UR1980-49

1980/49. Geophysical exploration of the East Coast Coalfields, Tasmania: A summary

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Abstract

Geophysical exploration of the East Coast Coalfields in Tasmania has been undertaken to enhance the rate of evaluation of the Triassic coal measures and provide the basis for a cost-efficient drilling programme. Geological methods are of little use due to concealment of exploitable rocks by thick sheets of dolerite and dolerite-derived talus deposits. The gravity method has been established as the most relevant overall and with some confirmatory magnetic data has provided a guide to faults, intrusion forms and basin structures. The magnetic method is particularly useful for location of local concealed boundaries. Although problems with reflection methods have not been completely resolved, they show great promise for examination of the continuity of both seams and capping dolerite sheets.

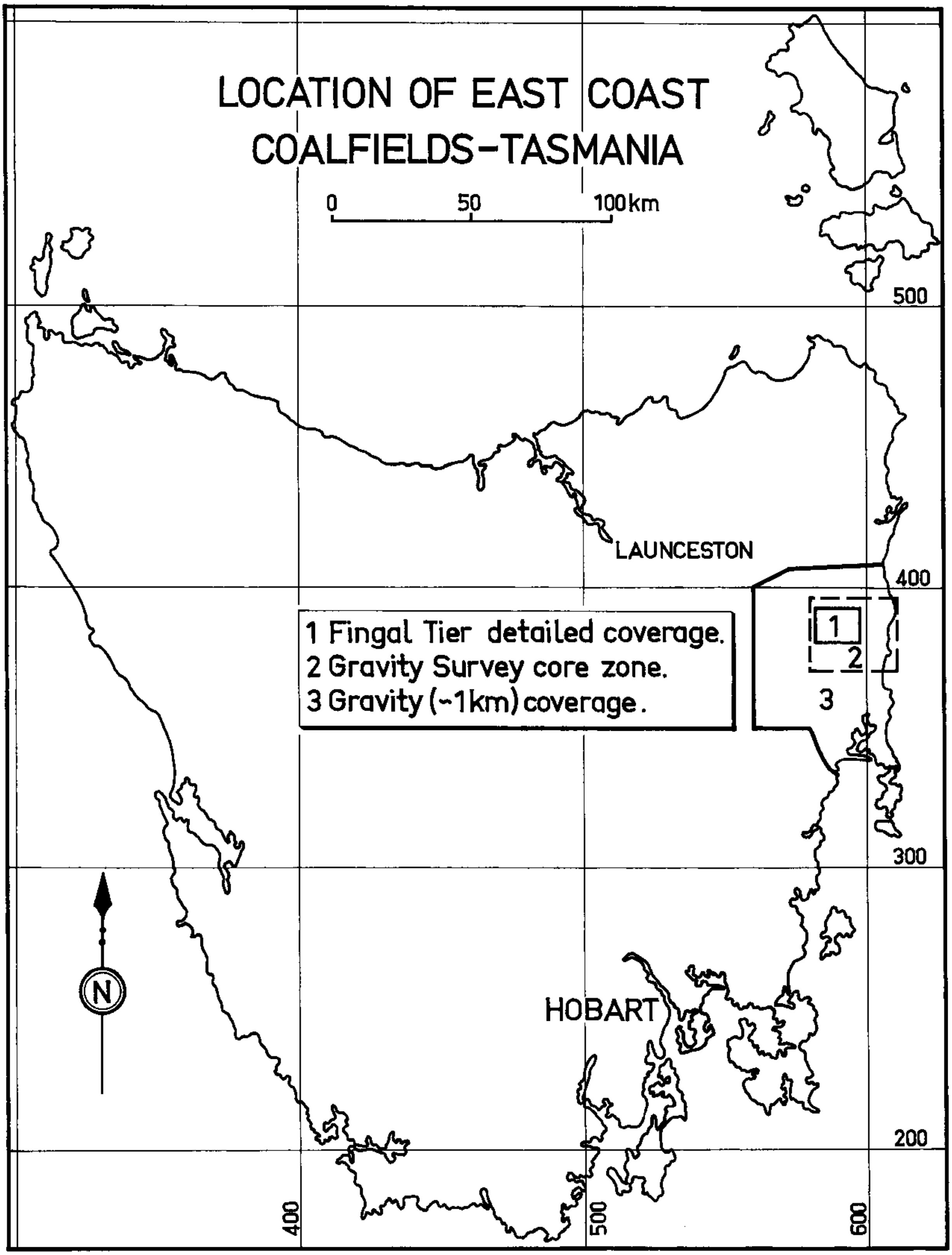
INTRODUCTION

The East Coast Coalfields comprise a large portion of eastern Tasmania and include the principal past and present coal producing areas in Tasmania. Many lesser fields, as designated in the monumental compilation of Hills *et al.* (1922), are also included. The area examined is indicated in Figure 1. In the following fifty years little new field work was undertaken on Tasmanian coal and during that period most mines closed - the result of conversions to oil, restricting geology, small operating scale, and limited planning.

The overall result of the early mining experiences and depression in the industry was an absence of research and exploration, plus a widely held assumption that local coals were poor, limited in reserve, and would never be of economic value. This view was enhanced in 1967 when the Hydro-electric Commission drilled a suite of holes in the valley near Fingal which failed to offer any encouragement. There is no doubt that the common variations in quality, working approach (roof variations *etc.*) and small disruptions do pose major problems for small operators. The ubiquity of dolerite intrusions has enforced the pessimistic assessment. Yet no objective comprehensive data exists concerning extent of fields, reserve, structures, quality variants or whether the problems noted in the past pose real problems for a properly planned and developed operation.

In the political climate of 1980 there is a market for this steaming quality coal - average 20 - 25% ash, 23 MJ/kg - if mines of economic scale can be established. But where are the best mining/reserve prospects? It was to fill this gap in knowledge and establish whether Tasmanian coals were of any significance that the Department of Mines began a drilling programme in the Fingal-Mt Nicholas region nearly twenty years ago. This region was selected because of past production and a State Reserve was placed on part of it.

Drilling proceeded slowly until changing priorities escalated funding in 1978, by which time only 35 holes had been completed. Early drilling was expensive, time-consuming and wasteful. Some sites were abandoned, especially in thick talus deposits. After drilling began on the dolerite-covered areas about 1970, site selection became a gamble and fears of drilling feeders or thick sheets arose. Thus a gravity survey was proposed and begun in 1972. Today, gravity surveys form the keystone



LOCATION OF EAST COAST COALFIELDS-TASMANIA
0
50
100km
500
LAUNCESTON
400
1 Fingal Tier detailed coverage.
2 Gravity Survey core zone.
3 Gravity (~1km) coverage.
1
2
3
300
N
HOBART
200
400
500
600

Figure 1.

5 cm

to the exploration approach and provide a predictive target guide for the drilling programme and mine planning.

Other procedures have been superimposed and evaluated. These include resistivity, magnetics, and seismic reflection. This report outlines the geophysical arm of an exploration programme in which the drill is now used more economically as a proving tool.

GEOLOGY

Geological factors account for the ignorance and confusion concerning Tasmanian coal. Consider the stratigraphy within the area designated as the East Coast Coalfields which is typical of most of eastern Tasmania.

