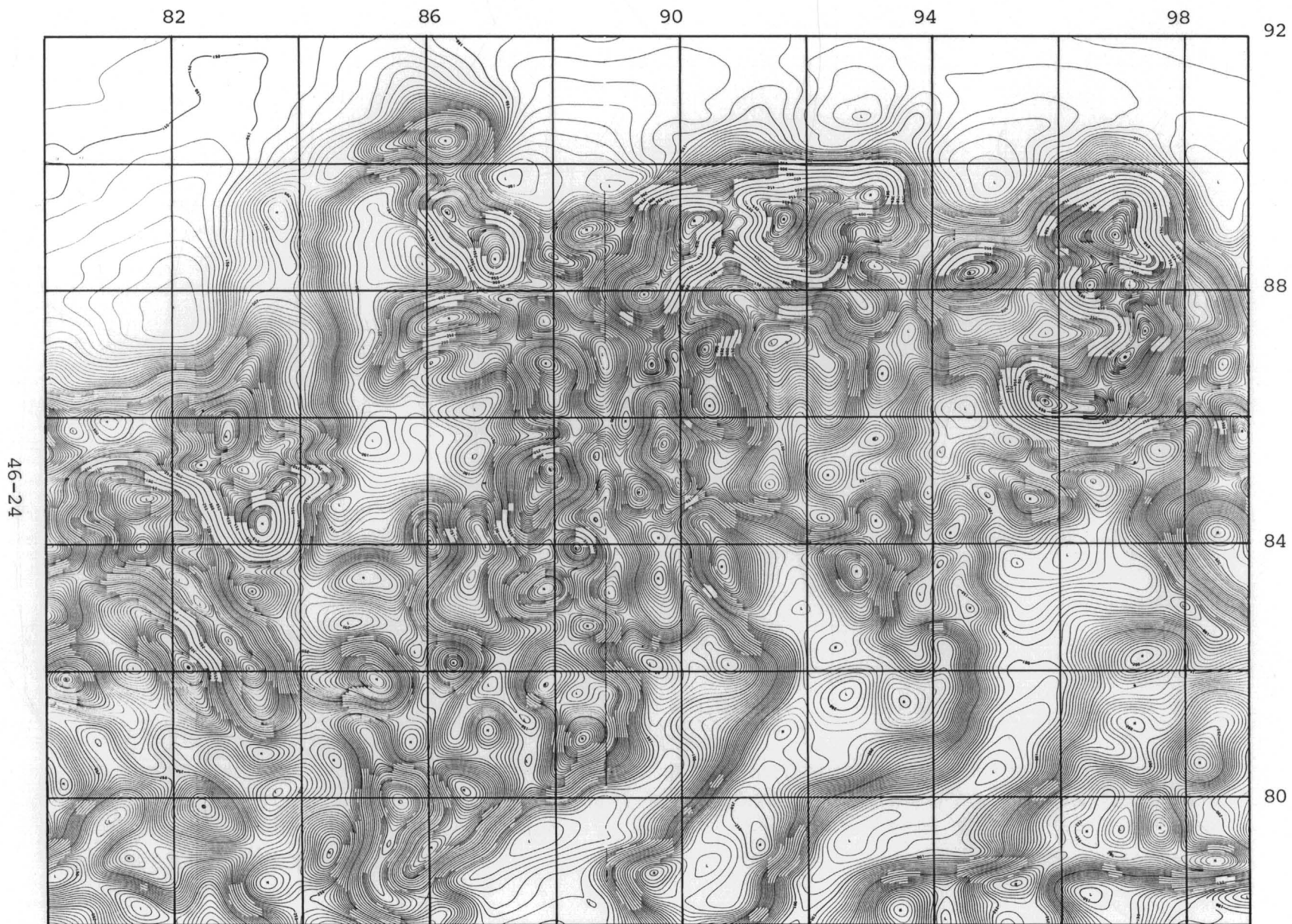


Figure 11. Aeromagnetic survey; $h = 1050$ m, 5 nT contour

5 cm

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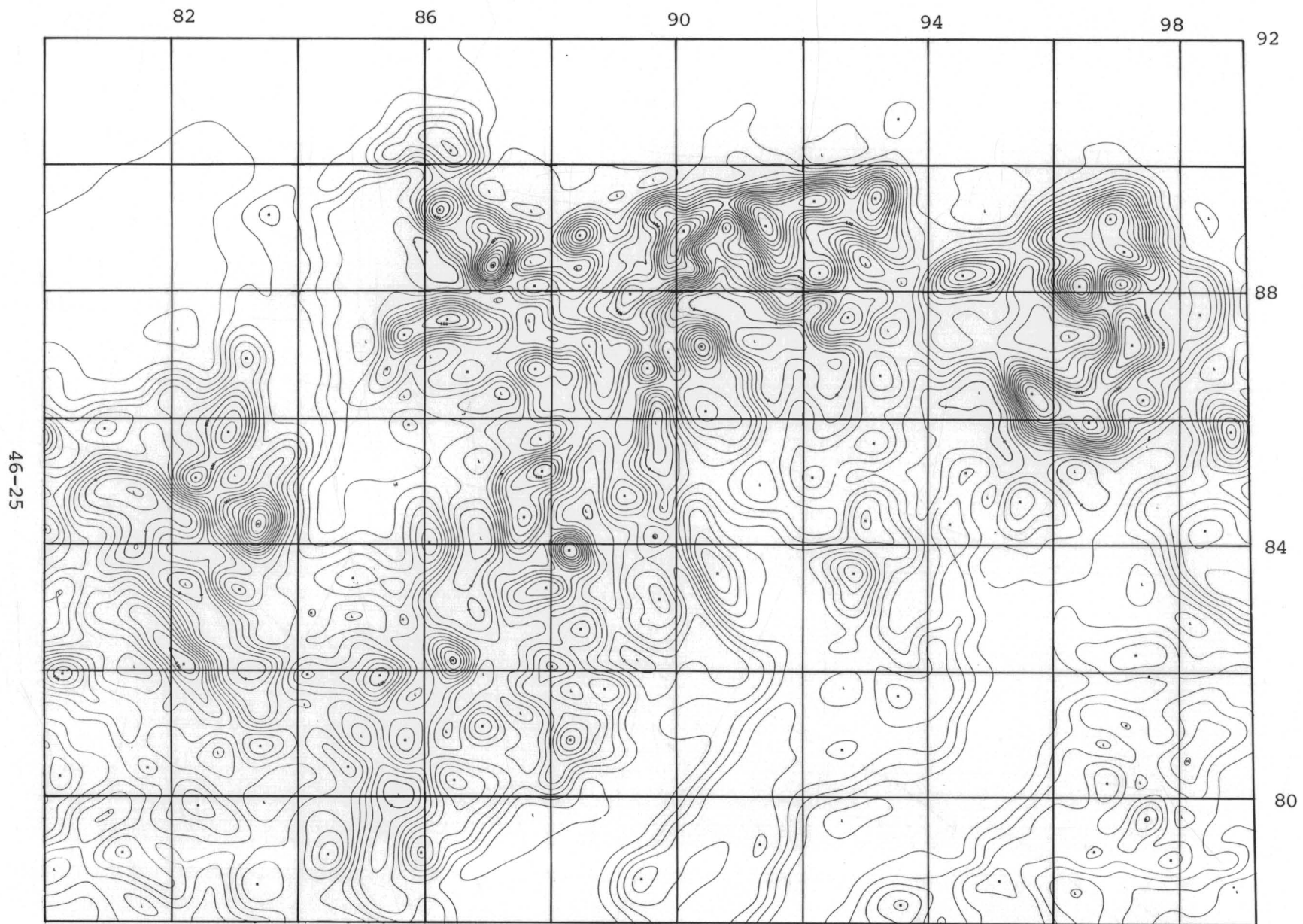


