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**Review of
structural implications of geophysical data,
Sorell Peninsula, western Tasmania.**

by

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INTRODUCTION

The regional gravity and magnetic interpretations of Leaman (1986a, b, c) advanced evidence for thrusting on a large scale in parts of western Tasmania. The proposition was first suggested in explanation of the Precambrian blocks on Sorell Peninsula south of Macquarie Harbour. The final stage of this early work implied thrusting of two ages (Late Cambrian and Devonian) and in differing senses (see Leaman, 1986c). As has often happened in science, others were forming similar conclusions using different data (e.g., Carey and Berry, 1986; Findlay and McClenaghan, 1987).

As the Sorell Peninsula appeared to contain the clearest evidence for, and most approachable thrust structures, drilling has been proposed to test and control these concepts (Findlay and McClenaghan, 1987: DDH 1 at 359000E, 5311500N, DDH2/3 at 359200E, 5298500N).

This report examines the geophysical data in the region in greater detail than was possible as part of the earlier regional studies. The review has been directed at evaluation of structural attitudes, depth limitations, and secondary definition of all relationships - data permitting. It was hoped that this process would assist or confirm site selection, allow some site rating, suggest required rig capacity, indicate issues which might lead to optimising site locations and provide an outline of predictions and assumptions which can be tested or revised by the drilling results. The prognosis method is the most honest and scientific approach in these conditions since it forces a solid pre drilling analysis and provides an objective test of concepts and solutions in a form which can be simply upgraded.

THE SORELL PENINSULA

The region studied is outlined in Figure 1. The basemap has been reproduced from the Queenstown 1:250 000 map sheet and an overlay of the total magnetic field at about 130 - 150 m was compiled from the Mines Department West Tasmania surveys of 1981 and 1985 (see Corbett et al, 1982; Leaman, 1986b).

The geology alternates between Cambrian and Precambrian units south east of Cape Sorell. Between Cape Sorell and Lagoon Creek Precambrian rocks outcrop. A zone of complex structures and Cambrian rocks are exposed east of Lagoon Creek. A second Precambrian block outcrops NNE of Point Hibbs. Its eastern margin is more complex, multiply structured and includes ultramafics and Ordovician rocks.

These four blocks have been termed Precambrian North and South, and Cambrian North and South throughout the text and figures.

Carey and Berry (1986) and Leaman (1986 b, c) have inferred a multiply overthrust zone dipping east with movement from the east at or near the contact of the southern Precambrian and Cambrian blocks. Findlay and McClenaghan (1987) and Leaman (1986 c esp) have inferred a west dipping overthrust at the contact between the northern Cambrian and Precambrian. These junctions had previously been considered to be simple faults. This is clearly not the case. Leaman (1986 b, c) also implied complex and partially thrust contacts at the other boundaries.

The present drilling proposal (Findlay and McClenaghan, 1987) is designed to test the two northernmost contacts.

ROCK PROPERTIES

Some preliminary property determinations were supplied to me by Dr. R.G. Richardson. Several were obtained specifically for this analysis. All will be included in the rock property data base now in preparation. Not all have yet been associated with a petrological description and some broad groupings have been attempted.

Block	Density (t/cu m)	Susceptibility (cgsX.001)
Precambrian North	2.44-2.61	0 - 0.01
Cambrian North		
basalt	3.04	2.3
siltstone	2.51	0.04
misc	2.42-2.84	0 - 0.3
Precambrian South	2.45-2.61	0 - 0.1
Cambrian South		
Sediments	2.53-2.72	0.015- 0.3
intermed volcs	2.50-2.82	0.029- 0.6
(u/)mafics	2.25-2.90	0.048- 80
misc volcs	2.65-2.83	0.4 - 3

The total number of determinations is less than fifty and the results are extremely variable. The magnetic properties are probably realistic indicators for induction effects and the wide range is to be expected. Rocks with susceptibilities in excess of 0.0005 cgs (0.5 on above scale) are likely to possess some remanence character and I have demonstrated for other lithologies that this usually means a conservative bulk estimate of magnetic contrast for modelling purposes is at least double the measured susceptibility. Thus the northern Cambrian basalt could be expected to possess a resultant contrast in practice of about 0.005 cgs.

The densities pose a greater problem. The wide range indicates many weathered samples. Only the maximum values should be considered reasonable - especially for the intermediate and basic igneous rocks. The sedimentary rocks may exhibit a greater natural range but experience elsewhere suggests that values of 2.70-2.78 are normal for such Cambrian rocks. Some results fall in this range. The values for the Precambrian rocks indicate some alteration of all samples. Siliceous, massive rocks normally lie in the range 2.60-2.68 and the noted values seem low. Even so, there is little doubt that a contrast of the order of 0.1 t/cu m exists between Precambrian and Cambrian rocks overall and up to 0.3 t/cu m where the Cambrian rocks are locally dominated by mafic rocks.

GEOFYSICAL DATA

The available gravity and magnetic data have been presented elsewhere (e.g., Corbett et al, 1982; Leaman, 1986 a, b, c). The gravity data base has, however, been updated since the original work of Leaman (1986c) and the number of stations on Cape Sorell peninsula has been tripled. Unfortunately, the coverage remains uneven and patchy due to access and vegetation problems for helicopter surveys. The two Precambrian blocks have been wholly covered at 1 km intervals but only a few stations have been observed on the northern Cambrian block.

The gravity coverage is regional and irregular, as noted above, and may only be used for broad brush assessments at this stage. The absence of stations in Macquarie Harbour and immediately off the west coast also limits the usefulness of the available data.

No such problems exist with the magnetic data base even though the east-west line spacing is 500 m. The coverage is uniform, at an elevation of 130-150 m, and able to resolve issues related to primary boundary features.

INTERPRETATION

Six profiles (4 magnetic, 2 gravity) across the northern part of Sorell Peninsula have been examined previously.

Three of the magnetic profiles (lines 40, 120, 270 at 5300 200, 5304 400 and 5312 000 mN resp) were examined at the commencement of the Mt Read Volcanics study and were reported in Leaman (1986a). It was recognised that the region was magnetically complex and that the Precambrian blocks were probably overthrust. I made no attempt to prove this proposition at the time since too little was known of the general characteristics of the Cambrian rocks or feasible structural effects. The time budget was spent on evaluation of rock property inferences and the contrasts implicit in the anomalies. It may be remarked that the properties inferred in Table 1 of Leaman (1986 a) are wholly consistent with the recent determinations. Time and evaluation of features within the Mt Read Volcanic arc precluded a return to the problems of Sorell Peninsula as part of that study.

However, by the time interpretation of the 1985 survey was begun the nature of the regional contrasts and their structural implications was better understood. This is reflected in the interpretation at 5295 000 mN (see Figure 5, from Leaman, 1986 b) where a thrust solution is unambiguously suggested for at least one boundary of the southern Precambrian block.

The two gravity profiles (5295 000, 5310 000 mN) were presented in Leaman (1986 c). The original solution for 5310 000 mN is reproduced as Figure 3. This solution clearly implies thrust relationships at both Precambrian blocks. It was simply not possible to explain either as part of a coherent basement mass or even shallow detachments from such a mass presuming normal west Tasmanian densities and contrasts.

This review has, given the limitations and presumptions of the earlier work, sought to verify and refine these interpretations. Any such analysis must update considerably the work reported in Leaman (1986 a) and refine that in Leaman (1986 b, c). The gravity solutions are also modified by the new observations. The orientation of the profiles used has been assessed in order to reliably describe the elements of the structure and key boundary relationships. In the gravity case coverage limitations and the 1 km spacing where extant means that orientation is not an issue - profiles must be located where the data is most continuous. The northings of the original profiles remain the preferred positions overall and both are conveniently located with respect to the proposed drill holes. In the magnetics case the preferred alignment is normal to strike (NNW or NW to SE) rather than E-W.

GRAVITY:

Revised solutions for lines 5295 and 5310 are given in Figures 2 and 4. Each has been corrected for new data - whose effect is most pronounced on line 5310, compare with Figure 3 - and modelled to incorporate contrasts and crustal parameters which apply consistently across NW Tasmania from Elliott Bay to the Tamar River. The shift differential of 55 mGal reflects these factors. No regional-residual separation has been attempted due to the high risk of introducing undefined errors.

Profile 5295 (Figure 2) offers a relatively poor fit west of 366 000 mE. This model version was included to illustrate how such a solution either understates the thickness of the Cambrian section or its density - even though a major portion of it has been assigned a density of 2.89 t/cu m (mafics) - or overstates the thickness of the southern Precambrian block. A reduction of 1 km in thickness of this block at the inferred density (2.66-2.68) could match the profiles but a reduction of 1.5 km is possible using the measured, but probably weathered, densities. A similar effect could be obtained by deepening the Cambrian trough a similar amount or including a larger volume of mafic volcanics. The nature of the coastal boundary is unclear due to inadequate coverage.

However the profile is viewed it is clear that the southern Precambrian slab is a relatively minor component and even if the exposed contacts are steeply dipping (not supported, see below) they cannot extend to depths in excess of 1.5 to 2.5 km anywhere.

The data are unable to resolve dips reliably due to the wide station spacing but the dips shown in the Figure seem reasonable given the existing geological control and station density.