The effective basement for the area is a dissected peneplain of folded Ordovician-Devonian rocks (the Mathinna Beds) composed of sandstone, slate, shale, and quartzite intruded by Devonian granite batholiths and granodiorite sheets. Permo-Triassic rocks (the Parmeener Super-Group) overlie the eroded basement. Permian rocks, including limestone, are generally marine and vary greatly in thickness and constitution. Triassic rocks, including coal seams, are lacustrine deposits and are less variable, being composed of lithic sandstone and shale. South and west of this region the Triassic section includes thick basal members of quartz sandstone and shale which are relatively barren of coal. The coal is allochthonous. The Permian section ranges in thickness from 0 - 250 m and the Triassic section usually exceeds 350 m. The Parmeener rocks have been intruded on a massive scale by Jurassic dolerite intrusions. Jurassic and Tertiary tensional faulting produced abrupt basins which are now filled by clay and sand, especially in the south of the area. Late Tertiary erosion and weathering followed by Pleistocene periglacial activity have left a dolerite-dominated terrain of high relief and many thick talus deposits on the hill slopes. Few sedimentary exposures exist away from the coastal hills or incised river beds.

The nature and origin of the coal measures sequence has produced the normal coal mining problems and variations, including washouts, roof and floor changes, splits and small faults. However, other structural implications of the geological history make the province unique.

High basement relief, often in excess of 400 m, may produce a range of on-lap situations and source-composition variations in rock units. However, it is the dolerite which creates the principal structural difficulties. The intrusions were accompanied by general tensional faulting on various scales and some very low angle thrusting adjacent to major bodies. The combination of irregular intrusion forms and faulting has made geological interpretation difficult. An indication of the structural possibilities has been given by Leaman (1975). In many cases transgressive intrusion has dilated the section and subsequent erosion has removed much material. This possibility makes all geologic predictions a gamble, especially as the thickness of most sheets exceeds 300 m and dolerite is almost universally exposed. Deep dissections do not often expose other materials.

More recent faulting has generally exhumed Jurassic or older structures and it is often impossible to distinguish fault ages. In summary, the geological history of the region has provided considerable variation and disruption, as is common to most coalfields, but the impact of the dolerite is twofold - additional disruption and almost total concealment. The latter factor, whether by *in situ* rock or talus, accounts for the prevailing ignorance on Tasmanian coal measures.

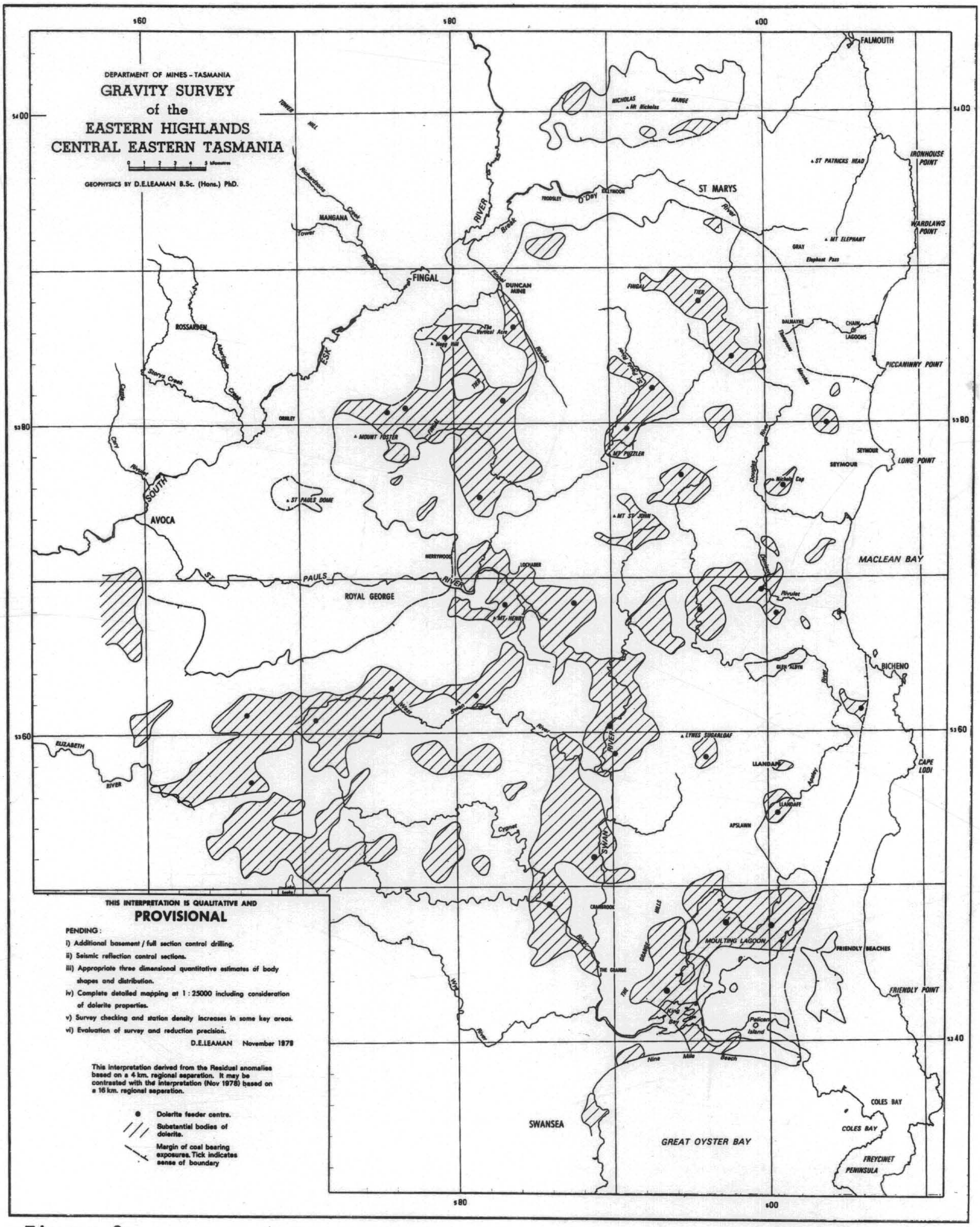

DEPARTMENT OF MINES - TASMANIA
GRAVITY SURVEY
of the
EASTERN HIGHLANDS
CENTRAL EASTERN TASMANIA
GEOPHYSICS BY D.E.LEAMAN B.Sc. (Hons.) PhD.
THIS INTERPRETATION IS QUALITATIVE AND
PROVISIONAL
PENDING:
i) Additional basement / full section control drilling.
ii) Seismic reflection control sections.
iii) Appropriate three dimensional quantitative estimates of body shapes and distribution.
iv) Complete detailed mapping at 1 : 25000 including consideration of dolerite properties.
v) Survey checking and station density increases in some key areas.
vi) Evaluation of survey and reduction precision.
D.E.LEAMAN November 1979
This interpretation derived from the Residual anomalies based on a 4 km. regional separation. It may be contrasted with the interpretation (Nov 1978) based on a 16 km. regional separation.
Dolerite feeder centre.
Substantial bodies of dolerite.
Margin of coal bearing exposures. Tick indicates sense of boundary
FALMOUTH
ST MARYS
FINGAL
DUNCAN MINE
ROSSARDEN
AVOCA
ROYAL GEORGE
MACLEAN BAY
BICHENO
CAPE LODI
FRIENDLY POINT
FRIENDLY BEACHES
MOULTING LAGOON
SWANSEA
GREAT OYSTER BAY
COLES BAY
FREYCINET PENINSULA
IRONHOUSE POINT
WARDLAWS POINT
PICCANINNY POINT
LONG POINT
SEYMOUR
MANGANA
MOUNT FOSTER
ST PAULS DOME
MT PUZZLER
MT ST JOHN
LLANDAFF
APSLAWN
CRANBROOK
GLEN ALBYN
NICHOLAS RANGE
ST PATRICKS HEAD
MT ELEPHANT
Nine Mile Beach
Pelican Island

Figure 2.