Figure 12. Aeromagnetic survey; $h = 900$ m, 50 nT contour

5 cm

25/44

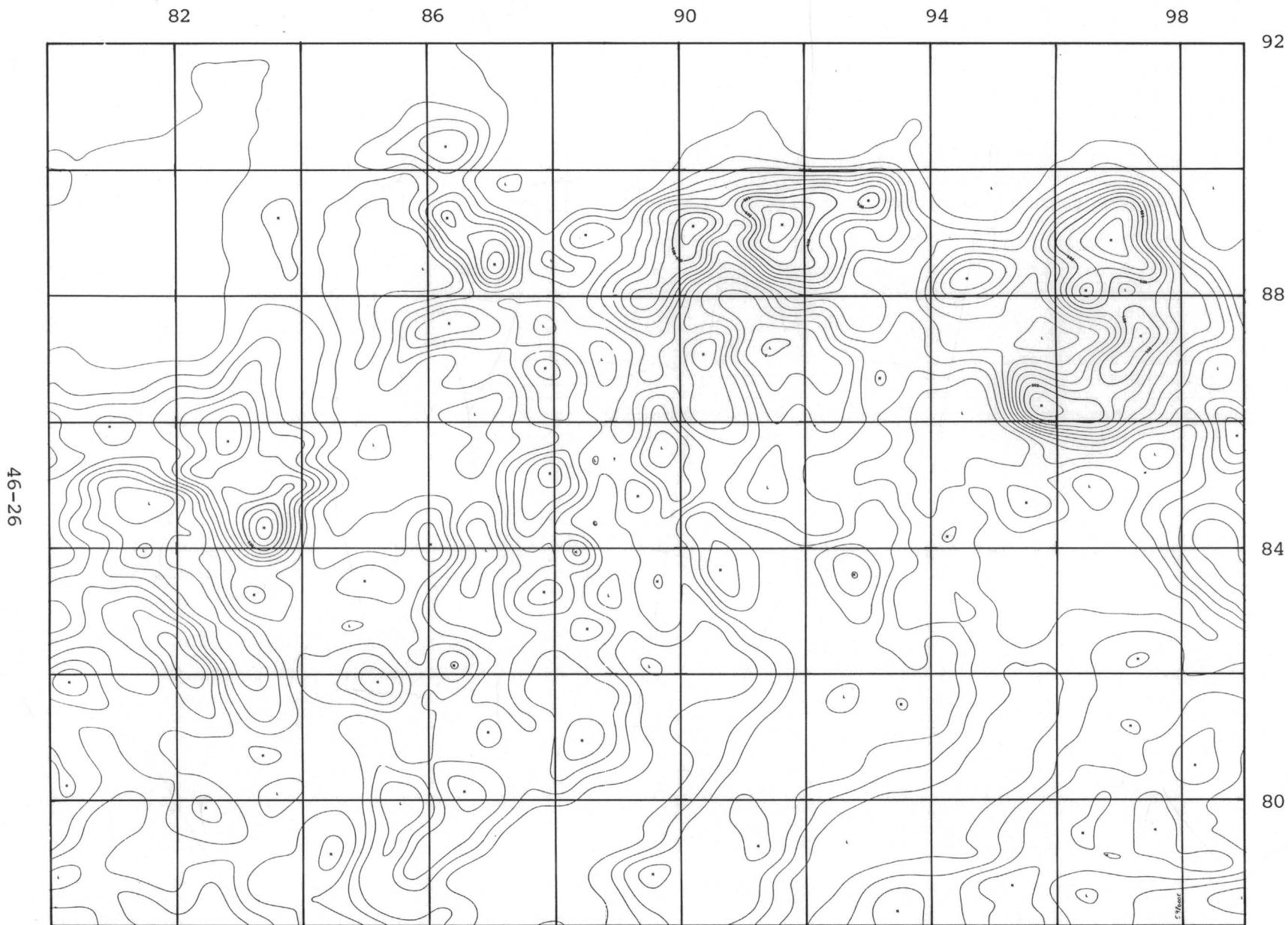


Figure 13. Aeromagnetic survey; $h = 1050$ m, 50 nT contour

other instances only the Triassic coal measures are exposed, immediately below the dolerite escarpments or in the valleys of the St Pauls or Dukes Rivers [EP890380, EP950380]. In every case the sedimentary rocks are patchily exposed, there being a substantial and variable cover of talus. The bulk of the area is covered by dolerite outcrop or dolerite products.

Figure 14 indicates the position of major gradients and anomalies in the magnetic field. Absolute value treatments are not possible due to the varying terrain clearance incorporated in the observations (50-400 m). Similarly, trend analysis is uncertain. However, some of the more obvious trends have been suggested. The anomalies shown are listed as highs or lows and some are localised and clearly related to topographic features. Some gradients are related to topographic alignments. All the escarpments have produced gradients, the strongest being related to the high level escarpment east of the Duncan mine.

The strongest gradients have been observed over the relatively gentle topography in the west and north-east of the area [near EP845825 and EP965875]. Such anomalies must reflect variations in dolerite composition or structure. In each case concealed discordant margins are implied. Similar gradients are observed where known margins are exposed [EP910381, EP920380].

If some allowance is made for the terrain the relative values of the field, or its smoothness, can be used to suggest the extent of the sedimentary rocks or the relative thickness of the dolerite.

For example, anomalies near the Duncan mine [EP850890] and at EP890380, EP950380 or EP870384, where coal measures are known to occur, can be interpreted using lateral variation. It may be implied that the dolerite cap is thin in the region of EP880875, EP860860, EP905820, EP950840, EP940860, EP960875 and EP980830. In the case of EP905820 and EP950840 the cap is possibly non-existent. Similar deductions may be made about other anomalous zones, and these are also indicated.

However such an interpretation is not supported by either drilling or gravity results. Only at EP905820 does the gravity interpretation suggest an absence of cap and at EP950840 and EP940860 a thinned cap. A total contradiction occurs in the region of EP960875 where the gravity results indicate a feeder system and very thick dolerite. The form of the concealed discordant margin corresponds with the +1 mgal Bouguer anomaly contour, but the intense magnetic anomalies are on the 'thin' dolerite side of the margin and lesser anomalies occur over the feeder axis. Similar low values may be observed on the feeder systems in the south and north-west of the area [EP920810, EP925825, EP840805, EP835885]. Detailed examination of the field near the two major feeder systems shows that the values are only relative lows. This distinction is suggested by the broken line (fig. 14) at EP945868 which shows the likely margin of the body. This distinction is especially clear in the observations at 1050 m. Thus although six dolerite structures can be identified (not including escarpment features - sheet base) there is no consistent anomaly gradient or amplitude pattern and the initial interpretation for cap thickness or coal measures extent must be ambiguous and uncertain.