The model implies thrust surfaces for the upper and lower faces of the southern Precambrian block. The model also demonstrates why modelling of these structures must be on a grand scale initially since the relationships are not evident and resolvable in first order terms unless the modelled section is at least 25 to 40 km long. In this case the 45 km of detailed section presented forms part of a gross model 300 km across.

Profile 5310 confirms these implications while sampling all four blocks. Figure 4 presents an acceptable solution using a revised form of the earlier solution shown in Figure 3. The revisions provide for regional patterns and new data. The levelling of the observed profile toward the coast reflects the effect of the northern Precambrian block and a newly confirmed granite within it off the coast. The southern Precambrian block is gravimetrically inconsequential.

Comparison of Figures 3 and 4 shows that the Precambrian component is minor and that variations in the Cambrian section are much more important. It is likely that the Cambrian section is deeper and/or more mafic than shown in Figure 3 and that the units adjacent to the northernmost Cambrian/Precambrian boundary dip steeply east. Similar dips may apply SE of the southern Cambrian/Precambrian boundary (see also line 5295).

The present data cannot resolve the form of the southern Precambrian block at this northing but the northern Precambrian block must be very thin - generally less than 1 or 1.5 km - with an irregular (probably folded), very shallowly dipping basal surface.

MAGNETICS:

Two samples of extended magnetic interpretation, here named lines 1 and 2, are presented in Figures 6 to 8. These particular lines pass through, or close to, the proposed drill sites (DDH 1 - line 1, 5200 m; DDH 2/3 - line 2, approx 13500 m). Both are effectively normal to the primary trends and sample all contacts. The two lines summarise the systematic changes which occur along strike between Ft Hibbs and Macquarie Harbour.

Line 1 shows how important it is to have some geological limitations on this kind of interpretation since the southern Precambrian block might not even be suspected from either gravity or magnetic data. It has an absolutely insignificant volume.

The volume of the northern Cambrian dominates the section since it represents the tip of the sectional ice berg (see also Figure 4). Mafic units either layered, differentiated or altered can be shown to dip steeply east while the lower surface of the northern Precambrian block dips shallowly west (approx 15 degrees). Parts of the surface may dip more steeply but the overall effect cannot exceed this estimate - a result which is consistent with the gravity model (Figure 4).

The southern Precambrian block appears as a slice with roughly parallel surfaces dipping shallowly east (7 degrees est). There is also a suggestion that the Cambrian materials extend beneath it and that it is not extensive in depth. This possibility was also implied in the gravity analysis.

Review of the requirements to satisfy the profile match and the implied properties within the northern Cambrian block has suggested that additional dislocations are present. Within this block there is evidence of discontinuities in properties which suggest that the Cambrian section is not

wholly conformable and that some elements are truncated in a way which could be consistent with the termination of the southern Precambrian block. More detailed study would be required than has been undertaken for this review but the twenty six structural and property theme variants tested and evolved indicates that only a solution of the style shown in Figure 6 is reasonable. Such a solution implies older thrusts now dipping west have been offset by younger structures dipping east. It may thus be possible to drill from a site south east of the southern Precambrian block toward the west and not encounter any Precambrian rocks at all.

The stack of mafic rocks in the southern Cambrian block may represent stacked thrust sheets of the type described by Carey and Berry (1986) but which, in this zone, involve mafic and ultramafic rocks as well as Ordovician materials. All appear to dip sympathetically with the slab of southern Precambrian.

Two solutions have been included for line 2 (Figures 7, 8). Although each results in identical shift - match parameters comparison reveals both the sensitivity and ambiguity of the modelling process.

The thrust surface beneath the northern Precambrian block is irregular but probably not steeper than 15 degrees overall (see effect on profile of steepening in Figure 8). The surfaces bounding the southern Precambrian block dip at about 12 degrees and the stack of mafic rocks above it dip at around this value, not less.

There is no evidence at this northing for stacking or discontinuity within the northern Cambrian block which still dominates the section. The layered mafic suites is still recognisable with its two principal members but a slightly shallower dip to the east (contrast Figure 6). Analysis of data between lines 1 and 2 indicates that a cross cutting feature affects the terminating structures - which may be projections of splays from it - north of line 2. The kinks and bends in surfaces bounding the southern Precambrian block may mark points of splintering within the structure.

SUMMARY

Detailed review has confirmed the original suggestion of thrusting across the Cape Sorell Peninsula. The term thrusting has been used throughout the text on the basis of the earlier work and implications from it and the clear recognition that no other term adequately describes the surfaces defined given the stratigraphic relationships. The present work reinforces this conclusion and the term has been used without condition. The data and interpretation support unconditionally the concept of multiple thrust stacking within the southern Cambrian block and a shallow west-dipping base to the northern Precambrian block (refer Carey and Berry, 1986; Findlay and McClenaghan, 1987 resp).

This review has also indicated that all Precambrian boundaries have a thrust origin. The southern Precambrian block virtually disappears northward, not merely due to narrowing in surface expression but due to truncation of the block at depth by a low angle cross cutting surface. The zone of change can be seen in changes in the character of the magnetic field near 5305 000 mN. I have not been able to resolve precisely what happens using the simple 2D assumptions. It is interesting that minor local near surface anomalies shift across the southern Precambrian-northern Cambrian boundary at this northing. It is possible that the concealed cross cutting structure is a dislocated extension of the surface which cuts off the northern Precambrian block. Both dip west and are probably the oldest structural features to affect the Cambrian in this region.

DDH 1, as proposed, is designed to test the shallowly dipping thrust base to the northern Precambrian block. I believe it will do so. A minimum rig capacity of 500 m is advised.

DDH 2/3, as proposed, are designed to test the attitude of the boundary between the northern Cambrian and the southern Precambrian blocks. Any hole 100 to 200 m SE of the contact and drilled NW at about 60 degrees will pass from the Precambrian within 100 to 200 m. Hole 3, facing SE, will not be necessary on the present interpretation.

Other holes may be proposed to test the stacked thrust (?) sheets involving the ultramafics/Ordovician within the southern Cambrian block or the discontinuities within the northern Cambrian block. The latter option would require a deeper hole, perhaps 1 km, for confirmation but would demonstrate that the entire peninsula, regardless of block, contains a series of thrust structures.

The present interpretation represents the practical limit for simple methods. Any further refinement must use more advanced methods which allow for 3D effects. The present work provides the necessary foundation. It may also be observed that the results of any drilling on this prognosis, whether positive or negative, will provide the necessary specific controls for any such refinement.

REFERENCES

Carey, S.P., and Berry, R.F., 1986. Identification of stacked thrust sheets at Point Hibbs, Tasmania: Palaeontology, sedimentology and structure. In Abstracts, Burnie Geol. Soc. Aust. Symposium, The Mt Read Volcanics and associated ore deposits., November.

Corbett, K.D., Richardson, R.G., Collins, P.L.F., Green, G.R., and Brown, A.V., 1982. The 1981 West Coast Aeromagnetic Survey: Summary of information and results. Unpub. Rep. Dep. Mines Tasm., 1982/39

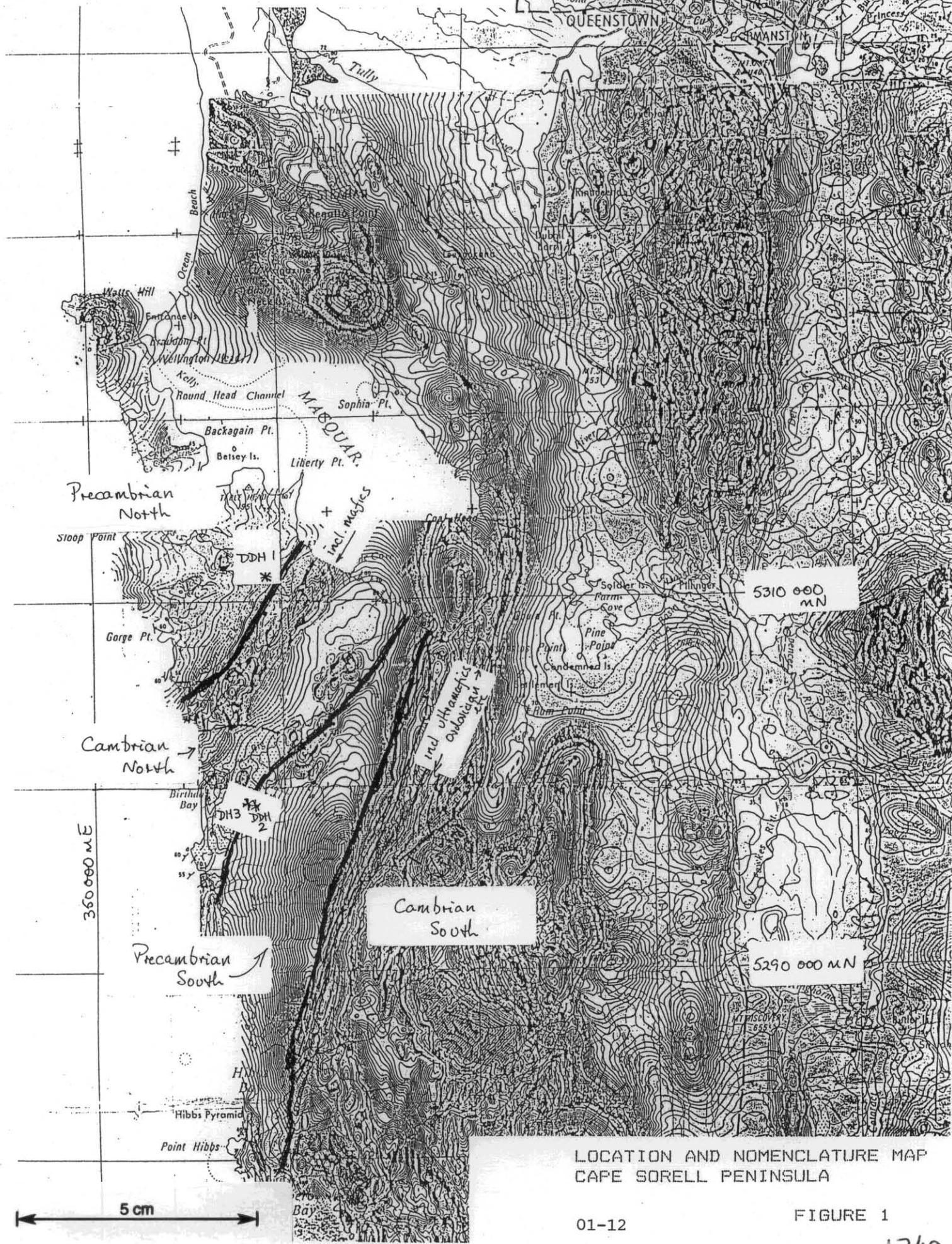
Findlay, R.H., and McClenaghan, M.F., 1987. Drilling proposal for the Macquarie Project 1987/8. Memo Dep. Mines Tasm. Apr 15.