5 cm

GEOPHYSICS

Geological methods provide only a skeletal exploration guide in this complex geological environment even though the high relief terrain would be expected to aid exposure. Drilling superimposed on such a guide is a risky and generally unrepresentative gamble. Indeed, early drilling around Fingal revealed massive talus deposits and variable dolerite intrusions and shortened sections. Many holes were wasted or abandoned. Clearly, other means were needed to provide an indication, at least, of regions where the dolerite was very thick, feeders were present, windows were possible or the section was thick so enhancing the chance of encountering a useful seam set.

Six geophysical methods have been utilised in this environment; gravity, air and surface magnetics, resistivity, seismic reflection, radiometrics, and down hole logging.

Gravity surveys

Two gravity surveys have been undertaken, one regional and one specific to the State Reserve on Fingal Tier. The regional survey covers the entire region defined as the East Coast Coalfields with a nominal station spacing of one kilometre (2800 km^2, 2600 stations), while the Fingal Tier coverage has a nominal 300 m spacing (180 km^2, 1600 stations). Complete details of the gravity surveys have been given by Leaman and Richardson (1980*a*).

Treatment of the Bouguer anomalies requires special processing and interpretation techniques since all the target structures are normally above the geoid and there is no appropriate horizontal reference plane for modelling. Consequently, equivalent source methods (after Dampney, 1969) have been used to derive continuations. In addition the Bouguer anomalies have been analysed by a range of filters. After establishing appropriate criteria for assessment of the targets (within 750 m of the land surface) continuation and residuation enabled three dimensional modelling.

A qualitative interpretaton has been provided for the entire regional survey which suggests that the Upper Parmeener Super-Group, including coal measures, is extensive and generally over 250 m thick across the entire field. Feeders and thick sheets possibly destroy about 15% of the possible volume. Some major faulting can be deduced. The general thickness of the dolerite sheets is extremely variable. Qualitative estimates may be based on the sign and value of the residual Bouguer anomaly. Large negative values (-40 to -60 $\mu m/s^2$) imply thick sedimentary sections whether or not dolerite is present. Since the Permian, Triassic or dolerite contrasts yield residual attractions of -8.4, -13.4, and +6.7 $\mu m/s^2$ per 100 m, it will be apparent that positive values imply either much dolerite in a section or no significant section. The qualitative interpretation is vague for values in the range -20 to +10 $\mu m/s^2$ due to possible section combinations, but values outside this range can be unambiguously related to either thick sections or thick dolerite. Only the proportions are uncertain. Rapid estimates of this type must be verified quantitatively. Figure 2 summarises the qualitative interpretation.

The regional core area (fig. 1) has been evaluated by three dimensional models. This zone was selected for analysis because it is the best controlled and currently subject to detailed exploration. The analysis confirmed the suggestion of a general persistence of the coal measures at 250 - 350 m thick but found that faulting is common, including at least two