The gradients and anomaly patterns shown in Figure 14 are derived from the survey at h = 900 m. As noted above it is instructive to consider the higher level observations which have a larger wavelength, smoothed appearance. There is an overall concurrence of character, except that trends are sometimes less obvious and the entire belt of large anomalies from EP900890

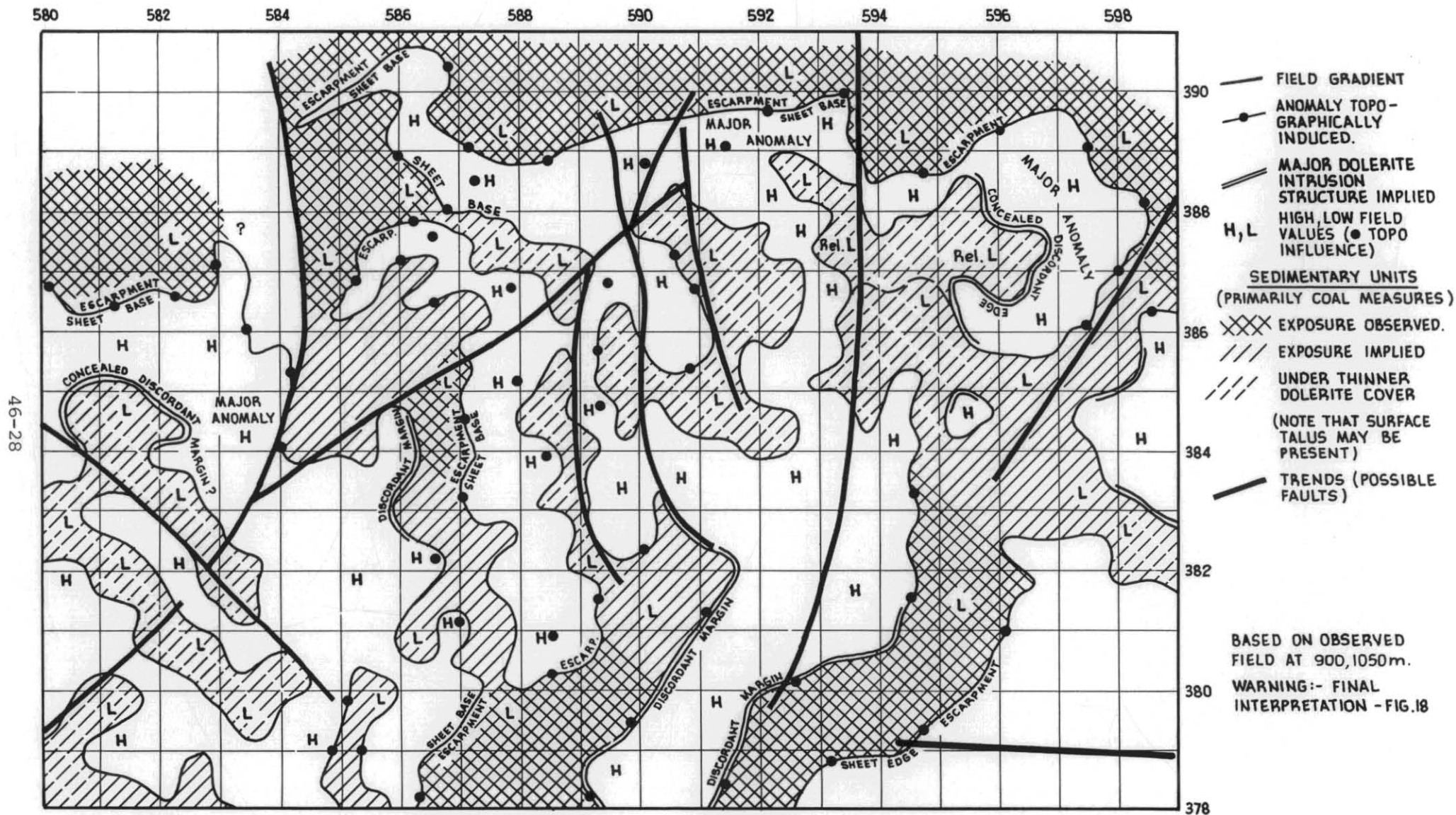


Figure 14. Qualitative interpretation, Fingal Tier aeromagnetic surveys

to EP980880 can be recognised as a single unit. While some of the anomalies are clearly reduced versions of those at 900 m, there is a suggestion of gross structures. Three anomalies are described as 'major' in Figure 14, two of which are at relatively low elevations. As discussed in Appendix 2, these features do not correlate directly with major dolerite structures, rather with a combination of large structures, all edges. The anomalies are considered large for this reason. Thus the anomaly at EP835845 is centrally disposed between pipes at EP835855, EP845840 and EP835835. The magnetic anomalies, especially those distinct at 1050 m, reflect sheet structures in an indirect way and that the field intensity over large pipes is relatively low.

In an effort to improve the quality of interpretation the data at 900 m has been continued to provide a 100 m drupe coverage (fig. 15) and a version of the field at 1050 m (nominal for comparison with the observed field (figs. 16, 13). The precise drupe reduction permits a considerable improvement in resolution and the interpretation given in Figure 17 is largely based on this continuation.

An examination of Figure 15 shows that the normal dolerite pattern - relatively small but intense anomaly cells - is ubiquitous, confirming geological inferences. Only north of the Fingal Tier escarpment and in the St Pauls or Dukes River incisions are there any significant changes in character. The broad, low amplitude swells are typical of talus-covered coal measures sections. Only in the area of EP960830 to EP990870 is the interpretation uncertain, and a very thin or patchy dolerite sheet is suggested (see fig. 17). A similar conclusion was derived from the raw data, but the continuation shows that the amount of dolerite increases to the north-west from the Dukes River axis. Thus although the sheet remains relatively thin, it is nowhere dissected to expose underlying coal measures.

Within the dolerite areas some significant anomalies or gradients may be recognised. The largest of these were noted in the assessment of the raw data (fig. 14). Many lesser features have been indicated in Figure 17. In general each is represented by couplet or gradient anomalies with a relief in excess of 500nT. (Most are easily recognised in the data for $h = 1050$ m (fig. 3) although the distribution shown in Figure 17 is based on the continued field of $h = 900$ m (fig. 15). The scale and depth extent is more clearly indicated in Figure 13). Consider for example the hatched areas at EP905860 and EP905865. While these are discrete features at low levels, examination of Figures 13 and 16 shows that they are part of a single structure. As noted in Appendix 2, neither separate feature shows any particular gravity-structure correlation. However the solitary anomaly could be considered an integration effect from two large edge structures [at EP905860 and EP905873]. See also Figure 18 which summarises data from the survey at 1050 m and indicates possible sources. Most anomalies shown could result from a concealed steeply dipping margin or from localised thickening of the sheet. Clearly these two possibilities may overlap, but they are essentially two or three dimensional effects. For this reason the features are simply hatched in Figure 17.

The gravity-magnetic interpretation correlation (Appendix 2) resolves many of these features. Although several can be interpreted reliably in isolation, many can only be understood in association with the gravity survey. There is no consistent magnetic means of separating the source types. The interpretive comments shown in Figure 20 are based on a review of Figures 17, 18 and 19, the latter reproduced from Leaman and Richardson (1980).