Leaman, D.E., 1986a. Interpretation and evaluation report. 1981 West Tasmania Aeromagnetic Survey. Dep. Mines Tasm. Mt Read Volcanics Project Report.

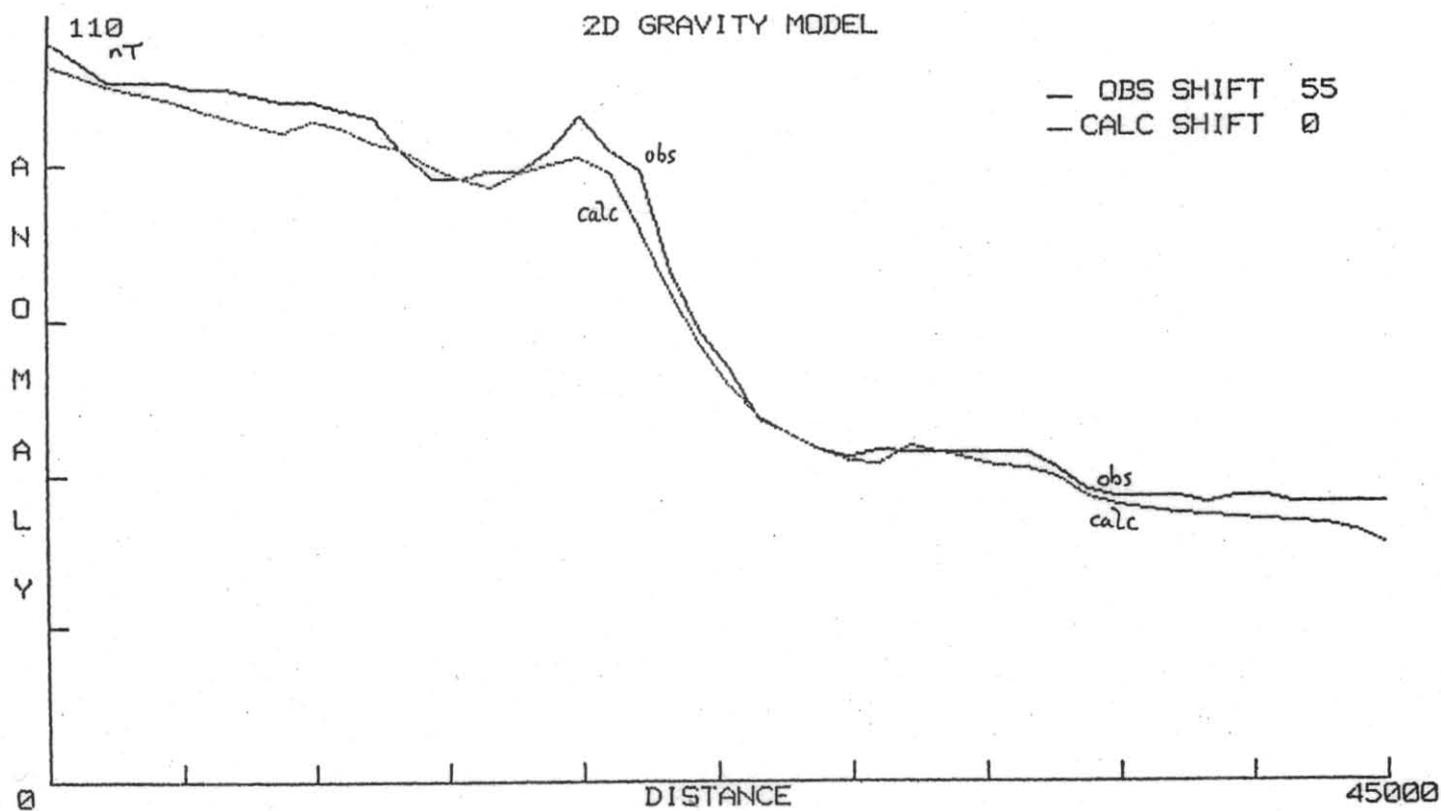
Leaman, D.E., 1986b. Preliminary interpretation report. 1985 West Tasmania Aeromagnetic Survey. Dep. Mines Tasm. Mt Read Volcanics Project Report.

Leaman, D.E., 1986c. Gravity interpretation West and North west Tasmania. Dep. Mines Tasm. Mt Read Volcanics Project Report.

Basemap: 1:250 000 Queenstown
 Magnetics: 1981, 1985 surveys
 All Mines Department data