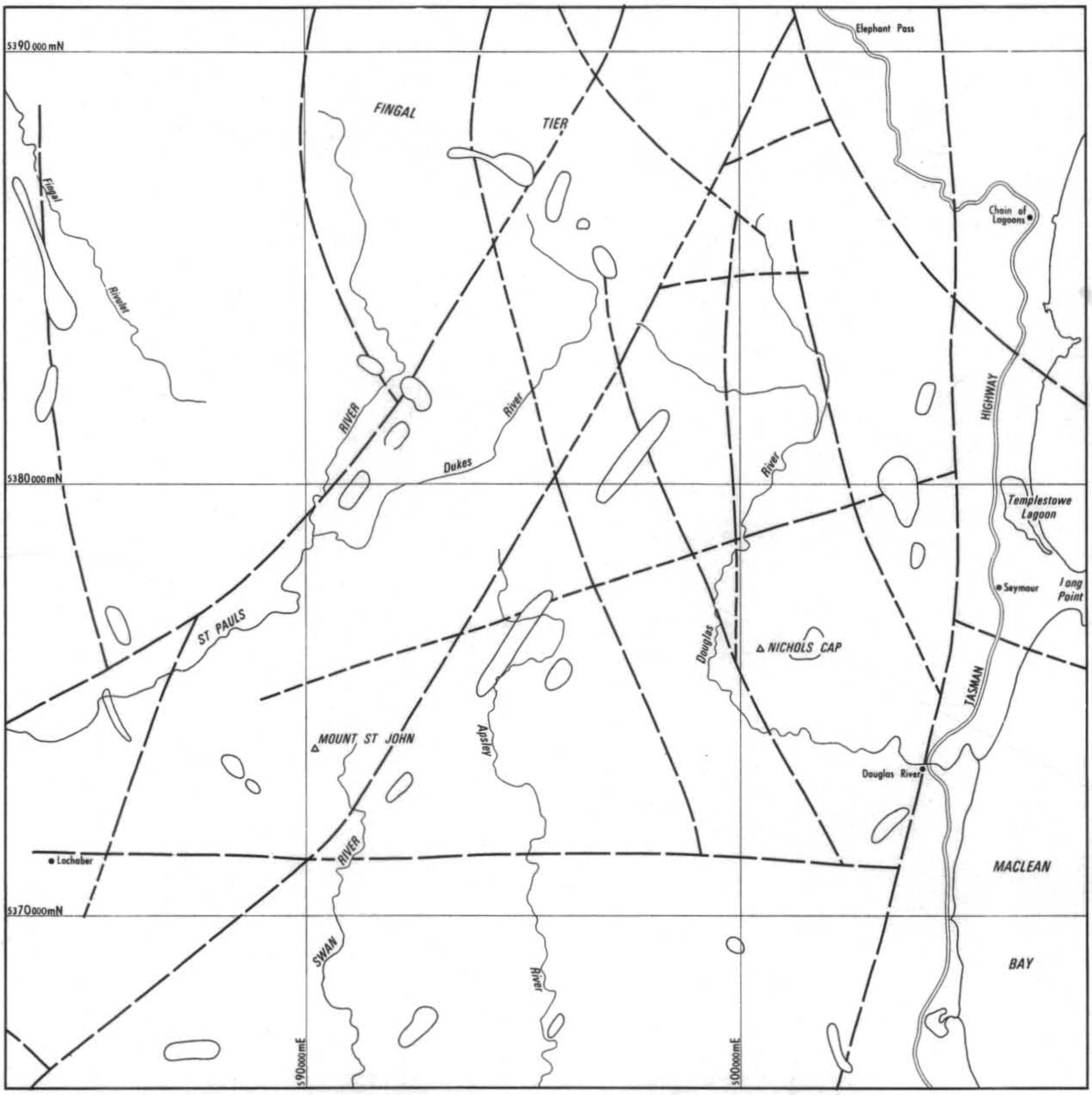


Figure 3. *Summary of dolerite feeders and implied faulting*

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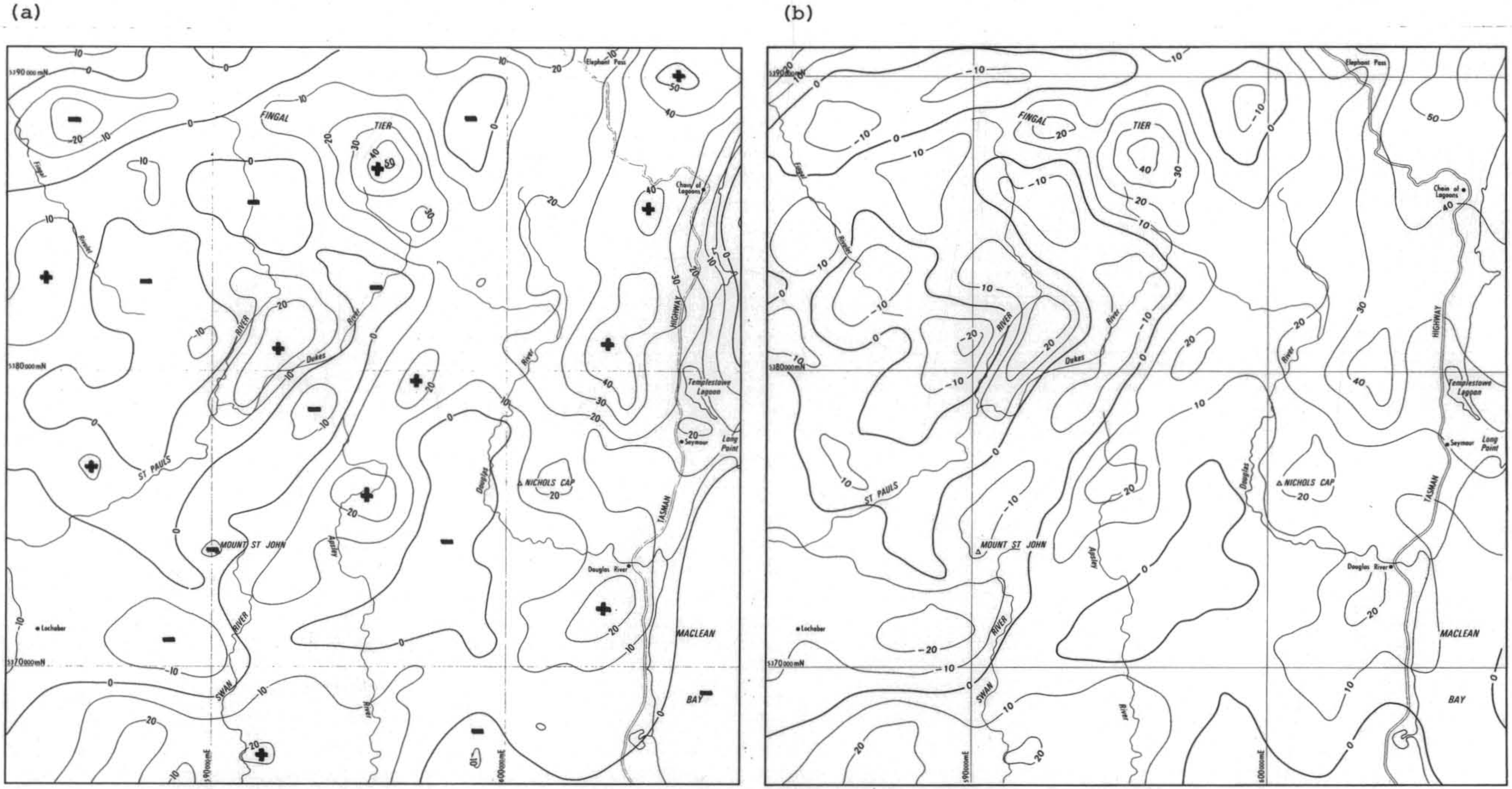

Figure 4. *Comparison of reduced observed field (a) and field calculated for model (b)*

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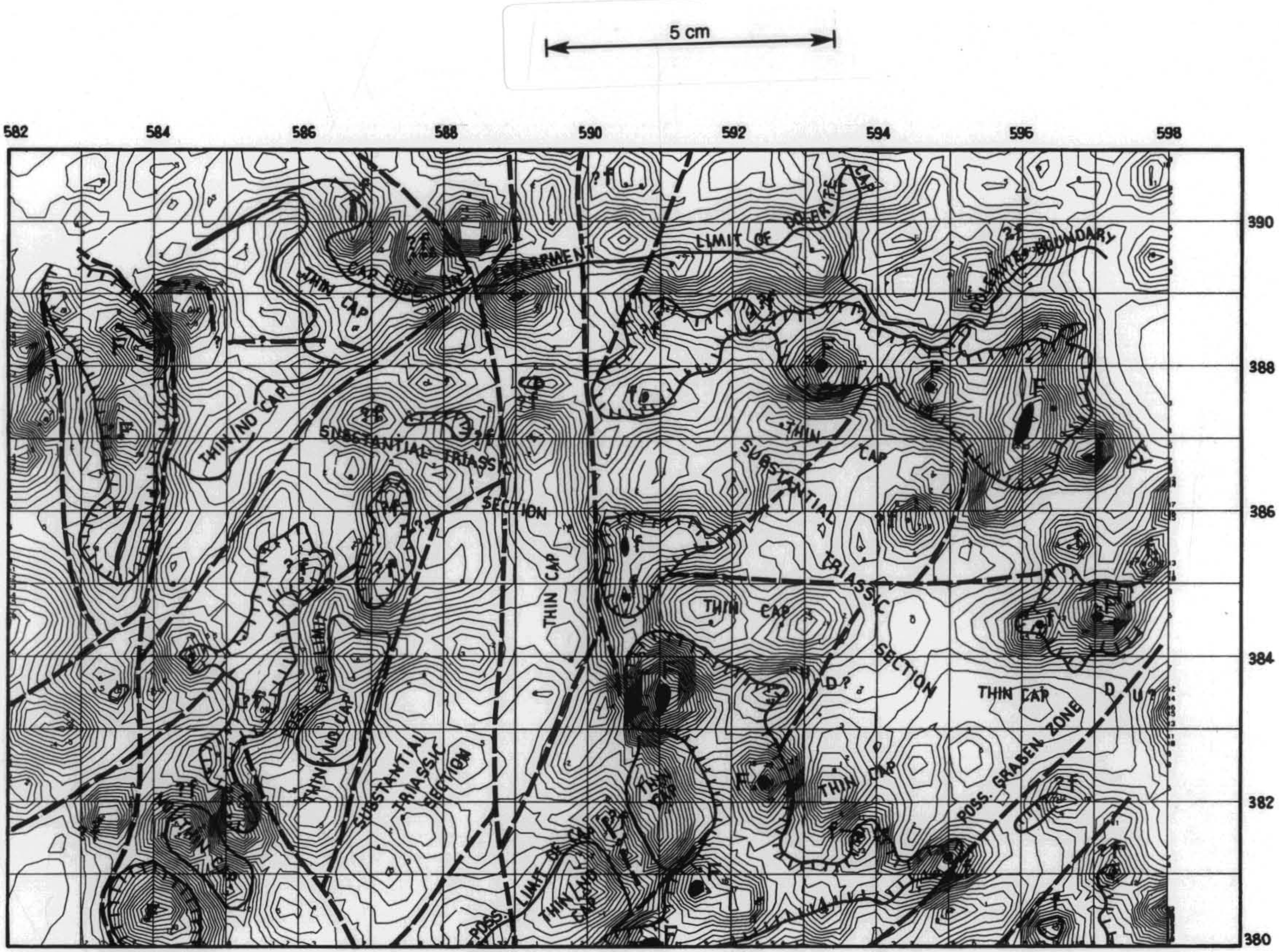

Figure 5. *Interpretation summary, Fingal Tier.*

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.

sizeable grabens. Fault trends are NE-SW, N-S, E-W. In addition, feeders were found to be much smaller and more numerous than suggested in Figure 2, and commonly occur as clusters. Figure 3 indicates the general fault patterns and feeder distribution revealed by modelling and analysis. Figure 4 compares the field derived by continuation and residuation with that of the model. The basis of the model was available mapping and drilling control extrapolated by the requirements of the gravity field. Differences apparent in Figure 4 may be accounted for entirely by the thickness of slices used to make up the models (50-100 m); thinner units could not be justified on either cost or control grounds. It is possible that only about 10% of the entire region is lacking a thick section. Pre-Permian basement materials were also found to be variable and the extent of granite batholiths and stocks has been defined. Intrusion of a thick granodiorite sheet into the basement rocks near Gray has accounted for the anomalous qualitative estimates of sheet thickness in this part of the region.