Several trends are indicated in Figure 17. Few correlate with those

46-30

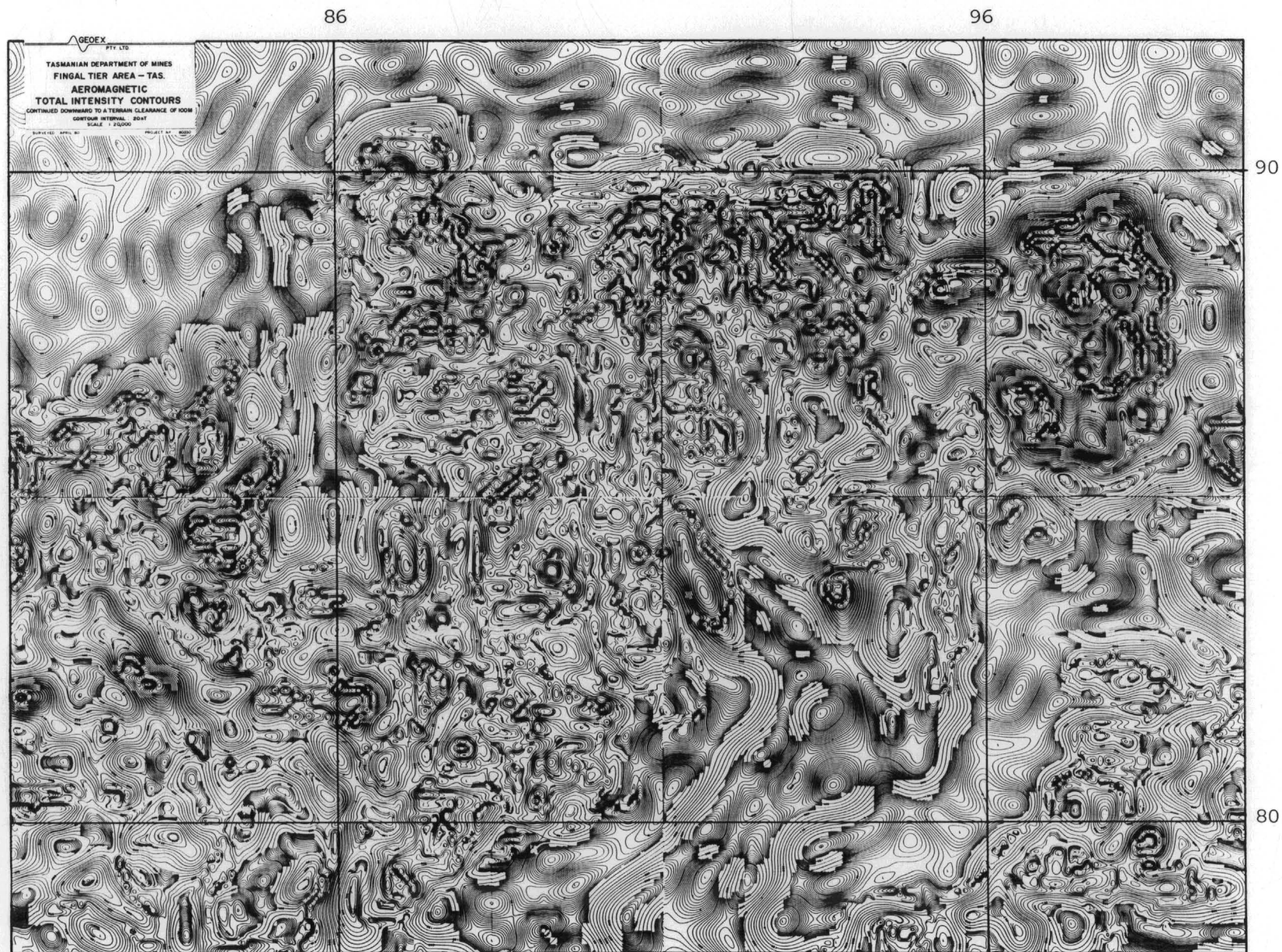


Figure 15. Aeromagnetic survey; downward continuation to 100 m

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46-31

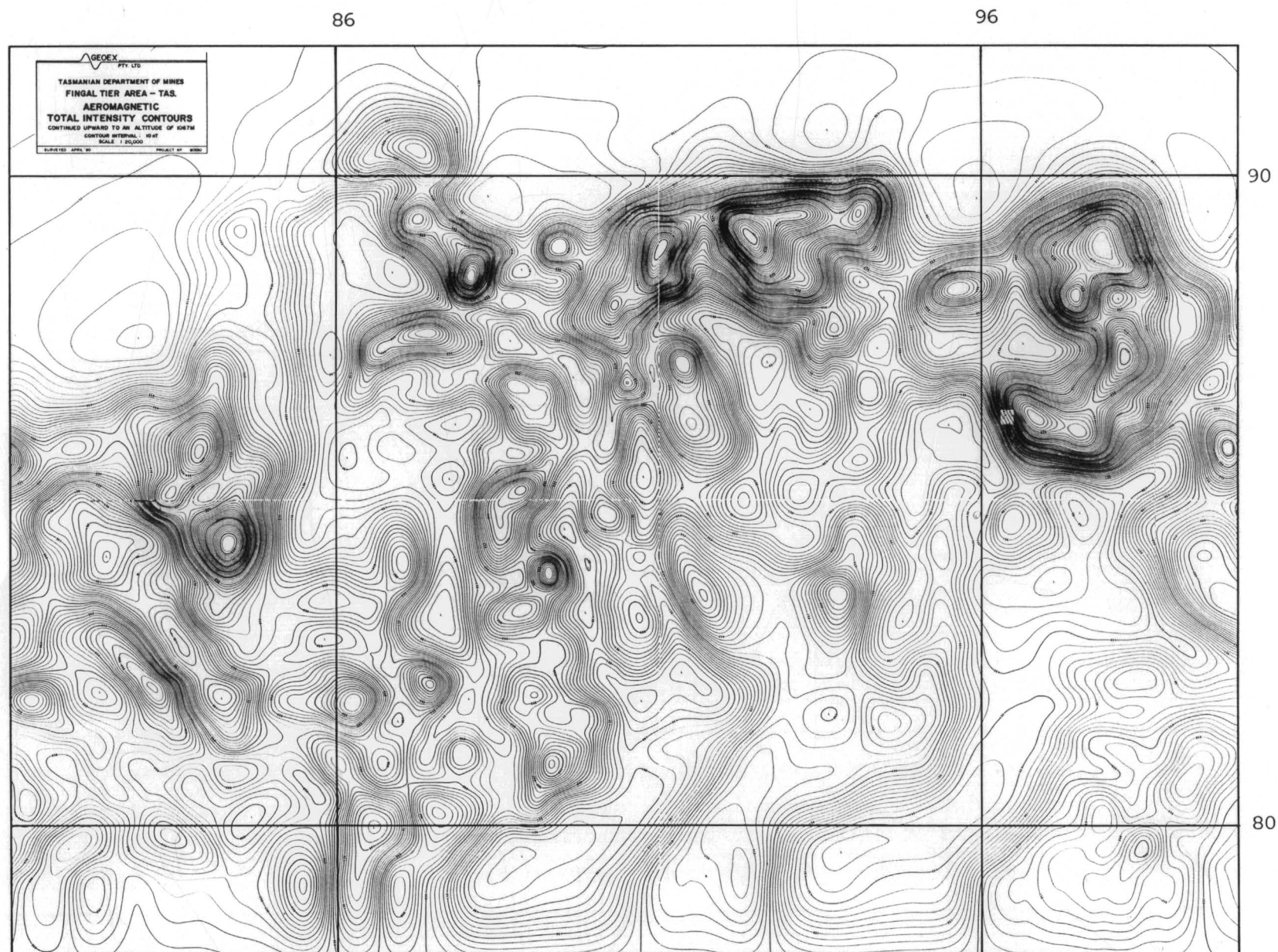


Figure 16. Aeromagnetic survey; upward continuation to 1067 m

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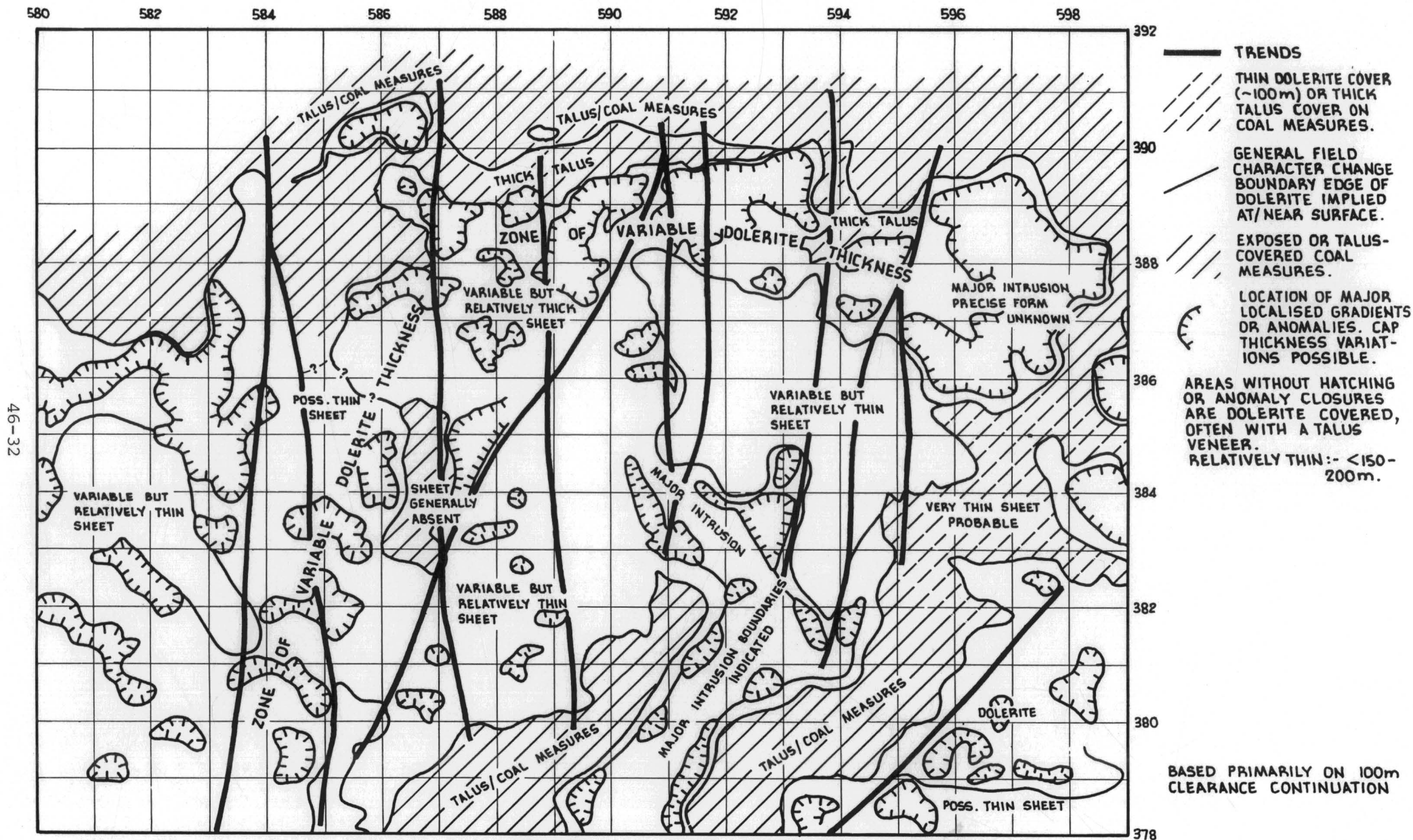


Figure 17. Qualitative interpretation, aeromagnetic survey, Fingal Tier

5 cm

given in Figure 14, suggesting that most shown in Figure 14 are topography-related.

Interpretations based on low altitude (near surface) surveys must be biased by high frequency surface effects, or, in the case of fixed level surveys, by some loss in resolution where the clearance exceeds 250 m. Continuation to a nominal 100 m drape cannot recover any data so lost or blurred. Consequently the next stage in interpretation has been to review the two surveys (900 m, 1050 m) and the observed and calculated field at about 1050 m.

Figure 18 summarises an interpretation based solely on features evident in the observed or continued field at about 1050 m. Some of these features have been included in Figure 14 and referred to in discussion of Figure 17. They are isolated here in order to examine their relevance to dolerite base structures. Only the most significant aspects of the field are evident at this height and no fine character obscures the anomaly sources. The fine character is important when near surface or boundary features are sought (e.g. figs. 14, 17). The trends suggested presumably have significance at depth, and the gradients or anomalies - often equi-dimensional - reflect substantial variations in the sheet. But, as suggested above, these features often relate to several structures. The possible positions of, often interfering, structures are shown in Figure 18. Several gradients or interactions have been ignored if the effect of an escarpment is obviously significant. Structurally, this is the most useful magnetic interpretation, but it indicates only the position of some boundaries. It does not generally define dip or scale. Only in the region of EP910800 is this possible.

The test of the continuation processing provided by a comparison of the 1050 m fields (figs. 13, 16) confirms the general validity of the processing undertaken. No significant differences have been noted.

CONCLUSIONS

The observations at fixed altitude permit a very restricted and misleading interpretation. Few trends are clearly visible and very few structures may be recognised which are not topography related. When the results are reduced to the form of a 100 m drape survey, characteristic dolerite signatures may be observed across virtually the entire area. The analysis has confirmed the suggestion of talus-covered coal measures around the northern escarpment and in the valleys of the St Pauls and Dukes Rivers. But the interpretation is nowhere able to extend the deductions laterally with any certainty.

Although many anomalies and gradients may be recognised which have structural significance, in terms of dolerite base structures, few can be unambiguously related to sheet thickness variations or edges. This restricts the value of the survey as an exploration aid. The magnetic surveys add little new information, but enable an improved definition of some structures when viewed with the gravity interpretation (Appendix 2). The method should not be used in isolation in this geological environment.

Furthermore many of the conclusions made, and the key parameters for integration with the gravity survey, depend on data from two flight levels. The specific dolerite-sedimentary characteristics may only be recognised at low levels and the major structural edges at high levels. Use of the low level data for the latter may be very misleading.