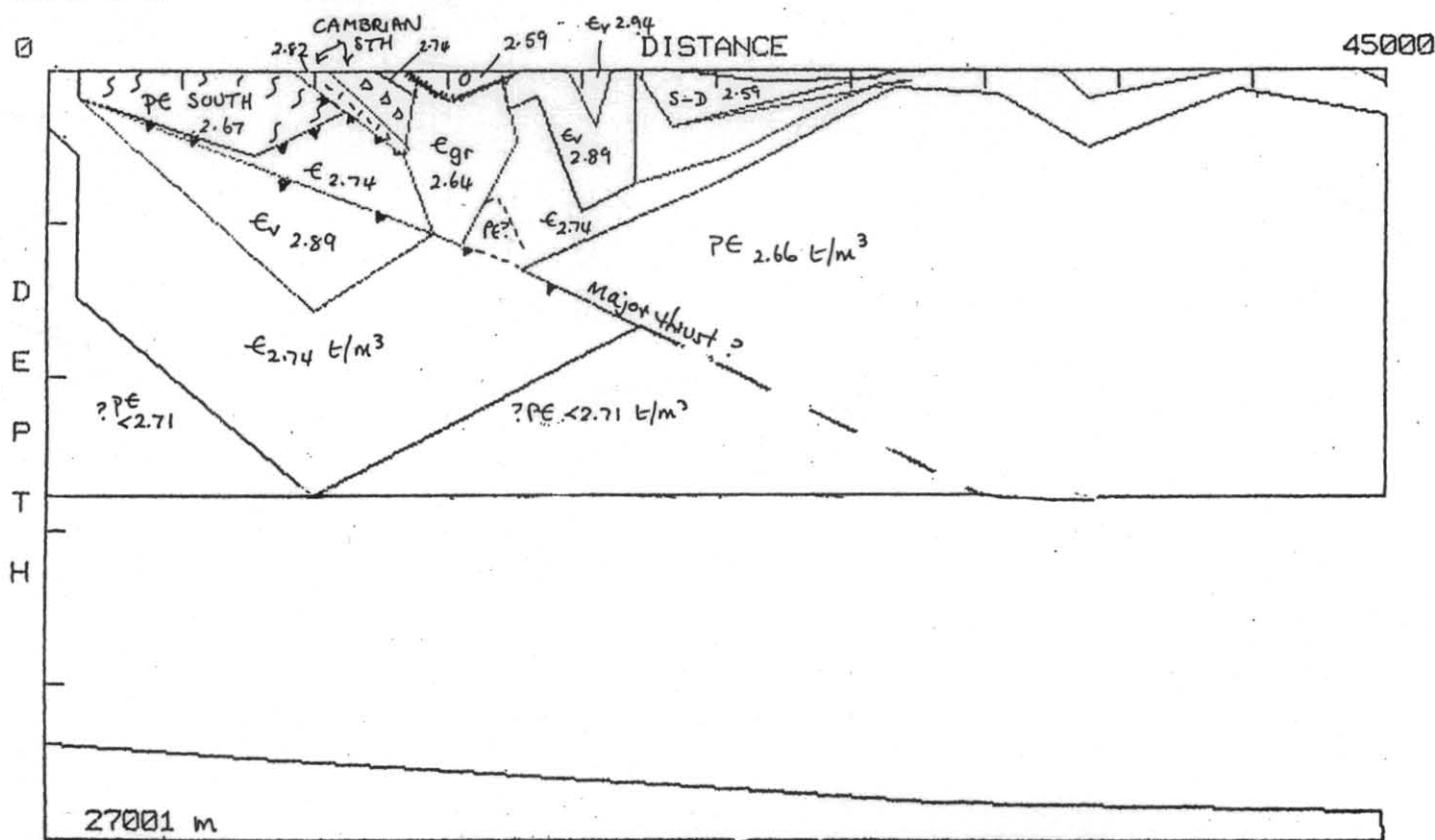


LOCATION AND NOMENCLATURE MAP
 CAPE SORELL PENINSULA



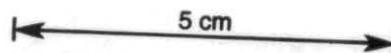
355000 ME 364 373 382 391 40000 ME E

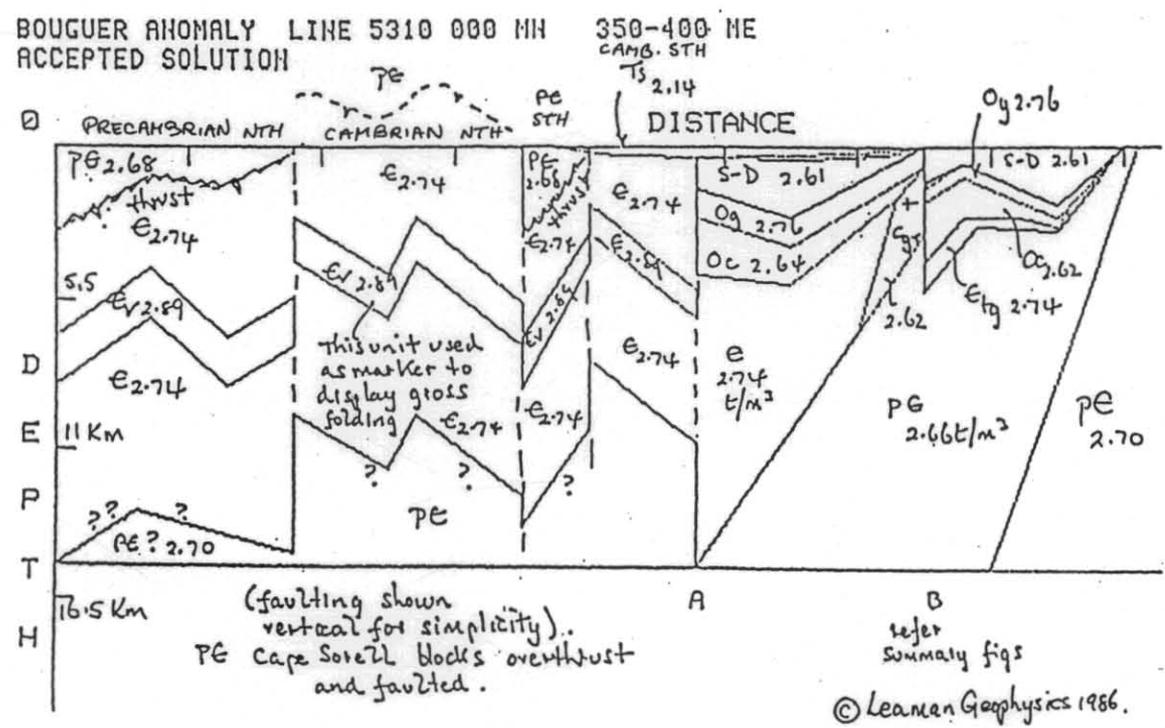
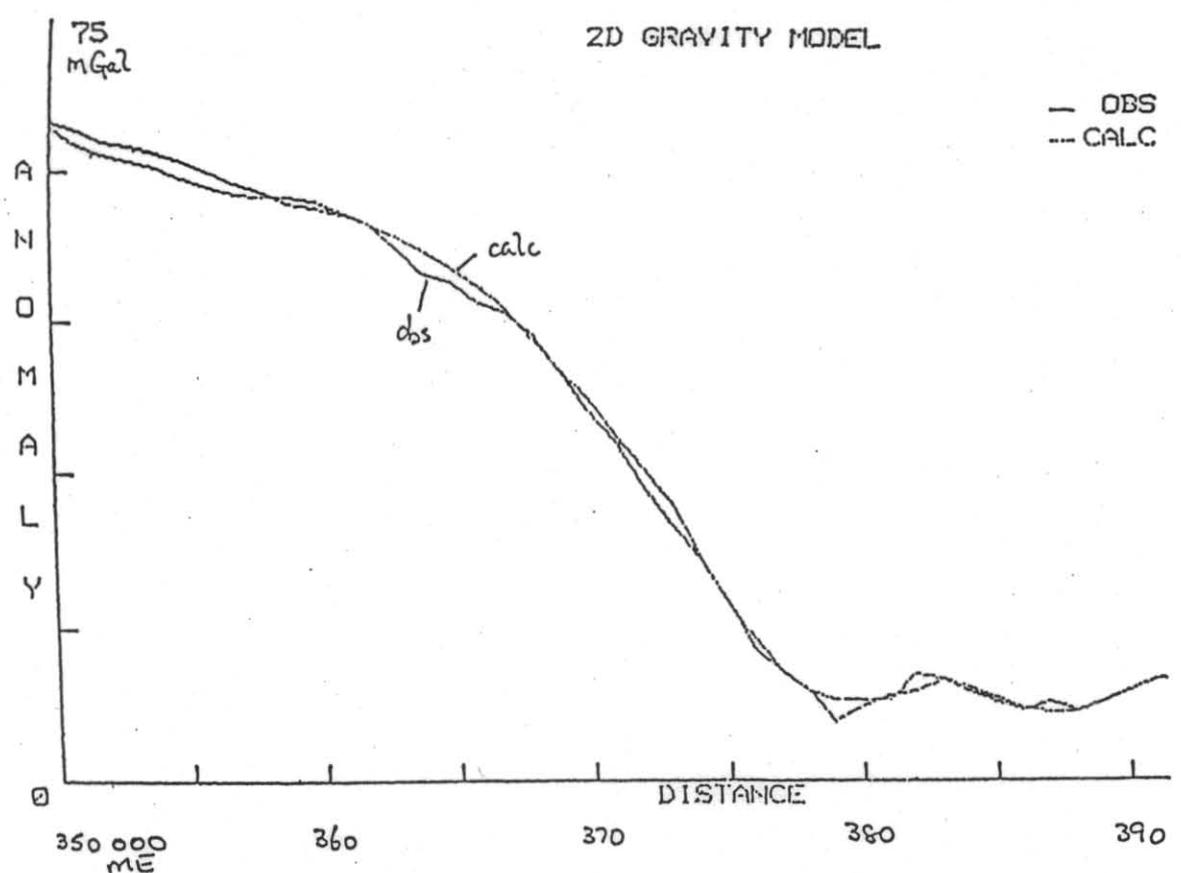
W SW TAS BOUGUER ANOMALY 355-400E/5295N ADJ 5 6 19 THRUST STACK



REGIONAL GRAVITY MODEL 5295 000 MN

FIGURE 2



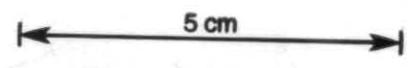


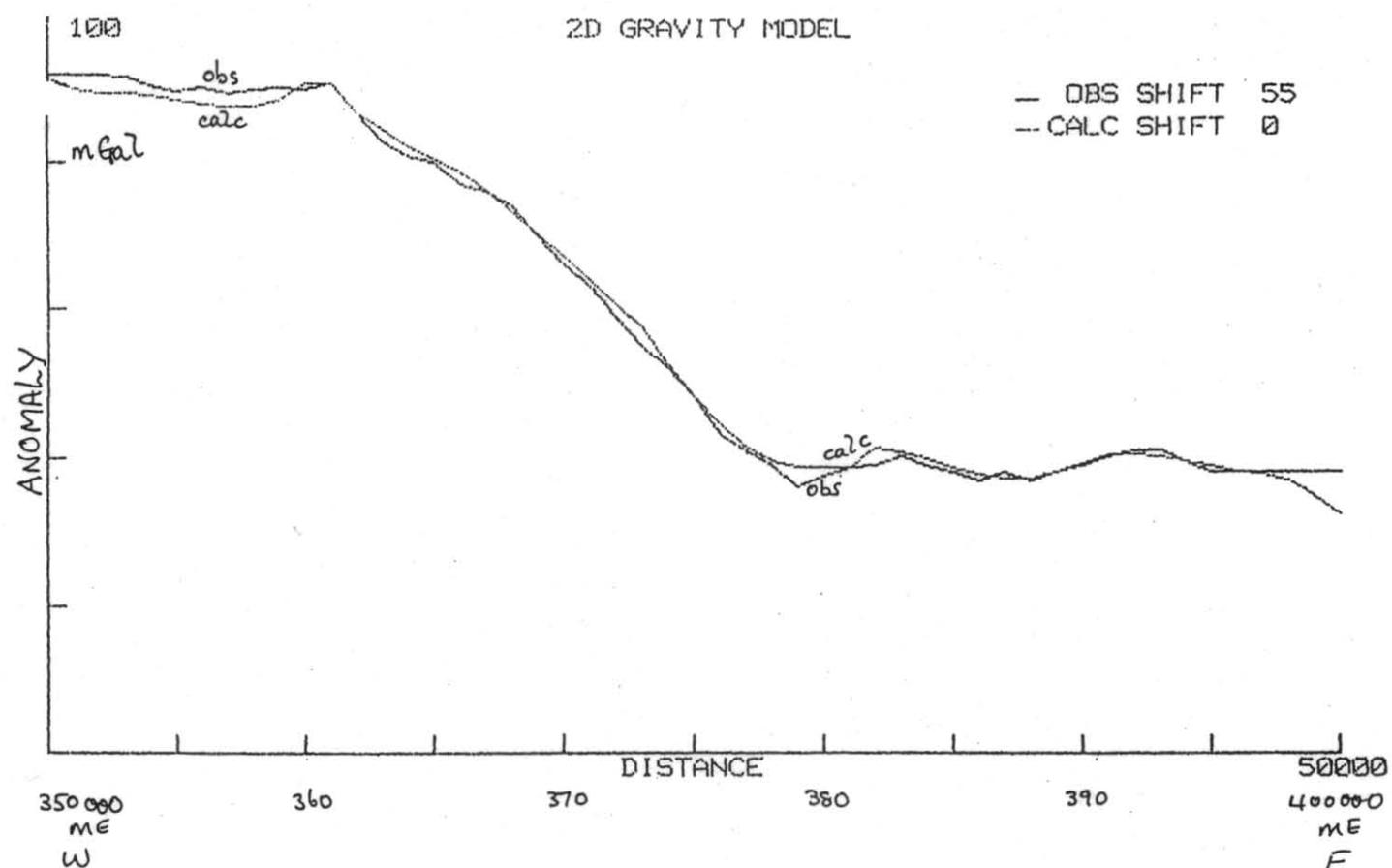
MODEL PROFILE AT 5310 000 MN - CAPE SORELL TO ENGINEER RANGE