The survey has also established the form of the St Marys intrusion - a sheet wedge thickening to about 1200 m at its western margin. The filter analysis of the total field defined the extent of the regional batholiths within the upper 5 km of the crust and also located a smaller stock west of Bicheno. The roof of the latter is at very shallow depth ($\sim$120 m) and has been confirmed by drilling.

The Fingal Tier detailed area has been treated by a similar filter, continuation and residual analysis. This has enabled improved definition of feeder position and size, limits of thickened sheets, sheet window location or thinnings and possible fault positions. The interpretation is summarised in Figure 5. An interpretation of this type can be used as a structural guide and a basis for drill site selection. The principal value relates to identification of marginal, promising or definitely excluded zones. The regional interpretation suggests the possibility of other promising areas at least comparable to the Fingal region.

Figure 5 also suggests the trend of any future mine planning should drilling confirm consistent and workable seams. The general distribution of intrusion (feeders and sheet truncations), escarpments and faulting suggests that three mines would be necessary for recovery (presuming the exclusion of shaft entry) in this zone.

Magnetic surveys

A dual level (900, 1050 m) aeromagnetic survey of the Fingal Tier detailed area (fig. 1) and some 54 km of selected but dispersed surface traversing have been undertaken. Surface surveys were mainly intended to evaluate the method as a means of locating geological boundaries in the area and so improve quality of mapping. The surface evaluation has established the method for this purpose and it is possible to resolve four conditions - coal measures, talus/coal measures, talus/dolerite, dolerite - by simple examination of frequency and amplitude fluctuations. A fluxgate magnetometer with 10nT sensitivity is adequate (strong gradients in some areas preclude the use of proton magnetometers) but the observation interval should not exceed 5 to 10 m. Figure 6 summarises the nature of observed responses.

The aerial survey was flown at two fixed heights to allow spectral and continuation analysis of the anomalies. A drape over the local terrain was not considered desirable or fully controllable and could be derived from the fixed flights in any case. The original objective of the survey was the provision of an independent structural control on dolerite forms, so reducing

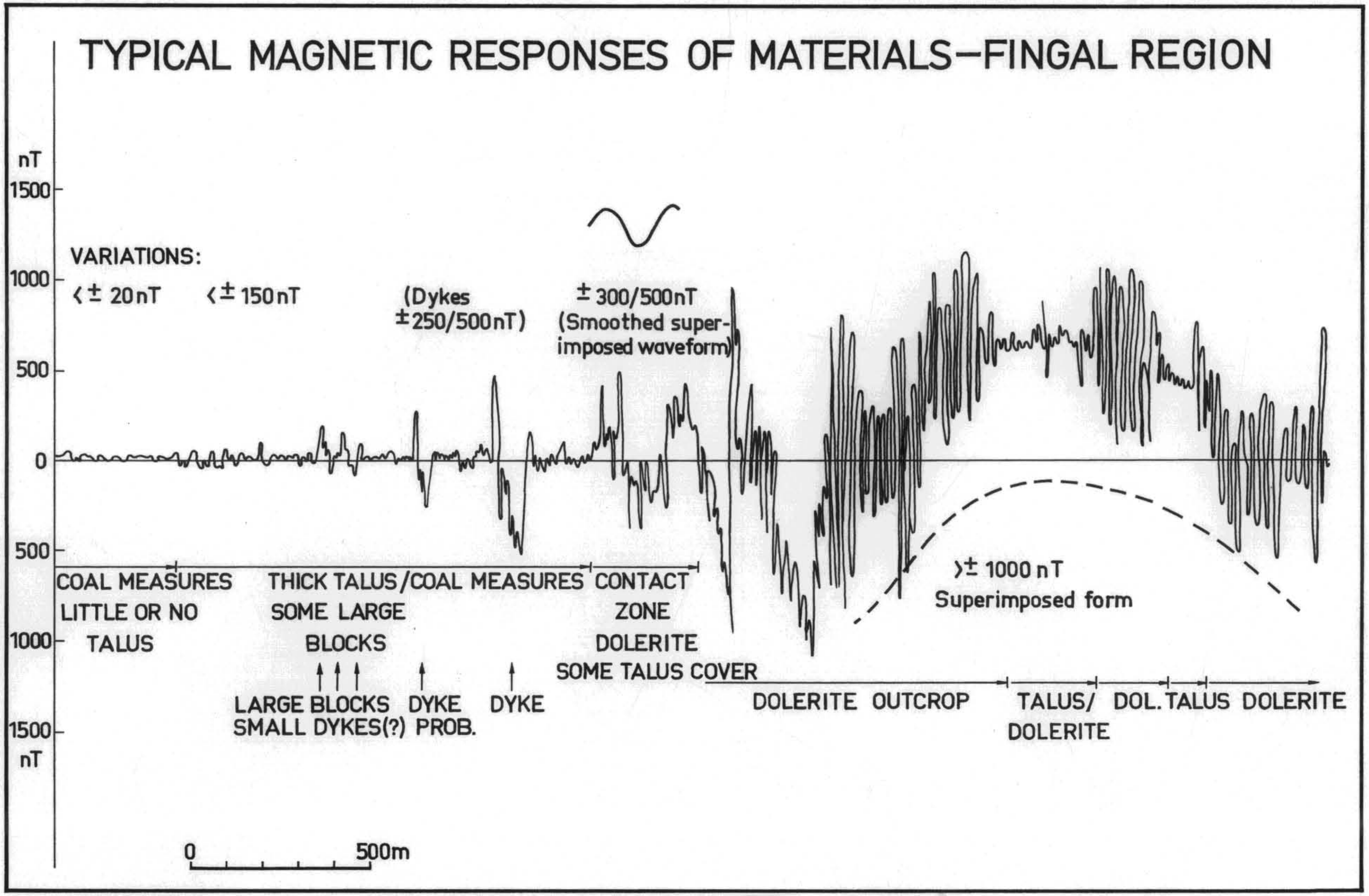

Figure 6.

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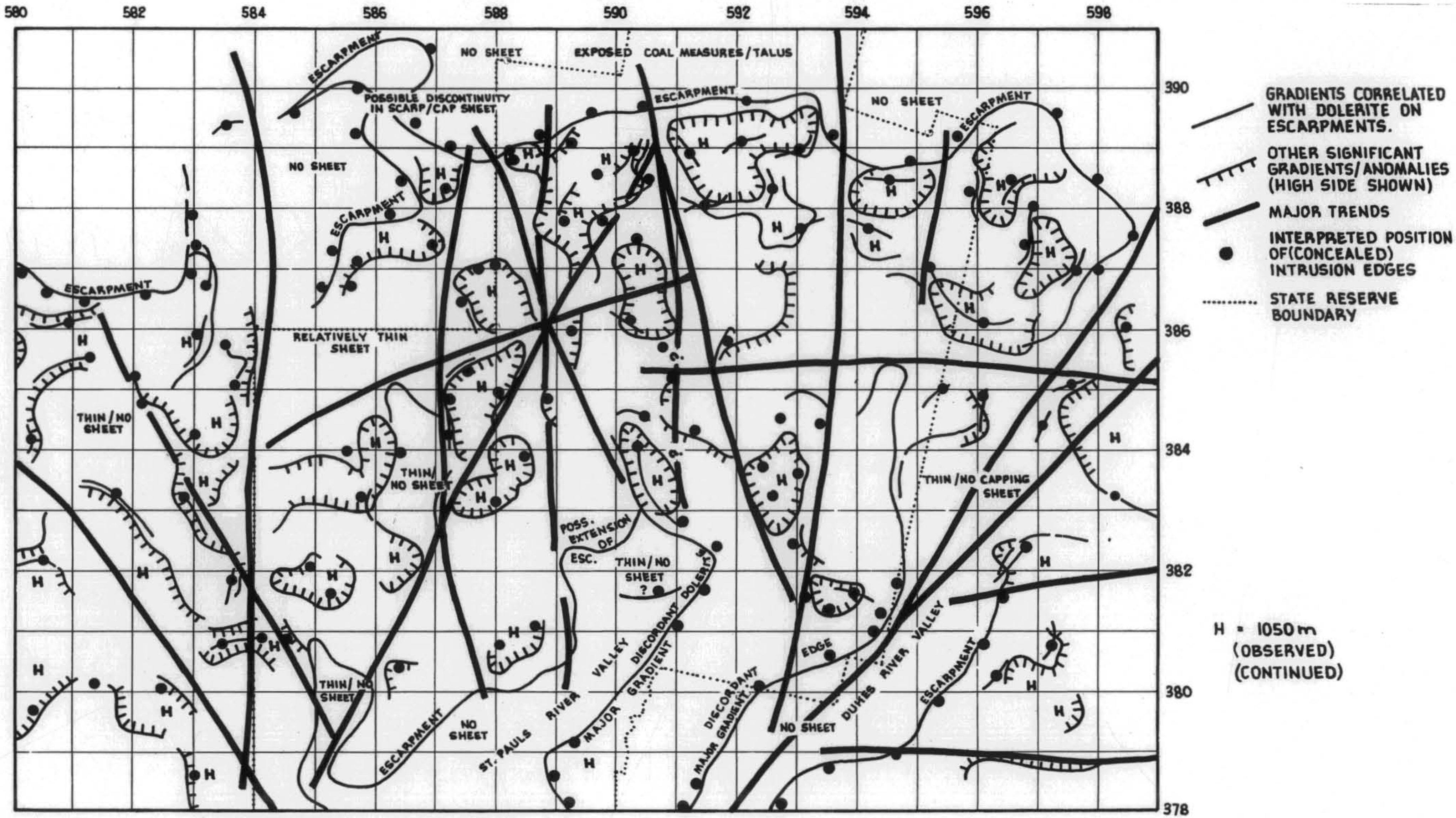