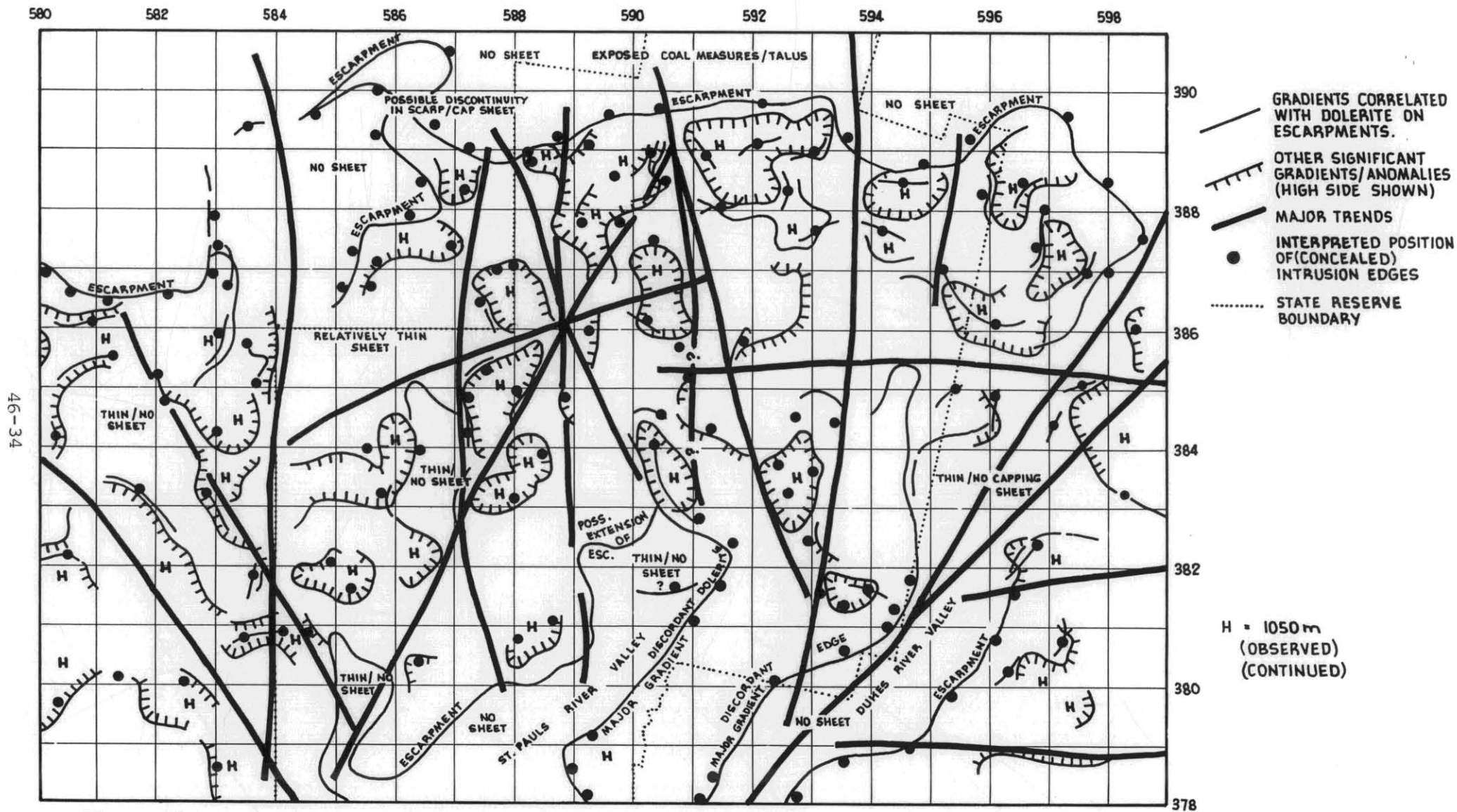


Figure 18. Qualitative interpretation based on high level survey

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[17 December 1980]

APPENDIX 1

Specifications for Fingal Tier airborne magnetic survey

Introduction

Fingal Tier is an elevated plateau in central eastern Tasmania with a total area of about 500 square kilometres. The plateau is of moderate relief internally but is bounded by major escarpments. Fingal Tier is capped by substantial sheets of Jurassic dolerite which conceal productive coal measures. The extent and continuity of the coal measures is unknown but disruptions by faulting and dolerite transgression are known to occur. The thickness of dolerite varies greatly and in some places coal seams are terminated. The object of the survey is therefore to define any major faults and dolerite structures in order to establish a sound overall exploration programme. Only that portion of Fingal Tier held on Government Reserve is to be covered by this survey. The town of Fingal, on the South Esk River, is situated at the NW corner of the survey area.

1. Survey area:

Area to be covered is enclosed by AMG grid lines 580, 599 km E and 378, 392 km N in eastern Tasmania. The area to be flown will be defined on 1:20 000 scale maps supplied by the Mines Department. Approximate line km for a single fly: 1200 km.

2. Flight specification:

- a) Flight lines to be flown in an east-west direction.
- b) Flight lines to be 250 metres apart.
- c) After recovery the line position must deviate less than 50 m from the specified position defined as a multiple of 250 m within the basic grid for 90% of line length. See also 3b.
- d) In-fill lines are to be flown at the operator's expense if line spacing anywhere exceeds 350 metres for greater than 10% of line length and are to cross two tie lines.
- e) Tie lines are to be flown normal to the traverse lines and must have a spacing of 2.5 to 3.5 kilometres. (Compare 3c).
- f) Elevation accuracy will be ± 10 metres.
- g) Elevation verification should be based on check plots of radio-altimeter plus terrain height versus altimeter height corrected for base variations over 1% of flight line distance.

3. Navigation and flight path recovery specification:

- a) All data will be collected in both digital and analog format.
- b) A visual record for flight path recovery must be obtained whether it is the sole or part means of navigation.
- c) The maximum distance between recovered points on each line will not exceed 1.5 km.
- d) The resultant plan will be presented in form of a navigation photo mosaic, line transparency and line dyeline plan at 1:20 000. Plans should show photo centres recovered, control points, observation points (if a Doppler system used) and AMG.

4. Geophysical data specification:

- a) Data shall be recorded with a precision of 1 nT and 50 m or better.
- b) Up to 2 nT peak to peak noise levels will be considered tolerable.
- c) The maximum acceptable error will be 4 nT after correction for diurnal variation with a repeatability of better than 4 nT over 5 km at an altitude of 500 metres morning and afternoon of each day. The test to be recorded.
- d) Magnetic and barometric base variations shall be observed and recorded.
- e) All data will be collected in both digital and analog format.
- f) Analog chart scales should maintain highest sensitivity but, in addition, a record of the magnetic observations shall be made which maintains a single scale setting throughout.
- g) Records will not be accepted where magnetic field variations at the base station exceed 5 nT in 5 minutes (non linear).

5. Digital record specification:

- a) Tape format will be 9 track 800 BPI, NRZI, EBCDIC.
- b) Records of navigation data, magnetic data, altitude data are to be provided.
- c) Each tape is to be fully labelled as to flight line, content, date and evaluation code for reference.
- d) An evaluation code is to be provided describing the internal formatting of data recorded.
- e) A tabulation listing instrument settings, scales and calibrations is to be provided with the record set.
- f) Details of all instrumentation specifications will also be provided.