Profile illustrates the style of the gravity field and its general relationship with Cambrian rocks. The insignificance of the Precambrian rocks at Cape Sorell is evident.

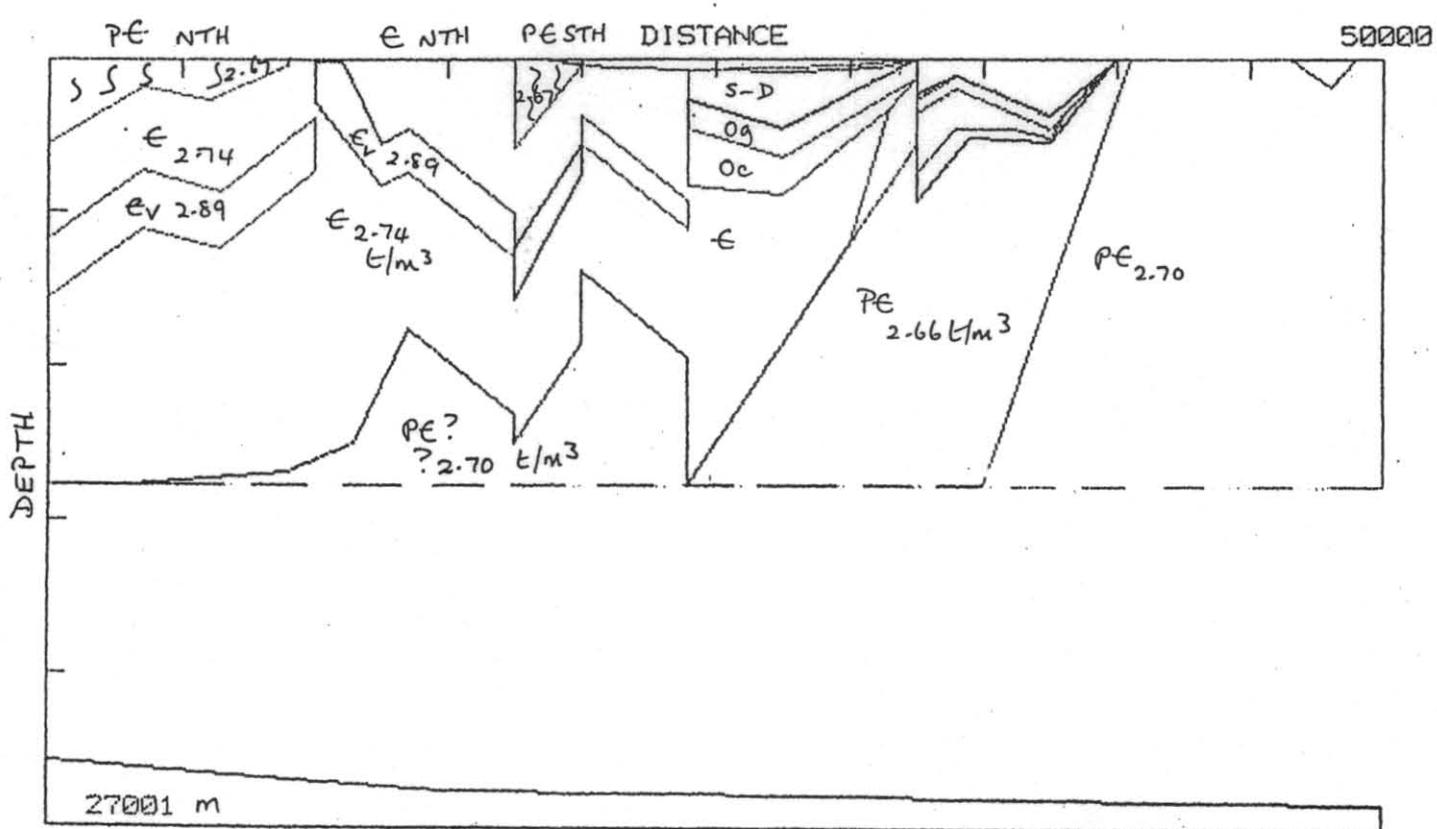
ORIGINAL GRAVITY MODEL 5310 000 MN (from Leaman, 1986c)

FIGURE 3



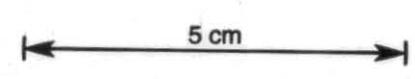


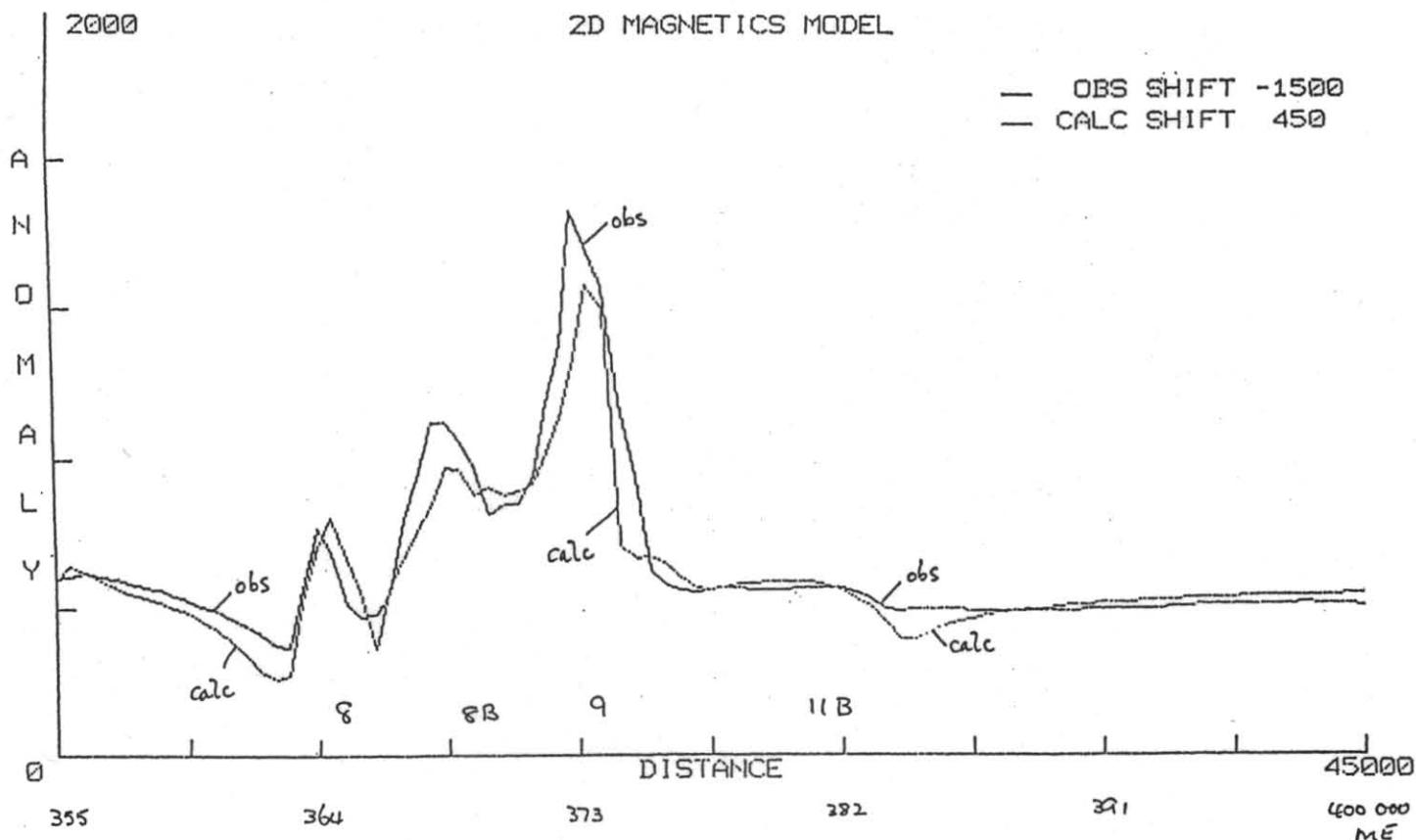
BOGNER ANOMALY LINE 5310 000 MN 350-400 ME
 DJ 11 16 17