Figure 7. *Interpretation of magnetic survey, Fingal Tier.*

5 cm

any inherent ambiguity in gravity interpretation. The success of the gravity survey overall, the limited interpretation accretion and confirmation provided by the magnetic survey, and the fact that many features could not have been resolved without the gravity data, suggests that the aeromagnetic approach is not particularly effective, if more rapid and less expensive. Complete details of the magnetic surveys are given by Leaman and Richardson (1980*b*).

Figure 7 summarises most of the structural information deduced from the magnetic surveys. It is based on observations at 1050 m which were found more relevant and less confusing than lower level data. Gradients and anomalies at this level can be definitely related to features displayed in the Bouguer anomalies. Even so the interpretation is patchy, and while intrusion margins are indicated, their sense and scale is not. Indeed many anomalies are enhanced due to the combination of several features in the same general locality. In general edges produce anomalies, feeder centres or talus/sedimentary tracts yield a nondescript field pattern. The lack of response over feeders was confirmed by susceptibility studies and surface profiles. The survey at 900 m provided more information on areas covered by talus or where the dolerite sheet has been eroded. However, due to the considerable terrain clearance variations (50-400 m) these observations are often misleading. The reduction of the 900 m survey to a 100 m drape by continuation enables rapid and clear identification of dolerite - non-dolerite areas, since the dolerite has a characteristic high amplitude cell pattern. However attempts to interpret the drape results in terms of principal structures proved unsatisfactory due to the compound sources of many anomalies. At 100 m it is not possible to resolve these from local surface variations.

Resistivity surveys

Resistivity surveys have been used in other coal-bearing provinces for the location and tracing of seams. Such areas are generally free of severe topographical problems and lack the equivalent of dolerite cover. Electrical methods cannot be used on Fingal Tier for structural purposes since the average array would exceed 2-3 km and terrain-induced problems would be excessive and uncontrolled. Consequently sounding and traverse trials were made on the narrow coastal plain at Seymour where several seams occur within 40 m of the surface; gentle dips are known and faulting is suspected. Even in this environment the method failed to yield reproducible or consistent results; most problems were related to variable or low contrasts and erratic surface conditions.

Seismic reflection surveys

Reflection techniques, given the failure or inapplicability of the electrical approach, offered the only chance of improved structural resolution (over potential methods) and direct assessment of the stratigraphy and seam continuity. But varied geological environments have made evaluation difficult. The coastal environment at Seymour is akin to the established usage of the method except that the target seams are at very shallow depth requiring small charges and high sample rates. Results at Seymour, recorded using short spreads with 6-geophone arrays (28Hz), 10 m apart and shallow shot holes (1.2 m) were processed to reveal very shallow seams and some faulting (fig. 8). The electrical approach in the same area compares particularly poorly. However, good seismic results depend on shot placement and shot size (very small) in relatively unweathered coal measures. Improved results may be obtained with single geophones and deeper shot holes. Details of the Seymour survey have been given by Richardson and Leaman (1980).