6. Calibration specification:

- a) Magnetometer and altimeter tests and calibrations will be made at least twice per day.
- b) Heading errors will be corrected to ± 1 nT prior to acquiring data or acceptability of heading corrections proved.
- c) The twice daily test will be made along at least one half of traverse line along grid 392 km N. The portion to be utilised may be chosen by the contractor according to adjudged ground control suitability. Refer also 4 (c) above.

7. Contour plan specification:

- a) All plans to be produced at a scale of 1:20 000.
- b) Plans are to be prepared with contour intervals of 5 nT (accentuated 50 nT) and 50 nT (accentuated 250 nT) except in areas of steep gradient where an appropriate interval shall be used to present a reasonable density of contour.
- c) All plans are to be supplied as transparencies and prints.
- d) All plans are to be supplied with recovered flight path and control identification.
- e) All plans are to show the AMG grid.

8. Sampling of 30 widely spaced sites on Fingal Tier including susceptibility and remanence tests.

All data derived from the survey will be the absolute property of the Mines Department and will be delivered to Hobart at the completion of the programme. The data includes, but is not limited to, analog and digital records, tracking film, etc.

RECOMMENDATION

Future surveys should be flown as an approximate drape with a nominal terrain clearance of 150 m. The contractor should observe the actual clearance with a continuous recording radar altimeter and maintain the clearance within 50-250 m. The data should be processed to yield plots at a constant 150 m clearance using the type of continuation treatment undertaken in this survey.

Flying near the desired clearance would maintain a more even data quality without the gross smoothing evident in parts of this survey and yet remain within the normal range of the radar altimeter for high precision.

In dolerite areas a higher level fixed height survey or continuation would also prove of value since a wide spectral content is essential.

APPENDIX 2

Integration of gravity and aeromagnetic interpretations

The application of both gravity and magnetic techniques in the Fingal Tier region has shown, for comparable line/station spacings, that the gravity method is superior in all respects. Although the cost of the magnetic surveys amounted to only one third of the gravity surveys (including processing in each case) the survey coverage is far less and the quality and relevance of the results is not comparable. The implication is clear. Exploration funding in eastern Tasmania is best directed toward gravity techniques, even though these are slower and more expensive.

The main body of this report describes the limited interpretations possible using the aeromagnetic data (as observed or processed) in isolation. It was implied that no consistent pattern of source types or anomalies could be recognised or, in some cases, that the interpretation was not consistent (especially that based on figs. 10, 12, 15) with the gravity interpretation. These aspects are explored in this appendix.

Consider first the interpretation shown in Figure 17. The differences between interpretations of Figures 14 and 17 have been discussed in the text. The following discussion is based largely on consideration of features recognised in the drape survey. As was pointed out in the main text several of these features are themselves part of larger features which may correlate more clearly. Figure 18 suggests those features and it may be contrasted with Figure 17. The purpose of this discussion is to show the need for twin observations - near surface and high level. Comparison of Figures 17 and 19 indicates the following.

- (1) The position of marginal escarpments to, and windows in, the sheet are in agreement.
 - a) both surveys suggest an extension of coal measures north-eastward of known exposures at EP900805 to EP915825 and also infer the presence of a dolerite dyke or extension of the sheet downslope from the topographic suggestion of sheet base [EP905815].
 - b) The interpretation of the magnetic survey is dubious north of grid 5382000mN. In this same zone the gravity interpretation suggests a thin but variable thickness of dolerite [EP950820 - EP965840].
 - c) The large window at EP865840, now proven by drilling, is identified in the magnetic survey but somewhat extended to the north. In the region west of EP860850 toward the known southern extent of coal measures at EP845865 the magnetic field suggests little dolerite. The gravity field supports this conclusion only in the westernmost part of this zone [between EP840840, EP855870 and EP840870].
 - d) The small window at EP850810 is not clearly recognised in the magnetic field, possibly due to the interaction of several large anomalies. It has not yet been proven by drilling. The magnetic field does suggest little or no sheet immediately to the south [EP855800].
 - e) The variable thickness of dolerite near the main northern escarpment is supported by the range in the magnetic field values.

Features near EP890890 correlate. However there are significant discrepancies. For example, the magnetic surveys suggest that the sheet is broken into two parts at EP865895. Surface form and gravity field cannot deny this possibility. More significantly the variations at EP920895, EP940885 and EP955885 are not supported positively by the gravity field if the variations are taken to imply thickness changes.

- (2) The fragments of anomalies and gradients correlate with sheet variations in most instances. As noted in the main part of this report, the anomalies may be produced by structural edges - faults or discordant intrusion forms or localised thickening of the dolerite sheet. Some 'thickening' may be a result of surface topography rather than basal variations.
 - a) If it is assumed that each anomaly relates to a simple thickening of the sheet, then features at EP820820, EP850820, EP855835, EP870875, EP895875, EP970865, EP870810, EP885825 and EP870832 correspond with the gravity anomalies due to feeders or thick sheets.
 - b) Features at EP820850, EP870875, EP885890, EP880880, EP905865, EP950870, EP930845, EP975825 and EP885840 correspond to gravity anomalies suggestive of thinner sheets, while those at EP830870, EP840850, EP830830, EP840810, EP850820, EP860840, EP915885, EP927875, EP960865, EP970875, EP905860, EP905840, EP920822, EP925835, EP940815, EP925805, EP915815, EP905805, and EP965805 correspond to portions of intrusion margins where the gravity field suggests major structural changes.
 - c) Some features correlate with moderate gravity gradients, [e.g. EP865805, EP890817, EP875850].

The tabulation above shows the relative inconsistency of the magnetic interpretation based on a drapage coverage. Several features may be combined to define a single structure. One good example relates to the large feeder system in the south of the area [centred on EP925815]. However, while the gravity method is able to resolve the feature into a series of pipes and a sheet slab, the magnetic method can only ghost its southern half. Some of the anomalies noted can be correlated either with the pipes or the edge of the intrusion. The anomalies define an outline but it is significant that the major magnetic variations occur adjacent to pipes [EP910830, EP920822, EP915810, EP905800]. A combination of effects is possible.

It will be obvious from comparison of Figures 17 and 19 that many established or gravity interpreted sheet structures lack any magnetic expression. It is this factor which reduces the value of the method in this environment. The overall interpretation is, however, compatible with the gravity interpretation in that;

- (a) zones lacking dolerite correlate
- (b) the capping sheet is thin in a 3 km radius about EP940850, between EP895865 and EP875800, south of the Duncan mine to EP845845, and in the central west of the area [near EP820840]
- (c) there is a very thin sheet near EP960835
- (d) there is a band of patchily thickened dolerite extending from EP840820 to EP895875 and from EP895875 to EP970870
- (e) gross structures occur around EP920830 to EP915800 and about EP955875