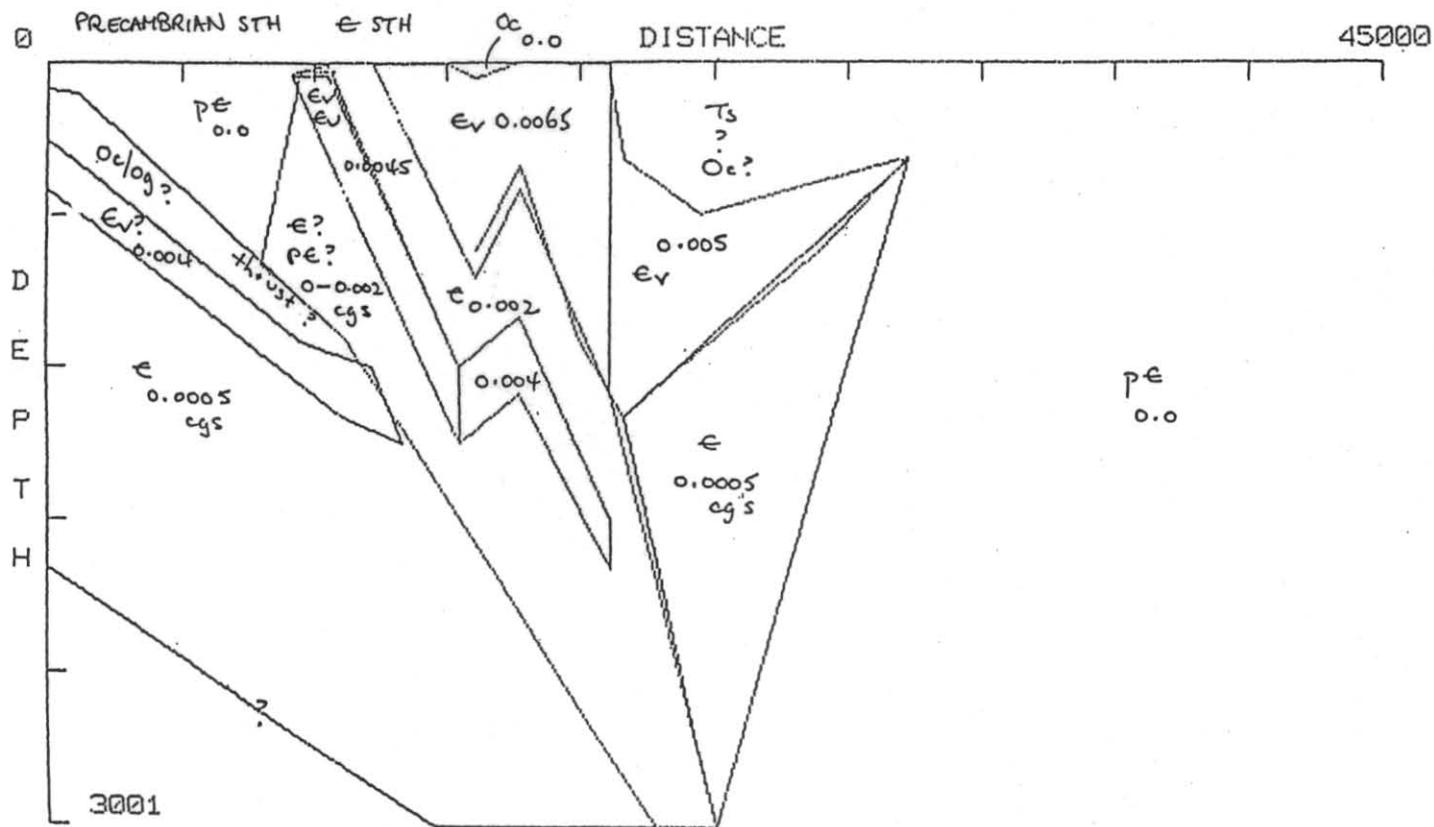
REVISED GRAVITY MODEL 5310 000 MN

FIGURE 4



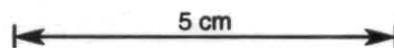


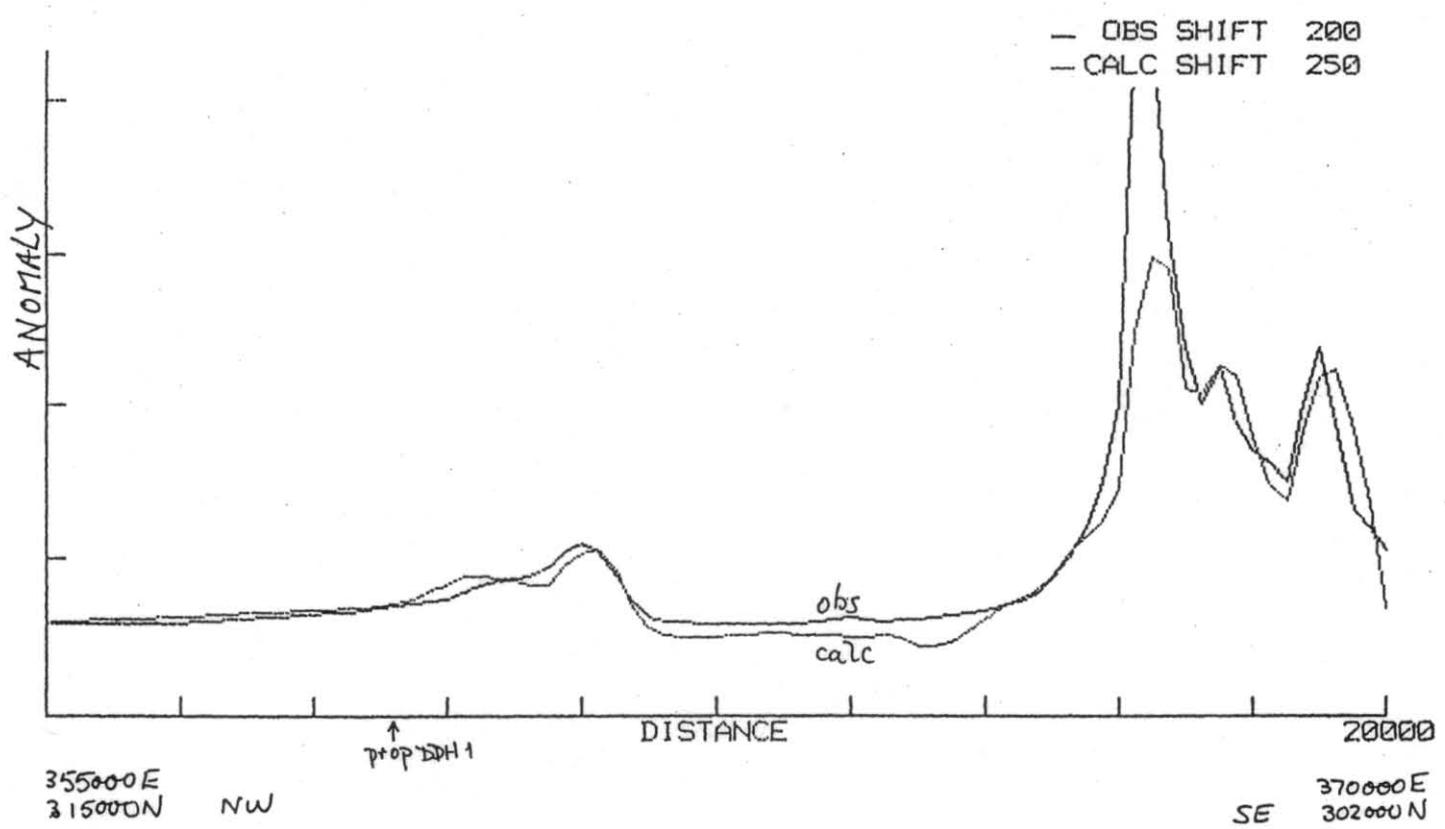
SH TAS MAGNETICS LINE 20120 355-400E/5295N