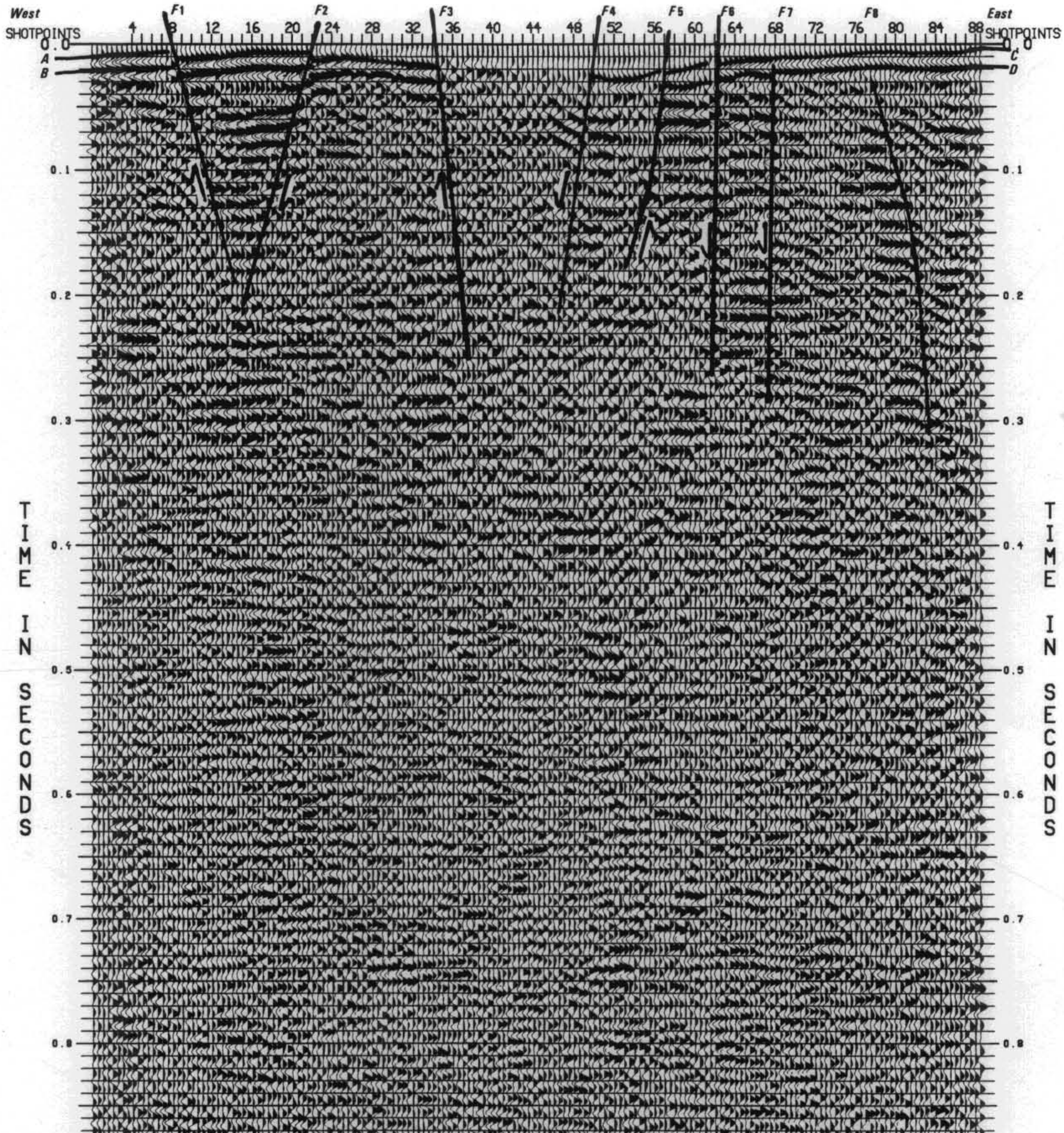

Figure 8. *Interpreted section, Seymour reflection traverse.*

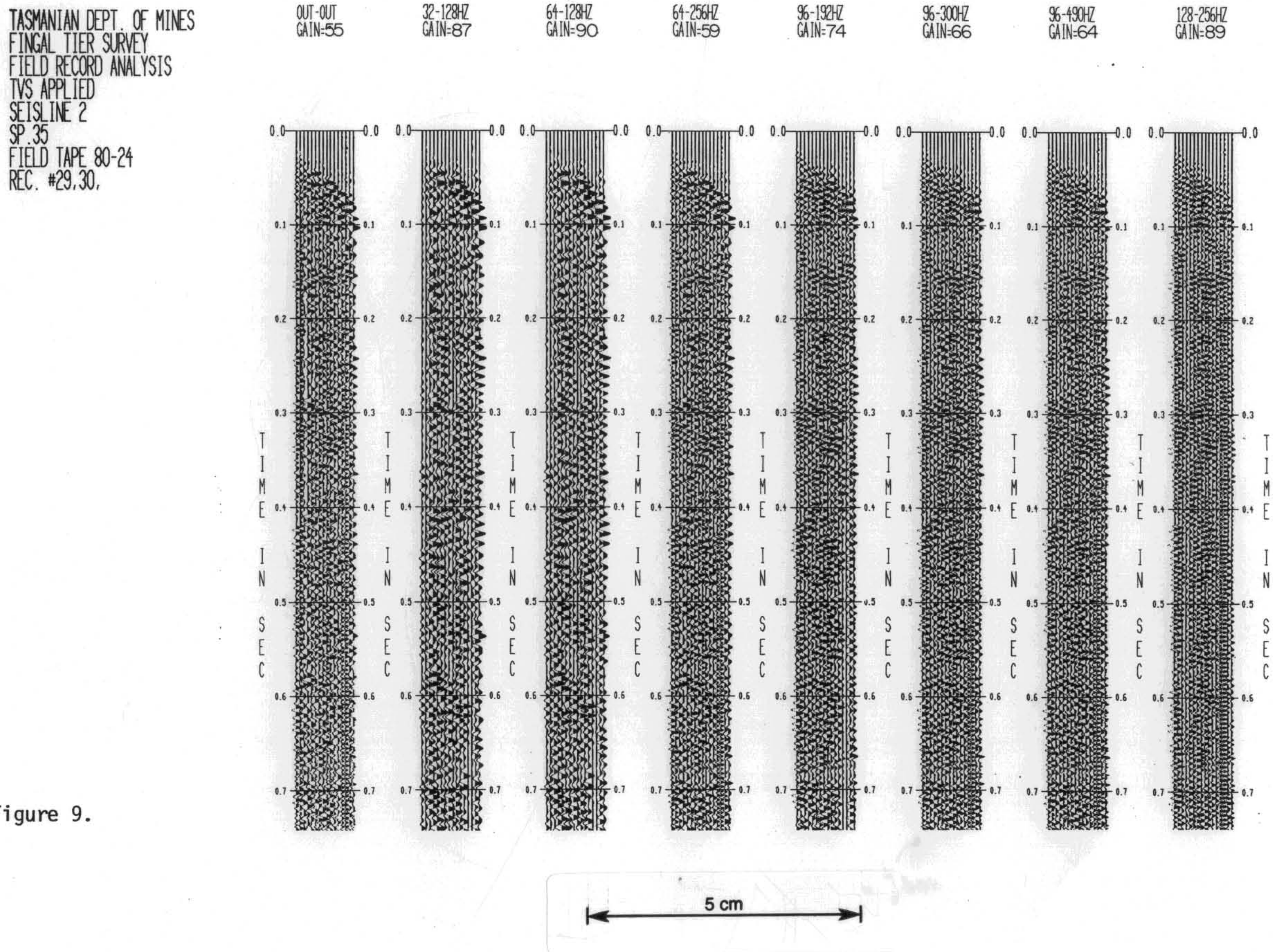
TASMANIAN DEPT. OF MINES
FINGAL TIER SURVEY
FIELD RECORD ANALYSIS
TVS APPLIED
SEISLINE 2
SP.35
FIELD TAPE 80-24
REC. #29,30,
OUT-OUT GAIN=55
32-128HZ GAIN=87
64-128HZ GAIN=90
64-256HZ GAIN=59
96-192HZ GAIN=74
96-300HZ GAIN=66
96-490HZ GAIN=64
128-256HZ GAIN=89
TIME IN SEC
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
5 cm

Figure 9.

The Fingal Tier type environment is quite unusual with velocities in excess of 5000 m/s within 5 m of the surface and persisting for more than 100-300 m. Three test traverses, including experiments with shot condition-depth and tamping, array geometry, single geophones and processing parameters, have been fired. Best results have been achieved where shots are fired consistently within rock (6 m deep) using single geophones. Lateral terrain effects and, apparently, jointing within the dolerite degrade the signals. The thickness of dolerite also affects the quality of the processed results. A substantial statics correction is also involved.

Feasibility traverse processing has been able to provide a general profile of the base of both dolerite and coal measures. Some disruptions are evident but only fragments of two seam zones can be identified. More research is needed to improve the method resolution under traverse synthesis due to variability in properties of both the dolerite and the terrain.

In contrast, examination of filter-processed records for individual shots enables consistent picking of dolerite base, two coal measures reflectors, and base of coal measures (*e.g.* fig. 9). The coal measures reflectors appear to represent the Duncan and East Fingal seams. Sampling of more distant geophones and their incorporation into traverse analysis (single fold) may yield improved traverse results since the required data are consistently recorded. Alternatively, shooting of a series of expander-soundings may prove more effective and economical since most of the survey expenses relate to shot hole drilling.

The method is clearly viable in both environments but is expensive and does require, at the present time, more fine honing at processing stage for the dolerite environment.

Airborne radiometrics

A radiometric survey using a NaI gamma detector was made concomitantly with the two-level aeromagnetic survey of the Fingal Tier detailed area (fig. 1). Initial results were distance dependent but correction has revealed no significant anomalies. Only occasionally do cap variations reflect in the results.

Downhole logging

Logging methods have been underemployed. In the initial stages of the programme (pre 1970) SP, resistivity and natural gamma logs were run to 300 m. The holes logged were not drilled on the dolerite cap. When drilling was commenced in dolerite the thickness of dolerite often exceeded the range of the logger. The tools available were not particularly appropriate to the project and logging ceased. This major deficiency in the programme has finally been overcome and logging may now proceed to 600 m in all holes using a full suite of sondes. It is not yet possible to advise any conclusions or correlations.

SUMMARY OF DOLERITE PROPERTIES

As indicated above, the properties of the Jurassic dolerite control the keys to resolution of the many structural problems associated with Tasmanian coal deposits and a current summary of relevant data is given below.