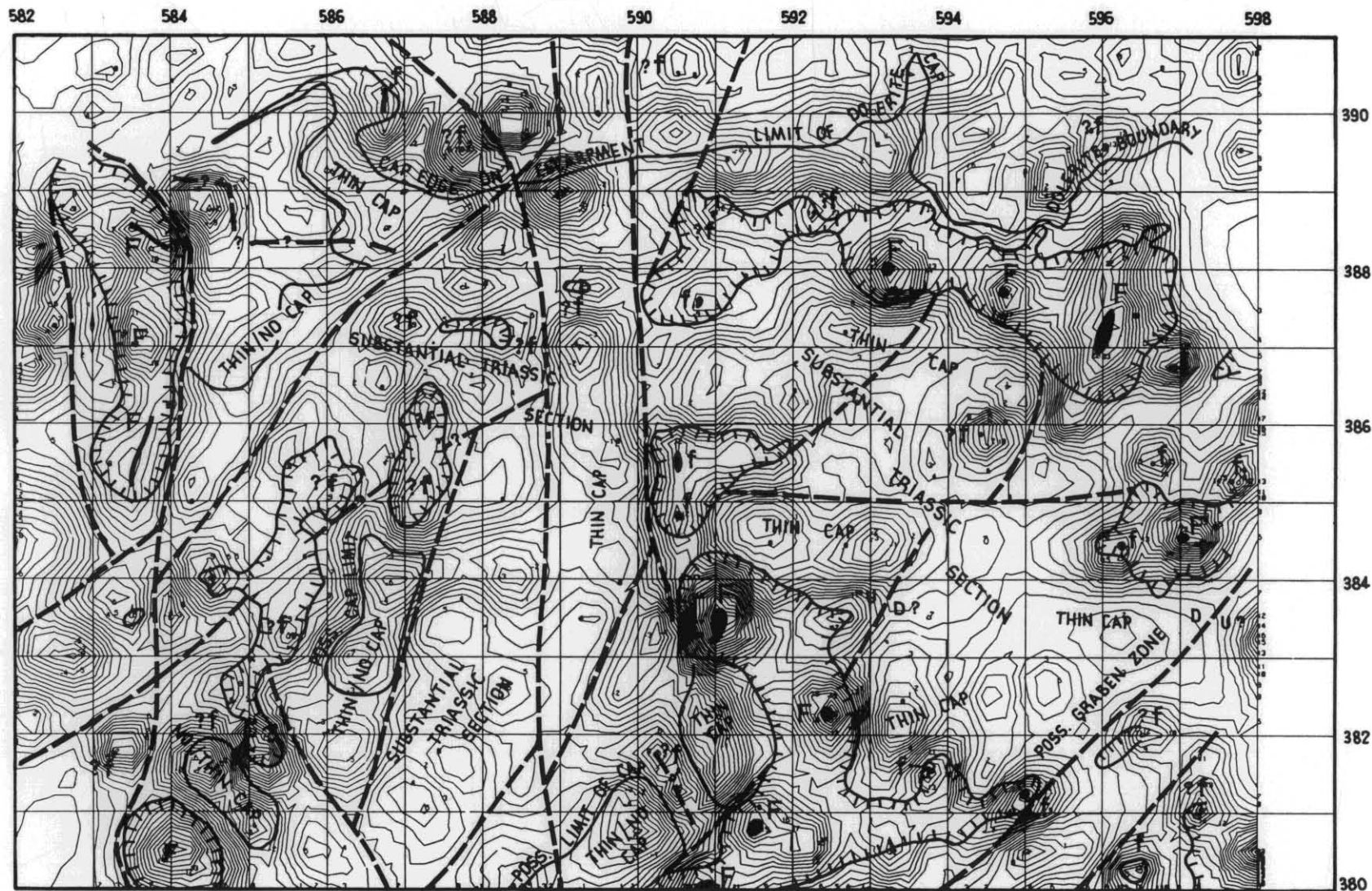





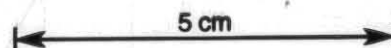
Figure 19. Gravity interpretation summary

 SHEET THICKENING
LIKELY TO RISK
TRUNCATION OR
DISRUPTION OF MAIN
COAL SEAMS.

REGIONS WITH SUBSTANTIAL
SEDIMENTARY SECTIONS WITH
OR WITHOUT THICK CAPPINGS
ARE UNHATCHED. RELATIVE
INDICATION SHOWN.

F MAJOR FEEDER PIPE/DYKE
f MINOR PIPE/DYKE
?f POSSIBLE SMALL PIPE/DYKE

 FAULT INFERRED
APPROX. POSITION
 FAULT INFERRED
NOT WELL INDICATED.

 5 cm

The high level interpretation provided in Figure 18 correlates more closely with Figure 19. Most of the interpreted edge points lie close to the critical thickness line for the sheet. These correlate directly with gradients in the Bouguer anomalies. Similarly, several of the trends are in close agreement. Figure 20 is a synthesis of Figures 18 and 19 with some additional detail added from Figure 17. The dependence on the gravity survey is apparent (compare figs. 19, 20). Overall the magnetic interpretations could not stand alone, they are too fragmental.

Examples of features not recognised by the magnetic surveys include the major feeder in Fingal Rivulet [EP830890 to EP835870], and bodies at EP915855 and EP970845.

Other interesting correlations relate to certain trends or implied faults. Only four may be recognised in each interpretation: NE-SW at EP970815; N-S through EP840860 and EP890850, and NNE-SSW from EP905890 to EP860800. Stratigraphic evidence suggests faulting in the centre of the area; the gravity survey suggests a N-S trending feature near grid 5390000mN, whereas the magnetic surveys (including surface surveys) suggest that the structure is nearer grid 5391000mN. This suggests that density and magnetic contrasts are separated, implying a compound structure.

The various aspects of the gravity and magnetic interpretations have been integrated into a single diagram. Consistent features are shown by firm lines or statements, while aspects considered reliable but only indicated by one method are shown by broken lines. Note that the integration of interpretations depended on the availability of two versions of the magnetic field; one low level, one high level.

Several aeromagnetic lows have been found to correspond with the larger dolerite pipes as located by the gravity survey. This is consistent with the surface magnetic data which found that

- (1) traverses across feeders revealed surprising low susceptibility values, and
- (2) such traverses also recorded relatively low amplitude variations.

APPENDIX 3

Specifications of equipment and survey details, aeromagnetic survey

The equipment utilised in the aeromagnetic survey was:

Cessna A185E aircraft

Sonotek integrated airborne survey system IGSS1, comprised of:

- Integrated 0.1nT sensitivity Proton Magnetometer.
- Integrated 256 channel Spectrometer/Analyser.
- 24 litre NaI (Tl) gamma ray detector package.
- Bonzer Mark 10 radar altimeter.
- 16 mm ground tracking frame camera.
- Digital recording on 9 track 800 bpi.
- Industry standard magnetic tape.
- 8 channel analogue recorder for all parameters.
- 3 channel 10" analogue recorder for magnetometer and radar altitude.

The nominal flight line separation was 250 m and the nominal tie-line bearing was 0°. The observed mean sample interval in the flight direction was 0 metres, achieved with a nominal aircraft speed of 100 knots and a reading interval of 0.8 seconds. The mean sensor height was 900 m using a towed bird configuration. The magnetometer accuracy is 1.0 nT and the resolution 0.1 nT.

The data presented is the residual magnetic intensity after subtracting the International Geomagnetic Reference Field from the observed Total Magnetic Intensity. The data was corrected for diurnal drift using a base station monitor at St Helens Airfield (latitude 41.342 S; longitude 148.292 E; altitude 36 m). The sensor height was three metres. The adopted value for this location was 61966 nT.

Final detailed levelling of the data was performed using tie-line cross-over analysis. A simple 3 point filter was applied to the data which was then gridded and contoured using a 100 m by 100 m mesh cell.