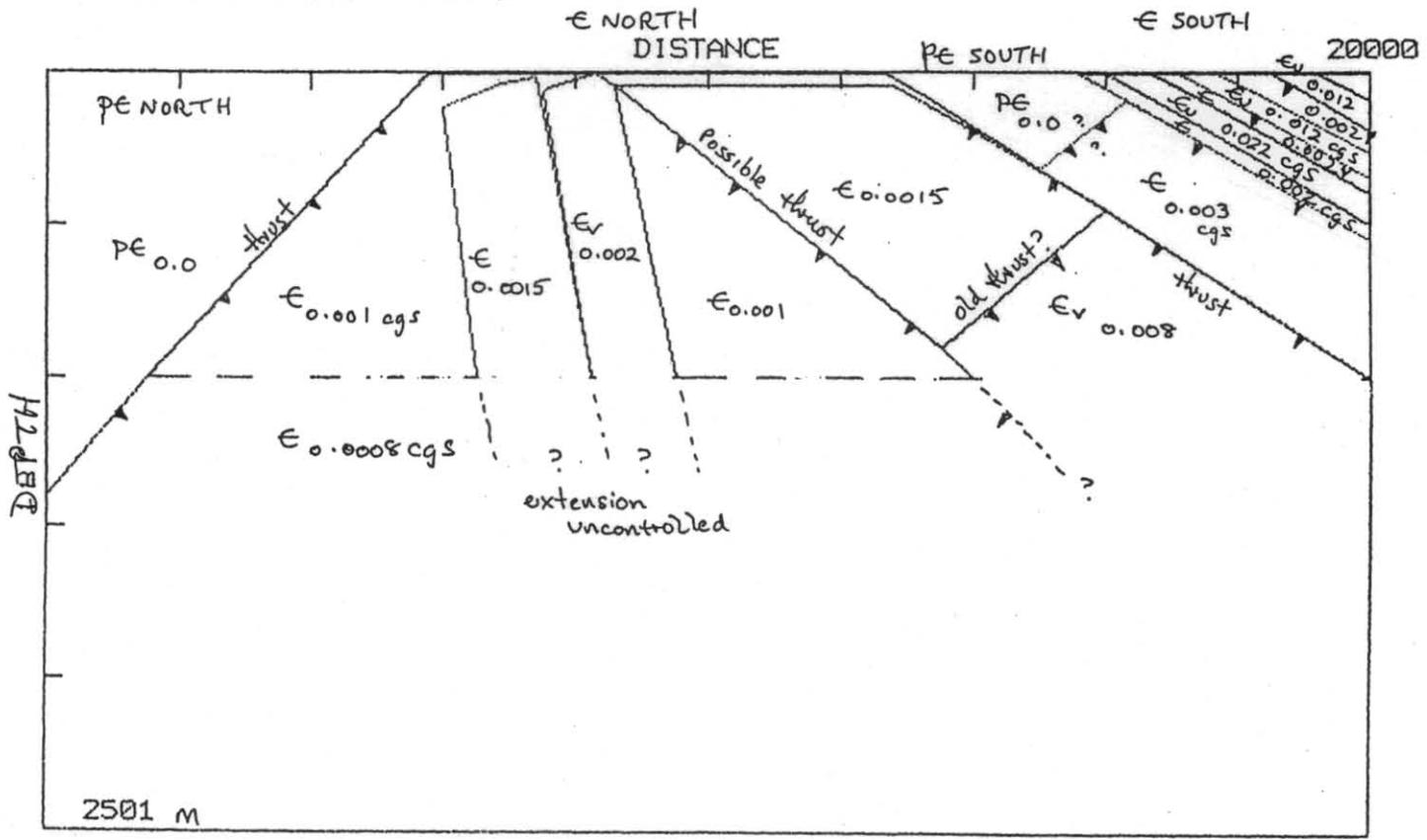
ORIGINAL MAGNETIC MODEL 5295 000 MN
(from Leaman, 1986 b)