Heat capacity of the magma was very low. In consequence thermal metamorphic effects are generally minimal and restricted to zones rarely more than 5 m wide, or near pipes. Coal is rarely affected and thermal changes are of no exploration significance.

Magnetic properties may be extremely variable. Remanence and susceptibility measurements of dolerite in the East Coast Coalfields are at variance with published data - usually from other areas. Many sampling problems have been experienced since large apparent outcrops may be part of rotated talus blocks. A consistent pole indication has been given ($\sim$0°, 55°) which contrasts with other data ($\sim$355°, 85°). Susceptibilities are very low, averaging 5-15 x 10^{-3} SI units. The remanent intensity, however, is comparable (0.08-0.60 Am^{-1}). Vertical component variations in the field may range from ± 500nT to ± 10 000nT.

Seismic velocities exceed 5000-6000 m/s in fresh rock but the velocity is joint and weathering dependent. These properties, and in particular low angle relaxation joints, absorb high frequency energy and generally reduce the resolving power of seismic methods. Velocities within the coal measures are in the general range 2200-3500 m/s but are not, pending sonic logging, well defined.

Dolerite throughout the coalfields lacks the extreme textural variations so common in central and southern Tasmania. The rock is generally darker, finer and less dense - averaging 2.83 t/m^3 and does not exceed 3.00 t/m^3. The material throughout the entire area may be the result of a later stage of intrusion within the province. Layering and differentiation, so characteristic of dolerite elsewhere, has not been recognised.

INTEGRATION OF SURVEY RESULTS

Preceding discussion summaries outlining the use and results of the various methods have presented the unilateral conclusions pertinent to each method. However, it is possible to synthesize some data from several methods; gravity, magnetic and reflection. Radiometric data has been excluded since the information, although extensive, has little real character. The seismic data, though restricted to four relatively short lines, can be assimilated in the form of additional control. Clearly, though, only the gravity and magnetic surveys are of comparable extent, detail and relevance to offer any real opportunity of singular upgrading. And, since the gravity interpretation is more comprehensive and reliable, it is this interpretation which is revised to account for structural implications deduced from the magnetic surveys.

The revision is shown in Figure 10. Most of the features suggested in Figure 7 relate directly to major sheet edges or pipes evident in the primary gravity interpretation. Several groups of features can only be understood in combination with the Bouguer anomalies, either observed or continued, since some anomalies have resulted from the interaction of up to four structures. However the magnetic surveys have suggested that some, more subtle, Bouguer variations are significant and most changes relate to the impact of such features.

Several trends were recorded in each survey and these are shown by firm lines. Others, unsupported, are indicated for completeness. It is not known how many of these features represent two dimensional variations in the sheets or how many are faults. The largest known fault in the area occurs between grid lines 590000mE and 591000mE. Each method has recognised a structure in this zone - but some 800 m apart. It is possible that the structure is multiple with the main density contrast in the west and more recently disrupted dolerite, producing the magnetic anomaly, in the east.

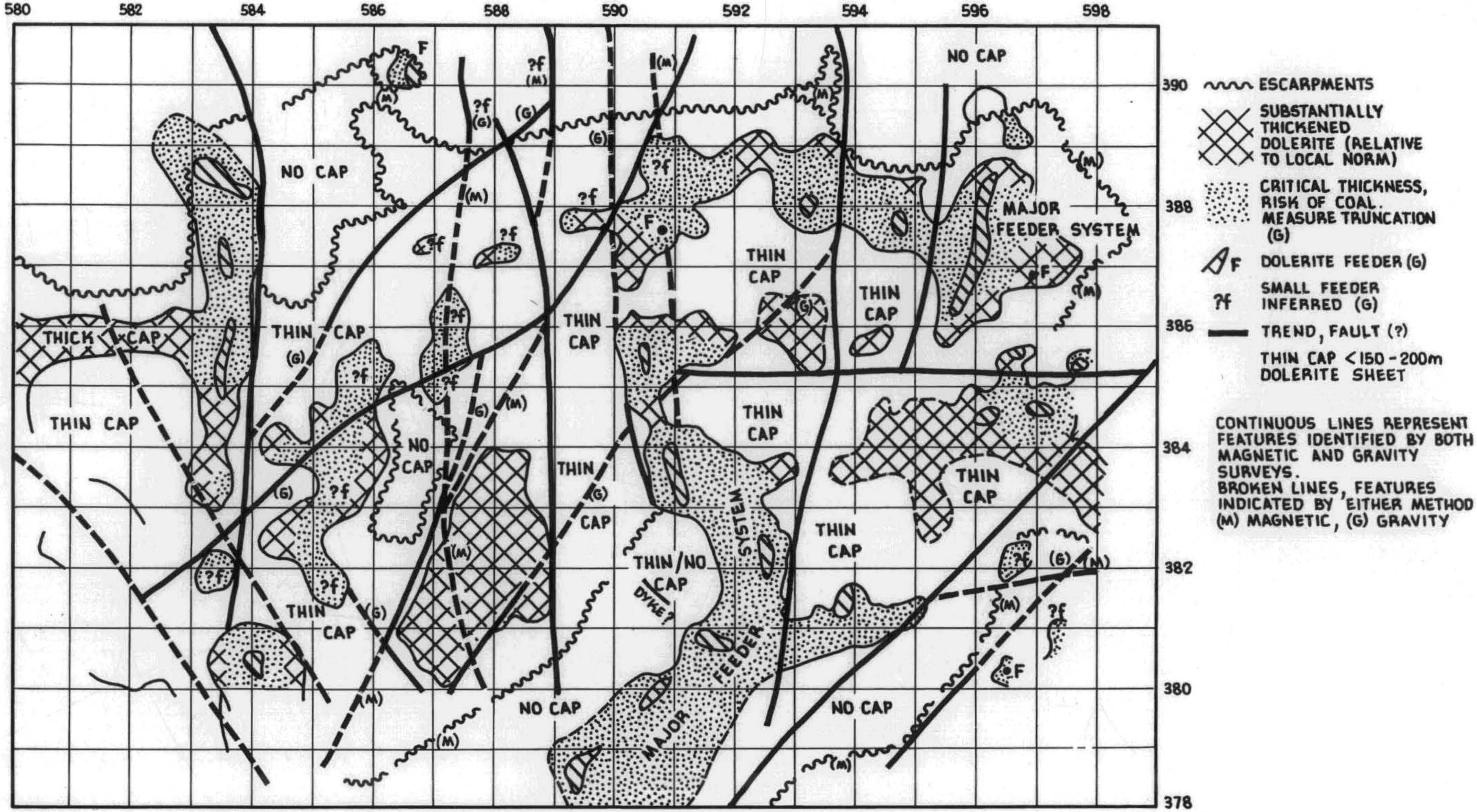

Figure 10. *Integrated gravity-magnetic interpretation, Fingal Tier.*

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Apart from such trend analysis discrepancies the two methods are in accord. The limited seismic data available from Fingal Tier is similarly not in conflict.

CONCLUSIONS

Geophysical methods have been incorporated into an accelerated coal exploration programme in eastern Tasmania. This development was essential if the cost, efficiency and coverage of the project was to be optimised. Difficult geological conditions have left a legacy of ignorance concerning coal reserves and drilling is not an appropriate basis for a wide-ranging evaluation. Although a range of methods have been used the gravity method has proven of most value, being able to resolve major faults, thick intrusions, feeders and estimate coal measures thickness. The reflection method, after some further processing development, is likely to form a useful adjunct. Apart from surface magnetic boundary mapping other methods are not recommended. The results to date are encouraging in the suggestion of the general extent of coal measures. It now remains to be seen how much coal can be won.

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