FIGURE 5

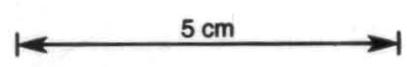




PE SORELL LINE 1 FOR DH1 PROPOSAL
OPEN CAMBRIAN SECTION 14 15 16



MAGNETIC INTERPRETATION LINE 1 FIGURE 6

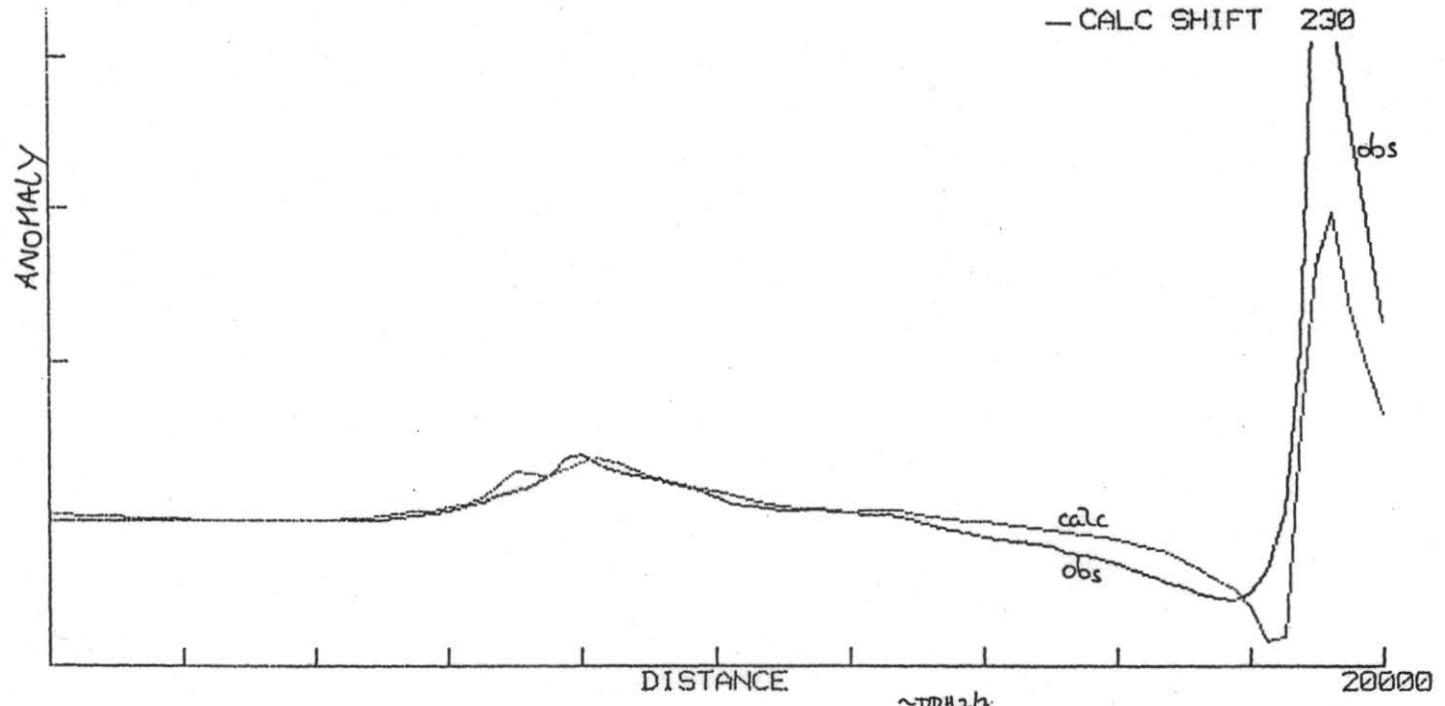


18/19

1200
nT

2D MAGNETICS MODEL

- OBS SHIFT 200
- CALC SHIFT 230

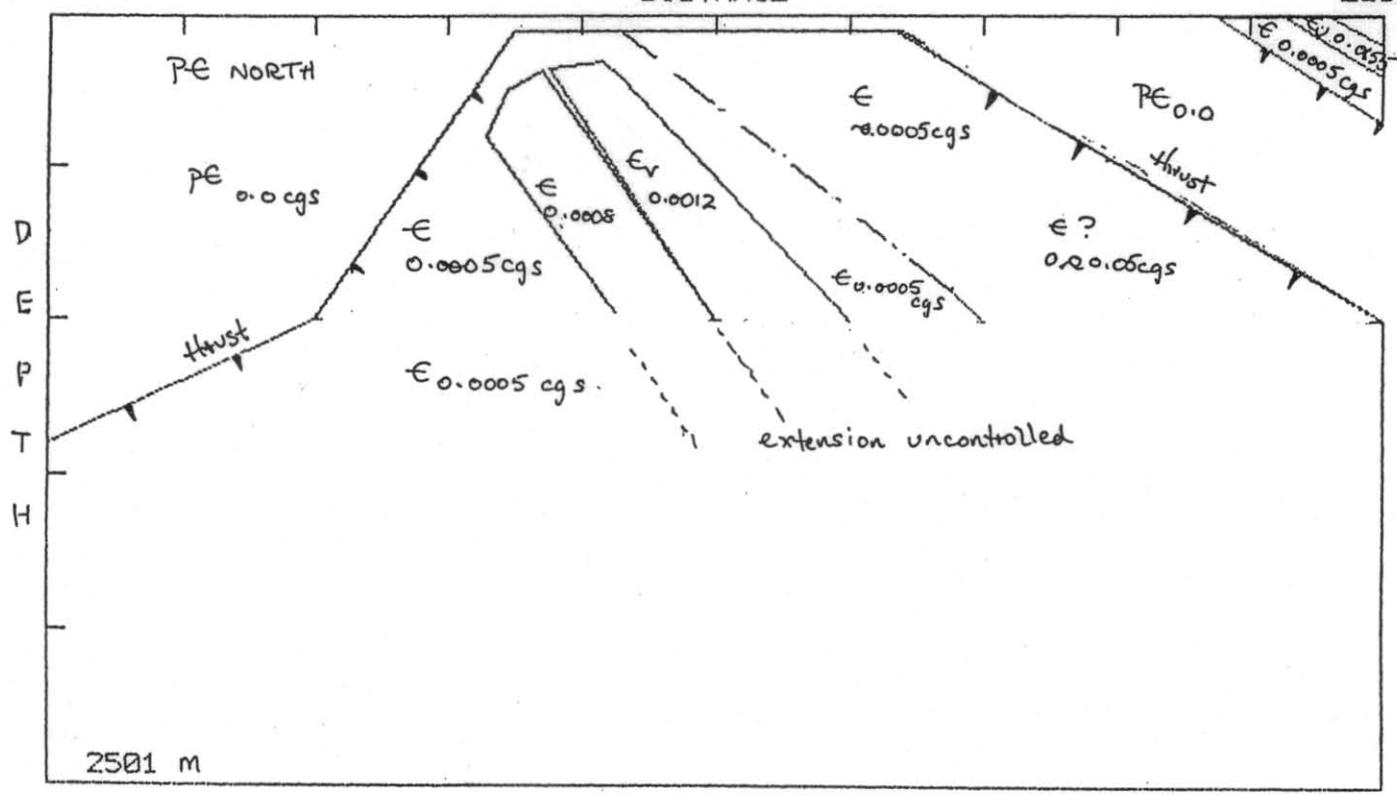


NW
APE SORELL LINE 2 FOR DDH1 PROPOSAL
DJ 1 14 REMOVE 7 ADJ K3=0007 K5=0003

~DDH1/3
|
360000 E
300000 N

365500 E
216000 N
SE
thrust stack
CAMBRIAN ST#1
20000

E NORTH DISTANCE PE SOUTH



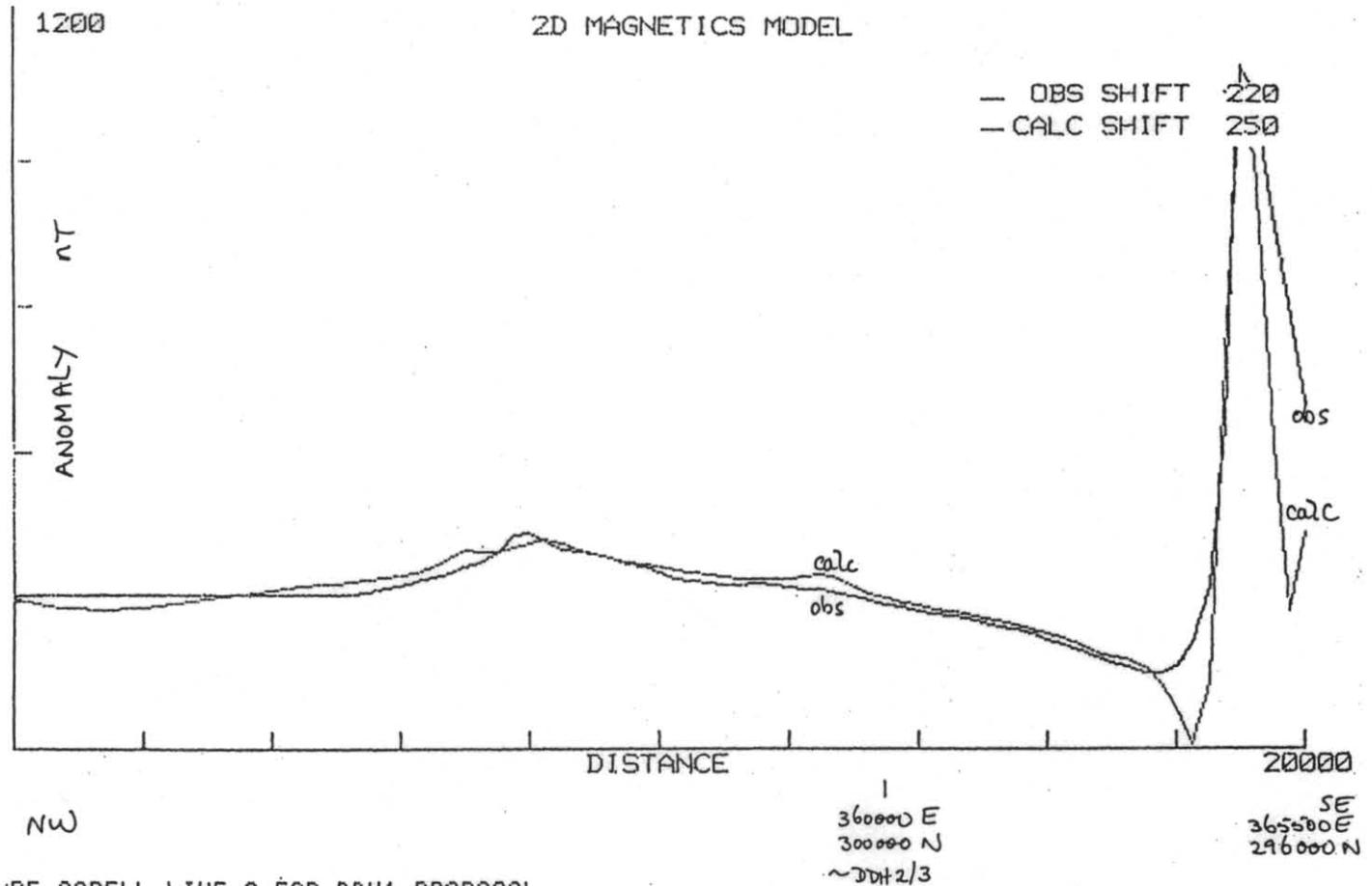
MAGNETIC INTERPRETATION

LINE 2 VERSION 1

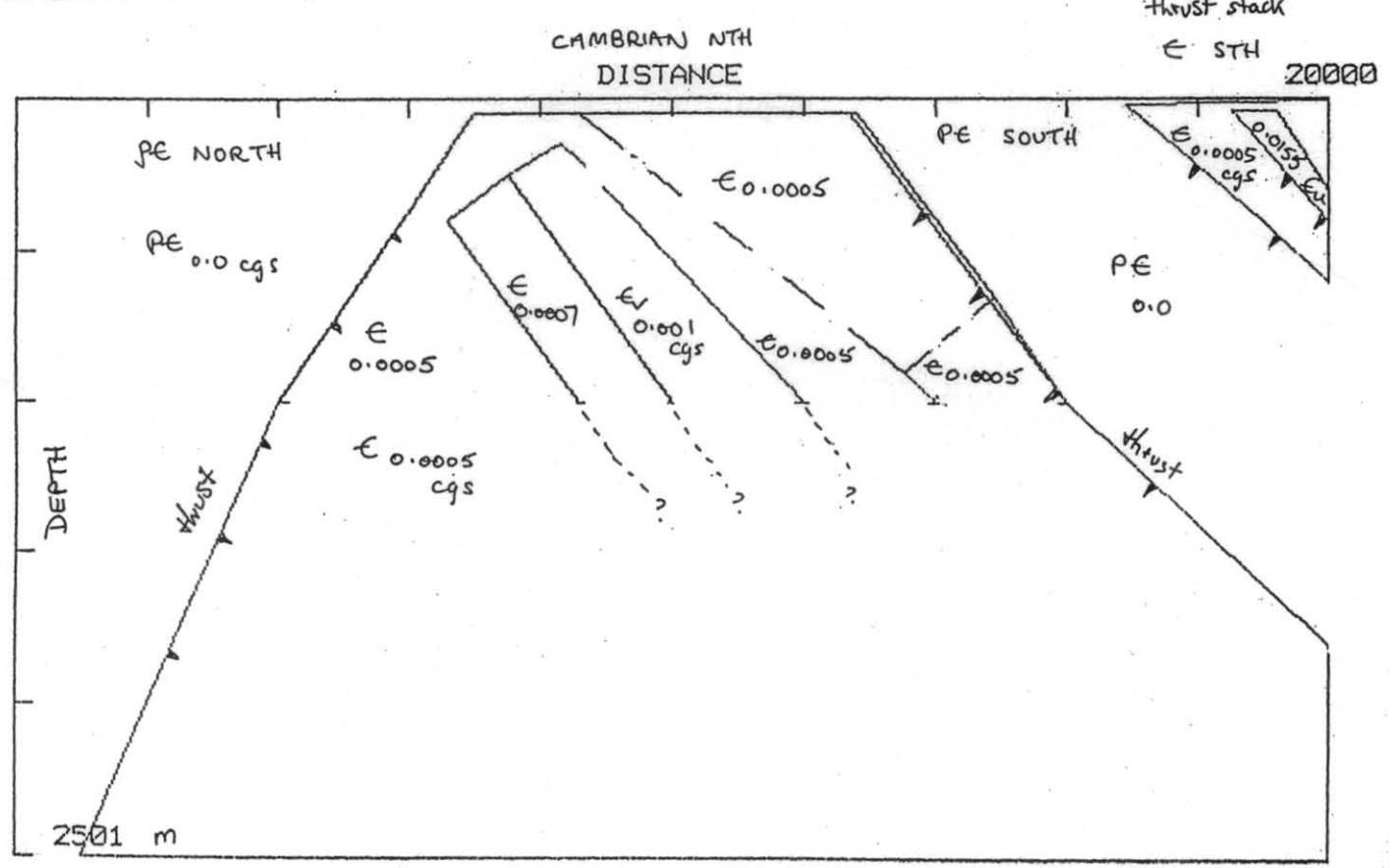
FIGURE 7

01-18

5 cm



IPE SORELL LINE 2 FOR DDH1 PROPOSAL



MAGNETIC INTERPRETATION

LINE 2 VERSION 2

FIGURE 8

